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(54) **STRATEGIC MODULAR REFRIGERATION SYSTEM WITH LINEAR COMPRESSORS**

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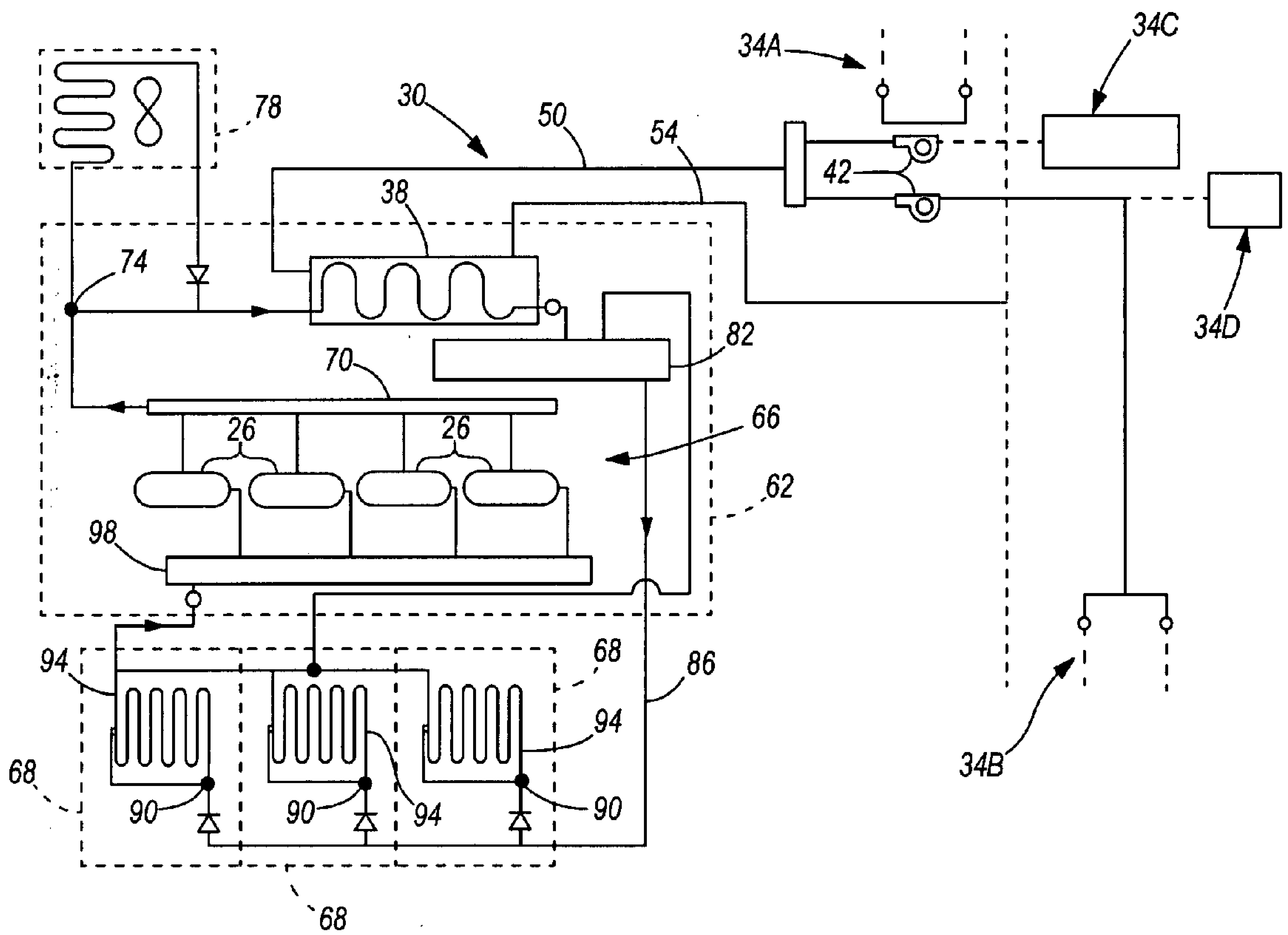
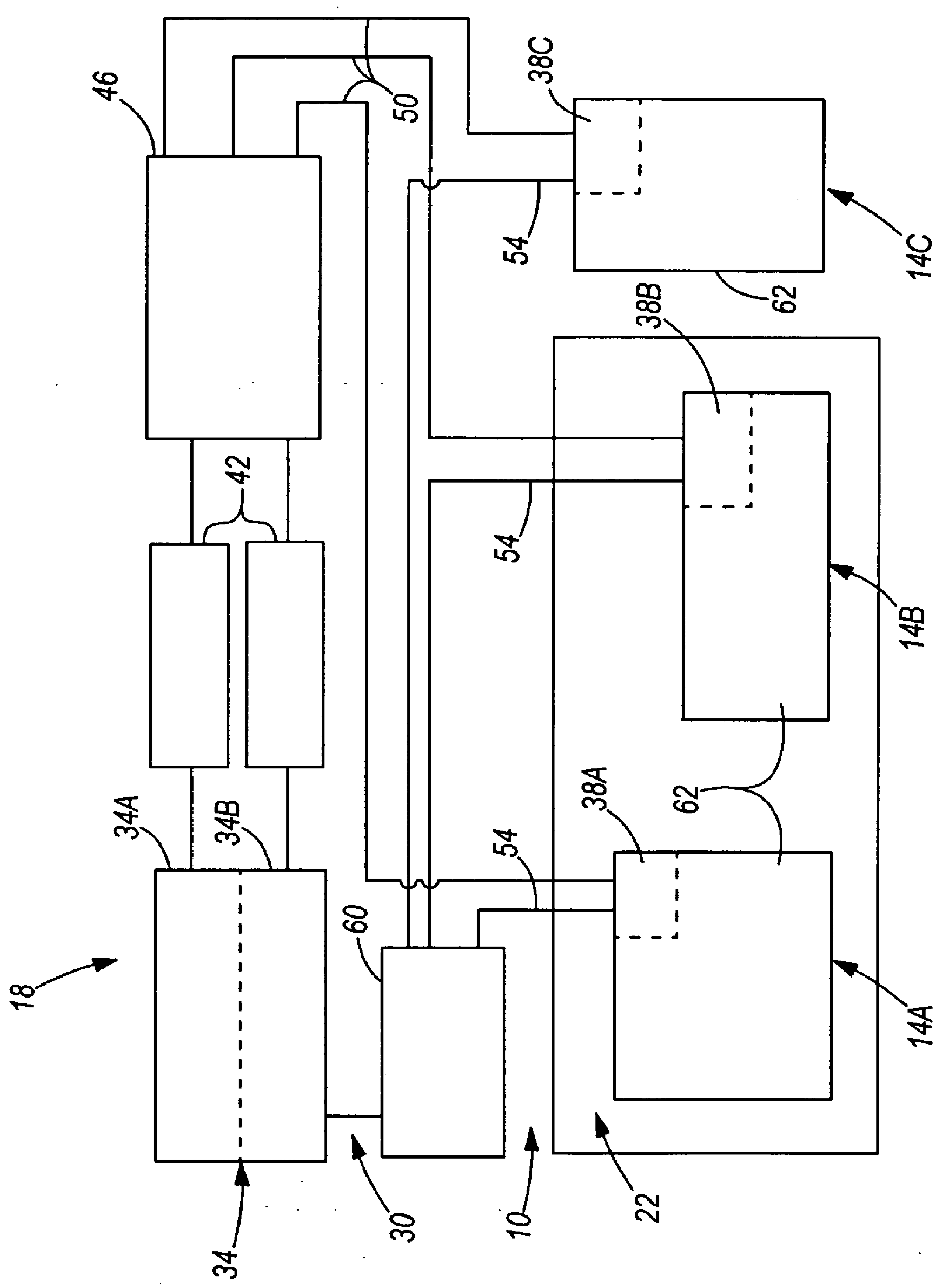
(52) **U.S. Cl.** **62/246**; 62/228.1

(57) **ABSTRACT**

A modular commercial refrigeration unit constructed and arranged for placement in strategic proximity to a plurality of associated product cooling zones within a shopping area includes a refrigeration rack proximate to a shopping area and configured to accommodate maximum refrigeration loads of the associated product cooling zones. The refrigeration rack has an optimum footprint. The refrigeration rack is constructed to support components of a closed refrigeration circuit including associated high side and low side refrigerant delivery and suction means extending from the rack and being operatively connected to a plurality of evaporators for cooling the associated product cooling zones. The modular refrigeration unit also includes a linear compressor and a cooling source remote from the refrigeration unit that provides a cooling relationship with a condenser for providing optimum condensing and efficiency of the evaporators in cooling the associated product cooling zones.

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50
38C
54
14C
62
38B
42
54
14B
38A
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54
34A
34B
60
18
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22
10
30
34

FIG. 1

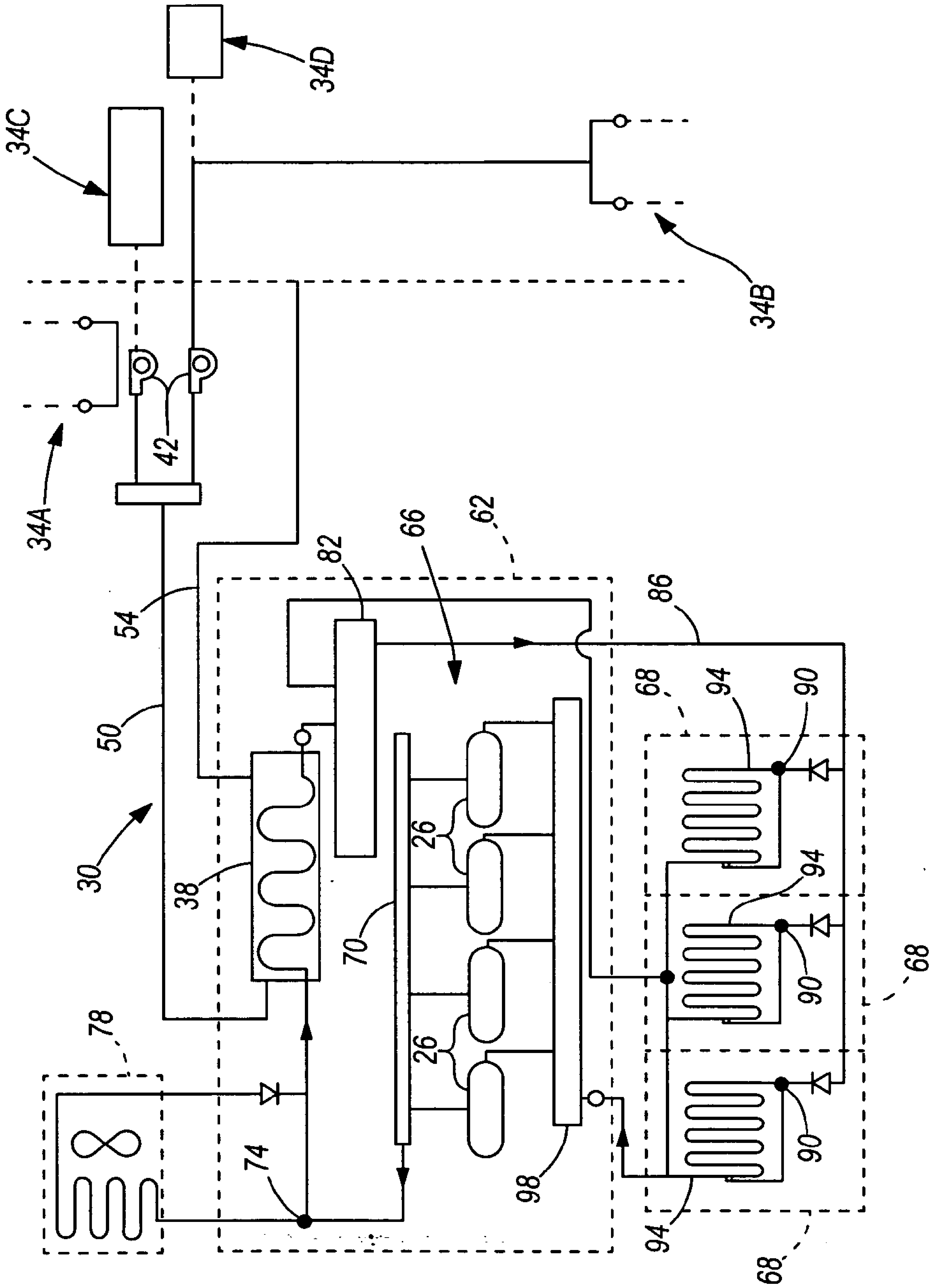
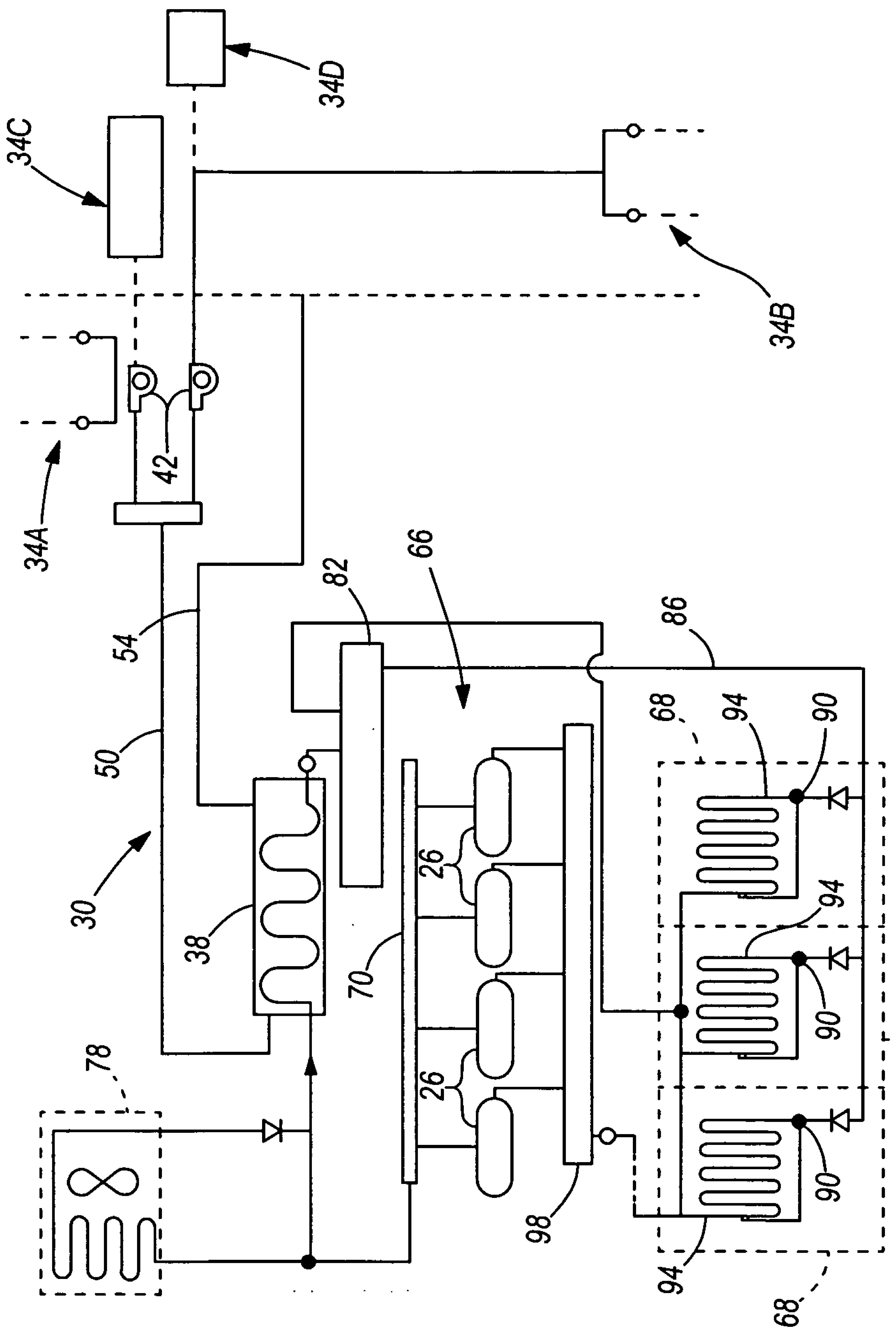


FIG. 2


34D
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34B
34A
42
54
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82
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68
94
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68
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78
98
94
90
68

FIG. 3

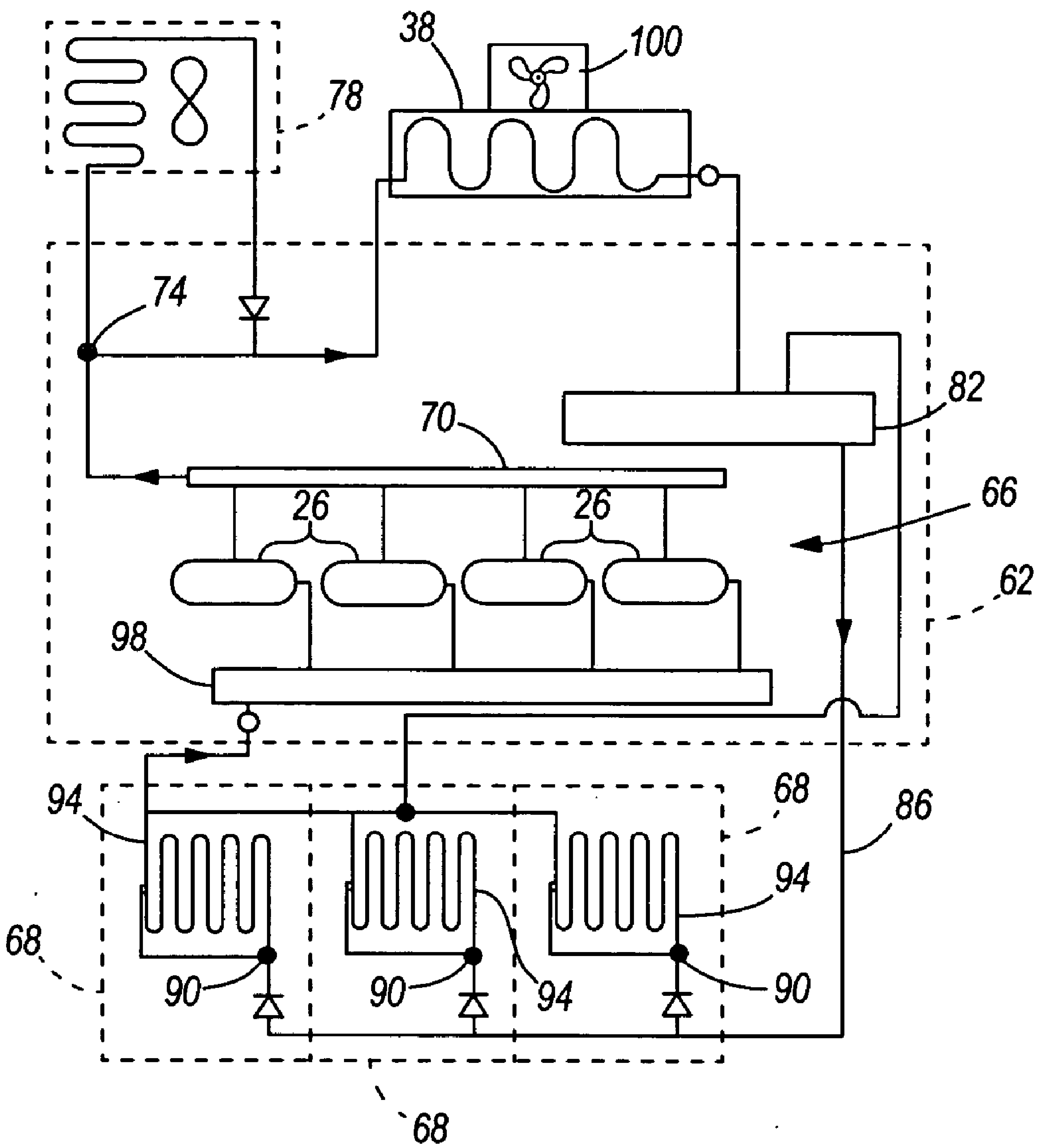
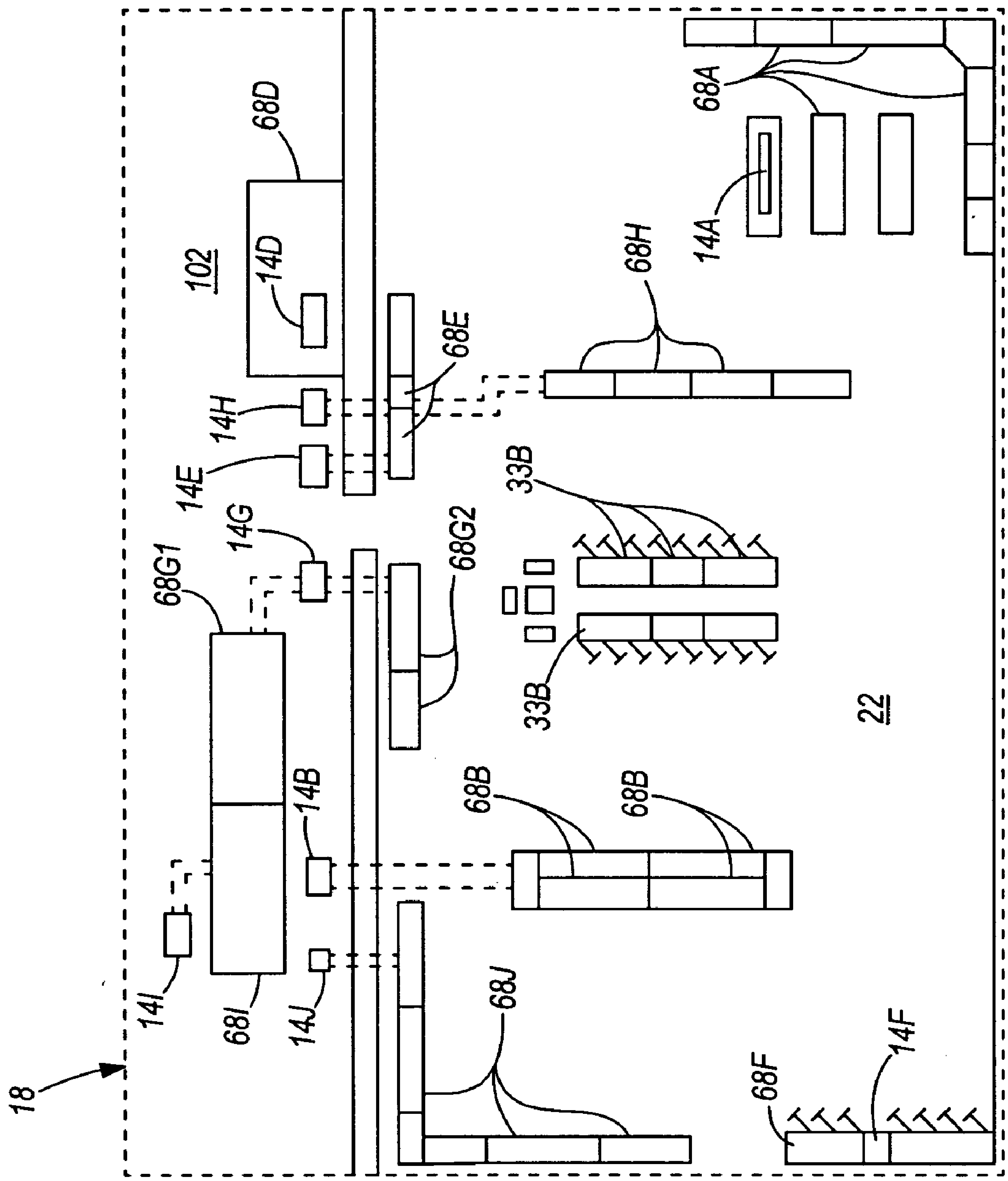


FIG. 4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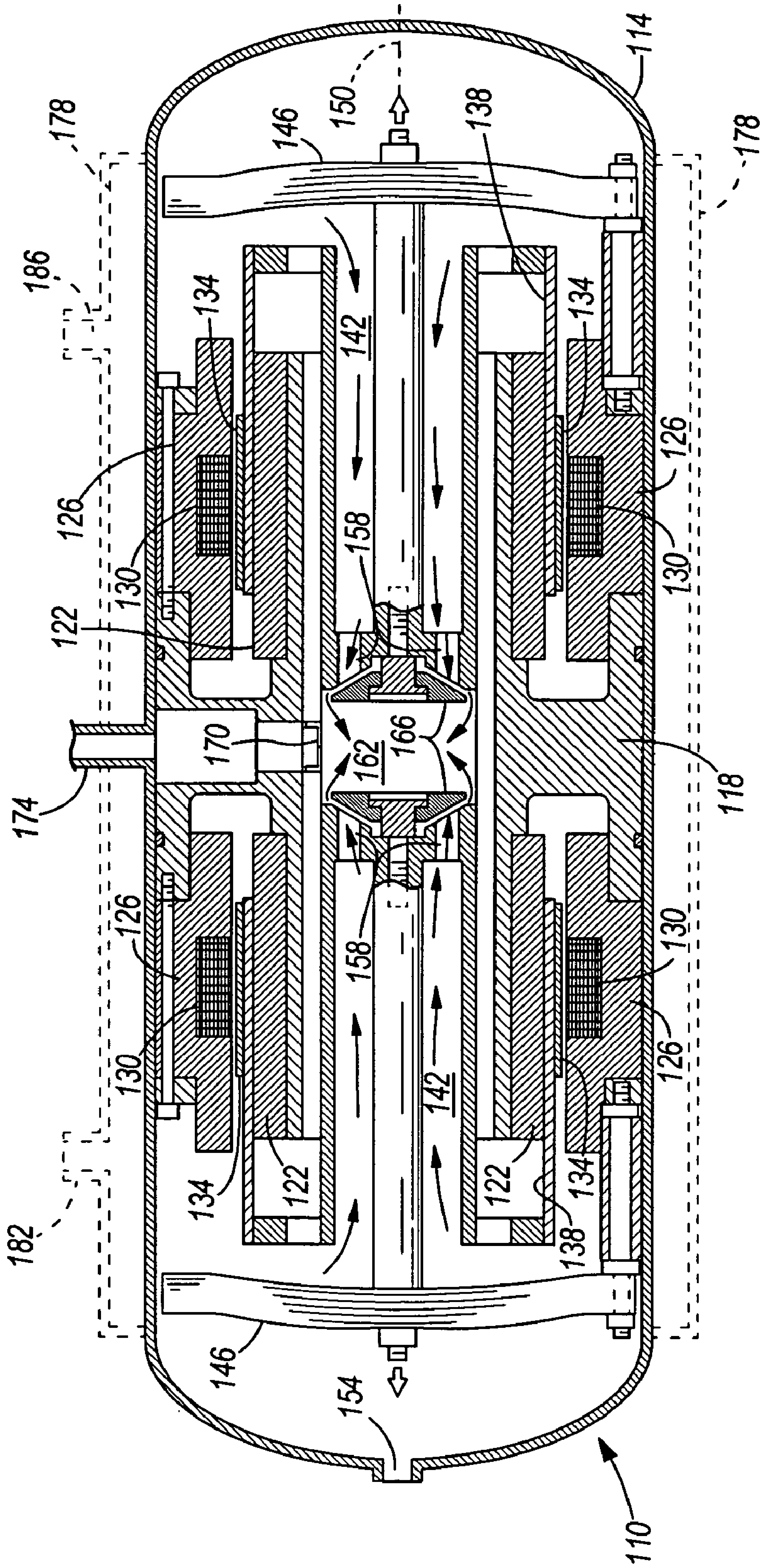
102
14D
68D
68A
14A
68H
68E
14H
14E
14G
68G1
68G2
33B
33B
22
14B
68B
68B
14I
68I
14J
68J
68F
14F

FIG. 5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178
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110

FIG. 6

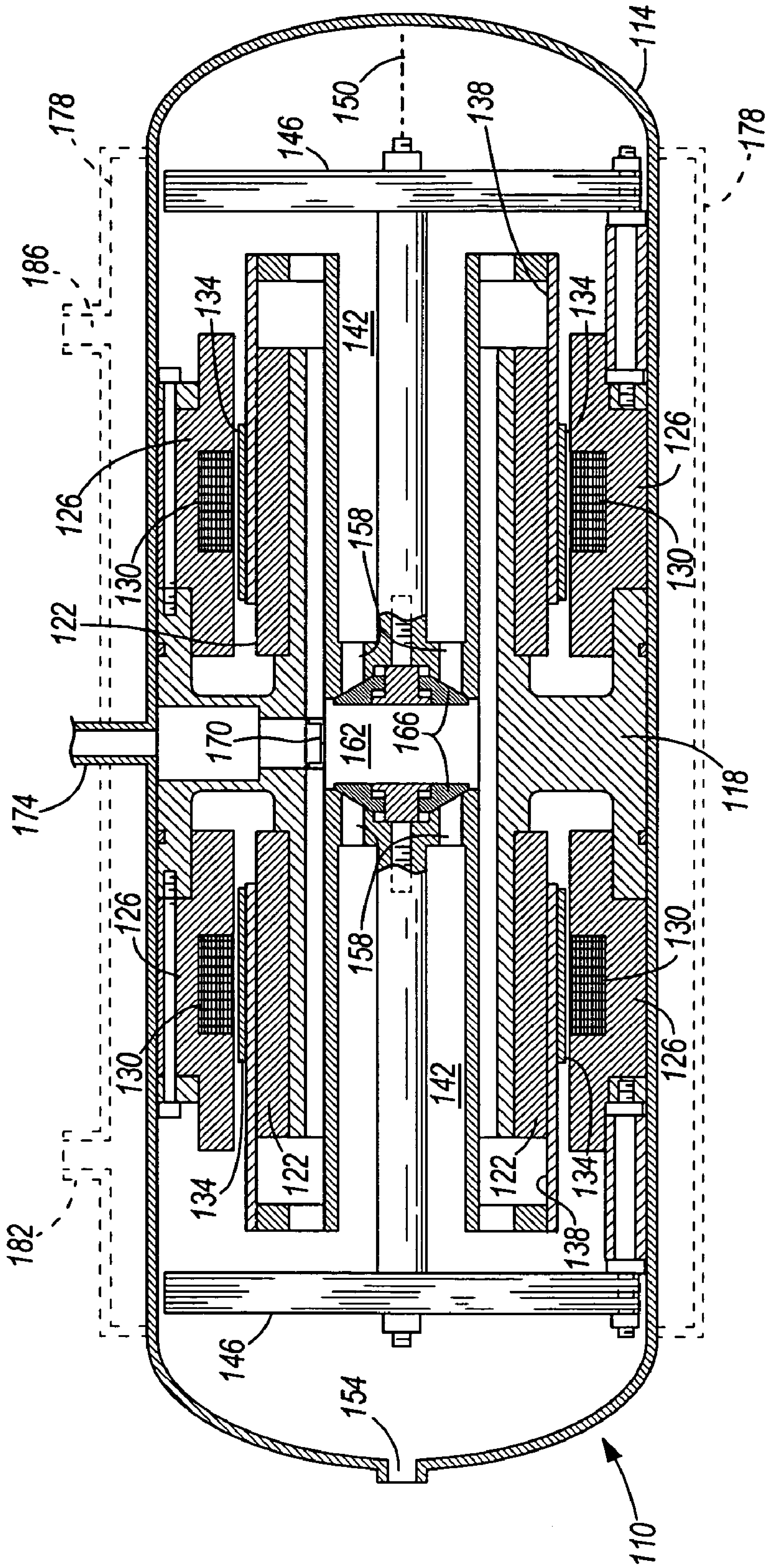
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FIG. 7

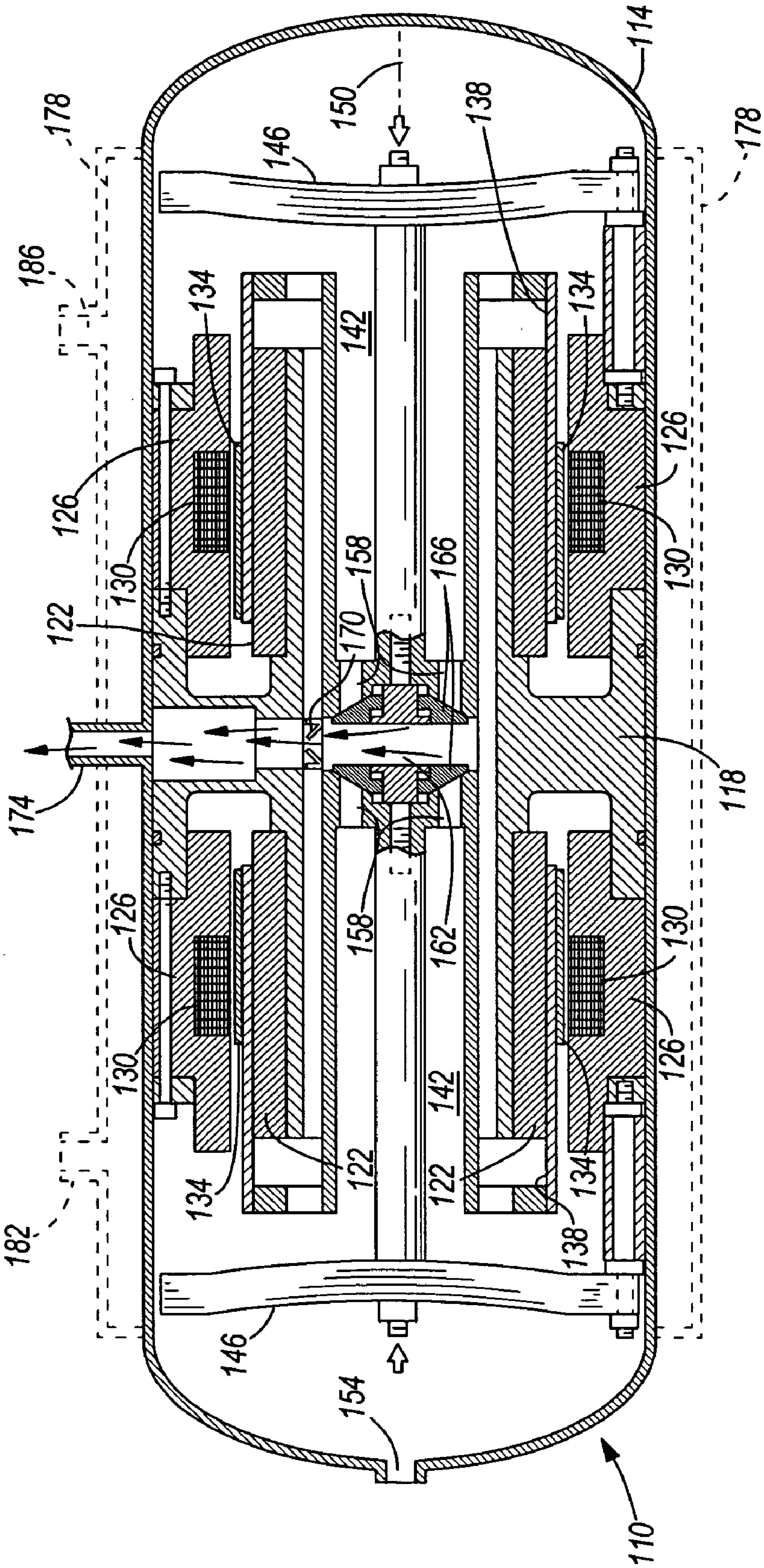
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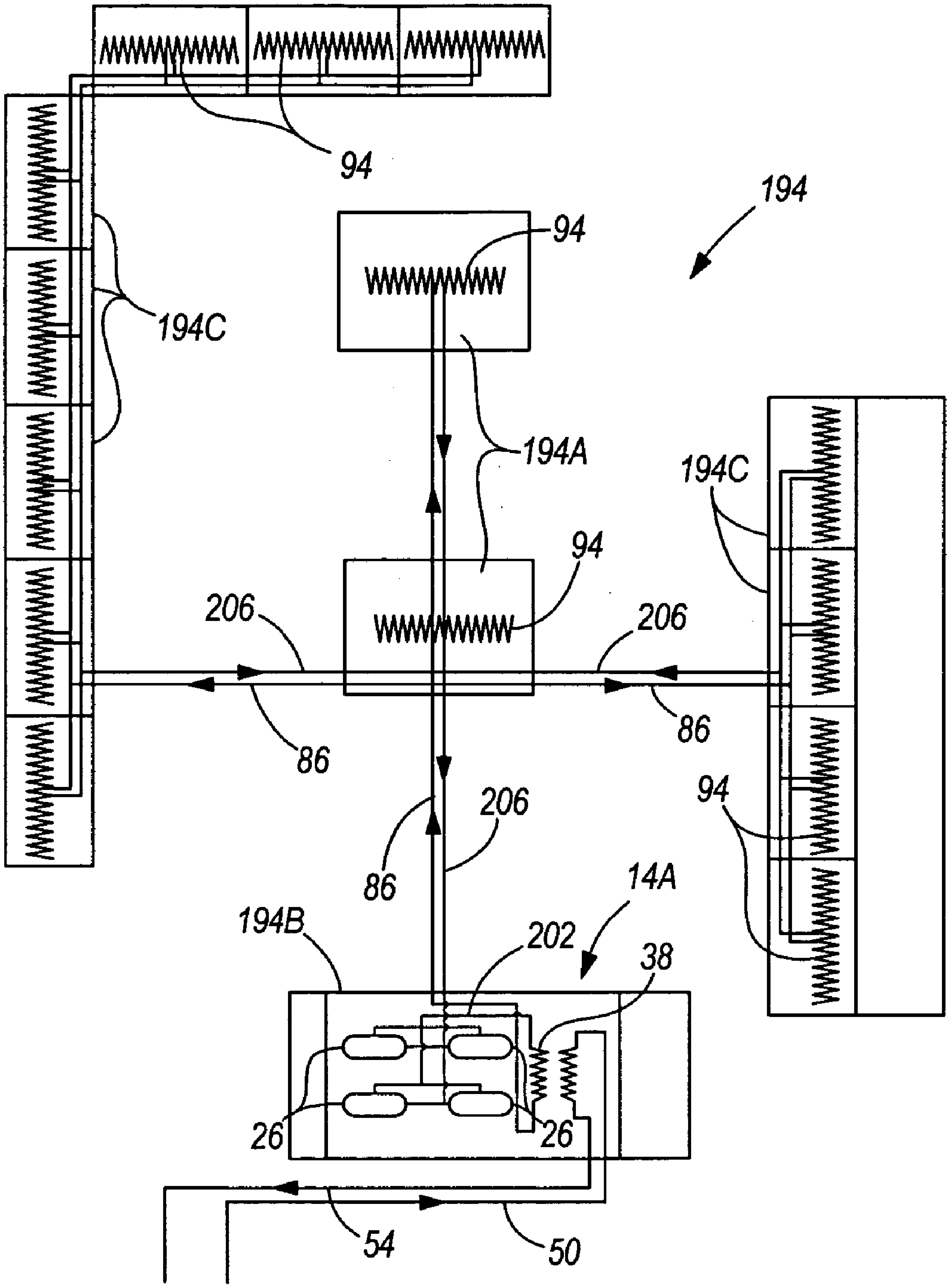
FIG. 8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194
94
194C
194A
194C
94
206
206
86
86
94
206
86
14A
194B
202
38
26
26
54
50

FIG. 9

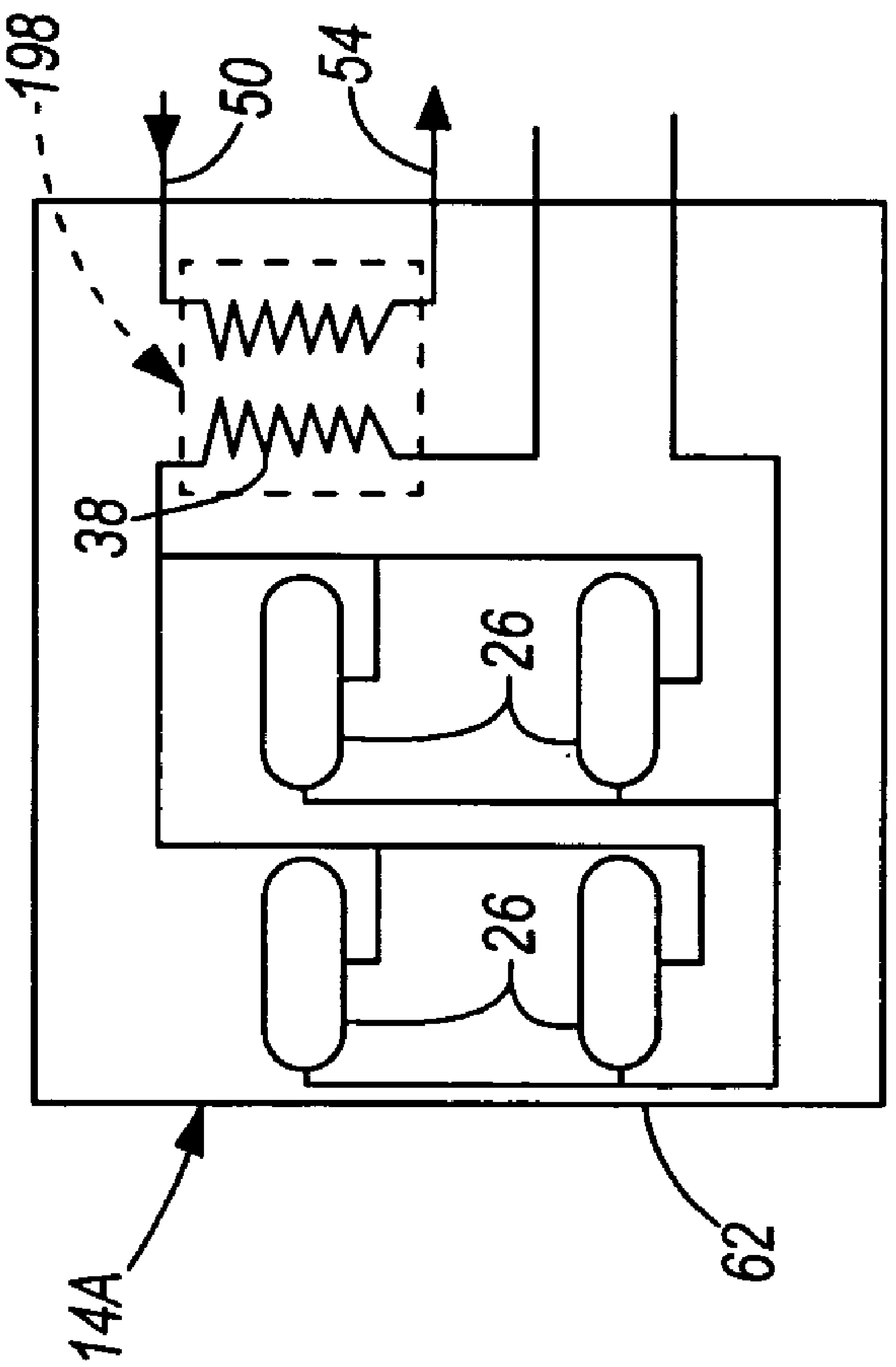
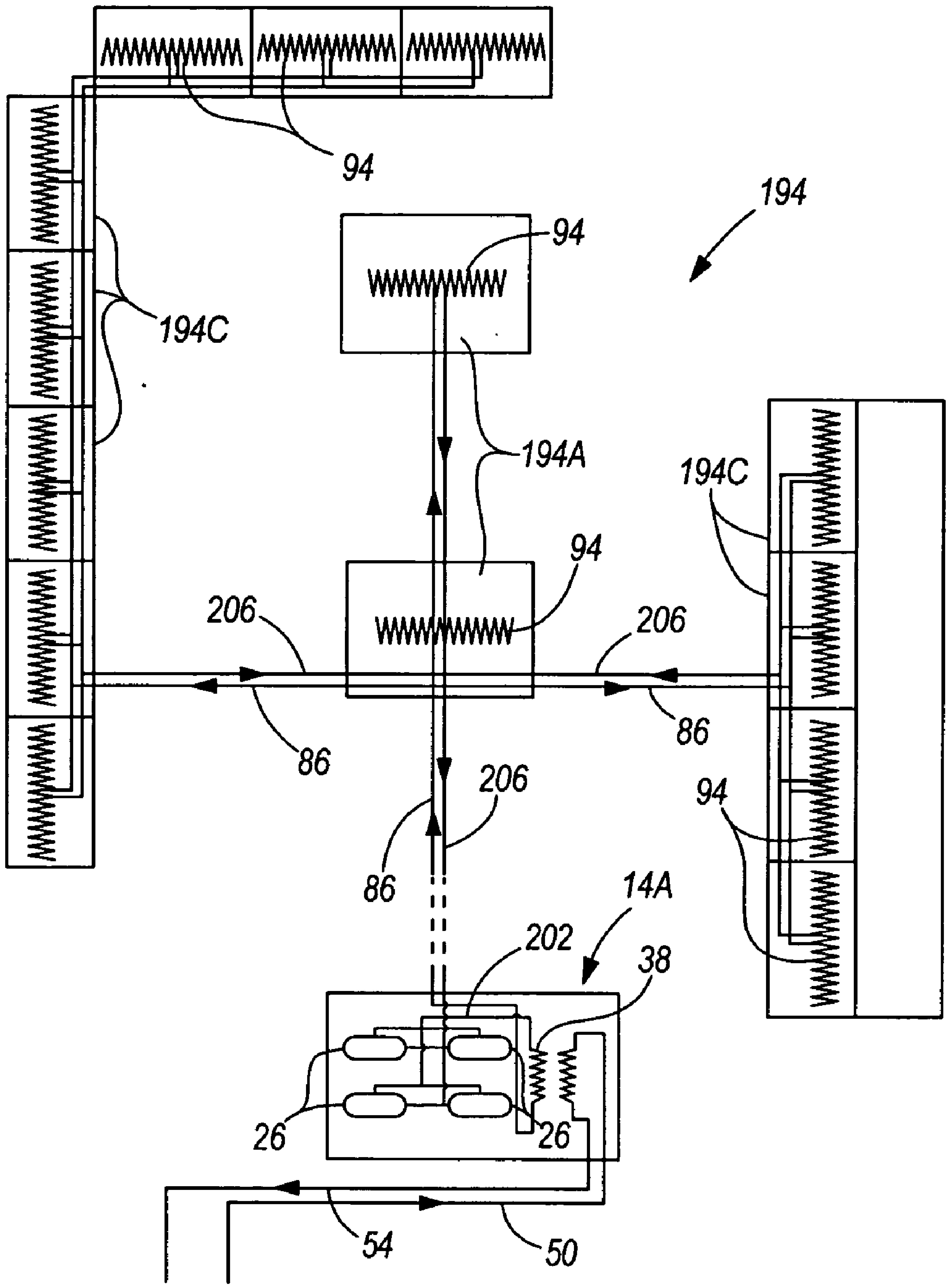


FIG. 9A



94
194
94
194C
194A
194C
94
206
206
86
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206
94
86
14A
202
38
26
26
54
50

FIG. 10

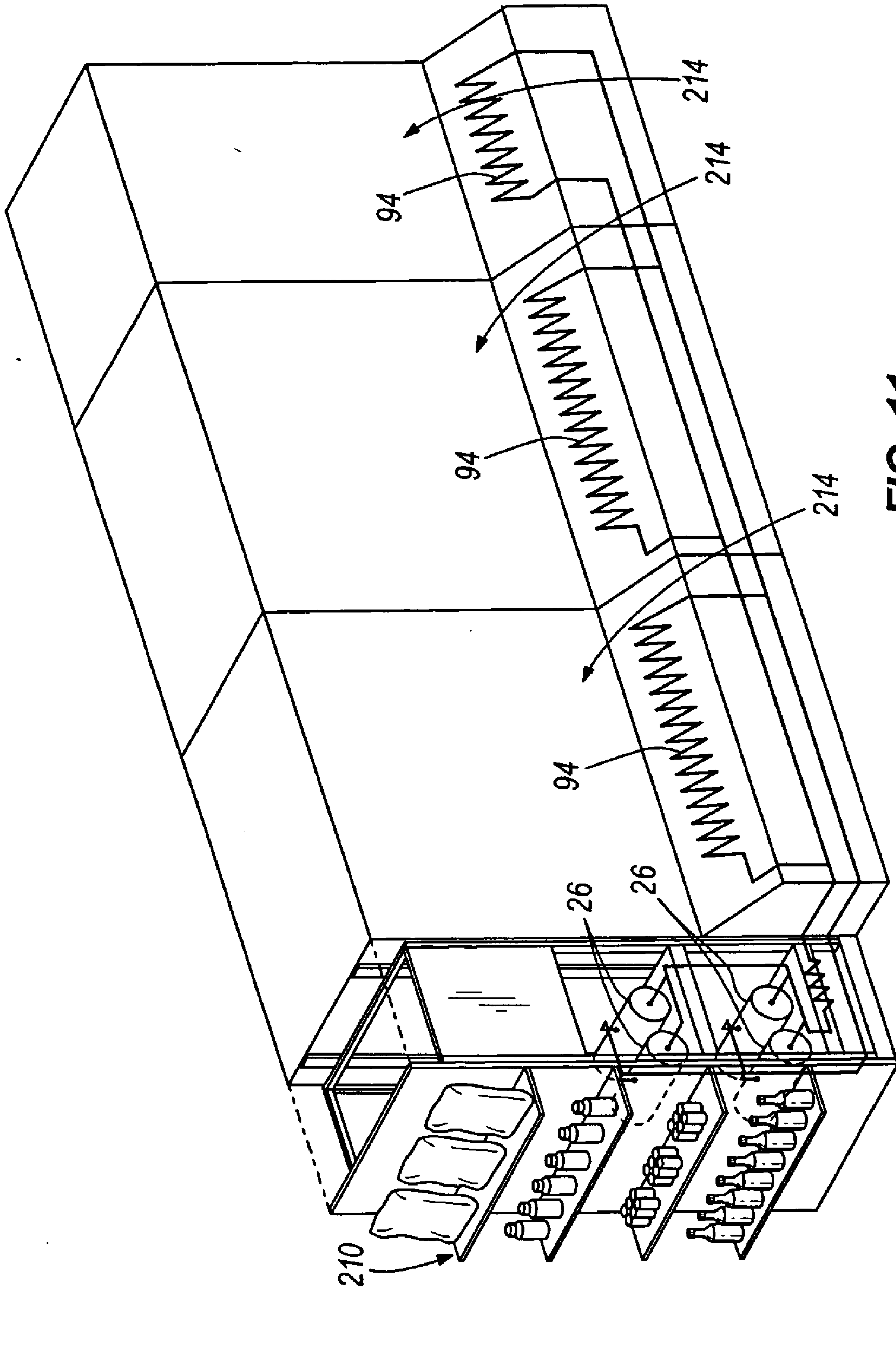

FIG. 11

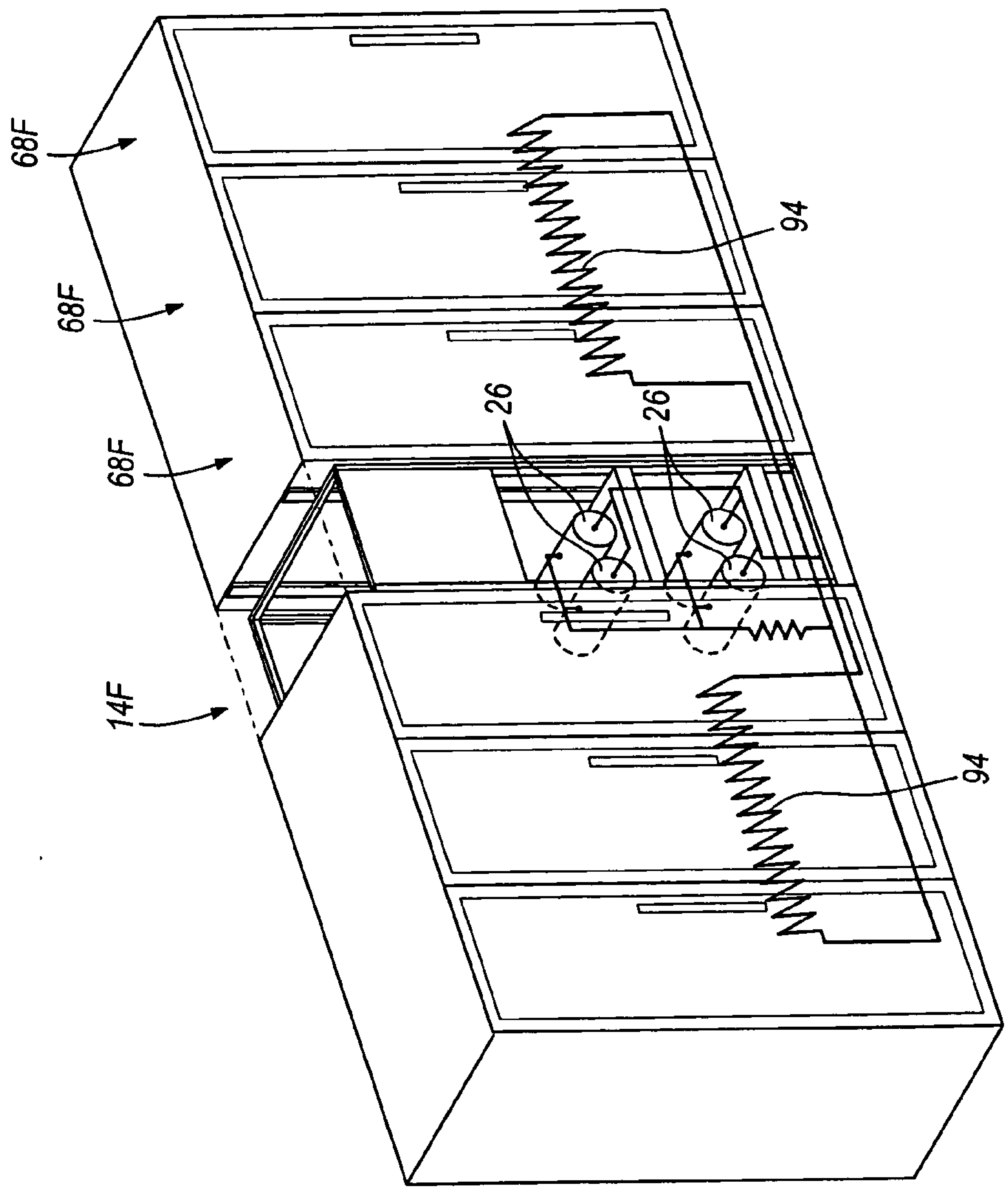

FIG. 12

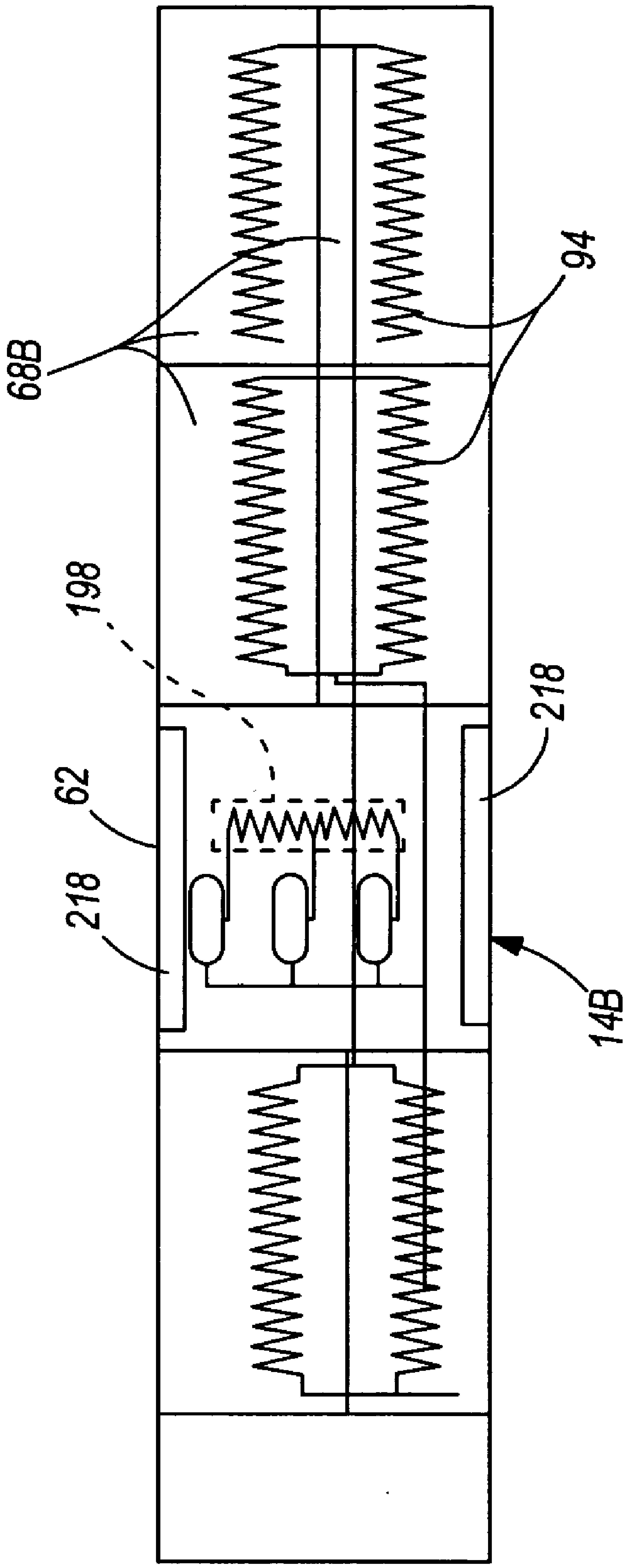

FIG. 13

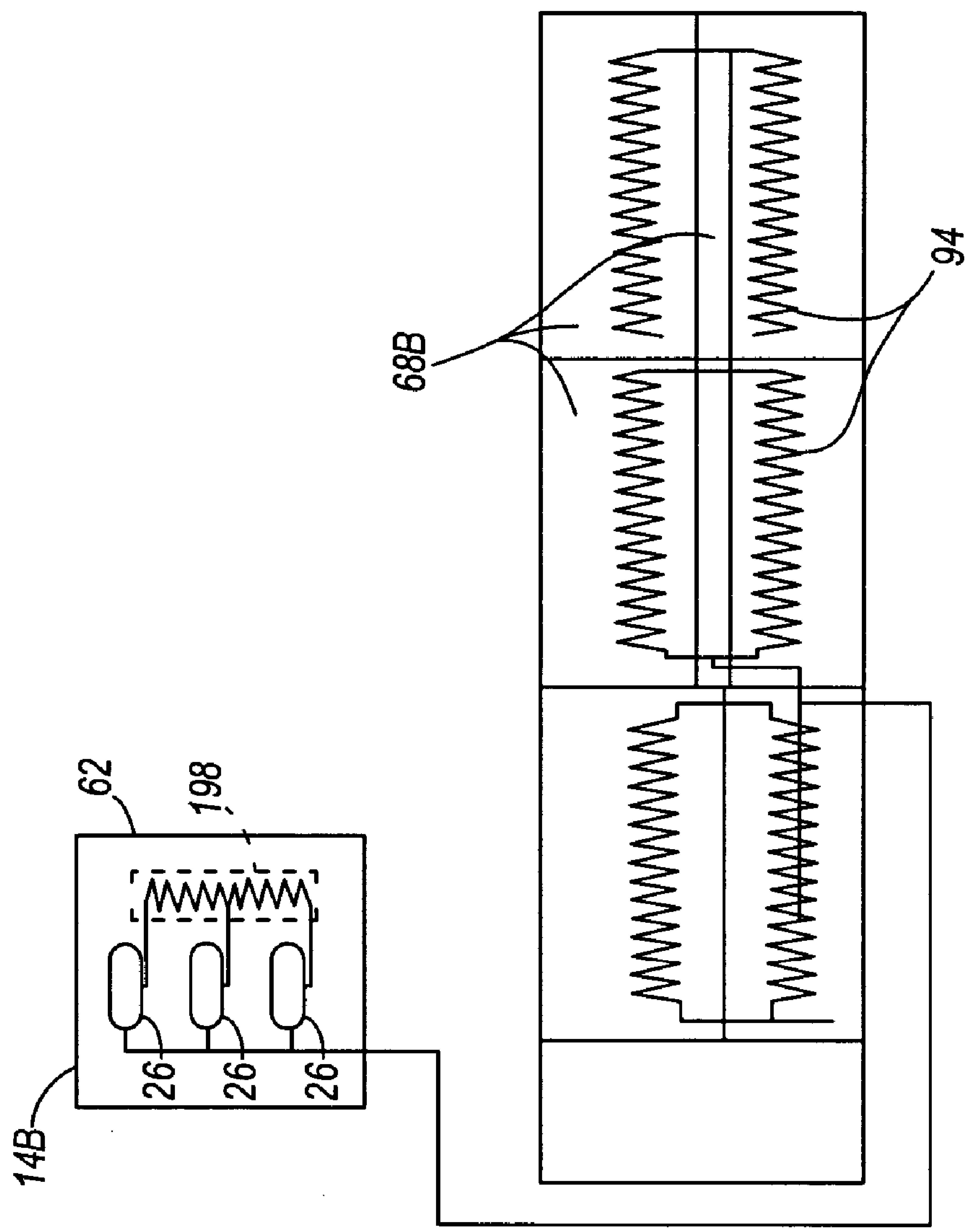

FIG. 14

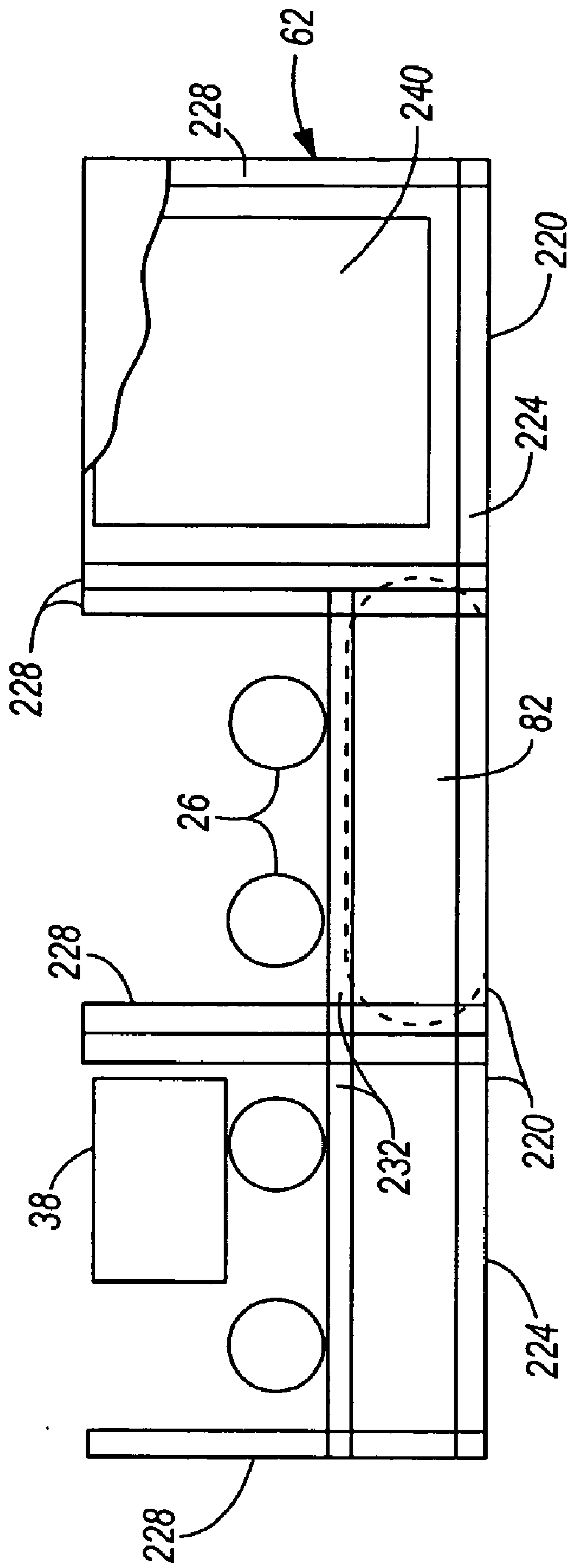

FIG. 15

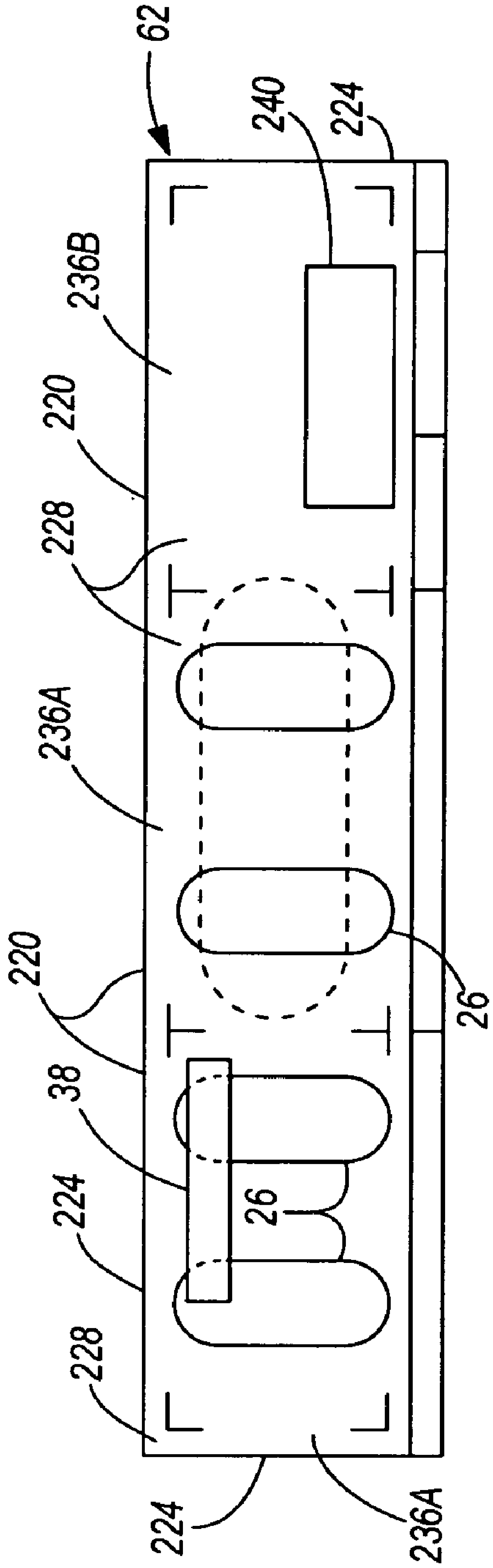

FIG. 15A

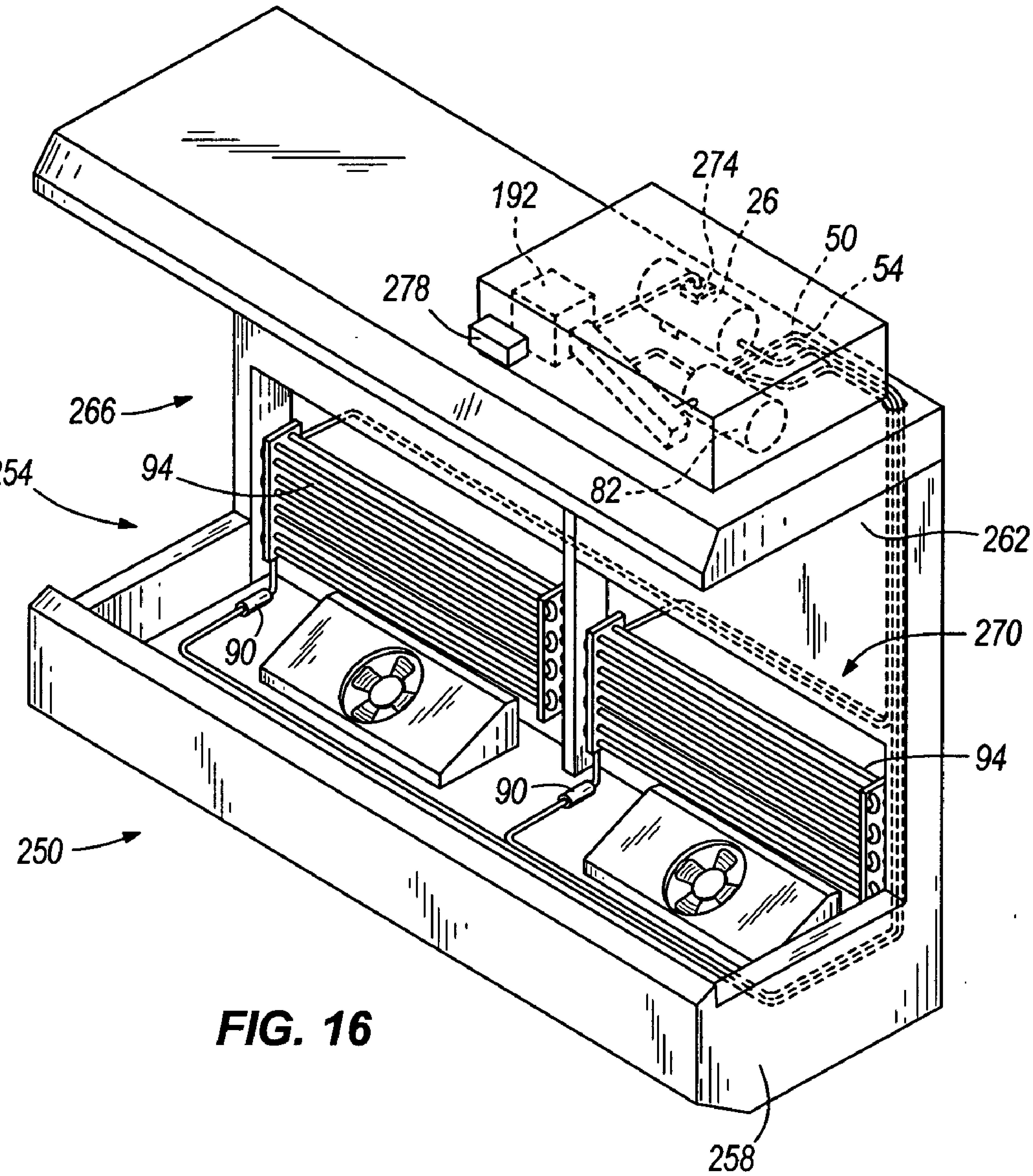

FIG. 16

STRATEGIC MODULAR REFRIGERATION SYSTEM WITH LINEAR COMPRESSORS

BACKGROUND

[0001] The present invention relates to commercial refrigeration systems, and in particular, commercial refrigeration systems having at least one linear compressor.

[0002] Commercial refrigeration systems have traditionally been accomplished via centralized parallel compressor systems with long liquid and suction branches piped to and from the evaporators in the refrigerated display cases. As an alternative, centralized parallel rack refrigeration systems have been developed for cooling a plurality of fixtures in multiple cooling zones within a shopping area. Another alternative is a self-contained, refrigeration display merchandiser including multiple horizontal scroll compressors.

[0003] A disadvantage to all these systems is the use of scroll compressors within the commercial refrigeration systems. Scroll compressors generate too much acoustic noise for the shopping area of a store and do not allow for variable capacity control of the refrigeration system. Because of the lack of variable capacity control, the compressor may perform unnecessary cycling, which may be detrimental to the stored commodity (e.g., sensitive food products) refrigerated by the merchandisers or refrigerated display cases. Further, scroll compressors use oil for operation, which results in inefficient performance due to oil film on evaporator and condenser surfaces, requires the use of expensive oil management components, and increases the installation cost of the refrigeration system.

[0004] It would be beneficial to have another alternative to the above systems and units utilizing scroll compressors.

SUMMARY

[0005] In one embodiment, the invention provides a modular commercial refrigeration unit constructed and arranged for placement in strategic proximity to a plurality of associated product cooling zones within a shopping area. The modular refrigeration unit includes a refrigeration rack proximate to a shopping area and configured to accommodate maximum refrigeration loads of the associated product cooling zones. The refrigeration rack has an optimum footprint. The refrigeration rack is constructed to support components of a closed refrigeration circuit including associated high side and low side refrigerant delivery and suction means extending from the rack and being operatively connected to a plurality of evaporators for cooling the associated product cooling zones. The modular refrigeration unit also includes a linear compressor and a cooling source remote from the refrigeration unit that provides a cooling relationship with a condenser for providing optimum condensing and efficiency of the evaporators in cooling the associated product cooling zones.

[0006] In another embodiment, the invention provides a modular refrigeration system including at least two refrigerated fixtures having first closely adjacent locations in a shopping area, at least one evaporator coil for cooling the refrigerated fixtures to maintain products therein within a predetermined temperature range, a linear compressor having a second location in close proximity to the refrigerated fixtures, and a condenser connected together with the linear compressor and the evaporator coils to form a closed loop refrigeration circuit. The modular refrigeration system also includes a heat exchange device located remote from the shopping area for transferring heat to an exterior atmosphere, and a closed heat transfer loop extending between the closed loop refrigeration circuit and the remote environment and interconnecting the heat exchange device and the condenser in continuous communication to transfer heat from the condenser to the heat exchange device.

[0007] In still another embodiment, the invention provides a commercial refrigeration network including a first modular refrigeration system unit in close strategic proximity to a first refrigerated product zone. The first modular refrigeration system unit includes a first refrigeration rack having first closed refrigeration circuit components including a linear compressor, high side receiver means and associated high side and low side refrigerant delivery, and suction means operatively connected to a first evaporator for cooling the first refrigerated zone. The first modular refrigeration system unit also includes a first condenser connected between the linear compressor and receiver means of the first closed refrigeration circuit. The commercial refrigeration network also includes at least one other modular refrigeration system unit in close strategic proximity to an associated other refrigerated product zone. The at least one other modular refrigeration system includes an other refrigeration rack having other closed refrigeration circuit components including a linear compressor, high side receiver means and associated high side and low side refrigerant delivery, and suction means operatively connected to an other evaporator for cooling the other refrigerated zone. The other modular refrigeration system unit also includes an other condenser connected between the linear compressor and receiver means of the other closed refrigeration circuit. Further, the commercial refrigeration network also includes a cooling source remote from the refrigeration unit that provides a cooling relationship with the first and other condensers for the respective first and other refrigeration system units.

[0008] In a further embodiment, the invention provides a commercial refrigeration network including a first refrigeration merchandiser, at least one other refrigeration merchandiser, and a cooling source. The first refrigeration merchandiser includes at least one first surface at least partially defining a first environmental space adapted to accommodate a commodity, first closed refrigeration circuit components, and a first frame. The first closed refrigeration circuit components include a free-piston linear compressor, a condenser, an expansion device, and an evaporator in fluid communication wherein the evaporator is in thermal communication with the environmental space to influence the temperature of the environmental space. The first frame supports the at least one first surface, the linear compressor and the evaporator. The at least one other refrigeration merchandiser includes at least one other surface at least partially defining an other environmental space adapted to accommodate a commodity, other closed refrigeration circuit components, and an other frame. The other closed refrigeration circuit components include a free-piston linear compressor, a condenser, an expansion device, and an evaporator in fluid communication wherein the evaporator is in thermal communication with the environmental space to influence the temperature of the environmental space. The other frame supports the at least one other surface, the linear compressor and the evaporator. The cooling source remote from the refrigeration unit provides a cooling relationship with the first and other condensers for the respective first and other refrigeration system units.

[0009] Other aspects and advantages of the invention will become apparent by consideration of the detailed description, claims and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** is a block diagram illustrating a modular commercial refrigeration network embodying the invention.

[0011] **FIG. 2** is a schematic flow diagram of a modular refrigeration system unit and coolant circulating system.

[0012] **FIG. 3** is a schematic flow diagram of a refrigeration system unit and coolant circulating system located remotely from the respective refrigeration loads.

[0013] **FIG. 4** is a schematic flow diagram of a modular refrigeration system unit with an air cooled condenser.

[0014] **FIG. 5** is a representative supermarket floor plan illustrating the strategic placement of dedicated modular refrigeration system units relative to the respective refrigeration loads and positioned remotely of the respective refrigeration loads.

[0015] **FIG. 6** is a sectional view of a dual opposing, free-piston linear compressor used in a refrigeration unit, which shows the compressor at an intake stroke.

[0016] **FIG. 7** is a sectional view of a dual opposing, free-piston linear compressor used in a refrigeration unit, which shows the compressor at neutral.

[0017] **FIG. 8** is a sectional view of a dual opposing, free-piston linear compressor used in a refrigeration unit, which shows the compressor at a compression stroke.

[0018] **FIG. 9** is an enlarged supermarket floor plan illustrating a department with a dedicated modular refrigeration unit having multiple linear compressors.

[0019] **FIG. 9A** is a top plan view of the refrigeration unit of **FIG. 9** illustrating a heat exchanger network with a cooling liquid source.

[0020] **FIG. 10** is an enlarged supermarket floor plan illustrating a department with merchandisers and a dedicated refrigeration unit having multiple linear compressors located remotely from the merchandisers.

[0021] **FIG. 11** is a diagrammatic perspective view showing an open front refrigerated merchandiser lineup and associated vertical modular refrigeration unit.

[0022] **FIG. 12** is another diagrammatic perspective view showing a lineup of reach-in merchandisers strategically incorporating a vertical modular refrigeration unit.

[0023] **FIG. 13** is a plan view of a lineup of wide island cases showing a linear compressor arrangement in the associated modular refrigeration unit.

[0024] **FIG. 14** is a plan view of a lineup of wide island cases with an associated refrigeration unit including multiple linear compressors located remotely of the wide island cases.

[0025] **FIG. 15** is a diagrammatic side elevational view illustrating a modular refrigeration rack for a refrigeration unit with multiple linear compressors.

[0026] **FIG. 15A** is a diagrammatic plan view of the modular refrigeration rack of **FIG. 15**.

[0027] **FIG. 16** is a perspective view of two refrigeration merchandisers and further showing elements of the refrigeration cycle of the merchandisers.

[0028] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including,""comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted,""connected,""supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

[0029] For purposes of disclosure, the term "high side" is used herein in a conventional refrigeration sense to mean a portion of a system from the compressor discharge to the evaporator expansion valves, and the term "low side" means the portion of the system from the expansion valves to the compressor suction. Also, "low temperature" as used herein shall have reference to evaporator temperatures in the range of about −35° F. to about −5° F., or the associated product temperatures in the range of about −20° F. to about 0° F. Further, "normal temperature" as used herein means evaporator temperatures in the range of about 15° F. to about 40° F., or the associated non-frozen product temperatures in the range of about 25° F. to about 50° F. "Medium temperature" is also used interchangeably for "normal temperature" in the refrigeration industry.

DETAILED DESCRIPTION

[0030] **FIG. 1** illustrates an inventive commercial refrigeration network **10** diagrammatically. The commercial refrigeration network **10** includes a plurality of modular refrigeration system units **14** constructed and arranged for placement in strategic proximity to corresponding product cooling zones within a commercial space **18** (e.g., a foodstore, supermarket, etc.). The location of the refrigeration units **14** may be within or remote from a customer shopping area **22** of the commercial space **18**. In **FIG. 1**, two modular refrigeration units **14**A and **14**B are shown within the shopping area **22**, and one modular refrigeration unit **14**C is shown outside of the shopping area **22**. Each refrigeration system unit **14**, or merchandiser, includes at least one linear compressor **22** (shown in **FIG. 2**) and is sized to efficiently maintain its associated discrete cooling zone at optimum refrigeration temperatures. Each of the cooling zones comprises one or more of the store coolers, freezers, preparation rooms or display merchandisers. A cooling zone is typically an area, department, or lineup of merchandising fixtures operating at substantially the same temperature.

[0031] The refrigeration network **10** includes a coolant circulating system **30** constructed and arranged to circulate a cooling fluid or coolant from a remote source **34** to a respective refrigeration unit condenser/heat exchanger **38**. The circulation of a controlled coolant in a heat exchange relationship with the unit condensers provides optimum condensing and refrigeration efficiency of the evaporators in cooling their respective product zones. The coolant system **30** derives a cooling liquid, such as chemically treated water or a glycol solution, from one or more sources **34** and circulates the cooling liquid by at least one pump **42** through a distribution arrangement. In the illustrated embodiment, the distribution arrangement includes a distribution manifold **46** and branch coolant delivery lines or conduits **50** to the condenser/heat exchanger **34** of each modular unit **14**. For example, and as shown in **FIGS. 2, 3**, and **16**, a secondary fluid (e.g., a liquid) provided by the fluid-input line **50**, or conduits, cools the condenser **38**. At least two alternate cooling sources **34**A, **34**B are illustrated as an arrangement to assure a back-up condenser cooling system. Branch return conduits **54**, or a fluid-output, and a return manifold **58** carry away the coolant fluid with the exchanged heat of rejection from the respective refrigeration unit condensers **38** for dissipation externally of the shopping area **22**.

[0032] The coolant sources **34**A, **34**B, **34**C, **34**D may be a single fluid cooling apparatus, such as a closed or open loop roof top cooling tower, a ground source water supply, a dedicated normal temperature refrigeration system, a chiller system or recirculating water source, or a combination of such alternate fluid cooling sources to assure a continuous supply of coolant at a substantially constant temperature, as will be discussed below. In an embodiment including multiple modular refrigeration units **14**, the refrigeration units **14** derive their respective condenser cooling from a common liquid cooling source **34** remote from the modular refrigeration units **14** in the shopping area **22**. In one embodiment, the heat exchanger is of the plate-to-plate type for optimal heat transfer of the heat of rejection transferred from the product zone through the unit condensers **38** to the coolant, which then carries the cumulative heat load in a heated coolant return mode for dissipation externally of the shopping area **22**. It will be readily apparent to those skilled in the art that the heat of rejection and the heat of compression from the linear compressors may be utilized for seasonal heating of the supermarket.

[0033] As will be discussed further below, the fluid can also be used to cool other components of the refrigeration unit **14**. In other embodiments, the merchandiser **14** includes a fan if the condenser **38** is air-cooled.

[0034] The modular nature of the refrigeration units **14** utilizes three basic variable forms of the refrigeration unit **14**: a vertical compressor configuration, such as **14**C (shown in **FIGS. 1, 11, 12**); a horizontal compressor configuration, such as **14**B (shown in **FIGS. 1, 2, 9, 13, 15**); and a combination or mixed horizontal and vertical compressor configuration, such as **14**A (shown in **FIGS. 1, 12, 16**).

[0035] During a refrigeration cycle, the linear compressor **26** compresses a refrigerant, resulting in the refrigerant increasing in temperature and pressure. The compressed refrigerant is sent out of the linear compressor **26** as a high-temperature, high-pressure heated gas. The refrigerant travels to a condenser **38** (shown in **FIG. 2**). The condenser **38** changes the refrigerant from a high-temperature gas to a warm-temperature gas/liquid, which maintain the associated discrete cooling zones at an optimum refrigeration temperature. As discussed above, air and/or a liquid are used to help the condenser **38** with this transformation.

[0036] **FIG. 2** is a schematic flow diagram of a modular refrigeration unit **14** and coolant circulating system **30**. In **FIG. 2**, each of the modular refrigeration units **14** includes a refrigeration rack **62** constructed and arranged to mount and support the operative components of a closed refrigeration circuit **66**. The closed refrigeration circuit **66** is dedicated to refrigeration load requirements of its associated discrete product cooling zone **68**. In the illustrated embodiment, the refrigeration rack **62** includes four linear compressors **26** connected in parallel. In further embodiments, at least one and up to ten linear compressors **26** may be included in the refrigeration unit **14** and supported by the refrigeration rack **62**. The linear compressors **26** are connected by a discharge header **70** to a diverting valve **74**. The diverting valve **74** selectively connects the discharge header **70** to a heat recovery means, such as a heat reclaim coil **78** or a hot water exchanger (not shown), or directly to the system condenser **38** located on the refrigeration rack **62**. In the illustrated embodiment, a liquid receiver **82** is connected to the condenser **38** to receive the condensate outflow from the condenser **38**.

[0037] The high side of the refrigeration circuit **66** is connected by liquid lines **86** to evaporative expansion valves **90** at each evaporator **94** associated with a discrete product cooling zone **68** to be cooled. On the low side, the refrigerant expands and vaporizes in the merchandiser evaporators **94** removing heat from the product zone **68** to maintain the preselected desired cooling. The outlets of the evaporators **68** connect to a common suction header or manifold **98**. The suction manifold **98** connects to the suction side of the compressors **26** to complete the refrigeration circuit **66**. It will be readily apparent to those skilled in the art that individual modular refrigeration units **14** may generally include other system components, such as defrost system means, system performance sensing and operating control panel, microprocessor apparatus, alarm systems and the like.

[0038] **FIG. 2** illustrates a unit heat reclaim coil **78** as part of the closed refrigeration circuit **66** of the refrigeration unit **14**. Such a heat reclaim coil **78** is generally housed in a conventional store air handler (not shown) for seasonal air conditioning and environmental heating of the store, but may be located remotely as a water heating unit (not shown). Due to the modularity of the refrigeration units **14** and their proximate location to their respective cooled product zones, it is contemplated that unit heat reclaim coils **78** may be strategically located under selected merchandisers or the like for environmental shopping arena heating. It will be readily apparent that a heat reclaim coil **78** is typically designed to function as a pre-condenser that removes heat from the compressed vaporous refrigerant on the high side upstream of the system condenser. The heat reclaim coil **78** does not reduce the refrigerant vapor to its saturated condensing temperature, because this is the final function of the condenser **38** at the unit heat exchanger.

[0039] The use of linear compressors **26** in the refrigeration units **14** provides for oil-free operation of the refrigeration system and gives performance and cost advantages over existing systems. Linear compressors **26** used in the refrigeration units **14** eliminate the need for oil management components (such as oil separators, oil controls, oil safety devices, etc) within the refrigeration system. Heat transfer within the refrigeration system is improved due to the absence of an oil film on evaporator and condenser surfaces. Further, installation costs are lower due to the elimination of the need for suction traps. The use of linear compressors **26** in the refrigeration units **14** also provides for continuously variable capacity of the refrigeration loads from about 30% to 100% (discussed below with respect to **FIGS. 6-8**), as compared to existing systems utilizing scroll compressors.

[**0040**] In the embodiment illustrated in **FIG. 2**, the modular refrigeration unit **14** is strategically placed in the commercial space **18** in close proximity to the dedicated cooling zone **68** of an associated merchandiser department or case lineup. In another embodiment illustrated in **FIG. 3**, the components of the closed refrigeration circuit **66** are located remotely of the dedicated cooling zone **68**, such as in a service area **102** (shown in **FIG. 5**) of the commercial space **18**. In some embodiments, the closed refrigeration circuit components, including the linear compressors **26**, are not arranged on a refrigeration rack and instead are positioned separately to form the closed refrigeration circuit **66**.

[**0041**] In another embodiment illustrated in **FIG. 4**, the modular refrigeration unit **14** includes an air cooled condenser **38** located remotely of the refrigeration rack **62**, for example on a roof of the commercial space **18**. A fan **100** mounted to or within the condenser **38** provides cooling to the refrigerant passing through the condenser. An air cooled condenser is an alternative cooling means from the coolant circulating system **30** shown in **FIGS. 2 and 3**. In further embodiments, the air cooled condenser **38** may be located remotely from the commercial space **18** or in the service area **102** of the commercial space **38**.

[**0042**] **FIG. 5** is a representative supermarket floor plan illustrating the strategic placement of dedicated modular refrigeration system units **14** relative to the respective refrigeration loads, as well as refrigeration units **14** located remotely from the respective refrigeration loads in a service area **102** of the commercial space **18**. In the embodiment illustrated in **FIG. 5**, refrigeration unit **14**A is a medium temperature system servicing the produce department merchandisers **68**A operating at temperatures in the range of about 45° F. to about 50° F. (see also **FIG. 9**). Refrigeration unit **14**B is a low temperature system dedicated to maintain ice cream product temperatures of about −20° F. in twin island "coffin" type merchandisers **68**B in the shopping area **22**. Although the refrigeration unit **14**B is located in the service area **102**, in further embodiments it may be located proximate the merchandisers **68**B (see also **FIG. 13**). Refrigeration unit **14**C is a low temperature system for a dual back-to-back lineup of frozen food reach-in merchandisers **68**C within the shopping area **22** (see also **FIG. 11**). Refrigeration unit **14**D is a low temperature system dedicated to maintain frozen meat products in a meat freezer (cooling zone **68**D) located in the service area **102** outside of the shopping area **22**. Refrigeration unit **14**E is a medium temperature system located in the service area **102**, but immediately adjacent to its discrete service load of multi-deck meat merchandisers **68**E in the shopping area **22**. Refrigeration unit **14**F is a medium temperature system for a lineup of non-frozen reach-in product fixtures **68**F in the shopping area **22**. Refrigeration unit **14**G is a medium temperature system also located in the service area **102**, but constructed and arranged to service both a deli walk-in cooler **68**G**1** in the service area **102** and a deli merchandiser lineup **68**G**2** in the shopping area **22**. Refrigeration unit **14**H is a medium temperature system for servicing a line of multi-deck produce merchandisers **68**H. In the illustrated embodiment, the refrigeration unit **14**H is located in the service area **102**, however, in another embodiment the refrigeration unit **14**H is located proximate the merchandisers **68**H (see also **FIG. 11**). Refrigeration unit **14**I is a low temperature system dedicated to an ice cream walk-in freezer **68**I in the service area **102**. Finally, refrigeration unit **14**J is a medium temperature system associated with a dairy department lineup of multi-deck merchandisers **68**J. In the illustrated embodiment, refrigeration unit **14**J is located in the service area **102**, however, in another embodiment the refrigeration unit **14**J is located proximate the merchandisers **68**J.

[**0043**] It will be readily apparent to those skilled in the art that a typical supermarket layout may also include a refrigerated floral merchandiser, an in-store bakery with coolers and retarder units, a seafood department and other non-refrigerated departments, dry goods shelving, customer checkout area and the like. As illustrated in **FIG. 5**, the conventional compressor machine room of existing supermarkets is eliminated in favor of the modular refrigeration units **14**A-**14**J strategically located in and around the shopping area **22** and in the service area **102** of the commercial space **18**. The refrigeration units **14** are specifically dedicated to discrete refrigeration loads. Those refrigeration units **14** located in close proximity to an associated group of storage or display merchandising zones operate at the same temperature and form the discrete load. In further embodiments, the service area **102** of the commercial space **18** may have a separate compressor machine room (not shown) for housing the linear compressors **26**. However, the use of linear compressors **26** results in virtually no vibration, therefore, the need for a separate space to acoustically isolate the compressors is not necessary.

[**0044**] As described herein, the refrigeration systems, refrigeration units, and merchandisers include at least one linear compressor **26**. It is envisioned that, in some embodiments, the linear compressor is a free-piston linear compressor, and in at least on envisioned embodiment, the free-piston linear compressor is a dual-opposing, free-piston linear compressor. A dual-opposing, free-piston linear compressor is obtainable from Sunpower, Inc. (Athens, Ohio, USA). Another example of a dual-opposing, free-piston linear compressor is disclosed in U.S. Pat. No. 6,641,377, issued Nov. 4, 2003, the content of which is incorporated herein by reference.

[**0045**] The free-piston linear compressor has some basic differences over conventional rotary compressors. The free-piston device is driven by a linear motor in a resonant fashion (like a spring-mass damper) as opposed to being driven by a rotary motor and mechanical linkage. One advantage with the linear motor is that the side loads are small, which greatly reduces friction and allows use of simple gas bearings or low-viscosity oil bearings. In addition, since friction has been greatly reduced, the mechanical efficiency of the device is greater, internal heat generation is lower, and acoustic noise is reduced. Additionally, inherent variable piston stroke allows for efficient capacity modulation over a wide range. For example, linear compressors have continuously variable capacity from about 30% to 100% by adjusting piston stroke. In constructions having dual-opposing pistons, the pistons vibrate against each other (i.e., provide a mirrored system) to virtually cancel all vibration. This reduces the acoustic noise of the linear compressor even further than a single piston linear compressor.

[0046] **FIGS. 6, 7**, and **8** show three sectional views of a dual-opposing linear compressor **110** capable of being used with the modular refrigeration systems, refrigeration units and merchandisers described above. **FIG. 6** shows the compressor **110** at an intake stroke, **FIG. 7** shows the compressor **110** at neutral, and **FIG. 8** shows the compressor **110** at a compression stroke. As shown in **FIGS. 6-8**, the dual-opposing linear compressor **110** includes a housing **114** supporting a main body block **118**. Inner and outer laminations **122** and **126** are secured to the main body block **118** and coils **130** are wound on the outer laminations **126**, thereby forming stators. The stators, when energized, interact with magnet rings **134** mounted on outer cylinders **138**. The outer cylinders **138** are fastened to pistons **142**, which are secured to springs **146**. The interaction between the magnet rings **134** and the energized stators results in the outer cylinders **138** moving the pistons **142** linearly along an axis of reciprocation **150**.

[0047] When the pistons **142** are at the intake stroke, refrigerant is allowed to flow from a suction port **154** through channels **158** into a compression space **162** (best shown in **FIG. 6**). When moving from the intake stroke to the compression stroke, valves **166** (best shown in **FIG. 7**) close the channels, and the refrigerant is compressed out through discharge valve **170** and discharge port **174** (best shown in **FIG. 8**). The linear motor allows for variable compression (e.g., from approximately 30% to 100%) by the pistons **142**, and therefore, the linear compressor **110** provides variable capacity control. In other words, the linear motors can cause the pistons **142** to move a small stroke for a first volume, or to move a larger stroke for a second, larger volume. The linear compressors **110** provide a variable refrigeration capacity (e.g., by varying piston stroke) balanced to the refrigeration loads imposed by the associated product cooling zones **68**. Accordingly, the refrigeration units **14** allow for variable loads, decrease compressor cycling, and reduce temperature swings.

[0048] In some embodiments, the linear compressor **110** includes a jacket **178** (shown in phantom) enclosing at least a portion of the housing **114**. The jacket **178** includes a fluid-input port **182** and a fluid-output portion **186**, and provides a plenum **190** containing a cooling fluid, thereby providing a fluid-cooled compressor. Other arrangements for cooling the compressor with a fluid are possible.

[0049] An example of a compressor controller for use with the dual-opposing, free-piston linear compressor shown in **FIGS. 6-8** is disclosed in U.S. Pat. No. 6,536,326, issued Mar. 25, 2003, the content of which is incorporated herein by reference. It is also possible for the coolant fluid to be used for cooling a controller **192** (shown in **FIG. 11**). Similar to the linear compressor, a jacket having input and output ports can be used to surround a housing of the controller.

[0050] An example of refrigeration unit **14**A and its associated refrigerated zone **68**A is illustrated in **FIGS. 9 and 9**A. The cooling zone illustrated is a medium temperature produce section or department **194** of a supermarket. The illustrated cooling zone **194** includes two refrigerated produce tables **194**A, one unrefrigerated produce table **194**B (used for products not requiring refrigeration), and one or more lineups of multi-deck or gondola produce merchandisers **194**C. The refrigeration unit **14**A may be concealed under one of the refrigerated tables **194**A, in the base of the unrefrigerated produce table **194**B, or in a merchandiser lineup **194**C. The refrigeration unit **14**A may be accessed by removing a front panel of the merchandiser, or by constructing and arranging a table top of the merchandiser to be hinged for vertical lifting movement or for horizontal side movement thereon. In the illustrated embodiment, the refrigeration rack **62** is constructed and arranged to support four linear compressors **26** in a combination arrangement of two pairs of horizontally disposed compressors in side-by-side relationship. The linear compressors are connected in parallel and may be operated individually, cyclically or variably to keep the merchandiser temperatures constant. **FIG. 9A** shows that the condenser **38** of the modular unit **14**A is part of a heat exchanger **198** containing a coolant loop having cool coolant delivery mode **50** and a warm coolant return mode **54**.

[0051] **FIG. 10** is an alternate configuration of the cooling zone **194** shown in **FIG. 9**. **FIG. 10** illustrates a refrigeration system having refrigeration components located remotely of the associated refrigerated zone **68**A. The refrigeration components may be located on a refrigeration rack **62** or positioned independently to form the closed refrigeration circuit **66**. Referring to **FIGS. 9 and 10**, a discharge conduit **202** connects the compressor head manifold **70** (i.e., discharge header) to the unit condenser **38** on the refrigeration rack **62**. The condenser **38** connects through the system receiver-accumulator **82** (shown in **FIG. 2**) to the liquid line conduits **86** that extend in short runs from the refrigeration unit **14**A beneath the floor to the evaporators **94** in the merchandisers **194**. A suction conduit **206** returns the vaporized refrigerant liquid to the compressors **26**. In the illustrated embodiment, a coolant delivery line **50** from the remote cooling liquid source **34** (shown in **FIG. 1**) is piped beneath the floor or overhead to the refrigeration rack **62** for removing the heat of rejection and compression from the unit condenser **38** in the heat exchanger **198**. Further, a coolant return line **54** is provided to expel this heat to a location exterior of the supermarket. In a further embodiment of the refrigeration unit **14**A shown in **FIGS. 9 and 10**, the condenser is air cooled and located remotely of the refrigeration unit **14**A.

[0052] Additional configurations of the linear compressors **26** accommodated by the modular refrigeration racks **62** and their associated discrete refrigeration loads are shown in **FIGS. 11-14**. In each embodiment, all of the closed refrigeration circuit components are rack mounted except for the merchandiser **68** or other zone evaporators **94** and associated refrigerant control and sensing means. Examples of other equipment not mounted on the refrigeration rack include expansion valves **90** and defrost control valves (not shown), as well as connecting discharge and suction lines between the evaporators and the refrigeration system racks.

[0053] In **FIG. 11**, the modular refrigeration unit **14** utilizes a vertical linear compressor unit that is positioned behind a shelving unit **210**. The shelving unit **210** is arranged to cover one side of the modular refrigeration unit **14** when positioned at the end of a merchandiser lineup, such as the open front multi-deck merchandisers **214** shown in **FIG. 11**. **FIG. 12** illustrates lineups of reach-in merchandisers, such as merchandiser **68**F, in which the modular refrigeration units and refrigeration racks are interposed into the middle of the lineups. In **FIG. 12**, the refrigeration unit **14**F includes a vertical stack of linear compressors **26**.

[0054] **FIG. 13** illustrates another configuration of a horizontal linear compressor unit centrally located between parallel rows or twin island coffin merchandisers **68**B of the type used for ice cream or other frozen products. The three linear compressors **26** are arranged on a horizontal line in the modular refrigeration unit **14**B and at least one exterior side of the refrigeration rack **62** has a removable panel **218** that can be replaced after service. In the embodiment illustrated in **FIG. 14**, the refrigeration unit **14**B and the refrigeration rack **62** are positioned remotely from the parallel rows or twin island coffin merchandisers **68**B, oftentimes in a service area **102** (shown in **FIG. 5**) of the commercial space **18**.

[0055] The location of the modular refrigeration units **14**, whether in the shopping area **22** or in the service area **102** of the commercial space **18**, are in close proximity to the associated refrigeration loads serviced by the respective units. Such placement greatly reduces the amount of refrigerant needed and the length of piping needed to carry the refrigerant to all the product merchandisers. The placement of the refrigeration units **14** in the shopping area **22** is commercially feasible only if the acoustic noise from the compressors is substantially eliminated or reduced to acceptable decibel levels. As discussed above, the use of linear compressors in the refrigeration units reduces the acoustic noise of the refrigeration unit and virtually cancels all vibration of the unit, as compared to compressors used in prior art systems.

[0056] The modularity of the refrigeration racks **62** for forming variant refrigeration unit arrangements is described with respect to **FIGS. 15 and 15**A. In the illustrated embodiment, the refrigeration rack **62**, for a horizontal linear compressor unit, includes a series of similar frame modules **220**. Each frame module **220** includes a main frame having lower or first level horizontal structural members **224** forming a rectangular base and vertical struts **228**, or stanchions, located at the corners of the base **224**. **FIGS. 15 and 15**A illustrate a four linear compressor unit with three frame modules **220** joined together. The two leftward modules also include upper or second level horizontal structural member **232** secured to the vertical stanchions **228** in spaced relation above the lower base level **224**. Each frame module **220** is provided with a horizontally extending metal support or mounting plate **236** that is preformed to receive and secure specific components of the closed refrigeration system. In the illustrated embodiment, the leftward mounting plates **236**A are each constructed and arranged to mount two linear compressors **26**. It will be readily apparent that the condenser/heat exchanger **38** and the receiver **82** are also accommodated by the modular refrigeration rack arrangement. The rightward unit **236**B is designed to mount a control panel **240** for operating the associated refrigeration system of the modular refrigeration unit.

[0057] It will also be readily apparent to those skilled in the art that the same base frame module **220**, lower level base frame **224**, vertical struts **228**, second level frame **232**, and mounting plate **236** may be used to form a vertically arranged refrigeration rack or a combination refrigeration rack. The embodiment shown and described with respect to **FIGS. 15 and 15**A is illustrative only. The refrigeration rack may assume other configurations, such as a vertical linear compressor arrangement in which single linear compressors **26** are stacked one above the other in a tier that affords a minimum floor space footprint and excellent accessibility for service.

[0058] The modular refrigeration unit **14** includes a single electrical junction to the refrigeration rack that permits the connection of all system components as well as local wiring control over the ancillary merchandiser electrical equipment (e.g., lighting, fans, antiswear heaters) for wiring from the same location. Only a single power circuit is required to extend from a remote power source (not shown) to the unit junction box usually associated with the control panel **240**. In the illustrated embodiment, the junction box is connected to the control panel that contains a remotely activated contactor and circuit breaker system for providing distributed electrical power via buss arrangement to the electrical components in the system.

[0059] In one embodiment, each of the modular refrigeration units is monitored and controlled by a personal computer linked to a microprocessor within the control panel **240**. The control system is conventional, except that the linear compressors are located around the commercial space, and are supplemented by individual control systems (i.e., microprocessors) associated with each rack. Interrogation of individual units to diagnose problems and override of the general control functions for purposes of testing and repair is accomplished at the specific refrigeration units. To reduce duplication of components such as visual system readouts on each control panel, it is envisioned that a hand-held monitor would be used to plug into the microprocessor and provide a visual readout of its settings and conditions.

[0060] The modularity of the refrigeration units **14** and the refrigeration racks **62** reduces the time and cost of installing the refrigeration system network and simplifies service, as compared to conventional back room refrigeration systems. Further, since the alternate configurations of the refrigeration units and racks are pre-designed, less field assembly of conduit joints are required. The flexibility in the modular refrigeration units permits the dedicated units to be located unobtrusively within a public area of a commercial space, such as a supermarket, in such a way as to blend with the closely adjacent configurations of refrigerated product storage coolers and display merchandisers having the associated cooling zones.

[0061] **FIG. 16** shows a self-contained refrigeration unit **250**, or merchandiser. The refrigeration unit **250** is shown as an open-unit display merchandiser having a single display fixture **254**. However, other types of merchandisers (e.g., a glass-door display merchandiser, a vending machine, a dispenser, etc.) can embody the invention. Also, it is envisioned that the merchandiser **250** can include more than one display fixture (e.g., is a combination merchandiser). As used herein, the term "self-contained refrigeration unit" means a refrigeration unit where the frame of the unit supports the linear compressors **26**, the condenser **38**, the expansion valve **90**, and the evaporator **94**.

[**0062**] With reference to **FIG. 16**, the merchandiser **250** includes a frame **258** supporting the display fixture **254** and the components providing the refrigeration cycle (discussed below). As used herein, the term "frame" is broadly defined as something composed of parts fitted together and united. The frame **258** includes the housing of the unit, the one or more components of the refrigeration cycle, and/or the display fixture. Alternatively, the frame **254** provides the foundation for the housing, the one or more components of the refrigeration cycle, and/or the display fixture. The display fixture **254** comprises a cabinet, case, container or similar receptacle adapted to accommodate a commodity. The fixture **254** includes at least one surface **262** that at least partially defines an environmental space. For a "glass-door" display merchandiser, at least one of the surfaces defining the environmental space is partially defined by a translucent material.

[**0063**] It should be noted that some merchandisers do not include a display fixture, however, the refrigeration unit still includes at least one surface at least partially defining an environmental space. Also the refrigeration unit **250** can include multiple environmental spaces. As used herein, the term "environmental space" is a three-dimensional space (defined at least in part by the at least one surface) where the environment is controlled by the refrigeration unit. For example, the refrigeration unit **250** of **FIG. 16** consists of two environmental spaces **266** and **270**, where the temperatures of the environmental spaces are controlled by the components of the refrigeration cycle. Other characteristics (e.g., humidity) of the environmental spaces **266** and **270** can be controlled.

[**0064**] As shown in **FIG. 16**, the components forming the refrigeration cycle comprises the linear compressor **26**, the condenser **38**, the expansion device **90** (also typically referred to as the expansion valve), and the evaporator **94**, all of which are in fluid communication. Of course, in further embodiments, the refrigeration cycle can include other components, such as the receiver **82** or a filter (not shown).

[**0065**] The refrigeration unit includes the controller **192** that controls the refrigeration unit. The controller **192** includes one or more temperature sensors and/or one or more pressure sensors (only one sensor **274** is shown) coupled to the refrigeration unit. The controller also includes a user-input device. The controller **192** receives refrigeration unit input information (i.e., signals or data) from the sensor(s) **274**, receives user input (e.g., temperature settings) from the user input device, processes the inputs, and provides one or more outputs to control the refrigeration unit (e.g., to control the compressor, control the expansion device, control a defrost system, etc.). In further embodiments, the controller **192** is used with other refrigeration units or merchandisers and may be located in the control panel **240** of such units.

[**0066**] For the refrigeration unit shown, the controller **192** includes the compressor controller. However, the refrigeration unit controller **192** can be separated into multiple controllers (e.g., a controller for overall control and a compressor controller), which is typically referred to as a distributed control system. An example of a distributed control system is disclosed in U.S. Pat. No. 6,647,735, issued Nov. 18, 2003, the content of which is incorporated herein by reference.

[**0067**] In one embodiment, the controller **192** includes one or more programmable devices (e.g., one or more microprocessors, one or more microcontrollers, etc.) and a memory. The memory, which can include multiple memory devices, includes program storage memory and data storage memory. The one or more programmable devices receive instructions, receive information (either directly or indirectly) from the devices in communication with the programmable devices, execute the instructions, process the information, and communicate outputs to the attached devices.

[**0068**] The user-input device is shown in **FIG. 16** as a user interface **278**. The user-input device can be as simple as a thermostat dial. Other user-input devices include push-buttons, switches, keypads, a touch screen, etc. The user interface **278** also includes a user-output device (e.g., a LCD display, LEDs, etc.). In another embodiment, the user interface **278** includes connections for communication to other interfaces or computers or is located in the control panel **240** of the refrigeration unit.

[**0069**] It is envisioned that the controller **192** can use at least one of a sensed pressure and a sensed temperature to control the linear compressor, the expansion device, and/or the fans. By controlling these components, the controller **192** thereby controls the temperature of the environmental space(s) of the refrigeration unit. For example, the controller **192** can include a temperature sensor that senses discharge air temperature. If the discharge air temperature is outside of a predetermined temperature range (e.g., set by an operator), the controller **192** can modulate or change the volume of the compressor (e.g., increase or decrease the stroke of the pistons of the compressor). How the controller **192** changes the compressor volume can be based on empirical test data. Other methods known to those skilled in the art for controlling the compressor are possible. Other parameters used by the controller **192** for controlling the compressor can include suction temperature, suction pressure, discharge pressure, evaporator air exit temperature, evaporator surface temperature, evaporator pressure, the temperature difference between discharge and return air temperature, product zone temperature, product simulator temperature, and similar parameters.

[**0070**] Various other features and advantages of the invention are set forth in the following claims.

What is claimed is:

1. A modular commercial refrigeration unit constructed and arranged for placement in strategic proximity to a plurality of associated product cooling zones within a shopping area, the modular refrigeration unit comprising:

a refrigeration rack proximate to a shopping area and configured to accommodate maximum refrigeration loads of the associated product cooling zones and having an optimum footprint,

wherein the refrigeration rack is constructed to support components of a closed refrigeration circuit including associated high side and low side refrigerant delivery and suction means extending from the rack and being operatively connected to a plurality of evaporators for cooling the associated product cooling zones;

a linear compressor; and

a cooling source remote from the refrigeration unit provides a cooling relationship with a condenser for providing optimum condensing and efficiency of the evaporators in cooling the associated product cooling zones.

2. The modular refrigeration unit of claim 1 wherein the closed refrigeration circuit includes a plurality of linear compressors.

3. The modular refrigeration unit of claim 2 wherein the linear compressors are connected in parallel.

4. The modular refrigeration unit of claim 1 wherein the linear compressor provides a variable refrigeration capacity balanced to the refrigeration loads imposed by the associated product cooling zones.

5. The modular refrigeration unit of claim 4 wherein the variable refrigeration capacity is in the range of about 30% and 100%.

6. The modular refrigeration unit of claim 1 wherein the linear compressor comprises a free-piston linear compressor including dual-opposing pistons.

7. The modular refrigeration unit of claim 1, and further comprising a controller to control the operation of the linear compressor wherein the controller comprises a sensor configured to sense a parameter representative of an operating condition associated with the modular refrigeration unit, and wherein the controller is operable to control the linear compressor based at least in part on the sensed parameter.

8. The modular refrigeration unit of claim 7 wherein the linear compressor comprises a free-piston linear compressor comprising dual-opposing pistons, and wherein the controller is operable to control the linear compressor by being further operable to control the stroke of the pistons for varying the effective displaced volume of refrigerant based at least in part on the sensed parameter.

9. The modular refrigeration unit of claim 1 wherein the linear compressor is located remote from the shopping area.

10. The modular refrigeration unit of claim 1 wherein the linear compressor is mounted on the refrigeration rack.

11. The modular refrigeration unit of claim 1, and further comprising a condenser connected between the linear compressor and receiver means of the refrigeration circuit.

12. The modular refrigeration unit of claim 11 wherein the condenser is mounted on the refrigeration rack.

13. The modular refrigeration unit of claim 11 wherein the condenser is air cooled.

14. The modular refrigeration unit of claim 1 wherein the cooling source provides a heat exchange relationship with the condenser for providing optimum condensing and efficiency of the evaporators in cooling the associated product cooling zones.

15. A modular refrigeration system comprising:

at least two refrigerated fixtures having first closely adjacent locations in a shopping area;

at least one evaporator coil for cooling the refrigerated fixtures to maintain products therein within a predetermined temperature range;

a linear compressor having a second location in close proximity to the refrigerated fixtures;

a condenser connected together with the linear compressor and the evaporator coils to form a closed loop refrigeration circuit;

a heat exchange device located remote from the shopping area for transferring heat to an exterior atmosphere; and

a closed heat transfer loop extending between the closed loop refrigeration circuit and the remote environment and interconnecting the heat exchange device and the condenser in continuous communication to transfer heat from the condenser to the heat exchange device.

16. The refrigeration system of claim 15 wherein the second location is in the shopping area closely adjacent to the refrigerated fixtures.

17. The refrigeration system of claim 15 wherein the second location is remote from the shopping area.

18. The refrigeration system of claim 15 wherein the closed loop refrigeration circuit includes a plurality of linear compressors.

19. The refrigeration system of claim 18 wherein the linear compressors are connected in parallel.

20. The refrigeration system of claim 15 wherein the linear compressor provides a variable refrigeration capacity balanced to the refrigeration loads imposed by the associated refrigerated fixtures.

21. The refrigeration system of claim 20 wherein the variable refrigeration capacity is in the range of about 30% and 100%.

22. The refrigeration system of claim 20 wherein the linear compressor comprises a free-piston linear compressor including dual-opposing pistons.

23. The refrigeration system of claim 22 wherein the variable refrigeration capacity is controlled by varying stroke of the pistons.

24. The refrigeration system of claim 15, and further comprising a controller coupled to the linear compressor, the controller comprising a sensor configured to sense a parameter representative of an operating condition associated with the refrigerated fixtures, and wherein the controller is operable to control the linear compressor based at least in part on the sensed parameter.

25. A commercial refrigeration network comprising:

a first modular refrigeration system unit in close strategic proximity to a first refrigerated product zone, the first modular refrigeration system unit including a first refrigeration rack comprising first closed refrigeration circuit components including a linear compressor, high side receiver means and associated high side and low side refrigerant delivery, and suction means operatively connected to a first evaporator for cooling the first refrigerated zone, and the first modular refrigeration system unit also including a first condenser connected between the linear compressor and receiver means of the first closed refrigeration circuit;

at least one other modular refrigeration system unit in close strategic proximity to an associated other refrigerated product zone, and including an other refrigeration rack comprising other closed refrigeration circuit components including a linear compressor, high side receiver means and associated high side and low side refrigerant delivery, and suction means operatively connected to an other evaporator for cooling the other refrigerated zone, and the other modular refrigeration system unit also including an other condenser connected between the linear compressor and receiver means of the other closed refrigeration circuit; and

a cooling source provides a cooling relationship with the first and other condensers for the respective first and other refrigeration system units.

26. The refrigeration network of claim 25 wherein the first and other refrigerated product zones are located within a shopping area at spaced locations therein, and the dedicated first and other refrigeration racks are closely associated with the respective product zones adjacent to their respective locations.

27. The refrigeration network of claim 25 wherein the refrigerated product zones comprise a plurality of merchandisers located in the shopping arena, the plurality of merchandisers comprising:

first merchandisers incorporating the first evaporator and associated first refrigerant control means and first refrigeration sensing means; and

other merchandisers incorporating the other evaporator and associated other refrigerant control means and other refrigeration sensing means.

28. The refrigeration network of claim 25 wherein at least one of the modular refrigeration system units includes a plurality of linear compressors.

29. The refrigeration network of claim 28 wherein the linear compressors are connected in parallel.

30. The refrigeration network of claim 25 wherein the linear compressors provide a variable refrigeration capacity balanced to the refrigeration loads imposed by the associated refrigerated zones.

31. The refrigeration network of claim 30 wherein the variable refrigeration capacity is in the range of about 30% and 100%.

32. The refrigeration network of claim 25 wherein each modular refrigeration system unit further comprises a controller coupled to the linear compressor, the controller comprising a sensor configured to sense a parameter representative of an operating condition associated with the modular refrigeration unit, and wherein the controller is operable to control the linear compressor based at least in part on the sensed parameter.

33. The refrigeration network of claim 32 wherein each linear compressor comprises a piston, and wherein the controller is operable to control the linear compressor by being further operable to control the stroke of the piston based at least in part on the sensed parameter.

34. The refrigeration network of claim 32 wherein each linear compressor comprises a free-piston linear compressor comprising dual-opposing pistons, and wherein the controller is operable to control the linear compressor by being further operable to control the stroke of the pistons for varying the effective displaced volume of refrigerant based at least in part on the sensed parameter.

35. The refrigeration network of claim 25 wherein the cooling source comprises a plurality of cooling sources, each cooling source mounted to a respective one of the first and other condensers.

36. The refrigeration network of claim 25 wherein the cooling source comprises a coolant circulating system having a plurality of heat exchanger circuits in heat exchange relationship with the respective first and other condensers for the respective first and other refrigeration system units, the coolant circulating system having at least one continuous cooling source for coolant in the circulating system.

37. A commercial refrigeration network comprising:

a first refrigeration merchandiser comprising at least one first surface at least partially defining a first environmental space adapted to accommodate a commodity, first closed refrigeration circuit components including a free-piston linear compressor, a condenser, an expansion device, and an evaporator in fluid communication wherein the evaporator is in thermal communication with the environmental space to influence the temperature of the environmental space, and a first frame supporting the at least one first surface, the linear compressor and the evaporator;

at least one other refrigeration merchandiser comprising at least one other surface at least partially defining an other environmental space adapted to accommodate a commodity, other closed refrigeration circuit components including a free-piston linear compressor, a condenser, an expansion device, and an evaporator in fluid communication wherein the evaporator is in thermal communication with the environmental space to influence the temperature of the environmental space, and an other frame supporting the at least one other surface, the linear compressor and the evaporator; and

a cooling source provides a cooling relationship with the first and other condensers for the respective first and other refrigeration system units.

38. The refrigeration network of claim 37 wherein the first frame also supports the condenser and the expansion device and the other frame also supports the condenser and the expansion device.

39. The refrigeration network of claim 37 wherein at least one of the refrigeration merchandisers includes a plurality of linear compressors.

40. The refrigeration network of claim 39 wherein the linear compressors are connected in parallel.

41. The refrigeration network of claim 37 wherein the linear compressor provides a variable refrigeration capacity balanced to refrigeration loads imposed by the refrigeration merchandiser.

42. The refrigeration network of claim 41 wherein the variable refrigeration capacity is in the range of about 30% to 100%.

43. The refrigeration network of claim 41 wherein the linear compressor comprises dual-opposing pistons.

44. The refrigeration network of claim 43 wherein the variable refrigeration capacity is controlled by varying stroke of the pistons.

45. The refrigeration network of claim 37 wherein the cooling source comprises a plurality of cooling sources, each cooling source mounted to a respective one of the first and other condensers wherein the first and other condensers are air cooled.

46. The refrigeration network of claim 37 wherein the cooling source comprises a coolant circulating system having a fluid input line and a fluid output line in fluid communication with the respective first and other condensers for the respective first and other refrigeration merchandisers, the coolant circulating system having at least one continuous cooling source for coolant in the circulating system.

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