



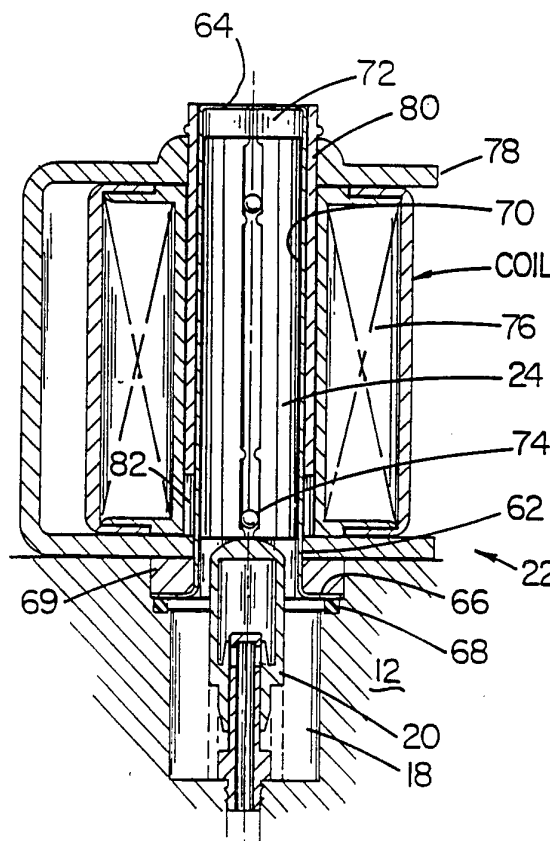
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(54) Title: EXPANSION VALVE FOR AIR CONDITIONING SYSTEM WITH PROPORTIONAL SOLENOID

(57) Abstract

An expansion valve (10) for heat transfer systems such as an air conditioning system, includes a control element (20) for controlling the flow rate of working fluid through the valve. The control element has a stem member (28) and movable member (42) movable on the stem member. Openings (38) to an internal passage (30) in the stem member are regulated by positioning the movable member to achieve regulated flow rate of refrigerant material through the valve. The movable member of the control element is moved by a plunger (24) of a proportional solenoid (22). The proportional solenoid has a magnetic flux circuit including a low permeance isolation tube (62) surrounding the plunger, which enables removal of the coil (76) and frame (78) of the solenoid from the valve. The solenoid further includes a variable permeance flux washer (69) the flux through which varies with plunger position, which is disposed from a gap (82) which provides an area of magnetic saturation. The proportional solenoid produces force/displacement characteristics which enable precise control of the control element and accurate regulation of the refrigerant flow rate through the valve.



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EXPANSION VALVE FOR AIR CONDITIONING SYSTEM WITH PROPORTIONAL
SOLENOID

TECHNICAL FIELD

1

This invention relates to heat transfer systems. Specifically this invention relates to an expansion valve for a heat transfer system such as a vehicle air conditioning system.

5

BACKGROUND ART

Heat transfer systems, such as air conditioning systems and heat pump systems, are well known in the prior art. In such systems a working fluid which can be any one of a number of refrigerant materials is used to transfer heat from one region to another.

10

The working fluid typically passes through a system that includes an evaporator, a compressor, a condenser and an expansion device. Of course the system may also include other components such as an accumulator or a receiver/dryer.

15

In an air conditioning application the evaporator is positioned in the space to be cooled and the condenser is positioned in the area to which heat removed from the cooled space is transferred. Working fluid in the vapor state is pumped by the compressor into the condenser. In the condenser the working fluid rejects heat and condenses to a liquid.

20

The liquid working fluid passes from the outlet of the condenser into an expansion device. Expansion devices known in the prior art include fixed orifices, capillary tubes and expansion valves.

25

From the expansion device the working fluid flows to the evaporator wherein it absorbs heat and undergoes a change of phase from liquid to vapor. The refrigerant vapor

30

1 then flows back to the compressor to begin another pass
through the system.

The expansion device is an important element of the
system. The amount of working fluid that passes through
5 the expansion device is a controlling factor in the
amount of cooling that can be achieved. However, because
the temperature of both the space being cooled and the
space to which heat transferred often vary, the pressure
and temperature of the liquid working fluid entering the
10 expansion device also varies. This impacts the cooling
capabilities of the system and affects the flow rate that
must be attained through the expansion device to achieve
the optimum cooling effect. In mobile systems such as
those used as air conditioning or refrigeration systems
15 on vehicles, the properties of the working fluid deliv-
ered to the expansion device can vary widely.

Due to the variable operating conditions of vehicle heat
transfer systems, fixed opening expansion devices such as
orifices and capillary tubes are sometimes used to reduce
20 cost but are not preferred. Expansion valves that
provide variable refrigerant flow rates are more desir-
able.

Prior art expansion valves have traditionally controlled
flow by passing the fluid through an internal opening in
25 the valve and employing a movable restricting body or
other element in close proximity to the opening. Moving
the restricting body closer to the opening reduces flow.
Conversely, moving the restricting body away from the
opening increases flow through the valve.

30 In prior art expansion valves the position of the re-
stricting body has been controlled by an actuator. A
common actuator is a diaphragm type which is mounted on

1 the valve. The actuator opens or closes flow through the
expansion valve in response to fluid pressure both inside
the valve and from a control source. The control source
for fluid pressure for positioning the restricting body
5 is delivered from a sealed bulb which holds a carefully
determined fluid charge. The bulb is commonly mounted
adjacent to the outlet line from the evaporator. When
the temperature of the working fluid exiting the space to
be cooled begins to increase, the temperature of the bulb
10 also increases. As the pressure of the fluid inside the
bulb increases it moves the diaphragm and the blocking
body inside the expansion valve to increase the flow rate
of working fluid to the evaporator. The increased flow
of working fluid provides more cooling and eventually the
15 temperature at the outlet of the evaporator drops. When
this occurs the pressure inside the bulb falls, moving
the diaphragm and the restricting body to reduce the flow
rate of working fluid through the valve. The charge in
the bulb is contrived to achieve a small amount of super-
20 heat in the refrigerant leaving the evaporator.

A problem with this type of prior art actuator is that
the expansion device is constantly seeking the optimum
rate of flow. The response time renders the expansion
device unable to react promptly to changing conditions.
25 This is particularly a problem in vehicle applica-
tions where changes in cooling loads and variations in
refrigerant properties are common. As a result, the
accuracy of control is also less than optimum.

Others have previously used electrically controlled
30 expansion valves to control the flow of working fluid in
a heat transfer system. These systems typically use
valves that are either fully open or fully closed. The
valve is periodically opened and closed for controlled
time periods to achieve an overall average flow rate that

1 is designed to handle the heat transfer load at the
evaporator.

A significant problem with such pulse width modulated
expansion valves is that they must open and close very
5 frequently. This causes rapid wear of the valve compon-
ents. The opening and closing action also often causes
"hammering" in the system. The vibration associated with
hammering may cause fatigue and premature failure of the
valve and the connected tubing. It also makes accurate
10 pressure measurement impossible.

The control elements used in prior art expansion valves
for controlling or regulating the flow of working fluid
also have drawbacks. The valves that meter flow must be
made to deal with the static and dynamic pressure effects
15 created by the working fluid as it passes through the
valve. In some designs efforts are made to use the
pressure of the working fluid to develop balancing
forces. These balancing forces enable more precise
movement of the restricting body or other control ele-
20 ment. This is intended to enable more precise control of
the flow rate.

The problem with attempts to design expansion valves that
use such balancing forces is that the forces vary sub-
stantially with the fluid conditions and the flow rate.
25 As a result it has been difficult to produce an expansion
valve that provides accurate control of fluid flow over a
wide range of operating conditions.

Thus there exists a need for an expansion valve for heat
transfer systems that provides accurate flow control for
30 the working fluid under a wide range of operating and
flow conditions.

1

DISCLOSURE OF INVENTION

It is an object of the present invention to provide an expansion valve that accurately controls the flow of working fluid therethrough.

5

It is a further object of the present invention to provide an expansion valve that includes a control element that minimizes the influence of flow and pressure effects.

10

It is a further object of the present invention to provide an expansion valve that includes a proportional solenoid actuator that accurately controls flow through the control element.

15

It is a further object of the present invention to provide an expansion valve that minimizes vibration and has a long useful life.

It is a further object of the present invention to provide an expansion valve that has few moving parts, is economical to manufacture and is readily repaired.

20

It is a further object of the present invention to provide an expansion valve that can be operated with flow in either direction.

Further objects of the present invention will be made apparent in the following Best Modes for Carrying Out Invention and the appended claims.

25

The foregoing objects are accomplished in the preferred embodiment of the invention by an expansion valve for controlling the flow of refrigerant material flowing to an evaporator of a heat transfer system, such as a vehicle air conditioning system. The valve has a body with

1 an inlet for receiving liquid refrigerant material and an
outlet for delivering expanded refrigerant material.

The expansion valve includes a control element between
the inlet and the outlet for controlling the flow rate of
5 refrigerant material through the valve. The control
element has a cylindrical stem member with an internal
passage. The stem member has a cylindrical outer sur-
face. The outer surface preferably includes a pair of
opposed longitudinally elongated openings.

10 The control element further includes a movable member
mounted for movement on the outside of the stem member.
The movable member is movable through a range of posi-
tions between a first position wherein the valve is fully
open and a second position wherein the valve is fully
15 closed.

In a first embodiment, the control element is configured
to be a normally closed element. However in other em-
bodiments the valve may be configured to be normally
open. The control element is not significantly in-
20 fluenced by flow or pressure forces, and is thereby
enabled to provide an accurate rate of flow through
selective positioning of the movable member. It also
accommodates flow in either direction through the ele-
ment.

25 The movable member of the control element is positioned
by a proportional solenoid actuator. The proportional
solenoid actuator is constructed with a novel low fric-
tion plunger as described in U.S. Patent Number
5,259,939. The proportional solenoid actuator also
30 includes a novel removable coil design that facilitates
repair or replacement of the actuator. The solenoid
actuator also includes a novel magnetic flux circuit that

- 1 includes a low permeance, non-magnetic isolation tube in series with a variable permeance element. This construction provides a proportional solenoid that achieves accurate positioning of the movable member of the control
5 element in response to electrical signals delivered to the proportional solenoid actuator.

Accurately positioning the control element of the valve through movement of the proportional actuator, enables accurate flow control through the expansion valve and
10 precise control of the cooling effects of the system in which the expansion valve is used.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a cross sectional view of a first embodiment of the expansion valve of the present invention.

- 15 Figure 2 is a side view of a normally closed control element of the expansion valve shown in Figure 1.

Figure 3 is a cross sectional side view of the control element shown in Figure 2.

- Figure 4 is a side view of a normally open control element of an alternative embodiment of the expansion valve
20 of the present invention.

Figure 5 is a cross sectional view of the control element shown in Figure 4.

- Figure 6 is a cross sectional view of the proportional
25 solenoid actuator of the expansion valve shown in Figure 1.

1 Figure 7 is a schematic view of a heat transfer system incorporating the expansion valve of the present invention.

BEST MODES FOR CARRYING OUT INVENTION

5 Referring now to the drawings and particularly to Figure 1, there is shown therein a first embodiment of the expansion valve of the present invention generally indicated 10. The valve has a body 12. The body 12 includes an inlet 16 for receiving liquid refrigerant working
10 fluid. The valve also has an outlet 14 for delivering expanded working fluid to an evaporator or other exothermic heat exchanger. As later explained, the expansion valve of the present invention may be operated with flow in either direction, so that the inlet and outlet connec-
15 tions may be reversed.

The body 12 further includes a chamber 18. A control element 20 is positioned in chamber 18. Fluid passing from inlet 16 to outlet 14 of the valve is required to pass through the control element.

20 Valve 10 further includes a proportional solenoid 22. Solenoid 22 includes a movable plunger element 24. Plunger element 24 is a low friction type plunger of the type described in U.S. Patent Number 5,259,939. As later described in detail, plunger element 24 is controlled to
25 move downward in response to electrical signals supplied to the proportional solenoid 22.

Body 12 of valve 10 further includes a return passage 26. Return passage 26 provides a path for working fluid from the evaporator as it returns to the compressor and the
30 remainder of the system (see Figure 7). Return passage

1 26 provides a convenient location for sensors for detect-
ing the character and properties of the refrigerant
material leaving the evaporator. However, in other
embodiments of the invention the expansion valve need not
5 include a return passage through body 12.

Control element 20 is shown in greater detail in Figures
2 and 3. Control element 20 has a stem member 28 that
includes an internal passage 30. The stem member has a
threaded lower portion 32 for attaching to a similarly
10 threaded opening in body 12 (not separately shown) which
is in fluid communication with outlet 16. The stem
member 28 also has a hex area 34 to facilitate installa-
tion and removal of the control element from the valve.

Stem member 28 includes a cylindrical outer surface 36.
15 A pair of opposed longitudinally elongated openings 38
extend on outer surface 36. Openings 38 are in fluid
communication with internal passage 30 through ducts 40.
Ducts 40 are similarly configured to openings 38.
Control element 20 further includes a movable member 42.
20 Movable member 42 has a cylindrical inner surface 44 that
is slightly larger in diameter than outer surface 36 of
stem member 28. As a result, movable member is axially
movable on stem member 28.

Movable member 42 includes an enlarged flange area 46.
25 Flange area 46 is in abutting relation at its lower side
with a compression spring 48 as shown in Figures 2 and 3.
Compression spring 48 biases the movable member upward as
shown in the drawings.

The upper surface of flange area 46 supports a cap por-
30 tion 50 of the movable member. Cap portion 50 includes a
open area 52 that enables it to move downward on stem
member 28 a significant distance without engaging a

1 closed top area 54 of the stem member. Cap portion 50
also has a rounded plunger engaging portion 56. Plunger
engaging portion 56 of movable member 42 engages plunger
24 as shown in Figure 1, as the movable member is biased
5 against the plunger by spring 48.

Movable member 42 further includes tapered peripheral
surface 58. Peripheral surface 58 is tapered as shown in
Figures 2 and 3 such that it is relatively thin in the
area of openings 38 and terminates in a sharp edge 60.

10 As shown in Figures 2 and 3, spring 48 biases movable
member 42 upward, and the peripheral surface 58 of the
movable member covers openings 38 in the outer surface of
stem member 28 when no downward force is applied by the
plunger of the actuator. As the control element is
15 biased towards the position in which openings 38 are
covered, it is a normally closed element. As discussed
later in conjunction with the description of the embodi-
ment of the control element shown in Figures 4 and 5,
other embodiments of the expansion valve of the present
20 invention may have normally open control elements.

When movable member 42 is moved in a direction downward
as shown in Figures 2 and 3, peripheral surface 58 and
edge 60 move to uncover openings 38 in stem member 28.
As a result, the area outside the control element in
25 chamber 18 is in fluid communication with internal pas-
sage 30 of the control element, and outlet 14 of the
valve, through ducts 40. The extent to which openings 38
are uncovered determines the flow rate of refrigerant
material through the control element, and thus the flow
30 rate of material passing from the inlet to the outlet of
the expansion valve.

1 The tapered peripheral portion 58 and the sharp edge 60
of the control element are important for achieving accu-
rate flow control through the expansion valve. The sharp
edge minimizes the surface area of the movable member 42
5 that is directly exposed to the high velocity fluid
stream passing out of the openings 38 in the stem.
Minimizing such surface area eliminates the tendency for
the fast moving fluid to exert forces on the movable
member through momentum of the moving fluid or suction
10 forces created in accordance with Bernoulli's Principles.
The thin and tapered configuration of the peripheral
surface further minimizes such forces by reducing the
surface exposed to the high velocity flow. By minimizing
variable flow induced forces, the movable member may be
15 stably positioned longitudinally on the outside of the
stem. This is a substantial improvement over control
elements which have significant surface area exposed to
the high velocity flow. The larger surfaces in prior art
valves are subject to being acted upon by substantial
20 fluid momentum and velocity induced suction forces, which
make the control element difficult to hold in a desired
position, and thus make it difficult to accurately con-
trol flow. Further, in the preferred embodiment of the
invention, forces applied by the moving fluid to the
25 movable member are balanced out. This minimizes side
loads and reduces frictional resistance to movement of
the movable member on the stem. This further enables
accurate flow control.

In the preferred embodiment of the invention the taper of
30 the tapered portion is a maximum of about 15 degrees and
the edge is less than about 0.0127 cm in thickness. The
stem member 28 is preferably about 0.381 cm in diameter.
In the preferred embodiment the movable member and stem
member are made from non-magnetic stainless steel. As
35 later explained, the non-magnetic character of the con-

1 trol element provides advantages in the operation of the
invention. In other embodiments other non-magnetic
materials such as brass, ceramics or other materials
having sufficient dimensional stability and rigidity to
5 withstand the fluid forces without deformation and which
provide wear resistance, may be used.

The proportional solenoid 22 of the expansion valve is
shown in greater detail in Figure 6. The proportional
solenoid 22 includes an isolation tube 62. Isolation
10 tube 62 is generally cylindrical and has a closed top 64.
Isolation tube 64 also has a flanged bottom 66 which
nests in a recess (not separately shown) in body 12. In
the preferred form of the invention isolation tube 66 is
made of non-magnetic stainless steel material having
15 approximately 1.27 cm O.D. and a 0.0305 cm thick wall.
The body 12 is preferably made of non-magnetic aluminum
alloy.

A resilient seal 68 is positioned under flange bottom 66
of isolation tube 62. Seal 68 serves to provide a fluid
20 tight seal which prevents the working fluid in chamber 18
from escaping around the isolation tube through the
recess. The isolation tube is fixed in the position
shown by fastening means (not shown). A flux washer 69
made of magnetic material is positioned in the recess
25 above flange bottom 66 of the isolation tube. The pre-
ferred form of the flux washer is sized with an opening
that accepts the isolation tube, has a 2.54 cm outside
diameter and is 0.4572 cm thick. The purpose of flux
washer 69 is later described in detail.

30 The isolation tube 62 has a cylindrical surface 70.
Plunger 24 is movable inside an internal area 72 of the
isolation tube. Internal area 72 is bounded by interior
surface 70. As described in U.S. Patent Number

1 5,252,939, plunger 24 is comprised of magnetic material
and non-magnetic rollable bodies 74 roll between the
surface of plunger and the interior surface 70 of the
isolation tube. Further, the isolation tube provides a
5 radial gap in which there is no magnetic material between
the plunger and the lower portion of the frame. This
radial gap is approximately 0.508 cm. This construction
enables plunger 24 to move with virtually no frictional
resistance.

10 Proportional solenoid 22 further includes a wound wire
coil 76 for providing an electromagnetic field when
electrical power is supplied thereto. Coil 76 is sup-
ported in a frame 78 made of magnetic material that is u-
shaped in cross section. A cylindrical sleeve 80 extends
15 part way through the center of coil 76. A longitudinal
gap 82 extends between the bottom of sleeve 80 and the
lower portion of frame 78 as shown in Figure 6. In the
preferred embodiment the length of this longitudinal gap
is 0.762 cm.

20 In the preferred embodiment of the invention the inside
diameter of sleeve 80 is slightly larger than the outside
diameter of isolation tube 62. In addition, in the pre-
ferred embodiment, frame 78 is releasably attached to
body 12 of the valve. This enables the coil and frame
25 assembly to be removed from the valve without releasing
any of the refrigerant working fluid 20 from the system.
This makes it easier to repair or replace the coil of the
solenoid actuator.

An operation of the expansion valve, when no electrical
30 power is applied to coil 76, the spring 48 of control
element 20 biases plunger 24 upward to the position shown
in Figures 1 and 6. Supplying power to coil 76 creates

1 an electromagnetic field. The electromagnetic field
produces a flux circuit about solenoid 22. The flux
circuit extends through the sleeve 80, the frame 78 and
the flux washer 69. However, gap 82 causes magnetic
5 saturation in the area of the gap.

The magnetic plunger functions as a member for completing
the magnetic flux circuit. Flux washer 69 serves as a
variable permeance element as its permeance varies with
the distance the plunger 24 is displaced downward. As
10 electrical power delivered to the coil of the solenoid
actuator increases, the magnetic saturation at the gap 82
also increases. This causes the plunger to move downward
until the force reaches an equilibrium with the biasing
force of the spring of the control element.

15 By varying the amount of power delivered to the coil of
the proportional solenoid, the position of the plunger
and the movable member 42 of the control element may be
precisely controlled. Because the movable member is not
subject to significant flow forces as a result of fluid
20 flowing through the valve, the rate of flow of working
fluid through the valve is predictably and accurately
regulated.

The proportional solenoid of the present invention is
novel in that unlike conventional solenoids the force it
25 produces does not increase exponentially as the plunger
approaches the end of its stroke. This enables the
solenoid actuator to achieve a force versus stroke char-
acteristic that enables precise and repeatable movement.
This in combination with the element which minimizes
30 forces from the flowing fluid provides a valve that
provides flow control accuracy that was previously unat-
tainable in expansion valves.

1 Solenoid 22 is further novel in that although it is a
proportional solenoid, it is removable from the body of
the valve. This facilitates repair or replacement.
Prior art type proportional solenoids have not generally
5 been used in expansion valves because they could not
tolerate a low permeance structure between the coil
sleeve and the plunger. In the present invention howev-
er, a low permeance non-magnetic isolation tube is posi-
tioned between the magnetic sleeve and the plunger ele-
10 ment. The presence of this low permeance tube actually
enhances the ability of the plunger to move. This is
believed to occur because the low permeance element
maintains the plunger away from other magnetic elements
and reduces resistance to movement that occurs when a
15 magnetic element that is attracted to the plunger is
immediately adjacent thereto.

It will be understood by those skilled in the art, that
although the preferred embodiment of the invention uses
an air gap to achieve a saturation area, in other embodi-
20 ments a non-magnetic spacer or thinned area of the sleeve
may be used. Likewise, although the preferred embodiment
includes a flux washer as a variable permeance element,
other embodiments may use other types of elements that
exhibit increasing permeance with plunger stroke.

25 In operation of the proportional solenoid, as greater
electrical power is delivered to coil 76 plunger 24 moves
in a downward direction as shown in Figure 1. Because
movable member 42 is engaged with plunger 24, it likewise
moves downward. This opens flow through openings 38 in
30 the outer surface of the stem member 28. As a result,
working fluid on the inside of the stem member flows into
chamber 28 and expands. Because openings 38 are elongat-
ed, the further the movable member moves downward the
greater the flow through the control element.

1 The configuration of the control element enables precise
control of the flow therethrough in response to the dis-
placement of the movable member. As previously dis-
cussed, the taper of peripheral surface 58 and sharp edge
5 60 of the movable member reduces to a minimum the area of
the movable member exposed to the fast moving fluid.
Forces tending to cause side forces on the movable member
which are perpendicular to its direction of motion are
balanced. As a result, the effects of flow and pressure
10 are minimized.

The non-magnetic character and configuration of the flow
control element provides a further advantage in the
operation of the valve. It is common for magnetic parti-
cles to flow in the working fluid in the flow circuit.
15 Such impurities may result from contamination or deterio-
ration of system components. Such magnetic particles can
become attached to the magnetic plunger and control
elements comprised of magnetic material. By making the
control element non-magnetic and engaging the plunger at
20 plunger engaging portion 56, which is far removed from
the flow openings 38, such particles do not tend to
collect near the openings or relatively moving parts of
the control element where they could otherwise restrict
flow or cause wear. This further assures accurate con-
25 trol of flow and increases valve life. The configuration
of the movable member with the plunger engaging surface
far removed from the flow openings, provides an internal
space that enables more uniform expansion within the body
of the valve. This further helps to achieve uniformity
30 of flow and accurate control.

The control element provides precise and predictable flow
control in response to the power delivered to the propor-
tional solenoid. As a result, the expansion valve of the

1 present invention may be used to achieve more accurate
control of the cooling characteristics when used in an
air conditioning or other heat transfer system.

5 A typical system in which the expansion valve 10 of the
present invention may be used is shown schematically in
Figure 7. Liquid working fluid enters inlet 16 of the
expansion valve. The expanded refrigerant leaves the
outlet 14 and is delivered in a suitable conduit to an
evaporator 84. The working fluid absorbs heat as indi-
10 cated by the arrows labeled Q-in, as the working fluid
flows through the evaporator. Of course in the preferred
form of the invention, which is an air conditioning
system for a vehicle, the evaporator is in the passenger
compartment or other area to be cooled. A fan 86 shown
15 schematically draws air through the evaporator to assist
in heat transfer.

Working fluid exiting the evaporator travels in a suit-
able conduit back through return passage 26 of valve 10.
As previously discussed, the return passage through the
20 valve provides a suitable location for temperature and/or
pressure sensors to detect the properties of the refrigerant
vapor exiting the evaporator.

The vaporized working fluid is compressed by compressor
90 and delivered in a suitable conduit to a condenser 92.
25 In condenser 92 the working fluid loses heat as reflected
by the arrows labeled Q-out. In the condenser 92 the
working fluid condenses to a liquid. A fan 94 shown
schematically draws air across the condenser and aids in
transferring heat from the working fluid as it passes
30 through the condenser. In the preferred embodiment of
the invention, which is an air conditioning system for a
vehicle, heat is transferred from the working fluid to
the environment.

1 From the condenser the liquefied working fluid is re-
turned to the inlet 16 of the expansion valve, after
first passing through a receiver-drier 88. Receiver-
drier 88 serves to remove impurities. Such receiver-
5 driers are well known to those skilled in the art.

The proportional solenoid 22 is actuated by an electronic control module shown schematically as 96. Control module 96 includes a processor and operates to deliver signals to the solenoid to selectively control the flow rate of
10 refrigerant through the expansion valve. The control module is further electrically connected to sensors (not shown) which detect the characteristics of the working fluid as it leaves the evaporator, and perhaps other characteristics of the system, and operator control,
15 which enables the control module to calculate the appropriate amount of working fluid that should optimally pass through the expansion valve and to convert this amount into a signal. Those skilled in the art may devise numerous ways of sensing the parameters desired to be
20 used to control the flow rate through the expansion valve and for the control module 96 to properly actuate the valve to provide the desired flow.

While the preferred embodiment of the invention includes a proportional solenoid to move the control element which
25 controls the rate of flow through the valve, in other embodiments other types of actuators may be used. Although such actuators may not provide as precise flow control as the proportional solenoid of the preferred embodiment, the novel control element of the present
30 invention may still be successfully used.

The embodiment of the valve shown in Figure 1 includes a normally closed control element 20. However other embodiments of the invention may include control elements

1 that are normally open. Such a normally open control
element 98 is shown in Figures 4 and 5. Control element
98 is designed to be a direct replacement for control
element 20, and element 98 may be substituted in expan-
5 sion valve 10 without changes to the valve construction.
However the actuation of the proportional solenoid by the
control module would have to be changed to reflect the
different character of the control element.

Control element 98 has a threaded lower portion 100
10 similar to threaded portion 32 of valve element 20. Also
like the previously described control element, element 98
has a stem member 102 with an internal passage 104.
Control element 98 also has an external hex area 106 for
ease of installation and removal.

15 Control element 98 further includes a cylindrical outer
surface 108. A pair of openings 110 in surface 108 are
connected through ducts 112 to internal passage 104.
Openings 110 are elongated longitudinally along the axis
of the stem member as shown.

20 Control element 98 also includes a movable member 114.
Movable member 114 has a cylindrical inner surface 116
slightly larger in diameter than outer surface 108. This
enables the movable member to move longitudinally on the
outside of the stem member. The stem member 102 also
25 includes a plurality of ridges 118 in the area above
openings 110 as shown in Figure 5.

Movable member 114 further includes a downwardly tapered
peripheral surface 120 which terminates at sharp edge 123
adjacent its lower end. Movable member 114 further
30 includes a plunger engaging portion 124 for engaging
plunger 24. A compression spring 126 biases the movable
member in the upward direction as shown in Figures 4 and

1 5. Stem member 102 further includes a detent 128 for
helping to center spring 126 in position.

In operation of an expansion valve that includes control
element 98, full flow is achieved when movable member 114
5 is disposed in its fully upward position. This occurs
when no power is delivered to the proportional solenoid
and plunger 24 is disposed fully upward as shown in
Figure 1.

As electrical power to the coil of the solenoid is
10 increased, the plunger moves downward and the movable
member 114 moves similarly against the force of spring
126. As the movable member partially covers openings
110, flow through the control element is reduced. The
flow is controlled by selectively moving the movable
15 member to cover the openings to achieve the desired flow
rate.

Like control element 20, control element 98 is not
materially influenced by forces generated by the flow of
the refrigerant therethrough. This is because the taper
20 of peripheral surface 120 and the sharp edge minimize the
amount of surface area exposed to the fast moving fluid
exiting from the stem. This is particularly important in
the normally open configuration of the control element as
fluid exiting through openings 110 will tend to have a
25 velocity that is both upward and outward in the orienta-
tion of the control element shown in Figure 5. The taper
of the peripheral surface, which is preferably a maximum
of about 15 degrees, and the sharp edge which is prefer-
ably less than about 0.0127 cm, minimizes the forces
30 imparted by fluid flow. This enables accurate and re-
peatable flow based on the position of the movable member
by the proportional solenoid. Control element 98 is also
preferably comprised of stainless steel or other rela-

1 tively rigid wear resistant non-magnetic material for the
reasons discussed in conjunction with the normally closed
control element.

5 A further advantage of the construction of the control
elements of the present invention is that fluid may flow
through the valve in either direction. This avoids the
need to connect the valve with particular ports as the
inlet and outlet. It is also useful in heat pump appli-
cations in which refrigerant flow is periodically re-
10 versed.

In the preferred construction of control elements 20 and
98, a pair of opposed fluid openings in the stem member
are used. These openings are elongated to achieve con-
trol through a wide range of flow rates. The opposed
15 nature of the openings also serves to balance the forces
on the movable member of the control element which facil-
itates accurate control. In other embodiments of the
invention, other numbers of openings and other configura-
tions of openings may be used depending on the range of
20 flow rates desired.

It will be understood by those skilled in the art that
although the proportional solenoid 22 of the expansion
valve of the present invention is adapted for use with
control elements such as control elements 20 and 98, the
25 proportional solenoid may also be used in other embodi-
ments of the invention to control other types of flow
control elements.

Thus, the new expansion valve for an air conditioning
system of the present invention achieves the above stated
30 objectives, eliminates difficulties encountered in the
use of prior devices and systems, solves problems and
attains the desirable results described herein.

1 In the foregoing description certain terms have been used
for brevity, clarity and understanding. However, no
unnecessary limitations are to be implied therefrom
because such terms are for descriptive purposes and are
5 intended to be broadly construed. Moreover, the descrip-
tions and illustrations given are by way of examples and
the invention is not limited to the exact details shown
or described.

Having described the features, discoveries and principles
10 of the invention, the manner in which it is constructed
and utilized, and the advantages and useful results
obtained; the new and useful methods, structures, devic-
es, elements, arrangements, parts, combinations, systems,
equipment, operations and relationships are set forth in
15 the appended claims.

CLAIMS

We claim:

1. An expansion valve for controlling flow of expanded refrigerant material into an evaporator of a heat transfer system, comprising:

a body, said body including an inlet for receiving liquid refrigerant material; an outlet for delivering expanded refrigerant material to an evaporator of a heat transfer system; and control element means for controlling the rate of flow of refrigerant material from said inlet to said outlet;

said body further including an opening, said control element means accessible through said opening;

a variable permeance element comprised of magnetic material, said variable permeance element in surrounding relation of said opening;

an isolation member comprised of nonmagnetic material, said isolation member extending outward on said body through said opening and terminating at an outer end, said isolation member having an enclosed interior area, said interior area extending longitudinally in said isolation member;

an actuating member, said actuating member positioned in said interior area of said isolation member and longitudinally movable therein, said actuating member comprised of magnetic material and sized for acceptance in

said opening, said actuating member adapted for engaging said control element means, and wherein flow through said control element means varies with movement of said actuating member;

biasing means for biasing said actuating member toward said outer end of said isolating member;

sleeve member means for surrounding said isolating member, said sleeve member means comprised of magnetic material;

electrical coil means in surrounding relation of said sleeve member means, for producing electromagnetic flux responsive to delivery of electrical power thereto, said electrical coil means having a first end adjacent said outer end of said isolating member, and a second opposed end adjacent said variable permeance element;

frame means comprised of magnetic material for supporting said coil means, said frame means in connection with said sleeve means and extending between said ends of said coil means;

flux saturation means disposed longitudinally between said opening and said sleeve member means for providing an area of magnetic flux saturation; and

wherein electrical power delivered to said coil means moves said actuating member against the force of said biasing means and into said opening, whereby control of flow rate through said control element means is achieved.

2. The expansion valve according to claim 1 wherein said sleeve member means includes a cylindrical interior sleeve surface, and said isolation member has a cylindrical outside isolation member surface, and wherein said surfaces are sized to fit in close abutting relation but are disengageable, whereby said coil means is detachable from said valve body.

3. The expansion valve according to claim 2 wherein said sleeve means terminates at an edge surface disposed outward from said opening, whereby said flux saturation means comprises a gap between said opening and said edge surface.

4. The expansion valve according to claim 3 wherein said isolation member comprises an isolation tube, and said variable permeance element comprises a flux washer in surrounding relation of said isolation tube and adjacent an inner end of said tube, said inner end opposed of said outer end.

5. The expansion valve according to claim 4 wherein said isolation tube includes a flange area adjacent said inner end, and wherein said valve further comprises an internal chamber, said control element means housed in said internal chamber, and wherein said valve further comprises resilient seal means intermediate of said chamber and said flange area, whereby said seal means prevents escape of refrigerant from said chamber.

6. The expansion valve according to claim 5 wherein said flux washer is supported on said flange area of said isolation tube.

7. The expansion valve according to claim 6 wherein said control element means includes a movable member, and

wherein movement of said movable member regulates flow through said element means, and wherein said movable member extends adjacent said flux washer in the interior area of said isolation tube.

8. The expansion valve according to claim 7 wherein said interior area of said isolation tube is cylindrical in cross section and is bounded by a cylindrical isolation tube interior surface, and wherein said actuating member is generally cylindrical in cross section.

9. The expansion valve according to claim 8 wherein said actuating member includes rollable bodies extending between said actuating member and said isolation tube interior surface, and wherein said rollable bodies roll as said actuating member moves.

10. The expansion valve according to claim 9 wherein said actuating member includes at least three longitudinally extending slots, said slots angularly spaced about said actuating member, and wherein said rollable bodies extend outward from said slots to engage said isolation tube interior surface.

11. An expansion valve for controlling flow of expanded refrigerant material into an evaporator of a heat transfer system, comprising:

a body, said body including an inlet for receiving liquid refrigerant material; an outlet for delivering expanded refrigerant material to an evaporator of a heat transfer system; and a control element means for controlling the flow rate of refrigerant material flowing from said inlet to said outlet;

an actuating member comprised of magnetic material, said actuating member in operative connection with said control element means, wherein positioning of said actuating member regulates the flow rate through said valve;

an isolation member comprised of nonmagnetic material in surrounding relation of said actuating member, said isolation member having an interior area, said actuating member longitudinally movable in said interior area;

biasing means for biasing said actuating member toward a first end of said interior area;

a variable permeance element in surrounding relation of said isolation member at a second opposed end of said isolation member;

sleeve member means overlying said isolation member, said sleeve member means overlying said isolation member from said first end a distance toward said second end;

electrical coil means in surrounding relation of said sleeve member means, for producing electromagnetic flux responsive to delivery of electrical power thereto, said coil means having a first coil end adjacent said first end of said isolation member and a second coil end adjacent said variable permeance element;

frame means comprised of magnetic material, for supporting said coil means, said frame means in engagement with said sleeve member means adja-

cent said first coil end, and said frame means extending to adjacent said second coil end;

flux saturation means disposed longitudinally between said variable permeance element and said first end of said isolation member for providing an area of magnetic flux saturation;

and wherein said actuating member moves against said force of said biasing means and traverses said magnetic flux saturation area responsive to electrical power delivered to said coil means and wherein a displacement of said actuating member is a function of a level of said power.

12. The expansion valve according to claim 11 wherein said sleeve member means is movable on and in closely adjacent relation with said isolation member, whereby said coil means is detachable from said valve body.

13. The expansion valve according to claim 12 wherein said magnetic saturation means comprises a gap extending between an edge of said sleeve member means and said variable permeance element.

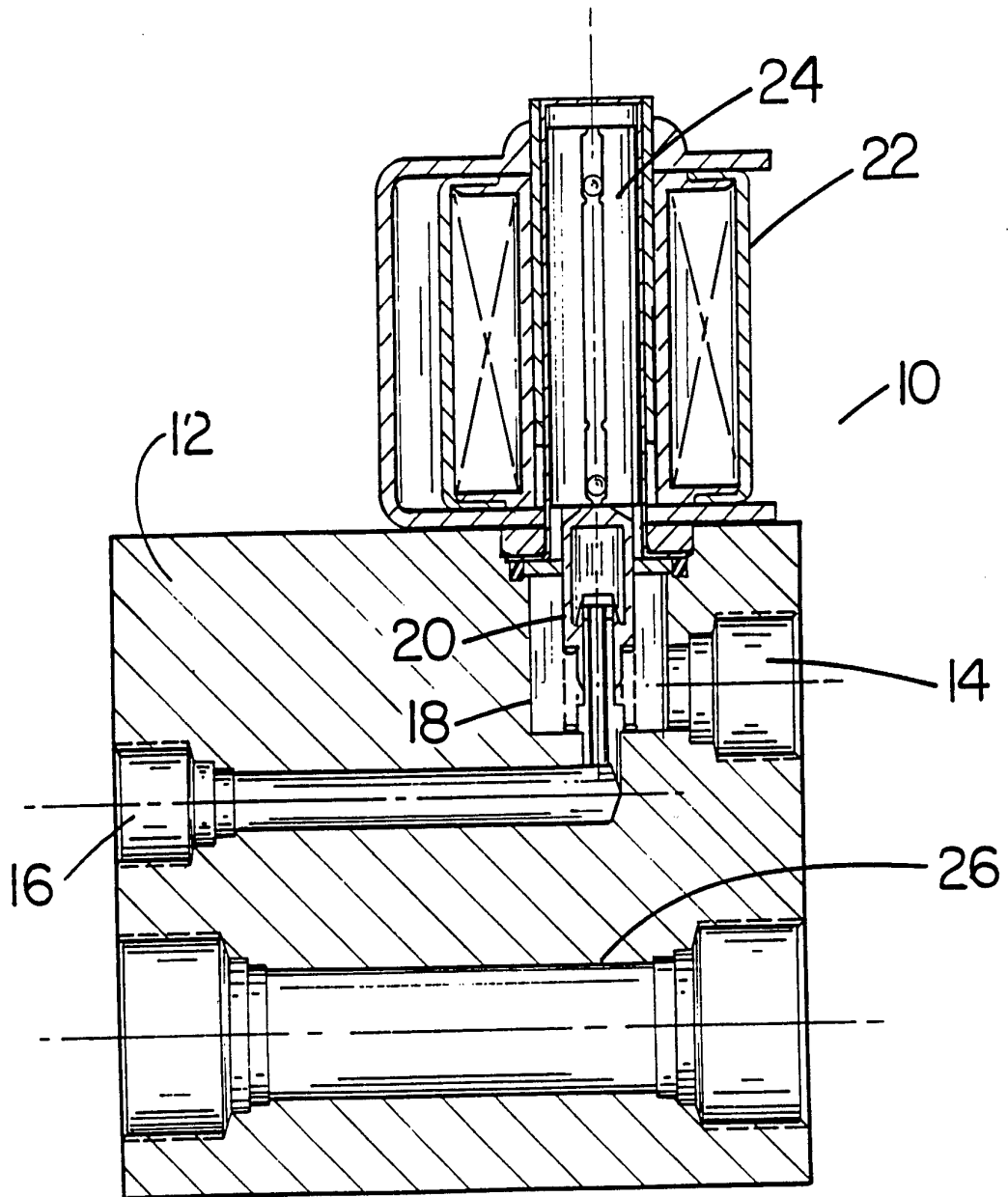


FIG. 1

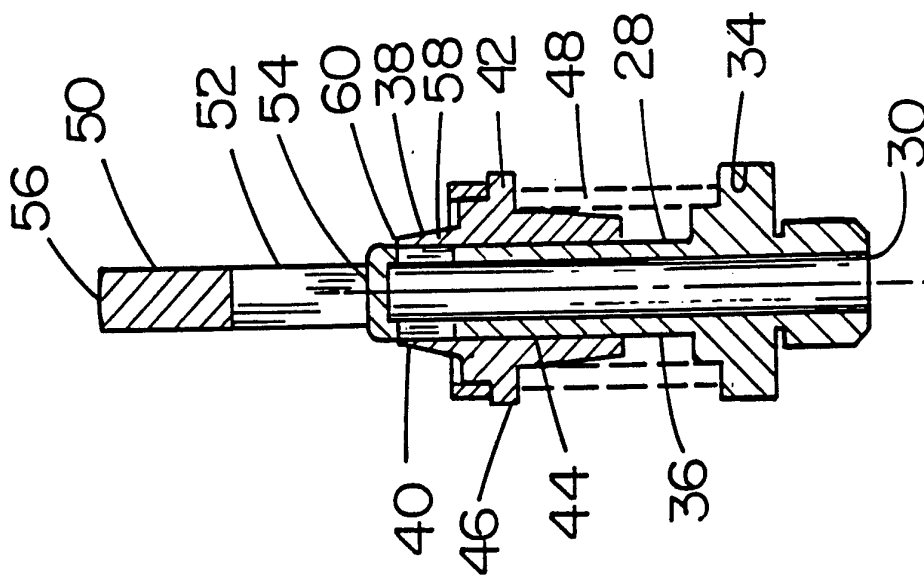


FIG. 3

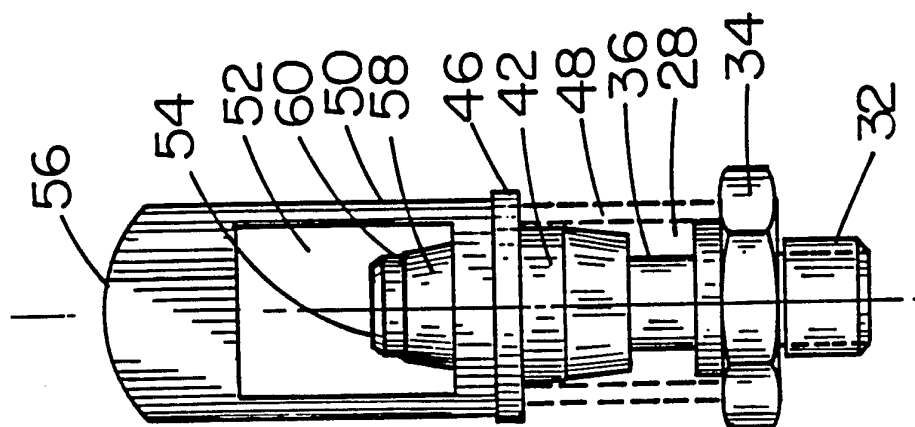


FIG. 2

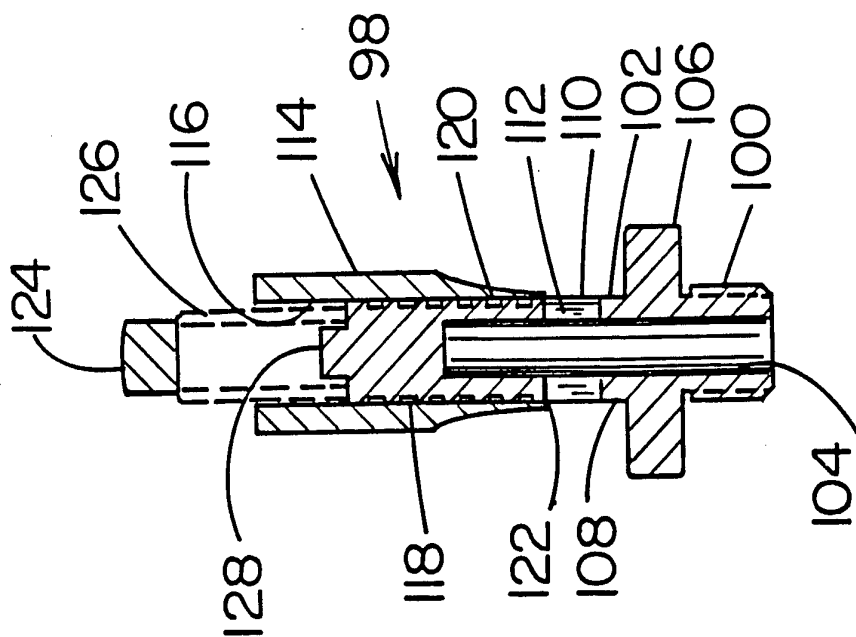


FIG. 5

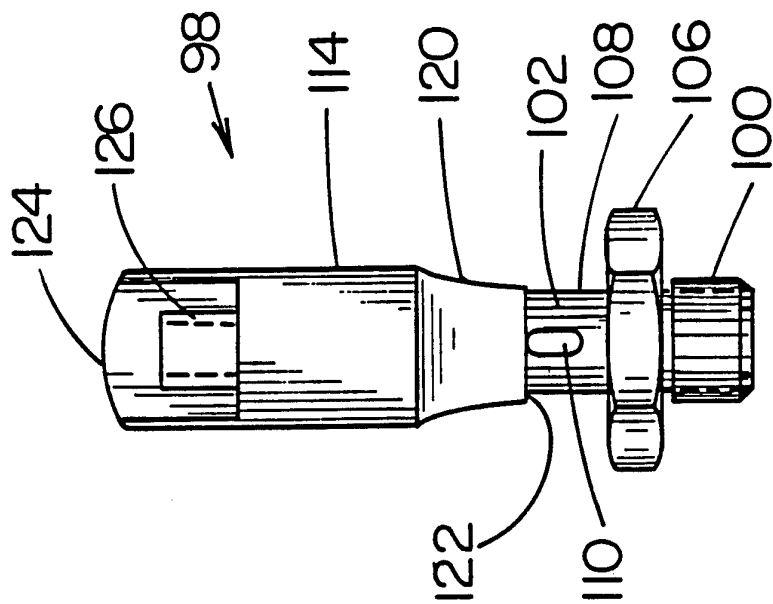


FIG. 4

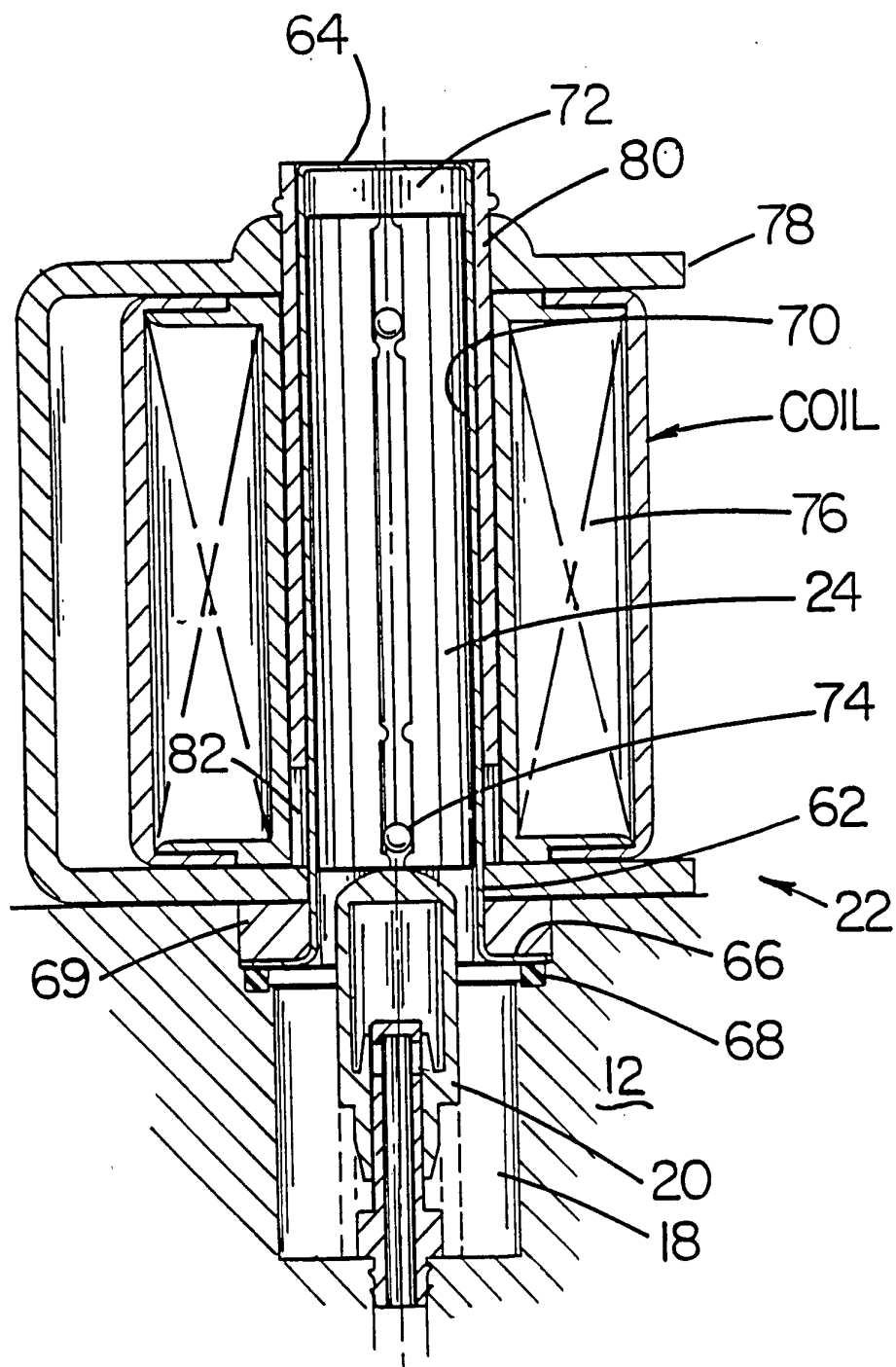


FIG. 6

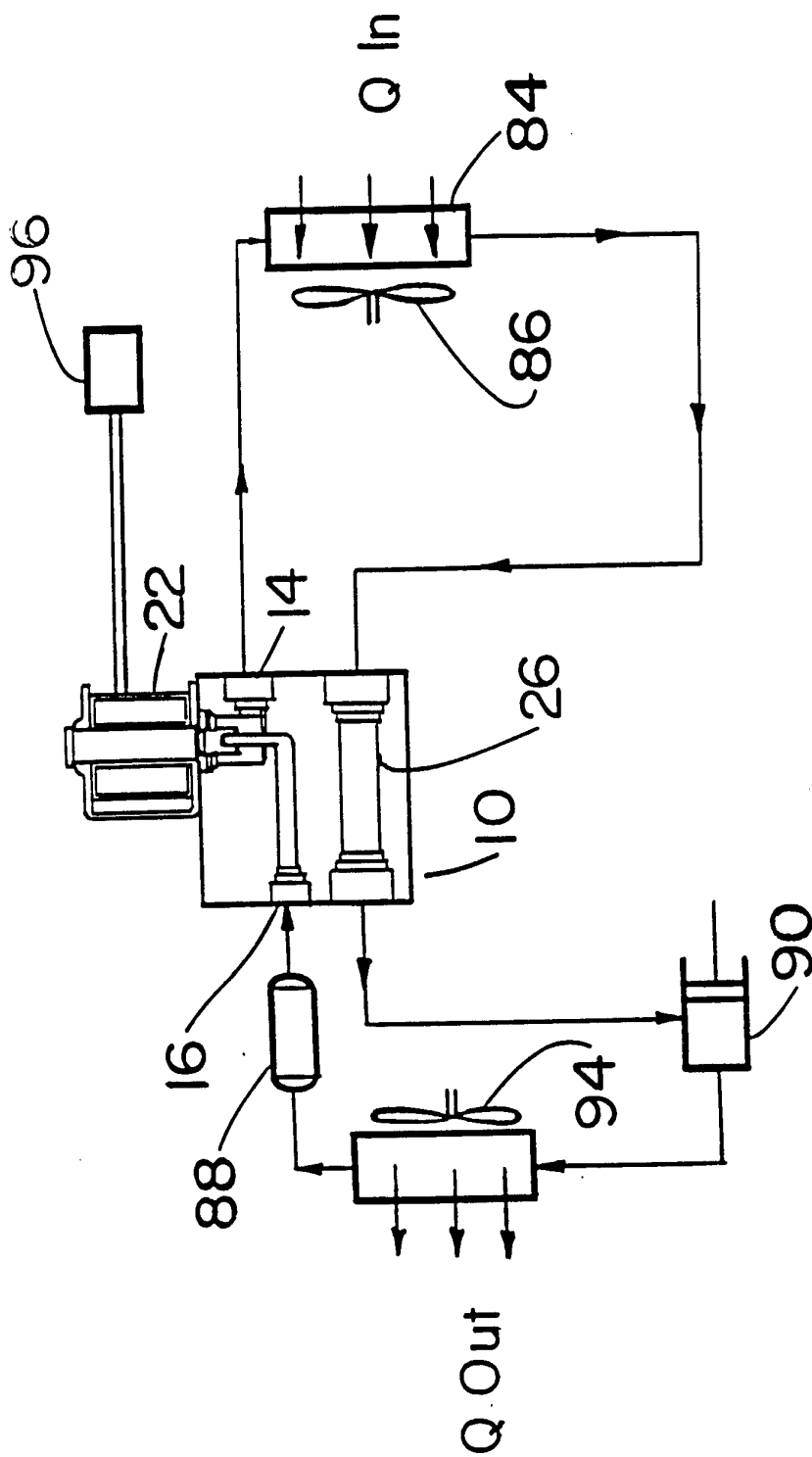


FIG. 7