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(54) **LUBRICATION MANAGEMENT OF A PUMP FOR A MICRO COMBINED HEAT AND POWER SYSTEM**

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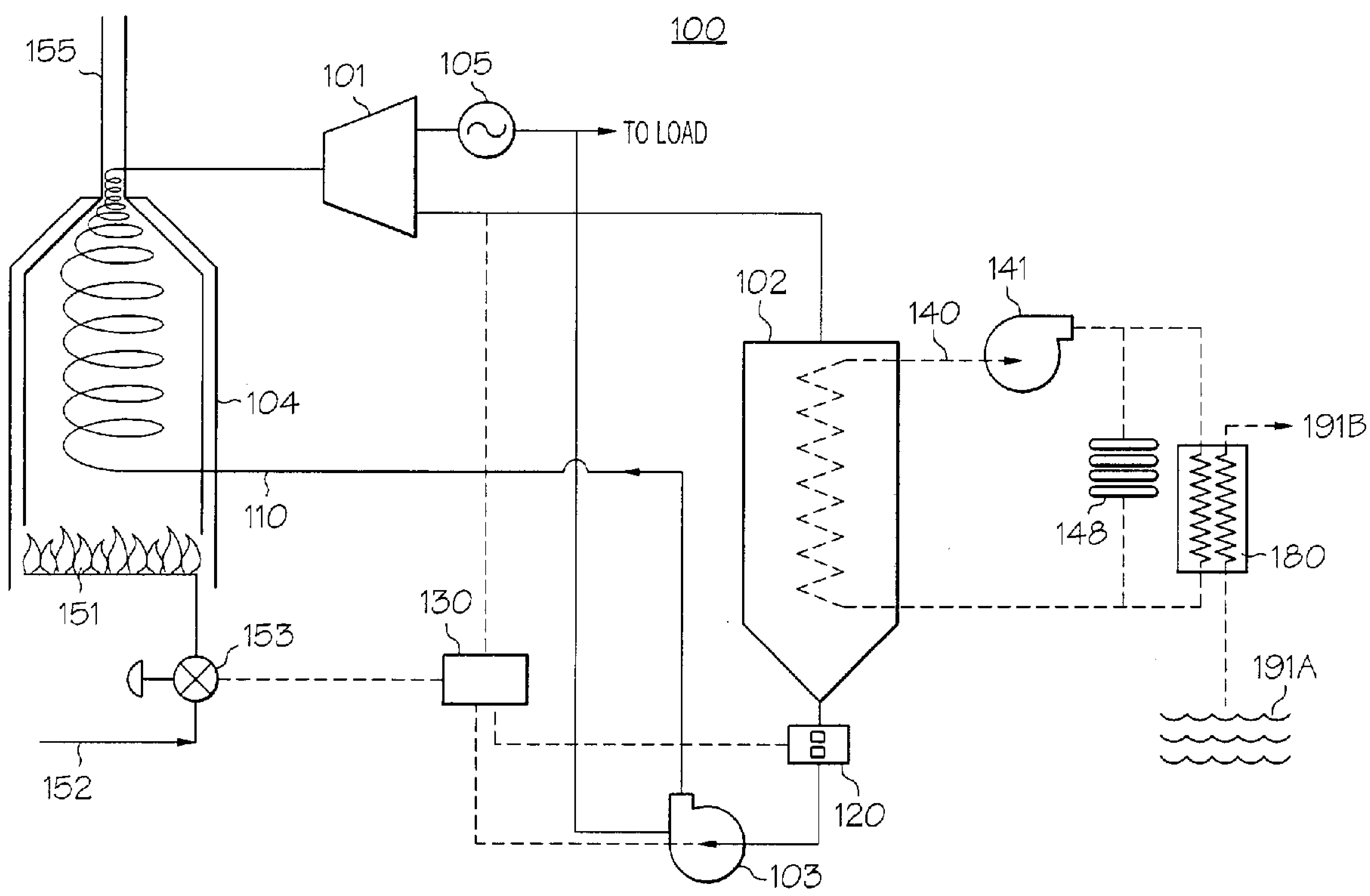
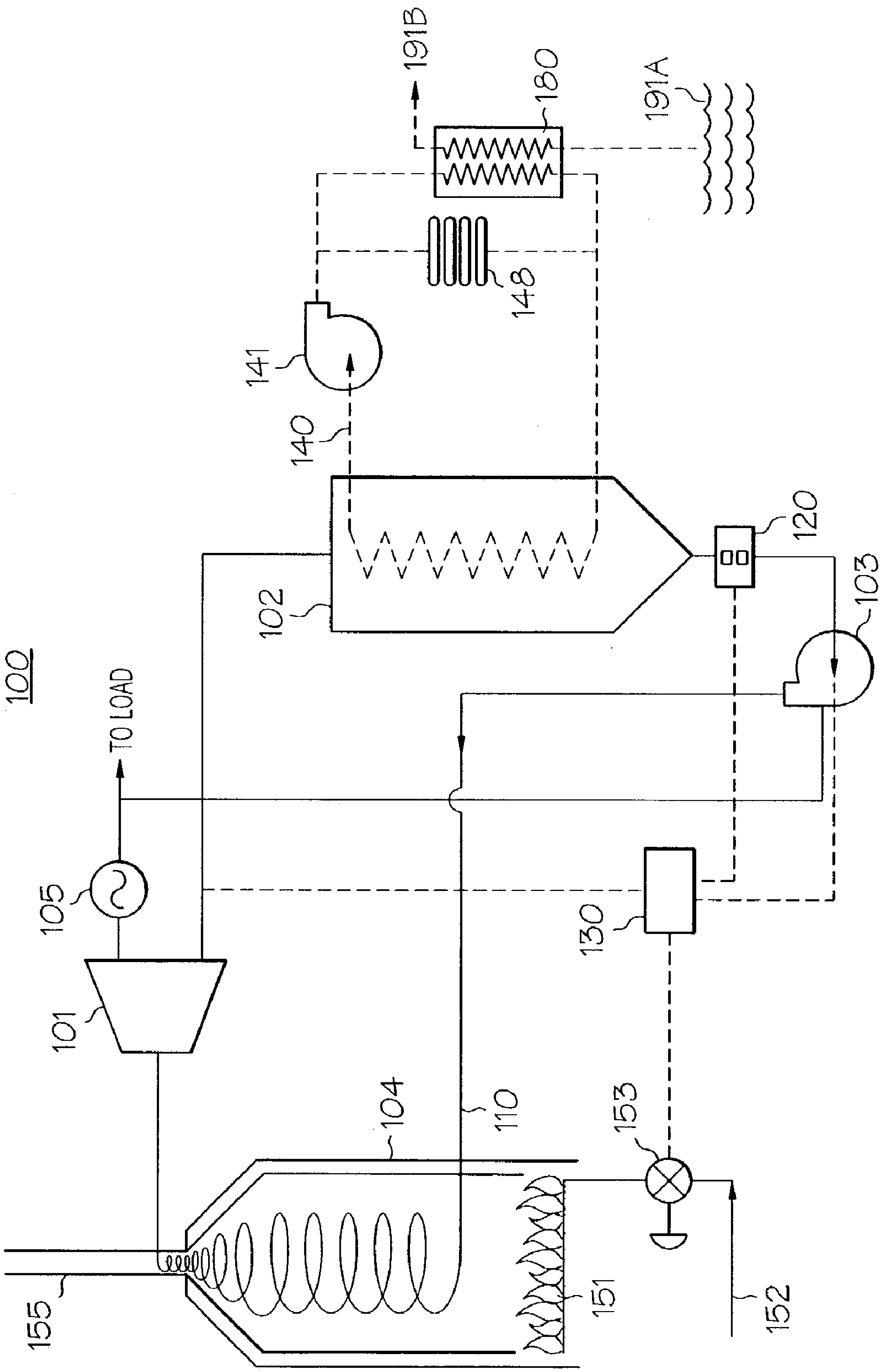
(57) **ABSTRACT**

A piston pump with a working fluid region, drive mechanism and a lubricating fluid region. The pump's working fluid region is configured to circulate a working fluid through an external circuit, such as a micro combined heat and power system. The working fluid region is separated from its lubricating fluid region by a seal. By keeping a sufficient quantity of lubricating fluid against the lubricating fluid region side of the seal, leakage of working fluid from the working fluid region to the lubricating fluid region can be significantly reduced. The pump may include various alternative forms of lubricant pumping devices to effect transport and pressurization of the lubricating fluid, including a variable volume pumping cavity, separate oil transfer pump, and mixture between the lubricating fluid and high pressure working fluid. Various piston configurations in the working fluid region may also be used to improve piston sealing.

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TO LOAD
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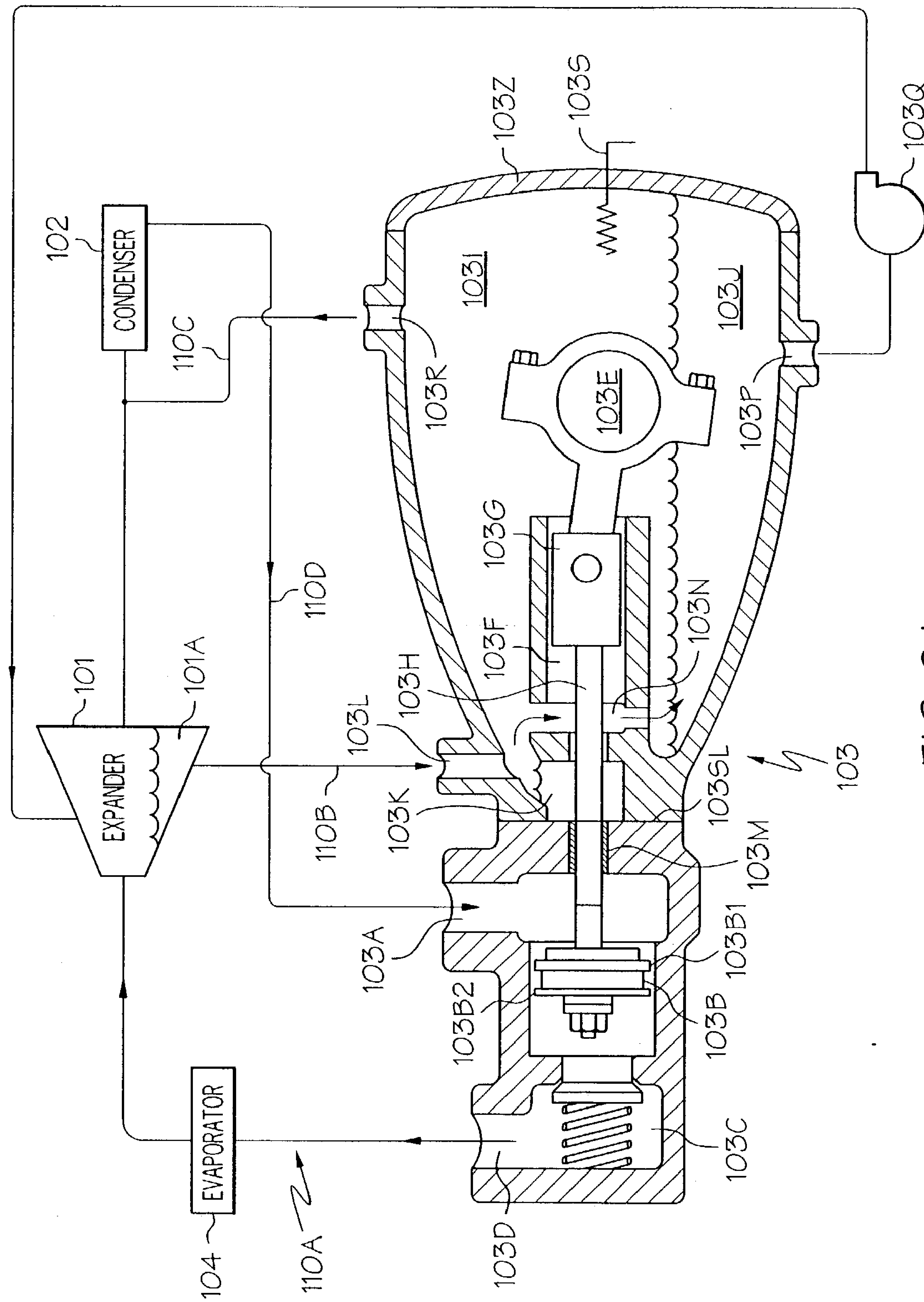
191A
191B

FIG. 1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103E
103G
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103B2
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103D

FIG. 2A

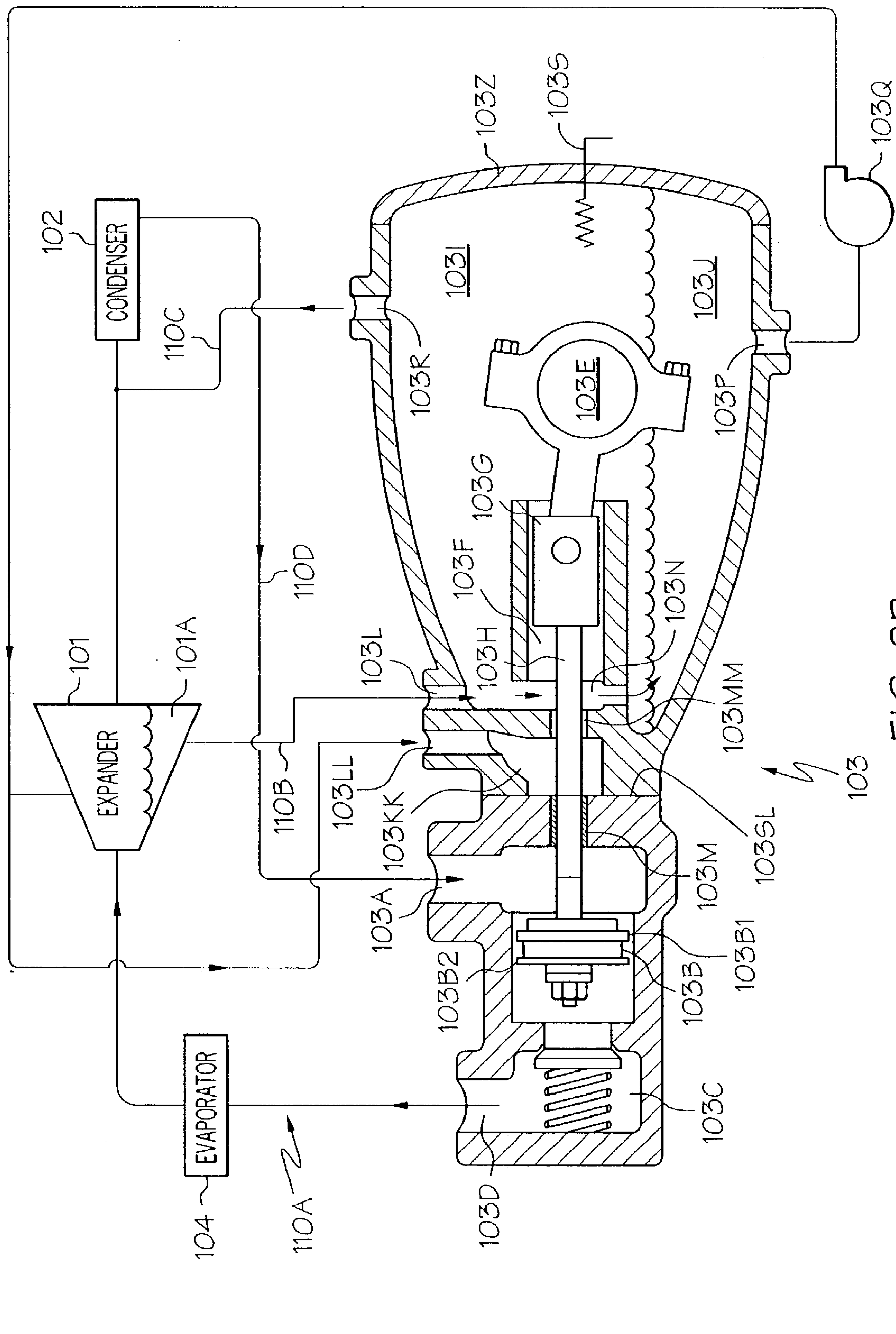
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FIG. 2B

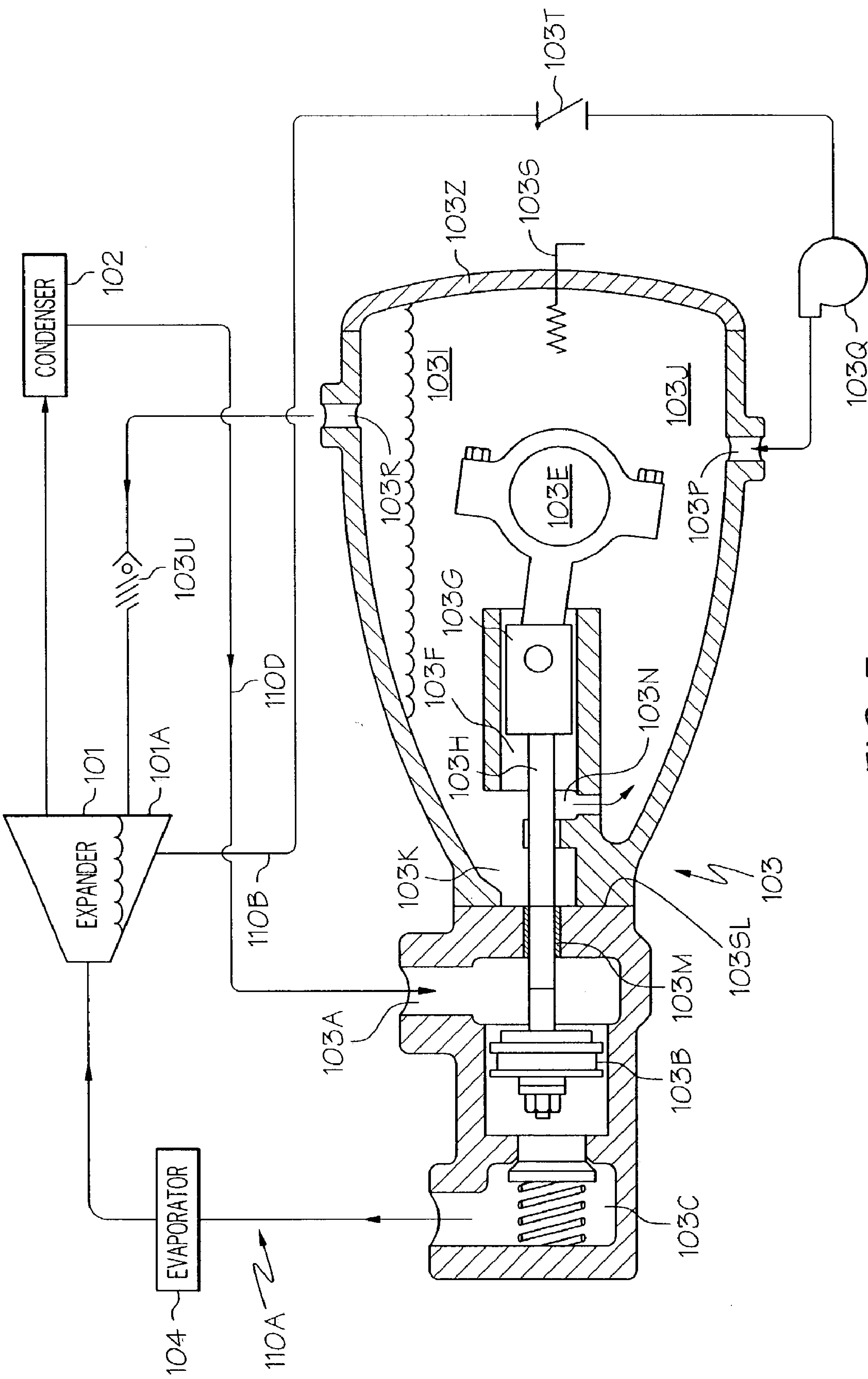
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FIG. 3

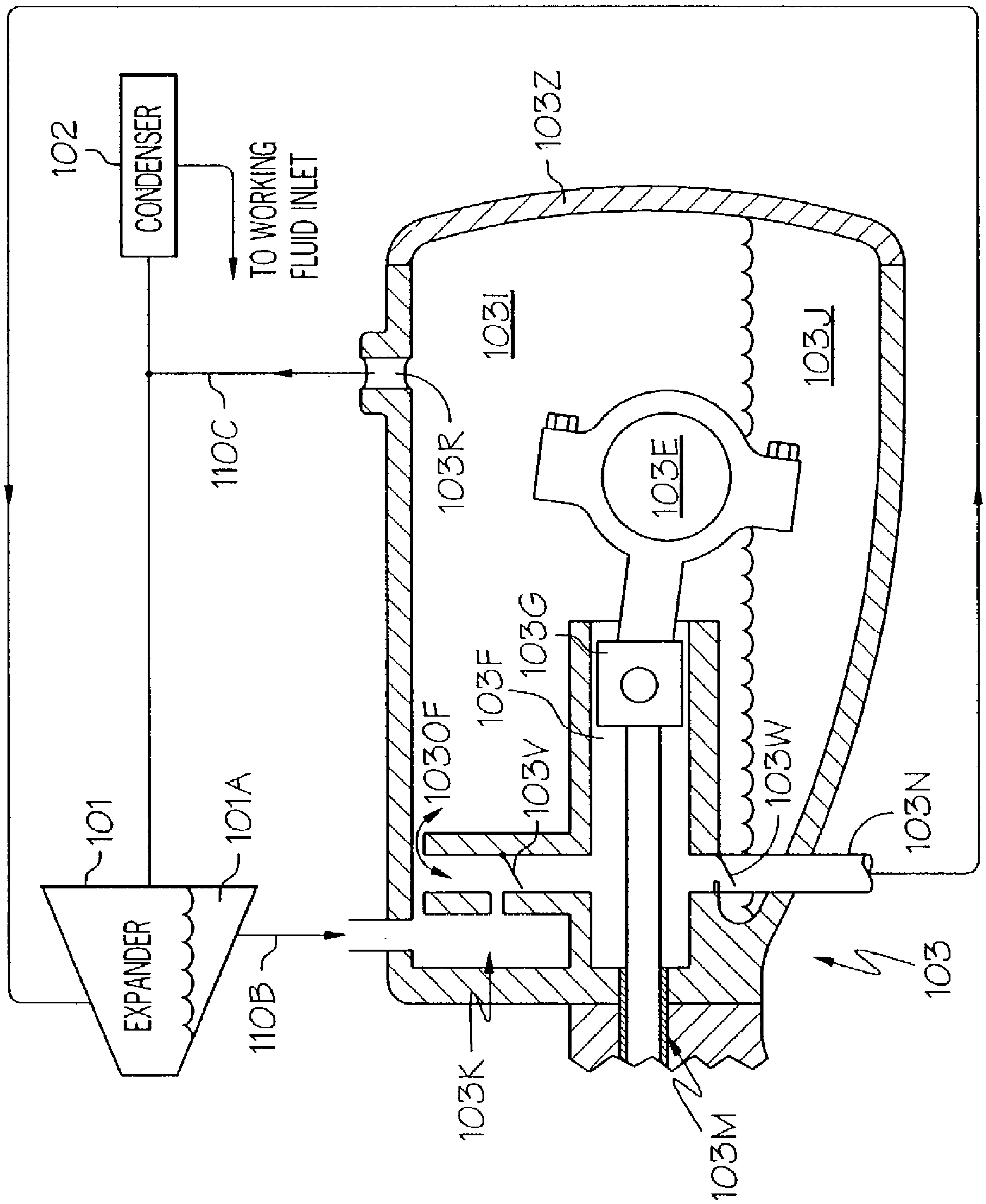
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FIG. 4A

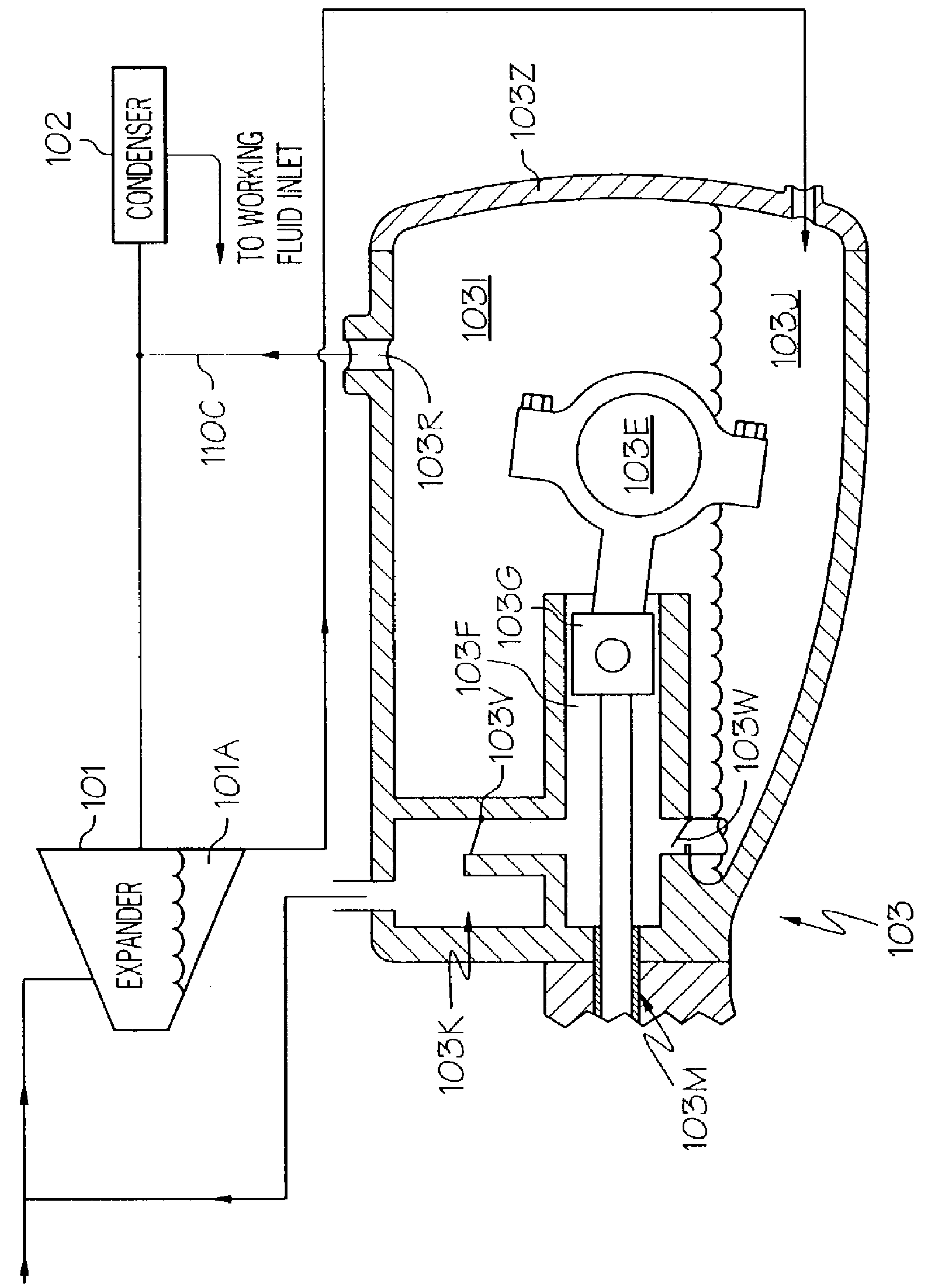
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FIG. 4B

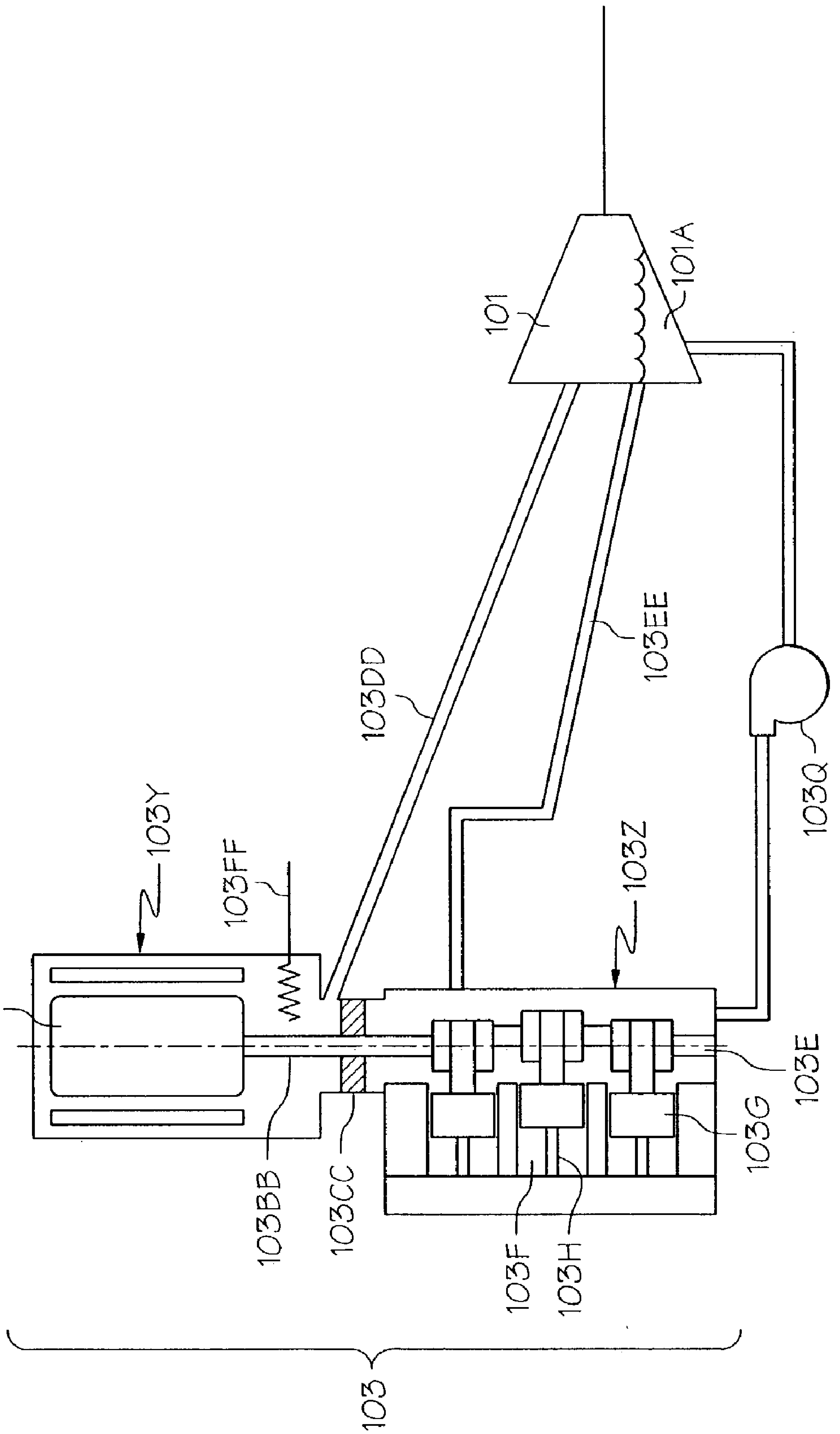
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FIG. 5A

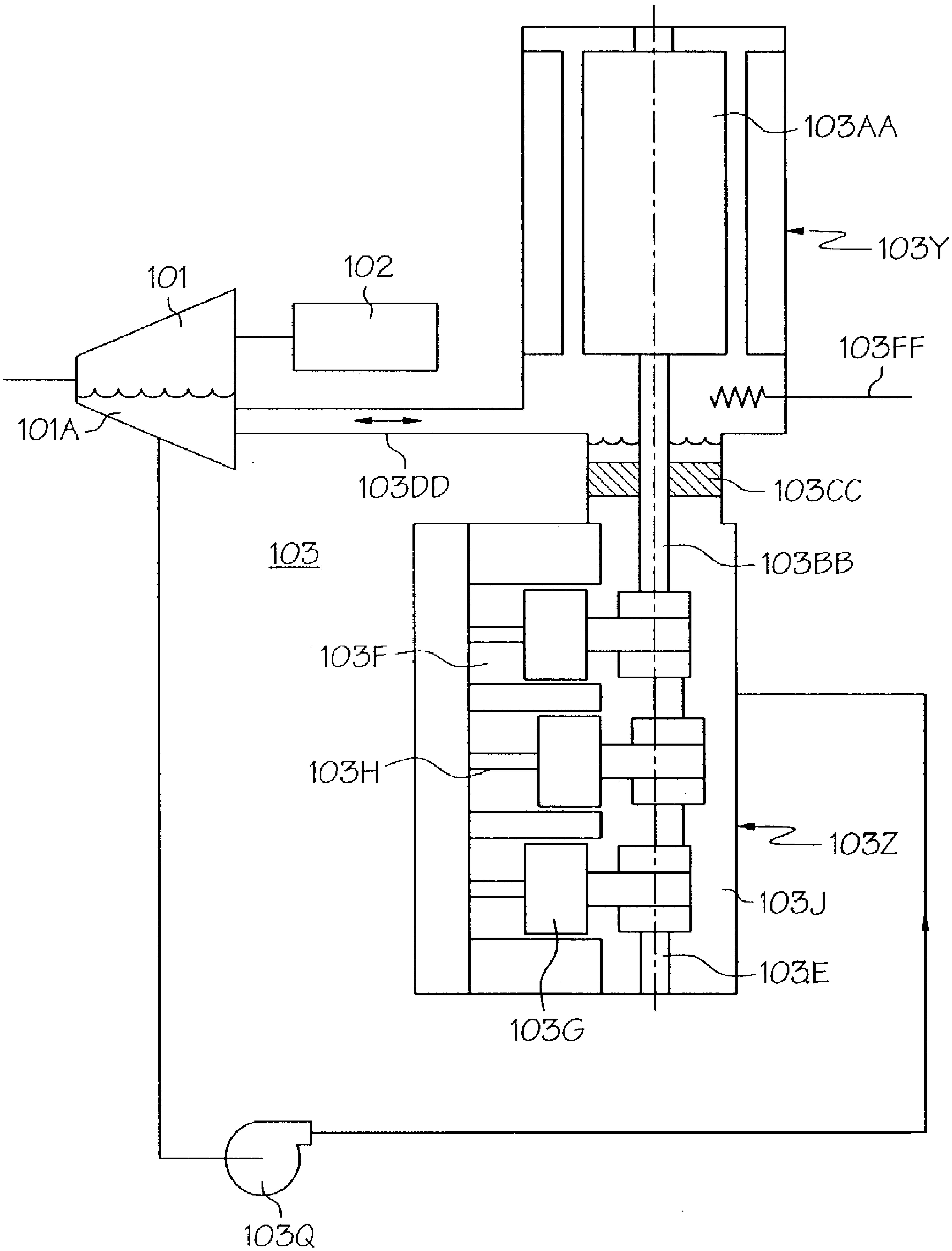
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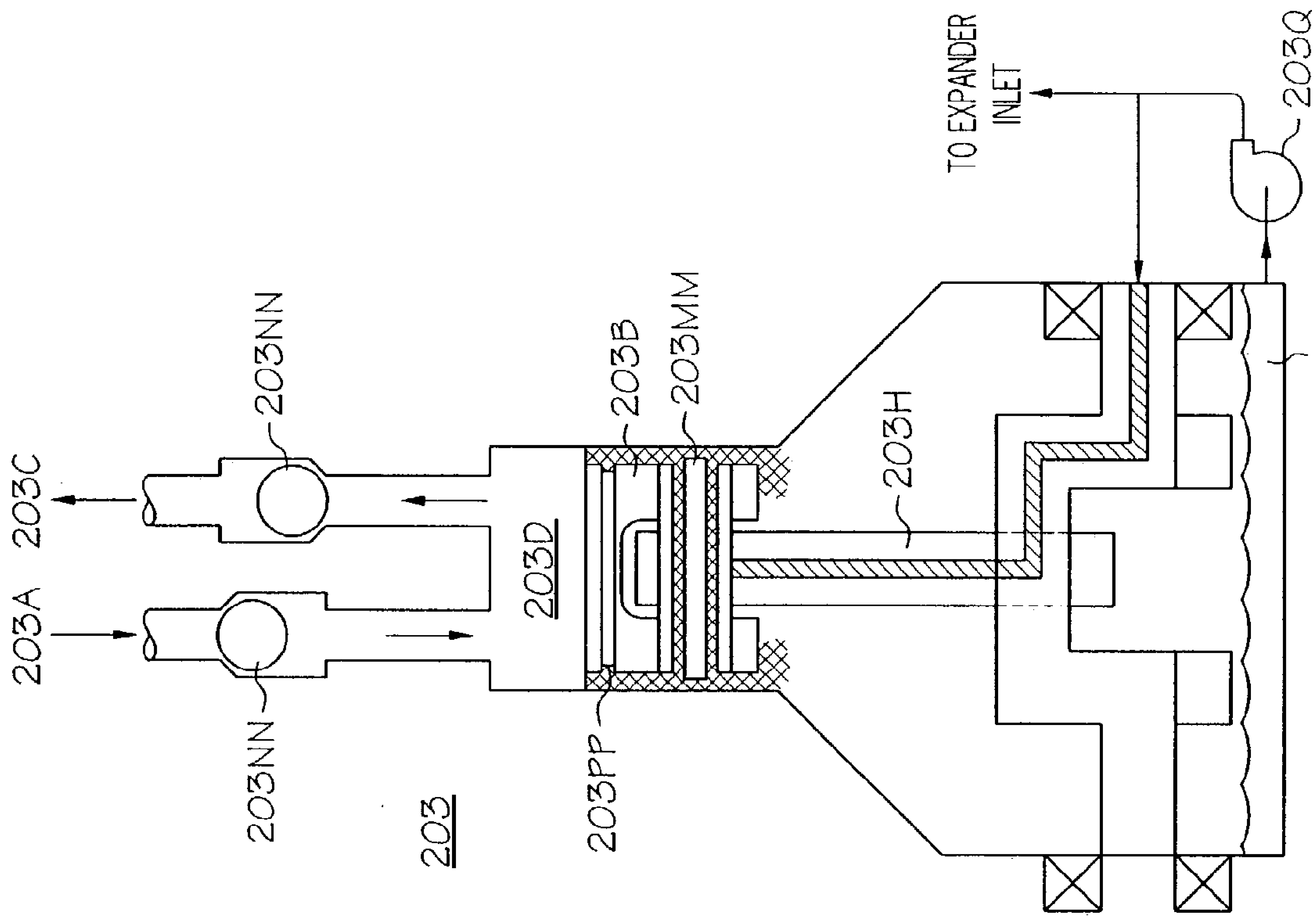
FIG. 5B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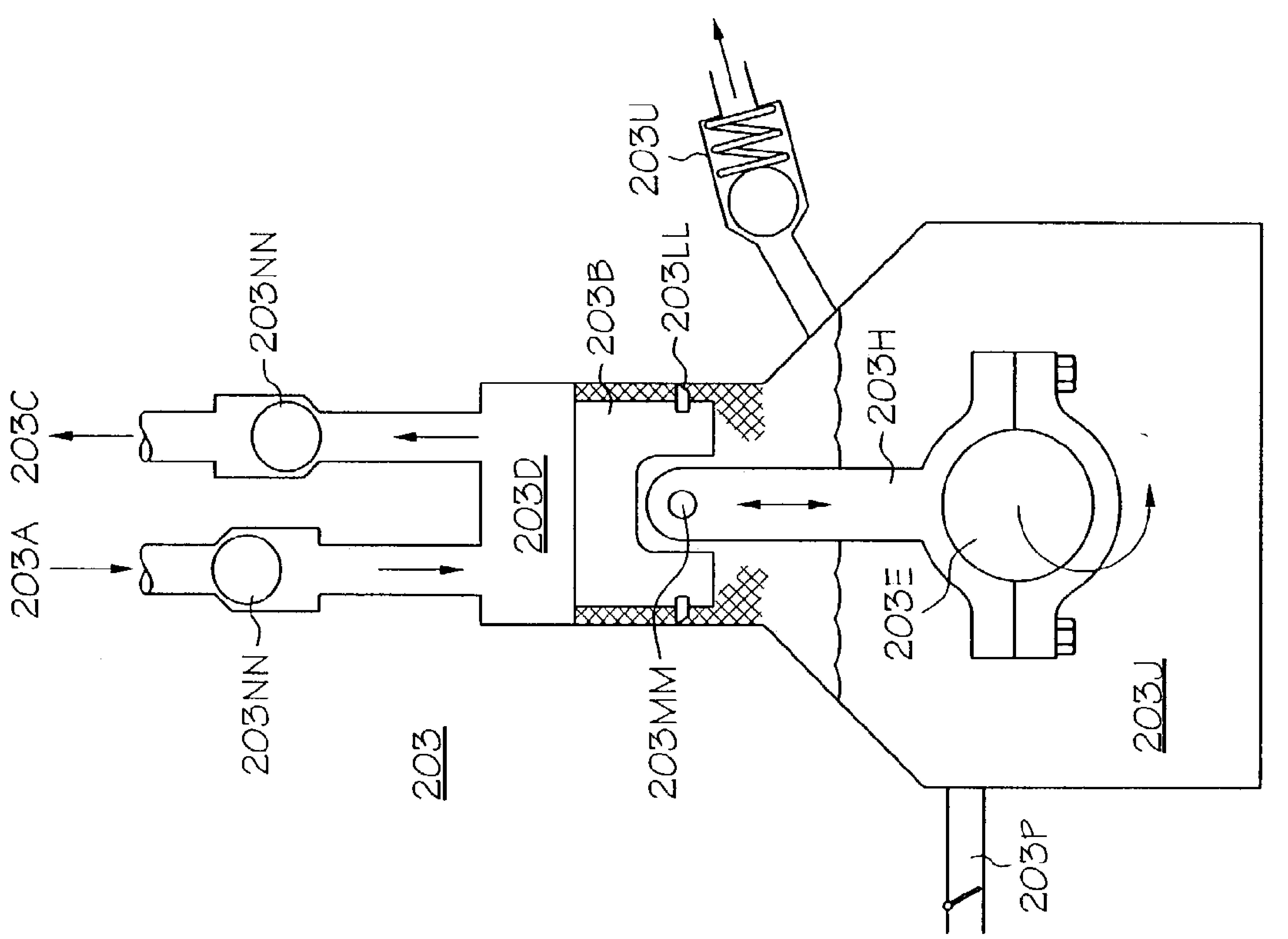
203PP
203H
TO EXPANDER INLET
203Q
203J

FIG. 6B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203H
203E
203J
203P

FIG. 6A

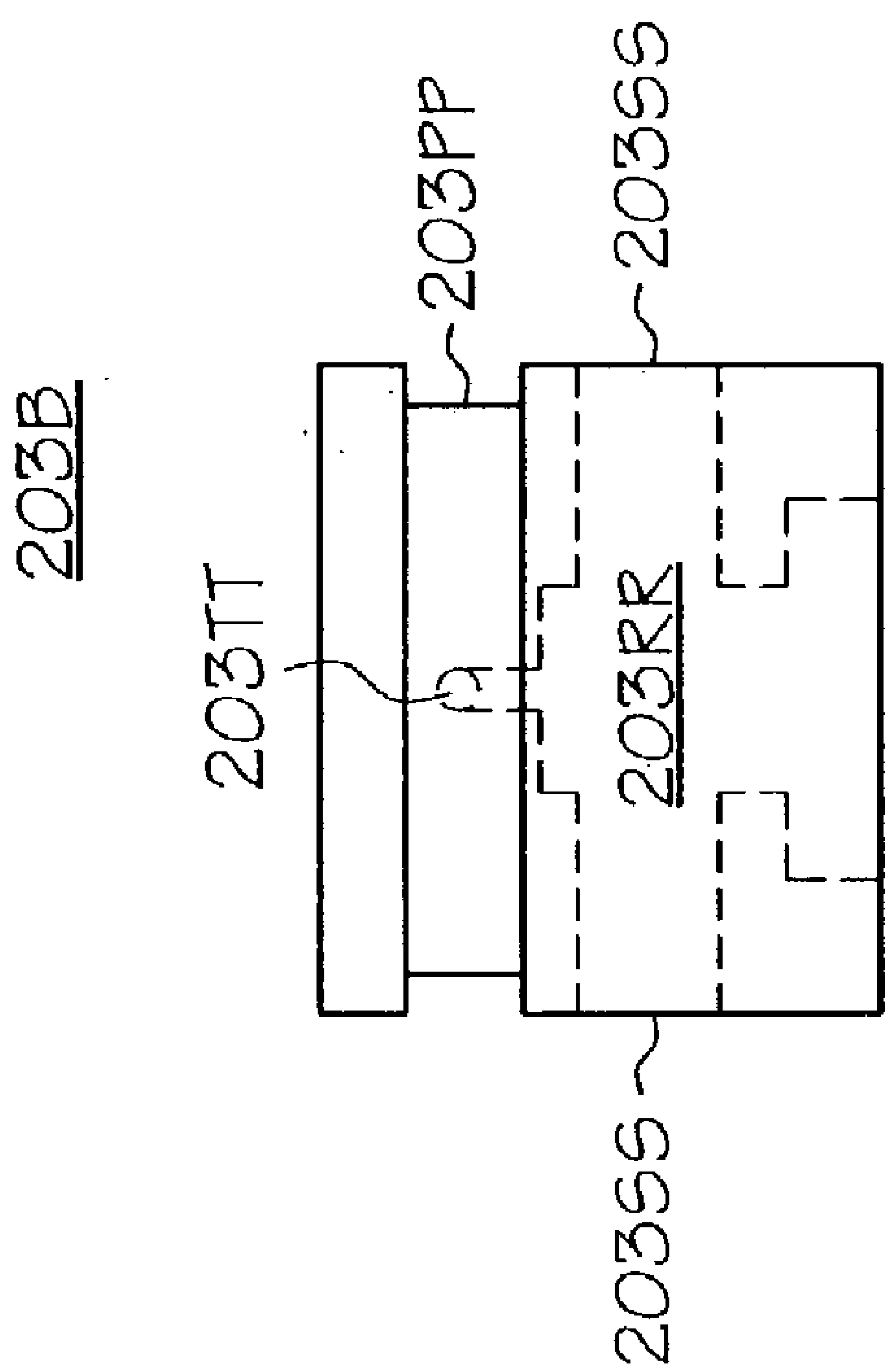


FIG. 6C

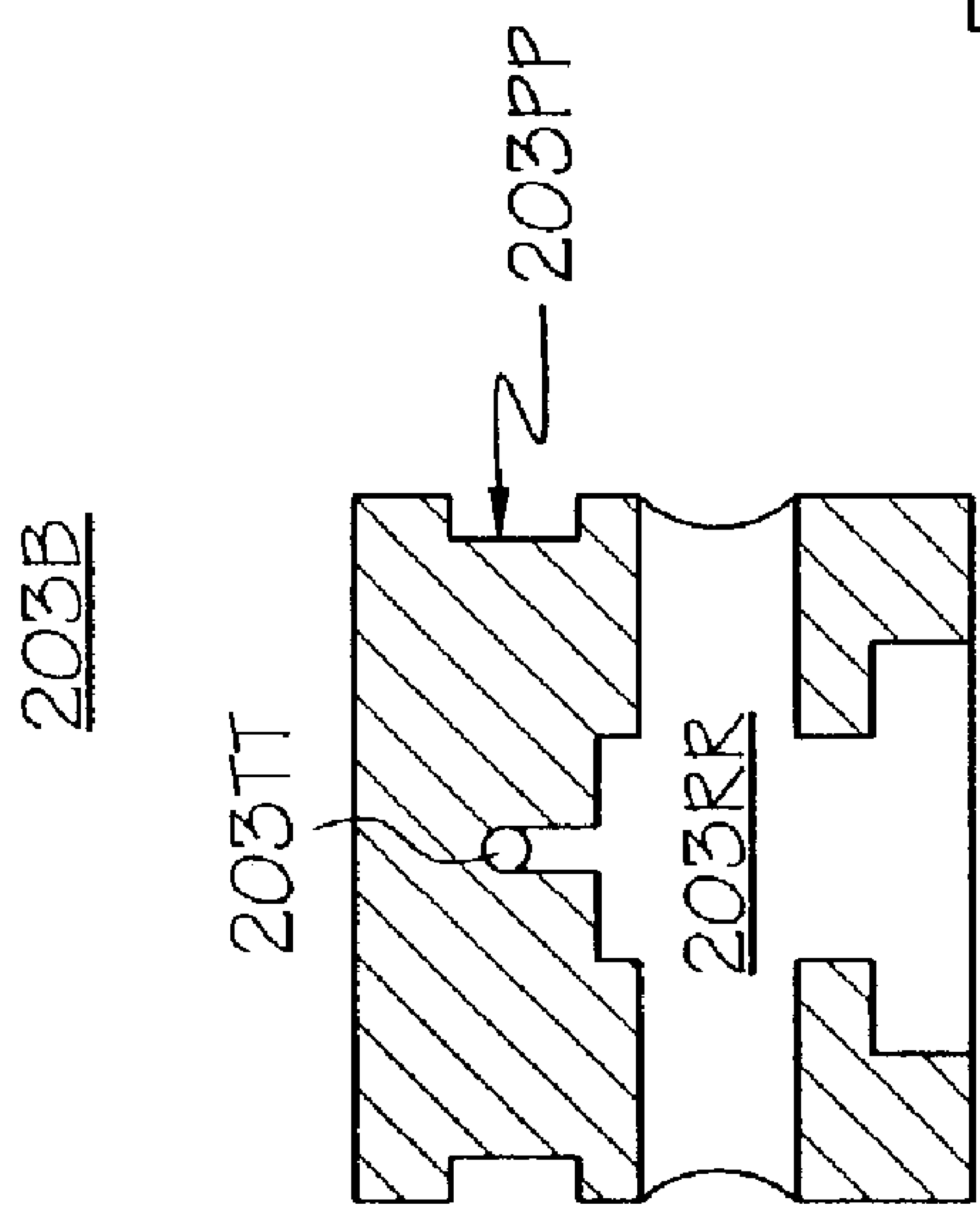


FIG. 6D

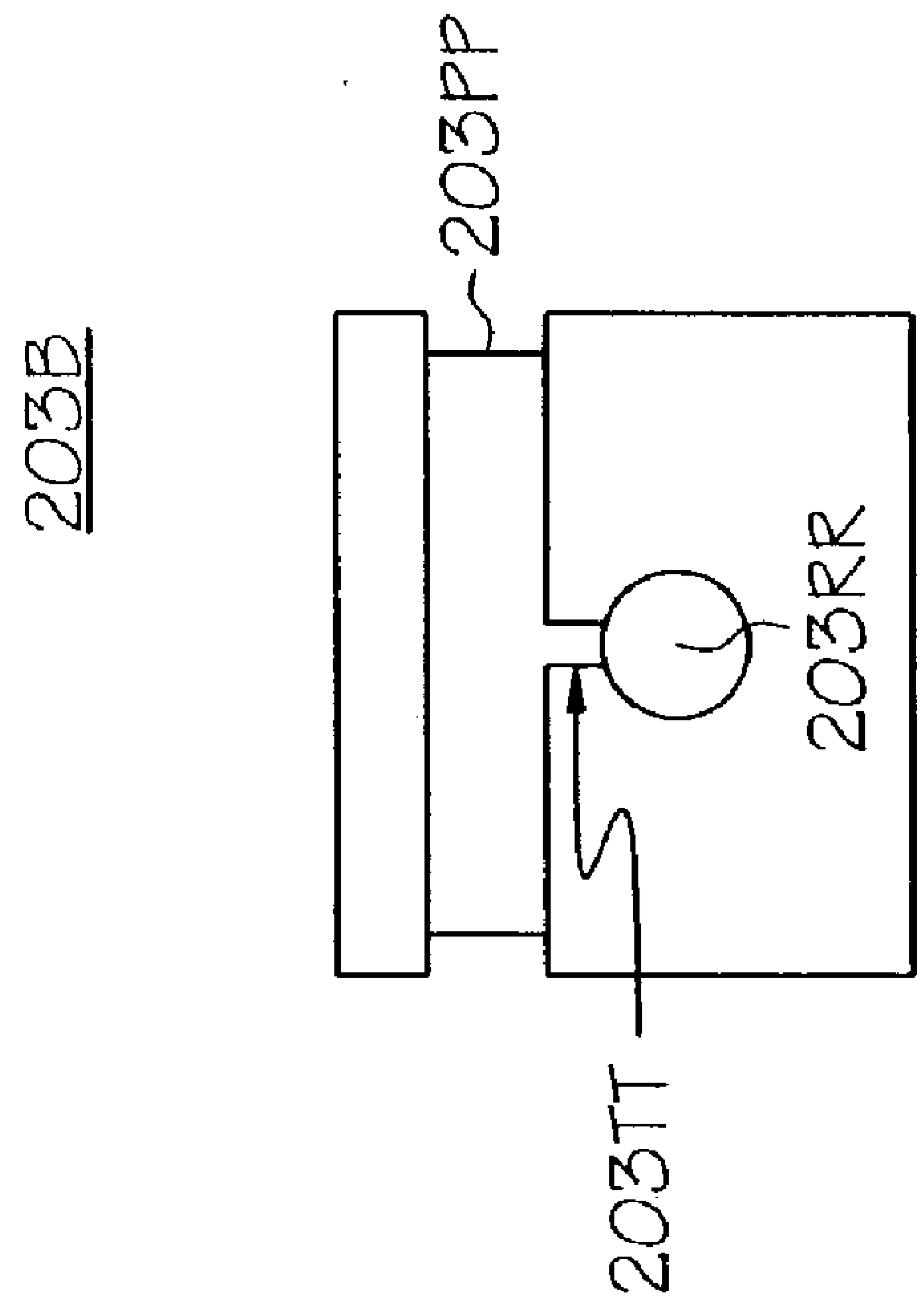
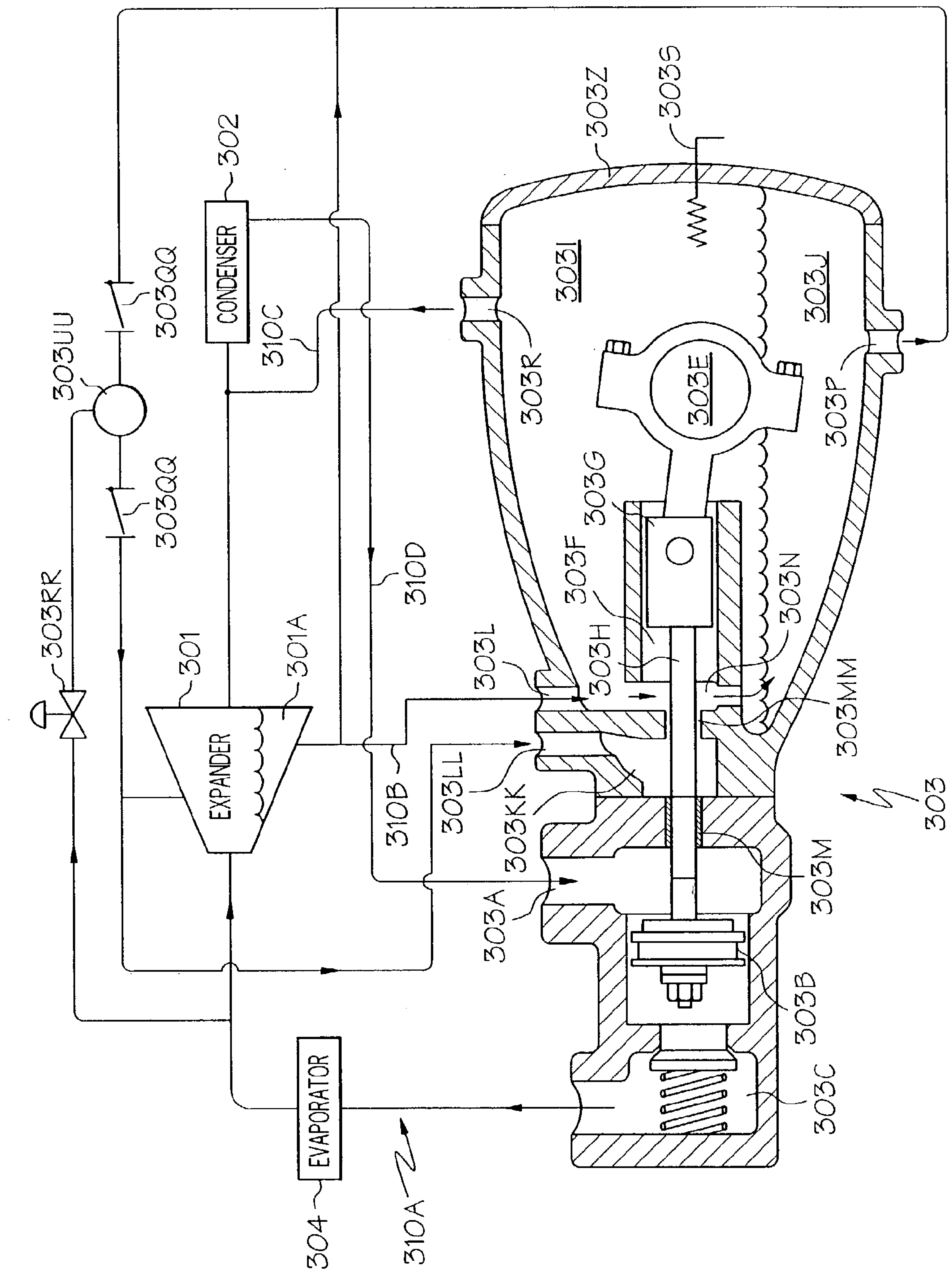


FIG. 6E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EXPANDER
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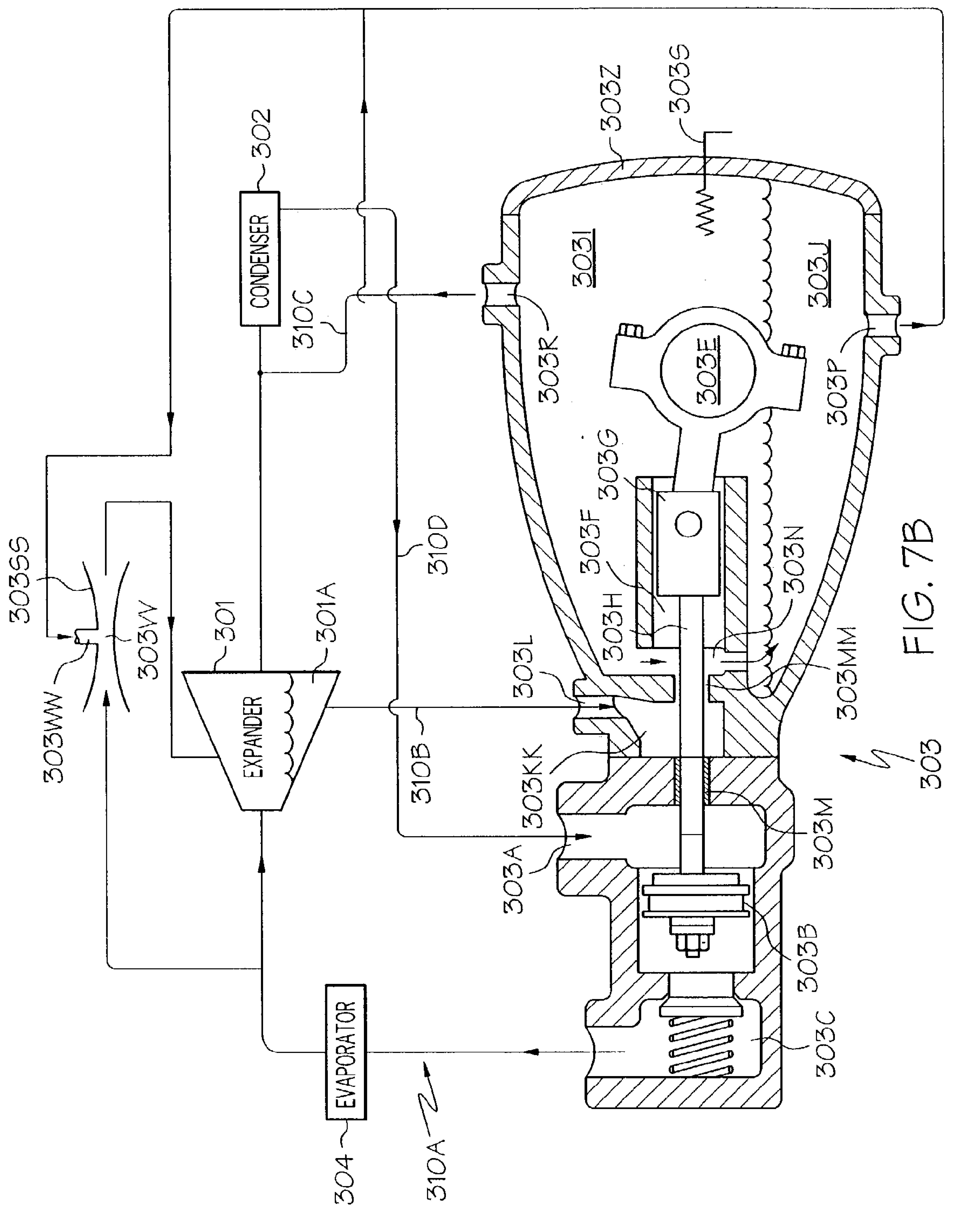
FIG. 7A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303KK
303
303M
303A
303B
303C
310D
310B
301
301A
EXPANDER
303SS
303VV
303WW
EVAPORATOR
304
310A

FIG. 7B

LUBRICATION MANAGEMENT OF A PUMP FOR A MICRO COMBINED HEAT AND POWER SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to improvements in lubrication of a piston pump, and more particularly to improvements in the handling, transport and efficacy of piston pump lubricant used in the presence of an organic working fluid.

[0002] The concept of cogeneration, or combined heat and power (CHP), has been known for some time as a way to improve overall efficiency in energy production systems. With a typical CHP system, heat (usually in the form of hot air or water) and electricity are the two forms of energy that are generated. In such a system, the heat produced from a combustion process can drive an electric generator, as well as heat up water, often turning it into steam for dwelling or process heat. Traditionally, CHP systems have been large, centrally-operated facilities under the control of the state or, a large utility company, sized to provide energy for many thousands of users. Recent trends in the deregulation of energy production and distribution have made viable the concept of distributed generation. With distributed generation, the large, central generating station is supplemented with, or replaced by numerous smaller autonomous or semi-autonomous units. These changes have led to the development of smaller CHP systems, called micro-CHP, which are distinguished from traditional CHP by the size of the system. For example, the electric output of a generating station-sized CHP could be in the tens, hundreds or thousands of megawatts (MW), where the electric output of a micro-CHP is fairly small, in the low kW_e or even sub-kW_e range. The inclusion of a distributed micro-CHP system into dwellings that already have fluid-carrying pipes for heat transport is especially promising, as little or no disturbance of the existing building structure to insert new piping is required.

[0003] Accordingly, the market for localized heat generation capability in Europe and the United Kingdom (UK), as well as certain parts of the United States, dictates that a single unit for residential and small commercial sites provide heat for both space heat (SH), such as a hydronic system with radiator, and domestic hot water (DHW), such as a shower head or faucet in a sink or bathtub, via demand (instantaneous) or storage systems.

[0004] The inventors have discovered that the use of an organic working fluid in a micro-CHP system produces specific benefits over conventional fluids, such as water. For example, many organic working fluids remain fluid at temperatures that cause water to freeze, where damage and inoperability could ensue after prolonged exposure of a water-filled system to such temperatures. In addition, by using an organic working fluid rather than water, corrosion issues germane to water in the presence of oxygen, and expander sizing or staging issues associated with low vapor density fluids, are avoided. The inventors have additionally discovered that certain organic working fluids, such as halocarbon refrigerants or naturally-occurring hydrocarbons, combine desirable operational attributes with environmentally benign features. Examples of the former include the refrigerant known as R-245fa, while examples of the latter include some of the alkanes, such as isopentane.

[0005] The inventors have further discovered that, as an outgrowth of the use of organic working fluids, the feed pump becomes one of the key components in a micro-CHP system. The feed pump is responsible for circulating the working fluid through various Rankine-cycle components, including an evaporator, expander and condenser. While there are numerous pump configurations to choose from, the inventors have additionally discovered that axial piston pumps are especially beneficial in situations where long, maintenance-free pump life is of paramount concern. In such pumps, a mechanism such as a crank or swashplate converts the rotary movement of a shaft into rectilinear motion of one or more pistons inside close-fitting cylinders. The cylinders are typically defined at a distal (working fluid) end by a working fluid pumping chamber, and at a proximal (lubricating fluid) end by means to accommodate the crank, with a coupling device and associated drive mechanism extending between the proximal and distal ends. The reciprocating motion of the piston in the pumping chamber allows the working fluid present therein to be pressurized and subsequently discharged. Lubricant (such as oil) contained within the crankcase is circulated throughout at least the lubricating fluid region and the drive mechanism of the pump to reduce component wear. A difficult problem for piston pumps is how to maintain an appropriate lubricant supply in the crankcase with an imperfect seal between the pumping chamber of the working fluid region and the drive mechanism and lubricating fluid region, where over time, leakage of the working fluid past the seal will collect in the crankcase with the lubricating oil. Such action tends to dilute the oil, and since the working fluid (such as one of the aforementioned organic working fluids) is typically a low viscosity fluid, such dilution can compromise the ability of the oil to perform its intended lubricating function. This problem worsens as the seals wear, such wear being exacerbated by the large pressure differential between the pumping chamber and the crankcase. In another scenario, backward migration of lubricant or a mixture of lubricant and working fluid from the lubricating fluid region across the seal to the pumping chamber is possible, and can show up under the wide variations in system operating conditions, where during at least part of the cycle, the crankcase pressure is greater than the intake pressure.

[0006] What is needed is a pump that operates efficiently under the myriad operating conditions inherent in a micro-CHP system. The present inventors have recognized that judicious management of the pump lubricant can make important contributions to pump operability, durability and efficiency, which in turn has a dramatic effect on overall micro-CHP system durability and efficiency.

BRIEF SUMMARY OF THE INVENTION

[0007] These needs are met by the present invention, where improved lubrication management features are incorporated into a piston pump to facilitate pump operability. According to a first aspect of the present invention, a piston pump is disclosed. The pump includes at least one working fluid region, a drive mechanism, a lubricating fluid region and a seal that defines a boundary between the working fluid and lubricating fluid regions. The working fluid region includes an intake port configured to receive a working fluid, an outlet port configured to dispense the working fluid, and a piston disposed between the intake and outlet ports such that upon oscillation of the piston, the working fluid is pumped from the intake port to the outlet port. The drive mechanism includes a power transfer shaft rotatably responsive to a drive source, a tubular passageway extending from a space adjacent the power transfer shaft to the working fluid region such that the piston is contained in the portion of the tubular passageway in the working fluid region, a crosshead slidably disposed in the tubular passageway, the crosshead pivotally connected to the power transfer shaft, and at least one piston rod connected at a first end to the crosshead (or to the piston that is configured for long life with the side loads otherwise carried by the crosshead) and at a second end to the piston, the piston rod configured to impart an oscillating motion to the piston. The lubricating fluid region is coupled to at least the drive mechanism and includes a lubricant sump disposed adjacent the power transfer shaft and configured to contain at least a portion of the lubricant (alternately referred to as lubricating fluid), a lubricant reservoir in fluid communication with the lubricant sump, and a lubricant pumping device fluidly coupled to the lubricant sump. The seal is configured to reduce migration of fluid between the working fluid region and the lubricating fluid region.

[0008] Optionally, the lubricant sump is hermetically sealed. In another option, the lubricant pumping device can be configured to include a lubricant inlet channel configured to receive lubricant from at least one of the lubricant sump and the lubricant reservoir; an inlet check valve disposed in the lubricant inlet channel; a lubricant outlet channel; an outlet check valve disposed in the lubricant outlet channel; and a variable volume pumping cavity at least partially disposed in the tubular passageway, the cavity in fluid communication with the lubricant inlet channel and the lubricant outlet channel, the cavity defined at a first end by the crosshead such that upon oscillating motion of the crosshead, the lubricant introduced into the cavity through the lubricant inlet channel becomes pressurized and exits through the lubricant outlet channel. In addition, wherein the lubricant inlet channel can be fluidly coupled to the lubricant reservoir. Moreover, the variable volume pumping cavity is defined at a second end by a wall intermediate the crosshead and the working fluid region, and the seal is disposed in the wall. A reservoir seal (different than the previously-described seal defined at the boundary between the working fluid region and the lubricating fluid region) can also be disposed about the piston rod between the lubricant reservoir and the lubricant pumping device. Together, the boundary-defining seal and the reservoir seal distinguish the multiple compartments along the lengthwise dimension of the tubular passageway. The working fluid region can additionally be configured as a multi-unit pump. For example, the pump may include multiple working fluid regions, lubricating fluid regions, check valves and drive mechanisms each configured to cooperate to define a single unit of the multi-unit piston pump. In such a multi-pump configuration, the plurality of tubular passageways can be fluidly connected with one another.

[0009] In other options, the lubricant pumping device can comprise a separately-powered oil transfer pump, while the lubricant reservoir can be fluidly coupled to the piston pump. The pumping capacity of the oil transfer pump is preferably a small fraction of the capacity of the piston pump, for example, five (5) percent or less. The lubricant reservoir can be made to be separately pressurizable from the remainder of the lubricating fluid region, thereby pressurizing the seal that defines the boundary between the working fluid region and the lubricating fluid region. In at least one configuration, the drive source is a motor, where a first compartment can be configured to contain the motor, while a second compartment can hold at least a portion of the lubricating fluid region and the drive mechanism. In addition, a coupling extends from the motor (in the first compartment) to the power transfer shaft in the second compartment, while a vapor space seal is disposed about the coupling to define a boundary between the first and second compartments. A lubricant drain line fluidly coupled to the first compartment and to the oil transfer pump can be added such that the lubricant drain line can remove at least one of the working fluid and the lubricant from the first compartment. A lubricant return line may also be included to fluidly couple the second compartment and the oil transfer pump. In one embodiment, the first and second compartments are disposed in a common housing, which may be hermetically sealed. The first compartment may further comprise a heating element to maintain the temperature in the first compartment above the saturation temperature of the working fluid, thus inhibiting condensation of the working fluid. The lubricant drain line and the surface of the first compartment that contains the vapor space seal can be made to occupy the substantially lowest vertical position in the first compartment such that any lubricant that collects in the first compartment will flow through the lubricant drain line.

[0010] In another option, the lubricant pumping device can comprise a high pressure vapor source fluidly coupled to the lubricant sump. By way of example, the high pressure vapor source could be a lubricant pressurization chamber fluidly coupled to the lubricant sump. The pressurization chamber includes at least one check valve and a flow regulating device configured to intermittently allow the transport of fluid contained in the lubricant pressurization chamber to at least one of the working fluid region and the lubricating fluid region. In one embodiment, the flow regulating device is a time-responsive valve. By way of another example, the high pressure vapor source is a jet pump configured to inject lubricant into a flow of high pressure vapor, thereby causing the two streams to mix and a pumping effect is obtained.

[0011] According to another aspect of the invention, a piston pump is disclosed. The piston pump includes at least one working fluid region, drive mechanism and seal similar to that of the previous aspect. The lubricating fluid region includes a lubricant sump, a lubricant reservoir in fluid communication with the lubricant sump, and a lubricant pumping device. The lubricant pumping device includes a lubricant inlet channel configured to receive lubricant from at least one of the sump and reservoir, inlet and outlet check valves disposed in respective inlet and outlet channels, and a variable volume pumping cavity. The cavity is at least partially disposed in the drive mechanism's previously-described tubular passageway, and is in fluid communication with the lubricant inlet and outlet channels. The cavity is defined at a first end by the drive mechanism's crosshead (previously-described) such that upon reciprocating motion of the crosshead, lubricant introduced into the cavity through the lubricant inlet channel becomes pressurized and exits through the lubricant outlet channel. While the fluid is being pressurized in the cavity, it can exert a force on the seal to further reduce migration of working fluid into the lubricating fluid region from the working fluid region.

[0012] According to yet another aspect of the invention, a piston pump is disclosed. The piston pump includes at least one working fluid region, a drive mechanism, a lubricating fluid region and a sealing fluid distribution network. The working fluid region includes a pumping chamber for pressurizing a working fluid, intake and outlet ports fluidly coupled to the pumping chamber, and a piston disposed in the pumping chamber such that upon oscillation of the piston, working fluid in the pumping chamber is moved. A sealing channel is defined in the space between the piston and the pumping chamber such that sealing fluid introduced into the sealing channel effects an improved seal between the piston and the chamber. The drive mechanism includes a power transfer shaft rotatably responsive to a drive source, a tubular passageway extending from a space adjacent the drive mechanism to the working fluid region such that the piston is contained in the portion of the tubular passageway in the working fluid region, at least one piston rod pivotally coupled at a first end to the power transfer shaft and at a second end to the piston, the piston rod configured to impart an oscillating motion to the piston, and a lubricating fluid region coupled to at least the drive mechanism. The lubricating fluid region includes a lubricant sump disposed adjacent the power transfer shaft and configured to contain at least a portion of the lubricant; and a lubricant pumping device fluidly coupled to the lubricant sump. The sealing fluid distribution network is configured to transport the sealing fluid from the lubricating fluid region to the sealing channel.

[0013] Optionally, the sealing fluid distribution network has a lubricant flowpath disposed within the piston and piston rod such that fluid communication is established between the two. In addition, the flowpath can be made to terminate along a radial surface of the piston such that sealing fluid routed through the network can provide sealing and lubrication in the sealing channel. The piston further comprises at least one circumferential groove that is in fluid communication with the lubricant flowpath. An axial passage is disposed between the circumferential groove and the lubricant flowpath such that lubricant can be conveyed from the lubricant flowpath to the circumferential groove. In another embodiment, the sealing fluid distribution network comprises the piston, a scraper ring coupled to the piston, and the tubular passageway in the working fluid region. In this embodiment, the scraper ring can traverse the sealing channel during piston oscillation. The scraper ring may include a taper on its outer surface to preferentially allow sealing fluid migration into the pumping chamber while inhibiting working fluid migration out of the pumping chamber. The sealing fluid distribution network can be configured such that the pressure of the sealing fluid flowing through the sealing channel is sufficient to ensure that the net flow of fluid between the pumping chamber and the lubricating fluid region during each oscillating piston cycle is toward the pumping chamber. Each of the intake and outlet ports may additionally include a check valve.

[0014] According to still another aspect of the invention, a micro combined heat and power system is disclosed. The system includes a working fluid circuit configured to transport a working fluid, and at least one energy conversion circuit operatively responsive to the working fluid circuit such that upon operation of the system, the energy conversion circuit is configured to provide useable energy. The working fluid circuit includes an evaporator configured to convert the working fluid from a subcooled liquid into a superheated vapor, an expander in fluid communication with the evaporator, the expander including a first lubricant sump, a condenser in fluid communication with the expander, and a working fluid feed pump. The feed pump includes features that are common with previously-described aspects, including having at least one working fluid region, a drive mechanism, a lubricating fluid region and a seal.

[0015] Optionally, the previously-described lubricant pumping device comprises a high pressure vapor source fluidly coupled to the lubricant sump, where, in one embodiment, the expander is the high pressure vapor source. Also as discussed with some of the previous aspects, a jet pump coupled to the expander can be used to achieve pressurization of the lubricating fluid. In another embodiment, the lubricant pumping device is a separately-powered oil transfer pump fluidly connected between the expander and the second lubricant sump such that it can move the lubricant from the second lubricant sump to the expander, or from the first lubricant sump to the second lubricant sump at least during periods of system operation. The oil transfer pump can also be used to maintain the second lubrication sump substantially full of lubricant at least during periods of system operation. A pressure relief valve may further be disposed between the first lubricant sump and the second lubricant sump. In one configuration, the expander is a scroll expander comprising a working fluid inlet, a working fluid outlet, an orbiting involute spiral wrap, a stationary involute spiral wrap and a working fluid outlet. In another embodiment, a vapor line may extend from the second lubricant sump to the condenser. The lubricant reservoir can be made to be fluidly coupled to the first lubricant sump to receive lubricant that has been separated out of the expander. Also as previously discussed, the lubricant pumping device may be equipped with a lubricant inlet channel configured to receive lubricant from at least one of the first or second lubricant sumps or the lubricant reservoir, inlet and outlet check valves disposed in respective channels and a variable volume pumping cavity in fluid communication with the lubricant channels such that lubricant introduced into the cavity through the lubricant inlet channel becomes pressurized and exits through the lubricant outlet channel. The working fluid feed pump may further comprise a motor configured to provide power to the pump, and a housing with a first compartment configured to contain the motor, a second compartment configured to contain at least the power transfer shaft and the second lubricant sump, a coupling extending from the motor to the power transfer shaft, a vapor space seal disposed about the coupling and defining a boundary between the first and second compartments, and a lubricant drain line fluidly connected between the first compartment and the first lubricant sump. Additionally, a lubricant return line can be included that extends from the second compartment to the first lubricant sump such that, in conjunction with the oil transfer pump, a continuous loop is formed therebetween. In one embodiment, the second compartment is situated below the first compartment such that any lubricant present in the first compartment will collect along a lower surface formed in part by the vapor space seal. The first lubricant sump is configured such that a lubricant fluid level therein is situated in a lower vertical elevation than a lubricant fluid level in the first and second compartments, while the lubricant drain line is spaced adjacent the vapor space seal such that at least one of the working fluid and the lubricant collecting therealong can flow through the lubricant drain line to the first lubricant sump. As before, the first compartment may include a heating element to maintain the temperature in the first compartment above the saturation temperature of the working fluid.

[0016] In another option similar to that discussed in conjunction with the previous aspects, a sealing fluid distribution network configured to maintain a sealing fluid between the piston and a complementary surface in the working fluid region can be included. The sealing fluid distribution network may be configured as previously described, including a piston, a scraper ring coupled to the piston, and the tubular passageway in the working fluid region, where the scraper ring (which may additionally be tapered, also as previously described) may traverse the sealing channel upon the oscillation of the piston within the tubular passageway. In another embodiment (also as previously described), the sealing fluid distribution network comprises a lubricant flowpath disposed within the piston and piston rod such that fluid communication is established therebetween. As before, the pressure of the sealing fluid flowing through the sealing channel is sufficient to ensure that the net flow of fluid between the pumping chamber and the lubricating fluid region during each oscillating piston cycle is toward the pumping chamber.

[0017] According to yet another aspect of the invention, a method of operating a piston pump is disclosed. The method includes the steps of configuring the pump, connecting the intake port and the outlet port to a supply of the working fluid; introducing the working fluid to the intake port; activating the drive source so that the piston moves at least a portion of the working fluid from the intake port to said outlet port; and maintaining a sufficient quantity of said lubricating fluid in said lubricant reservoir to ensure that the side of said seal that is adjacent said lubricant reservoir is exposed to a substantially vapor-free environment. As before, the pump includes at least one working fluid region, a drive mechanism, a lubricating fluid region coupled to the drive mechanism, and a seal disposed in the tubular passageway, the seal defining a boundary between the working fluid region and the lubricating fluid region.

[0018] Optionally, the lubricant pumping device is a separate oil transfer pump placed in fluid communication with said lubricant sump. An additional step can include configuring a sealing fluid distribution network to provide sealing fluid to a sealing channel disposed between the piston and a complementary surface in the working fluid region. The sealing fluid distribution network comprises a flowpath defined in the piston and the piston rod to establish fluid communication between the lubricant sump and the sealing channel such that a sealing fluid may be introduced into the sealing channel through the flowpath. In another embodiment, the sealing fluid distribution network comprises the piston, a scraper ring coupled to the piston, and the complementary surface in the working fluid region. As previously discussed, the scraper ring can traverse the sealing channel upon the oscillation of the piston within the complementary surface in the working fluid region. The step of configuring the pump may include providing a motor configured to provide power to the pump, providing a first compartment to contain the motor, providing a second compartment configured to contain at least the power transfer shaft and the second lubricant sump, extending a coupling from the motor to the power transfer shaft, and establishing a vapor space seal disposed about the coupling such that a boundary is formed between the first and second compartments. The step of configuring the pump may further comprise connecting a lubricant drain line adjacent the vapor space seal such that lubricant collecting therealong can flow through the lubricant drain line and out of the first compartment, and connecting a lubricant return line to the second compartment such that excess of the lubricant collecting therein can flow through the lubricant return line and out of the second compartment. The step of configuring the pump may also include activating a heating element disposed in the first compartment so that the temperature in the first compartment is maintained above the saturation temperature of the working fluid. The oil transfer pump can be used such that at least a portion of the lubricant flowing in at least one of the lubricant drain line or the lubricant return line is moved to the lubricant sump. In an alternate operating mode, the oil transfer pump can be used to substantially fill the lubricant sump.

[0019] According to another aspect of the present invention, a method of operating a micro combined heat and power system is disclosed. The method includes the steps of configuring the pump to comprise at least one working fluid region, a drive mechanism, a lubricating fluid region coupled to the drive mechanism, and at least one seal disposed in the tubular passageway, connecting the intake port and the outlet port to a supply of the working fluid, introducing the working fluid to the intake port, activating the drive source so that the piston moves at least a portion of the working fluid from the intake port to the outlet port, and increasing the pressure of the lubricating fluid at the boundary above that of the lubricating fluid remaining in the sump. The working fluid region includes an intake port configured to receive a working fluid, an outlet port configured to dispense the working fluid, and a piston disposed between the intake and outlet ports such that upon oscillation of the piston, the working fluid is pumped from the intake port to the outlet port. The drive mechanism includes a power transfer shaft rotatably responsive to a drive source, a tubular passageway adjacent the power transfer shaft, a crosshead slidably disposed in the tubular passageway, the crosshead pivotally connected to the power transfer shaft, and at least one piston rod connected at a first end to the crosshead and at a second end to the piston, the piston rod configured to impart an oscillating motion to the piston. The lubricating fluid region includes a lubricant sump disposed adjacent the power transfer shaft and configured to contain at least a portion of a lubricating fluid, a lubricant reservoir in fluid communication with the lubricant sump, and a lubricant pumping device fluidly coupled to the lubricant sump.

[0020] Optionally, the increased lubricant pressure at the boundary can be produced by configuring the lubricant pumping device to include a lubricant inlet channel configured to receive lubricant from at least one of the lubricant sump and the lubricant reservoir, an inlet check valve disposed in the lubricant inlet channel, a lubricant outlet channel, an outlet check valve disposed in the lubricant outlet channel, and a variable volume pumping cavity at least partially disposed in the tubular passageway, the cavity in fluid communication with the lubricant inlet channel and the lubricant outlet channel, the cavity defined at a first end by the crosshead such that upon oscillating motion of the crosshead, the lubricant introduced into the cavity through the lubricant inlet channel becomes pressurized and exits through the lubricant outlet channel. The increased lubricant pressure at the boundary could also be produced by the additional steps of configuring the lubricant pumping device as a separate oil transfer pump and operating the separate oil transfer pump to pressurize the lubricant reservoir to a pressure higher than the pressure of the remainder of the lubricating fluid region.

[0021] According to still another aspect of the invention, a method of operating a micro combined heat and power system is disclosed. In addition to configuring a working fluid circuit to transport a working fluid similar to that of the previous aspect, the method includes the steps of fluidly connecting the intake port to the condenser, fluidly connecting the outlet port to the evaporator, starting the system such that the working fluid within the evaporator is converted into superheated vapor, expanded in the expander, cooled in the condenser, and pumped by the pump back to the evaporator in a continuous loop, and maintaining a sufficient quantity of the lubricating fluid in the lubricant reservoir to ensure that the side of the seal that is adjacent the lubricant reservoir is exposed to a substantially vapor-free environment.

[0022] Optionally, the method includes the additional step of configuring the lubricant pumping device to comprise a lubricant inlet channel to receive lubricant from at least one of the first or second lubricant sumps or the lubricant reservoir, an inlet check valve disposed in the lubricant inlet channel, a lubricant outlet channel, an outlet check valve disposed in the lubricant outlet channel, and a variable volume pumping cavity at least partially disposed in the tubular passageway, the cavity in fluid communication with the lubricant inlet channel and the lubricant outlet channel, the cavity defined at a first end by the crosshead such that upon reciprocating motion of the crosshead, the lubricant introduced into the cavity through the lubricant inlet channel becomes pressurized and exits through the lubricant outlet channel. The step of configuring the working fluid circuit could also comprise incorporating a separate oil transfer pump as the lubricant pumping device. In another embodiment, the method could also comprise the additional step of introducing the lubricating fluid into a sealing channel disposed between the piston and the generally cylindrical passageway. Moreover, the sealing fluid can be transported from the lubricating fluid region to the sealing channel. In addition, the sealing fluid distribution network comprises a lubricant flowpath disposed within the piston and piston rod such that fluid communication is established therebetween. Also, as previously discussed, the pump can be configured to have a first and second compartment to house the motor and power transfer shaft with second lubricant sump, respectively. Similar construction of the lubricant drain line and lubricant return line to that previously discussed can also be provided, as can heating the first compartment with a heating element. The step of operating the oil transfer pump may occur independent of operation of the micro combined heat and power system. An additional step of pressurizing the lubricating fluid with high pressure vapor that has exited the evaporator can also be employed, where the step of pressurizing the lubricating fluid is accomplished a device that comprises a lubricant pressurization chamber fluidly coupled to the lubricant sump, the pressurization chamber including at least one check valve and a flow regulating device configured to intermittently allow the transport of fluid contained in the lubricant pressurization chamber to at least one of the working fluid region and the lubricating fluid region. More specifically, the flow regulating device is a time-responsive valve. The step of pressurizing the lubricating fluid can also be accomplished with a jet pump configured to inject the lubricating fluid into a flow of the high pressure vapor.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0023] The following detailed description of the preferred embodiments of the present invention can be best understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

[0024] **FIG. 1** shows a schematic diagram of a micro-CHP system according to an embodiment of the present invention with connection to external SH and DHW loops;

[0025] **FIG. 2A** shows a simplified cross section of an embodiment of the feed pump as well as fluid interconnection between it and other components of the micro-CHP system of **FIG. 1**;

[0026] **FIG. 2B** shows a variation of the feed pump of **FIG. 2A**. including a pressurizable lubricant reservoir;

[0027] **FIG. 3** shows an alternate interconnection between the feed pump and the expander;

[0028] **FIG. 4A** shows the pump of the present invention that achieves lubricant pressurization with a variable volume pumping cavity;

[0029] **FIG. 4B** shows the pump of the present invention in its presently preferred configuration;

[0030] **FIG. 5A** shows one configuration of a hermetic feed pump and motor with a vapor seal therebetween;

[0031] **FIG. 5B** shows an alternate configuration of a hermetic feed pump and motor;

[0032] **FIG. 6A** shows one configuration for effecting a sealing interface between a piston and tubular passageway of the feed pump;

[0033] **FIG. 6** shows an alternate configuration of the sealing interface;

[0034] **FIG. 6C** shows a variation of the piston of **FIG. 6A**;

[0035] **FIG. 6D** shows a cutaway view of the piston of **FIG. 6**C, showing the internal lubricant transfer path;

[0036] **FIG. 6E** shows a side view of the piston of **FIG. 6C**;

[0037] **FIG. 7A** shows an alternative system, where high pressure working fluid in conjunction with a timed valve are used for pressurizing lubricant; and

[0038] **FIG. 7B** shows a variation of the system shown in **FIG. 7**A, using a jet pump.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0039] Referring initially to **FIG. 1, a** micro-CHP system **100** capable of providing electric current and heated fluid is shown. The system **100** includes a working fluid circuit and an energy conversion circuit. The working fluid circuit includes an expander **101**, a condenser **102**, a pump **103** and an evaporator **104**. These four components define the major components that together approximate an ideal Rankine cycle system, where the evaporator **104** acts as a constant pressure heat addition, the expander **101** allows efficient, nearly isentropic expansion of the working fluid, the condenser **102** acts to reject heat at a constant pressure, and the pump **103** provides efficient, nearly isentropic compression. The evaporator **104** functions as the primary heat generator, where the heat (shown in the figure being produced by a combustion process where a fuel, such as natural gas, is transported via gas line **152** past gas valve **153** to a burner **151**) in the evaporator is transferred to an organic working fluid being transported through conduit **110** (alternately referred to as piping), while the hot exhaust gas stream from the combustion process is directed axially through exhaust duct **155**. The organic working fluid (such as naturally-occurring hydrocarbons or halocarbon refrigerants, not shown) leaves the evaporator **104** and circulates via conduit **110** through the expander **101**, condenser **102** and pump **103**. The embodiment of the micro-CHP system **100** presently shown is operated as a directly-fired system, where the fluid that passes adjacent the heat source is also the working fluid passing through the expander **101**. While the expander **101** can be any type, it is preferable that it be a scroll device, such devices being well known in the art. The energy produced by the expansion of the organic working fluid in the expander **101** is converted to electricity and heat in the energy conversion circuit, which is discussed in more detail below. The condenser **102** extracts excess heat from the organic working fluid after the fluid has been expanded and, in the process, returns the organic working fluid in liquid form to the pump **103**, after which it is returned to evaporator **104**. A controller **130** is used to regulate system operation. Sensors connected to controller **130** are used to measure key parameters, such fluid level information taken from level indicator switch **120**, and organic working fluid temperatures at various points within the organic working fluid circuit. Through appropriate program logic, it can be used to vary pump speed, gas flow rate and evaporator output temperature, as well as to open and close valves.

[0040] As previously mentioned, the energy conversion circuit takes the increased energy imparted to the working fluid in the working fluid circuit and converts it into useable electrical and thermal forms. The electrical form of the useable energy comes from a generator **105** (preferably induction type) that is coupled to expander **101**. The thermal form of the useable energy comes from a circulating fluid medium **140** (shown preferably as a combined SH and DHW loop) thermally coupled to condenser **102**. Hydronic fluid flowing through circulating fluid medium **140** is circulated with a conventional pump **141**, and can be supplied as space heat via radiator **148** or related device. The nature of the heat exchange process is preferably through either heat exchangers **180** (shown notionally for the DHW loop, but equally applicable to the SH loop), or through a conventional hot water storage tank (for a DHW loop). It will be appreciated by those skilled in the art that while the embodiments depicted in the figures show DHW and SH heat exchangers in parallel, it is within the spirit of the present disclosure that series or sequential heat exchange configurations could be used. It will also be appreciated that the heat exchanger **180** depicted in **FIG. 1** could be in the form of the aforementioned hot water storage tank, where the hot fluid circulating through circulating fluid medium **140** gives up at least a portion of its heat to incoming domestic cold water coming from water supply **191**A, which is typically from a municipal water source, well or the like. Once heated in the tank, the domestic water can then be routed to remote DHW locations, such as a shower, bath or hot water faucet, through DHW outlet **191**B.

[0041] Referring next to **FIG. 2**A, details of the pump **103** and its interconnection to evaporator **104**, expander **101** and condenser **102** are shown. The pump **103** provides the necessary pressurization to the working fluid to ensure that the fluid passes through all of the components in the working fluid circuit. As with many mechanical devices, pump **103** requires lubrication to avoid damage to and overheating of its various parts that come into moving contact with one another. The relatively compact nature of such pumps (including piston pumps), coupled with the commonality of some pump components between the working fluid and lubricant regions of the pump, is such that the working fluid and the lubricant can commingle if there is a leakage path between them. The construction of pump **103** according to the present invention is such that first, the likelihood of contamination of the lubricant by the working fluid is reduced, and second, fluid management features are included to meliorate the effects caused by the presence of working fluid that does happen to migrate to the lubricating fluid region so that working fluid can be at least partially purged from the lubricant and placed back in circulation in the working fluid circuit. The pump **103** is shown in a single piston configuration, although it will be appreciated by those skilled in the art that a multi-piston configuration would be equally applicable to the present micro-CHP system **100**. In multi-piston pumps (not presently shown), two or more pistons can be arranged side-by-side, each inside of a corresponding cylinder, to increase working fluid flow throughput. In either the single piston or multi-piston arrangements, the pump **103**, as described below, includes at least a working fluid region, a drive mechanism and a lubricating fluid region.

[0042] The working fluid region, through which the organic working fluid passes, accepts condensate from the condenser **102** through conduit branch **110**D at intake port **103**A and into engagement with an oscillating piston **103**B in a working fluid pressurization chamber. The piston **103**B forces the condensate to flow past check valve **103**C toward outlet port **103**D, after which it proceeds along conduit branch **110**A to evaporator **104** to repeat its thermodynamic cycle. In one embodiment, the piston **103**B can be configured as a generally hollow cylindrical member disposed coaxially about the piston rod **103**H in a generally cylindrical chamber. The tubular body of the piston **103**B includes disks **103B1**, **103B2** disposed at opposite axial ends thereof such that they can move independently of one another for at least a portion of the motion in one direction of the axial dimension traversed by the piston rod in the tubular passageway. The first disk **103B1** is mounted to the piston rod **103**H and is selectively engageable with a first end of the tubular body of piston **103**B during the compression portion of piston motion such that the first disk **103B1** confines the working fluid within the tubular body during the compression portion of the reciprocating motion. The second disk **103B2** is selectively engageable with a second end of the tubular body of piston **103**B, and is spaced axially apart from the first disk by an amount greater than the length of the tubular body such that the first and second disks alternately engage with respective ends of the tubular body. The second disk **103**B**2** includes at least one aperture therein such that the second disk **103**B**2** allows the introduction of the working fluid to pass through the tubular body during the suction portion of the piston's reciprocating motion. Seals can be disposed circumferentially about the piston **103**B to reduce working fluid leakage around the piston.

[**0043**] The drive mechanism includes a power transfer shaft **103**E, tubular passageway **103**F, crosshead **103**G and piston rod **103**H. The shaft **103**E is configured similar to a crankshaft in an internal combustion engine. The inherent eccentricity in shaft **103**E, in combination with the tubular passageway **103**F and the piston rod **103**H and related linkages (not shown), converts the purely rotational movement coming from an external power source (such as a motor, described in more detail below) to impart linear, oscillating motion on piston **103**B. The tubular passageway **103**F extends from a proximal end that terminates in the lubricating fluid portion (discussed in more detail below) to a distal end that terminates in the aforementioned working fluid pressurization chamber of the working fluid region. The tubular passageway **103**F can be cylindrical in shape, and may have multiple compartments along its axial dimension, each compartment defined by differing diameters and separated from one another by walls, seals or the like. An example of one compartment is the aforementioned working fluid pressurization chamber. The piston rod **103**H extends through the substantial entirety of the tubular passageway **103**F, terminating at one end in piston **103**B and the other end at crosshead **103**G. The crosshead **103**G effects a relatively tight fit against the internal wall of tubular passageway such that side loads are borne through them rather than through the piston **103**B. It will be appreciated by those skilled in the art that while the crosshead configuration does provide a reliable way to take some of the loads off the piston **103**B, thereby allowing simpler sealing between the piston **103**B and the corresponding inner wall of the tubular passageway **103**F, other pump configurations that do not incorporate a crosshead could be used in the present pump. An example of such a configuration will be discussed below.

[**0044**] The lubricating fluid region occupies the inner cavity **103**I (alternately referred to as a crankcase) of compartment **103**Z of the pump housing, and includes a lubricant sump **103**J that collects excess lubricant not being used on the internal pump machinery. The motion of shaft **103**E, crosshead **103**G and piston rod **103**H is sufficient to splash lubricant throughout the lubricating fluid region, causing it to coat the substantial entirety of the internal cavity **103I** and the various components therein. A lubricant reservoir **103**K is spaced below an expander sump return port **103**L such that lubricant travelling from the sump **101**A of expander **101** through lubricant return line **110**B is deposited into lubricant reservoir **103**K. The lubricant level in lubricant reservoir **103**K is such that it surrounds piston rod **103**H, as well as bathes seal **103**M. By having separate lubricant reservoir **103**K, adequate lubricant contact with the seal **103**M is maintained without having to flood the entire lubricant sump **103**J; such a quantity of lubricant (if present) would necessitate the use of more oil, and would cause an unduly large viscous drag on the moving shaft **103**E, crosshead **103**G and piston rod **103**H. While lubricant reservoir **103**K is currently shown open at the top, thereby allowing excess lubricant to spill over into the lubricant sump **103J** via channel **103**N, as well as generally retaining pressure parity with the rest of lubricant sump **103J**, another configuration (discussed in conjunction with **FIG. 2***b* below) can be separately pressurizable relative to the rest of lubricant sump **103**J. The bottom of lubricant sump **103**J includes a lubricant transfer port **103**P that is fluidly connected to expander **101**. Oil transfer pump **103**Q (which can be configured to pump in either direction) is used to distribute lubricant between pump **103** and expander **101**. As presently shown, the oil transfer pump **103**Q is configured to deliver lubricant from lubricant sump **103**J to either expander **101** (where it can enter into the working fluid stream to pass through the expander), or expander sump **101**A. In the case of a scroll expander, lubricant coming through the former path can be beneficial in getting lubricant to the scrolls in the aforementioned situation where the lubricant should not be exposed to the high temperature environment of the evaporator **104**. Similarly, the expander sump **101**A (essentially the shell for the power module), by virtue of its prevailing temperature regime, is a rather efficient separator of lubricant and working fluid; accordingly, lubricant routed therethrough can in effect be separated from the working fluid contaminant and sent back into the lubricant sump **103J** of pump **103**.

[**0045**] In a typical piston pump, the working fluid, being pressurized by a piston as well as having a low viscosity, can cross the boundary between the working fluid region and the lubricating fluid region. Since a lubricating fluid's viscosity is an important parameter to consider in determining the applicability of a lubricant for a particular application, the presence of a typically low-viscosity organic working fluid in the lubricating fluid region of a piston pump should be kept to a minimum, as any undue dilution of the lubricant caused by migration of the working fluid into the lubricant region can cause a reduction in pump lubrication, with a concomitant loss in pump performance and life. A significant leakage path for working fluid into the lubricant sump occurs along the piston rod in the space that bridges the working fluid region and the lubricating fluid region of a typical piston pump. In the present invention, seal **103M** is disposed between the working fluid region and the lubricating fluid region, and is used to minimize the amount of fluid cross-talk between the two. Seal **103**M and station line **103**SL define the boundary between the working fluid region and the lubricating fluid region. The seal **103**M is disposed about the portion of piston rod **103**H that extends between the working fluid region and the internal cavity of the lubricating fluid region. The presence of seal **103M** wrapped around the piston rod **103**H helps to reduce contamination of the lubricant by the organic working fluid, but does not entirely prevent it, especially as the seal **103M** wears out over time. Since operability concerns dictate that the pump **103** run for prolonged periods, and over myriad pressure and temperature regimes without the need to service the seal **103**M, it is preferable to sacrifice complete fluid isolation by the seal for longer seal life to keep service, cost and system down-time to a minimum. By keeping one side of the seal **103**M completely bathed in lubricant, the amount of working fluid that leaks into the lubricating fluid region is reduced. To further reduce the tendency of the working fluid to condense and subsequently mix with the lubricant in lubricant sump **103**J, a supplemental heating device **103**S can be added to the sump **103**J. The heat generated will keep the working fluid in vapor form, where it can then be routed to the inlet of condenser **102** via working fluid vapor port **103**R. This can be beneficial in system **100** startup, as residual liquid working fluid present in the evaporator sump **101**A can be heated up in lubricant sump **103**J to reduce working fluid contamination therein.

[**0046**] In operation of the micro-CHP system **100**, a small amount of lubricant travels with the organic working fluid through at least a part of the working fluid circuit. By way of example, with scroll-based expanders, if the flow of working fluid through the working fluid circuit is on the order of 20 lbs/min., the lubricant flow might be on the order of 0.1 to 0.4 lbs/min (0.5 to 2 percent of the working fluid flow rate). This lubricant is necessary to prevent wear and enhance sealing of the scroll components. The nature of the organic working fluid and the lubricant is such that they can be either miscible, partially miscible, or immiscible with one another. Either type of lubricant is potentially capable of meeting the lubrication and sealing requirements. The primary difference is the ease with which the lubricant may be separated from the working fluid. Miscible lubricants cannot be readily be separated from the working fluid while in the liquid state. Thus, any miscible lubricant that passes through pump **103** will continue through the evaporator **104** and on to the expander **101** where it may be separated from the working fluid vapor and collected in expander sump **101**A, which is fluidly connected to a lubricant return line **110**B into pump **103**. Immiscible lubricants can potentially be separated from liquid working fluid. Accordingly, the immiscible lubricant can be bypassed around the evaporator **104** to avoid adding heat to liquid which cannot do work in the expander. Therefore, a significant volume of immiscible oil could be passed through the pump for improved sealing and/or lubrication of the pump **103** without the need to have this additional, or large flow of working fluid passing through the evaporator **104** or the expander **101**.

[**0047**] The configuration of **FIG. 2A** is not intended to bypass all the lubricant around the evaporator. Some lubricant will be carried over in the expander discharge line to the condenser and this lubricant will necessarily pass through the evaporator **104**. The lubricant pump **103**Q is intended to recirculate the lubricant/working fluid mixture back to the expander sump **101**A so that the working fluid has the opportunity to separate-out and allow nearly pure lubricant to return through line **110**B. This separation occurs because the mixture in the expander sump is at a much higher temperature than the mixture at the main pump inlet, even though both mixtures are at the same nominal pressure. The lubricant retains less working fluid at higher temperature, so one can minimize the working fluid concentration in the lubricant by allowing working fluid to distill off of the mixture in the expander sump **101**A.

[**0048**] A variation of the system shown in **FIG. 2A** is depicted in **FIG. 2**B, where by action of oil transfer pump **103**Q, the pressurized fluid flowing from lubricant sump **103**J can be used to transport lubricant to pressurizable lubricant reservoir **103**KK. Unlike lubricant reservoir **103**K shown in **FIG. 2**A, the pressurizable lubricant reservoir **103**KK is closed (save the inlet that is coupled to oil transfer pump **103**Q) so that fluid pumped into it remains pressurized. A second seal **103**MM surrounds piston rod **103**H and is disposed in a wall used to compartmentalize pressurized lubricant reservoir **103**KK. This configuration keeps fluid pressure on seal **103**M that is at least equal to pressure on the seal from the working fluid region, thus minimizing leakage of working fluid into the lubricant. In this instance, the pressurized lubricant coming from the lubricant sump **103**J through oil transfer pump **103**Q can also be used for the expander **101**, adding to the lubricant entering the expander with the working fluid vapor, as previously discussed.

[**0049**] Referring next to **FIG. 3**, an alternate arrangement between the pump **103** and the expander **101** is shown. While the interconnection between the pump **103** and the evaporator **104** and condenser **102** is the same as shown in **FIGS. 2A and 2B**, the interrelationship between the pump **103** and the expander **101** differs. In the present embodiment, the expander sump **101**A is connected directly to the lubricant sump **103**J through working fluid vapor port **103**R such that oil transfer pump **103**Q is oriented to pump from the expander sump **101**A and into the sump **103**J. By such an approach, the lubricant sump **103**J is kept relatively full of lubricant (note the higher fluid level compared to **FIGS. 2A and 2B**). In the absence of active lubricant level controls, one of the lubricant sumps must be allowed to be full of lubricant, while the level in the other drops to some sustainable level and the lubricant pump maintains this status quo. The sustainable level and the lubricant charge to the system must allow for adequate lubricant and system function. As previously mentioned, the pumping direction of the oil transfer pump **103**Q can be oriented either way, and coupled with relative changes in the vertical position of the lubricant sump **103**J to expander sump **10**A, configured according to system **100** needs. A check valve **103**T is used to prevent the backflow of lubricant from the lubricant sump **103**J to the expander sump **101**A; this will help ensure that lubricant sump **103**J stays relatively full of lubricant during periods where the pump **103** is not running, such as during shutdown/off conditions. Similarly, a pressure relief valve **103**U is installed in a second recirculation line coming from the working fluid vapor port **103**R. Large pressure differences between **101** and **103**I are to be avoided. If the pressure in **101** is much higher than the pressure in **103**I, then both lubricant from the sump and refrigerant from the condenser flow into the into the pump. The lubricant flow is tolerable, but the refrigerant will flow past the seal **103**M and into **103**I: this will tend to dilute the lubricant in **1031**, inhibiting good lubrication of the working parts. This situation is preventable by allowing the lubricant to freely move through **103**T into the pump reservoir **1031**, thus pressurizing the reservoir and reducing the pressure difference. However, if the pressure in **1031** is higher than the pressure in **101**, then the vapor can flow to **101** via valve **103**U, thus equalizing the pressures, while the lubricant is trapped in the sump by valve **103**T.

[**0050**] Referring next to **FIGS. 4A and 4B**, variations on another form of achieving oil pumping and seal pressurization are shown. Instead of incorporating a separate piece of machinery (in the form of oil transfer pump **103**Q shown in **FIGS. 2A and 2B**), the present embodiments form a pumping device from the existing motion of the piston rod **103**H and attached crosshead **103**G in tubular passageway **103**F. The addition of fluid-activated inlet check valve **103**V and fluid-activated outlet check valve **103**W in the portion of tubular passageway **103**F in the lubricating fluid region that houses crosshead **103**G allows lubricant entrained therein to be pressurized and pumped for distribution to other locations within micro-CHP system **100**, such as to expander **101**. As shown with particularity in **FIG. 4**A, excess from the expander sump **101**A is pressurized and routed through conduit **103**N, while the configuration of **FIG. 4B** takes low pressure lubricant with a low concentration of working fluid from lubricant sump **103J** and after pressurizing it, routes it through lubricant reservoir **103**K and into the inlet line of expander **101**. As shown, the check valves **103**W, **103**V are configured to allow flow in the direction opposite of that of the embodiment shown in **FIG. 4A**. While both of these embodiments require the operation of pump **103** to function, and thus can not be run during periods of pump **103** inactivity, this limitation does not appear to have any practical consequences, based on the analysis of system testing. These embodiments are simple to operate, thereby providing a low-cost way to meet lubricant transfer needs.

[**0051**] An additional benefit to the approach of **FIG. 4A** is that the configuration of conduit **103**N is such that it can receive fluid input via either lubricant reservoir **103**K or lubricant sump **103J** (the latter in cases (not shown) where the lubricant level in the sump is allowed to pass through overflow **103**OF and to the inlet check valve **103**V in the inlet channel). In situations where the lubricant level in the lubricant sump **103J** is not above the inlet channel most, if not all, of any working fluid-rich fluid entering into the conduit **103**N from the pumping device formed by crosshead **103**G, piston rod **103**H, the inner wall of a portion of tubular passageway **103**F and the associated check valves **103**V and **103**W comes as overflow from lubricant reservoir **103**K, which generally has a higher concentration of working fluid contaminant. Another benefit of both the **FIGS. 4A and 4B** embodiments is that the side of the seal **103M** that is exposed to the variable cavity pumping device formed by passageway **103**F, crosshead **103**G, piston rod **103**H and check valves **103**V, **103**W can be directly pressurized by the pumping action, as it is formed in a wall that defines a remote end of the cavity. As an alternate to the fluid-activated check valves, rotary valves (not shown) built into the crosshead connecting rod pin or the crankshaft could be used.

[**0052**] Additional variations could leave the inlet check valve **103**V in place, while removing the outlet check valve **103**W by discharging the lubricant through an orifice at elevated pressure, where the orifice would cause sufficient backflow resistance during the intake stroke to cause the lubricant to preferentially enter the tubular passageway pumping cavity through the inlet check valve. This variation allows for less complex construction and potentially lower cost, at the expense of reducing pump efficiency. Using a long capillary tube as the orifice could reduce the backflow from the high pressure side of the lubricant pump during the filling stroke, effectively utilizing the dynamics of the flow to reduce backflow and maintain pump volumetric efficiency. In both figures, working fluid vapor port **103**R fluidly couples the top of the lubricating region of pump **103** to the inlet of the condenser **102** through conduit branch **110**C so that any working fluid in the lubricating fluid region that exists in vapor form can be vented out. By placing the working fluid in the condenser **102** inlet, it can combine with the stream of working fluid in the working fluid circuit, and be placed back into circulation.

[**0053**] Referring next to **FIG. 5**A, an approach for achieving vapor sealing between compartments in pump **103** is shown. Pump **103** is shown presently as a multi-unit variation of that of **FIGS. 2A and 2B**, specifically including a three piston pump. As previously mentioned, the lubrication management approach of the present invention is equally applicable to single unit or multi-unit pumps. The drive source for turning shaft **103**E is shown as an electric motor **103**AA, which is housed in first compartment **103**Y, while the remainder of pump **103** is housed in second compartment **103**Z. Two separate compartments are advantageous because the presence of a fluid lubricant, which is crucial to proper operation of the contacting components within the pump **103**, can cause excess viscous drag if present near the rotor of electric motor **103**AA. Thus, to avoid a buildup of lubricant in the first compartment **103**Y, it is substantially fluidly isolated from second compartment **103**Z. As with the space between the working fluid region and the lubricating fluid region discussed in conjunction with **FIGS. 2A and 2B**, a coupling **103**BB between components in adjacent compartments also provides a leakage path that, unless kept in check, will only worsen with use. In the present figure, the coupling **103**BB is used to transmit rotational power from motor **103**AA to shaft **103**E. In the alternate, coupling **103**BB can be a common shaft between the motor **103**AA and the pump **103**. Accordingly, a vapor seal **103**CC is disposed about the coupling between the first and second compartments **103**Y, **103**Z to minimize leakage of lubricant and organic working fluid from the latter to the former. As with seal **103**M discussed above, vapor seal **103**CC need not be a leak-free seal, as more emphasis is placed on its long-life properties than on its ability to provide complete fluid isolation between the two compartments. A lubricant drain line **103**DD fluidly connects the first compartment **103**Y to expander sump **101**A, while a lubricant return line **103**EE fluidly connects the second compartment **103**Y to expander sump **101**A. The lowest portion of the first compartment **103**Y is situated vertically higher than the expander sump **101**A so that any lubricant or organic working fluid that does get past vapor seal **103**CC can drain to the expander sump **101**A through lubricant drain line **103**DD. Ideally, the temperature in the first compartment **103**Y would remain (during system operation) above the local saturation temperature of the organic working fluid. If such conditions aren't always possible, a heater **103**FF can be included in the first compartment **103**Y to provide supplemental heating such that if heat from the motor **103**AA is insufficient to vaporize any organic working fluid present in the first compartment **103**Y, the heater **103**FF can be used to boil off excess organic working fluid as vapor, where it can be returned to the expander sump **101**A for reintroduction into the working fluid circuit of the system **100**. As before, an oil transfer pump **103**Q, shown presently pumping from evaporator sump **101**A to lubricant sump **103J** to overcome the effects of gravity between the two, circulates lubricant between the expander sump **10**A and lubricant sump **103J** in pump **103**.

[**0054**] Referring next to **FIG. 5**B, an alternate configuration for the vapor seal of **FIG. 5A** is shown. The present configuration is simpler than the one shown in **FIG. 5**A, in that it does not include a direct fluid connection to take excess lubricant collecting in the first compartment **103**Y back to either expander sump **101**A or second compartment **103**Z. Nevertheless, as with the configuration of **FIG. 5**A, it includes provisions (including heater **103**FF) to remove organic working fluid vapor from first compartment **103**Y and put it back in evaporator sump **10**A. During system operation, the pressure in second compartment **103**Z is greater than the pressure in first compartment **103**Y, due in part to organic working fluid build-up in the lubricant sump **103**J in second compartment **103**Z. This prevents the migration of lubricant that collects above the vapor seal **103**CC at least until system shutdown, where pressures on opposite sides of the vapor seal **103**CC can equalize. Lubricant drain line **103**DD is situated between the area immediately above seal **103**CC and the expander sump **101**A to avoid excess lubricant buildup above this seal, with proper function ensured by placing sump **101**A on a similar level with the seal. It will be appreciated by those skilled in the art that other pumping devices besides the oil transfer pump **103**Q can be used with the vapor seal configuration of the present figure. To prevent leakage of the organic working fluid to the outside environment, the first and second compartments **103**Y, **103**Z can be hermetically sealed.

[**0055**] Referring next to **FIGS. 6A and 6B**, alternate configurations for the piston and working fluid region of the pump of **FIGS. 2A and 2B** are shown. By delivering the relatively high viscosity fluid to the interface (hereinafter referred to as sealing channel) between piston **203**B and the inner wall of working fluid pressurization chamber **203**D, both improved sealing and wear resistance are affected. A sealing fluid distribution network is set up to effect sealing in the channel. In the first embodiment, shown with particularity in **FIG. 6**A, the piston **203**B is shown with scraper **203**LL disposed around the piston periphery. The scraper **203**LL is defined by a tapered shape such that only during the suction stroke of the piston **203**B does a portion of the lubricant in the lubricant sump **203**J pass the scraper **203**LL and into the discharge side at the working fluid pressurization chamber **203**D. The manner in which the lubricant reaches the scraper **203**LL is by splash, spray, flooding or related means well-known in engines and compressors. Once the lubricant gets past the scraper **203**LL and into the working fluid pressurization chamber **203**D, it gets trapped, thus effecting a seal in the sealing channel on the discharge stroke of the piston **203**B. Unlike the construction of piston **103**B shown in **FIGS. 2A and 2B**, where the piston itself included a pumping chamber, the present embodiment reflects the relatively simple construction similar to that found in an internal combustion piston engine, including a pivotal connection to piston rod **203**H at wrist pin **203**MM. Similar to the embodiment shown in **FIGS. 2A and 2B**, the working fluid region is fluidly connected to the working fluid circuit of a micro-CHP system (not presently shown) through an intake port **203**A and outlet port **203**D. Fluid-activated check valves **203**NN are placed in the respective inlet and outlet ports to ensure only one-way flow.

[**0056**] In a second embodiment of the sealing fluid distribution network, shown with particularity in **FIGS. 6B through 6E**, the piston **203**B of **FIG. 6A** includes a modification, in that in place of scraper **203**LL, a circumferential lubricant injection groove **203**PP is embedded in the piston periphery such that lubricant can be distributed to the sealing channel, thereby allowing it to act like a hydrodynamic bearing. Unlike the piston configuration of **FIG. 6**A, the present embodiment delivers the lubricant under pressure to the sealing channel via internal flowpaths in piston **203**B and piston rod **203**H, where pressurized lubricant can be introduced into piston rod **203**H from oil transfer pump **203**Q. **FIGS. 6C through 6E** show internal construction of the piston **203**B. Cutout **203**RR defines the region in piston **203**B that accommodates the wrist pin attached to the piston rod, neither of which are currently shown. The circumferential delivery made possible by groove **203**PP helps to ensure an even distribution of the lubricant to the sealing channel. Sealing fluid that enters the cutout **203**RR can both lubricate the wrist pin as well as escape side openings **203**SS to the sealing channel. **FIG. 6D** shows a section view of piston **203**B, highlighting how sealing fluid can pass through cutout **203**RR and extension **203**TT, terminating in one or more radial apertures in the surface of groove **203**PP. **FIG. 6E** shows the piston **203**B rotated 90° about the vertical axis relative to the position shown in FIGS. **6**C and **6**D, with an alternate way to deliver sealing fluid to groove **203**PP. Here, extension **203**TT is placed on the outer surface of piston **203**B such that it fluidly connects cutout **203**RR and groove **203**PP without an internal connection. This can be advantageous in that it is easier to make the external cut on the piston as shown in **FIG. 6E** than the internal passageways shown in **FIGS. 6C and 6D**. This embodiment functioning as a hydrodynamic bearing may enable the crosshead (not presently shown) to be removed, as side loads that were hitherto taken up by the crosshead can be absorbed by the sealing interface between the piston and the tubular passageway. In one embodiment, the sealing fluid used at the sealing channel is the same as the lubricant disposed in lubricant sump **203**J.

[**0057**] The previously-described oil transfer pump **103**Q and the variable volume pumping cavity are but two ways of achieving supplemental lubrication management within the micro-CHP system **100**. Referring next to **FIGS. 7A and 7B**, additional methods for pressurizing the lubricating fluid can be used. For example, high pressure organic working fluid can be extracted from the working fluid circuit prior to expansion in expander **301** and routed to chamber **303**UU. Referring with particularity to **FIG. 7**A, the check valves **303**QQ allow low pressure lubricating fluid sump **303**J to fill lubricant pressurization chamber **303**UU when vapor valve **303**RR is closed. When the vapor valve **303**RR is opened, the high pressure working fluid vapor pressurizes the fluid in lubricant pressurization chamber **303**UU and the mixture is forced out through one of the check valves **303**QQ to where the oil is needed, such as expander **301** or lubricant reservoir **303**KK. When the vapor valve **303**RR is closed, the residual vapor collapses and the pressure between the two check valves **303**QQ drops, allowing fresh oil to flow in through the check valve upstream of lubricant pressurization chamber **303**UU, refilling the chamber. The cycle is then ready to restart. Referring with particularity to **FIG. 7**B, the mixing of high pressure vapor and lubricant can occur in a jet pump **303**SS, where, as before, the lubricant can be added from lubricant sump **303**J. In the jet pump **303**SS, high pressure working fluid, taken upstream of expander **301**, is passed through a venturi **303**VV in pump **303**SS such that, in what is commonly known as the Bernoulli effect, the decreased pressure in the working fluid vapor stream draws in the low pressure lubricant at inlet **303**WW, thus promoting mixture between the two fluids. In a manner somewhat similar to the configuration shown in **FIG. 2B** (where lubricant can enter via inlet **103**LL), the lubricant exiting expander sump **301**A can enter blind reservoir **303**KK through inlet **303**L and be used to keep seal **303**M bathed in lubricant. Gap **303**MM between piston rod **303**H and the wall defining one side of blind reservoir **303**KK allows lubricant cross-talk between blind reservoir **303**KK and the inner cavity/crankcase **3031** of compartment **303**Z of the pump **303**. It will be appreciated by those skilled in the art that the configurations shown in **FIGS. 7A and 7B** can be coupled to any of the previously-disclosed configurations, as evidenced by the commonality of numerous piston pump components.

[**0058**] Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. More specifically, although some aspects of the present invention are identified herein as preferred or particularly advantageous, it is contemplated that the present invention is not necessarily limited to these preferred aspects of the invention.

We claim:

1. A piston pump comprising:

at least one working fluid region comprising:

an intake port configured to receive a working fluid;

an outlet port configured to dispense said working fluid, and

a piston disposed between said intake and outlet ports such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism comprising:

a power transfer shaft rotatably responsive to a drive source;

a tubular passageway extending from a space adjacent said power transfer shaft to said working fluid region such that said piston is contained in the portion of said tubular passageway in said working fluid region;

a crosshead slidably disposed in said tubular passageway, said crosshead pivotally connected to said power transfer shaft; and

at least one piston rod connected at a first end to said crosshead and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston;

a lubricating fluid region coupled to at least said drive mechanism, said lubricating fluid region comprising:

a lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of said lubricant;

a lubricant reservoir in fluid communication with said lubricant sump; and

a lubricant pumping device fluidly coupled to said lubricant sump; and

at least one seal disposed in said tubular passageway, said seal defining a boundary between said working fluid region and said lubricating fluid region such that said seal is configured to reduce migration of fluid between said working fluid region and said lubricating fluid region.

2. A piston pump according to claim 1, wherein said lubricant sump is hermetically sealed.

3. A piston pump according to claim 1, wherein said lubricant pumping device comprises:

a lubricant inlet channel configured to receive lubricant from at least one of said lubricant sump and said lubricant reservoir;

an inlet check valve disposed in said lubricant inlet channel;

a lubricant outlet channel;

an outlet check valve disposed in said lubricant outlet channel; and

a variable volume pumping cavity at least partially disposed in said tubular passageway, said cavity in fluid communication with said lubricant inlet channel and said lubricant outlet channel, said cavity defined at a first end by said crosshead such that upon oscillating motion of said crosshead, said lubricant introduced into said cavity through said lubricant inlet channel becomes pressurized and exits through said lubricant outlet channel.

4. A piston pump according to claim 3, wherein said lubricant inlet channel is fluidly coupled to said lubricant reservoir.

5. A piston pump according to claim 3, wherein said variable volume pumping cavity is defined at a second end by a wall intermediate said crosshead and said at least one working fluid region.

6. A piston pump according to claim 5, wherein said at least one seal is disposed in said wall.

7. A piston pump according to claim 1, further comprising a reservoir seal disposed about said piston rod between said lubricant reservoir and said lubricant pumping device.

8. A piston pump according to claim 7, wherein said at least one seal and said reservoir seal define boundaries between multiple compartments along the lengthwise dimension of said tubular passageway.

9. A piston pump according to claim 1, wherein said at least one working fluid region comprises a plurality of working fluid regions, each configured to cooperate with corresponding said tubular passageways, crossheads, piston rods and seals to define a single unit of a multi-unit piston pump.

10. A piston pump according to claim 9, wherein said plurality of tubular passageways are fluidly connected with one another.

11. A piston pump according to claim 1, wherein said lubricant pumping device comprises a separately-powered oil transfer pump.

12. A piston pump according to claim 11, wherein said lubricant reservoir is fluidly coupled to said piston pump.

13. A piston pump according to claim 11, wherein said lubricant reservoir is separately pressurizable from the remainder of said lubricating fluid region.

14. A piston pump according to claim 11, wherein the pumping capacity of said oil transfer pump is less than five percent of that of said piston pump.

15. A piston pump according to claim 11, wherein said drive source is a motor.

16. A piston pump according to claim 15, further comprising:

a first compartment configured to contain said motor therein;

a second compartment configured to hold a lubricant and at least a portion of said lubricating fluid region and said drive mechanism therein;

a coupling extending from said motor to said power transfer shaft in said second compartment;

a vapor space seal disposed about said coupling and defining a boundary between said first and second compartments; and

a lubricant drain line fluidly coupled to said first compartment and said oil transfer pump, said lubricant drain line configured to remove at least one of said working fluid and said lubricant from said first compartment.

17. A piston pump according to claim 16, further comprising a lubricant return line fluidly coupled to said second compartment and said oil transfer pump.

18. A piston pump according to claim 17, wherein said first and second compartments are disposed in a common housing.

19. A piston pump according to claim 18, wherein said common housing is hermetically sealed.

20. A piston pump according to claim 16, wherein said first compartment further comprises a heating element disposed therein, said heating element configured to maintain the temperature in said first compartment above the saturation temperature of said working fluid.

21. A piston pump according to claim 16, wherein said lubricant drain line and the surface of said first compartment that contains said vapor space seal occupy the substantially lowest vertical position in said first compartment such that any lubricant that collects in said first compartment will flow through said lubricant drain line.

22. A piston pump according to claim 1, wherein said lubricant pumping device comprises a high pressure vapor source fluidly coupled to said lubricant sump.

23. A piston pump according to claim 22, wherein said high pressure vapor source further comprises:

a lubricant pressurization chamber fluidly coupled to said lubricant sump, said pressurization chamber including at least one check valve; and

a flow regulating device configured to intermittently allow the transport of fluid contained in said lubricant pressurization chamber to at least one of said working fluid region and said lubricating fluid region.

24. A piston pump according to claim 23, wherein said flow regulating device is a time-responsive valve.

25. A piston pump according to claim 23, wherein said high pressure vapor source is a jet pump configured to inject lubricant into a flow of high pressure vapor.

26. A piston pump comprising:

at least one working fluid region comprising:

an intake port configured to receive a working fluid;

an outlet port configured to dispense said working fluid, and

a piston disposed between said intake and outlet ports such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism comprising:

a power transfer shaft rotatably responsive to a drive source;

a tubular passageway extending from a space adjacent said power transfer shaft to said working fluid region such that said piston is contained in the portion of said tubular passageway in said working fluid region;

a crosshead slidably disposed in said tubular passageway, said crosshead connected to said power transfer shaft; and

at least one piston rod connected at a first end to said crosshead and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston;

a lubricating fluid region coupled to at least said drive mechanism, said lubricating fluid region comprising:

a lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of said lubricant;

a lubricant reservoir in fluid communication with said lubricant sump; and

a lubricant pumping device comprising:

a lubricant inlet channel configured to receive lubricant from at least one of said lubricant sump and said lubricant reservoir;

an inlet check valve disposed in said lubricant inlet channel;

a lubricant outlet channel;

an outlet check valve disposed in said lubricant outlet channel; and

a variable volume pumping cavity at least partially disposed in said tubular passageway, said cavity in fluid communication with said lubricant inlet channel and said lubricant outlet channel, said cavity defined at a first end by said crosshead such that upon reciprocating motion of said crosshead, said lubricant introduced into said cavity through said lubricant inlet channel becomes pressurized and exits through said lubricant outlet channel; and

at least one seal disposed in said tubular passageway, said seal defining a boundary between said working fluid region and said lubricating fluid region such that said seal is configured to reduce migration of fluid between said working fluid region and said lubricating fluid region.

27. A piston pump comprising:

at least one working fluid region comprising:

a pumping chamber for pressurizing a working fluid;

an intake port fluidly coupled to said pumping chamber, said intake port configured to receive said working fluid;

an outlet port fluidly coupled to said pumping chamber, said outlet port configured to dispense said working fluid; and

a piston disposed in said pumping chamber and defining a sealing channel therebetween, such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism comprising:

a power transfer shaft rotatably responsive to a drive source;

a tubular passageway extending from a space adjacent said drive mechanism to said working fluid region such that said piston is contained in the portion of said tubular passageway in said working fluid region;

at least one piston rod pivotally coupled at a first end to said power transfer shaft and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston; and

a lubricating fluid region coupled to at least said drive mechanism, said lubricating fluid region comprising:

a lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of said lubricant; and

a lubricant pumping device fluidly coupled to said lubricant sump; and

a sealing fluid distribution network configured to transport a sealing fluid from said lubricating fluid region to said sealing channel.

28. A piston pump according to claim 27, wherein said sealing fluid distribution network comprises a lubricant flowpath disposed within said piston and piston rod such that fluid communication is established therebetween.

29. A piston pump according to claim 28, wherein said flowpath terminates along a radial surface of said piston such that sealing fluid routed through said sealing fluid distribution network can affect sealing and lubrication in said sealing channel.

30. A piston pump according to claim 28, wherein said piston further comprises at least one circumferential groove, said groove in fluid communication with said lubricant flowpath.

31. A piston pump according to claim 30, wherein an axial passage is disposed between said circumferential groove and said lubricant flowpath such that lubricant can be conveyed from said lubricant flowpath to said circumferential groove.

32. A piston pump according to claim 27, wherein said sealing fluid distribution network comprises said piston, a scraper ring coupled to said piston, and said tubular passageway in said working fluid region, said scraper ring configured to traverse said sealing channel upon said oscillation of said piston within said tubular passageway.

33. A piston pump according to claim 32, wherein said scraper ring is defined by a taper on its outer surface to preferentially allow sealing fluid migration into said pumping chamber while inhibiting working fluid migration out of said pumping chamber.

34. A piston pump according to claim 27, wherein said sealing fluid distribution network is configured such that the pressure of said sealing fluid flowing through said sealing channel is sufficient to ensure that the net flow of fluid between said pumping chamber and said lubricating fluid region during each oscillating piston cycle is toward said pumping chamber.

35. A piston pump according to claim 27, wherein each of said intake and outlet ports include a check valve disposed therein.

36. A micro combined heat and power system comprising:

a working fluid circuit configured to transport a working fluid, said working fluid circuit comprising:

an evaporator configured to convert said working fluid from a subcooled liquid into a superheated vapor;

an expander in fluid communication with said evaporator, said expander including a first lubricant sump;

a condenser in fluid communication with said expander; and

a working fluid feed pump comprising:

at least one working fluid region comprising:

an intake port configured to receive said working fluid;

an outlet port configured to dispense said working fluid, and

a piston disposed between said intake and outlet ports such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism comprising:

a power transfer shaft rotatably responsive to a drive source;

a tubular passageway extending from a space adjacent said power transfer shaft to said working fluid region such that said piston is contained in the portion of said tubular passageway in said working fluid region;

a crosshead slidably disposed in said tubular passageway, said crosshead pivotally connected to said power transfer shaft; and

at least one piston rod connected at a first end to said crosshead and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston;

a lubricating fluid region coupled to at least said drive mechanism, said lubricating fluid region comprising:

a second lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of said lubricant;

a lubricant reservoir in fluid communication with said second lubricant sump; and

a lubricant pumping device fluidly coupled to said second lubricant sump; and

at least one seal disposed in said tubular passageway, said seal defining a boundary between said working fluid region and said lubricating fluid region; and at least one energy conversion circuit operatively responsive to said working fluid circuit such that upon operation of said system, said at least one energy conversion circuit is configured to provide useable energy.

37. A micro combined heat and power system according to claim 36, wherein said lubricant pumping device comprises a high pressure vapor source fluidly coupled to said lubricant sump.

38. A micro combined heat and power system according to claim 37, wherein said expander is said high pressure vapor source.

39. A micro combined heat and power system according to claim 38, further comprising a jet pump disposed in a flowpath fluidly coupled to said expander so that high pressure vapor in said flowpath draws lubricant into a low pressure region within said jet pump for mixing between said vapor and said lubricant such that upon mixing the fluids can be used elsewhere.

40. A micro combined heat and power system according to claim 36, wherein said lubricant pumping device is a separately-powered oil transfer pump fluidly connected between said expander and said second lubricant sump.

41. A micro combined heat and power system according to claim 40, wherein said oil transfer pump is configured to move said lubricant from said second lubricant sump to said expander.

42. A micro combined heat and power system according to claim 40, wherein said oil transfer pump is configured to move said lubricant from said first lubricant sump to said second lubricant sump at least during periods of system operation.

43. A micro combined heat and power system according to claim 42, wherein said oil transfer pump is configured to maintain said second lubrication sump substantially full of lubricant at least during periods of system operation.

44. A micro combined heat and power system according to claim 43, further comprising a pressure relief valve disposed between said first lubricant sump and said second lubricant sump.

45. A micro combined heat and power system according to claim 36, wherein said expander is a scroll expander comprising a working fluid inlet, a working fluid outlet, an orbiting involute spiral wrap, a stationary involute spiral wrap and a working fluid outlet.

46. A micro combined heat and power system according to claim 40, further including a vapor line extending from said second lubricant sump to said condenser.

47. A micro combined heat and power system according to claim 36, wherein said lubricant reservoir is fluidly coupled to said first lubricant sump to receive lubricant that has been separated out of said expander.

48. A micro combined heat and power system according to claim 36, wherein said lubricant pumping device comprises:

a lubricant inlet channel configured to receive lubricant from at least one of said first or second lubricant sumps or said lubricant reservoir;

an inlet check valve disposed in said lubricant inlet channel;

a lubricant outlet channel;

an outlet check valve disposed in said lubricant outlet channel; and

a variable volume pumping cavity at least partially disposed in said tubular passageway, said cavity in fluid communication with said lubricant inlet channel and said lubricant outlet channel, said cavity defined at a first end by said crosshead such that upon reciprocating motion of said crosshead, said lubricant introduced into said cavity through said lubricant inlet channel becomes pressurized and exits through said lubricant outlet channel.

49. A micro combined heat and power system according to claim 36, wherein said working fluid feed pump further comprises:

a motor configured to provide power to said pump; and

a housing comprising:

a first compartment configured to contain said motor;

a second compartment configured to contain at least said power transfer shaft and said second lubricant sump;

a coupling extending from said motor to said power transfer shaft;

a vapor space seal disposed about said coupling and defining a boundary between said first and second compartments; and

a lubricant drain line fluidly connected between said first compartment and said first lubricant sump.

50. A micro combined heat and power system according to claim 49, further comprising a lubricant return line that extends from said second compartment to said first lubricant sump such that, in conjunction with said oil transfer pump, a continuous loop is formed therebetween.

51. A micro combined heat and power system according to claim 50, wherein said second compartment is situated below said first compartment such that any lubricant present in said first compartment will collect along a lower surface formed in part by said vapor space seal.

52. A micro combined heat and power system according to claim 50, wherein said first lubricant sump is configured such that a lubricant fluid level therein is situated in a lower vertical elevation than a lubricant fluid level in said first and second compartments.

53. A micro combined heat and power system according to claim 50, wherein said lubricant drain line is spaced adjacent said vapor space seal such that at least one of said organic working fluid and said lubricant collecting therealong can flow through said lubricant drain line to said first lubricant sump.

54. A micro combined heat and power system according to claim 49, wherein said first compartment further comprises a heating element disposed therein, said heating element configured to maintain the temperature in said first compartment above the saturation temperature of said working fluid.

55. A micro combined heat and power system according to claim 36, further comprising a sealing fluid distribution network configured to maintain a sealing fluid between said piston and a complementary surface in said working fluid region.

56. A micro combined heat and power system according to claim 55, wherein said sealing fluid distribution network comprises said piston, a scraper ring coupled to said piston, and said tubular passageway in said working fluid region, said scraper ring configured to traverse said sealing channel upon said oscillation of said piston within said tubular passageway.

57. A piston pump according to claim 56, wherein said scraper ring is defined by a taper on its outer surface to preferentially allow sealing fluid migration into said pumping chamber while inhibiting working fluid migration out of said pumping chamber.

58. A micro combined heat and power system according to claim 55, wherein said sealing fluid distribution network comprises a lubricant flowpath disposed within said piston and piston rod such that fluid communication is established therebetween.

59. A micro combined heat and power system according to claim 57, said sealing fluid distribution network is configured such that the pressure of said sealing fluid flowing through said sealing channel is sufficient to ensure that the net flow of fluid between said pumping chamber and said lubricating fluid region during each oscillating piston cycle is toward said pumping chamber.

60. A method of operating a piston pump, said method comprising:

configuring said pump to comprise:

at least one working fluid region comprising:

an intake port configured to receive a working fluid;

an outlet port configured to dispense said working fluid, and

a piston disposed between said intake and outlet ports such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism comprising:

a power transfer shaft rotatably responsive to a drive source;

a tubular passageway adjacent said power transfer shaft;

a crosshead slidably disposed in said tubular passageway, said crosshead pivotally connected to said power transfer shaft; and

at least one piston rod connected at a first end to said crosshead and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston;

a lubricating fluid region coupled to at least said drive mechanism, said lubricating fluid region comprising:

a lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of a lubricating fluid;

a lubricant reservoir in fluid communication with said lubricant sump; and

a lubricant pumping device fluidly coupled to said lubricant sump; and

at least one seal disposed in said tubular passageway, said seal defining a boundary between said working fluid region and said lubricating fluid region;

connecting said intake port and said outlet port to a supply of said working fluid;

introducing said working fluid to said intake port;

activating said drive source so that said piston moves at least a portion of said working fluid from said intake port to said outlet port; and

maintaining a sufficient quantity of said lubricating fluid in said lubricant reservoir to ensure that the side of said seal that is adjacent said lubricant reservoir is exposed to a substantially vapor-free environment.

61. A method according to claim 60, wherein said lubricant pumping device is a separate oil transfer pump placed in fluid communication with said lubricant sump.

62. A method according to claim 60, comprising the additional step of configuring a sealing fluid distribution network to provide sealing fluid to a sealing channel disposed between said piston and a complementary surface in said working fluid region.

63. A method according to claim 62, wherein said sealing fluid distribution network comprises a flowpath defined in said piston and said piston rod to establish fluid communication between said lubricant sump and said sealing channel such that a sealing fluid may be introduced into said sealing channel through said flowpath.

64. A method according to claim 62, wherein said sealing fluid distribution network comprises said piston, a scraper ring coupled to said piston, and said complementary surface in said working fluid region, said scraper ring configured to traverse said sealing channel upon said oscillation of said piston within said complementary surface in said working fluid region.

65. A method according to claim 61, wherein said step of configuring said pump further comprises:

providing a motor configured to provide power to said pump;

providing a first compartment to contain said motor;

providing a second compartment configured to contain at least said power transfer shaft and said second lubricant sump;

extending a coupling from said motor to said power transfer shaft;

establishing a vapor space seal disposed about said coupling such that a boundary is formed between said first and second compartments.

66. A method according to claim 65, wherein said step of configuring said pump further comprises:

connecting a lubricant drain line adjacent said vapor space seal such that lubricant collecting therealong can flow through said lubricant drain line and out of said first compartment; and

connecting a lubricant return line to said second compartment such that excess of said lubricant collecting therein can flow through said lubricant return line and out of said second compartment.

67. A method according to claim 66, wherein said step of configuring said pump further comprises activating a heating element disposed in said first compartment so that the temperature in said first compartment is maintained above the saturation temperature of said working fluid.

68. A method according to claim 67, comprising the additional step of operating said oil transfer pump such that at least a portion of said lubricant flowing in at least one of said lubricant drain line or said lubricant return line is moved to said lubricant sump.

69. A method according to claim 68, wherein said step of operating said oil transfer pump substantially fills said lubricant sump.

70. A method of operating a piston pump, said method comprising:

configuring said pump to comprise:

at least one working fluid region comprising:

an intake port configured to receive a working fluid;

an outlet port configured to dispense said working fluid, and

a piston disposed between said intake and outlet ports such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism comprising:

a power transfer shaft rotatably responsive to a drive source;

a tubular passageway adjacent said power transfer shaft;

a crosshead slidably disposed in said tubular passageway, said crosshead pivotally connected to said power transfer shaft; and

at least one piston rod connected at a first end to said crosshead and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston;

a lubricating fluid region coupled to at least said drive mechanism, said lubricating fluid region comprising:

a lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of a lubricating fluid;

a lubricant reservoir in fluid communication with said lubricant sump; and

a lubricant pumping device fluidly coupled to said lubricant sump; and

at least one seal disposed in said tubular passageway, said seal defining a boundary between said working fluid region and said lubricating fluid region;

connecting said intake port and said outlet port to a supply of said working fluid;

introducing said working fluid to said intake port;

activating said drive source so that said piston moves at least a portion of said working fluid from said intake port to said outlet port; and

increasing the pressure of said lubricating fluid at said boundary above that of the lubricating fluid remaining in said sump.

71. A method according to claim 70, wherein said increased lubricant pressure at said boundary is effected by configuring said lubricant pumping device to comprise:

a lubricant inlet channel configured to receive lubricant from at least one of said lubricant sump and said lubricant reservoir;

an inlet check valve disposed in said lubricant inlet channel;

a lubricant outlet channel;

an outlet check valve disposed in said lubricant outlet channel; and

a variable volume pumping cavity at least partially disposed in said tubular passageway, said cavity in fluid communication with said lubricant inlet channel and said lubricant outlet channel, said cavity defined at a first end by said crosshead such that upon oscillating motion of said crosshead, said lubricant introduced into said cavity through said lubricant inlet channel becomes pressurized and exits through said lubricant outlet channel.

72. A method according to claim 70, wherein said increased lubricant pressure at said boundary is effected by the additional steps of:

configuring said lubricant pumping device as a separate oil transfer pump; and

operating said separate oil transfer pump to pressurize said lubricant reservoir more than the remainder of said lubricating fluid region.

73. A method of operating a micro combined heat and power system, said method comprising:

configuring a working fluid circuit to transport a working fluid, said working fluid circuit comprising:

an evaporator configured to convert said working fluid from a subcooled liquid into a superheated vapor;

an expander in fluid communication with said evaporator, said expander including a first lubricant sump; and

a condenser in fluid communication with said expander; and

a working fluid feed pump comprising:

at least one working fluid region with an intake port configured to receive a working fluid, an outlet port configured to dispense said working fluid, and a piston disposed between said intake and outlet ports such that upon oscillation of said piston, said working fluid is pumped from said intake port to said outlet port;

a drive mechanism with a power transfer shaft rotatably responsive to a drive source, a tubular passageway adjacent said power transfer shaft, a crosshead slidably disposed in said tubular passageway, said crosshead connected to said power transfer shaft, and at least one piston rod connected at a first end to said crosshead and at a second end to said piston, said piston rod configured to impart an oscillating motion to said piston;

a lubricating fluid region with a second lubricant sump disposed adjacent said power transfer shaft and configured to contain at least a portion of a lubricating fluid, and a lubricant pumping device fluidly coupled to said second lubricant sump; and

at least one seal disposed in said tubular passageway, said seal defining a boundary between said working fluid region and said lubricating fluid region;

fluidly connecting said intake port to said condenser;

fluidly connecting said outlet port to said evaporator;

starting said system such that said working fluid adjacent said evaporator is converted into superheated vapor, expanded in said expander, cooled in said condenser, and pumped by said pump back to said evaporator in a continuous loop; and

maintaining a sufficient quantity of said lubricating fluid in said lubricant reservoir to ensure that the side of said seal that is adjacent said lubricant reservoir is exposed to a substantially vapor-free environment.

74. A method according to claim 73, comprising the additional step of configuring said lubricant pumping device to comprise:

a lubricant inlet channel to receive lubricant from at least one of said first or second lubricant sumps or said lubricant reservoir;

an inlet check valve disposed in said lubricant inlet channel;

a lubricant outlet channel;

an outlet check valve disposed in said lubricant outlet channel; and

a variable volume pumping cavity at least partially disposed in said tubular passageway, said cavity in fluid communication with said lubricant inlet channel and said lubricant outlet channel, said cavity defined at a first end by said crosshead such that upon reciprocating motion of said crosshead, said lubricant introduced into said cavity through said lubricant inlet channel becomes pressurized and exits through said lubricant outlet channel.

75. A method according to claim 73, wherein said step of configuring said working fluid circuit further comprises incorporating a separate oil transfer pump as said lubricant pumping device.

76. A method according to claim 73, comprising the additional step of introducing said lubricating fluid into a sealing channel disposed between said piston and said generally cylindrical passageway.

77. A method according to claim 76, wherein said step of introducing said lubricating fluid comprises the additional step of configuring a sealing fluid distribution network to transport a sealing fluid from said lubricating fluid region to said sealing channel.

78. A method according to claim 77, wherein said sealing fluid distribution network comprises a lubricant flowpath disposed within said piston and piston rod such that fluid communication is established therebetween.

79. A method according to claim 73, wherein said step of configuring said pump further comprises:

providing a motor configured to provide power to said pump;

providing a first compartment to contain said motor;

providing a second compartment configured to contain at least said power transfer shaft and said second lubricant sump;

extending a coupling from said motor to said second compartment;

establishing a vapor space seal disposed about said coupling; and

defining a boundary between said first and second compartments such that said lubricant is substantially contained in said second compartment.

80. A method according to claim 79, wherein said step of configuring said pump further comprises:

fluidly coupling a lubricant drain line between said first compartment and said first lubricant sump, said lubricant drain line spaced adjacent said vapor space seal such that lubricant collecting therealong can flow through said lubricant drain line to said first lubricant sump; and

fluidly coupling a lubricant return line between said second compartment and said first lubricant sump.

81. A method according to claim 80, comprising the additional step of heating said first compartment with a heating element such that the temperature in said first compartment is maintained above the saturation temperature of said fluid to be pumped.

82. A method according to claim 75, wherein said step of operating said oil transfer pump occurs independent of operation of said micro combined heat and power system.

83. A method according to claim 73, comprising the additional step of pressurizing said lubricating fluid with high pressure vapor that has exited said evaporator.

84. A method according to claim 83, wherein said step of pressurizing said lubricating fluid is accomplished a device that comprises:

a lubricant pressurization chamber fluidly coupled to said lubricant sump, said pressurization chamber including at least one check valve; and

a flow regulating device configured to intermittently allow the transport of fluid contained in said lubricant pressurization chamber to at least one of said working fluid region and said lubricating fluid region.

85. A method according to claim 84, wherein said flow regulating device is a time-responsive valve.

86. A method according to claim 84, wherein said step of pressurizing said lubricating fluid is accomplished with a jet pump configured to inject said lubricating fluid into a flow of said high pressure vapor.

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