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(54) **WATER EXTRACTION FROM AIR AND DESALINATION**

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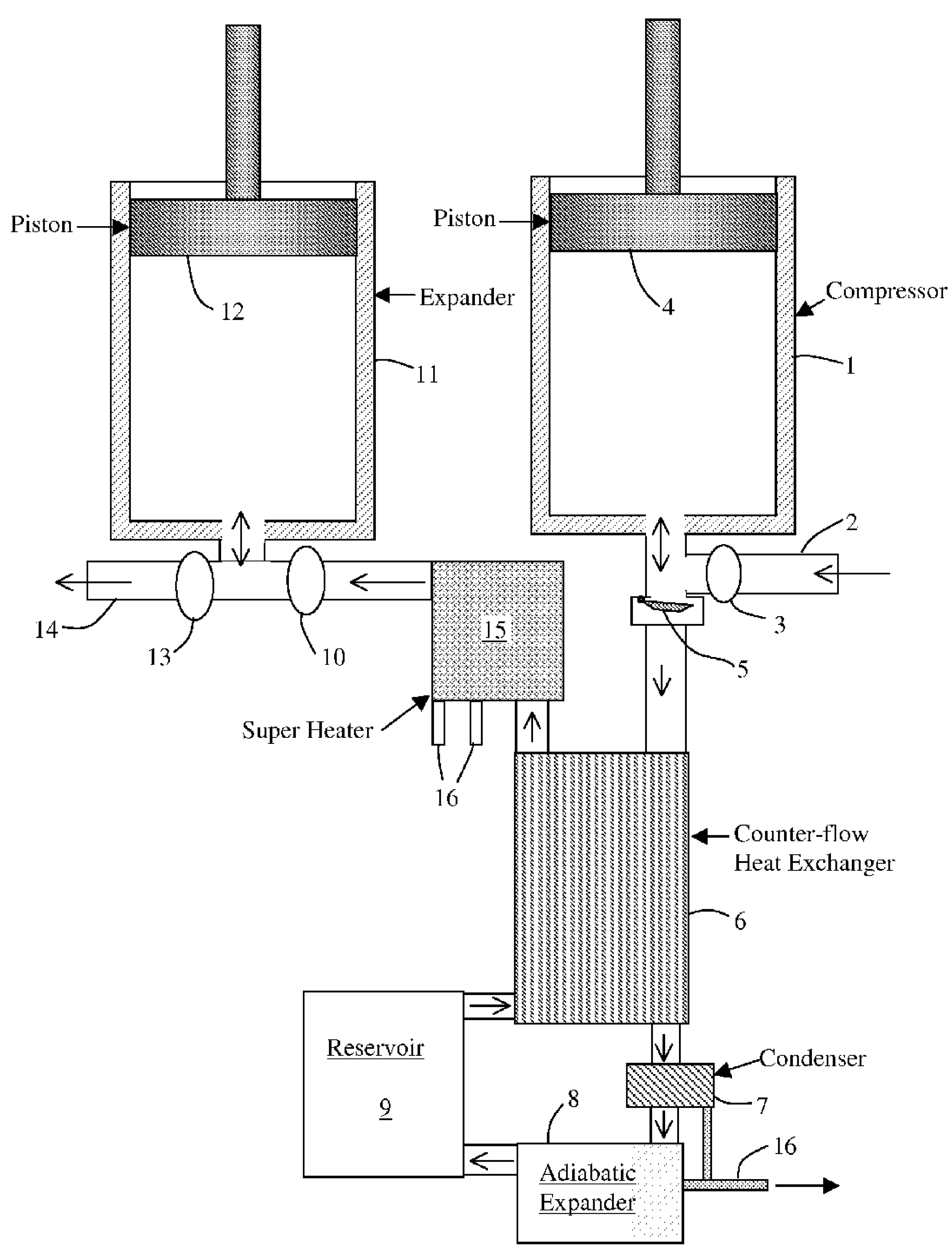
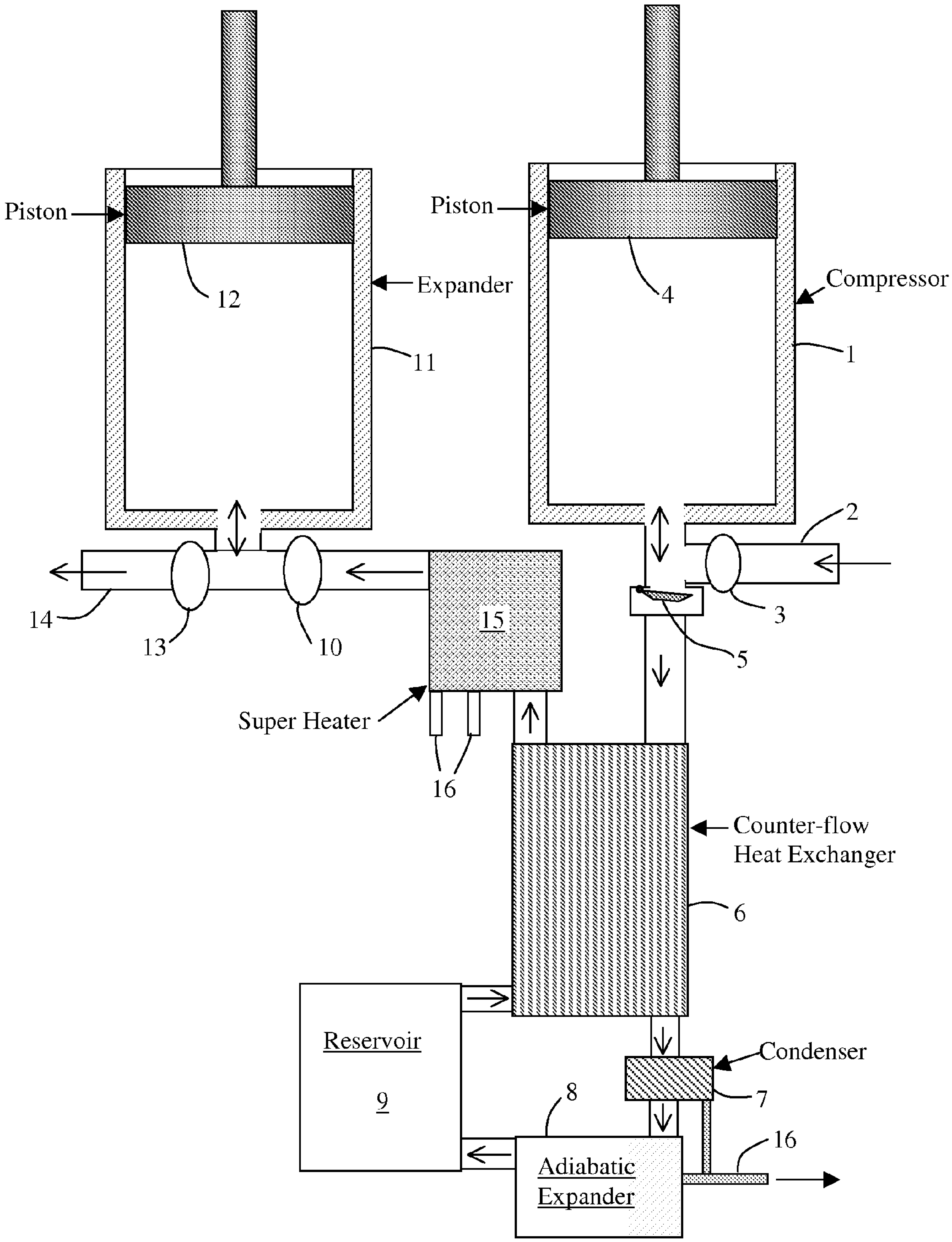
(57) **ABSTRACT**

This invention is a water producer that extracts water from the air. One embodiment of the invention adiabatically compresses and heats the air. The heated air is cooled through a counter-flow heat exchanger so that it becomes supersaturated and water condenses. The air is then cooled further and passed back through the heat exchanger to recover its former heat. It then passes through an adiabatic expander to recover energy. A second embodiment utilizes a unique isothermal compressor/expander to compress the humid air isothermally so that the air becomes supersaturated with water, and the water condenses. The air is then cooled to remove the heat of condensation of the water and returned to the isothermal compressor/expander to recover energy. A third embodiment draws in humid air through a counter-flow heat exchanger to cool it down below its dew point so that water is collected. The air is then cooled adiabatically and passed back through the counter-flow heat exchanger and on to a compressor, which compresses the air back to ambient pressure and pushes the air out. These embodiments can be used to desalinate seawater, brackish water, or desiccant aqueous solutions by having a humidifier evaporate water from the liquids to make the input air to the water producer very humid.





Piston
12
Expander
11
Piston
4
Compressor
1
2
14
13
10
15
3
5
Super Heater
16
Counter-flow
Heat Exchanger
6
Reservoir
9
Condenser
7
8
16
Adiabatic
Expander

Figure 1

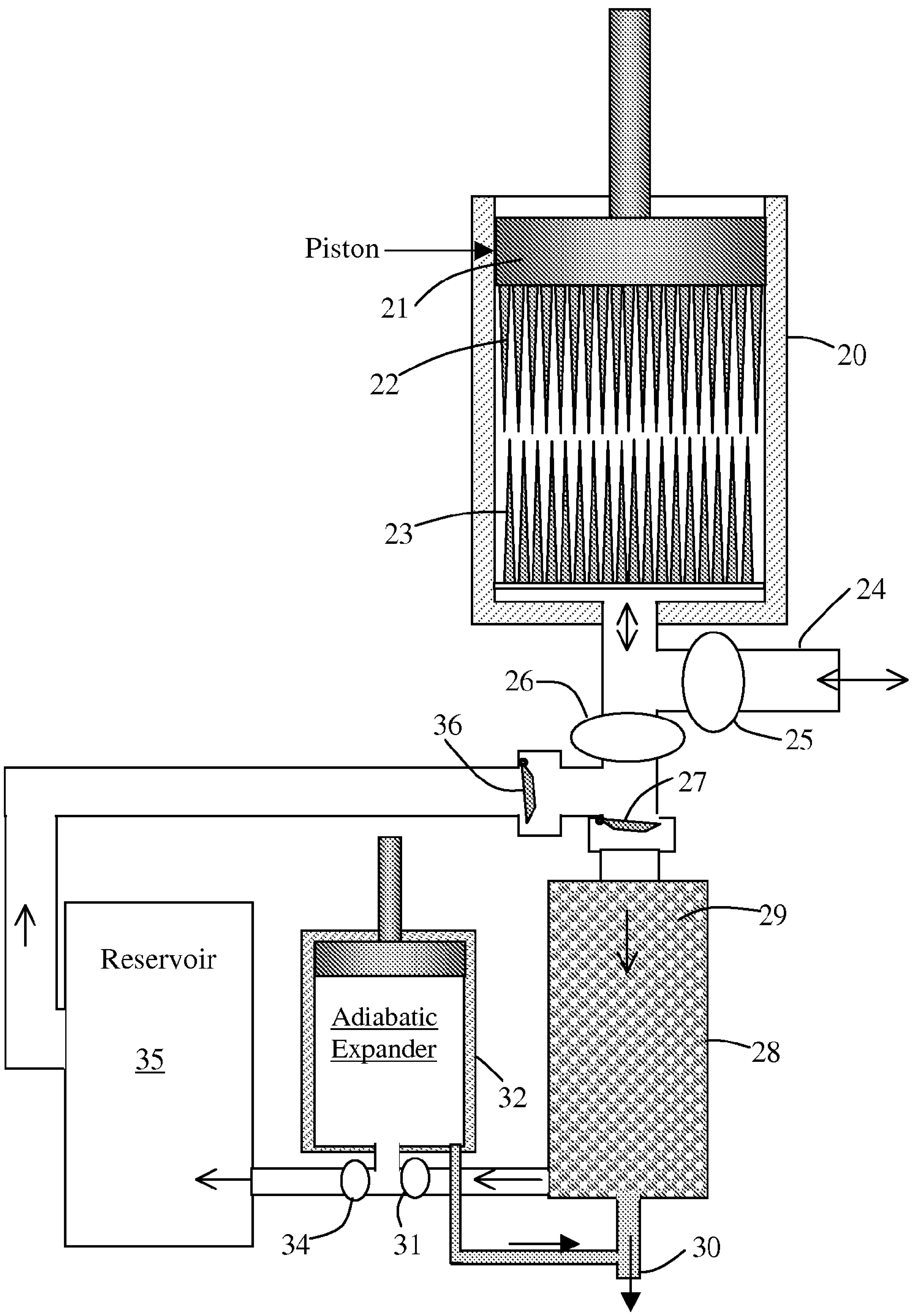

Piston
21
22
20
23
24
26
25
36
27
29
Reservoir
35
Adiabatic
Expander
32
28
34
31
30

Figure 2

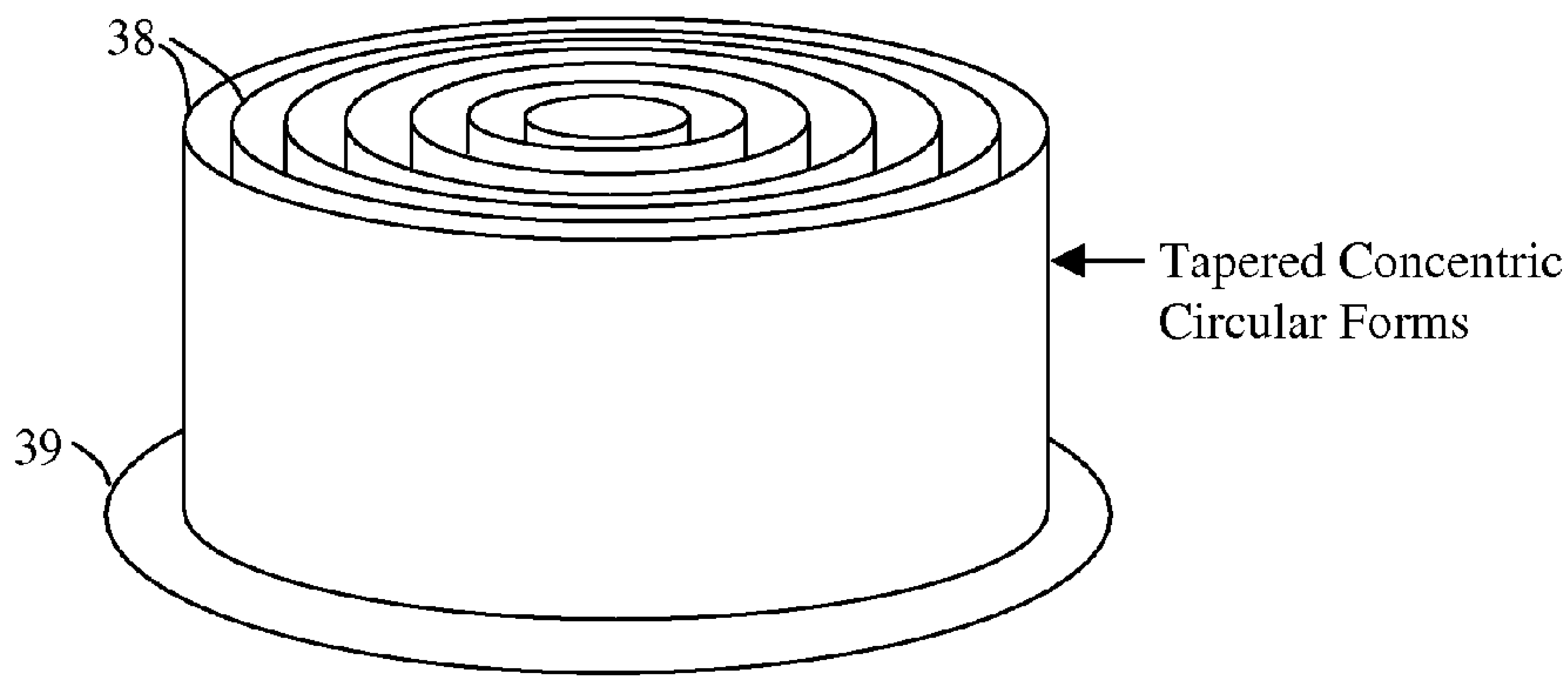


Figure 2A

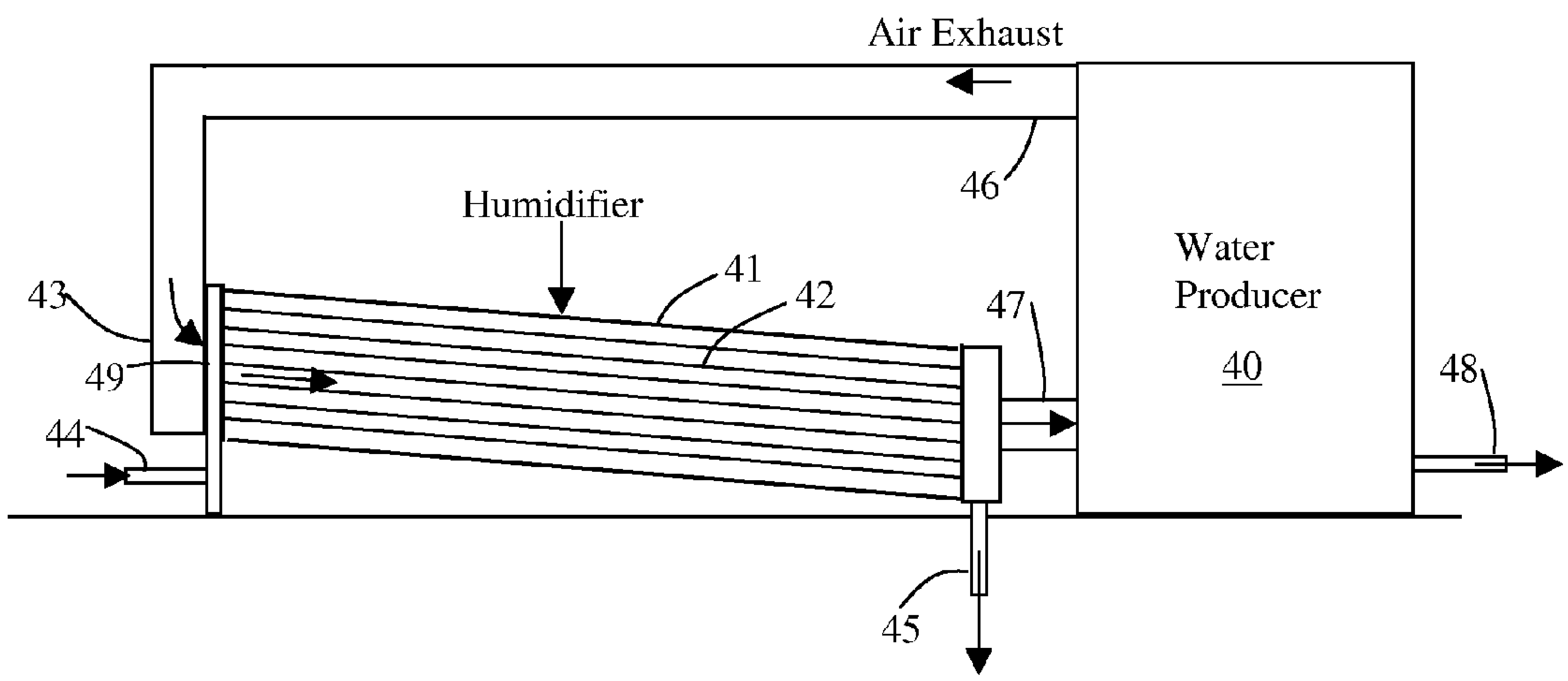


Figure 3

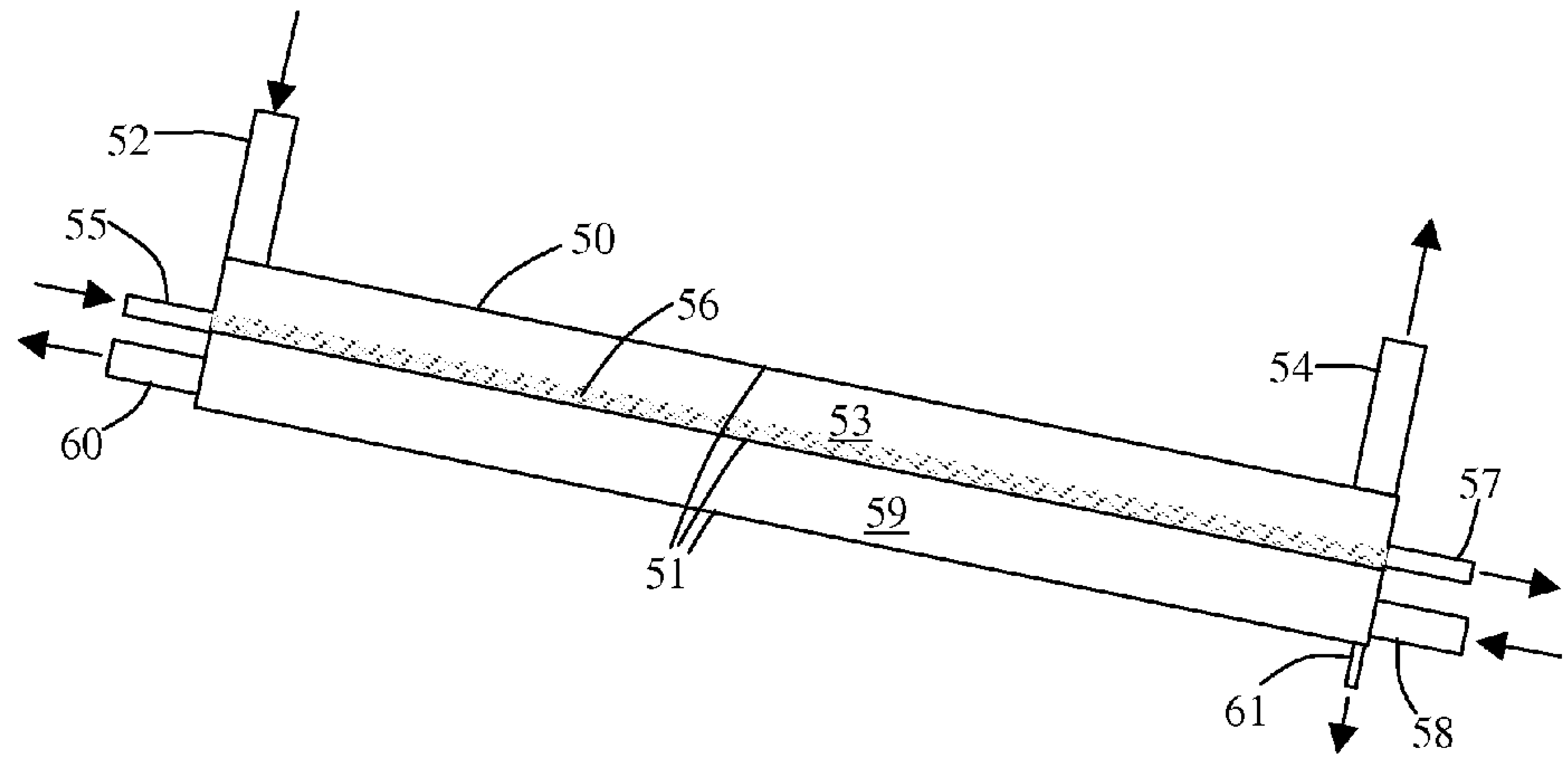


Figure 4

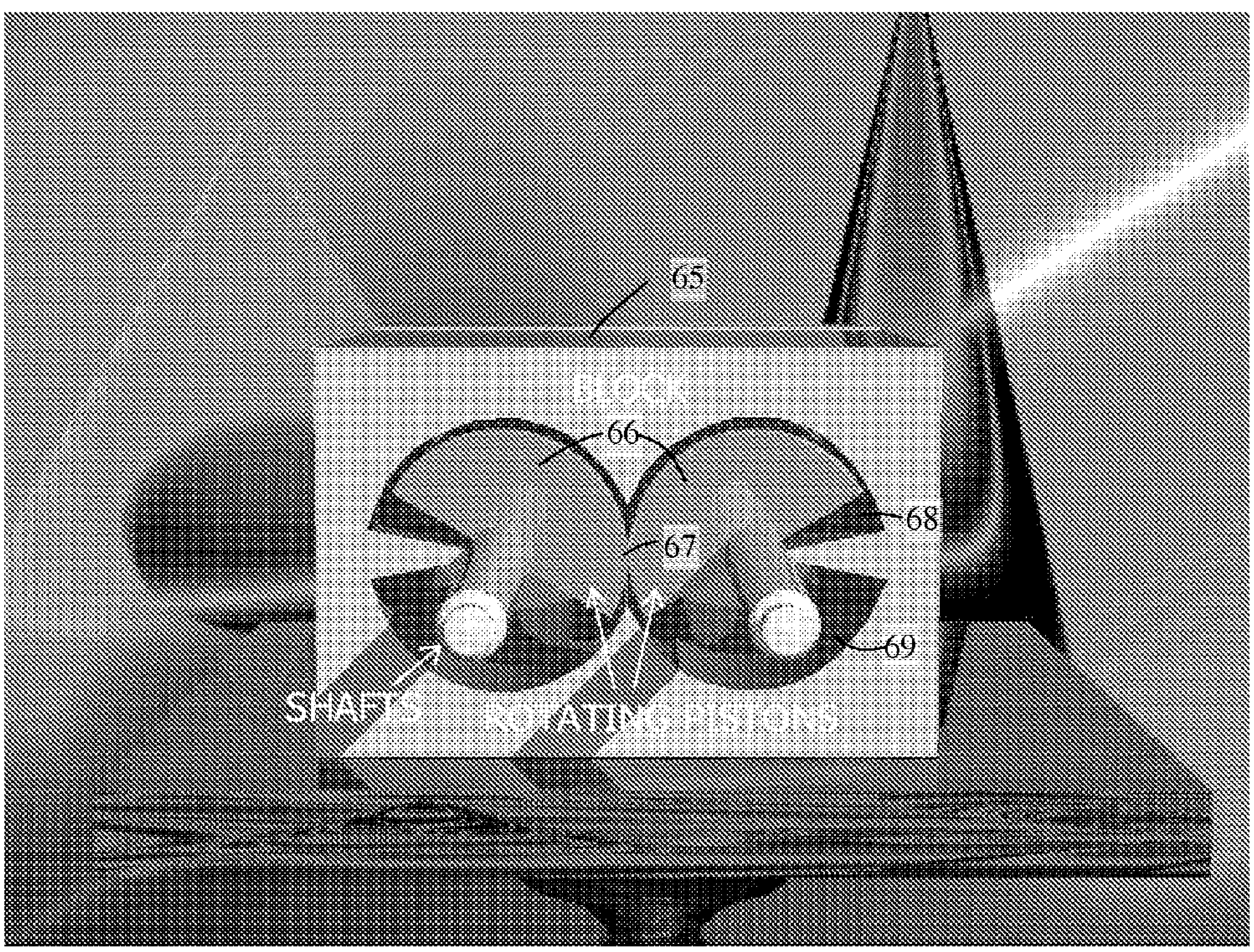


Figure 5

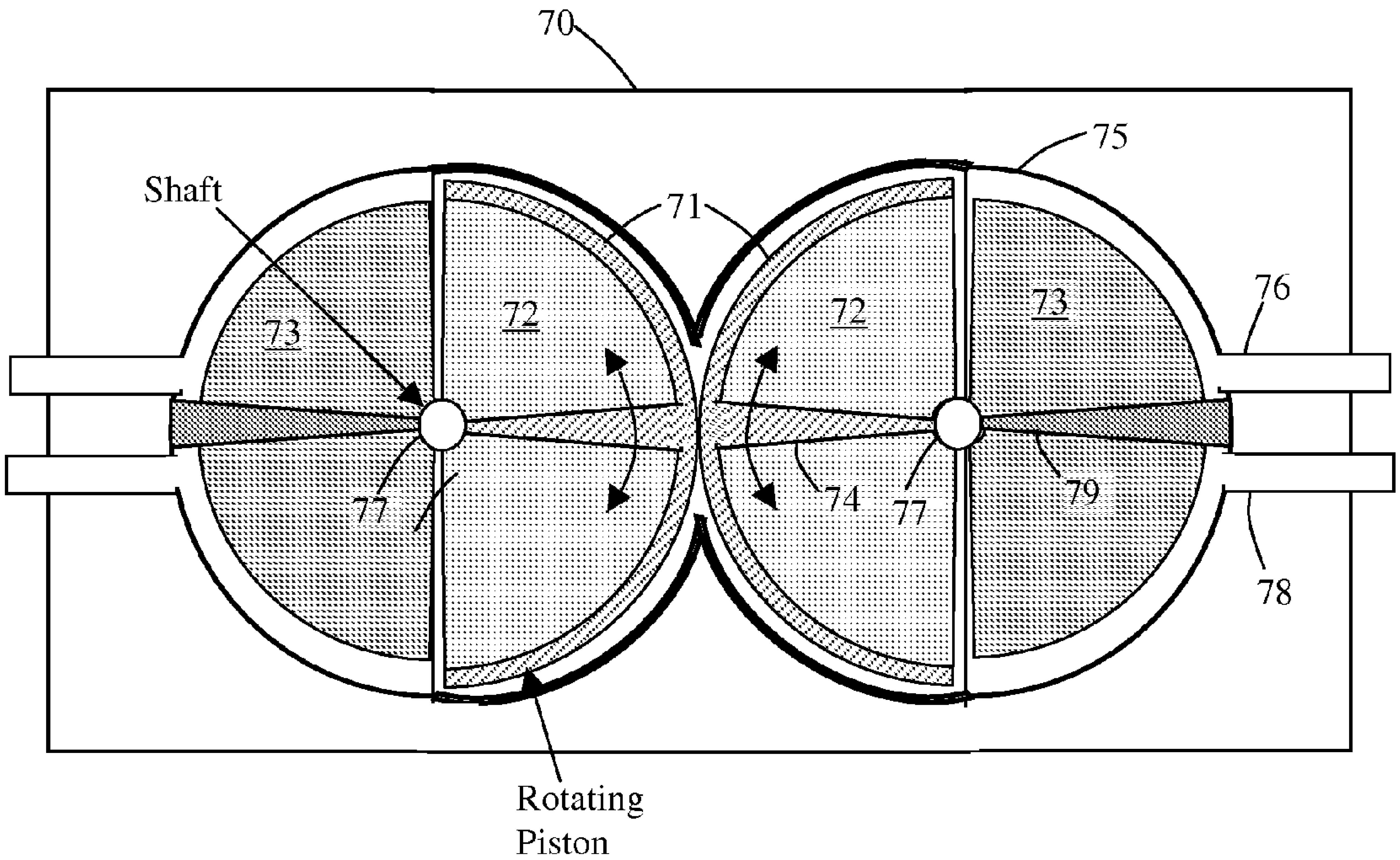


Figure 6

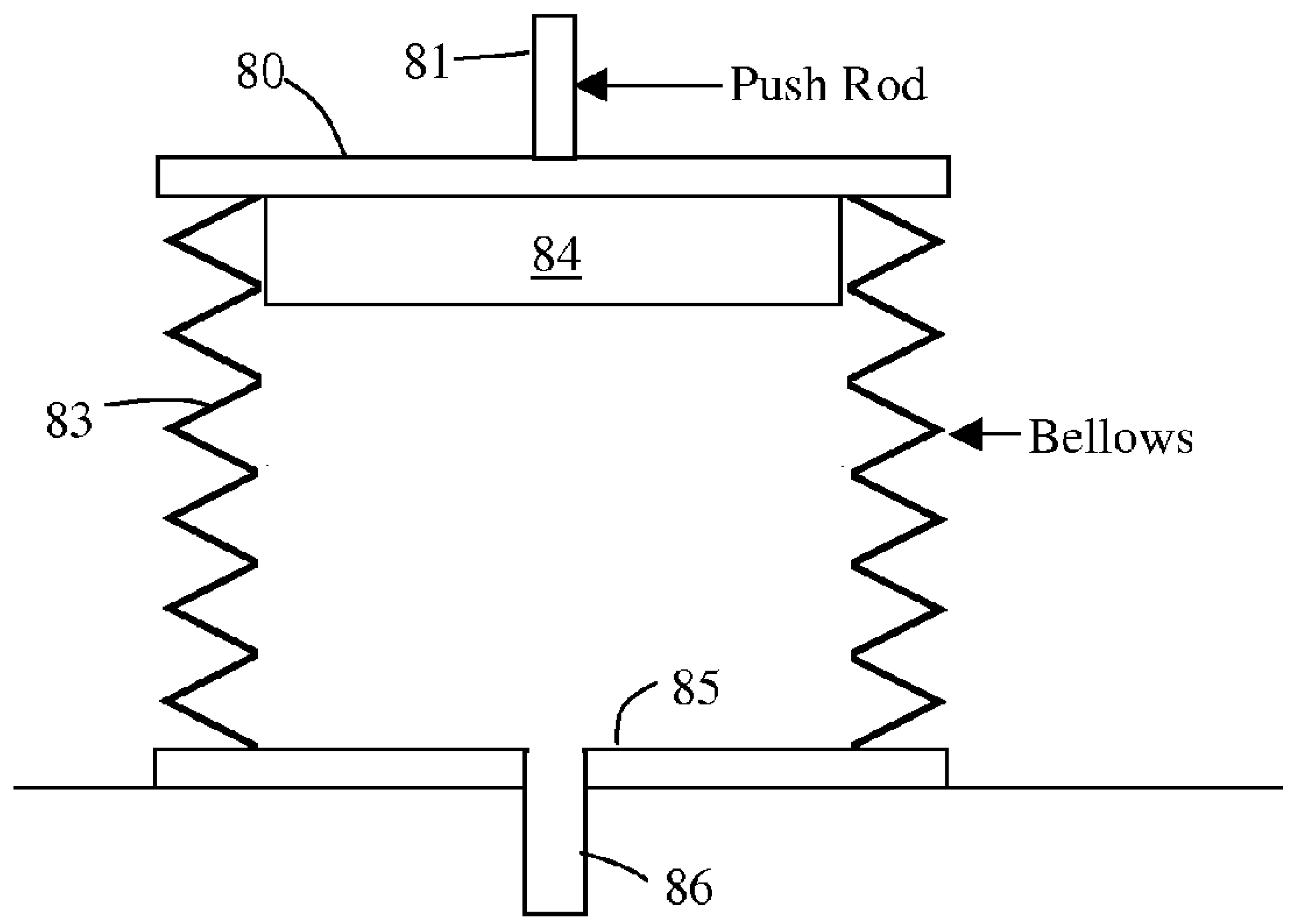


Figure 7

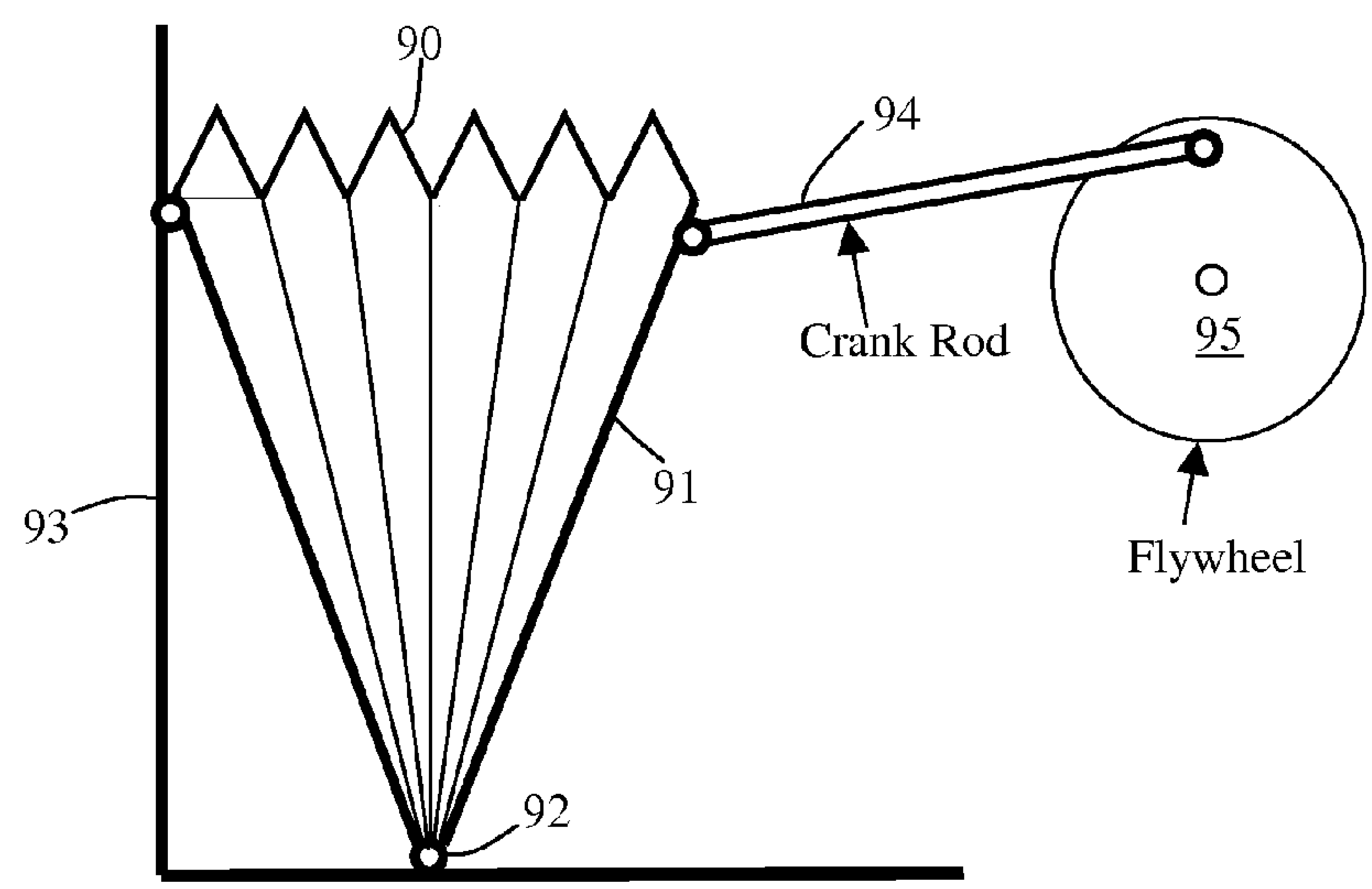


Figure 8

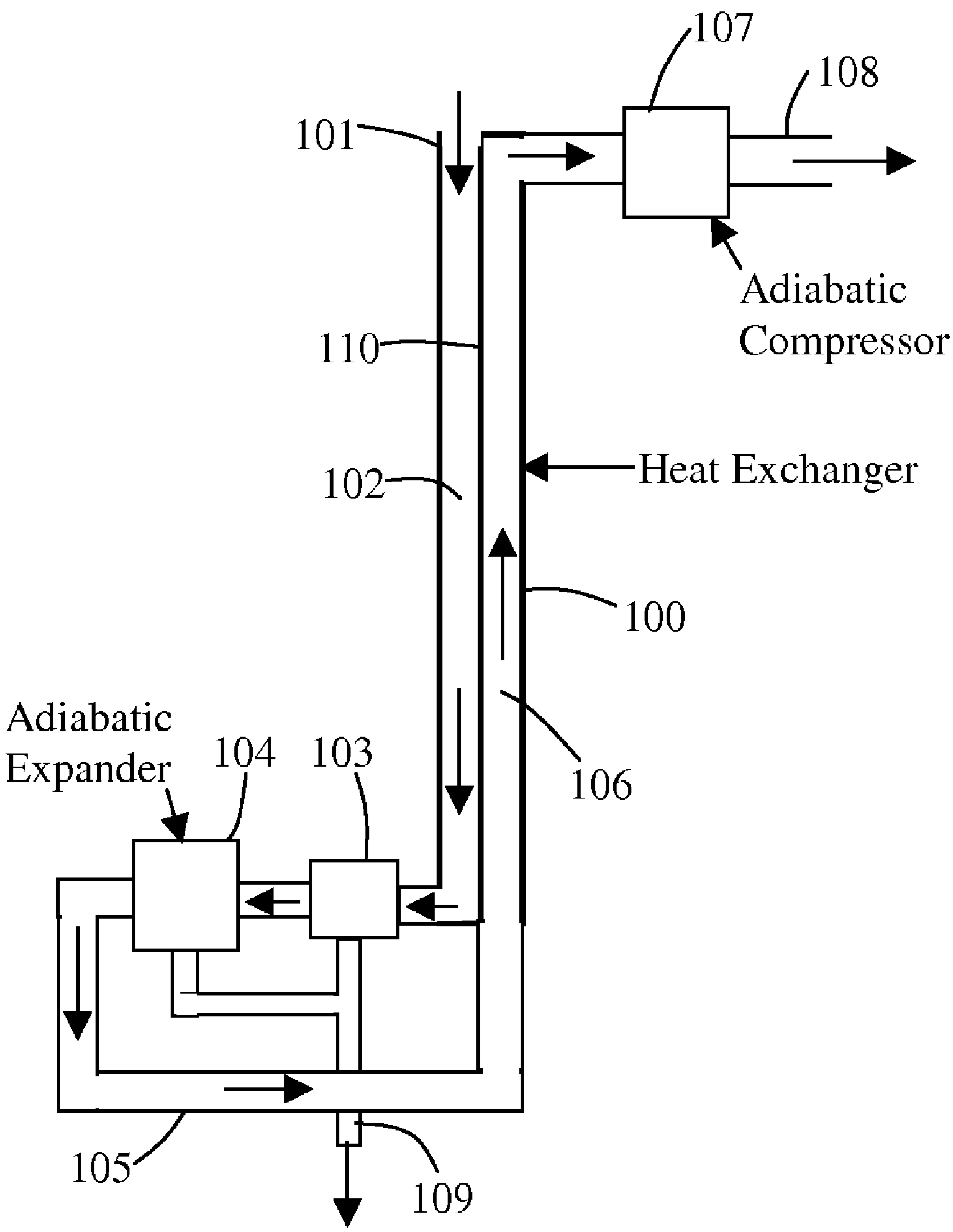

107
108
101
Adiabatic
Compressor
110
Heat Exchanger
102
100
Adiabatic
Expander
104
103
106
105
109

Figure 9

WATER EXTRACTION FROM AIR AND DESALINATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This claims priority to and the benefit of Provisional U.S. Patent Application Serial No. 60/746,271, filed May 3, 2006, the entirety of which is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The earth's atmosphere carries an enormous amount of water. At 50% relative humidity, the amount of water flowing in a 10 mile per hour wind over a farmer's square-mile farm in Kansas with a clear sky overhead amounts to 6.9 billion gallons per day. That is 21,140 acre-feet, enough to cover the farmer's land to a depth of 33 feet of water every day. The winds over the U.S. carry far more water than all the American rivers combined. Most of that water is carried back out over the oceans without being used.

[0003] There are many places in the world that have a severe shortage of water, but machinery could be built to supply water from the air. Most water extraction mechanisms require a lot of energy. Some of them use refrigeration that cools a surface to cause water condensation. A typical refrigeration device that removes water from the air requires about 2 kWh (depending on the humidity) to produce a gallon of water. If the electricity costs 9 cents per kWh, the cost is 18 cents per gallon or $180 per thousand gallons. Current seawater desalination plants can produce fresh water for $2 to $6 per thousand gallons. (But 18 cents per gallon is cheap compared to bottled water prices).

[0004] It is well known that compression of air can increase the relative humidity of the air. If the air is compressed sufficiently, the relative humidity can exceed 100%, which means that it will condense on surfaces. One problem is that when air is compressed adiabatically, it gets hot, and that lowers the relative humidity. U.S. Pat. No. 6,360,549, Spletzer, et al, from the Sandia National Laboratories describes a device that incorporates a piston in a cylinder to compress air into a porous medium where the water can condense. The claim is that it is near isothermal (constant temperature) operation, which means that it does not get hot. The problem with this design is that the air that is being compressed gets hot before it reaches the porous medium. It cools inside the medium so that condensation can occur. Then, when the piston moves the other direction, the air that comes out of the medium expands and cools almost adiabatically unless the piston is moving slowly. This means that the expansion of the air returns less of the energy that was put into it. These problems can be overcome by operating the engine very slowly so that the air can cool against the piston and cylinder walls during compression and receive heat during expansion. But this would mean that the device would be very slow and would take a long time to produce a gallon of water.

[0005] The patent from the Sandia National Laboratories states that it is theoretically possible to get excess energy from their system. That is, since the condensing water releases heat, the machine becomes a heat engine that not only produces water but also produces energy. That will not work with their system, because if their system is isothermal, any extra heat produced by water condensation would be absorbed by the same mechanism that keeps the air isothermal. If their system were adiabatic, the mechanical parts would heat up until water would no longer condense.

[0006] Parenthetically, it should be noted that one of the problems with the Spletzer patent discussed above is that the water is deposited in a porous material at the end of the cylinder in which the piston is located. When the piston finishes compressing the air into the material, the piston withdraws, and the air pressure drops. At that point, the water would start evaporating from the porous material just as fast as it condensed. In the patent, it explains that the water would not evaporate, because it is drained out of the material. If the machine has to wait until the water is drained, it will be a very slowly operating device. Furthermore, and water clinging to the inside of the pores of the material will evaporate.

[0007] Other US patents that are somewhat related to embodiments of the present invention are U.S. Pat. Nos. 4,676,067, 5,641,273, and 6,511,525.

SUMMARY OF THE INVENTION

[0008] A device that we may call the "Water Producer" overcomes the problems outlined above. The air is removed from the compression device before condensation occurs. It is theoretically possible to use very little energy to separate the water from the air. Most of the energy requirements are used to overcome friction and aerodynamic losses. Since large quantities of air must be handled, these friction losses must be reduced as much as possible. There are some methods to reduce the mechanical losses considerably, and some of these are considered later in this document. We also need to use highly efficient counter-flow heat exchangers.

[0009] An added advantage to one of the devices described below is that if solar energy is available, the solar heat can be introduced at a specific point in the cycle, and it can generate electric power, and the use of the solar energy is very efficient. This eliminates the problem of having to set up a separate engine to drive the Water Producer.

[0010] Note that this system can not only be placed next to the ocean, but it can be placed in the desert, where it will need no cooling towers to generate water and electric power. The water output will be less, if the humidity is low. There are places in Africa and elsewhere where the humidity is high but the rainfall is low.

[0011] The Water Producer can be used not only as large power plants, but small units can be built to put in people's back yards to generate electricity and fresh water for the home and can be placed on rooftops of businesses.

[0012] Military units can use portable Water Producers in the field to provide water without having to haul tank loads of water.

[0013] It is therefore an object of the present invention to efficiently extract water vapor from the air and condense the vapor to liquid water using an adiabatic compression and expansion machine.

[0014] It is another object of the present invention to efficiently extract water vapor from the air and condense the vapor to liquid water using an isothermal compression and expansion machine.

[0015] It is another object of the present invention to provide methods of humidifying intake air to the Water Producer by flowing air over seawater, brackish water, or desiccant aqueous solutions.

[0016] It is another object of the present invention to utilize solar energy or other heat sources to provide energy to run the Water Producer and to generate electric power.

[0017] It is another object of the present invention to provide means for reducing mechanical losses in the compression and expansion devices.

[0018] It is another object of the present invention to provide methods of preventing or slowing condensation of water at inappropriate times in the machine cycles.

[0019] It is another object of the present invention to provide methods to effectively allow approximate isothermal compression and expansion.

[0020] It is another object of the present invention to provide simplified Water Producer that does not involve high temperatures or pressures.

[0021] Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0022] The accompanying drawings, which are incorporated into and form a part of the specification, illustrate embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating preferred embodiments of the invention and are not to be construed as limiting the invention. In the drawings:

[0023] FIG. **1** is a schematic side view of the adiabatic embodiment of the present invention showing an adiabatic compressor and an adiabatic expander.

[0024] FIG. **2** is a schematic side view of an embodiment of the present invention showing an isothermal compressor/expander.

[0025] FIG. **2**A is a schematic isometric view tapered concentric circular forms for increasing surface contact with gases for isothermal compressors and expanders.

[0026] FIG. **3** is a schematic that illustrates the use of a humidifier to humidify air that can be drawn into a Water Producer to desalinate seawater, brackish water, or a desiccant aqueous solution.

[0027] FIG. **4** is drawing representing one form of the cooler for desalination systems, and at the same time, it provides humid air for the Water Producer.

[0028] FIG. **5** is an artists conception of an inside view of a rotating piston engine.

[0029] FIG. **6** is a schematic top view of a modified rotating piston engine featuring tapered plates for isothermal operation.

[0030] FIG. **7** is a side view schematic of a bellows compressor and/or expander.

[0031] FIG. **8** is a schematic side view drawing of a low friction bellows compressor utilizing a hinge on one side.

[0032] FIG. **9** is a schematic side view of an embodiment of the present invention that provides a simplified method of extracting water from the air efficiently.

DETAILED DESCRIPTION OF THE INVENTION

Adiabatic Water Producer

[0033] We can use isothermal compression or adiabatic compression to provide the increased pressure of the air. We first consider the adiabatic method. In this case, we would prefer to minimize the heat exchange between the air and the cylinder walls and the piston, since this represents an energy loss. The interior volume of the cylinder should be relatively large, and the cylinder walls and the piston face should be lined with Teflon or other insulating material. Having the machine run fast also reduces heat loss.

[0034] FIG. **1** shows one embodiment of the adiabatic Water Producer. For the first stroke, the piston **4** in the compressor **1** moves upward and draws in ambient air through intake **2** with valve **3** open. Then valve **3** closes, and the piston **4** moves downward and compresses and heats the air. When the air pressure in the compressor **1** becomes greater than the pressure in the counter-flow heat exchanger **6**, the check valve **5** opens and compressed air flows into the counter-flow heat exchanger **6**, which has parallel chambers with down-flowing and up-flowing air flowing in alternate chambers. The air in the heat exchanger **6** is continually pressurized with air.

[0035] It would be preferable to have the interior surfaces of the heat exchanger in the down-flowing chambers coated with a hydrophobic material, such as Teflon to prevent condensation. When the air flows out the bottom of the heat exchanger, it flows into a condenser **7**, which is filled with fibrous hydrophilic material to provide condensing surfaces for the water. This heats and expands the air. The condensed water flows out a drainpipe **16**.

[0036] The air flows out the bottom of the condenser and into a cooler **8**, which is shown as an adiabatic expander in FIG. **1**. The purpose of the cooler is to maintain the temperature gradient from the top to the bottom of the counter-flow heat exchanger **6**. By using an adiabatic expander as a cooler, the energy that the condensing water imparts to the air can be reclaimed. This energy can be used to help drive the moving parts of the Water Producer. Alternatively, the cooler could be cooled by ambient air blown through cooling fins or by other means, but this does not recover any mechanical energy. More water condenses in the cooler **8** and flows out the drainpipe **18**. The air flows into the reservoir **9** and then flows back up through the counter-flow heat exchanger **6**, where it heats up as it receives heat from the down-flowing air. By the time it reaches the top, it is nearly as hot as the down-flowing air at the top.

[0037] If an external heat source, such as solar energy, is used, that energy flows into the super heater **15**. If no external source of heat is used, the super heater is eliminated. The high-pressure air then flows through valve **10** into the expander cylinder **11** and returns energy to the system as it pushes piston **12** upward. Valve **10** closes, and the air continues to push the piston in an adiabatic expansion. When the piston reaches the top, the air has returned to near ambient conditions (minus some water). Valve **13** opens, and the air is forced out the exhaust pipe **14**. The system is ready for a repeat performance. In fact, the compressor and expander should be operating at the same time, 180 degrees out of phase. There could be a number of compressors and expanders feeding the same heat exchanger.

[0038] In the adiabatic embodiment of the Water Producer, the air is heated by the compression, and then the air is cooled in the heat exchanger to enhance water extraction. The heat is returned to the air so that it can return energy to the system through adiabatic expansion. Again, theoretically, very little energy is used to remove water from the air.

[0039] Instead of using a piston compressor and a piston expander, other types of compressors and expanders, such as turbines or scroll devices could be used.

[0040] The adiabatic method requires more energy to compress the air, but it gets more energy back during expansion. An advantage of the adiabatic method is that water is less likely to condense in the compressor but will readily condense in condenser and the cooler.

Isothermal Water Producer

[0041] FIG. **2** is a schematic that illustrates a new type of isothermal compressor and expander. In order to increase heat transfer from the air to the metal, the surface area is greatly increased by placing tapered plates **22** on the front of the piston **21** and tapered plates **23** on the bottom of the cylinder **20**, leaving channels for air flow. These plates could have flat surfaces as shown in the diagram, or they could have circular concentric configurations as shown in FIG. **2**A.

[0042] In operation, valve **25** is opened and the piston **21** in the pump cylinder **20** moves upward so that it draws in fresh air from the outside through intake **24**. When the piston reaches its maximum height, valve **25** is closed, and the piston is forced downward, compressing the air. As the air is compressed, it tends to increase in heat, but the tapered plates absorb the heat of the air. Since the heat capacity of the metal plates is about 2000 times as great as the air (per unit volume), the plates' temperature does not rise very much during one half cycle.

[0043] When the piston has traveled down far enough to provide the appropriate pressure the air, valve **26** opens to allow the air and its water vapor to flow through check valve **27** and to enter the condensation tank **28**, which has about the same pressure as the air in the pump cylinder **20**. The piston continues to move downward to force the air into the condensation tank.

[0044] The inside pump cylinder walls and the tapered plates should be coated with a very thin layer of Teflon or other hydrophobic material. This prevents the water vapor from readily condensing on the plates. Any droplets that do form would tend to be thrown downward as the piston decelerates and to be blown out by the air rushing into the condensation tank. The coating should be as thin as possible so that it does not hinder heat transfer. The condensation tank **28** is filled with hydrophilic material **29** that could be fibrous. The water vapor in the air at this point is above the saturation value (greater than 100% relative humidity), so it condenses on the hydrophilic material and runs down out of the tank for useful purposes. There could be several cylinders and pistons that alternately feed air to the tank and take air out of the tank.

[0045] While the pump **20** forces air into the condensation tank **28**, the adiabatic expander **32** draws in air through valve **31** from the condensation tank. When the appropriate amount of air is drawn in, valve **31** closes, and the air in the expander **32** is expanded adiabatically until it reaches a specified volume. The piston reverses direction, and valve **34** is opened so that the air is expelled into the reservoir **35**. When piston **21** moves upward, it draws air from reservoir **35** through check valve **36** and valve **26**. The air tends to cool during expansion, but the tapered plates **22** and **23** supply heat to keep the air near isothermal. When piston **21** reaches the top, it reverses, as valve **26** closes and valve **25** opens. The air is forced out intake pipe **24**.

[0046] Calculations show that the air will remain near isothermal during both compression and expansion, since the air has close proximity to the plates for heat transfer, and the motion of the plates create turbulence that further enhance heat transfer.

[0047] The condensation of the water in the condensation tank releases the latent heat of condensation, and this heats the air, causing expansion of the air. If the condensation tank does not have sufficient volume to accommodate the extra volume without significantly increasing the pressure, a reservoir can be placed adjacent to the tank.

[0048] Expansion of the air causes the system to behave as a heat engine, since the volume of the air flowing out of the expander is greater than the volume of air flowing out of the pump.

[0049] In the Water Producer, described in this document, the air is forced out of the pump into the condenser, and the water condenses in a separate chamber, where the air pressure is maintained so that it causes condensation and prevents evaporation. This is in contrast to the method used in the Sandia National Laboratories' patent, which has the condensation system inside the compressor.

[0050] In the discussion above, tapered plates are described as providing large surfaces for heat transfer to the air. In many applications, it may be better to use tapered concentric circular forms that are approximately cylindrical. FIG. **2**A is a schematic drawing showing the tapered concentric circular forms **38** mounted on a base **39**. The circular forms would fit better in a cylinder such as **20** in FIG. **2** than flat plates. The tapered plates **23** of FIG. **2** could actually be the tapered concentric circular forms **38**. Similar circular forms could be attached to piston **21** in FIG. **2**.

Desalination

[0051] FIG. **3** shows humidifier **41** for providing high humidity to the air. The air flows from the Water producer **40** through pipe **46** to a manifold **43**, which distributes the air between metal plates **42**. The humidifier consists of a number of flat plates **42**, that can be metal or a hydrophilic plastic. Seawater or brackish water enters through pipe **44** and flows through a manifold **49** on the left and is distributed to the top surfaces of the plates **42**. The water runs down the plates as a film. Air flowing between the plates becomes humidified and is drawn through pipe **47** into the Water Producer **40**, where some of the water is removed as fresh water. The exhaust air from the Water Producer flows back to the humidifier to be re-humidified again. Collected fresh water flows out drain **48**. An important feature of this method is that the air will be dust-free. If there is particulate matter in air drawn directly from the atmosphere, water will condense on these particles before the air reaches the condenser.

[0052] Incoming seawater can be used as the heat exchange fluid in a cooler **8** of FIG. **1** (if an adiabatic expander is not used) to cool the air before it returns to the heat exchanger. In FIG. **2**, cool seawater could be used to cool the air in place of the adiabatic expander **32** is not used.

[0053] FIG. **4** shows an effective way to humidify air, and at the same time, act as a cooler in FIGS. **1** and **2** when the Water Producer is used as a desalination unit, in case the adiabatic expander **8** or **32** is not used. It consists of metal sheets **51** that form two enclosed chambers **53** and **59**. Seawater enters through pipe **55** and flows as a film **56** down the floor of the upper chamber **53** and is heated by heat from below. The seawater flows out pipe **57**. Exhaust air from the Water Producer flows in through pipe **52** over the water film **56** and becomes humidified. It then flows back to the Water Producer through pipe **54**. Air flowing out of the condenser (**7** in FIG. **1** or **28** in FIG. **2**) enters the bottom chamber **59** and deposits heat into the seawater film in chamber **53**. After being cooled, this air flows out through pipe **60** and to the air reservoir (**9** of FIG. **1** or **35** of FIG. **2**). This method will transfer heat from the air in the bottom chamber **59** and heat the water in the top chamber **53**, but it will not generate any power.

[0054] Since the exhaust air from the expander **11** of FIG. **1** is warmer than the intake air, it can also be used to heat the seawater.

[0055] For the devices described in FIGS. **4** and **5**, instead of using seawater or brackish water, a solution of desiccant and water can be pumped through the water channels. The desiccant solution can then be pumped back to a device that blows air across the surface of the solution so that it can absorb more water from the air. It would then flow back to the humidifier again.

More Efficient Compressors and Expanders

[0056] One of the main sources of inefficiency for a compressor/expander engine that is needed for the Water Producer is sliding friction of the piston. I have a U.S. Pat. No. 6,401,686) that is often referred to as "MECH," which stands for motor, expander, compressor, and hydraulics. Since it uses rolling friction between two rotating pistons rather than sliding friction of a standard piston engine, the friction losses are much less. The rotating pistons do not touch the cylinder walls. There is sliding friction on the ends of the pistons, but this can be relatively small by making the pistons long compared to the diameter.

[0057] It is well known that rolling friction is only about 1/100 as large as sliding friction. A MECH prototype that we built demonstrated only 8% as much energy loss as a comparable size piston engine. It provides an engine with unprecedented economy for producing water from the air or for desalinating seawater.

[0058] FIG. **5** is an artist's conception of a MECH engine **65** with the end plate removed. One can see how the two rotating pistons **66** roll together at the contact line **67**. It could be used as a compressor and expander for the design of FIG. **1**. In fact, a single MECH engine could be compressing air in the top chambers **68** while it is expanding air in the bottom chambers **69**, and vice versa.

[0059] FIG. **6** shows a top view of a compressor/expander (it can be used as a compressor or expander or both) that is similar to a MECH engine in that it has two rotating surfaces that roll together. It is designed to be an isothermal compressor and/or expander. The MECH compressor already has one advantage over standard compressors for isothermal compression: it has larger surface areas of the cylinder walls and piston surfaces for absorbing heat during compression and for returning heat during expansion. The rotating pistons rotate almost **180** degrees in one direction and then reverse directions for almost **180** degrees. The pistons do not touch the cylinder walls. Sliding friction occurs only at the ends of the pistons where they meet the end of the cylinders. The seal to prevent air leakage is formed at the rolling contact point between the two pistons.

[0060] FIG. **6** is a schematic top view of a modified MECH compressor. Cylinders **75** are machined out of a block **70**. Each rotating piston **71** consists of a hollow half-cylinder that is open on one side. The half-cylinder is connected to the shaft **77** by a partition **74**. Tapered plates **72**, like those in FIG. **2** are placed inside the half cylinder **71**. The top and bottom of the rotating piston **71** are closed with half-circle plates; they are not shown, because they are on the near end and far end of the half-cylinder (above and below the page). When the right piston rotates to the right and the left piston rotates to the left, the upper tapered plates will move into the volume where stationary tapered plates **73** are located and will fit between the stationary plates. The stationary tapered plates are attached to the separator **79**. The air in the spaces will be compressed and squeezed out the exhaust/intake pipes **76**. At the same time, air will be drawn into the bottom half of the engine through the other pipes **78**. When it rotates the other direction, air in the bottom half will be compressed.

[0061] The tapered plates provide large surface areas for the transfer of heat to and from the air. The motion of the tapered plates relative to the stationary plates causes air turbulence in the small gaps between them, and this enhances heat flow.

[0062] FIG. **7** shows a design that incorporates bellows **83** to compress and expand air. The bellows is connected to the top **80** and to a base **86**. Push rod **81** moves the top up and down. The inside surfaces can be coated with hydrophobic materials. The purpose of the displacer **84** is to push out as much air as possible when the bellows is compressed as far as possible. Air flows in and out of pipe **86**.

[0063] For an isothermal compressor, the tapered plates like those of FIG. **2** can be connected to the displacer **84** and to the base **85**.

[0064] One source of friction in the design of FIG. **7** is that the push rod **81** would need to have a sliding bearing on it to keep it aligned with the center of the bellows compressor. It would also need a bearing on the upper end of it that connects a connecting rod to a flywheel. The design of FIG. **8** avoids problem by having a bellows **90** that opens like a fireplace bellows. There is a hinge **92** on the bottom. Rigid side **91** provides a place to attach a connecting rod **94** that connects to flywheel **95**. Rigid structure **93** supports the other side of the bellows. In the center of the bottom, there is an inlet/outlet (not shown). This design has low friction bearings at the ends of the crank rod.

Required Cooling and Heating

[0065] There may be some situations in which the tapered plates of the embodiment of FIG. **2** need some cooling or heating. The incoming air provides some stabilization of the temperatures. If more cooling or heating is needed, the tapered plates can be hollow and cooling or heating fluid can flow through them. In the case of the compressor/expander of FIG. **6**, the liquid can flow through an axial hole in the center of the shaft **77** to cool the rotating plates **72**. The stationary plates **73** can receive liquid through the separator **79**. The cylinder walls **75** can have fluid channels on the outside.

[0066] For the desalination system, cool ocean water can provide cooling for the compressor. Rather than flow ocean water through the compressor plates and walls, the seawater could cool a coolant fluid in a heat exchanger, and the coolant could flow through the compressor. Also, since evaporating seawater gets cold, a device like that of FIG. **4** could provide coolant by having the liquid coolant flow through the bottom chamber **59** rather than having air flow through. The heat supplied to the seawater would help to evaporate the seawater and humidify the air. In this case, ambient desert air could supply heat for the expander. Simple solar collectors could also supply the heat.

A Simple Water Producer

[0067] FIG. **9** presents a simple method of extracting water from the air that will reduce the required energy in comparison to present day water producers, but it cannot produce excess energy. Humid air is drawn into a counter-flow heat exchanger **100** at the top left opening **101**. The heat exchanger is shown as two long chambers with a heat transfer partition **110** between them, but in a real device, it would have many parallel chambers.

[0068] As the air flows down through the heat exchanger in chamber **102**, it is cooled by releasing heat through the partition **110** to the rising cool air on the right of the partition in chamber **106**. As the air cools at atmospheric pressure, the relative humidity rises. At the bottom, the air flows into a condenser **103**, which is filled with hydrophilic fibers that collect the water from the supersaturated air.

[0069] The water flows out the drainpipe **109**, while the air is drawn into an adiabatic expander **104**. When the air is adiabatically expanded, it cools further, and more water condenses. The cold air then flows through pipe **105** to the right side of the heat exchanger and into chamber **106**, where it absorbs heat from the down-flowing intake air. At the top, the air is drawn into the compressor **107** and is compressed adiabatically back to atmospheric pressure and then expelled to the atmosphere through pipe **108**.

[0070] A computer Fortran program, Waterair.f, calculates the performance of this machine for various input parameters. If the ambient temperature is 25 degrees C and the relative humidity is 90%, for each cubic meter of air processed, the device theoretically produces 18 grams of water and requires 28 calories (117 joules) of energy. If the humidity is 50%, it produces 10 grams of water at a cost of energy of 37 calories per gram. With 30% relative humidity, it produces 5 grams at 43 calories per gram.

[0071] Modern water producers that use a refrigeration system to remove water from the air require 300 to 1,000 calories per gram of water. The present invention does not require Freon refrigerant, with its complications, and it does not require fans to cool a refrigerant condenser. An advantage of this design over the Water Producers of FIGS. **1** and **2** is that it does not have high temperatures and high pressures. But it does not produce any excess energy.

[0072] If we can reduce the cost to a tenth (or even a fourth) that of other machines, we should be able to help the world with its water problems.

What is claimed is:

1. A water and power producing system comprising:

an adiabatic compressor for compressing and thus increasing the temperature of humid air; and

a counter-flow heat exchanger to cool the compressed humid air; and

a condenser to condense water from the compressed and cooled humid air; and

a cooler to further cool the humid air and condense more water and to provide cooling to the cool end of the counter-flow heat exchanger; and

a pipe to conduct the cool air back to the cool end of counter-flow heat exchanger; and

a heater to heat the air further after the air leaves the counter-flow heat exchanger, which heater may receive heat from solar energy or other energy source; and

an adiabatic expander for expanding the air after it has flowed back through the counter-flow heat exchanger and become re-heated;

a drain to drain condensed water; and

valves to control the flow of air;

wherein the adiabatic compressor draws in ambient air, compresses it, and forces it into the counter-flow heat exchanger, where the air cools and becomes supersaturated with water vapor, some of the water vapor condenses in the condenser and flows out the drain, the air flows to the cooler, where it is cooled further and more water is condensed and flows out the drain, the air flows back through the counter-flow heat exchanger to be heated as it cools the air that flows the opposite direction, the re-heated air flows through the heater to be further heated and flows into an adiabatic expander that extracts mechanical energy from the air as the air expands, which mechanical energy may be used to drive an electric generator, and the adiabatic expander pushes the air into the atmosphere.

2. A water and power producing system according to claim **1**, wherein the cooler is an adiabatic expander cooler that extracts additional energy from the air as it cools the air and condenses water, which is drained through the drain.

3. A water and power producing system according to claim **1**, wherein the adiabatic compressors and adiabatic expanders are reciprocating piston-in-cylinder type compressors and expanders.

4. A water and power producing system according to claim **1**, wherein the adiabatic compressors and adiabatic expanders are rotating piston type compressors and expanders.

5. A water and power producing system according to claim **1**, wherein the adiabatic compressors and adiabatic expanders are turbine type compressors and expanders.

6. A water and power producing system according to claim **1**, wherein the adiabatic compressors and adiabatic expanders are bellows type compressors and expanders.

7. A water producing system comprising:

an isothermal compressor/expander for compressing humid air and thus increasing the relative humidity of the air, and for expanding the air after some water has been removed from the air; and

a condenser to condense water from the compressed air; and

a cooler to further cool the humid air and condense more water and to provide cooling to remove the latent heat of condensation of the water and to keep the isothermal compressor/expander cool; and a pipe to conduct the cool air back to the isothermal compressor/expander; and

a drain to drain condensed water; and

valves to control the flow of air;

wherein the isothermal compressor/expander draws in ambient air, compresses it, and forces it into the condenser, where some of the water vapor condenses in the condenser and flows out the drain, the air flows to the cooler, where it is cooled further and more water is condensed and flows out the drain, the air flows back into the isothermal compressor/expander that extracts mechanical energy from the air as the air expands, and the isothermal compressor/expander pushes the air into the atmosphere.

8. A water producing system according to claim **7**, wherein the isothermal compressor/expander consists of:

a piston contained in a cylinder; and

closely spaced tapered plates or tapered concentric circular forms attached to the face of the piston for the purpose of receiving heat from compressing air and supplying heat to expanding air to keep the air close to isothermal; and

closely spaced tapered plates or tapered concentric circular forms attached to the bottom of the cylinder for the purpose of receiving heat from compressing air and supplying heat to expanding air to keep the air close to isothermal;

wherein the closely spaced tapered plates or tapered concentric circular forms attached to the face of the piston fit between the closely spaced plates attached to the bottom of the cylinder when the piston approaches the bottom of the cylinder.

9. A water producing system according to claim **7**, wherein the isothermal compressor/expander consists of:

two rotating pistons within a housing, which rotating pistons roll together to form a seal; and

closely spaced tapered plates or tapered concentric circular forms attached to the inside of the rotating pistons for the purpose of receiving heat from compressing air and supplying heat to expanding air to keep the air close to isothermal; and

closely spaced tapered plates or tapered concentric circular forms attached to the housing for the purpose of receiving heat from compressing air and supplying heat to expanding air to keep the air close to isothermal;

wherein the closely spaced tapered plates or tapered concentric circular forms attached to first side of the rotating pistons fit between the closely spaced tapered plates or tapered concentric circular forms attached to the first side of the housing when the rotating piston rotate toward the first side of the housing, and wherein the closely spaced tapered plates or tapered concentric circular forms attached to the second side of the rotating pistons fit between the closely spaced plates or tapered concentric circular forms attached to the second side of the housing when the rotating piston rotate toward the second side of the housing.

10. A water producing system according to claim **7**, wherein the isothermal compressor/expander consists of:

a bellows compressor/expander; and

closely spaced tapered plates or tapered concentric circular forms attached to the inside top of the bellows for the purpose of receiving heat from compressing air and supplying heat to expanding air to keep the air close to isothermal; and

closely spaced tapered plates or tapered concentric circular forms attached to the bottom of the bellows for the purpose of receiving heat from compressing air and supplying heat to expanding air to keep the air close to isothermal;

wherein the closely spaced tapered plates or tapered concentric circular forms attached to the top of the bellows fit between the closely spaced plates or tapered concentric circular forms attached to the bottom of the bellows when the top of the bellows approaches the bottom of the bellows.

11. A water producing system according to claim **7**, wherein the cooler is an adiabatic expander cooler that extracts additional energy from the air as it cools the air and condenses water, which is drained through the drain.

12. A water and power producing system according to claim **1**, wherein a humidifier provides high humidity to the air that is drawn into the water and power producing system, which humidifier has a plurality of slanted sheets on which a film of seawater, brackish water, or desiccant aqueous solutions flow while the air flows over the film of liquid to absorb the water vapor from the liquid.

13. A water producing system according to claim **7**, wherein a humidifier provides high humidity to the air that is drawn into the water producing system, which humidifier has a plurality of slanted sheets on which a film of seawater, brackish water, or desiccant aqueous solutions flow while the air flows over the film of liquid to absorb the water vapor from the liquid.

14. A water and power producing system according to claim **1**, wherein a humidifier provides high humidity to the air that is drawn into the water producing system, which humidifier has an upper and lower chamber with a slanted sheet separating the two chambers on which sheet a film of seawater, brackish water, or desiccant aqueous solutions flow while the air flows over the film of liquid to absorb the water vapor from the liquid, and wherein heat is supplied from the lower chamber to help evaporate the water, which heat is provided by air flowing from the condenser of the water producing system, and which air flows out of the lower chamber after having been cooled back to the counter-flow heat exchanger.

15. A water producing system according to claim **7**, wherein a humidifier provides high humidity to the air that is drawn into the water producing system, which humidifier has an upper and lower chamber with a slanted sheet separating the two chambers on which sheet a film of seawater, brackish water, or desiccant aqueous solutions flow while the air flows over the film of liquid to absorb the water vapor from the liquid, and wherein heat is supplied from the lower chamber to help evaporate the water, which heat is provided by air flowing from the condenser of the water producing system, and which air flows out of the lower chamber after having been cooled back to the isothermal compressor/expander.

16. A water producing system comprising:

a counter-flow heat exchanger to cool inflowing humid air; and

a condenser to condense water from the cooled humid air; and a an adiabatic expander cooler to further cool the air and condense more water and to provide cooling to the cool end of the counter-flow heat exchanger; and

a pipe to conduct the cool air from the adiabatic expander cooler back to the cool end of counter-flow heat exchanger; and

an adiabatic compressor for compressing the air after it flows back through the counter-flow heat exchanger and becomes re-heated;

a drain to drain condensed water;

wherein the adiabatic expander cooler draws in ambient air through the counter-flow heat exchanger, which cools the air, and draws the air through the condenser where water condenses and flows out the drain, and the adiabatic expander cooler expands the air, further cooling it and condensing more water, which water flows out the drain, and the adiabatic expander cooler forces the air through the pipe back into the counter-flow heat exchanger to be heated as it cools the air that flows the opposite direction, the re-heated air flows into an adiabatic compressor that compresses the air and pushes the air into the atmosphere.

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