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(71) Applicant; and
(72) Inventor: SORENSEN, Jens, Ole [DK/US]; P.O. Box 2274, Rancho Santa Fe, CA 92067 (US).

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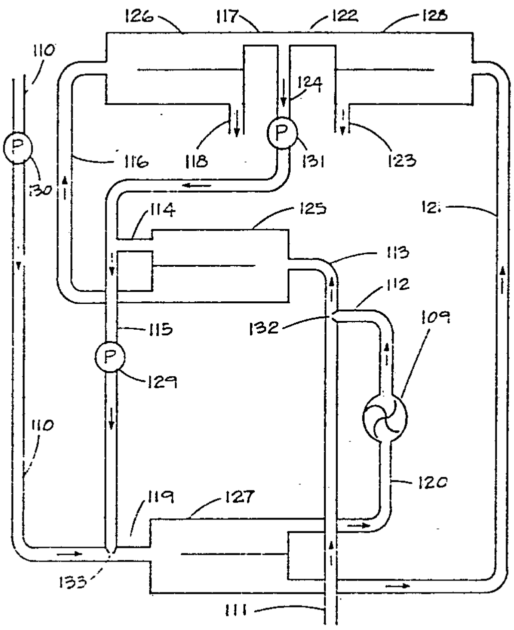
(57) Abstract

The method includes the steps of (a) providing a mass of unencased fluid expandite in a mass transport conduit circuit at a first combination of temperature and pressure; (b) introducing a thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a second combination of temperature and pressure; (c) combining the provided expandite mass with the introduced thermal fluid in a given conduit of the circuit to create an expandite-fluid mixture having a density at some place in the given conduit that is changed from the average proportional density of the expandite mass and the thermal fluid at their respective prevailing combinations of temperature and pressure prior to such combination with each other to create a pressure differential that enhances the flow of the fluids contained within the circuit; (d) directing at least a portion of the fluids contained with the circuit to flow vertically through a given portion of the conduit circuit to create a pressure differential in the given portion of the circuit in relation to the remainder of the conduit circuit to thereby enhance the flow of the fluids contained with the conduit circuit, and (e) converting the pressure of at least a part of the enhanced flow of the contained fluids through the conduit circuit into a useful form of energy. Step (a) includes the step of: (f) separating from the expandite-fluid mixture, and expandite base which comprises at least a portion of the expandite mass.



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THERMAL ENERGY CONVERSION SYSTEM AND METHOD UTILIZING UNENCASED EXPANDITES

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part application of co-pending application No. 25,800 filed April 2, 1979 by the present inventor for "Thermal Energy Conversion System Utilizing Expandites."

BACKGROUND OF THE INVENTION

The present invention generally pertains to thermal energy conversion systems and is particularly directed to an improvement in ocean thermal energy conversion systems.

In typical closed cycle ocean thermal energy conversion systems warm surface water is used to heat a working fluid with a low boiling point. Ammonia is a typical working fluid. The fluid is heated in a boiler. Vapor is then cooled by frigid water that is drawn up from deep in the ocean. The vapor condenses, and is pressurized and returned to the boiler; and the cycle is repeated.

Heretofore, it has been believed that ocean thermal energy conversion systems must be deployed in at least sub-tropical waters in order to obtain a large enough temperature differential within the ocean to provide a system that is sufficiently efficient to warrant commercial development.

Another concern with close-cycle ocean thermal energy conversion systems is the cost of heat exchangers that typically are used to transfer heat to the working fluid.

A concern with typical open cycle ocean thermal energy conversion systems is a requirement for bulky tanks having heavy walls so as to enable the sea water to be evaporated at a low pressure in relation to ambient or atmospheric pressure.

SUMMARY OF INVENTION

The present invention is a thermal energy conversion system and method for converting a relatively low temperature differential in fluids into a high pressure differential at a minimum of capital investment, cost and maintenance.

Although the present invention is particularly directed to an ocean thermal energy conversion system and method, it also is applicable to other types of thermal energy conversion systems and methods including those in which the surrounding fluid is other than water. The term "fluid" as used herein not only includes a gas or a liquid, but also includes a slurry, a mist, a slush, bubbles, a foam and a suspension of solid particles within a gas or liquid. However, the term "thermal fluid", as used herein, includes only non-gaseous fluids, such as a liquid, a slurry, a slush, and a suspension of solid particles within a liquid.

The patent application of the present inventor cross-referenced herein, is directed to a thermal energy conversion system which includes a mass of expandites that change density in response to changes in temperature at a given pressure to thereby change buoyancy with respect to a surrounding thermal fluid; a mass transport conduit circuit for introducing the expandites to a surrounding thermal fluid at different combinations of temperature and pressure and directing the expandites and surrounding thermal fluid in response to pressure differentials created by density changes and concomitant buoyancy changes of the expandites as the expandites are exposed to the surrounding thermal fluid at different combinations of pressure and temperature; and a transducer for converting the pressure of fluid transported by the circuit to a useful form of energy. Expandites are defined as substances that expand or contract when heated or cooled, thereby changing their density. Some expandites expand upon being heated, while others expand upon being cooled.

In the specific preferred embodiments described in such cross-referenced patent application, the expandites are separate objects encased in flexible coverings.

The present invention is directed to those embodiments of the thermal energy conversion system and method wherein the expandites are unencased fluids. The method of thermal energy conversion according to the present invention includes the steps of: (a) providing a mass of unencased fluid expandites in a mass transport conduit circuit at a first combination of temperature and pressure; (b) introducing a thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a second combination of temperature and pressure; (c) combining the provided expandite mass with the introduced thermal fluid in a given conduit of the circuit to create an expandite-fluid mixture having a density at some place in the given conduit that is changed from the average porportional density of the expandite mass and the thermal fluid at their respective prevailing combinations of temperature and pressure prior to such combination with each other to create a pressure differential that enhances the flow of the fluids contained with the circuit; (d) directing at least a portion of fluids contained within the circuit to flow vertically through a given portion of the conduit circuit to create a pressure differential in the given portion of the circuit in relation to the remainder of the conduit circuit to thereby enhance the flow of the fluids contained within the conduit circuit, and (e) converting the pressure of at least a part of the enhanced flow of the contained fluids through the conduit circuit into a useful form of energy. Step (a) includes the step of: (f) separating from the expandite-fluid mixture, an expandite base which comprises at least a portion of the expandite mass.

An expandite is a material (or combination of materials) circulated through the mass transport conduit circuit that changes density in response to a change in temperature at a given pressure. The expandite material may be a combination of materials that are chosen to provide a desired density at a given combination of temperature and pressure.

A thermal fluid is a fluid that is introduced from a source external to the mass transport conduit circuit at a temperature that is either substantially above or substantially below the temperature of the expandite prior to initial combination therewith.

Either, or both, of the thermal fluid and the expandite material may change phase as a result of the combination with each other. However, a phase change is not required.

The expandite and the thermal fluid are different materials that do not react with each other chemically, whereby their respective chemical compositions remain essentially unchanged upon their combination with one another in the preferred embodiment.

Additional features of the present invention are described in the description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWING

Figures 1 through 5 are schematic diagrams of different preferred embodiments of the system of the present invention.

In each figure, the system is shown in a vertical plane, wherein the upper portion of the system is shown in the upper portion of the view. In an OTEC system, the upper portion of the system typically is at or near the ocean surface.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 1, one preferred embodiment of the system of the present invention is an OTEC system having a turbine generator 10, and a mass transport conduit system including a warm water intake conduit 11; a cold water intake conduit 12; gravity separation tanks 13, 14, 15, 16, 17, and 18; pumps 19, 20, 21, 22, and 23; outlet conduits 26 and 27, injection nozzle systems 28 and 29; vertical conduit sections 31, 32, 33, 34, 35, 36, 37, 38, 39 and 40; and separation tank outlet conduits 41, 42, 43, 44, 45 and 46.

In the system of Figure 1, a mass of unencased expandites, such as liquid ethane, is provided in the conduit 44 at a first combination pressure and temperature, and a first thermal fluid, such as warm ocean water, is introduced into the circuit through the conduit 11 at a second combination of pressure and temperature. The expandite mass is injected through the nozzle system 28 into the vertical conduit 31 where it is combined with the warm ocean water to create a first expandite-fluid mixture that flows upward through the conduit section 31 in response to the pressure differential created by the change in average proportional density of the first expandite-fluid mixture resulting from such combination. Further, by directing the first expandite-fluid mixture vertically through the conduit section 31, a pressure differential is created in the conduit section 31 in relation to the remainder of the mass transport conduit circuit for drawing the mixture upward through the conduit section 31.

The first expandite-fluid mixture is directed from the conduit section 31 through a first series of gravity separation tanks 13, 14 and 15, for separating the first expandite-fluid-mixture into an expandite base and a separated first thermal fluid. Ethane gas is lighter than ocean water, and thereby may be drawn from the top of the gravity separation tanks 13, 14 and 15, whereas the ocean water may be drawn from the bottom of these tanks. Accordingly, some expandite base is drawn through conduit 41 from the gravity separation tank 13 and a diluted first expandite-fluid mixture which contains a greater proportion of thermal fluid is drawn up through conduit section 32.

The first expandite-fluid mixture is passed through the series of gravity separation tanks 13, 14 and 15 to provide successively lower pressures for enabling separation from the first expandite-fluid mixture at successively lower pressures, of expandite base that was not separated at the higher pressures. Additional expandite base is separated from the mixture by the gravity separation tank 14 and is drawn therefrom through the conduit 42. The further diluted first expandite-fluid mixture is drawn from the separation tank 14 through vertical conduit 33.

The turbine generator 10 is positioned in the conduit 33 for converting the pressure of the flow of the first expandite-fluid mixture through the conduit 33 into a useful form of energy, such as electricity.

The pressure of the flow of the first mixture through the conduit 33 is greatly decreased upon the first mixture flowing through the turbine generator 10. As a result, the pressure of the first mixture flowing from conduit 33 into the separation tank 15 is at a relatively low pressure for enabling almost all of the remaining expandite base to be separated therefrom and drawn from the tank 15 through the conduit 43.

Also the tank is at or near the ocean surface, and thereby at an elevation where the ambient pressure outside the tank 15 is close to the pressure of the mixture inside the tank. By positioning the separation tanks 14 and 15 at depths (or elevations) which enable the gravity separation process to be carried out with the pressure of the first mixture close to or approximately the same as the ambient pressure, the walls of the tanks need not be very thick, thereby enabling the use of less expensive gravity separation tanks.

The pressure within the gravity separation tank 15 typically is below atmospheric pressure for enhancing the separation of the expandite from the first expandite-fluid mixture.

The separated thermal fluid separated from the first mixture by the gravity separation tank 15 is discharged from the mass transport conduit circuit through the outlet conduit 26.

The separated expandite base drawn from the separation tanks 13, 14 and 15 is directed to the conduit 40, from which it is injected under pressure by the nozzle system 29 into a second thermal fluid, such as cold ocean water, within the conduit 34. The cold ocean water is introduced into the circuit through inlet conduit 12 at a third combination of temperature and pressure and is combined with the separated expandite base in the conduit 34 to form a second expandite-fluid mixture.

The second expandite-fluid mixture also is passed through a series of gravity separation tanks, to wit: tanks 16, 17 and 18. Expandite mass is separated from the second expandite-fluid mixture in the gravity separation tank 16 and is directed through the conduit 44. By combining the expandite mass in the conduit 40 with the cold ocean water and then separating the resultant second expandite-fluid mixture, the expandite base is thermally conditioned (cooled) to provide the expandite mass at the first combination of pressure and temperature in the conduit 44. The pressure of the expandite mass in the conduit 44 may be increased by the pump 23 to increase the dispersal rate of the expandite mass into the ocean water to thereby increase the rate of the density change of the first expandite-fluid mixture.

The second expandite-fluid mixture is diluted by the separation of the expandite mass from the separation tank 16. The diluted second expandite-fluid mixture is drawn from the separation tank 16 through the vertical conduit 35 into the separation tank 17. Additional expandite is separated from the second expandite-fluid mixture in the separation tank 17 and drawn therefrom through the conduit 45. The further diluted second expandite-fluid mixture is directed upward through the vertical conduit 36 to a final separation tank 18, which is at or near the ocean surface. Almost all of the remaining expandite is separated from the second expandite-fluid mixture in the separation tank 18 and drawn therefrom through the conduit 46. The second thermal fluid that is separated from the expandite-fluid mixture in the separation tank 18 is discharged from the mass transport conduit circuit via the outlet conduit 27. The separated expandite drawn from the separation tanks 15 and 18 is drawn through the conduit 37 by the pump 19, is combined with the expandite drawn from the separation tank 17. This combination is drawn through the conduit 38 by the pump 20 and is combined with the expandite drawn from the separation tank 14. This combination is drawn through the conduit 39 by the pump 21 and is combined with the expandite base drawn from the separation tank 13 to provide the separated expandite base in the conduit 40 that is combined with the cold ocean water. The separated expandite base may be pumped through the conduit 40 by the pump 22 to be at an increased pressure when combined with the cold ocean water so as to increase the rate of dispersal to thereby increase the rate of cooling of the separated expandite base. The pumps 19, 20 and 21 also aid in increasing the pressure of the flow of the separated expandite base. The amount of added pressure that is provided by the pumps 19, 20, 21 and 22 is related to the pressure of the flow of the separated expandite base from the respective separation tanks 13, 14, 15, 17 and 18. These pumps consume negligible energy in relation to the energy converted by the system.

By separating expandite from the first and second expandite-fluid mixtures at the higher pressures prevailing within the gravity separation tanks 13, 14, 16 and 17 energy is saved, in that not as much pumping is required to increase the pressure of the separated expandite prior to combining it with the first and second thermal fluids respectively in vertical conduits 31 and 34.

The separation tanks 16, 17 and 18 are positioned at depths where the ambient pressure outside the tanks is close to or approximately the same as the pressure of the second expandite-fluid mixture within the tanks so as to enable the use of separation tanks having relatively thin walls. The pressure within the gravity separation tank 18 typically is below atmospheric pressure to enhance separation of the expandite from the second expandite-fluid mixture.

Pressure differentials are created in the respective vertical conduit sections 32, 33, 34, 35 and 36 in relation to the remainder of the conduit circuit for drawing the mixtures contained therein vertically upward through the respective conduit sections in the same manner as the first expandite-fluid mixture is drawn vertically upward through the vertical conduit section 31.

Alternatively, or in addition to the placement of the turbine generator 10 in the conduit 33, turbine generators (not shown) may be placed in the inlet conduit 11 to provide energy by converting the pressure of the flow of the warm ocean water drawn into the circuit; in the inlet conduit 12 to provide energy by converting the pressure of the flow of the cold ocean water drawn into the circuit; in the conduit 36 to provide energy by converting the pressure of the flow of the second expandite-fluid mixture; and/or in either or both of the outlet conduits 26 and 27 to convert the pressure of the flow of the separated thermal fluid. By placing the turbine generator in the inlet conduit 11, the pressure of the first thermal fluid is reduced, whereby the pressure of the first expandite-fluid mixture within the conduit 31 is also reduced. This enables the gravity separation tank 13 to be at an ocean depth where the pressure inside the tank is approximately the same as the ambient pressure.

The turbine generator must be positioned at a depth of the intake conduit 11 sufficient to provide a sufficient pressure differential across the turbine generator.

The warm water intake conduit 11 and the cold water intake conduit 12 draw ocean water from such respective depths as required to provide water at temperatures that are sufficiently different to create sufficient pressure differentials within the circuit to enable economical energy conversion.

When the expandite material has the property of becoming more dense when heated, the system shown in Figure 1 can nevertheless be used if it is modified to reverse the connections of the warm water intake conduit 11 and the cold water intake conduit 12 to the remainder of the circuit. That is the conduit 11 is connected to the conduit 34 and the conduit 12 is connected to the conduit 31.

Other modifications of the system also will be obvious to those skilled in the art when using other expandite materials, such as modifying the system to combine the expandite mass with the first thermal fluid at an elevation at or near sea level and to direct the flow of the resulting expandite-fluid mixture vertically downward in response to the change in average proportional density in the mixture resulting from such combination.

Alternative preferred embodiments are shown in Figures 2 through 5. In these embodiments, generally only one separation tank is shown for each separation step. However, it should be understood that in actual practice, a cascaded series of separation tanks may be used, as described in relation to the system of Figure 1.

The embodiment of Figure 2 includes a turbine generator 109, and a mass transport conduit circuit including a warm water inlet conduit 110; a cold water inlet conduit 111 conduit sections 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123 and 124, gravity separation tanks 125, 126, 127 and 128; pumps 129, 130 and 131; and injection nozzle systems 132 and 133.

An expandite mass such as ethane or butane, is provided in the conduit 112 at the first combination of temperature and pressure; and a first thermal fluid, such as cold ocean water, is introduced into the circuit through the conduit 111 at a second combination of pressure and temperature. The expandite mass in the conduit 112 is injected through the nozzle system 132 into the conduit 113, where it is combined with the cold ocean water to create a first expandite-fluid mixture that flows through the conduit section 113 in response to the pressure differential created by the change in average proportional density of the first expandite-fluid mixture resulting from such combination.

The first expandite-fluid mixture is directed into the separation tank 125, where it is partially separated into a separated expandite base, which flows from the tank 125 through the conduit 114, and a partially separated first expandite-fluid mixture, which flows from the tank 125 through the conduit 116 and into the separation tank 126 located at a higher elevation. The partially separated first expandite-fluid mixture is separated within the separation tank 126 into separated expandite, which flows from the tank 126 through the conduit 117, and separated first thermal fluid which flows from the tank 126 and is discharged from the circuit through the conduit 118.

The separated expandite in the conduit 117 is combined with separated expandite flowing from the conduit 122 and directed downward through the conduit 124. The pressure of the flow in the conduit 124 is increased by the pump 131. The separated expandite in the conduit 124 is combined with the separated expandite base flowing from the conduit 114 and directed downward through the conduit 115. The pressure of the flow in the conduit 115 is increased by the pump 129.

A second thermal fluid, such as warm ocean water, is introduced into the circuit through the inlet conduit 110 and pumped by the pump 130 to be at a third combination of pressure and temperature. The separated expandite base in the conduit 115 is injected through the nozzle system 133 into the conduit 119, where it is combined with the warm ocean water to thermally condition (heat) the separated expandite base and to create a second expandite-fluid mixture that flows through the conduit section 119 in response to the pressure differential created by the change in average proportional density of the second expandite-fluid mixture resulting from such combination.

The second expandite-fluid mixture is directed into the separation tank 127, where it is partially separated into the expandite mass, which flows from the tank 127 through the conduit 120, and a partially separated second expandite-fluid mixture, which flows from the tank 127 through the conduit 121. The partially separated second expandite-fluid mixture is directed vertically through the conduit 121, whereby a pressure differential is created in the conduit section in relation to the remainder of the mass transport conduit circuit for drawing the mixture upward through the vertical portion of the conduit 121. The partially separated second expandite-fluid mixture is directed into the separation tank 128 where it is separated into separated expandite, which flows from the tank 128 through the conduit 122, and a separated second thermal fluid, which flows from the tank 128 and is discharged from the circuit through the conduit 123.

The expandite mass in the conduit 120 is directed through the turbine generator 109, which converts the pressure of the flow into electricity and also reduces the pressure of the expandite mass in the conduit 112 at the first combination of pressure and temperature.

The turbine generator 109 and the separation tanks 125 and 127 are positioned at ocean depths in relation to each other for causing the pressure within the tanks 125 and 127 to be such that the tanks 125 and 127 are located at ocean depths where the respective ambient pressures outside the tanks are approximately the same as the pressures within the tanks.

The embodiments of Figures 3, 4, and 5 are systems wherein fewer separation steps are employed. Although such embodiments may be somewhat less efficient than the other embodiments discussed herein, they do provide savings in construction costs.

The embodiment of Figure 3 includes a turbine generator 212, and a mass transport conduit circuit including a warm water inlet conduit 213, a cold water inlet conduit 214; an outlet conduit 216, vertical conduits 217 and 218; conduits 219 and 220; a gravity separation tank 222 and injection nozzle system 224 and 226.

An expandite mass is provided in the conduit 219 at a first combination of pressure and temperature, and a first thermal fluid, such as warm ocean water, is provided in the conduit 220 at a second combination of pressure and temperature. The first thermal fluid is introduced into the circuit through the inlet conduit 213 and diverted through the turbine generator, which converts the pressure of the fluid flow into electricity. The first thermal fluid flows from the turbine generator 212 through the conduit 220 at the second combination of pressure and temperature.

The expandite mass in the conduit 219 is injected through the nozzle system 224 into the vertical conduit 217 where it is combined with the first thermal fluid to create a first expandite-fluid mixture that flows vertically upward in the conduit 217 in response to the pressure differential created by the change in average proportional density of the first expandite-fluid mixture resulting from such combination. By directing the first expandite-fluid mixture vertically through the conduit 217, a pressure differential is created in the conduit section 217 in relation to the remainder of the conduit circuit for drawing the mixture upward through the conduit section 217.

A second thermal fluid, such as cold ocean water, is introduced into the circuit through the inlet conduit 214 at a third combination of pressure and temperature, and is injected through the nozzle system 226 into the vertical section of the conduit 218 where it is combined with the first expandite-fluid mixture to thermally condition (cool) the first expandite-fluid mixture. Such combination creates a second expandite-fluid mixture in the conduit 218.

The second expandite-fluid mixture in the conduit 218 is directed into the separation tank 222, where it is separated into the expandite mass, which flows from the tank 222 through the conduit 219 at the first combination of pressure and temperature, and a separated thermal fluid, which flows from the tank 222 and separated from the system through the conduit 216.

The embodiment of Figure 4 includes a turbine generator 228, and a mass transport conduit circuit including a warm water inlet conduit 229, a cold water inlet conduit 230, vertical conduit sections 232 and 233, conduits 235 and 236, an outlet conduit 238, a gravity separation tank 240 and injection nozzle systems 241 and 242.

An expandite mass, such as a mixture of ethane and ocean water, is provided in the conduit 236 at a first combination of pressure and temperature. A first thermal fluid, such as warm ocean water, is introduced into the circuit through the inlet conduit 229 and directed through the turbine generator 228.

The turbine generator 228 converts the pressure of the flow of the first thermal fluid into electricity and reduces the pressure of the flow to provide the first thermal fluid in the conduit 235 at a second combination of pressure and temperature.

The expandite mass in the conduit 236 is injected through the nozzle system 241 into the vertical conduit 232 where it is combined with the first thermal fluid to create a first expandite-fluid mixture that flows vertically upwards in the conduit 232 in response to the pressure differential created by the change in average proportional density of the first expandite-fluid mixture resulting from such combination. By directing the first expandite-fluid mixture vertically through the conduit 232, a pressure differential is created in the conduit section 232 in relation to the remainder of the conduit circuit for drawing the mixture upward through the vertical conduit section 232.

The first expandite-fluid mixture in the conduit 232 is directed into the separation tank 240, where it is separated into a separated expandite base, which flows from the tank 240 through the vertical conduit section 233, and a separated thermal fluid which flows from the tank 240 and is discharged from the circuit through the conduit 238. By directing the separated expandite base vertically through the conduit section 233, a pressure differential is created in relation to the remainder of the conduit circuit for drawing the separated expandite base downward through the conduit section 233.

A second thermal fluid, such as cold ocean water, is introduced into the circuit through the inlet conduit 230 and is injected through the nozzle system 242 into the conduit 236, where it is combined with the separated expandite base (ethane) to thermally condition (cool) the ethane and create the expandite mass consisting of the mixture of ethane and ocean water at the first combination of pressure and temperature.

The embodiment of Figure 5 includes a turbine generator 244 and a mass transport conduit circuit including a warm water inlet conduit 245; a cold water inlet conduit 246; an outlet conduit 247; conduit sections 248, 250, 251, and 252; a gravity separation tank 254 and injection nozzle systems 255 and 256.

An expandite mass, such as ethane, is provided in the conduit 250 at a first combination of pressure and temperature; and a first thermal fluid, such as cold ocean water, is introduced into the circuit through the inlet conduit 246 at a first combination of pressure and temperature. The first thermal fluid in the conduit 246 is injected through the nozzle system 255 into the conduit 251 where it is combined with the expandite mass from the conduit 250 to create a first expandite-fluid mixture that flows through the conduit 251 in the direction indicated by the arrows therein in response to the pressure differential created by the change in average proportional density of the first expandite-fluid mixture resulting from such combination.

A second thermal fluid, such as warm ocean water, is introduced into the circuit through the inlet conduit 245 at a third combination of pressure and temperature. The first expandite-fluid mixture in the conduit 251 is injected through the nozzle system 256 into the vertical conduit section 248, where it is combined with the second thermal fluid to thermally condition (heat) the first expandite-fluid mixture. Such combination creates a second expandite-fluid mixture in the conduit 248 that is directed vertically therein to create a pressure differential in the vertical conduit 248 in relation to the remainder of the circuit for drawing the second mixture upward through the conduit 248.

The second expandite-fluid mixture is directed into the separation tank 254, where it is separated into the expandite mass, which flows from the tank 254 through the conduit 252, and a separated thermal fluid, which flows from the tank 254 and is discharged from the system through the conduit 247.

The separated expandite base in the conduit 252 is directed through the turbine generator 244, which converts the pressure of the flow into electricity and provides the expandite mass in the vertical conduit 250 at the first combination of pressure and temperature. The separated expandite base is directed vertically through the conduit 250, and thereby creates a pressure differential therein in relation to the remainder of the circuit for drawing the separated expandite base vertically upward through the conduit 250.

Each of the gravity separation tanks included in the various systems described hereinabove for separating an expandite-fluid mixture preferably includes a nucleation system (not shown) for creating films, bubbles and/or sprays of the expandite mixture to create more surface area of the expandite-fluid mixture for enabling the expandite to become free of the thermal fluid and to separate more readily from the mixture. Nucleation may be enhanced by shock waves or sonar vibrations.

Even after all of the series of separation steps have been completed some of the expandite mass typically remains dissolved in the separated thermal fluid that is discharged from the mass transport conduit circuit. It is important that the expandite mass material be non-polluting to the environment in which it is discharged. Also, it should be inexpensive since it will have to be replenished within the circuit. However, these factors are of less concern in a system wherein the warm and cold thermal fluids are provided from reservoirs external to the circuit that are of a limited size, such as a lagoon or a solar collector. This is because the expandite mass that is dissolved in a thermal fluid will eventually constitute a certain percentage of the fluid in the reservoir and thereby remain in the system.

CLAIMS

1. A method of thermal energy conversion comprising the steps of:

(a) providing a mass of unencased fluid expandites in a mass transport conduit circuit at a first combination of temperature and pressure;

(b) introducing a thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a second combination of temperature and pressure;

(c) combining the provided expandite mass with the introduced thermal fluid in a given conduit of the circuit to create an expandite-fluid mixture having a density at some place in the given conduit that is changed from the average proportional density of the expandite mass and the thermal fluid at their respective prevailing combinations of temperature and pressure prior to such combination with each other to create a pressure differential that enhances the flow of the fluid contained within the circuit;

(d) directing at least a portion of said fluids contained with the circuit to flow vertically through a given portion of the conduit circuit to create a pressure differential in the given portion of the circuit in relation to the remainder of the conduit circuit to thereby enhance the flow of said fluids contained with the conduit circuit; and

(e) converting the pressure of at least a part of said enhanced flow of said contained fluids through the conduit circuit into a useful form of energy;

wherein step (a) comprises the step of:

(f) separating from the expandite-fluid mixture an expandite base which comprises at least a portion of said expandite mass.

2. A method according to claim 1 characterized by step (f) comprising the step of:

(g) separating from the expandite fluid mixture, a separated expandite base; and by

step (a) further comprising the action of thermally conditioning the separated expandite base to provide at least said first mentioned expandite mass at said first combination of temperature and pressure comprising the steps of:

(h) introducing a second thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a third combination of temperature and pressure; and

(i) combining the second thermal fluid with the separated expandite base to create a second expandite fluid mixture; and

(j) separating from the second expandite-fluid mixture, a separated second thermal fluid and expandite mass which comprises at least said expandite mass at said first combination of temperature and pressure.

3. A method according to claim 1, wherein the expandite base is separated from the expandite-fluid mixture while the expandite fluid mixture is in mixture with a second thermal fluid, characterized by step (a) further comprising the steps of:

(g) introducing a second thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a third combination of temperature and pressure;

(h) combining the second thermal fluid with the expandite-fluid mixture to create a second expandite-fluid mixture; and by

step (f) comprising the step of:

(i) separating from the second expandite-fluid mixture, separated thermal fluid and the expandite base which comprises the expandite mass at said first combination of temperature and pressure.

4. A method according to claim 1, where the expandite mass consists of a mixture of a second thermal fluid and the expandite base.

characterized by step (f) comprising the step of:

(g) separating from the expandite fluid mixture, separated thermal fluid and the expandite base; and by

step (a) further comprising the steps of:

(h) introducing a second thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a third combination of temperature and pressures, and

(i) combining the separated expandite base with the introduced second thermal fluid to create the second mixture, which comprises the expandite mass at said first combination of temperature and pressure.

5. A method according to claims 2, 3, and 4 wherein at least one of said separating steps comprises a gravity separation process.

6. A method according to claim 5, wherein at least one of said gravity separation processes includes creating films, bubbles, and/or sprays of the mixture to create more surface area of the mixture for enabling the expandite to become free of the thermal fluid and to separate more readily from the mixture.

7. A method according to Claim 5, wherein at least one of said gravity separation processes is carried out at an elevation where the ambient pressure is approximately the same as the pressure of the mixture.

8. A method according to Claim 5, wherein the gravity separation process comprises passing the expandite-fluid mixture through a series of gravity separators to provide successively lower pressures for enabling separation from the mixture at said lower pressures, of expandite that was not separated at said higher pressures.

9. A thermal energy conversion system comprising a mass of unencased fluid expandites;

a mass transport conduit circuit, including

means for introducing a thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit;

means for combining the expandite mass at a first combination of temperature and pressure with the introduced thermal fluid at a second combination of temperature and pressure in a given conduit of the circuit to create an expandite-fluid mixture having a density at some place in the given conduit that is changed from the average proportional density of the expandite mass and the thermal fluid at their respective prevailing combinations of temperature and pressure prior to such combination with each other to create a pressure differential that enhances the flow of fluids contained within the circuit;

means for directing at least a portion of said fluids contained within the circuit to flow vertically through a given portion of the conduit circuit to create a pressure differential in the given portion of the circuit in relation to the remainder of the conduit circuit to thereby enhance the flow of said fluids contained within the conduit circuit; and

a transducer for converting the pressure of at least a part of said enhanced flow of said contained fluids through the conduit circuit into a useful form of energy;

where the mass transport conduit circuit comprises

means for separating from the expandite-fluid mixture; and expandite base which comprises at least a portion of said expandite mass.

10. A system according to claim 9, characterized by the separating means comprising

means for separating from the expandite-fluid mixture, a separated expandite base; and by

the circuit further comprising

means for thermally conditioning the separated expandite base to provide at least said first mentioned expandite mass at said first combination of temperature and pressure, the thermal conditioning means comprising

means for introducing a second thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a third combination of temperature and pressure; and

means for combining the second thermal fluid with the separated expandite base to create a second expandite-fluid mixture; and

means for separating from the second expandite-fluid mixture, a separated second thermal fluid and expandite mass which comprises at least said expandite mass at said first combination of temperature and pressure.

11. A system according to claim 9 wherein the circuit includes means for separating the expandite base from the expandite-fluid mixture while the expandite-fluid mixture is in mixture with a second thermal fluid, characterized by the circuit further comprising

means for introducing a second thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a third combination of termperature and pressure; and means for combining the second thermal fluid with the expandite-fluid mixture to create a second expandite-fluid mixture; and by

the first recited separating means comprising

means for separating from the second expandite-fluid mixture, separated thermal fluid and the expandite base which comprises the expandite mass at said first combination of temperature and pressure.

12. A system according to claim 9 wherein the expandite mass consists of a mixture of a second thermal fluid and the expandite base,

characterized by the separating means comprising

means for separating from the expandite-fluid mixture, separated thermal fluid and the expandite base; and by

the circuit comprising

means for introducing a second thermal fluid into the mass transport conduit circuit from a source external to the mass transport conduit circuit at a third combination of temperature and pressure, and

means for combining the separated expandite base with the introduced second thermal fluid to create the second mixture, which comprises the expandite mass at said first combination of temperature and pressure.

13. A system according to claims 10, 11 and 12 wherein at least one of said separating means comprises a gravity separation system.

14. A system according to claim 13, where at least one of the said gravity separation systems includes means for creating films, bubbles, and/or sprays of the mixture to create more surface area of the mixture for enabling the expandite to become free of the thermal fluid and to separate more readily from the mixture.

15. A system according to Claim 13, wherein at least one of said gravity separation systems is positioned at an elevation where the ambient pressure approximately is the same as the pressure of the mixture.

16. A system according to Claim 13, wherein the gravity separation system comprises a series of gravity separators to provide successively lower pressures for enabling separation from the mixture at said lower pressures, of expandite that was not separated at said higher pressures.

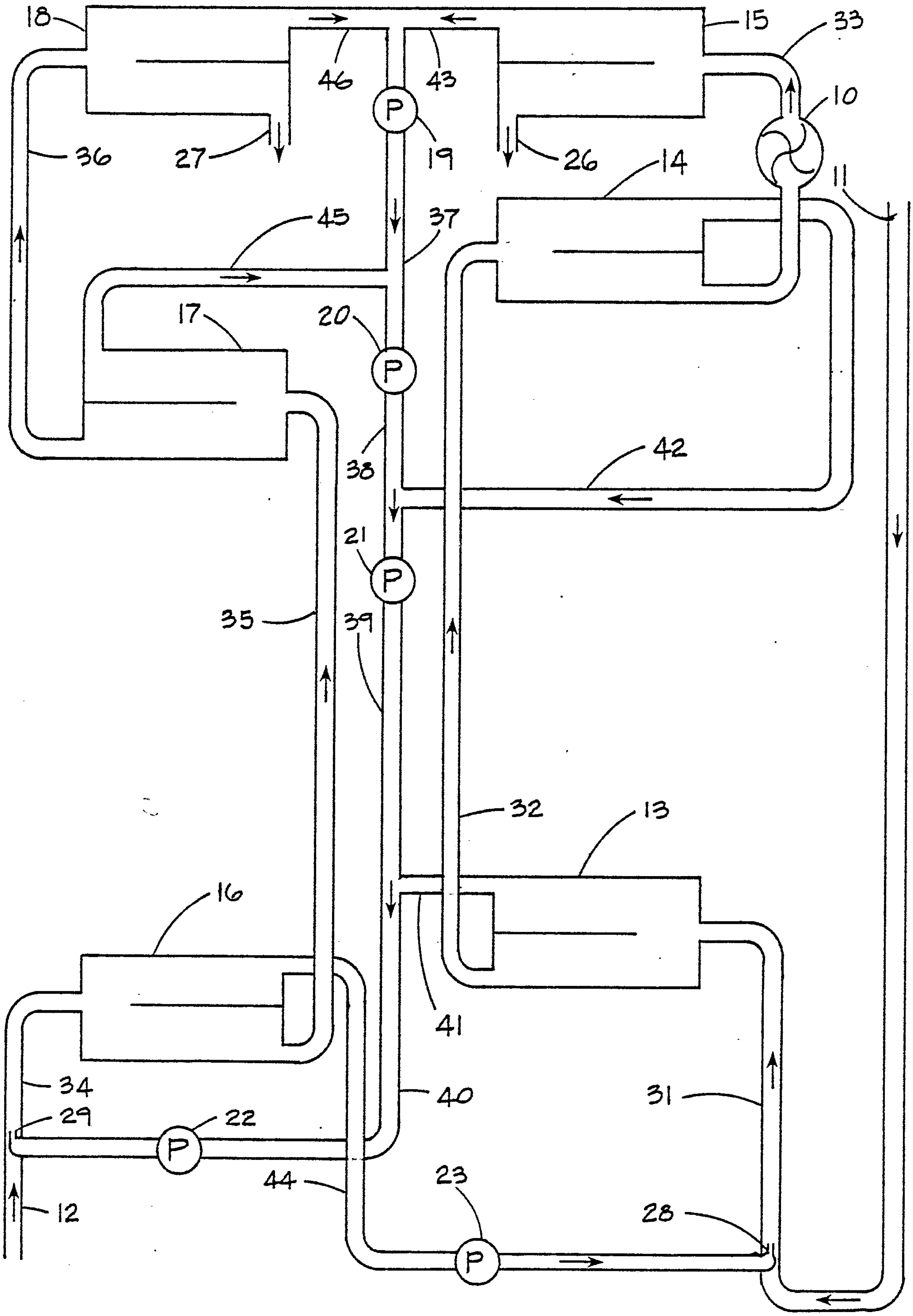
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FIGURE 1

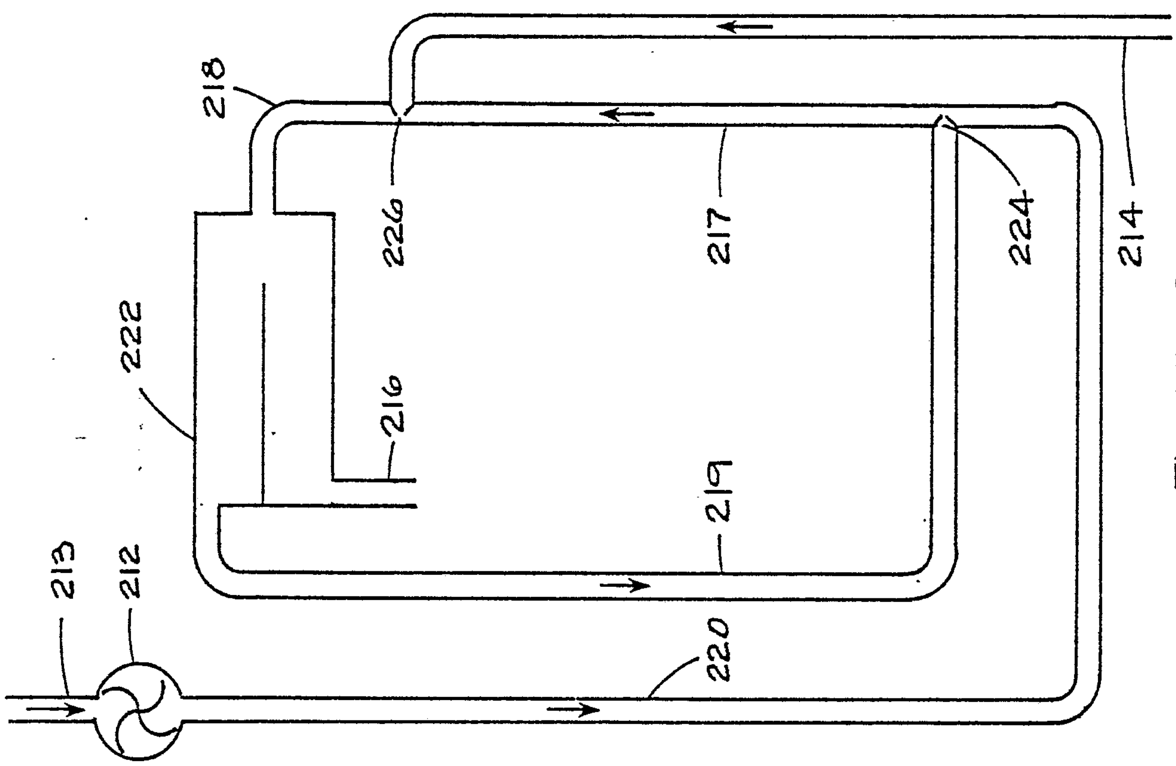

FIGURE 3

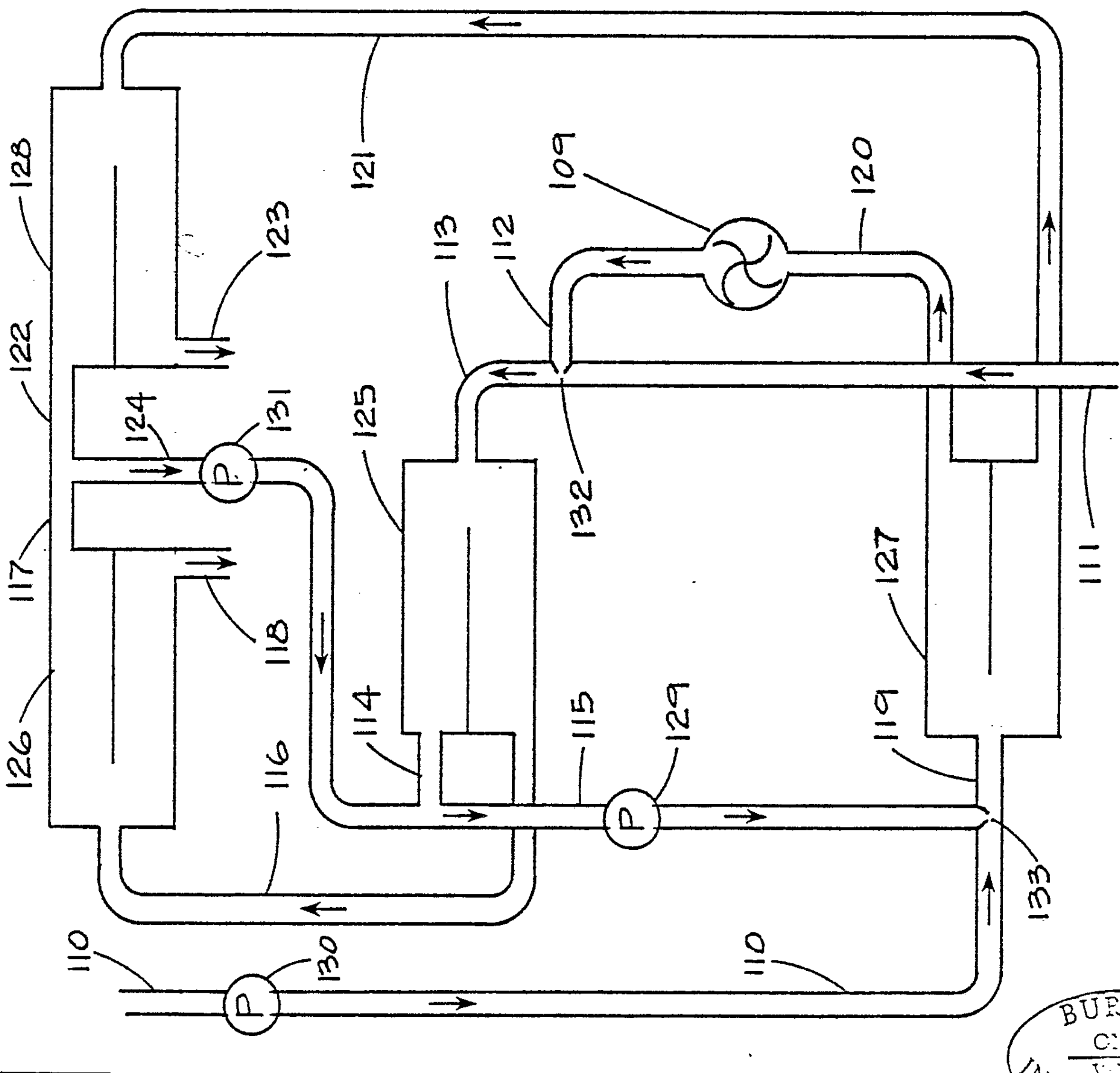

FIGURE 2

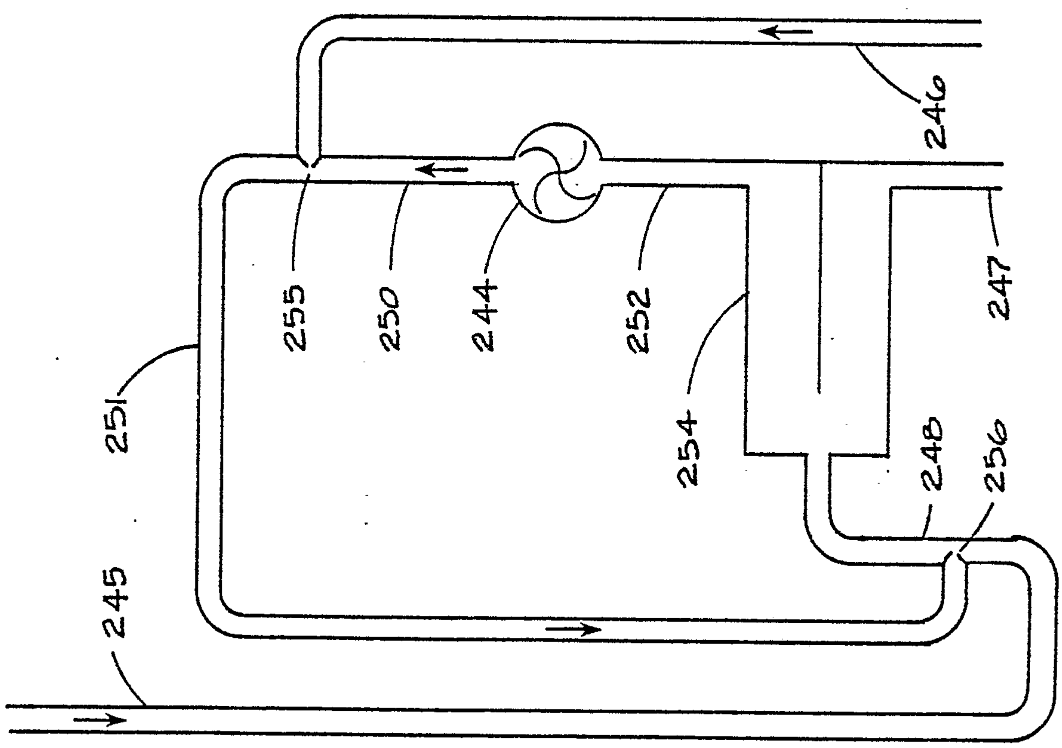

FIGURE 5

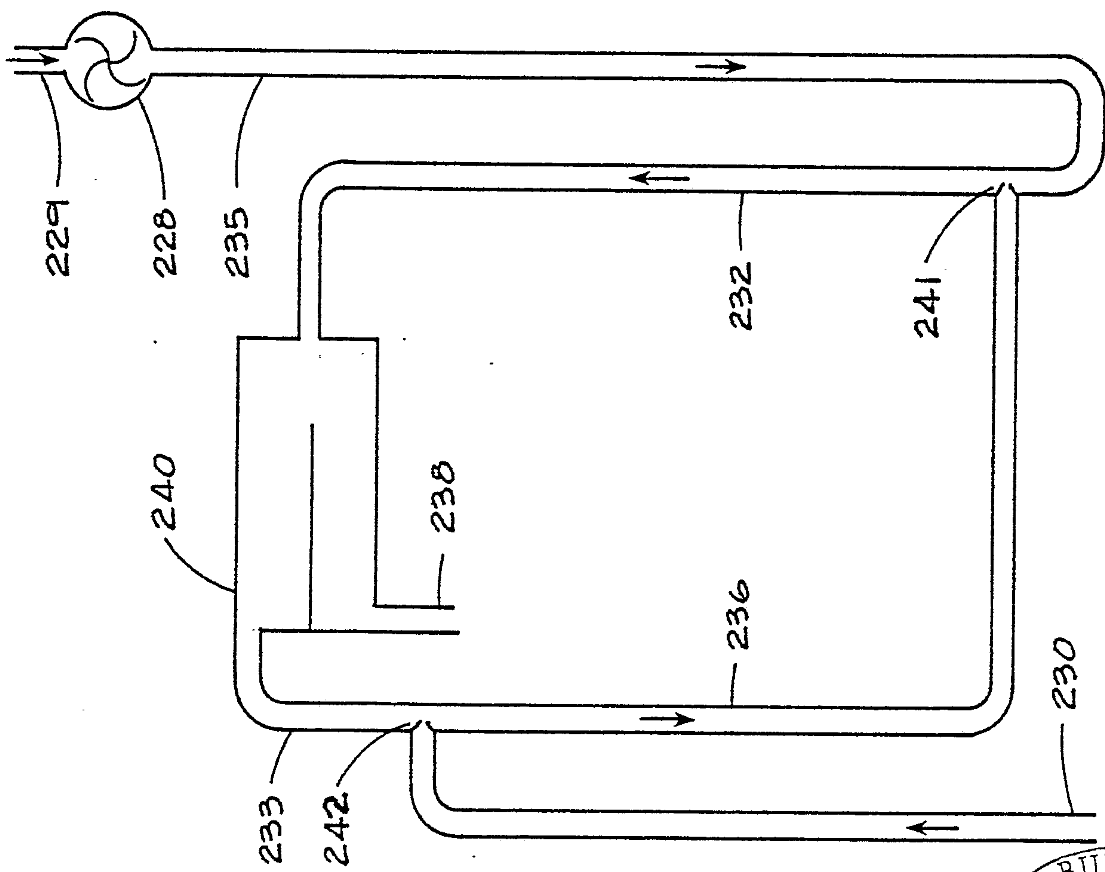

FIGURE 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/01764

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[3] F01K 25/06
U.S. CL. 60/649, 641B

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	60/398, 641B, 649, 673, 721

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	U.S., A, 3,938,335, Published 17 February 1976, Marwick	1-16
X	U.S., A, 4,041,710, Published 16 August 1977, Kraus et al.	1 and 9
A,P	U.S., A, 4,214,449, Published 29 July 1980, Sorensen	1-16
A	AT, A, 73,279, Published 26 March 1917, Inchiostri	1-16
A	JP, A, 52-56242 Published 09 May 1977, Takahashi	1-16

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
10 March 1981	17 MAR 1981
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Stephen F. Husar Stephen F. Husar