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[54] POWER SYSTEM
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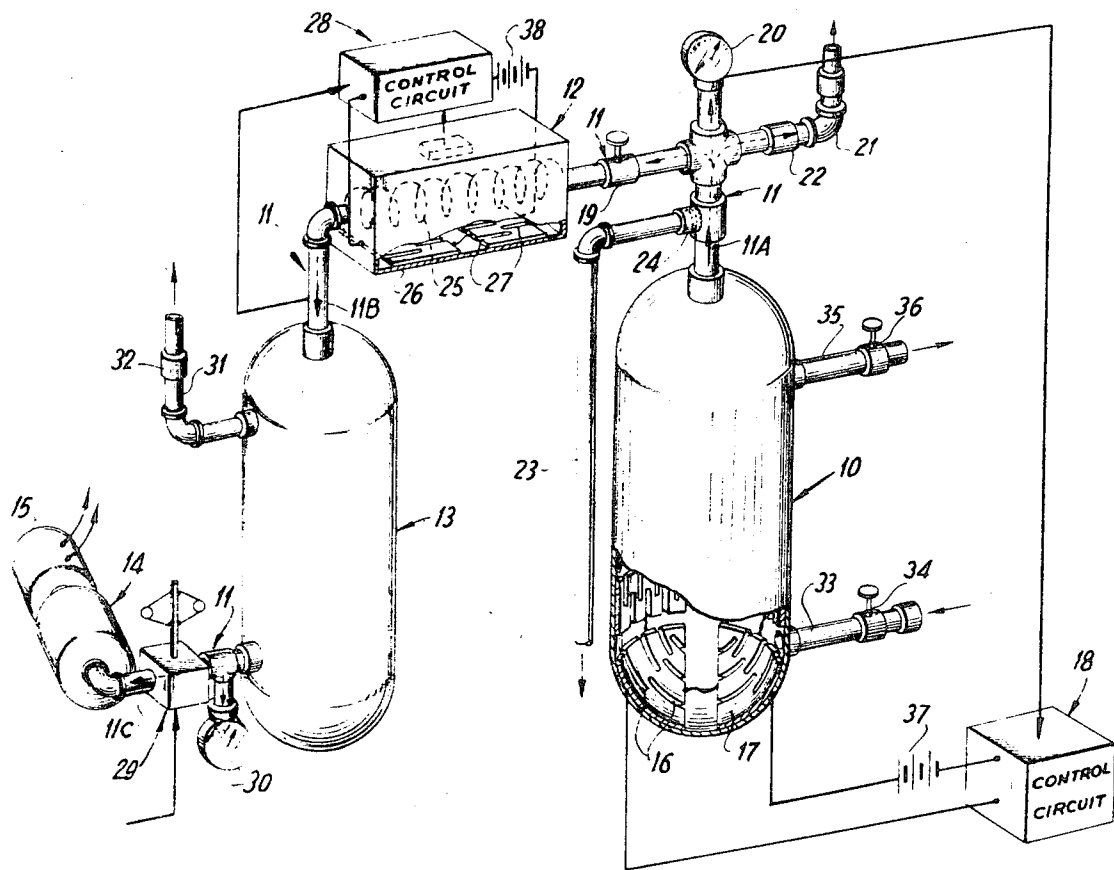
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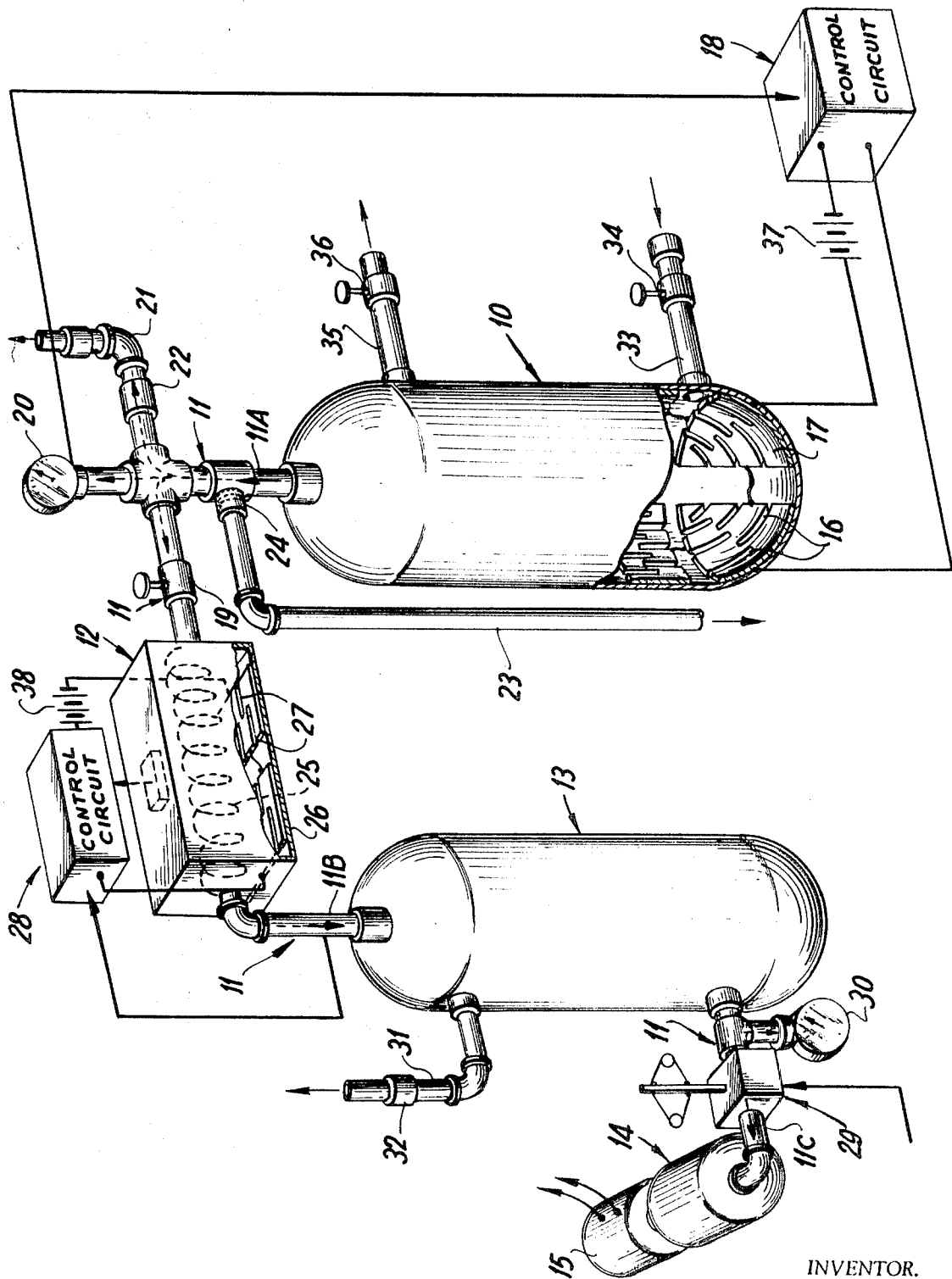
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ABSTRACT: The production of power by the utilization of a supply of a gaseous working fluid under pressure to drive a turbine, wherein a substantially unlimited supply of working fluid is provided by the controlled evaporation of a reservoir of the working fluid in a liquefied state in accordance with pressure variations at an appropriate point in the system. Heating of the gaseous working fluid to a preselected temperature and pressure prior to utilization is advantageous.





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POWER SYSTEM

BACKGROUND AND SUMMARY OF THE INVENTION

Ever since the inception of the industrial revolution, a constant search has been underway for new and improved ways and means for producing power. This is true even in today's highly industrialized and mechanized world, where the huge and varied demands for power have rendered the problem more acute than ever. One factor contributing to the widespread experimentation that is taking place today is the realization that the conventional fuels are likely to become exhausted in the not unforeseeable future at the ever-increasing rates at which they are being consumed. Of more immediate concern, however, and a major motivating factor towards increased experimentation is the danger to health and property resulting from the continuing uncontrolled pollution of our environment. Poisonous exhaust gases from the internal combustion engine are continually polluting the air we breathe. Waste products from petroleum processing plants are polluting our streams and rivers.

At a time when increasing pressures are being brought to bear on private industry by public and private interests to clean up the atmosphere, the automobile industry in particular has been hard pressed to come up with a practical solution to the problem. In order to meet certain safety standards set up for the industry, experimentation has resulted in the provision of special carburetors designed to eliminate or cut down on the contaminants which result from internal combustion. Obviously, these measures do not provide the desired solution to the problem and, moreover, they lead to less efficient combustion of the fuel with commensurate losses of power being the result.

The concept of an electrically driven car has received considerable attention. However, the major stumbling block to the application of this concept has been the industry's inability to provide a practical source of electrical energy in the quantities required. Storage batteries have been tried but represent a grossly inefficient source of energy.

In view of the shortcomings and limitations of the prior art, the instant invention has as an objective the provision of new and improved ways and means for producing power in a clean, safe and efficient manner.

It is another object of the instant invention to provide methods and instrumentalities for developing and channeling the power source potentialities of supercooled fluids such as liquid air.

It is more particular object of the instant invention to provide a practical solution to the problem of air pollution with particular reference to the effects of the internal combustion engine by the utilization of a media which will provide efficient and economical service without the danger of objectionable contaminus being introduced into the atmosphere.

Briefly and generally, the foregoing and other objects and advantages are accomplished in accordance with the instant invention by the provision of a system including a plenum chamber containing a gaseous working fluid in operative communication with a turbine and means for regulating the withdrawal of working fluid from the chamber to drive the turbine in accordance with demand for power, the pressure head in the plenum chamber being constantly maintained by the closely controlled conversion to its natural gaseous state of a reservoir of liquefied working fluid in accordance with pressure variations sensed at an appropriate point in the system. Advantageously, a heat exchanger is provided for raising the temperature of the working fluid in its gaseous state to ambient or above prior to entering the plenum chamber, and a check valve is provided between the reservoir of liquefied working fluid and the heat exchanger to maintain one-way fluid flow towards the plenum chamber, pressure sensing for fluid conversion taking place on the upstream side of the check valve.

Having summarized the invention, a more detailed description follows with reference being had to the accompanying drawings which form a part of this specification and in which an exemplary embodiment of a power-producing system in accordance with the invention is diagrammatically illustrated.

DETAILED DESCRIPTION OF THE INVENTION

Turning now in detail to the accompanying drawings, the exemplary system illustrated therein comprises a tank 10 wherein the controlled evaporation of a reservoir of liquefied gas such as liquid air takes place, and from which the evaporated fluid is transported via high-pressure conduit system 11 through a heat exchanger 12 and thence to a plenum chamber 13 from which it is withdrawn, as needed, to drive a turbine 14 having an associated generator 15. The invention will hereinafter be described in terms of a liquid air system for exemplary purposes only.

As mentioned above, the initial liquid air conversion takes place in tank 10. It is necessary therefore that a supply of liquid air be stored and held ready for use within the tank. Accordingly, tank 10 is particularly adapted to maintain, as nearly as possible, the air in its liquefied state and is accordingly designed to prevent or retard heat transfer with the atmosphere. A Dewar vessel typifies the kind of storage tank presently contemplated. Of course, it is recognized that complete prevention of heat transfer may not be attainable and that some conversion of liquid to gas probably will occur due to uncontrollable heat transfer during normal periods of nonuse. The system is provided with safety pressure relief means described below for counteracting the possibility of an uncontrolled pressure buildup in the tank and in other parts of the system as well.

Tank 10 is provided with pressure-responsive heating means for heating the liquid air stored therein in order to effect the controlled evaporation of the liquid air in accordance with pressure variations in the system. As embodied herein, the aforesaid heating means comprises a plurality of electrical strip heaters 16 incorporated into the inner wall 17 of the tank 10 at and adjacent to its lower end. Control of the operation of the strip heaters is accomplished by means of a suitable control circuit diagrammatically illustrated at 18 which is adapted to energize and deenergize the strip heaters in response to instantaneous pressure conditions in the system. The control circuit means contemplated for use herein can comprise conventional instrumentalities such as pressure-sensing devices and switches arranged in a conventional manner. It is believed that the nature of the control circuit arrangement required to accomplish the desired heater control will be immediately apparent to one possessing ordinary skill in the art.

The tank 10 is coupled at its upper end to heat exchanger 12 by a first high-pressure conduit section 11A including a check valve 19 for maintaining one-way flow through the system. The pressure-sensing elements of the control circuit 18 are illustratively inserted into the system at first conduit section 11A on the upstream side of check valve 19. Also coupled into the system at this point is a pressure gauge 20 for indicating the operating pressures in the tank.

In order to maintain safe pressure conditions in the tank, a pressure relief line 21 and valve 22 of the conventional type are operatively coupled into the system at conduit section 11A. An additional safety factor is provided by the inclusion of a secondary pressure relief arrangement including a pressure relief line 23 and rupture disc 24 located at the juncture of line 23 and conduit section 11A. Disc 24 is adapted to rupture when the pressure in the tank and hence in conduit section 11A exceeds a preselected magnitude preferably greater than the operating pressure of pressure relief valve 22. Thus, should pressure relief valve 22 malfunction or should its associated relief line 21 be incapable of providing the necessary pressure relief, the disc 24 will rupture providing a second escape route to the atmosphere via secondary pressure relief line 23.

Heat exchanger 12 comprises in its illustrative form coils of high-pressure tubing 25 surrounded by a suitable heat transfer medium, e.g., water, which is encapsulated in an outer jacket or shell 26. Suitable controlled heater means is provided for maintaining a suitable temperature condition of the heat transfer medium. As embodied herein, the walls of the outer jacket 26 are provided with a plurality of electrical strip heaters 27 in like manner to the inner wall of tank 10.

In order to assure that the working fluid leaving the heat exchanger is at the desired temperature and pressure, control means 28 is provided for energizing and deenergizing heaters 27 to regulate heat transfer to the working fluid. The control means 28, which is diagrammatically illustrated, comprises means indicated by the arrow for monitoring the fluid in conduit section 11B as it departs the exchanger 12 and initiating the appropriate responses in a control circuit arrangement which would include suitable switching elements or equivalent means for providing the heater control to obtain the desired fluid conditions. The means for monitoring the fluid can include conventional fluid temperature, pressure and/or flow rate sensing devices (not shown) optimally inserted within conduit section 11B. An alternative arrangement can find temperature-sensing devices within the heat transfer medium surrounding the exchanger tubes 25. The overall arrangement contemplated with its various components is believed to be well within the ordinary skill of the art and further description here is thought to be unnecessary. The temperature rise to be imparted to the air as it passes through exchanger 12 is a matter for determination through practice of the invention. At present, it is contemplated that the air will be brought to a temperature at least coinciding with the ambient temperature of the atmosphere, it being understood, however, that the higher the temperature, the greater the pressures developed for utilization.

After it passes through heat exchanger 12, the heater air is channeled to the plenum chamber 13 via a second high-pressure conduit section 11B. The plenum chamber 13 functions as a form of reservoir to provide a ready supply of working fluid under pressure to drive air motor 14. No special requirements exist for the construction of the vessel serving as the plenum chamber other than may be dictated by pressure and temperature requirements. In other words, the wall of the vessel must be of a construction to withstand the internal pressures to which it will be subjected during operation, and, where the temperature of the working fluid is to be above ambient, the vessel should be of a type similar to the liquid air tank 10 in order to retard or limit heat transfer with the atmosphere. The optimum pressures and temperatures for the working fluid in plenum chamber 13 are matters for determination through practice of the invention. However, the nature of the turbine 14 and the power requirements of particular applications are obviously important factors to be considered in this regard.

Operatively connecting plenum chamber 13 with turbine 14 is the third or final high-pressure conduit section 11C. The pressurized working fluid of the plenum chamber is channeled, as needed, directly to the turbine via this conduit section. This is accomplished by means of a flow-regulating device such as the centripetal governor 29 situated in the conduit section 11C. In practice, this regulating device can be responsive to external control so that the operator will be able to directly regulate the power output of the system.

Situated in conduit section 11C just prior to the governor 29 in the illustrative embodiment is a pressure gauge 30 enabling the operator to maintain a close check on pressures at this critical point in the system.

As will be understood, in normal operation the rate of egress of working fluid from chamber 13 via conduit section 11C should equal the rate of ingress of fluid to the chamber via conduit section 11B. However, a safety factor is provided in the event that these rates do not coincide and excessive pressures tend to build up within the chamber. Pressure relief means including a pressure relief line 31 and conventional

pressure relief valve 32 provides an auxiliary and immediate escape route to the atmosphere to counteract any such imbalance in the system.

Tank 10 is provided with means for the introduction of fresh supplies of liquid air when needed. An inlet line 33 having a shutoff valve 34 is provided at the lower end of the tank. Near the upper end of the tank is a vent line 35 having a similarly associated shutoff valve 36. When it is desired to introduce a fresh supply of liquid air into tank 10, the inlet line 33 is coupled to the supply source of the liquid air. Vent line shutoff valve 36 and inlet line shutoff valve 34 are then opened. The fresh supply of liquid air is then transported via inlet line 33 to the interior of the tank until it is filled to the desired level. As the tank is being filled, some of the liquid air will undoubtedly evaporate and escape through the vent line 35. However, as the inner wall 17 of tank 10 cools through contact with the supercooled liquid air, less evaporation will occur. When the desired level has been reached, the shutoff valves of the vent and inlet lines are closed and the system is ready for operation.

The manner in which the invention achieves its objectives will now be explained with the aid of the system illustrated herein. The operator of the system provides manual control over the centripetal governor 29 for the purpose of regulating the operation of the turbine. As the conduit section 11C is opened by governor 29, for greater power, greater volumes of working fluid are channeled to the turbine from the plenum chamber 13. The greater the rate of withdrawal of air from the plenum chamber, the greater the speed of the turbine and the greater the power output. Hence, direct control is provided over the power output of the system. The turbine, in turn, can be utilized to drive a generator 15 for the production of electrical energy for any purpose desired.

In order to obtain optimum efficiency and predictable response in the operation of the system, it is very important that the pressure within the plenum chamber be constantly maintained at the optimum operating condition determined for the particular application. As already discussed, pressure relief line 31 and valve 32 play an important role in preventing excessive pressure buildups within the chamber.

When working fluid is withdrawn from the plenum chamber 13 for operation of the turbine, a drop in pressure obviously occurs in the chamber. This pressure variation immediately results in fluid movement from heat exchanger 12 towards plenum chamber 13, the ultimate result being a pressure drop in liquid air tank 10 and conduit section 11A on the upstream side of check valve 19. This ultimate drop in pressure on the upstream side of valve 19 is picked up by the pressure-sensing devices of heater control means 18 actuating the appropriate mechanisms for energizing electrical strip heaters 16. Energization of strip heaters 16 results in the production of heat causing practically immediate evaporation of the supercooled liquid air in the tank back to its natural gaseous state. The gaseous working fluid thereby produced moves through the system towards the plenum chamber, passing through check valve 19 and heat exchanger 12 where its temperature is raised. When power is no longer required and the pressures in the system are again in equilibrium, the sensing devices of the heater control means 18 initiate the appropriate response to deenergize the strip heaters 16 and discontinue the evaporative process.

It should be apparent that individual control of the plurality of strip heaters by control means 18, or the utilization of variable heaters the rate of heat production of which can be closely controlled, may be a desirable feature of the invention. In normal operation a continuous withdrawal of working fluid from plenum chamber 13 will be taking place, but the rate of withdrawal will, in all probability, fluctuate. Individual heater control and/or the provision of controlled variable heaters will enable the rate of evaporation of liquid air to be more closely controlled with this in mind.

The evaporated working fluid after having undergone a change of state is still at a temperature far below that of ambient. By passing it through the heat exchanger 12, the

evaporated fluid can be raised to ambient temperature or above with concurrent increases in working pressures being developed to thereby greatly increase the operating efficiency of the system. As stated earlier, the optimum increase in temperature to be imparted to the working fluid can be determined through practice of the invention. Due to the increased pressures developed in the system on the downstream side of the check valve, lesser quantities of liquefied working fluid need be evaporated to meet power output requirements than would be the case if secondary heating were not included in the process. Accurate control of the rate of evaporation in terms of the need for actual working fluid is attained by sensing pressure variations on the upstream side of the valve.

In order to impart the desired temperature rise to the working fluid passing therethrough, the heat transfer medium, e.g., water, surrounding the high-pressure coils 25 of the exchanger 12 is maintained at a suitably high temperature. Maintenance of the appropriate temperature is accomplished automatically by the strip heaters 27 and control means 28. The temperature, pressure and/or flow rate sensing elements of heater control means 28, which are preferably suitably located in the conduit section 11B leading from the heat exchanger 12 to the plenum chamber 13, monitor the working fluid and initiate the appropriate response signal to either energize or deenergize one or more of the strip heaters 27 to attain the proper rate of heat transfer to achieve the desired temperature.

As a result of the rise in temperature of the evaporated air, greater pressures are developed for possible utilization in driving the turbine, these greater pressures being directly related to greater system efficiency. If it is desired to maintain fairly high temperatures above ambient within the plenum chamber 13, the chamber should be constructed in a manner similar to liquid air tank 10, i.e., to retard heat transfer with the atmosphere.

Both heater control means 18 and 28 can be powered by individual batteries as shown in the drawings at 37 and 38, respectively, or they can be powered by electrical energy which has been shunted off the generator 15 for that purpose.

It will be seen from the foregoing that a relatively simple yet potentially highly efficient power system is provided. The liquid air takes up relatively little space compared to the tremendous working pressures which can be built up and utilized through proper channeling. Moreover, the exhaust of the system consists solely of air so that no harmful contaminants reach the atmosphere. Clean working energy is produced.

It is to be understood that the invention in its broader aspects is not limited to the specific elements, steps, techniques, combinations and arrangements herein shown and described, but departures may be made therefrom without departing from the scope and spirit of the invention as defined in the appended claims and without sacrificing its chief advantages. For example and without limitation, placement of the pressure sensing instrumentalities of the liquid air heater control means can be made at points in the system other than where illustrated herein, if such proves desirable. Thus, practice of the invention may determine that in certain instances it

may be desirable to sense pressure variations directly within the plenum chamber. As another example, different types and forms of heat exchangers can be utilized in the practice of the invention as long as they are suitable for providing the desired temperature rise to the working fluid. Moreover, the invention is not to be limited to the particular working fluid discussed herein, i.e., air, provided, however, that a proper substitute is available. Other variations and departures from the disclosure herein within the scope of the invention will undoubtedly occur to those skilled in the art through practice of the invention.

What I claim is:

1. A system for producing power comprising
 - a. a turbine having a fluid outlet;
 - b. a plenum chamber filled with a working fluid in its natural gaseous state at a pressure greater than the pressure at said turbine outlet;
 - c. first fluid conduit means operatively connecting said plenum chamber and said turbine, said conduit means including flow-regulating means responsive to external control for regulating the mass rate of flow of working fluid to said turbine;
 - d. an insulated fluid vessel containing a reservoir of said working fluid in a liquefied state, said vessel having internal heater means for heating said liquefied working fluid;
 - e. heater control means including pressure-sensing means for sensing fluid pressure conditions at a suitable point in the system and automatically selectively energizing and deenergizing said heater means in accordance with said conditions; and
 - f. second fluid conduit means operatively connecting said fluid vessel and said plenum chamber such that reductions in fluid pressure within said plenum chamber result in the energization of heater means, the gasification of liquefied working fluid within said insulated vessel, and the movement of said gasified working fluid towards said plenum chamber.
2. A system in accordance with claim 1 further comprising heat exchanger means operatively coupled into said second fluid conduit means for raising the temperature of said gasified working fluid as it moves from said insulated vessel to said plenum chamber.
3. A system in accordance with claim 2, said second fluid conduit means comprising check valve means intermediate said insulated vessel and said heat exchanger means operative to prevent fluid movement towards said insulated vessel.
4. A system in accordance with claim 3, said pressure-sensing means of said heater control means being operatively positioned in said system to detect pressure variations on the upstream side of said check valve means.
5. A system in accordance with claim 4, further comprising control means for monitoring said working fluid as it departs said exchanger means and regulating the rate of heat transfer to said working fluid to obtain the desired temperature and pressure conditions for said fluid.