Oct. 30, 1962 H. H. HUMPAL 3,061,733

HERMETICALLY SEALED POWER GENERATOR

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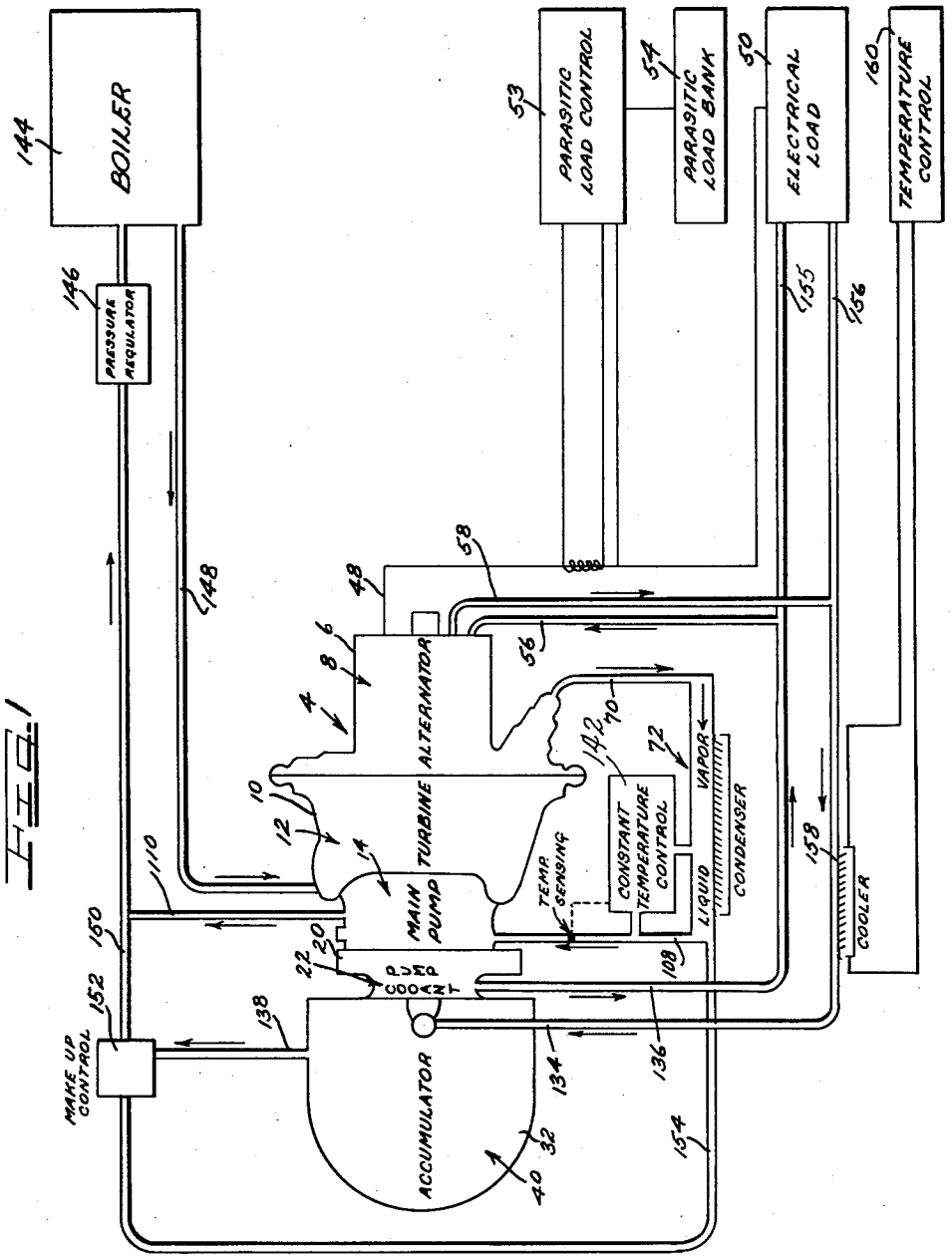


FIG. 1

Inventor
HAROLD H. HUMPAL

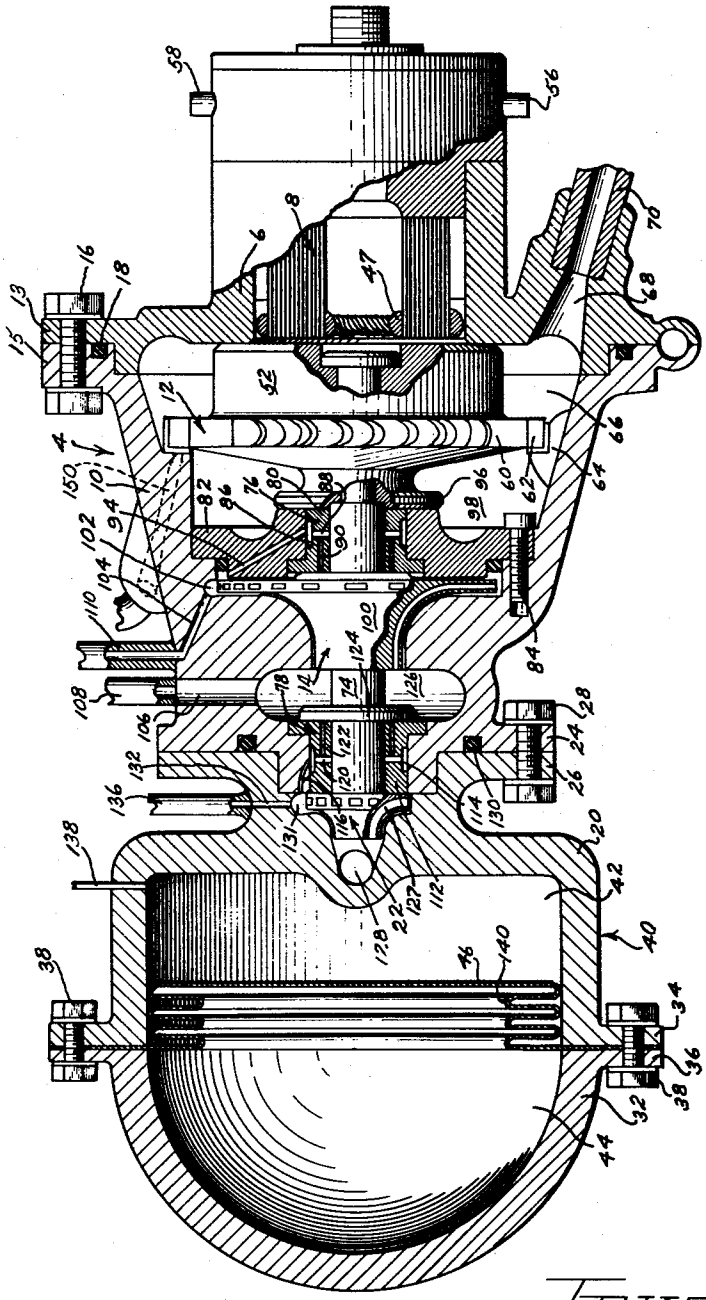
By Hill, Sherman, Meroni, Gross & Simpson Attys

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FIG. 2



Inventor
HAROLD H. HUMPAL

By Hill, Sherman, Meroni, Gross & Simpson Attys.

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HERMETICALLY SEALED POWER GENERATOR

Harold H. Humpal, Maple Heights, Ohio, assignor to Thompson Ramo Wooldridge Inc., a corporation of Ohio

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The present invention relates to improvements in power plants and particularly to an improved mechanism having a prime mover which is capable of unattended continuous operation on a Rankine cycle.

An object of the inventinon to provide a closed prime mover in a gas system which eliminates all seals and, therefore, eliminates any possible leakage paths.

Another object of the invention is to provide an improved power plant wherein all moving components are mounted on a single shaft and sealed in a single housing with no parts connected to the outside of the housing to have relative movement.

A further object is to provide an improved power plant unit which employs a single working fluid for a plurality of functions such as operating the prime mover, cooling component parts, lubricating the bearings, etc.

Another object of the invention is to provide a power mechanism having an improved lubrication system.

A further object of the invention is to provide a complete sealed power plant unit with an improved fluid flow system.

A still further object of the invention is to provide an improved power plant assembly producing an electrical energy output with improved heat transfer arrangements.

Other objects and advantages will become more apparent with the teaching of the principles of the invention in connection with the disclosure of the preferred embodiments in the specification, claims and drawings, in which:

FIGURE 1 is an elevational view shown partly in schematic form of the power plant assembly embodying the principles of the present invention; and

FIGURE 2 is a detailed sectional view taken through the housing for the power plant and with parts of the system shown in FIGURE 1 removed for clarity of illustration.

As shown on the drawings:

The power plant assembly is shown substantially in its entirety in FIGURE 1 and various sections are indicated by labels. The moving parts of the mechanism are all enclosed within a sealed housing 4. The housing is formed of cast iron or the like with the various parts held together in sealed relationship and with all of the moving parts contained within. The only openings from the sealed housing 4 consist of the passages for connection of conduits for the flow system for the working fluid, and leads for delivering electrical energy from the electrical generator portion of the power plant.

As illustrated in FIGURE 2, the housing 4 may be formed of a casting or the like having a head end part 6 which is somewhat cylindrical in form to enclose the coils of an alternator 8, as also shown in FIGURE 1. Adjacent the housing part 6 is a part 10 with chambers formed therein to enclose the turbine 12, and a circulating pump 14 which is also indicated as the main pump. The housing parts 6 and 10 are respectively provided with annular flanges 13 and 15 and these flanges have axially aligned holes to receive bolts such as 16 for clamping the housing parts together. An annular seal 18 is provided to positively seal the parts and prevent leakage from the interior.

In placing all of the moving parts within the housing 4 and in providing absolute seals, leakage to the atmosphere is positively prevented. This is essential to use in certain environments and the Rankine cycle uses a mercury vapor turbine making a seal essential for maintenance of a closed cycle for the operation and for protecting personnel. The prevention of leakage is achieved with the arrangement of the present invention and this is also essential in certain uses wherein the working fluid may attain radioactive properties. An important use of the continuous operating self-contained power plant of the present invention is found wherein heat for the working fluid is obtained from atomically active material.

The part 10 of the housing 4 is joined to a part 20 which houses a coolant pump 22. Parts 10 and 20 have annular flanges 24 and 26, respectively, provided with aligned axial holes to receive bolts 28 for clamping the parts together. An annular sealing ring 130 is provided between the parts.

Adjoining the housing part 20 is an end housing part 32 and the parts are provided with annular flanges 34 and 36, respectively. Aligned holes in the flanges receive bolts 38 to clamp the parts together and gasket means may be provided between the parts to seal the chamber formed therein. The part 20 coacting with the part 32 form an accumulator 40 therein and the accumulator includes an accumulator chamber 42 and a gas chamber 44. The chambers are separated by a diaphragm wall 46 whose function will be described later.

The alternator 8 is provided with coils 47 and suitable electrical terminals lead through the housing part 6 and connect to a line 48 leading to an electrical load 50. The turbine 12 is provided with a rotor with a permanent magnet head 52 to cause the generation of electricity in a well known manner and the generator or alternator is of the type known as a radial gap alternator.

The generated electricity is delivered to the electrical load 50 and the total load may be controlled in various ways such as by a parasitic load control 53 having a parasitic load bank 54. This obtains a constant load on the alternator 8 for constant speed operation. The electrical load 50 is provided with means for cooling in accordance with the present invention in a manner which will later be described. The alternator 8 is also cooled and for this purpose has a jacket which is formed as a part of the sealed housing 4, and has an inlet line 56 for cooling fluid and an outlet line 58 for cooling fluid.

A feature of the present invention is the utilization of the same fluid as used for the working fluid for purposes of cooling units of the power plant, as will be fully described.

The turbine 12 includes a turbine rotor 60 with turbine blades 62 arranged around the outer periphery in the usual manner. The rotary turbine blades 62 coact with stationary turbine blades 64 mounted on the inside of the hollow housing part 10 which forms a turbine chamber 66 therein. Leading from this chamber is a turbine exhaust passage 68 to which is connected a turbine exhaust line 70.

In the form of the invention disclosed as a preferred embodiment, the turbine is designed to operate on a mercury vapor cycle. The exhaust line 70 will thus be carrying mercury vapor and leads to a condenser 72, FIGURE 1.

The turbine rotor 60 is mounted on a power shaft 74. The power shaft 74 is shown supported on a rotary bearing 76 at its head end, and on a rotary bearing 78 at the other end. The rotary bearings may be of any suitable type which can operate under the conditions imposed by the high temperatures of the working fluid and are illustrated as sleeve bearings with appropriate passageways for conducting lubricating fluid.

As illustrated by the bearing 76, the bearing includes a

sleeve 80 mounted in a collar 82 secured, such as by bolts 84, within the housing part 10. The sleeve has an annular groove 86 in its outer surface with radial passageways 88 leading to the bearing surface between the shaft and sleeve. An axial passage 90 leads through the bearing sleeve to open to the intake pressure of a feed pump 14. Lubricating fluid delivery to the bearing is obtained through a passage 94 leading through the collar 82 from the discharge of the feed pump 14.

Leakage from the bearing in the other direction causes the lubricating fluid to engage a slinger ring 96 with the lubricant being thrown outwardly in a chamber 98 at the head end of the turbine rotor 60. The turbine chamber 98 slopes in a downward direction, when the housing is positioned with its axis substantially horizontal, so that the lubricating fluid will run downwardly past the turbine rotor 60 and into the turbine chamber 66 to flow through the exhaust passage 68 of the turbine. Inasmuch as the working fluid is used also as the lubricating fluid, this lubricating fluid will continue to circulate and joins the mercury exhaust vapor from the turbine.

The pump 14 is also mounted on the power shaft 74 and includes a pump impeller 100 discharging into a volute chamber 102 which communicates with a pump discharge passage 104 leading through the housing part 10. The intake of the pump is through a passage 106 also leading through the housing part 10. A pump intake line 108 connects to the intake pasage 106 for the pump and a pump discharge line 110 connects to the discharge passage 104 for the pump.

The bearing 78 at the rear end of the power shaft 74 also includes a sleeve 112 rotatably supporting the shaft. The sleeve is mounted in the housing part 10 and has an annular groove 114 on its outer surface communicating with the lubricating supply passage 116 which supplies lubricating fluid from a coolant pump 22. The bearing sleeve 112 has radial passages 120 leading from the groove 114 to lubricate the inner surface of the sleeve on which is supported the power shaft 74. Axial passages 122 lead from the radial passage 120 to open to a slinger ring 124 which also catches the leakage from the bearing and throws it into an intake chamber 126 for the circulating pump 92. Leakage in the other direction along the shaft flows into the intake of the coolant pump 118.

The coolant pump 22 includes a rotor 127 mounted on the power shaft 74 and is supplied through an inlet passage 128 and discharges through a volute chamber 131 which communicates with an outlet passage 132. Coolant fluid flows into passage 128 through a line 134, FIGURE 1, and flows out through the pump discharge passage 132 through a line 136.

At the left end of the housing 4, as shown in FIGURE 2, is the accumulator. The accumulator chamber 42 is provided with a flow passage, not shown, which connects to a make-up control line 138. This line supplies working fluid to the system to provide make-up working fluid to the boiler-turbine combination, to the cooling system and to the lubricating system. The working fluid is maintained at a static pressure in the make-up control line 138 by the movable bellows wall 46 which is part of an expansible annular bellows wall 140 and which backs against the gas chamber 44.

The housing 4 contains all of the moving parts within and opens only for passages for conducting the working fluid. As illustrated in FIGURE 1, the working fluid leaving through the exhaust line 70 of the turbine passes into the condenser 72 and is condensed from a vapor to a liquid. A temperature control device 142 is provided to sense the temperature of the liquid leaving the condenser and to control operation thereof. The condenser preferably will be of the air cooling type in order that the mechanism may be best adapted to unattended continuous operation. The condensed liquid leaves the condenser through a line 108 and is pumped up to a boiler

unit 144 by the main pump 14. The line 110 leaving the main pump 14 leads to the boiler 144 through a pressure regulator 146 which controls the pressure differentials for the high and low side of the Rankine cycle turbine 12.

The boiler 144 is provided with a supply of heat and for unattended continuous operation may be heated by atomic heat sources. The heated working fluid leaves the boiler 144 through a line 148 to enter an inlet passage 150 leading to the turbine. Make-up working fluid is supplied to the line 110 leading to the boiler through a line 150 which leads from a make-up control 152 supplied by the line 138 leading from the accumulator. Another line 154 leads from the make-up control to the line 108 leading from the condenser 72 to the main pump 14.

The working fluid is also used as a coolant. For this purpose the coolant pump 22 circulates the coolant through a line 136 which connects to a line 56 to circulate the coolant through the alternator or generator 8. A branch line 155 also leads from the line 136 to a heat exchange unit, not shown, which is part of the electrical load 50. Return from the electrical load is through a line 156 to the line 134 back to the coolant pump 22. Flow through this return line 134 is cooled by a cooling unit 158 which is controlled by a temperature control unit 160. While other types of coolant might be employed, mercury is preferred to prevent accidental contamination of the fluids through bearing leakage.

In operation of the power plant, the working fluid is heated in the boiler unit 144 and, being preferably in the form of mercury, is delivered as a vapor to the turbine 12 to drive the turbine rotor 60. The rotor carries the permanent magnet head 52 to operate the generator or alternator 8 and supply electricity through leads 48 to the electrical load 50. The mercury vapor exhausts through a line 70 and is condensed in the condenser 72 to be returned by the main pump 14 to the boiler through the pressure regulator 146. Makeup working fluid is supplied through a line 138 leading from the accumulator chamber 42 as controlled by the make-up control 152. Another line 154 also conducts make-up fluid to the circuit by being connected to the line 108. The main pump 14 is driven by the power shaft 74 which also carries the turbine rotor 60 and the coolant pump rotor 127. The coolant pump 22 delivers coolant through a line 136 to cool the electrical load 50 and the alternator 8. The coolant returns through a line 134 from a cooler 158 for the coolant. The bearings 76 and 78 for supporting the power shaft 74 are lubricated by the working fluid. The bearing 76 receives a flow of working fluid through a passage 94 leading from the discharge of the main pump 14 and leakage from the bearing flows through the turbine housing out through the turbine exhaust passage 68. The bearing 78 is lubricated through a passage 116 which leads from the outlet of the coolant pump 22. Leakage from the bearing 78 flows into the chamber 126 to the inlet of the main pump. The accumulator is arranged to maintain a balance between the coolant system and the fluid system for operating the turbine to compensate for fluid leakage, with the entire system being sealed.

Thus it will be seen that I have provided an improved power plant which meets the objectives and advantages hereinbefore set forth. The features of the invention are well adapted to use in the unattended continuous operation engine of the type operating on the Rankine cycle. The arrangement of elements which provides for sealed systems is well adapted to utilizing heat energy from an atomic source and for safe reliable continuous operation.

I have, in the drawings and specification, presented a detailed disclosure of the preferred embodiments of my invention, but it is to be understood that I do not intend to limit the invention to the specific form disclosed but intend to cover all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by my invention.

I claim as my invention:

1. A sealed power plant operating on the Rankine cycle comprising, an enclosing housing completely sealing moving parts of the power plant; a first group of elements located completely within the housing including a working fluid supply chamber within the housing, a Rankine cycle turbine within the housing having a rotor carried on a power shaft, a circulation pump mounted on the power shaft, a coolant pump mounted on the power shaft for circulating cooling fluid, and an electrical generator having a driven element mounted on the power shaft; and a second group of elements outside of the housing including electrical lines leading from the housing, and a boiler outside the housing with lines for working fluid leading to the housing, said second group of elements including no moving parts.

2. A sealed power plant comprising in combination an enclosing housing for completely sealing moving parts of a power plant constructed and arranged for operation on a Rankine cycle, a rotary power shaft mounted within said housing, support bearings for said power shaft mounted within the housing, a Rankine cycle engine positioned within the housing and connected in driving relation to said power shaft, a boiler outside of said housing connected to deliver heated working fluid to said power plant for operation and to receive working fluid from the power plant in a closed cycle flow, an accumulator chamber within said housing connected to maintain a supply of working fluid in the boiler for circulation through the power plant, and conduit means leading from the accumulator to said bearings for conducting said working fluid to supply the bearings with working fluid as a lubricant.

3. A working fluid supply system for a power plant operating under a Rankine cycle including an engine, a boiler for supplying heated working fluid to operate the engine, an electrical generator driven by the engine and an electrical load provided with cooling means supplied by the generator, the system comprising a sealed accumulator containing a single unit supply of working fluid, a first conduit means leading from the accumulator and connecting to a working fluid circuit between the boiler and engine for providing make-up fluid, a second conduit means leading between the accumulator and the cooling means for the electrical load to provide a supply of working fluid to cool the electrical load, a working fluid cooler in the second conduit means between the electrical load and the accumulator to reduce the temperature of the working fluid used for cooling the electrical load, pump means in the second conduit means for circulating the working fluid, and means in the first conduit means for controlling the flow of make-up control working fluid to the boiler.

4. A flow system for working fluid for a closed cycle power plant including a housing, a rotary shaft supported on bearings within the housing, a turbine having a rotor mounted on the shaft, a pump with an impeller mounted on the shaft, a generator driven by the power shaft and supplying an electrical load, and a boiler for supplying heated working fluid to the turbine rotor, the working fluid system including conduit means for conducting the flow of working fluid between the boiler and turbine, an accumulator chamber within the housing containing a supply of working fluid, a make-up control conduit leading from the accumulator to said conduit means for a make-up supply of working fluid to the boiler, a coolant fluid conduit connected to the accumulator and leading to the pump and to the electrical load for cooling the electrical load with said working fluid, and a lubricating fluid conduit connected to the accumulator and leading to a bearing for directing working fluid under static pressure to lubricate a bearing whereby said working fluid accumulator provides a single source of fluid for the functional requirements of fluid for the power plant.

5. A sealed power plant adapted for operation on a Rankine cycle comprising a closed housing, an engine having a power shaft with supporting bearings enclosed in the housing, an accumulator chamber located within said housing, a boiler connected to furnish a supply of working fluid to the engine connected to receive a return of working fluid from the engine for heating, a make-up control conduit means connected between the accumulator and the boiler for a supply of make-up working fluid, a condenser located between the turbine and the boiler, a circulating pump between the condenser and the boiler for the circulation of working fluid, and a by-pass line between the circulating pump and boiler leading to one of said bearings whereby said working fluid is directed to lubricate the bearing.

6. A sealed power plant operating on a Rankine cycle for continuous operation comprising in combination a power shaft, a mercury turbine having a rotor constructed and arranged to be driven by mercury vapor and mounted on the power shaft, a circulating pump for liquid mercury having an impeller mounted on said power shaft, a condenser connected between the turbine and the circulating pump, a boiler connected between the circulating pump and the turbine for converting the mercury to a heated mercury vapor, an accumulator provided with a chamber for supplying a make-up control mercury to said boiler and turbine, make-up conduit means connected between the accumulator chamber and the boiler and turbine, an alternator driven by said turbine, an electrical load electrically connected to be operated by the alternator and having a cooling means, a coolant conduit leading between said accumulator and said cooling means for the electrical load for maintaining the load at an operating temperature, a coolant pump having an impeller mounted on said power shaft connected in the coolant conduit for circulating said coolant, bearings supporting said power shaft, and lubrication conduit means connected between said accumulator and said bearings whereby the mercury functions as a working fluid for operating the turbine and also as a cooling fluid for the electrical load and a lubricant for the bearings.

7. A closed continuously operable Rankine cycle power plant comprising an enclosing housing devoid of moving seals, a power shaft supported on bearings enclosed completely within said housing, a Rankine cycle engine mounted within the housing and in driving connection with said power shaft, an accumulator chamber for containing working fluid, a boiler located externally of said housing, cooling apparatus located externally of said housing, openings connecting to conduit means leading from said housing and consisting of lines for conducting the working fluid between the housing and boiler and between the housing and said cooling apparatus, a static pressure chamber in said accumulator, and an expansible wall dividing the accumulator chamber for the working fluid and the static pressure chamber whereby static pressure is maintained on the working fluid within the accumulator chamber.

8. A power plant constructed and arranged for continuous operation and comprising in combination an engine for operation under a Rankine cycle having operating bearings, a condenser positioned to receive working fluid from said engine, a boiler located to receive working fluid from the condenser and to deliver it to the engine, a circulating pump connected between the boiler and condenser for circulating condensed working fluid, a cooling circuit for cooling elements of the power plant, a coolant circulating pump in the cooling circuit driven by the engine and having operating bearings, an accumulator chamber for working fluid and provided with lines supplying the boiler and engine with make-up working fluid and supplying the coolant system with working fluid, a first lubricating by-pass line connected to the discharge of the circulating pump for the working fluid and connected to the operating bearing for the engine to lubricate the bearing with working fluid, and a second lubri-

cating conduit connected to the discharge from the coolant pump and connecting to the operating bearings for the coolant pump whereby working fluid will lubricate the pump operating bearings.

9. A power plant for isolated sealed continuous self-sustained operation comprising in combination a sealed housing, a power shaft supported on bearings within the housing and carrying a turbine rotor, a boiler located externally of the housing, a conduit means leading between the boiler and the turbine rotor for operation of the rotor with a working fluid, a circulating pump drivingly connected to the operating shaft and positioned to circulate the working fluid through the boiler, an alternator connected in driven relationship to the turbine and totally sealed within the housing, an accumulator chamber located completely within the housing for containing working fluid, a make-up conduit leading from the accumulator to supply make-up control working fluid to the boiler and turbine rotor, a coolant conduit means leading from the accumulator to cool the alternator, a coolant pump located wholly within the housing and connected in the coolant conduit means for circulating the working fluid used as a coolant, rotary bearings located wholly within the housing for supporting the power shaft, and lubrication conduit means connected to distribute working fluid to said bearings whereby said working fluid acts as a fluid for driving the turbine and as a coolant and as a lubricating fluid for the bearings.

10. A closed cycle integral Rankine cycle engine assembly comprising in combination an engine driving a power shaft supported on bearings, an intake line for working fluid delivering heated working fluid to the engine for operation under a Rankine cycle, a boiler connected to deliver heated working fluid to said intake line, an exhaust line means leading from said engine and leading back to said boiler, a by-pass line connected to the exhaust line means at a first location and connected to said bearings for delivering working fluid to said bearings, a bearing waste line positioned for collecting said working fluid from the bearings and connected to said exhaust line means at a second location upstream from said first location whereby the working fluid is utilized for lubrication, and pump means in said exhaust line means between said first and second locations for pumping the working fluid from the engine to the boiler and through said by-pass line.

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