# United States Patent

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[72] Inventor Curtis V. Burkland
Calabasas, Calif.



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[73] Assignee CCI Aerospace Corporation
Van Nuys, Calif.


[54] **DUAL FLUID RANKINE CYCLE POWERPLANT**
**11 Claims, 3 Drawing Figs.**


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[50] Field of Search .......... 60/104, 90, 64, 91, 93, 92, 94, 95, 36; 62/470–473, 468; 91/46; 184/6 L, 6 TS; 92/154



[56] **References Cited**

UNITED STATES PATENTS

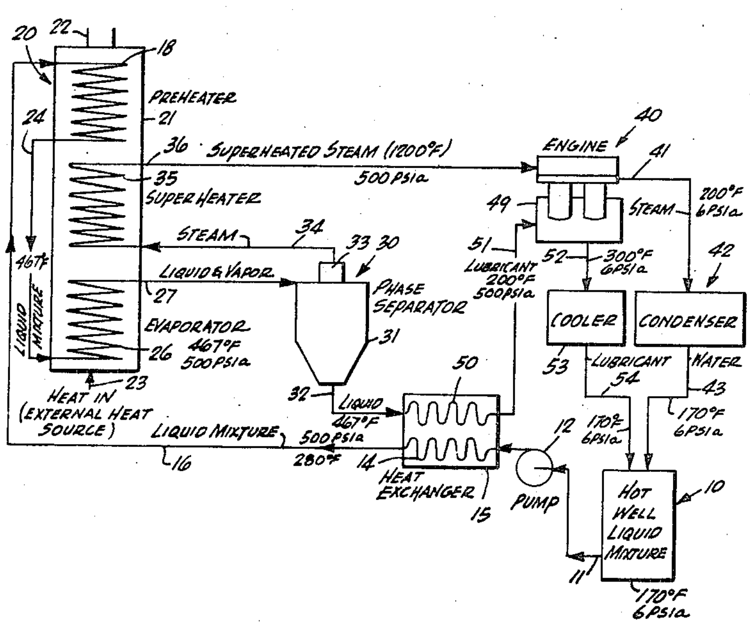
| | | | |
|---|---|---|---|
| 2,684,579 | 7/1954 | Hieatt et al. .......... | 62/468 |
| 3,462,951 | 8/1969 | Moore .......... | 60/36 X |



*Primary Examiner*—Martin P. Schwadron
*Assistant Examiner*—Allen M. Ostrager
*Attorney*—Robert E. Geauque



**ABSTRACT:** A dual fluid Rankine cycle powerplant utilizes one fluid, such as water, as the working medium and another fluid, such as a glycol, ether, polyglycol ether (both alkyl and aryl) or polyphenyl as the lubricant. The lubricant is fully soluble in the working medium and has a substantially higher boiling point than the working medium. The two fluids are separated from one another prior to entering the engine by heating the mixture of the two liquids to the evaporation temperature of the working medium and then separating the vapor from the liquid lubricant. Thereafter, the vapor can be superheated to increase the thermal efficiency.

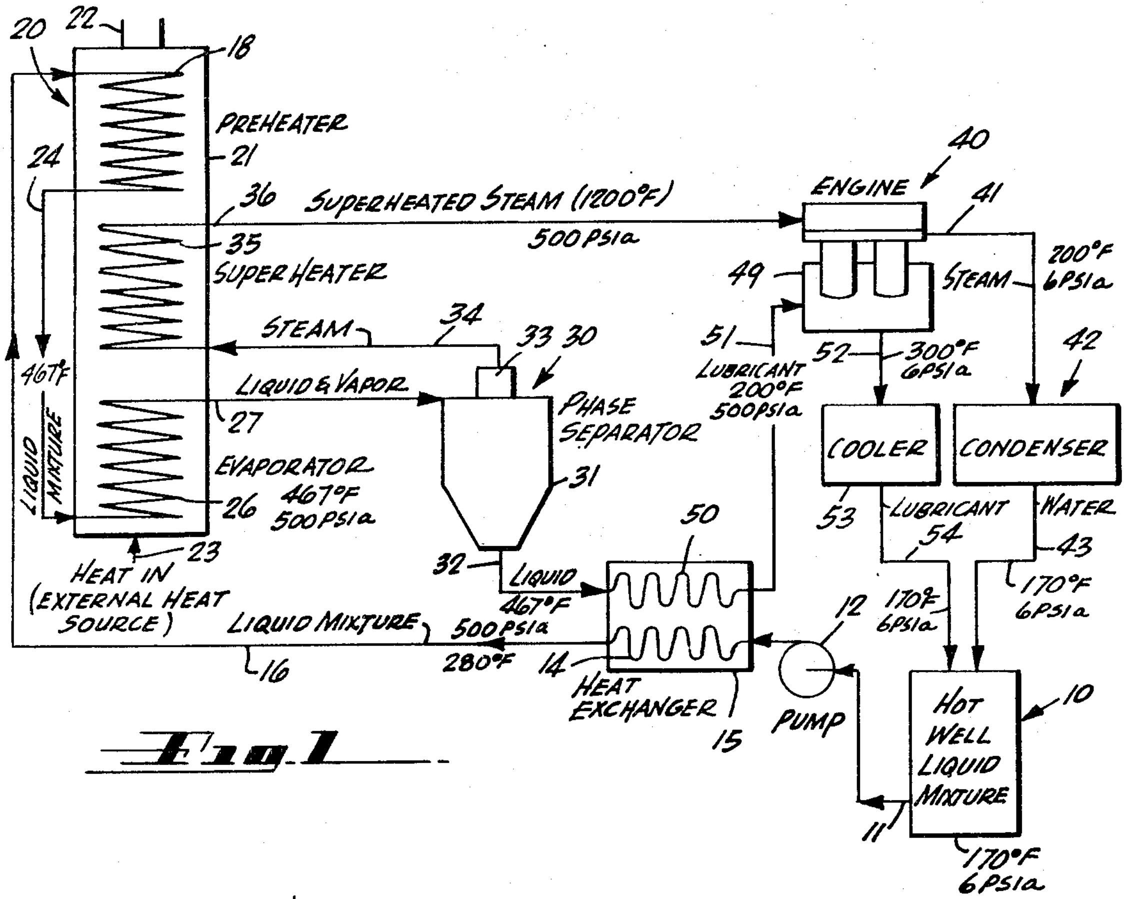



Fig. 1

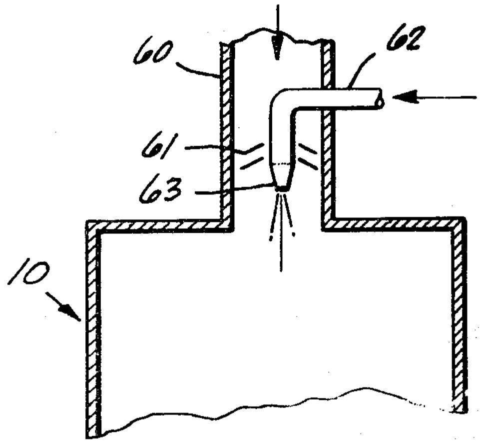



Fig. 3

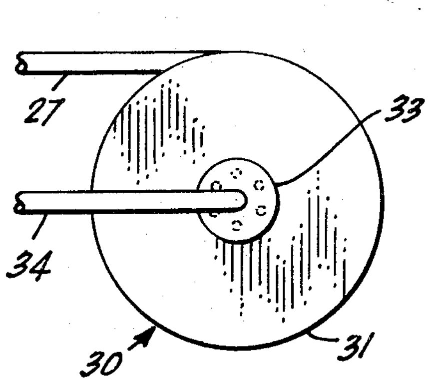



Fig. 2

INVENTOR.
CURTIS V. BURKLAND
BY R. E. Beauque
ATTORNEY

# DUAL FLUID RANKINE CYCLE POWERPLANT

## BACKGROUND OF THE INVENTION

Steam Rankine cycle powerplants employing turbines, generate the majority of electrical power in the United States and are used for the propulsion of ships and submarines using both fossil fuel and nuclear heat sources. At lower power levels, the efficiency and cost of a turbine is less competitive, and engines of both reciprocating and rotary types are used. However, engines are limited in their upper cycle temperatures, if oil lubrication is required for the piston or rotors, in order to prevent thermal decomposition of the lubricants. Also a problem exists of oil carryover from the crankcase into the steam and from steam leakage into the oil supply. The presence of oil in the working fluid will reduce heat transfer in the boiler and condenser. Steam that leaks into the oil may cause foaming and will reduce lubricating properties. Separators may be used to partly clean the oil and/or water but part of the working fluid and the lubricant is lost and a completely sealed, closed cycle is not feasible. Further, for applications that require start and stop operations out of doors and in cold climates, freezing of the working fluid is a major problem.

## SUMMARY OF THE INVENTION

The present invention relates to a dual fluid Rankine cycle powerplant in which the lubricant and working fluid are mixed in certain portions of the cycle and separated in the high temperature portions of the cycle. One of the fluids can be water which is used as a steam working fluid in the engine and the other of the fluids can be a synthetic organic liquid having lubricating qualities. The lubricant is selected from organic liquids which are thermally stable in the high temperature range of the cycle and are water soluble in all proportions and have a substantially higher boiling point than the working fluid. Examples of such a lubricant are glycols, ethers, polyglycol ethers (both akyl and aryl), and polyphenyls.

The dual fluid Rankine cycle powerplant of the present invention takes advantage of the separate properties of the two different fluids to perform several unique functions. The two liquids are thoroughly mixed together in a hot well and then heated in a heat exchange until all the water is vaporized into steam and the lubricant remains in liquid form at the vaporization temperature. The steam is then superheated and utilized as the working fluid for the engine and the lubricant is cooled before being sprayed into the engine crankcase to lubricate the bearings. After discharge from the engine, both the working fluid and the lubricant are cooled again and mixed together in the hot well. Therefore, an absolute seal between the steam and lubricant in the engine is not required.

The present invention provides a closed system which is particularly suitable for small engines up to 100 horsepower which are required to run without maintenance over a period of time. Since there is no loss of water from leakage into the lubricant and thus removal from the lubricant, there is no requirement for makeup water. Also, there is no danger of the lubricant getting into the boiler and carbonizing the boiler and thereby clogging the boiler. The powerplant can be set up to run continuously over a period of time in a cold climate since the mixture of the organic fluid with the water causes a freezing point depression of the water so that the water will not freeze in cold temperatures when the engine is shut down.

It is therefore an object of the present invention to provide a dual fluid Rankine cycle powerplant in which two fluids having different boiling temperatures are separated from one another by vaporization of one of the fluids which becomes the working medium for the engine of the powerplant, and the other fluid remains a liquid and becomes the lubricant for the engine.

Another object of the invention is to provide a dual fluid Rankine cycle powerplant in which the working fluid and lubricant are mixed together in portions of the cycle and are separated in other portions of the cycle, one of the fluids being water and the other being an organic lubricant.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic illustration of the dual fluid Rankine cycle powerplant indicating the temperature, pressure and substance at each point in the cycle.

FIG. 2 is a top plan view of a suitable phase separator.

FIG. 3 is a sectional view of a suitable hot well inlet which mixes the return water and lubricant at the entrance to the hot well.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the diagrammatic sketch of the powerplant of FIG. 1, both the liquid lubricant and the liquid working medium exist as a mixture in the hot well **10** in a proportion and at a pressure depending upon the requirements of the powerplant. In the example chosen for purposes of illustration only, the working medium is water and the lubricant can be any one of a number of organic substances, such as Ansul E-181 or Pluracol P-410, presently available on the market. The product known as Ansul E-181 is a polyglycol either produced by the Ansul Company of Marinette, Wis., and is described in the Ansul Company data sheet published June 1, 1967. Some of the various properties of this product are as follows: (a) boiling point of the product at atmospheric pressure is about 527° F.; (b) molecular weight of about 222; (c) freezing point is about −16° F. and (d) viscosity is 4.05 centipoise at 20° C. The product known as Pluracol P-410 is a polypropylene glycol produced by the Wyandotte Chemical Company.

In general, the lubricant can be chosen from glycols, ethers, polyglycol ethers (both akyl and aryl), and polyphenyls and the properties of the lubricant, in addition to good lubricating qualities, are as follows: (a) mixes well with water; (b) has a higher boiling point than water; (c) high thermal stability; (d) hydrolytic stability. Further, it is desirable that the lubricant have a molecular weight in the vicinity of about 400 and have a low vapor pressure to minimize the gas leaving the organic liquid during the steps of the cycle.

Referring again to FIG. 1, a passage **11** connects the hot well **10** with a pump **12** which pumps the liquid mixture in the hot well **10** to the coil **14** of heat exchanger **15**. Pump **12** raises the pressure of the liquid mixture to about 500 p.s.i.a. and the heat exchanger raises the temperature of the liquid mixture to about 280° F. before it leaves the heat exchanger through passage **16** leading to preheater tube bundle **18** of heat exchanger **20**. The heat exchanger **20** has a shell **21** containing a top flue opening **22** and a source of external heat **23** is applied to the lower end of the shell **21** to produce a heat exchange medium within the shell **21**. The discharge from the tube bundle **18** is through passage **24** which contains a liquid mixture of the organic lubricant and water at about 467° F., which is the boiling point of water at 500 p.s.i.a. Passage **24** leads to a second bundle of evaporator tubes **26** of heat exchanger **20** in which the water is changed from liquid to vapor and the discharge line **27** from the bundle **26** contains liquid organic lubricant and water vapor at about 467° F. and 500 p.s.i.a. Since the boiling point of the liquid lubricant at 500 p.s.i.a. is substantially above that of water, only sufficient heat is added in tube bundle **26** to evaporate all of the water in the mixture. Passage **27** connects the discharge from tube bundle **26** to phase separator **30** and enters the phase separator at the outer circumference tangentially thereto (see FIG. 3) to cause the mixture of liquid and vapor to swirl in the casing **31** of the separator. In the separator, the droplets of liquid lubricant go outwardly to the interior wall of the casing and fall under gravity to the line **32** whereas the vapor remains in the center of the casing **31** and rises into the top compartment **33** which is connected to the steam discharge line **34**. It is understood that any suitable type of phase separator could be utilized which will separate efficiently the organic liquid from the vapor. The separator is intended to prevent any entrainment of liquid lubricant in the steam and may combine elements of inertial separation, filtering and other known means of separating liquids and gases.

The steam in passage **34** then enters the superheater tube bundle **35** of heat exchanger **20** and leaves this tube bundle by line **36**. In line **36**, the steam is at 500 p.s.i.a. and is superheated to about 1,200° F. and in this condition, it is introduced into the engine **40** for expansion in the engine and exhaust through line **41** leading to condenser **42**. The steam leaving the engine is about 200° F. and 6 p.s.i.a. and the heat of condensation is removed in the condenser **42** so that exhaust leaves the condenser through discharge line **43** as water at about 170° F. and 6 p.s.i.a. and is returned by line **43** to the hot well **10**.

The liquid lubricant leaving the phase separator **30** in the passage **32** passes through tube bundle **50** of heat exchanger **15** in counterflow heat exchange relationship with the liquid mixture discharged from pump **12** and then is connected to the engine crankcase **49** through the passage **51**. The lubricant is at a temperature of about 200° F. and pressure of 500 p.s.i.a. and is pressure fed through nozzles into the crankcase to produce both a cooling effect and a lubrication of the engine parts, such as bearings. The lubricant discharged from the engine through passage **52** has been raised in temperature to about 300° F. and has dropped in pressure to about 6 p.s.i.a. while passing through the engine. The passage **52** connects to oil cooler **53** in which the temperature of the lubricant is further decreased to a discharge temperature of about 170° F. in line **54** leading to the hot well **10**.

The two liquid substances enter the hot well **10** through passages **43** and **54** at the same temperature and pressure and are mixed in any suitable manner, such as by the inlet illustrated in FIG. 3 in structural form. The water in passage **43** is connected to the enlarged passage **60** and is given a swirl by the swirl vanes **61**. The lubricant in passage **54** is connected to the passage **62** which passes through the swirl vanes and discharges the lubricant in spray form at the jet end **63**. Thus, the lubricant is mixed into the swirling water in order to obtain a thorough mixture of the two liquids upon entering the hot well **10**.

From the above description, it is apparent that the organic lubricant must remain a liquid at the temperature and pressure at which the water is converted into steam and that the liquid must be readily soluble in water so that it can be easily separated from the steam in the phase separator **30**. Also, the organic lubricant must have a high thermal stability so that it will not vaporize into the steam when the temperature of the liquid mixture is raised to the evaporation temperature of the water. Most importantly, the liquid must retain good lubricating qualities at the elevated temperature in which it must lubricate the engine and it must not be flammable at these temperatures. When the engine is shut down, the mixture of organic lubricant and water is stored in the hot well **10** and since the organic liquid depresses the freezing temperature of water, the mixture remains liquid at much lower temperatures than if unmixed water were separately stored for use in the engine. Thus, the engine can be used in much colder climates than the conventional type of steam engine.

In prior engines, when the steam gets into the lubricant, foaming of the oil can result, thereby reducing the lubricating properties and elaborate separators must be utilized to separate the oil from the steam. In this separation, water is removed from the cycle which must be made up continually and requires an attendant for this purpose. In the event the oil gets into the steam, it has a tendency to carburize the boiler and therefore must be separated from the steam and new oil added for lubrication. In order to guard against these happenings, it is necessary to have an absolute seal between the steam and the lubricant in the engine, which seal involves very expensive design elements and results in an expensive engine. In utilizing separate liquids as the working medium and the lubricant in the present invention and having these two substances thoroughly miscible and easily separated, it is not important to keep the two substances completely separate in the crankcase of the engine or in the exhaust from the engine. Any addition of lubricant to steam and steam to lubricant is taken care of in the phase separator prior to the reentry of these substances into the engine. It is only necessary that the separation be such that no lubricant passes from the separator to the superheater where it would break down and carburize at the elevated temperature, thus reducing the efficiency of the superheater. Since there is no necessity of adding makeup water to the engine of the present invention, the engine can be run without maintenance over a considerable period of time as a closed system and is particularly suitable for small engines such as 100 horsepower. It is understood that the desired example is simply illustrative of liquids that can be used as the working medium and the lubrication and is simply illustrative of pressures and temperatures at various locations in the powerplant. It is understood that the engine can be any suitable type, such as reciprocating or rotating, and that the external heat source **26** can utilize either chemical, isotope or nuclear fuel. Higher steam temperatures can be used in the powerplant of the present invention with resulting higher thermal efficiencies, because the lubricant is not mixed with the working medium at the higher steam temperatures. The lubricants used in the invention are the best type available and are satisfactory for use in subfreezing environments in which the engine can be operated.

I claim:

**1**. A dual fluid Rankine cycle powerplant comprising:
an expansion engine;
a first liquid providing a working medium for the engine;
a second liquid utilized as the lubricant for the engine, said second liquid being soluble in all proportions in said first liquid and having a higher boiling point than said first liquid;
means for storing said liquids as a mixture at the lowest temperature and pressure in said powerplant;
pump means connected with said storage means for increasing the pressure of said mixture of liquids;
heat exchanger means connected with said pump means for raising the temperature of said mixture of liquids to vaporize said first liquid only;
separator means connected with said heat exchanger means for separating the vapor from said second liquid;
means for superheating said vapor prior to introduction of said vapor into said engine for expansion therein;
means for introducing said second liquid to said engine as a lubricant; and
means for exhausting said second liquid and said vapor from said engine through cooling means to said storage means and recombining said liquids into a mixture.

**2**. A powerplant as defined in claim **1** wherein said first liquid is water and said second liquid is an organic lubricant.

**3**. A powerplant as defined in claim **2** wherein said organic lubricant is selected from the group consisting of glycols, ethers, polyglycol ethers (akyl and aryl), and polyphenyls.

**4**. A powerplant as defined in claim **2** wherein said organic lubricant is selected from the group consisting of polyglycol ether and polypropylene glycol.

**5**. A powerplant as defined in claim **2** wherein said organic lubricant is thermally stable at the vaporization temperature of said first liquid and will not hydrolyze.

**6**. A powerplant as defined in claim **1** wherein said heat exchanger means comprises a preheater for raising the temperature of said liquid mixture to the vaporization temperature of said first liquid and an evaporator for vaporizing said first liquid.

**7**. A powerplant as defined in claim **1** having a counterflow heat exchanger connected with output of said pump upstream of said heat exchanger means and with the liquid output of said separator means upstream of said engine.

**8**. A dual fluid Rankine cycle powerplant comprising:
an engine;
a first substance providing a working medium for the engine;
a second substance providing a lubricant for the engine having a higher boiling point than said first substance, said

first and second substances when in liquid form being completely miscible in one another to provide a liquid mixture;

heat exchanger means for raising the temperature of said mixture to vaporize said first substance only;

separator means for separating the vapor of said first substance from said second substance;

means for superheating said vapor prior to introduction of said vapor into said engine for expansion therein; and

means for introducing said second liquid to said engine as a lubricant.

9. A powerplant as defined in claim 8 wherein said first substance is water and said second substance is an organic lubricant.

10. A powerplant as defined in claim 9 wherein said organic lubricant is selected from the group consisting of glycols, ethers, polyglycol ethers (akyl and aryl), and polyphenyls.

11. A power plant as defined in claim 9 wherein said organic lubricant is selected from the group consisting of polyglycol ether and polypropylene glycol.