Sept. 15, 1964 H. E. KARIG 3,148,508

CLOSED CYCLE POWER PLANT

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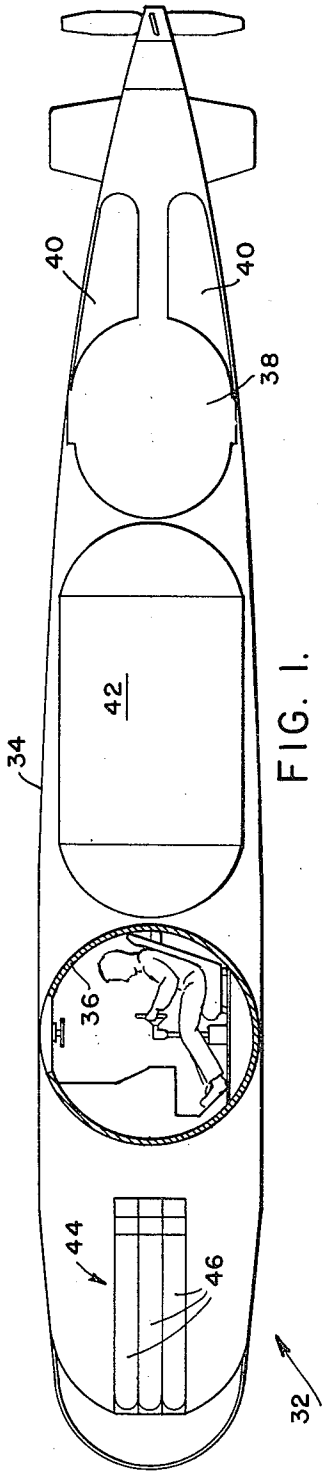


FIG. 1.

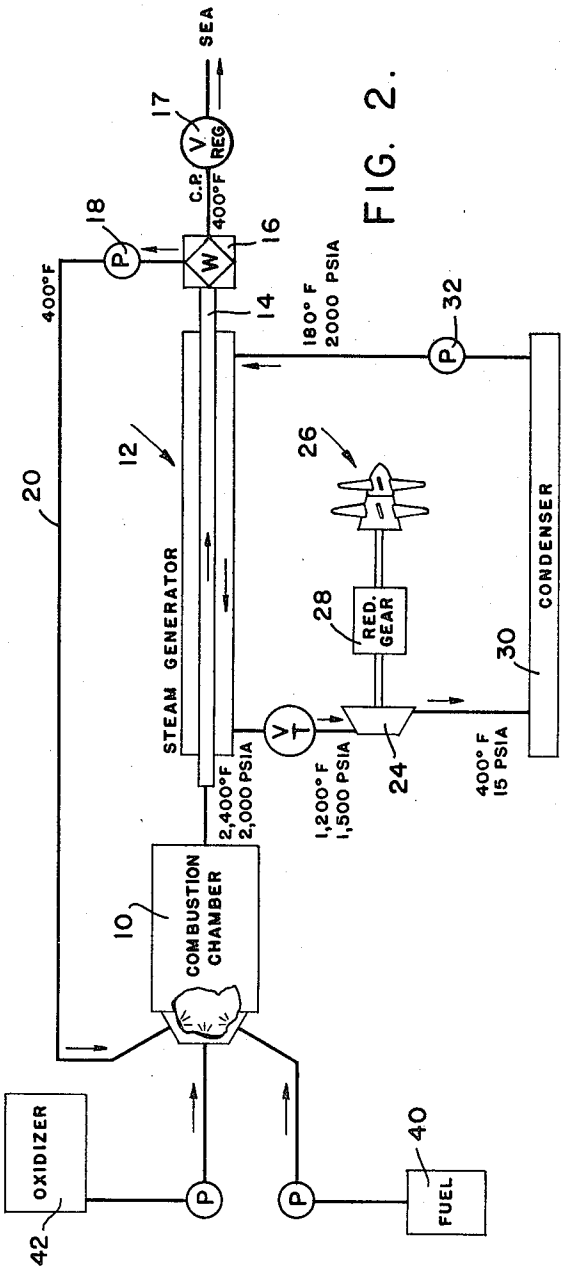


FIG. 2.

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CLOSED CYCLE POWER PLANT

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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to power plants for propelling underwater vehicles, such as torpedoes and submarines, and particularly at considerable depths of submergence.

Torpedoes, the principal armament of submarines, have long been used for destroying surface ship targets. In seeking the destruction of enemy submarines, when submerged, it has long been the practice to employ depth charges. During the past two decades the homing torpedo has been developed to a high state of perfection and has been employed as a more effective weapon than the depth charge. To evade destruction by such torpedoes, submarines have been redesigned to submerge to greater depths, and in turn, torpedoes have been redesigned to seek submarine targets at these greater depths. The development of the weapon and the target thus proceed in a seemingly endless race in which the submarine must submerge to depths beyond the capabilities of enemy torpedoes if it is to evade their destructive action and the torpedo must submerge to the greater submarine depths if it is to be effective.

Warfare at these continually increasing depths has imposed vastly different requirements on the propulsion apparatus of torpedoes and submarines. Capability of operating at greater depths is obviously a basic requirement. Speed of operation at increased depths is also important since the faster submarine may evade the slower torpedo or the faster torpedo may destroy the slower submarine. Increased speed, in turn, has imposed more severe requirements on the propulsion systems, particularly their power per unit volume or weight. Since fuel carrying capacity, particularly with torpedoes, is limited, the efficiency of the power plant must be as high as possible to thus enable a payload explosive to be delivered to its target at maximum depth, with maximum speed and without seriously detracting from the weight of payload.

Gas operated engines have been employed to propel torpedoes and submarines. In one type an open cycle is employed in which combustion gases are exhausted into the sea after passing through the engine. Such type of engine suffers the disadvantage that its power output materially decreases with increased depth due to the back pressure of ambient water.

The Walter cycle is another form of gas operated engine in which the back pressure on the system is maintained at a lower pressure than the ambient depth pressure by condensing the large fraction of water vapor in the exhaust gases by direct contact with seawater. It is then necessary to pump out the condensate with the seawater coolent and also the non-condensible fraction of the exhaust gases. At increasing depths, this pumpout power represnts a large portion of the power available. Also, this system does not utilize any of the latent heat in the exhaust gases nor provide salt free water for diluent hot gas cooling.

Another recent development is exemplified by patent application of H. E. Karig, Serial No. 833,899, filed August 14, 1959, now Patent No. 3,109,401. In this development a closed condensing steam cycle is employed,

analogous to parts of the present invention, the source of boiler heat being a propellant grain, the products of combustion of which are exhausted into the ambient water.

It thus becomes apparent that while power plants have been developed for deep running underwater vehicles they are still subject to considerable improvement and it is one of the objects of this invention to provide a power plant which obviates disadvantages of those heretofore proposed, and utilizes heretofore wasted energy.

Another object is to provide a power plant which is not adversely affected by the submergence pressure of increased depths.

Another object is to provide means for maintaining the hot gas side of a boiler pressurized at a desired pressure under all conditions of operating depth.

Another object is to transform a greater proportion of the heat content of fuel into useful work by utilizing the latent heat of a diluent.

Another object is to provide a power plant which employs diluent fresh water in a combustion chamber and obviates the use of sea water, or a carried tankage source of fresh water.

Another object is to employ the diluent water without lowering the heat available from the propellant employed in the combustion process.

Another object is to improve the rate of heat transfer from combustion gases to a steam boiler.

A further object is to reduce the size and weight of heat exchange surface of a steam boiler.

Still further objects, advantages, and salient features will become more apparent from the description to follow, the appended claims, and the accompanying drawing in which:

FIG. 1 depicts a small deep running submarine, equipped with torpedo armament, both of which may employ power plants forming the subject of the invention, and

FIG. 2 diagrammatically illustrates the principal components of such a power plant.

With reference to FIG. 2, the principal components of the invention may be divided into a high pressure or hot gas side and a low pressure or steam side. The purpose of the hot gas side is to generate heat energy by the combustion of fuel and the purpose of the steam side is to receive the heat energy and convert it to work in an engine and recirculate steam for again elevating its heat energy content. A boiler or steam generator connects the two sides and provides the means for transferring heat energy from the hot gas side to the steam side.

The hot gas side comprises a combustion chamber 10 into which is injected a liquid fuel, such as diesel oil, an oxidizer such as oxygen or hydrogen peroxide, and diluent water. These are all injected into the same zone of the combustion chamber, the water serving to reduce the combustion temperature below that which it would be in the absence of water. This reduction in temperature (from 3600° F. to 2400° F., for example) is essential since the materials chosen in the system, their weight and other factors dictate this lowered temperature. For example, bulky and heavy refractory materials which might otherwise be required to withstand the higher temperatures are thus obviated and the combustion chamber, as well as the steam generator to be subsequently described, may be constructed with less bulk and weight which are among the requirements for the power plant in its particular environments. Hot gas generated in the combustion chamber then flows through steam generator 12 and the diluent water formerly injected condenses, along with other water formed by chemical reaction of the fuel and oxidizer during the combustion process and its subsequent cooling. The gases leaving the steam generator at its exit

14 thus contains entrained water. A portion of the water is separated from the gases by any suitable separator 16 and the gases and excess water are exhausted into the sea through a pressure regulating valve 17. Water collected by the separator thence flows to a diluent pump 18 which returns it to the combustion chamber through conduit 20.

An important feature of the invention will now become apparent. When the diluent water was injected into the combustion chamber and the combustion temperature was thus lowered below that which it would have been in the absence of the diluent, a part of the heat of combustion was transferred to the diluent, principally in the form of latent heat of vaporization. In passing through the steam generator, however, this latent heat is transferred to the steam side of the system and hence there is no net heat loss attributable to latent heat of vaporization of the diluent.

The steam side comprises any suitable type of steam engine, such as a steam turbine 24 which rotates propellers 26 through reduction gearing 28, a condenser 30, and a feed water pump 32 which returns the condensate to the steam generator. The condenser is preferably of the surface type, having a heat transfer surface forming a portion of the hull of a torpedo or submarine which is in contact with seat water. By use of this expedient, the condenser is simplified and circulation of a condenser coolant is obviated.

FIG. 1 illustrates an application of the invention in which the power plant previously described may be employed for propelling a small submarine 32 which is adapted to destroy enemy submarines. The submarine comprises a hull 34 having balanced ambient water pressure on its exterior and interior and containing a spherical personnel compartment 36 constructed to withstand ambient pressure. The power plant is contained within a sealed capsule 38, also adapted to withstand ambient pressure, and is supplied with fuel and oxidizer from tanks 40, 42, respectively. One or more torpedo tubes 44 may be employed which contain torpedoes 46 propelled by a power plant such as the one employed in the submarine but of considerably smaller dimensions.

The source of heat, as illustrated, comprises a fuel and an oxidizer and a specific example of a liquid fuel and liquid or gaseous oxidizer has been described. Such fuels and oxidizers are commonly known as propellants or rocket propellants, distinguishable from fuels which are combusted by ambient air in that the source of oxidizer is carried by the vehicle or other device employing the propellant. "Propellant" as hereinafter employed in the description and appended claims is thus intended to be construed in that sense. Other propellants which may be employed include a solid powder grain such as employed in rockets or a metal which may be oxidized by water, such as finely divided lithium, such as in a slurry, and sea water. Hydrogen peroxide is also a well known oxidizer and, if employed, it may be decomposed in a chamber (not shown) ahead of the combustion chamber. Oxygen may be employed, either as a liquid or as a compressed gas. Carried oxidants, such as hydrogen peroxide or oxygen and a liquid fuel such as diesel oil or other hydrocarbon are advantageous in that their rates of flow and hence the rate of formation of heat may be easily controlled by throttling valves.

Pressure regulating valve 17, previously referred to may be varied as desired to produce various operational characteristics. Since the combustion gases in all embodiments of the invention must be exhausted into the sea, it will be apparent that a minimum requirement is to maintain the hot gas side above the back pressure produced by the ambient water at all depths of submergence. The magnitude of pressure above ambient may, however, be varied depending upon desired operational characteristics. Thus, in some applications it will be desired to maintain the hot gas pressure a fixed amount above ambient pressure, that is, maintain a fixed differential pressure, while in others it may be desired to maintain a substantially constant absolute pressure irrespective of the ambient water back pressure. If the overall efficiency of the system, irrespective of power, were the only consideration a small differential pressure would generally be more desirable. If the same power output is desired, however, at all depths a sacrifice in efficiency may become of relatively small importance. Thus, for tactical or other purposes, it may be desirable to operate the vehicle at a certain maximum speed irrespective of depth and, since vehicle drag is substantially independent of depth its speed is proportional to power output. The availability of such maximum power output may thus become the important consideration. To render available such maximum power output with the present invention at all depths may not be readily apparent, which can best be understood as follows by assuring that maximum depth hot gas pressure will be maintained at all depths. In the conventional boiler operating in the air, the pressure in the fire box or combustion chamber is only sufficiently above atmospheric pressure to produce adequate draft. The mass flow of hot gas across a unit area of heat conduction surface is thus relatively low and large areas are necessary. Since the amount of heat which may be transferred is a function of mass flow it becomes apparent that if the mass flow per unit area of conduction surface can be increased then the amount of surface necessary to transfer the same amount of heat may be reduced. As an example of the foregoing, the heat transfer coefficient for a boiler operating at 2000 p.s.i. is about 50 times greater than a boiler operating near atmospheric pressure. This high rate of heat transfer thus permits reduction in size and weight of the boiler and also reduces the size of the combustion chamber as compared with a combustion chamber operating slightly above atmospheric pressure. It becomes apparent, therefore, that since the size of the boiler and combustion chamber of this invention are designed for a certain maximum depth and constant available power for the vehicle is contemplated for all depths, the pressure in the hot gas side may be varied to suit the variable operating conditions.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A power plant for propelling underwater vehicles of the type which carry a fuel-oxidant propellant and are propelled by a steam system including a heat exchanger having a hot gas side and a closed cycle steam side, said closed cycle steam side including a steam engine, means for condensing the exhaust steam from the steam engine to feed water, and means for returning the feed water to the steam side of the heat exchanger, the improvements, in combination, comprising:

(*a*) a combustion chamber in which the propellant is adapted to combust and produce products of combustion and

(*b*) into which water diluent is adapted to be injected for lowering the temperature of the products of combustion by transferring latent heat of vaporization to the diluent, whereby the products of combustion contain water vapor,

(*c*) said products of combustion and water vapor adapted to pass through said hot gas side and transfer heat contained in the products of combustion and the latent heat of the water vapor to said steam side, condensing the water vapor to diluent water,

(*d*) means for separating the condensed diluent water from the remaining products of combustion,

(*e*) means for returning the condensed diluent water to the combustion chamber, and

(*f*) means for exhausing the remaining products of combustion to ambient water.

2. Apparatus in accordance with claim 1 including means disposed between the combustion chamber and the exhausting means for maintaining the pressure in the hot gas side above the exhaust back pressure resulting from variation in depth of submergence of the vehicle.

3. A power plant for propelling underwater vehicles of the type which carry a fuel-oxidant propellant and are propelled by a steam system including a heat exchanger having a hot gas side and a closed cycle steam side, said closed cycle steam side including a steam engine, means for condensing the exhaust steam from the steam engine to feed water, and means for returning the feed water to the steam side of the heat exchanger, the improvements, in combination, comprising:

(*a*) a combustion chamber in which the propellant is adapted to combust and produce products of combustion,

(*b*) said products of combustion adapted to pass through said hot gas side and transfer heat contained in the products of combustion to said steam side,

(*c*) means for exhausting the products of combustion to ambient water, and

(*d*) means disposed between the combustion chamber and the exhaust means for maintaining the pressure in the hot gas side above the exhaust back pressure resulting from variation in depth of submergence of the vehicle.

4. Apparatus in accordance with claim 3 wherein said means for maintaining the pressure in the hot gas side above the back pressure is constructed to maintain the pressure in the hot gas side a predetermined amount above the back pressure.

5. Apparatus in accordance with claim 3 wherein said means for maintaining the pressure in the hot gas side above the back pressure is constructed to maintain the pressure in the hot gas side substantially constant irrespective of the back pressure.

References Cited in the file of this patent

UNITED STATES PATENTS

1,983,294	Huttenmiller	Dec. 4, 1934
2,294,700	Stroehlen	Sept. 1, 1942
2,424,765	McCollum	July 29, 1947