United States Patent [19]

Payne

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[54] **HEAT ENGINE IN THE FORM OF A WATER PULSE-JET**

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[21] Appl. No.: **358,232**

[52] **U.S. Cl.** .... **60/227;** 60/221; 115/11; 115/12 R

[51] **Int. Cl.** **B63h 11/12;** F02k 7/02

[58] **Field of Search** .... 60/221, 227; 115/11, 12 R

[56] **References Cited**

UNITED STATES PATENTS

789,641	5/1905	Weeks	115/11
1,200,960	10/1916	McHugh	46/95
1,480,836	1/1924	Purcell	60/227
1,787,844	1/1931	Widdis	60/227
2,020,566	12/1935	Nelson	60/227
2,848,972	8/1958	Orzynski	115/11
2,885,988	5/1959	Myers	60/221 UX
3,013,384	12/1961	Smith	60/221 X
3,079,751	3/1963	Lewis	60/227
3,103,783	9/1963	Smith	60/221 X
3,365,880	1/1968	Grebe	60/39.6 X
3,647,137	3/1972	Naydan	60/221

FOREIGN PATENTS OR APPLICATIONS

443,255	2/1936	United Kingdom	115/11
602,034	5/1948	United Kingdom	115/11
478,917	1/1928	Germany	60/227
347,591	1/1905	France	60/221

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Attorney, Agent, or Firm—Sughrue, Rothwell, Mion, Zinn & Macpeak

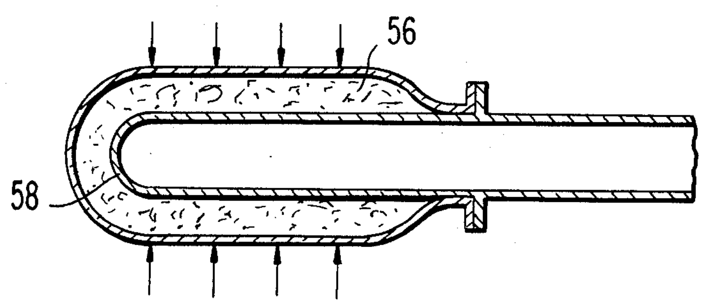
[57] **ABSTRACT**

A new heat engine in which liquid moves in a tube, one end of which is closed. The tube is heated at the closed end, and the liquid oscillates along the length of the tube. When the liquid interface enters the hot section, some of the interface vaporizes, so that the pressure in the space between the interface and the end of the tube increases, and the interface is forced back into the cooler section of the tube. The vapor then condenses, the pressure falls, and the liquid moves back toward the hot end.

The longer the tube in relation to size of the hot section or "boiler," the greater the momentum of the liquid when it enters the boiler, and the higher the peak pressure ratio which is developed. High pressure ratios are essential for efficient operation. It is also generally necessary for the boiler walls to be heavy enough to "store" the heat required for one complete cycle, and to be able to reject it to the water during the very short time that the interface is within the boiler.

The engine as described is immediately applicable to boat propulsion. With variations, it can be applied to many other uses, including the production of shaft power and the pumping of fluids.

9 Claims, 14 Drawing Figures



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SHEET 1

FIG.1 PRIOR ART

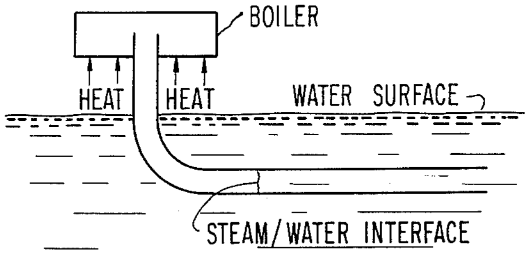


FIG.2

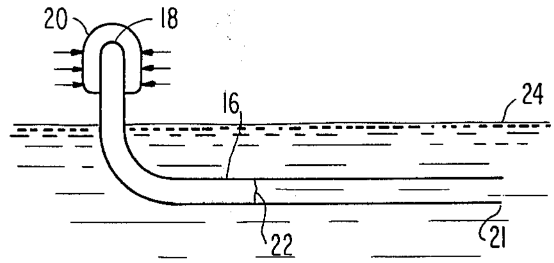


FIG.3

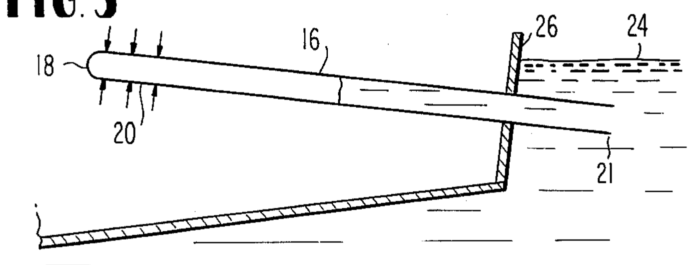


FIG.4

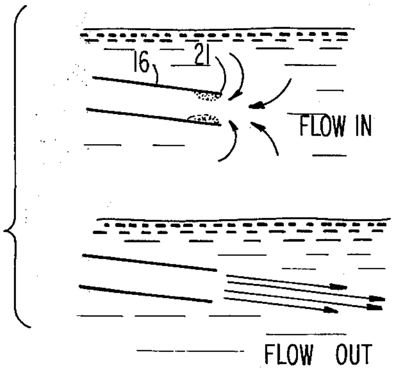


FIG.5

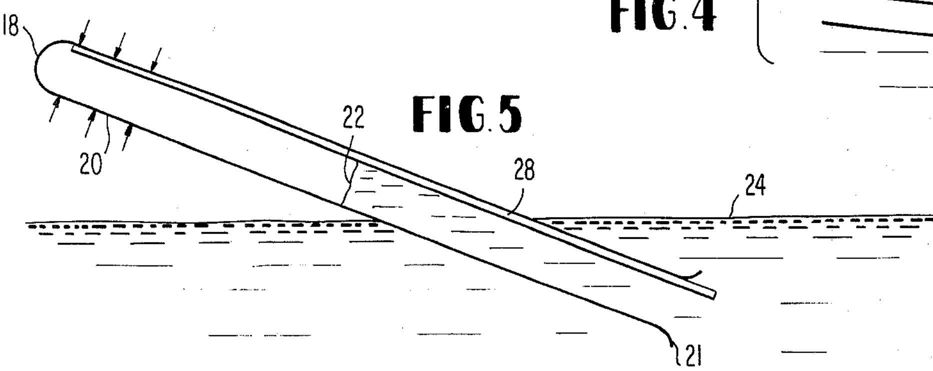


FIG.6

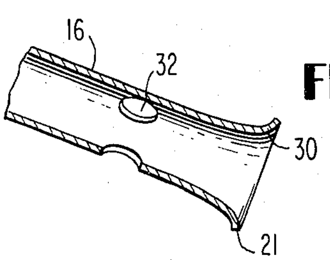


FIG.7

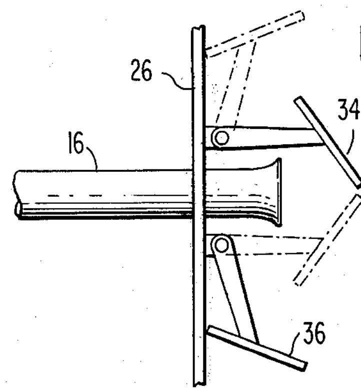


FIG.8

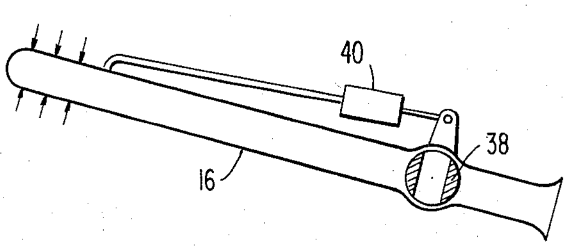


FIG.9

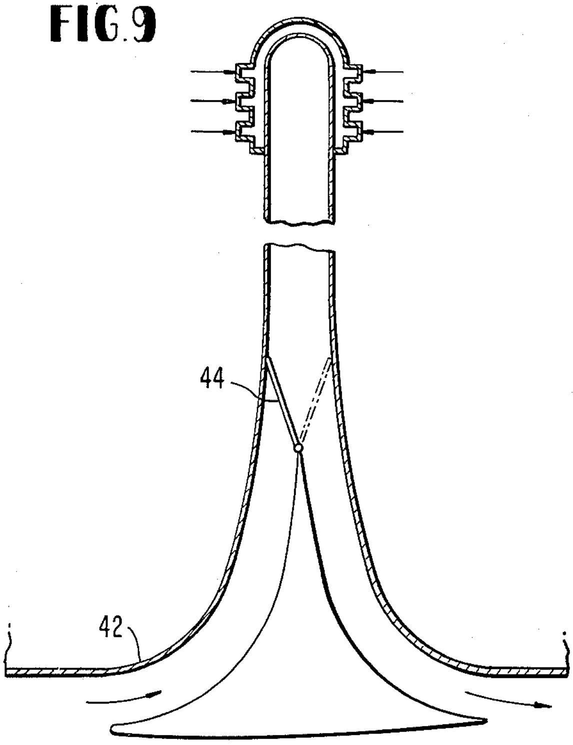


FIG.10

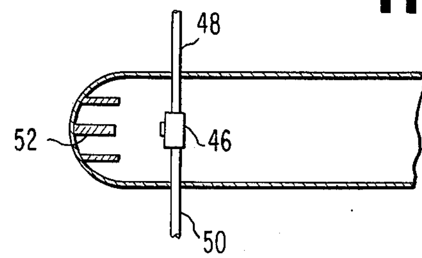
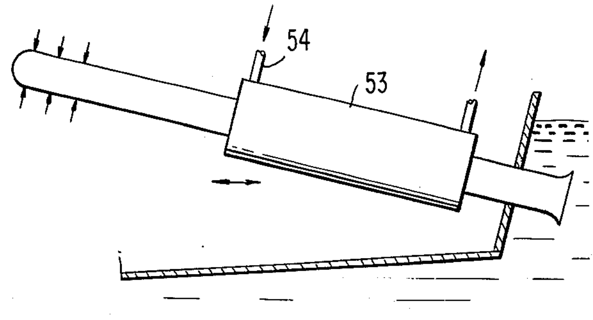


FIG.11



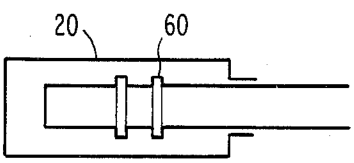


FIG.13

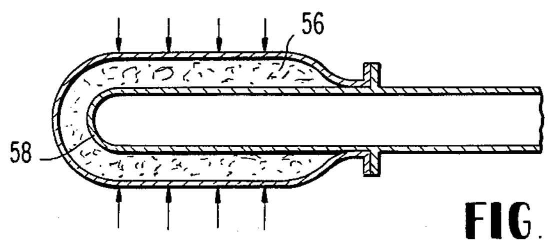


FIG.12

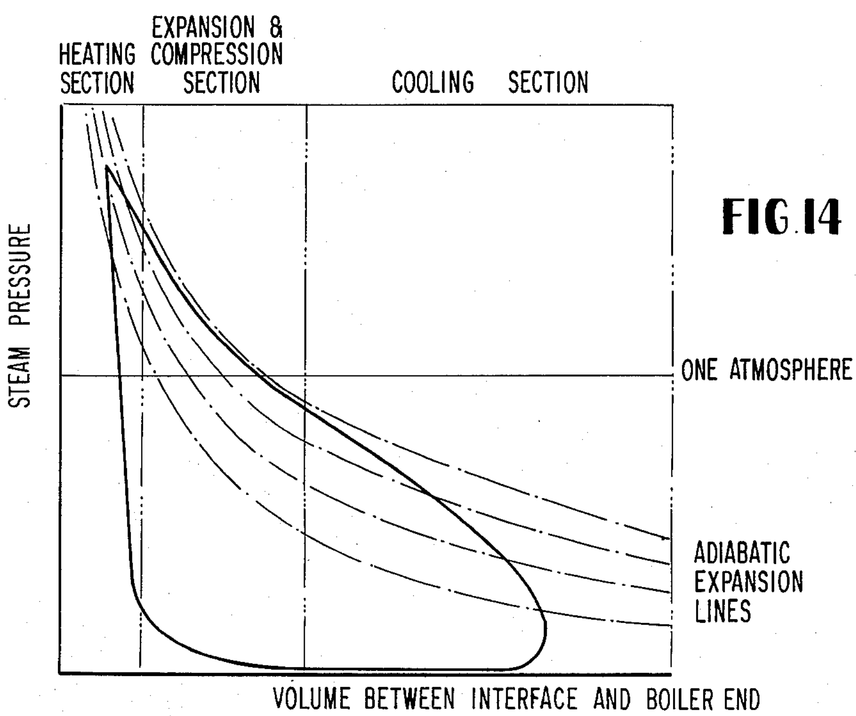


FIG.14

HEAT ENGINE IN THE FORM OF A WATER PULSE-JET

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a new heat engine particularly adaptable for use with water as a working fluid and producing useful energy by the pulse-jet principle.

2. Description of the Prior Art

In boat propulsion, it is conventional to start with a source of energy, e.g., fuel, which produces heat energy and to impart kinetic energy to the ambient water, so that the boat will be pushed forward by reaction. It is usual to have a great deal of machinery between these two extremes. For example, the fuel heats water in a boiler to make steam, which drives a turbine, which drives a water propeller via a gearbox, which develops a reactive thrust. In the present invention, the heat is applied directly to the ambient water in order to achieve the same effect, thus eliminating the intervening machinery. A known propulsive unit of this general type was patented by McHugh in **1916** (U.S. Pat. No. **1,200,960**), and the principle of his engine is illustrated in FIG. **1**. Assuming that there is initially some water in the boiler, the heat turns it to steam and pushes the ambient water interface down the tube. When all the water in the boiler has been turned to steam, the steam condenses in the cool section of the pipe, the pressure drops, and the water interface moves back toward the boiler. When it reaches the boiler, some water splashes in, and because the tube is raised above the floor of the boiler, this splashed water is trapped and is again turned to steam, pushing the interface down the tube. A net thrust force to the left is produced, principally because when the ambient water is flowing into the tube, it comes from all directions (a "sink" flow) while when it emerges, it comes out as a jet, because finite fluid viscosity prohibits "source" flows from a pipe (see FIG. **4**). Numerous other later patents all operate on the same principle of trapping a small quantity of water in the boiler at the end of each induction phase.

McHugh's invention was specifically for a toy boat, and most of the following inventors specify or imply the same application. It was recognized that the principle could not be scaled up to "full scale" boats principally because many people had attempted to accomplish this, particularly in the early **1920***s*, without success. There were two key reasons for this inability to scale up the phenomena. Firstly, the steam-water interface, shown in FIG. **1**, was preserved by surface tension, and this is only possible in very small diameter tubes. In larger tubes, there was no stable interface, and the steam bubbled into the ambient water and was condensed without moving the bulk of the water in the tube. More importantly, even if this problem had been solvable, the pressures developed were inherently low so that there was no possibility of achieving efficient operation.

SUMMARY OF THE INVENTION

In the present invention, illustrated in FIGS. **2** and **3**, the boiler is an integral part of the tube, and the momentum acquired by the water column as it moves toward the boiler is relied upon to hold the interface in the boiler long enough to produce a useful quantity of steam at high pressure. Stability of the interface between the steam and the water is obtained because, for most of the cycle, the water column is being accelerated toward the boiler. It is only accelerated away from the boiler when close to it or actually inside it, and this leaves very little time for the then unstable interface to actually disintegrate.

A P-V diagram of the unit's operation is given in FIG. **14.** For most of the cycle, the steam is condensing and the interface is slowing down from its initial rapid expulsion from the boiler. A "condensing section" is formally required, but in many practical cases, contact of the exhaust end of the tube with the ambient fluid is sufficient to provide this heat sink.

Since the fluid interface is in the boiler for only a very short period of time, it is important that sufficient heat for one cycle be "stored" in the boiler wall material, and that this heat be released to the water rapidly. This implies either a material having high conductivity and high specific heat or a material having high conductivity and substantial weight.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of the prior art water pulse-jets.

FIG. **2** is a schematic illustration of the water pulse-jet of this invention.

FIG. **3** is another schematic illustration of the water pulse-jet of this invention as applied to marine propulsion.

FIG. **4** is an illustration of the flow in and out of the open end of the tube.

FIG. **5** is a schematic illustration of one form of an air bleed.

FIG. **6** is a partial sectional view illustrating the exit end of the tube with a bell-mouth design.

FIG. **7** is a schematic illustration of mechanically operated vanes to deflect the exhaust.

FIG. **8** is a schematic illustration of the use of a valve for modulating thrust in the heat engine of this invention.

FIG. **9** is a schematic illustration of a water pulse-jet operable to recover ram pressure at high forward speeds.

FIG. **10** is a schematic illustration of the use of an internal burner.

FIG. **11** is a schematic illustration of an embodiment in which a condenser or cooling jacket is positioned inside the boat hull.

FIG. **12** is a schematic illustration of a high specific heat boiler.

FIG. **13** is a schematic illustration of a boiler for extended steam making.

FIG. **14** is a pressure volume diagram of the new cycle of this invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** is a typical prior art construction in which heat is applied to a boiler and a tube extends upwardly into the boiler. The disadvantages of such a construction and its limitations and lack of ability to scale it up have been described above.

FIG. **2** illustrates the present invention in which a tube **16** has one closed end **18** and one open end **21.** Heat is applied to an area adjacent the closed end **18** which may be termed a boiler **20.** The heat causes water in the tube **16** to vaporize and push the interface **22** to the right as viewed in FIG. **2** after some of the steam has condensed and the temperature of the remaining steam has been lowered by virtue of being under the surface of water **24**, the volume of the remaining steam contracts and the water-steam interface moves back to the left for additional water to be heated in the boiler.

FIG. **3** illustrates the invention as shown in FIG. 2 as applied to a boat hull **26** operating in the water **24.** Again, the tube **16** has a closed end **18** to which heat is applied at a boiler section **20** and an open end **21** for thrust propulsion as in FIG. **1.**

FIG. **4** illustrates the problems with the open end **21** of the tube **16** during the flow in and the flow out. During the flow in, there is a separated flow region as illustrated.

Various means are contemplated within the scope of the invention to bleed trapped air or other gas from the closed end of the tube. One such means is illustrated in FIG. **5.**

The problem arises when air or other gas can become trapped in or near the boiler region of a pulse-jet. This may be due to the exhaust exit momentarily coming out of the water; to a leak in the joint between the tube and boiler or elsewhere in the system; or because gas is boiled out of the water at the interface. In some engine configurations, as air leaks into the unit, or gas is boiled out, it collects near the end of the boiler and inhibits complete penetration of the boiler by the incoming interface. Eventually, after enough gas has accumulated, the unit stops operating entirely because the interface penetration of the boiler is so small that insufficient steam is generated to overcome the losses and the work involved in expelling the exhaust water. One solution to this problem is to orient the unit so that the boiler is near the lowest level, and most of the pipe inclines up toward the exhaust exit. (It can be sloped down again close to the exit.) Due to gravity, the bubbles of gas will then "work" their way towards the exit and escape to the ambient water.

Another solution to this problem is provided by a pressure relief valve in the boiler which is spring loaded to remain closed below a certain pressure, but vents steam and air when that pressure is exceeded. The degree of venting is controlled by the force at which the valve opens.

Another way of venting trapped gas, illustrated in FIG. **5,** is to run a very small diameter tube **28** from the top of the boiler to the ambient water. This tube may be external to the pulse-jet or it may run inside the main duct as shown. Gas at the top of the boiler flows into this tube when pressure is above ambient, and out when it is below. Because the flow in a small tube is laminar and because water-air interfaces are stabilized by surface tension, there is a net flow of the gas out of the boiler and down to the ambient water, so long as the unit is producing thrust; that is to say, so long as the integral of gauge pressure with respect to time is positive.

The exhaust end **21** of the tube **16,** may have a bell-mouth shape **30** as illustrated in FIG. **6,** and may have the holes **32** in its side, to reduce losses during the inflow stroke. If the Bell-mouth is not used, the intake flow shown in FIG. 4 causes separation just inside the tube, resulting in energy loss, and a reduction in the velocity at which the interface approaches the boiler, so that less penetration is achieved.

For steering and reversing purposes, mechanically or power-operated vanes **34, 36,** as shown in FIG. **7,** permit deflection of the exhaust. These are located far enough downstream from the nozzle so as not to interfere with the intake flow. A distance of one diameter is usually sufficient. If FIG. **7** is a top plan view, then the vanes are shown positioned to deflect the jet in such a way as to cause the boat to turn to the left. If both vanes come aft to meet behind the exhaust, then reverse thrust is obtained.

A thrust modulation valve **38** shown in FIG. 8 (shown in a closed position) may be provided and is opened by steam pressure. Assuming that the unit is charged, the water above the valve is trapped until the steam pressure rises above a certain preset value. This preset value can be applied with a spring, for example. WHen the pressure exceeds this value, a piston **40** opens the valve and the unit discharges. In practice, it generally recharges itself before the spring has time to reclose the valve, but in some cases where the valve inertia and friction are very low, it is necessary to mount a damper or time-delay device on the valve. The advantage of this valve is that the unit will still operate when the heat input to the boiler is too low for conventional (valveless) operation, or if the boiler is too light to store the heat required for one cycle.

The water pulse-jet of this invention may be provided with a forward facing intake. A unit is shown in FIG. **9** which accepts induction water from ahead through inlet **42** and expels it astern, thereby taking full advantage of the ram water pressure in the induction phase.

A two position valve **44** (self operating) may be utilized as a ram recovery valve. Alternatively, it is believed that a system may be provided in which three position valve is driven by an external motor in accordance with signals from a logic circuit which determines the optimum valve position. The logic circuit would be connected to one or more pressure or temperature sensors in the unit so that the location of the interface would be known.

FIG. **10** shows this invention with internal heating means, i.e., a pulse-jet in which the heat is supplied from a flame within the boiler. Because of its location, burner **46** must be supplied with air as well as fuel. This can be done by pressurizing air and fuel to force them into the unit through tubes **48** and **50,** respectively, or by allowing the low pressure which exists in the unit for part of the cycle to draw them in through non-return valves. The insoluble gases resulting from combustion are bled off, using one of the bleeder techniques described earlier.

When the fuel and air are supplied under pressure, it is predicable that some improvement in performance could be obtained by pulsating them so that little or no heat is added when the interface is away from the boiler, while the flame is at its maximum heat setting when the interface is in the boiler.

In order to obtain very quick "starts," it may be advantageous to substitute oxygen for air for the first few seconds of the pulse-jet's operation, so that steam is made very rapidly. Substitution of oxygen for air can also be used as a "booster" when it is required to increase the thrust output of the unit temporarily.

The embodiment shown in FIG. **10** also differs from the previously discussed embodiments in that it utilizes heat storage baffles **52.**

A condenser or cooling jacket as indicated in FIG. **11** may be used to promote condensation. The cold water supply **54** to the water jacket **53** may be from a pump or it may be induced by the motion of the boat through the water. Sliding such a water jacket towards the boiler would in general increase the frequency of operation, but reduce the thrust of the unit, so that movement of the water jacket **53** can be used as a method of thrust control.

In all external heating schemes and with internal heating when the flame is not "pulsed," most of the heat for one cycle has to be stored in the boiler wall and given up during a very short period, during which the interface is in the boiler. Metals having high specific heats (C_p) are therefore desirable. Examples are tin ($C_p = 0.55$) and lithium ($C_p = 0.79$), as compared with copper, for which C_p is only **0.1**. Because of their low melting points, the use of such metals in a boiler requires that it be jacketed. An idealized scheme is illustrated in FIG. **12** where high specific heat metals **56** are jacketed by highly conductive metals **58**.

As in all other cases, the boiler may contain fins such as the heat storage baffles **52** shown in FIG. **10** to better conduct the heat from the hot boiler material to the water and steam.

Means of trapping a small quantity of water in the boiler after the interface has left, such as the grooves **60** in FIG. **13,** so that steam is still made after the interface leaves the boiler may be used for steam making. The size of the trap is adjusted to ensure that all of the trapped water is boiled before the first part of the condensation cycle is complete, and the interface starts to return to the boiler. In certain configurations, such water traps can increase the thrust of the unit, for a given heat input.

FIG. **14** is an idealized P-V diagram for the cycle of this new engine. As the steam condenses, the inertia of the water rushing back toward the heating section carries the water well into the heating zone where it flashes into steam and the pressure builds very rapidly as shown on the left hand side of FIG. **14.** The high pressure steam arrests the movement of the water and accelerates it rapidly back in the other direction, which constitutes the expansion phase. The expansion is a little better than adiabatic because some heat is still being added to the steam by the boiler. When the water interface reaches the cooling section, steam starts to condense and the pressure falls. Despite the rapid fall off in pressure, the momentum of the water carries it well down into the cooling section so it is possible for virtually all of the steam to condense resulting in a very low pressure.

The starting procedure for a water pulse-jet (which is not self-starting, as some are) is as follows:

When the boiler is the highest part in the system, starting the unit can present difficulties. The boiler warms up, steam is made, and the interface moves down away from the boiler until a position of equilibrium is reached where the heat in is balanced by the heat out. If this happens, it is necessary to perturb the interface in some way in order for the unit to commence oscillating. A small piston, pushed up the tailpipe and then pulled out rapidly will achieve this, as will many other devices which will be obvious to those skilled in the art. For example, admission of a small quantity of cold water close to the boiler, cooling the outside of the pipe with cold water, use of a pyrotechnic charge, and so on.

While the requirements for the boiler have been described above, it is still necessary to define the best material for the tube itself. In general, that portion of the tube which sees either steam or water, depending on the position of the interface (that is to say, from the boiler proper down to a location at least halfway along the tube), the material should be

1. A poor conductor so that heat is not carried away from the boiler and dissipated uselessly in the water behind the interface;
2. A poor absorber of heat so that it does not extract heat from the steam too quickly.

One way of avoiding boiler heat loss along the tube is to introduce an insulated section close to the boiler, which effectively blocks any heat flow. An easier solution, although somewhat less efficient, is the use of thin-walled stainless steel tube, since this is a relatively poor conductor of heat. Other solutions are to coat the inside of the tube with a ceramic having the desired low absorption and low conductivity characteristics.

When the interface enters the boiler and is arrested, very high peak pressures can be developed, and in some configurations, these can be high enough to cause failure of either the boiler or the joint between the boiler and the pipe. The peak pressures are principally associated with the interface striking the top end of the boiler, and they may be alleviated by

1. Increasing the length of the boiler so that enough steam is made to arrest the interface before reaching the end;
2. Introducing some trapped gas into the boiler;
3. Mounting either the boiler or the entire unit resiliently with respect to the structure to which it is attached.

An example of the latter is a short section of rubber hose between the exhaust exit and the main portion of the pulse-jet pipe. Each time the unit experiences the peak pressure pulse, the hose stretches, allowing the entire unit to move forward and cushion the shock.

Water pulse-jets so far built have circular tubes and boilers for convenience. In principle, the duct can be of any shape and cross section that is convenient, although a circular section is to be preferred at the boiler and close to it because of the high pressures developed. The duct can also be coiled for compactness of installation or bent into any convenient shape, so long as it is remembered that each sharp bend causes a loss in efficiency. In some cases, the gyroscopic moment associated with the water flow in coiled ducts will give a steadying action to a boat in waves. The cross-sectional area of the duct and boiler can also change longitudinally.

If an outlet **21** is uncovered (by a motion of the boat in waves, for example) some water will ordinarily drain out of the unit or air will be drawn in, depending on where in the cycle this event occurs. Three means which is believed could be used to alleviate this problem are as follows:

1. A water height sensor could be connected to an electric motor so that, when the unit is within a certain critical distance of the surface, water is force fed to the pulse-jet from the side, so there is a constant outflow, and no room for air to enter.
2. An exhaust valve could be connected to a buoyant element which normally holds the exhaust valve open, but which closes when the water surface approaches the pulse-jet exit.

3. A valve could be provided in the unit, near the exit, which would shut off the unit entirely on receipt of a signal from a local water height sensor, and a second valve could be provided which would vent the boiler steam (at pressure) until the exhaust nozzle was back in the water. The logic network connected to the water height sensor could also cut back fuel flow to the heater during this shutdown period.

It is believed that a boiler could have a valve along its length so that only part of the boiler would be available to the water when operating at low thrust or at low forward speed. When the craft was moving at higher speeds, so that ram pressure (e.g., FIG. 9) provides more impetus for incoming flow, the valve could be opened to permit the full length of the boiler to be used in making steam. A multiplicity of such valves could be used to permit optimization of boiler length for various speeds through the water.

Various means of heating other than the burners described could probably be used. Several such means are set forth below.

A lens to focus the sun's rays on the boiler, in order to provide all or part of the necessary heat for the pulse jet's operation, could be utilized.

Instead of the boilers discussed so far, a heat exchanger which permits the coolant of an atomic pile to give up heat to the water each time the water enters the heat exchanger and hence operate the pulse-jet may be used. Such a system would be advantageous for use in atomic submarines, for example. Some isotopes can maintain a temperature in the range **300°–600°F.** for periods in excess of a month, and hence provide the necessary power for a pulse-jet. The isotopes may be mounted inside the boiler, or the boiler wall itself may be coated with or manufactured from the isotope.

THe foregoing discloses in detail the application of this new cycle to a particular problem, that of marine propulsion. But it will be understood that this new heat engine cycle can be applied in many other ways, to produce fluid or mechanical power from heat. That is to say, it can act as a pump or an engine. If water, or any other suitable fluid, is trapped in a pulse-jet by a piston, with an appropriately located water jacket for the condensing section, it will cause the piston to oscillate and do work. The same configuration could be used to make a pile driver. On a separated intake-exit unit, such as that illustrated in FIG. 9, one could connect a reservoir of fluid to the "inlet" and use the water pulse-jet to pump this fluid through the exhaust exit. Such a unit would be advantageous for producing a jet of water for fire fighting, for example. Small such units, equipped with reservoirs, could be used as water guns. Their nozzle velocity could be increased by multi-staging, whereby one pulse-jet element discharges the liquid into a second and from thence to a third, kinetic energy being added at each cycle until the liquid is finally discharged.

A separate inlet-exit pulse-jet can act as a pump to both heat and pump water around a hot water heating system. Operating the water column against an air or other spring, a water pulse-jet could be used as a steam generator.

In describing the present invention, water is referred to as the working fluid. However, any working fluid capable of changing from liquid to vapor on the application of heat may in principle be used. Alternatively, a trapped gas could be used as the working fluid, in which case it is not necessary for the fluid to vaporize.

Although one heat engine has been shown and described, it is within the scope of this invention to gang a plurality of such engines and synchronize their outputs in staggered fashion.

I claim:

1. A heat engine comprising:

a. a tubular member, said tubular member being completely closed at one end and open at the other to a source of working fluid such that the working fluid has access to said tubular member through the open end thereof;

b. heating means for heating the working fluid at the closed end of said tubular member;

c. a material having high specific heat around the closed end of said tubular member to store heat;

d. a jacketing material having high heat conductivity arranged around said material having high specific heat; and

e. cooling means for cooling said tubular member adjacent the open end thereof,

whereby, when said heating means are functioning during use of the heat engine, the working fluid has a liquid and a vapor phase and the working fluid oscillates within the tube as it is alternately vaporized by said heating means and condensed by said cooling means, thereby producing useful power.

2. A heat engine as recited in claim 1 wherein said jacketing material makes up at least a portion of the closed end of said tubular member.

3. A heat engine as defined in claim 2 which operates on the P-V cycle of FIG. 14.

4. A heat engine as in claim 2 wherein the working fluid is water.

5. A heat engine as in claim 2 wherein the walls of the tubular member store sufficient energy for one cycle.

6. A heat engine as in claim 2 wherein the tubular member is circular in section.

7. A heat engine as in claim 2 wherein the walls of the tubular member adjacent to closed end are of a material having high conductivity and high specific heat or substantial weight.

8. A heat engine as in claim 3, wherein the open end of the tubular member is immersed in the water.

9. A heat engine as in claim 2, wherein the tubular member has an internal diameter sufficiently large so that the surface tension of the working fluid in its liquid phase does not stabilize a liquid-vapor interface of the working fluid within the tubular member, said interface being stabilized both by momentum of the working fluid in its liquid state as it moves toward the closed end of the tube.

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