United States Patent [19]

Matvey

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[54] **ALTERNATING VANE TYPE ROTARY ENGINE WITH PLANETARY GEAR SYSTEM**

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[52] **U.S. Cl.** **418/18**, 418/36

[51] **Int. Cl.** **F01c 1/00**, F01c 21/16, F04c 29/10

[58] **Field of Search** 60/95, 108; 165/86; 418/18, 36, 37

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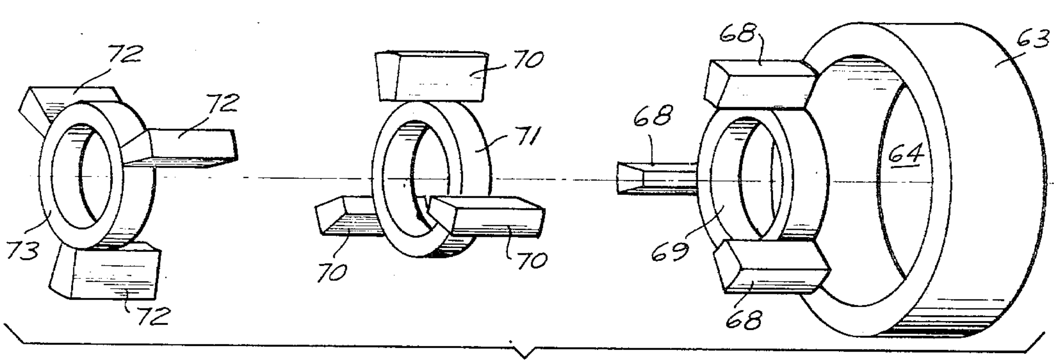
[57] **ABSTRACT**

This invention is directed to a closed cycle vapor power generating system and includes (1) a rotary vapor condenser enclosed by (2) an associated rotary vapor generator with both being operably connected to (3) an energy converter that receives high pressure vapor from the generator and returns low pressure expanded vapor to the condenser, and to (4) a combustion unit therefor, and to (5) a vapor process therefor. The energy convertor preferably is a rotary vapor engine including three sets each of three radial vanes located 120° apart which are operatively connected to a hypocycloidal planetary gear system for progressive movement of the sets toward and away from each other, the gear system being adjustable to vary the torque of the engine.

3 Claims, 16 Drawing Figures



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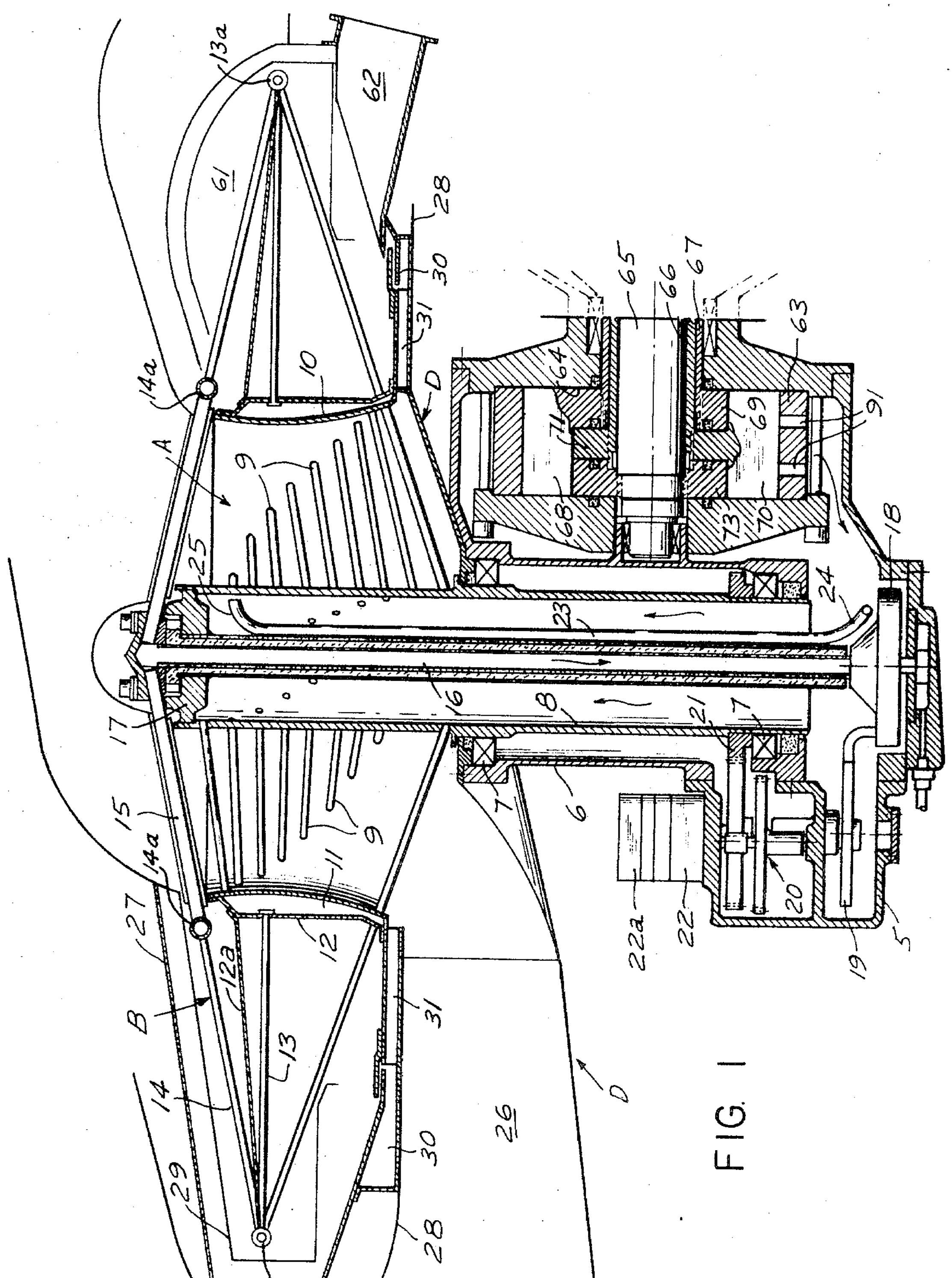

FIG. 1

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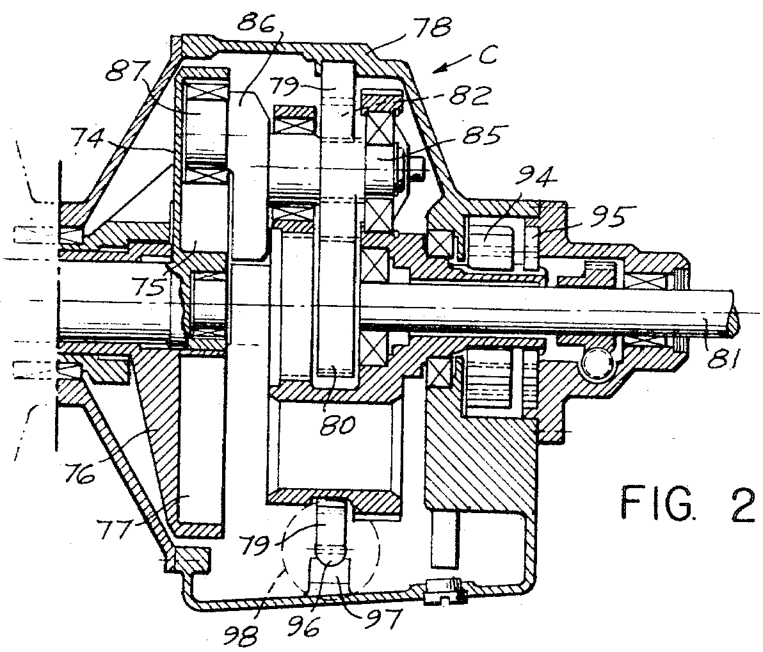

FIG. 2

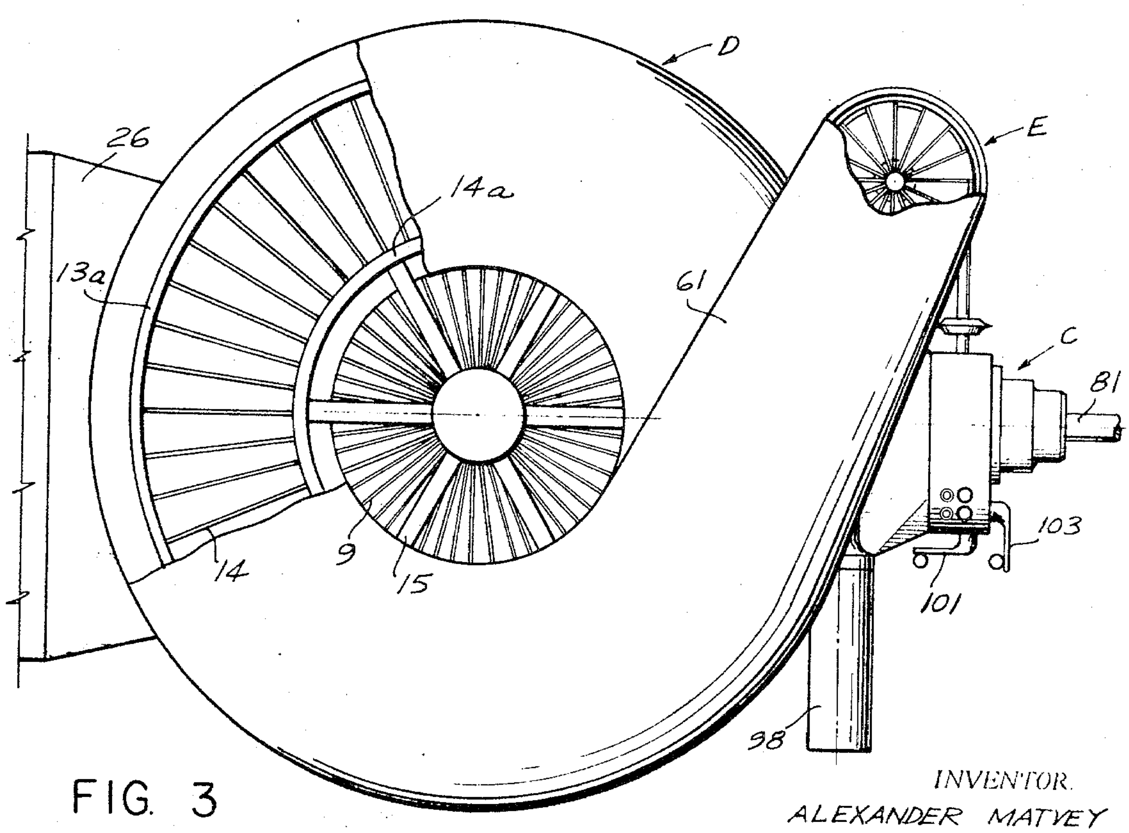

FIG. 3

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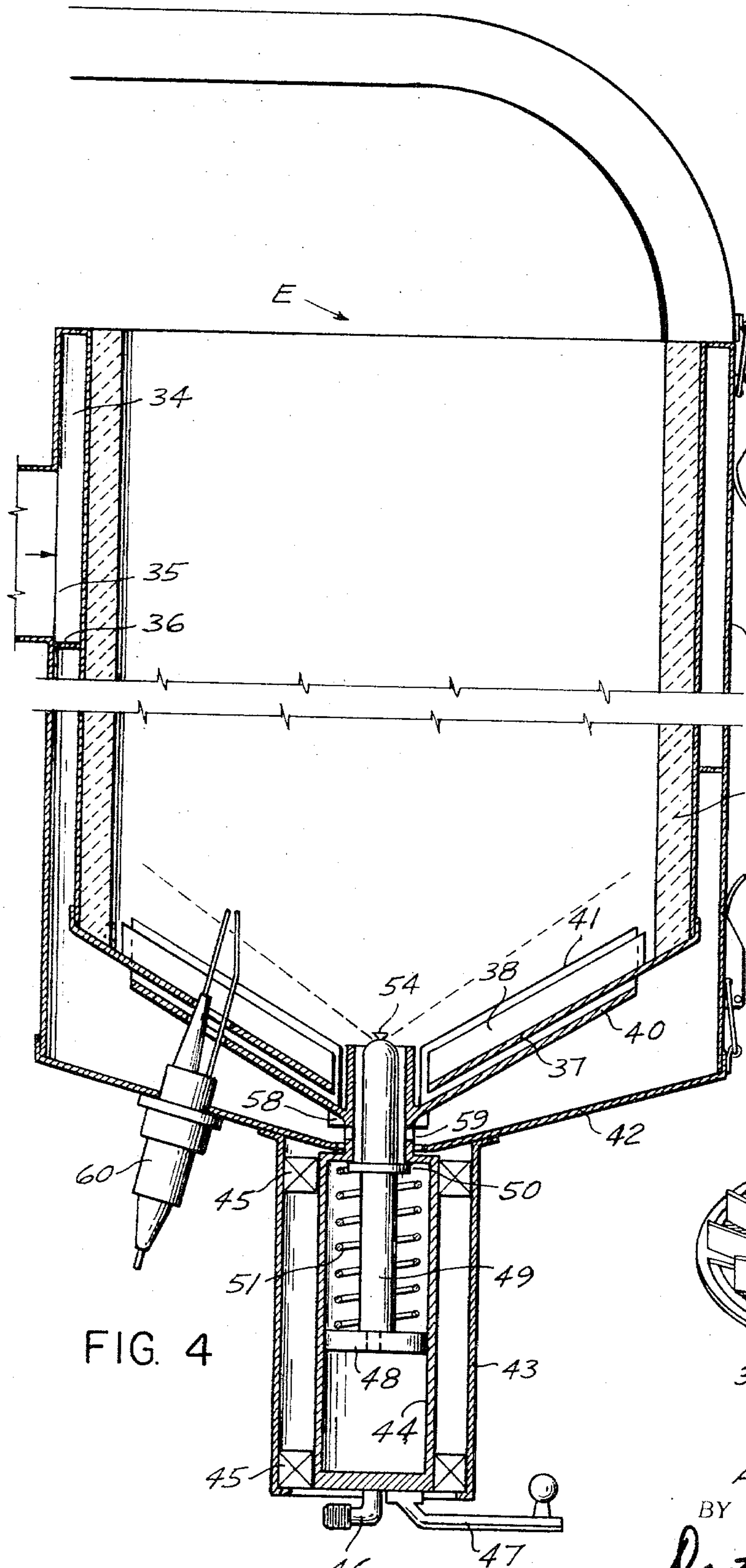

FIG. 4

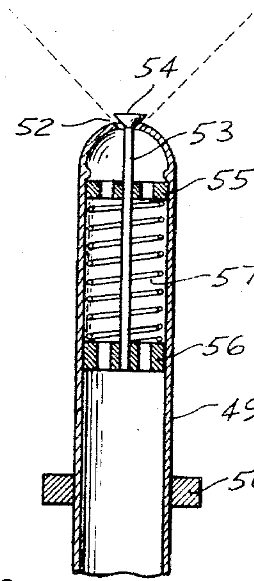

FIG. 5

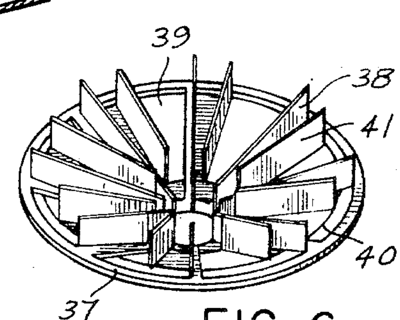

FIG. 6

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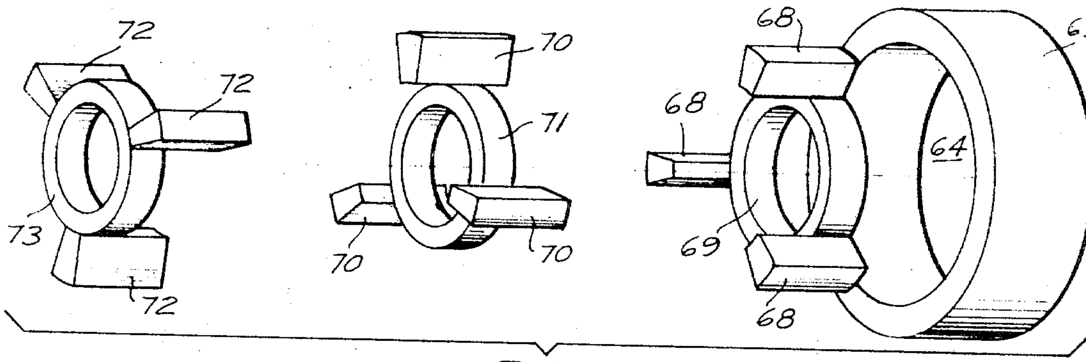

FIG. 7

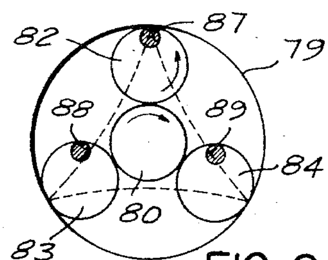

FIG. 8

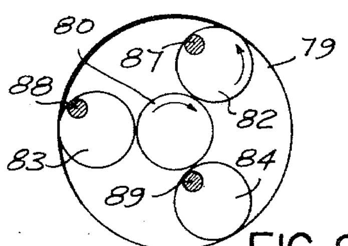

FIG. 9

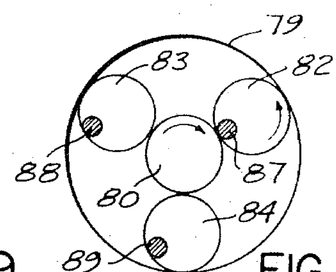

FIG. 10

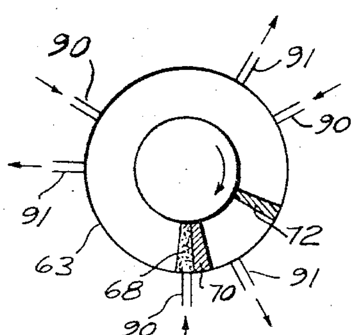

FIG. 11

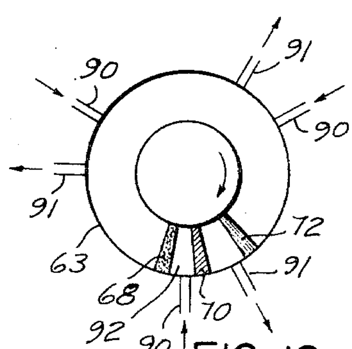

FIG. 12

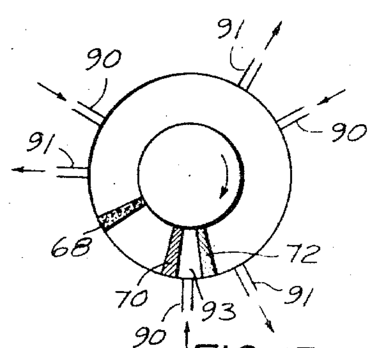

FIG. 13

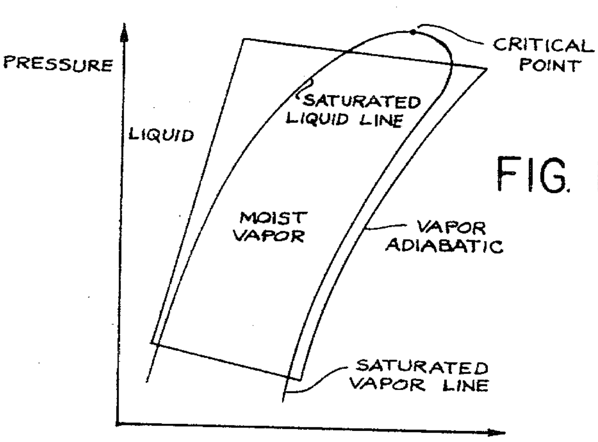

FIG. 15

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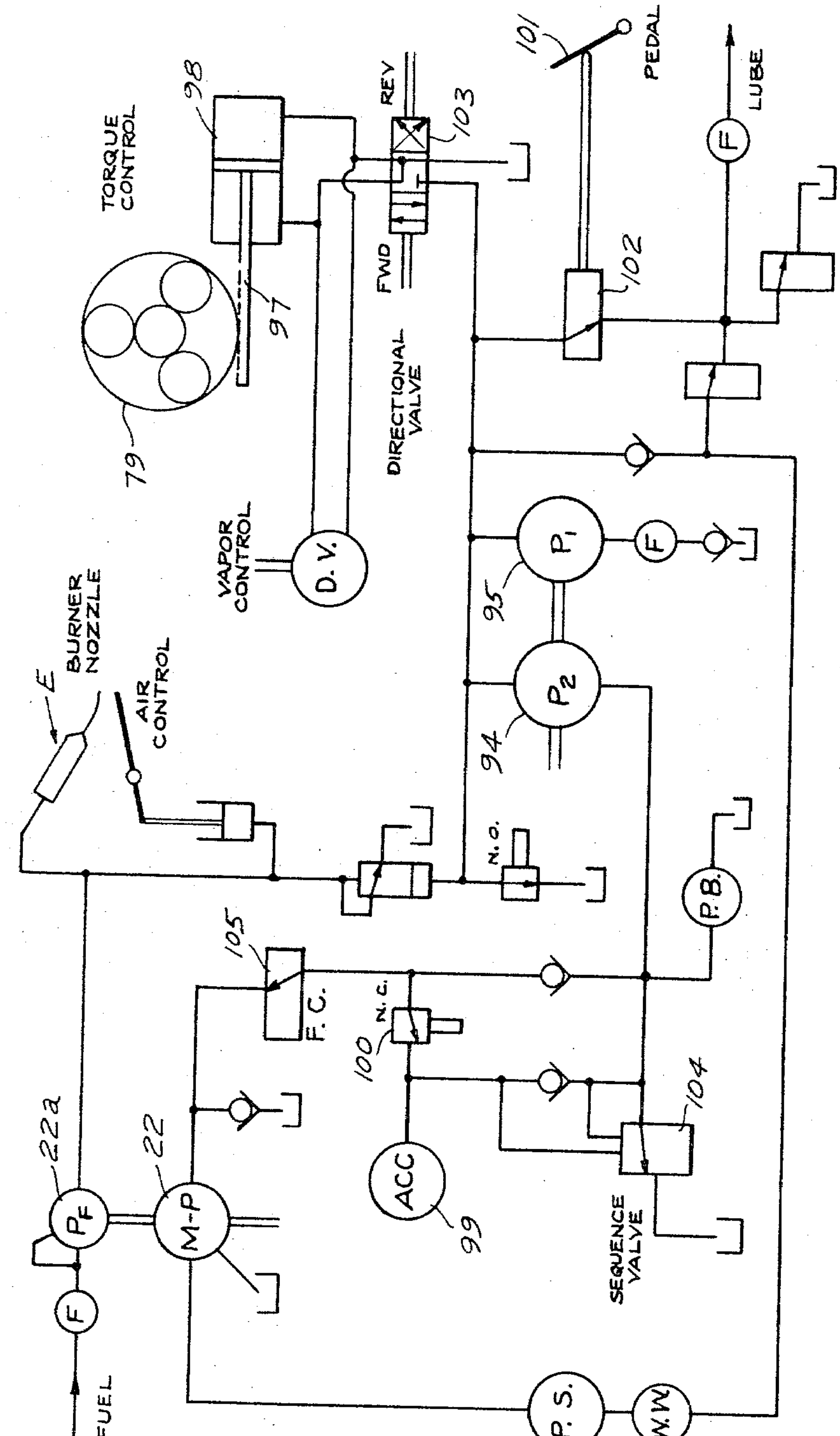

FIG. 14

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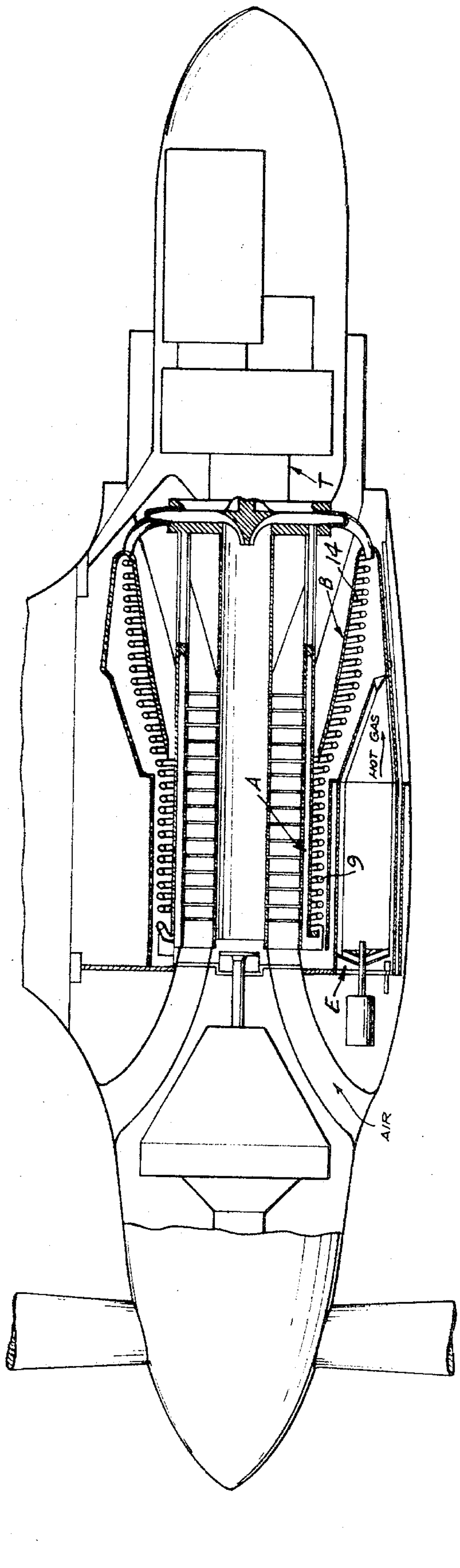

FIG. 16

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ALTERNATING VANE TYPE ROTARY ENGINE WITH PLANETARY GEAR SYSTEM

THE INVENTION

This invention relates generally to new and useful improvements in power generating systems and particularly seeks to provide a completely closed system that includes (1) a novel rotary vapor generator and condenser assembly that is operatively connected to (2) an energy converter that may be, for example, a novel rotary vane-type engine or to a high speed turbine that receives high pressure vapor from the generator and returns the expanded vapor to the condenser, (3) a novel combustion unit therefor and (4) a novel vapor process therefor.

Atmospheric pollution, particularly in metropolitan areas, has become a serious problem and it is well known that the exhaust gases from automobile internal combustion engines operating on either the Otto or Diesel cycles are substantial contributors to such pollution. Many efforts have been made to reduce these pollutants as by recycling crankcase vapors and catalytically treating the exhaust gases, but a major reduction in such pollutants is not believed to be either technically or economically possible because all such engines operate under conditions of incomplete combustion and result in a relatively low thermodynamic efficiency. Such engines also have a high noise level.

On the other hand, noise can be reduced and atmospheric pollution can be prevented through the use of a closed cycle external combustion engine system in which an energy converter receives high pressure vapor from a vapor generator and exhausts expanded low pressure vapor into a condenser that is operatively connected to the vapor generator. In such systems the combustion unit or burner that is used to supply heat to the vapor generator is operated with hot walls and an excess of air to assure complete combustion of the fuel.

It would seem that the energy converter for an external combustion engine system could be a steam engine, but up to the present time at least there are too many limitations in the use of steam engines or steam turbines for this purpose to make them practical. For example, the overall efficiency is quite low; the boilers are too bulky; transfer pumps are needed; and the systems are complex.

Furthermore, two thermodynamic properties of water make it inefficient and undesirable for energy conversion. First, the latent heat of evaporation of water is extremely high, when compared to the useful converted heat, thus requiring considerable energy just to evaporate it once the boiling point is reached and most of this energy will also have to be extracted from the expanded steam in the condenser in a closed cycle system, and therefore is wasted energy. Second, the slope of the saturation line of steam is such that the expansion of saturated or moderately superheated steam will always create moist steam which is inefficient and damaging to engine components, unless pressures and temperatures are very high. To avoid this effect superheating is necessary and reheating is mandatory in turbines or piston engines with multiple stages.

The use of very high pressures and temperatures, with or without superheating and reheating is considered impractical and undesirable for vehicle propulsion systems.

Accordingly, it is desirable to provide a closed cycle vapor generator-engine-condenser system that can be operated with fluids other than water. Such fluids have a lower latent heat of evaporation and their saturated vapor lines should follow the general direction of the adiabatic expansion line or the constant entropy line to increase the potential efficiency without requiring reheating. Such fluids should have a specific gravity greater than 1.4; a molecular weight less than the 190; a boiling point less than 100° C at atmospheric conditions; the slope of the saturated vapor line on an estropy-enthalpy diagram should be negative; and the ratio between the latent heat of vaporization and the heat available during adiabatic expension (when operating between the normal limits of temperature, i.e., 500° C and the ambient temperature) should be less than 2.

Examples of commercially available fluids that are usable for this purpose are trichloroethylene, carbon tetrachloride and the following halogenated hydrocarbons, trichlorofluoromethane, dichlorodifluoromethane, chlorotrifluoromethane, chlorodifluoromethane, 1,1,2-trichloro-1,2,2-trifluoroethane and sym-dichlorotetrafluoroethane.

A power system constructed in accordance with this invention can operate with such fluids in a unique manner with high efficiency and without causing any substantial air pollution.

The system also contemplates the use of a novel rotary vane-type engine that is particularly adapted for use with vehicles whose operation require wide variations in torque and speed. Novel features of such an engine include; the capability of operating without separate lubricants for many of the moving parts; zero head space; no valves; time control of full pressure vapor admission, rather than variations in orifice size, to avoid throttling effect; built-in torque controlled vapor admission to vary output power and speed; easy reversing or power braking; and pedal actuation of an analog hydraulic control circuit to regulate the amount of air and fuel supplied to the combustion unit for heating the vapor to be supplied to the engine and to control the duration of vapor admission into the engine.

Therefore, an object of this invention is to provide a novel vapor cycle and power plant which will enable the extraction, from the vapor, of all of the available energy in a single stage without requiring reheating or regeneration.

Another object of this invention is to provide a power plant of the character stated that includes a novel rotary condenser.

Another object of this invention is to provide a power plant of the character stated that includes a novel rotary combined condenser and vapor generator.

Another object of this invention is to provide a power plant of the character stated in which the combined condenser-generator is operably connected to an energy converter that receives high pressure vapor from the generator and returns the expanded low pressure vapor to the condenser.

Another object of this invention is to provide a power plant of the character stated in which the energy converter is a rotary vane-type engine or a turbine.

Another object of this invention is to provide a power plant of the character stated in which the combined condenser-generator is driven by the high pressure vapor during idling and from the output shaft of the engine at other times.

A further object of this invention is to provide a power system of the character stated that is compact, light weight, has no external piping for working fluid, operates under a high thermal and mechanical efficiency, has low transfer losses and has a high engine efficiency due to very low chamber residual volume and high expansion ratio.

Another object of this invention is to provide a thermal power system of the character stated that operates on a thermodynamic cycle along polytropic lines.

Another object of this invention is to provide a power system of the character stated that employs only a small predetermined amount of fluid in the fluid-vapor-fluid cycle.

Another object of this invention is to provide a power system of the character stated in which the drive for the combined rotary vapor generator and condenser is also used to drive certain items of auxiliary equipment.

Another object of this invention is to provide a rotary engine that includes three power rotors having three vanes each and assembled within a cylinder or cage to form three sets of chambers of variable volumes.

A further object of this invention is to provide a rotary engine of the character stated in which the relative positions of the rotors are controlled by three crankpins attached to three satellite gears of a hypocyclic gear train that includes an internal ring gear and may include a sun gear.

A further object of this invention is to provide a rotary engine of the character stated in which the rotor vanes themselves control vapor admission and exhaust, and the cut off points therefor, and thus the torque, may be varied either by changing the angular position of the vane cage or that of the internal ring gear of the hypocyclic gear train.

A further object of this invention is to provide a novel combustion unit for supplying heat to a vapor generator.

A further object of this invention is to provide a novel method for generating power in a closed cycle fluid system.

With these and other objects, the nature of which will be apparent, the invention will be more fully understood by reference to the drawings, the accompanying detailed description and the appended claims.

In the drawings:

FIG. 1 is a longitudinal vertical section of the condenser and vapor generator portion of a vehicle propulsion system constructed in accordance with this invention;

FIG. 2 is an extension to the right of FIG. 1 and is a longitudinal vertical section of the rotary vane engine portion of the vehicle propulsion system;

FIG. 3 is a top plan view of the mechanism shown in FIG. 1;

FIG. 4 is an enlarged vertical transverse section of the combustion chamber for the vapor generator;

FIG. 5 is an enlarged vertical transverse section of the fuel nozzle for the combustion chamber;

FIG. 6 is an enlarged detail perspective of the air control vanes for the combustion chamber;

FIG. 7 is an exploded isometric view of the three sets of engine vanes;

FIG. 8–10 are schematic views showing the successive relative positions of the planetary gears during one cycle of operation of the engine vanes;

FIGS. 11–13 are schematic views corresponding to FIGS. 8–10 and show the relative positions of the engine vanes during one cycle of operation thereof;

FIG. 14 is a schematic flow sheet for the hydraulic, fuel and lubricating systems;

FIG. 15 is a representative pressure-enthalpy diagram and shows the vapor cycles for this power system; and

FIG. 16 is a somewhat schematic longitudinal vertical section of the condenser and vapor generator portion of a vehicle propulsion system constructed in accordance with this invention but adapted for use with aircraft or other types of turbine energy convertors.

Referring to the drawings in detail the invention, as illustrated, is embodied in a closed cycle system and includes a rotary vapor condenser generally indicated A, an annular vapor generator generally indicated B that surrounds the condenser A and rotates therewith, and a vane type rotary engine generally indicated C that operates on high pressure vapor from the generator B and exhausts the expanded vapor back to the condenser A.

More specifically, the condenser-generator assembly A and B includes a base casing **5** provided on its top with an upstanding tubular casing **6** having upper and lower ball or roller bearings **7, 7** that rotatably support a tube **8** that carries the condenser-generator assembly.

The condenser A includes a plurality of sets of helically arranged tubes **9** that extend generally radially from the tube **8** to an annular shell **10** that is concentric with the tube. Low pressure expanded vapor from the engine C is admitted through the open bottom of the tube **8** and passes upwardly therealong and hence radially outwardly through the tubes **9** where it not only condenses but becomes subjected to progressively increasing pressure as the condensate approaches the outer ends of the tubes due to the centrifugal force developed as the result of the rotation of the condenser-generator. Cooling air passes around the exteriors of the condenser tubes as will be hereinafter more fully described.

The condensate from the tubes **9** is thrown rapidly by centrifugal force into an annular void **11**, defined by the shell **10** and a complementary outer shell **12**, which preheats the condensate, as a thin layer which did not become undercooled within the condenser area, from which it is directed into a multiplicity of radially extending pre-heater tubes **13**, the outer ends of which are connected to an annular header tube **13***a*, and superheater tubes **14**, the inner ends of which are connected to an annular collector tube **14***a*, of the vapor generator B (see FIG. **1** and **3**) which are heated by the hot gases from a fuel burner to revaporize the liquid as will be hereinafter more fully described. In this manner the condenser is self-purging and a very rapid circulation of the vapor - liquid - vapor is established and maintained.

The collector tube **14***a* connects with a plurality of inwardly extending insulated radial tubes **15** that extend into open communication with an insulated vertical duct **16** that delivers the high pressure vapor to the engine C and to a single wheel turbine for driving the condenser-generator at its desired speed of rotation. The upper end of the duct **16** is supported by a plug **17** that closes the upper end of the tube **8** and its lower end is closed by a rotary seal in a directional valve generally indicated at **18**.

The condenser-generator assembly A and B is power driven from a single wheel turbine 19, mounted in the base casing 5, and reduction gears generally indicated 20 which in turn drive a gear 21 rigidly affixed to the tube 8 adjacent the lower end thereof. The reduction gears 20 may also be used to drive certain auxiliary pumps such as a motor-pump indicated 22 and fuel pump 22a that may be mounted on the top of the base casing 5.

A tubular condensate scoop 23, having a curved lower end 24 located adjacent the seal 18 and a curved upper end 25 directed toward the inner wall of the tube 8, is secured to the outside of the duct 16 and serves to lift any liquid condensate from the bottom of the unit up into the condenser where it will be removed by centrifugal force as the unit rotates.

The condenser and generator tubes 9, 13 and 14, are enclosed by a fixed housing generally indicated D (see FIG. 1 and 3) that somewhat resembles an oblate spheroid in shape and includes a radially extending air intake 26, a generally convex upper portion 27 and a generally convex lower portion 28. A fixed heat shield 29 is carried beneath the upper portion 27 and surrounds the generator tubes 13 and 14. Forced circulation of air for the burner and heating system is assured by the provision of a scroll 30 and a multiplicity of radially extending fan blades 31 that are secured to and project downwardly from the lower inner portion of the generator B.

Cooling air for the condenser A passes from the intake 26, across the condenser tubes 9 and leaves the unit through a suitably large aperture in the top of the housing D. The helical arrangement of the condenser tubes 9 assists this movement of the air.

Vaporizing and superheating heat is supplied to the generator B from a combustor that includes a generally cylindrical vertical combustion chamber indicated E having an inner refractory lined sleeve 32 to keep the inside wall at high temperature for complete combustion and an outer spaced concentric sleeve 33 with the void therebetween defining an air jacket 34 for insulation, preheating and cooling purposes. Air is admitted from the scroll 30 at 35 and is further preheated by circulation around the sleeve 32 which is assured by the provision of a circumferential spiral baffle 36 interposed between the sleeves 32 and 33.

The bottom of the sleeve 32 is provided with a two piece inverted conical air control valve that includes a stationary element 37 secured to the sleeve 32 and provided with a plurality of upstanding radial wedge-shaped vales 38 struck from the material of the element 37 and bent upwardly at a substantial angle to create turbulence, thus leaving a corresponding number of radially extending wedge-shaped openings 39 in that element. A complementary element 40 is positioned beneath the element 37 for oscillation with respect thereto about a vertical axis and is provided with a plurality of upstanding wedge-shaped vanes 41 that fit within the wedge-shaped openings 39 to form a variable opening register. Thus compressed and preheated air will pass upwardly between each pair of vanes 38 and 41 and the volume of air flow may be regulated by oscillating the element 40 to open or close the spaces between the vanes. As the vanes move from their maximum spacing toward their minimum spacing, the metal between the vanes 41 will progressively close the openings 39, thus forcing the air to flow only between the pairs of vanes.

The bottom of the sleeve 33 is closed by a conical member 42 to which is affixed a depending tube 43 coaxially aligned with the air valve elements 37 and 40. A closed-end cylinder 44 is rotatably supported within the tube 43 by upper and lower bearings 45, 45 and is provided at its bottom with a fuel line connector 46 and a radially extending air control lever 47.

A piston 48 is carried within the cylinder 44 and supports a tubular upwardly projecting nozzle body 49 provided intermediate its end with an abutment flange 50 adapted to engage the upper end of the cylinder 44 as a limit for the upward projection of the nozzle body when fuel under pressure is admitted to the lower part of the cylinder. A compression spring 51 constantly urges the nozzle body 49 toward its fully retracted position so that it will not get too hot from radiation when the burner is shut down and result in carbonation before restarting. Spring 51 is overcome at a relatively low pressure in cylinder 44, e.g., 10 psi so that flange 50 will be engaged.

The upper end of the nozzle body 49 preferably is hemispherical in shape (see FIG. 5) and is provided with an inverted conical orifice 52 through which a valve needle 53, having an enlarged conical tip 54 complementary to the orifice 52, passes. The intermediate portion of the nozzle 53 is reciprocably supported by a perforated disc 55 and its lower end is affixed to a perforated piston 56. A compression spring 57 is interposed between the disc 55 and piston 56 to constantly urge the needle 53 toward its fully retracted position with the tip 54 thereof seated against the walls of the orifice 52. Spring 57 is barely overcome at an intermediate pressure, e.g., 100 psi, but overcome to completely open orifice 52 at a higher pressure, e.g., 1,000 psi to thus provide a variable fuel rate to the chamber.

The top of the cylinder 44 is provided with a tubular neck 58 that is affixed to and supports the lower air valve element 40 so that when the air control lever 47 is oscillated in either direction, a corresponding oscillation of the air valve element will take place. The neck 58 preferably is provided with a plurality of radial apertures 59 located above the conical closure 42, so that air may also pass around and along the upper part of the nozzle body 49 for cooling purposes.

A spark plug 60, which extends upwardly through the members 42, 40 and 37 provides ignition at start up.

It will be appreciated from the foregoing description of the construction of the combustion unit that it is designed to supply varying amounts of heat to the vapor generator B throughout the full range of vapor demand in accordance with the operating speeds and loads of the engine C from idle to full speed or full load operation. Accordingly, fuel pressure is variable, the fuel-air ratio is automatically adjusted as the air inlet is a function of fuel pressure, the fuel flow through the orifice 52 is automatically varied in accordance with changes in the fuel pressure and aneroid means are provided to automatically compensate for changes in barometric pressure and temperature compensation may be provided to finely adjust the air flow as changes in weather, absolute altitude or temperature may occur.

The hot gases from the combustion pass along a generally convolute duct 61 which confines the gases to contact with the various tubes of the vapor generator B in counter flow fashion and exhausts and cooled gases through an exhaust outlet **62** (see FIGS. **1** and **3**). The baffle **12***a* isolates the preheater tubes from the superheater tubes.

The vane engine C is mounted to one side of the condenser-generator assembly (see FIG. **2**) for rotation about a horizontal axis and includes a vane cage or casing **63** having a cylindrical chamber **64** within which are fitted three horizontal concentric rotor shafts respectively designated **65, 66** and **67.** The shaft **65** carries at its left end three radial vanes **68** (see FIG. **7**) mounted 120° apart on a hub **69**; the shaft **66** similarly carries three radial vanes **70** mounted 120° apart on a hub **71**; and the shaft **67** carries three radial vanes **72** mounted 120° apart on a hub **73.** It will be noted that the vanes **68** are axially offset from the hub **69** in one direction, the vanes **70** are symmetrical with respect to the hub **71** and the vanes **73** are axially offset from the hub **73** in a direction opposite to that of the vanes **68** so that when the hubs **69, 71** and **73** are brought together along their common axis the vanes will interfit and smoothly rotate as a unit within a cylindrical chamber **64.** The shafts **65–67**, in addition to being bodily rotatable, are oscillatable with respect to each other whereby to vary the relative positions of the vanes and thus create variable volume vapor chambers therebetween.

To this end, the right end of the rotor shaft **65** is provided with a radial crank arm **74** and has formed therein an open face radial slot **75**; the intermediate rotor shaft **66** is provided with a similar crank arm **76** and radial slot **77**, and the outer rotor shaft is similarly provided with a slotted crank arm (not shown).

A gear housing **78** encloses the above described crank arms and contains a hypocycloidal planetary gear system comprising an internal ring gear **79**, a central sun gear **80** mounted on an output shaft **81** and three satellite gears **82, 83** and **84** interposed between the ring and sum gears (all three satellite gears are schematically indicated in FIGS. **8–10** and are rotatable in carrier **81***a* at 120° of each other). The satellite gear **82** carries a crank shaft **85** provided with a balanced crank arm **86** having an offset crank pin **87** that is operably received within the slot **75** of the rotor shaft crank arm **74.** Similar crank pin connections **88** and **89** are provided between the other two satellite gears and their respectively associated rotor shaft crank arms.

The vane cage **63** is provided with a set of radial inlet ports (indicated at **90** in FIGS. **11–13**) spaced 120° apart for receiving high pressure vapor from the directional valve **18** through suitable piping (not shown) and a companion set of exhaust ports (indicated at **91** in FIGS. **11–13**) that are angularly offset a predetermined distance from the inlet ports.

As the vanes become impelled by admission of high pressure through the inlet ports **90,** they cyclically move apart and together, as the engine turns under the control of the planetary gear system to create a series of variable volume chambers. For example, FIG. **11** shows that the vanes **68** and **70** are closed together each time the vanes **68** block off the inlet ports **90,** and as their rotational movement continues they progressively separate (see FIG. **12**) so that a first variable volume chamber **92** is formed between the vanes **68** and **70** to receive high pressure vapor from **90** until it is closed by the vane **70** and then (see FIG. **13**) a second variable volume chamber **93** is formed between the vanes **70, 72,** etc. As each of the chambers **92,** and **93** reaches its maximum volume, the contained vapor has become expanded, with a corresponding pressure drop, and exhausts through one of the associated exhaust ports **91** uncovered by the leading vane as it slows and as the following vane closes the gap. FIGS. **8–10** indicate the corresponding positions of the crank pins **87–89** during one cycle of vane movements and show how the satellite gears **82–84** consequently drive the sun gear **80** and its associated output shaft **81,** while the ring gear **79** remains fixed.

The identical process occurs simultaneously in each of the three chambers of each set thus resulting in a smooth operation and perfectly balanced forces acting on the bearings and seals.

The relative sizes of the ring, sun and satellite gears are such that the satellite gears make three complete turns per revolution of the engine shaft and the output shaft makes four turns per revolution of the engine shaft.

The expanded low pressure vapor from the exhaust ports **91** enters the condenser-generator casing and then passes into the bottom of the vertical rotating tube **8** and is conducted therethrough into the condenser A to commence a repetition of the vapor cycle.

Thus far, the rotary engine C has been described as running in one direction and as if at a constant speed and torque. However, for the purposes of land vehicle propulsion for example, means should be provided for varying the torque and/or stopping or reversing the engine without having to employ a clutch or a reversing gear box.

It is possible to vary the effective torque and speed by changing the relative positions between the rotary vanes **68, 70, 72** and the vapor inlet ports **90** within relatively narrow limits in order to vary the cut off point and to cause a reversal of direction of rotation by changing such relative positions over wider limits. These relative position changes could be effected either by bodily rotating the vane cage **63** in either direction or by changing the relative positions of the satellite gears **82–84** through rotation of the ring gear **79** in either direction. The latter is considered more practical due to the fact that the vane cage **63** must be sealed against vapor leakage and rotary movement thereof, with its attendant piping connections, would require a more complicated and expensive sealing means.

To this end, and as indicated in FIGS. **2** and **14,** a portion of the ring gear **79** is provided with external gear teeth **96** that mesh with the teeth of a rack **97** that is adapted to be reciprocated by a double acting hydraulic cylinder **98.** At the full limit of stroke in one direction the rack **97** will have rotated the ring gear **79** sufficiently to change the positions of the satellite gears **82-84** enough that the vanes **68, 70, 72** will no longer properly receive vapor from the inlet ports **90** for forward drive and will be in positions for reverse drive. Accordingly, the vapor piping to the engine includes the valve **18** that shuts off the vapor flow to the inlet ports **90** and admits vapor to a second set of inlet ports (not shown) that are symmetrically located on the opposite sides of the exhaust ports to drive the vanes and their associated elements in the reverse direction. The same exhaust ports are used for both directions of rotation.

The output torque of the engine is imposed on the ring gear **79** which is arrested in a given position by the prevailing oil pressure in the cylinder **98.**

If the admission of vapor is more than that necessary for the desired torque as controlled by the accelerator pedal, the ring gear is rotated by the satellite gears against the piston, thus modifying the relationship between the positions of the vanes and the vane cage 63 into which the inlet and exhaust ports are incorporated. This tends to close the admission of vapor ahead of the originally preset position and reduce the pressure in the variable capacity vapor chambers between the vanes of the engine rotor. When the position of the accelerator pedal is changed to vary the output torque, the above described reactions modify the vapor admission and therefor the torque. If the response of this analog control is made to be fast enough, the system is capable of dampening the pulses of the engine as the vapor is admitted into each set of chambers, thus resulting in smooth operation of the engine.

It should be noted that at the high torque position of the ring gear 79 (late cut-off) the exhaust is delayed to obtain a longer power action through residual high pressure from the vapor expansion, and at the low torque position (early cut-off) the exhaust is advanced to obtain a shorter power action.

All controls and accessories for this embodiment of the invention preferably are hydraulic. From an inspection of FIG. 14 which is a schematic flow sheet for the hydraulic, fuel and lubrication systems, it will be seen that a single source of hydraulic oil is used for all functions.

A power system of this type naturally requires certain auxiliary equipment such as a stater for the condenser-generator, torque control, direction control, vapor throttle control, fuel feed control, power steering, power brakes, and windshield wipers if it is mounted on a vehicle, and for these purposes in addition to the dual pumps 22 and 22a on top of the casing 5, a pair of internally driven hydraulic pumps 94 and 95 (see FIG. 2) may be mounted in association with the engine shaft 81*a* and operatively driven thereby at a slower speed than output shaft 81. The pump 95 is supplied with oil from the pump in the casing 78 and delivers oil to all control circuits: direction control, vapor control, torque control and air and fuel delivery controls. The pressure in this circuit is essentially variable and is determined by the relief valve 102 operated by the accelerator pedal 101. The higher the pressure exerted on pedal 101, the higher the oil pressure in this circuit and consequently the more vapor is admitted by the vapor control valve 18, the longer the admission time as controlled by torque control cylinder 98 and the larger the volumes of air and fuel admitted into the combustion chamber for higher rates of evaporation. Exhaust oil from valve 102 is directed to the lubrication circuit. The pump 95 is also supplying pressurized oil to a second stage hydraulic pump 94 which feeds the oil to the power circuits. The first function of the pump 94 is to charge or recharge the accumulator 99 at high pressure controlled by the sequence and relief value 104 and to operate the motor pump 22, acting as a motor, to drive the condenser-generator-fan assembly A and B and to drive pump 22*a* through a flow control valve 105 which controls the speed of the condenser-generator. As the pressure in the accumulator 99 reaches a preset value, the sequence relief valve 104 is set for lower pressure limit to supply the motor-pump 22 and accessories such as power steering, windshield wipers, etc. It will be noted that in this flow circuit the pumps 94 and 95 are operated by the engine shaft and do not operate while the engine is standing still. The condenser-generator assembly and the fuel pump 22a are driven by the turbine 19 and the motor pump 22, acting as a pump, supplies oil to all accessories, control circuits and lubrication. The motor pump 22 rotates the condenser-generator at higher speed for full power than does the turbine 19 which is operative only during idling periods.

To start the system a normally closed solenoid valve 100 is opened for a short time to permit oil from the accumulator to operate the motor-pump 22, which drives the fuel pump 22a and the condenser-generator assembly. The accumulator could be replaced by an electric starter to drive the motor-pump 22. As fuel reaches the nozzle 49, the nozzle extends, the fuel becomes ignited in the flow of air to commence vapor generation in the then rotating condenser-generator assembly. As soon as sufficient vapor is generated, the motor-pump 22, the fuel pump 22*a* and the condenser-generator assembly becomes driven from the turbine 19 and the solenoid valve 100 has been closed.

When the engine C is running, the pump 94 recharges the accumulator 99 and drives the motor-pump 22 rotate the condenser-generator assembly, and the turbine 19 is disconnected by a one way clutch (not shown). Under these running conditions vapor to the turbine 19 is shut off by valve 18. The pump 95 supplies oil to the torque control cylinder and to the general lubricating system. When the engine C is stopped, the turbine 19 is reactivated to drive the motor-pump 22, the fuel pump 22*a* and the condenser-generator assembly.

Fuel feed and air flow to the burner E are automatically regulated in accordance with variations in torque demand of the engine C and the fuel-air mixture is always maintained at the proper ratios for high combustion efficiency with a minimum of pollutants in the exhaust gases.

A pedal 101, acting through a valve 102, controls the hydraulic cylinder 98 to vary the torque of the engine by oscillating the ring gear 79; and the direction of rotation of the engine is controlled by a three-position selector valve 103 that includes a neutral position to stop indirectly vapor flow to the engine, a forward position to permit vapor to flow only to the forward drive inlet ports of the engine and a reverse position to permit vapor to flow only to the reverse drive inlet ports of the engine. The valve 103 controls oil flow to cylinder 98 and oil actuated by oil-motor 18*a* directional valve 18.

All hydraulic and lubrication systems work with the same oil.

It should be mentioned that the power plant also may be started up through the use of a battery powered motor-generator geared to the motor-pump 22. After start up the motor-generator serves to recharge the battery during operation of the power plant. Whenever such a starting system is employed, the accumulator 99 will be unnecessary and may be eliminated.

FIG. 16 of the drawings somewhat schematically illustrates how a power plant constructed in accordance with this invention may be used for constant speed-constant torque applications such as those required for aircraft propulsion units or for electric generators. In this figure an aircraft installation has been shown for convenience. Here the vapor condenser A and vapor generator B are assemblied into a generally cylindriform structure that is rotated at about 4,000 R.P.M. on a horizontal axis. High pressure vapor from the generator is supplied to a turbine T through which it expands and is exhausted back into the vapor condenser A. The turbine T, which operates at 30,000 R.P.M., is reduction gear-connected to the condenser-generator assembly which in turn is reduction gear-connected to the propeller to drive same at about 2,000 R.P.M. The reduction gearing between the turbine and the condenser-generator assembly also provides an 8,000 R.P.M. take off to drive the accessories.

In any type of installation an air conditioning auxiliary unit may be operated by tapping high pressure vapor from a suitable location, cooling same in a separate radiator, expanding same through an evaporater in the vehicle cab or other location and then feeding the expanded vapor back into the condenser portion of the system.

Exhaust air from the rotary condenser may be used to supply heat to the vehicle cab or other location.

The power fluid specifications are arrived at from two different lines of consideration namely, thermodynamic efficiency and specific characteristics desirable for centrifugal rotary systems. In regard to thermodynamic efficiency, opinions vary in this field and several, very often contradictory, statements are to be found. Many researchers are still inclined to pick fluids with characteristics which require economizers, reheaters, etc., as a result of their deeply entrenched training from steam engines.

First, the ideal fluid temperature limits should be set with an upper limit compatible with the materials employed in the equipment and the lower limit a condensing temperature that is compatible with the existing atmospheric temperature if the condenser is to be air-cooled. Thus, with a condenser pressure of a few psi, the condensing temperature should be between 0° F and 100° F, depending on available air temperature (the lower, the better for efficiency). The adiabatic expansion line along which the cycle is operating should run parallel to or into the saturated vapor line at the condensing point and the vapor should be saturated or dry at this point.

The operating pressure should be as high as possible or compatible with the allowable stress in the equipment. The fluid should mainly be chosen because of its ability to provide the maximum efficiency within the operating limits of the system. This is measured by the ratio of the available energy during expansion over the energy stored by the fluid during preheating, evaporation and superheating. This ratio is very low with steam, for example, and much higher with many of the fluorocarbons and chlorocarbons.

Turning to specific characteristics for centrifugal rotary systems, one must consider the specific weight of the liquid, the net weight of the liquid column in elements **13** and **14**, the distance of this column from the center of rotation, the rotational speed, and the counterpressure due to any liquid in the vapor column in the element **14**.

The specific gravity of the liquid should be high enough to achieve the desired pressure at minimum speed and liquid height. The height of the column of liquid in **13** must be maintained short enough to limit the overall diameter of the system and the radius of rotation must be maintained as small as possible for the same reason. In addition, the vessels containing the liquid are also subjected to centrifugal forces developed within their walls which creates stress due to the fluid pressure and particularly a high temperatures which reduce their capability to withstand the stresses.

To reach a required final fluid pressure, a much higher pressure is developed at the furthest point from the rotation axis i.e., at point **13***a* because of the counterpressure developed in element **14**. To reduce this counterpressure, the vapor's specific gravity should be low which depends upon the molecular weight of the fluid.

Accordingly, it has been found that the adabiatic expansion line should run parallel to or across the saturation line at the exhaust point. The condensing temperature should be between 0° F and 100° F. The operation should be at a high pressure of about 500 psi and a temperature of about 500° F which will allow a critical point of these conditions at about 600 psi and 600° F.

The specific gravity of the fluid should be at a minimum of 1.4 and the molecular weight should be a maximum of 190 . The molecular limitation does not apply for the turbine type embodiment shown in FIG. **16.**

To improve on certain aspects of the characteristics of the fluid, it is possible to admix some fluids to assure desirable characteristics. This is possible generally, without fractional distillation and separation of the fluids when flash boilers or evaporators are used, i.e., where the fluid is instantly evaporated in small areas. In this way, the freezing point may be lowered, boiling point raised, specific weight increased, etc., by addition of other fluids with similar characteristics and yet which will not affect other desired aspects adversely.

For example, carbon tetrachloride which is the desirable fluid for certain aspects has a melting point of approximately —9.5° F, which would create difficulty under many climatic contions. However, if one were to add 10 percent of trichloroethylene having a melting point of −126° F, the melting point of the mixture would be appreciably lower than carbon tetrachloride by itself and yet the other desirable characteristics of the carbon tetrachloride would not be changed appreciably. It is thus contemplated that mixture of most of the fluids disclosed herein would be advantageous in certain circumstances.

The fluid mixtures are applicable to any flash boiler situation as well as the instant evaporator shown.

I claim:

1. A rotary vane engine including, a stationary rotor cage having a cylindrical bore; a rotor including a shaft rotatably mounted along the axis of said bore and provided at one end with a set of three radial vanes located 120° apart and provided at its other end with a radial slotted crank arm; a first sleeve shaft rotatably mounted on said first shaft and provided at one end with a second set of three radial vanes located 120° apart and in juxtaposition to the vanes of said first set and provided at its other end with a radial slotted crank arm; a second sleeve shaft rotatably mounted on said first sleeve shaft and provided at one end with a third set of three radial vanes located 120° apart and in juxtaposition to the vanes of said second set and provided at its other end with a radial slotted crank arm; a hypocycloidal planetary gear system positioned adjacent said radial crank arms and including a rotatable internal ring gear and three satellite gears disposed 120° apart in meshing relationship with said internal ring gear, each of said satellite gears being provided with an eccentrically mounted crank pin extending into engagement with the slot of an associated one of said radial crank arms whereby to cause the vanes of said sets of vanes to be moved progressively toward and away from each other as said rotor bodily rotates and form variable capacity vapor chamber; means to admit from a source external to said engine high pressure vapor to said rotor cage to cause said rotor to rotate; means to discharge expanded low pressure vapor therefrom; and an output shaft operably connected to said satellite gears.

2. The rotary vane engine of claim 1 in which said hypocycloidal planetary gear system additionally includes a sun gear disposed in meshing relationship with said satellite gears and in which said output shaft is connected to said sun gear.

3. The rotary vane engine of claim 1 additionally including means to rotate said internal ring gear in either direction whereby to change the positions of said satellite gears and their associated sets of vanes relative to said rotor cage and thus vary the effective torque of said engine.

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