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- [22] Filed: **July 19, 1974**

- ### Related U.S. Application Data

- [52] U.S. Cl..... 60/665; 60/667

- [51] Int. Cl.² F01K 13/02

- [58] **Field of Search** 60/660-667

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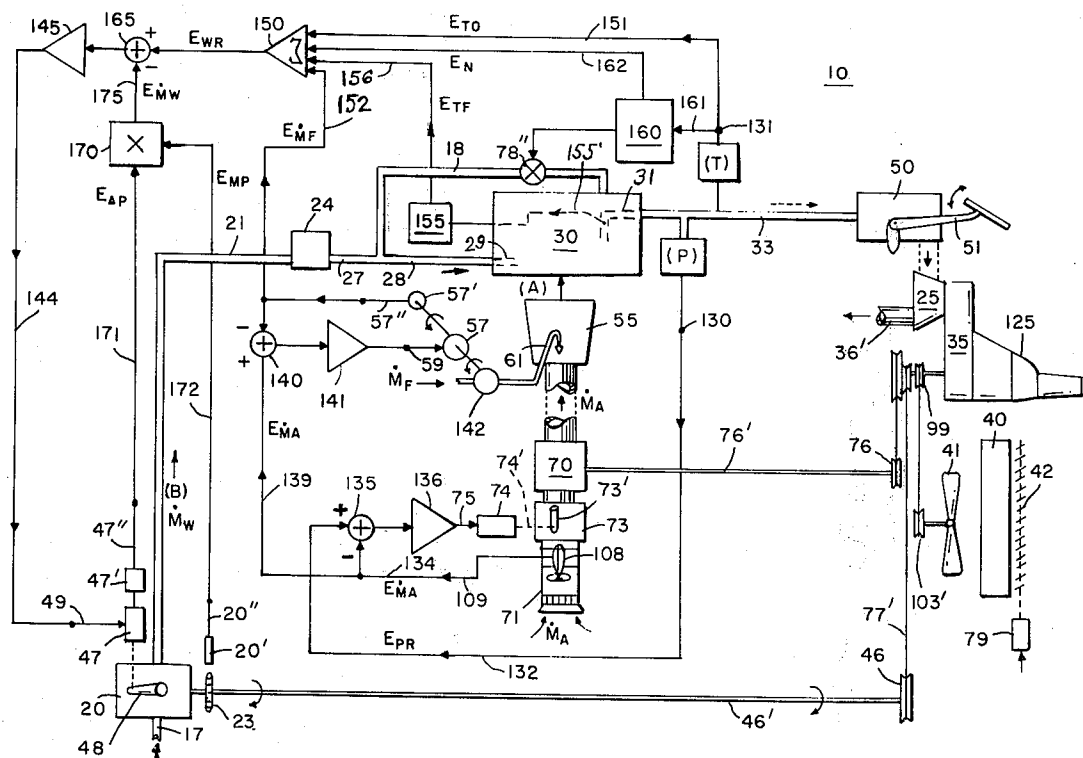
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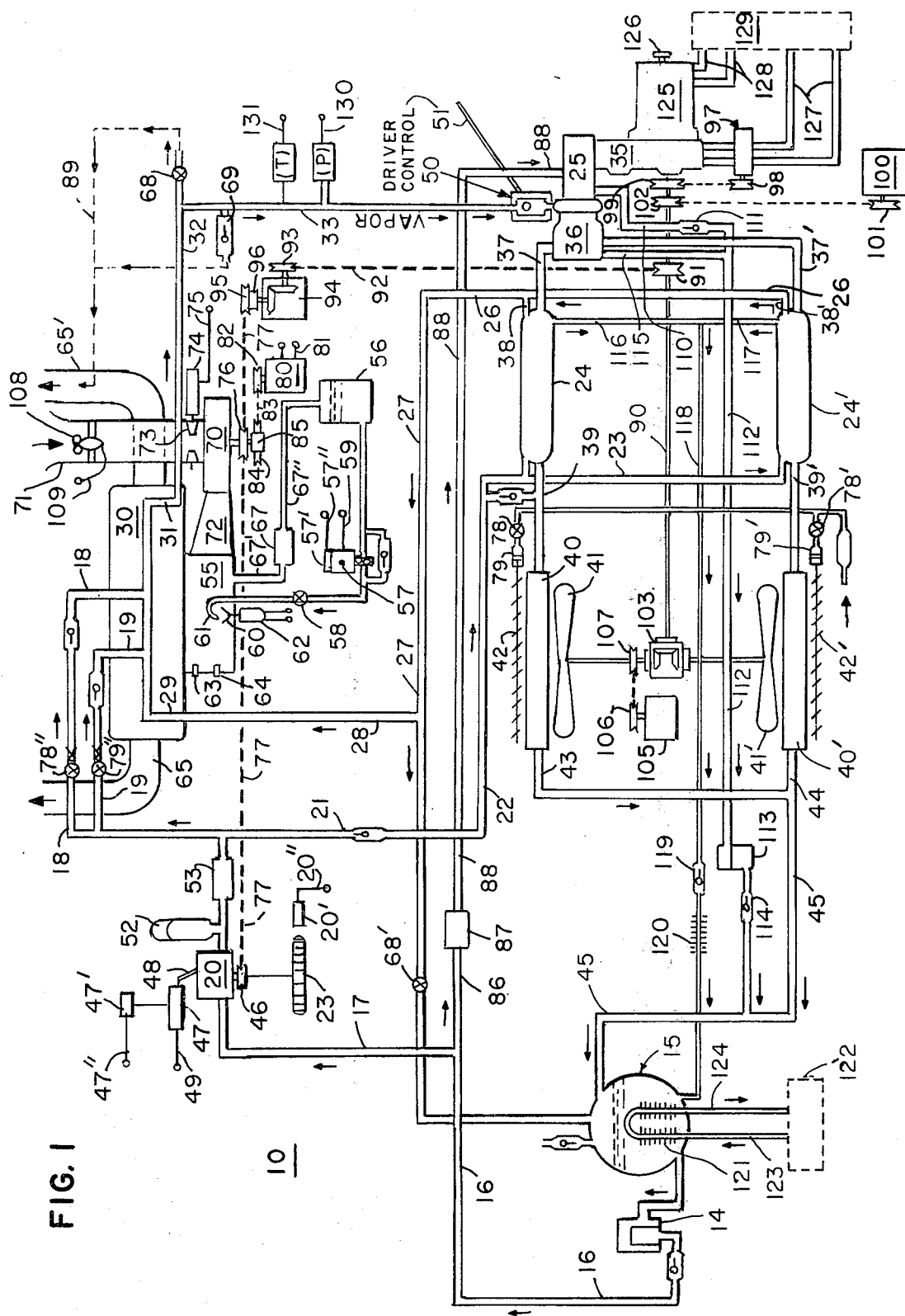
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ABSTRACT

The control system hereof is for external combustion vapor engines. The vapor is superheated, and by the control system is maintained at substantially predetermined pressure and temperature for the output power expander, such as a turbine. The mass of the vapor supplied to the expander is proportional to power demand. The vapor is generated in a boiler that is fired by a combustor. Generation of the required vapor is under the control of both the heat rate to the boiler, as well as the rate that liquid is supplied to it. The heating rate is determined in direct response to the fall and/or rise of the pressure of the vapor from its rated level. The feedwater rate is in response to both the said heating rate, as well as to fall and/or rise of the vapor temperature from its rated level.

8 Claims, 2 Drawing Figures





CONTROL SYSTEM FOR VAPOR ENGINES

This is a continuation of patent application for "Control System For Vapor Engines," Ser. No. 326,434, filed Jan. 24, 1973, now abandoned.

BACKGROUND AND SUMMARY OF THE INVENTION

In the external combustion engine system herein a vapor generator is used to provide superheated steam substantially at rated levels of temperature and pressure; as at 1000°F and 1000 psi. The volume of the output vapor is determined by the power requirement for the vehicle in operation. The control system is arranged to continuously maintain the rated pressure and temperature of the superheated vapor as it is supplied to an output power expander such, as a turbine. The control action hereof is in rapid response to power output demand. The heat rate (A) supplied to the combustor section of the vapor generator is directly responsive to the degree of pressure error or departure of the output vapor from its rated pressure as caused by the power output variation. The burn rate (A) is determined by the rate of fuel input to the combustor with accompanying air in predetermined ratio to insure relatively low exhaust pollutants.

Further, the rate (B) of feedwater that is simultaneously supplied to the boiler section of the vapor generator is controlled basically by the said heating rate (A) together with the degree of temperature error or departure of the output vapor from its rated temperature. When the power demand by the output expander is increased the pressure and temperature of the generated output vapor tend to decrease. However, the control system promptly increases the heat rate (A) to the combustor and the feedwater rate (B) to the boiler in proper amounts to substantially maintain the vapor at rated pressure and temperature; and vice versa. The rated vapor is delivered smoothly and in response to the power output demands, as required.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic showing a power vapor engine incorporating the control system of the present invention.

FIG. 2 is a diagram of the exemplary control system.

THE VAPOR ENGINE

The power vapor engine 10 to be described has a turbine drive for operating a 50-passenger intercity bus with 240 horsepower gross output. Fluid water from make-up tank 15 is drawn by boost pump 14, and a positive inlet pressure is maintained along main fluid supply lines 16 and 17 to high pressure feedpump 20, during the startup of the vapor generator. A small portion of the high pressure fluid is divertable through normalizers 18,19 for generator control, used intermittently for steam over-temperature safety in a manner to be described. The main fluid flow is through feedpump 20 at sufficiently high pressure to main fluid lines 21,22 and through regenerators 24, 24'. As the water passes through regenerators 24, 24' it is heated by exhaust steam therein from turbine 25, as later described. The heated fluid flows along main lines 26, 27, 28 to inlet 29 of the vapor generator 30.

The water is rapidly converted into superheated steam in vapor generator 30. This action permits rapid

response to driving needs, and for control effectiveness. The superheated steam emerges in outlet line 31, as in the order of 1000°F and 1000 psia. The steam outlet 31 connects with vapor lines 32 and 33, towards the input of power turbine (expander) 25. Rapid response to power demands, up and down, is also afforded by the relatively low rotational inertia of the turbine rotor, as well as its having good power conversion efficiency over the power range. The steam expands through the turbine which, through reduction gearbox 35 powers the vehicle and the system accessory devices.

Exhaust steam from turbine 25 passes into exhaust plenum 36 and via steam lines 37, 37' through the vapor side of regenerators 24, 24'. The main feedwater fluid flow from output line 23 is through the regenerators 24, 24' via schematically indicated connection lines 38, 38', to return main fluid lines 26, 27, 28. The bus engine system 10 involves generation of the order of 240 horsepower of output at the turbine 25. Two spaced condensers 40, 40', one on each side of the bus are used. One such condenser is sufficient for a passenger car when about one-half said power is used.

Vapor output lines 39, 39' of the regenerators respectively pass the exhaust steam into the condensers 40, 40'. The condensers have respective fans 41, 41', with sufficient capacity to condense all the exhaust steam under all operating modes of the bus, so that excess steam need not be vented. Inlet shutters 42, 42' are used at the air inlet position to condensers 40, 40' to avoid excessive fluid cooling at low power condition, which would reduce cycle efficiency. The fluid phase from condensers 40, 40' is returned to make-up tank 15 via output lines 43, 44 through line 45. The position of shutters 42, 42' may be controlled as through compressed air on the bus by respective electrically actuated solenoid valves 78, 78' and cylinder/piston units 79, 79'.

The exemplary pressure of the water and steam in vapor generator 30 herein is of the order of 1000 psi. The feedwater is fed at sufficient pressure into the boiler tubes of vapor generator 30, via inlet 29. Boost pump 14 initiates the fluid from tank 15. Feedpump 20 is of the positive variable displacement type. The feedwater is controllably directed into the inlet 29 by the feedpump 20. Pump 20 is driven through pulley 46. Actuator 47 couples to lever 48 extending from pump 20. The position of lever 48 controls the rate of feedwater pumped.

Pump displacement control actuator 47 is controlled through a small servo-motor therein, connected to the control signals hereof by leads 49. The control signals are derived in a manner hereinafter described. A pump displacement sensor 47', as a potentiometer, is coupled to the actuator 47, and electrically conveys its position via lead 47''. The speed of feedwater pump 20 is fed into the control system hereof. One way is through a toothed wheel 23 driven with the pump, and a sensor 20' electromagnetically related to it, that produces corresponding signals in output lead 20''. A photoelectric method is another way to accomplish this function. The control operation on pump 20 is described hereinafter.

Fluid output of feedwater pump 20 is directed to fluid line 21, in series with surge tank 52 and filter 53, as of 10 micron size. The main fluid enters input line 29 of vapor generator 30 at sufficient pressure to replace evaporating water in the boiler tubes. Vapor gen-

erator 30 converts the fed-in feedwater into high-temperature high-pressure vapor, as superheated steam. Combustor 55 is constructed integrally with vapor generator 30. Combustor 55 is fired with a continual flow of fuel mixed with air in generally predetermined mass proportion, as will be explained. Towards this end, fuel tank 56 connects to electric motor fuel pump drive 57. The fuel is directed through open solenoid 58 to U-shaped feed nozzle 61 into spin cup 60. An electric motor 62 of small power spins cup 60 at a predetermined rate as 12,000 rpm, atomizing the fuel that impinges thereon into a radially spread-out fine spray in torroidal shape within combustor 55. Once ignited by spark-plug 63 an intense combustion starts and is maintained therein.

The gaseous exhaust passes through ducts 65, 65' arranged to emit then generally from the rear of the vehicle. Fuel pump 57 is electrically operated through its leads 59 by an electric control current derived in a manner described in connection with FIG. 2. The basic fuel energy supplied to combustor 55, as well as the mass of feed fluid flow into vapor generator 30, are maintained in direct relation over the operating range of the engine system. The volume and power of the superheated steam responsively delivered from vapor generator 30 to turbine 25 through throttle 50, drives the turbine rotor for the output torque/power demand, whether transient or sustained. The temperature and pressure controls hereof maintain the vapor input to the turbine close to predetermined temperature and pressure. The superheated steam is rapidly generated in mass and volume at a rate proportional to that requisite to drive the turbine expander (25) as determined by the bus output demand.

The engine system 10 hereof utilizes superheated steam generated in the order of 1000°F at a pressure input to the turbine 25 of the order of 1000 psia. Other pressure and temperature levels may be used within the principles and scope of the present invention. In operation, the combustor/vapor generator for the bus can be steamed-up from initial ignition start to full rated condition for vehicle drive in about 50 seconds.

Should the combustion process flame out, or not take hold for any reason, unburned fuel drops to the floor of combustor 55 and exits in drain tube 67' directly into flame arrest device 67 that prevents its ignition. From there it drains out through tube 67'' back to fuel tank 56. A photocell flame detector 64 is mounted in the combustor frame. It connects to a fail-safe circuit that promptly disconnects fuel flow and stops other activity in the system if the detector indicates no-flame at anytime when it should be ON.

Ambient air is directed into combustor 55 by blower 70 that draws in air through inlet duct 71. The air is swirled into combustor 55 through a scroll shaped surround 72, and intermixed with the atomized fuel sprayed-out by spin cup 60. Air is blown into combustor 55 in controlled amount to insure optimum combustion of the fuel as fed-in concurrently. A safe ratio of air quantity to fuel quantity is maintained for this purpose. A preferred ratio is the order of twice the basic stoichiometric ratio. A practical air-fuel mass ratio used is 30:1 for particular fuels over the operating range, presenting sufficient oxygen for complete fuel combustion at about 2100°F or less. This upper temperature limit minimizes the generation of oxides of nitrogen, as well as unburned HC and CO. A suitable

power vapor generator, combustor, and blower therefor are shown and described in the copending patent application Ser. No. 261,691 filed June 12, 1972 for "Vapor Generators With Low Pollutant Emission," assigned to the assignee hereof.

Adjustable inlet guide vanes 73 are controllable automatically, as will be set forth, to maintain the predetermined safe air/fuel ratio as directed into combustor 55 over the power operating range. Actuator 74 controls the setting of vanes 73 for the blower air, and thus its volume or mass flow into the combustor. This is accomplished through actuator 74 coupled to the vanes 73, and through its electrical leads 75 connected to the control system hereof to be described in conjunction with FIG. 2. Towards this end an air mass flow measuring propeller unit 108 is mounted at the input end of the air inlet duct 71. The signal output 109 of unit 108 is proportional to the rate of air mass flow passed the inlet guide vanes to the blower 70 and on to combustor 55.

The basic air blower 70 is driven by pulley 76 through belting 77 that also drives the feedpump pulley 46. During start-up of the engine system 10 starter motor 80 is operated by connection to battery power through its lead terminals 81. Its output pulley 82 drives belt 83 and pulley 84 at the blower. An overrunning clutch (ORC) 85 couples pulley 84 to blower pulley 76 and thereby to belting 77. Thus, initial starter 80 operation as by the ignition key, directly starts up blower 70 and the feedwater pump 20. At the same time, these lower powered fuel and spin cup motors 57 and 62 are electrically connected to the battery. They perform fuel pumping and spin cup 60 rotation for fuel atomization. Initial ignition of the atomized fuel in combustor 55 is accomplished by spark plug 63. Combustion thereupon takes hold, firing-up the vapor generator and promptly generating steam. Rapid response of vapor generation is facilitated by the tube array, and direct combustion at high intensity in combustor 55, as set forth in the said copending patent application.

The superheated vapor output into steam lines 32, 33 leads on to turbine 25 through throttle 50. In startup position the throttle passes vapor to the turbine 25 in idling status. Idle drive of the gearing occurs in reduction gearbox 35. Such turning of this gearing 35 directly rotates auxiliary drive shafting 90. A pulley 91 thereon drives belt 92 which operates pulley 93 of 1:1 ninety degree gear unit 94. Gear unit 94 in turn drives pulley 95 through overrunning clutch 96. The initiation of gearbox 35 rotation by the idling power of turbine 25 is thus by starter motor 80 as just described. When at sufficient power level shafting 90 drives gear unit 94 and its pulley 95, and takes-over the operation of blower 70 at its pulley 76, and feedpump 20 at its pulley 46. ORC 85 at pulley 76 thereupon mechanically disconnects starter 80. Conversely, during starter 80 use, ORC 96 at pulley 95 disconnects the belt 77 drive from gear unit 94 and thus also shaft 90. Switch-off of starter 80 power may be effected automatically when the vapor pressure generated reaches 750 psi.

The other auxiliary units of engine system 10 are driven by the shafting 90 upon its rotation during the idling mode of turbine 25, and also throughout the operational course under driver control of lever 51, of throttle 50. As shown in FIG. 1, these auxiliaries include the gearbox oil pump 97 through pulleys 98, 99; alternator 100 through pulleys 101, 102; fans 41, 41'

of condensers 40, 40' through bevel gearing unit 103; and in turn air compressor 105 (optional in a bus) through pulleys 106, 107. A take-off line 86 from main fluid supply line 16 passes through filter 87, 10 micron size, to line 88 supplying seal purge fluid to turbine 25. Fluid drain from turbine 25 passes through line 110, pressure relief valve 111, and drain line 112 on to the make-up tank input line 45. A fluid holding tank 113 of about 1 gallon capacity is in series therewith, together with check valve 114.

Fluid drain from turbine exhaust plenum 36 enters drain line 115, and return line 112. Non-condensable gas from condensers 40, 40' are directed to make-up tank 15 by conduits 116, 117, 118. A check valve 119 and a finned cooler 120 is in series therewith. It is practicable to provide heating for the whole bus by inserting finned tubing 121 in the hot return fluid in make-up tank 15, for heat transfer and heating-up of fluid contained in the tubing 121. The bus heating system 122 is schematically indicated, through which this heated fluid is transmitted via tubes 123, 124, as will now be understood. A double reduction gear train 35 reduces the top operating speed of the turbine to a ratio that permits coupling to a standard automatic transmission (125), namely a torque converter to transmit its output drive 126 to the differential gearing, and the vehicle wheels. The stepped transmission 125 utilizes saver-ger/pressure oil pump 97 with oil lines 127 and 128, and oil cooler/oil reservoir unit 129.

The normalizer tubes 18, 19 are arranged to divert feedwater controllably through their indicated solenoid valves 78'', 79'' should vapor temperature rise substantially above the system value, as 1000°F, and thus avoid excess vapor temperature. Their control is indicated hereinafter. An electrical temperature sensor/transducer (T) is placed in the vapor path in steam pipe 33 to throttle 50; as is an electrical pressure sensor/transducer (P). These may have direct parameter readouts for the system control network. In the exemplary control system, the circuits thereof are preset and provide differential or error-temperature and error-pressure signal outputs.

Further elements are incorporated as safe-guards in the operation and use of engine system 10, for vehicle, boat or stationary installation. A speed sensor on the turbine (25) opens solenoid valves 68 and 68' at a preset overspeed. Valve 68 thereupon directly discharges superheated vapor from line 32, one way as into exhaust ducts 65, 65' as indicated at 89; and valve 68' may directly discharge main fluid from line 27 into make-up tank 15. The turbine thereupon slows and promptly stops; the auxiliaries thus stopping as well, to shut down the power and operation. A safety pressure relief valve 69 in vapor delivery line 33 should the superheated vapor pressure exceed a given high design valve, as 1300 psi. The vapor is preferably directed into the exhaust ducts 65, 65' as schematically indicated at 89. Other safety sensors, check valves and relief valves are utilized, some of which are indicated in FIG. 1.

CONTROL PRINCIPLES FOR ENGINE SYSTEM

The vapor power plant hereof is controlled and designed to safely provide ample horsepower output over the wide power requirements of the vehicle in operation, in environments usually encountered as ambient temperatures and altitude. The turbine (25) system has variable admission wherein the mass flow of the vapor

(steam) through the turbine nozzles is proportional to the area exposed by throttle position. Mass flow of the vapor is thus independent of the turbine speed. Delivery of air by the blower (70) and feedwater water by the pump (20) are separately controlled, and are variable with respect to the output drive speed. The feedwater pump 20 and the combustion blower 70 are driven directly from the output gearbox 35, as auxiliary units. Their respective delivery of fluid and air is controlled through their actuators that correspondingly effect their displacements.

The control system is continuous over the full range of power, from idling to maximum demand and output. Fuel and air are fed to the combustor at all times; the preset temperature and pressure of the vapor generator output are monitored and controlled. The flow of feedwater is made not too low or ever off. This prevents undue rise of temperature in the vapor generator (30) or precipitous drop in pressure, and avoids unnecessary automatic system shut down. A normal or rated operating temperature T_o and pressure P_o are selected for the system; as 1000° or 1100°F, and 1000 or 1100 psia.

The control system directly increases the burn or heat rate (A) to the combustor (55) when the pressure transducer (P) signals a pressure decrease from rated P_o and vice versa. The feedwater rate (B) into the vapor generator (30) is correspondingly raised when the heat rate (A) increases; and in reverse direction as well. However, the rate (B) is also made responsive to the temperature (T) of the vapor, rising with higher temperature, and vice versa. Thus, when a pressure divergence from P_o of even 25 psi causes a change (up or down) in the air mass and fuel rate, still held at 30:1 ratio; and in turn correspondingly alters the feedwater rate (B) in conjunction with the temperature control signal from (T).

The power demand by the turbine (25) is thereby rapidly accommodated, as an increased demand would tend to lower (P) and (T), which promptly act to compensate with the heat rate (A) and feed rate (B) to bring the pressure and temperature of the vapor towards their rated P_o and T_o . As this control system is continuous and rapid in its operation wide power vapor demands are delivered smoothly. In practice the control system in some cases may be made somewhat "loose" in that the control responses to pressure change may be at the 50 psi error level; it being understood that ± 25 psi or even less is contemplated herein. It has been determined that a pressure drop in the vapor generator of 200 psi from normal P_o cannot be felt by the vehicle driver.

OPERATION OF THE CONTROL SYSTEM

FIG. 2 is a simplified schematic diagram of the engine system 10, showing the control system. The pressure transducer (P) is preset at the rated system vapor pressure P_o , and arranged to provide electrical signals at lead 130 that are proportional to pressure error or deviation from P_o that the vapor in pipe 33 is at. Similarly, the temperature transducer (T) extending from pipe 30 is preset to rated system temperature T_o , and provides electrical output signals at lead 131 that are proportional to temperature error or deviation from T_o of the condition of the vapor in pipe 33.

The air mass flow or rate $\dot{M}_A$ into the blower 70 and on to combustor 55 is determined by the air measuring propeller unit 108. Its voltage signal E_{MA} appears at

lead 109. The pressure error signal E_{PR} from terminal 130 is impressed on summing junction 135 through lead 132, as in the air mass rate signal E_{MA} through lead 134. The resultant signal is amplified at 136 and applied by lead 75 to actuator 74. The actuator correspondingly controls the degree of opening of the inlet guide vanes 73 to the blower. The blower 70 is powered as an auxiliary unit through pulley 76 and shaft 76' basically by the turbine drive. The guide vanes (73) adjustments hereof are sufficiently wide to provide the proper mass air flow ($\dot{M}_A$) for the combustor 55 to maintain the rated pressure P_0 in pipe 33. The actuator 74 is linked at 74' to the vane position controller 73'.

The rate of fuel pumped into the combustor 55 is held directly proportional to the mass air flow $\dot{M}_A$, in order to maintain the desired air/fuel ratio, as 30:1 set forth above. Towards this end the air mass flow signal E_{MA} from lead 134 is impressed on add junction 140 thru lead 139. The signal from fuel pump tachometer 57' is also impressed on adder 140, the output of which is connected to amplifier 141. The amplifier drives the small fuel pump motor 57 through leads 59. The fuel pump per se is indicated at 142. The fuel output rate is proportional to the speed of motor 57, the fuel rate thus being tied to the air input to the blower as projected to control the pump motor 57 by the air mass rate signal E_{MA} .

The heat rate (A) input to the vapor generator 30 is thus determined by controlled rate of air/fuel through the pressure error signal E_{PR} from transducer (P). Its air/fuel ratio is maintained to keep the combustion with low pollutant output. The propeller air flow measure of unit 108 integrates variables that would otherwise occur in air mass due to altitude and ambient temperature.

The variable displacement feedpump 20 is driven as an auxiliary unit by the turbine drive through pulley 46 and shaft 46'. Its fluid output rate $\dot{M}_W$ is controlled through the position of its lever 48 as controlled by the actuator 47, as hereinabove stated. Its feedwater output is to water pipe 21, to regenerator 24, and on to input 29 of the boiler-tubing of vapor generator 30 via water pipes 27, 28, as hereinabove described. The operation of actuator 47 is controlled by the output of signal amplifier 145, connected to its input lead 49 by line 144.

In accordance with the present invention the net fluid output rate (B) of pump 20 is basically controlled by the heat rate (A) into the combustor 55 and the temperature error (E_{TO}). Specifically, the temperature error signal E_{TO} at terminal 131 of the steam output temperature sensor (T), is connected to water flow rate summer 150 via lead 151. The fuel feed rate signal E_{MF} from tachometer 57' is also fed to summer 150 input, by lead 152. An input is impressed on summer 150 that is related to the temperature of the feedwater in the vapor generator, measured by sensor 155. The signal output E_{TF} of sensor 155 is fed into summer 150, via lead 156.

Temperature sensor 155 has its thermocouple 155' extend to the interior of the vapor generator 30. The position of thermocouple 155' is preferably at the superheat end of the evaporation zone of the boiler tube array. Such position is determined at idle condition, and is schematically indicated in FIG. 2. The boiler of the vapor generator is formed with continuous tubing, as shown in the aforesaid patent application. The input

feedwater is heated, and evaporated centrally of the tubing. The evaporation zone is followed by the vapor superheat section, before the steam output. It has been determined that when the feedwater rate (B) is trimmed to hold the input water to say 700°F, excellent control is achieved of the water inventory in the vapor generator over a wide range of load conditions.

A comparator 160 is used to start the normalizers (18,19) by opening their respective solenoid valves (78,79) for boiler safety, at a preset temperature as 960°F. The comparator 160 is impressed with the temperature signal E_{TO} via lead 161. A normalizer signal E_N is preferably impressed onto summer 150, through lead 162. The signal output of summer 150 is basically determined by variations in the fuel flow rate E_{MF} signal and the output steam temperature E_{TO} (or its error vs T_0). Its outer two inputs, namely E_{TF} and E_N , provide refinement of the control hereof.

The output of summer 150 is voltage signal E_{WR} that is impressed on summing junction 165. The pump displacement (ΔP) determines the water rate $\dot{M}_W$, as aforesaid. The signal $E_{\Delta P}$ from its sensor 47' is connected multiplier 170, via lead 171. The signal E_{MP} from pump speed sensor 20' connects to multiplier 170, via lead 172. Multiplier 170 thus derives a voltage signal E_{MW} at its output lead 175 that is directly proportional to the feedwater rate. This signal is thereupon impressed on summing junction 165, at its (-) side by the lead 175. The net of summing junction 165 thereby is a signal proportional to the required pump displacement. This net signal is passed through amplifier 145 and impressed on the actuator 47 to continually effect the requisite displacement, as set forth.

What is claimed is:

1. An improvement in a vapor powered vehicle having a power expander coupled to its transmission drive, said vehicle being operated at variable speed and power output demands through corresponding vapor that is generated and applied to its expander, upon demand, in a Rankine cycle configuration by a vapor generator having a combustor and a boiler that is fired thereby to provide superheated vapor substantially at a rated pressure and temperature, said improvement comprising:

means for regulating the air mass flow to said combustor at a rate that is directly related to the departure from rated pressure of the vapor being supplied to said expander;

means for regulating the fuel feed into said combustor at a rate that is directly related to the air mass flow rate into said combustor; and

means for feeding liquid into said boiler at a rate that is controlled by the departure from rated temperature of the vapor and by the fuel feed rate.

2. A vapor powered vehicle as claimed in claim 1, further including:

a temperature transducer in contact with the generated output vapor;

fuel flow measuring means for providing a fuel flow rate signal;

summer means coupled to both said temperature transducer and said fuel flow measuring means; and

means connecting the output of said summer means to said liquid feeding means for regulating the feed rate of said liquid feeding means.

3. A vapor powered vehicle as claimed in claim 2, in which said means for regulating the air mass flow to said combustor includes:

- an air blower with an air flow control device;
- a pressure transducer in contact with the generated vapor; and
- means connecting said pressure transducer to said air flow control device, thereby effecting delivery of the requisite air mass to said combustor, needed to maintain the rated vapor pressure condition.

4. A vapor powered vehicle as claimed in claim 3, further including:

- an air mass flow measuring unit responsive to the air flow through said air blower into said combustor; and
- circuit means connected to said air mass flow measuring unit and said pressure transducer connecting means for regulating the delivery of air to said combustor.

5. A control system for a vapor powered vehicle having a power expander coupled to its transmission drive, said vehicle being operated at variable speed and power output demands through corresponding vapor that is generated and applied to said expander by a vapor generator having a combustor and a boiler that is fired thereby to provide superheated vapor substantially at a constant rated temperature and pressure, said control system comprising:

- means for measuring a departure from rated pressure of the vapor being supplied to said expander;
- means for measuring air mass flow into said combustor;
- means for measuring fuel flow into said combustor;

means for generating an air mass flow control signal in response to the difference between the signals from said pressure measuring means and said air mass flow measuring means; and

means for generating a fuel flow control signal in response to the difference between the signals from said air mass flow measuring means and said fuel flow measuring means.

6. The control system of claim 5, further comprising: means for measuring a departure from rated temperature of the vapor being supplied to said expander; means for summing the signal from said fuel flow measuring means with the signal from said temperature measuring means;

means for pumping fluid to said boiler; means for measuring the rate of fluid flow into said boiler; and

means for generating a fluid flow control signal in response to the difference between the signal from said summing means and the signal from said fluid flow measuring means.

7. The control system of claim 6, further comprising: means for measuring the temperature of the vapor in said boiler and supplying a signal representative thereof to said summing means.

8. The control system of claim 6 wherein said fluid flow rate measuring means comprises:

- means for measuring pump displacement;
- means for measuring pump speed; and
- means for forming a product with the signal from said displacement measuring means and the signal from said speed measuring means.

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