

[54] **BOILER CONTROL SYSTEM**

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[58] Field of Search 122/3, 448 R, 448 S, 451 R, 122/451 S

[56] **References Cited**

UNITED STATES PATENTS

1,675,600 7/1928 Doble 122/448

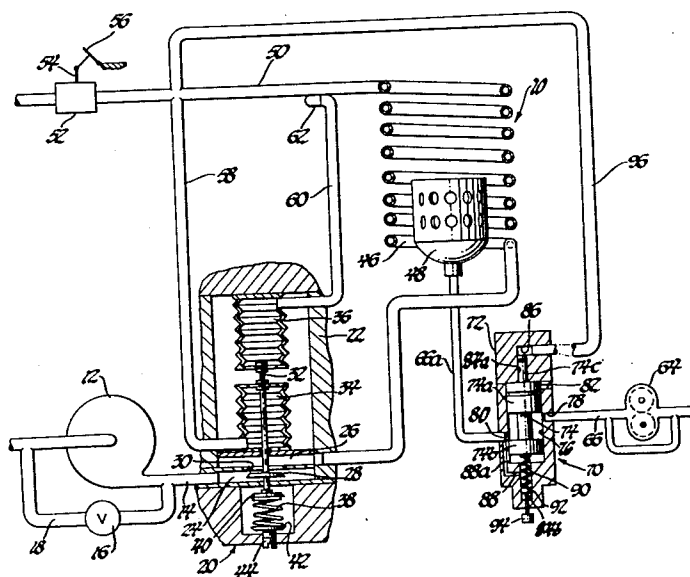
2,081,948 6/1937 Michel et al. 122/448
2,022,728 12/1935 Lieberherr 122/448
1,385,845 7/1921 Scott 122/448

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[57] **ABSTRACT**

A boiler control system to control the vapor temperature and pressure at the boiler outlet of a Rankine cycle heat engine utilizing a super heat control valve to throttle the liquid flow to the boiler and a boiler pressure actuated fuel control valve to regulate the flow of fuel to the burner supplying the heat input to the boiler.

6 Claims, 3 Drawing Figures



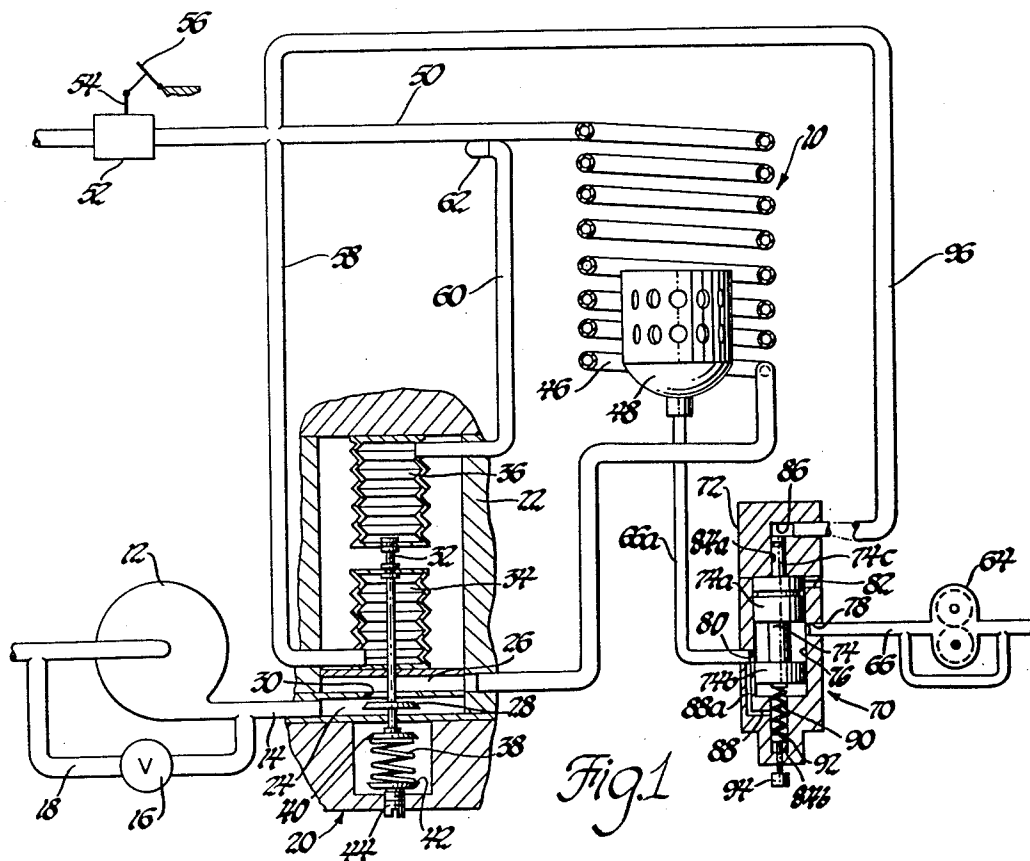


Fig. 1

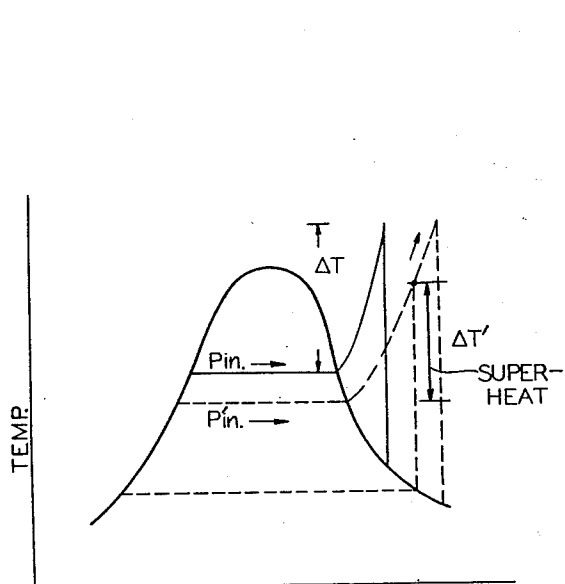


Fig. 3

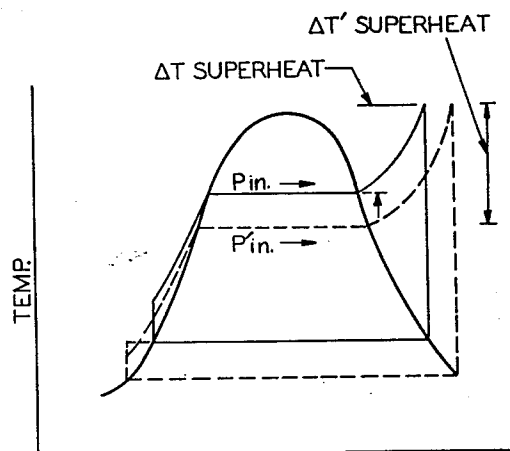


Fig. 2

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BOILER CONTROL SYSTEM

This invention relates to a boiler control system and, in particular, to a boiler control system for use with a low thermal inertia mono-tube or similar type boiler for a Rankine cycle heat engine.

In recent years, there has been renewed interest in vapor type engines for use as prime movers in automotive vehicles. A once-through or mono-tube type boiler is ideally suited for such use due to its small thermal storage and its ability to rapidly respond to changing output demands as would be required in such an automotive application. However, to date, there have been no simple and dependable controls to properly operate this type boiler in a manner suitable for use in automotive vehicles.

It is, therefore, the principal object of this invention to improve a boiler control system for use in a Rankine cycle heat engine wherein the fluid flow to a mono-tube type boiler is quickly and continuously modulated as a function of boiler output pressure and temperature, and in which the heat input to the boiler is varied to match rapidly changing demands, such as those expected in an automotive application wherein the thermal storage of the boiler would typically be small.

Another object of this invention is to improve a boiler control system for use in maintaining the vapor temperature and pressure at the boiler outlet for a Rankine cycle heat engine at preset values despite rapidly changing demands for the fluid.

These and other objects of the invention are attained by a super heat control valve, similar to a conventional thermal expansion valve used in air conditioning refrigeration and heat pump evaporators, connected at the input line to a mono-tube type boiler to control the fluid flow into the boiler from a constant pressure liquid supply as a function of a pressure differential between boiler discharge pressure and pressure in a closed liquid-filled bulb secured to the boiler to sense boiler output temperature, with a variable super heat adjustment being provided to impose a biasing force to act with the boiler discharge pressure, and wherein a boiler pressure control system sensitive to boiler output pressure is used to control the operation of a fuel control valve to regulate the amount of fuel delivered to the burner for the boiler.

For a better understanding of the invention, as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic elevation view of a boiler and its associated components for a vapor engine and utilizing the boiler control system of the invention:

FIG. 2 is a simplified ideal Rankine cycle temperature-entropy diagram illustrating what will happen when the super heat control valve of the subject boiler control system indicates the need for more super heat; and,

FIG. 3 is a diagram similar to FIG. 2 illustrating how the boiler pressure control valve reacts to control the flow of fuel to the burner.

Referring now to FIG. 1, there is schematically illustrated a boiler 10 and its associated components of the boiler control system of the invention for supplying vapor to the expander of a suitable vapor engine, not shown. A liquid supply pump 12, which may be a feed water pump in a steam system, provides a constant pressure liquid supply of a working fluid in conduit 14, the upper pressure limit of the liquid supplied being controlled by a pressure bypass valve 16 in the bypass conduit 18 interconnected between the discharge and inlet of the pump 12.

In accordance with one of the subsystems of the subject boiler control system of the invention, the rate of flow of liquid from this constant pressure liquid supply into the boiler 10 is controlled as a function of boiler output pressure and temperature by a superheat control valve, in the form of a conventional thermal expansion valve 20.

As shown schematically, the super heat control valve 20 includes a valve housing 22 provided with an inlet conduit or chamber 24 and an outlet conduit or chamber 26 in communication with each other by a valve 28 controlled passage 30.

The valve 28 is fixed to a valve stem 32 suitably journaled in the valve housing for sliding motion to carry valve 28 between a valve closed position with respect to the passage 30 and a valve open position with respect thereto as controlled by a differential pressure actuated movable membrane means. The membrane means may be in the form of a single diaphragm, or as shown, in the form of the movable end walls of variable volume chambers of bellows 34 and 36. The movable walls of these bellows are suitably fixed to valve stem 32 and the bellows are connected to the boiler as described in detail hereinafter.

In addition, in order to permit adjustment in the opening and closing pressures required to effect operation of the valve 28, and thereby control super heat temperatures in the boiler output, the valve 28 is operatively connected to a bias spring 38. Spring 38 abuts at one end against a spring retainer 40 fixed to the valve stem 32 and at its other end abuts against a spring retainer 42 adjustably positioned by an adjusting screw 44 threaded into the valve housing 22.

As shown, conduit 14 from the discharge side of feed water pump 12 is connected to the inlet chamber 24 of valve 22 while the outlet chamber 26 of the valve is connected to supply working fluid to the tube portion 46 of the boiler 10, part of the tube portion being coiled about and above a suitable heat source, such as burner 48, and terminating in an outlet tube portion 50. The outlet tube portion 50 of boiler 10 is connected to vapor throttle valve 52 which controls admission of vapor to the expander of the vapor engine, not shown. The operation of the vapor throttle valve 52 may be effected through a suitable linkage 54 and a throttle control lever 56, as desired.

Outlet tube portion 50 is also connected by conduit 58 to the variable volume chamber of bellows 34 of control valve 20 whereby output boiler pressure acts upon the movable wall of this bellows to bias the valve 28 toward the closed position. To counteract this, the variable volume chamber of bellows 36 is connected by conduit 60 to closed bulb 62 suitably positioned in thermal contact with discharge vapor from boiler 10, as by being positioned within the outlet tube portion 50, or as shown, positioned in thermal contact with outlet tube portion 50. The variable volume chamber of bellows 36, conduit 60 and closed bulb 62 are filled with a suitable working fluid which can be the same as the fluid supplied to boiler 10 or a different fluid, as desired.

Referring now to the operation of this subsystem of the subject boiler control system, the liquid pump 12 provides a constant pressure liquid supply for delivery to the boiler as controlled by the super heat control valve 20. The super heat control valve 20 throttles the fluid to the boiler where the liquid thus supplied is heated, vaporized and super heated. The boiler outlet temperature is sensed by the closed bulb 62 which, if filled with the same fluid as in the boiler, will assume the saturation pressure associated with the boiler output temperature in the outlet tube portion 50. This pressure is transmitted to the variable volume chamber of the bellows 36 to bias the valve 28 toward the open position. However, at the same time, boiler pressure is transmitted through the conduit 58 to the variable expansion chamber of bellows 34 which, together with the biasing action of the spring 38 as regulated by adjusting screw 44, balances the position of the valve 28 to maintain proper boiler fluid flow.

FIG. 2 demonstrates on a simplified ideal Rankine cycle temperature-entropy (T-S) diagram what would happen when the super heat control valve in effect calls for more super heat from ΔT to $\Delta T'$. If the super heat adjusting screw 44 has been adjusted to set the super heat control valve to maintain a super heat temperature of $\Delta T'$ and the temperature of the fluid in output conduit portion 50 decreases to ΔT , this decrease in temperature will be reflected in the heat of the fluid in the closed bulb 62 reducing the saturation pressure of the liquid therein including the variable volume chamber of bellows 36, thus allowing spring 38 and the boiler pressure within the variable volume chamber of bellows 34 to move the valve 28

toward the closed position to reduce the fluid flow from m to m' to the boiler and effecting a reduction in pressure of the liquid in the boiler from P to P' . If the heat input is constant, at that time, this heat input is used to heat a reduced flow of working fluid and thus more super heat will occur. As more super heat occurs, this increase in temperature will be sensed by the liquid in the closed bulb 62 effecting an increase in the pressure of this fluid in the variable volume chamber of bellows 36 to counterbalance the biasing action of the boiler pressure on the movable wall of bellows 34 and the biasing action of spring 38 to readjust the position of the valve 28 accordingly, to allow for an increase in fluid flow to the boiler.

Again referring to FIG. 1, fuel supplied to the burner 48 for combustion therein is controlled by a fuel control valve forming the second subsystem of the subject boiler control system. This fuel control valve, which directly responds to working fluid pressure in the boiler 10, controls boiler heat input by regulating the input of fuel to the boiler to establish a predetermined working pressure of the working fluid in the boiler.

The fuel which can be any suitable fuel or mixture of fuel and air is delivered to the burner by a conventional fuel delivery device, such as for example, when a liquid fuel is being used, by a fuel pump 64. The inlet to the fuel pump 64 is connected to a source of fuel, not shown, and the pump is used to provide a constant pressure fuel supply in the discharge conduit 66 with the flow of fuel therefrom to the burner 48 being regulated by a fuel control valve, generally designated 70, the operation of which is controlled by boiler discharge pressure. This fuel control valve may be any one of a number of types of hydraulic, pneumatic or electrically operable devices for valve control in response to pressure.

In the embodiment illustrated schematically in FIG. 1, fuel control valve 70 includes a valve housing 72 and a valve spool 74. Valve housing 72 has a central bore 76 in communication with inlet port 78 and outlet port 80, connected to conduit 66 from fuel pump 64 and conduit 66a to burner 48, respectively, and with a vent port 82. In addition, valve housing 72 has reduced bores 84a and 84b, on opposite sides of the central bore 76, in communication with ports 86 and 88, respectively. Port 88, a vent port, is connected by a passage 88a to outlet port 80.

The valve spool 74 has two lands 74a and 74b slideably received in bore 76 with land 74a movable relative to inlet port 78 to control the flow of fuel through this port into bore 76 and from there via outlet port 88 to the burner 48. In addition, the spool valve 74 is provided with a reduced land 74c at one end thereof forming an actuating piston slideably received in bore 84a. The spool valve 74 is normally biased upward, in reference to FIG. 1 to the position shown therein with the inlet port 78 then uncovered by land 74a, by means of a spring 90 abutting at one end against the end of the spool valve 74 and at its other end against the spring retainer 92 slideably received in bore 84b with the axial position of the spring retainer 92 in bore 84b determined by the position of the adjusting screw 94 which is threaded in the valve housing 72 to extend into bore 84b. To effect movement of the spool valve 74 in the opposite direction, the port 86 is connected by conduit 96 to the outlet tube portion 50 of boiler 10 whereby the working fluid pressure from boiler 10 is applied to the end of the actuating piston of the spool valve.

With this arrangement, the adjusting screw 94 can be positioned so that the biasing force of spring 90 acting on the end of the spool valve 74 can be such that a predetermined working fluid boiler pressure will be required to move the spool valve against the biasing action of the spring force to position the land 74a to throttle or close off the inlet fuel flow through inlet port 78, thereby controlling the fuel delivered to the burner 48.

FIG. 3 demonstrates on a simplified ideal Rankine cycle temperature-entropy (T-S) diagram how this pressure actuated, fuel control valve 70 functions as part of the subject boiler control system. If the pressure of the working fluid in

the boiler at the outlet tube portion 50 is decreased or lowered to a pressure P' which is below the preset pressure P , as determined by the position of the adjusting screw 94 in the fuel control valve 70, by either operation of the super heat control valve 20 to reduce the flow of working fluid to the boiler or by opening of the throttle valve 52, more heat input is called for in proportion to the pressure difference between the preset opening pressure P for the control valve 70 and the actual pressure P' in the discharge from the boiler 10. Accordingly, the spool valve 74 is moved by the spring 90 toward the position shown in FIG. 1 to allow increased fuel flow from the fuel pump 64 to the burner 48.

With increased fuel flow, the immediate result is an increase in the super heat $\Delta T'$, which in turn, as described in reference to FIG. 2, will cause the control valve 20 to open more, as a result of an increase in pressure of the fluid in bulb 62, increasing pressure P' to P and the fluid flow to the boiler from m' to m . As pressure P' approaches P in the output from the boiler 10, the fuel input and therefore, heat output from burner 48 would be progressively modulated back by the control valve 70 to the correct flow rate for steady state operation of the boiler.

The fuel control system of the subject boiler control system directly responds to working fluid pressure and controls fuel input to the boiler and thus heat output to establish a predetermined boiler output pressure. It operates with the working fluid flow control to the boiler subsystem to maintain boiler exit temperature and pressure at predetermined values.

As previously described, it is not necessary that the working fluid in the enclosed bulb 62 of the super heat control valve 20 be the same as the working fluid in the boiler 10. As a practical matter, it is preferred to use a different fluid in the bulb 62 when the super heat vapor temperature leaving the boiler exceeds the temperature at which saturated vapor and liquid can exist, that is, at a temperature above the critical point. Even if the temperature is below the critical point, it may result in excessively high saturation pressures. For example, consider a water steam boiler system with a boiler exit temperature of 700° F and exit pressure of 800 pounds per square inch absolute. These steam exit conditions represent about 180° F of super heat. With water as the working fluid in the bulb 62, this would represent a saturation pressure at 700° F of 3,100 pounds per square inch absolute or nearly critical. Under these conditions, it would be advisable to use a liquid in bulb 62 with a lower vapor pressure to yield a lower working pressure to act on the diaphragm or bellows of the super heat control valve 20 and these latter elements can then be suitably designed to balance the resulting forces, in a known manner. Since the saturation pressure of Dowtherm A, a eutectic mixture of Diphenyl oxide and Diphenyl containing 73.5 percent of Diphenyl oxide and 26.5 percent of Diphenyl and melting at 53.6° F, a product of the Dow Chemical Company, is only 104 pounds per square inch absolute at 700° F, while that of mercury is only 20 pounds per square inch absolute, it would be obviously more desirable to use either of these fluids, for example, in lieu of water as the fluid in the closed bulb arrangement in a water steam boiler system.

What is claimed is:

1. A boiler control system for a vapor engine including a source of working fluid under pressure, a boiler for working fluid having an inlet for connection to said source of working fluid and an outlet adapted for connection to the vapor engine, a thermal expansion valve connected to said source of working fluid and to said inlet and adapted to regulate the input flow of working fluid from said source of working fluid to said boiler as a function of the pressure and temperature of the working fluid in said outlet, a heat source disposed in heat transfer relation to said boiler to heat the working fluid therein, a source of pressurized fuel for said heat source, and pressure responsive valve means connected between said source of pressurized fuel and said heat source, said pressure responsive valve means including pressure responsive means connected to said outlet of said boiler to regulate the flow of

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fuel to said heat source as a function of the pressure of the working fluid in said outlet, and said thermal expansion valve including a valve housing having a passage therein in communication with said source of working fluid and said inlet to said boiler, a valve mounted in said valve housing for movement from a first position to a second position relative to said passage to vary the flow of fluid therethrough, movable wall means positioned in the said valve housing and connected to said valve to effect movement thereof, said movable wall means defining with said valve housing a first variable volume chamber and a second variable volume chamber, means connecting said first variable volume chamber to said outlet whereby working fluid from said outlet acts on one side of said movable wall means to bias said valve toward said first position and closed bulb means connected to said second variable volume chamber and positioned in thermal relation to the working fluid in said outlet, said closed bulb means and said second variable volume chamber containing a fluid therein acting on said movable wall means to bias said valve toward said second position.

2. A boiler control system according to claim 1 wherein said thermal expansion valve further includes adjustable bias means operatively connected to said valve to normally bias said valve toward said first position.

3. A boiler control system according to claim 1 wherein said fluid in said closed bulb means and said second variable volume chamber is the same as said working fluid.

4. A boiler control system according to claim 1 wherein said fluid in said closed bulb means and said second variable

volume chamber is a fluid with a lower vapor pressure than said working fluid.

5. A boiler control system according to claim 1 wherein said boiler is a mono-tube type boiler.

6. A boiler control system for a vapor engine including a source of working fluid under pressure, a boiler for working fluid having an inlet and an outlet, said outlet being adapted for connection to the vapor engine, control valve means connected to said source of working fluid and to said inlet, said control valve means having a movable valve and valve actuating means, said valve actuating means being positioned in communication with the working fluid in said outlet and with fluid in a closed bulb positioned in heat transfer relationship to the working fluid in said outlet whereby said valve is moved to control the flow of working fluid to said inlet of said boiler as a function of a pressure differential between boiler discharge pressure and the pressure of the fluid in said closed bulb, said valve actuating means further including adjustable bias means to vary the pressure differential between said boiler discharge pressure and the pressure of the fluid in said closed bulb required to effect movement of said valve, a heat source disposed in heat transfer relationship to said boiler, a source of pressurized fuel for said heat source, and valve means connected between said source of pressurized fuel and said heat source, said valve means including pressure responsive means connected to said outlet of said boiler to regulate the flow of fuel through said valve means to said heat source as a function of the pressure of the working fluid in said outlet.

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