

Jan. 27, 1959

J. F. SHANNON ET AL

2,870,729

CONTROL SYSTEMS

Filed Jan. 10, 1952

3 Sheets-Sheet 1

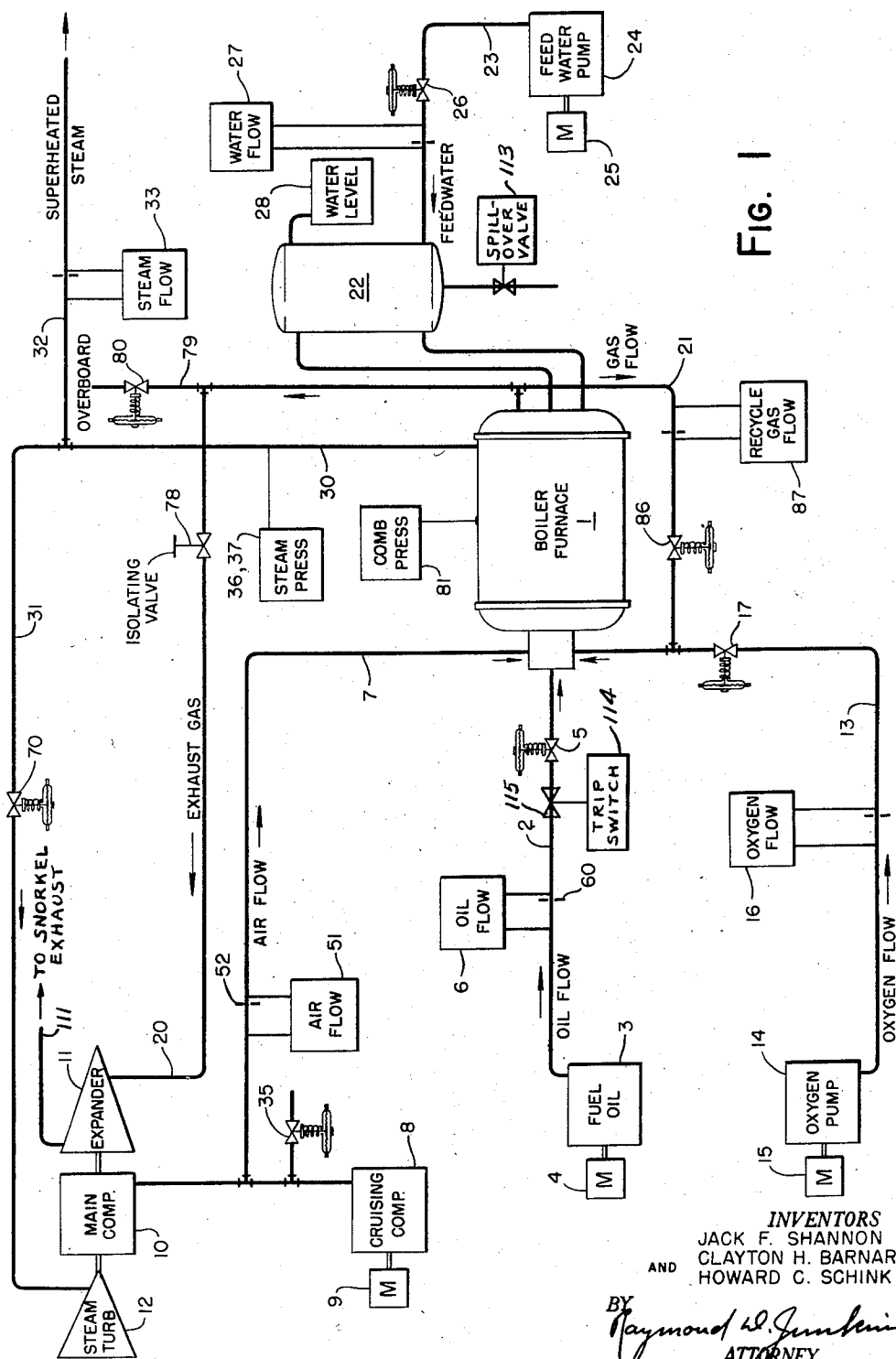


FIG. 1

INVENTORS
JACK F. SHANNON
CLAYTON H. BARNARD
HOWARD C. SCHINK

BY *Raymond W. Jenkins*
ATTORNEY

Jan. 27, 1959

J. F. SHANNON ET AL

2,870,729

CONTROL SYSTEMS

Filed Jan. 10, 1952

3 Sheets-Sheet 2

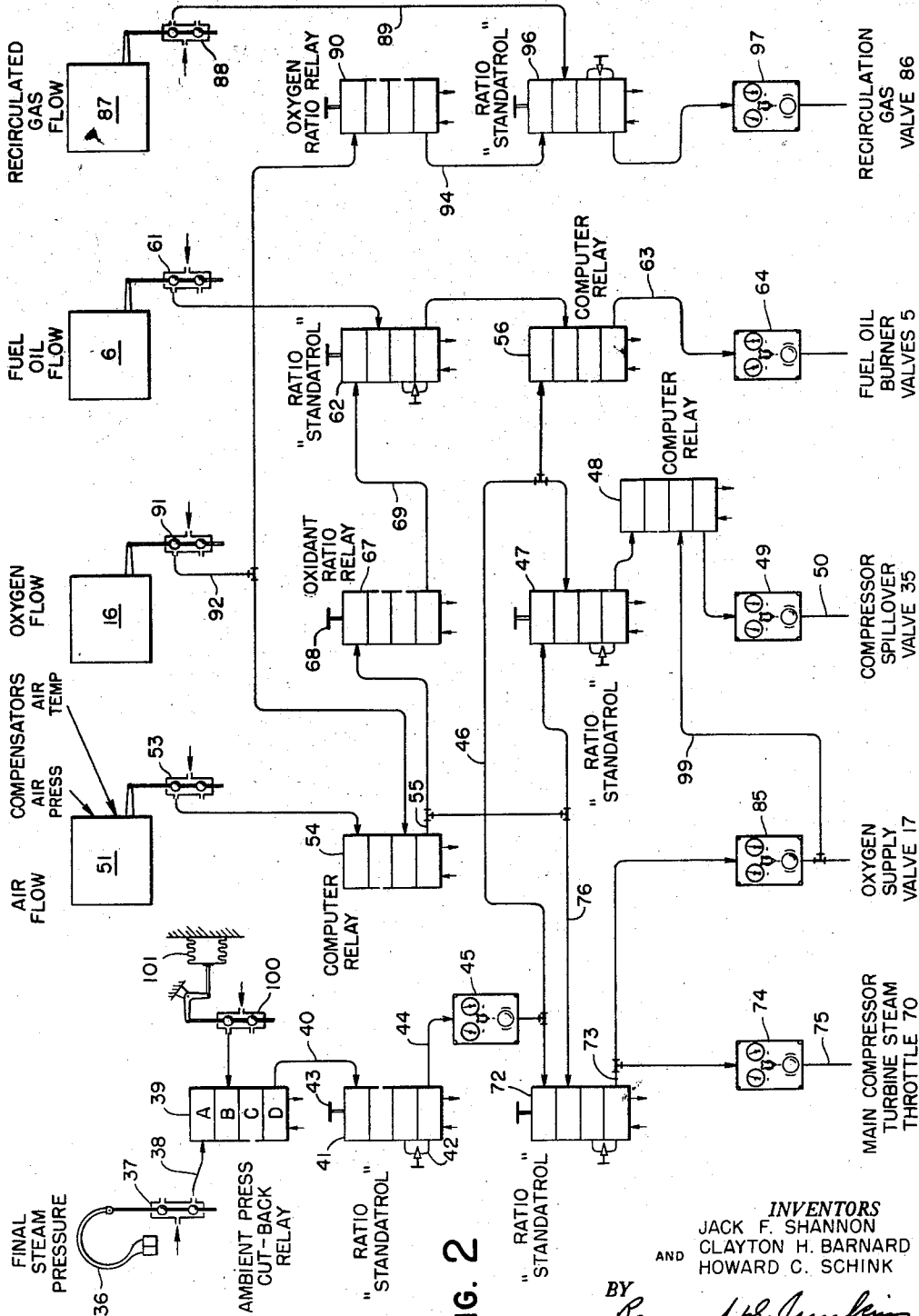


FIG. 2

INVENTORS
 JACK F. SHANNON
 CLAYTON H. BARNARD
 AND
 HOWARD C. SCHINK
 BY
Raymond W. Jenkins
 ATTORNEY

Jan. 27, 1959

J. F. SHANNON ET AL

2,870,729

CONTROL SYSTEMS

Filed Jan. 10, 1952

3 Sheets-Sheet 3

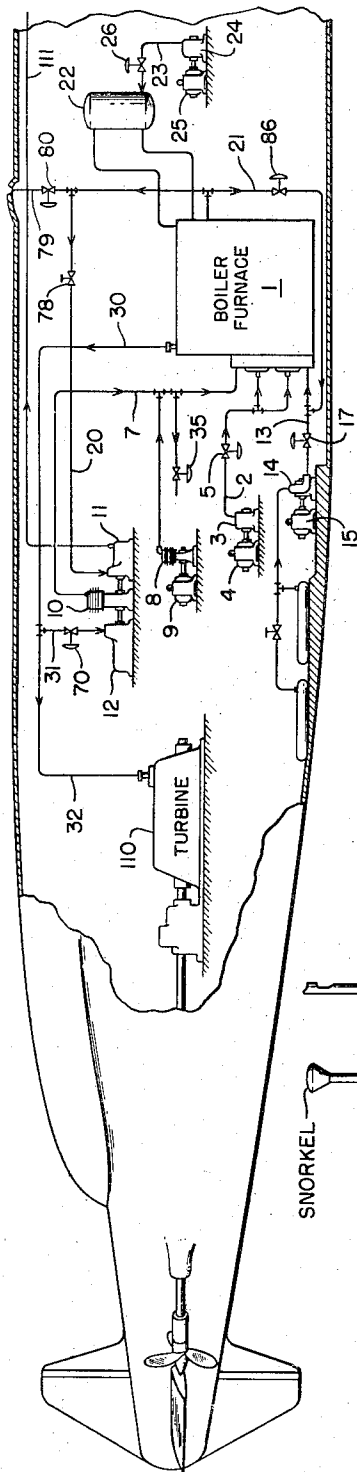


FIG. 3

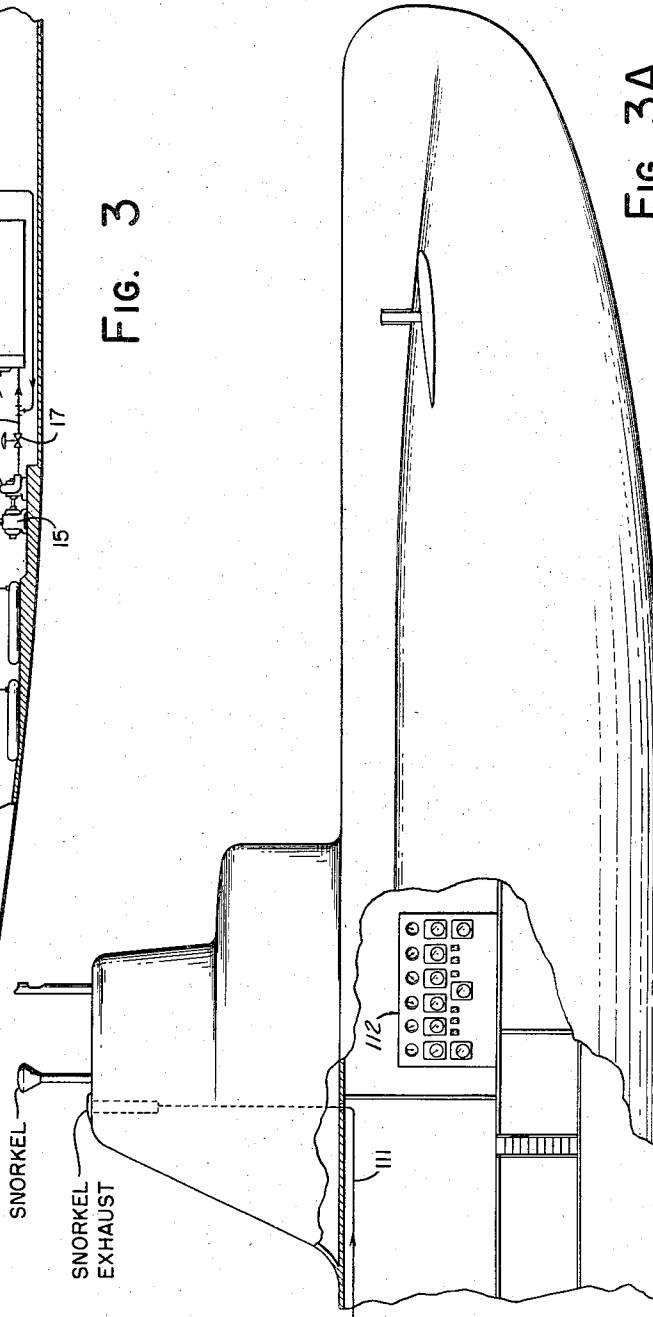


FIG. 3A

INVENTORS
 JACK F. SHANNON
 AND CLAYTON H. BARNARD
 HOWARD C. SCHINK
 BY *Raymond W. Jenkins*
 ATTORNEY

1

2,870,729

CONTROL SYSTEMS

Jack F. Shannon, Euclid, Clayton H. Barnard, South Euclid, and Howard C. Schink, Cleveland Heights, Ohio, assignors to Bailey Meter Company, a corporation of Delaware

Application January 10, 1952, Serial No. 265,897

8 Claims. (Cl. 114—16)

This invention relates to control systems and apparatus for steam-powered submarine propulsion plants equipped with boilers having pressurized furnaces. Oil is the fuel to be burned preferably, although any fuel burned in suspension, such as gas or pulverized coal might equally as well be utilized with our invention. Under surface and snorkel operating conditions, air for combustion is to be furnished by means of centrifugal compressors, while under submerged operation, liquid oxygen will be pressurized, heated to normal temperature, vaporized under pressure and supplied to the furnace for combustion.

It will be understood that a snorkel is a breathing device used by a submarine and may include a tube or a pair of tubes housing air intake as well as air and gas exhaust pipes that can be extended above the surface of the water for allowing operation with furnace or engine when the submarine is submerged. The arrangement allows discharge of exhaust air and gases at all times without entry of water when waves submerge the exhaust port. The inlet port allows air entrance when not covered by a wave but closes against water entry when the port is submerged by a wave.

When using gaseous oxygen for supporting combustion exit products of combustion will be recirculated to dilute the gaseous oxygen and thus limit furnace temperature.

During submerged operation, furnace pressure is necessarily held high enough to permit the exit gases to be discharged overboard against the submergence pressure then existing.

A principal object of our present invention is to provide method and apparatus for controlling the operation of such a steam generating plant operating under surface, snorkel, or submerged conditions.

Another object is to provide an automatic control system of the fluid pressure actuated type for steam-powered submarine propulsion plant.

Other objects will become evident from a study of the drawing and of the description thereof as well as the claims appended hereto.

In the drawings:

Fig. 1 is a diagrammatic showing of a steam-powered submarine propulsion plant to which our invention has been applied.

Fig. 2 is a schematic showing of the measuring and controlling instrumentalities of Fig. 1.

Figs. 3 and 3A illustrate a submarine, in side elevation, with a portion of the hull broken away to disclose a diagrammatic showing of the vapor generator, propulsion equipment, auxiliaries, control panel, and principal interconnecting piping.

The showing of the drawing is quite diagrammatic and not to any scale. The same numbers are used to designate like parts on the sheets.

A pressurized boiler furnace 1 is shown as being supplied with fuel oil through a conduit 2, by means of a pump 3 which is driven by a constant speed electric

2

motor 4. Regulation of the rate of supply of fuel oil is had through the agency of a diaphragm actuated control valve 5 located in the conduit 2; while its rate of flow is continuously measured by a flow meter 6.

Air to support combustion is supplied to the furnace 1 by way of a conduit 7 to which is connected a cruising compressor 8 driven (when operating) by a constant speed electric motor 9. Also connected to the air supply conduit 7 is a main compressor 10 which is driven by an exhaust gas expander 11 and a steam turbine 12. When the main compressor 10 is in operation approximately 30 percent of its driving power is supplied by the expander 11 and the remaining 70 percent by the steam turbine 12.

Under certain conditions of operation, to be explained hereinafter, oxygen to support combustion is supplied to the furnace 1 through a conduit 13 by an oxygen pump 14 driven by a variable speed drive electric motor 15. The showing is quite diagrammatic and omits the equipment for gasification of liquid oxygen and two stages of gaseous oxygen pressure control. The rate of gaseous oxygen supplied to the furnace through the conduit 13 is measured by an oxygen rate of flow meter 16 and is controlled by a diaphragm actuated control valve 17 located in the conduit 13.

Under certain conditions of operation all of the exhaust products of combustion from the furnace 1 pass through a conduit 20 to the expander 11 whereas, under other conditions of operation, a portion of the products of combustion are diverted through a branch conduit 21 which joins the oxygen supply conduit 13 on the furnace side of the oxygen regulating valve 17.

A separation drum 22 is connected to the fluid circuits of the boiler 1 and is supplied with feed water through a conduit 23 by means of a feed water pump 24 driven by a motor 25. Feed water supply rate through the conduit 23 is under the control of a diaphragm actuated valve 26 while the rate of water flow through the conduit 23 is continuously measured by a rate of flow meter 27. A water level measuring device 28 is continuously sensitive to liquid level within the drum 22 for a purpose to be explained hereinafter.

Superheated steam leaves the boiler 1 through a conduit 30 which branches as at 31 to supply the steam turbine 12 when it is operating. The principal output of the power system, namely superheated steam, leaves through a conduit 32 and is measured by a rate of flow meter 33. The conduit 32 supplies superheated steam to one or more main propulsion turbines 110.

There are certain basic requirements to be met in the operation of such a power plant. The rate of combustion must be controlled to satisfy steam demand. Fuel should be proportioned to oxidant when using air during surface or snorkel operation, or when using oxygen during submergence. A proportioning control is provided capable of supplying sufficient oxygen for efficient combustion of the fuel oil. Control of feed water supply will proportion the water inflow in accordance with requirements, and a spill-over valve from the drum to the main condenser provides against excessively high drum levels during maneuvering or rapid start operations. When using gaseous oxygen for combustion, exit gases will be recirculated to limit furnace temperature. During submerged operation, furnace pressure will be maintained high enough to permit the exit gases to be discharged overboard against the submergence pressure then existing.

The boiler plant will function under three phases of operation; surface, snorkel and submerged. The first two modes of operation will utilize air from either the cruising or the main compressor, depending upon load requirements. During submerged operation, liquid oxy-

gen will be evaporated and supplied to the furnace in gaseous form.

Surface operation—Light load

The cruising compressor 8 will be used to supply air for combustion during periods of light load operation. Since this unit is driven by a constant speed direct current motor 9, control of the amount of combustion air supplied is obtained by throttling a compressor spill-over valve 35 which wastes (to the hull) the air not required for combustion. Control of the quantity of the fuel oil fired is accomplished by adjusting a stroke operator on pump 3 and regulating one or more burner control valves 5.

A steam pressure measuring-transmitter including Bourdon tube 36 and pneumatic pilot valve 37 measures steam pressure in the superheater outlet header 30 and develops a proportional air pressure signal in pipe 38 joining the A chamber of an ambient pressure cut-back relay 39 which may be of the general type described and claimed in Dickey Patent 2,098,913. The output pressure of relay 39, available in chamber D, is subjected through a pipe 40 upon the A chamber of a ratio standardizing relay 41 which is of the type described and claimed in Gorrie Re. 21,804. Relay 41 provides a proportional control with reset characteristics. It provides for the demand index (final steam pressure), a floating control of high sensitivity superimposed upon a positioning control of relatively low sensitivity. A function of the adjustable bleed 42, between the C and D chambers of the relay, is to supplement the primary control of the pressure effective in pipe 40 with a secondary control of the same or of different magnitude as a follow-up or supplemental action to prevent over-travel and hunting. The relay 41 is also provided with ratio adjusting means illustrated as a hand knob 43.

When we speak of "ambient" pressure or temperature, we mean the pressure or temperature "ambient to" or "adjacent" the particular apparatus under discussion and within the hull or other confined space in which the apparatus is located. It is intended to mean the pressure or temperature within the submarine hull, airplane body, or other confined space containing the controlling instrumentalities and/or the controlled devices. In the present submarine embodiment it might be termed "hull interior" pressure or temperature.

The output signal of relay 41, available in a pipe 44, is passed through a hand-automatic selector valve station 45 of the type described and claimed in the Fitch Patent 2,202,485 providing a possibility of selective remote hand or automatic operation.

The output signal from selector station 45, whether by automatic means or hand adjustment, is available in a pipe 46 and acts through the various relays to adjust the supply rates of the elements of combustion to satisfy the demand for steam. Under cruising operation (light load) this is through a control of the compressor spill-over valve 35 and the fuel oil burner valve 5.

The master signal in pipe 46 is subjected upon the B chamber of a ratio standardizing relay 47, whose output acts through a computer relay 48 and selector station 49 to a pipe 50 joining the diaphragm chamber of the spill-over valve 35. The relay 47 is used for the purpose of furnishing an air flow tie-back control. Since a change in steam pressure is represented by a change in loading pressure which functions through relays 39, 41, 47 and 48, to vary the degree of throttling of spill-over valve 35, the resultant change in combustion air supplied to the furnace through conduit 7 is measured by an air flow rate meter 51 and its effect is balanced against the master air pressure signal.

The air flow meter 51 is connected across an orifice 52 located in conduit 7 and actuates the movable element of a pneumatic pilot 53 to thereby establish in the A chamber of a computer relay 54 an air pressure con-

tinuously proportional to the amount of air being furnished the furnace. The output of relay 54, available in a pipe 55, is subjected upon the A chamber of relay 47 to balance against the master steam pressure signal of the B chamber. Thus the relay 47 continuously checks the master demand for air flow against the actual measured air flow and provides a readjusting effect upon valve 35 if necessary.

Control of fuel oil supply rate is accomplished through a computer relay 56 which balances the master signal (pipe 46 to A chamber of relay 56) against a signal (in B chamber of relay 56) originating from a fuel oil flow meter 6 previously mentioned.

The meter 6 is sensitive to the pressure differential produced by fuel oil flow through an orifice 60 located in oil supply conduit 2; and positions the movable element of a pilot 61 thereby establishing in the B chamber of a ratio standardizing relay 62 an air pressure signal continuously representative of fuel oil supply rate. The output of relay 62 is subjected upon the B chamber of computer relay 56 in tie-back opposition or balance to the master steam pressure signal. If the pressures acting upon the relay 56 are not in balance, indicative of a need for change in fuel oil supply rate, the unbalance is represented by a change in control pressure in pipe 63 which acts through a selector station 64 to readjust the throttling position of fuel oil burner valves 5 and/or the oil pump stroke mechanism.

In order to provide the possibility of manual adjustment of the ratio of fuel to air flow required, an oxidant ratio relay 67 is installed in the control circuit for this purpose. The input pressure to this relay, subjected upon the relay A chamber from pipe 55, is proportional to combustion air being supplied and by means of a knob 68 adjustment, the ratio of the output to input pressures may be adjusted. The output pressure (in pipe 69) in turn acts upon the A chamber of relay 62 where it is balanced against the B chamber pressure proportional to oil flow. The output of relay 62 to computer relay 56 is therefore proportional to any deviation from the desired ratio of oil to combustion oxidant. While the primary changes on both the combustion air and the oil flow are made from the steam pressure controller 36, 37, deviations in the desired proportion of fuel oil to combustion air are accomplished by variations in the air pressure signal from the ratio relay 62.

During this type of surface operation a hand isolating valve 78 is closed and all of the exhaust products of combustion from the furnace are discharged overboard by way of a pipe 79 through a control valve 80.

Overboard valve 80 is under direct automatic control of controller 81 in order to balance the submergence pressure against that of furnace 1 to insure continuous discharge overboard of the products of combustion during submergence. The structural arrangement of controller 81 may take any of the elementary, obvious forms whereby pressure responsive members may be linked to a pilot valve for establishing a control pressure going to the diaphragm of valve 80. The mechanical advantage of one link over the other may be altered by manually adjustable means. The furnace pressure is placed in one pressure responsive member and the submergence pressure is placed in another pressure responsive member. The resulting control pressure output of the pilot valve adjusts overboard valve 80 to continuously exhaust products of combustion during various degrees of submergence without substantial variation of the furnace pressure.

Surface operation—Heavier loads

For operation at greater than cruising load conditions, the main air compressor 10 is used as the source of combustion air. Control of the compressor 10 is accomplished by the turbine throttle valve 70 in steam conduit 31. The master steam pressure signal is impressed upon the A chamber of a ratio standardizing relay 72

5

whose output signal (in pipe 73) acts through a selector station 74 in pipe 75 to position the steam throttle 70. Relay 72 serves as an air flow tie-back by having its B chamber loaded from air flow through a branch 76 of the pipe 55. A change in air pressure signal from the master selector 45 will cause the main compressor 10 to continually change speed in one direction until the air pressure signal from the air flow relay 54 (in pipes 55, 76) indicates that the required change in combustion air flow rate has been accomplished. During this phase of operation, the compressor spill-over valve 35 remains in a closed position with all changes in combustion air rate being effected by varying the speed of the main air compressor. The transition from the cruising to the main compressor is made a semi-manual operation as it occurs rather infrequently and under preselected desire by the operator.

During this somewhat heavier load operation the exhaust products of combustion are utilized by way of expander 11 to provide about 30 percent of the power requirements of main compressor 10. The hand isolating valve 78 is opened and the controller 81 is hand adjusted to maintain valve 80 normally closed so that all of the products of combustion will pass through the expander.

Exhaust gases from the expander 11 leave through a conduit 111 to the snorkel exhaust (Fig. 3A). Under surface operation the snorkel exhaust freely passes gases to the atmosphere. Under snorkel operation the intermittent or occasional wave submergence of the snorkel exhaust does not introduce sufficient back pressure, relative to expander discharge pressure, to disturb or pulsate air supply to conduit 7 from the main compressor 10.

We have indicated in Fig. 2 that the air flow meter 51 is provided with automatic compensators sensitive to ambient air pressure and temperature.

Submerged operation

During submerged operation it becomes necessary to use oxygen as the oxidant of combustion, and liquid oxygen is vaporized, pressure controlled, and diluted with recirculated products of combustion. In addition to providing automatic control of steam pressure, the correct fuel-oxidant ratio, and drum liquid level; the system maintains the correct ratio of recycled exhaust gases to gaseous oxygen and the desired furnace combustion pressure.

The main compressor is not used and hand isolating valve 78 is closed. Selector station 74 is turned to "hand" and throttle valve 70 is remotely manually closed. Selector 74 thereafter isolates valve 70 from pressure signals of pipe 73.

The control of gaseous oxygen flow, through selector station 85 from steam pressure and total oxidant is accomplished in the same manner as when firing with the main compressor with the exception that the control signal in pipe 73 is used to throttle valve 17.

Gaseous oxygen flow rate is measured by a rate meter 16 arranged to position the movable element of a pilot 91 thereby establishing in a pipe 92 a loading pressure continuously representative of oxygen supply. The computer relay 54, previously sensitive to measured air flow, is now sensitive to measured oxygen flow (pipe 92) and its output in pipe 55 controls the oxygen valve 17 and fuel oil valve 5.

The oxygen ratio relay 90 determines the proportions of recirculated gas mixed with gaseous oxygen to dilute the latter. The input air pressure signal to the A chamber of relay 90 (from pipe 92) is proportional to gaseous oxygen flow and the knob adjustment of relay 90 serves as a means of varying the ratio of the input to the output pressure in a pipe 94 and thus provide selection of the proportions desired. A measuring device sensitive to furnace temperature indicates the same on the control

6

panel 112 (Fig. 3A) available to the operator who may adjust the ratio knob of relay 90 to regulate the ratio of recirculated gas flow to gaseous oxygen flow and thus maintain furnace temperature below an excessive value.

Recirculated gas flow through a conduit 21, is regulated by a control valve 86 and is measured by a rate meter 87. Meter 87 is arranged to position the movable element of a pilot 88, establishing in a pipe 89 a fluid loading pressure continuously representative of recirculated gas flow rate.

The output pressures from the oxygen ratio relay 90 and the gas flow controller 87, 88 then act through a ratio standardizing relay 96 which produces an air loading pressure proportional to deviation from the desired ratio of gas to oxygen flow, and through selector station 97 to adjust the positioning of recycled gas flow valve 86.

Under this mode of operation, with a portion of the products of combustion recirculated to dilute gaseous oxygen and thus limit furnace temperature, the remainder of the exit gases are discharged overboard through valve 80 and pipe 79. Combustion chamber pressure must be maintained sufficiently high to discharge the gases overboard against the depth of submergence. Oxygen gaseous supply is used to aspirate the recycled gas to the furnace. Combustion pressure control is accomplished by throttling valve 80 in overboard conduit 79.

Both the main compressor and the cruising compressor have characteristics such that flow and pressure rise and fall together. When it is desired to transfer from air burning (particularly from the main compressor) to oxygen firing, it will be seen that, as we begin to open oxygen valve 17 through hand manipulation of selector station 85, the oxygen flow meter 16 will act through pipe 92, relay 54, pipe 76 and relay 72 to indicate an excess of oxidant and tend to cut back on valve 70. To prevent this and maintain combustion chamber pressure, we tie the output of selector 85 to relay 48 (through pipe 99) which controls the spill-over valve 35 to dump air without changing compressor speed.

For all three modes of operation the feed water control supplies the boiler in accordance with load demand. This is accomplished by metering superheated steam flow in the outlet header 32 with flow rate meter 33 and feed water inflow rate through conduit 23 by flow meter 27. Air pressures proportional to steam outflow and water inflow are developed by these measuring controllers, and through a relay develop an air pressure which positions the feed water control valve 26 to maintain the same rate of water inflow to the boiler as steam flow therefrom. Deviations in separator drum (22) water level are sensed by measuring controller 28 which develops an air pressure proportional to water level and acts upon the relay to modify the steam flow-water flow control of valve 26 as necessary to maintain the correct separator drum level. During rapid load swings, excessively high drum levels are prevented by opening the drum spill-over valve 113 by the air pressure developed by controller 28.

Snorkel operation

When firing the unit under snorkel conditions, changes in ambient pressure within the hull are expected although the depth of submergence is relatively constant. The ambient pressure cut-back relay 39 has been included in the control system for the purpose of reducing firing rate (and consequent use of hull air) during periods of low hull pressure. This is accomplished by loading the B chamber of relay 39 with a loading pressure representative of hull interior pressure changes as sensed by a pressure member 101 positioning a pilot 100. Thus the pressure signal in pipe 38 is modified by a pressure in proportion to changes in hull ambient pressure. This modified control signal (in pipe 40) acts to reduce firing rate whether operating under the cruising or the

main air compressor, when the air for combustion is drawn from the hull interior. Were the firing rate not reduced (and the air withdrawal from the hull undiminished) during snorkel closure of some 8 seconds, the hull air would be exhausted to such an extent as to be dangerous to the personnel. Additionally, a trip switch 114 measuring hull pressure has been included for the purpose of tripping out the fires by valve 115 upon reaching a dangerously low hull pressure.

Referring specifically to Fig. 2, relays 41, 72, 47, 62 and 96 have been designated as standardizing type relays. For use under ambient-pressure-changing conditions, such as might be encountered during snorkel operation, or even under varying depth of submergence, it was found that this relay would tend to hold a constant absolute pressure following a sudden change rather than a constant gage pressure which is required of the system, and which the remainder of the components produce. To compensate for this, an additional bellows was added, together with a bleed valve, which would compensate for the reset rate bleed adjustment in such a way that the output during variable ambient pressure conditions will remain on a constant gage pressure basis. Details of this compensation was not shown in the present drawing and reference should be made to the copending application of Howard C. Schink, Serial No. 318,308, filed November 1, 1952, now Patent 2,860,650 which is directed particularly to such an ambient pressure or barometric pressure compensated relay.

It will be seen that we have provided apparatus and a method of operation to handle a steam boiler plant for a submarine which will function under three definite phases of operation; surface, snorkel and submerged. The first two conditions of operation take air from the hull interior by way of either a cruising or main compressor, depending upon load requirements. During submerged operation, liquid oxygen is evaporated and supplied to the boiler furnace in gaseous form. Regardless of the method of operation, the automatic combustion control performs the following basic functions; maintaining steam pressure at the correct value, maintaining combustion pressure, maintaining the correct ratio of fuel to oxidant, and maintaining feed water supply rate as needed. Change-over from one method of firing to another is manual through remotely actuated instrumentalities and immediately following such change-over, the automatic control system functions under the new mode of operation.

While we have described certain automatic methods and systems of operation under different conditions of service, it will be apparent that our methods may be manually performed through observation of the various measuring instrumentalities and remote manual control of the controllable factors. In Fig. 3A we show a central control panel 112 upon which may be mounted various measuring devices of variables in the operation of the plant, for example, meters 36, 51, 16, 6, 87, 81, 33, 28, 27 etc., as well as manual-automatic selector stations 45, 74, 85, 49, 64, 97, and 125. Some, or all of the relays may also be mounted on the panel 112, as well as controllers 101 and 114. The operator may observe the measuring instrumentalities and remotely manually operate the selector stations to perform the claimed methods.

It will be evident that, while we have chosen to illustrate and describe one preferred embodiment of our invention in connection with a submarine as exemplifying an enclosed space, we contemplate that our invention is equally as well adapted to enclosed spaces as, for example, the pressurized hulls of airplanes, the pressurized or evacuated containers of automatic piles, or the like.

What we claim as new, and desire to secure by Letters Patent of the United States, is:

1. The method of operating the steam generating process of a submarine propulsion unit having a pressurized combustion furnace supplied a fluent fuel and fluid oxidant including, supplying the oxidant from the sub-

marine interior, controlling the fuel and oxidant supply rate to satisfy steam demand upon the unit, discharging the products of combustion to the submarine exterior by maintaining the pressure within the furnace substantially constant and sufficiently high to maintain discharge from the furnace at various depths of submergence, and limiting the furnace fuel and oxidant supply from the air pressure within the submarine.

2. The method of claim 1 wherein the air is the combustion oxidant withdrawn from the submarine interior at a relatively constant rate and any excess air is continually returned to the submarine interior.

3. A system for controlling the steam generation process of a submarine propulsion unit subject to surface, snorkel and submerged operating conditions, including in combination, a steam generating furnace combustion chamber in the submarine interior, a fuel supply conduit for the furnace, an oxidant supply conduit for the furnace, a first meter for the fuel conduit, a second meter for the oxidant conduit, regulating valves in each of the conduits, a master steam pressure controller positioning the conduit valves simultaneously, a ratio determining means sensitive to the first and second meters modifying the regulation of the fuel supply conduit valve, a constant supply of fuel for the fuel supply conduit of the furnace, a compressor of constant speed connected to the oxidant supply conduit for supplying air from the submarine interior, and a valve in the oxidant conduit between the compressor and furnace under the conjoint control of the master steam pressure controller and the oxidant meter.

4. The combination of claim 3 in which the compressor is driven by a steam turbine and gas expander and there is included, a duct for conveying the gaseous products of combustion from the furnace to the expander, a control valve for the steam duct coming to the turbine, and means sensitive to the master steam pressure controller and the oxidant meter to conjointly position the control valve.

5. The combination of claim 4 wherein means responsive to the interior air pressure of the submarine opposes the master steam pressure controller to decrease the rate of fuel and oxidant supply when the interior air pressure of the submarine decreases below a predetermined value.

6. The combination of claim 5 including a pressure sensitive trip switch responsive to the interior air pressure of the submarine to close a valve in the fuel line when the interior air pressure of the submarine decreases below a predetermined value.

7. The combination of claim 3 wherein the oxidant supply conduit is connected to a source of oxygen and there is included in the combination, a meter for the oxygen in the oxidant supply conduit, a valve in the oxidant supply conduit positioned by the master steam pressure controller and the oxygen meter, and a system for mixing with the oxygen a portion of the products of combustion.

8. The combination of claim 7 in which the mixing system includes, a conduit from the furnace exhaust to the furnace burners, a meter for the products of combustion in the conduit, and a valve in the conduit for the products of combustion positioned by the oxygen meter and the products of combustion meter.

References Cited in the file of this patent

UNITED STATES PATENTS

1,126,616	Cage	Jan. 26, 1915
1,345,757	Emmet	July 6, 1920
1,380,304	Norton	May 31, 1921
1,695,472	Roucka	Dec. 18, 1928
1,721,800	Wunsch	July 23, 1929
2,247,595	Besler	July 1, 1941

(Other references on following page)

UNITED STATES PATENTS

2,289,682	Rasor -----	July 14, 1942
2,321,940	Roberston -----	June 15, 1943
2,400,116	Holthouse -----	May 14, 1946
2,412,739	McCracken -----	Dec. 17, 1946
2,519,240	Fellows -----	Aug. 15, 1950
2,623,698	Dickey -----	Dec. 30, 1952
2,679,979	Bristol -----	June 1, 1954

5

2,681,418
2,720,856

105,495
579,125

Bristol ----- June 15, 1954
Hoke ----- Oct. 18, 1955

FOREIGN PATENTS

Great Britain ----- Apr. 19, 1917
Great Britain ----- July 24, 1946

OTHER REFERENCES

"Popular Science," June 1949, pp. 98-104.