Oct. 30, 1945. A. CLARKSON 2,387,717

STEAM QUALITY CONTROLLER

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Fig. 1.

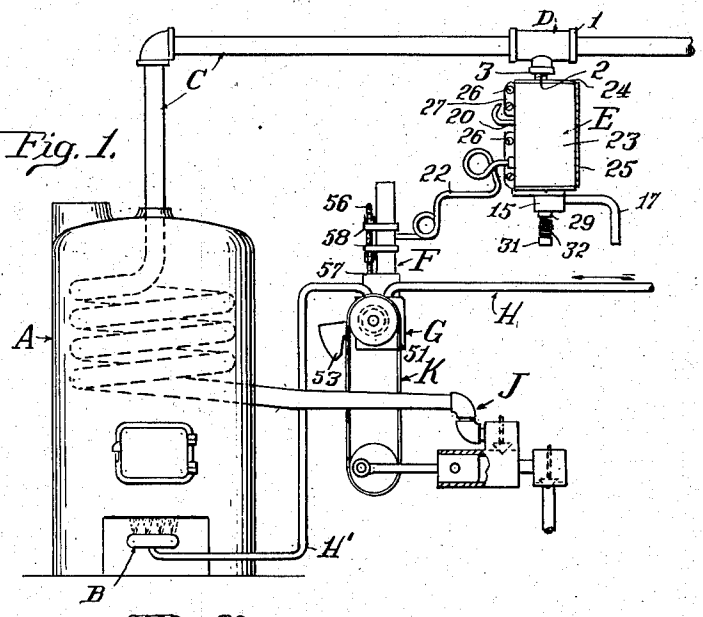
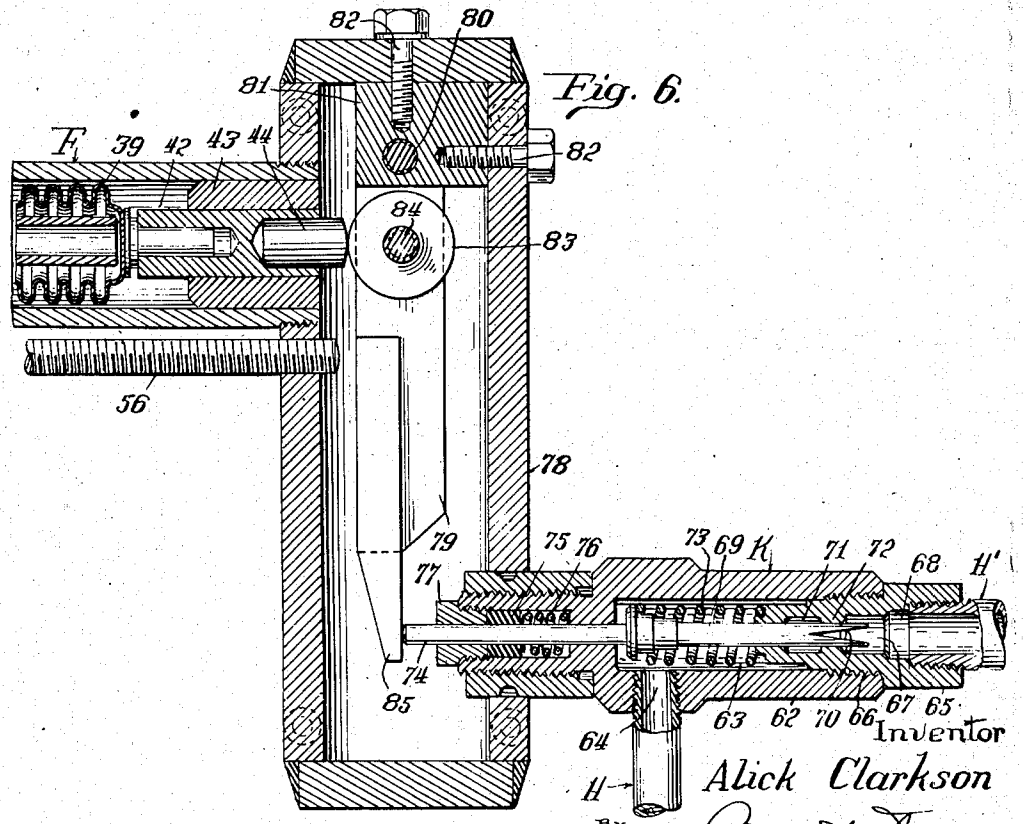


Fig. 6.



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Fig. 2.

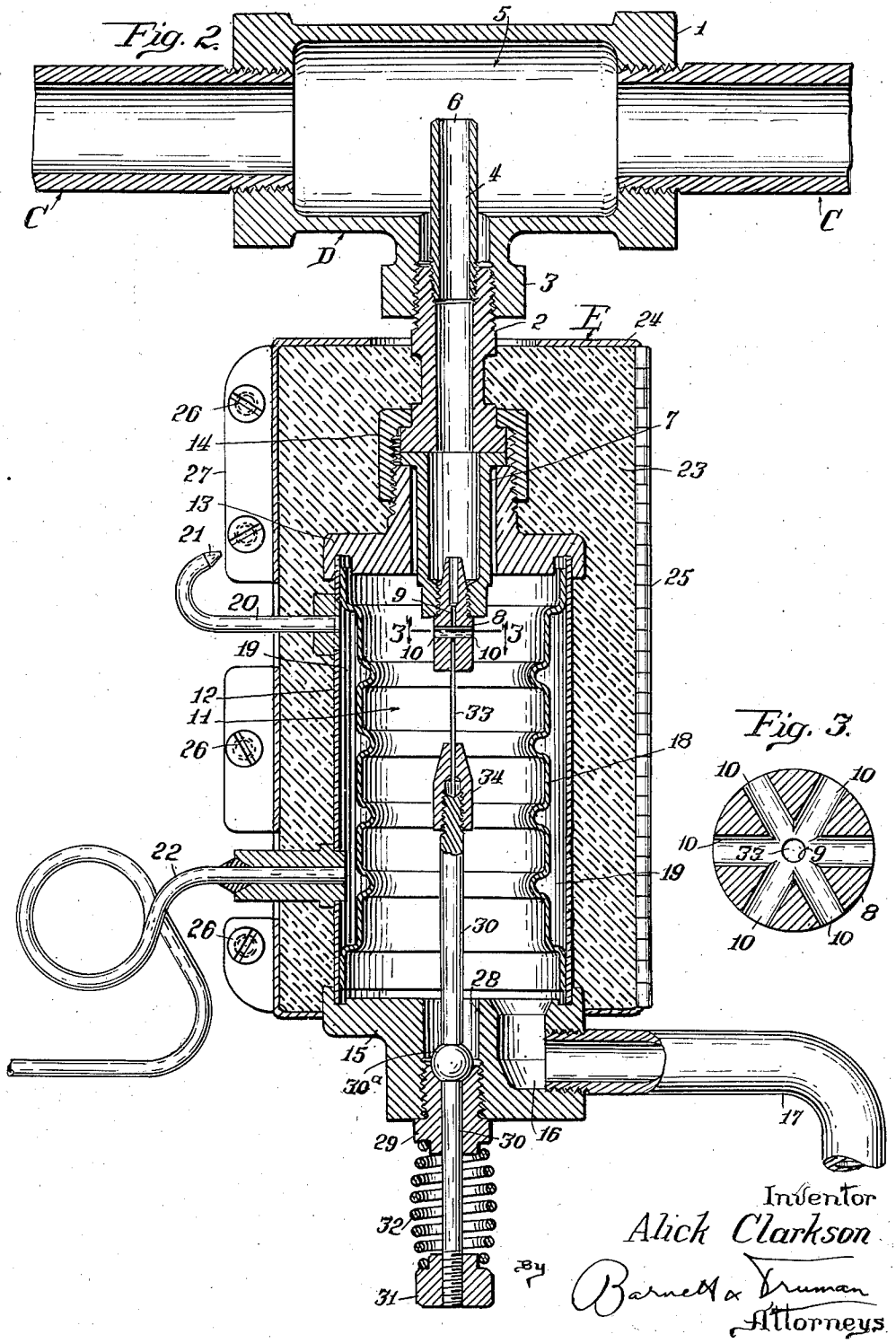


Fig. 3.

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Fig. 4.

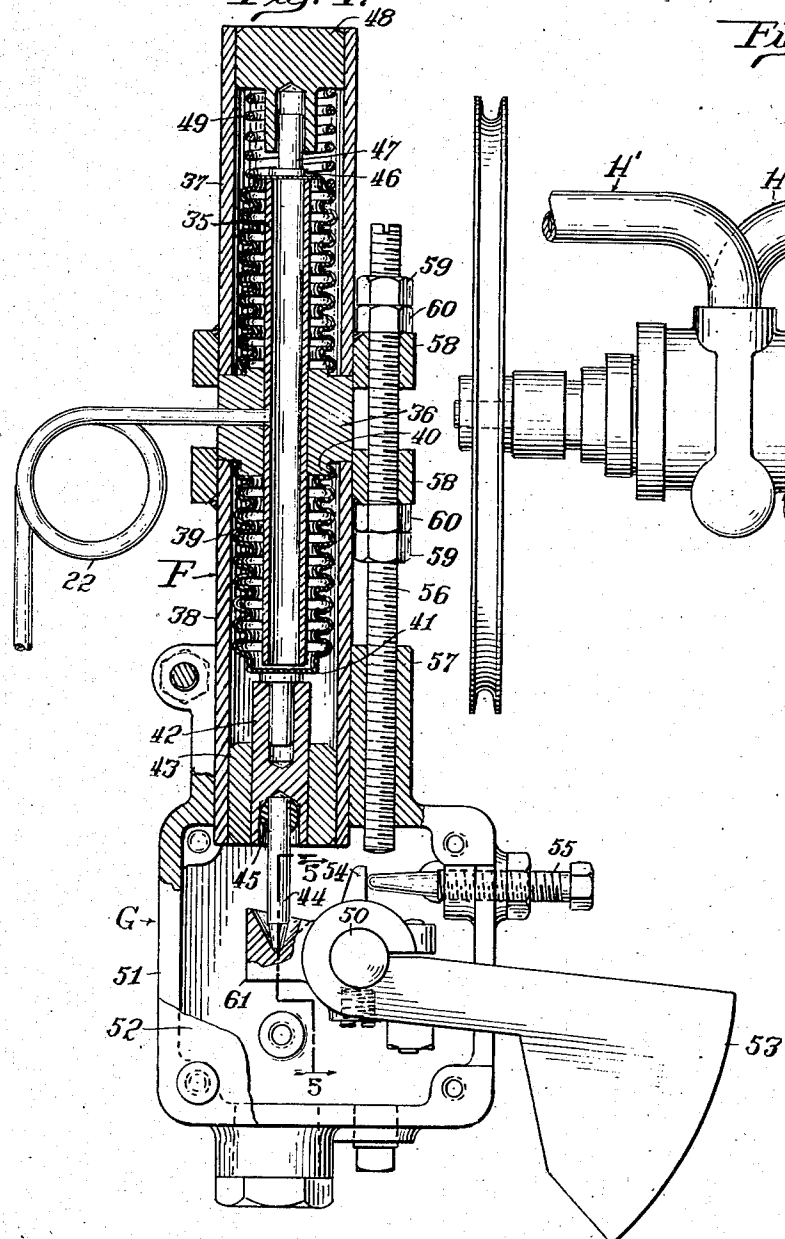
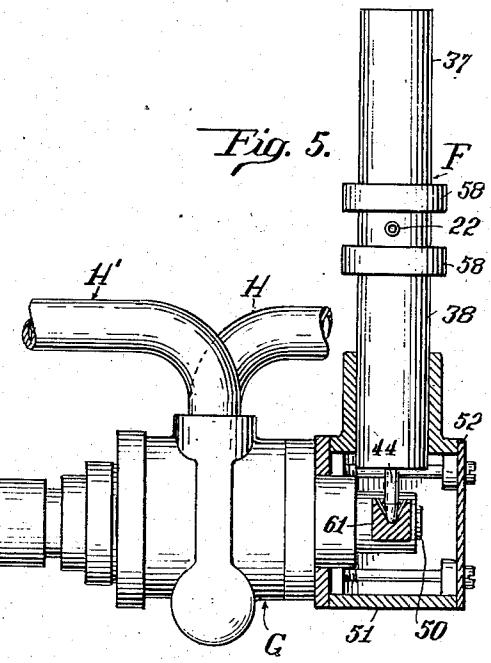


Fig. 5.



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STEAM QUALITY CONTROLLER

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Application January 31, 1942, Serial No. 429,032

6 Claims. (Cl. 236—32)

This invention relates to certain new and useful improvements in a method and apparatus for controlling the production of steam of a substantially constant quality. The "quality of steam" depends upon the percentage of moisture or unvaporized water in the steam, and steam at any given pressure may show any one of three conditions of "quality," that is, the steam may be wet saturated, dry saturated, or super-heated. The quantity of heat contained in each pound of steam will vary with each change of quality at the given pressure. If the liquid is completely converted into vapor at the given pressure, the steam is said to be in the "dry saturated" condition and has a quality equal to 1.0. Assuming, however, that not all of the liquid is converted into vapor but that at the end of the process only $x\%$ of the liquid has been vaporized, then the steam is said to be in the "wet saturated" condition, often called simply "wet steam." The percentage x is then said to be the quality of the steam. If the heat supply to the steam is not interrupted after all the liquid is vaporized, the result will be an increase in the temperature of the steam, and the steam is said to be "super-heated."

It is important, especially for certain uses, to keep the steam supply of a substantially constant "quality," and the present invention relates to an improved method and apparatus for controlling the production of steam so that the quality will remain substantially constant.

Many different forms of instruments have been used for determining or measuring the quality of steam, one of the most practical of these being known as the "throttling calorimeter." This instrument comprises means for withdrawing a sample of steam from the main steam supply pipe and permitting this sample to issue through a throttling orifice into an expansion chamber that is insulated to prevent heat losses, but which is open to the atmosphere so that the enclosed steam will expand to substantially atmospheric pressure. When the pressure of this steam is thus lowered, the heat units contained in the steam are more than necessary to maintain the steam in saturated condition and the steam in the expansion chamber thus becomes superheated a definite number of degrees. This increase in temperature is measured by a thermometer positioned in the expansion chamber, and the pressure of the steam both before and after expansion is also measured. From this data the "quality" of the steam may be computed.

The principle of the "throttling calorimeter" is utilized in the present improved control apparatus by substituting for the ordinary thermometer a closed container or connected containers having an expansible and contractible portion and containing a quantity of heat responsive fluid to which the heat released from the expanded steam is transferred. The movement of the expansible portion of this container as the fluid expands or contracts is utilized to actuate means for adjusting the flow of fuel to the burner of the steam generator, or the water delivery can be altered to obtain a change in the proportion of fuel to water. The fuel-control means may be, for example, a flow-control valve or a variable stroke fuel pump.

If the "quality" of the steam increases above a desired normal, more heat will be released to expand the motive fluid, and the fuel-control means will be adjusted to cut down the rate of fuel flow to the generator, this resulting in the production of steam of a lower quality so as to offset the increase in steam-quality which initiated this adjusting process. If, on the other hand, the quality of the steam produced should decrease, the heat responsive connections will function to increase the rate of fuel flow to the generator so as to increase the quality of the steam produced.

The principal object of the present invention is to provide an improved process and apparatus for regulating the quality of steam, as briefly described hereinabove and disclosed more in detail in the specifications which follow.

Another object is to provide a fuel-control apparatus operating on the general principle of the throttling calorimeter.

Another object is to provide an improved apparatus responsive to variations in the quality of steam to adjust a fuel flow-control valve.

Another object is to provide an improved apparatus responsive to variations in the quality of steam for adjusting a variable stroke fuel pump.

Another object is to provide improved means for closing a steam expansion nozzle.

Other objects and advantages of this invention will be more apparent from the following detailed description of one approved form of apparatus constructed and operating according to the principles of this invention.

In the accompanying drawings:

Fig. 1 is a diagrammatic elevation of a steam-generator combined with the improved controlling apparatus of this invention.

Fig. 2 is a central vertical section through a portion of the main steam supply pipe, the steam

sampling apparatus, and the expansion chamber, all taken substantially in a plane parallel to the plane of the drawing in Fig. 1.

Fig. 3 is a detail horizontal section on an enlarged scale taken substantially on the line 3—3 of Figure 2.

Fig. 4 is a central vertical section through the bellows motor mechanism and the operating connections to the fuel-pump.

Fig. 5 is a side elevation of the bellows motor and the pump, with the interposed operating connections shown in vertical section, substantially on a line 5—5 of Fig. 4.

Fig. 6 is a vertical section of a modification, showing the bellows motor, a fuel flow-control valve and an interposed lever mechanism, all of which may be substituted for the members F and G shown in Fig. 1.

Referring now first to Fig. 1, at A is indicated a coil type steam generator, provided with the burner or heater B, and having a main steam supply pipe C through which is conducted the steam produced by generator A. At D is indicated a steam-sampling device which continuously withdraws a sample of the steam from pipe C and introduces this steam into the chamber indicated generally at E, wherein the steam is permitted to expand substantially to atmospheric pressure thereby releasing heat which is transferred to a quantity of heat-responsive fluid. This fluid expands in the bellows-motor F and thereby adjusts the stroke of a variable-stroke fuel pump G which enforces and controls the flow of liquid fuel from a supply pipe H to an extension of this pipe H' which conducts the fuel to the burner B. A suitable water-pump J, for supplying water to the generator coil is driven, together with fuel-pump G, from a power-source K.

Referring now more particularly to Fig. 2 of the drawings, the fitting 1 is mounted between and connects two aligned horizontal sections of the steam main C. The pipe section 2 is mounted at its upper end in the outlet portion 3 which projects downwardly from the central portion of fitting 1, the member 2 carrying the sampling tube 4 which projects upwardly into the central portion of the steam chamber 5 with the upper end of this tube open at 6 to permit a sample of the steam to continuously flow outwardly and downwardly through the sampling tube 4, the pipe extension 2 and a further extension 7 supported as an extension of the fitting 2. Into the lower end of fitting 7 is threaded the spray-nozzle 8 which has a restricted passage 9 extending vertically downward through the central portion thereof. At a point intermediate its length this passage 9 discharges into a plurality of laterally extending branch passages 10 (see Fig. 3). The sample of steam, when discharged through the orifice at the lower end of this passage 9, flows out and further expands through the branch outlets 10 into the expansion chamber 11.

An outer upright cylindrical hollow shell 12 is closed at the top by an upper cap member 13 on the upper end portion of which is threaded the closure member 14 which clamps together on the cap 13 the steam tubes 2 and 7, already described. The lower end of the cylindrical shell 12 is closed by the lower cap member 15 formed with a vent passage 16 open to the atmosphere through tube 17 so that the expansion chamber 11 will be under only atmospheric pressure. An inner substantially cylindrical corrugated shell 18 is secured adjacent its ends to the inner portion of the outer shell 12 so as to form a substantially cylindrical hollow closed container serving as the outer wall of expansion chamber 11. This container, as well as the bellows motor F, (see Figs. 1 and 4), are filled with a suitable heat-responsive fluid through the inlet pipe 20 communicating with an upper portion of container 19 and suitably sealed at its upper end 21 after the fluid has been admitted. The lower portion of container 19 is suitably connected with the bellows mechanism F (hereinafter described) by the small flexible tubing 22 (see Figs. 2 and 4).

The greater portion of the steam-expansion device, hereinabove described, is enclosed in insulating material or packing 23, held in place by a sectional outer sheet metal casing 24, the sections of which are hinged together at one side 25 and connected by bolts or rivets 26 inserted through the flanges 27 at the opposite side.

In operation, the sample of steam will flow downwardly through the tubular members 4, 2 and 7 and thence through the discharge passages 9 and 10 so as to be discharged into and expand within the chamber 11. The heat released by this expanded steam will be transferred to the fluid within the cylindrical container 19 which will expand in proportion to the amount of heat transferred thereto, the pressure being transmitted through the tubing 22 to the bellows motor F, hereinafter described.

Still referring to Fig. 2, a central passage 28 in the bottom cap 15 is closed at its lower end by the screw plug 29 which serves as a guide for the vertically extending rod 30. A cap nut 31 is screwed on the lower end of this rod, an expansion spring 32 being confined between the nut 31 and plug 29. A cleaning wire 33 of a diameter sufficient to have a close sliding fit within the passage 9 of the spray nozzle, is supported at its lower end by a nut 34 on the upper end of rod 30. Normally the spring 32 will expand so as to hold the swivel ball 30*a* in the tapered socket formed at the upper end of plug 29, this ball being fixedly secured at an intermediate point on rod 30. At this time the upper end of cleaning wire 33 will be housed in and fill the lower end portion of passage 9 below the branch discharge passages 10. Should the spray nozzle 8 become clogged or dirty, the lower knob 31 should be pushed up against the resistance of spring 32 whereby the cleaning wire 33 will be pushed up through the aligned portions of the discharge passage 9 so as to clean same. After the proper flow of steam has been restored, the spring will return the swivel ball 30*a* to its seat on nut 29, thus removing the cleaning wire from the upper section of passage 9.

Referring now more particularly to Figs. 1 and 4, the bellows motor mechanism F will be described. A central tube 35, open at both ends, is centrally mounted in a spacing block 36 forming part of the supporting frame. The tubing 22 (hereinbefore referred to) extends through the block 36 and connects into the space within tube 35. The outer shell of the bellows mechanism consists of two similar sections of tubing 37 and 38 secured to and extending in opposite directions from the central block 36. A flexible bellows member 39 is secured at its upper end (Fig. 4) 40 to the central block 36 and is closed at its lower end by a cap member 41 which is positioned below the lower open end of tube 35. It will thus be seen that this lower motor bellows

is formed by the heat expansible fluid confined within the lower portion of tube 35 and in the space between the bellows 39 and this tube. As the fluid expands (or more fluid is forced into the tube 35 through tubing 22 from the container 19, Fig. 1) the expansible bellows member 39 will be pushed downwardly so that the head 41 will push the slide member 42 downwardly through guide sleeve 43 mounted in the lower end of the outercasing member 38. A swivel stem 44 is mounted through the ball member 45 in the lower end portion of slide member 42. As this stem 44 is pushed downwardly it acts to adjust the stroke of the fuel pump, as shown in Figs. 4 and 5, or the flow-control valve K, as shown in Fig. 6 and described hereinafter.

An exactly similar bellows member is formed on the other side of the spacing block 36 and within the upper outer casing 37. The upper closure cap 46 of this upper bellows is carried by a plunger 47 guided in the closure plug 48 at the end of tube 37. A rather strong compression spring 49 is confined between plug 48 and the movable head 46. Under all usual pressures of the heat-responsive fluid, the spring 49 will hold the upper bellows in its contracted position, as shown in Fig. 4. Under this condition, all of the expansion and contraction will be imparted to the lower bellows 39 so as to adjust the pump or valve. Any excessive expansion of the heat-responsive fluid will result in the extension of the upper bellows and compression of the spring 49.

In the form of the invention shown in Figs. 1, 4 and 5, the control of the fuel supply to the burner B is accomplished by means of a variable stroke fuel pump G (see Figs. 1 and 5). This pump may be of any approved form. In the present instance a stroke-control shaft 50 extends from one end of the pump into the casing 51 mounted between the pump and bellows mechanism. The cover plate 52 at one end of this casing is removed in Fig. 4. The weighted lever arm 53 secured on control shaft 50 tends to swing this shaft in a clockwise direction (Fig. 4) so as to increase the stroke of the pump. The lug 54 projecting upwardly from the lever assembly 53 bears against the end of adjusting screw 55 mounted in the casing 51. By adjusting the screw 55 the pump can be set to deliver the desired amount of fuel to the burner.

A threaded rod 56 is screwed into the collar portion 57 extending upwardly from frame 51. This rod projects freely through the lugs 58 on the supporting frame of the bellows assembly, and this assembly may be adjusted up and down along the rod 56 by the nuts 59 and 60 threaded on the rod. The lower end portion of the bellows assembly projects slidably downward through a suitable opening in the collar portion 57. The bellows assembly will be first moved upwardly by the adjusting nuts 59 and 60 and then the adjusting screw 55 will be positioned to properly adjust the stroke of the pump. Afterwards the nuts 59 and 60 will be adjusted so as to lower the adjusting plunger 44 into its socket in the crank arm 61 (also projecting laterally from shaft 50) until the control of the lever 53 is transferred from the screw 55 to the plunger 44.

A subsequent increase in the amount of heat transferred from the expanded sample of steam, that is, an increase in the quality of the steam, will cause the bellows motor to cut down the stroke of the fuel pump and thus decrease the steam quality. On the other hand, as the steam quality is reduced and the heat responsive fluid tends to contract, the plunger 44 will be lifted and the weighted arm 53 will become effective to increase the stroke of the pump, this increase being limited by the position of the adjusting screw 55.

Referring now to the modification shown in Fig. 6, a fuel-flow control valve K is used in place of the variable stroke pump G. This valve assembly K comprises the housing 62 for closing the fuel inlet chamber 63 into which fuel is admitted from supply pipe H through inlet port 64. The metering plug 65 threaded at 66 into one end of housing 62 contains the outlet chamber 67 from which fuel flows through port 68 into the pipe H' leading to the burner B (see also Fig. 1). The valve stem 69 is fitted slidably through webs formed in the closure plug 65, and the inner end portion of stem 69 is formed with a tapering slot 70. The oil or other fuel from chamber 63 flows through openings 71 and slot 70 into the outlet chamber 67 and thence to the burner. Obviously as the stem 69 is pushed further to the right (Fig. 6) the slot 70 will be completely closed by web 72, whereas as stem 69 is withdrawn further toward the left, a wider portion of the slot 70 will be in communication with openings 71 and the flow of fuel to the valve will be increased. A spring 73 is confined between the inner end of plug 65 and the collar 66 on the valve stem 69 so as to normally move the valve to the position of maximum opening. As the outer end portion 74 of the valve stem is progressively pushed in, or to the right, the valve will be progressively closed to cut off the flow of fuel.

The escape of fuel along the valve stem 69 is minimized by the sealing means or packing 75 confined between spring 76 and the threaded plug or gland 77.

The fuel-controlling connections also comprise a suitable power transmitting connection between the motor-bellows F (which may be substantially the same as shown in Fig. 4) and the valve K. In the example here shown, these connections comprise a fixed frame or casing 78 which houses the power transmitting lever 79 pivoted adjacent its upper end at 80 in the block 81 mounted by the screws 82 in casing 78. The motor-bellows F is supported in the frame 78 in any suitable manner so that the outer end of plunger 44 of the bellows engages the roller 83 pivoted at 84 in an intermediate portion of lever 79. The lower free end 85 of lever 79 engages the outer end 74 of the valve stem, and it will be noted that the power transmitting lever 79 serves to transform a rather small longitudinal movement of the plunger 44 into a relatively longer movement of valve stem 69. The relative length of the effective arms of lever 79 can be varied as may be desirable to secure the desired valve movement.

With either form of the invention, it will be understood that the parts are originally adjusted so that the flow of fuel to burner B will be just sufficient to supply enough heat to the generator A to produce steam of the desired quality. Assuming that the quality of this steam should increase, the heat transferred from the expanding steam sample in chamber 11 (Fig. 2) to the thermostatic fluid in container 19 and the bellows-motor F will cause this bellows to swing the lever 79 (Fig. 6) in a counter-clockwise direction and push in the valve steam 69 so as to partially close the slot 70 and cut down the rate of fuel flow

to the burner B. The result will be to decrease the heat imparted to the water in the generator and slightly decrease the quality of the steam. Conversely, should the quality of the steam decrease, the heat transferred to the thermostatic fluid will decrease and the resulting contraction of the bellows-motor will permit the spring 13 to slightly open the valve and increase the fuel flow to the burner B. As the result of these operations, the fuel flow will be substantially balanced to produce steam of a substantially constant quality. By reversing its metering characteristics, this valve K can be arranged to bypass fuel from the burner, and thus obtain much the same control of the generator. As already described, similar results are produced by the variable stroke pump shown in the first described modification.

When super-heated steam is being used, this steam will still be super-heated but to a higher degree when the pressure is released, and the control mechanism, hereinbefore described, will operate in the same manner as already noted to produce a constant quality of super-heated steam.

In place of an expanding liquid and bellows arrangement any heat expansion means can be used such as bimetal or two dissimilar expansion metals, either with or without servo mechanisms.

When referring in the following claims to the production of "steam," it is to be understood that the invention applies to other similar gases or vapors.

I claim:

1. Apparatus for controlling a steam generator to continuously produce steam of a substantially constant quality, comprising an insulated expansion chamber having an opening to the atmosphere so that the chamber is maintained at substantially atmospheric pressure, means for continuously selecting a sample of the generated steam and releasing said sample into the chamber, a closed container for a heat responsive fluid, said container comprising a portion of substantially constant volume positioned in heat transfer relation to the expansion chamber and an expansible and contractible portion positioned outside the chamber, a variable positioned device for regulating the rate of fuel flow to the generator, and means actuated by the movable portion of the container for limiting the operating range of said device.

2. Apparatus for controlling a steam generator to continuously produce steam of a substantially constant quality, comprising an insulated expansion chamber having an opening to the atmosphere so that the chamber is maintained at substantially atmospheric pressure, means for continuously selecting a sample of the generated steam and releasing said sample into the chamber, a closed container for a heat responsive fluid, said container comprising a portion of substantially constant volume positioned in heat transfer relation to the expansion chamber and an expansible and contractible portion positioned outside the chamber, a variable stroke fuel pump for regulating the rate of fuel supply to the generator, and stroke adjusting means actuated by the movable portion of the container.

3. Apparatus for controlling a steam generator to continuously produce high pressure steam of a substantially constant quality, comprising a steam supply pipe leading from the generator, an expansion chamber having an opening to the atmosphere so that the chamber is maintained at substantially atmospheric pressure, a sampling tube having one open end portion positioned near the center-line of the supply pipe and a throttling orifice adjacent its outlet end for continuously discharging a small quantity of steam into the expansion chamber, a pair of connected closed containers for a heat responsive fluid, one of said containers comprising a hollow enclosure of substantially constant volume for a portion of the expansion chamber, the other container comprising an expansible and contractible bellows positioned outside the chamber, a covering of heat insulating material for the expansion chamber and the container of constant volume, means including a variable stroke fuel pump for adjusting the rate of fuel supply to the generator, and actuating connections between a movable portion of the bellows and the fuel adjusting means.

4. Apparatus for controlling a steam generator to continuously produce steam of a substantially constant quality, comprising a steam supply pipe leading from the generator, an expansion chamber having an opening to the atmosphere so that the chamber is maintained at substantially atmospheric pressure, a sampling tube having one open end portion positioned near the center-line of the supply pipe and a throttling orifice adjacent its outlet end discharging into the expansion chamber, a pair of connected closed containers for a heat responsive fluid, one of said containers comprising a hollow enclosure of substantially constant volume for a portion of the expansioun chamber, the other container comprising an expansible and contractible bellows positioned outside the chamber, a covering of heat insulating material for the expansion chamber and the container of constant volume, of a flow-control device for adjusting the rate of fuel supply to the generator, and actuating connections between a movable portion of the bellows and the said device.

5. Apparatus for controlling a steam generator to continuously produce steam of a substantially constant quality, comprising a steam supply pipe leading from the generator, an expansion chamber having an opening to the atmosphere so that the chamber is maintained at substantially atmospheric pressure, a sampling tube having one open end portion positioned near the center-line of the supply pipe and a throttling orifice adjacent its outlet end discharging into the expansion chamber, a pair of connected closed containers for a heat responsive fluid, one of said containers comprising a hollow enclosure of substantially constant volume for a portion of the expansion chamber, the other container comprising an expansible and contractible bellows positioned outside the chamber, a covering of heat insulating material for the expansion chamber and the container of constant volume, a variable-stroke pump for supplying fuel to the generator, and stroke-varying means actuated by a movable portion of the bellows.

6. In apparatus for controlling the supply of fuel to a steam generator, a motor-mechanism to be actuated by the expansion of a heat-responsive fluid, comprising an expansion chamber, means for introducing a sample of steam into said chamber, a container of constant volume forming a portion of the enclosing wall of said chamber, a supporting frame, a tube open at both ends and centrally mounted in the supporting member, said tube and the container of constant volume being connected and holding a quantity of the heat-responsive fluid, a pair of similar bellows members, each closed at its outer

end, and each enclosing one end portion of the tube, and secured at its inner end to and closed by a central portion of the supporting member, a variable positioned device for regulating the rate of supply of fuel to the generator, a power-transmitting plunger slidably mounted in one end portion of the supporting frame and moved outwardly by the adjacent bellows when the fluid expands for limiting the range of movement of said device, and a compression spring mounted between the opposite end portion of the frame and the second bellows, said spring normally holding the second bellows in compressed position but permitting the expansion of this second bellows to accommodate excessive expansion of the operating fluid.

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