Aug. 12, 1941. W. E. GERMER 2,252,368

REGULATING APPARATUS AND METHOD

Filed Sept. 6, 1938 2 Sheets-Sheet 1

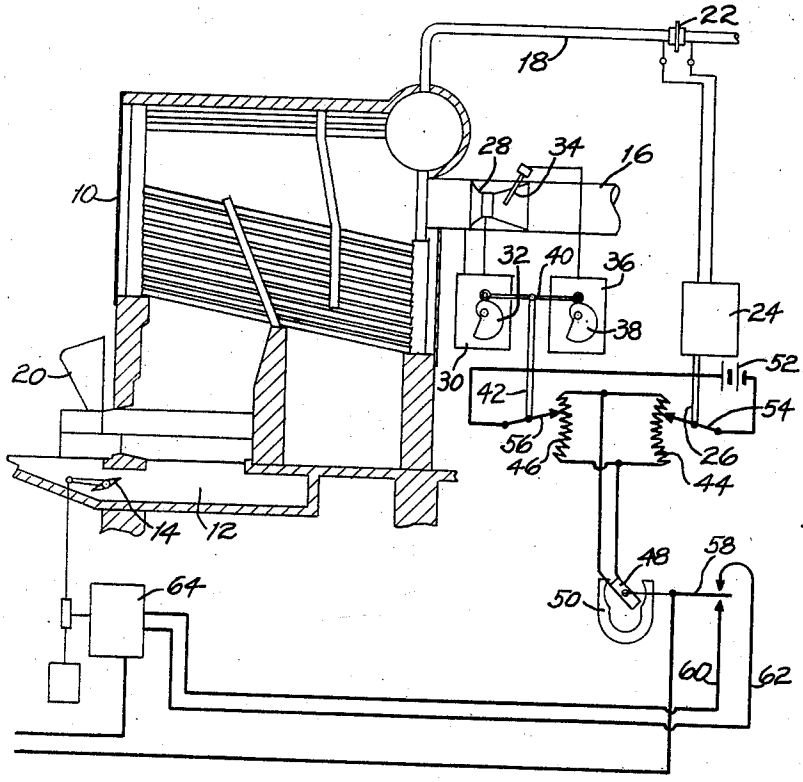


Fig. 1.

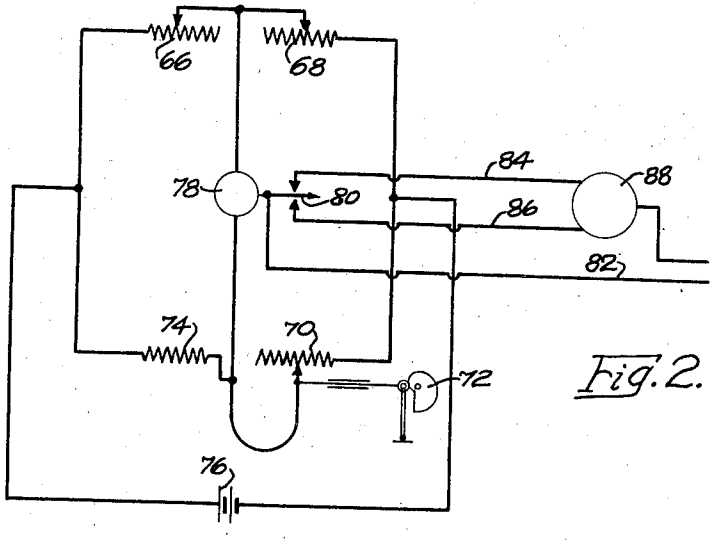


Fig. 2.

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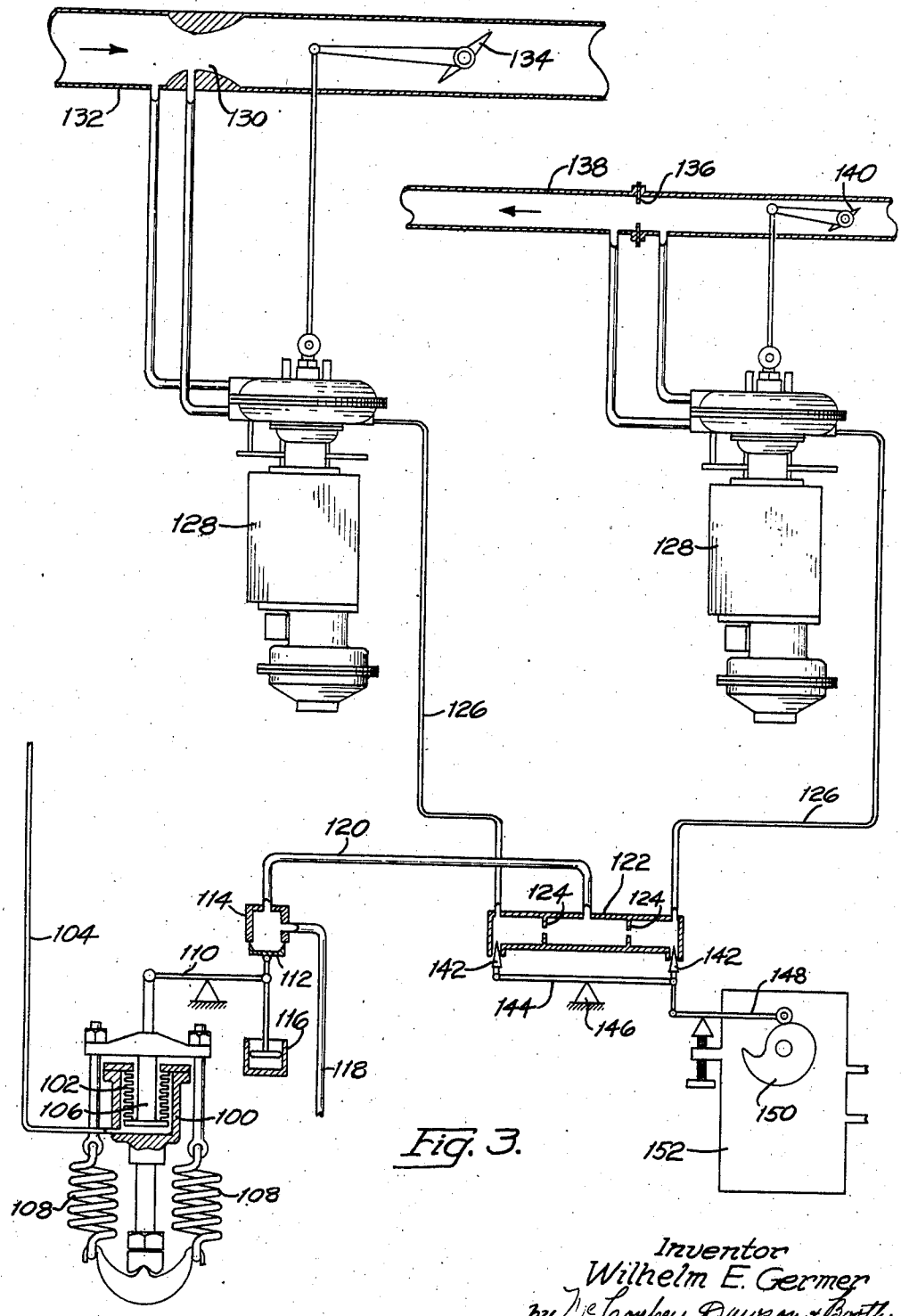


Fig. 3.

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UNITED STATES PATENT OFFICE

2,252,368

REGULATING APPARATUS AND METHOD

Wilhelm E. Germer, Berlin-Charlottenburg, Germany

Application September 6, 1938, Serial No. 228,711
In Germany February 23, 1937

7 Claims. (Cl. 236—14)

This invention relates to a regulating apparatus and method and more particularly to the regulation of steam boilers or the like to maintain them at maximum efficiency at all times.

One of the objects of the invention is to provide a regulating apparatus and method for boilers or the like in which the ratio of fuel and air supplied to the boiler is varied under different conditions of operation to maintain the boiler at its maximum operating efficiency.

Another object of the invention is to provide a regulating apparatus and method in which the fuel-air ratio is varied in accordance with variations in efficiency.

Yet another object is to provide a boiler regulating system including control elements for the fuel and air in which the fuel and air controls are individually modified in accordance with the boiler efficiency.

Other objects, advantages and novel features of the invention will be apparent from the following description when read in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of a boiler equipped with a regulating system embodying the invention;

Figure 2 is a diagram of a modified circuit for use in the system of Figure 1; and

Figure 3 is a diagram of another system according to the invention.

The efficiency of a steam boiler is represented by the percentage of the total heat put in the fuel which is converted to useful energy in the steam. The heat input may be divided into three parts; that flowing out in the steam, that flowing out the stack in the gas, and that lost through radiation and in the ash pit, etc.

Expressing it mathematically:

$$E=E_1E_2E_3$$

where E is the total heat, E_1 is the heat flowing out in the gas, E_2 is the heat flowing out in the steam, and E_3 is the heat lost through the ash pit, radiation, etc. In the case of incomplete combustion a fourth factor E_4 enters in representing the heat lost through unburned gases flowing out the flue.

The factor E_1 may be expressed

$$E_1=RM(Rt—t)\,cpm$$

where RM is the quantity of gas flow, Rt is the gas temperature, t is the temperature of air in the boiler room, and cpm is the specific heat of the flue gas. It will be noted that this is independent of the amount of air infiltration (after gases leave boiler) contained in the flue gas as this air increases the quantity of flow and simultaneously decreases the temperature so that the product remains unaffected. In this formula and in other formulae throughout the specification, the term RM is an abbreviation for "Rauchgas Menge," which is the German for flue-gas flow; the term Rt is an abbreviation for "Rauchgas temperatur," which is the German for flue-gas temperature; and cpm is the official German abbreviation for the mean specific heat in kilogram-calories per cubic meter at constant pressure.

The factor E_2 may be expressed

$$E_2=D(i—ts)$$

where D is the quantity of steam flow, i is the heat capacity of the steam, and ts is the feedwater temperature. The heat capacity i of saturated steam is substantially constant regardless of pressure and the changes in heat capacity of superheated steam are substantially compensated by errors in an ordinary uncorrected steam flow meter so that a constant mean value of i can be used with very accurate results. Changes in feedwater temperature are small and infrequent and may be taken care of by manual adjustment of a flowmeter or other mechanism operated thereby. Therefore for practical purposes E_2 may be said to be equal to the steam flow indication D of an uncorrected flowmeter.

The heat losses E_3 are substantially constant for a given boiler and are relatively small. They may be determined partly by ash analysis and partly empirically and may thereafter be corrected for by calibration or adjustment of the instrument.

If η is the boiler efficiency in percent, Va the heat loss in the gas in percent, and a the sum of the constant losses in percent

$$100=\eta+Va+a$$

From this equation and the previous equation the following relation may be derived:

$$\frac{E_2}{E_1+E_2}=\frac{\eta}{100-a}$$

$$\frac{\eta}{100-a}=\frac{D(i-ts)}{D(i-ts)+RM(Rt-t)cpm}$$

$$\eta=\frac{100-a}{1+\frac{RM(Rt-t)}{D}\cdot\frac{cpm}{i-ts}}$$

Since cpm and $i-ts$ may be considered as a constant, the constant

$$u=\frac{cpm}{i-ts}$$

may be substituted and the equation may be written:

$$\eta=\frac{100-a}{1+\frac{RM(Rt-t)}{D}\cdot u}$$

The factor a is also substantially constant so the boiler efficiency becomes a function of the variable quotient

$$\frac{RM(Rt-t)}{D}$$

and can be determined by measuring these factors. As the boiler room temperature t does not vary widely nor frequently it can be set manually by adjustment or calibration of the instrument.

This method of determining the boiler efficiency and suitable apparatus for carrying it out are more fully disclosed and claimed in copending applications Serial No. 174,173, now abandoned, filed November 12, 1937, of which this application is a continuation in part and Serial No. 227,136, filed August 27, 1938.

In operating a boiler it has been found that the maximum efficiency may be different at different ratings and that in order to operate the boiler at maximum efficiency at all times it may be necessary to change the fuel-air ratio as the boiler rating changes. According to the present method the efficiency curve of the boiler is determined and the fuel-air ratio is varied according to this curve as the rating changes.

In carrying out the method of the invention the fuel supply to the boiler is controlled in any desired manner in accordance with steam flow or pressure and the fuel-air ratio is varied according to the maximum efficiency curve of the boiler. In some cases this may be substantially constant while in other cases it may vary considerably with the boiler rating depending upon the characteristics of the particular boiler.

As shown in Figure 1 a boiler 10 is formed with an air inlet 12 having a damper 14, a gas outlet or flue 16 and a steam outlet 18. Fuel may be supplied by a stoker 20 or other suitable fuel supply means controlled by suitable regulators or the like, not shown.

The flow of steam through pipe 18 is measured by placing in the pipe an orifice 22 whose opposite sides are connected to a standard uncorrected flow meter 24 which operates a rod 26 proportionally to variations in flow through the pipe 18. Since the flow meter is uncorrected, movements of the rod 26 will be proportional to the quantity of heat in the steam as pointed out above.

The gas flow is measured by placing a venturi or the like 28 in the flue 16 and connecting it to a standard flow meter 30 which operates a logarithmic cam 32. Thermometer 34 is preferably inserted in the venturi 28 and is connected to a relay mechanism 36 which operates a logarithmic cam 38. Preferably the connection between the instrument 36 and the cam 38 is adjusted to compensate for the temperature in the boiler room corresponding to the factor t. A bar 40 carries rollers engaging the cams 32 and 38 and is connected at its center to a rod 42 so that the rod will be moved proportionally to the sum of the logarithms of the gas flow and the gas temperature.

The ratio of the steam flow to the product of gas flow and gas temperature to obtain an indication the variable quotient set out above is obtained by an electrical circuit including variable resistances 44 and 46 connected to a coil 48 which is movable in the field of a magnet 50. A battery 52 is connected to wipers 54 and 56 movable over the resistances 44 and 46 respectively and connected respectively to the rods 26 and 42. The resistance 46 is preferably a logarithmic resistance arranged to take the antilogarithm of the movement of the wiper 56 so as to give resistance values directly proportional to the product of gas flow and gas temperature. This arrangement provides a balanced circuit effecting a division of the two factors to obtain the quotient to which boiler efficiency is proportional.

The coil 48 forms part of a relay mechanism and operates a contact 58 adapted to engage contacts on a line 60 or a line 62. The lines 60 and 62 are connected to a reversible electric motor 64 which is connected to the damper 14 to operate it. Current is supplied to the motor from a suitable power line, one side of which is connected directly to the motor and the other side of which is connected to the switch arm 58.

In operation the arm 58 is moved by the coil 48 in accordance with variations in the efficiency of the boiler. If the boiler is not operating, at its maximum efficiency, the pointer 58 will close a circuit through one or the other of lines 60 and 62 to increase or decrease the supply of air to the boiler until the correct amount of air is supplied to produce operation at maximum efficiency.

Figure 2 illustrates a modification of the circuit of Figure 1 in which three variable resistances are combined in a bridge circuit. As shown, a resistance 66 is adjusted by the gas flow meter 30, a resistance 68 is adjusted by the steam flowmeter 24 and a resistance 70 is adjusted through a cam 72 by the temperature instrument 36. A fourth fixed resistance 74 completes a bridge circuit and may be constant or if desired may be made variable to adjust for the constant losses in the boiler. A battery 76 is connected across the circuit and a galvanometer or the like 78 is connected across the resistances to operate a contact pointer 80. The pointer 80 is connected to one side of a power line 82 and is adapted to engage lines 84 and 86 leading to a motor 88 which is connected to the other side of the power line.

When the boiler is operating at maximum efficiency the bridge is in balance but if the boiler is not operating at maximum efficiency, the bridge becomes unbalanced and deflects the pointer 80 to complete a circuit through motor 88. This motor may be connected to an air damper, such as 14 and will increase or decrease the air supply to bring the boiler back to a condition of maximum efficiency.

Figure 3 illustrates a modified control system in which the boiler is normally controlled by a master controller such as shown for example in Smoot Reissue Patent 16,507 and in which the fuel air ratio is changed as the rating changes to maintain the boiler at maximum efficiency. As shown, a casing 100 has one face closed by a flexible wall 102 and is connected through a pipe 104 to the steam outlet pipe or steam header of

the boiler. Steam pressure urging the flexible wall 102 upwardly is opposed by a plunger 106 engaging the wall and urged downwardly by springs 108. The plunger 106 is connected to one end of a lever 110 carrying at its other end a cup valve 112 which controls the bleeding of air or the like from a casing 114. If desired, a dash pot 116 may be connected to the cup valve to prevent fluttering thereof. Fluid under pressure is supplied to the casing 114 through a pipe 118 and flows out through a pipe 120 into an air box 122. The box 122 is provided with partitions 124 having restricted openings therein through which it is connected by pipes 126 to regulators 128 for controlling the supply of fuel and air respectively to the boiler. As shown, the air regulator is connected to a restriction 130 in an air conduit 132 and has a power element connected to a damper 134 in the conduit. The fuel regulator is similarly connected across an orifice 136 in a fuel control element 140. The arrangement shown is particularly adapted for regulating fluid fuel such as gas or oil but it will be understood that the fuel regulator might equally well control a stoker, a powdered fuel mill or the like as will be appreciated by those skilled in the art.

The loading pressure supplied to the regulators 128 through pipes 126 are preferably bled down in the box 124 by suitable bleed valves 142. The bleed valves 142 are carried by a lever 144 fulcrumed at its center on a fixed pivot 146. One end of lever 144 is connected to a second lever 148 fulcrumed at its center and carrying a roller engaging a cam 150 which is operated by a steam flowmeter 152. The cam 150 is formed according to the efficiency curve of the boiler, that is, according to the curve of fuel-air ratio for maximum efficiency plotted against boiler rating and serves to move the valves 142 to change the fuel air ratio in response to variations in boiler rating as indicated by steam flow. Thus with this arrangement, the boiler is at all times operated at the correct fuel-air ratio for maximum efficiency.

While several embodiments of the invention have been shown and described in detail, it will be understood that numerous changes might be made therein and it is not intended to limit the scope of the invention to the exact form shown nor otherwise than by the terms of the appended claims.

What is claimed is:

1. The method of regulating a steam boiler or the like which comprises measuring the flow of steam from the boiler, controlling the flow of gas through the boiler in accordance with variations in the steam flow, measuring the flow of gas and the temperature of the gas leaving the boiler, and modifying the gas flow control in accordance with variations in the product of gas flow and gas temperature to increase the gas flow as said product increases and decrease the gas flow as said product decreases.

2. The method of regulating a steam boiler or the like which comprises measuring the flow of steam from the boiler, measuring the flow of gas from the boiler, measuring the gas temperature, multiplying the last two measurements to obtain a product proportional to the quantity of heat leaving the boiler in the gas, combining this product with the steam flow to obtain a quotient indicative of boiler efficiency, and varying the ratio of fuel and air supplied to the boiler in accordance with said quotient.

3. The method of regulating a steam boiler or the like which comprises measuring the flow of steam from the boiler, measuring the flow of gas from the boiler, measuring the gas temperature, multiplying the last two measurements to obtain a product proportional to the quantity of heat leaving the boiler in the gas, combining this product with the steam flow to obtain a quotient indicative of boiler efficiency, and varying the flow of air through the boiler in accordance with said quotient.

4. Apparatus for regulating a steam boiler or the like comprising means for measuring the flow of steam from the boiler, means to vary the ratio of fuel and air supplied to the boiler, a connection from the first named means to the last named means, and means in said connection for modifying the control of the fuel-air ratio of the boiler in accordance with the product of gas flow and gas temperature to decrease said ratio as said product increases and to increase said ratio as said product decreases.

5. Apparatus for regulating a steam boiler or the like comprising an electric control circuit having two adjustable devices for changing the circuit characteristics, a flowmeter responsive to the flow of steam from the boiler for adjusting one of said devices, a flowmeter responsive to the flow of gas from the boiler, means for measuring the gas temperature, means for multiplying the gas flow by the gas temperature and for adjusting the other device according to the product, and means operated by said circuit for varying the ratio of fuel and air supplied to the boiler.

6. Apparatus for regulating a steam boiler or the like comprising an electric control circuit having two adjustable devices for changing the circuit characteristics, a flowmeter responsive to the flow of steam from the boiler for adjusting one of said devices, a flowmeter responsive to the flow of gas from the boiler, means for measuring the gas temperature, means for multiplying the gas flow by the gas temperature and for adjusting the other device according to the product, and means operated by said circuit for controlling the supply of air to the furnace.

7. The method of regulating a steam boiler or the like which comprises measuring the rate of gas flow from the boiler, measuring the gas temperature, multiplying said measurements to obtain a product proportional to the quantity of heat leaving the boiler in the gas, and varying the rate of air supply to the furnace in accordance with said product.

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