July 2, 1957 R. BOUREK ET AL 2,797,746

SYSTEM FOR MAINTAINING THE CORRECT SUPPLY OF AIR FOR BURNING A GAS OF VARYING COMPOSITION

Filed May 12, 1955 2 Sheets-Sheet 1

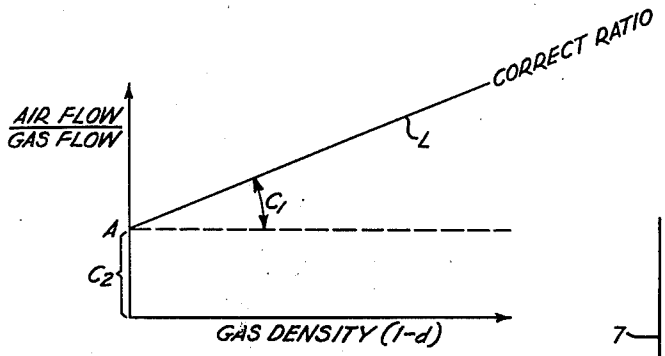


Fig. 2

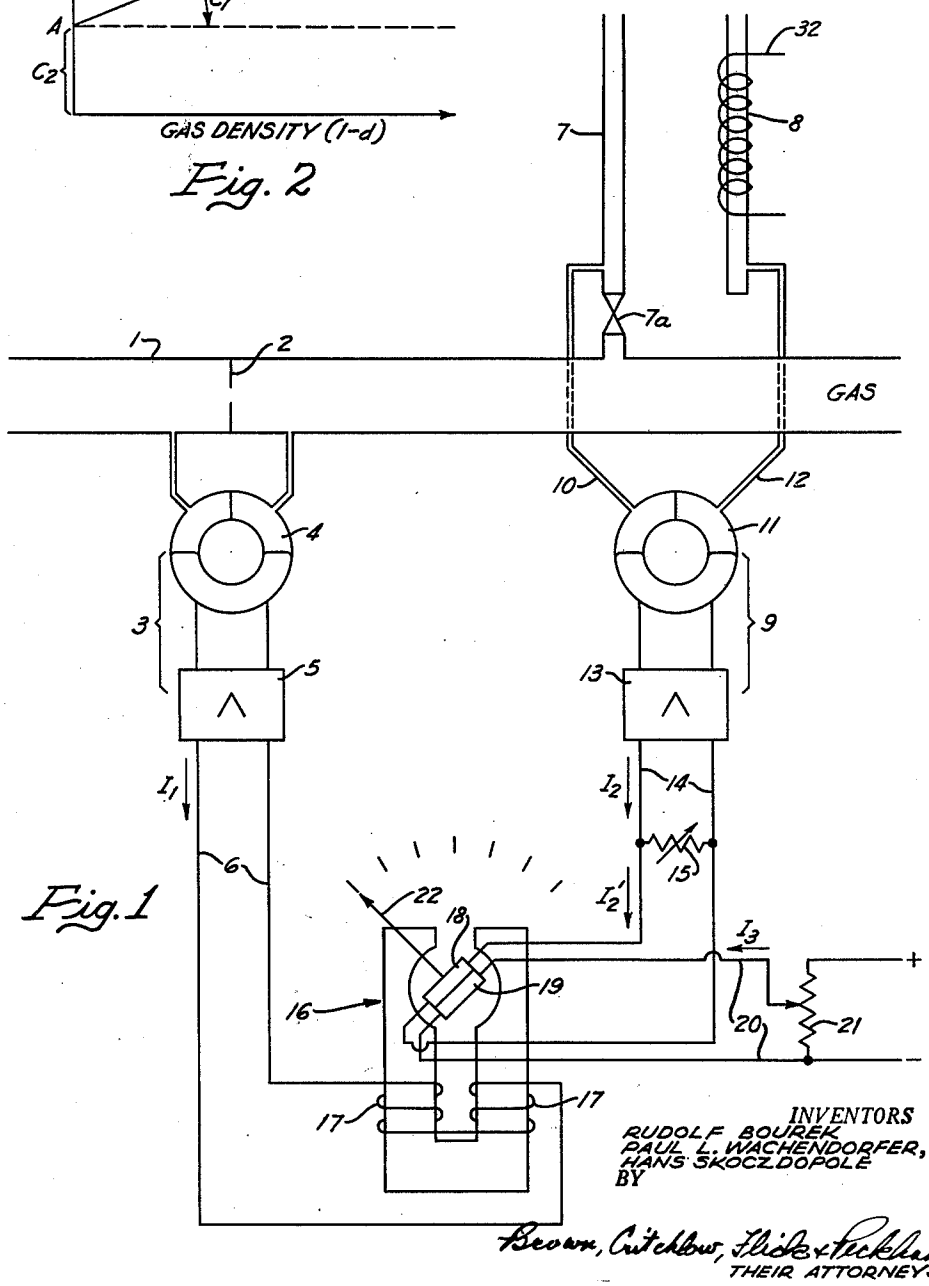


Fig. 1

INVENTORS
RUDOLF BOUREK
PAUL L. WACHENDORFER, SR.
HANS SKOCZDOPOLE
BY

Brown, Critchlow, Flick & Peckham
THEIR ATTORNEYS

July 2, 1957 R. BOUREK ET AL 2,797,746

SYSTEM FOR MAINTAINING THE CORRECT SUPPLY OF AIR FOR BURNING A GAS OF VARYING COMPOSITION

Filed May 12, 1955 2 Sheets-Sheet 2

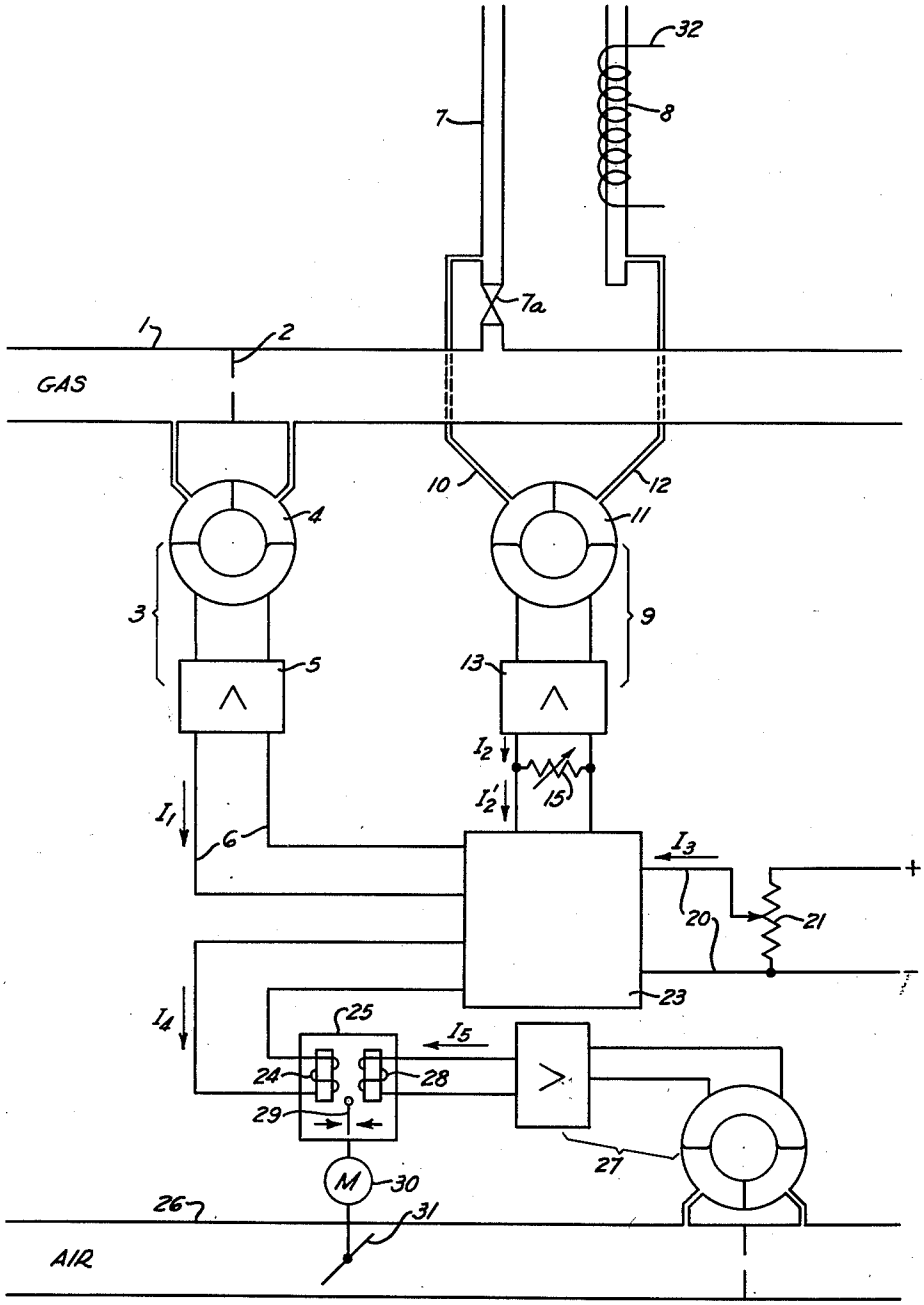


Fig. 3

INVENTORS
RUDOLF BOUREK
PAUL L. WACHENDORFER, SR.
HANS SKOCZDOPOLE
BY

Brown, Critchlow, Flick & Peckham
THEIR ATTORNEYS

United States Patent Office

2,797,746

Patented July 2, 1957

2,797,746

SYSTEM FOR MAINTAINING THE CORRECT SUPPLY OF AIR FOR BURNING A GAS OF VARYING COMPOSITION

Rudolf Bourek and Hans Skozdopole, Vienna, Austria, and Paul L. Wachendorfer, Sr., Joliet, Ill., assignors to James G. Murray, Jr., Pittsburgh, Pa.

Application May 12, 1955, Serial No. 507,944

1 Claim. (Cl. 158—119)

For maximum efficiency of combustion when burning a gas, a definite predetermined volume of air must be supplied for a definite volume of gas. If too little air is supplied, the combustion is incomplete. If too much air is supplied, the excess of air tends to cool down the combustion gases, lowering the efficiency of combustion.

In certain industrial furnaces it is desirable to burn gases that are a by-product of other processes. These gases, for example blast-furnace gas or coke-oven gas, consist of a mixture of gaseous elements, such as hydrogen, carbon monoxide, nitrogen, etc. Due to unavoidable variations in the processes which produce these by-product gases, their composition varies from time to time, and since the air requirement differs for the different component gases, the over-all air requirement for efficient combustion of the gaseous mixture varies with changes in the composition.

Because some of the constituent gases, such as hydrogen, are lighter than others, and since these lighter constituents require more air for efficient combustion, it has been found that the relative weight of the gaseous mixture may be taken as an accurate measure of the air requirement of the mixture.

Thus, having once established the correct volume of air for efficient combustion of a particular mixture of gases, it has been found that as the composition of the mixture changes, the air requirement varies directly with changes in the relative weight of the mixture. And it has been found that the changes in relative weight may be measured and used to indicate the changing air requirements, or they may be used to automatically regulate the amount of air supplied to the gas burner.

The present applicants do not claim to be the first to recognize that in burning a mixture of gases the changing relative weight of the mixture may be taken as an index of the changing air requirements of the mixture. This fact is recognized in United States Patent No. 2,251,019 to James K. Mawha, and in this patent he proposes to utilize these changes in relative weight to modify the amount of air supplied to the gas burner. Mawha uses these changes to control an adjustable leak-off which changes the pressure of the fuel gas acting on pressure regulators which control valves in the air and gas lines.

The present invention provides an improved system in which the change in relative weight is converted into an electric current which is multiplied by an electric current representing the rate of flow of the gas. The product of these two currents is used either to give a direct indication of the air requirements, or to automatically adjust the supply of air to the flow of gas, without changing the flow of gas.

These and other objects and advantages of the invention will become apparent as the description proceeds.

In the drawings:

Fig. 1 is a diagram illustrating a form of the invention in which the system operates an indicating device;

Fig. 2 is a chart illustrating one phase of the operation of the system; and

Fig. 3 is a diagram illustrating a form of the invention in which the system operates automatically to adjust the supply of air to the changing air requirements of the flowing gas.

Referring first to Fig. 1, the fuel line **1** is provided with an orifice plate **2**. A flow meter, indicated generally by the numeral **3**, converts the flow through the fuel line **1** into an electrical current I_1 which is rigidly proportional to the flow Q_1 in the fuel line.

(1) Then $I_1 \propto Q_1$

The current I_1 will be referred to in the claim as the "first electrical current."

The details of the flow meter form no part of the present invention, but are fully explained in a co-pending application Serial No. 459,163. It is sufficient to state that the flow meter **3** includes a ring-type manometer **4** coupled to an electrodynamometer **5**. The current I_1 flows through the circuit **6** to the electrodynamometer **16**, which serves as a multiplying device, as subsequently explained.

In order to determine the relative weight of the fuel gas passing through line 1 at a particular time, a device is used to compare the weight of the gas with air. This is done by permitting a small amount of the gas to pass from the line **1** through a small leak-off orifice **7***a* into the lower end of a vertical pipe **7**, the upper end of which is open to the atmosphere.

A pipe **8** of size and shape identical with pipe **7** has a closed bottom and is also open at the top to the atmosphere, so that it will contain a column of air equal to the column of gas in the pipe **7**. Since the tubes **7** and **8** are both subject to atmospheric pressure at their upper ends, the difference in pressure at their lower ends will be a direct measure of the relative weight of the gas.

For the purpose involved here, it is sufficient to know the weight of the fuel gas at its actual temperature, and it is therefore not necessary to change the temperature of the gas, nor to make any temperature correction. However, to have a standard of comparison, the column of air is brought to a definite temperature that is the same at all times. This may be done in any preferred manner, as by an electrical heating coil **32**.

The difference in pressure at the lower ends of tubes **7** and **8** is measured by a pressure meter indicated generally by the numeral **9**, which converts the pressure difference into an electrical current I_2, which is rigidly proportional to the pressure difference.

It is to be noted that the current I_2 is a direct measure of the difference between (*a*) the weight of a volume of the fuel gas at its existing temperature (as it comes from the blast furnace or other source), and (*b*) the weight of an equal volume of air at a standard temperature. This difference is herein called the "relative weight" of the fuel gas. Since this difference is not corrected to standard conditions, it will not be called "specific gravity."

The details of the pressure meter form no part of the present invention, but are fully explained in a co-pending application Serial No. 459,162. It is sufficient to state that tube **10** connects the pipe **7** to one chamber of a ring-type manometer **11**; tube **12** connects pipe **8** to the other chamber of the manometer; and that the manometer **11** is coupled to an electromagnetic device **13** which has a permanent magnet. In this type of pressure meter, the current I_2 flowing through circuit **14** to the electromagnetic device **13** is rigidly proportional to P, the difference in pressures at the lower ends of the two pipes **7** and **8**.

(2) Then $I_2 \propto P$

The current I_2 will be referred to in the claim as the "second electrical current."

The pressure difference P is the result of multiplying

the height (H) of the pipes **7** and **8** by the difference between the weight (g_1) of air and the weight (g_2) of the gas.

(3) Then $P=H(g_1-g_2)$

Combining Equations 2 and 3,

(4) $I_2 \propto H(g_1-g_2)$

Developing Equation 4 we find that,

(5) $$I_2 \propto Hg_1\left(1-\frac{g_2}{g_1}\right)$$

Letting d represent the ratio

$$\frac{g_2}{g_1}$$

and solving Equation 5, we find that,

(6) $$I_2 \cdot \frac{1}{Hg_1} \propto 1-d$$

Since

$$\frac{1}{Hg_1}$$

is a constant, it may be represented by C, then

(7) $I_2 \propto (1-d)C$

The current I_2 is passed through an adjustable resistance **15**, which makes a correction for a constant C_1, which will be explained subsequently. (The adjustable resistance **15** will be referred to in the claim as the "first adjustable means.") The current I_2 then becomes I_2' and Equation 7 becomes

(8) $I_2' \propto (1-d)C_1$

In order to obtain a product of the current I_1 and I_2', they are conducted through an electrodynamometer device **16** in the following manner.

The current I_1 from the circuit **6** passes through the stationary field coils **17**.

The current I_2' from the circuit **14** passes through the moving coil **18**.

A second moving coil **19** receives the current I_3 from a circuit **20**, connected to a constant D. C. source, and includes an adjustable resistance **21**. (The current I_3 will be referred to in the claim as the "third electrical current" and the adjustable resistance **21** will be called "second adjustable means.") The resistance **21** may be set according to a constant C_2, which will be explained subsequently. Then

(9) $I_3 \propto C_2$

The known action of the dynamometer **16** is such that the movement of its pointer **22** will be rigidly proportional to the formula

(10) $(I_1(I_2'+I_3)$

Referring again to the constants C_1 and C_2, it has been found that measuring the change in the relative weight of the gas can be used as a measure of the changing air requirements for a certain type of gaseous mixture, such as blast-furnace gas. However, when making a change to an entirely different type of gaseous mixture, such as coke-oven gas, it has been found advisable to introduce certain corrective constants. These constants, C_1 and C_2, are determined in advance for each different type of gaseous mixture to be used in the furnace, and the variable resistances **15** and **21** are set according to the type of gaseous mixture being burned.

If in a particular installation it is intended to burn only one type of gaseous mixture, for example blast-furnace gas, it is not necessary to provide for corrections corresponding to the constants C_1 and C_2. The system may then be somewhat simplified.

The relative weight of the gas is affected to a certain extent by barometric pressure, and, if it is desired to control the air supply with maximum accuracy, it is necessary

to make a correction for barometric pressure. Such a correction may be introduced into the system by changing the value of the current I_2'. The method of introducing the correction for barometric pressure into the system as an electrical current will not be explained in detail here, as it is being made the subject of a co-pending patent application.

The relation of the constants C_1 and C_2 to the correct air ratio is shown in Fig. 2, where the ordinate represents the air-flow to gas-flow ratio; the abscissa represents the gas density $(1-d)$; and the line "L" represents the correct ratio of air to gas. The constant C_2 represents the height of the point A above the base line, and the constant C_1 represents the angle between the line "L" and the base line.

The equation for line "L" is

$$\frac{\text{Air flow}}{\text{Gas flow}}=\frac{Q_2}{Q_1}=C_1(1-d)+C_2$$

(11) Hence, $Q_2=[C_1(1-d)+C_2]Q_1$

(11a) Or, Airflow $Q_2=Q_1[(1-d)C_1+C_2]$

In Equation 10 above, it has been shown that the movement of pointer **22** will be rigidly proportional to the formula

(12) $I_1(I_2'+I_3)$

It has also been shown that each of these currents varies rigidly as the following values:

(1) $I_1 \propto Q_1$

(8) $I_2' \propto (1-d)C_1$

(9) $I_3 \propto C_2$

Substituting these values in Equation 12, we have:

(13) Movement of pointer$=Q_1[(1-d)C_1+C_2]$

or,

Movement of pointer=Required air flow

Comparing equations we find that in Equation 11a the air flow, Q_2, equals the expression of Equation 13. This proves that the movement of pointer **22** will be rigidly proportional to the required air flow for the gas passing through the gas line **1**. As the relative weight in the gas line changes, the pointer **22** will automatically move to show the correct air flow for the changed gaseous mixture. The movement of pointer **22** will give a linear indication of the air requirements.

In the device of Fig. 3, the same principles are applied, but instead of merely giving an indication, as by pointer **22**, of the correct flow of air, additional means is provided to automatically regulate the flow of air.

The currents I_1, I_2' and I_3 are led to a measuring transformer **23**, which in a known way obtains a current I_4 which is directly proportional to the air requirement for the gas flowing through the fuel line **1**. (The current I_4 will be referred to in the claim as the "resultant current.") The current I_4 is led through the winding **24** of a differential relay **25**.

The quantity of air flowing through the air line **26** is measured by a flow meter **27** which is similar to the flow meter **3** connected to the gas line. A current I_5 flowing through the flow meter **27** is rigidly proportional to the quantity of air flow, and is led through the winding **28** of the differential relay **25**. (The current I_5 will be referred to in the claim as the "supply-indicating current.")

When the actual flow of air through air line **26** is exactly equal to the air requirement of the gas flowing in gas line **1**, the current I_5 will be equal to the current I_4, and the switch lever **29** of the relay **25** remains in its central neutral position, as illustrated.

If now a change occurs in the relative weight of the gas flowing through the gas line **1**, a proportionate change takes place in the current I_4. If current I_4 now becomes weaker than current I_5, the switch lever **29** will move to the right and close a contact which will actuate motor **30** to close

valve 31 to permit less air to pass through air pipe 26. As soon as the air flow, as indicated by current I_5, equals the air requirement, as indicated by current I_4, the regulating process ceases, and switch lever 29 again moves to its central neutral position.

If current I_4 becomes stronger than current I_5, a similar regulating action to increase the air flow takes place.

It will be apparent to those skilled in the art that the system of the present invention provides a simple and practical means of adjusting the flow of air according to the changing air requirements of the gaseous fuel mixture. In this system all of the important factors of the situation are converted into electrical currents and these currents are then multiplied or compared by known electrical means to give an automatic indication, or an automatic regulation, of the air requirements.

All pieces of apparatus used in the system are quick-acting and reliable, thus avoiding the use of heavy complicated parts that would interfere with accuracy and sensitivity.

According to the provisions of the patent statutes, we have explained the principle of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that, within the scope of the appended claim, the invention may be practiced otherwise than as specifically illustrated and described.

In the appended claim reference is made to the fact that the first and second electrical currents are combined to obtain a "resultant." The word "resultant" is there used to refer either to the indication of the pointer 22 of Fig. 1 or to the current I_4 of Fig. 3.

We claim:

A furnace system which comprises a gas line for conducting a gaseous mixture to the burner and an air line for conducting air to the burner, and a system for maintaining the correct supply of air for burning the gaseous mixture which comprises: means for measuring the quantity of flow in the gas line and converting the quantity into a first electrical current which is rigidly proportional to the quantity of gas, means for measuring the relative weight of the gaseous mixture and converting the relative weight into a second electrical current which is rigidly proportional to the relative weight, a first adjustable means for modifying the second electrical current according to a first predetermined constant, a circuit conducting a third electrical current, a second adjustable means for modifying the third electrical current according to a second predetermined constant, an electrical device for combining the first, second and third electrical currents to obtain a resultant current which is rigidly proportional to the air requirement of the gaseous mixture, means for measuring the quantity of flow in the air line and converting the quantity into a supply-indicating current which is rigidly proportional to the quantity of air, and electrical control means responsive to the resultant current and the supply-indicating current, a valve in the air line, a motor connected to operate the valve, the motor being responsive to current from said electrical control means whereby the supply of air is regulated according to the specific gravity of the gaseous mixture passing through the gas line.

References Cited in the file of this patent

UNITED STATES PATENTS

1,527,721	Willey	Feb. 24, 1925
2,082,539	Fischer	June 1, 1937
2,322,374	Lowe	June 22, 1943
2,352,584	Zieboltz et al.	June 27, 1944
2,394,297	Fayles	Feb. 5, 1946
2,570,410	Vetter	Oct. 9, 1951
2,688,253	Markson	Sept. 7, 1954
2,723,559	Germer	Nov. 15, 1955

FOREIGN PATENTS

900,696	France	Oct. 16, 1944