LOW EXCESS AIR OPERATION OF MULTIPLE-BURNER RESIDUAL-FUEL-FIRED FURNACES

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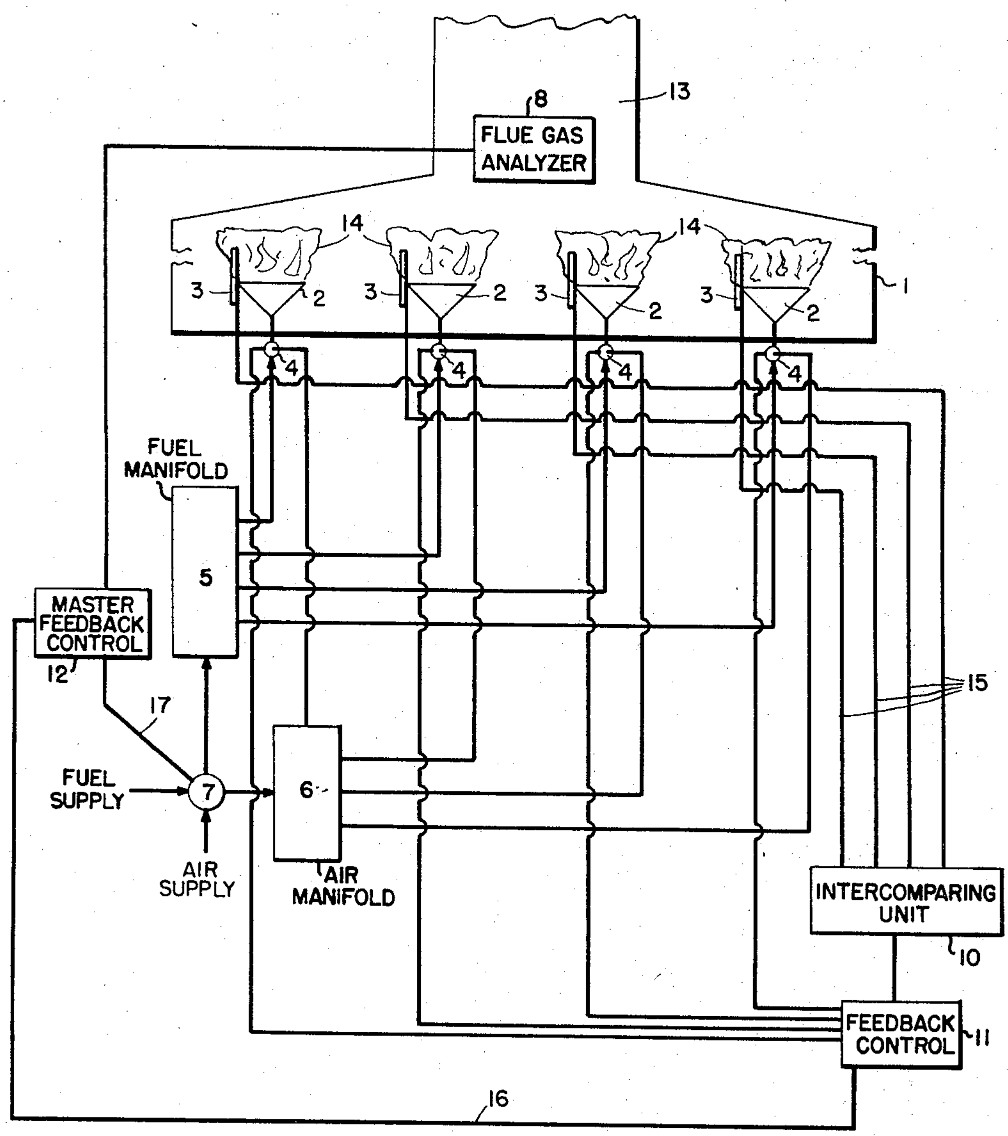


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# LOW EXCESS AIR OPERATION OF MULTIPLE-BURNER RESIDUAL-FUEL-FIRED FURNACES

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5 Claims. (Cl. 236—15)

## ABSTRACT OF THE DISCLOSURE

A process and apparatus is provided for establishing and maintaining optimum combustion at a low level of excess air in a multiple-burner furnace or boiler. The air and fuel feed to each individual burner of a multiple-burner furnace are adjusted so that the flame temperatures of the burners are essentially equal. The flue gas from the furnace is then analyzed and the feed to the air and fuel manifolds of the multiple-burner furnace is adjusted so that a desired level of excess air is delivered as determined by analysis of the flue gas.

*Cross-references to related applications*

This is a continuation of application Ser. No. 447,293, filed Apr. 12, 1965.

The present invention relates to a multiple-burner residual-fuel-fired furnaces and boilers. In general, it concerns a process and apparatus for establishing and maintaining optimum combustion at a low level of excess air in a multiple-burner furnace or boiler. In particular, it provides a process for achieving this optimum combustion by achieving the proper adjustment of the individual burners of such multiple-burner systems.

Multiple-burner residual-fuel-fired furnaces or boilers are commonly used in firing power plants. Such furnaces or boilers may have a dozen burners, be as tall as an eight story building and consume up to 400 barrels of fuel oil per hour. The residual fuel oils employed in such burners contain ash (i.e. metallic contaminants that are both non-volatile and non-combustible) and sulfur. Ash is troublesome in nearly all types of combustion equipment. The most common problem is deposit formation or slagging which reduces heat transfer, etc. Sulfur is found in varying amounts and chemical combinations in all grades of residual fuel oil. Some heavy fuels from high sulfur crudes contain as much as 5 wt. percent sulfur, while others from low sulfur crudes may have less than 1 wt. percent. Typical is a No. 6 oil having an average sulfur level of 2.5 wt. percent. When sulfur-containing fules are burned, part of the sulfur is converted to sulfur trioxide which in turn causes surfuric acid corrosion.

It is well known that the operation of residual-fuel-fired systems is substantially improved in terms of reducing superheater slagging and corrosion of both superheaters and their preheaters by carrying out the combustion at levels of "low excess air" only slightly higher than stoichiometric, e.g. 0.01–3% excess. This is an effective method of optimizing combustion, but in the past has been limited in application because smoke formation and poor combustion usually result before the "low excess air" combustion is achieved. One of the problems associated with achieving this "low excess air" combustion is assuring that the individual burners of a multiple-burner system are each operating at the same level of excess air. For instance, if half the burners in a multiple-burner system operate at 6% excess air, and the remainder operate at stoichiometric conditions, the flue gas analysis of the stack gases for the percent oxygen will show the overall combustion to be at 3% excess air (i.e. optimum

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combustion conditions). However, conditions are actually poor in terms of smoke and corrosion, since the burners operating at or slightly below stoichiometric conditions will produce dense smoke, and those operating at 6% excess air will tend to cause superheater and air preheater corrosion.

According to the present invention, there is provided a process and apparatus which assure that the individual burners of a multiple-burner system are each operating at the same level of excess air and thus afford a practical means of realizing the inherent benefits of "low excess air" combustion.

In the present invention the air and fuel feed to each individual burner of a multiple-burner furnace are adjusted so that the flame temperatures of the burners are essentially equal. Subsequently, the overall level of air or fuel feed to all burners is adjusted so that the furnace operates at the optimum level of excess air.

The initial step of adjusting each individual burner so that the flame temperatures associated with all the burners are essentially equal can be accomplished in various ways. This step may be conveniently referred to as "balancing" the burners. While the burners can be balanced by any of several methods, all of the methods involve a manipulation of the air or fuel feeds to the individual burners. The various methods used to balance the burners differ primarily in the different temperature sensing devices used to determine flame temperatures. That is, different temperature sensing devices can be employed to provide the information about the flame temperatures. Among these various devices that can be used are thermocouples, photopyrometers (employed both within the flame and immediately adjacent to it), ultraviolet analyzers, and microwave analyzers. In a preferred embodiment of the present invention a closed tube photopyrometer is employed as the temperature sensing device.

A closed tube photopyrometer includes a sensing element which is a hollow tube of a refractory material, such as alumina, closed at one end plus an optical detection device i.e. optical detector, for measuring the intensity of radiation; for example a photoresistive cell such as, a cadmium selenide or cadmium sulfide cell, a photomultiplier, or the like can be employed as the optical detector. The closed end of the tube is placed into or adjacent to the flame where it quickly achieves a temperature essentially equal to the temperature of the flame. It then glows, and emits radiation, which is characteristic of this temperature. When the optical detector is placed adjacent to the open end of the tube, the detector will produce a signal which will change as a function of the intensity of the radiation. When the optical detector is a photoresistive cell, its resistance will change as a function of the intensity of the radiation. This resistance can be measured by any standard means such as a Wheatstone bridge.

The purpose of the closed tube is to shield the detector from any incident radiation except that from the end of the tube and to smooth out the rapid fluctuations in temperature characteristic of a single location in a flame to give a steady temperature characteristic of the overall flame. Without the tube, background radiation which is not characteristic of the flame temperature would affect the detector. In addition, the resistance of the detector would fluctuate rapidly as it responded to the flicker of the flame.

If desired, the detector can be placed in a more convenient location remote from the open end of the tube, by inserting one end of a so-called fiber optic into the open end of the tube and placing the other end adjacent to the detector.

After the burners are balanced (i.e. the burners' flame temperatures are essentially equal) the step of achieving the desired level of excess air combustion at each burner is effected by adjusting the air and/or fuel flow to the entire assembly i.e., all burners. This may be done by various methods. For example, if the multiple-burner furnace is provided with an air manifold and a fuel manifold which substantially evenly distribute the air and fuel feeds, respectively, to the individual burners, the air and/or fuel flow to all the burners may be adjusted by manipulation of the manifold controls so as to achieve overall air/fuel ratio optimization. This overall optimization is determined by flue gas analysis. Flue gas analysis is a well-known procedure to those skilled in the art and need not be described further.

In one embodiment of the present invention the process and apparatus described herein is employed to automatically control desired levels of excess air in multiple-burner furnaces.

In a preferred embodiment of the present invention a temperature intercomparison technique is employed. This technique is far more accurate and much less costly than techniques based upon measurement of absolute temperature values. The technique compirses providing a means, hereinafter referred to as an intercomparing unit, for comparing the flame temperatures of the various burners directly with one another as opposed to first measuring the absolute temperature values of the individual flames and then comparing the measured temperatures.

For example, the intercomparison unit can be a series of calibrated optical detectors placed adjacent to the ends of sensing elements (e.g. hollow alumina tube closed at one end) which are inserted into the flames of individual burners in a multiple-burner furnace. The air/fuel ratio to each burner can be adjusted so that, for example, the resistances of all of the optical detectors are essentially equal. When this has been accomplished, the burners are balanced, i.e. the air level at all burners is essentially equal, and the overall level can be adjusted to the optimum level.

An alternate and preferred method is to insert a series of matched fiber optics into the open ends of the tubes. The radiation issuing from the other end of each in turn is permitted to strike a single optical detector. While the radiation from the tube inserted into the first flame is striking the optical detector the resistance is noted. Then the radiation from the second is permitted to strike the optical detector and the air/fuel ratio to the second burner is adjusted to give the same resistance as the first. This sequence is followed until all burners give the same resistance. By this scheme the need for calibrated optical detectors is eliminated because the same detector is used for all of the flames.

The invention is further understood by reference to the accompanying drawing in which FIGURE 1 is a schematic diagram of a process and apparatus for automatically controlling the level of excess air combustion in a four-burner furnace according to the present invention.

With reference to FIGURE 1 there is shown a furnace **1** equipped with four burners **2**. Sensing elements **3**, e.g. a hollow alumina tube closed at one end, extend into or near each burner flame **14** where the sensing elements **3** glow and produce radiation according to the well-known Planck's law for radiation from a black body. Air and fuel are supplied to each burner **2** through the respective control valves **4**. Fuel is supplied to each control valve **4** from a fuel manifold **5**. Air is supplied to each control valve **4** from an air manifold **6**. A master control valve **7** regulates the air/fuel ratio to the fuel manifold **5** and the air manifold **6**. A flue gas analyzer **8** is located in the furnace stack **13** and analyzes the mixture of flue gases from the four burners **2**. Signals from the sensing elements **3** are conducted through suitable conduit means **15**, e.g. fiber optics, and compared at an intercomparing unit **10** and in the event of imbalance intercomparing unit **10** activates an imbalance signal, e.g., an electrical signal, to suitable feedback control **11** to



effect a "balance" of the imbalanced burner. The overall excess air level is determined by flue gas analyzer **8**. Master feedback control **12**, which includes a timer (not shown), periodically compares the overall excess air level as determined by analyzer **8** with the desired level, and in the event of a difference activates an error signal through suitable conduit means **17** to master control valve **7** which adjusts the air and/or fuel feeds to their respective manifolds bringing the overall level of combustion to the desired level. Each control valve **4** and master control valve **7** are shown as single valves, however two separate valves, one on the fuel supply line and one on the air supply line, can also be employed at any or all of these points in the system. The timer in master feedback control **12** also periodically actuates through a suitable conduit **16**, such as an electrical wire, feedback control **11**, allowing feedback control **11** to respond to any imbalance signal from intercomparing unit **10** and thereby effect a balance of the imbalanced burner. The timer, of course, coordinates the steps of balancing and the step of adjusting the overall level of combustion so that these steps do not take place concurrently. Both the balance and the overall level are thus maintained automatically and indefinitely assuring achievement of desired low excess air levels and its inherent benefits.

As mentioned supra, a suitable intercomparing unit provides a means for comparing the individual flame temperatures of the various burners directly with one another, without measuring absolute temperature values. Such means are apparent to those skilled in the art. In a preferred embodiment, radiation from the various sensing elements is conducted to the intercomparing unit through a series of matched fiber optics (one fiber optic for each burner) and the unit includes a single optical detector, means for permitting the radiation from only one fiber optic at a time to strike the optical detector, means for noting the resistance of the optical detector, means for comparing resistance levels of the optical detector and means for producing an imbalance signal representative of different optical detector resistance levels. The matched fiber optics can be fiber optics such as LG–3, obtained from American Optical Company, which are matched or calibrated so that they will conduct equal amounts of radiation.

The optical detector can be a cadmium selenide photoresistive cell such as Catalogue No. CL–603AL, obtained from Clairex Corporation.

The means for permitting the radiation from only one fiber optic at a time to strike the optical detector can be an "optical chopper" which is further described in a cofiled application, Ser. No. 447,292, filed Apr. 12, 1965. The optical chopper consists of an opaque disc with a wedge removed of an angle$=360°/n$ where $n$ equals the number of burners in the furnace. The disc is driven by a small electrical motor.

The means for noting the resistance of the optical detector can be a Wheatstone bridge.

The means for comparing the resistance levels of the optical detector and the means for producing an imbalance signal are well known in the art. For example, the resistance levels of the optical detector may be viewed as voltage signals and such signals can be compared with one another to produce an imbalance signal which is sent to suitable feedback controls.

Suitable feedback controls are well known in the art. For example, such controls can include an amplifier for amplifying the imbalance signal from the intercomparing unit and proportioning control valves (e.g. electrical or pneumatic) on the air and/or fuel feeds to the individual burners.

Suitable master feedback controls are likewise well known in the art. For example, such controls can include a timer for coordinating and periodically actuating the feedback controls, the flue gas analyzer, and the master control valve(s) to the air and/or fuel feeds; comparing means, such as a differentiator, for comparing the measured with the desired overall air level in the flue gas and for producing an error signal; amplifying means to amplify error signals; and means to transmit amplified error signals to suitable control valves. Usually, master feedback controls will include means for allowing an operator to effect a step change in the fuel supply when for example, steam output requirements change.

While the embodiment shown in FIGURE 1 describes a preferred process and apparatus for automatically controlling the level of excess air combustion at each individual burner of a multiple-burner system, the process of the present invention can also be employed without the automatic control features. That is, an operator may take the information obtained from a flue gas analysis and manually adjust the air/fuel ratio by adjusting the air and/or fuel master valve. In a similar manner, the operator may also use the information from the intercomparison unit to manually operate the air and/or fuel control valve at each burner (i.e. to "balance" the burners).

While a general description has been given and preferred embodiment of the present invention has been described and illustrated, it is to be understood that various modifications and adaptations thereof can be made without departing from the spirit of the invention and the scope thereof.

For instance, while a photoresistive cadmium selenide cell has been described as the optical detector employed in the preferred embodiments, a photoemissive device (e.g. a photomultiplier) can be used as the detector. Similarly, while in the described preferred embodiment, the system is provided with air and fuel manifolds, other means can be used to supply substantially equal amounts of air to each individual burner and to supply substantially equal amounts of fuel to each individual burner.

What is claimed is:

**1.** A process for the control of low excess air combustion in a multiple-burner residual-fuel-fired furnace provided with an air manifold and a fuel manifold, which comprises:



(a) comparing the flame temperature of each individual burner;

(b) adjusting the ratio of air and fuel delivered to each individual burner so that the flame temperature of said burners are essentially equal;

(c) analyzing the flue gas from the furnace; and

(d) adjusting the feed to the air manifold and the fuel manifold so that a desired level of excess air is delivered as determined by flue gas analysis.

**2.** A process according to claim **1** wherein said desired level of excess air does not exceed about 3%.

**3.** Apparatus for the automatic control of combustion in a multiple-burner residual-fuel-fired system comprising (a) a temperature sensing means adapted to measure the individual flame temperature of each of said burners; (b) an intercomparing unit adapted to compare the individual flame temperatures directly with one another and further adapted to produce imbalance signals representative of any difference between said temperatures, (c) feedback controls responsive to said imbalance signals and adapted to control the air-fuel feed to each individual burner; (d) a flue gas analyzer adapted to produce a first signal representative of the overall air level in the stack of said system; and (e) master feedback controls responsive to said first signal and adapted to compare said first signal with a second signal representative of the desired overall air level and further adapted to produce an error signal and to control the air-fuel feed to all burners simultaneously.

**4.** An apparatus according to claim **3** wherein said master feedback controls are further adapted to actuate periodically said feedback controls.

**5.** An apparatus according to claim **3** wherein said master feedback controls control the air-fuel feed to all burners simultaneously through an air manifold and a fuel manifold.

No references cited.

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