

TITLE: BURNER SYSTEMSTECHNICAL FIELD

The present invention relates to burner systems, e.g., boiler systems, and more particularly to fault detection apparatus for a burner system as hereinafter defined.

BACKGROUND ART

Commercial and industrial burner systems, whether heating fluid or producing steam, are inherently dangerous in view of the potential consequences of catastrophic burner failure. Fuel, usually in gaseous form, is supplied to a combustion chamber where it is burnt in a controlled manner, usually in air likewise supplied to the chamber. The fuel supply is commonly regulated by a valve and the air supply by a damper control linked to a fan, with regulation of both supplies being used to control the heat being generated. As soon as control is lost for whatever reason, an explosion becomes a distinct possibility.

A small number of boiler plant now have oxygen trim systems fitted which may improve burner safety, but many boiler controls will continue to be solely reliant on rudimentary pressure switches and linkage or actuator proving switches since the capital cost of trim systems may not be warranted on smaller plant with low running hours. A small number of larger boiler plants have an oxygen or carbon dioxide sensor, but almost invariably require operators to monitor for safe or efficient

operation. Importantly, oxygen sensors do not prove safe conditions prior to ignition and although oxygen sensing can be utilised to shut unsafe plant down, there is a significant time delay and all too often the 'lockout' -
5 if fitted - is disabled due to occasional 'nuisance' alarms.

Currently, the integrity of the gas/air ratio control mechanism is typically only checked by: a) a low air pressure alarm which is set to trigger if the pressure
10 falls below the minimum pre-set level prior to and after ignition (often set at minimum); and b) micro-switches which prove the integrity of the linkages or actuator motor only prior to ignition. These switches are frequently found to be set course to prove actuation only,
15 not to prove the conditions have been precisely met. Some switches are integral within the driving servo motor and are therefore not able to prove the integrity of the linkage; quadrants; damper or valve.

After ignition on existing burner controls, the low
20 pressure switch will typically only be activated if the air supply is lost altogether, (e.g. burner fan failure). Thus, on a burner with a 5-1 turn-down ratio (i.e. 20% to 100% of maximum heat), only 20% of the required air could be supplied at high fire, without the burner 'locking
25 out'. This is a not infrequent occurrence, and results in high emissions of oxides of nitrogen, carbon monoxide, unburned fuel, damage to the tubes as well as a potential for a serious accident.

US patent 4915613 (assigned to Honeywell, Inc.) discloses method and apparatus which monitor fuel pressure in a heating system where a controller controls activation of the fuel valves. A fuel pressure limit signal is provided to the controller for determining if the fuel pressure crosses predetermined thresholds. In order to avoid nuisance shut downs, the fuel pressure limit signal is ignored by the controller for a predetermined interval after the controller has actuated a fuel valve. The predetermined interval is selected to prevent nuisance shut-downs as a result of responding to pressure transients in the fuel main.

It is a concern for safety inspectors, burner operators and technicians that such typical events as partial or total failure of the fuel valve or air damper during operation are not detected by existing systems. With more emphasis on de-manning of boiler houses and less frequent inspections and maintenance checks, there is a need for improved burner safety. For the purposes of the present specification, a burner system is defined as comprising a burner and combustion chamber for burning fluid fuel in oxygen-containing gas, both of which are supplied to the burner. The combustion products exit the combustion chamber through a flue.

DISCLOSURE OF THE INVENTION

In accordance with the present invention there is provided fault detection apparatus for a burner system as hereinbefore defined, comprising means for monitoring the

supply of fluid fuel (eg natural gas, propane or butane) to the combustion chamber; means for monitoring the supply of oxygen-containing gas to the combustion chamber; means for comparing readings from the monitoring means with reference values; and means for generating a signal in dependence on the comparison made.

The system provides a way of evaluating the relative proportions of the components (fluid fuel and oxygen-containing gas) undergoing combustion by monitoring the effective quantities per unit time of both as actually supplied to the combustion chamber, rather than believed to have been supplied to the combustion chamber. The effective quantity relates to the number of moles of useful component supplied, although when dealing with gaseous supplies at the same temperature and pressure, the effective quantity is simply related to the volume supplied.

When the burner system is being commissioned, the reference values may be determined by taking readings from the monitoring means when optimum burner conditions are established. It is relatively easy to ascertain when such conditions are achieved using a multi-gas flue analyzer to ensure complete combustion (i.e. the flue-gas is free of low oxygen nitrogen oxides and carbon monoxide) and the correct excess air has been established. Alternatively, a given burner system fitted with standard supply lines may have predictable characteristics which enable the reference values to be pre-set, obviating the need for

in situ determinations to be made.

In ordinary operation, if the instantaneous readings from the monitoring means match the reference values, indications will be all is well and that no further action
5 need be taken, other than to continue monitoring the supplies. If, however, the instantaneous readings from the monitoring means are different to the reference values, a signal is generated, perhaps either to warn the operator of potential danger or to override the operation
10 of the combustion apparatus, eg inhibit ignition or shut down the combustion apparatus during operation. The signal may even simply warn of a departure from optimum combustion efficiency.

The burner system may further comprise valve means
15 for regulating the flow of fluid fuel into the combustion chamber, in which case the fluid fuel supply monitoring means is located downstream of the valve means. The burner system may further comprise valve means for regulating the flow of oxygen-containing gas into the
20 combustion chamber, in which case the oxygen-containing gas supply monitoring means is located downstream of the respective valve means. Preferably, the monitoring means are located in the burner, immediately adjacent the burner head where the fuel and oxygen containing gas mix prior to
25 combustion.

In this way, the readings from the monitoring means accurately reflect the ratio of fuel to oxygen-containing gas being supplied to the combustion chamber. Thus, the

monitoring means are sensing what is actually being supplied to the combustion chamber, not what is believed to be supplied to the combustion chamber.

At least one of the monitoring means may comprise a
5 sensor for sensing the pressure of the respective supply.
In the case of the oxygen-containing supply, the quantity of gas supplied to the combustion chamber is proportional to the pressure of the supply. Thus, continuous monitoring of the pressure gives an accurate indication of
10 the rate at which gas is supplied to the combustion chamber. In addition, the pressure sensor may be utilized during purge to identify increased back pressure which might result, for example, from fouled heat transfer surfaces in the boiler or a flue blockage. Furthermore,
15 purge pressure sensor signals could be used to identify other malfunctions such as induced draft damper control or induced draft fan operation. Fouling or faults would be detected by comparison of the ambient air pressure and back pressure as measured by the pressure sensor during
20 purge.

Alternatively, at least one of the monitoring means may comprise a flow sensor. The flow sensor may prove useful in situations where pressure variance may be too small to measure flow rate accurately.

25 The fault detection apparatus may further comprise a temperature sensor for sensing the temperature of the oxygen-containing gas, and means for compensating for the temperature variations prior to the comparison being made.

The volume of a fixed amount of gas at constant pressure varies with temperature, and hence temperature variations will effect the actual amount of gas delivered to the combustion chamber. A plurality of reference values could
5 be provided, with different reference values being used at different temperatures. Preferably, the oxygen-containing gas is air, and thus the temperature sensor may be mounted to sense ambient conditions.

In a preferred form, the signal generated in
10 dependence on the comparison made is further dependent on the magnitude of any difference between the reference values and the readings from the monitoring means. One embodiment of the present invention is designed to provide a configured, measured response to departures
15 from safe operating conditions, permitting early identification of maintenance needs without an unscheduled shutdown if possible. The signal generating means may thus provide a range of signals depending upon the perceived seriousness of the difference between
20 actual readings and reference values. In the most serious situation (perhaps indicative of a potential explosion), the signal could effect automatic and immediate shut down of the combustion apparatus; in less serious situations, the signal could activate an alarm
25 with a view to initiating a routine maintenance check.

The fault detection apparatus may further comprise means for monitoring the flow of combustion by-products (flue gas) exiting the combustion chamber. The flue gas

monitoring means may enable more accurate comparisons to be made by providing a way of checking the relative amounts of fuel and oxygen-containing gas supplied to the combustion chamber. The flue gas monitoring means may be
5 a pressure transducer. The pressure transducer may, in combination with the pressure sensors already mentioned, enable pressure drops across the combustion chamber to be detected. Any such pressure drop may be indicative of a blockage somewhere in the system, leading to a further
10 safety control.

The fault detection apparatus may further comprise means for sensing the temperature of combustion by-products (flue gas) exiting the combustion chamber, means for predicting the temperature of combustion by-products
15 (flue gas) exiting the combustion chamber based on the calorific value of the fuel/oxygen containing gas supplied, means for comparing the sensed and predicted temperatures and producing an output in dependence upon the comparison made. If, for example, the sensed and
20 predicted temperatures differed by more than a predetermined amount (perhaps indicative of fouling of either the fireside or water side heat transfer surfaces or loss of heat transfer fluid), the output may include controlled shut down of the system. With such apparatus,
25 it should be borne in mind that "cold start" readings may differ significantly from "steady state" readings.

The fault detection apparatus may further comprise means for regulating the supply of oxygen-containing gas

in dependence upon a comparison between the supply of oxygen-containing gas as monitored and a predetermined level of supply. The regulating means may produce a measured response in fan motor speed in order to increase or decrease the supply of oxygen-containing gas to restore the supply to the predetermined level, e.g., to maintain the required supply of combustion air for any given gas pressure. The fan motor speed typically controlled by an ac variable speed drive which may readily be regulated by a proportional integral derivative function within the ac drive. An alternative if on ac drive is not used is to provide a position trim with feedback to the combustion air damper servo motor.

According to a second aspect of the present invention, there is provided a method of detecting a fault in a burner system as hereinbefore defined, comprising: monitoring the rate of fluid fuel supply to the combustion chamber; monitoring the rate of oxygen-containing gas supply to the combustion chamber; comparing monitored readings with reference values; and generating a signal in dependence upon the comparison made.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawing, in which :

Figure 1 shows schematically a burner system embodying the present invention.

MODES OF CARRYING OUT THE INVENTION

A burner or boiler system 10 comprises a combustion chamber 12 having gaseous fuel supply line 14 and air supply line 16. Valve 15 regulates the flow of fuel into the combustion chamber 12 and fan and damper 17 regulate the supply of air to the combustion chamber 12. The by-products of burning the fuel at burner 18 are vented through flue 20 and heat generated by combustion is absorbed by boiler heat exchanger 22.

Fault detection apparatus comprises a first pressure sensor 24 in the air supply line 16, downstream of the fan and damper 17; and a second pressure sensor 26 in the fuel supply line 14, downstream of the valve 15. (The pressure sensors are readily available components, typically of silicon diaphragm design, and measure pressures typically in the range 100 to 3500 pascals, with a range output of 4 to 20 mA or 0 to 10 volts). The pressures P_1 and P_2 sensed respectively by sensors 24, 26 are fed to micro-processor 30, together with a temperature indication T_1 of the air supply which is provided by temperature sensor 28.

The micro-processor 30 stores a range of reference pressure values across a range of temperatures which are indicative of optimum combustion conditions. The values may have been determined when the burner was being commissioned using a flue gas analyzer to ascertain the pressures in the supply lines at a given temperature which give rise to a fuel/air mixture required for complete

combustion.

Having selected the reference values for the temperature detected by sensor 28, the micro processor 30 compares them with the pressure readings sensed by sensors 24, 26, and produces a measured response 32 in dependence upon the results of the comparison. The comparison may be made by firstly determining quotients for the reference values and sensed readings and then comparing the quotients. However, for simplicity, direct comparison of the reference values and sensed readings will be considered hereinafter. The measured response 32 is graded as follows:

0. If P_1 , P_2 match the reference values, the micro-processor 30 simply continues monitoring the boiler system 10, comparing fresh pressure and temperature readings with the reference values.
1. If P_1 , P_2 show a slight deviation from the reference values, possibly indicating inefficient combustion and/or an undesirable increase of emissions of carbon monoxide and lesser nitrogen oxides, the micro-processor 30 activates an alarm for non-urgent servicing of the system whilst continuing to monitor the combustion operation.

2. If P_1 , P_2 show a more serious deviation from the reference values, indicative of likely damage to components through prolonged use, the micro-processor 30 shuts down the boiler system 10 after a time delay which first allows further readings to be taken to verify the initial readings.

3. If either P_1 or P_2 exceed pressure thresholds indicative of a catastrophic control failure, the microprocessor 30 aborts an ignition sequence or, if the fuel is already burning, shuts down the boiler system immediately.

A combustible-gas detector 40, spaced from the burner 18, detects for combustible gases in the plant room 42.

(The detector may be of the well known and proven electro catalytic type, in which two beads, one active and the other a compensator, form one half of a Wheatstone bridge

configuration). The output D_1 of the detector 40 is received by micro-processor 30 which assess whether the level is close to or above a lower explosive limit. If flammable gas is detected close to or above the lower explosive limit, the micro-processor 30 isolates power and gas supply to the boiler instantly.

BENEFITS

- Greatly improved safety - instantaneous shut down if an

unsafe fuel/air condition is sensed.

- Impending fault diagnosis allowing scheduling of servicing - minimising fuel wastage and downtime inconvenience and losses.
- 5 ▪ Averts the risk of overfiring the boiler/burner and consequent costly boiler damage and fuel inefficiency.
- Flue gas temperature monitoring alerts the operator to fireside or waterside faults with limiter (lockout) if a serious fault is detected.
- 10 ▪ Does not compromise any existing burner safety controls.
- Optional gas leak detection system alarms out and prevents burner ignition in potentially explosive atmosphere.
- Provides an important stand alone 'watch dog' for
15 electronic direct drive servo fuel/air ratio systems.
- Facilitates fast routine maintenance by existing service personnel through inclusion of fault diagnostics software.
- Enables burners to be operated within optimum
20 commissioned values and be safely shut down if inadmissible deviations from manufacturers stated conditions are detected.
- Ensures sustained operation of the boiler does not occur when emissions to atmosphere would be unacceptable.
- 25 ▪ Prevents sustained operation of the burner if this would result in damage to the boiler shell or tubes.

- Improves the environmental performance of the site.
- Reduces fuel and maintenance costs.

EXAMPLES OF DETECTABLE FAULTS

- 5 ▪ Failure or partial failure of gas pressure regulation valve.
- Failure of a gas booster set.
- Incorrectly set purge proving switches.
- Catastrophic loss of boiler water.
- 10 ▪ Build up of deposits or scale on the fire or water side and consequent inefficiency and thermal stress.
- Blocked or partially blocked fire tubes or flue.
- Sticking diaphragms on modulating gas valves e.g., SKP 70 Landis & Gyr valves.
- 15 ▪ Failure of air damper linkages or slippage of damper blade connection clamps.
- Failure of air characterising cams.
- Partially blocked air inlet on combustion air fan (e.g., Polythene blown onto/into the air inlet).
- 20 ▪ Failure of valves such as Landis & Gyr SKP 70 which can fail in a fuel rich mode.
- Failure of a balance damper or induced draft fan/damper.
- Fouling of air fan blades or damper vanes.
- Shearing of gas valve spindle or connecting linkages.
- 25 ▪ Electronic failures in fuel air direct drive servo systems e.g., (RFI induced 'scrambling' of set up).

- Incorrect maintenance or repair procedures.
- Gas leaks I the plant room, leading to potentially explosive conditions (Optional).

CLAIMS

1. Fault detection apparatus for a burner system as hereinbefore defined, comprising: means for monitoring the supply of fluid fuel to the combustion chamber; means for monitoring the supply of oxygen-containing gas to the combustion chamber; means for comparing readings from the monitoring means with reference values and means for generating a signal in dependence on the comparison made.
2. Fault detection apparatus according to claim 1, in which the fluid fuel supply monitoring means is located downstream of valve means regulating the flow of fluid fuel into the combustion chamber.
3. Fault detection apparatus according to claim 1 or 2, in which the oxygen-containing gas supply monitoring means is located downstream of valve means regulating the flow of oxygen-containing gas into the combustion chamber.
4. Fault detection apparatus according to any one of claims 1, 2 or 3 in which at least one of the monitoring means comprises a sensor for sensing the pressure of the respective supply.
5. Fault detection apparatus according to any one of the preceding claims, further comprising a temperature sensor for sensing the temperature of the oxygen-containing gas and means for compensating for sensed temperature variations prior to the comparison being made.
6. Fault detection apparatus according to claim 5, in which the compensating means comprises means for selecting

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from a set of values reference values appropriate to the temperature sensed.

7. Fault detection apparatus according to any one of the preceding claims, in which the oxygen-containing gas is
5 air.

8. Fault detection apparatus according to any one of the preceding claims, in which the signal generated is further dependent on the magnitude of any difference between the reference values and the readings from the monitoring
10 means.

9. Fault detection apparatus according to any one of the preceding claims, in which the reference values are indicative of conditions for complete combustion.

10. Fault detection apparatus according to any one of
15 claims 1 to 9, further comprising means for monitoring the flow of combustion by-products (flue gas) exiting the combustion chamber.

11. Fault detection apparatus according to claim 10, in which the flue gas monitoring means is a pressure
20 transducer.

12. Fault detection apparatus according to claim 10, in which the flue gas monitoring means is a temperature sensor.

13. Fault detection apparatus according to claim 12,
25 further comprising means for predicting the temperature of combustion by-products (flue gas) exiting the combustion chamber based on the calorific value of the fuel/oxygen containing gas supplied, and means for comparing the



sensed and predicted temperatures and producing an output in dependence upon the comparison made.

14. A burner system comprising fault detection apparatus according to any one of claims 1 to 13.

- 5 15. A method of detecting a fault in a burner system as hereinbefore defined, comprising: monitoring the rate fluid fuel is supplied to the combustion chamber; monitoring the rate oxygen-containing gas is supplied to the combustion chamber; comparing the rates monitored with
10 reference values; and generating a signal in dependence upon the comparison made.



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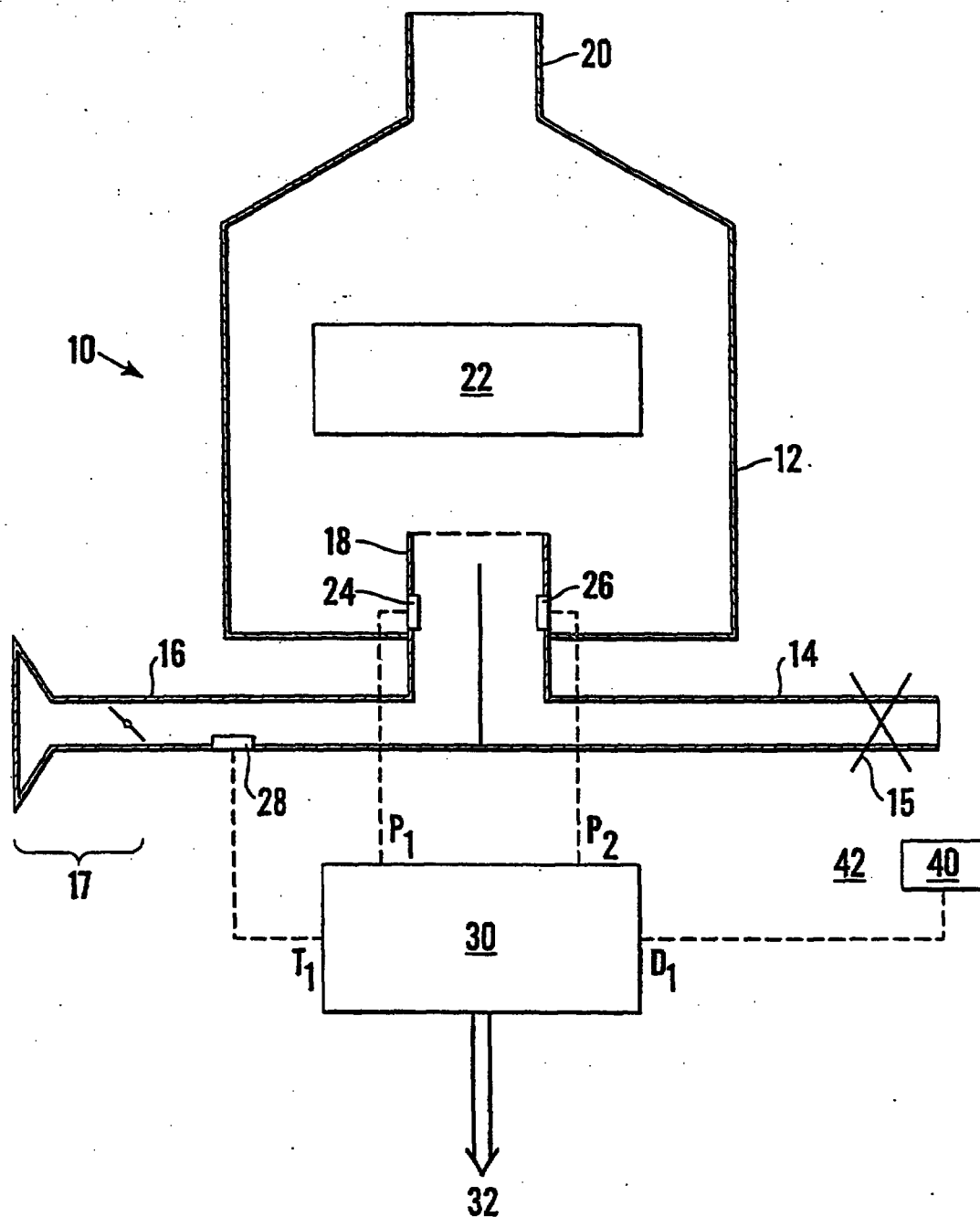


Fig. 1

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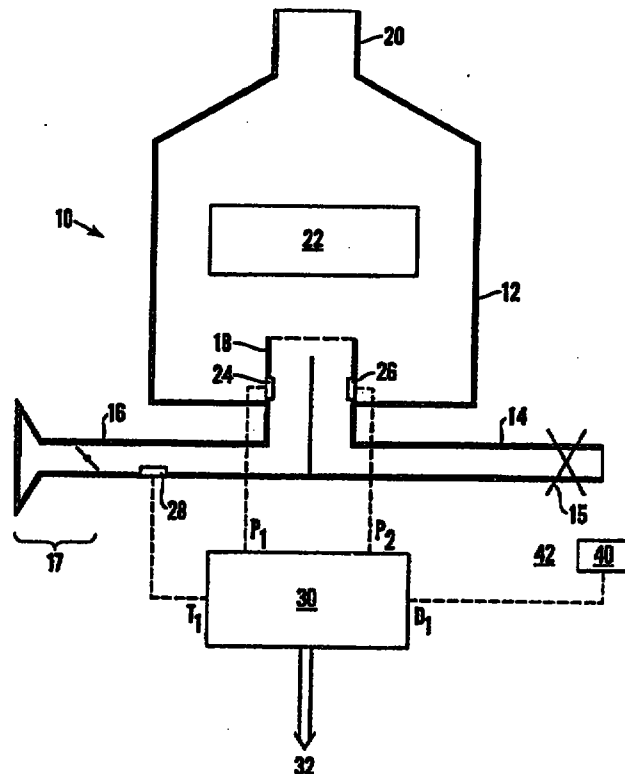
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(54) Title: **BURNER SYSTEMS**

(57) Abstract

Fault detection apparatus for a boiler system (10) comprises a first pressure sensor (24) in air supply line (16), downstream of fan and damper (17); and a second pressure sensor (26) in the fuel supply line (14), downstream of the valve (15). Pressures P_1 and P_2 sensed respectively by sensors (24, 26) are fed to microprocessor (30), together with an indication from sensor (28) of the temperature T_1 of the air supply. The microprocessor (30) stores a range of pressure values across a range of temperatures which are indicative of optimum combustion conditions. Having selected the reference values appropriate for the temperature sensed, microprocessor (30) compares them with P_1 and P_2 and produces a measured response in dependence upon the results of the comparison, and ranging from further monitoring (slight deviation between stored and sensed valves) to emergency shutdown (major deviation between stored and sensed valves).



combustion.

Having selected the reference values for the temperature detected by sensor 28, the micro processor 30 compares them with the pressure readings sensed by sensors 24, 26, and produces a measured response 32 in dependence upon the results of the comparison. The comparison is made by direct comparison of the reference values and sensed readings. The measured response 32 is graded as follows:

10

0. If P_1 , P_2 match the reference values, the micro-processor 30 simply continues monitoring the boiler system 10, comparing fresh pressure and temperature readings with the reference values.

15

1. If P_1 , P_2 show a slight deviation from the reference values, possibly indicating inefficient combustion and/or an undesirable increase of emissions of carbon monoxide and lesser nitrogen oxides, the micro-processor 30 activates an alarm for non-urgent servicing of the system whilst continuing to monitor the combustion operation.

25

CLAIMS

1. Fault detection apparatus for detecting departure from predetermined operation of a burner system including a combustion chamber, comprising: means for monitoring the supply of fluid fuel to the combustion chamber; and means for monitoring the supply of oxygen-containing gas to the combustion chamber; characterised by means for comparing readings from the monitoring means with reference values of fluid fuel supply and oxygen-containing gas supply indicative of predetermined operation, and means for generating a signal in dependence on the comparison made.
2. Fault detection apparatus according to claim 1, in which the fluid fuel supply monitoring means is located downstream of valve means regulating the flow of fluid fuel into the combustion chamber.
3. Fault detection apparatus according to claim 1 or 2, in which the oxygen-containing gas supply monitoring means is located downstream of valve means regulating the flow of oxygen-containing gas into the combustion chamber.
4. Fault detection apparatus according to any one of claims 1, 2 or 3 in which at least one of the monitoring means comprises a sensor for sensing the pressure of the respective supply.
5. Fault detection apparatus according to any one of the preceding claims, further comprising a temperature sensor for sensing the temperature of the oxygen-containing gas and means for compensating for sensed temperature



variations prior to the comparison being made.

6. Fault detection apparatus according to claim 5, in which the compensating means comprises means for selecting from a set of values reference values appropriate to the
5 temperature sensed.

7. Fault detection apparatus according to any one of the preceding claims, in which the oxygen-containing gas is air.

8. Fault detection apparatus according to any one of the
10 preceding claims, in which the signal generated is further dependent on the magnitude of any difference between the reference values and the readings from the monitoring means.

9. Fault detection apparatus according to any one of the
15 preceding claims, in which the reference values are indicative of conditions for complete combustion.

10. Fault detection apparatus according to any one of claims 1 to 9, further comprising means for monitoring the flow of combustion by-products (flue gas) exiting the
20 combustion chamber.

11. Fault detection apparatus according to claim 10, in which the flue gas monitoring means is a pressure transducer.

12. Fault detection apparatus according to claim 10, in
25 which the flue gas monitoring means is a temperature sensor.

13. Fault detection apparatus according to claim 12, further comprising means for predicting the temperature of

combustion by-products (flue gas) exiting the combustion chamber based on the calorific value of the fuel/oxygen containing gas supplied, and means for comparing the sensed and predicted temperatures and producing an output
5 in dependence upon the comparison made.

14. A burner system comprising fault detection apparatus according to any one of claims 1 to 13.

15. A method of detecting departure from predetermined operation of a burner system including a combustion
10 chamber, comprising: monitoring the rate fluid fuel is supplied to the combustion chamber; monitoring the rate oxygen-containing gas is supplied to the combustion chamber; characterised by comparing the rates monitored with reference values of fluid fuel supply and oxygen
15 containing gas supply indicative of predetermined operation, and generating a signal in dependence upon the comparison made.

