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(54) Title: COMBUSTION FURNACE AND METHOD OF OPERATION

(57) Abstract: A combustion furnace and a method of its operation are described. The furnace comprises a chamber defining a com-
bustion volume having at least one primary inlet for fuel and combustion supporting gases and at least one primary outlet for com-
bustion product gases, which chamber is provided with one or more additional ports, for example in fluid communication with a sup-
ply of gas for secondary gas flow, allowing for secondary gas flow into and/ or out of the combustion volume.



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COMBUSTION FURNACE AND METHOD OF OPERATION

5 The invention relates to a furnace and its method of operation. The invention in particular relates to furnace pressure control. The invention in particular relates to a control system for and a method of operation of a furnace for a thermal power plant, and in particular a furnace having a conventional and an oxyfuel fired capability, but is not limited to application in such preferred cases.

10

Control of both furnace pressure and combustion conditions is important for safe, efficient and flexible operation of a thermal power plant. In a conventional air fired power plant the maintenance of correct combustion conditions is normally achieved by control of the FD and ID fans. These are operated such that the total flow of combustion air into the furnace from the environment to match fuel flow is controlled by the FD fan, whilst control of furnace pressure, normally to a value slightly below ambient atmospheric pressure, is achieved by modification of the mass flow extracted by the ID fan to the environment. In oxyfuel fired power plant, whilst the detailed arrangement of the combustion controls may differ from those for an air fired plant, there is a similar need to maintain accurate control of furnace pressure.

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In particular the control of furnace pressure is important for a number of reasons including:-

25

1. to prevent leakage of combustion products and unburned fuel into the boiler house
2. to minimise the effects of unnecessary in-leakage of ambient air on the combustion process and combustion control

30

3. to avoid structural damage to the furnace and associated ductwork as a result of excessive pressure excursions

5 In the case of oxyfuel plant the invention recognises and addresses the following additional needs:-

4. to maintain a high efficiency of CO₂ compression by avoiding the dilution of CO₂ in the re-cycled gas by the Nitrogen present in ambient air
- 10 5. to avoid continuous venting of concentrated CO₂ gas to atmosphere found to be necessary in current designs in order to stabilise and maintain furnace pressure at the design condition
- 15 6. to avoid large scale venting of concentrated CO₂ gas to atmosphere found to be necessary in current designs to avoid potentially damaging furnace pressure excursions during events such as sootblowing and rapid load changes

20 Excursions in furnace pressure from the required 'operating or setpoint value' arise due to both imbalances in mass flow into and out of the furnace and due to changes in heat release and gas temperature within the furnace.

25 Short term excursions in pressure, often referred to as 'combustion noise', tend to be associated with 'random' changes in heat release whilst longer term excursions tend to be associated with events such as load changing, changes in the number of operating mills and more extreme disturbances such as loss of ignition.

30 The level of pressure excursion for any particular event or disturbance within the furnace and combustion system of existing furnace designs is

influenced by the level of furnace leakage and therefore mass balance caused by the ingress or egress of gas through imperfections in the air-tightness of the furnace itself. Such imperfections typically arise due to the construction of the furnace walls and seals associated with penetrations such as inspection doors and ashing facilities.

In particular the level of furnace leakage also has a significant effect on the sensitivity of furnace pressure to changes in the mass flow of gas extracted from the system. In the case of conventional air fired plant this manifests itself as the sensitivity between controlled movement of the ID fan vane assembly (or fan speed) and changes in furnace pressure. This sensitivity affects control performance and tunings and changes both with the level of furnace leakage and the actual furnace pressure itself. All of these factors influence the ultimate performance of the control system

It is therefore clear from the above discussion that improved means and methods to control furnace pressure are desirable for both air fired and oxyfuel plant.

In accordance with the invention a combustion furnace comprises a chamber defining a combustion volume having at least one primary inlet for fuel and combustion supporting gases and at least one primary outlet for combustion product gases, which chamber is provided with one or more additional ports allowing for secondary gas flow into and/ or out of the combustion volume.

It can be shown that an increase in the level of gas leakage into or out of the furnace via the additional ports reduces the sensitivity and coupling between the extracted mass flow out of the primary outlet and the furnace pressure. It can also be shown that the presence of leakage reduces the

transient excursions in furnace pressure caused by fluctuations in heat release within the combustion chamber.

5 The invention therefore recognises that a number of benefits may be realised by the use of additional, controlled 'leakage' or re-cycling of gas into the furnace.

10 Air fired furnaces typically have a nominal uncontrolled leakage in the range of 2 to 5% of the full load combustion gas flow. This level of leakage, coupled with typical 'random' variations in heat release and dynamic response of furnaces results in the operating setpoint for furnace pressure being fixed in the range -0.5 to -1.0mbarg (-0.05 to -0.1kPaG); this figure being a compromise of considerations of preventing leakage of combustion products and unburned fuel into the boiler house and
15 minimising the effects of unnecessary in-leakage of ambient air on the combustion process and combustion control.

The invention therefore recognises the scope to dynamically optimise the furnace pressure setpoint, without any necessary addition of further
20 'controlled leakage air subject to the constraining objective of avoiding significant instances of gas leakage into the boiler house. In particular this part of the invention reduces any impact of leakage air on combustion and reduces ID fan works power

25 In the case of oxyfuel fired boilers efforts are made in the design to reduce the level of furnace leakage because of the reduction in the efficiency of the CO₂ compression and extraction process resulting from the presence of Nitrogen in the CO₂ rich gas stream. This has the effect of increasing the sensitivity of furnace pressure to control actions taken by the ID fan,

chimney vents and/or CO₂ compressors further increasing the inherent control and stability issues demonstrated by oxyfuel pilot plants.

5 The invention therefore recognises that by the addition of controlled 'leakage' or re-cycled gas taken from outside the gas closed loop re-circulation system of the oxyfuel cycle, a reduction in furnace pressure sensitivity may be achieved, reducing or eliminating the need for continuous venting of gas from the combustion system to the environment

10 The invention also recognises that, by appropriate control and adaption of the level of injection of gas into the furnace as described above, that the large and potentially damaging excursions in furnace pressure demonstrated by oxyfuel pilot plants for commonly occurring process operations may be significantly reduced.

15 The invention therefore recognises that these characteristics may be used as a basis to realise improved levels of furnace pressure control for both conventional air fired plant and oxyfuel equipped plant in both air and oxyfuel modes of operation and that a reduction in the overall level of
20 furnace air leakage may also be achieved by the use of a control based optimisation technique.

The one or more additional ports may be provided in fluid communication with a supply of gas for secondary gas flow, being for example a
25 connection to ambient environment in the case of air firing and a connection to a CO₂ rich gas source in the case of an oxyfuel fired system. Multiple ports may be provided in fluid communication with one or more secondary supplies of gas. For example the furnace may be provided with at least two sets of additional ports each in fluid
30 communication with a different supply of gas for secondary gas flow. For

- example one supply may be ambient air and another supply may be a CO₂ rich gas source where a CO₂ rich gas source will be understood to mean a gas source with CO₂ levels in excess of that of atmospheric air and in particular substantially above that of atmospheric air. Alternatively
- 5 another supply may be a nitrogen rich gas source where an nitrogen rich gas source will be understood to mean a gas source with nitrogen levels above that of atmospheric air and for example a source of substantially pure nitrogen.
- 10 Control means are preferably provided adapted to control the secondary flow of gas through the one or more ports and for example the supply of gas to the furnace, for example in by way of dynamic response in real time to provide additional (or reduced) mass flow to the furnace in order to limit pressure excursions for events such as mill start-up, shut-down, partial or
- 15 full loss of ignition etc, and in the case of a furnace adapted for transition between air firing and oxyfuel firing during transition between air and oxyfuel modes.
- The invention in the first aspect introduces a physical modification to a
- 20 conventional furnace consisting of an additional port, or ports, in the furnace wall for example connected to the environment via additional ductwork and a control device or, additionally or alternatively in the case of an oxyfuel plant, to a CO₂ rich gas source via additional ductwork and a control device.
- 25 In the case of a conventional air fired plant the invention reduces the coupling between extraction mass flow and furnace pressure by controlled admission of leakage gas into the furnace during events such as plant start-up or shut-down, the starting or stopping of mills, partial or full loss of
- 30 Ignition etc. The resulting reduction in furnace pressure deviations

associated with such events then also allows the operating setpoint for furnace pressure control to be reduced dynamically and on a statistical basis in order to minimise the long term level of air ingress.

- 5 In the case of an oxyfuel plant the invention provides all of the above features and operational benefits with additional benefits relating to the transition to and from air firing and oxyfuel mode and the ability to reduce the level of air ingress and nitrogen pick-up in oxyfuel mode of operation.
- 10 Additionally in the case of an oxyfuel plant the invention might be used optionally to maintain the CO₂ concentration in the furnace exit flue gas and reduce utilisation of the rich CO₂ gas from the storage by mixing it with air in the mixer. In this optional embodiment the total mass flow is defined by the furnace pressure excursion reduction control and the mixer
- 15 is changing the proportions of the air and the rich CO₂ mass flows This enables to maintain quality of flue gas produced and minimise the utilisation of rich CO₂ gas from storage as an addition to all the above features associated and operational benefits.
- 20 In another optional embodiment of the invention one furnace could have two controlled leakage systems installed where a first one is connected to air source and a second one is connected to a rich in CO₂ gas source. It is recognised that this optional embodiment could be used for furnace pressure excursions reduction together with the control of CO₂ and N₂
- 25 concentration in the furnace flue gas.

- In accordance with the invention in a further aspect a method of control of furnace pressure in a combustion furnace comprising a chamber defining a combustion volume having at least one primary inlet for fuel and
- 30 combustion supporting gases and at least one primary outlet for

combustion product gases comprises the step of allowing secondary gas flow into and/ or out of the combustion volume via one or more additional ports in the chamber.

- 5 The secondary gas flow is additional to the primary control of furnace pressure effected by primary extraction mass flow.

10 In a particular preferred case the method comprises controlled admission of secondary gas into the combustion volume as a method of secondary control of furnace pressure.

15 In a particular preferred case the method comprises controlled admission of secondary gas from a secondary supply of gas, being for example ambient air in the case of air firing and a CO₂ rich gas source in the case of an oxyfuel fired system.

20 The method for example comprises the supply by way of dynamic response in real time a quantity of secondary gas to provide additional control of furnace pressure for events such as mill start-up, shut-down, partial or full loss of ignition etc, and in the case of a furnace adapted for transition between air firing and oxyfuel firing during transition between air and oxyfuel modes.

25 In accordance with a preferred embodiment of the method of the invention a step of controlling primary mass flow of gases out of the combustion volume via the primary outlet in conjunction with controlling of secondary gas into the combustion volume is used as a method of control of furnace pressure, and in particular as a process control step to vary gas in-leakage in a coherent and stable fashion to produce fast, accurate responses to
30 changes in operating conditions in response to changes in load demand.

In particular the invention recognises and makes it possible to achieve a reduction in furnace pressure excursions associated with operational changes such as mill start-up and shut down, sootblowing etc.

5

In particular the invention recognises and makes it possible to achieve a reduction in furnace pressure excursions due to transient changes in heat release.

10 In particular the invention provides a method to reduce total uncontrolled air leakage into the furnace.

In particular the invention recognises that the optimisation and adaption of furnace pressure setpoint made possible by the invention will reduce the long term, uncontrolled level of furnace air leakage thereby improving the CO₂ concentration and efficiency of the CO₂ compressors in an oxyfuel system.

15

In particular the invention recognises the accompanying improvement in control of combustion conditions and flame stability for an oxyfuel system.

20

The invention potentially reduces the time taken to change from air firing to oxyfuel mode of operation by improvements in the controllability of the system for an oxyfuel plant. Hence, the furnace is in the preferred embodiment of the invention adapted for oxyfuel firing, and in the preferred case having a conventional and an oxyfuel fired capability.

25

The invention provides potential benefits of improved control during plant start-up and shut down, trips, partial or full Loss of Ignition (LOI) and transition to and from conventional air firing and oxyfuel mode of operation

30

The invention may confer additional protection to the plant structure in response to severe events such as partial or full Loss of Ignition (LOI) for both conventional air fired and oxyfuel plant.

5

In particular, for an oxyfuel plant, the invention enables the oxyfuel mode of operation to be adopted at an early point in the plant start-up cycle by the injection of CO₂ rich gas from a storage facility.

10 In particular, for an oxyfuel plant the invention enables a reduction in the overall quantity of gas emitted during start-up from the injection of stored CO₂ rich gas or a mixture of air and CO₂ rich stored gas.

15 In particular, for an oxyfuel plant the invention recognises the improvement in operational flexibility and increased range of firing rates available for plant start-up or re-starting in oxyfuel mode.

20 In particular for an oxyfuel plant the invention recognises that the large, positive excursions in furnace pressure seen at the onset of sootblowing with existing control schemes may be substantially reduced or eliminated by the use of an optional integrated control strategy for pre-adaption of the operating level of CO₂ recycling from the CO₂ compressors prior to planned sootblowing events.

25 In particular for an oxyfuel plant the invention recognises that significant improvements in the ability to respond to rapid increases in load demand without the occurrence of large scale positive excursions in furnace pressure seen with existing control schemes are possible by the use of an appropriate operating level of CO₂ recycling from the CO₂.

30

In particular for an oxyfuel plant the invention recognises that significant commercial advantages may be achieved by optimising the level of CO₂ recycling such that the cost of any additional recycling of CO₂ is outweighed by additional payments for increased plant flexibility

5

The invention will now be described by way of example only with reference to figures 1 to 5 of the accompanying drawings in which:

Figure 1a is an outline schematic process flow chart of a furnace leakage control method in accordance with an embodiment of the invention applied to a conventional air fired power plant;

10

Figure 1b is an outline schematic process flow chart of a furnace leakage control method in accordance with an embodiment of the invention applied to an oxyfuel fired power plant;

15

Figure 2a is a process flow chart of an example of an air leakage control system for a conventional air fired power plant;

Figure 2b is a process flow chart of an example of an air leakage control system for an oxyfuel fired power plant;

20

Figure 3 is a graph showing the effect of controlled leakage mass flow on furnace pressure;

Figure 4 is a process flow chart of an example of how to control furnace pressure setpoint;

Figure 5 is an outline schematic of a possible furnace leakage and controlled leakage flow optimiser method to make use of the principles of the invention.

25

The general principles of a furnace leakage control method in accordance with an embodiment of the method of the second aspect of the invention and applicable to a system of the first aspect of the invention are shown in Figure 1, respectively applied to a conventional air fired power plant (Figure 1a) and an oxyfuel fired power plant (Figure 1b).

30

Detailed principles for a furnace leakage control method in accordance with the method of the invention might include the following.

5 **Specific features relating to an Oxyfuel Plant**

During initial start-up in conventional air firing mode, the operation of the Leakage Control System will ideally maintain the minimum controlled leakage flow commensurate with the attainment of satisfactory control
10 over the key process variables. In a well designed plant the additional leakage flow should be zero (i.e. the leakage control device closed).

Immediately prior to commencement of the transition process the level of controlled leakage mass flow may be increased in a manner and to an
15 appropriate level for satisfactory control of key process variables during the transition process

During the transition process the Leakage Control System may adjust the level of controlled leakage in a manner appropriate to provide the best
20 control of Furnace Pressure and associated combustion variables commensurate with any limiting factors such as any contractual maximum permitted level of air ingress to the system

On completion of the transition process the Leakage Control System will
25 control the Leakage Control damper to minimise excursions in furnace pressure and therefore uncontrolled air leakage and Works Power.

The system may be used to limit large scale negative going pressure excursions caused by partial or full LOI, thereby providing additional
30 protection to the structure of the furnace and ductwork system.

An arrangement for the admission of control leakage flow may include the following options in any combination:

- 5 i) admission via a simple orifice with or without an isolating damper
- ii) Flow or pressure controlled admission via a control damper with or without an isolating damper.
- iii) Pressure controlled admission via a simple orifice with or
- 10 iv) Admission from a mixer supplied by air, O₂ and CO₂ rich gas from suitable sources with each stream controlled by any of the above options and with or without isolating damper(s)
- v) Admission via an optional gas accumulator

15

General Considerations applicable to Conventional Air Fired Plant and Oxyfuel Plant

20 Although the invention is not limited by theory of operation, it is can be shown that the sensitivity Pressure to changes in total leakage flow has the form:-

$$\frac{\partial P_f}{\partial \dot{m}_f} = \kappa \approx - \frac{2P_f (a_0 + a_1 \dot{m}_{fuel})^2}{\dot{m}_f^3} \quad \dots(1)$$

25 where the total leakage flow $\dot{m}_f$ is the sum of the uncontrolled casing leakage flow $\hat{m}_f$ and the controlled leakage flow $\dot{m}_f^{control}$.

In particular modification of the controlled leakage flow with fuel flow to provide a constant sensitivity κ according to:-

$$\dot{m}_{fl}^{control} \approx \left(\frac{1}{\kappa} \sqrt{2|P_f|} (a_0 + a_1 \dot{m}_{fuel}) \right)^{2/3} - \hat{\dot{m}}_{fl} \quad \text{for } P_f < 0.0 \quad \dots(2)$$

5

may provide improved control for transitions over a wide range of firing levels by maintaining a more constant pressure sensitivity.

10

Modification of the controlled leakage flow may be applied to both conventional air fired power plant and to oxyfuel power plant and allows the required sensitivity to be achieved at minimum leakage flow.

15

In particular modification of the controlled leakage flow may be achieved by direct use of equation 2 or similar calculations or by the use of functional look-up tables within the control system software determined either from equation 2 (or similar derivations) or by results from plant tests.

20

The level of controlled air admission may be limited to a maximum contractual value for overall air leakage.

25

In the case of an Oxyfuel plant, day to day operational requirements may require the transition from air firing to Oxyfuel mode to occur at a range of fuel firing rates. A control system for the invention preferably provides for this.

In the case of an Oxyfuel plant the use of CO₂ injected from storage facilitates operation of the CO₂ compressors at an earlier point in the Power Plant Start-up process. Preferably, the system provides for such injection from storage via suitable storage and injection means.

Preferably, the system provides the ability to select any mixture of air and CO₂ rich gas injected into the furnace.

- 5 In particular the invention recognises that the ability to select any mixture of gas enables the optimum operational and cost strategy to be adopted for any particular set of circumstances.

10 The general principle of the control structure and method may be as shown in Figures 2a and 2b, respectively applied to a conventional air fired power plant (Figure 1a) and an oxyfuel fired power plant (Figure 1b), although the principles of the invention are not limited to any particular manifestation of the general control concept. Where a process control or method step is described, a combustion furnace or combustion system in
15 accordance with the invention is analogously provided with suitable control means and systems to enable implementation of the process control or method step and vice versa.

20 For example the control concept may encompass alternative simple forms of modification of gas injection based on the opening of the damper to a pre-determined position or by the use of a fixed orifice.

For example the control concept may encompass the use of pressure control as a method for the achievement of the required level of injection
25 flow.

For example the control concept may encompass the use of flow control as a method for the achievement of the required level of injection flow.

Optionally, for an Oxyfuel plant, injection of CO₂ may (discretionally) be permitted for instances where the Furnace Pressure is below ambient atmospheric pressure.

- 5 Optionally, for an Oxyfuel plant and instances where the Furnace Pressure increases to a value above ambient atmospheric pressure, the Mixer control unit or a similar manifestation of the concept may permit the exhausting of furnace gas where provisions for such safe exhausting are in place.

10

The invention recognises that by control of the level of additional gas flow during negative going excursions in furnace pressure and by control of the venting of additional gas flow when furnace pressure rises above ambient atmospheric pressure a reduction in furnace pressure excursions may be achieved. This may be seen with reference to Figure 3.

15

The use of a maintained level of injected flow about which level the instantaneous injected flow is varied may be used to further reduce short term excursions in furnace pressure.

20

Such use of a maintained gas flow permits a further reduction in the set operating furnace pressure by means of the reduction in transient excursions.

- 25 The dynamic and statistical minimisation of operating furnace pressure setpoint is subject to the need to maintain any short term egress of hot gas from the furnace within permitted levels.

Figure 4 is a schematic of a method to control furnace pressure setpoint.

30

In most systems the furnace operates at a sub-atmospheric pressure in order to minimise the leakage of hot gas into the boiler house. Typical control systems operate with a fixed setpoint value, usually determined by the plant operator and usually in the range -0.5 to -1.0 mbarg (- 0.05 to - 0.10 kPag); the actual value generally being set at a conservative negative pressure value to limit the number and level of positive pressure excursions in worst case transients.

In practice the chosen setting depends on the performance of the furnace pressure control loop, the pressure sensitivity of the plant (as described above), the level of firing changes and on the level of short term fluctuations in furnace pressure due to 'random' changes in heat release within the furnace.

For negative furnace pressures the long term average mass flow of leakage air into the furnace is:-

$$E(\dot{m}_{air}) \approx k \int_{-\infty}^{-\delta} f(P_f) \cdot (|P_f + \delta|)^{0.5} dP_f \quad \dots(3)$$

where δ is a pressure offset reflecting the vertical distribution of leakage and pressure within the furnace relative to the furnace pressure measurement point and is the inflexion point in Fig 3. If, for example, the main point of leakage is at the bottom of the furnace δ will have a (small) positive value reflecting the fact that the pressure in the bottom of the furnace is greater than that at the measurement point due to the buoyancy of hot gas above the burners.

The long term average mass flow of combustion gas discharged into the Boiler house for positive furnace pressure is:-

$$E(\dot{m}_{gas}) \approx k \int_{-\delta}^{\infty} f(P_f) \cdot (P_f + \delta)^{0.5} dP_f \quad \dots(4)$$

5

The short term average discharge of combustion gas over a period τ is given by:-

$$\overline{\dot{m}_{gas}} \approx \frac{k}{\tau} \int_0^{\tau} (P(t) + \delta)^{0.5} dt \Big|_{P(t)+\delta \geq 0} \quad \dots(5)$$

10

In general the furnace should be operated such the both the long and short term average discharge is within an acceptable limit determined by either the plant owner or applicable statute giving:-

15

$$0 \leq E(\dot{m}_{gas}) \leq Limit_1 \quad \dots(6)$$

$$0 \leq \overline{\dot{m}_{gas}} \leq Limit_2 \quad \dots(7)$$

and that

20

$$Limit_1 < Limit_2 \text{ if } Limit_2 > 0 \quad \dots(8)$$

25

The overall level of air leakage from the environment into the boiler may be minimised by continuous adaption of the furnace pressure operating point to a value as close as possible to atmospheric pressure and subject to either or both the short and long term limits described above. Figure 5 illustrates this schematically.

A number of manifestations of the basic principle to adapt the furnace pressure setpoint may be realised in a control scheme and that control action to adjust the furnace pressure setpoint value may, for example on be based on:-

- 5 1. Estimation of the mass flow of combustion gas leaking from the furnace with limits also based on mass flow
2. A count of the number of positive pressure excursions in a given time period with limits being also based on the number of positive excursions.
- 10 3. A weighted count based on the number and level of the positive pressure excursions and using appropriate weighted limits.

The furnace pressure setpoint optimiser may be used either in conjunction with the leakage control scheme or as a stand-alone system.

15

When used as a stand-alone scheme the setpoint optimiser may enable a reduction in the level of in-leakage to the furnace

20

The addition of a controlled leakage of air or CO₂ or mixture reduces the effect of combustion variations on furnace pressure. The basis of this is described in the simple analysis in Figure 5.

25

The use of the setpoint optimiser in conjunction with the controlled admission of leakage gas (air or CO₂ rich gas or a mixture) may permit a further reduction in the level of air in-leakage to the furnace by virtue of the reduction in furnace pressure variability associated with the presence of the controlled leakage mass flow.

The invention recognises that by varying the level of controlled injection mass flow it is possible to modify the level of uncontrolled leakage by optimisation of the furnace pressure setpoint.

- 5 The invention recognises that by the above process it is possible to maintain an optimum level of controlled injection mass flow in order to maintain a required level of air leakage mass flow (see Figure 5).

CLAIMS

1. A combustion furnace comprises a chamber defining a combustion volume having at least one primary inlet for fuel and combustion supporting gases and at least one primary outlet for combustion product gases, which chamber is provided with one or more additional ports allowing for secondary gas flow into and/ or out of the combustion volume.
2. A combustion furnace in accordance with claim 1 wherein the one or more additional ports are provided in fluid communication with a supply of gas for secondary gas flow.
3. A combustion furnace in accordance with claim 2 wherein the furnace is adapted for air firing and the additional ports are provided in fluid communication with ambient air.
4. A combustion furnace in accordance with claim 2 or claim 3 wherein the furnace is adapted for oxyfuel firing and the additional ports are provided in fluid communication with a CO₂ rich gas source.
5. A combustion furnace in accordance with one of claims 2 to 4 wherein the furnace is provided with at least two sets of additional ports and wherein a first set of ports is connected to an air source and a second set is connected to rich in CO₂ gas source.
6. A combustion furnace in accordance with any preceding claim comprising control means adapted to control the secondary flow of gas through the one or more ports.

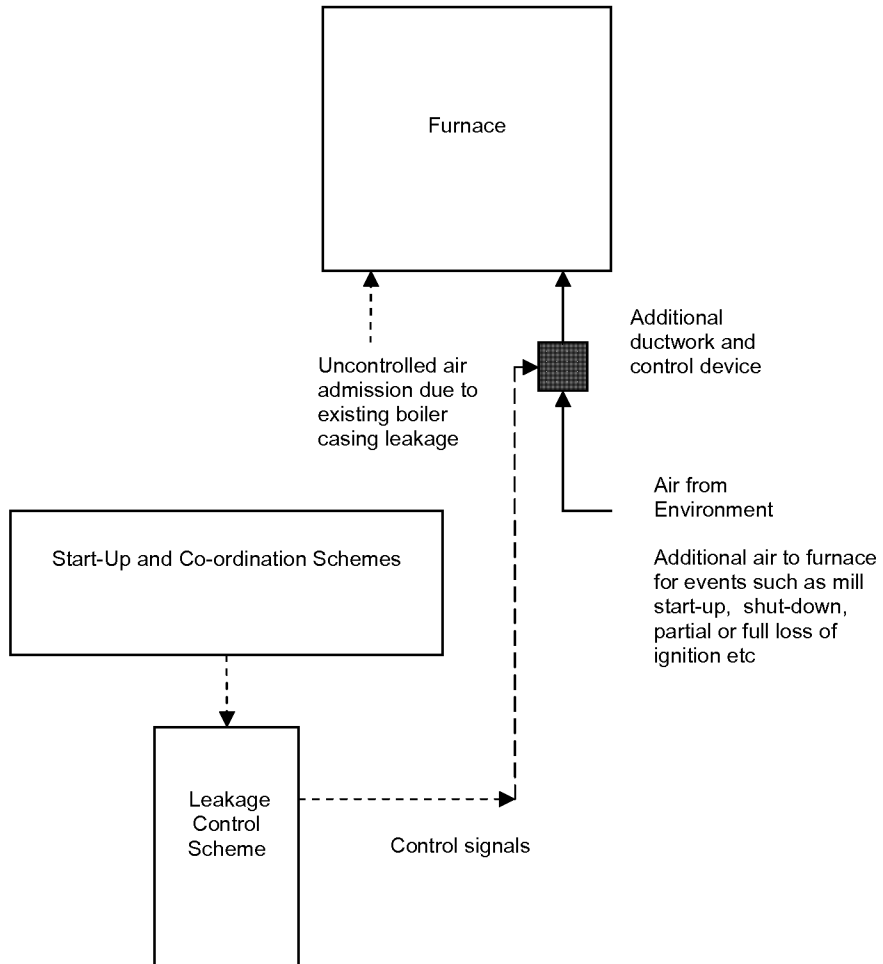
7. A combustion furnace in accordance with claim 6 wherein the control means are adapted to control the secondary flow of gas through the one or more ports by way of dynamic response in real time to provide variation in mass flow to the furnace as required.
- 5
8. A combustion furnace in accordance with claim 7 wherein the furnace is adapted for firing in air and oxyfuel firing modes and the control means are adapted to control the secondary flow of gas through the one or more ports at least to provide variation in mass
- 10 flow to the furnace during transition between air and oxyfuel modes.
9. A method of control of furnace pressure in a combustion furnace comprising a chamber defining a combustion volume having at least one primary inlet for fuel and combustion supporting gases and at least one primary outlet for combustion product gases,
- 15 comprising the step of allowing secondary gas flow into and/ or out of the combustion volume via one or more additional ports in the chamber.
- 20 10. The method of claim 9 comprising the step of controlled admission of secondary gas into the combustion volume as a method of secondary control of furnace pressure.
11. The method of claim 9 or 10 comprising the controlled admission of
- 25 secondary gas from a secondary supply of gas.
12. The method of one of claims 9 to 11 wherein the furnace is adapted for air firing and the secondary gas is ambient air.

13. The method of one of claims 9 to 12 wherein the furnace is adapted for oxyfuel firing and the secondary gas is a CO₂ rich gas source.
- 5 14. The method of one of claims 9 to 12 wherein the furnace is adapted for oxyfuel firing and the secondary gas is a source of nitrogen rich gas having a nitrogen content in excess of that of atmospheric air.
- 10 15. The method of one of claims 9 to 12 wherein the furnace is adapted for oxyfuel firing and the secondary gas is sourced from CO₂ compressors vent gas.
- 15 16. The method of one of claims 9 to 12 wherein the furnace is adapted for oxyfuel firing and the secondary gas is sourced from the CO₂ transportation pipeline.
- 20 17. The method of one of claims 9 to 16 comprising the supply by way of dynamic response in real time of a quantity of secondary gas to provide additional control of furnace pressure for an event selected from one or more of: mill start-up, shut-down, partial or full loss of ignition etc, and in the case of a furnace adapted for transition between air firing and oxyfuel firing during transition between air and oxyfuel modes.
- 25 18. The method of one of claims 9 to 17 wherein a step of controlling primary mass flow of gases out of the combustion volume via the primary outlet in conjunction with controlling of secondary gas flow into the combustion volume is used as a method of control of furnace pressure.

19. The method of claim 18 wherein a step of controlling primary mass flow of gases out of the combustion volume via the primary outlet in conjunction with controlling of secondary gas flow into the combustion volume is used as a process control step to vary gas in-
leakage in a coherent and stable fashion to produce fast, accurate responses to changes in operating conditions in response to changes in load demand.

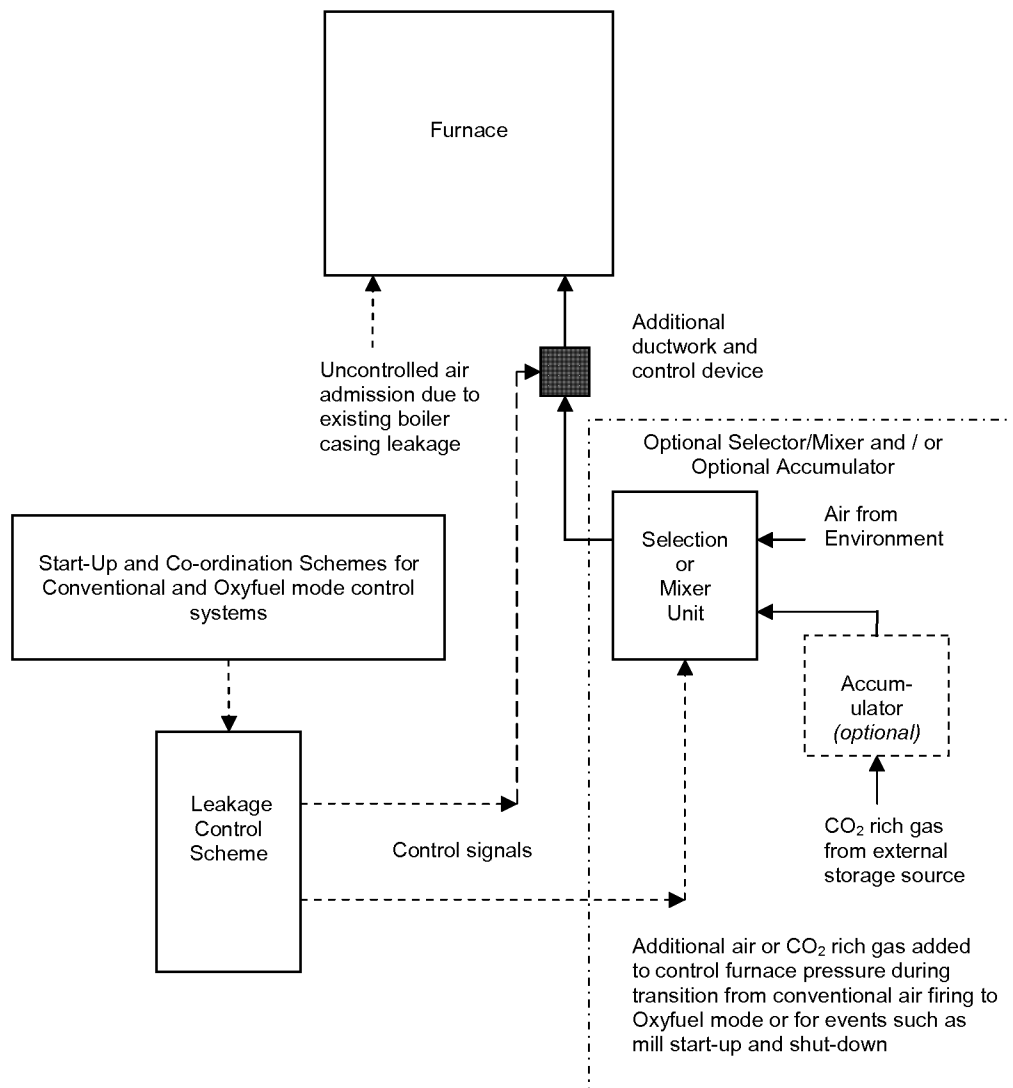
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Fig 1a

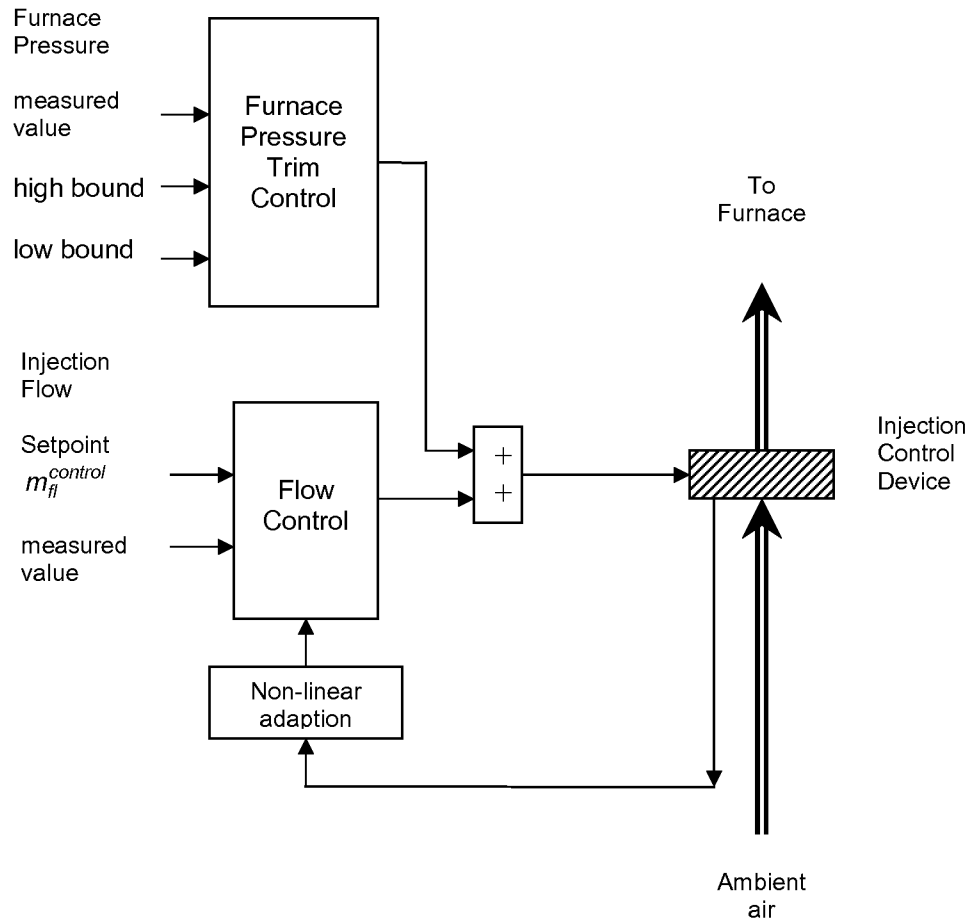


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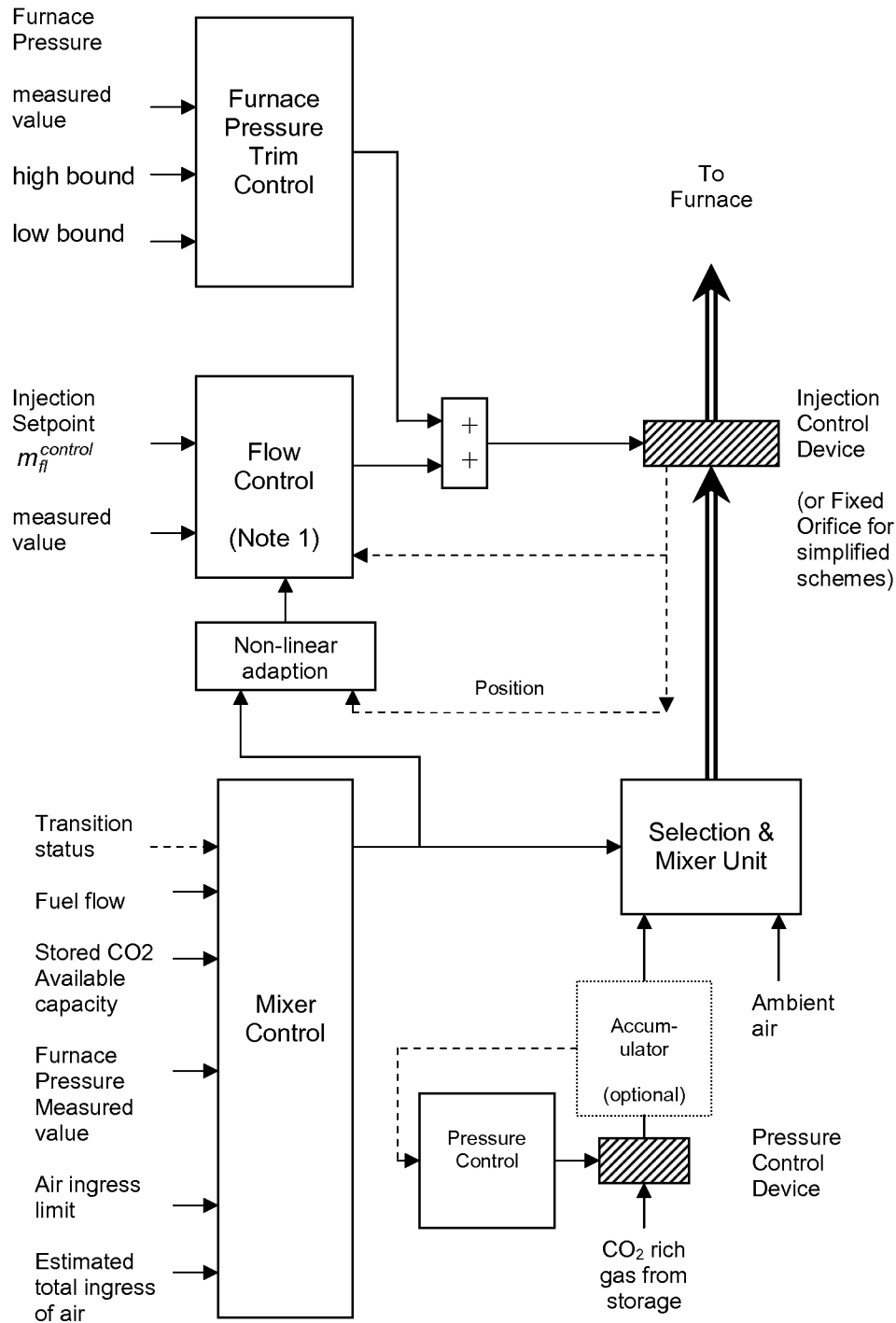
Fig 1b



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Figure 2a

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Figure 2b

Note 1 The Flow control may optionally be replaced by a simple positioning control

Fig 3
Effect of Controlled Leakage Mass Flow on
Furnace Pressure

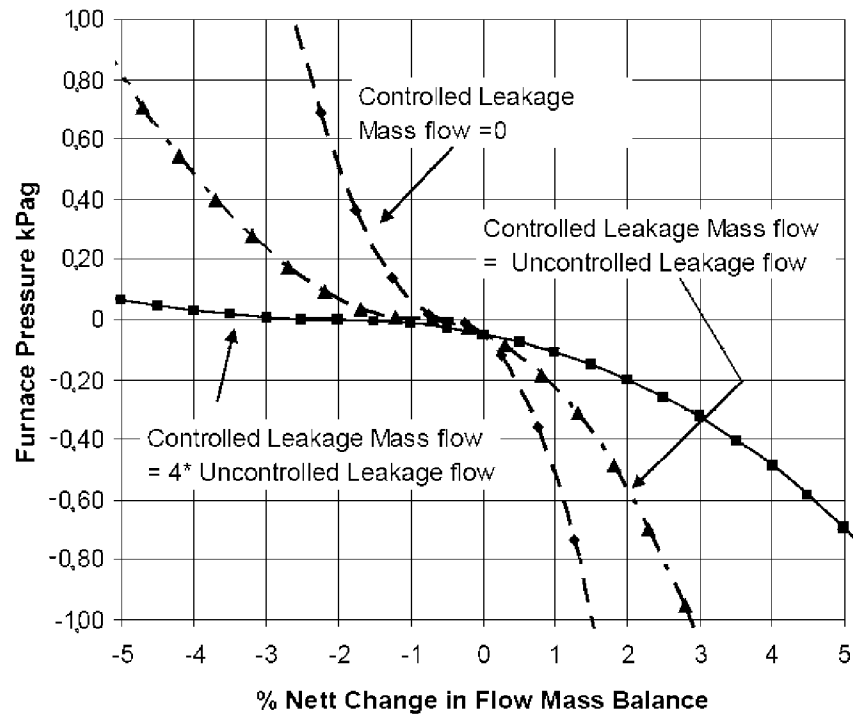
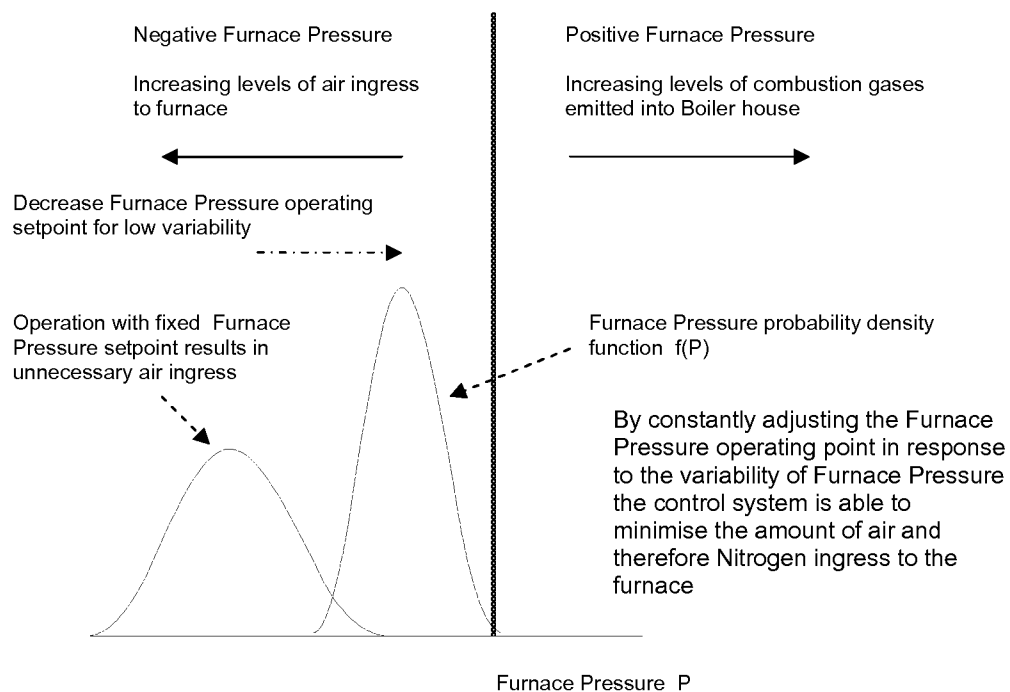


Fig 4

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Fig 5