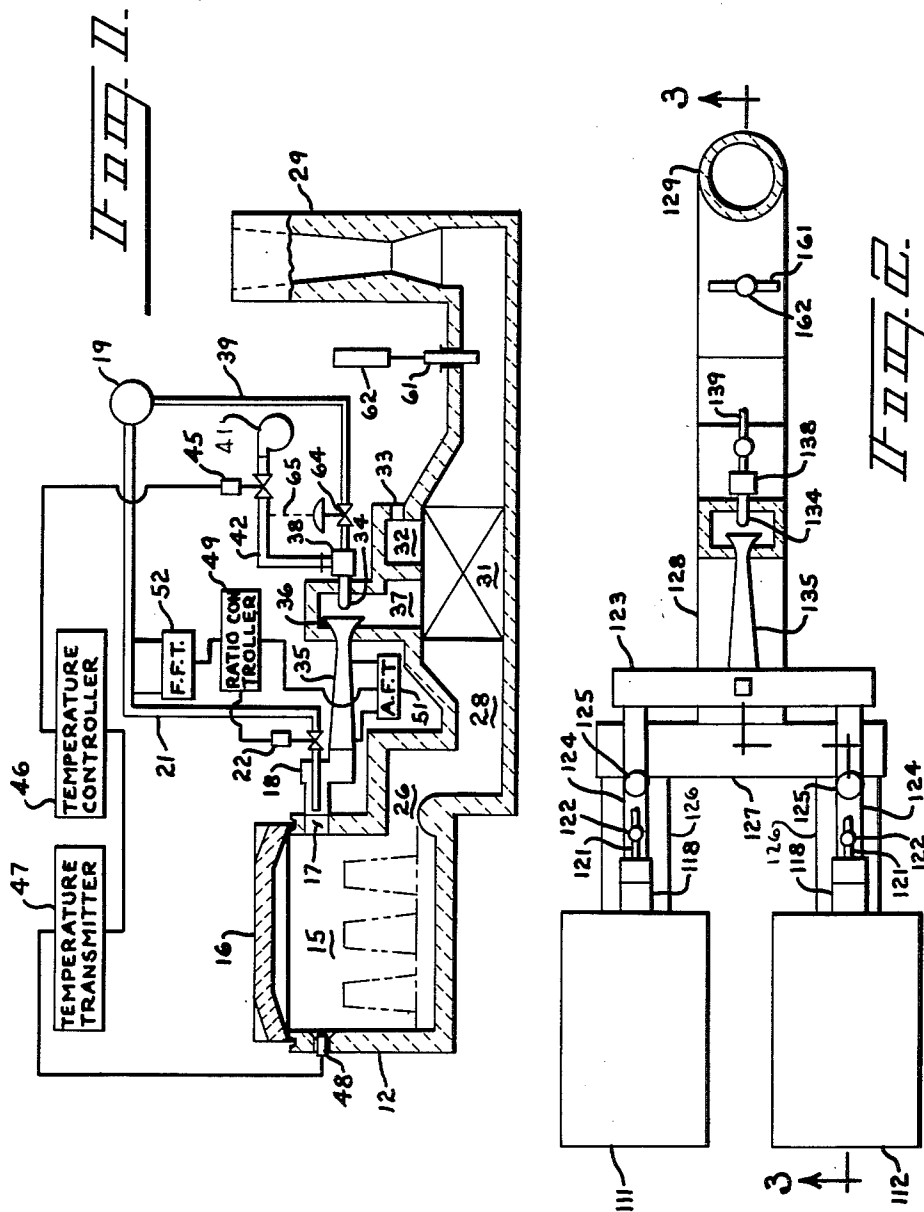


3,199,852

COMBUSTION SYSTEM FOR SOAKING PITS

2 Sheets-Sheet 1



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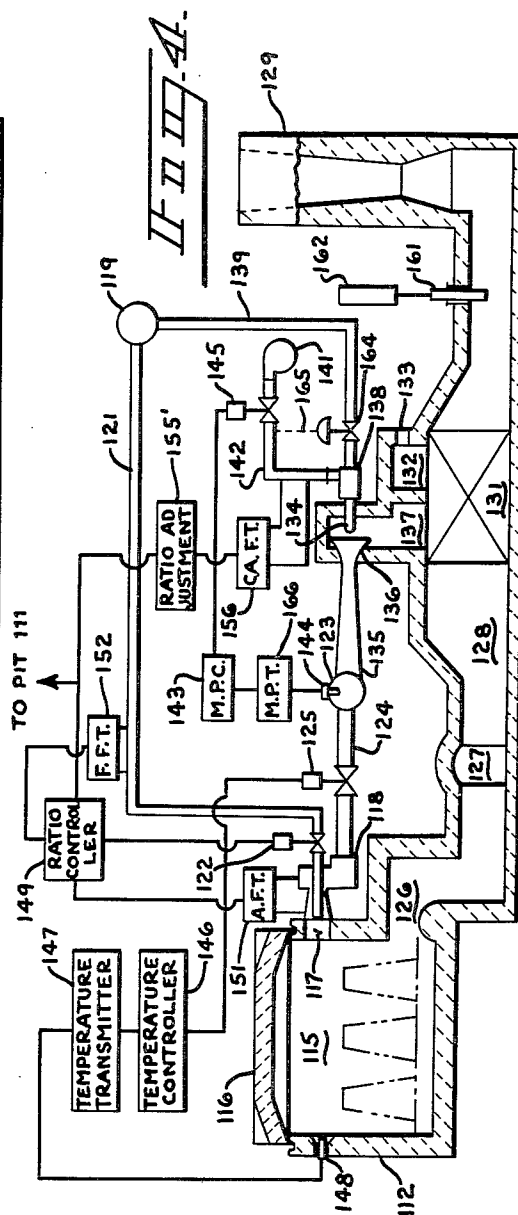
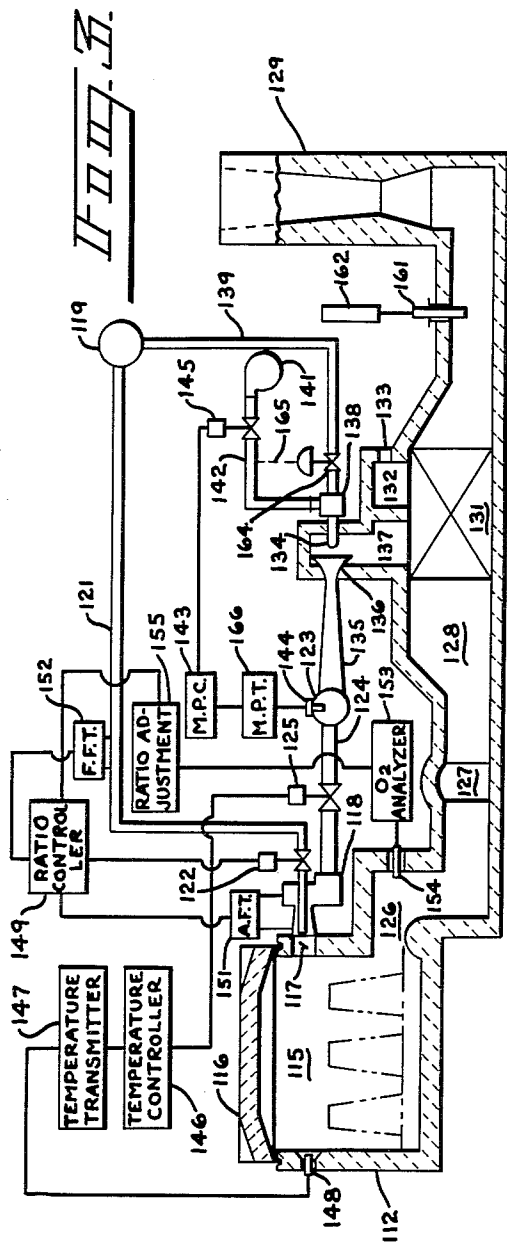
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COMBUSTION SYSTEM FOR SOAKING PITS

Filed May 7, 1962

2 Sheets-Sheet 2



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COMBUSTION SYSTEM FOR SOAKING PIT

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4 Claims. (Cl. 263—36)

This invention relates to a combustion system for high temperature furnaces. In particular, the invention relates to an improved system for supplying preheated combustion air to a soaking pit burner. The system uses an entrainment type jet pump to draw air for combustion through a ceramic recuperator with the entraining effect being derived from a jet of motive fluid comprising products of combustion.

Co-pending United States application Serial No. 189,487, filed on April 23, 1962, by W. H. Dailey, Jr., now U.S. Patent 3,107,904, describes a system of the aforesaid type for supplying air to a manifold common to a plurality of individual pits. To combat the decrease in the percentage of oxygen in the mixture of air and combustion products delivered to the combustion air manifold at low delivery rates, caused by the inherent tendency for the entrainment ratio of a jet pump to decrease when the pump is operated at reduced capacity at constant pressure rise, it was proposed to operate the combustor for providing motive fluid at higher air to fuel ratios during periods of lower jet pump combustion air delivery. Such a system requires a minimum of control apparatus for proper operation and is desirable because of its simplicity. However, the wide variations in the air to fuel ratio of the air and fuel delivered to the jet pump combustor to which such a system is subject causes large variations in the temperature of the mixture delivered to the combustion system. Temperature variations of the magnitude encountered seriously complicate the structural problems associated with the design of motive fluid injection nozzle, the jet pump venturi, and the combustion air piping. In addition, there is a decrease in the maximum attainable pumping efficiency which follows the decrease in temperature of the jet of motive fluid from the combustor as the air to fuel ratio of the air and fuel delivered to the combustor increases.

Accordingly, it is the object of this invention to provide an improved system for supplying preheated combustion air to a soaking pit burner utilizing a jet pump motivated by a jet of motive fluid comprising products of combustion from a combustor wherein the flow of air and fuel to the combustor is maintained at a predetermined ratio without significant variation in the percentage of oxygen in the mixture of air and combustion products supplied to the soaking pit burner.

For a further consideration of what is considered to be novel and inventive attention is directed to the following portion of the specification, the drawing, and the appended claims.

In the drawing:

FIG. 1 is a horizontal sectional view of a soaking pit having an independent system for supplying preheated combustion air constructed in accordance with the present invention,

FIG. 2 is a plan view, partially in section, of a plurality of soaking pits, shown as two (2) in number for purposes of illustration, having a common system for supplying preheated air constructed in accordance with the present invention;

FIG. 3 is a sectional view taken on line 3—3 of FIG. 2 with appropriate control instrumentation added; and

FIG. 4 is a view similar to FIG. 3 showing an alternative arrangement of control instrumentation.

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Referring more particularly to FIG. 1 there is illustrated a single soaking pit 12 having wall means forming a combustion and heating chamber 15. Soaking pit 12 is used to reheat for rolling partially chilled or cold ingots as indicated in outline by discontinuous lines. Chamber 15 is normally closed by means of a removable cover 16. Heating flame enters chamber 15 through firing port 17 whose inlet is coincident with the outlet of a burner 18. Fuel is delivered to burner 18 from main 19 by means of a conduit 21 which has a flow control valve 22. A fluid containing preheated air for combustion of the fuel from conduit 21 is delivered to burner 18 from venturi tube 33 in a manner hereafter described. Flue gas comprising products of combustion is vented from chamber 15 through outlet port 26 to exhaust passage 28 from whence it is drawn toward stack 29 by the draft created thereby. Means comprising an adjustable damper 61 actuated by a cylinder 62, preferably automatically in a manner well known to those skilled in the art, are provided to regulate pressure in passageway 28.

Disposed within exhaust passageway 28 is a recuperator 31 having an air passageway in indirect heat exchange relationship with flue gas flowing therethrough. Recuperator 31 must be constructed of suitable refractory materials, as in the manner described in United States Patent 1,404,721 to Stein, because available metallic materials are not well suited to withstand the deleterious effects of the high temperature flue gas flowing therethrough. Air is drawn from the atmosphere into inlet housing 32 of recuperator 31 through inlet port 33 by virtue of the draft produced by a jet pump comprising a nozzle 34 adapted to inject a stream of motive fluid into venturi tube 35. Venturi tube 35 has an inlet portion 36 disposed in air outlet housing 37 of recuperator 31 in fluid communication with heated air from the air outlet of recuperator 31. The mixture of heated air and motive fluid from nozzle 34 is thence delivered to burner 18 as previously described.

The motive fluid which is delivered to nozzle 34 comprises products of combustion from a combustor 38 which is disposed in fluid communication with nozzle 34. It is to be expressly noted that the term "products of combustion," as used in this regard, is intended to include a mixture of combustion products and air in excess of that required for combustion. Fuel for combustion is delivered to combustor 38 from main 19 by means of conduit 39. Air for the combustion of the fuel from conduit 39 is delivered to combustor 38 from blower 41 by means of conduit 42.

The quantity of fluid which is delivered to burner 18 by venturi tube 35 is regulated in response to the demand of the combustion system of heating chamber 15 for heated air. Since the quantity of fluid flowing through venturi tube 35 is a function of the quantity of motive fluid injected therein from nozzle 34 the control function may be accomplished by controlling flow from nozzle 34. Accordingly, a flow control valve 45 is provided in one of conduits 39 and 42, preferably air conduit 42, for controlling flow therethrough to combustor 38. Valve 45 is automatically operated by means of a signal from temperature control device 46. This signal is indicative of the difference between the temperature in chamber 15, as detected by sensing element 48 and transmitted to controller 46 by transmitter 47, and a set-point temperature. Since it is desirable to maintain the flow of fuel and air to combustor 38 in a fixed ratio to one another ratio control means are provided to control flow through the other of conduits 42 and 39 in a manner which is directly proportional to the flow through the conduit wherein control valve 45 is located. The simplest form of ratio control means comprises a pressure regulating

valve 64 located in the other of conduits 39 and 42 in which control valve 45 is located and means comprising a loading line 65, shown dotted, for delivering a signal to valve 64 indicative of pressure downstream of valve 45 in the conduit in which valve 45 is located.

The advantage of controlling the flow of fuel and air to combustor in a fixed ratio to one another is that the temperature of the combustion products which passes into venturi tube 35 from nozzle 34 will remain relatively constant. This, in turn, will simplify the structural design of all the components exposed to motive fluid from nozzle 34 by eliminating the need for the ability to withstand the variations in temperature characteristic of the system wherein only the flow of fuel to the combustor is modulated such as the system described in the aforesaid co-pending application Serial No. 189,487 of William H. Dailey, Jr., now U.S. Patent 3,107,904.

The flow of fuel through conduit 21 to burner 18 is controlled by flow control valve 22 which is operated in response to a signal from ratio controller 49. Ratio controller 49 is sensitive to a signal from fuel flow transmitter 52 indicative of fuel flow through conduit 21 and to a signal from air flow transmitter 51 indicative of the flow of air containing fluid through venturi tube 35. In this manner the flow of fuel to burner 18 is controlled at a fixed ratio to the flow of air-containing fluid from venturi tube 35.

It is noteworthy in the operation of a soaking pit in the manner of FIG. 1 that the pressure rise across venturi tube 35 will be proportional to the square of the quantity of fluid flowing therethrough. It is a characteristic of entrainment type pumping devices when operated in this manner that the ratio of entrained fluid to entraining fluid will remain relatively constant over a wide range of flow rates. Thus, the percentage of oxygen in the mixture of heated air from recuperator 31 and combustion products from combustor 38 which is delivered to burner 18 will remain relatively constant.

Referring now the embodiment of FIGS. 2 and 3, and the embodiment of FIG. 4 wherein the elements are denoted by 100-series numerals the last two digits of which correspond to the two digits used to denote the analogous element, if any, of the embodiment of FIG. 1, there are illustrated two soaking pits 111 and 112. Each of pits 111 and 112 has wall means forming a combustion and heating chamber 115 which is normally closed by a removable cover 116. Heating flame enters chambers 115 through firing port 117 whose inlet is coincident with the outlet of the burner 118. Fuel is delivered to burner 118 from a suitable source, such as main 119, by means of conduit 121 which has a flow control valve 122. A fluid comprising heated air for combustion of the fuel from conduit 121 is delivered to each chamber from a manifold 123, common to both soaking pits, by means of individual conduits 124 each of which is provided with a flow control valve 125.

Flue gas (products of combustion) is vented from each chamber 115 by means of an outlet port 126 to a flue gas exhaust manifold 127 which is common to both soaking pits. The flue gases from exhaust manifold 127 are drawn through exhaust passageway 128 toward stack 129 by the draft created thereby. Means comprising an adjustable damper 161 actuated by a cylinder 162, preferably automatically in a manner well known to those skilled in the art, are provided to regulate pressure in passageway 128.

Disposed within exhaust duct 128 is a refractory recuperator 131, which has an air passage in indirect heat exchange relationship with flue gases flowing therethrough. Air is drawn from the atmosphere into inlet housing 132 of recuperator 131 through inlet port 133 by virtue of the draft produced by a jet pump comprising a nozzle 134 adapted to inject a stream of motive fluid into venturi tube 135. Venturi tube 135 has an inlet portion 136 disposed in air outlet housing 137 of recuperator 131

in fluid communication with heated air from the air outlet of recuperator 131.

The motive fluid which is delivered to nozzle 134 comprises products of combustion from a combustor 138 which is disposed in fluid communication with nozzle 134. Fuel for combustion is delivered to combustor 138 from fuel main 119 by means of conduit 139. Air for the combustion of the fuel from conduit 139 is delivered to combustor 138 from a blower 141 by means of conduit 142.

In operation of the system it is desirable that the combustion system for each pit be capable of operation independent of influence of the operation of other pits. To achieve this, it is necessary that the pressure of the mixture of heated air and products of combustion in manifold 123 be maintained at a constant value. Accordingly, control means comprising a manifold pressure controller 143 are provided to control the operation of the jet pump in response to a signal from manifold pressure transmitter 166, as sensed by pressure sensing element 144. Pressure controller 143 produces a control signal which is used to control the operation of a flow control valve 145 located in one of conduits 139 and 142, preferably air conduit 142. Ratio control means comprising a pressure regulating valve 164 in the other of conduits 139 and 142 back-loaded by means of loading line 165, shown dotted, to the conduit in which valve 145 is located at a point downstream of valve 145 are provided to control flow through the other of conduits 139 and 142 at a fixed ratio to flow through the conduit in which valve 145 is located.

The flow of fuel through conduit 121 and the flow of fluid through conduit 124 to burner 118 are, respectively, controlled by the operation of flow control valves 122 and 125. One of the valves 122 and 125, preferably valve 125, is operable in response to a control signal from temperature controller 146 indicative of the difference between a signal indicative of set point temperature and a signal from temperature transmitter 147 indicative of chamber temperature, as sensed by element 148. The other of valves 122 and 125 is operable in response to a control signal from ratio controller 149 to maintain flow through conduits 121 and 124 according to a fixed ratio. Ratio controller 149 is responsive to a signal from air flow transmitter 151, indicative of flow through conduit 124, and to a signal from fuel flow transmitter 152 indicative of fuel flow through conduit 121.

In the operation of a soaking pit battery in the manner described, wherein the pressure rise across the jet pump must be maintained relatively constant regardless of variations in the rate of flow therethrough, it is characteristic that the ratio of entrained fluid to entraining fluid will be lower at low flow rates than at higher flow rates. Since the entraining fluid in this case comprises products of combustion it will have a lower percentage of oxygen than the entrained heated air from the recuperator. Thus, the percentage of oxygen in the fluid which is delivered to manifold 123 will vary depending on the rate of delivery. In practice, the percentage of oxygen in the fluid can vary from a value approaching 20% at maximum delivery to a value as low as 13% at delivery rates within the range of turndown required of a jet pump air supply system, assuming that the jet pump combustor is operated on an air:fuel ratio equal to twice the ratio required for stoichiometric combustion.

Because satisfactory combustion requires a proper ratio of oxygen to fuel, it is desirable to provide means responsive to a condition indicative of change in the percentage of oxygen in the mixture in manifold 123 to adjust the fixed ratio at which ratio controller 149 controls the ratio of delivery of mixture and fuel to burner 118 so as to increase the fixed ratio of mixture:fuel when the percentage of oxygen in the mixture decreases and vice versa. In the embodiment of FIG. 3 the condition indicative of change in the percentage of oxygen in the mixture

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is change in the percentage of oxygen in the flue gas from each pit. Accordingly, an oxygen analyzer 153 having a sample sensing element 154 adapted to sample flue gas from chamber 115 is provided to transmit a signal indicative of flue gas oxygen concentration to ratio adjustment mechanism 155 which operates to increase the fixed mixture: fuel set point of ratio controller 149 when the flue gas oxygen concentration decreases and vice versa. Since the concentration of oxygen in the flue gas from a soaking pit is dependent on factors of operation peculiar to each pit, for reasons which are pointed out in Canadian Patent 625,207, it is desirable to provide separate ratio adjusting means for each pit in cases where ratio adjustment is made in response to change in flue gas oxygen concentration.

In the embodiment of FIG. 4 the condition indicative of change in the percentage of oxygen in the manifold mixture comprises change in the rate of delivery of combustion products from combustor 138 to venturi tube 135 as sensed by combustor air flow transmitter 156 which transmits a signal to ratio adjustment mechanism 155' indicative of the rate of flow of air through conduit 142 to combustor 138. Ratio adjustment mechanism 155' operates to increase the fixed mixture: fuel set point of both ratio controller 149 associated with pit 112 and its counterpart associated with pit 111. Thus, the system of FIG. 4 has the advantage over the system of FIG. 3 in that only one ratio adjustment device is required.

As will be evident to those skilled in the art, various modifications and alternatives can be made to the embodiments of this invention without departing from the spirit or scope of the disclosure or the claims.

We claim:

1. In soaking pit apparatus having wall means defining a plurality of combustion and heating chambers, a burner associated with each chamber for delivering heating flame thereto, an exhaust, passageway in fluid communication with all of the chambers for exhausting combustion products from each chamber, recuperator means disposed in the exhaust passageway and having an air passageway in indirect heat transfer relationship with the flow of combustion products through the recuperator, jet pump means for drawing heated air through the recuperator and delivering heated air to each burner, said jet pump means comprising, in combination: a manifold; a venturi tube having a diffuser portion in fluid communication with the manifold and an inlet portion in fluid communication with the outlet of the air passageway of the recuperator; a combustor adapted to promote the combustible reaction of fuel and air to produce a stream of products of combustion and disposed adjacent to and directed toward the inlet portion of the venturi tube for introducing products of combustion from the combustor into the venturi tube in inspirating relationship with heated air from the recuperator; pipe means for delivering fuel and air to the combustor; control means responsive to fluid pressure within the manifold for controlling the rates of flow of fuel and air to the combustor at a fixed ratio to each other in a manner to maintain fluid pressure in the manifold substantially constant; a first conduit associated with each chamber for delivering fluid from the manifold to the burner; a second conduit associated with each chamber for delivering fuel to the burner; temperature control means comprising a flow control valve in one of said first and second conduits operable in response to a signal in-

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dicative of the difference between the temperature within the chamber with which said one of the first and second conduits is associated and a predetermined set point temperature for controlling the rate of flow therethrough; ratio control means associated with each chamber for controlling the rate of flow through the other of the first and second conduits associated with the chamber in a manner to maintain a fixed ratio between the rates of flow through the first and second conduits associated with each chamber; and ratio adjustment means responsive to a condition indicative of change in the percentage of oxygen in the fluid in the manifold to adjust the fixed ratio at which the ratio control means controls the rate of flow through the other of the first or second conduits in a manner to increase the ratio of the rate of flow of fluid through the first conduit to the rate of flow of fuel through the second conduit when the percentage of oxygen in the fluid in the manifold decreases.

2. Apparatus according to claim 1 wherein each chamber is provided with ratio adjustment means and wherein the condition indicative of change in the percentage of oxygen in the fluid in the manifold is change in the percentage of oxygen in the combustion products exhausted from each pit and further comprising an oxygen analyzer associated with each chamber for determining the percentage of oxygen in the combustion products exhausted from the respective chamber and transmitting means responsive to the oxygen analyzer for transmitting to the ratio adjustment means associated with the chamber a signal indicative of the percentage of oxygen in the flue products exhausted from the respective chamber.

3. Apparatus according to claim 1 wherein the condition indicative of change in the percentage of oxygen is change in the rate of delivery of combustion products from the combustor to the venturi tube and further comprising sensing means for sensing the rate of delivery of combustion products from the combustor to the venturi tube; and transmitting means sensitive to the sensing means for transmitting to the ratio adjustment means a signal indicative of the rate of delivery of combustion products from the combustor.

4. Apparatus according to claim 3 wherein the signal indicative of the rate of delivery of combustion products to the combustor is a signal indicative of the rate of flow of air to the combustor and wherein the sensing means comprises metering means for metering the rate of flow of air to the combustor.

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