

Description

This invention relates to methods of and apparatus for reducing losses in a combustion operation (e.g. in a boiler, heater, or other device) for burning fuel with air at a load level with the combustion operation producing flue gas having unburned by-product and oxygen and being at a stack temperature.

Techniques are known in the area of combustion control which involve the measurement of various products of combustion in the flue gases and the use of these measurements to adjust the amount of excess air (or air/fuel ratio) supplies beyond the stoichiometric level required for ideal combustion. The prior art recognises that there is a tradeoff between a high level of excess air, in which air heating losses predominate, and too low a level of excess air, in which unburned fuel losses predominate.

Prior approaches to optimising the combustion process fall into one of three categories, depending on what product or products of combustion are being measured in the flue gases: oxygen only, combustibles only, or a combination of the two. These are discussed separately in the following.

The oxygen only approach is used in Bailey Meter Company U.S. Patent No. 3 049 300, "Combustion Control for a Furnace Fired With Fuels Having Different Oxygen-Excess Air Characteristics," dated 14 August 1962. An analyser is used to measure the oxygen in the flue gas, and the excess air is reduced until the measured oxygen reaches a preselected set point.

The combustibles only (Carbon monoxide-CO, hydrocarbons, and/or opacity) approach is used in Standard Oil Company (Indiana) U.S. Patent No. 4 260 363, "Furnace Fuel Optimiser," dated 7 April 1981, and a copending U.S. patent application of Econics Corporation, referenced in a technical paper by Keith Swanson, "An Advanced Combustion Control System Using Distributed Microcomputer Techniques", ISA Publication ISBN 0-87664-521-X, 1981. An analyser or analysers are used to measure one or more of these parameters, and excess air is adjusted until they reach a preselected set point. If more than one variable is measured and controlled, some switching between controlled variables is done to attain the most "conservative" value of excess air.

The combination of oxygen and combustibles approach is used in Measurex Corporation U.S. Patent No. 4 162 889 entitled "Method and Apparatus for Control of Efficiency of Combustion in a Furnace," dated 31 July 1979, Westinghouse Electric Corporation U.S. Patent No. 4 231 733 entitled "Combined O₂/Combustibles Solid Electrolyte Gas Monitoring Device," dated 4 November 1980, and The Babcock & Wilcox Company U.S. Patent No. 4 492 559 entitled "A system for CO and O₂ Control of Combustion Processes". In this case, both oxygen and combustibles are measured. In the Measurex patent and in The

Babcock & Wilcox Company patent, the deviation of CO from its preselected set point is used to adjust the set point of an oxygen (O₂) controller in a cascade fashion. In the Westinghouse patent, excess air is adjusted to control, to a preselected combustibles set point, until the oxygen moves outside preselected limits. The the control mode is switched to bring the oxygen back within limits at which point combustibles control is resumed.

Shortcomings of the current approaches to combustion control are as follows.

All of the approaches attempt to control to arbitrary selected set points one or more of the products of combustion. There is, however, no guarantee that combustion conditions are such that these set points can be reached or that these set points are the best ones from an economic point of view.

In approaches that attempt to switch among multiple variables to be controlled, it is likely that limit cycling will occur as the various switch points are reached and the modes of control change. This leads to undesirable cyclic stresses on the process equipment.

None of the approaches attempts to directly minimise any explicit measure of economic loss, such as the cost of unburned fuel up the stack, the cost of heating the excess air, or the cost of violating governmental emission regulations.

Our European Patent Application Publication No. EP-A-0 081 980, which was published on 22nd June 1983 and, by virtue of EPC Article 54(3), forms part of the state of the art as regards the present application for the purposes of novelty but not inventive step, discloses a system for enabling the efficiency of fossil fuel-fired vapour generators to be automatically and continuously monitored. In this system, the amounts of oxygen and combustibles present in flue gas resulting from combustion of the fuel are measured, as is also the flue gas or stack temperature. Various heat losses are calculated from the measurements and the heat losses are summed. The summed heat loss signal is then converted into a signal proportional to the efficiency of the vapour generator.

UK Patent Application Publication No. GB-A-2 064 780 discloses apparatus for measuring the efficiency of combustion appliances. In this apparatus, the temperature of flue gas resulting from combustion of a fuel in the appliance is measured. Also, either the oxygen or carbon dioxide content of the flue gas is measured. The efficiency of the appliance can be determined by computing the heat loss or stack loss of the flue gas. The stack loss can be computed from a formula in which the temperature and oxygen measurements are variables or from a formula in which the temperature and carbon dioxide measurements are variables.

An article by Hewlon Zimmer entitled "How to cut fuel costs by using a computer to distribute boiler loads for peak efficiency" appears in POWER, Vol. 125, No. 1, January 1981, Concord, New Hampshire, USA at pages 41 to 44. The



Zimmer article outlines a technique for computer control of a plural boiler system to minimise the cost of operation. In a first phase, a preliminary boiler analysis is carried out to select a simplified equation or model approximately defining the boiler efficiency. The equation may employ a heat loss method, according to which the equation contains variables including the stack temperature and the amount of oxygen in the flue gas. After the efficiency model or equation has been selected, an optimisation algorithm or program is selected to distribute the loads among individual boilers in such a way that a given steam demand is satisfied at a minimum cost.

The present invention provides a method of reducing losses in a combustion operation for burning fuel with air at a load level with the combustion operation producing flue gas having unburned by-product and oxygen and being at a stack temperature, the method comprising:

measuring a load index for the combustion operation which is proportional to the load level thereof;

measuring an air heating loss for the combustion operation which is proportional to the stack temperature, an amount of excess oxygen in the flue gas, the load index, and a cost factor for air heating;

measuring an unburned by-product loss for the combustion operation which is proportional to an amount of unburned by-product in the flue gas, the load index, and a cost factor for the unburned by-product;

measuring a characteristic loss for the combustion operation which is proportional to the opacity of the flue gas, the load index, and a cost factor for the opacity;

adding the unburned by-product loss to the characteristic loss to generate a total fuel loss for the combustion operation;

varying air demand to the combustion operation to obtain different values of air heating loss rate, fuel loss, and a summation of air heating loss rate and fuel loss;

selecting an air demand point for the combustion operation at which the total cost of the air heating and fuel losses are as low as possible for a selected load index; and

using the air demand point to control the combustion operation.

The invention also provides apparatus for reducing losses in a combustion operation for burning fuel with air at a load level with the combustion operation producing flue gas having unburned by-product and oxygen and being at a stack temperature, the apparatus comprising:

a temperature transmitter for measuring the stack temperature;

an oxygen sensor for sensing unburned oxygen in the flue gas;

at least one unburned by-product sensor for sensing an amount of unburned by-product in the flue gas;

an opacity sensor for sensing the opacity of the flue gas;

means for establishing a load level for the combustion operation which is proportional to a load index thereof;

a first multiplier connected to the temperature transmitter and oxygen sensor for multiplying the values generated thereby together;

a second multiplier connected between the load level establishing means and an output of the first multiplier;

a first cost factor unit connected to an output of the second multiplier for generating an air heating loss value;

a third multiplier connected between the load level establishing means and the at least one unburned by-product sensor;

a second cost factor unit connected to an output of the third multiplier for generating a quantity proportional to an unburned by-product loss for the combustion operation;

a function generator connected to the opacity sensor for multiplying an amount of opacity sensed by the opacity sensor by an amount which increases to a fine that is exacted for reaching a limit in opacity;

a fourth multiplier connected between the load level establishing means and an output of the function generator for generating an opacity loss quantity;

a summing unit connected to an output of the second cost factor unit and the fourth multiplier for generating a total fuel loss for the combustion operation; and

a loss index minimising unit connected to an output of the summing unit, an output of the first cost factor unit and to the load level establishing means for generating an air demand signal, for controlling the amount of air for the combustion operation, at which the total cost of the air heating and fuel losses is minimised.

A preferred embodiment of the invention described hereinbelow differs from and seeks to improve upon the prior art in the following respects:

(1) The combustion control approach is based explicitly on minimising a penalty function that represents the sum of economic losses in running the combustion process.

(2) The control approach does not rely on selecting a set point for any one product of combustion parameter (e.g. CO, oxygen, or opacity) that may or may not be the best one under current operating conditions.

(3) The control approach takes into account the economic penalty of not meeting governmental emission regulations.

The preferred embodiment operates by effecting measurements of excess air and of each of the combustibles elements. These are multiplied by a boiler/heater load index to produce a "rate of loss" estimate for each element. These rates are multiplied by appropriate economic factors to convert them into the "dollars lost" per unit time of operation, and then added together to produce a combined loss index. The air/fuel ratio is then adjusted during on-line operation to search for

the minimum value of this loss index. The economic impact of violating regulations on smoke emissions (e.g. those of the U.S. Government Environmental Protection Agency or "EPA") is taken into account by significantly increasing the rate of penalising the opacity component as it approaches the EPA limit.

The preferred apparatus described below is simple in design, rugged in construction, and economical to manufacture.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of apparatus embodying the invention for minimising loss in a combustion operation;

Figure 2 is a graph plotting the best previous air demand against a load index for the combustion operation; and

Figure 3 is a graph plotting the cost in dollars against the air demand and reflecting various losses in the combustion operation.

An embodiment of the present invention will now be described with reference to Figures 1 to 3. In this embodiment, the cost of heating excess air is estimated by using measurements of stack temperature from a transmitter 30 and oxygen from a transmitter 32 in flue gas produced by a combustion operation in which fuel is burnt with air at a load level. A function generator 34 and a multiplier 36 convert these measurements into an effective heat value of the excess air. This value is multiplied in a multiplier 42 by a boiler/heater load index provided on a line 38. In this case this value is fuel demand as measured in a fuel demand transmitter 40. It could also be steam flow in a boiler or product flow in a process heater. The multiplier 42 thus generates a heat loss rate, which is then multiplied by a K\$ factor in a multiplier 44 to convert the loss rate into an air heating loss per unit time in dollars.

On the combustibles side, measurements are made in transmitters 46, 48 and 50 of carbon monoxide (CO), hydrocarbons (HC) and opacity. The CO and HC measurements are multiplied by the load index and the K\$ factors in multipliers 52, 54, 56 and 58, to generate a fuel loss rate per unit time. The opacity measurement is handled in the same way, except that a function generator 60 is used instead of a simple K\$ multiplication factor. The function generator 60 sharply increases the effective K\$ factor when the opacity approaches an allowed EPA limit L, then settles out at the magnitude of the fine when the limit is reached or exceeded. All of the combustibles loss rates then are added together in a summing unit 62 and smoothed (filtered in time) in a smoothing filter to generate a total fuel loss rate in dollars per unit time. The summing unit 62 thus generates a total of the unburned by-product loss and loss due to a characteristic of the flue gas (opacity) which may cause a fine.

The air and fuel loss rates are fed into a "Loss Index Minimisation Algorithm" block 64 shown in

Figure 1. A "high opacity alarm" is generated by a limit and alarm unit 66 when the opacity exceeds the EPA limit. This alarm and the load index are also fed into the minimisation algorithm block 64. Air demand is set by an optimum air demand value provided on a line 70 from the block 64.

The operation of the "Loss Index Minimisation Algorithm" block 64 is illustrated in Figures 2 and 3. The block 64 keeps track of the "best previous" values of air demand that have been found for each value of load index (Figure 2). Also, the corresponding dollar values of air heating loss, fuel loss, and total loss (the sum of the other two losses) are stored for each load index value (Figure 3). Under normal operating conditions (defined as occurring when the high opacity alarm is not active and the boiler/heater load is not changing), the minimisation algorithm then searches for the minimum value of the total loss parameter by adjusting the air demand output from the block. The algorithm increases or decreases the air demand, depending on the deviation of the current values of air and fuel losses from the corresponding "best previous" values stored. That is, if the fuel loss parameter is near its previous "best value" but the air loss is significantly higher, the algorithm will reduce the air demand. On the other hand, if the deviation in fuel losses predominates compared to the previous best values, the algorithm will increase the air demand. After waiting for a period of time equal to the time lag of the process, the algorithm then measures the new value of the total loss parameter. If it is less than the stored "best previous" value for the current load index, the new air demand replaces the old one as the "best previous" value. Also, the corresponding new loss parameters then replace the old ones and the search continues incrementally in the same direction until a minimum is found as shown at M in Figure 3.

The optimisation algorithm operates as described only under "normal" operating conditions as defined above. If the load index is changing, the optimisation operation is suspended and the air demand output is adjusted to match the "best previous" value stored for the current load index. If the load index is stable but the "high opacity" alarm is active, the loss minimisation operation still continues, but the "best previous" air demand and loss values found under these alarm conditions are discarded after the alarm becomes inactive. This is done because the fuel loss parameter is made artificially high during these alarm conditions. Therefore, its value is not relevant under normal operating conditions.

Claims

1. A method of reducing losses in a combustion operation for burning fuel with air at a load level with the combustion operation producing flue gas having unburned by-product and oxygen and being at a stack temperature, the method comprising:

measuring a load index (38) for the combustion

the minimum value of this loss index. The economic impact of violating regulations on smoke emissions (e.g. those of the U.S. Government Environmental Protection Agency or "EPA") is taken into account by significantly increasing the rate of penalising the opacity component as it approaches the EPA limit.

The preferred apparatus described below is simple in design, rugged in construction, and economical to manufacture.

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On the combustibles side, measurements are made in transmitters 46, 48 and 50 of carbon monoxide (CO), hydrocarbons (HC) and opacity. The CO and HC measurements are multiplied by the load index and the K\$ factors in multipliers 52, 54, 56 and 58, to generate a fuel loss rate per unit time. The opacity measurement is handled in the same way, except that a function generator 60 is used instead of a simple K\$ multiplication factor. The function generator 60 sharply increases the effective K\$ factor when the opacity approaches an allowed EPA limit L, then settles out at the magnitude of the fine when the limit is reached or exceeded. All of the combustibles loss rates then are added together in a summing unit 62 and smoothed (filtered in time) in a smoothing filter to generate a total fuel loss rate in dollars per unit time. The summing unit 62 thus generates a total of the unburned by-product loss and loss due to a characteristic of the flue gas (opacity) which may cause a fine.

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Claims

1. A method of reducing losses in a combustion operation for burning fuel with air at a load level with the combustion operation producing flue gas having unburned by-product and oxygen and being at a stack temperature, the method comprising:

measuring a load index (38) for the combustion



operation which is proportional to the load level thereof;

measuring an air heating loss for the combustion operation which is proportional to the stack temperature (30), an amount of excess oxygen (32) in the flue gas, the load index (38), and a cost factor (44) for air heating;

measuring an unburned by-product loss for the combustion operation which is proportional to an amount of unburned by-product in the flue gas (46, 48), the load index (38), and a cost factor (56, 58) for the unburned by-product;

measuring a characteristic loss for the combustion operation which is proportional to the opacity of the flue gas (50), the load index (38), and a cost factor (60) for the opacity;

adding (62) the unburned by-product loss to the characteristic loss to generate a total fuel loss for the combustion operation;

varying air demand to the combustion operation to obtain different values of air heating loss rate, fuel loss, and a summation of air heating loss rate and fuel loss;

selecting (64) an air demand point (70) for the combustion operation at which the total cost of the air heating and fuel losses are as low as possible for a selected load index (38); and

using the air demand point (70) to control the combustion operation.

2. A method according to claim 1, including storing air demand points (Figure 2) for various load indexes (38) and utilising the stored air demand points as best previous air demand values.

3. A method according to claim 2, including supplying a best previous air demand point to the combustion operation, varying the air demand away from the best previous air demand point, and, if the value for the total of fuel loss and air heating loss rate is reduced, storing a new best previous air demand point.

4. A method according to any one of the preceding claims, including measuring (40) a fuel demand for the combustion operation, the load index (38) being proportional to the fuel demand.

5. A method according to any one of the preceding claims, including generating an alarm (66) when a limit for the characteristic loss is reached.

6. A method according to any one of claims 1 to 5, wherein the cost factor for the opacity comprises a fine for exceeding a selected limit for opacity.

7. A method according to any one of claims 1 to 5, including measuring (30) the stack temperature, calculating (34) a heating value which is proportional to the stack temperature, measuring (32) the amount of unburned oxygen in the flue gas, multiplying (36) the amount of unburned oxygen by the heating value, and multiplying (42) the outcome of this multiplication by the load index to obtain a load index weighted air heating measurement and multiplying (44) the air heating measurement by the cost factor for air heating to obtain the air heating loss.

8. A method according to claim 7, wherein the

unburned by-product is carbon monoxide or hydrocarbons, including measuring (46, 48) the amount of unburned by-product in the flue gas, multiplying (52, 54) the measured amount of unburned by-product by the load index and multiplying (56, 58) the outcome by the cost factor for unburned by-product.

9. A method according to claim 8, including measuring (50) the opacity of the flue gas, the cost factor for the opacity increasing to a fine for reaching a selected limit for opacity as the selected limit for opacity is approached.

10. A method according to any one of the preceding claims, including smoothing the fuel loss using a smoothing filter to reduce irregularities in a change for the fuel cost over time.

11. Apparatus for reducing losses in a combustion operation for burning fuel with air at a load level with the combustion operation producing flue gas having unburned by-product and oxygen and being at a stack temperature, the apparatus comprising:

a temperature transmitter (30) for measuring the stack temperature;

an oxygen sensor (32) for sensing unburned oxygen in the flue gas;

at least one unburned by-product sensor (46, 48) for sensing an amount of unburned by-product in the flue gas;

an opacity sensor (50) for sensing the opacity of the flue gas;

means for establishing a load level for the combustion operation which is proportional to a load index thereof;

a first multiplier (36) connected to the temperature transmitter (30) and oxygen sensor (32) for multiplying the values generated thereby together;

a second multiplier (42) connected between the load level establishing means and an output of the first multiplier (36);

a first cost factor unit (44) connected to an output of the second multiplier (42) for generating an air heating loss value;

a third multiplier (52, 54) connected between the load level establishing means and the at least one unburned by-product sensor (46, 48);

a second cost factor unit (56, 58) connected to an output of the third multiplier (52, 54) for generating a quantity proportional to an unburned by-product loss for the combustion operation;

a function generator (60) connected to the opacity sensor (50) for multiplying an amount of opacity sensed by the opacity sensor by an amount which increases to a fine that is exacted for reaching a limit on opacity;

a fourth multiplier connected between the load level establishing means and an output of the function generator (60) for generating an opacity loss quantity;

a summing unit (62) connected to an output of the second cost factor unit (52, 54) and the fourth multiplier for generating a total fuel loss for the combustion operation; and



a loss index minimising unit (64) connected to an output of the summing unit (62), an output of the first cost factor unit (44) and to the load level establishing means for generating an air demand signal, for controlling the amount of air for the combustion operation, at which the total cost of the air heating and fuel losses is minimised.

Patentansprüche

1. Verfahren zur Verlustverringerung in einem Verbrennungsvorgang zum Verbrennen von Brennstoff mit Luft bei einem Lastniveau, bei dem der Verbrennungsvorgang Abgas mit unverbranntem Nebenprodukt und Sauerstoff erzeugt und sich auf einer Essentemperatur befindet, wobei das Verfahren umfaßt:

Messen eines Lastindex (38) für den Verbrennungsvorgang, der proportional dessen Lastniveau ist,

Messen eines Luftheizverlustes für den Verbrennungsvorgang, der proportional der Essentemperatur (30), einem Betrag an Überschußsauerstoff (32) im Abgas, dem Lastindex (38) und einem Kostenfaktor (44) für Luftheizung ist,

Messen eines Verlustes unverbrannten Nebenproduktes für den Verbrennungsvorgang, der proportional einem Betrag von unverbranntem Verbrennungsprodukt im Abgas (46, 48), dem Lastindex (38) und einem Kostenfaktor (56, 58) für das unverbrannte Nebenprodukt ist,

Messen eines charakteristischen Verlustes für den Verbrennungsvorgang, der proportional der Opazität des Abgases (50), dem Lastindex (38) und einem Kostenfaktor (60) für die Opazität ist,

Addieren (62) des Verlustes unverbrannten Nebenproduktes zum charakteristischen Verlust, um einen Gesamtbrennstoffverlust für den Verbrennungsvorgang zu bilden,

Variieren des Luftbedarfs zum Verbrennungsvorgang, um unterschiedliche Werte von Luftheizverlustbeträgen, Brennstoffverlust und eine Summierung des Luftheizverlustbetrages und des Brennstoffverlustes zu erhalten,

Auswählen (64) eines Luftbedarfspunktes (70) für den Verbrennungsvorgang, bei dem die Gesamtkosten der Luftheiz — und Brennstoffverluste für einen ausgewählten Lastindex (38) so niedrig wie möglich sind; und

Verwenden des Luftbedarfspunktes (70) zum Steuern des Verbrennungsvorganges.

2. Verfahren nach Anspruch 1, mit dem Speichern von Luftbedarfspunkten (Figur 2) für verschiedene Lastindizes (38) und dem Verwenden der gespeicherten Luftbedarfspunkte als beste vorausgehende Luftbedarfswerte.

3. Verfahren nach Anspruch 2, mit dem Zuführen eines besten vorausgehenden Luftbedarfspunktes zum Verbrennungsvorgang, dem Variieren des Luftbedarfs weg vom besten vorausgehenden Luftbedarfspunkt und, falls der Wert für den Gesamtbrennstoffverlust und der Luftheizverlustbetrag reduziert ist, speichern eines neuen besten vorausgehenden Luftbedarfspunktes.

4. Verfahren nach einem der vorgehenden

Ansprüche, mit dem Messen (40) eines Brennstoffbedarfs für den Verbrennungsvorgang, wobei der Lastindex (38) proportional zum Brennstoffbedarf ist.

5. Verfahren nach einem der vorhergehenden Ansprüche, mit dem Erzeugen eines Alarms (66), wenn ein Grenzwert für den charakteristischen Verlust erreicht ist.

6. Verfahren nach einem der Ansprüche 1 bis 5, wobei der Kostenfaktor für die Opazität einen Zusatzbetrag für das Überschreiten eines ausgewählten Grenzwertes für die Opazität umfaßt.

7. Verfahren nach einem der Ansprüche 1 bis 5, mit dem Messen (30) der Essentemperatur, Errechnen (34) eines Heizwertes, der proportional der Essentemperatur ist, Messen (32) der Menge von unverbranntem Sauerstoff im Abgas, Multiplizieren (36) der Menge unverbrannten Sauerstoffs mit dem Heizwert und Multiplizieren (42) des Ergebnisses dieser Multiplikation mit dem Lastindex, um eine lastindexgewichtete Luftheizungsmessung zu erhalten, und Multiplizieren (44) der Luftheizungsmessung mit dem Kostenfaktor für die Luftheizung, um den Luftheizungsverlust zu erhalten.

8. Verfahren nach Anspruch 7, wobei das unverbrannte Nebenprodukt Kohlenmonoxid oder Kohlenwasserstoffe sind, mit dem Messen (46, 48) der Menge von unverbranntem Nebenprodukt im Abgas, Multiplizieren (52, 54) der gemessenen Menge unverbrannten Nebenproduktes mit dem Lastindex und Multiplizieren (56, 58) des Ergebnisses mit dem Kostenfaktor für das unverbrannte Nebenprodukt.

9. Verfahren nach Anspruch 8, mit dem Messen (50) der Opazität des Abgases, wobei der Kostenfaktor für die Opazität auf einen Zusatzbetrag ansteigt, um einen ausgewählten Grenzwert für die Opazität zu erreichen, wenn man dem ausgewählten Opazitätsgrenzwert näherkommt.

10. Verfahren nach einem der vorstehenden Ansprüche, mit dem Glätten des Brennstoffverlustes durch Verwendung eines Glättfilters, um Unregelmäßigkeiten in einer Änderung für die Brennstoffkosten über eine Zeitdauer zu reduzieren.

11. Vorrichtung zum Verringern der Verluste in einem Verbrennungsvorgang zum Verbrennen von Kraftstoff mit Luft bei einem Lastniveau, wobei der Verbrennungsvorgang Abgas mit einem unverbranntem Nebenprodukt und Sauerstoff bei einer Essentemperatur erzeugt und die Vorrichtung aufweist:

einen Temperaturmeßwertgeber (30) zum Messen der Essentemperatur;

einen Sauerstoffsensor (32) zum Erfassen des unverbrannten Sauerstoff im Abgas;

mindestens einen Sensor (46, 48) für das unverbrannte Nebenprodukt zum Erfassen der Menge unverbrannten Nebenproduktes im Abgas;

einen Opazitätssensor (50) zum Erfassen der Opazität des Abgases;

Mittel zum Errichten eines Lastniveaus für den Verbrennungsvorgang, das proportional zu einem Lastindex davon ist;



eine erste Multipliziereinheit (36), die mit dem Temperaturmeßwertgeber (30) und dem Sauerstoffsensoren (32) verbunden ist, um die dadurch erzeugten Werte miteinander zu multiplizieren;

eine zweite Multipliziereinheit (42), die zwischen den Mitteln zum Errichten eines Lastniveaus und einem Ausgang der ersten Multipliziereinheit (36) in Verbindung steht;

eine erste Kostenfaktoreinheit (44), die mit einem Ausgang der zweiten Multipliziereinheit (42) verbunden ist, um einen Luftheizungsverlustwert zu erzeugen;

eine dritte Multipliziereinheit (52, 54), die zwischen den Mitteln zum Errichten eines Lastniveaus und dem zumindest einen Sensor (46, 48) für das unverbrannte Nebenprodukt in Verbindung steht;

eine zweite Kostenfaktoreinheit (56, 58), die mit einem Ausgang der dritten Multipliziereinheit (52, 54) verbunden ist, um eine Größe proportional einem Verlust unverbrannten Nebenproduktes für den Verbrennungsvorgang zu erzeugen;

einen Funktionsgenerator (60), der mit dem Opazitätssensor (50) verbunden ist, um eine durch den Opazitätssensor erfaßte Menge Opazität mit einer Menge zu multiplizieren, die auf einen Zusatzbetrag ansteigt, der gefordert wird bei Erreichen eines Opazitätsgrenzwertes;

eine vierte Multipliziereinheit, die zwischen den Mitteln zum Errichten eines Lastniveaus und einem Ausgang für den Funktionsgenerator (60) in Verbindung steht zum Erzeugen einer Opazitätsverlustgröße;

eine Summationseinheit (62), die mit dem Ausgang der zweiten Kostenfaktoreinheit (52, 54) und der vierten Multipliziereinheit verbunden ist, um einen Gesamtbrennstoffverlust für den Verbrennungsvorgang zu erzeugen; und

eine Verlustindexminimiereinheit (64), die mit einem Ausgang der Summationseinheit (62), einem Ausgang für die erste Kostenfaktoreinheit (44) und den Mitteln zum Errichten eines Lastniveaus für das Erzeugen eines Luftbedarfs-signals verbunden ist, um die Menge von Luft für den Verbrennungsvorgang zu steuern, bei dem die Gesamtkosten der Luftheizung und der Brennstoffverluste minimiert sind.

Revendications

1. Procédé de réduction des pertes dans une opération de combustion destinée à brûler du combustible avec de l'air à un certain niveau de charge, l'opération de combustion fournissant des gaz brûlés qui comportent du sous-produit non brûlé et de l'oxygène et sont à une température de cheminée, le procédé comprenant:

la mesure d'un indice de charge (38) affecté à l'opération de combustion qui est proportionnel au niveau de charge de l'opération;

la mesure d'une perte de chauffage d'air affectant l'opération de combustion qui est proportionnelle à la température de cheminée (30),

à la quantité d'oxygène excédentaire (32) présente dans les gaz brûlés, à l'indice de charge (38) et à un facteur de coût (44) de chauffage d'air;

la mesure d'une perte de sous-produit non brûlé affectant l'opération de combustion qui est proportionnelle à la quantité de sous-produit non brûlé présent dans les gaz brûlés (46, 48), à l'indice de charge (36) et à un facteur de coût (56, 58) du sous-produit non brûlé;

la mesure d'une perte caractéristique affectant l'opération de combustion qui est proportionnelle à l'opacité des gaz brûlés (50), à l'indice de charge (38) et à un facteur de coût (60) de l'opacité;

l'addition (62) de la perte de sous-produit non brûlé à la perte caractéristique effectuée pour générer une perte de combustible totale affectant l'opération de combustion;

une variation de la demande d'air de l'opération de combustion assurée pour obtenir différentes valeurs de taux de perte de chauffage d'air, de perte de combustible, et la sommation du taux de perte de chauffage d'air et de la perte de combustible;

la sélection (64) d'un point de demande d'air (70) affecté à l'opération de combustion auquel le coût total des pertes de chauffage d'air et de combustible soit aussi faible que possible pour un indice de charge (38) choisi; et

l'utilisation du point de demande d'air (70) au réglage de l'opération de combustion.

2. Procédé selon la revendication 1, comportant la mise en mémoire de points de demande d'air (figure 2) pour divers indices de charge (38) et l'utilisation des points de demande d'air mis en mémoire en tant que meilleures valeurs antérieures de demande d'air.

3. Procédé selon la revendication 2, comportant l'application à l'opération de combustion d'un point de meilleure demande antérieure d'air, la variation de la demande d'air provoquée en s'écartant du point de meilleure demande antérieure d'air et, si la valeur du taux total de perte de combustible et de perte de chauffage d'air diminue, la mise en mémoire d'un nouveau point de meilleure demande antérieure d'air.

4. Procédé selon l'une quelconque des revendications précédentes, comportant la mesure (40) d'une demande de combustible pour l'opération de combustion, l'indice de charge (38) étant proportionnel à la demande de combustible.

5. Procédé selon l'une quelconque des revendications précédentes, comportant la génération d'une alarme (66) lorsqu'une limite fixée à la perte caractéristique se trouve atteinte.

6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel le facteur de coût affecté à l'opacité est constitué par une amende pour dépassement d'une limite d'opacité choisie.

7. Procédé selon l'une quelconque des



revendications 1 à 5, comportant la mesure (30) de la température de cheminée, le calcul (34) d'un pouvoir calorifique qui est proportionnel à la température de cheminée, la mesure (32) de la quantité d'oxygène non brûlé présent dans les gaz de cheminée, la multiplication (36) de la quantité d'oxygène non brûlé par le pouvoir calorifique, et la multiplication (42) du résultat de cette multiplication par l'indice de charge pour l'obtention d'une mesure de chauffage d'air pondérée par l'indice de charge et la multiplication (44) de la mesure de chauffage d'air par le facteur de coût du chauffage d'air pour l'obtention de la perte de chauffage d'air.

8. Procédé selon la revendication 7, dans lequel le sous-produit non brûlé est du monoxyde de carbone ou des hydrocarbures, comportant la mesure (46, 48) de la quantité de sous-produit non brûlé présent dans les gaz de cheminée, la multiplication (52, 54) de la quantité mesurée de sous-produit non brûlé par l'indice de charge et la multiplication (56, 58) du résultat par le facteur de coût du sous-produit non brûlé.

9. Procédé selon la revendication 8, comportant la mesure (50) de l'opacité des gaz brûlés, le facteur de coût de l'opacité augmentant jusqu'à une amende applicable quand se trouve atteinte une limite d'opacité choisie, à mesure qu'on se rapproche de la limite d'opacité choisie.

10. Procédé selon l'une quelconque des revendications précédentes, comportant le lissage de la perte de combustible opéré à l'aide d'un filtre de lissage pour réduire les irrégularités dues à ce que le coût du combustible se modifie au cours du temps.

11. Appareil pour la réduction des pertes dans une opération de combustion destinée à brûler du combustible avec de l'air à un certain niveau de charge, l'opération de combustion fournissant des gaz brûlés comportant du sous-produit non brûlé et de l'oxygène et étant à une température de cheminée, l'appareil comprenant:

un transmetteur de température (30) pour la mesure de la température de cheminée;

un détecteur d'oxygène (32) pour la détection de l'oxygène non brûlé présent dans les gaz brûlés;

au moins un détecteur de sous-produit non brûlé (46, 48) pour la détection de la quantité

de sous-produit non brûlé présent dans le gaz de cheminée;

un détecteur d'opacité (50) pour la détection de l'opacité des gaz brûlés;

un moyen pour l'établissement d'un niveau de charge affecté à l'opération de combustion qui est proportionnel à une indice de charge de celle-ci;

un premier multiplicateur (36) relié au transmetteur de température (30) et au détecteur d'oxygène (32) pour multiplier l'une par l'autre les valeurs générées par ceux-ci;

un second multiplicateur (42) monté entre le moyen d'établissement de niveau de charge et une sortie du premier multiplicateur (36);

une première unité de facteur de coût (44) reliée à une sortie du second multiplicateur (42) pour générer une valeur de perte de chauffage d'air;

un troisième multiplicateur (52, 54) monté entre le moyen d'établissement de niveau de charge et le ou les détecteurs de sous-produit non brûlé (46, 48);

une seconde unité de facteur de coût (56, 58) reliée à une sortie du troisième multiplicateur (52, 54) pour générer une quantité proportionnelle à une perte de sous-produit non brûlé affectant l'opération de combustion;

un générateur de fonction (60) relié au détecteur d'opacité (50) pour multiplier une grandeur d'opacité détectée par le détecteur d'opacité par une grandeur qui augmente jusqu'à l'amende applicable quand se trouve atteinte une limite d'opacité;

un quatrième multiplicateur monté entre le moyen d'établissement de niveau de charge et une sortie du générateur de fonction (60) pour générer une quantité de perte par opacité;

une unité de sommation (62) reliée à une sortie de la seconde unité de facteur de coût (52, 54) et au quatrième multiplicateur pour générer une perte de combustible totale affectant l'opération de combustion; et

une unité de minimisation d'indice de perte (64) reliée à une sortie de l'unité de sommation (62), à une sortie de la première unité de facteur de coût (44) et au moyen d'établissement de niveau de charge pour générer un signal de demande d'air, pour le réglage de la quantité d'air affectée à l'opération de combustion, auquel le coût total des pertes de chauffage d'air et de combustible se trouve minimisé.

