Nov. 30, 1965 R. R. SWAIN 3,220,825

CONTROL FOR BLAST FURNACES

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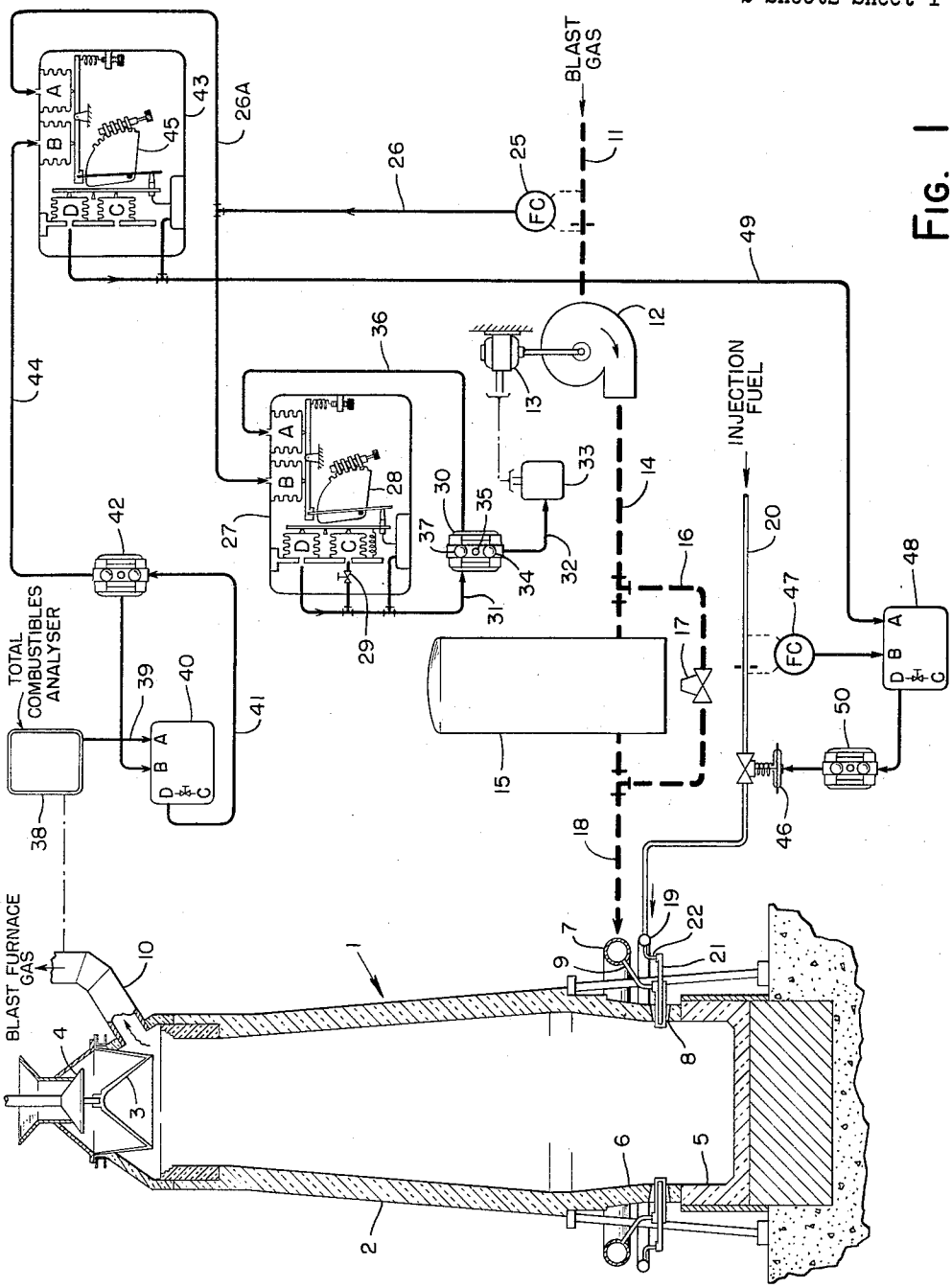


FIG. 1

INVENTOR.
RALPH R. SWAIN

BY
John F. Luhrs
ATTORNEY

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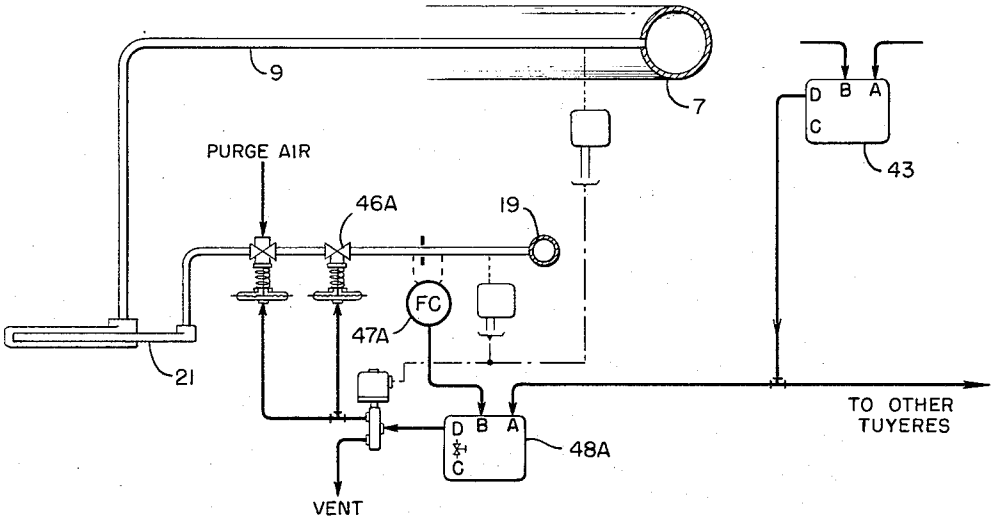


FIG. 2

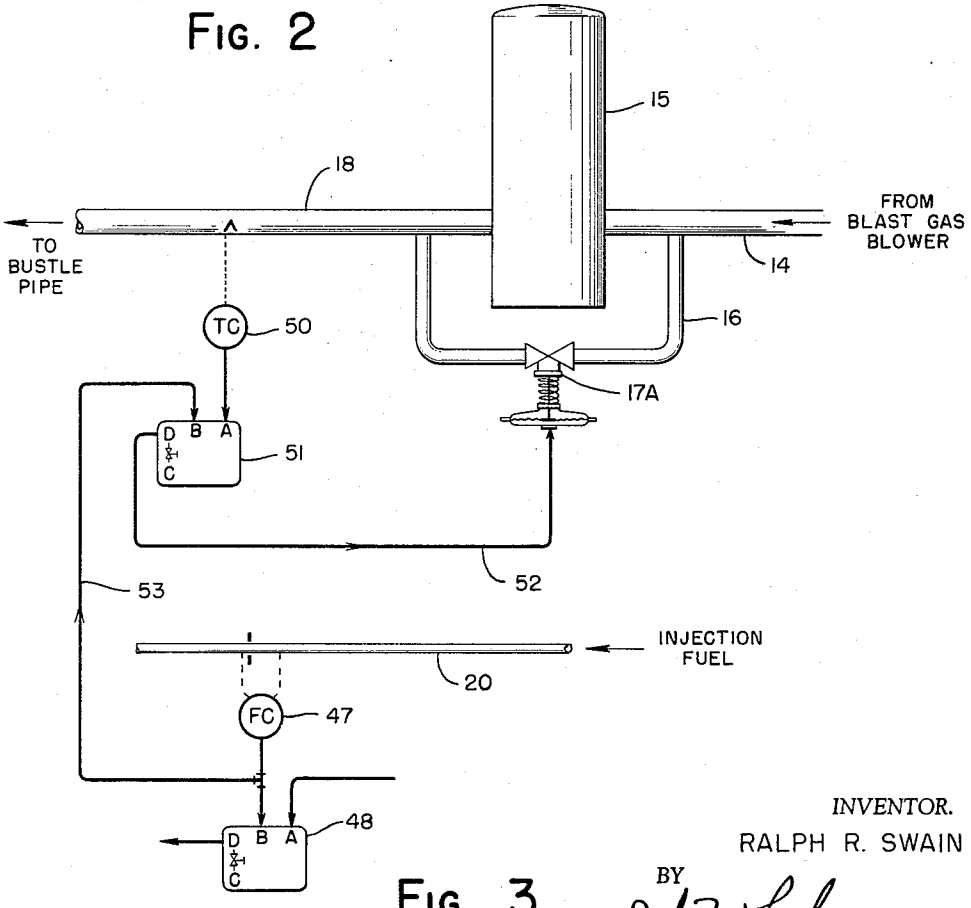


FIG. 3

INVENTOR.
RALPH R. SWAIN

BY Jack F. Lahrs
ATTORNEY

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CONTROL FOR BLAST FURNACES

Ralph R. Swain, South Euclid, Ohio, assignor to Bailey Meter Company, a corporation of Delaware

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16 Claims. (Cl. 75—42)

This invention relates to the control of blast furnaces used in the production of pig iron from iron ore.

The conventional blast furnace comprises an elongated section known as the stack, a lower section known as the hearth and an intermediate section known as the bosh located between the hearth and the stack. A blast gas, usually compressed air, is blown through tuyeres into the upper portion of the hearth, and the burden, including limestone, ferrous bearing material and a carbonaceous material such as coke is intermittently charged into the furnace at the top of the stack. The burden moves down the stack. In the zone adjacent the tuyeres the coke or other carbonaceous material burns and the heat of combustion smelts the ore to produce molten pig iron. The products of combustion, as they pass upwardly through the stack, being at relatively high temperature serve to preheat the burden and reduce the iron ore.

The gaseous products of combustion are discharged from the top of the blast furnace through one or more off-take pipes and are commonly referred to collectively as top gas or blast furnace gas. The composition of this gas may vary considerably; however, typically it will be composed of approximately 30% combustibles, largely hydrogen and carbon monoxide, with the balance carbon dioxide, nitrogen and water vapor.

In the operation of a blast furnace it is not uncommon to experience erratic operation. Once such erratic operation occurs it is difficult to restore normal operation because a change in the burden, which is the principal adjustment available, requires a number of hours to be effective. While the amount of hot blast can be changed in a direction to restore normal operation, practically the amount of adjustment which can be made is limited due to the effect on pig iron and flue dust production.

The recently introduced practice of enriching the blast gas with oxygen as a means of increasing pig iron production has tended to accentuate the problem as the increased rate of downward movement of the burden causes it to be insufficiently heated before reaching the hearth. In attempting to correct for this condition an over-correction or under-correction is frequently made. Because of the "dead time" between an adjustment and the adjustment becoming effective, the furnace may be placed in a cycling condition which cannot be attenuated in any reasonable period of time and while existing results in poor production and generally unsatisfactory performance.

A further recently introduced practive involves the introduction of a supplementary fuel, known as an, "injection fuel" into the hearth along with the blast gas. This fuel, which may be a gas, such as natural gas or coke oven gas, or a fuel oil, has been found to increase iron output and decrease the amount of coke or other carbonaceous material required. A fairly comprehensive report on the practice is to be found in an article entitled, "Fuel Injection Increases Blast Furnace Iron Output," beginning on page 112 of the Dec. 5, 1960, issue of the publication "Steel."

I have found that this fuel may also be used to stabilize blast furnace operation, resulting in increased production, higher quality product, higher operating efficiency and lower maintenance. In accordance with my invention the rate of flow of injection fuel is controlled to maintain a predetermined combustibles content in the top gas. I have found that any upset in the operation of a blast

furnace is reflected immediately by a corresponding change in the composition of this gas. I have further found that the injection fuel provides a corrective agent immediately effective to restore the furnace to normal operation. Thus I may say use the combustibles content of the top gas as an index of furnace operation and the injection fuel as a corrective agent to maintain the index at a predetermined or desired value. The long "dead time" formerly existing between the taking of a corrective measure and the effect of that measure being felt is eliminated to the end that the furnace may be continuously maintained at the point of optimum operation.

In the drawings:

FIG. 1 is a schematic illustration of a control system incorporating my invention.

FIGS. 2 and 3 illustrate modifications which may be incorporated in the control system shown in FIG. 1.

Referring to FIG. 1, I therein show a blast furnace **1** having a stack **2** which at the top is provided with a large bell **3** and a small bell **4** through which the burden is charged into the furnace. At the lower end of the furnace there is a hearth **5** separated from the stack **2** by a bosh **6**. A bustle pipe **7** encircles the lower portion of the furnace for supplying blast gas under pressure to the hearth. The blast gas is admitted to the furnace through a plurality of tuyeres **8**, connected to the bustle pipe **7** by means of pipes **9**. The molten slag and iron collects in the hearth and is periodically tapped from the furnace through suitable tap holes (not shown).

As previously described, the blast gas burns the carbonaceous material, of which the burden is partially composed, in the vicinity of the hearth and the products of combustion pass upwardly through the stack and are discharged through one or more off-take pipes such as shown at **10**.

The blast gas, obtained from the atmosphere, after passing through a suitable filter (not shown) to remove dust and dirt and being enriched with oxygen as is sometimes done in modern practice passes through a suction conduit **11** to a large capacity blower **12** driven by a motor **13**. The blast gas is discharged from the blower **12** through conduit **14** into a stove **15** in which it is preheated. Usually at least three stoves, such as I have shown at **15**, are provided for each blast furnace. In customary practice two stoves are being heated, usually by burning the top gas from the blast furnace, while the third is preheating the blast gas. This operation is rotated, one stove after another being used to preheat the blast gas while the remaining two are being heated thereby maintaining the blast gas at a fairly uniform temperature.

A by-pass line **16** is ordinarily placed around each stove so that the blast gas leaving the stove **15** may be tempered with unheated gas. A valve **17** either manually or automatically controlled, as later to be described, is provided in the by-pass line so that the amount of tempering gas may be adjusted as required to maintain a desired constant temperature of the hot blast which may, for example, be in the order of 1000° F. From the stove **15** the blast gas is transported to the bustle pipe **7** through a conduit **18**.

The injection fuel, obtained from any suitable source (not shown) is introduced by way of pipe **20** into a header **19** encircling the blast furnace. I have, for purposes of illustration, shown an arrangement for the use of fuel oil as the injection fuel. Obvious modifications in regard to pipe sizes, header arrangement and the like would be made in the event another fuel such as natural gas or coke oven gas was used as the injection fuel. The injection fuel is discharged through each tuyere by a suitable burner arrangement such as I have diagram-

matically shown at **21** which is connected to the header **19** by pipe **22**.

Turning now to a consideration of control for the blast furnace **1** I illustrate a system of the pneumatically operated type for the reason that the components of such type are well known and understood in the art. However, I could equally as well use for illustrative purposes an electrically or hydraulically operated control system as will be readily appreciated as the description proceeds.

In FIG. 1 I show a constant flow control for the blast gas. Therein a flow controller diagrammatically illustrated at **25** establishes a loading pressure proportional to the rate of flow of blast gas which is transmitted through a pipe **26** to the B chamber of a relay **27**. This relay may, for example, be of a type illustrated and described in United States Patent 2,805,678 issued to Michael Panich on Sept. 10, 1957, and establishes at ports D a control pressure varying both in accordance with changes in the loading pressure in pipe **26** and the time integral of the deviation of this pressure from a predetermined value corresponding to the desired rate of flow of blast gas in conduit **11**. Such a relay is spoken of in the art as having proportional plus reset action. Both the proportional and reset actions may be adjusted in accordance with the time constants of the system by means of sector **28** and bleed valve **29** respectively.

The control pressure is transmitted to a Manual-Automatic Selector Station **30** through pipe **31** and thence by way of a pipe **32** to a control unit **33** for the motor **13**. The control unit **33** may take any conventional form and serves to regulate the speed of motor **13** and accordingly of blower **12** in accordance with the magnitude of the control pressure in pipe **32**.

The Selector Station **30** and other Selector Stations in the control system may be of the type illustrated and described in the Panich Patent 2,805,678 and afford a means for transferring the control from Automatic to Remote Manual. Thus there is provided a knob **34** by which the control pressure in pipe **32** may be manually adjusted with the Station in Manual Position. With the Station in Automatic Position the Set Point, that is, the rate of flow maintained by the control may be adjusted by a knob **35** which establishes a pressure transmitted through a pipe **36** to the A bellows of relay **27** and against which the loading pressure established by transmitter **25** is balanced. The Selector Station **30** is also provided with a pneumatic switch **37** for transferring the control from Automatic to Manual and vice versa.

In accordance with my invention the rate of flow of injection fuel is regulated to maintain a predetermined total combustibles in the top gas. While I show and prefer to use the total combustibles in the top gas as the control index, a particular constituent of the gas such as hydrogen, carbon monoxide or carbon dioxide may in some circumstances be employed as there may in some cases be a fixed ratio between a particular combustibles constituent and the total combustibles. In employing the term "combustibles" it is to be understood that in its broader aspects it comprehends one, more than one or all of the combustible constituents in the top gas. By "combustibles content" I mean the percent by volume or percent by weight of a unit volume or unit weight of the top gas.

I show at **38** a combustibles controller for establishing a loading pressure proportional to the combustibles in the top gas leaving the blast furnace through off-take pipe **10**. This loading pressure is transmitted through a pipe **39** to a relay **40**, similar to the relay **27**, and incorporating proportional plus reset action. The control pressure established at port D of this relay is transmitted through a pipe **41** to a Selector Station **42** and thence to a relay **43** through a pipe **44**. In relay **43** (which may be of a type illustrated and described in Panich Patent 2,805,678) changes in pressure at output port D are produced inversely proportional to changes in pressure

at inlet port B, thus an increase in pressure at B will produce a corresponding decrease in pressure at port D and vice versa. An adjustment **45** is provided for adjusting the ratio between changes at B and resulting changes at D. This is spoken of in the art as a, "proportional band" adjustment.

While the control pressure established at port D of relay **43** could act directly on control valve **46** to adjust the rate of flow of injection fuel, I prefer, in accordance with well established principles in the control art, to have this loading pressure adjust the Set Point of a constant flow control of the injection fuel. Thus I show a flow controller **47** for establishing a loading pressure proportional to the rate of flow of injection fuel which by means of a relay **48** having proportional plus reset action, maintains a constant rate of flow of injection fuel. The Set Point of this control is adjusted from the combustibles in the top gas by introducing the control pressure established by relay **43** through a pipe **49** into the A bellows of relay **48**. Thus the rate of flow of injection fuel is varied to maintain the loading pressure established by flow controller **47** in balance with the control pressure established by relay **43** to the ultimate end that the rate of flow of injection fuel is adjusted as required to maintain a constant combustibles content in the top gas. A Selector Station **50** provides a means for remote Manual control of the valve **46**.

To anticipate changes in the combustibles content of the top gas occasioned by changes in the rate of flow of blast gas and thereby provide a closer control, the loading pressure established by flow controller **25** is transmitted through a branch pipe **26A** to the A bellows of relay **43**. Changes in this loading pressure will thus produce corresponding changes in the control pressure produced by relay **43** and in the rate of flow of injection fuel. Changes in the combustibles content of the top gas which would otherwise occur by virtue of changes in the rate of flow of blast gas and which the control from combustibles content would be called upon to correct are thereby avoided.

In FIG. 1, as described, I show a constant flow control of the total injection fuel. In the usual application this is satisfactory, however, as can be appreciated even with the total flow maintained as desired, objectionable variations may occur in the flow of each individual tuyere occasioned by variations in the relative resistance to flow and the like. A minor modification may readily be incorporated in the control as illustrated in FIG. 1, and which I have shown in FIG. 2 to assure the flow to each individual tuyere being maintained at the desired value. Therein I have shown my modified control applied to one tuyere, it being understood that a similar control would be provided on every other tuyere through which injection fuel is admitted to the blast furnace.

In the modification shown in FIG. 2 a constant flow controller **47A** establishes a loading pressure corresponding to the rate of flow of injection fuel to the burner **21**. This loading pressure by means of a relay **48A** maintains this flow constant at a value determined by the control pressure admitted into the A bellows and generated in relay **43** as described with reference to FIG. 1. Thus changes in the relative resistance to flow and the like will not affect the uniform discharge of injection fuel through the tuyeres as the constant flow control associated with each tuyere will adjust its valve **46A** to maintain the rate of flow to the tuyere at a value established by the relay **43**.

I have mentioned with respect to the description relating to FIG. 1 that the preheated blast gas is usually maintained at a desired temperature by adjusting the flow through a by-pass line around the stove. In FIG. 3, I have shown a typical arrangement wherein a temperature controller **50** responsive to the temperature of the preheated blast establishes a corresponding loading pressure which is introduced into the A chamber of relay **51** having a proportional plus reset action. The relay **51** produces a con-

trol pressure which is transmitted through a pipe **52** to a diaphragm operated valve **17A** disposed in the by-pass line **16**. The arrangement is such that an increase in temperature in conduit **18** causes a corresponding increase in flow through the by-pass line **16** and a continuing change in this flow proportional to the deviation in this temperature from Set Point value and in sense dependent upon the sense of the deviation.

As I have found that the temperature of the preheated blast gas may be desirably modified with changes in the rate of flow of injection fuel, I further show in FIG. 3 the Set Point of the temperature control adjusted from the rate of flow of injection fuel. Such a modification may be desirable to compensate for the cooling effect of the injection fuel on hearth temperature and other effects on the blast furnace which changes in the rate of flow of injection fuel may have. Referring to FIG. 3 I show the loading pressure established by flow controller **47** introduced into the B chamber of relay **51** through a pipe **53**. Accordingly the relay **51** will act to vary the flow through the by-pass line **16** as required to maintain the loading pressure established by the temperature controller **50** in balance with the loading pressure introduced into the B chamber by way of pipe **53** to the ultimate end that the Set Point, or in other words the temperature in conduit **18** is maintained at a value established by the rate of flow of injection fuel.

The present invention thus provides a novel method and apparatus for controlling the operation of a blast furnace. Although only one basic embodiment of the invention has been disclosed and described herein, it is expressly understood that various changes and substitutions may be made without departing from the spirit of the invention. Reference will therefore be had to the appended claims for a definition of the limits of the invention.

What I claim as new and desire to obtain by Letters Patent of the United States is:

1. The method of controlling a blast furnace having an elongated vertical stack into the top of which a burden consisting essentially of limestone, a carbonaceous material and a ferrous bearing material is charged and a lower hearth section into which a blast gas and an injection fuel are discharged and burned the hot gases of combustion passing up through the stack for the reduction of the iron ore to iron which includes regulating the flow of the injection fuel in accordance with the combustibles content in the top gas leaving the furnace.

2. The method in accordance with claim **1** wherein the rate of flow of the injection fuel is regulated to maintain a predetermined constant combustibles content in the top gas leaving the furnace.

3. The method in accordance with claim **2** including the further steps of maintaining the rate of flow of injection fuel constant and adjusting the constant rate maintained as required to maintain the predetermined constant combustibles content in the top gas leaving the furnace.

4. The method of claim **3** including the further step of adjusting the temperature of the blast gas in accordance with the rate of flow of injection fuel.

5. The method of claim **3** including the further step of increasing the temperature of the blast gas in proportion to increases in the rate of flow of the injection fuel and vice versa.

6. The method of claim **5** including the further step of maintaining the rate of flow of blast gas to the furnace constant.

7. The method of controlling a blast furnace having a vertical elongated stack into the top of which a burden consisting essentially of limestone, a carbonaceous material and a ferrous bearing material is periodically charged and a lower hearth section into which a blast gas and an injection fuel are continuously discharged through a plurality of tuyeres surrounding the hearth section and burned, the hot gases of combustion passing up through the stack for the reduction of iron ore to iron which includes maintaining the rate of flow of injection fuel to each of the plurality of tuyeres constant and adjusting the constant rate of flow maintanied as required to maintain the combustibles content in the top gas leaving the furnace constant at a predetermined value.

8. The method of claim **7** wherein the rates of flow of all the tuyeres is adjusted in parallel to maintain the combustibles content at a predetermined value.

9. The method of controlling a blast furnace having a vertical elongated stack into the top of which a burden consisting essentially of limestone, a carbonaceous material and a ferrous bearing material is periodically charged and a lower hearth section into which a blast gas and an injection fuel are continuously discharged through a plurality of tuyeres adjacent the hearth section and burned, the hot gases of combustion passing through the stack for the reduction of iron ore to iron which includes, measuring the rate of flow of injection fuel to each tuyere, utilizing the measurements to maintain the rate of flow to each tuyere constant, measuring the combustibles content of the top gas leaving the furnace and simultaneously adjusting the rate of flow of injection fuel to all of the tuyeres as required to maintain the measure of combustibles content at a predetermined value.

10. In a control system for a blast furnace for the reduction of iron ore to iron having an elongated vertical stack into the top of which a burden consisting of carbonaceous material, limestone and a ferrous bearing material is charged and a lower hearth section into which a blast gas and an injection fuel are discharged and burned, comprising, in combination, means for establishing a control signal corresponding to the combustibles content in the top gas leaving the furnace, and means for regulating the flow of injection fuel to the furnace responsive to said signal.

11. In a control system for a blast furnace for the reduction of iron ore to iron having an elongated vertical stack into the top of which a burden consisting of a carbonaceous material, limestone and a ferrous bearing material is charged and a lower hearth section into which a blast gas and an injection fuel are discharged and burned, comprising in combination constant flow control means of the injection fuel having an adjustable set point, means responsive to at least one of the combustibles constituents in the top gas leaving the furnace and means under the control of said last named means for adjusting said set point to maintain said combustibles constituent at a predetermined value.

12. In a control system for a blast furnace for the reduction of iron ore to iron having an elongated vertical stack into the top of which a burden consisting of a carbonaceous material, limestone and a ferrous bearing material is charged and a lower hearth section into which a blast gas and an injection fuel are discharged and burned, comprising in combination, means for heating the blast gas, means for controlling the heating means to maintain the temperature of the blast gas entering the furnace at a constant value and means for adjusting the constant value in accordance with the rate of flow of injection fuel into the furnace.

13. In a control system for a blast furnace for the reduction of iron ore to iron having a vertical elongated stack into the top of which a burden consisting of limestone, a carbonaceous material and a ferrous bearing material is charged and a lower hearth section into which a blast gas and an injection fuel are discharged and burned through a plurality of tuyeres surrounding the hearth section, comprising in combination, constant flow control means of the rate of flow of injection fuel to each tuyere having an adjustable set point, measuring means of the combustibles content of the top gas leaving the furnace and means under the control of said last named means for simultaneously adjusting the set points of all of the constant flow control means to maintain the combustibles content in the top gas at a predetermined value.

14. In a control system for a blast furnace for the reduction of iron ore to iron having a vertical elongated stack into the top of which a burden consisting of limestone, a carbonaceous material and a ferrous bearing material is charged and a lower hearth section into which a blast gas and an injection fuel are discharged and burned, comprising in combination, regulating means of the rate of flow of injection fuel, a meter of the combustibles in the top gas leaving the furnace establishing a pneumatic loading pressure proportional to the combustibles, a controller responsive to said loading pressure generating a control pressure varying in accordance with changes in the loading pressure and the time integral of the deviation of aid loading pressure from a predetermined value and means operated by control pressure for positioning said regulating means.

15. A control system according to claim **14** wherein the regulating means is a constant flow control means having an adjustable set point and the control pressure is effective for adjusting the set point.

16. A control system according to claim **15** including means for maintaining the temperature of the blast gas at a predetermined value having an adjustable set point and also including means responsive to the rate of flow of injection fuel for adjusting said set point to vary the temperature of the blast gas in accordance with changes in the rate of flow of injection fuel.

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JOHN F. CAMPBELL, *Primary Examiner.*

RAY K. WINDHAM, JAMES H. TAYMAN, JR., *Examiners.*