FLUID FUEL CONTROL PROCESS FOR BLAST FURNACES

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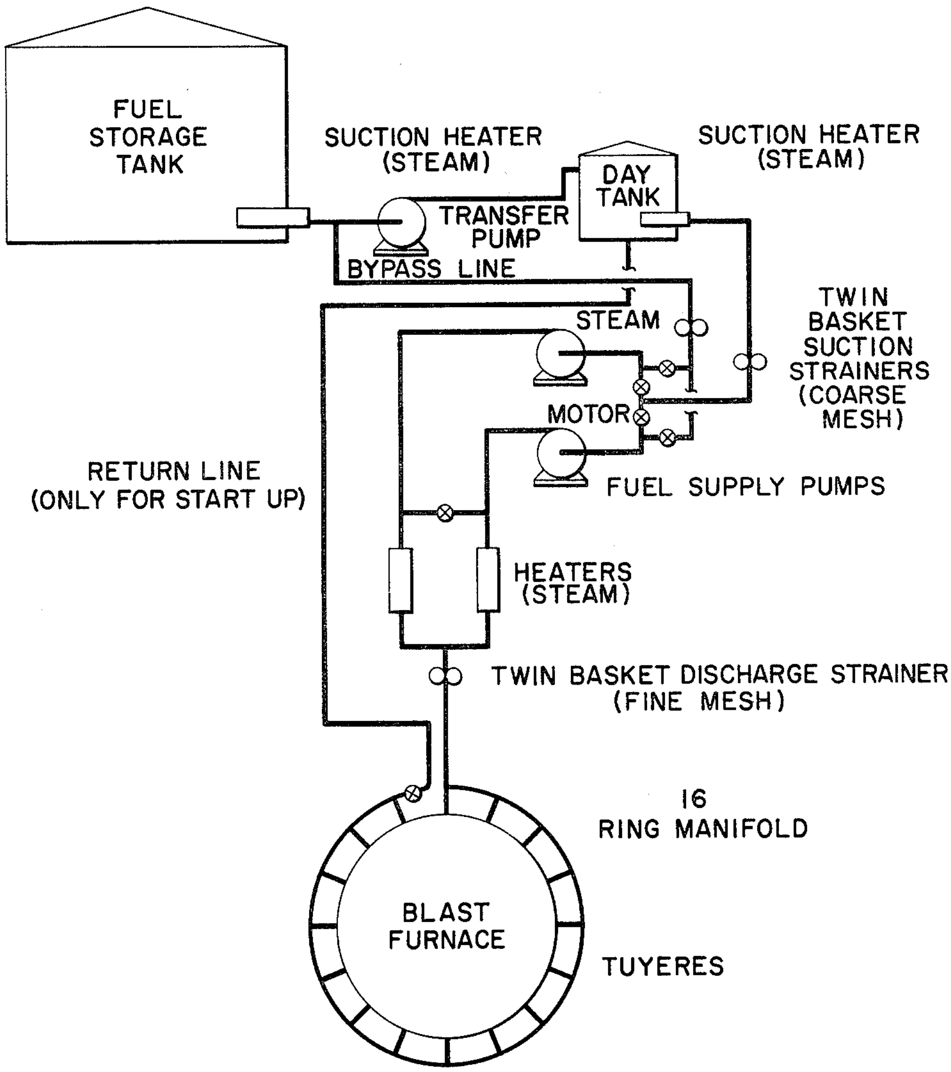

Figure 1

FUEL STORAGE AND HANDLING SYSTEM FOR BLAST FURNACE

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FLUID FUEL CONTROL PROCESS FOR BLAST FURNACES

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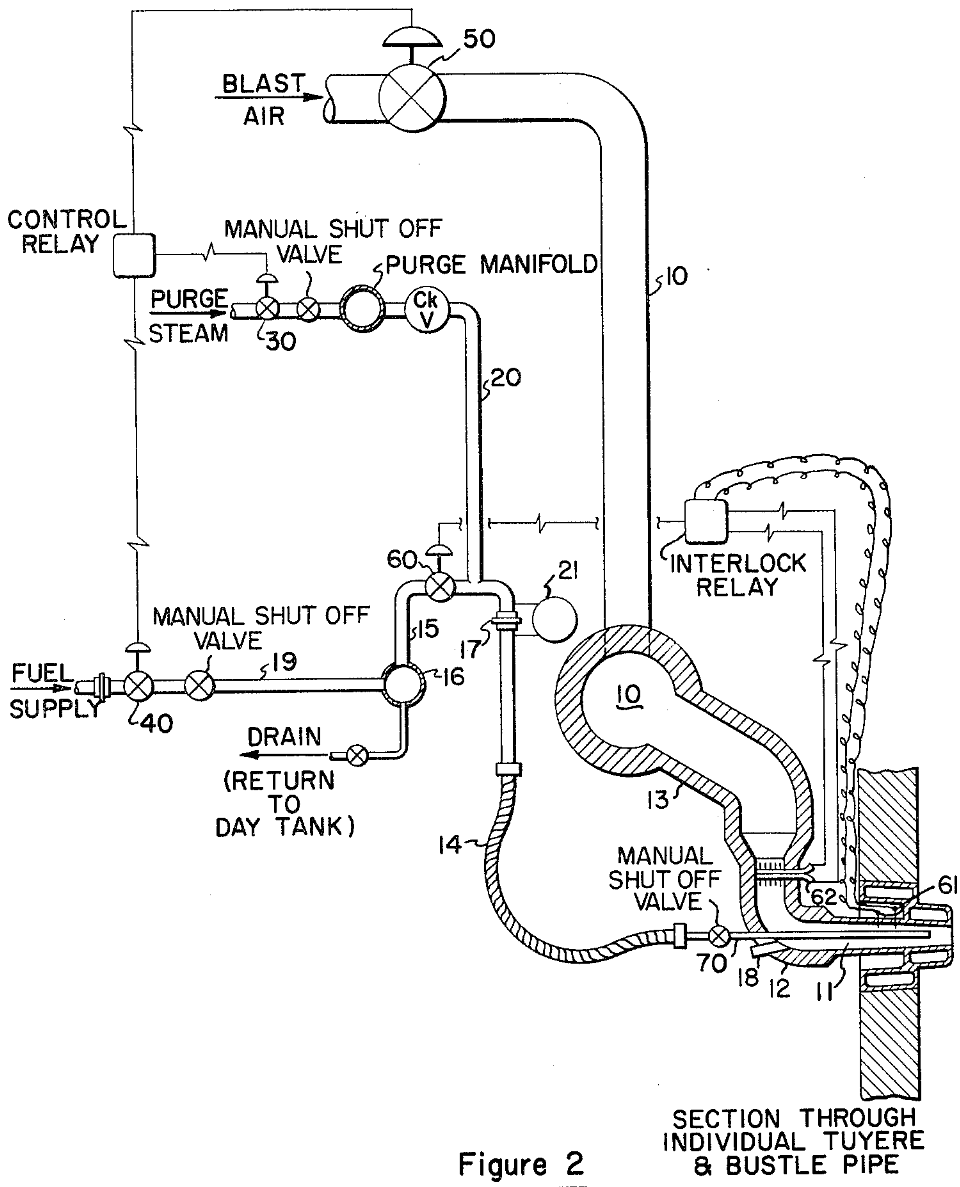

Figure 2

FUEL CONTROL SYSTEM FOR BLAST FURNACE

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FLUID FUEL CONTROL PROCESS FOR BLAST FURNACES

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The present invention relates to a fluid control apparatus and method for furnaces. In particular, the invention concerns an apparatus and process for controlling the injection of fuels and blast gases into a furnace, and more particularly, the controlling of the injection of liquid petroleum fuels and heated blast air into a blast furnace.

In the operation of a conventional blast furnace, the furnace is charged with iron ore (iron oxides), flux materials (limestone) and carbonaceous materials (coke). This mixture is then heated to drive off carbon dioxide and water, and as the ore descends downward through the stack, it is reduced to iron by reducing gas moving in a countercurrent direction. The reduced iron is then melted in the lower bosh portion of the furnace, and the liquid metal withdrawn through the iron notch at the hearth. A blast furnace thus requires a source of reducing gas in the upper part of the stack to reduce the ore and, a high temperature in the lower part of the stack (bosh section) sufficient to melt and liquefy the reduced ore. Both requirements are generally provided for by introducing a heated air or an oxygen enriched air mixture through a series of circumferential tuyeres located near the bottom of the furnace. The air blast combusts with the coke to furnish the necessary high temperature to melt the iron (2500 to 3000° F.) and a reducing gas (carbon monoxide) to reduce the ore further up the stack.

It is known in the art as set forth for example by U.S. Patent 325,293, issued September 1, 1885, and U.S. Patent 1,964,727, issued July 3, 1934, that other hydrocarbon fuels may be used as a partial replacement for coke in the blast furnace. Suitable fuel for this purpose would include any liquid, liquefiable, gaseous or emulsifiable hydrocarbon fuel product such as petroleum type residual fuel oils, distillate fuel oils derived from crude petroleum by distillation, thermal cracking, catalytic cracking, hydroforming and the like, crude petroleum, diesel fuels, gas oils, kerosine, gasoline, petroleum naphthas. For economic reasons those liquid fuel oils of ASTM Specification D–396–48T will generally be preferred with the residual fuel oils **5** and **6** especially preferred. In some geographic areas circumstances will justify the use of the more volatile liquid petroleum naphtha products other than residual fuel oils. These fuels will be most suitably utilized by injecting them in conjunction with the heated blast air either through the tuyeres or near the tuyeres into the lower or bosh portion of the blast furnace, cupola, open hearth furnace, or other furnace to produce high temperatures and suitable reducing gases.

Although the invention is described utilizing liquid petroleum fuels, it is also within the scope of this invention that petroleum and natural fuel gases may also be utilized in the invention control system and apparatus.

The hydrocarbon fuel suitable for use in furnaces can also be those liquid petroleum fuels containing various additive materials such as corrosion inhibitors, viscosity index improvers, pour point depressants, detergents, sludge inhibitors, and the like. In particular, the use of liquid fuels containing sulfur wherein limestone or lime is added to the fuel oil is within the contemplation of the inventive process. It is known that excessive amounts of sulfur in iron is objectionable and that limestone added to the furnace as a fluxing material is also helpful in controlling the sulfur content of the iron by acting as a sulfur absorber. The addition of minor amounts of powdered lime in liquid fuels such as bunker C oil will allow the more efficient control of sulfur content in the iron than by present practices. Thus, the addition of lime to the fuel oil as an additive agent prior to the injection of the fuel oil into the furnace will allow more complete contacting and absorption of the objectionable sulfur in the fuel than by the use of limestone placed in the stack.

The problems associated with the injection of liquid petroleum fuels and the efficient operation of a blast furnace involve the close control of certain blast furnace variables. It is important that the injection of the liquid fuel be closely controlled so that the injection of excessive fuel at the blast air temperature employed will not upset the furnace operation. High temperatures will allow the partly reduced ore in the upper part of the shaft to become pasty, slump together, and reduce or cut off the pasage of the blast and reducing gases thus choking the furnace, while even higher temperatures may destroy the furnace by causing the lining to slag. Low temperatures also must be avoided in order not to freeze the furnace, thereby causing uncontrolled cooling with consequent failure of the material to move down the stack and possible destruction of the furnace lining. The correct operation of the furnace is usually the responsibility of the furnaceman, who by visual observations of the furnace operations through the peephole in each individual tuyere and the data available maintains the furnace at the optimum conditions, and detects and corrects operating difficulties.

Control of operating conditions has in the past been usually affected by controlling the volume, temperature, and other factors of the blast air. The injection of liquid petroleum fuels with the blast air creates novel, additional and critical problems in the proper control of fuel flow, air blast flow, temperatures, the detection of operating difficulties and the like. Thus, for example, blast air and fuel flow must be maintained in certain critical operating proportions to ensure proper operating temperatures. The cutoff or reduction in flow of the fuel or blast must be accompanied by a suitable reduction or cutoff of the other component, otherwise operating temperatures may not be suitable for proper furnace operation. In addition, the clogging of individual tuyeres by coke, slag, iron or carbonaceous material, and the burning of fuel oil in the individual tuyere, must be detected and corrected promptly for efficient operation. Another problem in the use of liquid petroleum fuels is that the blast air temperature must be higher to achieve maximum coke reduction than conventional blast air temperature. Preferably, the air blast temperature should be at least 1000° F. with a range of 1800° F. to 2000° F., the present maximum practical, especially preferred with residual fuel oils. This is necessary since the initial reaction of the relatively cold liquid petroleum fuel with the air blast produces less heat than that produced with coke, the total heat quantity of which varies according to the fuel used. In order to reduce any absorption of heat from the bosh section at high liquid fuel injection rates the temperature of the air blast must be increased. To avoid initial lower temperature effects in the furnace the temperature of the blast air must preferably then be kept above a certain predetermined temperature level to achieve maximum reduction in coke consumption. Thus, blast air temperature and fuel flow must be closely correlated for efficient operation. The approximate uniform injection of fuel at all the tuyeres is another requirement of proper fuel injection. Of course, the handling of combustible petroleum fuels also requires that certain safety requirements be observed so that fuel flow is not uncontrolled. Another novel problem in this system is the prevention of fuel oil carbonization in the fuel injection system due to air blast and furnace heat. These and other problems associated with the use of liquid fuel injection systems render the conventional operation of furnaces entirely by the judgment of the furnaceman with limited observation and data, quite inefficient and subject to gross errors with resulting disaster to furnace operations and to the furnace itself.

It is therefore an object of the present invention to provide a method and apparatus for the proper detection and control of certain critical variables in the operation of furnaces utilizing a liquid fuel-air injection system. Other objects are the proper control of liquid fuel flow and blast air flow in blast furnaces, the detection and control of flow reductions at individual tuyeres, the detection of plugged tuyeres, the maintenance of fuel flow with certain minimum air blast temperature, the prevention of fuel oil carbonization in the injection pipe and the detection and control of other blast furnace variables and problems associated with the use of liquid fuel-blast injection systems. These and other objects as well as the nature and scope of the instant invention will be more apparent from the following drawings and description.

The present invention will be more fully understood by reference to the accompanying drawings wherein:

FIGURE 1 is a diagrammatical representation of a fuel storage and handling system for blast furnaces.

FIGURE 2 is a diagrammatical representation of the inventive liquid fuel-air blast control system for a blast furnace.

Referring now to FIGURE 1 in greater detail, there is shown a cone roof type fuel storage tank capable, for example, of holding approximately a month's supply of a liquid petroleum fuel such as bunker C oil, while the smaller day tank has a capacity, for example, of about two days' fuel supply. Located at the outlet of each tank is a steam heated suction heater for heating the bunker C oil to approximately 125° F. to facilitate ease in handling. The transfer pump located between the tanks accomplishes the transfer of fuel between the tanks. Two fuel supply pumps are also located forward of the day tank to provide flexibility and dependability in maintaining continuous fuel supply to the blast furnace. In addition, a bypass line has been provided in order that these fuel pumps can draw directly from the main storage tank if needed. Forward of the fuel pumps are located two steam heated fuel oil heaters to facilitate the liquid injection of the fuel, and to raise the temperature of the fuel oil to about 225° F. where atomized injection of the fuel is desired. Suitable twin basket suction strainers are located as shown with the fine mesh strainer placed in the line prior to the entry of the fuel into the ring manifold surrounding the blast furnace. The ring manifold **16** as shown is circumferentially arranged about the blast furnace, preferably about the bosh portion of the shaft, while radially inwardly extending from the fuel oil ring manifold are individual fuel oil injection pipes (see FIGURE 2) to each individual tuyere of the blast furnace. The return line from the ring manifold to the day tank is used only during startup operations to circulate the fuel until the required atomizing temperature is reached prior to starting injection.

Atomized fuel injection by pressure atomization of the liquid petroleum fuel is one preferred method of operation. Thus, when pressure atomization is desired, a fuel oil ring manifold pressure of a minimum of 50 p.s.i. should be employed with a pressure of at least 150 p.s.i. preferred. Pressure atomization is defined herein to include atomization by mechanical means, air, steam, and the like. The system as described is also suitable for liquid injection without atomization where this method is deemed desirable. A suitable method of injecting liquid fuels without placing the fuel itself under pressure or using pressure atomization means described above is to use the high viscosity air blast to atomize the liquid fuel as it emerges from the end of the fuel injection pipe. Atomization using compressed air is particularly suitable and provides additional advantages in shielding the oil injection pipe from the pickup of heat from the blast air and raceway. The system and apparatus as described is suitable as shown for high viscosity residual petroleum fuel oils and/or low viscosity liquid naphtha products, where there is economic justification for the use of such naphtha products. The maintenance of 150 p.s.i. in the ring manifold will, in addition to providing atomization means for the liquid fuel, also help to prevent the vaporization of the naphtha in the injection pipe by the absorption of heat. In addition, the use of a low viscosity naphtha-type fuel will allow the elimination of the two steam heated suction heaters and the two steam heated fuel oil heaters shown in FIGURE 1.

Referring now to FIGURE 2, there is shown a preferred fuel-air injection control system with a sectional view of an individual tuyere wherein preheated atmospheric air or oxygen enriched air at about 50,000 to 100,000 cu. ft./min. at a higher than atmospheric pressure, for example, 25 p.s.i., is forced through a bustle pipe **10**, which circumferentially surrounds the blast furnace. An individual tuyere blowpipe **11** communicates through an elbow **12** and a gooseneck **13** with the bustle pipe and provides means whereby the blast air is admitted into the blast furnace. Within the individual tuyere chamber or blowpipe is located a fuel injection pipe **70**, the outside end of which extends through the elbow and has a manual shutoff valve. The fuel injection pipe could, if desired, be located outside of the tuyere, but adjacent to the tuyere to ensure proper combustion conditions.

The fuel injection pipe can be a straight tube injection pipe as shown, a conventional air pressure atomization nozzle, or, if desired, a fluid shrouded tube, for example, a shrouded air cooled tube. The latter nozzle would be suitable and preferred where the heated blast gas and furnace heat are sufficient to cause excessive carbonization, sludging, or thermal cracking of the liquid fuel, by preheating of the oil before emergence from the injection pipe. Under these circumstances, for example, where the high viscosity residual fuel is diluted with a low viscosity cracked fuel, clogging or the significant lowering of fuel injection rates would occur. Thus, the latter nozzle comprising an annular-type tube or duct-type conduit or its equivalent surrounding the fuel injection pipe would be desired. By passing relatively cool air through the surrounding tube, the fuel being injected would be protected from excessive heat effects and carbonization and sludging of the fuel inhibited. The protecting air flow and pressure would be such that on stoppage of the fuel flow, the air effect on the furnace temperature conditions would be negligible. A suitable fluid shroud would be air having a temperature of from 60–150° F. at a pressure of from 2–10 pounds per square inch and an air flow rate not greater than $\frac{8}{10}$ of the liquid fuel flow and preferably about $\frac{1}{10}$ of the liquid fuel flow. The preferred location of the injection end of the fuel injection pipe is such that partial combustion of the fuel occurs before the fuel enters the furnace. This preferred position of the pipe tends to minimize the formation of excessive smoke and unburned carbon particles while promoting efficient use of the fuel. The preferred location of the pipe within the tuyere varies with the fuel used, furnace conditions, and other operating conditions and circumstances. Direct injection of the fuel into the furnace by a fuel injection pipe which does not permit some partial combustion of the fuel may result in incomplete combustion of the fuel in the raceway with the consequent formation of excessive smoke and carbon particles.

The outside end of the injection pipe is connected to a braided corrugated flexible metal tubing **14**, which communicates in turn with a fuel oil supply line **15** which is further connected to the ring manifold **16**, where the liquid fuel is preferably under suitable pressure for atomization and at an elevated temperature. The ring manifold is supplied liquid fuel by a main supply line **19**. The corrugated tubing **14** permits quick disconnection of the fuel injection pipe and convenient access to the individual tuyere. Located below the injection pipe in the elbow is the conventional eyesight or peephole **18**, whereby the furnace conditions are observed by the furnaceman. In the fuel supply line is located a differential pressure gauge **21**, positioned across an orifice **17**, whereby any obstruction in the individual fuel injection pipe of the tuyere resulting in an unequal fuel flow with other individual tuyeres will be promptly detected by a change in pressure across the orifice, and the furnaceman alerted by an alarm, e.g., signal light, that the injection pipe is plugged or partially clogged and must be cleaned to restore normal fuel flow. The sluding tendencies of liquid fuels especially those derived from or containing cracked stocks, and subjected to high temperatures by the furnace makes the maintaining of individual fuel flow to the individual tuyere a distinct problem. Communicating with the fuel supply line between the ring manifold and the fuel injection pipe is a purge line **20**, which communicates, in turn, to a purge manifold having a purge supply of steam or a compressed gas, such as air, at approximately 100 p.s.i.g. The use of steam as a purging medium is preferred due to its availability, and since its use will not unduly upset the furnace temperature like unheated air.

The purge steam supply to the purge manifold is controlled by a purge controller **30**, the fuel supply to the ring manifold by a fuel flow recorder-controller **40**, and the blast air of the bustle pipe by a blast air controller **50**, all of which controllers communicate and interlock with a control relay as shown. The controllers are any suitable flow control means capable of manual or automatic operation from a control relay system. Suitable controllers would thus include diaphragm, power cylinder, or electric motor operated steam, air, or liquid flow controllers or flow recorder-controllers of the globe or V port type which are well known in the art. The preferred controllers are a standard globe valve flow control apparatus operated by pneumatic means. Suitable flow controllers include those set forth in the ASME Mechanical Catalogue of 1960 particularly FIGURE 13, page 43; and in the December 1949 issue of Power, pages 71–106 and in particular FIGURE 3 of page 101. The fuel flow controller can be modified slightly to provide for visual or graphic recording means for observing the quantity of fuel being used or used during a certain period of time. The blast air and fuel flow are capable of manual control by the furnaceman or can be automatically controlled by the control relay. The control relay can be any suitable mechanical, hydraulic, electronic and the like, relay system which will interlock with the controller used so as to perform the functions intended. These types of control relay systems like the controllers are well known to those skilled in the art. Suitable control relays would include pneumatic relays such as the "Standatrol" type, a proportioning diaphragm pneumatically operated, relay manufactured by the Bailey Meter Company, and electronic relays such as the magnet bar type. Suitable and preferred relays are further listed in the ASME Mechanical Catalogue of 1960 on page 43, FIGURE 10 (pneumatic type) and in the December 1949 issue of Power on page 88, FIGURE 5 (pneumatic type) and page 104, FIGURE 2 (magnet bar type).

In the automatic operation, the blast air controller and the fuel cntroller are interlocked through the control relay so that the fuel controller will close (fail-safe) on low blast air pressure or flow and on low fuel supply

pressure, as indicated by low pressure in the ring manifold or bustle pipe. In addition, the fuel controller will close at a predetermined miniumum blast temperature level or, if desired, to be left to the judgment of the furnaceman, appropriate visual or aural signals can call his attention to lower blast air temperatures. The interlocking operation of the fuel and blast air controller will thus prevent safety hazards from occurring, and prevent the furnace from freezing or otherwise malfunctioning. The control relay by measuring the flow rates and pressures can also maintain a proper preselected fuel/air ratio. When blast air is modulated in volume, the fuel flow will be automatically reduced or increased in flow to maintain a proper fuel oil/air blast ratio. When blast air flow is reduced or shut off, such as in the tapping cycle, the fuel flow recorder-controller will automatically shut off the fuel supply. Manual control through the control relay also allows the furnacemen, upon resumption of operations, to delay the injection of fuel to the furnace until furnace conditions are satisfactory.

The purge steam controller is additionally interlocked into the control relay. When the blast air and the fuel flow both stop, the fuel supply line and injection pipes are full of liquid fuel. These oil filled lines are subjected to a considerable amount of radiant heat from the furnace, so that there is danger of clogging the injection pipe by the carbonization of the fuel oil remaining in the lines especially the fuel oil in the injection pipe whether located within as shown or adjacent to the tuyere. In order to prevent this danger of malfunctioning when the blast air is shut off, either manually by the furnacemen or automatically by the control relay, the control relay opens the purge steam controller automatically so that the fuel supply lines and injection pipe are blown clear of oil with any interruption of the fuel oil supply or the blast air supply. The purge line can then be closed manually (if desired) by the furnaceman by the use of the manual shutoff valve shown, until operations are resumed, whereby the resumption of fuel supply and air blast will close the purge line valve. Of course, the manual valve must then be opened by the furnaceman for the automatic purge operation to take place again. In the purge line there is located as shown a check valve between the purge manifold and the individual tuyere fuel oil supply line. This one-way check valve prevents the higher pressure fuel oil from being forced into the purge steam supply line during normal operations.

An individual fuel safety controller **60** is located in the fuel supply line and interlocked by an interlock relay shown to a thermocouple **61** and a pitot tube **62** in each individual tuyere. The interlock relay as shown is a standard relay control and can be any suitable mechanical, hydraulic, electronic means capable of performing the functions described. Suitable interlock relays would include those relays as described for the control relay since the function and structure of the interlock relay is the same as the control relay except that interlock relay operates on individual tuyere lines rather than on the total manifold flow. This interlock relay is designed to shut off the fuel supply to the individual tuyere and signal the furnacemen upon the stoppage of blast air or burning within the tuyere or blowpipe. The pitot tube installed in each tuyere operates to indicate the blast air flow, and that the tuyere is not plugged or partially clogged. When the tuyere becomes plugged by coke, slag, molten iron, and the like, the drop in differential pressure actuates the relay to shut off the individual fuel supply to that tuyere. In the absence of such control, there will be no simple way of detecting the stoppage of air flow; thus combustible fuel will continue to flow and fill the tuyere. The pitot tube controls detect this occurrence, stops the fuel flow and notifies the furnacemen. In addition the blast air flow in the tuyere as monitored by the pitot tube through the interlock relay maintains the correct individual tuyere fuel/air relationship. This is particularly important since the air flow in each individual tuyere varies considerably depending upon the internal furnace conditions such as channelling and the like. The location of a thermal sensing means such a switch or thermocouple, in each individual tuyere prevents fuel oil from burning in the tuyere adjacent said fuel injection pipe undetected. The high temperature of the air blast and the raceway make individual fires in the tuyere with subsequent destruction of the slender injection pipe a real possibility. Thus, upon an increase in temperature in the tuyere, the fuel supply is automatically shut off through the interlock relay, by the fuel safety controller, and the furnaceman's attention is called to the situation by a signal alarm system.

The control system described solves many of the novel and intricate problems in the utilization of combustible liquid fuels in furnaces. In particular, the control system and apparatus have been seen to have the advantages of admitting fuel to blast furnace through a fuel recorder-controller either automatically or manually in step with blast furnace operating variables. It also shuts off fuel automatically with either the shutting off or failure of the blast air supply; does not permit fuel injection unless blast air temperature is sufficient; automatically opens a purge controller to permit steam to purge the fuel system upon either shutting off or failure of the blast air supply; shuts off fuel automatically (fails safe) with stoppage of blast air flow or burning within the tuyere; and detects pluggage or partial clogging of fuel injection pipes.

What is claimed is:

1. A process for controlling the injection of fluid fuel and heated blast air into a blast furnace, said process comprising: injecting heated blast air into a blast furnace; injecting fluid hydrocarbon fuel into admixture with said blast air; measuring the rate at which said blast air is flowing into said blast furnace; increasing and decreasing the rate of fuel injection as the blast air flow rate increases and decreases respectively, thereby maintaining the preselected fuel/air ratio.

2. A process for controlling the injection of fluid fuel into a furnace so as to avoid upsetting furnace operation, said process comprising: injecting heated blast air into a furnace; injecting a fluid hydrocarbon fuel through a fuel injection conduit into admixture with said blast air; measuring the blast air temperature; terminating said fuel injection when the temperature of the blast air falls below a predetermined temperature; and purging said injection conduit of fuel.

3. A process for controlling the injection of liquid fuel into a furnace so as to avoid upsetting furnace operation, said process comprising: injecting heated blast air through a tuyere into a furnace; injecting a fluid hydrocarbon fuel through a fuel injection pipe into admixture with said heated blast air; measuring the temperature within the tuyere to detect combustion adjacent said fuel injection pipe within the tuyere; stopping the flow of fuel upon detection of combustion adjacent said fuel injection pipe within the tuyere; and subsequently purging the injection pipe of fuel with a pressurized fluid.

4. A process as defined in claim **3** wherein said purging fluid is steam.

5. A process as defined in claim **3** wherein said liquid hydrocarbon fuel is a petroleum fuel oil.

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