Sept. 29, 1964 L. PEARSON 3,150,962

PULVERIZED COAL FIRING METHOD AND SYSTEM FOR BLAST FURNACE

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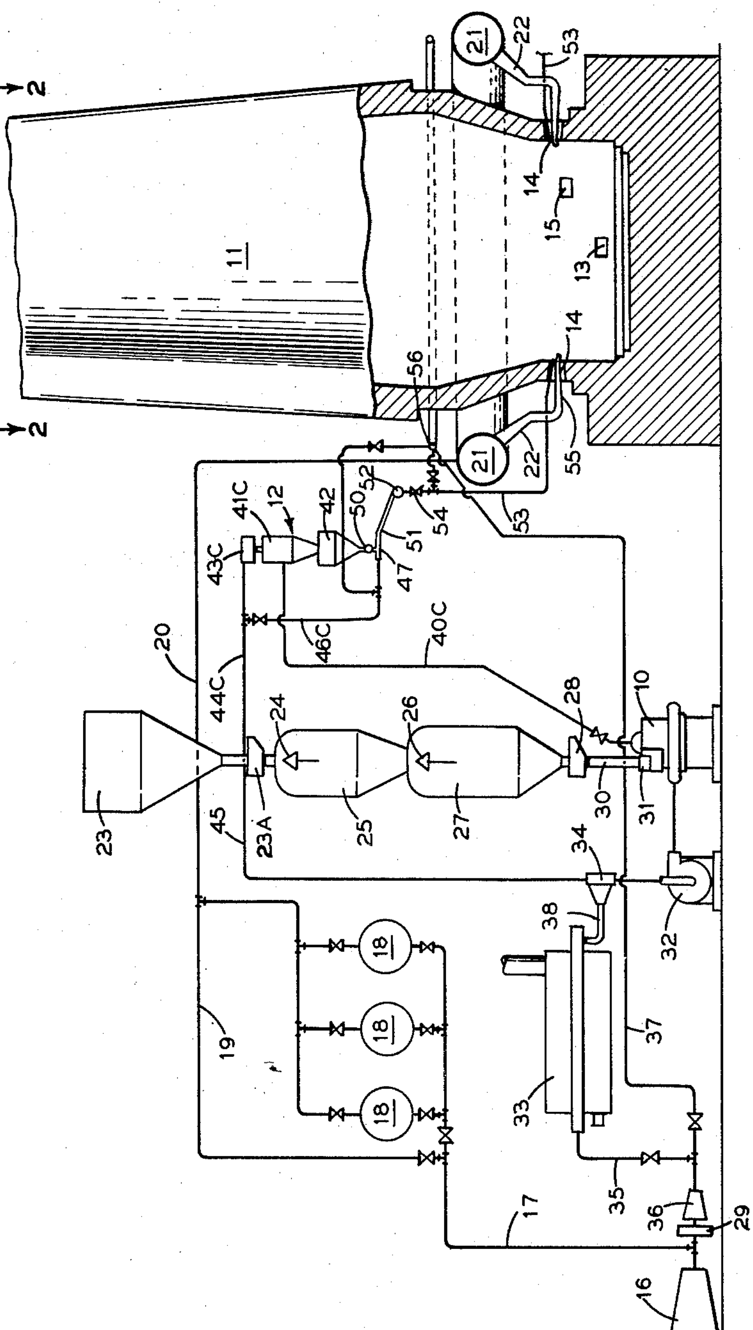

FIG.1

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PULVERIZED COAL FIRING METHOD AND SYSTEM FOR BLAST FURNACE

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FIG. 2

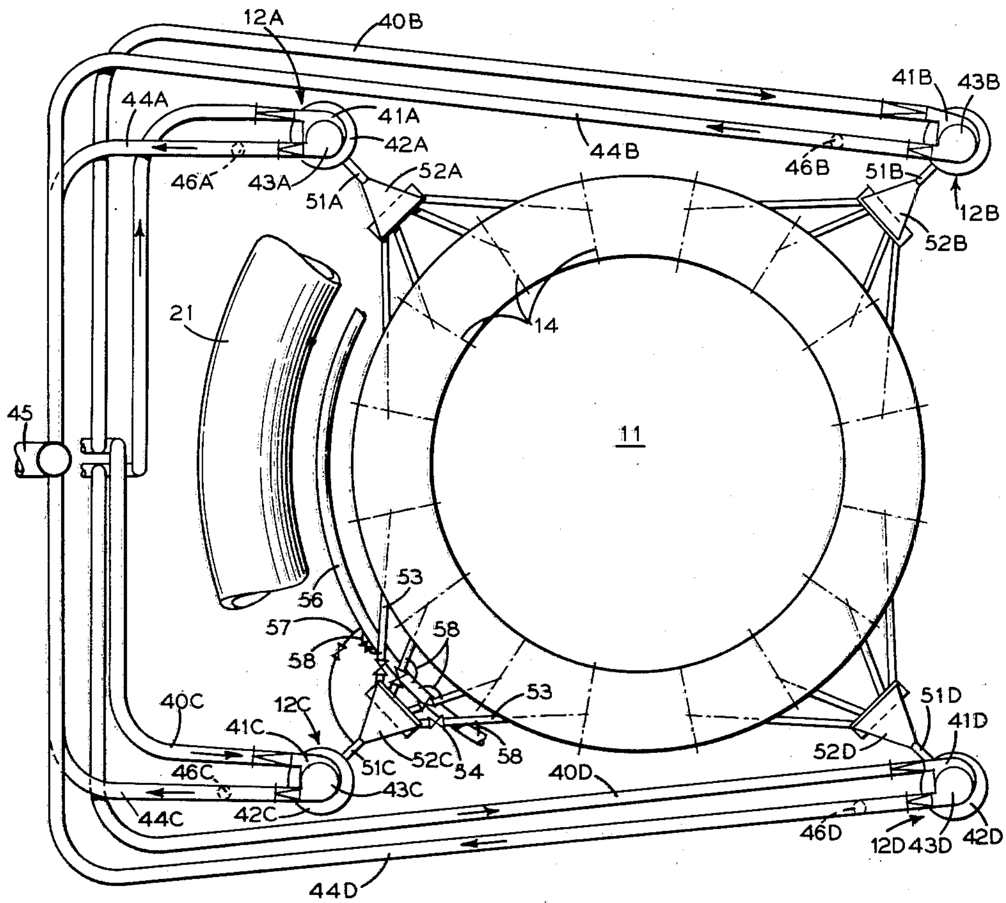

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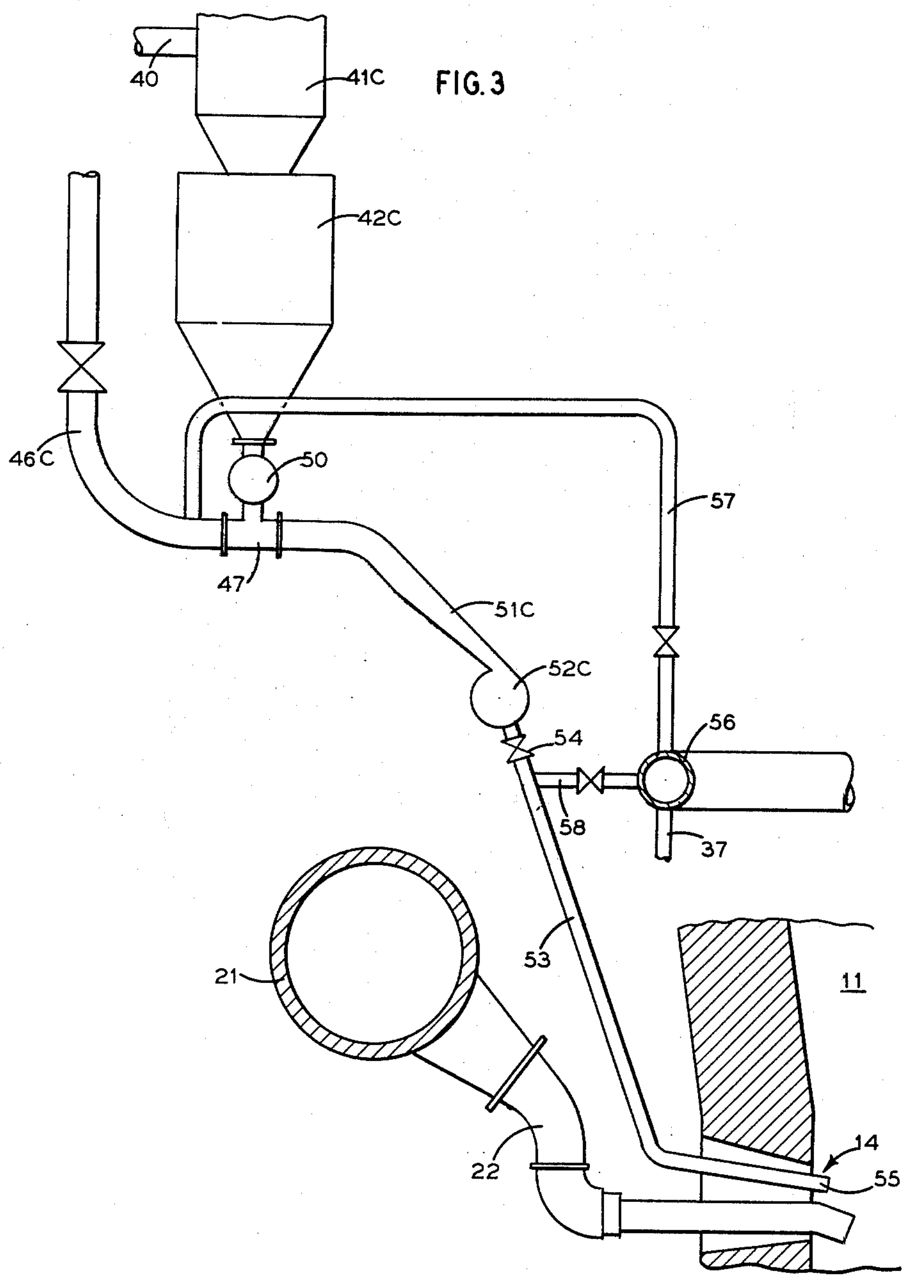
FIG. 3



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PULVERIZED COAL FIRING METHOD AND SYSTEM FOR BLAST FURNACE

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9 Claims. (Cl. 75—42)

This invention relates to the smelting of iron ore, and more particularly to an improved method of and apparatus for the smelting of iron ore in a blast furnace.

Traditionally the steel industry has operated blast furnaces with a charge of lump or granular iron ore, limestone (or other fluxing material) and coke. The coke not only provides the carbon necessary in the smelting of the ore, but also provides the source of heat for the chemical reactions occurring in the smelting process. Normally the coke used will be of a high quality and of a size large enough not to be blown out of the furnace by the flow of gases upwardly therethrough. In addition the coke should be firm and strong enough to withstand the weight of the blast furnace burden or charge. Coke is expensive to produce and requires a heavy capital investment for the construction of coke ovens for the tonnage required. Any reduction in the amount of coke needed for the production of pig iron in a blast furnace is of economic importance, and is particularly important if, through the substitution of cheaper coal as a source of heat and carbon in the iron ore reduction process, a 30 to 50 percent reduction in the coke tonnage may be realized.

The present invention provides for the introduction of pulverized coal into a blast furnace, with the pulverized coal replacing a portion of the usual coke charge on at least a pound for pound basis. The unit cost of the coke is approximately double that of the pulverized coal on an equal tonnage basis, hence there is a saving in fuel costs and a major reduction in the cost of producing steel. Moreover the furnace volume occupied by the pulverized coal, as compared to that which would be occupied by coke of equivalent heat value, permits an increased charge of iron ore and limestone to the furnace thus increasing the smelting capacity of the blast furnace.

In preparing the pulverized coal for injection into the furnace, the pulverizer is operated under high pressure conditions so that the pressure of the coal being injected will be greater than the pressure prevailing in the lower portion of the furnace. The carrier air is preheated to provide for drying the coal by vaporizing the moisture in the coal. The vaporized moisture may be vented from the coal preparation system or introduced into the blast furnace. The coal and carrier air discharged from the pulverizer is delivered to coal and air separators positioned adjacent the furnace with a major portion, for example 80%, of the air being recirculated to the pulverizer. The remainder, i.e. a minor portion (20% in the example), of the separated air may be vented to remove the water vapor therein, or recombined with the separated pulverized coal for injection into the furnace. In effect, the pulverized coal system is substantially of the direct fired type, where the pulverizer is operated as long as fuel is required for the furnace, but with the proportionate amount of air mixed with the pulverized coal for delivery to the combustion space of the furnace being only a fraction of the air to coal ratios usually employed in pulverizer operations. Such a pulverized coal system is sometimes known as a semi-direct arrangement, and is particularly advantageous in an application of pulverized coal to a blast furnace where a minimum amount of low temperature injection air is desirable.

Since the fuel requirements to the blast furnace will vary from time to time, as for example due to a local upset in the blast furnace, it may be necessary to remove individual pulverized coal injectors from operation. Such removal from service may be automatic or manual and will require the introduction of a purging flow of air to remove pulverized coal from the individual coal injector. The flow of purging air through the injector will be continued to cool the injector elements and to prevent a backflow of molten slag or high temperature blast air or gas into the coal injection system.

In the embodiment of the invention illustrated in the drawings, the pulverized fuel system is arranged to serve a blast furnace where one pulverizer supplies the pulverized coal for one furnace. In many installations it will be both desirable and necessary to provide a plurality of pulverizers for each blast furnace, to insure the requisite flexibility of operations. Sometimes it will be desirable to provide one or more additional pulverizers tied into a common fuel supply system, this equipment being used for stand-by purposes, as when a pulverizer is withdrawn from service for maintenance purposes.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

In the drawings:

FIG. 1 is a schematic elevation, partly in section, of a pulverized coal supply system as applied to a blast furnace according to the invention;

FIG. 2 is an enlarged plan of the blast furnace with the pulverized coal injection system, as viewed from line 2—2 of FIG. 1; and,

FIG. 3 is a further enlarged schematic elevation of the pulverized coal injection system of the invention.

In the illustrated embodiment of the invention shown in FIG. 1, a single pulverizer **10** provides pulverized coal through a semi-direct supply system for use in a blast furnace **11**. In some installations it may be desirable to use a plurality of pulverizers, and/or provide standby pulverizing equipment to permit servicing equipment without seriously penalizing output. Whether one or more pulverizers are used, the coal from the pulverizers will be separated from the carrier medium in a separating zone **12** adjacent the blast furnace, with a major portion of the carrier air being recycled to the pulverizer **10** for reuse. The recycled carrier air, with the required make-up air, is used as a carrier medium for transportation of the pulverized coal to the separating zone. The remaining, minor portion of the separated carrier air may be used to inject the pulverized coal into the blast furnace.

Referring particularly to FIG. 1 of the drawings the blast furnace **11** illustrated is of the usual or conventional construction wherein provisions are made for the delivery of iron ore, coke and flux (such as limestone) to the upper end of the blast furnace. The charge of solid materials so introduced fills the blast furnace **11** and as the iron is smelted and tapped from the tap hole **13**, fresh supplies of iron ore, coke and flux are delivered through suitable pressure sealing valves into the top of the furnace. Since the equipment for charging a blast furnace is well known in the art, this structure is not illustrated in the drawings.

As is usual in blast furnace construction the lower portion of the furnace is provided with a plurality of tuyeres **14** for the introduction of the high temperature, high pressure blast air. The lower portion of the blast furnace is also provided with a port 15 immediately below the level of the tuyeres 14 for the removal of slag.

As shown, high pressure air is compressed in a suitable compressor, such as an axial flow compressor 16. A major portion of the high pressure air, which may be at a pressure of as much as 40 p.s.i. is passed through a duct 17 to known regenerative heaters or stoves 18 which are heated by the combustion of suitable fuel. In such heaters all of the air or some portion of it is passed periodically through the stoves to absorb heat stored in the regenerative material by passage of hot combustion gas therethrough. The hot air which may reach a temperature of 2600° F. is blended with high pressure air directly from the compressor 16 and then passed through a duct 20 to a header 21 encircling the lower portion of the blast furnace 11. Blending provides a controlled and more uniform temperature of blast air to the blast furnace during the period in which each of the regenerative air heaters gives up its stored heat to the air. The header is connected with each of the tuyeres 14 of the furnace by individual goosenecks or pipes 22 for the injection of the blast air into the charge, or burden, within the furnace.

In the present invention some of the fuel required for the reduction of the iron ore is provided in the form of pulverized coal. The pulverized coal is substituted for some of the relatively expensive coke in the blast furnace charge, generally on a pound for pound basis. As shown in FIG. 1 the pulverizer 10 is located at a convenient position adjacent the blast furnace 11 and is supplied with raw coal and carrier air for preparation of the pulverized coal and its subsequent use in the blast furnace. Since, as hereinafter described, the pulverized coal is delivered to the furnace under high pressure conditions the pulverizer and its accessories are operated under a superatmospheric pressure of the order of 40 to 60 p.s.i. Under these conditions, the raw coal delivery for the pulverizer will include pressurized raw coal containers, which are provided with suitable valves and sealing means for pressurization of the raw coal therein.

As shown in FIG. 1 the uppermost hopper 23 is open to the atmosphere, with raw coal delivered thereto by any convenient means, such as by a belt conveyor or an overhead crane (not shown). Advantageously the raw coal supply system is automated. The bottom outlet from the hopper 23 is provided with a discharge spout having a coal gate 23A and a tightly closing bell type valve 24 which is positioned immediately above an intermediate closed tank 25 which is also provided with a suitable valve 26 at the bottom thereof capable of withstanding the high pressure of the pulverizing system. The intermediate tank 25 opens to a lower bin 27 which in turn is provided with a valve 28 and a discharge duct 30 leading directly to a feeder 31 positioned on the side of the pulverizer 10.

The coal delivery system illustrated is of the general type shown in U.S. Patent 2,511,017, may be automatically regulated and is arranged for the continuous controlled delivery of raw coal to the pulverizer under high pressure operating conditions.

The pulverizer illustrated may be of the type shown in U.S. Patent 2,275,595 which is of the air-swept type supplied with carrier medium, such as air, delivered thereto from a blower 32. The blower receives recirculated carrier air, at a temperature of for example 220° F. with make-up air which may be heated to the order of 1440° F. in a tubular air heater 33. The make-up carrier is delivered to the heater 33 through a pipe 35 connected with the discharge side of a booster compressor 36. The compressor 36 may be of the axial flow type with its inlet connected to the duct 17 to receive high pressure air from the compressor 16. An indirect heat exchanger 29 is provided to remove the heat of compression from the air leaving compressor 16 before delivery to booster compressor 36 to reduce the volume of air to be further compressed. The recirculated low temperature air is mixed in a mixing T 34 with the high temperature make-up air discharged through pipe 38 for delivery to the blower 32 and thence to the pulverizer 10. The temperature of the carrier air leaving the pulverizer 10 is controlled to a desired temperature such as 250° F. as by regulating the quantity and temperature of air passed to the mixer 34 from the heater 33. An illustrative temperature of the order of 450° F. entering the pulverizer 10 is suitable for drying a raw coal containing 6 percent moisture during its pulverization. The temperature of the air may be increased or decreased in relationship to an increase or decrease, respectively, of moisture in the raw coal delivered to the pulverizer. The air passing through the air heater 33 is indirectly heated by hot gases produced by combustion of fuel. The fuel may be blast furnace or coke oven gas, or the like, with the products of combustion from the furnace being discharged to atmosphere or to a heat trap.

Referring again to FIG. 1 it will be noted some of the high pressure air from the compressor 36 may pass through a separate purge line 37 for a purpose hereinafter described.

In the following description it will be noted the schematic showing of the invention illustrated in FIG. 1 discloses only one coal and air separating zone 12, while in FIG. 2 four separating zones are shown. The separate elements of each zone in FIG. 2 are designated by the same numerals with corresponding elements in the zone further identified by letters A, B, C and D common to each distinct separating zone.

The pulverized coal prepared in the pulverizer 10 suspended in a stream of carrier air discharges through a plurality of pipes 40. As shown in FIG. 2, each of the four discharge pipes 40A, 40B, 40C and 40D from the pulverizer 10 open to 4 cyclone separators 41A, 41B, 41C and 41D, respectively, positioned adjacent the blast furnace. The cyclone separators are uniformly spaced circumferentially of the blast furnace 11 and each is intended to separate the pulverized coal from its carrier medium. The separated pulverized coal discharges downwardly from each cyclone separator into the associated discharge hoppers 42A, 42B, 42C and 42D, respectively, positioned immediately below each of the corresponding cyclone separators. The separated carrier air discharges upwardly from each of the cyclone separators to associated cyclonic discharge heads 43A, 43B, 43C and 43D, respectively, where each is provided with a tangential carrier air outlet therefrom. Each outlet opens to a pipe 44A, 44B, 44C and 44D, respectively, where the pipes combine adjacent the furnace in a conduit 45 which discharges to the mixer 34 and thence to the inlet of the blower 32.

A minor portion of the separated carrier medium passing through each of the pipes 44A, 44B, 44C and 44D is withdrawn through associated connecting valved pipes 46A, 46B, 46C and 46D, respectively, each of which leads to a mixing T 47 (see FIGS. 1 and 3) positioned beneath the discharge end of each of the pulverized coal hoppers 42. A motor driven pocket feeder or rotary valve 50 serves both as a feeding and sealing mechanism between each of the pulverized coal storage hoppers 42 and the associated mixing T 47. During normal operation the valve 50 serves only as a seal between each of the hoppers 42 and the fuel injection systems hereinafter described. Each of the rotary valves 50 is driven by a variable speed motor for controlled start up for reasons which will hereinafter become apparent, and in normal operation will have a pulverized coal feeding capacity of at least twice the maximum delivery rate of pulverized coal to each of the hoppers 42. In the usual operation of the pulverized coal system pulverized coal will not accumulate in the hopper 42 since pulverized coal is used in the blast furnace substantially as rapidly as it is prepared. Coal will however accumulate in each of the hoppers during pulverizer shut-downs, while the valves 50 have been stopped.

The coal and air mixture leaving each of the mixing T's 47 passes through a duct 51 to a distributor 52 from which a multiplicity of coal pipes 53 lead to each of the tuyeres 14 adjacent the distributors. As shown in FIG. 2 there are four tuyeres 14 served from each of the four distributors 52. It will, of course, be understood that a greater or lesser number of distributors as well as the number of tuyeres served by each distributor can be used, depending on the size of the blast furnace. Each of the pipes 53 leading from the distributor is provided with a nozzle 55 which extends through the tuyere opening directly into the furnace, and is provided with a plug type cut-off valve 54. It will be understood the pulverized coal discharged through the nozzles 55 into the blast furnace may be positioned above or below or to either side of, or directly into, the blast air stream introduced through tuyeres. It is however convenient to discharge the pulverized coal stream through the tuyere opening so as to quickly mix the coal with the blast air within the furnace.

During the usual operation of a blast furnace, conditions may arise wherein it is necessary to reduce the quantity of pulverized coal delivered thereto. Ordinarily the pulverizer will have a load or coal output capacity range of approximately 4 to 1. Under these conditions it may be necessary to shut off one or more tuyeres 14 and the pulverized coal delivery in connection therewith. When this happens it is necessary to protect the fuel injector nozzle and the tuyeres against overheating, and at the same time prevent backup of slag or other materials into the coal pipe 53. Purge air may be used for this purpose.

As shown in FIGS. 1, 2 and 3, high pressure purge air may be passed through the pipe 37 to purge air manifold 56 encircling the blast furnace 11 immediately above the header 21. Each of the distributors 52 may be provided with purge air through a connecting valved pipe 57 leading from the purge air manifold 56 to the pipe 46 on the upstream side of the mixing T 47. (See FIGS. 2 and 3.) The purge air connection will be used when one of the separators 41 and the associated set of tuyeres and burners is taken out of service. If one or less than all of the individual supply pipes 53 leading from a distributor 52 to the tuyeres is removed from service, each of such pipes is provided with purge air delivered through a valved connecting pipe 58. The pipe 58 connects with the pulverized coal pipe immediately below the plug valve 54, one of which is located in each of the pulverized coal pipes 53. With this arrangement each of the coal delivery lines may be supplied with purge air for cleaning and cooling purposes. When necessary or desired all or any of the pipes 53 serving the tuyeres 14 and each of the distributors serving such pipes may be provided with purge air to avoid pluggage or overheating.

As hereinbefore pointed out, it is sometimes desirable to discharge the vent air from the cyclone separators to the atmosphere rather than to the blast furnace 11, as shown in FIG. 1. Under such circumstances the air stream passed through the pipes 46 would be directed to the atmosphere, preferably through wet or dry dust separators to clean the air prior to its atmospheric release. The injection air passed to the mixing T's 47 would then be obtained from the blower 36, as for example from the pipe 37. Under the conditions of venting the moisture laden separated air to the atmosphere, the air quantities used for pulverized coal injection into the blast furnace would then be regulated for most advantageous operating conditions in the blast furnace, and would not be regulated to satisfy the coal moisture conditions within the pulverizing system, as would be necessary in the arrangement of FIG. 1.

In the operation of the apparatus described the pulverizer is supplied with a controlled weight of raw coal and preheated air to remove the surface moisture from the coal during pulverization. Control systems are known wherein a selected substantially uniform rate of raw coal is delivered to the pulverizer, and the rate of air flow to the pulverizer is coordinated with coal flow for a desired coal to air ratio resulting in desirable pulverizing efficiency. See, for example, my copending application S.N. 801,539, now U.S. Patent No. 3,050.018, issued August 21, 1962.

The mixture of coal and air from the pulverizer is delivered in substantially equal quantities to the cyclone separators 41 where the coal and air is separated with the coal passing through the hopper 42 and the sealing valve 50 into the mixing T 47. A major portion of the air discharging from the cyclone separators is returned to the pulverizer for use, with make-up air, as a carrier medium in the pulverizing system. A minor portion of the separated air is vented from the pulverizing system and either used for injecting the pulverized coal into the blast furnace or discharged to the atmosphere, as hereinbefore described.

In the fuel injection system described each of the separators 41 receives a substantially equal share of the total pulverized coal prepared in the pulverizing system, and each of the tuyere pipes 53 normally receives an equal share of the coal and air mixture delivered through pipe 51 to the distributors 52. However, as the pulverized coal and air injection rate through any one of the tuyeres 14 is dependent, at least to some extent, upon the pressure existing in the blast furnace adjacent the tuyere, the distributor 52 tends to inject a larger portion of the fuel through the tuyere wtih the lower back pressure. As the blast air flow will also be higher through the same tuyere or tuyeres, the pulverized coal injection system has a tendency to maintain the fuel to blast air ratio in balance for good combustion conditions within the furnace.

It will be appreciated that operating conditions will change in the blast furnace, sometimes resulting in either general or localized variation in the prevailing furnace pressures adjacent the tuyeres. Under these changing conditions it may be necessary to remove from service one or more of the pulverized coal injectors. Such conditions may be detected by pressure changes in the furnace in the vicinity of the tuyeres, and static differential pressure devices can be used to indicate such conditions for operating usage. For example, the differential pressure between the discharge end of an injector 55 and the corresponding distributor 52 may be used as an operating guide for the manual shut down of one or a group of such injectors. If desired, the same differential pressure can be used as an impulse to automatically shut down one or a group of such injectors. When one or more injectors are shut down, even though for a short period of time, it is desirable to correspondingly and proportionately reduce the rate of air and coal delivery to the pulverizing system, as may be accomplished by manual or automatic devices. When the furnace conditions necessitating the shut down of one or a group of injectors has been corrected, as indicated by the differential pressure or similar devices, the injectors are reinstated in use, with a corresponding correction in the rate of air and raw coal delivery to the pulverizing system. Whenever, an injector or group of injectors is withdrawn from service the air purge system, hereinbefore described, will be in use to maintain the injection system cool and to prevent backup of slag in the pipes.

Whenever the fuel injection is shut down, for any reason, the raw coal feeder 31 and the valves 50 are stopped. The pulverizing system, including the pulverizer will contain coal which will be delivered to the separators 41 and accumulate in substantially equal quantities in the hoppers 42. In a relatively short period of time, of the order of five minutes, substantially all of the pulverized coal will be in the hoppers and the flow of carrier air through the system will be discontinued. When the system is again started the stored pulverized coal should be removed from the hoppers 42 at a relatively slow rate so that the blast furnace is not flooded with fuel. This is accomplished by a selected pattern of starting the rotation of the seal valves 50, where the driving motors are arranged for slow starting speed. When the hoppers 42 are again empty and the pulverizing system is providing pulverized coal at the normal rate the motor speed is increased so that the sealing valves 50 again operate as a seal mechanism and not as a feeder.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form and mode of operation of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. The process of firing a blast furnace with pulverized coal which comprises the steps of preparing a mixture of pulverized coal and carrier air in a pulverizing zone at a pressure sufficiently high to overcome the combined static pressure within said furnace and the pressure drop through the entire conveying system between said pulverizing zone and said furnace, maintaining said prepared mixture in a predetermined air to coal ratio, separating the carrier air from the pulverized coal of said mixture, and injecting the pulverized coal into said blast furnace in a plurality of streams of high pressure air at an air to coal ratio less than the ratio in said pulverizing zone.

2. The method of operating, in conjunction with a blast furnace, a coal preparation and conveying system including a pulverizing zone and a separating zone comprising the steps of introducing coal into said pulverizing zone, entraining pulverized coal in a stream of carrier air in said pulverizing zone, separating said pulverized coal from said carrier air in said separating zone, circulating said carrier air in a continuous cycle through said pulverizing zone and said separating zone at a pressure sufficiently high to overcome the cumulative static pressure within said blast furnace and the pressure drop through said conveying system, withdrawing a minor portion of said carrier air from said cycle for use in conveying the separated pulverized coal to said blast furnace, and introducing into said cycle a quantity of heated make-up air equal to the quantity of said minor portion of said carrier air.

3. The method of operating, in conjunction with a pressurized blast furnace, a coal preparation and conveying system including a pulverizing zone and a separating zone comprising the steps of introducing coal into said pulverizing zone, entraining pulverized coal in a stream of carrier air in said pulverizing zone, separating said pulverized coal from said carrier air in said separating zone, circulating said carrier air in a continuous cycle through said pulverizing zone and said separating zone at a super-atmospheric pressure sufficiently high to overcome the cumulative static pressure within said blast furnace and the pressure drop through said conveying system, withdrawing a minor portion of said carrier air from said cycle downstream of said separating zone in a carrier air flow sense for use in conveying the separated pulverized coal to said blast furnace, and introducing into said cycle a quantity of heated make-up air equal to the quantity of said minor portion of said carrier air further downstream of said separating zone and upstream of said pulverizing zone.

4. Apparatus for injecting pulverized coal into a blast furnace having a plurality of circumferentially spaced tuyeres positioned in the lower portion thereof comprising means for introducing a stream of high temperature air through said tuyeres into said blast furnace, and means for injecting pulverized coal into said blast furnace including a pulverizer, means for delivering a controlled flow of coal to said pulverizer, means for delivering drying and carrier air to said pulverizer at a pressure sufficiently high to overcome the cumulative static pressure in said furnace and the pressure drop through said pulverized coal injection means, a coal and air separator, means for delivering a mixture of pulverized coal and air to said separator, means for returning a major portion of the separated air from said separator to said pulverizer, a coal and air mixer located beneath said separator, means for passing air through said mixer to entrain pulverized coal from said separator and to inject said air and coal mixture into said blast furnace adjacent each of said tuyeres.

5. Apparatus for injecting pulverized coal into a blast furnace having a plurality of circumferentially spaced tuyeres positioned in the lower portion thereof comprising means for introducing a stream of high temperature air through said tuyeres into said blast furnace, and means for injecting pulverized coal into said blast furnace including a pulverizer, means for delivering a controlled flow of coal to said pulverizer, means for delivering high pressure hot air to said pulverizer as a drying and carrier medium, a coal and air separator, means for delivering a mixture of pulverized coal and air to said separator, means for passing a minor portion of said air through a mixer to entrain pulverized coal from said separator, a distribution system for dividing the entrained pulverized coal into a plurality of streams equal in number to the number of said tuyeres, and means for conveying each of said streams to a corresponding one of said tuyeres for injection into said blast furnace.

6. Apparatus for injecting pulverized coal into a blast furnace having a plurality of circumferentially spaced tuyeres positioned in the lower portion thereof comprising means for introducing a stream of high temperature air through said tuyeres into said blast furnace, and means for injecting pulverized coal into said blast furnace including a pulverizer, means for delivering a controlled flow of coal to said pulverizer, means for delivering drying and carrier air to said pulverizer at a pressure sufficiently high to overcome the cumulative static pressure in said furnace and the pressure drop through said pulverized coal injection means, a coal and air separator, means for delivering a mixture of pulverized coal and air to said separator, means for discharging air from said separator with a major portion of siad air returned to said pulverizer, a coal and air mixer positioned beneath said separator, means for passing a minor portion of said separated air through said mixer to entrain pulverized coal from said separator, and a distribution system for dividing the entrained pulverized coal into a plurality of streams equal in number to the number of said tuyeres, and means for conveying each of said streams to a corresponding one of said tuyeres for injection into said furnace.

7. Apparatus for injecting pulverized coal into a blast furnace having a plurality of circumferentially spaced tuyeres positioned in the lower portion thereof for the introduction of blast air into said blast furnace comprising means for injecting pulverized coal into said blast furnace including an air-swept pulverizer, means for delivering a controlled flow of raw coal to said pulverizer, means for passing a flow of high pressure carrier air through said pulverizer to entrain pulverized coal, a coal and air separator positioned adjacent said blast furnace, means for passing the carrier air with entrained pulverized coal from said pulverizer to said separator, rotary seal means at the bottom of said separator for the discharge of pulverized coal therethrough as the coal is separated from the carrier air, means for entraining said separated pulverized coal in a stream of high pressure injection air, means for discharging a plurality of substantially equal streams of injection air and coal into said blast furnace, means for stopping the flow of each of said streams in response to a change of pressure within a corresponding localized portion of said blast furnace, and means responsive to flow of said streams to said furnace to proportionally change the flow of raw coal to said pulverizer.

8. Apparatus for injecting pulverized coal into a blast furnace having a plurality of circumferentially spaced

tuyeres positioned in the lower portion thereof for the introduction of blast air into said blast furnace comprising means for injecting pulverized coal into said blast furnace including an air-swept pulverizer, means for delivering a controlled flow of raw coal to said pulverizer, means for passing a flow of high pressure carrier air through said pulverizer to entrain pulverized coal, a coal and air separator positioned adjacent said blast furnace, means for passing the carrier air with entrained pulverized coal from said pulverizer to said separator, a rotary seal at the bottom of said separator for the discharge of pulverized coal therefrom as the coal is separated from the carrier air, means for entraining the pulverized coal from said rotary seal in a stream of high pressure injection air, a distribution system for receiving the mixture of coal and injection air for discharge therefrom in a plurality of substantially equal streams of mixed injection air and coal, pipe means for directing each of said streams of injection air and coal into said blast furnace, a valve in each of said pipe means for stopping flow therethrough in response to a change of pressure within said blast furnace adjacent the furnace discharge end of each pipe means, means responsive to lack of flow through any of said pipe means to proportionally reduce the flow of raw coal to said pulverizer, and means for individually purging each of said pipe means by a flow of cool air therethrough while the corresponding pipe means valve is closed.

9. Apparatus for injecting pulverized coal into a blast furnace having a plurality of circumferentially spaced tuyeres positioned in the lower poriton thereof for the introduction of high temperature blast air into said blast furnace comprising means for injecting pulverized coal into said blast furnace including an air-swept pulverizer, means for delivering a controlled flow of raw coal to said pulverizer, means for passing a flow of high pressure carrier air through said pulverizer to entrain pulverized coal, more than one coal and air separator positioned adjacent said blast furnace, means for passing the carrier air with entrained pulverized coal from said pulverizer to the

separators, a rotary seal at the bottom of each separator for the discharge of pulverized coal therefrom as the coal is separated from the carrier air, means for entraining the pulverized coal from each rotary seal in a stream of high pressure injection air, a main valve for stopping the flow of said high pressure injection air upstream of each rotary seal, a distributor cooperating with each rotary seal for receiving the mixture of coal and injection air and for discharging said mixture in a plurality of substantially equal streams, a plurality of pipes equal in number to the number of said tuyeres for directing each of said streams to a corresponding one of said tuyeres, a valve in each of said pipes for stopping flow therethrough in response to a change of pressure within said blast furnace, and means for selectively and individually purging each distributor and each of said pipes, said last named means including a purging air manifold, a plurality of purging air lines equal in number to the number of said pipes, each of said purging air lines being connected from said manifold to a corresponding one of said pipes at a location downstream of said valve, and a plurality of main purge lines equal in number to the number of said distributors, each of said main purge lines being connected from said manifold to a location between its corresponding main valve and rotary seal.

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