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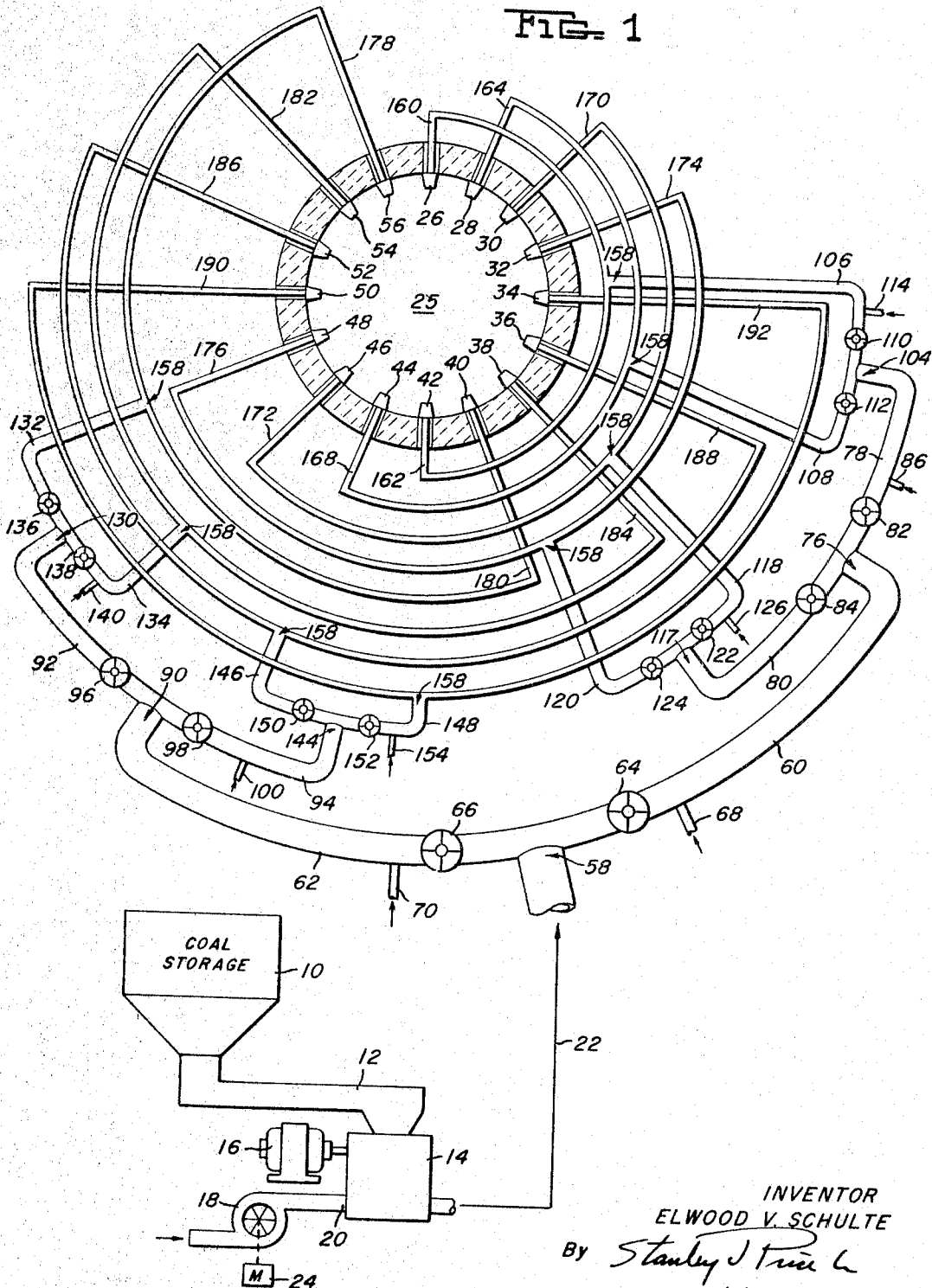
Filed July 2, 1963

E. V. SCHULTE
METHOD AND APPARATUS FOR TRANSPORTING PARTICULATE
MATERIAL TO A METALLURGICAL FURNACE

3,318,686

2 Sheets-Sheet 1

FIG. 1



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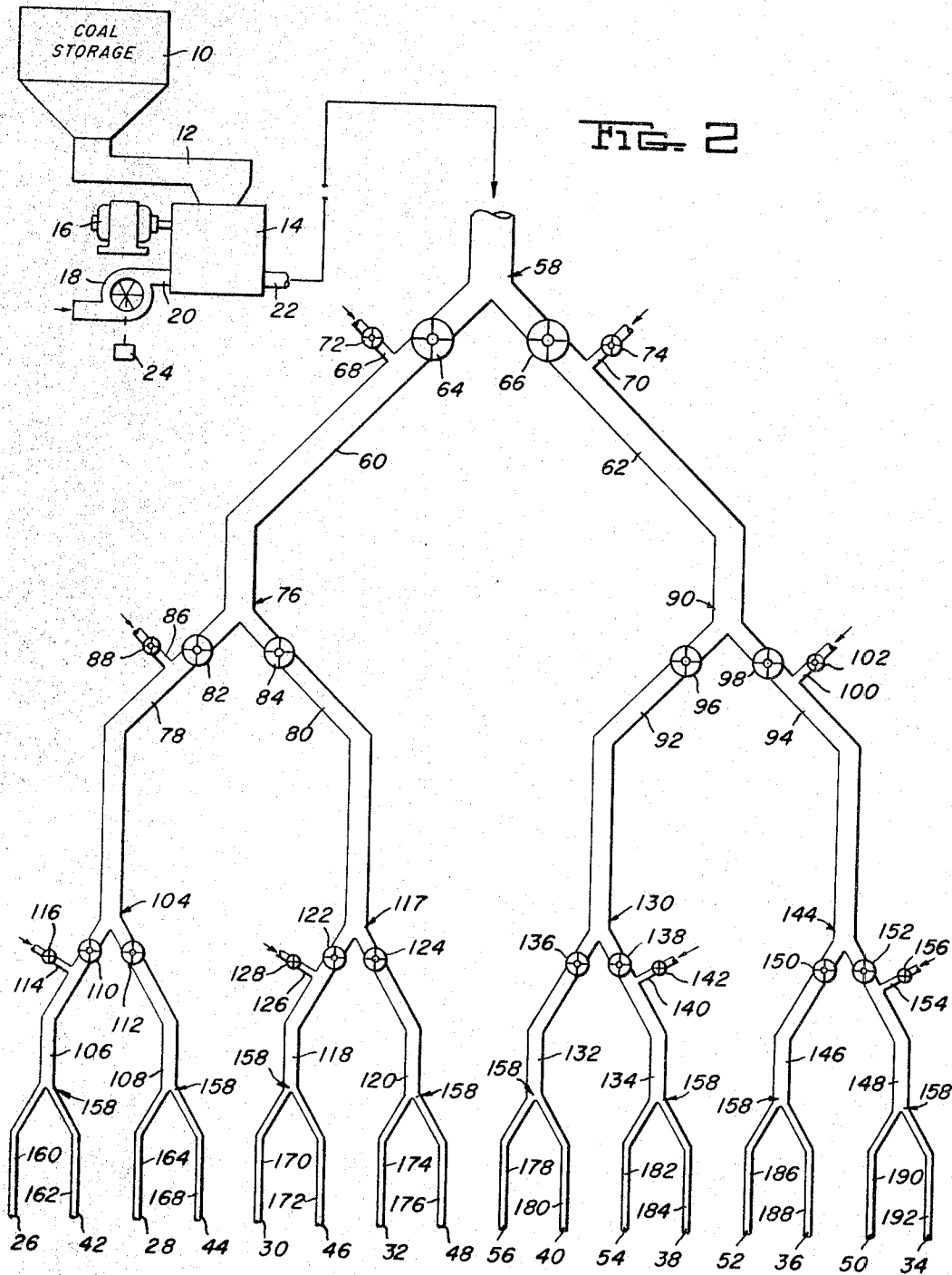
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METHOD AND APPARATUS FOR TRANSPORTING PARTICULATE MATERIAL TO A METALLURGICAL FURNACE

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7 Claims. (Cl. 75—42)

This invention relates to the construction and operation of apparatus for transporting particulate material to a metallurgical furnace and more particularly to a method and apparatus for transporting preselected quantities of coal particles through a plurality of conduits to the tuyere zone of a blast furnace.

Coke, the presently used blast furnace fuel, represents a substantial portion of the costs incurred in the ore reduction process. Numerous attempts have been made in the past to reduce the process costs by either mixing a less expensive fuel with the charge and introducing the mixture into the top of the blast furnace, or injecting a less expensive fuel into the tuyere or hearth zone of the blast furnace. Admixing less expensive fuel with the charge met with little success. The addition of less expensive fuels to the charge presented operating difficulties in that the less expensive fuels hampered the upward flow of blast gas and did not adequately support the burden within the blast furnace.

From the over-all economic standpoint, introducing coal particles into the tuyere zone of the furnace offers the most favorable incentives. It is difficult, however, in injecting coal particles, to accurately control the quantity of the coal introduced into the furnace and control the distribution of the coal particles in the various quadrants of the blast furnace tuyere zone. Accurate quantitative control and controlled distribution of the coal particles are prerequisites to proper blast furnace operation.

It has been found that coal particles can be injected into the tuyere zone of a blast furnace by suspending the coal particles in a gas. An improved rotary coal feeder has been suggested wherein the coal particles are delivered from a feed bin under atmospheric pressure into peripheral pockets of a rotary feeder wheel. The rotary feeder wheel rotates within a casing and transfers the coal particles to a pressurized gas stream. The gas is flowing at a sufficiently high velocity to suspend the particles as a dilute phase fluidized mass. It has been suggested that individual rotary feeders and supply conduits be provided for one or, at most, two injection ports in the side of the blast furnace. This type of installation requires a substantial investment in rotary coal feeders and conveying conduits to the blast furnace.

It has now been found that it is possible to reduce the number of rotary coal feeders and conveying conduits required to transport the same coal-air mixture from a common feeder bin to the injection tuyeres positioned in the side wall of the blast furnace. The coal-air mixture is transported through a common conduit to a splitting device where the mixture is divided into a plurality of separate streams. The separate streams are conducted through individual supply conduits to the respective tuyeres. With this arrangement the number of coal feeders required for each installation is substantially reduced.

To maintain a smooth, continuous operation of the blast furnace it is necessary that the quantity of coal introduced into the furnace be accurately controlled. The coal furnishes the heat necessary to maintain thermal equilibrium in the blast furnace and further supplies the carbon monoxide used for effecting the reduction of the ore to metallic iron. It is readily apparent if the quantity of coal introduced into the blast furnace is not accurately controlled, erratic blast furnace operation would result.

Where a substantial number of coal feeders are used to introduce the coal particles into separate supply conduits, coordinated control of all the coal feeders is required. It has been found with the apparatus herein disclosed that accurate metering of the total quantity of coal fed to the furnace is easily obtained by regulating the flow through the primary conduit.

It has further been found to be highly advantageous to selectively control the flow of coal to certain of the tuyeres.

The conventional blast furnace is cylindrical in shape with tuyeres arranged circumferentially in the blast furnace wall. Coal particles are injected into the tuyere zone through all of the circumferentially spaced tuyeres. When, because of operating conditions present inside the blast furnace, it is desirable to reduce the quantity of coal injected into the tuyere zone of the furnace flow of coal particles through certain of the tuyeres is stopped.

The manner in which the various tuyeres are taken off stream is critical in that the total quantity of coal particles fed to the blast furnace should be evenly distributed throughout the entire cross sectional area of the tuyere zone. Otherwise, one section of the tuyere zone would have an excess of coal particles fed thereto and another section would have an insufficient amount of coal particles fed thereto. Uneven distribution of the fuel in the tuyere zone could result in uneven temperature gradients in the blast furnace. Uneven distribution of fuel could further cause excess reducing gas to flow upwardly through one section of the furnace and insufficient reducing gas to flow upwardly through another section of the furnace. Uneven distribution of sufficient quantities of fuel in the tuyere zone would result in erratic blast furnace operation and an inferior metal product. The apparatus herein disclosed includes means for stopping the flow of particulate coal to certain of the tuyeres when it is desired to reduce the amount of coal fed to the blast furnace. The selective control to the various tuyeres of the blast furnace provides for uniform distribution of the coal particles within the tuyere zone of the blast furnace.

Briefly, the invention includes a coal feeder that transfers preselected quantities of coal to a gas stream. The gas stream is flowing at a sufficiently high velocity to suspend the coal particles therein and convey the suspended coal particles as a fluidized mass. The gas stream with the suspended coal particles is transported through a common conduit to divider means where the coal is split into a plurality of streams containing substantially equal amounts of coal. The streams are transported through separate conduits to circumferentially spaced tuyeres in the blast furnace side wall. Valve means are included to close certain of the supply conduits and thereby channel the coal to selected sections of the tuyere zone. Means are provided for purging the supply conduits with a purge gas after the flow of coal particles therethrough has stopped. The gas used to purge the supply conduits may be either air or an inert gas. Throughout the specification the purge gas will be designated an inert gas. It should be understood, however, that air can also be used as the purge gas. The velocity of the gas stream and the amount of coal fed to the gas stream may be regulated to further control the amount of coal periodically fed to the blast furnace. It is now possible with the herein disclosed invention to supply preselected quantities of coal to preselected portions of the tuyere zone for uniform distribution of the coal particles in the blast furnace.

Accordingly, an object of this invention is to provide a method and apparatus for supplying coal particles to a substantial number of blast furnace tuyeres from a single coal feeder.

Another object is to provide a method and apparatus for accurately controlling the quantity of coal transported

to the tuyere zone of a blast furnace and for delivering the coal particles to the blast furnace in a manner that the coal particles are uniformly distributed within the blast furnace tuyere zone.

These and other objects and advantages of this invention will be more completely disclosed and described in the following specification, the accompanying drawings and the appended claims.

In the accompanying drawings there is shown for purposes of illustration one form which the invention may assume in practice.

In the drawings:

FIGURE 1 is a schematic representation of a transportation and distribution means for particulate coal that is transported to a blast furnace.

FIGURE 2 is a schematic representation of the distributors for the pulverized coal.

Referring to FIGURE 1, there is illustrated a coal storage hopper 10 with a conduit 12 extending therefrom and to a coal feeder 14. The storage hopper 10 is preferably arranged to supply particulate coal by gravity through conduit 12 to the coal feeder 14. A variable speed motor 16 is arranged to drive the coal feeder 14 at preselected speeds.

The coal feeder 14 may be a positive displacement type of coal feeder as is described in Patents 2,750,233 and 2,750,234. The coal feeder described in the above-mentioned patents includes a casing enclosing a gear shaped rotor. Coal is fed radially to the gear shaped rotor at atmospheric pressure and the openings or pockets in the rotor are filled with particulate coal. The rotor rotates through approximately 180° where a conduit, arranged substantially parallel to the axis of the rotor, supplies pressurized air to the coal feeder casing. The air ejects the coal from the pockets aligned with the conduit and conveys the coal in a fluidized state from the coal feeder to the blast furnace at a preselected pressure and velocity. The coal particles are thus fluidized in the pressurized air and are transported to the blast furnace in this fluidized state.

A blower or compressor 18 has its outlet conduit 20 connected to the coal feeder 14 and is arranged to provide the pressurized air to coal feeder 14 to fluidize the particulate coal and conduct the particulate coal in a fluidized state from the coal feeder 14 to the main conduit 22. The compressor 18 has a variable speed motor 24 associated therewith to provide air at a preselected pressure for the coal feeder 14. Thus, both the coal feeder 14 and the compressor 18 may be regulated to supply a preselected quantity of particulate coal and air in a fluidized state.

In FIGURE 1 a plan view of the system employed to distribute the coal particles in the air carrier to blast furnace 25 is schematically illustrated. The fluidized coal is preferably delivered to the existing hot blast tuyeres in the blast furnace. For example, the blast furnace illustrated in FIGURE 1 has sixteen tuyeres numbered in a clockwise direction 26 to 56 inclusive. The tuyeres 26-56 are arranged symmetrically about the blast furnace 25 and fluidized particulate coal may be supplied to all or some of the tuyeres 26-56 as required by the conditions of the reduction process within the blast furnace 25.

In FIGURE 2 the distribution system for the fluidized coal is schematically illustrated in elevation. The main supply conduit 22 lifts the fluidized coal upwardly through the upwardly extending portion of main conduit 22 and introduces the fluidized coal into a first splitter or distributor 58 indicated schematically by the inverted arrangement in the main supply conduit 22. The splitter or distributor 58 is preferably the type that will distribute equal amounts of fluidized coal into two branch conduits.

Two equal streams of fluidized coal are delivered from main conduit 22 by means of splitter 58 to a pair of primary branch conduits 60 and 62. Adjacent the split-

ter 58 each of the primary branch conduits 60 and 62 has a control valve 64 and 66 positioned therein. Downstream of control valves 64 and 66 the primary branch conduits 60 and 62 have inert gas inlet conduits 68 and 70 connected thereto. The inert gas conduits 68 and 70 have normally closed control valves 72 and 74 that control the flow of inert gas therethrough. A suitable supply of inert gas at preselected pressures is provided for the inert gas conduits 68 and 70.

The primary branch conduit 60 conducts one half of the fluidized particulate coal supplied to main conduit 22 from coal feeder 14 to a splitter or distributor 76 which is similar to the distributor or splitter 58 in main conduit 22.

The splitter or distributor 76 further divides the fluidized coal in primary branch conduit 60 into substantially equal amounts and distributes the equal amounts to secondary branch conduits 78 and 80. Valves 82 and 84 are positioned in secondary branch conduits 78 and 80 downstream of the splitter 76 and are arranged to close the respective secondary branch conduits 78 and 80. The secondary branch conduit 78 has an inert gas inlet conduit 86 connected thereto downstream of the valve 82. A normally closed control valve 88 is positioned in inert gas conduit 86 and controls the flow of inert gas through conduit 86 to the secondary branch conduit 78.

The primary branch conduit 62 terminates at a distributor or splitter 90 which divides the fluidized coal stream flowing through primary branch conduit 62 into two equal streams which flow into secondary branch conduits 92 and 94. Both secondary branch conduits 92 and 94 have control valves 96 and 98 therein arranged to control the flow through the respective secondary branch conduits. An inert gas inlet conduit 100 is connected to secondary branch conduit 94 downstream of valve 98 and has a valve 102 therein arranged to control the flow of inert gas into the secondary branch conduit 94.

The secondary branch conduit 78 terminates at a splitter device 104. Tertiary branch conduits 106 and 108 are connected to the splitter device 104 and are arranged to receive equal amounts of fluidized particulate coal from secondary branch conduit 78. Both tertiary branch conduits 106 and 108 include valves 110 and 112 to control the flow of fluidized coal therethrough. The tertiary branch conduit 106 has an inert gas inlet conduit 114 connected thereto downstream of valve 110. A control valve 116 is positioned in inert gas inlet conduit 114.

The secondary branch conduit 80 similarly terminates in a splitter device 117 and supplies equal amounts of fluidized particulate coal to tertiary branch conduits 118 and 120. Valves 122 and 124 are positioned in tertiary conduits 118 and 120 to control flow therethrough. An inert gas inlet conduit 126 is connected to tertiary conduit 118 downstream of valve 122 and includes a control valve 128.

Secondary branch conduit 92 similarly terminates in a splitter device 130 and equal amounts of fluidized coal are conducted from secondary branch conduit 92 to tertiary branch conduits 132 and 134. Valves 136 and 138 are positioned in tertiary branch conduits 132 and 134 and control flow therethrough. An inert gas inlet conduit 140 is connected to conduit 134 downstream of valve 138 and includes a control valve 142.

The secondary branch conduit 94 is connected to a splitter device 144 and equal amounts of fluidized particulate coal are conveyed from secondary branch conduit 94 to tertiary branch conduits 146 and 148. The tertiary branch conduits 146 and 148 have valves 150 and 152 therein. Tertiary branch conduit 148 has an inert gas inlet conduit 154 connected thereto downstream of the valve 152. A control valve 156 in gas conduit 154 controls flow of inert gas through conduit 154 to tertiary branch conduit 148.

All of the tertiary branch conduits 106, 108, 118, 120, 132, 134, 146, and 148 are connected at their discharge

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ends to splitter devices which supply equal amounts of fluidized particulate coal to supply conduits connected to the branches of the respective splitter devices. For convenience the latter splitter devices are all identified by the numeral 158. The supply conduits are numbered in even numbers consecutively from left to right as supply conduits 160-190. The respective tuyeres supplied by the supply conduit are designated directly below the respective supply conduits in FIGURE 2. Supply conduit 160 provides fluidized particulate coal for tuyere 26 and supply conduit 162 supplies fluidized coal for tuyere 42. It should be noted that the tuyeres supplied from a common tertiary conduit are diametrically opposed as viewed in FIGURE 1. For example, tuyere 26 is diametrically opposed from tuyere 42 and both tuyeres 26 and 42 are supplied from tertiary conduit 106 through supply conduits 160 and 162. A similar arrangement is provided for all of the remaining tuyeres and supply conduits. The arrangement whereby a common tertiary branch conduit supplies a pair of diametrically opposed tuyeres is readily apparent in FIGURE 1. Thus, the closing of a valve in one of the tertiary conduits stops the flow of fluidized coal to a pair of diametrically opposed tuyeres.

It should also be noted that the tertiary branch conduit 148 supplies fluidized particulate coal to a pair of tuyeres that are arranged in approximately transverse diametrical relation to the pair of tuyeres supplied by tertiary conduit 106. With this arrangement it is possible to stop the flow of particulate coal to four tuyeres spaced 90° from each other by closing two valves. The relationship of the various supply conduits and tertiary branch conduits is clearly illustrated in the plan view schematic representation in FIGURE 1. It should be understood that if a blast furnace has a lesser or greater number of tuyeres, the distributor and control arrangement illustrated in FIGURES 1 and 2 could be modified to provide for the distribution and operation hereinafter described.

The various conduits or headers are preferably sized to provide the following conditions. To suitably transport the particulate coal through the various conduits in the distribution system, the coal-air mixture must remain fluidized as it is transported from the coal feeder 14 through the main conduit. The velocity of the air and coal and the ratio of air and coal in the main conduit 22 must be at least sufficient to maintain the coal in a fluidized state. For exemplary purposes, it will be assumed that the maximum amount of coke that will be replaced in the blast furnace by the coal would be 30 percent of the total coke used in the ore reduction process. Thus, when 15 percent of the coke is being replaced by coal, the velocity in the main conduit 22 between coal feeder 14 and the primary branch conduits 60 and 62 will be such that it is safely above the velocity required to keep the coal in a fluidized state. If the full 30 percent replacement of coke is desired, then the velocity of the coal-air mixture in the main conduit will be increased substantially above the minimum designated to maintain the coal in a fluidized state.

To supply the maximum amount of coal to the blast furnace, all the valves in the primary, secondary, and tertiary branch conduits are opened. All the valves in inert gas conduits are closed. If it is desired to reduce the amount of coal fed to the blast furnace without shutting off any of the flow to any of the tuyeres, the rate of feed of coal through the coal feeder 14 and the amount of air supplied to the coal feeder 14 is reduced to maintain a non-explosive coal mixture and retain the coal in a fluidized state. A nominal air velocity in the pipelines should be kept above a minimum of 25 feet per second during operation. The coal feeder 14 and compressor 18 can be regulated by the variable speed motors 16 and 24 to continually reduce the rate of coal flow and air velocity until approximately 15 percent of the coke would be replaced by particulate coal fed into the blast furnace through the tuyeres. Any further reduction in the air flow through the pipeline would result in the deposit of coal particles in the various conduits with ultimate plugging of the supply conduits.

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If it is desired to further reduce the amount of coal fed to the blast furnace, the rate of feed of the coal from feeder 14 can be further reduced, but the air velocity must not be reduced below a predetermined minimum. The further reduction in the rate of coal feed to the air stream results in a more dilute phase fluidized stream with a sufficient air velocity to maintain all the coal particles suspended in the air stream. It is therefore readily apparent from an operability standpoint why it is necessary to maintain the coal particles in a dilute phase fluidized state while the particles are being transported from the coal feeder 14 to the blast furnace 25.

If it is desired to reduce the coal flow beyond the 50 percent reduction by the coal feeder 14 and compressor 18, or if it is desired to stop the flow of coal to certain sections of the blast furnace tuyere zone, the valve 110 in tertiary conduit branch 106 is closed and valve 116 in inert gas conduit 114 is simultaneously opened. The closing of valve 110 stops the flow of fluidized coal to supply conduits 160 and 162 and hence to tuyeres 26 and 42 located on diametrically opposite positions in the side wall of blast furnace 25. The valve 116 in inert gas supply conduit 114 is opened to purge the tertiary conduit 106 and supply conduits 160 and 162. As soon as the conduits are purged of coal and air downstream of valve 110, the flow of inert gas through conduit 114 may be either continued or discontinued depending upon the need to keep the conduits cool and in working condition. If suitable cooling means is provided for the conduits adjacent the respective tuyeres, the valve 116 may be closed. Suitable control means can be provided to simultaneously control the coal feeder 14 and the compressor 18 to either change the coal and air ratio or decrease the rate of feed of both the coal and air to the main conduit 22. It should be understood, however, that the velocity of the mixture flowing through the conduit 22 should be sufficiently high to maintain the coal particles in a fluidized state.

If a further decrease in the coal rate to the blast furnace 25 is desired, or if it is desired to stop the flow of coal to other tuyeres, the tuyeres 34 and 50, which are 90° removed from tuyeres 26 and 42, are taken off stream. To take tuyeres 34 and 50 off stream the valve 152 is closed in tertiary branch conduit 148 and the valve 156 in inert gas conduit 154 is opened to purge the tertiary conduit 148 and the supply conduits 190 and 192. The coal feeder 14 and compressor 18 are adjusted to reduce the amount of coal introduced into the blast furnace.

If a still further decrease in coal is desired, tuyeres 30 and 46 are taken out of service. Tuyeres 30 and 46 are 45° removed from tuyeres 26, 42 and tuyeres 34 and 50 previously taken off stream. The valve 122 in tertiary conduit 118 is closed and the conduit 118 and supply conduits 170 and 172 are purged by means of an inert gas flowing through conduit 126. If it is desired to remove additional tuyeres from service, tuyeres 54 and 38 which are also 45° removed from tuyeres 26, 42, and tuyeres 50, 34 are removed from service. The valve 138 in tertiary branch conduit 134 is closed and valve 144 in inert gas conduit 140 is opened to purge tertiary conduit 134 and supply conduits 182 and 184.

Thus, the flow of coal to the blast furnace 25 has been reduced to one-fourth of its original maximum by first reducing the rate of coal flowing through the main supply conduit 22 and also by shutting off eight of the sixteen individual supply conduits feeding the individual tuyeres. At this point valves 110, 152, 122 and 138 are closed and valves 112, 124, 136, and 150 are open.

To shut off additional tuyeres, the next tuyeres preferably deactivated are 28 and 44. To stop the flow of coal through tuyeres 28 and 44, the valve 82 in secondary branch conduit 78 is closed. It is preferable to close valve 82 in secondary branch conduit 78 rather than valve 112 in tertiary branch conduit 108 in order to prevent the deposition of coal in the secondary branch conduit 78. Automatically with the closing of valve 82, valve 88 in inert gas conduit 86 is opened to purge secondary

branch conduit 78, tertiary branch conduit 108 and supply conduits 164 and 168. If desired, valve 110 in tertiary branch conduit 106 may be opened so that the inert gas entering through conduit 86 will purge all conduits downstream therefrom. With the above discussed valves closed, two-thirds of the fluidized coal that is added to the blast furnace is flowing through the primary branch conduit 62 and one-third of the coal is flowing through the other branch conduit 60.

To stop the flow of coal through another pair of tuyeres, the valve 98 in secondary branch conduit 94 is closed and valve 102 in inert gas conduit 100 is opened. The closing of valve 98 stops the flow of coal to tuyeres 36 and 52. The inert gas entering through conduit 100 purges all conduits downstream therefrom.

With the valve 82 in secondary branch conduit 78 closed and valve 98 in secondary branch conduit 94 closed, one-eighth of the maximum amount of coal expected to be added to the blast furnace is being supplied thereto and is being distributed through the secondary branch conduit 80 and secondary branch conduit 92.

The next tuyeres that are deactivated, if a further reduction in the number of active tuyeres is desired, are 32 and 48. Valve 64 in primary branch conduit 60 is closed and valve 72 in inert gas conduit 68 is opened to purge all the conduits downstream of valve 64. Certain of the valves downstream of valve 64 may be closed or, if desired, all valves downstream of valve 64 may be opened.

It is apparent the closing of valve 66 in primary branch conduit 62 would close the last two remaining tuyeres, i.e., tuyeres 40 and 56. However, in lieu of closing valve 66, the coal feeder 14 could be stopped when the entire coal feeding system is stopped. The compressor 18 could be operated for a sufficient period of time to purge the main supply conduit 22 and the remaining conduits leading to the blast furnace.

It should be noted that in proceeding to reduce the coal flow to the individual tuyeres when the velocity of the coal-air mixture in the conduits decreases below a predetermined satisfactory velocity to maintain the coal particles fluidized in the transport air, it becomes necessary to increase the ratio of conveying air to coal to thereby maintain the desired velocities in these main supply and branch conduits.

As previously described, the initial reduction in the coal fed to the blast furnace 25 is accomplished by reducing the output from coal feeder 14 and the gas volume and pressure from compressor 18 to an extent that the total maximum feed is reduced 50 percent. An alternative procedure would be to maintain the coal feeder 14 and compressor 18 at the preselected settings to supply sufficient coal to replace 30 percent of the coke normally used in the ore reduction process. To reduce the amount of coal below the 30 percent ratio preselected tuyeres are taken out of service, preferably in the order previously discussed. Half of the tuyeres could be removed at the time that one-half of the rate of flow of coal is passing between the coal feeder 14 to the main supply conduit 22. By suitable control means at the closing of valve 110, for example, the coal feeder 14 and compressor 18 would have their output reduced to slow the feeder to one-eighth and would reduce the flow of air from compressor 18 to one-eighth at the same time. In this manner the total flow of coal to the blast furnace 25 would be reduced by one-eighth of its maximum by closing valve 110 and simultaneously reducing the output of coal from coal feeder 14 and, if desired, the output of air from compressor 18.

If further reduction in coal supplied to the blast furnace 25 is desired by the present procedure, valve 152 in tertiary supply conduit 148 would be closed and the flow from feeder 14 and compressor 18 would be further reduced one-seventh. The reduction in both the supply of coal and air to the main supply conduit would con-

tinue in this order until the rates have been reduced to a point approaching the minimum velocity required to maintain the coal particles suspended in the air carrier. From this point the ratio of air to coal could be gradually increased as the flow of coal to additional tuyeres is stopped in order to maintain the reduced quantity of coal in a fluidized state as it travels from the feeder 14 through the main conduit 22. A velocity of between 10 feet per second and 150 feet per second is required to properly remove the coal particles from the rotor ports in coal feeder 14. The various conduits would preferably be sized to give preferred velocities between 20 and 50 feet per second.

The minimum air velocity required to carry coal particles is a variable quantity which varies exponentially with the mass flow rate of coal, with the air density within the pipe at upstream temperature and pressure conditions, and with the coal size. At a given coal rate, the mass flow rate is a function of the pipe diameter. The air density being a function of pressure would vary with the blast furnace pressure and the friction drop in the transfer line. The friction drop varies with pipe length, air velocity and coal velocity. The minimum air velocity is, therefore, highly dependent upon the characteristics of the particular system.

The air velocities should be such that the coal particles will not drop from suspension in the main conduit 22. Because of the expansion of the air as it progresses further through the system the velocities should increase with progression toward the blast furnace provided that the branch lines are sized correctly.

A sixteen tuyere furnace may produce about 1375 net tons of hot metal per day. At an assumed coke rate of 1500 pounds per net ton hot metal the coke consumed per hour would be about 85,800 pounds. The coal rate for 30 percent coke replacement would be about 25,750 pounds per hour and at a 5 percent replacement would be about 4,300 pounds per hour.

Assuming a coal mass velocity of about 118 pounds per square foot per second, the main conduit 22 could be fabricated from 3½ inch schedule 80 pipe to transport coal at 25,750 pounds per hour for 30 percent coke replacement. Assuming the coal particles have a mean diameter of about 0.03 inch and assuming a pressure of 60 p.s.i.g. at the upstream end of the pipe and a temperature of 60° F., the minimum superficial air velocity would be about 32 feet per second. About 600 s.c.f.m. of air would be used. The air-coal ratio would be about 1.45 s.c.f. per pound.

For 5 percent coke replacement, approximately 4,300 pounds of coal per hour is transported through the respective conduits. The mass velocity would be about 19.4 pounds per square foot per second through the 3½ inch main conduit 22. Because the friction drop is much less than at the 30 percent coke replacement a line pressure of about 35 p.s.i.g. is assumed. The minimum superficial air velocity would be about 15 feet per second and the total quantity of air would be about 185 s.c.f.m. The coal-air ratio for a 5 percent replacement would be about 2.6 s.c.f. per pound.

It will be appreciated the above exemplary ratios are for minimum air velocities and it should be understood to maintain the air velocity sufficiently high to prevent the coal particles from dropping out of suspension that the air velocities in the system would be above those set forth.

It should be understood that a suitable control means and instrumentation may be provided to automatically control the respective valves in the distribution system and to simultaneously control the output of the coal feeder 14 and compressor 18.

Although the distributors are illustrated as splitting the stream of coal and air into two streams, it should be understood that suitable splitters could be provided to split a single stream of coal and air into a greater number of streams, such as four or eight streams of coal.

With the above arrangement it is now possible to feed a blast furnace from a single coal feeder. Where, however, a blast furnace with a greater number of tuyeres is contemplated, it may be preferable to utilize a plurality of coal feeders.

According to the provisions of the patent statutes, the principle, preferred construction, and mode of operation of the invention have been explained, and what is now considered to represent its best embodiment has been illustrated and described. However, it should be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A method of injecting particulate coal particles into the tuyere zone of a blast furnace which comprises
 - (a) supplying particulate coal to a coal feeder,
 - (b) supplying a conveying air stream at superatmospheric pressure to said coal feeder,
 - (c) admixing said conveying air stream and said coal particles in said coal feeder to entrain coal particles in said conveying air stream as a fluidized mass of said coal particles suspended in said conveying air stream,
 - (d) introducing said fluidized mass into a primary conduit at a sufficient velocity to maintain said coal particles suspended in said conveying air stream,
 - (e) transporting said fluidized mass through said primary conduit to a first splitter device,
 - (f) maintaining said particulate coal entrained in said conveying air stream as a fluidized mass in said first splitter device,
 - (g) dividing said fluidized mass in said splitter device into two substantially equal and separate streams,
 - (h) transporting each of said separate streams as a fluidized mass through a separate secondary conduit to a second splitter device,
 - (i) maintaining said particulate coal entrained in said conveying air stream as a fluidized mass in said second splitter device,
 - (j) dividing each of said streams into two separate smaller substantially equal substreams,
 - (k) transporting each of said substreams through a tertiary conduit to the tuyere zone of said blast furnace, and
 - (l) introducing said separate substreams from said tertiary conduits into different quadrants of said blast furnace tuyere zone.
2. A method for injecting coal particles into the tuyere zone of a blast furnace as set forth in claim 1 which includes
 - (a) interrupting the flow of at least one of said substreams while said other substreams continue to flow through their respective tertiary conduits thereby controlling the introduction of said coal particles to more than one quadrant of said blast furnace tuyere zone.
3. A method of injecting coal particles into the tuyere zone of a blast furnace as set forth in claim 1 which includes
 - (a) interrupting the flow of at least one of said substreams while said other substreams continue to flow through their respective tertiary conduits thereby controlling the introduction of said coal particles to certain quadrants of said blast furnace tuyere zone, and
 - (b) introducing a gas into said tertiary conduits after the flow therethrough has been interrupted to purge said tertiary conduits of said coal particles.
4. A method of injecting particulate coal particles into the tuyere zone of a blast furnace which comprises
 - (a) supplying particulate coal to a coal feeder,
 - (b) supplying a conveying air stream at superatmospheric pressure to said coal feeder,
 - (c) admixing said conveying air stream and said coal

- particles in said coal feeder to entrain said coal particles in said conveying air stream as a fluidized mass of said coal particles suspended in said conveying air stream,
 - (d) introducing said fluidized mass into a primary conduit at a sufficient velocity to maintain said coal particles suspended in said conveying air stream,
 - (e) transporting said fluidized mass through said primary conduit to a first splitter device,
 - (f) dividing said fluidized mass in said splitter device into two substantially equal and separate streams,
 - (g) transporting each of said separate streams as a fluidized mass through a separate secondary conduit to a second splitter device,
 - (h) dividing each of said streams into two separate smaller substantially equal substreams,
 - (i) transporting each of said separate substreams through a tertiary conduit to a third splitter device,
 - (j) dividing each of said substreams into two separate substantially equal smaller substreams,
 - (k) transporting each of said separate smaller substreams through feed conduits to the tuyere zone of said blast furnace, and
 - (l) introducing said separate smaller substreams from said feed conduits into different quadrants of said blast furnace tuyere zone.
5. Apparatus for selectively injecting particulate material into preselected portions of a metallurgical furnace comprising
- (a) a feeder device,
 - (b) means to supply a conveying air stream at superatmospheric pressure to said feeder device,
 - (c) said feeder device operable to admix preselected quantities of particulate material with conveying air supplied thereto to entrain said coal particles in said conveying air stream as a fluidized mass of said particulate material suspended in said conveying air,
 - (d) conduit means to convey said fluidized mass to said metallurgical furnace,
 - (e) said conduit means including a first splitter means to divide said fluidized mass into more than two substantially equal streams, second splitter means to divide said streams into substantially equal substreams while said particulate material remains suspended in said conveying air streams, and third splitter means to further divide said substreams into smaller substreams while said particulate material remains suspended in said conveying air stream,
 - (f) said conduit means having a plurality of separate outlets arranged around the periphery of said metallurgical furnace for injecting separate streams of said fluidized mass into different portions of said metallurgical furnace, and
 - (g) valve means in said conduit means to close preselected portions of said conduit means to thereby inject streams of said fluidized mass into preselected portions of said metallurgical furnace.
6. Apparatus for selectively injecting particulate material into preselected portions of a metallurgical furnace as set forth in claim 5 which includes
- (a) other conduit means connected to said first conduit means between said valve means and said outlets, said other conduit means operable to supply a gas to portions of said first named conduit means to purge said first conduit means of said particulate material.
7. Apparatus for selectively injecting coal particles into preselected circumferential portions of a blast furnace tuyere zone comprising
- (a) a coal feeder device,
 - (b) means to supply a conveying air stream at superatmospheric pressure to said coal feeder,
 - (c) said coal feeder operable to entrain preselected quantities of coal particles in said conveying air

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- supplied thereto as a fluidized mass of said coal particles suspended in said conveying air,
- (d) conduit means to convey said fluidized mass to said blast furnace,
- (e) said conduit means including splitter means to divide said fluidized mass into more than two substantially equal streams, second splitter means to divide said streams into substantially equal substreams while said particulate material remains suspended in said conveying air streams, and third splitter means to further divide said substreams into smaller substreams while said particulate material remains suspended in said conveying air stream,
- (f) said conduit means having a plurality of separate outlets arranged around the periphery of said blast furnace tuyere zone for injecting separate streams of said fluidized mass into different portions of said blast furnace tuyere zone,
- (g) valve means in said conduit means to close preselected portions of said conduit means to thereby inject streams of fluidized mass into preselected

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- circumferential portions of said blast furnace tuyere zone, and
- (h) means to control the quantity of coal fed to said conduit means and the rate of flow of conveying air introduced into said conduit means to thereby regulate the amount of coal particles injected into preselected circumferential portions of said blast furnace tuyere zone.

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