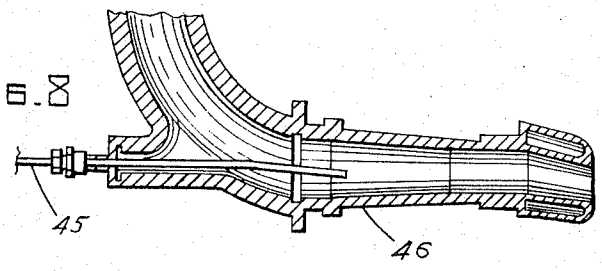
March 5, 1968 L. E. MYLTING 3,371,917

APPARATUS FOR FEEDING FUEL INTO A BLAST FURNACE

Filed Oct. 21, 1965 4 Sheets-Sheet 1

Fig. 8



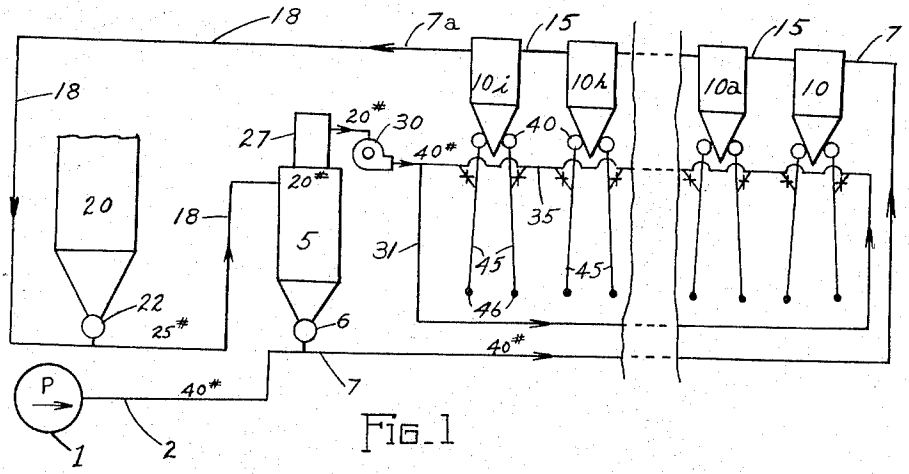


Fig. 1

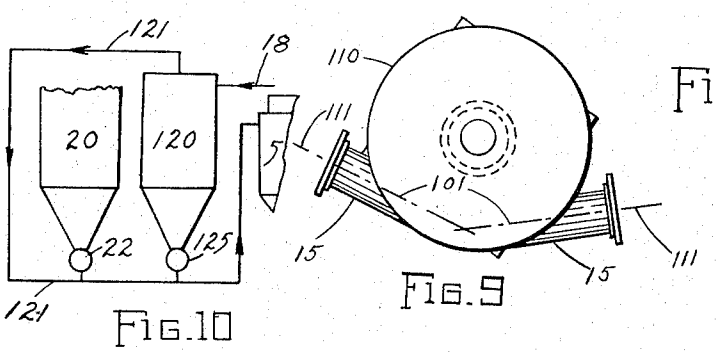
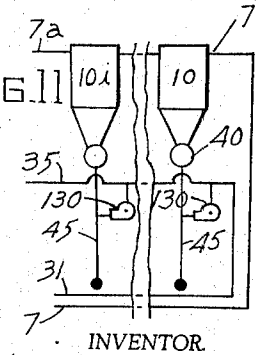


Fig. 10

Fig. 9

Fig. 11



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March 5, 1968 L. E. MYLTING 3,371,917

APPARATUS FOR FEEDING FUEL INTO A BLAST FURNACE

Filed Oct. 21, 1965 4 Sheets-Sheet 2

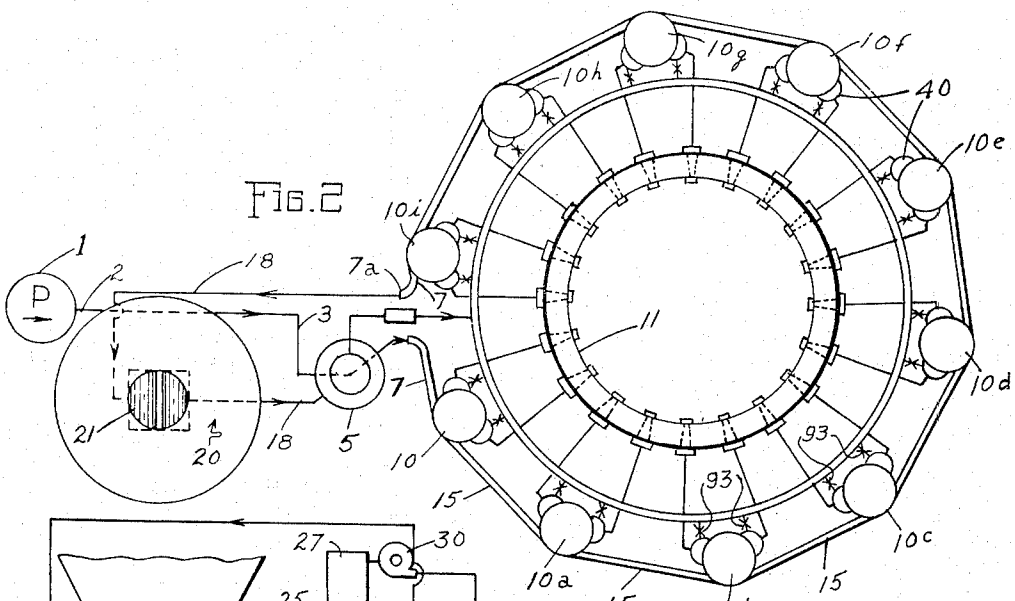


Fig. 2

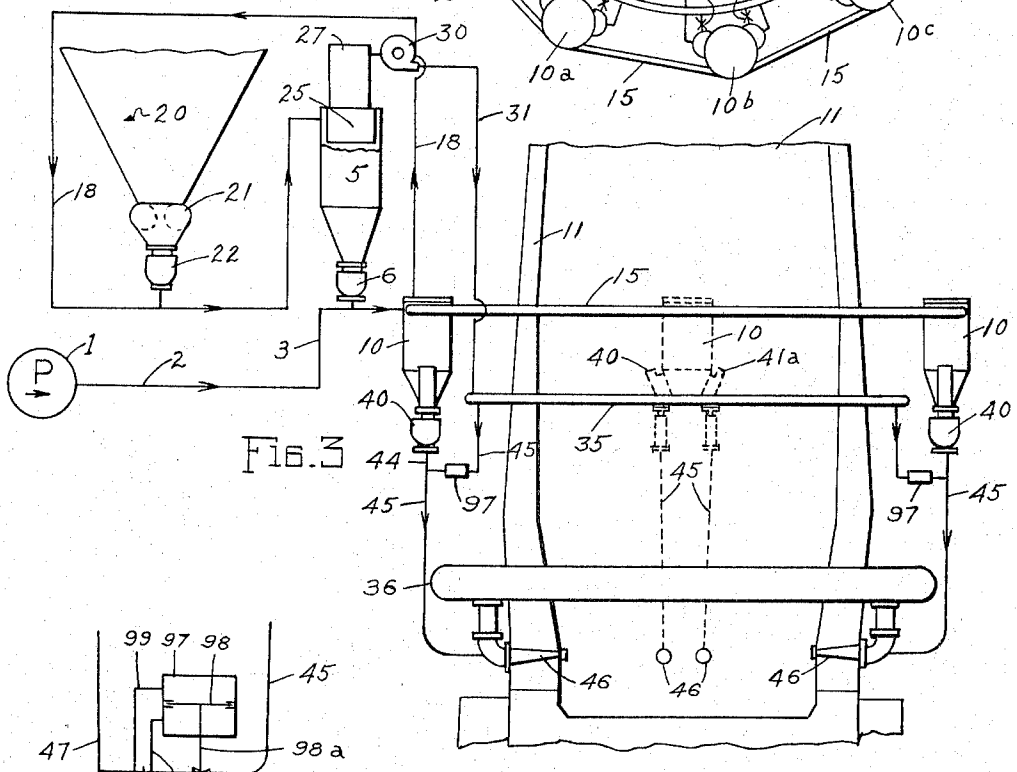


Fig. 3

Fig. 7

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March 5, 1968 L. E. MYLTING 3,371,917

APPARATUS FOR FEEDING FUEL INTO A BLAST FURNACE

Filed Oct. 21, 1965 4 Sheets-Sheet 3

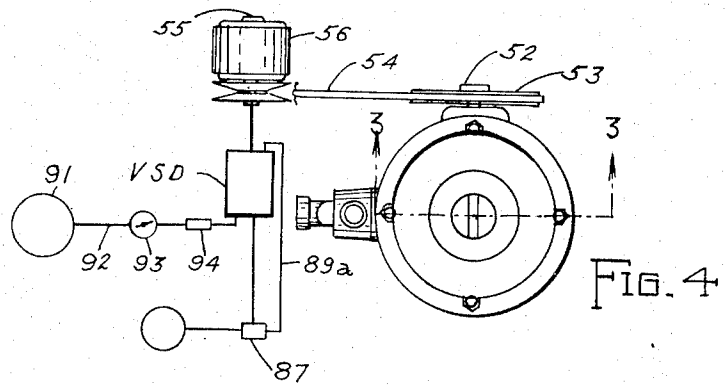


FIG. 4

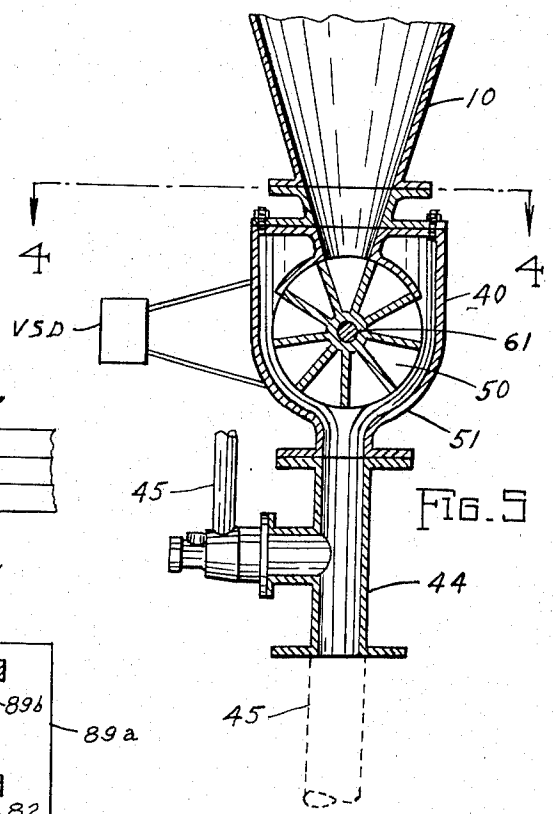


FIG. 5

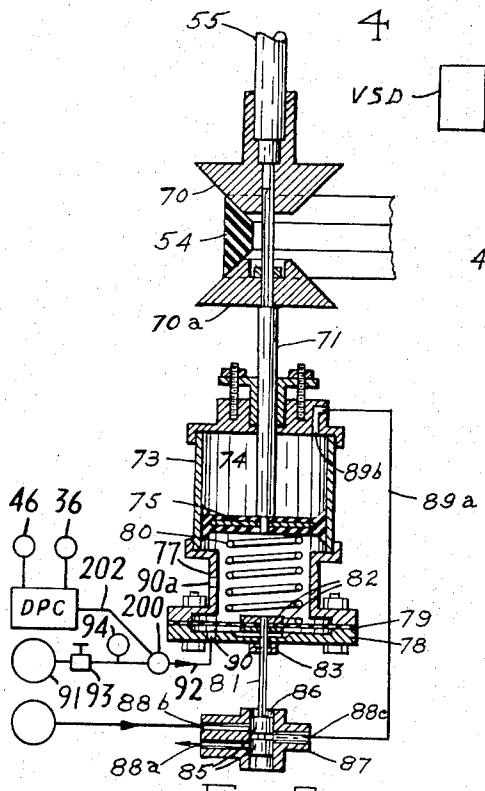


FIG. 6

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March 5, 1968 L. E. MYLTING 3,371,917

APPARATUS FOR FEEDING FUEL INTO A BLAST FURNACE

Filed Oct. 21, 1965 4 Sheets-Sheet 4

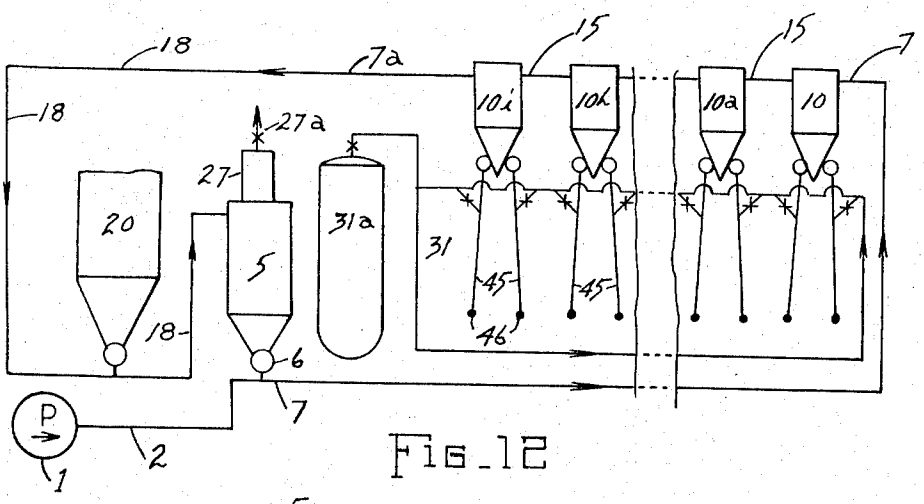


Fig. 12

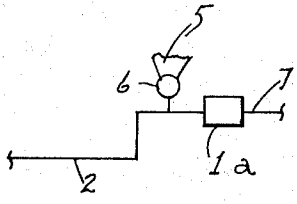


Fig. 13

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3,371,917

APPARATUS FOR FEEDING FUEL INTO A BLAST FURNACE

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Continuation-in-part of application Ser. No. 471,765, June 4, 1965. This application Oct. 21, 1965, Ser. No. 499,744

28 Claims. (Cl. 266—29)

This application is a continuation-in-part of co-pending application Ser. No. 471,765, filed June 4, 1965, for "Apparatus and Method for Feeding Fuel Into a Blast Furnace." That application (Ser. No. 471,765) is a continuation-in-part of application Ser. No. 259,910, filed Feb. 20, 1963, entitled, "Apparatus for Feeding Fuel Into a Blast Furnace," and a continuation of application Ser. No. 288, 849, filed May 31, 1963, entitled, "Method of Feeding Fuel Into a Blast Furnace," both now abandoned. The latter application (Ser. No. 288,849) was a continuation-in-part of application Ser. No. 260,083 filed Feb. 20, 1963, entitled, "Method of Feeding Fuel Into a Blast Furnace."

This invention relates generally to the blast furnace art and is particularly concerned with a method and apparatus for introducing finely divided solid fuel, such as crushed coal or coke, into a blast furnace through its tuyeres.

Until recently pig iron was made in blast furnaces by charging ore, limestone and coke into the top of the furnace to form successive layers. The coke was the only fuel in the charge and served the dual purpose of (1) reducing the FeO to Fe in the zone above the smelting zone and at temperatures ranging between about 1300° F. and about 1475° F., and (2) producing temperatures above about 2300° in the smelting zone.

Efforts have been made over the past twenty years or so to increase the rate of production of pig iron in a blast furnace. One proposal was to increase considerably the gas pressure in the furnace and to accelerate combustion by using oxygen. Another proposal was to introduce a combustible fuel, such as natural or artificial gas or oil, through the tuyeres to replace some of the coke. Another proposal was to combine both of those proposals. While these proposals increased the rate of pig iron production somewhat, they did not materially decrease the cost of producing pig iron and they required new apparatus which was expensive and the operation was also expensive.

It would be economically quite important if the high rate of production, attained when oxygen and oil or gas are used, could be approximately maintained while using a much less expensive fuel than those fluids and while employing apparatus which is less expensive and with which the operation may be readily controlled. Accordingly, this invention aims to satisfy that economic need and attains that object by providing a new method and apparatus of introducing finely divided fuel, such as crushed coal or other solids, through the tuyeres of a blast furnace operating under conventional high pressure and with or without the injection of oxygen and with the use of smaller amounts of coke introduced into the top of the furnace.

The present invention will be better understood by those skilled in the art from the following specification and the accompanying drawings forming a part thereof, in which:

FIG. 1 is a diagrammatic view showing a system for use in carrying out the present method invention;

FIG. 2 is a schematic top plan view of the system of FIG. 1;

FIG. 3 is a fragmentary, schematic view showing the system of FIG. 2 in side elevation;

FIGS. 4 and 5 are, respectively, top plan and vertical sectional views of a rotary feeder for feeding finely divided fuel to one of the tuyere hoppers;

FIG. 6 is a cross sectional view of apparatus suitable for controlling the rate of feed of fuel through the feeder of FIGS. 4 and 5;

FIG. 7 is a diagrammatic showing of means for maintaining a substantially constant air flow from the air bustle into each tuyere of the furnace;

FIG. 8 is a fragmentary, vertical sectional view showing one of the tuyeres and its solid fuel carrying pipe;

FIG. 9 is a top plan view, partly in section, showing the means for supplying the tuyere hoppers with the finely divided solid fuel;

FIG. 10 shows a modification of the system shown in FIG. 1;

FIG. 11 shows another modification of the system shown in FIG. 1;

FIGS. 12 and 13 show other modifications of the system of FIG. 1 which are adapted for use of oxygen enriched air, and oxygen, respectively, instead of air for conveying the fuel through the tuyeres and burning it.

FIGS. 1 to 3 show diagrammatically one form of apparatus embodying the present invention. In those figures, **1** indicates means for discharging air under pressure into conduit means **2**. This conduit means includes a pipe **3** which extends beneath a distributing hopper **5** provided with a feeder **6** for feeding finely divided solids into pipe **3**. This pipe **3** communicates with one end of a cylindrical tube **7** which opens tangentially into the first tuyere hopper **10** of a plurality of similar hoppers **10** to **10*i***, inclusive, positioned in a circle around a blast furnace **11** and a similar tube **7*a*** opens tangentially out of the last hopper **10*i***. The said first hopper **10** is connected to the next adjacent tuyere hopper **10*a*** by a cylindrical tube **15** and each successive tuyere hopper is similarly connected to the tuyere hopper adjacent to and beyond it by similar tubes **15**. Each tube **15** opens tangentially out of one tuyere hopper and tangentially into the next tuyere hopper in the direction of air flow therethrough. The tubes **7** and **7*a*** and all the tubes **15** have their longitudinal axes disposed in substantially the same horizontal plane and the projections of those axes intersect in each tuyere hopper at an included angle which is, preferably, less than 180°. When there are twenty tuyere hoppers around the blast furnace, each included angle preferably approximates 162° and when there are only ten tuyere hoppers in the circle, the included angle may be about 144°. While these angles are preferred, the included angle may vary depending on the number of hoppers or chambers to be supplied successively with finely divided solid material. If only two hoppers or chambers are to be supplied for such material in succession, the included angle between the cylindrical tubes which conduct the solids-carrying air stream into and through the hoppers or chambers may range from about 170° to about 90°.

The cylindrical tube **7*a*** conducts air tangentially out of the last hopper **10*i*** and into a pipe line **18** which extends below a coarse solid fuel storage hopper **20** provided with rolls or grinders **21** to reduce the size of the fuel and feeder **22** which serves to feed the crushed reground fuel into line **18**.

Pipe line **18** enters tangentially into the cylindrical upper portion of distributing hopper **5**. This hopper is provided with means for separating the solids from the solids-carrying air stream. A suitable means for this purpose is the conventional cyclone separator which includes a cylindrical baffle **25** (see FIG. 3) extending down from the inner side of the top end of the hopper with an air outlet opening through the top end of the

hopper within the baffle. The air outlet portion 27 of hopper 5 is connected to a means for increasing the pressure of the air escaping from hopper 5. Suitable apparatus for this purpose is a conventional air compressor, for example a positive displacement blower 30. Out let portion 27 may be provided with a conventional filter or other suitable means for thoroughly cleaning the air before it passes into blower 30.

The high presure outlet from blower 30 is connected with pipe line 31 which opens into an air bustle 35. This bustle extends around the blast furnace adjacent to the tuyere hoppers and hot air bustle 36. Each of the tuyere hoppers is provided with one or more feeders 40 to feed fine solids therefrom. Small diameter tubes 44 extend beneath each of the tuyere hoppers and project into tuyeres 46. Feeders 40 serve to discharge finely divided fuel into tubes 45 through branch tubes 47.

FIGS. 4 and 5 show a suitable conventional rotary feeder 40 but it is to be understood that any other conventional feeders suitable for the purpose of feeding finely divided solids into the furnace may be used in lieu of the feeders 40. As these figures show, each feeder 40 includes a rotor 50 positioned to rotate within a housing 51 which communicates at its upper end with a tuyere hopper 10 and at its lower end with tube 44.

Each feeder 40 is also provided with tube 45 which extends down from bustle 35, communicates with tube 44 and projects into tuyere 46 (see FIG. 8). The tube 44 serves to deliver solids from the feeder into the high pressure air stream which is flowing in tube 45 and by means of which the solids are projected into the interior of the furnace. The shaft 52 of rotor 50 has a pully 53 keyed thereon and is driven by a belt 54 which engages pulley 53 and variable speed drive means carried by the rotor shaft 55 of motor 56 and designated generally by the rectangle marked VSD on FIG. 4.

FIG. 6 shows in some detail a suitable variable speed drive (VSD), which is associated with each tuyere and includes a form of the conventional Reeves drive, for controlling the rate of feed of finely divided solids from each tuyere hopper 10 into its tube 44.

The drive means illustrated in FIG. 6 includes shaft 55 of motor 56 on which is keyed one sheave 70 of the two sheaves belt drive. The other sheave 70*a* is rotatably mounted on rod 71 which has sliding engagement in, and on the axis of, sheave 70. Belt 54 is trained around pulley 53 of rotor 50 and engages the opposed faces of sheaves 70 and 70*a*, suitable idlers (not shown) being positioned to engage the belt and maintain it in alignment with the pulley and sheaves and under suitable tension at all times. The rod 71 extends through one end of cylinder 73 and into chamber 74 therein and is connected to a piston 75 which has sliding, fluid sealing engagement with the inner walls of the said cylinder. Suitable stuffing box means indicated at 76 serve to prevent escape of fluid under pressure from chamber 74.

The end of cylinder 73 opposite the stuffing box means 76 is closed by a cylinder 77 and an end plate 78. A flexible diphragm is positioned between the cylinder 77 and plate 78. A spring 80 is positioned within cylinder 77 and is compressed between piston 75 and diaphragm 79. A rod 81 is attached, as by means of nuts 82, to diaphragm 79 and passes through a fluid sealing bearing 83 connected to cover 78. At its outer end, rod 81 carries a spool consisting of two cylindrical valve members 85 which have sliding, fluid sealing engagement in the clyindrical bore 86 in valve body 87. That valve body is provided with a vent passage 88*a* and with an inlet passage 88*b* for entry of air under considerable pressure, for example from about 80 to about 100 pounds per square inch. Valve seat body 87 is also provided with an outlet passage 88*c* for the high pressure air which enters through passage 88*b* and passage 88*c* is connected by a pipe line 89*a* to an inlet passage 89*b* in the end of cylinder 73 adjacent to the stuffing box 76. Cover 78 of cylinder 77 is provided with an inlet passage 90 and cylinder 77 is provided with a vent passage 90*a*.

In some cases the furnace operator will want to separately control the fuel feed rate through each tuyere manually. In addition, however, it is contemplated that automatic control will be desired so that the coal feed rate through each tuyere will be related to the rate at which blast air enters the furnace through that tuyere.

For manual control of the fuel feed rate through each tuyere, pressure regulating valve 93 is actuated to admit air under manually variable pressure from source 91 through passage 90 into the space on cylinder 77 on one side of diaphragm 79, a gauge 94 indicating the pressure of air so admitted. The air pressure applied against one side of the diaphragm 77 flexes it toward spring 80 thereby tending to compress the spring 80. One reason of such tendency to compress spring 80 is that piston 75 is urged toward the stuffing box end of cylinder 73 and sheave 70*a* is moved toward sheave 70 with resultant movement of the belt 54 into engagement with surfaces of sheaves 70 and 70*a* of increased diameter and with resultant increase in speed of the belt and, hence, this speed of rotation of rotor 50 in feeder 40. The other result of the tendency to compress spring 80 is that the valve members 85 will be moved in valve body 87 to close the passage 88 and to connect inlet passage 88*b* with pipe line 89*a*. High pressure fluid so admitted into pipe line 89*a* will enter chamber 74 and exert a pressure on piston 75 tending to effect the expansion of spring 80 and movement of piston 75 as just described.

The piston 75 will take a position within chamber 74 which results from the balancing of the fluid pressure bearing against flexible diaphragm 79 and the force exerted by spirng 80 on the piston and the fluid pressure exerted on the other side of the piston. That position of the piston may be predetermined by the adjustment of valve 93 and the pressure required to maintain that adjustment may be noted with gauge 94. So long as portion 75 remains in the predetermined position in chamber 74, the belt 54 will be driven at a speed in accordance with the position of its engagement with the sheaves 70 and 70*a*. The speed of belt 54 may be varied by manually varying the setting of the valve 93. For example, if valve 93 is operated to increase the pressure, the eventual position of piston 75 will be closer to the stuffing box end of chamber 74 and the belt will be driven at an increased rate of speed. Conversely, if the valve 93 is actuated to admit less fluid under pressure through passage 90, there will be less force exerted on piston 75 tending to move it toward the sheaves and, hence, it will occupy a position closer to diaphragm 79, the sheaves will be moved farther apart and the belt will be driven at a lower rate of speed. Of course, the speed of rotation of the rotor 50 of feeder 40 controls the rate of feed of the finely divided material into pipe line 45 and into the furnace.

As mentioned above, it is desirable to provide for automatically controlling the feed rate of fuel through each tuyere. In this regard, the pressure in the furnace varies in point of time and, equally importantly, between different regions of the furnace. The variations in furnace pressure adjacent the respective tuyeres cause corresponding variations in the flow rates of the blast air through the several tuyeres.

With the manual control system, as described above, the fuel feed rate through each tuyere is substantially constant, aside from manual changes which can be made from time to time. Thus, if there is a pressure increase adjacent one or more tuyeres, fuel continues to be delivered through that tuyere at a substantially constant rate, while the flow of blast air through that tuyere is reduced because of the increased back-pressure. If the reduction in blast air delivery through a tuyere continues for an extended time, it is possible, though quite unusual, for unburned solid fuel to build up in the furnace adja-

cent the tuyere, thus contributing to a further increase in pressure.

In accordance with the invention, the rate of introduction of solid fuel through each tuyere is automatically varied to maintain a predetermined relationship to the rate of introduction of blast air through that tuyere, the relationship preferably being proportional but it being understood that any other desired relationship can be provided. Referring to FIG. 6, the control line **92** of the rotor feeder variable speed drive controller includes a selector valve **200**, of which one inlet is coupled to the manual control valve **93** and control pressure source **91** and the outlet leads to inlet **90**. Coupled by a tubing **202** to the other inlet of the selector valve **200** is a differential pressure controller (DPC), which may be of any suitable type, many of which are commercially available. For example, a "Nullmatic" Differential-Pressure Transmitter, made by Moore Instument Company, Philadelphia, and described in Moore Bulletin No. 102, can be used. The differential pressure controller (DPC) detects the difference in pressure between the tuyere **46** and the blast air bustle **36** and produces a proportionate, amplified control pressure which, when the valve **200** is turned to the automatic control position in communication with tubing **202**, is supplied to and controls the variable speed drive controller.

It will be understood that the difference in pressure between the tuyere **46** and the bustle **36** is a function of the flow rate through the tuyere. Therefore, the differential pressure controller acts on the variable speed drive controller to regulate the speed of the rotary feeder, and thus solid fuel is introduced into the coal feed pipe at a rate related to, and preferably proportional to, the rate of delivery of blast air through the tuyere into the furnace. For example, a high value of differential pressure is indicative of a high flow rate of blast air through the tuyere into the furnace and will function in the manner described above in connection with manual variation of feeder delivery rate to decrease the separation between the conical pulley sheaves **70** and **70***a*, thereby increasing the speed of rotation of the feeder and, consequently, the rate of introduction of solid fuel in the pipe line **44** to the tuyere. Conversely, a low differential pressure between the tuyere and blast air bustle, indicative of a low delivery rate of blast air into the furnace, results in the decrease of the rate of the feeder **40**. It is to be noted that the rate of introduction of fuel through each tuyere into the furnace is thus controlled automatically in accordance with blast air supply rate through that tuyere.

Regardless of whether the fuel feed rate into the pipe to each tuyere is held constant, except for manually initiated changes, or whether it is varied automatically in accordance with the rate of delivery of blast air through the tuyeres, it is preferable to maintain substantially constant the air flow through each of the pipes **45** and into the tuyeres despite the usual variations in pressure within the blast furnace. While any suitable conventional means may be used for this purpose, a satisfactory means is shown in FIG. 7. In that figure, a valve **95** and an orifice plate **96** are provided in each pipe **45**. A cylinder **97** is provided with a piston **98** which is slidably movable therein under air pressure. This piston is connected by rod **98***a* to valve **95**. Tubes **99** and **100** connect pipe **45** on opposite sides of the orifice plate **96** with the ends of cylinder **97** on opposite sides of piston **98**. It will be understood that valve **95** is initially adjusted for a given pressure in the furnace and that, at such time, the air pressure on opposite sides of orifice plate **96** will be substantially equal. If and when the pressure within the furnace varies, the piston **98** will vary the setting of the valve **95** so that the pressure on the downstream side of orifice plate **96** will be varied in accordance with the furnace pressure. For example, if the furnace pressure adjacent to a given tuyers should increase, the flow through tube **100** and into cylinder **97** on one side of piston **98** would be opposed by the increased fluid pressure in tube **99** and on the other side of pistons **98**. Since the latter pressure would exceed the former pressure, piston **94** would be moved downwardly, all as viewed in FIG. 6. Valve **95** would, thereupon, open to admit more air to orifice plate **96** and thereby restore the predetermined flow of air through line **45**. Similarly, if the pressure in the furnace adjacent to a tuyere should decrease, the pressure on the downstream side of orifice plate **96** would decrease and greater air pressure existing in pipe **100** would move piston **98** upwardly and would correspondingly move valve **95** toward closed position and thereby re-establish the predetermined air flow to the pipe **45**.

FIG. 8 shows one manner of injecting finely divided solid fuel into a tuyere of a blast furnace. In this figure, the tuyere is indicated at **46** and the pipe through which the solids and air are discharged through the tuyere and into the furnace is indicated at **45**. While the outlet end of pipe **45** may be positioned at various distances from the outlet end of the tuyere, it should be positioned far enough away from that end of the tuyeres to resist burning by the heat in the furnace for a suitable length of time.

FIG. 9 discloses, in some detail, the arrangement of the cylindrical tubes for conducting an air stream carrying finely divided solids into and out of the tuyere hoppers or chambers. As shown, the upper part **110** of a tuyere hopper **10***a* is cylindrical and cylindrical tubes **15** lead into and out of part **110** tangentially and with their axes **111** in substantially the same horizontal plane. Projection of these axes intersect within the hopper and make an included angles of about 144°, this being a satisfactory angularity when ten hoppers are engaged in a circle, as illustrated. The finely divided solids carried by the stream in the entering cylindrical tube diverge and flatten against the side of the tank wall. This flattened stream tends to drop. Part of this stream enters the outlet, and part drops into the tank filling it with fine solids. Part bypasses to fill successive hoppers. When the first hopper is filled up close to the inlet tube, substantially all of the solids in the air stream will enter the exit tube and proceed to the next hopper. This operation is repeated from hopper to hopper until each one has been substantially filled with the solids. By introducing material of the first hopper in excess of the quantity used by all the hoppers in the circuit, complete maintenance of all hoppers with material is assured.

The amount of solids leaving the last hopper is of no consequence because it is returned to the distributing hoppers and is thus returned with new material to the tuyere hoppers. This excess material and air joins the new material under hopper **20**.

The reason for the separation of the solids from the air stream in the tuyere hoppers between the ends of the inlet and outlet tubes is not fully understood. It seems possible that the entering air stream which was confined in the cylindrical tube begins to spread towards the center of the hopper as the stream enters the cylinder and loses part of its supporting side walls. Since the inlet tube is tangential to the hopper, only the inner surface of the hopper can exert any support in the hopper to the solids in the air stream and that support is afforded only on one side of the stream. It also seems possible that the air stream is partially divided at the inlet end of the outgoing cylindrical tube or, in effect, part of the stream peels off and continues on around the inner surface of the hopper. Any solids in such divided or peeled off portion of the air stream will tend to move downwardly in the hopper and, hence, be lost to the outgoing stream of air.

But whatever may be the correct theory of operation, the fact is that solids are effectively separated from the air stream and deposited in a cylindrical chamber when the inlet and outlet tubes are disposed with their axes in

the same plane and with the projections of those axes intersecting in the hopper or chamber at an included angle of between about 170° and about 90° depending on the number of hoppers or chambers through which the air stream passes. The distance between the outlet and inlet ends of the tubes of any cylinder necessarily varies as the included angle between the intersecting axes of the tubes. With the largest included angle, the distance is least. This disposition of tubes makes for economy of construction and efficiency of operation. The pressure loss through one hopper is very low, in the order of less than ½" of mercury.

It is to be understood that an important part of the present invention is the means disclosed for separating solids from an air stream in the cylindrical portion of a hopper or chamber and that this phase of the invention is susceptible of uses in addition to that of supplying finely divided solids for injection into a blast furnace, for example wherever conventional separators, including cyclone separators, are used.

An important feature of the present invention is the simplicity and economy of transporting solids from a storage hopper into the tuyeres of a blast furnace. Only one source of air under pressure is required and the air supplied by it serves multiple purposes. It conducts solids from the distributing hopper **5** into each of the tuyere hoppers. After leaving its burden of solids in those hoppers, the air stream under somewhat reduced pressure, picks up solids from feeders **22** of hopper **20** and delivers those solids to the distributing hopper **5**. The pressure of the same air is increased after it leaves the distributors and it then passes into air bustle **35** from which it flows at a substantially constant rate and carries finely divided solids to the tuyeres and injects those solids into the furnace.

The method performed by the present invention is disclosed in FIG. 1 where illustrated variations in air pressure at different stages of the method and in different parts of the apparatus are shown. As FIG. 1 indicates, a suitable pressure of the air discharged from source **1** is 40 pounds per square inch (p.s.i.). This pressure will not drop to a material extent prior to entering the first tuyere hopper and, while its pressure will decrease somewhat in going through the several tuyere hoppers, it still possesses enough pressure when passing under storage hopper **20** to entrain and carry sufficient quantities of finely divided fuel into distributing hopper **5**. A pressure of 25 p.s.i. in pipe line **18** will be suitable for this purpose. Preferably, the pressure of the air leaving distributing hopper **5** should be increased to a pressure greater than that existing in the furnace so that air can flow from the air bustle **35** through the tuyeres and into the furnace. For example, the pressure of the air should be increased to about 40 p.s.i. before it is discharged into bustle **35**. Pipes **1**, **3**, **7**, **15**, *7a*, **18** and **31** and air bustle **35** may each be about 6" in diameter while pipe lines **45** may be about 1" in diameter.

FIG. 10 shows a modification of the system of FIG. 1 in which a separator has been added to that system. In this instance, the tube *7a* from the last tuyere hopper **10***i* opens into a separator **120** in which the solids are separated from the air. This air from this separator escapes through the top central part of separator **120** to line **121**. This line extends beneath, and in communication with, feeder **125** at the lower end of separator **120**. Pipe line **121** opens into the upper end of distributing hopper **5**. Any conventional separator suitable for the purpose may be used as indicated at **120**, for example, a cyclone separator is suitable. Solids may be discharged from hoppers **20** and **120** into the air stream flowing in line **121** and are thereby carried into hopper **5**.

Thus, the system of FIG. 1 has, in essence, been modified by the inclusion therein of a separator between storage tank **20** and distributing hopper **5** of FIG. 1. One effect of such modification is that the solids carrying capacity of the air flowing past storage hopper **20** has been increased at least to the extent that solids had been removed from the air leaving the last tuyere hopper **10***i*.

It is to be understood that the complete system contemplated by FIG. 10 includes not only the parts just described but also all the parts of the system of FIG. 1.

FIG. 11 shows the provision of a blower in conjunction with each tube **45** of the several tuyere feeders **40**. In FIG. 1 a single blower **30** is shown as providing the air pressure necessary for transporting solids through the plurality of tubes **45** into their tuyeres. In FIG. 11, blower **30** of FIG. 1 has been omitted and a plurality of blowers **130** have been included, one blower for each tube **45**. These blowers **130** may be separately adjusted so that the pressure of air delivered by each one to its tube **45** will bear a predetermined relation to the pressure conditions existing in the furnace at the outlet end of the tube. Thereby the pressure adjacent the several tuyeres may be made more nearly uniform. Each blower **130** may be of any conventional construction and may be small and inexpensive as compared with the single blower **30** of FIG. 4.

It is to be understood that, although FIG. 11 shows only one blower **130** and one tube **45** for each tuyere hopper, one blower may serve two tubes **45** from one hopper, if desired.

It is also to be understood that the complete system contemplated by FIG. 11 includes not only the parts just described but also all the parts of the system of FIG. 1 which are not specifically excluded by the foregoing description of FIG. 11.

It is further to be understood that the parts shown in FIGS. 10 and 11 may be included in the same system.

The system of FIG. 12 is quite like that of FIG. 1, like parts being indicated by like reference characters and new parts being indicated by new reference characters.

In FIG. 12 the outlet portion **27** of hopper **5** is provided with a pressure regulated vent *27a* through which gases may be vented to the atmosphere rather than directed into a blower such as **30** of FIG. 1. A supply *31a* of oxygen enriched air is connected to line **31** and this gas is employed to transport a finely divided combustible solid fuel, for example coal, down through tubes **45** and into the tuyeres **46**. It will be understood that this oxygen enriched air also affords more oxygen for combustion of the fuel than exists in the air which was described above as being used in the apparatus of FIG. 1. Thus, by substituting oxygen enriched air for atmospheric air, greater quantities of fuel may be burned or the fuel may be burned more completely than when air alone is used.

In this embodiment of the method invention, as in the embodiment in which air alone is used as a source of oxygen for burning fuel in the furnace, it is important that the oxygen enriched air should be discharged into lines **31** at a pressure which is at least equal to that existing in the furnace in order to insure discharge of the fuel and that gas into the furnace. For example, if the furnace is operating at a pressure of 40 p.s.i., the pressure of the oxygen enriched air released from the source *31a* should be at least 40 p.s.i. and, preferably, enough higher than that pressure to insure the passage of the oxygen enriched air through each of the tuyeres and into the furnace.

The system of FIG. 13 is quite like FIG. 12, like references indicating like parts, the main differences being a substitution of a source of oxygen for the oxygen enriched air source *31a* of FIG. 12; and the inclusion of booster *1a* in line 7.

The source of oxygen should be at a pressure at least as high as that existing in the blast furnace and, preferably, enough higher than that pressure to insure that the oxygen will propel the fuel through tubes **45** and tuyeres and into the furnace. To that end, the oxygen pressure should be at least as great, and preferably a little greater, than the pressure existing in the furnace.

The booster 1*a* may be a turbo-blower similar to the blower indicated at **1** or any other conventional air compressor such as a positive displacement blower. The function of this booster 1*a* is to increase the pressure existing in line **7** sufficiently to prevent substantially all escape of oxygen from the tuyere tanks. For example, if the pressure existing in the furnace is 40 p.s.i. and the pressure in line **21** is at least 40 p.s.i., the pressure existing in each of the tuyere tanks should be at least 40 p.s.i. to insure against the loss of substantial amounts of oxygen through the tuyere feeders and into and through the tuyere hoppers. It will be seen, by referring to FIG. 5, that unless special precautions are taken, if the oxygen in tubes **45** is at a pressure higher than the gas pressure in tuyere tanks **10**, some oxygen may escape through the rotating feeder rotor **50**. Any oxygen which so enters any of the tuyere tanks will be withdrawn through pipe line **18** and vented to the atmosphere through vent **27***a*. Such loss of oxygen is avoided by maintaining the gas pressure in the tuyere tanks substantially equal to the oxygen pressure in tubes **45**. As just stated, that gas pressure in the tuyere tanks may be obtained by use of the blower **1** and booster 1*a*, although it may be possible to use only one blower provided it can furnish the desired pressure to the air in the tuyere tanks.

Since oxygen systems commercially available generally deliver oxygen at a pressure of approximately 100 p.s.i., it is possible to use very simple fixed orifice plates in the pipe from the oxygen supply pipe **31** to tubes **45** leading to the tuyeres. As long as the downstream pressure is below about 58% of the upstream pressure, the flow rate will remain constant without the use of any regulators due to the inherent well known characteristics of an orifice operating under these conditions.

It will be seen from the foregoing description that each of the oxygen containing gases above described performs two important functions, namely, transporting the solid fuel through tubes **45** and tuyeres **46** and into the furnace and affording oxygen for combustion of that fuel by being intimately mixed with and surrounding all the solid fuel particles.

Since the amount of oxygen varies in the three above mentioned oxygen containing gases, namely, air, oxygen enriched air and oxygen, it follows that the amount of solid fuel which can be burned with those gases will vary with the amount of oxygen present. Thus, by using oxygen more fuel can be burned with a given amount of gas than when air is the gas or more of the fuel can be burned. Accordingly, the particular oxygen containing gas which is selected for use may be determined partly by the amount of fuel which is to be burned in a given time.

Having thus described this invention in such full, clear, concise and exact terms as to enable any persons skilled in the art to which it pertains to make and use the same, and having set forth the best mode contemplated of carrying out this invention, I state that the subject matter which I regard as being my invention is particularly pointed out and distinctly claimed in what is claimed, it being understood that equivalents or modifications of, or substitutions for, parts of the above described embodiment of the invention may be made without departing from the scope of the invention as set forth in what is claimed.

I claim:

1. Apparatus for feeding solid fuel into a blast furnace comprising means including feed pipes entering each of the tuyeres for continuously discharging gas streams under pressure into the furnace through the tuyeres, means for varying the pressure of the gas stream in the feed pipe to each tuyere in accordance with the pressure in the furnace adjacent to that tuyere to maintain a substantially constant rate of gas flow through the feed pipes into the several tuyeres, and means for introducing solid fuel into the gas stream through each feed pipe at an individually controlled rate of introduction for each tuyere.

2. Apparatus according to claim **1**, wherein the means for introducing solid fuel into the gas stream through each feed pipe includes means for automatically varying the rate of introduction of solid fuel in accordance with the rate of delivery of blast air through the respective tuyere.

3. Apparatus for feeding solid fuel into a blast furnace comprising a plurality of hoppers disposed around the furnace, means for pneumatically transporting solid fuel to the hoppers, means including feed pipes entering each of the tuyeres for continuously discharging gas streams under pressure into the furnace through the tuyeres, means for varying the pressure of the gas stream from each feed pipe and through each tuyere in accordance with the pressure in the furnace adjacent to that tuyere to maintain a substantially constant rate of gas or flow through each feed pipe into each of the tuyeres, and means for delivering solid fuel out of each hopper into the gas stream through each feed pipe at an individually controlled rate of introduction for each tuyere.

4. Apparatus according to claim **3**, wherein the means for introducing solid fuel into the gas stream through each feed pipe includes means for automatically varying the rate of introduction of solid fuel in accordance with the rate of delivery of blast air through the respective tuyere.

5. Apparatus for feeding solid fuel into a blast furnace comprising means including feed pipes entering each of the tuyeres for continuously discharging gas streams under pressure into the furnace through the tuyeres, means for varying the pressure of the gas stream in the feed pipe to each tuyere in accordance with the pressure in the furnace adjacent to the tuyere to maintain a substantially constant rate of gas flow through the feed pipes into the several tuyeres, means for introducing solid fuel into the gas streams through each feed pipe, and means responsive to the differential pressure between the source of blast air and the respective tuyeres for automatically varying the rate of introduction of solid fuel by the introducing means into each feed pipe to each tuyere in accordance with the rate of introduction of blast air into the furnace through that tuyere.

6. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,

(b) conduit means communicating successively with each of said tuyere hoppers in succession,

(c) means for supplying a gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,

(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(e) means for conducting gas under pressure into said bustle,

(f) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(g) means associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into each of the tuyeres,

(h) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,

(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

7. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,

(b) conduit means communicating successively with each of said tuyere hoppers in succession,
(c) means for supplying gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,
(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,
(e) means for conducting gas under pressure into said bustle,
(f) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,
(g) means including fluid flow control valves associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into each of the tuyeres,
(h) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,
(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

8. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,
(b) conduit means communicating successively with each of said tuyere hoppers in succession,
(c) means for supplying gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,
(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,
(e) means for conducting gas under pressure into said bustle,
(f) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,
(g) means including positive displacement blowers with said bustle and associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,
(h) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,
(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

9. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,
(b) conduit means communicating successively with each of said tuyere hoppers in succession,
(c) means for supplying gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,
(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,
(e) means for increasing the pressure of the gas from said tuyere hoppers and conducting it into said bustle,
(f) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,
(g) means including fluid flow control valves associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,
(h) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,
(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

10. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,
(b) conduit means communicating successively with each of said tuyere hoppers in succession,
(c) means for supplying gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,
(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,
(e) means for conducting gas under pressure into said bustle,
(f) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,
(g) means including fluid flow control valves associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,
(h) means including fluid control valves for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,
(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

11. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,
(b) conduit means communicating successively with each of said tuyere hoppers in succession,
(c) means for supplying gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,
(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,
(e) means for conducting gas under pressure into said bustle,
(f) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,
(g) means including fluid flow control valves associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,
(h) means including positive displacement blowers communicating with said bustle and for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,
(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

12. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,
(b) conduit means communicating successively with each of said tuyere hoppers in succession,

taining a substantially constant gas flow therethrough into the tuyeres,
(h) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,
(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

(c) means for supplying gas under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,

(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(e) means for conducting gas under pressure into said bustle,

(f) means for increasing the pressure of gas from said conduit means after passing through the last tuyere hopper and delivering it under pressure into said bustle at an increased pressure,

(g) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(h) means including fluid flow control valves associated with the piping means including fluid flow control valves to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,

(i) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,

(j) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

13. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding solid fuel therefrom,

(b) a storage hopper having a feeder for feeding finely divided solid fuel therefrom,

(c) a primary distributor having a feeder for feeding said solid fuel therefrom,

(d) conduit means communicating successively with the feeder from said primary distributor, each of said tuyere hoppers in succession, the feeder of said storage hopper and the upper part of said primary distributor,

(e) means for supplying gas under pressure to said conduit means in advance of the feeder of said primary distributor,

(f) means for separating gas from said solid fuel in said primary distributor,

(g) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(h) means for removing gas from said primary distributor and delivering it into said bustle at an increased pressure,

(i) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(j) means including fluid control valves associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,

(k) means for conducting said solid fuel from the feeders of each of said tuyere hoppers into the piping means associated therewith,

(l) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

14. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding solid fuel therefrom,

(b) a storage hopper having a feeder for feeding finely divided solid fuel therefrom,

(c) a primary distributor having a feeder for feeding said solid fuel therefrom,

(d) conduit means communicating successively with feeder from said primary distributor, each of said tuyere hoppers in succession, the feeder of said storage hopper and the upper part of said primary distributor,

(e) means for supplying gas under pressure to said conduit means in advance of the feeder of said primary distributor,

(f) means for separating gas from said solid fuel in said primary distributor,

(g) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(h) means for removing gas from said primary distributor and delivering it into said bustle at an increased pressure,

(i) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(j) means including positive displacement blowers communicating with said bustle and associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining a substantially constant gas flow therethrough into the tuyeres,

(k) means for conducting said solid fuel from the feeders of each of said tuyere hoppers into the piping means associated therewith and,

(l) means automatically operative to maintain a controlled rate of feed of said solid fuel out of each of the tuyere hoppers.

15. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding solid fuel therefrom,

(b) a storage hopper having a feeder for feeding finely divided solid fuel therefrom,

(c) a primary distributor having a feeder for feeding said solid fuel therefrom,

(d) conduit means communicating successively with the feeder from said primary distributor, each of said tuyere hoppers in succession, the feeder of said storage hopper and the upper part of said primary distributor,

(e) means for supplying gas under pressure to said conduit means in advance of the feeder of said primary distributor,

(f) means for separating gas from said solid fuel in said primary distributor,

(g) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(h) means for removing gas from said primary distributor and delivering it into said bustle,

(i) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(j) means including positive displacement blowers communicating with said bustle and associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to each of the tuyeres for maintaining substantially constant gas flow from the bustle into the tuyeres,

(k) means for conducting said solid fuel from the feeders of each of said tuyere hoppers into the piping means associated therewith and,

(l) means automatically operative to maintain a controlled rate of feed of said solid fuel out of each of the tuyere hoppers.

16. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of hoppers positioned around a blast furnace,

(b) conduit means communciating successively with each of the hoppers in succession,
(c) means for providing a flow of gas under pressure through the conduit means,
(d) means for introducing finely divided fuel into the conduit means,
(e) means including pipes for discharging a gas under pressure in confined streams into each of the furnace tuyeres,
(f) feeder means on each of the hoppers for introducing the finely divided fuel therefrom into the pipes of discharging means,
(g) means associated with the pipes to each of the tuyeres and automatically responsive to pressure variations in the furnace adjacent to the tuyeres for maintaining a substantially constant gas flow through the tuyeres and into the furnace,
(h) and means for maintaining a substantially constant predetermined rate of feed of the fuel out of each of the feeder means.

17. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of hoppers positioned around a blast furnace,
(b) conduit means communciating successively with each of the hoppers in succession,
(c) means for providing a flow of gas under pressure through the conduit means,
(d) means for introducing finely divided fuel into the conduit means,
(e) means including pipes for discharging a gas under pressure in confined streams into each of the furnace tuyeres,
(f) feeder means on each of the hoppers for introducing the finely divided fuel therefrom into the pipes of discharging means,
(g) means associated with the pipes to each of the tuyeres and automatically responsive to pressure variations in the furnace adjacent to the tuyeres for maintaining a substantially constant gas flow through the tuyeres and into the furnace,
(h) and means associated with the feeder for each tuyere and automatically responsive to the pressure differential between the source of blast air for the furnace and the respective tuyere which that feeder supplies for varying the rate of feed of fuel out of that feeder in accordance with the rate of introduction of blast air into the furnace through that tuyere.

18. Solids distributing apparatus comprising a plurality of hoppers having cylindrical upper portions substantially free of internal obstructions, conduits connected to and communicating with the hoppers in succession, the conduits opening tangentially into the upper portions and the projections of the conduit axes intersecting within the hoppers at included angles of between about 170° and about 90°, and means for establishing a flow of gas-entrained finely divided solids to a first one of the conduits and through the succession.

19. Solids distributing apparatus comprising a plurality of hoppers, each hopper having an upper portion substantially free of internal obstructions, inlet and outlet openings in the upper portion of each hopper, and arcuate wall portions in the upper portion of each hopper disposed between the inlet and outlet thereof, piping means communicating the outlets of each hopper with the inlet of a succeeding hopper, the portions of the piping means adjacent the inlet and outlet of each hopper disposed generally tangentially to the arcuate wall portion and having axes which intersect at an included angle of about 90° and 170°, and means for establishing a flow of gas-entrained finely divided solids through the piping means.

20. Apparatus according to claim 19 wherein the axes of said portions of the piping means lie substantially in the same horizontal plane.

21. Apparatus for supplying hoppers with finely divided solids which comprises:
(a) a plurality of hoppers having cylindrical upper portions substantially free of internal obstructions,
(b) and continuously open and unobstructed conduit means connecting the cylindrical portions of said hoppers together in succession and to a source of gas under pressure and a source of finely divided solids, said conduit means including cylindrical tubes connecting each hopper to an adjacent hopper, the tubes having portions adjacent the hoppers disposed substantially tangentially to the cylindrical upper portions and serving to conduct gas under pressure and finely divided solids from one of said hoppers to the adjacent hopper, the longitudinal axes of the said tube portions connected to each hopper lying in substantially the same horizontal plane and projections of said axes intersecting and making an included angle within the hopper of between about 170° and about 90°.

22. Apparatus for supplying hoppers with finely divided solids which comprises:
(a) a plurality of hoppers arranged in succession and having cylindrical upper portions substantially free of internal obstructions,
(b) a tubular conduit disposed tangentially to the first of said successive hoppers and serving to conduct gas under pressure carrying finely divided solids into said hopper,
(c) a tubular conduit disposed tangentially to the cylindrical portion of the last of said hoppers and serving to conduct gas out of said hopper,
(d) and continuously open and unobstructed conduit means connecting the cylindrical portions of each of the several hoppers in succession from the said first one to the said last one, said conduit means including cylindrical tubes connecting each hopper to an adjacent hopper, being disposed tangentially to both hoppers and serving to conduct gas under pressure in the finely divided solids from one of the said hoppers to the adjacent hopper, the longitudinal axes of the tubes connected to each hopper lying in substantially the same horizontal plane and projections of said axes intersecting and making an included angle within the hoppers of between about 170° and about 90°.

23. Apparatus for supplying hoppers with finely divided solids which comprises:
(a) a plurality of hoppers arranged on a circle and having cylindrical upper portions substantially free of internal obstructions,
(b) and continuously open and unobstructed conduit means connecting the cylindrical portions of said hoppers together in succession and to a source of gas under pressure and a source of finely divided solids, said conduit means including cylindrical tubes connecting each hopper to an adjacent hopper, being disposed tangentially to both hoppers and serving to conduct gas under pressure and finely divided solids from one of said hoppers to the adjacent hopper, the longitudinal axes of the tubes connected to each hopper lying in substantially the same horizontal plane and projections of said axes intersecting and making an included angle within the hopper of between about 170° and about 90°.

24. An apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:
(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,
(b) pneumatic means for supplying fuel to said hoppers,
(c) a source of gas rich in oxygen under pressure,
(d) piping means for conducting the gas under pressure and discharging it into each of the tuyeres of the furnace,

(e) means associated with each of said piping means to each of said tuyeres and responsive to pressure variations in the furnace adjacent to each of said tuyeres for maintaining a substantially constant gas flow therethrough into the tuyere, and

(f) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith.

25. Apparatus according to claim **24** wherein the pneumatic fuel supplying means is under pressure greater than the pressure of the gas source.

26. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,

(b) conduit means communicating successively with each of said tuyere hoppers in succession,

(c) means for supplying air under pressure and carrying said solid fuel to said conduit means in advance of the first tuyere hopper,

(d) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(e) a source of gas rich in oxygen under pressure, the pressure being less than the air pressure from said supplying means, communicating with said bustle,

(f) piping means for conducting the gas under pressure from said bustle and discharging into each of the tuyeres of the furnace,

(g) means associated to the piping means to each of said tuyeres and responsive to pressure variation in the furnace adjacent to the tuyere for maintaining substantially constant gas flow therethrough into the tuyere,

(h) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith,

(i) and means for individually controlling the rate of feed of solid fuel out of each tuyere hopper into the respective piping means associated therewith.

27. An apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around a blast furnace and having feeders for feeding finely divided solid fuel therefrom,

(b) pneumatic means for supplying fuel to said hoppers,

(c) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(d) means for conducting gas under pressure into said bustle,

(e) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(f) means associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjcaent to the tuyere for maintaining a substantially constant gas flow therethrough into the tuyere, and

(g) means for conducting finely divided solid fuel from each of said tuyere hoppers into the piping means associated therewith.

28. Apparatus for feeding solid fuel into a blast furnace through its tuyeres comprising:

(a) a plurality of tuyere hoppers positioned around the blast furnace,

(b) means for supplying solid fuel to said hoppers,

(c) a bustle surrounding the furnace adjacent to said tuyere hoppers,

(d) means for conducting gas under pressure into said bustle,

(e) piping means for conducting gas under pressure from said bustle and discharging it into each of the tuyeres of the furnace,

(f) means associated with the piping means to each of said tuyeres and automatically responsive to pressure variations in the furnace adjacent to the tuyeres for maintaining a substantially constant gas flow through the tuyeres and into the furnace, and

(g) means for conducting finely divided solid fuel from each of the tuyere hoppers into the piping means associated therewith.

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