Nov. 19, 1968 L. D. SCHMIDT 3,411,765

APPARATUS FOR CHARGING COARSELY COMMINUTED COAL INTO TUYERES OF A BLAST FURNACE

Original Filed Dec. 21, 1962 3 Sheets-Sheet 1

FIG. 1

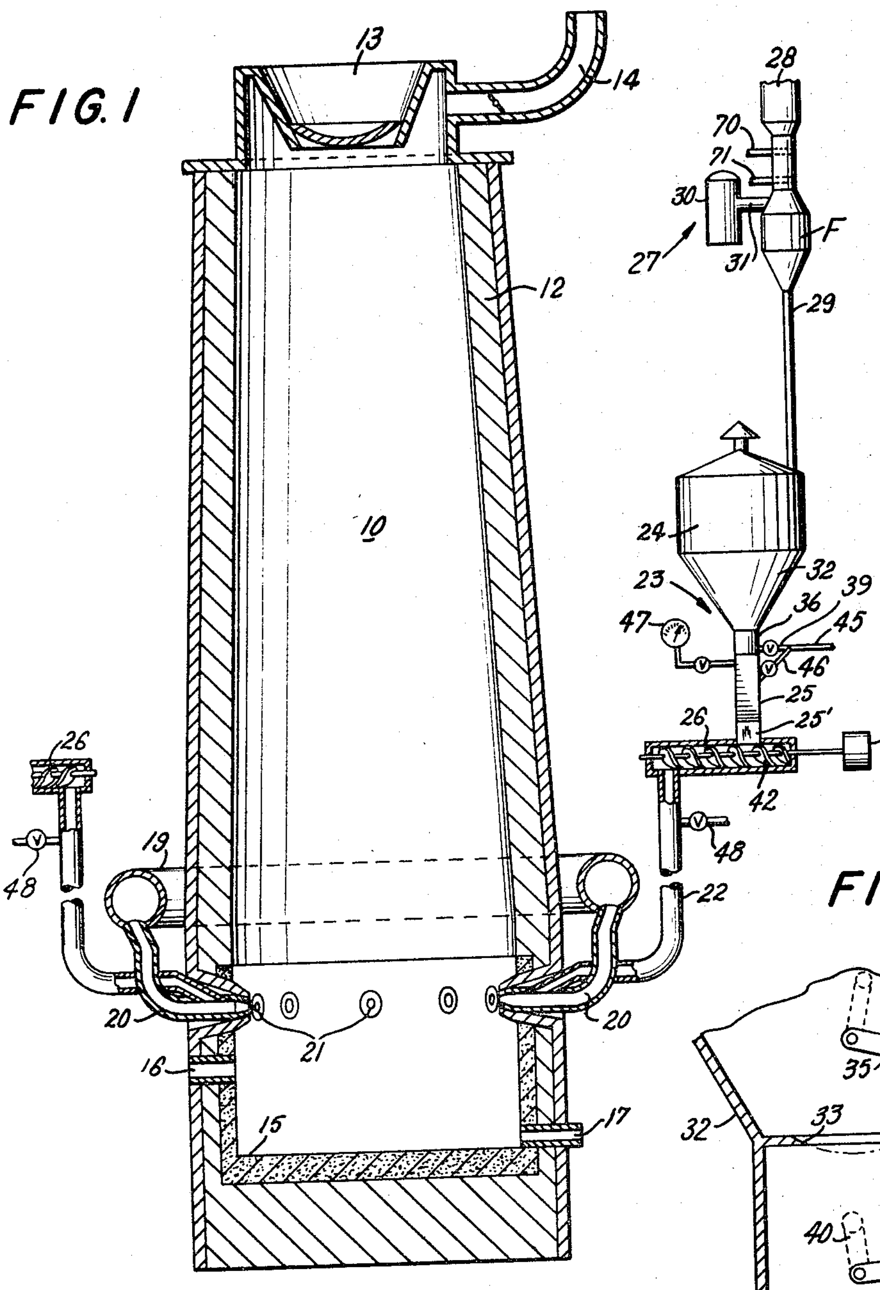

FIG. 2

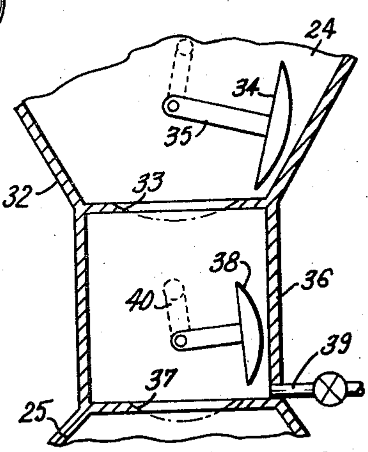

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FIG. 3

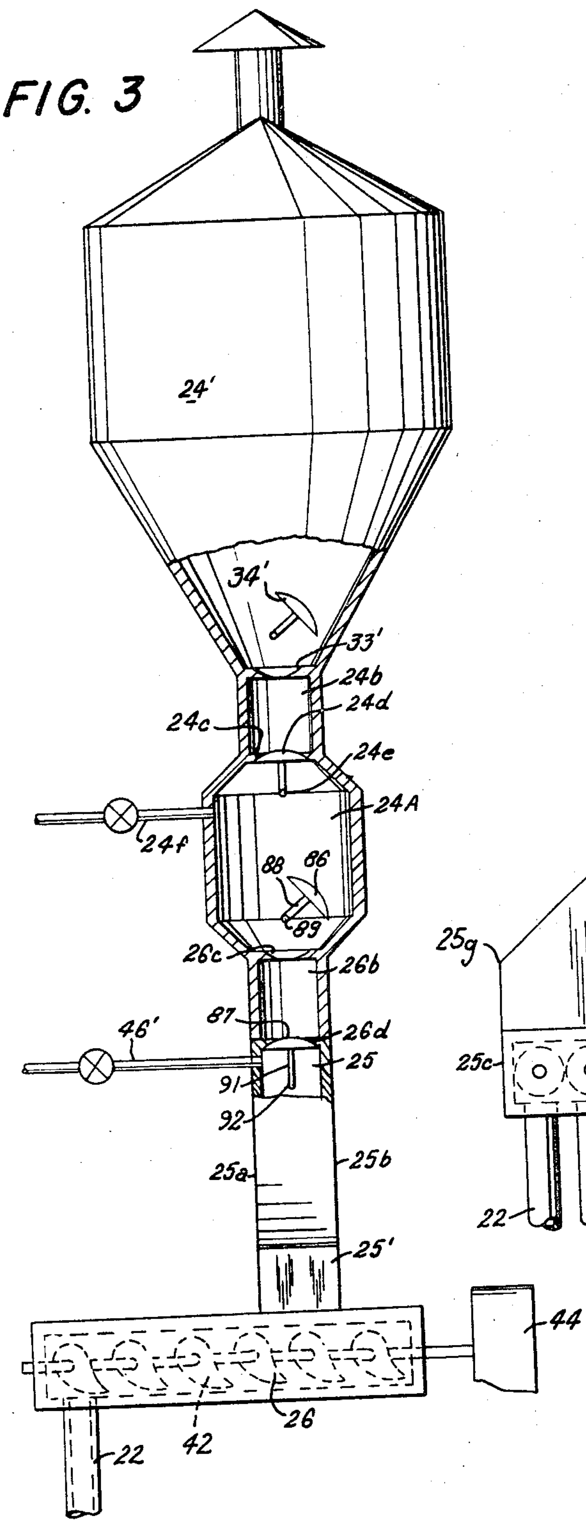
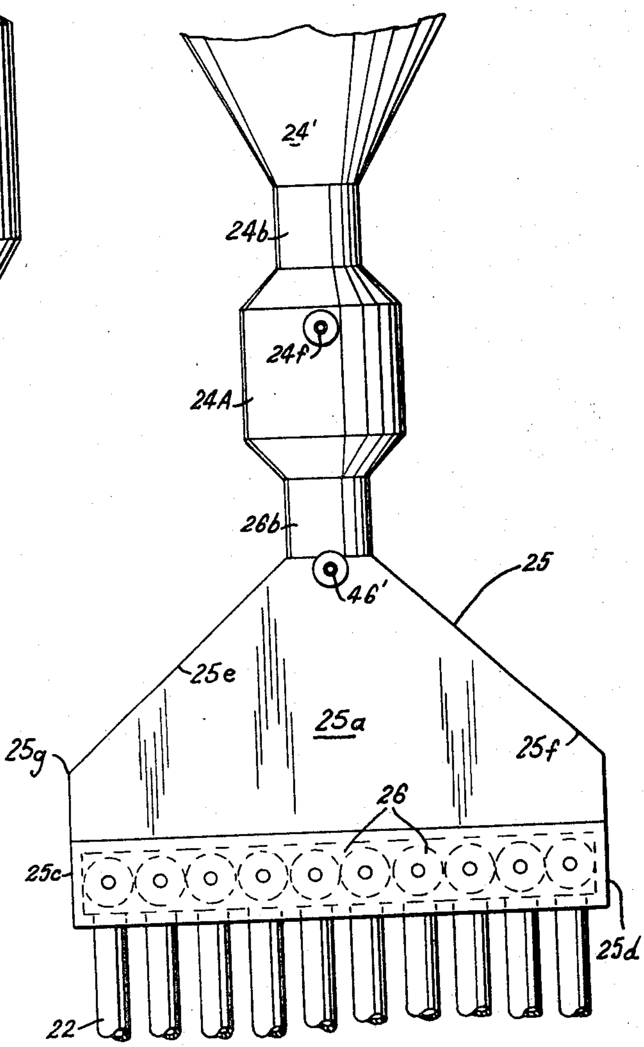


FIG. 4



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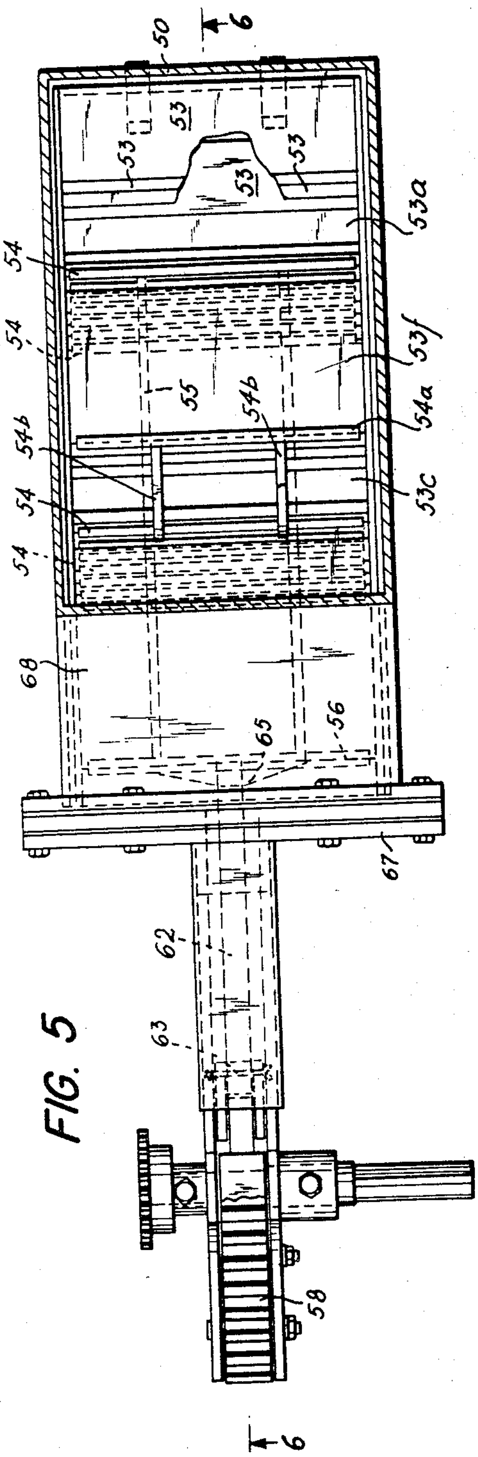

FIG. 5

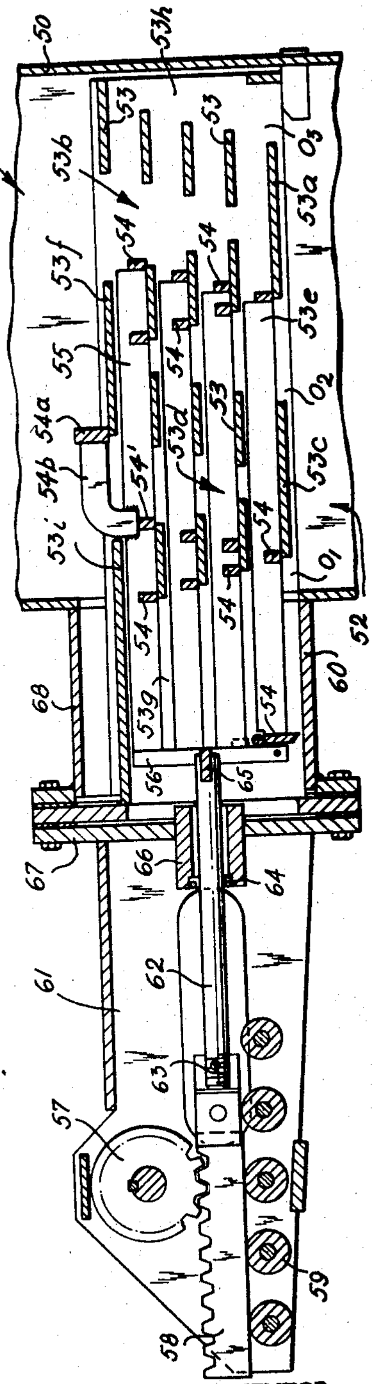

FIG. 6

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3,411,765

APPARATUS FOR CHARGING COARSELY COMMINUTED COAL INTO TUYERES OF A BLAST FURNACE

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Original application Dec. 21, 1962, Ser. No. 246,397, now Patent No. 3,240,587, dated Mar. 15, 1966. Divided and this application Oct. 20, 1965, Ser. No. 516,182
7 Claims. (Cl. 266—29)

ABSTRACT OF THE DISCLOSURE

Apparatus for charging dry, preheated, coarsely comminuted coal as an auxiliary fuel to a blast furnace, in combination, a hot bin to receive and store the coal, a gas tight valved pressure bin into which the coal is introduced and provided with means for introducing pressure fluid, jet means for scouring the valve seat of pressure bin, means for removing coal from pressure bin while still under pressure and screw conveyor for injecting the coal from pressure bin into tuyere of blast furnace.

This is a division of application Ser. No. 246,397 filed Dec. 21, 1962, now Patent No. 3,240,587, issued Mar. 15, 1966.

This invention relates to blast furnaces and the operation thereof, particularly the manner of supplying the heat, for effecting the smelting of metallurgical materials, particularly iron ore.

Blast furnace operation involves the charging of the iron ore, coke, and flux, usually limestone and/or dolomite into the top of the furnace and blowing heated air, with or without added oxygen, into the bottom and up through the charge. Present good blast furnace practice employs a hot blast, usually air, temperature which averages about 1600° F. With the advent of better refractories in the air preheating stoves, it is visualized that hot blast temperatures as high as 2200° F. can be used with consequent increase in the productivity of the blast furnace.

To effect reasonably efficient reduction of the ore, a good grade of metallurgical coke must be used of a size and crushing strength to sustain the burden, maintain the charge relatively open and permit the blast to pass up through the burden to effect the desired reduction of the oxides to metal and the melting of the metal so that ready separation of the molten metal from the slag can be effected. Coke of good metallurgical quality is costly. Attempts to replace a portion of the coke by coal in the charge have proven unsuccessful because the coal deleteriously affects the charge, resulting in agglomerates which interfere with the reduction and smelting of the ore.

In this specification, all percentages are given on a weight basis.

It has been suggested that the coke requirements of a blast furnace be reduced by introducing pulverized coal, at atmospheric temperature, having a moisture content of 2–3% into the tuyeres of the blast furnace. The term "pulverized coal" or "powdered coal" by common usage means coal of the type used for pulverized coal firing of steam boilers. Such coal invariably has a particle size as follows:

99.5% through 50 mesh (U.S. Sieve Opening 297 microns);
96.5% through 100 mesh (U.S. Sieve Opening 149 microns);
80% through 200 mesh (U.S. Sieve Opening 74 microns).

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The injection of pulverized coal at atmospheric temperature having a moisture content of 2–3% has the objection that the moisture content of the coal results in a loss of heat from the hot blast which heat would otherwise be beneficially used in effecting the smelting and refining of the metal. The use of pulverized coal also requires the added expense of pulverizing the coal. Moreover, a large part of the pulverized coal invariably passes too far into the blast furnace (or may pass all the way through the furnace and out at the top) to be used efficiently in the hottest part of the blast furnace. Furthermore, the introduction of pulverized coal through the tuyeres as heretofore conducted presents the ever present hazard that the coal particles will ball up and plug the injection pipes of the tuyeres. It was found with coal of 2–3% moisture content that the content of minus 100 mesh sieve must be carefully controlled below a maximum of about 20%; otherwise plugging of the injection pipes of the tuyeres would take place.

The introduction of coal at atmospheric temperature containing from 2–3% moisture requires a conveying or carrier gas in relatively large amounts because the moisture content of the coal tends of cause agglomeration of the particles, and to maintain the particles in the dispersed or relatively fluid phase required to effect the introduction thereof into the blast furnace, relatively large amounts of conveyor or carrier gas must be used. This is, of course, objectionable in that it involves loss of heat utilized in raising the temperature of the conveyor or carrier gas to the high temperatures in the tuyere zone of the blast furnace. This loss of heat represents a reduction in efficiency of the blast furnace in smelting metals.

It is a principal object of the present invention to provide apparatus for operating a blast furnace resulting in a marked saving in coke consumption by employing coal introduced into the tuyeres, and this without sacrifice to the blast temperature, without the hazard or balling up or plugging of the injection pipes, without the necessity of pulverizing the coal, and with the use of relatively small amounts of carrier or conveying gas for introducing the coal through the tuyeres into the blast furnace.

Still another object of this invention is to provide apparatus in which the coal used is of the same particle size as commonly employed for charging coke oven batteries, invariably employed as an adjunct of a steel plant containing the blast furnace or furnaces to supply the latter with their coke requirements.

Other objects and advantages of this invention will be apparent from the following detailed description thereof.

In accordance with this invention, hammer-milled coal, invariably available at steel plants as the feed for the coke oven battery or batteries, is used without further size reduction, screening or impairment of coking properties by oxidation. Hammer-milled coal has a particle size (by "particle size" as used herein is meant the largest dimension of the particle), not exceeding about three-eighths of an inch, from 5% to 20% of the particles are larger than about one-quarter inch, from 20% to 40% of the particles are larger than one-eighth inch, and over 50% of the particles are larger than 0.04 inch. Such coal having a moisture content of 2% to 8%, usually 7% to 8%, is preheated to a temperature of 220° F. to 600° F., preferably 400° F. to 600° F., and thus the moisture content is substantially completely removed, and the preheated coal introduced into a confined storage zone, herein sometimes called a hot bin. This storage zone communicates with a confined charging zone, herein sometimes called a pressure bin, arranged to be pressurized with steam, coke oven gas or other carrier gas, to a pressure above the pressure of the blast gases introduced into the tuyeres.

Charges of preheated hammer-milled coal are introduced into the charging zone. In one modification of this invention, the charges are introduced while the charging zone is at ambient pressure and this zone is pressurized after the introduction of each charge. In another modification, the charges are introduced under pressure and without releasing the pressure in the charging zone. In both modifications the charging zone is pressurized to a pressure above the tuyere pressure and the preheated hammer-milled coal is introduced through the tuyeres into the blast furnace.

Where the preheated hammer-milled coal is available, as for example in coke oven battery installations embodying my invention of United States Patent 3,047,473 granted July 31, 1962, such coal can be fed directly to the storage zone to provide the latter with the predetermined charge for feed to the charging zone communicating with the tuyeres of the blast furnace.

The amount of carrier gas used for conveying the hammer-milled coal is approximately the minimum amount which can be used to obtain the desired transport of the coal particles from the charging zone into and through the tuyeres into the blast furnace. Steam can be used in accordance with the present invention because the preheated hammer-milled coal is dry and at a relatively high temperature so that the steam will not condense on and wet the coal, making it difficult or impossible to be conveyed by the conveying steam. When coke oven gas is used, it is employed under pressure somewhat greater than that in the tuyere zone of the blast furnace and pre-heated desirably to a temperature at least as high as that of the preheated coal. The amount of coke oven gas thus used is that required to effect conveyance of the hammer-milled coal particles from the storage zone into and through the tuyeres into the blast furnace. Coke oven gas is preferred carrier gas for effecting injection of the hammer-milled coal particles through the tuyeres into the blast furnace because the coke oven gas does not react with constituents present in the high heat zone of the blast furnace as does steam, nor decompose as does natural gas, and hence minimizes loss of heat due to the introduction of the carrier gas along with the hammer-milled coal through the tuyere into the blast furnace.

In the accompanying drawings, showing for purposes of exemplification a preferred embodiment of this invention, to which, however, the invention is not limited:

FIGURE 1 is a vertical section partly in elevation of a blast furnace embodying this invention;

FIGURE 2 is a sectional detail, on an enlarged scale, of the connection between the bottom of the hot bin and top of the pressure bin showing the valves therein in elevation;

FIGURE 3 is a fragmentary view partly in vertical section and partly in elevation of a modified arrangement involving a hot bin, lock bin and pressure bin which arrangement is designed for continuous feed to each tuyere;

FIGURE 4 is a fragmetary side elevational view of the apparatus of FIGURE 3;

FIGURE 5 is a plan view, partially in section, of one form of coal drier for drying and preheating wet coal for feed to the hot bin; and

FIGURE 6 is a vertical section of the drier on line 6–6 of FIGURE 5.

In FIGURE 1, is a conventional blast furnace having a shaft wall **12**, a charging device **13** and an outlet **14** for the furnace gases at its top. A hearth **15** supports the charge. A slag notch **16** and an iron notch **17** are provided for tapping off slag and iron, respectively. Blast gas is introduced through bustle pipe **19** and branches **20** to tuyeres **21** into the furnace.

One or two preheated coal (hammer-milled coal as hereinabove described) feeders **23** are provided for supplying preheated coal to screw conveyers **26**, hereinafter described each communicating by a pipe **22** with a tuyere **21**. FIGURE 1 shows diagrammatically a construction in which two coal feeders **23** are employed, located on op-

posite sides of the blast furnace, and each provided with a group of screw conveyers **26** to supply through the pipes **22**, each individual to a tuyere **21**, approximately half the tuyeres **21**. Each coal feeder **23** comprises a hot bin **24**, and a pressure bin **25** hereinafter more fully described, communicating with the screw conveyers **26** and provided with necessary steam and power suppliers. Each tuyere **21** has a screw conveyer **26** individual thereto for feeding coal thereto, thus giving positive control on coal and carrier gas feed to each tuyere. FIGURE 1 shows one feeder **23** at the right hand side of the blast furnace **10** and shows only a fragment of the feeder **23** on the left hand side of the blast furnace, viewing FIGURE 1. It will be understood that only one feeder **23** can be used, the screw conveyers **26** of which are arranged at one side of the blast furnace and communicate through pipes **22** with the tuyeres **21** each having a screw conveyer and pipe **22** individual thereto.

A coal drier **27** is arranged to receive raw wet hammer-milled coal at **28**, dry and preheat it, and deliver it to hot bin **24** through pipe **29**. Any suitable drier for this purpose may be used, including that disclosed in my aforesaid United States Patent 3,047,473. A furnace **30** furnishes hot combustion gases through pipe **31** to dry the coal. It will be understood that the showing of FIGURE 1 exemplifies one embodiment of the invention, that the invention is not limited to the relative position of the drier **27** and feeder **23** shown in this figure and that, if desired, the drier **27** can be positioned at ground level and the dried hammer-milled coal conveyed by a carrier gas from about ground level into the top of hot bin **24**.

Hot bin **24** preferably cylindrical and built of sheet iron or steel, has downwardly converging bottom walls **32** terminating in a valve seat **33** (FIGURE 2) adapted to be closed by a swinging cup-shaped disc **34**, providing a guard valve for the pressure bin **25**. Lever **35** operated from any suitable source of power swings the disc **34** to open or closed position. The guard valve consisting of seat **33** and disc **34** controls the discharge from hot bin **24** into the pressurized bin **25** and need be only sufficiently tight to shut off the flow of coal by gravity from bin **24**.

The pressure bin **25** is the same in both the modifications of FIGURE 1 and that of FIGURES 3 and 4 and hence has been identified by the same reference characters in these figures. As best shown in FIGURE 4, it is a vessel having a relatively narrow elongated lower portion **25′** defined by the longitudinally elongated substantially parallel side walls **25*a*** and **25*b*** (FIGURE 3) and the narrow walls **25*c*** and **25*d*** (FIGURE 4). The side walls **25*a*** and **25*b*** are shaped as shown in FIGURE 4; the lower portion of the opposite side edges are substantially vertical and parallel up to level **25*g*** and above this level the opposite edges **25*e*** and **25*f*** converge towards the top of bin **25**. End walls **25*c*** and **25*d*** consist of oppositely disposed substantially vertical lower portions extending to level **25*g*** and converging upper portions extending from level **25*g*** to the top of pressure bin **25**.

Pressure bin **25** preferably, is of smaller capacity than bin **24**, but of sufficient capacity to hold the predetermined charge of preheated coal for the blast furnace. The capacity of the pressure bin **25** will depend on the size of the blast furnace; a pressure bin **25** having one cubic foot of volume per **100** cubic feet of working volume of the blast furnace will be found satisfactory. Both bins are advantageously lagged to minimize loss of heat from the preheated coal.

The bottom of bin **24** is connected with the top of bin **25** by a vertical duct **36** isolated from bin **25** by a valve seat **37** and a valve disc **38**, both in general similar to valve **33–34** but with this difference that valve **37–28** is constructed to close pressure tight. For this purpose a valved jet **39**, preferably a steam jet, is provided to clean or scour seat **37** before the valve is closed. Lever **40**, operated from the same power source that operates valve **34**, operates disc **38**. While valve disc **38** is shown seated on seat **37** so that the pressure in vessel 25 acts against the valve disc 38 on its seat, this valve disc 38 can be inverted as hereinafter described in connection with FIGURE 3 so that the pressure in pressure bin 25 maintains the valve 37–38 sealed. Valve disc 34 can be inverted similarly.

The elongated base portion of pressure bin 25 communicates with a row of screw conveyers 26, which can be located in separate chambers or in one common chamber extending from the base of pressure bin 25 towards the blast furnace. FIGURE 4 shows 10 screw conveyers at the base of hot bin 25. Thus a hot bin construction for supplying 10 tuyeres is illustrated; the number of screw conveyers at the base of the hot bin will depend on the number of tuyeres supplied by that hot bin. Each screw conveyer 26 has a conveyer screw 42 driven from a power source 44 and feeds the hot dry coal, under pressure into the communicating pipe 22 which leads into a tuyere 21. Employing a single feeder 25 for the blast furnace the pressurized bin 25 is dimensioned to supply all of the tuyeres and feeds the preheated pressurized hammer-milled coal to the respective screw conveyers each individual to a tuyere through a pipe 22 of sufficient length to provide communication between the tuyere and the screw conveyer which supplies that tuyere. Carrier gas such as steam or coke oven gas is introduced into each pipe 22 through a valve controlled line 48 to insure smooth trouble-free transport of the preheated hammer-milled coal particles through pipes 22 into the tuyeres 21.

Steam, coke oven gas or other carrier gas for pressurizing bin 25 is supplied by pipe 45 and valved branch 46. A gauge 47 indicates the pressure in the bin.

In the arrangement shown in FIGURE 1, coal flow from pressure bin 25 stops when the bin has been emptied, and does not re-start until after bin 25 is refilled and repressurized. Preferably two assemblies, each containing a drier 27, hot bin 24 and pressure bin 25 are used, as indicated in FIGURE 1 where one assembly, that on the left hand side, is shown fragmentarily. One assembly feeds one-half of the tuyeres and the other assembly feeds the other half of the tuyeres of the blast furnace. In this way the feed of hammer-milled coal into the blast furnace through the tuyeres is maintained more uniform, especially by increasing the speed of rotation of the screw conveyers 26 during the interim when one or the other pressure bin 25 is refilling. The capacity of the pressure bins 25 and the rate of discharge of the coal therefrom are such that one or the other of the pressure bins 25 feeds coal through the tuyeres of the blast furnace at all times during operation.

In the modification of FIGURE 3, continuous feed of hot hammer-milled coal, preheated to a temperature of 220° F. to 600° F. to each tuyere is effected. This facilitates uniform operation of the blast furnace. In FIGURE 3 a hot bin 24′ for receiving preheated hammer-milled coal, as in the case of hot bin 24 of FIGURE 1, communicates through a connecting chamber 24*b* with lock hopper 24A. A valve disc 34′ arranged to seat on seat 33′ controls the communication between base of hot bin 24′ and the top of chamber 24*b*. The base of this chamber is provided with a valve seat 24*c* on which the valve disc 24*d* pivoted at 24*e* is adapted to seat to make a gas tight seal. This disc 24*d* is inverted relative to position of valve disc 38 shown in FIGURE 2. In the construction of FIGURE 3 the lock hopper 24A, after valve disc 24*d* is seated on its seat 24*c*, is pressurized by steam, coke oven gas or other carrier gas introduced into lock hopper 24A through valve controlled main 24*f*.

The base of lock hopper 24A communicates with the top of pressure bin 25 through chamber 26*b* having a valve seat 26*c* at its top and a valve seat 26*d* at its base. Valve disc 86 carried by arm 88 pivoted at 89 is arranged to seat on seat 26*c*. Pressure carrier fluid admitted through main 24*f* in lock hopper 24A acts on valve disc 24*d* to maintain it seated on valve seat 24*c*.

Pressurizing bin 25 is provided with a valve controlled line 46′ for introducing carrier gas under pressure such as steam or coke oven gas. This pressure acts on valve disc 87 to maintain it seated on seat 26*d* and thus provide a pressure tight seal for bin 25. Valve disc 87 is mounted on an actuating arm 91 pivoted at 92.

The apparatus of FIGURE 1 as well as that of FIGURE 3 is equipped with conventional timer mechanism for operating the valves at predetermined intervals and in the desired sequence.

The operation of the apparatus of FIGURE 3 will now be described. Valve disc 87 is moved from its seat 26*d* and previously pressurized coal in lock hopper 24A drops into pressurized bin 25. Guard valve 86, 26*c* closes after a suitable time delay to clear chamber 26*b* of coal. Valve 87, 26*d* then closes, no coal being present on the valve seat 26*d* to erode the valve disc 87. The absence of coal on gas tight valve seat 26*d* is a result of the prior closure of guard valve 86, 26*c*. Guard valve 86, 26*c* need not be gas tight but merely fit closely enough to stop coal flow. Valve seat 26*d* can be provided with a jet similar to 39 to insure removal of all coal from the seat. The time controlled actuation mechanism then opens valve 24*d*, 24*c* and valve 34′, 33′ thus allowing coal to fall from bin 24′ filling lock hopper 24A. Guard valve 34′, 33′ is then closed; and guard valve 86, 26*c* opened, thus lowering the coal level in lock hopper 24A so that gas-tight valve 24*d* can close free of coal on or close to seat 24*c*. Valve 24*f* opens and carrier gas is admitted to lock hopper 24A to bring it up to the pressure in pressurized bin 25; the cycle can then be repeated.

The drier and coal preheater, shown in FIGURES 5 and 6, comprise a shell 50 open at the top and bottom but closed at the sides, and adapted to receive raw wet hammer-milled coal at the top of 51 and hot ascending combustion gases from furnace 30 at the bottom at 52. Fixed to the opposite walls of shell 50 is a series of staggered horizontal baffles or supports 53, arranged as shown in FIGURE 5 to prevent the downward passage of quiescent coal in the drier. It will be noted that the bottom baffle 53*a* is positioned to provide a stop or obstruction for the space 53*b* defined by the oppositely disposed side edges of the baffles 53 thereabove, which side edges define the space 53*b* diverging in an upward direction. Bottom baffle 53*c* acts as a stop for the space 53*d* defined by the adjacent side edges of baffles 53 thereabove. Space 53*e* is disposed below baffle 53*f* and diverges from top to bottom providing passageway for both ascending hot gases and freely falling coal. Spaces or openings 53*e*, 53*g* and 53*h*, i.e., areas through which coal can fall, are provided in the drier; space 53*h* is positioned contiguous to wall of shell 50 and space 53*g* at the opposite side of the drier beneath top baffle 53*i* and above the base wall 60. The bottom 52 of drier communicates with the passageway leading into the drier therebelow or the feed bin F leading into the line 29, at spaced discharge openings O_1, O_2 and O_3.

Reciprocating on the baffles is a series of scrapers 54, so arranged as to agitate and move the coal in the drier to dislodge the coal from the supporting baffles and cause it to fall through openings O_1, O_2 and O_3. Scrapers 54 are rigidly affixed to a frame comprising longitudinal bars 55 connected to a vertical cross member 56 at the opposite ends of the latter so that all the scrapers reciprocate together, including top scraper 54*a* movable to scrape the top of the left hand end of baffle 53*f*. Top scraper 54*a* is fixed to one end of arms 54*b* (FIGURE 5), the opposite ends of which are suitably fastened to the upper edge of scraper 54′ shown in FIGURE 6.

Reciprocation of the scrapers is effected by oscillating toothed pinion 57 meshing with rack 58 which reciprocates on rollers 59 rotatably supported, as is pinion 57, on frame 61. The reciprocating motion of rack 58 is transmitted to the frame carrying scrapers 54 by means of rod 62 which at one end is threaded and pinned to rack 58 at **63**, passes through seal **64**, and at the other end is fastened to cross member **66** of the scraper frame.

Seal **64** is mounted in stub cylinder **66** welded to head plate **67** which is bolted to and closes flanged extension **68** of shell **50**.

Oscillating pinion **57** may be operated by any suitable drive, preferably provided with speed control, to give any desired rate of feed of the coal.

The coal in its descent through the drier loses its moisture and is heated, and the heated coal falls into bin **24** or **24'** in a hot dry condition. It will be clear that by suitable regulation of the speed of reciprocation of the scrapers, the downward flow of coal can be so controlled with respect to the upward flow and temperature of the combustion gases that the coal drops into bin **24** or **24'** at a desired temperature, within the range of 220° F. to 600° F. preferably 400° F. to 600° F.

Instead of one set of baffles and scrapers such as that described, the drier may contain two or more, one above another. In FIGURE 1, two such sets are indicated diagrammatically at **70** and **71**. Furnace **30** may be fired by any suitable fuel. The baffle-scraper assemblies serve to meter the coal flow countercurrent to the hot gases rising up therethrough.

In operation the metallurgical materials, e.g., iron ore, along with coke and flux are introduced through the charging device into the blast furnace and heated air with or without added oxygen supplied to the tuyeres of the blast furnace from the bustle pipe. The hammer-milled coal having the particle size hereinabove disclosed and having a moisture content ordinarily from about 2% to 8%, usually 7% to 8%, is passed through the drier to preheat it to 220° F. to 600° F., preferably 400° F. to 600° F. The hot dry coal is fed continuously or intermittently through transfer line **29** (FIGURE 1) to hot bin **24** (FIGURE 1) or **24'** (FIGURE 3), and fed intermittently into pressure bin **25** as needed for introduction into the blast furnace **10**. Employing the continuous procedure of FIGURE 3, the hot dry coal is fed intermittently as above described into lock hopper **24**a and thence intermittently into pressurized bin **25** in which a charge of coal is always maintained under pressure for feed to the tuyeres, which charge is replenished intermittently and often enough to always maintain enough coal in bin **25** to supply the screw conveyors **26**. With a hot blast gas pressure of 20 p.s.i.g., the pressure in pressurized bin **25** should be raised to 30 p.s.i.g. or higher by steam, coke oven gas or other carrier gas from pipe **46** or **46'**, desirably superheated steam at temperatures of 500° F. to 700° F.

From 20% to 40% of the coke requirements of the blast furnace can be replaced by the preheated coal introduced into the tuyeres as hereinabove described.

The introduction of the preheated coal, as herein described, does not result in loss of heat from the hot blast. The coal being hot, dry and at a temperature within the range of from 220° F. to 600° F., preferably 400° F. to 600° F. and being coarse enough to be retained in the coke bed in the tuyere zone of the blast furnace, burns readily there and supplies heat where needed at the maximum temperature zone of the blast furnace. The preheated coal being at or near the temperature where it begins to get "sticky", due to melting and formation of tar, is heated in the tuyere zone of the furnace to a temperature such that upon entry into the blast furnace into contact with the coke bed therein it sticks to the coke and is burned where it can contribute best to the local heat balance of what must necessarily be the hottest zone of the furnace. I have found that when coking coals are preheated or dried in air or conveyed to the blast furnace using air as the carrier gas, their coking properties are impaired and the oxidized coal particles do not melt and stick to the coke bed in the hot zone of the blast furnace where they can best contribute to the conservation of the relatively expensive coke. The use of dry hammer-milled coal, which as noted is relatively coarse and yet can be injected under pressure through the tuyeres into the blast furnace is especially important because the coarse particles are retained in the high temperature zone of the blast furnace long enough to be burned there to supply heat where it is needed, and this without loss of coal by passage up through the charge in the blast furnace as takes place when pulverized or powdered coal is employed. Moreover, the preheated coarse coking coal particles do not ball up or stick together and clog the tuyeres even with high weight ratios of coal to carrier gas. Such clogging of the tuyeres frequently takes place when using pulverized or powdered coal, and this even though much lower weight ratios of coal to carrier gas are used. This advantage of the described procedure is indeed surprising and unexpected because from the experience with injection of pulverized or powdered coal through the tuyeres of a blast furnace, one would expect that the difficulties encountered with clogging of the tuyeres would be aggravated by the use of larger coal particles, yet the injection of preheated hammer-milled coal as herein disclosed proceeds smoothly, so much so that relatively greater quantities of the cheaper hammer-milled coal can be introduced through the tuyeres to replace relatively expensive coke.

Operating as herein described, the amount of gas, preferably steam or coke oven gas, employed to pressurize the pressurized bin **25** or **25'** and aid in conveying the coal into and through the tuyeres is kept to a minimum, thus conserving the high temperature of the blast.

By feeding the preheated dry coal by the screw conveyers each individual to a tuyere, which screw conveyers give positive control of the feed to each tuyere, the amount of carrier gas supplied to the conveying line for each tuyere can be kept low. The amount of carrier gas is markedly lower than is required in procedures involving the feed of wet coal or employing splitters to apportion the feed to the tuyeres.

It will be noted that guard valve discs **34**, **34'** and **86** (FIGURES 2 and 3) open and close through coal and that they need make only a loose fit with their respective valve seats to prevent feed of coal into the zones in which gas tight valves **37–38**, **24**c–**24**d and **87–26**d operate. In this way those valves which must be gas tight, avoid the serious erosion which arises when they are forced to close with coal on their seats. Steam or inert gas introduced through jet **39** cleans the valve seat before disc **38** seats on seat **37**. A gas tight closure is thus insured each time valve disc **38** is seated. The above described operation of valve disc **38** also applies to valve discs **24**d and **87** of FIGURE 3 which close in the absence of coal and make pressure tight closure on their respective valve seats. In the structure of FIGURE 3 the pressure in lock hopper **24**a aids in maintaining valve disc **24**d on its seat **24**c. Similarly the pressure in pressurized bin **25** holds valve disc **87** tightly against its seat **26**d. By inverting valve disc **38** so that it seats against a seat at the top of pressurized bin **25**, similar to the structure shown in FIGURE 3 for valve disc **87** and its seat **26**d, the pressure in pressurized bin **25** will hold the inverted valve disc tightly against its seat .

Since raw hammer-milled coal is available at steel plants and is relatively cheap, and since the cost of pulverizing or screening required by some prior processes is avoided, it will be apparent that this invention provides an unusual economical and efficient improvement in the operation of blast furnaces.

This invention is not to be limited to the disclosure herein, including that of the drawings, except as indicated in the appended claims.

What is claimed is:

1. Apparatus for charging coarsely comminuted coal, at least 20% of said coal being comprised of particles having a particle size of over one-eighth up to three-eighths of an inch in a dry state preheated to a temperature of from 220° F. to 600° F. as an auxiliary fuel to a blast

furnace having a plurality of tuyeres, in combination, a hot bin adapted to receive and store said coal, a pressure bin having a charging inlet for the feed therethrough of said coal, valve means providing a gas tight seal for said inlet, jet means for scouring said valve means providing a gas tight seal for said inlet to remove coal particles therefrom, a valved means for introducing pressure fluid into said pressure bin, a screw conveyer individual to each tuyere, means for removing said coal from said pressure bin while still under pressure and introducing said coal into said screw conveyers, and means for injecting said coal fed from said screw conveyers into the tuyeres of said blast furnace.

2. Apparatus for charging hot dry coarsely comminuted coal, at least 20% of said coal being comprised of particles having a particle size of over one-eighth up to three-eighths of an inch, preheated to a temperature of from 220° F. to 600° F. as fuel to a blast furnace comprising in combination, a coal drier, means for passing wet coarsely comminuted solid coal through the drier countercurrent to hot combustion gases, a hot bin having a valved bottom outlet, means for passing hot dry comminuted solid coal from the drier into the hot bin, a pressure bin having a top inlet and a bottom outlet, a valve seat and cooperating valve disc providing a gas tight closure for said top inlet, a duct connecting the bottom outlet of the hot bin with the top inlet of the pressure bin, jet means for scouring said seat of the valve providing a closure for said top inlet of said pressure bin, valved means for admitting pressure fluid to the pressure bin, means for removing the hot dry coarsely comminuted coal from the pressure bin while still under pressure, and pressure tight duct means connecting said removing means with the tuyeres of said blast furnace.

3. Apparatus for charging coarsely comminuted coal, at least 20% of said coal being comprised of particles having a particle size of over one-eighth up to three-eighths of an inch, preheated to a temperature of from 220° F. to 600° F. as solid coal through the tuyeres of a blast furnace, comprising in combination, a hot bin, a pressure bin positioned below said hot bin and communicating therewith through a vertically disposed conduit positioned between the base of said hot bin and the top of said pressure bin, a valve at the upper edge of said conduit controlling the discharge of coal from said hot bin, a valve seat in said conduit below said first mentioned valve, a pivoted valve disc adapted to seat on said valve seat and movable in said conduit when no coal is discharged therethrough upon closure of said first mentioned valve, jet means for projecting a gaseous jet on said valve seat to remove coal particles therefrom before said pivoted valve is seated on said seat to provide a gas tight closure for said pressure bin, means for supplying pressure fluid to said pressure bin, a screw conveyer individual to each tuyere, means for removing said coal from said pressure bin while still under pressure and introducing said coal into said screw conveyers, and means for injecting said coal fed from said screw conveyers into the tuyeres of said blast furnace.

4. Apparatus for charging coarsely comminuited coal, at least 20% of said coal being comprised of particles having a particle size of over one-eighth up to three-eighths of an inch in a dry state preheated to a temperature of from 220° F. to 600° F., through the tuyeres of a blast furnace, comprising in combination, a hot bin, a lock hopper positioned below said hot bin and communicating therewith through a vertically disposed conduit positioned between the base of said hot bin and at the top of said lock hopper, a valve at the upper edge of said conduit controlling the discharge of coal from said hot bin into said lock hopper, a valve at the lower edge of said conduit providing a pressure tight seal for said lock hopper, a pressurized bin below said lock hopper, a conduit communicably connecting the base of said lock hopper with the top of said pressurized bin, a valve at the top of said last mentioned conduit providing a pressure tight seal for said lock hopper, a valve at the base of said last mentioned conduit providing a pressure tight seal for said pressurized bin, and screw conveyer feed means connecting the discharge outlet of said pressurizing bin with the tuyeres of said blast furnace.

5. The apparatus as defined in claim 4, in which the lock hopper has means for supplying a carrier fluid under pressure to produce superatmospheric pressure conditions in the lock hopper, the pressurized bin has means for supplying a carrier fluid under pressure to produce superatmospheric pressure conditions in the pressurized bin, the valves for the lock hopper are constructed and arranged to be maintained tightly sealed when closed by the pressure in said lock hopper and the valve for the pressurized bin is constructed and arranged to be tightly sealed by the pressure in said pressurized bin.

6. The apparatus as defined in claim 1, in which the hot bin has a discharge outlet substantially circular in cross section, the pressure bin has an inlet of substantially the same configuration as said outlet and communicably connected therewith and the said pressure bin has a longitudinally elongated base communicating with a plurality of said screw conveyers.

7. The apparatus as defined in claim 4, in which the hot bin has a discharge outlet substantially circular in cross section, the lock hopper has an inlet of sustantially the same configuration as said outlet and communicably connected therewith and said lock hopper has a discharge outlet substantially circular in cross section, the pressurized bin has an inlet of substantially the same configuration as the outlet from said lock hopper and communicably connected therewith and said pressurized bin has a longitudinally elongated base communicating with a plurality of said screw conveyers.

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