

March 2, 1954

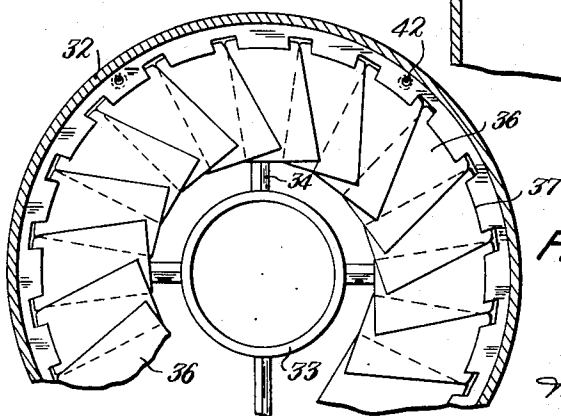
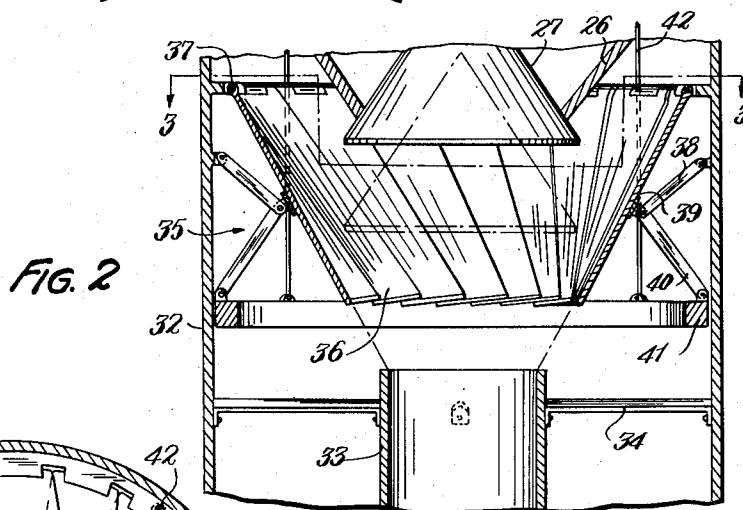
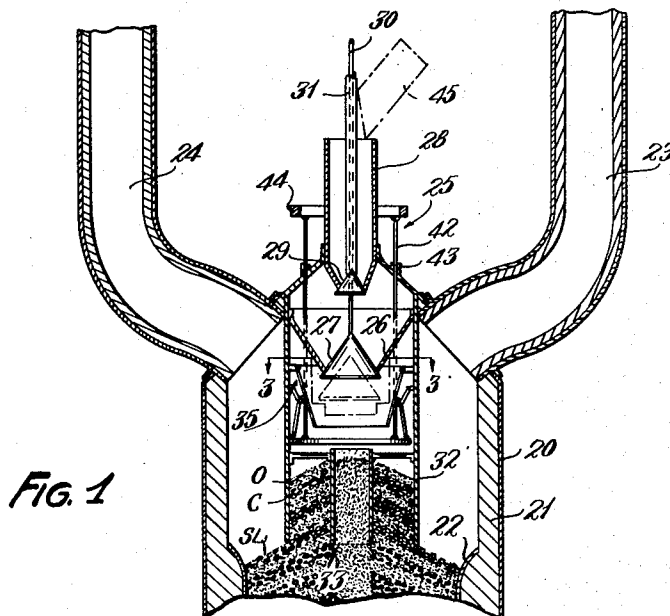
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2,671,017

METHOD OF CHARGING A BLAST FURNACE

Filed Sept. 24, 1949

4 Sheets-Sheet 1



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METHOD OF CHARGING A BLAST FURNACE

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4 Sheets-Sheet 2

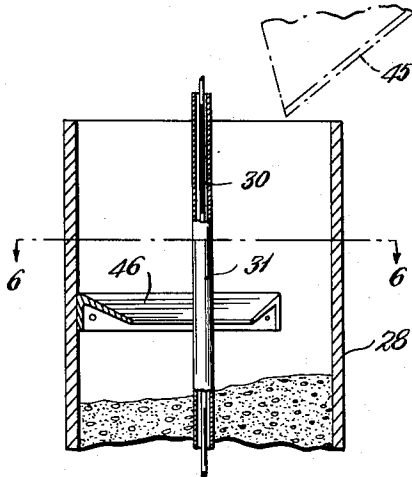


FIG. 5

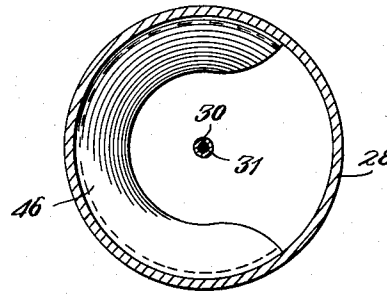


FIG. 6

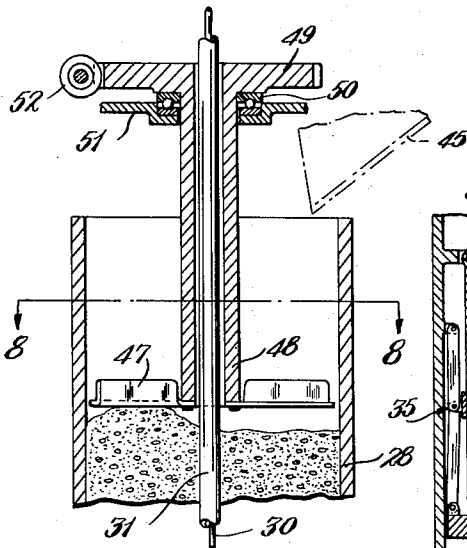


FIG. 7

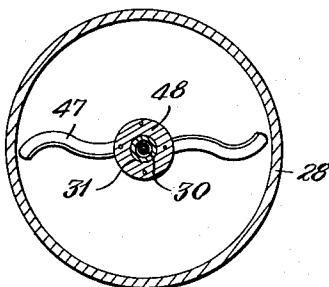


FIG. 8

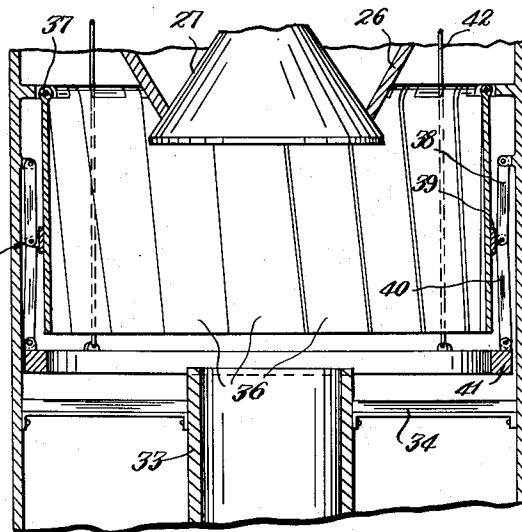


FIG. 4

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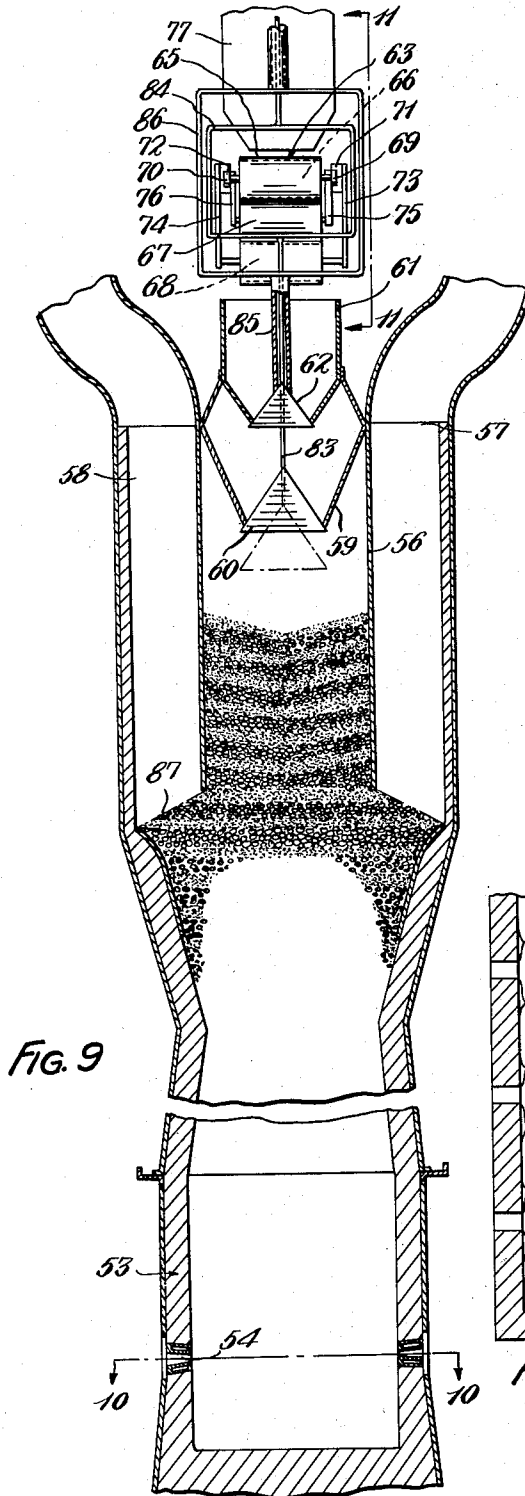


FIG. 9

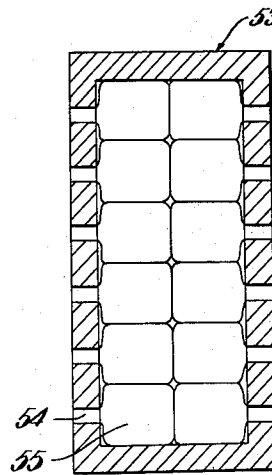


FIG. 10

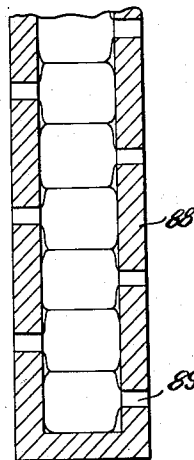


FIG. 13

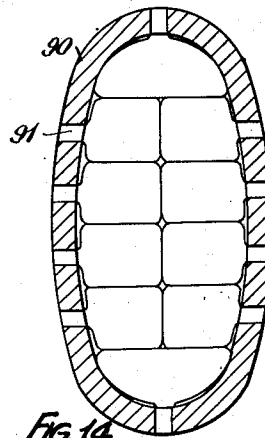


FIG. 14

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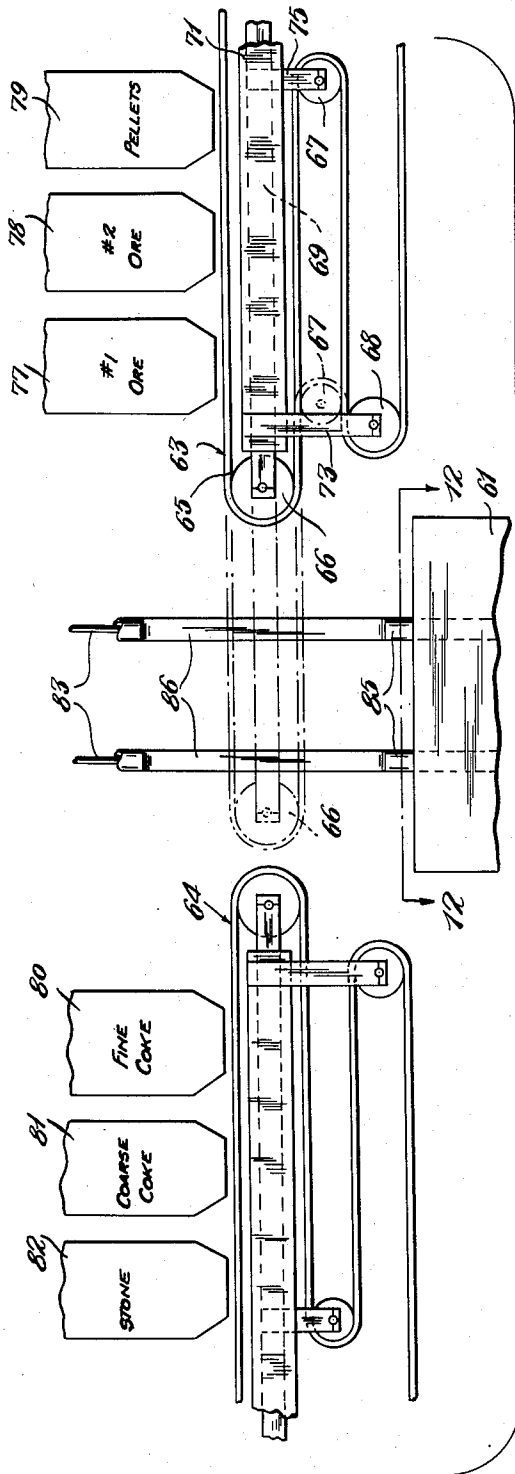


FIG. 11

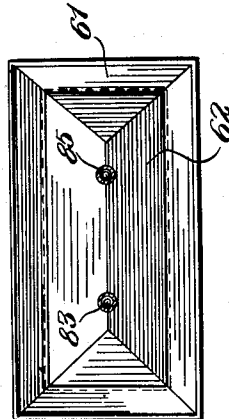


FIG. 12

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UNITED STATES PATENT OFFICE

2,671,017

METHOD OF CHARGING A BLAST FURNACE

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Application September 24, 1949, Serial No. 117,652

3 Claims. (Cl. 75-41)

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This invention relates to blast furnaces; more particularly, to a method for charging a blast furnace, which, although not limited thereto, is especially applicable to blast furnaces for reducing iron ores.

In a blast furnace there is counter-current flow of descending materials and rising gases; that is to say, the solid materials such as ore, flux, and fuel are charged at the top and move downwardly against the flow of gases which are moving in an upward direction as the result of the introduction of air and/or other gases under pressure adjacent the bottom. The temperatures of all the solids increase as they descend, reducing gas being formed by the reaction of the oxygen introduced either in the form of air or as a separate gas with the fuel. This reducing gas in its ascension causes reduction of the iron or other metal and calcination of the limestone or other flux, the reduced metal and resulting gangue being melted adjacent the tuyères and drawn off, thus making room for the descent of the materials thereabove. The more intimate the contact of the rising gases with the descending solids of the charge, the more rapidly and uniformly are the reactions carried on. Under ideal conditions of operation there would be substantially uniform reaction and downward movement of the charge in all parts of the furnace, so that no unreduced ore reaches the hearth, the quantity of coke or other fuel being only that necessary to maintain the proper temperature and provide a sufficient volume of reducing gas to effect the reactions. Unfortunately, however, conventional blast furnaces and methods of charging fall far short of ideal operation, thereby greatly increasing the cost of the metal produced as well as resulting in excessive "wear and tear" on the furnace.

Many, if not all, of the difficulties encountered in blast furnace operation, for example, slips, hanging, excessive coke consumption and the like, are directly the result of insufficient or improper contact between the ascending gases and the descending solid materials and this is, in turn, largely the result of improper distribution of the charge within the furnace due to undesirable segregations of various components of the material. The improper distribution and segregation are, in turn, directly traceable to defects in the method and apparatus conventionally employed to introduce or charge the solid materials into the furnace, and/or to the design of the furnace with respect to the area of the stock column adjacent to the point of charging relative to the effective area of the tuyère activity in the smelt-

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ing zone. Moreover, conventional charging methods and apparatus result in excessive flue dust, requiring expensive equipment for its recovery, which further reduces the efficiency of the operation.

Charging of a conventional blast furnace is effected by means of a double bell, each bell forming the bottom of a hopper with the upper bell and hopper generally being smaller than the lower or charging bell and hopper into which the upper bell discharges. The upper hopper generally has a somewhat larger cubical capacity than the skip or bucket used to hoist the material to the top of the furnace, while the volume of the charging hopper is usually as large as the conventional round of materials charged, that is, it may hold several skip loads. In accordance with the usual procedure, the upper bell is closed when each skip or bucket load is delivered thereto and is opened to drop this load into the charging hopper, with the charging bell closed, when the skip or bucket returns for another load, the charging bell being operated only once or twice for each complete charge of materials, commonly spoken of as a round. The distribution of each skip load of material on the large or charging bell is dependent upon the slope of the bells, the size of the charging hopper, sizes of the particles of the material charged, and the amount and distribution of the material present in the charging hopper from previous operations of the smaller bell. Since the skip or bucket does not drop the material uniformly throughout the cross sectional area of the smaller hopper and since different materials have different flow properties and different angles of repose, the distribution on the small bell is seldom uniform.

The lack of uniform distribution on the small bell results in a corresponding lack of uniformity of distribution of the material on the large bell which is further accentuated by the mounds and hollows made by irregularities of distribution of the material previously deposited upon the large bell by operation of the small bell. These irregularities in the distribution of the material upon the large bell are not corrected when the material on the latter is discharged into the furnace since the particles of the material are not of uniform size. Moreover, the materials charged into the furnace are subjected to rising currents of gases while dropping from the charging hopper which alter the distribution of the materials and carry off quantities of the fine particles as dust.

As a result of the use of a circular bell, the

ore, being relatively fine and heavy, is concentrated mainly under the lip of the charging bell while the larger particles of coke and limestone roll against the furnace wall and into the center of the stock column. Broadly speaking, therefore, the stock column has the ore deposited in a somewhat annular layer of generally doughnut shape, thicker under the lip of the bell with coke above and below, because the coke occupies about three times the space of the ore in each charge, the coarse coke and limestone particles being disposed in the center and around the outer circumference of this doughnut of fine ore. In addition, the annulus or doughnut of fine ore is thicker in some circumferential locations than in others.

It will be apparent, therefore, that the permeability of the stock column with respect to the ascending gases is not uniform. The ore, being more dense, the layers thereof offer more resistance to gas flow than a corresponding volume of coke and this resistance by the ore layers is increased when the layers are relatively thick and the ore contains a large percentage of fines. Investigations have shown that zones in the stock column offering high resistance to gas flow are zones of lower degree of reduction than are the more permeable zones and hence, when ore is charged in the manner just mentioned, a part of the ore ordinarily must be reduced by direct contact with incandescent carbon lower down in the furnace, thus causing excessive coke consumption. Moreover, as the size of the furnaces has increased, the customary procedure has been to increase the size of the charging bell and this has increased the volume of the relatively open center, thus increasing channeling of gases there-through with consequent inefficient operation. The usual solution for this increased volume of open center has been to increase the size of the ore charge and to also charge a part of the ore in the center of the furnace to reduce the porosity in that region. Larger ore charges, however, make the ore layers thicker and hence more impervious, thus further contributing to poor gas-solid contact and inefficient operation while charging ore to the center of the furnace increases the quantity of ore which reaches the smelting zone in an unreduced state since in the larger furnaces there is an inactive or "dead" center centrally of the tuyères and extending thereabove.

Investigations have also shown that when the percent reduction of iron ore to metallic iron has reached about 80%, due to the action of reducing gases, the iron bearing compounds are soft and plastic and begin to stick together. Where there is a thick layer of ore, this action is even more pronounced and the stock column stops moving loosely and freely and begins to hang until a sufficient cavity is formed therebelow to set it in motion again. When downward motion does begin again, the material tends to drop in a body and when this action is of sufficient magnitude, it is called a "slip" which, as is well known, causes excessive dust losses and other difficulties. Prior attempts to overcome the above mentioned difficulties have been directed primarily towards changes in the sequence of charges and to the use of distributors. These procedures and devices, however, generally produce uniform segregation as contrasted with uniform distribution of the materials. That is to say, the ore and other materials of the stock column are deposited in the furnace in more or less uniform piles rather

than as uniform layers and hence, while some improvement is effected in the operation, optimum conditions cannot be reached or even closely approximated. In order to further increase production and effect savings in coke and flux, it is necessary to improve the gas-solid contact by securing more uniform permeability in the stock column than can be secured by these conventional expedients.

An object of this invention is to provide an improved method for charging a blast furnace which provides a better distribution of the material charged, reduces dusting, and provides better gas-solid contact, thereby reducing the quantity of fuel consumed per ton of metal produced and otherwise increasing the efficiency of operation.

Another object of the invention is to provide an improved method for charging a blast furnace wherein the ore is charged in relatively thin, substantially uniform layers which are preferably annular in shape, the transverse dimensions of the layers being so related to the transverse dimensions of the smelting and tuyère zones as to prevent hanging and improve the permeability of the stock column.

A further object of the invention is to provide an improved method for charging a blast furnace as defined in the preceding object wherein the ore is charged in thin layers between layers of coarser coke, while the finer coke is charged into the center of the furnace.

A still further object of the invention is to provide an improved method for charging a blast furnace as defined in the two preceding paragraphs and wherein the flux material is more uniformly distributed throughout the charge with substantially none of this material in the central section or core of the furnace, thereby promoting more uniform fluxing action and preventing the center of the charge from becoming too open or porous.

An additional object of the invention is to provide an improved method for charging a blast furnace such that the ore is deposited within the furnace between two concentric tubes with fine coke charged into the inner tube, whereby the ore, flux, and coarser coke are in relatively thin annular layers of substantially uniform thickness with fine coke in the center of such annular layers.

A still further object of the invention is to provide an improved method for charging a blast furnace wherein the materials are periodically delivered therein without appreciably altering the height of the stock column so that the permeability of the latter remains substantially constant.

The invention further resides in certain novel steps of procedure, and further objects and advantages thereof will be apparent to those skilled in the art to which it pertains from the following description of an apparatus by which it may be performed, described with reference to the accompanying drawings in which similar reference characters represent corresponding parts in the several views and in which:

Fig. 1 is a somewhat schematic longitudinal sectional view through the upper portion of a blast surface illustrating an apparatus for performing the improved method of charging;

Fig. 2 is an enlarged view of a portion of the structure shown in Fig. 1 illustrating the adjustable deflector mechanism positioned to deliver material to the central or inner tube;

Fig. 3 is a transverse sectional view taken substantially on the section indicating line 3-3 of

Fig. 2 with the charging bell removed and further illustrating the adjustable deflector;

Fig. 4 is a view similar to Fig. 2 but with the deflector mechanism positioned to deliver material between the inner and outer tubes;

Fig. 5 is an enlarged fragmentary longitudinal sectional view of the upper hopper or supply tube of the furnace illustrating the manner in which a fixed deflector may be employed therein;

Fig. 6 is a transverse sectional view taken substantially on the section indicating line 6—6 of Fig. 5;

Fig. 7 is an enlarged fragmentary longitudinal sectional view of the upper hopper or supply tube of the furnace illustrating the manner in which a rotatable scraper or material leveling means may be employed therein;

Fig. 8 is a transverse sectional view taken substantially on the section indicating line 8—8 of Fig. 7;

Fig. 9 is a somewhat schematic longitudinal sectional view through the upper and lower portions of a blast furnace of rectangular cross section illustrating a modification of the improved charging method as adapted to such furnace;

Fig. 10 is a transverse sectional view through the tuyeres of the rectangular furnace illustrating the action thereof, the view being taken substantially on the line 10—10 of Fig. 9;

Fig. 11 is a fragmentary side elevational view of the upper or supply hopper, material conveying mechanisms and the material supply bins shown in Fig. 9, the view being taken substantially on the line 11—11 of Fig. 9;

Fig. 12 is a top plan view of the upper or supply hopper and bell of the furnace illustrated in Fig. 9, the view being taken substantially on the line 12—12 of Fig. 11;

Fig. 13 is a view similar to Fig. 10 but showing a modified arrangement of the tuyeres for a rectangular furnace; and

Fig. 14 is a view similar to Figs. 10 and 13 but showing the arrangement of the tuyeres of a furnace having an elliptical cross section.

In accordance with this invention, improved distribution of the materials charged, and hence improved permeability in the stock column and better gas-solid contact, is accomplished by changes in the top of the furnace and changes in the charging methods. Thus, irregularities in distribution of the material over the smaller bell, due to the delivery thereto by the skip or bucket, are equalized by making the cross sectional area of the upper hopper smaller than in conventional constructions or, alternatively, means are provided in the upper hopper or supply tube to assist the distribution of the material therein. Consequently, the material is delivered to the charging bell with a substantially uniform circumferential distribution. In addition, the larger or charging bell is preferably operated separately for each different type of material delivered thereto, i. e., for ore, flux, and coke, so that the different materials are charged sequentially in layers into the furnace. Alternatively, the ore, flux, and coarse coke may be deposited on the large bell and charged together into the furnace by one drop or operation of the large bell. Furthermore, the upper portion of the furnace is so arranged that the materials dropped therein do not fall against rising currents of gases but instead enter a relatively quiescent zone and, in the preferred embodiment, the materials are so directed as they fall as to aid their distribution and direct them to desired predetermined locations. Moreover, the quies-

cent zone is so arranged as to provide a constant head or height of material within the blast furnace proper, which is unaffected by the sequential operations of the bells. In addition, the area of the quiescent zone is so related to the areas of the smelting and tuyère zones that the flow of gases is not impeded and the materials moving from the quiescent zone substantially maintain their initial distribution within the upper portion of the furnace proper. Also, the materials are delivered in a manner such as to form an annulus of ore with the relatively fine coke preferably being charged centrally thereof, while the coarse coke and flux materials are intermediate the separate layers of ore. Details of the manner in which these operations and results are achieved will become apparent from the following description of the present preferred embodiment of the invention and certain modifications thereof.

In Fig. 1 of the drawings the upper portion of a furnace is somewhat schematically illustrated in section. The construction comprises the outer shell 20, lining 21, and wear plates 22, which are provided over a shoulder of the lining adjacent to the top of the stock line designated SL. The furnace further comprises a closed top with the usual gas outlets 23 and 24 intermediate which are provided the hoppers and bells generally designated 25. The charging hopper 26 is formed in a conventional manner, with the lower portion shaped as an inverted frustum of a cone. The opening at the bottom of this hopper is adapted to be closed by a conically shaped charging bell 27. Above and concentric with the charging hopper 26 and charging bell 27 is the feed or supply hopper 28, which is generally of circular cross section but has an inverted frusto-conical lower portion the opening of which is closed by the upper or smaller bell 29. Connected with the lower or charging bell 27 is an actuating rod 30 which extends upwardly through the upper bell 29 and through a hollow actuating tube 31 for the latter, the rod 30 and tube 31 being operated by conventional mechanisms not shown. The furnace and bells just described are of conventional construction with the exception that the feed tube or upper hopper 28 is preferably of smaller diameter than that normally employed.

In accordance with this invention, the furnace just described is provided with a downwardly extending impervious partition wall 32 formed of heat-resistant metal and connected with the top of the furnace at its upper end intermediate the charging hopper 26 and the gas outlets 23, 24. Where the furnace is of circular cross section, as shown in Figs. 1-3, this partition wall 32 may be in the form of a cylindrical tube, the lower end of which is open and extends downwardly into the furnace to a point adjacent the wear plates 22. The lower end of the tube or partition wall 32 may be supported by radially extending braces not shown, if necessary. Disposed within the partition wall or tube 32 and concentric therewith is a second cylindrical tube 33 open at top and bottom with its lower end substantially coplanar with the lower end of the partition wall or tube 32. This tube 33 is supported from the tube 32 by suitable radially extending bracing means 34, the upper end of the tube 33 being spaced below the lower end of the charging bell 27 and the diameter of the tube 33 being less than the diameter of this bell.

Intermediate the charging bell 27 and the upper end of the tube 33, the interior of the tube

32 is provided with an adjustable deflecting means generally designated 35. As shown in detail in Figs. 2 and 3, this adjustable deflecting means 35 preferably comprises a plurality of metal plates or vanes 36, the upper edges of which are hinged-ly connected, as at 37, to a portion of the wall or tube 32, the plates extending downwardly from their pivotal connections in overlapping relationship and being adapted to be inclined different extents, while maintaining their overlapping relationship, to direct material falling from the bell 27 in its descent within the tube 32. To effect this adjustment of the deflecting means, a plurality of links 38 each has its upper end pivotally connected to the inner wall of the tube 32 and its lower end pivotally connected to a shoe member 39. Also pivoted to the shoes 39 are a second set of links 40, the lower ends of which are pivoted to an actuating ring 41. In the illustrated embodiment, the shoes 39 are shown as separate members for each plate 36 with an inclined inner face of each shoe engaging a portion of the rear surfaces of the corresponding pivoted plate 36. It will be understood, however, that two or more of the separate shoes may be connected together or a ring member formed of a plurality of segments may be employed in place of separate shoes in which event there need not be a set of links 38 and 40 for each plate 36. Connected with the actuating ring 41 and extending upwardly therefrom are a plurality of pull rods 42 which extend through sealing gaskets such as 43, the upper ends of the rods 42 being connected to a ring 44 which is adapted to be moved upwardly and downwardly by mechanism not shown.

In accordance with the preferred procedure of this invention, the materials such as ore, coke, and flux which are to be charged to the furnace are delivered to the top thereof in a conventional manner, as for example, by the use of a skip or bucket, indicated in broken lines at 45 in Fig. 1. Since the feed supply hopper 28 has a capacity only slightly greater than that of a skip load and since the diameter of the hopper is less than that conventionally employed, inequalities in the upper level of the material in the hopper as the result of the directionalized delivery from the skip represent only a relatively small percentage of the total depth of the material in the hopper, so that the material is substantially uniformly distributed over the bell 29. As the skip or bucket 45 returns for another load of material, the bell 29 is lowered through operation of its actuating tube 31, thus discharging the contents of the hopper 28 into the hopper 26, the bell 27 being closed at this time. Since the material within the upper hopper 23 is substantially uniformly distributed therein, this material in moving downwardly, upon opening of the bell 29, will be substantially uniformly distributed over the bell 27 for the hopper 26.

Preferably the bell 27 is operated after each delivery of material to the hopper 26 to, in turn, charge the material into the area within the tube 32. At this time the deflecting means 35 is so positioned, through operation of the ring 44, that the material discharging from the hopper 26 is guided to the desired location within the tube 32. That is to say, with the deflector 35 so disposed that the plates 36 extend substantially vertically downwardly, as shown in Fig. 4, the distribution of the material discharging from the hopper 26 is controlled simply by the shape of the bell 27, the nature of the material, and the dimensions of the tube 32. Where

the particles of the material charged roll easily, such as large coke or relatively large pieces of flux, the deflector 35 may be positioned, as just mention, to extend substantially vertically, so that the particles strike the inner side wall of the tube 32 and bound therefrom to their resting place. However, where the material charged is relatively fine, as, for example, ore containing a large percentage of fines, the deflecting means 35 may be positioned to intercept the material as it falls and direct it either against the outer side wall of the tube 33 or to intermediate positions between the tube 33 and the tube 32. The particular position of the deflecting means is, of course, selected in accordance with the material handled and may be varied for each separate operation of the bell 27 if the operator so desires.

As mentioned above, in the preferred embodiment of the procedure the ore is charged separately from the other materials and is so directed by the deflector 35 as to form a substantially uniform layer of annular form between the tubes 32 and 33, one of the layers of ore being designated O in Fig. 1. The coke is preferably sized to separate the fines therefrom prior to charging and the coarse coke is charged before and after the ore forming annular layers C intermediate the tubes 32 and 33. The fluxing materials may be charged with the large particles of coke or may be separately charged intermediate a coke and ore layer. By employing tube 33 and the deflecting means 35, the large particles of coke and of fluxing materials are prevented from entering the central portion of the furnace, thereby preventing the formation of a very porous and relatively unrestricted passageway for gases therethrough.

The fine coke, which was separated before charging, is preferably charged into the interior of the tube 33 by operation of the bell 27 and adjustment of the deflecting means 35 to direct the coke falling from the bell into the tube 33, see Fig. 2. This fine coke prevents the formation of a too porous center in the stock column and at the same time eliminates the necessity of charging ore to the center to overcome this undue permeability, as is customary in conventional practice. Moreover, the fine coke provides a path of controlled permeability and insures that this coke will not interfere with porosity through the large particles of coke, flux, and the ore layers by filling the voids therein. In addition to facilitating charging of the fine coke to the center, the tube 33 prevents this coke from being mixed with the other materials until after the materials enter the main body of the furnace thereby insuring that the distribution achieved within the tubes 32 and 33 will be substantially maintained throughout the descent of the materials through the upper portion of the furnace, since the several layers are not subjected to appreciable agitation as they move downwardly.

Preferably, the rate of charging, by virtue of the operation of the skip 45 and of the bells 27, 29, is such that the upper level of material within the tube 32 and tube 33 is above the lower edges of these tubes during normal operation of the furnace. Therefore, since the wall or tube 32 is impervious and is sealed to the top of the furnace, the zone or enclosed space within the tube 32 is substantially free of upwardly rising currents of gases, the latter being channeled around this zone to the gas outlets 22, 23. Therefore, the charging of materials into this rela-

tively quiescent zone, which is not in direct communication with the gas outlets, greatly reduces dusting and turbulence, thereby insuring a more uniform distribution of the materials and materially reducing loss of fine materials in the form of dust. This factor, as well as the control of the porosity of the stock column by the layering method of charging, enables a larger percentage of ore fines to be employed than can now be utilized with conventional methods and apparatus.

The materials delivered into the relatively quiescent zone within the tubes 32 and 33 move downwardly during normal operation of the furnace and maintain the level SL of the stock within the furnace proper substantially constant at a point adjacent the lower edge of the tubes, the slope of this stock level depending upon the dimensions of the tube 32 with respect to the furnace, the angle of repose of material, and the like. Since the upper level of materials within the tubes 32, 33 is maintained above the lower end thereof, these tubes provide what may, in effect, be termed a constant head feeder, since the elevation of the stock level SL is not altered by variations in the height of the materials within the tubes so long as the upper levels of the materials within the tubes is above the lower edges thereof. Moreover, the delivery of the materials from within the tubes 32, 33 into the furnace proper is dependent upon the need therefor in the furnace as the stock descends therein during operation of the furnace and is not affected by irregularities in the rate of operating the bells. Therefore, the layers of the material established within the tubes are substantially maintained within the furnace proper with the result that the stock column has a controlled porosity and an optimum distribution of material for the reducing operation. Since the fine coke within the tube 33 has been maintained out of contact with the other materials, as the layers thereof were being established, the said fine coke tends to continue as a discrete core at least in the upper portion of the furnace, thereby controlling the porosity through this portion of the furnace and preventing channeling of the reducing gases therethrough.

The improved method of charging by means of the concentric tubes and the deflecting means disclosed may be readily employed in a conventional furnace without appreciable alteration therein since, while the tubes and deflector somewhat decrease the height of the stock column in the furnace, this is compensated for by the improved distribution of the charge and controlled porosity thereof which affords a more efficient operation and removes the necessity of using excessive pressures on the gases supplied to the tuyères. In order that the velocity of the gases issuing from the top surface of the stock column be not materially increased and to obtain optimum use of the rising gases, it is desirable that the area between the outer surface of the wall or tube 32 and the upper portion of the lining 21 above the wear plates 22 be substantially the same as in the area of the furnace below the upper edge of the wear plates 22. To accomplish this, the upper portion of the furnace above the wear plates 22 may be increased in diameter, although by suitable selection of the diameters of the tubes 32, 33, the invention may be advantageously employed without material alteration in the diameter of the furnace.

By way of example, it may be stated that the diameter of the outer tube 32 may be such as to

provide an area which is between 35% and 60% of the area of the furnace in the region of the wear plates 22, while the inner tube 32 will have a diameter such as to be in the order of 5% to 25% of this area. For example, where the diameter of the furnace in the region of the wear plates 22 is 20 feet, the diameter of the outer tube 32 may be between 11.8 and 15.6 feet while the diameter of the tube 33 may be from 4½ to 10 feet. The corresponding diameter of the interior of the furnace above the wear plates would then be from 23.2 to 25.2.

The larger the area within the tube 33 the greater is the necessity to slow down flow of gases through the corresponding center of the furnace by means of the fine coke, while the larger the area between the tubes 32 and 33 the thinner can be the ore layers deposited therein. These variations, corresponding with a particular installation, are under control of the operator by variation of the amount deposited in each layer and by varying the order in which material is delivered by the skip. That is to say, where a thicker layer is to be deposited, an extra skip load of ore may be delivered before the coke in which event the bell 27 need not be operated for each skip load deposited but only when the type of material charged is changed. The necessary prerequisite is that the ore be spread thinly and uniformly entirely around the periphery of the furnace and this is accomplished in a broader and more uniform band than is possible without using this method. The sizing of the ore and charging the coarser portions between the concentric tubes in layers renders the resulting bands of ore and coke more permeable, while the fine coke charged to the center prevents too much of the reducing gases from channeling therethrough. Moreover, by employing the concentric tubes, the flux material such as limestone, which rolls relatively easy, is kept out of the center where it would promote an undesired porosity, the flux material being more uniformly scattered throughout the charge, thereby promoting more uniform fluxing action. By proper use of the deflector 35, it is possible to control the depositing of the material radially in the annulus between 32 and 33 so that the ore layer is of uniform thickness or thicker at either end or in the middle of the annulus as may be desired or necessary for a particular installation. The resulting more uniform permeability of the stock column promotes more efficient and rapid reduction and a more uniform movement of the solid materials in the furnace, thereby reducing hanging and slipping.

As mentioned above, the material should be substantially uniformly distributed on the upper bell 29 and one way of effecting this is to make the upper or supply hopper 28 of smaller diameter than conventionally employed for a furnace of given dimensions. Other means for effecting this result may be employed with supply hoppers of conventional size. Figs. 5 and 6 illustrate an example of one such means. As shown therein, the wall of the upper hopper 28, which may be either small or large diameter, is provided with a deflector plate 46. Preferably this plate is fixed to the wall and extends only partially thereabout being located principally on the side of the hopper opposite the lower edge of the skip or bucket 45. The deflector is inclined inwardly and downwardly in a manner to deflect a portion of the material striking the side wall of the hopper, as it discharges from the inclined skip, and direct it across the hopper

towards the opposite side wall thereof. The shape and degree of inclination of this deflector is, of course, dependent upon the diameter of the hopper, the inclination of the skip in its discharging position, and similar factors.

Figs. 7 and 8 illustrate a rotatable leveling means to distribute the material within the hopper 28 and thereby provide a substantially uniform height thereof. As shown therein, a rotatable scraping arm or arms 47 are fixed at the lower end of a hollow tube 48 extending upwardly in spaced relationship with respect to the bell operating tube 31. The upper end of the tube 48 is provided with a worm gear 49, the tube and gear being supported by bearings 50 on a stationary supporting plate 51, the gear 49 being driven by means of a worm 52 through the mechanism not shown. By this arrangement, material delivered to the hopper 28 by means of the skip 45 is levelled by the rotation of the blade or blades 47 which may be either continuously or intermittently operated.

It has been found that the effective or active area in front of each tuyère is limited. The estimated dimensions of this effective or active area vary somewhat but evidently does not exceed 6 feet as measured radially of the furnace. Consequently, as the diameter of furnaces have been increased, to increase capacity, there develops a dead center substantially through the heart of the core of the furnace to which the air and other gases from the tuyères does not directly penetrate. Therefore, with the larger size conventional furnaces operated in the conventional manner, ore charged into the center of the furnace to control the porosity therethrough finds its way to the hearth without being reduced and hence must be reduced in this melting or smelting zone by direct contact with incandescent carbon. As is well known, this type of reduction is wasteful of coke and slows the operation. The improved apparatus and procedure described above with respect to Figs. 1 to 8 overcome this difficulty by keeping the ore out of the center of the furnace and allowing only fine coke to descend therethrough where it is available for supplying heat and/or reducing gases upon encountering the heat of the melting or smelting zone; the ore, being in an annulus, is subjected to the reducing gases during its descent and hence reaches the melting zone as metallic iron. Consequently, in addition to the considerations mentioned above as determinative of the dimensions of the tubes 32, 33, there must also be considered the diameter of the furnace and the corresponding dimension of the "dead center," as it is called, since the diameter of the inner tube 33 should be in the order of this dimension.

In order to eliminate the above-mentioned dead center, proposals have been made heretofore for employment of furnaces having either rectangular or elliptical hearths. Furnaces of this configuration have not, however, been adopted probably because of the difficulties of properly charging them, since the conventional circular bells and hoppers are not adapted thereto. In accordance with this invention, the improved method of charging may also be adapted to use with furnaces of rectangular or elliptical cross section which have their tuyères so arranged as to substantially or completely eliminate the dead center. Thus, Fig. 9 shows a furnace 53 of rectangular configuration having the tuyères 54 arranged in pairs on opposite sides thereof so that the active areas thereof, indicated at 55 in

Fig. 10, substantially meet. To effect charging of such a furnace, the upper portion thereof is provided with a rectangular partition wall 56 intermediate the charging bells and the gas outlets 57 and 58, thereby defining an open bottomed enclosure into which the materials are to be charged, this enclosure corresponding to the tube 32 of the preferred embodiment. Since there is now no dead center, there is no need for a central tube corresponding to the tube 33 and hence none is provided.

To effect charging of a furnace of this nature, the top thereof is provided with a charging hopper 59 of generally rectangular cross section having downwardly converging side walls, the open end being closed by a charging bell 60 of substantially rectangular configuration with downwardly sloping side walls. The upper portion of the hopper 59 is in communication with the lower end of a supply or feed hopper 61 which may be constructed similar to the charging hopper 59 and is provided with an upper or small bell 62 similar to the bell 60, the configuration of bell 62 being shown in Fig. 12.

In order to supply material to the hoppers and bells and properly distribute the material therein, one or more conveyors are provided, two such conveyors, 63 and 64, being illustrated. These conveyors are each preferably positioned to extend longitudinally with respect to the larger transverse dimension of the supply hopper 61 and are so constructed that the delivery ends of the conveyors are movable backwardly and forwardly over the hopper 61 to deposit the material substantially uniformly therein. One suitable form of conveyor operating in this manner is of the endless belt type in which the forward roller or drum for the upper flight of the belt is mounted on a reciprocating frame.

As somewhat schematically illustrated in Fig. 11, each of the conveyors 63, 64 comprises an endless belt 65 trained about supporting rollers or drums such as 66, 67 and 68, the belt being driven by conventional mechanism, not shown, associated with one of the rear belt supporting rollers or drums, not shown. The drum of roller 66 is supported upon spaced bars 69 and 70 adjacent the forward ends thereof, these bars being longitudinally movable relative to the main frame of the conveyor by being movably supported in stationary channel shaped members 71 and 72. The belt roller or drum 68 is supported by brackets 73 and 74 extending downwardly from the stationary channel members 71 and 72, respectively, while roller or drum 67 is supported for movement with the bars 69 and 70 by being journaled in brackets 75 and 76 connected with the bars 69 and 70. The bars 69 and 70 are longitudinally reciprocated by any conventional mechanism thus moving the delivery end of the belt 65 and the roller 67 from their positions shown in full lines in Fig. 11 to the positions shown in broken lines in the same figure. Since the belt is being driven at the same time, any material on its upper surface is deposited in the hopper 61 substantially uniformly throughout the cross sectional area thereof. In view of the sloping nature of the bell 62 it is not necessary that the belt 65 have a width equal to that of the hopper 61 nor is it necessary that the belt be reciprocated a distance equal to the entire length of the hopper.

Material is preferably supplied to the belt 65, for delivery to the hopper 61, in a manner such as to provide substantially uniform distribution

of the material over the entire width of the belt. This is readily effected by employing supply bins for the materials the discharge openings of which are substantially equal to the width of the conveyor belt. In the illustrated form three such supply bins are indicated for the belt 65, although a greater or lesser number may be utilized. As shown, bin 77 is provided with one type or grade of ore, bin 78 with a second grade or type of ore, while bin 79 may contain pellets or agglomerates of fine ores.

The conveyor 64 is identical in construction and operation with the conveyor 63 and hence will not be described in detail. As shown, three supply bins are also provided for this conveyor. Bin 80 may, for example contain fine coke, bin 81 may contain coarse coke, while bin 82 may contain limestone or other flux material. Of course, other materials may be provided in the bins and more than one bin may contain the same material if desired. The conveyor 64 has the delivery end thereof reciprocated over the hopper 61 in the same manner as described for conveyor 63, one conveyor being advanced while the other is being retracted, or remains in its retracted position, thereby preventing interference therebetween.

The actuating rods and tubes for the bells are preferably provided with intermediate yoke portions to accommodate the ends of the conveyors 63 and 64 so that the latter may be reciprocated over the hopper 61, as described above. Thus, as shown in Fig. 9, the actuating rods 83 for the lower bell 60 are each provided with an intermediate substantially rectangular shaped yoke portion 84 providing an opening for passage of the conveyors 63, 64. The actuating tubes 85 for the upper bell 62 likewise are each provided with a rectangularly shaped yoke portion 86 which surrounds the yoke 84. While two spaced rods and surrounding tubes are shown, it will be apparent that a single rod 83 and tube 85 could be used if desired, provided the connections to the respective bells are such as to prevent tilting of the bells.

In a furnace as shown in Figs. 9 through 12, the conveyor belts are preferably sequentially operated to sequentially deliver ore, coke, and flux to the upper hopper 61 when the bell 62 thereof is closed, each material thus delivered being equal in amount to that necessary to form a layer of such material of desired thickness within the furnace. The bell 62 is then operated after delivery of each material and while the belts are not delivering material, to deposit the material in the hopper 59 upon the bell 60, the latter being closed at this time. While the bell 62 is next closed, a different material is delivered to the hopper 61 by one of the conveyors and the material within the hopper 59 is then delivered to the interior of the enclosure provided by the partition 56 by operation of the bell 60, the configuration of this bell acting to substantially uniformly deposit the material in a layer within the enclosure. While not shown, it will be apparent that an adjustable deflecting means may be employed within the tube 56, if desired, to aid in this distribution. Instead of sequentially operating the conveyors and bells for each material, these devices may be operated to deposit more than one material at a time at one drop or actuation of the bell 60.

As in the preferred embodiment, the delivery of material to the upper hopper and the operation of the bells is so timed that the level of material

within the enclosure 56 is maintained above the lower end of that enclosure so as to segregate the interior thereof from the rising gases and serve as a constant head feeder of material to the furnace. Therefore, the layered material within the partition or enclosure 56 moves downwardly in a uniform manner and without material disturbance between the layers to maintain the stock level substantially constant during the normal operation of the furnace, this level being indicated by the broken line 87. In this form of the apparatus as well as in the preferred embodiment, the materials are charged substantially without subjection to rising currents of gases and hence a more uniform distribution is effected with less loss of fine material than in conventional practice. Moreover, the layering of the material provides a controlled porosity throughout the furnace which is further maintained substantially uniform by virtue of the fact that the stock level of material within the furnace remains substantially unaltered even though the rate of operation of the bells is not uniform.

A similar construction to that shown in Figs. 9 through 12 may be employed for use with a rectangular furnace 88 having staggered tuyères 89 as indicated at Fig. 13, it being understood that in both of these rectangular furnaces the capacity of the furnace is increased by altering only one transverse dimension thereof, while maintaining the other dimension substantially equal to the effective active area in front of the tuyères.

The principles of this invention may also be employed with a furnace 90 having an elliptically shaped hearth, with the tuyères 91 arranged as indicated in Fig. 14. In this event, the charging mechanism would be substantially similar to that shown in Figs. 9 through 11 except that the partition wall 56 should preferably be altered to substantially coincide with the configuration of the furnace wall and the charging hoppers and bells should be provided with rounded ends so as to be substantially a flat ellipse in cross section.

It will be apparent that a furnace constructed either as shown in Figs. 1 to 8, or as shown in Figs. 9 to 14, and operated in accordance with the improved procedure of this invention provides a more uniform permeability of the stock column, maintains the latter substantially at constant height, and enables the material to be charged into a relatively quiescent zone, thereby greatly reducing dusting. Consequently, the furnace may be operated with a more uniform volume and pressure of air or other gas and will produce metal of more uniform analysis at a higher production rate and with a lower consumption of coke per ton of metal produced. Furthermore, ores containing a larger percentage of fines may be employed and slipping, hanging, and other operational difficulties are substantially eliminated. Moreover, the improved procedure and apparatus of the preferred form may be employed in conventional furnaces without appreciable alteration thereof by simply altering the top thereof slightly.

Numerous variations in the method will be apparent to those skilled in the art after having had the advantage of this disclosure. For example, the deflector plates 36 shown in Figs. 1 to 3 may be individually operated, if desired, by employing separate actuating rods for the shoe 39 of each plate. Likewise, the shape of the several hoppers and bells may be varied, or means other than those shown in Figs. 1, 5 and 7 may be employed for effecting a more uniform distribu-

tion of the material in the upper or feeding hopper. Moreover, when employing a rectangular or elliptical furnace, the central area of the top may be utilized for the withdrawal of gases, charging then being effected through two sets of charging mechanisms extending longitudinally of the greater transverse dimension of the furnace on either side of the central area. Furthermore, the order of charging the materials may be varied from that disclosed. These and other variations, which may be effected by those skilled in the art, are contemplated as coming within the scope of the invention, the specific description and drawings being intended only as illustrative.

Having thus described the invention, I claim:

1. The method of charging ore, coke and flux materials into a blast furnace comprising, separating the coke into portions of fine particles and relatively coarse particles, establishing a first zone substantially free of upwardly rising currents of gas within the upper portion of the furnace in communication with the charging opening of the furnace and spaced inwardly from the side walls of said furnace with the interior of the furnace being in communication with the said zone only at the lower end of the latter, establishing a second substantially gas free zone interiorly of the first zone and communicating with the charging opening and the interior of the furnace, the lower ends of said zones being at substantially the same elevation within the furnace and the cross-sectional area of said second zone being in the order of 5% to 25% of the cross-sectional area of the interior of the furnace adjacent the lower ends of said zones, withdrawing the gases from said furnace exteriorly of said zones, charging the ore, flux and coarse coke into said first zone exteriorly of said second zone and charging the fine coke into the interior of said second zone, the rate of charging of the materials to said zones being such that the level of material in each is continuously maintained above the lower end thereof thereby excluding furnace gases therefrom with the fine coke prevented from mixing with the other charged material until after passage thereof from said zones.

2. The method of charging ore, coke and flux materials into a blast furnace comprising, separating the coke into portions of fine particles and relatively coarse particles, establishing a first zone substantially free of upwardly rising currents of gas within the upper portion of the furnace in communication with the charging opening of the furnace and spaced inwardly from the side walls of the said furnace with the interior of the furnace being in communication with the said zone only at the lower end of the latter, establishing a second substantially gas free zone interiorly of the first zone and communicating with the charging opening and the interior of the furnace, the lower ends of said zones being at substantially the same elevation within the furnace and the cross-sectional area of said second zone being in the order of 5% to 25% of the cross-sectional area of the interior of the furnace adjacent the lower ends of said zones, withdrawing the gases from said furnace exteriorly of said zones, separately charging the ore, flux and coarse coke into said first zone exteriorly of said second zone to provide layers of these materials in said first zone, and charging the fine coke only into the interior of said second zone, the rate of charg-

ing of the materials to said zone being such that the level of the material in each is continuously maintained above the lower end thereof thereby excluding furnace gases therefrom with the fine coke prevented from mixing with the other charged materials until after passage thereof from said zones.

3. The method of charging ore, coke and flux materials into a blast furnace equipped with a charging bell, comprising separating the coke into portions of fine particles and relatively coarse particles, establishing a first zone substantially free of upwardly rising currents of gas within the upper portion of the furnace in communication with the charging bell and spaced inwardly from the side walls of the furnace with the interior of the furnace being in communication with the said zone only at the lower end of the latter, establishing a second substantially gas free zone interiorly of the first zone and communicating with the charging bell and the interior of the furnace, the lower end of said zones being at substantially the same elevation within the furnace and the cross-sectional area of said second zone being in the order of 5% to 25% of the cross-sectional area of the interior of the furnace adjacent the lower ends of said zones, withdrawing the gases from said furnace exteriorly of said zones, depositing the ore, flux, coarse and fine coke separately upon the charging bell in a manner to provide a substantially uniform distribution of each material thereon, sequentially operating the charging bell to separately drop the ore, flux and coarse coke into said first zone exteriorly of the second zone, operating the charging bell to drop the fine coke into said second zone, the rate of charging of the materials to said zones being such that the level of the material in each is continuously maintained above the lower end thereof thereby excluding furnace gases therefrom with the fine coke prevented from mixing with the other charged materials until after passage thereof from said zones.

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