

[54] **SHAFT FURNACE CHARGING PROCESS**

[75] Inventors: **Edouard Legille**, Luxembourg; **Rene' N. Mahr**, Howald-Hesperange, both of Luxembourg

[73] Assignee: **S.A. des Anciens Etablissements Paul Wurth**, Luxembourg, Luxembourg

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[51] Int. Cl.<sup>2</sup>..... **F27B 1/20**

[58] Field of Search..... **214/35 R, 17 CB, 152; 266/27**

[56]

**References Cited**

**UNITED STATES PATENTS**

|           |        |                  |            |
|-----------|--------|------------------|------------|
| 1,668,968 | 5/1928 | Lambot.....      | 214/35 R X |
| 3,693,812 | 9/1972 | Mahr et al. .... | 214/35 R   |

*Primary Examiner*—Robert G. Sheridan

[57]

**ABSTRACT**

A uniform height of the charge burden deposited on the hearth of a blast furnace is achieved through exercising control over the inclination angle of a rotatable charge distribution device mounted within the furnace while maintaining a constant supply of charge material per unit of time to the distribution device. The inclination angle of the distribution device is adjusted in step-wise fashion whereby the deposited charge material will transcribe concentric but unevenly spaced circles or a spiral pattern on the furnace hearth.

**5 Claims, 2 Drawing Figures**

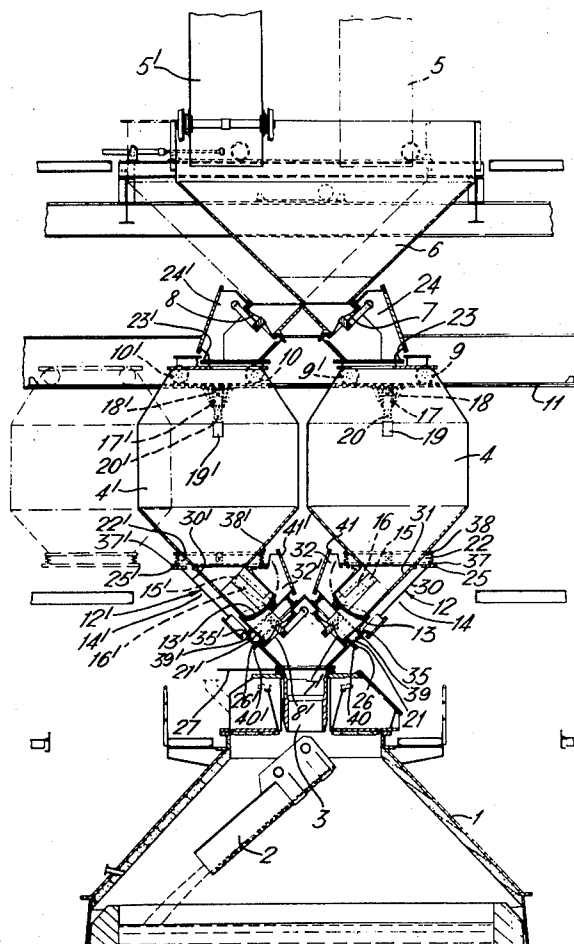
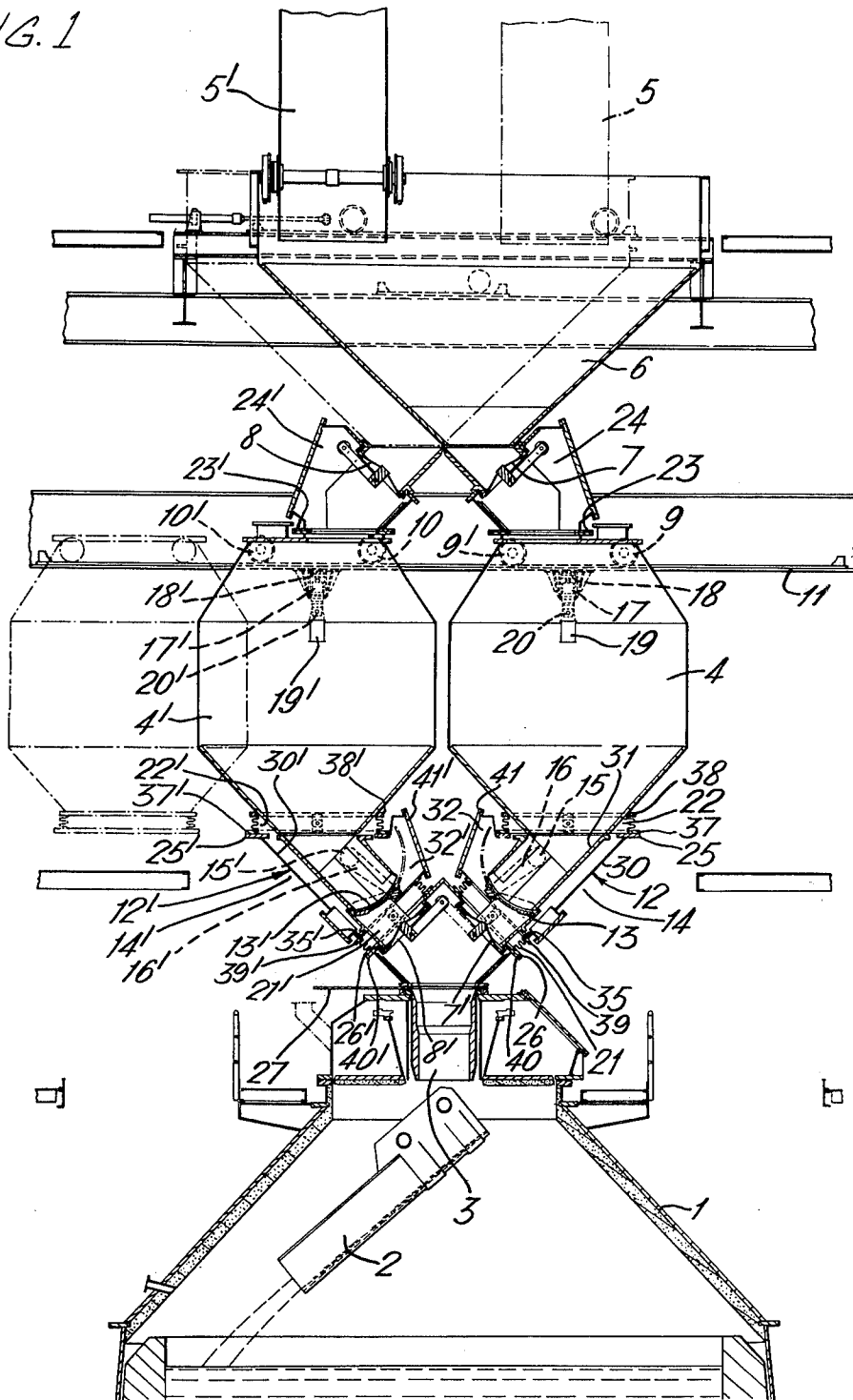


FIG. 1





## SHAFT FURNACE CHARGING PROCESS

### CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 374,089 filed June 27, 1973, now abandoned.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to the delivery of charge material to the interior of a shaft furnace. More specifically, this invention is directed to achieving a predetermined charge distribution on the hearth of a blast furnace. Accordingly, the general objects of the present invention are to provide novel and improved methods of such character.

#### 2. Description of the Prior Art

There has, in recent years, been considerable effort devoted to increasing the productivity of blast furnaces. Increases in furnace productivity can, of course, be achieved either through improved methodology or by increases in furnace size. It is, however, believed that the state of the art has approached or arrived at a point where further increases in furnace size will not produce corresponding increases in productivity. Thus, recent efforts in the steel industry have been directed to identifying and removing any impediments to enhanced efficiency of operation of existing furnace installations.

At least as part of the effort to increase furnace productivity, modern blast furnaces are operating at higher furnace throat counter-pressures and temperatures than characterized the prior art. Additionally, for the reasons to be discussed briefly below, improvements in the charging processes whereby the raw material is delivered to the furnace hearth have been actively sought. A constant and uniform ore or charge distribution on the furnace hearth constitutes one of the optimum blast furnace process operating parameters according to the present state of theoretical knowledge. The failure to achieve uniform charge distribution, for example, operation with a charge profile of the M-curve variety which results from use of prior art bell-type charge distribution apparatus, will result in a non-uniform furnace through-gassing as well as furnace operation which is difficult to regulate and control. Compensation for non-uniform through-gassing can not be fully achieved by means of exercising control over the hot air supply delivered to the furnace through tuyere stocks. Non-uniform through-gassing is known to reduce furnace yield well below the maximum obtainable level.

A problem closely allied to the lack of charge profile control is the difficulty in achieving complete sealing of the furnace throat relative to the outer atmosphere. This problem is particularly prevalent when using prior art charging apparatus at modern high throat counter-pressures. With the exception to be discussed below, previous attempts at modification of charging apparatus to enhance sealing have resulted in improvements which were not cost justifiable.

A bell-less charging installation, for mounting on and in the throat of a blast furnace, has recently been introduced which overcomes the above briefly discussed technical disadvantages of prior charging devices. This improved charging installation is disclosed and claimed in U.S. Pat. No. 3,693,812 which is assigned to the

assignee of the present invention; U.S. Pat. No. 3,693,812 being incorporated herein by reference. In accordance with the patented device, which will be described below, random control of charge distribution is possible by means of exercising control over the position and angle of inclination of a charge distribution chute mounted within the throat of a blast furnace.

### SUMMARY OF THE INVENTION

The present invention constitutes an improvement over the prior art in that it permits, through the use of apparatus of the type disclosed in referenced U.S. Pat. No. 3,693,812, the obtaining of a uniform charge distribution on the hearth of a shaft furnace. Thus, in accordance with the invention, a charge material distribution device will be caused to rotate while the pitch angle of the distribution device is adjusted in stepwise fashion relative to the blast furnace central axis. The adjustments in pitch or inclination angle of the distribution device is controlled such that the spacing between individual concentric circles or turns of the spiral of the deposited furnace charge will increase as a function of the distance between the blast furnace outer wall and each circle or each turn of the spiral. This procedure of stepwise inclination angle change is accomplished while maintaining constant delivery of material to the distribution device; delivery being either at a constant quantity per unit of time or a constant weight per unit of time. Also, a constant rotational speed of the distribution device is simultaneously maintained.

### BRIEF DESCRIPTION OF THE DRAWING

The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein:

FIG. 1 is a schematic cross-sectional side elevation view of apparatus for use in the practice of the present invention; and

FIG. 2 is a diagrammatic representation depicting the problem geometry, FIG. 2 representing various dimensional variables which are taken into account in the practice of the present invention.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

In order to facilitate understanding of the invention the bell-less charging installation of the drawing will be described in some detail. The superstructure of the blast furnace, which defines the furnace throat or charge supply port, is indicated at 1. A rotary and angular adjustable distribution chute 2 is mounted in the furnace port in such a manner as to receive charge material from a centrally arranged inlet or feed spout 3; spout 3 being coaxial with the furnace axis and supplying charge material to chute 2 from two or more bins such as intermediate storage hoppers 4 and 4'. As will be described in greater detail below, storage hoppers 4, 4' alternately feed the ore or other charge material into spout 3. The furnace charge or burden is supplied to storage hoppers 4, 4' by means of skips 5, 5' via a displaceable feeding hopper 6 or alternately by means of a belt via a reversible feed charging device.

The storage hoppers 4, 4' are preferably in the form of pressure sluices so as to seal the furnace port 1 against the outer atmosphere during the charging operation. In order to accomplish this pressure isolation the charging hoppers 4 and 4' are sealed by means of re-

spective upper sealing flaps 7 and 8 and respectively lower sealing flaps 7' and 8'. The sealing flaps, when open, are withdrawn from the charge material flow path.

On introducing the charge into hoppers 4 and 4', or when charging the furnace, sealing flaps 7, 7' and 8, 8' are opened or closed in a charging cycle in the manner known in the art and pressure compensation within the hoppers is also performed in the known manner. The hoppers 4 and 4' are provided, in their upper portions, with respective intakes 24, 24' via detachable flange connections 23, 23'. The hoppers 4 and 4' at their outlets, are also connected via respective detachable flange connections 37 and 37' with appropriate outflow channels indicated generally at 12 and 12'. Flange connections 23, 23' and 37, 37' permit rapid interchanging of hoppers 4, 4'. The hoppers 4 and 4' are displaceably supported by respective rollers 9, 9' and 10, 10' on support rail 11.

The discharge channels 12 of hoppers 4 empty into the central feed spout 3 at an angle of approximately 45° to the perpendicular. The discharge channels 12 are fixed to central feed spout 3 by means of flange connections. A horizontally displaceable diaphragm 27, which can be inserted in the feed channel 3 and thus seal the blast furnace port in a gas tight manner, is installed in the upper portion of the feed spout. The diaphragm 27 is employed when it is desired to dismantle one of the lower sealing flaps 7', 8' and permits isolation of the blast furnace throat pressure relative to the outer atmosphere during such a dismantling process. When repair or replacement of one of the storage hoppers 4 or its associated discharge channel 12 is necessary, as opposed to repair of the lower sealing flaps 7', 8', the sealing flaps may be used to obtain the requisite isolation.

The discharge channels 12 and 12' are provided with respective throttling valves 13 and 13' for controlling the flow of material to chute 2 during the charging process. The throttle valves 13 may be employed to seal the discharge channels 12 relative to the charge material but not with respect to the furnace throat pressure. The valves 13 are moved by means of an external drive, not shown, via rotary shafts 15 and lever arms 16. The flow interrupting portions of throttle valves 13 are helmet-shaped and, in the course of regulating the passage of raw material to distribution chute 2, valves 13 move into and out of the discharge channel. The discharge of material from storage hoppers 4 is precontrolled by selection of an average position for the throttle valves 13 dependent upon the charge material type and granulation. This "average" setting may be adjusted in accordance with correction signals generated by a weight or quantity measurement of the residual charge material in the storage hoppers. Alternatively, between subsequent chargings, a new average throttle valve position may be calculated as a function of the results obtained from the previous charging process.

Measurement of the weight of the charge material in the storage hoppers 4 may be performed by trackless load measuring cells 17, 17' rigidly connected to the underside of support rail 11 at points 18, 18'. For weight measurement, as opposed to a possible volume determination, a fixed or reference point is required for load cell 17, 17'. This reference point will be the attachment points 18 to bearing rail 11. In order for the attachment to the bearing rail 11 to function as the

reference point, the storage hoppers are suspended, by means of devices 19, on the load cells 17 by means of swivels 20. The storage hoppers 4 must, of course, not be rigidly connected to the blast furnace port if an accurate weight measurement is to be obtained.

As previously observed, the outlets of the storage hoppers 4 are connected to the central feed spout 3 by means of discharge channels 12. The discharge channels 12 comprise rigid pressure-tight protective or outer casings 30, inner tubular material discharge channel defining members 31 and the aforementioned charge metering valves 13. The outer casings 30 are provided, at their upper ends, with flanges 25 and, at their lower ends, with further flanges 35. The outer casings 30 are also provided with control devices for the charge metering valves 13. As also previously noted, the metering valves 13 are connected via lever arms 16 with rotary adjusting shafts 15 whereby valve members 13 may be rotated about shafts 15 during the metering process. The outer casings 30 are designed in such a manner that the valves 13, in the open state, are guided in recesses 32 of casings 30. A hatch is provided on the wall of recesses 32 for the purpose of inspection or maintenance of metering valves 13. This hatch is sealed by means of blind flanges 41 during furnace operation. The inner tubular material discharge channels 31 are provided, on their inner surfaces, with a wear resistant coating so as to minimize the erosion of these elements resulting from movement of charge material therethrough.

The central feed spout 3 is rigidly connected to the blast furnace port and thus means must be provided to permit a limited angular displacement of channels 31 relative to storage hoppers 4. To this end, a first externally supported corrugated compensator 22 is connected, by an upper flange 38, to the outer casing of each storage hopper. The compensators 22 are also attached, via lower flanges 37, to the upper flanges 25 of the outer casing of discharge channels 12. A second externally supported corrugated compensator 21 is attached, via an upper flange 39, to the lower flange 35 of the outer casing of each discharge channel 12. The second compensator 21 is also connected, via a lower flange 26, to a flange 40 on the central feed spout 3.

The swivel 20, the upper externally supported corrugated compensator 22 and the lower externally supported corrugated compensator 28 define a three-point hinged connection between each fixed point 18, each load cell 17 and the central feed spout 3 which, as noted, is rigidly connected to the blast furnace port 1. The vertical forces and corresponding displacement components produced by thermal expansion and pressures generated during furnace operation are absorbed by this three-point hinged connection and converted into angular displacements. The storage hoppers 4 can therefore be considered as virtually freely suspended on load cells 17.

In order to achieve uniform distribution of the charge material or burden in accordance with the present invention, the pitch angle of chute 2 is adjusted, relative to the blast furnace central axis, in stepwise fashion while the chute is rotated whereby the charge material deposited on the furnace hearth will transcribe concentric circles or a spiral. The spacing between each concentric circle, or between individual turns of the spiral, will be varied as a function of the distance between the blast furnace outer wall and each circle or turn of the spiral. As chute 2 is moved the discharge from the

"active" supply hopper is controlled, typically in a passive manner, so that a constant quantity of charge material per unit of time or a constant weight of charge material per unit of time is supplied to the distribution chute. Also, the rotational speed of the distribution device is maintained constant.

In order to produce the desired uniform distribution of the charge material or burden with constant chute rotational speed and constant charge supply per time unit, the circles described by the discharge end of the chute must be closer together adjacent the blast furnace wall than towards the blast furnace central axis. As a result of the varying spacing between adjacent paths transcribed by the charge delivered to the furnace hearth from the distribution chute, the constant charge supply per unit of time to the distribution chute is converted into a constant charge quantity per unit of furnace throat or hearth cross-section. With constant spacing between individual circles, for example, the segmental areas supplied per unit of time with charge from the chute are larger on the outer concentric circles than on the circles located closer to the furnace central axis. The height of the material deposit at the furnace throat would accordingly increase from the furnace wall to the furnace central axis.

Since a constant charge distribution, i.e., constant burden height is sought, the spacing between the individual concentric circles or turns of a spiral must increase from the furnace wall to the furnace central axis. It is to be noted that test results have shown that the spaces between the individual concentric rings or turns of a spiral are filled by the sliding or running of the charge material thereby producing approximately uniform charge height when the distribution chute is controlled in accordance with the present invention.

Referring now to FIG. 2, the method of the present invention will be described in more detail through the use of equations. Test results have shown, and the following mathematically based explanation will presume, that the path of the charge material between the end of the distribution chute 2 and the furnace hearth is rectilinear. For purposes of explanation a process wherein the charge material is deposited on the furnace hearth as a series of concentric circles will be discussed.

Practice of the invention requires that the surface area,  $s$ , of each deposited ring of charge material must be identical and constant. The quantity of material delivered to the chute per unit of time, the rotational velocity of the chute and, of course, the dimensions of the chute must also be maintained constant. Additionally, the characteristics of the material being delivered to the furnace hearth must not change during each cycle of the process; a cycle being the deposition of a single layer of material on the furnace hearth. The surface area,  $s$ , of each ring equals the total cross-sectional surface area of the furnace divided by the number of rings,  $n$ . The number  $n$  is determined before the charging process and also remains constant during each charging cycle. The surface area of each ring may be expressed as follows:

$$(1) \quad s = \frac{\pi R^2}{n}$$

where

$R$  = furnace hearth radius (constant)

The surface area of a particular ring may be expressed as follows:

$$s = 2 \pi R_i^m l_i \quad (2)$$

where

$R_i^m$  = average radius of the ring  $i$  = average radius of the circle of impact of material delivered to ring  $i$   
 $l_i$  = width of ring  $i$

Equations (1) and (2) above may be combined to give the relationship between  $R_i$  and  $l_i$  as follows:

$$(3) \quad R_i^m = \frac{R^2}{2n l_i} = \frac{k}{l_i}$$

where  $k$  = constant.

and

$$(4) \quad l_i = \frac{R^2}{2n R_i^m} = \frac{k}{R_i^m}$$

Equations (3) and (4) give the relationship between the width of a ring and the distance between the ring and the furnace axis. The product  $R_i^m l_i$  is a constant and the width  $l_i$  of a ring  $i$  is inversely proportional to the average radius  $R_i^m$  of said ring  $i$ . Considering that the formula  $xy = a$  represents a hyperbola it may be seen that the two variables  $l_i$  and  $R_i^m$  vary according to a hyperbolic function.

Equation 1 may also be employed to define the relationship between the outer radius of a ring,  $R_i$ , and the number,  $i$ , of the ring. Thus, substituting  $R_i$  for  $R$  and  $i$  for  $n$  in equation 1 is may be seen that:

$$(5) \quad s = \frac{\pi R_i^2}{i} = \frac{\pi R_i^2}{i}$$

and, therefore,

$$(6) \quad R_i^2 = \frac{i R^2}{n}$$

and

$$(7) \quad R_i = R \sqrt{\frac{i}{n}}$$

From equation (6) it may be seen that the square of the outer radius of ring " $i$ " is a linear function of the number,  $i$ , of the ring. Employing equation (7), the relationship between the number,  $i$ , of a ring and its average radius is as follows:

$$(8) \quad R_i^m = \frac{R_i + R_{i-1}}{2} = \frac{R}{2n} [\sqrt{ni} + \sqrt{n(i-1)}]$$

Referring to FIG. 2, it may be shown that the pitch angle of the distribution chute may be expressed as follows:

$$\tan \alpha = \frac{R_i^m}{h_i}$$

$$R_i^m = h_1 \tan \alpha = (H - h_2) \tan \alpha \quad (9)$$

From FIG. 2, it may be seen that

$$h_2 = \frac{a}{\sin \alpha}$$

which relation may be introduced in equation (9)

$$(10) \quad R_i^m = \left( H - \frac{a}{\sin \alpha} \right) \tan \alpha = \frac{H \sin \alpha}{\cos \alpha} - \frac{a}{\cos \alpha}$$

The following trigonometric relations may be introduced in relation (10):

$$(11) \quad \sin \alpha = \frac{2t}{1+t^2}$$

$$(12) \quad \cos \alpha = \frac{1-t^2}{1+t^2}$$

$$(13) \quad \tan \frac{\alpha}{2} = t$$

$$(14) \quad R_i^m = \frac{H \frac{2t}{1+t^2}}{\frac{1-t^2}{1+t^2}} - \frac{a}{\frac{1-t^2}{1+t^2}}$$

$$R_i^m (1-t^2) = H 2t - a (1+t^2)$$

$$(15) \quad 0 = (R_i^m - a)t^2 + 2Ht - (R_i^m + a)$$

The solution of equation (15) is

$$(16) \quad t = \frac{-H \pm \sqrt{H^2 + (R_i^m - a)(R_i^m + a)}}{R_i^m - a}$$

Equations (16) and (13) may be combined to give the following relationship:

$$(17) \quad \tan \frac{\alpha}{2} = \frac{-H \pm \sqrt{H^2 + (R_i^m)^2 - a^2}}{R_i^m - a}$$

From equation (8) it may be seen that

$$(R_i^m)^2 = \frac{R^2}{4n^2} (ni + n(i-1) + 2 \sqrt{n^2 i(i-1)})$$

$$(18) \quad (R_i^m)^2 = \frac{R^2}{4n} (2i - 1 + 2 \sqrt{i^2 - i})$$

Equations (8), (17) and (18) may be combined to give the following relationship:

$$(19) \quad \tan \frac{\alpha}{2} = \frac{-H \pm \sqrt{H^2 - a^2 + \frac{R^2}{4n} (2i - 1 + 2 \sqrt{i^2 - i})}}{\frac{R}{2n} (\sqrt{ni} + \sqrt{n(i-1)})}$$

where  $H$ ,  $a$  and  $n$  are constant.

Equation (19) shows the relationship between the pitch angle of the distribution chute and the number,  $i$ , of the ring of charge material.

In all of the above equations  $R_i^m$  or  $R_i$  may be replaced with the distance between the furnace wall and the ring; i.e.,  $D_i = R - R_i$ . It will be understood that continuous variation of the pitch angle during one or more revolutions results in the charge material being supplied to the furnace hearth in a spiral pattern. It will also be understood that the maximum pitch angle is selected, at the outer ring or turn of the spiral, such that the charge material will not impinge against the furnace wall.

It will now be apparent to those skilled in the art that, in accordance with the preferred embodiment, with constant material supplied per unit of time the distribution chute describes circles with constant rotational speed and the inclination angle of the chute relative to the blast furnace central axis is adjusted in stepwise fashion in such a manner that the width of the rings of material deposited on the hearth increases from the wall of the blast furnace towards the central axis according to an inverse function of the distance from each ring to the central axis. As also previously noted, it is possible for the charge distribution to describe a spiral instead of concentric circles whereby the distance between the individual turns of the spiral will be increased toward the central axis. The rotational speed of the distribution chute and the feed quantity of charge material per unit of time will, with the charge transcribing a spiral pattern, be maintained constant.

While a preferred embodiment has been shown and described various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A process for charging a shaft furnace, the furnace having a hearth and side wall, the furnace having a rotatable and angularly adjustable charge distribution chute centrally mounted therein, the chute being supplied with charge material from a storage hopper and the furnace installation including means for adjusting the quantity of material delivered from the storage hopper to the chute per unit of time, the process including the steps of:

35 rotating the charge distribution chute at constant speed;

supplying a constant quantity of charge material per unit of time to the rotating distribution chute to thereby deliver the charge material to the furnace hearth along an arcuate path; and

40 varying the pitch angle of the rotating distribution chute relative to the blast furnace central axis in uneven steps in order to convert the constant charge material applied per unit of time into a constant charge quantity per unit of furnace hearth cross-section, the magnitude of said pitch angle step variations increasing in the direction of vertical chute orientation.

2. The process of claim 1 wherein the step of varying the pitch angle of the distribution chute comprises:

adjusting the angle of the distribution chute so as to deposit the charge material on the furnace hearth in concentric circles.

3. The process of claim 1 wherein the step of varying the pitch angle of the distribution chute comprises:

adjusting the angle of the distribution chute to form a spiral deposit of the charge material on the furnace hearth.

4. The process of claim 2 wherein the step of adjusting the distribution chute pitch angle comprises:

increasing the width of the rings of the deposited charge from the furnace wall to the furnace central axis in accordance with an inverse function of the distance between the furnace axis and each ring.

5. The process of claim 3 wherein the step of adjusting the distribution chute pitch angle comprises:

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increasing the width of the turns of the spiral of the deposited charge from the furnace wall to the furnace central axis in accordance with an inverse

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function of the distance between the furnace axis and each turn.

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