CONTINUOUS TAPPING OF METALLURGICAL FURNACE

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INVENTOR.
JOSEPH T. ROY

BY
Harrell T. Wilhelm
ATTORNEY
This invention relates to metallurgical furnaces, and more particularly to the tapping of slag and lead bullion from a conventional lead blast furnace.

In one conventional lead blast furnace practice, the molten slag is removed through a tap hole located above the crucible and below the level of tuyeres. The tap hole is plugged with refractory material. To tap the furnace, the refractory is bored out by a steel tapping bar which allows the molten slag to run out. During tapping it is necessary continually to break crustations around the hole to keep the molten slag flowing. After tapping, the hole is closed with a refractory plug. In some cases the lead bullion runs out through the same tap hole along with the slag; in other cases, the lead is removed separately as by the conventional lead well.

In the tapping practice the tapping process must be frequently repeated—in some cases, often as every six minutes, day and night, for the duration of the smelting operation. It consumes many man hours of labor and large quantities of steel tapping bars. It also consumes large numbers of oxygen lances which must be used to bore out the tap holes when the ordinary tapping bar will not open the hole.

The object of the invention is to provide a method and apparatus for the continuous tapping of both molten bullion and molten slag from the furnace, and thus eliminate the aforesaid expensive repetitive tapping.

Other objects and features of the invention will be more apparent from the following description when considered with the following drawings in which:

Fig. 1 is a semi-diagrammatic end elevation of a typical blast furnace with the invention applied thereto, the lead not being omitted in this figure;

Fig. 2 is a semi-diagrammatic side elevation of one-half of the blast furnace shown in Fig. 1, together with the tapping bay and auxiliary apparatus used therewith;

Fig. 3 is an enlarged vertical section taken on the line 3—3 of Fig. 1 showing the tapping bay and illustrating the various bath levels in the tapping bay used with the various blast pressures; and

Fig. 4 is an enlarged front view of the tapping bay showing the shape of the deep narrow pouring notch (without the dam).

In the accompanying drawings and in the description forming part of this specification, certain specific disclosures of the invention are made for purposes of explanation, but it will be understood that the details may be modified in various respects without departure from the broad aspect of the invention.

The blast furnace used to illustrate the invention is largely conventional in construction, and hence will not be described in detail. It is in the general shape of an upright column elongate in horizontal cross section. It comprises the usual shaft 10 lined with fire brick; it has an upper charge opening 11 and a water cooled metal bosh 12 below the shaft. The bosh has a line of tuyeres 13 on both side walls and end walls, below which is located a slag space 14, as explained more fully hereinafter. Only the center line of the tuyeres is indicated by 13 in Fig. 3 since no tuyere is visible in this figure. Under bosh 12 is crucible 48. At the end wall is a cast iron water cooled tapping block 15 under which is the breast opening 16. The breast opening communicates with the tapping bay 17, as explained more in detail hereinafter.

A pressure gauge 18, reading in ounces per square inch gauge pressure, is attached to the bosh pipe 19 which supplies the tuyeres with compressed air. The volume of air supplied to the bosh pipe, and thus also the air pressure on the bosh pipe, may be varied by the operator of the furnace in a well known manner. The blast pressure inside the furnace will vary widely due to a variety of causes discussed below. In any event, the reading of the pressure gauge 18 is a measure of pressure actually in the furnace, and it is customary to refer to the pressure reading on the pressure gauge as "blast pressure." The usual suction blower (not shown) is applied to the top of the furnace for removing the gaseous products. The effect of the suction blower on blast pressure is practically nil and will be ignored in the present disclosure.

The tapping bay 17 has a deep notch 20 in its front wall 19. The notch 20 is closed by a dam 23 of refractory material, which may be removed, in whole or in part, to adjust the height of the dam. The stream 24 overflowing the dam falls into a first settler 25, as discussed below. The top of the bay 17 has an insulated cover 26 through which is disposed a gas burner 36 whose flame may be directed on the material in the bay to prevent freezing of the molten slag and bullion.

The first settler 25 separates the slag from the bullion in a well known manner. The heavier bullion runs from a tap hole in the lower part of the first settler 25 through trough 26 into the lead pot 27. The slag runs from the top of the first settler 25 through trough 30 into a second settler 28, in which a further separation takes place. The lighter slag from the top of the second settler 28 flows through trough 31 into the slag pot 29. The slag pot 29 is either taken to the slag dump or to a plant for further processing if the slag contains further values. The second settler 28 with the heavier material collected below trough 31 is removed, from time to time, so that its contents may be used as part of the charge for the blast furnace.

A stove 33 having a gas burner 34 is applied over trough 30 to keep the bath molten. A hood 32 is applied over trough 31 and slag pot 29 to take away fume. A hood 40 surrounds the falling stream 24 to take away fume.

The tapping bay 17 is for the purpose of continuously and simultaneously tapping molten bullion and molten slag from the furnace. It comprises an anti-chamber 41 located in such position that the molten material flows through the breast opening 16 and rises in the bay to such height as to counterbalance the forces inside the furnace. The breast opening 16 is made large enough to insure free flow of the molten material through it. Being submerged in molten material, the breast opening cannot become closed by freezing of slag or bullion. As shown, the tapping bay 17 is installed on the end of the furnace; but it may also be installed on the side of the furnace, depending on convenience in subsequent operations.

The tapping bay 17 is made with steel plates on the bottom 37 and two sides 38 of the bay appropriately secured to the frame of the furnace. The front of the bay comprises a hollow wall 19 having an interior water space and water circulation inlet and outlet pipes 41, 42. Wall 19 contains the upright deep notch 20 which is surrounded on bottom and two sides by the water space; the sides of the notch 20 are tapered. The two sides 38
and bottom 37 of the bay are lined with fire brick as at 43. The slope of the front wall 19 of the bay provides clearance for free falling of the stream 24 spilling over the dam 23, and the water cooling of the front wall helps protect the material of the dam 23 from the high temperatures of the molten material. The bottom wall 37 is shown horizontal, but if desired, it may slope downwardly from the breast opening 16 to facilitate flow of bath when draining the furnace.

The dam 23 is preferably made of fire brick except at the top 22 which is preferably of adobe-fireclay mix. The fire brick stands up better than the mix and is just as easy to knock down in case of emergency. The adobe-fireclay mix is used for making minor variations in the height of the dam.

The height of the forebay 17 and of the deep notch 20 must be sufficient to allow for widely varying blast pressures, for example from 0 to 80 ounces or more per square inch. The height of the dam 23 may be quickly changed, by removing or adding refractory, to any point in the height of the deep notch, to fix the level of the bath in the bay, and in the furnace, as explained more in detail hereinafter. The height of the forebay 17 must also be sufficient to provide combustion space for the gas burner 36.

The tapping block 15 has the breast opening 16 under it. In practice, in the furnace illustrated, good results have been obtained by making the breast opening approximately 8" wide and 64½" high. This opening 16 is located in the refractory brick wall of crucible 48 which supports the bosh packets 49 and tapping block 15. The bottom of the tapping block 15, which defines the top of the breast opening, is 13" from the horizontal center line of the tuyeres 13. The slag space 14 constitutes the space between the tuyeres 13 and the top of breast opening 16 (line 54). The adjoining jackets 49 are shaped to accommodate the tapping block 15 as shown in the drawing.

The tapping block 15 has an emergency tapping opening 53; this may be 4" in diameter at the outside, tapering to 3" inside the furnace as indicated. This hole 53 is normally plugged with adobe-fireclay mix and is only used in case the slag does not flow readily through the breast opening, as after a prolonged blast furnace slag stop. After the slag flows through this tap opening 53, the breast opening 16 will open itself promptly, after which the operator plugs the tap hole 53. The tap hole then remains plugged and may not be used again until another prolonged shut-down occurs. Water cooled coil 50 cast into block 15 keeps it cool and protects the plug.

To assist in understanding the operation of this invention, the relationship between the specific gravity, tonnage, and volume, both of slag and bullion, will be considered. Typical production of the illustrated blast furnace is about 150 tons of lead bullion and about 500 tons of slag per 24-hour day. No appreciable amount of matte or speiss is produced. The specific gravity of the lead bullion, will, of course, vary with the impurities present, but, for simplicity in explanation, may be taken at 10.6. The specific gravity of the slag will also vary with composition but for purposes of explanation may be taken at 3.23. Taking into consideration the relative tonnages and relative specific gravity of lead bullion and slag, it will be seen that there is produced, by volume, about ten times as much slag as lead bullion.

The horizontal cross dimensions of the illustrative furnace at the slag space is about 5 feet by about 20 feet, making a cross section of about 100 square feet. The inside of the forebay 17 is about 1 foot 5 inches wide by about 2 feet 9 inches long, making a horizontal cross section of about 4 square feet at the average level of overflow. Thus even relatively great change in the level of the bath in the forebay produces very little effect on the level of the bath in the furnace.

The effect of blast pressures in the furnace on the relative hydraulic heads of molten material in the furnace and in the bay will now be considered. In a furnace having no blast pressure, the bath level in the bay 17 may be at the same height as the bath level in the furnace; whereas, in a furnace with blast pressure, the level of the bath in the bay 17 should be higher than that in the furnace. The difference in elevation in the latter case will be equal to the head of the molten bullion and slag required to counter-balance the blast pressure.

The foregoing assumes, for simplicity, that no head is needed to overcome friction resisting bath flow. Actually, the hydraulic head in the furnace plus head due to blast pressure must be greater than the hydraulic head in the forebay to provide sufficient resultant head to cause the molten bath to flow out of the furnace and over the dam.

Regulation of the height of the dam 23 in the deep notch (which determines the level of overflow from the forebay) is of vital consideration. On a furnace having no blast pressure, the point of overflow must be at least at the same level as the top of the breast opening 16 to keep the furnace sealed.

On a furnace having blast pressure, the maximum permissible height of the dam 23 is that point corresponding to a level of the bath inside the furnace at the tuyeres; while the minimum permissible height of the dam is that point corresponding to the level of the bath inside the furnace at the top of the breast opening 16. If the maximum is exceeded, the tuyeres become plugged and the air is shut off from the furnace. If the minimum height is not maintained, the blast will blow out through the breast opening 16, causing a hazardous spraying of molten material and an intolerable smoking condition.

In analyzing the relationship between the hydraulic head of bath and blast pressure, the head due to slag will be ignored for simplicity; most of the hydraulic head is assumed to be due to the bullion when the furnace is operating normally. Assuming the above given density of bullion, it is estimated that about 1.63 inches of lead bullion is required to counter-balance each 10 ounces of blast pressure.

This relationship has been used in computing the various bath levels in the forebay corresponding to the different blast pressures, indicated by the dot-and-dash lines in Fig. 3. Figs 3 and 4 are drawn to scale. At the left of Fig. 3 is given a scale in inches showing the heights of the various bullion levels in the forebay 17 above the zero level 54 taken through the top of the breast opening 16. At the left of Fig. 3 is also a scale indicating the blast pressure in ounces corresponding to the bullion level.

For example, with the bullion level in the furnace at zero—even with the top of the breast opening 16—if the furnace is operating under 10 ounces of blast pressure, the level of the bullion in the forebay to balance that pressure must be at the line marked 10 ounces which is 1.63 inches above the zero line; with 20 ounces of blast pressure, the level of bullion in the forebay must be at the line marked 20 ounces or 3.26 inches above the zero line; and so on for each of the indicated blast pressures.

A typical condition of bath level in furnace and in forebay is illustrated by the stream 24 in Fig. 3. Here, according to our scale, the blast pressure, as measured by the gauge 18 on the bosh pipe, is slightly more than 40 ounces per square inch and the bullion level in the furnace is even with the top of the breast opening 16. The bullion level in the forebay 17 will then have a height of approximately 7 inches above the level of the top of the breast opening. There is assumed to be a layer of slag floating on the bullion in the furnace; a
5 layer 51 of slag is shown floating on the bullion in the forebay. The stream 24 flowing over the top of the dam 25 may be about 2 inches thick (high) and will comprise by volume about ½ slag and about ½ bullion. On the site, the bath level in the furnace is at a safe height. If the bath surface in the forebay becomes too smooth (as a millpond), this is an indication that the bath level in the furnace is too high and may reach the tuyeres. As a remedy for a too smooth condition, the operator then lowers the dam until a condition of proper turbulence is again reached.

On the other hand, if the surface of the bath in the forebay becomes too turbulent, for example, if geyser-like eruptions occur, or if the falling stream "gallops," this is an indication that the slag level in the forebay is too low and that the blast is in danger of blowing through the breast hole and forebay, which would cause an intolerable condition.

As a remedy, the Operator then raises the dam level by adding more adobe clay mix to the height of the dam in the deep notch.

As a practical matter, with skilled operation, it is not necessary to vary the height of the dam very often. In fact, marks (not shown) may be placed on the forebay 17 corresponding to different blast pressures. Regulation of the dam height to the proper mark corresponding to the blast pressure in use is sufficient for insuring long periods of operation without further change in dam height. The invention provides a certain amount of automatic correcting action. With any given blast pressure—as the level of the bath rises in the furnace— the level of the bath in the forebay automatically rises, resulting in a thicker stream flowing over the dam, the flow rate over the dam equalizing the rate at which the bath is generated inside the furnace. The slag space 14 allows a certain amount of leeway in fixing the bath level inside the furnace.

The invention will also handle emergency conditions. If, for example, the bath level in the furnace does accidentally reach the level of the tuyeres 13, this will be indicated by an abrupt rise in gauge pressure on the baffle pipe gauge 12. This requires emergency action on the dam. The brick work forming the lower part of the dam 23 in the deep notch may be removed to drain the furnace sufficiently, or the top of the dam may be removed sufficiently to lower the slag level in the furnace to a safe position. Just before the slag level reaches the tuyeres, this dangerous condition can be noted by a "blinking" action when the operator looks into the furnace through the skylight window at the outer end of the tuyeres. If, on the other hand, the bath level in the furnace accidentally gets too low, the furnace will actually blow through. This requires a rapid building up of the dam to raise the bath level in the furnace to stop the blow through.

It will thus be seen that different dam heights are required under different conditions. In practice, assuming 80 ounces per square inch as maximum practical blast pressure, the dam adjustment must be able to handle blast pressure from 80 ounces down to zero ounces. Thus a total of about 20 inches of dam height will be required to meet the conditions due to change in blast pressure and for draining, as illustrated above in Fig. 3.

The width of the deep notch 20 holding the dam is proportionately about 4 inches at the bottom and may be a little over 8 inches at the 80 ounces level. This width is sufficiently small to enable the side walls of the notch to effectively support the refractory dam against the hydraulic pressure behind it.

Thirty-five ounces of blast pressure is a good practical working pressure but this will vary considerably, under normal conditions of operation, both above and below the 35 ounce point for reasons as discussed below. The effect of change in blast pressure will be briefly discussed.

Assume that the blast pressure is 50 ounces and that the bullion level in the furnace is at the top of the breast opening 16—at the zero reference level. This gives maximum leeway for raising the level of the slag space 14. Actually, the bath level in the furnace will be somewhat higher than the zero mark because of the accumulation of slag and because of the necessity for extra head to cause the bath to flow. The bullion level in the forebay will be at the 50 ounce level.

If the blast pressure now drops to 20 ounces, the bullion level in the forebay will drop to the 20 ounce mark without any immediate perceptible rise in furnace bath level. However, if the dam is not lowered, continued smelting will cause the furnace bath level to rise, and in time this level may reach the tuyeres 13 unless the dam is lowered.

If 20 ounce blast pressure is to be continued for any length of time, the dam 23 should be lowered to the 20 ounce level to reach a condition of equilibrium.

Consider now the effect of rise in blast pressure from zero to 60 ounces. If the blast pressure is zero, smelting will, of course, cease. The dam level at the zero mark would theoretically be sufficient to hold the blast. If the blast pressure is increased without raising the dam level, blow-through will likely occur. Therefore, it is advisable to raise the dam level to a point corresponding to the desired new blast pressure before increasing the blast pressure. If, for example, it is desired to change to a 60 ounce blast pressure, the dam level should be raised to the 60 ounce point and then the blast pressure should be increased slowly but fast enough as compared to the smelting rate, as to prevent the bath level inside the furnace from reaching the tuyeres 13.

Reasons for the wide variation in blast pressure will be briefly discussed. These variations may be caused by involuntary or voluntary reasons. It will be understood that the blast pressure is determined by the volume of air which the blower is adjusted to deliver to the tuyeres and by the resistance to air flow in the tuyeres and furnace. For example, the blower may be adjusted to deliver 10,600, 11,000 or 11,600 cubic feet per minute.

Among the reasons for involuntary change in blast pressure are the following: The pressure may change with the type of material charged to the furnace. In the example given, the furnace may be fed by charges of from 10,000 to 11,000 pounds per charge, at the rate of about 5½ charges of this weight per hour. These charges will vary considerably in nature, thus changing the porosity of the material in the furnace and thus changing the blast pressure. Further reasons for involuntary change of blast pressure is change in height of the column of material in the shaft of the furnace. Other reasons are power failure on the blowers, accidental backing up of the slag level to the tuyeres, etc.

Examples of voluntary change in blast pressure are as follows: The blast may be increased, lowered or reduced to repair the dam, to change a first settler, to repair the forebay, or because of a slag pot or bullion pot being off the track. Other reasons for voluntary change in blast pressure are for top barring, that is, removing accretions that adhere to the water cooled bosh or brick lined shaft; punching partially or full clogged tuyeres, "shaking" the furnace, etc.

Thus, for any of the above or other reasons, blast pressure may change radically. The change may occur quickly or slowly. The amount of change may be small or considerable, and the length of time the furnace
runs at abnormally reduced blast pressure or abnormally high blast pressure will vary, depending upon the type and reason for the change in pressure.

In general, the speed of an involuntary change will depend upon the cause. The speed of a voluntary change will depend upon the change desired. In general, voluntary changes may be quickly made although some operators may prefer to make voluntary changes more slowly to minimize disturbance of the furnace. Whatever the nature of the blast pressure change, the adjustable dam can handle it.

It is advantageous to knock out the entire dam in the event of a prolonged furnace shutdown so that the furnace can be completely drained and the tapping block inspected for wear and tear. This is a very simple operation as it takes only a few seconds to knock out the refractory and a very few minutes to put it back.

The invention has many advantages. It results in a saving in manpower and in materials used; improved metallurgical results are obtained. It has been possible to eliminate one man per shift, or three men per day. Great savings in adobe, and great savings in iron bars and oxygen for oxygen lances have been effected. In addition, the invention has caused savings in coke and in scrap iron; and lower lead loss in the slag.

In addition, the invention eliminates the frequent starting and stopping, necessary with the former repetitions tapping procedure. The invention eliminates loss of reducing gas and consequently the furnace suffers less cooling effect and loss of smelting time. Faster smelting and increased tonnage is obtained. With less cooling effect, less fuel is required. Constant running conditions make for more effective control. With the slag and metal flowing constantly, these materials remain hotter and more fluid, and thus effect more complete separation of bullion and slag.

This invention may be applied to any type of smelting furnace where similar problems exist. Furthermore, the invention may also be applied to furnaces where the slag is tapped through the forebay and the metal is tapped through a different opening which is entirely separate from the forebay.

While certain novel features of the invention have been disclosed herein, and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:
1. A method of continuously operating a lead blast furnace during the smelting therein of a lead bearing material to continuously form a molten product comprising lead bullion and slag, said furnace having a line of tuyeres to supply blast to the furnace and a discharge opening below said tuyeres together with a forebay for sealing said discharge opening, said furnace also being subject to variations in the pressure of the gas therein during the smelting operation, said method comprising establishing in said furnace a molten bath comprising a layer of lead bullion and a layer of slag thereabove, replenishing said molten bath by said molten product of the smelting, withdrawing lead bullion and the slag produced during said melting from said blast through said discharge opening into said forebay thereby forming a molten bath comprising a layer of lead bullion and a layer of slag thereabove in said forebay, withdrawing from the forebay the molten material thus charged thereinto, maintaining the level of the bath in the forebay sufficiently above the level of the bath in the furnace to balance the pressure of the gas in the furnace, maintaining said furnace bath slag layer level below said line of tuyeres and above said discharge opening by controlling the withdrawal of slag from said furnace bath through said discharge opening, and adjusting said furnace bath bullion layer level in said discharge opening to control the withdrawal of slag from said furnace bath by adjusting the level of said bullion layer in said forebay as required by changes in gas pressure in said furnace by increasing the level of said bullion layer in the forebay when the gas pressure in the furnace rises and by decreasing the forebay bullion level when said furnace gas pressure falls whereby interruptions of the smelting operation due to plugging of the tuyeres with slag and loss of furnace gas due to escape thereof through said discharge opening are avoided.

2. A process according to claim 1 in which the volume of slag produced during said smelting is greater than that of the bullion, said molten material in said forebay is withdrawn therefrom over a common lip provided on the forebay, and the height of said lip above the top of said discharge opening in said furnace is adjusted upwardly to increase the level of said bullion layer in the forebay when the gas pressure in the furnace rises and said lip is adjusted downwardly to decrease the forebay bullion layer level when said furnace gas pressure falls.

References Cited in the file of this patent

UNITED STATES PATENTS
334,015 Goetz Jan. 12, 1886
385,424 Peck July 3, 1888
691,474 Lincoln Jan. 21, 1902
1,126,028 Kekich Jan. 26, 1915
2,669,446 Doat Feb. 16, 1954

FOREIGN PATENTS
389,963 Germany Feb. 11, 1924
450,491 Great Britain July 20, 1936