(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 March 2009 (19.03.2009)

PCT

(10) International Publication Number
WO 2009/034544 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/IB2008/053683

(22) International Filing Date: 12 September 2008 (12.09.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2007/05703 12 September 2007 (12.09.2007) ZA

(71) Applicant and
(72) Inventor: PRICE, Christopher James [ZA/ZA]; 642 Bluegrass Close Dainfern, 2055 Johannesburg (ZA).

(74) Agent: DESSINGTON DE BEER; PO Box 1238 Rivonia, 2128 Johannesburg (ZA).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

(54) Title: STATIC SLOPE REDUCTION FURNACE

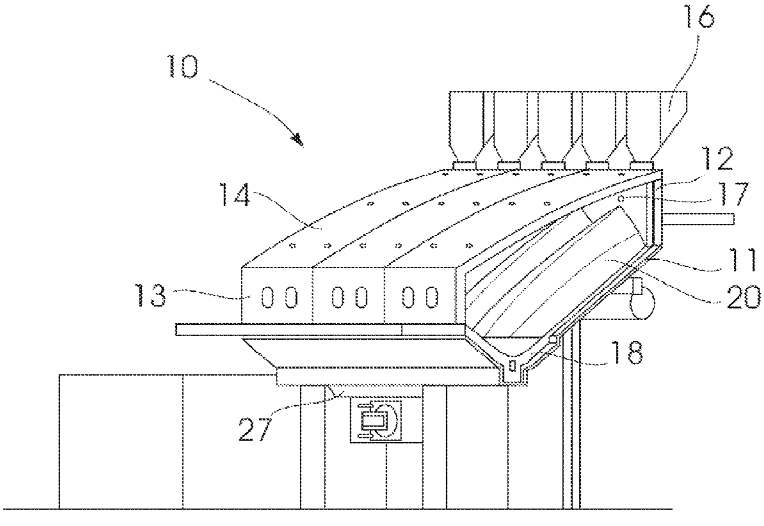

FIGURE 4

(57) Abstract: A static reduction furnace for the reduction of metal oxides is disclosed. The furnace includes a floor and a roof with walls extending between the floor and the roof, a feeder proximate a first end of the furnace, and a collector proximate a second end of the furnace opposite the 5 first end configured to receive reduced feedstock from the floor. The feeder is configured to feed feedstock comprised of metal oxide and reductant onto the floor for reduction and to control the extent to which the feedstock extends from the first end to the second end of the furnace to allow feedstock to extend at least to the collector.

WO 2009/034544 A2

STATIC SLOPE REDUCTION FURNACE

FIELD OF THE INVENTION

This invention relates to a static furnace which is utilized to heat particulate material, and in particular reduce oxide particles.

BACKGROUND TO THE INVENTION

Oxide bearing materials, such as iron, chrome and manganese oxides, have to be reduced to liberate valuable elements from the oxides in which they are located.

Traditionally, iron oxides such as hematite or magnetite have been processed in blast furnaces to produce raw iron, containing excess carbon. This raw iron is then further processed in steel plants, typically in electric arc or oxygen furnaces, to reduce the amount of carbon to form steel.

Iron ore is converted into iron through reduction, which is the process in which oxygen in the oxide is caused to react with a reductant, typically carbon monoxide which could be produced from carbon, to disassociate from the iron oxide and leave the iron for further treatment. When carbon is used as a reductant, the oxygen in the ore combines with the carbon monoxide (CO) to form carbon dioxide (CO_2) gas. The carbon dioxide reacts with carbon to form carbon monoxide to sustain the reduction reactions. The reaction to reduce the oxides from a metal oxide such as iron oxide requires a reductant and heat.

Blast furnaces require specific feedstock to operate optimally. Specifically, in the case of iron oxide the oxides have to be either ore lumps or in indurated pellet form of specific size or sintered form. Blast furnaces cannot handle fine materials (“fines”).

It is possible to circumvent the use of blast furnaces through direct reduction processes in which oxides are reduced by reducing gasses at specific temperatures. In a typical direct reduction process the load is first preheated, then reduced.

Heat is supplied to the load through gas which is burned over the load. The reduced material is then fed to an electrical arc furnace where it is then melted. The liquid metal is transferred to final purification and alloying stages and cast into ingots or billets.

Direct reduction processes are used in many types of furnaces, including rotary kilns in which lumps or hard pellets of iron oxide are tumbled together with coal in the furnace while combusting the gasses so formed to provide heat to sustain the reactions. Conventional direct reduction furnaces, such as rotary kilns, cannot handle fine particles since the air blown into the kiln and the gas formed in the kiln simply blows the particles away.

In another configuration, a rotary hearth, a bed of metal oxides is rotated on a disc and exposed to different reaction zones in which the material is preheated, reduced and cooled. These furnaces are very expensive and are not generally used for reducing iron ore.

In yet another configuration, particles are fed onto a bath of liquid metal and exposed to heat in the presence of a reducing agent. After being reduced the reduced oxide would be melted into the bath from where it could be transported for further use. A problem with such an arrangement is that the electrical power consumption is too high, rendering the process uneconomical.

Partly for this reason, a characteristic of the prior art processes is that they either comprise heaps of metal oxide material which are exposed to heat, or pellets of the metal oxide which are individually exposed to a reducing atmosphere.

For the sake of clarity, in this specification the term “horizontal” refers to a plane which is orientated substantially perpendicular to the direction in which the force of gravity operates.

OBJECT OF THE INVENTION

It is an object of the invention to provide a furnace which at least partly overcomes the abovementioned problems.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a static reduction furnace for the reduction of metal oxides, the furnace including a floor and a roof with walls extending between the floor and the roof, feed means proximate a first end of the furnace, and collection means proximate a second end of the furnace opposite the first end; the feed means being configured to feed feedstock comprised of metal oxide and reductant onto the floor for reduction, and configured to control the extent to which the feedstock extends from the first end to the second end of the furnace to allow feedstock to extend at least to the collection means which is configured to receive reduced feedstock from the floor.

There is further provided for the feed means to be configured to allow feedstock to extend to the second end of the furnace.

There is still further provided for the feed means to include at least one gravity fed hopper with a feed port in communication with the interior of the furnace and which includes means to adjust the height to which the feedstock is fed onto the floor.

There is further provided for the feed port to comprise a tube with an opening of which the location which is vertically adjustable in relation to the floor, alternatively for the feed port to comprise a vertical slot in the hopper which is progressively closable by means of a movable gate; further alternatively for the feed port to comprise a rotary feed valve of which the opening is vertically adjustable in relation to the floor.

There is further provided for the floor to be angled downwards from the first end of the furnace to the collection means, and for the angle of the floor to be lower than the lowest expected angle of repose of the feedstock, and preferably for the angle of the floor to be lower than the lowest angle of repose by about 5 degrees.

There is further provided for the furnace to include means to control the rate of removal of reduced feedstock in relation to the rate of feeding of feedstock into the furnace to ensure that feedstock has a residence time in the furnace within a predetermined range suitable for the specific feedstock, for a specific operating temperature of the furnace.

There is further provided for the furnace to include an upper wall which extends at the first end of the furnace between the floor and the roof, and for the feed means to be configured to feed the feedstock into the furnace through the upper wall, alternatively through the roof proximate the upper wall.

There is further provided for the furnace to include a lower wall which extends at the second end of the furnace between the floor and the roof, and for the collection means to be located proximate or underneath the lower wall.

There is further provided for the furnace to include at least one burner configured to burn one or more of gas, oil, or coal with preheated air or oxygen or combination of air and oxygen in the furnace, for the burner to extend through either the roof or the lower wall, and preferably for the furnace to include a plurality of burners.

There is still further provided for the furnace to include access ports for rakes to mechanically move feedstock on the floor, and preferably for the ports to be located in the walls or roof of the furnace.

There is further provided for the collection means to comprise a trough with discharge means to receive and continuously or periodically discharge reduced feedstock.

According to a further feature of the invention there is provided for the trough to include heating means for melting reduced material, preferably an induction heater as claimed in PCT patent application WO01/99473, and for the means to discharge liquid reduced feedstock from the trough to comprise a weir located in the trough which is shaped and configured in relation to the trough to allow liquid reduced feedstock to preferentially flow over it out of the trough, alternatively for the discharge means to comprise a bung which may be selectively removed from the trough to allow discharge of its liquid contents.

There is also provided for the trough to include cooling means and for the trough to be shaped and configured to receive, cool and discharge reduced feedstock, in a non-oxidising atmosphere; and preferably for the cooled reduced feedstock to be discharged through a mechanical gate or valve.

According to a further feature of the invention there is provided for the trough to include discharge means configured to deposit reduced feedstock in a sealed container within which a non-oxidising atmosphere is maintained, and preferably for the container to be insulated.

There is further provided for the metal oxide to comprise iron oxide, chromite, or manganese ore, and the reductant to comprise carbonaceous material.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of a furnace according to the invention is described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of two maximum angles of repose for two types of particulate material;

Figure 2 shows the angle of repose for a material on an inclined slope;

Figure 3 shows the angle of repose for a material on an inclined slope with a horizontal run-off area;

Figure 4 is a front perspective view of a furnace with the one side wall removed;

Figure 5 is a side perspective view of the furnace of Fig 4; and

Figure 6 is a schematic representation of the interior of the furnace of Fig 3 showing the processes which occur inside the furnace.

DETAILED DESCRIPTION OF THE INVENTION

A furnace of the type described above reduces iron oxide feedstock in the solid state. The feedstock is fed onto a floor where it is exposed to a reducing atmosphere and heat for reduction to take place. This is solid state reduction, which means the material is substantially completely reduced in the solid state without being molten. The still solid reduced feedstock is then fed into a collector for further processing.

To automate the process as much as possible the feedstock is allowed to slope from the point of entry to the collector. The rate at which the feedstock moves between the point of entry and the collector is controlled to ensure that the feedstock is reduced to the desired degree by the time it moves into the collector. Normally this means the feedstock is substantially entirely reduced by the time it reaches the collector.

The movement of the feedstock down a slope is used since it relies on gravity to move the material from the entry point to the collector. To make use of the sloping of the material the feedstock is heaped at the entry point and allowed to flow to the collector. The higher the feedstock is piled at the entry point the further the footprint of the heap will stretch. Thus by stacking the feedstock to a specific height it is possible to form a slope that reaches from the entry point to the collector.

This phenomenon relies upon the concept of the angle of repose of the feedstock. The feedstock has a maximum angle at which it can be stacked, beyond which particles will roll down the heap and increase the footprint of the heap.

The angle of repose for a feedstock is dependant on the characteristics of the feedstock. The angle of repose may differ with differences in composition of the feedstock. It is therefore possible that one type of feedstock may need to be stacked higher than another to have the same size footprint. This is shown in Figure 1 which shows two heaps of particulate material

(1, 2), with the one (1) being behind the other (2) to illustrate the concept. The heap (1) at the back is stacked higher than the heap (2) in the front. The material in the rear heap (1) is less slippery than the material in the front heap (2), which allows it to be stacked to a steeper angle. Both heaps are stacked at their maximum slope gradient, i.e. at their angle of repose. Neither heaps can be stacked higher without increasing its footprint (3). This means that should more material be added to either heap (1, 2), their footprints (3) will increase, which makes the toes (4, 5) of the heaps stretch further. It is this characteristic which is used to control the extent to which feedstock reaches from the point of entry into the furnace towards the collector.

The stability of such stacked material does not depend on the depth of material but rather on its orientation relative to the force of gravity. This can be illustrated by considering Figure 2, which again shows two heaps (6, 7) of particulate material stacked on an inclined floor (8). As in Figure 1, the one heap (7) is located in front of the other (6), and the front heap (7) has a shallower angle of repose than the rear heap (6). If more material is stacked on either heap (6, 7) it would move down its slope since it exceeds its stable condition. If the angle of the floor (8) is set steeper than the angle of repose of either heap (6, 7), it would not be possible to stack any material on the floor (6), unless the stacking angle is modified.

The stacking angle of a heap may be modified by introducing a static zone of material. This may be done by including a section in the floor which has a different angle than the existing portion. An example of this is given in Figure 3 which shows the floor (8) of Figure 2 with a horizontal portion (8B) at its base. As shown in Figure 3 the upper portion (8A) of the floor (8) has a steep angle and the lower portion (8B) is flat.

A particulate material (9A) is shown on the floor (8) which has an angle of repose lower than the angle of the upper portion (8A) of the floor (8). The particulate material therefore flows down the upper portion (8A) onto the lower portion (8B). The material stacks on the floor at an angle up to its angle of repose. Any additional material added to this heap would flow down the upper surface (8A) of the heap (9A) over the edge (8C) of the flat portion (8B). The material (9A) underneath the surface remains static, forming a static zone that effectively creates a base at the angle of repose of the particulate material. Any material (9B) added onto the surface forms a dynamic zone that moves down the slope under the force of gravity.

The material in the static zone (9A) does not move down the floor (8) under force of gravity. Save for the effect of mechanical interaction with particles in the dynamic zone (9B) that are flowing down the slope, the particles in the static zone (9A) do not move.

In a furnace of the type described above, any material in the static zone effectively becomes part of the furnace. This material is not available for the desired reaction and simply serves the purpose of forming a base over which the dynamic zone moves. It forms a heat and abrasion barrier which protects the lining of the furnace, allowing less expensive material to be used for the furnace lining. However, this has to be balanced by the monetary value of material that is kept in the static zone, essentially becoming material permanently locked into the process.

It is therefore possible to create a furnace with a floor which has an angle to the horizontal just below the angle of repose of feedstock that will be processed in such a furnace, or with a steeper slope but having a lower angled run-off portion at the base. This allows a static zone of material to be formed on the floor and for a dynamic zone of material to move over the static zone.

A cross section of a furnace (10) that utilizes this principle is shown in Figure 4 to 6. As shown in the drawings, the furnace (10) includes a floor (11) which is inclined relative the horizontal, an upper wall (12), a lower wall (13) and a roof (14) which extends over the floor (11) between the upper and lower walls (12, 13). The furnace (10) also includes side walls which extend from the floor to the roof on the sides of the furnace (10), and which are not shown in the drawings for the sake of viewing the interior (15) of the furnace (10). The floor (11) runs into a horizontal portion (25) which leads into a collector, in the form of a trough (18). The lower wall (13) extends from adjacent the side of the trough (18) to the roof (14).

Feeding hoppers (16) are located adjacent the upper wall (12) outside the furnace (10). Each hopper (16) is connected to the furnace (10) through a feeding port (17) in the upper wall (12).

Feedstock is fed into the furnace (10) through the feeding ports (17) to form a layer of feed (20) on the sloped floor (11). The feed layer (20) extends from the upper wall (12) onto the horizontal portion (25) and over the trough (18). The floor (11) is inclined at an angle relative to the horizontal which is just less than the angle of repose of the feedstock. This means it is still possible to form a static layer (20) of feedstock on the inclined floor (11).

The furnace (10) includes three distinct zones in which sequential steps in the reduction process occur, as shown in Figure 6. The first zone indicated as T_1 in Figure 6 is a preheating zone in which the feedstock (20), which comprises a mixture of iron ore and coal, is brought to a temperature at which devolatisation of the coal occurs. This also heats the iron oxide to the required temperature to allow reduction to take place.

The second zone, which is indicated as T_2 in Figure 6, is the reduction zone in which the iron oxide is converted to metallic iron as in any other coal based direct reduction process.

CO gas is typically generated from this reaction. In the third zone, which is indicated as T_3 in Figure 6, all or most of reduction has taken place and the amount of CO gas that is formed diminishes. Combustion gas, air, heated air, oxygen or a combination of those gases is typically blown into the furnace for reaction with the CO emitted from the feed slope to burn in the enclosed space above the slope (termed the freeboard). The heat from this is radiated off the roof of the furnace back onto the feedstock (20) thereby maintaining the reduction thereof.

Additional fuel burners located either in the roof above the trough or in the wall adjacent the trough (18) are used to increase the heat in this area. As shown in Figure 6, the gas (21) that enters the furnace via the auxiliary fuel burners (26) burns above the trough (18) and then moves towards the upper wall (12). At the same time CO gas (22) that is liberated during the reduction burns above the heap and the heat (23) generated from this is radiated back onto the heap (20) by the roof (14). The off-gas (24) is eventually evacuated from the furnace through outlet ports (not shown) in the upper wall (12).

During reduction particles in the dynamic zone (27) of the feedstock (20) shrink. The shrinkage is caused by the loss of volume of the coal due to the devolatisation and reaction with the oxygen in the ore to form CO gas. The smaller coal particles take up less volume and also fit into gaps between larger partly or fully reduced iron oxide particles. This reduces the volume of the material in the heap and settles the dynamic layer (27), both factors which alter the angle at which the material located the further down the sloped floor (11) is located.

This is equivalent to an increase in the stacking angle of the feedstock in the dynamic zone (27) which exceeds the angle of repose of the feedstock (20) and causes the reduced material in the dynamic zone (27) to move down the floor (11) under force of gravity. This is not a sudden movement but a controlled and steady flow of the particles down the floor (11).

As mentioned, the reduction in size of the coal particles causes the smaller particles to move down in the heap, fitting into the gaps between the larger particles. This leaves the larger, less reduced particles more exposed to the reducing atmosphere at the surface which increases the efficiency of the reducing process. This movement is continues and naturally promotes uniform reduction of all particles in the heap.

The heat distribution in the furnace is such that $T_3>T_2>T_1$. However the heat in T_3 is such that the reduced iron ore does not melt in this zone to form liquid iron. The solid reduced iron ore falls into the trough (18) from where it is removed by means of the collection means.

As shown in Figures 4 to 6 the base of the floor is connected to a trough (18), which in the preferred embodiment comprises an induction heater (), for example as described in PCT patent application WO01/99473, which melts the reduced feedstock and allows it to be tapped and processed further. It is also possible for the collection means to comprise a collection hopper which feeds the reduced material to a cooling chamber. The cooling chamber comprises an externally cooled outer containment surface which contains the reducing atmosphere until cooling to the desired temperature is complete.

The design of the furnace (11) makes it possible to directly reduce iron oxide fines. It is typically possible to treat particles which mostly range in size between about 1mm and 8mm, and which includes a fraction of as much as about 20% of particles smaller than 1mm. It is not possible to treat these types of particles in blast furnaces or in conventional direct reduction furnaces without sintering.

It is possible to achieve feed rates for iron oxide in the order of 90 to 115 $kg/h/m^2$ yet for other materials it is possible to operate the furnace at federates in the order of 35 $kg/h/m^2$. The furnace may be operated in a temperature range of between 900℃ to 1550℃, and preferably in a range of about 1200℃ to 1500℃. This makes the furnace very versatile since it can be adjusted to meet a wide range of requirements for various materials that are to be reduced. The feed rate of feedstock into the furnace and the rate of removal of reduced material from the furnace via the collector can be adjusted to match the rate of reduction of the material, thereby ensuring that the material is reduced optimally.

It will be appreciated that the embodiment described above is given by way of example only. It is possible to alter aspects of it without departing from the scope of the invention. It is for example possible for the trough to be filled with liquid iron which is kept at temperature by an induction heater and which melts the reduced feedstock into it from contact at its top surface. The molten reduced feedstock, i.e. liquid iron, may then be tapped from it.

CLAIMS

1. A static reduction furnace for the reduction of metal oxides, the furnace including a floor and a roof with walls extending between the floor and the roof, a feeder proximate a first end of the furnace, and a collector proximate a second end of the furnace opposite the first end configured to receive reduced feedstock from the floor; the feeder being configured to feed feedstock comprised of metal oxide and reductant onto the floor for reduction and to control the extent to which the feedstock extends from the first end to the second end of the furnace to allow feedstock to extend at least to the collector.

2. A furnace as claimed in claim 1 in which the feeder is configured to allow feedstock to extend to the second end of the furnace.

3. A furnace as claimed in claim 1 or 2 in which the feeder includes at least one gravity fed hopper with a feed port in communication with the interior of the furnace, and means to adjust the height to which the feedstock is fed onto the floor.

4. A furnace as claimed in claim 3 in which the feed port comprises a tube with an opening of which the location which is vertically adjustable in relation to the floor.

5. A furnace as claimed in claim 3 in which the feed port comprises a vertical slot in the hopper which is progressively closable by means of a movable gate.

6. A furnace as claimed in claim 3 in which the feed port comprises a rotary feed valve of which the opening is vertically adjustable in relation to the floor.

7. A furnace as claimed in any one of claims 1 to 6 in which the floor is angled downwards from the first end of the furnace to the collector at an angle lower than the lowest expected angle of repose of the feedstock.

8. A furnace as claimed in claim 7 in which the floor is angled at an angle more than 5 degrees lower than the lowest expected angle of repose of the feedstock.

9. A furnace as claimed in any one of claims 1 to 8 which includes an upper wall which extends at the first end of the furnace between the floor and the roof, and for the

feeder to be configured to feed the feedstock into the furnace through the upper wall or through the roof proximate the upper wall.

10. A furnace as claimed in any one of claims 1 to 9 which includes a lower wall which extends at the second end of the furnace between the floor and the roof, and the collector is located proximate or underneath the lower wall.

11. A furnace as claimed in any one of claims 1 to 10 which includes at least one burner configured to burn one or more of gas, oil, or coal with preheated air or oxygen or combination of air and oxygen in the furnace, with the burner extending through either the roof or the lower wall.

12. A furnace as claimed in any one of claims 1 to 11 which includes access ports for rakes to mechanically move feedstock on the floor.

13. A furnace as claimed in claim 12 in which the access ports are located in the walls or roof of the furnace.

14. A furnace as claimed in any one of claims 1 to 13 in which the collector comprises a trough with discharge means to receive and continuously or periodically discharge reduced feedstock.

15. A furnace as claimed in claim 14 in which the trough includes heating means for melting reduced material.

16. A furnace as claimed in claim 15 in which the heating means comprises an induction heater with a weir for the discharge of liquid reduced feedstock from the trough or a bung which may be selectively removed from the trough to allow discharge of its liquid contents.

17. A furnace as claimed in claim 14 in which the trough includes cooling means and the trough is shaped and configured to receive, cool and discharge reduced feedstock, in a non-oxidising atmosphere.

18. A furnace as claimed in claim 17 in which the cooled reduced feedstock is discharged through a mechanical gate or valve.

19. A furnace as claimed in claim 14 in which the discharge means is configured to deposit reduced feedstock in a sealed and preferably insulated container within which a non-oxidising atmosphere is maintained.

20. A furnace as claimed in any one of claims 1 to 19 in which the metal oxide comprises iron oxide, chromite, or manganese ore, and the reductant comprises carbonaceous material.

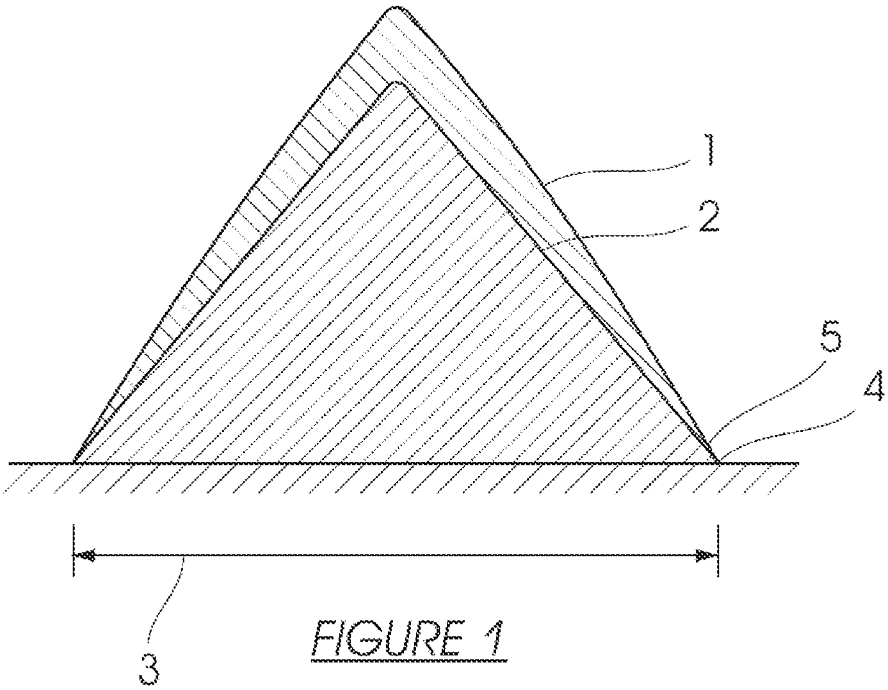

FIGURE 1

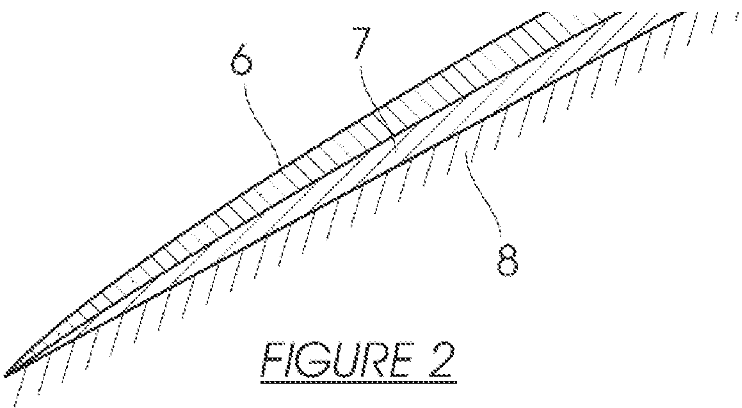

FIGURE 2

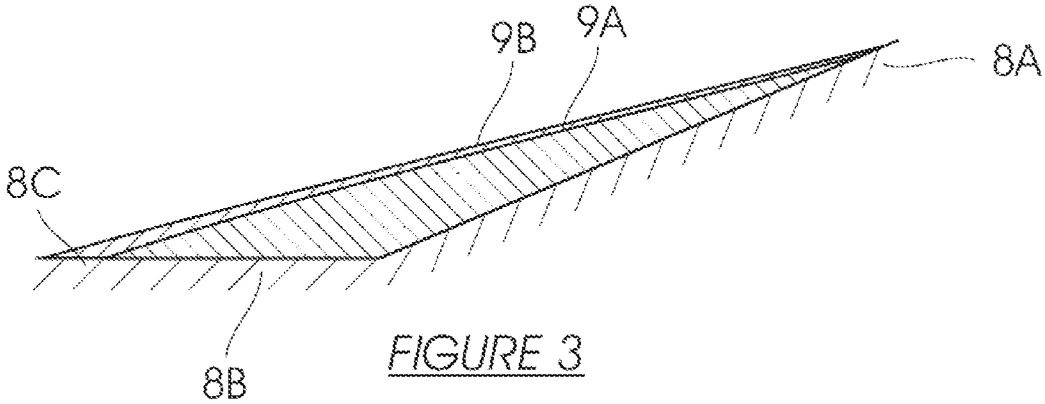

FIGURE 3

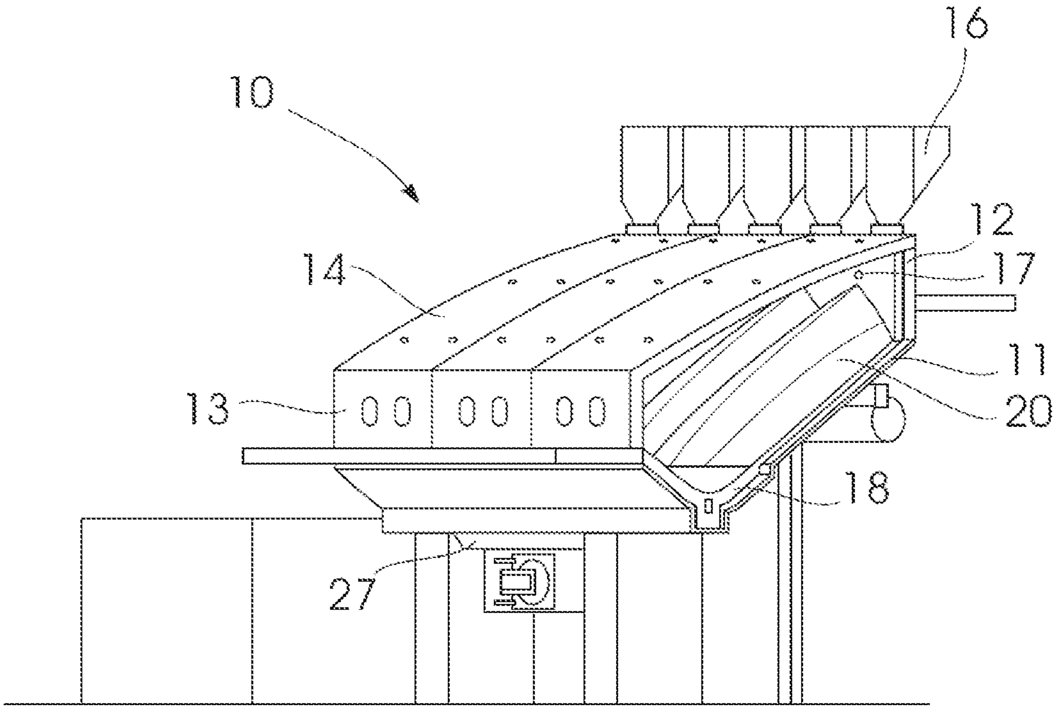

FIGURE 4

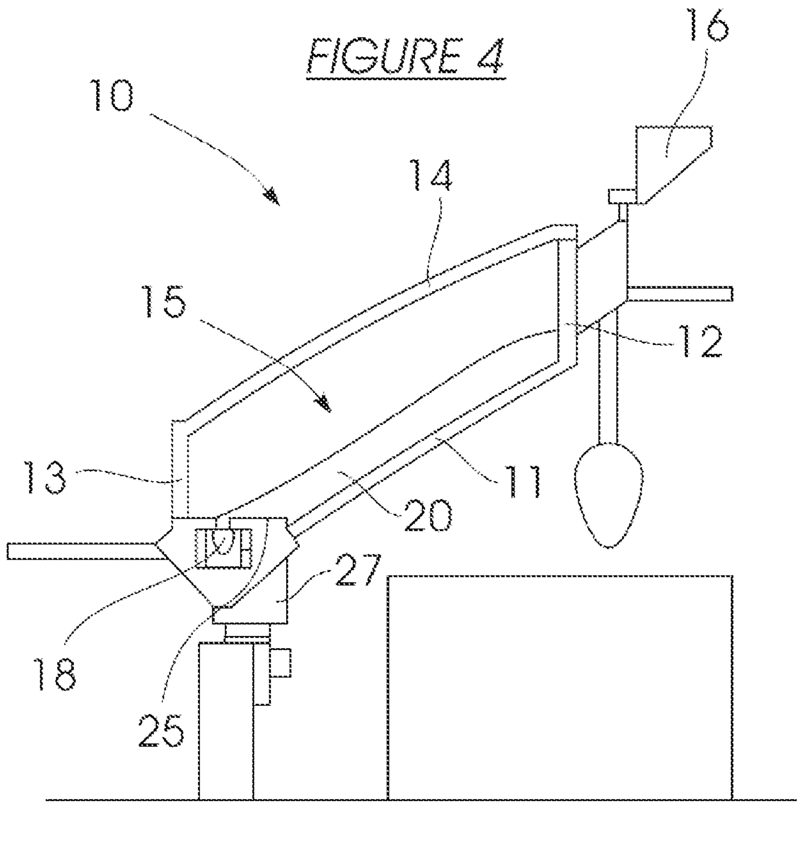

FIGURE 5

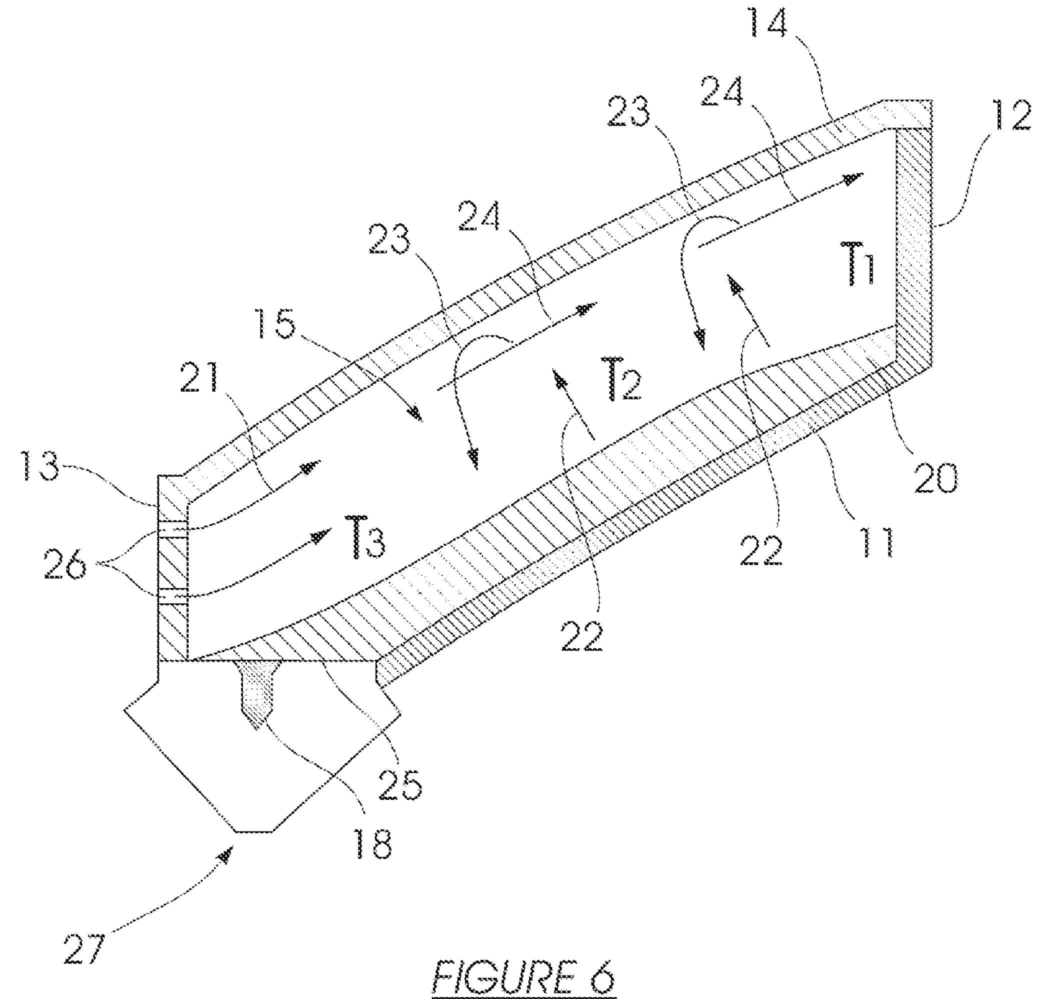

FIGURE 6