A system and method for cooling and removing metallic iron and other aggregate from a moving hearth is provided. Cooling may be provided by a secondary cooling system and a spray cooling system in a cooling zone. The secondary cooling system may include an arrangement of coolant tubes for absorbing heat. A flow of nitrogen may be provided through the cooling zone. The spray cooling system may provide evaporative cooling. Aggregate removal may be provided by a magnetic removal system, a plow system, and a sweeper system. The magnetic removal system uses a magnetic device and a moving belt to remove iron materials. The plow system uses a plow to separate and remove aggregate from the moving hearth. The sweeper system may use a vacuum device to pull materials from the moving hearth.
SYSTEM AND METHOD FOR COOLING AND REMOVING IRON FROM A HEARTH

Abstract: A system and method for cooling and removing metallic iron and other aggregate from a moving hearth is provided. Cooling may be provided by a secondary cooling system and a spray cooling system in a cooling zone. The secondary cooling system may include an arrangement of coolant tubes for absorbing heat. A flow of nitrogen may be provided through the cooling zone. The spray cooling system may provide evaporative cooling. Aggregate removal may be provided by a magnetic removal system, a plow system, and a sweeper system. The magnetic removal system uses a magnetic device and a moving belt to remove iron materials. The plow system uses a plow to separate and remove aggregate from the moving hearth. The sweeper system may use a vacuum device to pull materials from the moving hearth.
BACKGROUND AND SUMMARY OF DISCLOSURE

[0001] This international patent application claims priority to and the benefit of U.S. Provisional Patent Application serial number 60/884,829 filed on January 12, 2007, the disclosure of which is hereby incorporated by reference.

[0002] Direct reduction of iron ore and other iron oxides with a source of carbon in a controlled hearth furnace results in an aggregation of reduced metallic iron nodules, slag and carbon-bearing material at high temperature, which needs to be efficiently cooled, separated and selectively removed from a moving hearth. The iron oxide source may be mixed with finely divided carbon-bearing materials such as coke or coal, and on a layer of carbon-bearing material to protect the moving hearth.

[0003] One method of processing iron ore uses a moving hearth furnace operated at temperatures reaching up to 2,500 °F (1,370 °C) or higher. The iron oxide and carbon-bearing reducing materials may travel through the furnace on a moving hearth at temperatures up to 2,500 °F (1,370 °C) or higher, and result in reduced metallic iron mixed with slag, carbon-bearing material and other by-products on the moving hearth before cooling. A continuous process may be maintained by using a linear hearth furnace or rotary hearth furnace, wherein the raw materials travel through various controlled processing environments inside the moving hearth furnace.

[0004] There is need for a system for continuously handling such high temperature iron and carbon-bearing materials. Removal systems in the prior art have provided apparatus and systems for handling some of these materials in an ambient environment (e.g. less than about 120 °F (about 50 °C)). These systems and apparatus cannot operate successfully for long periods in environments up to 500 °F (about 260 °C), 800 °F (about 425 °C), or higher, or involve handling all these materials in aggregate as presented in a moving hearth for direct reduction of metallic iron in a commercial plant.

[0005] The present disclosure provides a system and method for efficient cooling of the aggregation, removal of the metallic iron nodules at relatively high temperature, separation of slag from the removed metallic iron nodules, and selective removal and classification of slag and carbon-bearing material, while leaving a selected and controlled amount of the carbon-bearing material on the moving hearth ready for reuse in the moving hearth furnace.
[0006] A method of removing metallic iron and associated materials from a moving hearth may comprise the steps of:

a. providing a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
b. cooling the aggregate on the moving hearth in a cooling zone by secondary cooling, such as coolant tubes, generally to a temperature in the adjacent atmosphere at or below about 1200 °F;
c. optionally spraying water over the aggregate on the moving hearth to cool the aggregate on the moving hearth by evaporation without substantial water run off generally to a temperature in the adjacent atmosphere at or below about 800 °F;
d. causing the moving hearth supporting aggregate to move beneath a moving belt positioned between the moving hearth and a magnetic device; and
e. removing magnetic material from the moving hearth by using the magnetic device to remove magnetic material from the aggregate, and moving the removed magnetic material for separate processing.

[0007] Secondary cooling of the aggregate in the method may include providing a plurality of coolant tubes, positioned adjacent the aggregate, through which coolant such as water is circulated.

[0008] The method for removing metallic iron and carbon-bearing and slag materials from a moving hearth may include moving the removed magnetic material transverse to, or along, the direction of travel of the hearth. The material may be removed at a velocity in a range of about 20 to 100 feet per minute (about 6 to 30 meters per minute). Alternately, the material may be removed at a higher speed, such as a velocity of about 100 to 400 feet per minute (about 30 to 120 meters per minute), and may be impacted against a surface to assist in separating metallic iron material from slag.

[0009] The method may include causing the moving hearth to move beneath a belt, the belt supported by a drum capable of moving removed magnetic material traverse or along the direction of the hearth. The drum may include a magnetic device adjacent the belt. The magnetic device, which may be in the drum or adjacent the belt, may be cooled by coolant if desired.

[0010] The method may also include the steps of moving the hearth beneath a plow capable of selectively removing a regulatable amount of aggregate, and moving the hearth beneath a sweeper capable of selectively removing a regulatable amount of aggregate. The step of moving the hearth beneath a plow may include removing aggregate over a plow edge.
and adjacent inclined surface, and brushing the removed aggregate to a conveying device. The step of moving the hearth beneath a sweeper may include removing aggregate using a vacuum device.

[0011] The method may further include separating the removed aggregate according to size, and returning classified particles smaller than a selected size to the moving hearth.

[0012] The system for removing metallic iron and associated materials from a moving hearth may comprise:

a. a moving hearth capable of supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;

b. a cooling zone capable of cooling the aggregate on the moving hearth by secondary cooling, such as coolant tubes, generally to a temperature in the adjacent atmosphere at or below about 1200 °F;

c. optionally, a spray of water capable of cooling the aggregate on the moving hearth to a temperature in the adjacent atmosphere generally at or below about 800 °F by evaporation without substantial water run off; and

d. a moving belt positioned between a magnetic device and the moving hearth, the magnetic device being capable of removing magnetic material from the aggregate, and the moving belt being capable of moving the removed material traverse or along the direction of travel of the moving hearth for separate processing.

[0013] The secondary cooling may include a plurality of coolant tubes, positioned adjacent the aggregate, through which coolant such as water may be circulated.

[0014] The moving belt may be positioned traverse or along the direction of movement of the hearth. The belt may move at a velocity in a range of about 20 to 100 feet per minute (about 6 to 30 meters per minute). Alternately, the belt may move at a higher speed, such as a velocity of about 100 to 400 feet per minute (about 30 to 120 meters per minute). The moving belt may be capable of impacting the removed material against a surface to assist in separation of metallic iron material from slag.

[0015] The system may include a drum positioned traverse or along the moving hearth and supporting a belt capable of moving removed material traverse or along the direction of the hearth. The drum may include a magnetic device, and the drum and/or magnetic device may be cooled by coolant.

[0016] The system may include a plow and a sweeper. The plow may include a plow edge and adjacent inclined surface, and a brush adjacent the surface. The sweeper may include a vacuum.
BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is a side elevational view of a portion of a hearth furnace including one embodiment of a system for cooling and removing iron from a hearth;
[0018] FIG. 2 is a cross sectional view through a hearth across section 2-2 in FIG. 1;
[0019] FIG. 3 is a cross sectional view through a hearth across section 3-3 in FIG. 1;
[0020] FIG. 4 is a cross sectional view of an alternate embodiment through a hearth across section 3-3 in FIG. 1;
[0021] FIG. 5 is a front perspective view of a first embodiment of coolant tubes of the present disclosure;
[0022] FIG. 6 is a front perspective view of a second embodiment of coolant tubes;
[0023] FIG. 7 is a front perspective view of sections of the moving hearth before entering a magnetic removal system;
[0024] FIG. 8 is a cross sectional view showing one embodiment of a magnetic removal system across section 8-8 in FIG. 1;
[0025] FIG. 9 is a side elevational view of a second embodiment of a magnetic removal system of the present disclosure;
[0026] FIG. 10 is a cross sectional view showing the second embodiment of the magnetic removal system across section 10-10 in FIG. 9;
[0027] FIG. 11 is a cross sectional view of one embodiment of a plow system of the present disclosure;
[0028] FIG. 12 is a cross sectional view of a plow system including a roll classifier;
[0029] FIG. 13 is a side perspective view of one embodiment of a sweeper system;
[0030] FIG. 14 is a front perspective view of sections of the moving hearth before entering one embodiment of the sweeper system; and
[0031] FIG. 15 is a front perspective view of sections of the moving hearth after exiting one embodiment of the sweeper system.

DETAILED DESCRIPTION OF THE DRAWINGS

[0032] Referring now to FIG. 1, a hearth furnace 10 includes a moving hearth 30 and a system for cooling and removing metallic iron and related materials from the moving hearth 30. The hearth furnace 10 may contain a plurality of controlled sections, where a different
processing environment may be maintained in each section for use in directly reducing iron from an iron oxide source. As an example, the hearth furnace 10 may include a preheating zone, a reduction zone, and a fusion zone. Baffles may be provided to at least partially separate each section. As shown in FIG. 1, a fusion zone 20 of the hearth furnace 10 may have a baffle 22 between the fusion zone 20 and a cooling zone 24.

[0033] The furnace 10 may be used for processing iron oxide and carbon-bearing materials at selected temperatures for providing metallic iron materials. Aggregate material for processing, including metallic iron materials, carbon-bearing materials, and other associated material may move through the furnace 10 on the moving hearth 30. In some embodiments, a track 32 may cause the hearth 30 to move through the furnace 10. At a discharge portion of the furnace 10, the hearth 30 may move past the baffle 22 through an opening 34 to enter the cooling zone 24. The fusion zone 20 may have a controlled atmosphere having a temperature up to about 2,500 °F (1,370 °C) or more. Further, the aggregate on the moving hearth 30 moving from the fusion zone 20 into the cooling zone 24 may have a temperature of up to about 2,500 °F (1,370 °C) or more.

[0034] The aggregate, including selected ferrous, carbon-bearing, and other materials for processing, may be loaded onto the moving hearth 30 in layers. After processing, the products and by-products of the process may remain on the hearth 30 in layers. For example, the moving hearth 30 may support aggregate in a hearth layer 62 and a layer of reduced metallic iron material 66, as illustrated by FIG. 2. The layer of metallic iron material 66 may also have an overlayer of carbon-bearing materials.

[0035] The hearth layer 62 may be used to cover and protect the surface of the moving hearth 30. The hearth layer 62 may be a carbon-bearing material such as coke, coal, or char. The hearth layer 62 may have a thickness capable of protecting the moving hearth 30 from slag and other by-products of the hearth furnace process. The protective hearth layer 62 may be re-used in subsequent hearth furnace processes through the furnace. As such, the iron removal system may leave a portion of the hearth layer 62 on the hearth. Alternately, the hearth layer 62 may be removed if desired.

[0036] The moving hearth 30 may comprise a hearth surface 50 and raised curbs 56 along the left-hand and right-hand sides of the hearth surface 50. The moving hearth 30 may comprise a plurality of sections or segments, such as but not limited to hearth cars, positioned end to end along the track 32. The plurality of sections of the moving hearth 30 may be arranged in a contiguous line on the track 32, such that the hearth surface 50 can extend through the furnace 10 as an approximately continuous surface. After the moving hearth 30
exits the furnace 10, the track 32 may continue in a return loop back to the entrance of the furnace.

[0037] The hearth sections may be moved by suitable drive apparatus, such as chains, hydraulics, belts, or other drive mechanisms. The drive apparatus may cause one hearth section or segment to push against the hearth section in front of it, which correspondingly pushes the next section forward, continuing as such, thereby causing the sections of the moving hearth 30 to maintain contact and to move in a line through the furnace along the track 32. The moving hearth 30 may comprise a plurality of sections connected together by linkages so that the sections do not appreciably separate as the moving hearth travels through the furnace.

[0038] In the embodiment of FIG. 1, when the moving hearth 30 exits the fusion zone 20 of the furnace 10, the hearth enters the cooling zone 24. The cooling zone 24 shown in FIG. 1 comprises a secondary cooling system 36. The secondary cooling system 36 of FIG. 1 may be positioned within the furnace housing 26, and include a system of coolant tubes 70 oriented over the moving hearth 30. A coolant circulates through the coolant tubes 70 in a manner that absorbs heat from the metallic iron and related material on the hearth. In the embodiment of FIGS. 1 and 3, the coolant tubes 70 are oriented approximately transverse to the track 32, and may be spaced adjacent the aggregate on the hearth about 1 to 2 inches (about 2 to 5 cm) apart. Alternately, the coolant tubes 70 may extend along the direction of travel of the moving hearth.

[0039] The cooling zone 24 may cool the aggregate on the moving hearth by secondary cooling, such as coolant tubes, generally to a temperature in the adjacent atmosphere at or below about 1200 °F. The cooling zone 24 may comprise the secondary cooling system 36. The temperature of the adjacent atmosphere at the exit of the secondary cooling system 36 may be in a range of approximately 800 to 1200 °F (approximately 425 to 650 °C) or lower.

[0040] In the embodiment of FIG. 3, the coolant tubes 70 are formed such that when the moving hearth 30 moves through the secondary cooling system 36, the coolant tubes 70 are adjacent to the aggregate on moving hearth 30. Alternately, as shown in FIG. 4, the coolant tubes 70 may be positioned to be adjacent to the sides around the moving hearth with the aggregate material thereon. However, the coolant tubes 70 may be positioned in any suitable adjacent orientation for removing heat from the metallic iron and related material on the hearth. The coolant tubes 70 may be positioned approximately 2 to 5 inches (approximately 5 to 13 centimeters) from the surface of the aggregation on the moving hearth.
[0041] The coolant tubes 70 of the secondary cooling system 36 may be enclosed by the furnace housing 26 as shown in FIG. 1, having entry through the baffle opening 34 in the fusion exit baffle 22. At the exit of the secondary cooling system 36 may be a baffle 76, having a baffle opening 78 for the moving hearth 30 to move through. The temperature of the atmosphere at the exit of the furnace housing 26 adjacent the cooling baffle 76, in the atmosphere, may be less than about 1200 °F (650 °C). In another embodiment, the temperature of the adjacent atmosphere may be less than approximately about 800 °F (approximately 425 °C). Optionally, the furnace housing 26 may not extend over the coolant tubes 70 in the cooling zone 24 in particular embodiments as desired.

[0042] The coolant tubes 70 may pass over the moving hearth 30 in a serpentine or S-shaped configuration as illustrated in FIGS. 4 and 5. Alternately, the coolant tubes 70 may extend from an intake manifold 72 on one side of the moving hearth 30 to an outlet manifold 73 on the other side of the hearth as illustrated in FIG. 6. It is contemplated that various configurations and orientations of coolant tubes 70 may be used to cool the atmosphere in the furnace housing 26.

[0043] In the serpentine configuration of FIGS. 4 and 5, the coolant tubes 70 pass back and forth over the moving hearth 30 to form at least a partial enclosure over the moving hearth. The cooling zone 24 may include the area over the moving hearth 30 within the partial enclosure formed by the coolant tubes 70.

[0044] The coolant tubes 70 with circulating coolant inside comprise the secondary cooling system 36, which absorbs heat from the aggregate, and may circulate through a conditioning process to remove heat from the coolant. The coolant may be routed to a heat exchanger to extract heat for other uses or to a cooling tower to dissipate the absorbed heat from the aggregate. In an alternate embodiment, the coolant tubes 70 may be divided into two or more zones. A first zone of coolant tubes 70 may be routed to a heat exchanger to extract heat for use, and a second zone may be routed to a cooling tower for dissipation of heat.

[0045] In the embodiment of FIG. 1, the coolant tubes 70 may extend over approximately 53 feet (16 meters) of the moving hearth 30. The coolant tubes 70 may have approximately a 1.5 inch (3.8 centimeter) diameter for circulating water, or coolant, such as through the coolant tubes 70 at a rate of approximately 1,300 gallons per minute (4.9 cubic meters per minute). The temperature gradient of the water through the coolant tubes 70 may be, for example, 10 °F to 20 °F (about 6 °C to 11 °C) or higher. Additional cooling may be developed by additional coolant tubes 70, or by increasing the size of the coolant tubes 70, or by increasing the circulation rate of coolant through the coolant tubes. It is contemplated that
coolants other than water may be used as desired. The secondary cooling system 36 may cool the aggregate on the moving hearth 30 to a temperature with an adjacent atmosphere at or below about 1200 °F (approximately 650 °C).

[0046] Additional cooling may be provided by providing a flow of gas over the moving hearth 30 in the cooling zone 24. The flow of gas may be nitrogen or other inert gas. Nitrogen evaporated from liquid nitrogen may be introduced into the furnace housing 26. The gas may flow over the moving hearth and then be exhausted, processed through a heat exchanger or circulated to another part of the furnace for use. If desired, the gas may be cooled and recirculated over the moving hearth 30.

[0047] The nitrogen or other gas may flow in the direction counter to the direction of the moving hearth 30. Alternatively, the gas may flow in a concurrent direction or cross flow direction, transverse to the direction of the hearth. The volume and direction of gas flow may be determined to create a turbulent flow of gas over the moving hearth. Nitrogen may flow opposite the direction of travel of the moving hearth in a volume of approximately 500 cubic feet per minute (approximately 14.2 cubic meters per minute).

[0048] The flow of gas through the cooling zone 24 may be such that the pressure in the cooling zone 24 is slightly higher than the pressure in the fusion zone 20 of the furnace. Maintaining a pressure in the cooling zone 24 slightly higher than the pressure in the fusion zone 20 may reduce leakage of the controlled atmosphere of the fusion zone 20 into the furnace housing 26. The pressure in the cooling zone 24 may be selected to reduce the amount of gas from the cooling zone 24 entering the fusion zone 20.

[0049] However, before magnetic separation, the aggregate may be partially cooled, if desired, by spray cooling system 38. The spray cooling system 38 may have a plurality of nozzles 80 for spraying liquid over the aggregate on the moving hearth 30 so as to evaporate the liquid, causing an evaporative cooling effect. The spray cooling system 38 may be positioned outside of the furnace housing 26, and may comprise a plurality of nozzles 80 capable of spraying water. It is contemplated that various spray patterns, droplet sizes, and volume flow rates may be utilized to create a suitable evaporative cooling effect. The spray cooling system 38 may dispense a spray of water over the aggregate on the moving hearth so as to substantially evaporate the water without substantial water run-off, thereby preventing the aggregate materials on the moving hearth from remaining wet. Thus, the aggregate materials may be recycled into the hearth furnace without an additional drying process. Also, an environment condition presenting the need for discharge of water is not presented.
In the embodiment of FIG. 1, the spray cooling system 38 extends approximately 10 feet (3 meters), and comprises four rows of nozzles positioned above the moving hearth. The aggregate on the moving hearth may be cooled by the spray cooling system 38 to a temperature in the adjacent atmosphere at or below about 800 °F (approximately 425 °C). The aggregate on the hearth may be cooled by approximately 0.15 gal/min (0.57 liter/min) flow rate of water from a temperature of approximately 1200 °F (approximately 650 °C) to approximately 300 °F (approximately 150 °C). A vent hood 82 may optionally be positioned above the moving hearth to remove evaporated water and other fluidized materials that come off of the hearth during the spray cooling. The evaporated coolant may be directed into a condenser for treatment and recycling.

Following the cooling zone 24, a system for removing iron may include a magnetic removal system 88 for removing metallic iron material from the moving hearth 30, along with magnetic slag. Aggregate comprising processing by-products and reactants including slag and carbon-bearing material may then be removed from the moving hearth 30 by a plow system 42. Finally, additional such material may be removed from the moving hearth 30 by a sweeper system 44. It is contemplated that a combination of one or more of these removal systems may be utilized.

The metallic iron material 66 may contain metallic iron nodules 60 and other metallic iron material. The iron removal system may remove the iron nodules 60 and other iron containing materials while leaving other aggregate, such as the hearth layer 62 on the moving hearth 30.

The metallic iron material 66 may be removed from the moving hearth 30 by the magnetic removal system 88. The magnetic removal system 88 may be capable of operating in a high temperature environment. It is contemplated that the magnetic removal system 88 may operate to continually remove metallic iron material at temperatures in the adjacent atmosphere of up to about 800 °F (approximately 425 °C), as the hearth moves beneath the removal system. In a continuous operating environment, portions of the magnetic removal system 88 may increase in temperature to approximately the same temperature as the metallic iron material 66, due to heat transfer to the removal system.

As shown in FIG. 8, the magnetic removal system 88 includes a moving belt 90, positioned over the moving hearth 30 and oriented traverse the direction of the moving hearth 30. In this embodiment, the belt 90 is driven in a continuous loop around a support structure 92. The magnetic removal system 88 further comprises at least one magnetic device 94, located above the belt and moving hearth 30, and positioned such that a lower span of the
continuous loop of belt 90 passes between the magnetic device 94 and the moving hearth 30. In the embodiment of FIG. 8, the magnetic device 94 and belt 90 are capable of operating in a high temperature environment.

[0055] The magnetic device 94 may be an electromagnet, a permanent magnet, or a combination of electromagnets and permanent magnets. The magnetic device 94 may be cooled by a coolant, as such water, for maintaining a selected operating temperature. Cooling for the magnetic device may be achieved by a cooling jacket, with inlets and outlets surrounding the magnetic device, bores through the magnet, or other cooling techniques. The magnetic device 94 may be connected to a cooling system capable of circulating coolant to cool the magnetic device.

[0056] The hearth 30 moves beneath the belt 90 and the magnetic device 94, causing the belt 90 to remove the metallic iron material along the direction of the moving belt 90. As the hearth advances beneath the magnetic device 94, the magnetic device attracts the iron and other magnetic metallic materials contained in the moving hearth 30. The magnetic device 94 attracts the magnetic materials and temporarily holds the magnetic materials against the intervening belt 90. The magnetic device 94 may attract other magnetic materials besides metallic iron, such as magnetic slag. There may also be slag and the like physically attached to the magnetic material attracted by the magnetic device 94.

[0057] The belt 90 may move at a velocity of about 30 feet per minute (about 9 meters per minute). In some embodiments, the belt may have a velocity within a range of approximately 20 to 100 feet per minute (about 6 to 30 meters per minute). The belt 90 may be driven at a velocity such that the attracted materials including iron and other magnetic materials that are held against the belt 90 become removed by the lower span of the continuous loop of the belt 90 in the direction of the travel of the belt indicated by the arrow marked “A” in FIG. 8.

[0058] The belt 90 may include protrusions 96 extending from an outer surface of the belt to aid in moving the attracted metallic iron materials away from the magnetic device 94. The protrusions may be of various shapes, sizes, and orientations to move the metallic iron materials away from the magnetic device 94. The belt 90 may be made from fiberglass, austenitic stainless steel, or other appropriately nonmagnetic material capable of withstanding the temperatures encountered by the magnetic removal system 88. Alternatively or additionally, the belt 90 may have a rough surface to aid in removing the metallic iron materials.
[0059] The magnetic materials removed by the belt may be received by a collection system 100. The collection system 100 may include a collector 104 and magnetic material conveyor 106. The conveyor 106 may be a screw conveyor.

[0060] As shown in FIG. 8, the collection system 100 may include a feeder 103. The feeder 103 may be positioned between the moving hearth 30 and the collector 104, located so that removed material falling from the belt 90 lands in the feeder 103. The feeder 103 may be inclined so that material in the feeder 103 slides into the collector 104. The feeder 103 may include one or more surfaces capable of vibrating, such as a vibratory feeder, to move the removed magnetic material and assist in supporting metallic iron materials from slag adhering to it.

[0061] Optionally, the removed materials may be impacted against a surface to separate metallic iron material from adhering slag and other associated material. As shown in FIG. 8, an impact plate 102 may be provided adjacent to the belt 90, located to intersect the path of the metallic iron materials falling from the belt 90. In this embodiment, the belt 90 may move the magnetic material at a sufficient velocity to remove from iron nodules 60 slag and other non-ferrous materials that adhered. This velocity may be a range of about 100 to 400 feet per minute (about 30 to 120 meters per minute) to break the slag and other associated materials adhering to the iron nodules 60, upon impacting the impact plate 102. After impacting the impact plate 102, the impacted materials may fall into the collector 104, where the iron material conveyor 106 transfers the materials away from the collection system 100.

[0062] In an alternate embodiment illustrated in FIGS. 9 and 10, the magnetic removal system 188 comprises a belt 90, positioned above the aggregate on the moving hearth 30 and positioned in the direction of travel of along the moving hearth 30. The belt 90 is driven in a continuous loop around a support structure 92 having a drum 93 and a secondary pulley 91. As shown in FIG. 9, the drum 93 has at least one magnetic device 94 positioned within the drum, and may have an outer cooling jacket 95 operably positioned between the belt and the magnetic device. The magnetic device 94 may be an electromagnet, a permanent magnet, or a combination of both. In the embodiment of FIG. 9, the magnetic device 94 and belt 90 are capable of operating in a high temperature environment.

[0063] In the embodiment of FIG. 9, the drum 93 has a substantially cylindrical shape, with a longitudinal axis positioned traverse the direction of movement of the hearth. One or more magnetic devices 94 may be positioned within the drum 93. As shown in FIG. 9, the drum 93 may comprise a plurality of magnetic devices 94 capable of lifting metallic iron material from the moving hearth 30.
The cooling jacket 95, positioned between the magnetic device 94 and the belt 90, is capable of cooling the magnetic devices 94 such that the magnetic devices maintain a desired temperature. The cooling jacket 95 may comprise one or more passageways 97 capable of receiving a flow of coolant. In the embodiment shown in FIG. 10, the coolant enters the passageway 97 from one end of the drum 93 and leaves the passageway 97 from the other end of the drum. The cooling jacket 95 may comprise a plurality of coolant tubes positioned between the belt 90 and the magnetic device 94. The cooling jacket 95 may be in any desired coolant flow arrangements as desired for the particular embodiment. The magnetic device 94 is cooled by the coolant to maintain a selected operating temperature. The cooling of the magnetic device may be achieved by a cooling jacket, a plurality of cooling tubes surrounding and/or through the magnetic device.

In the embodiment of FIGS. 9 and 10, the moving hearth 30 moves beneath the belt 90, and the magnetic device 94, causing the belt 90 to remove the metallic iron material. As the moving hearth advances beneath the drum 93, the magnetic device 94 attracts the iron and other magnetic metallic materials contained in the hearth 30. The magnetic device 94 attracts the magnetic materials from the aggregate toward the magnetic device 94 and temporarily holds the magnetic materials against the belt 90. As the drum 93 rotates, the magnetic iron material and the belt 90 move adjacent to the drum 93 as the drum moves. When the magnetic iron material magnetically adhering to the belt 90 adjacent to the drum 93 reaches an upper span of the loop between the drum 93 and the secondary pulley 91, the belt moves the metallic iron material away from the drum 93 and across the upper belt span.

The magnetic removal system 188 further comprises the collector 104, and the iron material conveyor 106. In this embodiment, the conveyor 106 is a screw conveyor. The collector 104 and conveyor 106 are positioned to cooperate with the belt 90 to receive the removed material. In the embodiment of FIG. 9, as the removed materials convey across the belt 90 and over the secondary pulley 91, the removed materials convey into the collector 104, and are then conveyed away from the hearth by the conveyor 106. The velocity of the belt 90 may be approximately the same speed as the moving hearth 30, such as within a range of approximately 5 to 50 feet per minute (approximately 1.5 to 15 meters per minute). The belt 90 velocity may be approximately 10 feet per minute (approximately 3 meters per minute) or more. The belt velocity may be faster than the speed of the moving hearth 30.

As shown in FIG. 9, the belt 90 may include protrusions 96 extending from the outer surface of the belt. The protrusions 96 assist in moving the metallic iron materials away from the magnetic device 94. Protrusions may be of various shapes, sizes, and orientations, as
desired, to remove the metallic iron materials away from magnetic device 94. The belt 90 may be made from fiberglass, austenitic stainless steel, or other appropriately nonmagnetic material able to withstand the operating temperatures. Alternatively or in addition, the belt 90 may have a rough surface to aid in removing the metallic iron materials.

[0068] Multiple magnetic removal systems 88, 188 may be used to remove the metallic iron materials from the moving hearth 30. Two or more belts 90 and magnetic devices 94 may be positioned over the moving hearth 30 in a staggered arrangement. In a three-device embodiment, the first magnetic removal device may be positioned over the left edge of the moving hearth 30, the second magnetic removal device positioned over the center of the moving hearth 30, and the third magnetic removal device positioned over the right edge of the moving hearth 30. The multiple magnetic removal systems 88, 188 may be positioned in a staggered arrangement such that the second device is downstream of the first, and the third is downstream of the second to accommodate the physical structure of the devices. A first belt may remove material toward the left side of the moving hearth, and a second belt may remove material toward the right side of the moving hearth. In any event, a plurality of magnetic removal systems 88 are arranged in various staggered arrangements and orientations to accomplish removal of metallic iron materials from the width of the moving hearth 30.

[0069] The conveyor 106 may transfer removed materials to a second magnetic separator (not shown), to further separate slag from iron. The second magnetic separator may be used to further remove slag and other low- or non-magnetic aggregate from the removed material stream. Low- or non-magnetic aggregate separated by the second magnetic separator may be classified by size, where pieces smaller than -6 Tyler mesh returned to the moving hearth 30. The removed magnetic materials may be conveyed to a crusher before entering the second magnetic separator. The second magnetic separator may be a magnetic drum separator known in the art.

[0070] The iron material conveyor 106 may convey the removed iron materials to one or more totes or other material handling units. In some embodiments, the iron materials may remain in totes until the iron cools. It is contemplated that the iron materials may be conveyed to a cooling system for additional cooling. The spray cooling system 38 may dispense a spray of water over the removed magnetic material so as to evaporate and cool the removed magnetic material without substantial water run off. Optionally, additional cooling may be provided by the conveyor 106, such as by using a screw conveyor having a cooled screw, such as, but not limited to, a Therma-Flite® screw.
The plow system 42 may remove at least a portion of the aggregate including carbon-bearing reductants and other materials. The aggregate removed may include metallic iron materials, slag, other processing by-products and reactants. However, generally the plow system 42 is positioned after the magnetic removal system 88 has removed the magnetic material. The removed materials may be separated and recycled in subsequent hearth furnace processes. The plow system 42, shown in FIGS. 11 and 12, comprises a plow 112 capable of selective removal of aggregate material while leaving other aggregate material on the moving hearth 30. The plow system 42 may include a brush 118 capable of removing plowed material from the inclined surface 116. The plow system 42 may further include an aggregate conveyor 120. As shown in FIGS. 11 and 12, the brush 118 may be a rotary brush, and the conveyor 120 may be a screw conveyor.

As shown in FIGS. 11 and 12, the plow 112 may be positioned above the moving hearth 30 but positioned to engage the aggregate materials contained in the hearth. The plow 112 comprises a plow edge 114 adjacent to an inclined surface 116. As the moving hearth 30 moves beneath the plow 112, the plow removes a selected portion of aggregate material from the moving hearth.

The plow edge is approximately stationary, as shown in FIGS 11 and 12, or adjustable as desired. In any case, as the moving hearth 30 advances, the hearth pushes the materials contained in the hearth against the plow edge 114. The moving hearth 30 moves toward and beneath the plow 112, causing the plow to remove material from the hearth. As the moving hearth 30 continues beneath the plow 112, the material above the plow edge 114 becomes pushed up onto the inclined surface 116, and the material below the plow edge 114 remains on the hearth.

When the moving hearth 30 advances beneath the plow 112, the removed material may accumulate on the inclined surface 116. The brush 118 may be used to assist the movement of removed material along the inclined surface 116 and onto the conveyor 120, where the conveyor 120 moves the material away from the plow system 42. In the embodiment of FIG. 11, the brush 118 comprising the rotating brush sweeps the removed material accumulating beneath the brush. The brush 118 may be a pushing or pulling mechanism such as a wiper bar or a conveyor belt. Alternately, the load surface may vibrate to cause the aggregate material to move along the surface, such as by way of a vibratory feeder.

As shown in FIG 12, the plow system 42 may further comprise a classifier 122 positioned between the inclined surface 116 and the conveyor 120. The classifier 122 may
comprise a roll classifier having at least two rolls 124 positioned generally side-by-side, each roll separated from the adjacent roll by a selected distance creating a transverse aperture 126 between adjacent rolls, as those particles of smaller size fall through and, if desired, return to the hearth. The rolls may rotate such that they move material and classify material at the same time. The roll classifier 122 screens the material by allowing particles smaller than aperture 126 to fall down through the apertures 126 between the rolls 124.

[0076] In this embodiment, the roll classifier 122 is capable of being adjusted within a range of aperture sizes. The roll classifier 122 may be adjusted to an aperture size of about 6 Tyler mesh (3.327 millimeters), so that smaller particles fall through the apertures 126 between the rolls 124. The roll classifier 122 may be positioned so that material that falls between the rolls 124 falls back onto the moving hearth 30. Alternately, material that falls between the rolls may be collected and removed from the plow. Particles larger than the selected aperture size move over the rolls and into the conveyor 120.

[0077] Alternately, the classifier 122 may comprise a screen classifier in place of the roll classifier 122 (not shown). The screen classifier may comprise one or more screens having apertures of a selected size for allowing particles smaller than the selected aperture size to fall through. The screen classifier may be positioned so that material that falls through the screen falls onto the moving hearth 30. The selected aperture size may be about 6 Tyler mesh (3.327 millimeters).

[0078] In the embodiments of FIGS 11 and 12, the height of the plow edge 114 from the hearth surface 50 may be adjustable to accommodate the removal of selected aggregate material. The plow edge 114 may be positioned to skim a portion of the hearth layer 62 from the moving hearth 30 while leaving a portion of the hearth layer 62 in place. If desired, the plow may be held close to the hearth surface 50 to remove a larger portion of the materials on the moving hearth. In an alternate embodiment, the plow edge 114 may move in a side to side motion, or alternately, vibrates, to better provide separation of the aggregate material. The plow 112 may also include cooling for maintaining the plow edge 114, the load surface 116, and the brush 118 at a selected temperature.

[0079] Two or more plows 112 may be positioned over the hearth in a staggered arrangement. In a three-plow embodiment, the first plow may be positioned over the left edge of the moving hearth 30, the second plow positioned over the center of the hearth, and the third plow positioned over the right edge of the hearth. The multiple plows 112 may be positioned in a staggered arrangement such that the second plow is downstream of the first, and the third is downstream of the second to accommodate the physical structure of the
devices. The plows 112 may feed into the aggregate conveyor 120. The plurality of plows 112 may be arranged in various staggered arrangements and orientations to accomplish removal of material from the width of the moving hearth 30. In alternate embodiments, the plows feed into two or more conveyors 120.

[0080] The aggregate conveyor 120 may convey the removed aggregate through a secondary cooling system to further reduce the temperature of the removed aggregate. The spray cooling system 38 may dispense a spray of water over the removed aggregate so as to evaporate and cool the removed aggregate without substantial water run off. Optionally, additional cooling may be provided by the conveyor 120, such as by using a screw conveyor having a cooled screw, such as, but not limited to, a Therma-Flite® screw. The spray cooling system 38 may also dispense a spray of water over the aggregate on the moving hearth after the moving hearth moves past the plow 112, so as to evaporate and cool the aggregate on the moving hearth without substantial water run off.

[0081] As shown in FIG. 13, aggregate may also be removed from the moving hearth 30 using the sweeper system 44. The sweeper system 44 may comprise a sweeper 128 that uses pressure or vacuum to selectively remove the aggregate material left after the magnetic separation with magnetic removal system 88, 188 and the operation of the plow system 42. The sweeper 128 may be a pneumatic device that creates back pressure or vacuum, such as by a vacuum pump 133, to pull material from the moving hearth. Alternately, the sweeper 128 uses air pressure to push the aggregate material, such as by way of an air broom. As the hearth moves beneath the sweeper 128, the sweeper selectively removes material from the moving hearth 30.

[0082] The sweeper 128 may comprise a vacuum device 130 capable of being regulated to selectively remove aggregate material. In the embodiment of FIG. 13, the sweeper 128 may include a controller capable of cooperating with the moving hearth 30 to regulate the selective removal of material. The controller may identify when the sweeper 128 is operatively positioned near a selected portion of the hearth.

[0083] The moving hearth 30 may form an approximately continuous surface, as illustrated in FIG. 14, containing various hearth materials. At the end of the hearth furnace process, sections or segments of the moving hearth 30 may separate from one another as the moving hearth changes direction or spaces apart for other reasons. The sweeper 128 may be used to remove aggregate material from the front edge 52 and rear edge 54 of each passing moving hearth section, as illustrated in FIG. 15, thereby preventing material from falling off the ends when sections of the moving hearth are subsequently separate.
To remove material from the front and rear portions of the moving hearth sections, the vacuum device 130 may activate when the front and rear portions of the moving hearth sections pass the vacuum device 130. The controller may cooperate with the moving hearth to identify when the vacuum device 130 is operatively positioned over the front and rear edges 52, 54 before selectively activating the vacuum device 130. The moving hearth sections may comprise physical features, such as but not limited to protrusions or cams that activate the controller. The controller and moving hearth may comprise controlling devices such as, but not limited to, limit switches, electric eyes, proximity switches or other suitable devices to selectively activate the sweeper 128. If desired, the sweeper 128 may remain activated continuously for removing a large portion of the material from the moving hearth 30.

The vacuum device 130 may discharge the removed material into a collector system 132. The sweeper system 44 may further comprise a sweeper system conveyor 134, where the conveyor 134 moves the material away from the collector system 132.

Multiple vacuum devices 130 may be used to remove the materials from the moving hearth 30. Two or more vacuum devices 130 are positioned over the moving hearth 30 in a staggered arrangement. In the two-vacuum embodiment shown in FIG. 13, the first vacuum device may be positioned over the left edge of the moving hearth 30, and the second vacuum device positioned over the right edge of the moving hearth. The multiple sweepers 128 may be positioned in a staggered arrangement such that the second sweeper is downstream of the first to accommodate the physical structure of the devices. In alternate embodiments, the vacuum devices 130 may feed into two or more collectors 132. It is contemplated that some embodiments may utilize a plurality of vacuum devices 130, arranged in various staggered arrangements and orientations to accomplish removal of material from the width of the moving hearth 30.

The sweeper 128 may connected to a heat exchanger or cooler for cooling the air in the sweeper system 44. It is contemplated that the air may be at an elevated temperature after it passes over the moving hearth. A heat exchanger may be used to reduce the air temperature to approximately 150 °F (approximately 66 °C) or below.

The sweeper system conveyor 134 may convey the removed material through a cooling system to further reduce the temperature of the removed material. The spray cooling system 38 may dispense a spray of water over the removed aggregate so as to evaporate and cool the removed aggregate without substantial water run off. Optionally, additional cooling may be provided by the conveyor 134, such as by using a screw conveyor having a cooled screw, such as, but not limited to, a Therma-Flite® screw. It is contemplated that the sweeper
system conveyor 134 and the aggregate conveyor 120 from the plow system 42 may convey material through the same cooling system. It is further contemplated that the sweeper system conveyor 134 and the aggregate conveyor 120 may be combined into one conveyor or material handling system, or alternately feed into the same material handling systems.

[0103] While the invention has been described with detailed reference to one or more embodiments, the disclosure is to be considered as illustrative and not restrictive. Modifications and alterations will occur to those skilled in the art upon a reading and understanding of this specification. It is intended to include all such modifications and alterations in so far as they come within the scope of the claims, or the equivalence thereof.
What is claimed is:

1. A method of removing metallic iron and associated materials from a moving hearth comprising the steps of:
   a. providing a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
   b. cooling the aggregate on the moving hearth in a cooling zone by secondary cooling;
   c. spraying water over the aggregate on the moving hearth so as to evaporate and cool the aggregate on the moving hearth without substantial water runoff to a temperature in the adjacent atmosphere at or below about 800 °F;
   d. causing the moving hearth supporting aggregate to move beneath a moving belt positioned between the moving hearth and a magnetic device; and
   e. removing magnetic material from the moving hearth by using the magnetic device to remove magnetic material from the aggregate.

2. The method according to claim 1, where the step of cooling the aggregate by secondary cooling comprises the step of:
   providing coolant tubes in a serpentine configuration adjacent the moving hearth, the coolant tubes being capable of circulating coolant therethrough to remove heat from the aggregate on the moving hearth.

3. The method according to claim 1, where the step of cooling the aggregate by secondary cooling comprises the step of:
   providing a plurality of coolant tubes capable of cooling the aggregate on the moving hearth to a temperature of the adjacent atmosphere at or below about 1200 °F.

4. The method according to claim 1, where the step of removing magnetic material from the moving hearth comprises the step of:
   moving such removed magnetic material traverse or along the direction of travel of the moving hearth.

5. The method according to claim 4, the step of moving such removed magnetic material traverse or along the direction of travel of the moving hearth being performed at a
velocity in a range of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

6. The method according to claim 5, further comprising the step of:
causing the removed magnetic removed material to be impacted against a surface to
separate metallic iron material from slag and other associated material.

7. A method of removing metallic iron and associated materials from a moving hearth
comprising the steps of:
a. providing a moving hearth supporting aggregate comprising metallic iron
material, slag, and carbon-bearing material;
b. cooling the aggregate on the moving hearth in a cooling zone by secondary
cooling;
c. causing the moving hearth supporting aggregate to move beneath a moving
belt positioned between the moving hearth and a magnetic device;
d. removing magnetic material from the moving hearth by using the magnetic
device to remove magnetic material from the aggregate; and
e. then moving the moving hearth with aggregate thereon beneath a plow capable
of selectively removing from the hearth a regulated amount of aggregate while
leaving other aggregate on the moving hearth if desired.

8. The method according to claim 7, further comprising the step of:
spraying water over the aggregate on the moving hearth to cool the aggregate by
evaporation without substantial water run off to a temperature of the adjacent
atmosphere at or below about 800 °F;

9. The method according to claim 7, where the step of cooling the aggregate by
secondary cooling comprises the step of:
providing coolant tubes in a serpentine configuration adjacent the moving hearth, the
coolant tubes being capable of circulating coolant therethrough and removing
heat from the aggregate on the moving hearth.

10. The method according to claim 7, where the step of cooling the aggregate by
secondary cooling comprises the step of:
providing a plurality of coolant tubes capable of circulating coolant to cast the aggregate on the moving hearth to a temperature in the adjacent atmosphere at or below about 1200 °F.

11. The method according to claim 7, where the step of removing magnetic material from the moving hearth comprises the step of: moving such removed magnetic material traverse or along the direction of travel of the moving hearth.

12. The method according to claim 11, where the step of moving such removed magnetic material traverse or along the direction of travel of the moving hearth is performed at a velocity in a range of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

13. The method according to claim 11, further comprising the step of: causing the removed magnetic removed material to be impacted against a surface to separate metallic iron material from slag and other associated material.

14. The method according to claim 7, where the step of moving the moving hearth beneath a plow comprises the steps of: removing aggregate from the moving hearth over a plow edge and adjacent inclined surface as the hearth moves beneath the plow; positioning a brush adjacent to the inclined surface capable of moving aggregate along the surface of the plow; and brushing the removed aggregate to a conveying device to remove the removed aggregate.

15. The method according to claim 14, further comprising the steps of: positioning at an edge of the inclined surface a classifier for segregating the removed aggregate according to size; and returning classified particles smaller than a selected size to the moving hearth.

16. A method of removing metallic iron and associated materials from a moving hearth comprising the steps of:
a. providing a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;

b. cooling the aggregate on the moving hearth in a cooling zone by secondary cooling;

c. spraying water over the aggregate on the moving hearth so as to evaporate and cool the aggregate on the moving hearth by evaporation without substantial water run off to a temperature at or below about 800 °F;

d. causing the moving hearth supporting aggregate to move beneath a moving belt positioned between the moving hearth and a magnetic device;

e. removing magnetic material from the moving hearth by using the magnetic device to remove magnetic material from the aggregate;

f. then moving the moving hearth with aggregate thereon beneath a plow capable of selectively removing from the hearth a regulated amount of aggregate while leaving other aggregate on the moving hearth if desired; and

g. moving the hearth beneath a sweeper capable of selective removal of a regulated amount of aggregate from the moving hearth, and causing the sweeper to remove at least selected aggregate from the hearth.

17. The method according to claim 16, where the step of cooling the aggregate by secondary cooling comprises the step of:

providing coolant tubes in a serpentine configuration adjacent the aggregate on the moving hearth, the coolant tubes being capable of circulating coolant therethrough to remove heat from the aggregate on the moving hearth.

18. The method according to claim 16, where the step of cooling the aggregate by secondary cooling comprises the step of:

providing a plurality of coolant tubes capable of cooling the aggregate on the moving hearth to a temperature in the adjacent atmosphere at or below about 1200 °F.

19. The method according to claim 16, where the step of removing magnetic material from the moving hearth comprises the step of:

moving such removed magnetic material traverse or along the direction of travel of the moving hearth.
20. The method according to claim 19, where the step of moving such removed magnetic material traverse or along the direction of travel of the moving hearth is performed at a velocity in a range of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

21. The method according to claim 20, further comprising the step of: causing the removed magnetic material to be impacted against a surface to separate metallic iron material from slag and other associated material.

22. The method according to claim 16, where the step of moving the moving hearth beneath a plow comprises the steps of: removing aggregate from the moving hearth over a plow edge and adjacent inclined surface as the hearth moves beneath the plow; positioning a brush adjacent to the inclined surface capable of moving aggregate along the surface of the plow; and brushing the removed aggregate to a conveying device to remove the removed aggregate.

23. The method according to claim 22, further comprising the steps of: positioning at an edge of the inclined surface a classifier for segregating the removed aggregate according to size; and returning classified particles smaller than a selected size to the moving hearth.

24. The method according to claim 16, where the step of causing the sweeper to remove at least selected aggregate comprises the step of: removing aggregate from the moving hearth using a vacuum device.

25. The method according to claim 16, where the step of causing the sweeper to remove at least selected aggregate comprises the step of: intermittently removing material from the hearth.

26. A method of removing metallic iron and associated materials from a moving hearth comprising the steps of:
a. providing a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
b. causing the moving hearth supporting aggregate to move beneath a moving belt positioned between the moving hearth and a magnetic device;
c. removing magnetic material from the moving hearth by using the magnetic device to remove magnetic material from the aggregate;
d. then moving the moving hearth with aggregate thereon beneath a plow capable of selectively removing from the hearth a regulated amount of aggregate while leaving other aggregate on the moving hearth if desired; and
e. moving the hearth beneath a sweeper capable of selective removal of a regulated amount of aggregate from the moving hearth, and causing the sweeper to remove at least selected aggregate from the hearth.

27. The method according to claim 26, further comprising the steps of:
prior to the step of moving the aggregate beneath the moving belt, cooling the aggregate on the moving hearth in a cooling zone by secondary cooling.

28. The method according to claim 27, where the step of cooling the aggregate by secondary cooling comprises the step of:
providing coolant tubes in a serpentine configuration adjacent the aggregate on the moving hearth, the coolant tubes being capable of removing heat from the aggregate on the moving hearth.

29. The method according to claim 27, where the step of cooling the aggregate by secondary cooling comprises the step of:
providing a plurality of coolant tubes capable of circulating coolant therethrough to cool the aggregate on the moving hearth to a temperature of an adjacent atmosphere at or below about 1200 °F.

30. The method according to claim 26, further comprising the step of:
spraying water over the aggregate on the moving hearth to cool the aggregate on the moving hearth by evaporation without substantial water run off to a temperature in the adjacent atmosphere at or below about 800 °F.
31. The method according to claim 26, where the step of removing magnetic material from the moving hearth comprises:
moving such removed magnetic material traverse or along the direction of travel of the moving hearth.

32. The method according to claim 31, where the step of moving such removed magnetic material traverse or along the direction of travel of the moving hearth is performed at a velocity in a range of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

33. The method according to claim 32, further comprising the step of:
causing the removed magnetic removed material to be impacted against a surface to separate metallic iron material from slag and other associated material.

34. The method according to claim 26, where the step of moving the moving hearth beneath a plow comprises the steps of:
removing aggregate from the moving hearth over a plow edge and adjacent inclined surface as the hearth moves beneath the plow;
positioning a brush adjacent to the inclined surface and capable of moving aggregate along the surface of the plow; and
brushing the removed aggregate to a conveying device to remove the removed aggregate.

35. The method according to claim 34, further comprising the steps of:
positioning at an edge of the inclined surface a classifier for segregating the removed aggregate according to size; and
returning classified particles smaller than a selected size to the moving hearth.

36. The method according to claim 26, where the step of causing the sweeper to remove at least selected aggregate comprises the step of:
removing aggregate from the moving hearth using a vacuum device.

37. The method according to claim 26, where the sweeper is capable of intermittently removing material from the hearth.
38. A method of removing metallic iron and associated materials from a moving hearth comprising the steps of:
   a. providing a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
   b. causing the moving hearth to move beneath a drum positioned transverse to the aggregate on the moving hearth and supporting a belt moving in a continuous loop capable of moving magnetic material counter to the direction of travel of the moving hearth, with a magnetic device being positioned within the drum; and
   c. removing magnetic material from the aggregate, and moving the removed magnetic material for separate processing.

39. The method according to claim 38, further comprising:
   causing a coolant flow through a cooling jacket within the drum.

40. A system for removing metallic iron and associated materials from a moving hearth comprising:
   a. a moving hearth capable of supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
   b. a cooling zone capable of cooling the aggregate on the moving hearth by secondary cooling;
   c. a spray of water capable of cooling the aggregate on the moving hearth to a temperature in the adjacent atmosphere at or below about 800 °F by evaporation without substantial water run off; and
   d. a moving belt positioned between a magnetic device and the moving hearth, the magnetic device being capable of removing magnetic material from the aggregate, and the moving belt being capable of moving the removed magnetic material transverse or along the direction of travel of the moving hearth for separate processing.

41. The system according to claim 40, the secondary cooling comprising:
coolant tubes in a serpentine configuration adjacent the moving hearth, the coolant tubes being capable of circulating coolant therethrough to remove heat from the aggregate on the moving hearth.

42. The system according to claim 40, the secondary cooling comprising: a plurality of coolant tubes capable of circulating coolant therethrough to cool the aggregate on the moving hearth to a temperature in the adjacent atmosphere at or below about 1200 °F.

43. The system according to claim 40, where the velocity of the moving belt is in a range of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

44. The system according to claim 43, where the moving belt is capable of impacting the removed magnetic material against a surface to separate metallic iron material from slag and other associated material in a direction transverse to the travel of the moving hearth.

45. A system for removing iron from a moving hearth comprising:
   a. a moving hearth comprising a plurality of sections capable of supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
   b. a moving belt positioned between a magnetic device and the moving hearth, the magnetic device being capable of removing magnetic material from the aggregate, and the moving belt being capable of moving the removed magnetic material traverse or along the direction of travel of the moving hearth for separate processing; and
   c. a plow capable of selective removal from the moving hearth a regulated amount of aggregate while leaving other aggregate on the moving hearth if desired.

46. The system according to claim 45, further comprising:
   a sweeper capable of selective removal of a regulated amount of aggregate from the moving hearth when the hearth moves beneath the sweeper.
47. The system according to claim 45, further comprising:
a cooling zone capable of cooling the aggregate by secondary cooling.

48. The system according to claim 47, the secondary cooling comprising:
coolant tubes in a serpentine configuration adjacent the moving hearth, the coolant
tubes being capable of circulating coolant therethrough to remove heat from
the aggregate on the moving hearth

49. The system according to claim 47, the secondary cooling comprising:
a plurality of coolant tubes capable of circulating coolant therethrough to cool the
aggregate on the moving hearth to a temperature of the adjacent atmosphere at
or below about 1200 °F.

50. The system according to claim 45, further comprising:
a spray of water capable of cooling the aggregate on the moving hearth to a
temperature in the adjacent atmosphere at or below about 800 °F by
evaporation without substantial water run off.

51. The system according to claim 45, where the velocity of the moving belt is in a range
of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

52. The system according to claim 51, where the moving belt is capable of impacting the
removed magnetic material against a surface to separate metallic iron material from
slag and other associated material in a direction transverse to the travel of the moving
hearth.

53. The system according to claim 45, where the plow comprises:
a plow edge and an adjacent inclined surface positioned to remove aggregate from the
moving hearth when the hearth moves beneath the plow; and
a brush adjacent to the surface capable of moving aggregate along the surface of the
plow to a conveying device to remove the removed aggregate.

54. A system according to claim 53, further comprising:
a classifier capable of segregating the removed aggregate according to size positioned at an edge of the inclined surface and positioned such that classified particles smaller than a selected size return to the moving hearth.

55. A system according to claim 46, where the sweeper comprises a vacuum device capable of removing aggregate from the moving hearth.

56. A system according to claim 46, where the sweeper is capable of removing material from front and rear portions of the moving hearth sections.

57. A system for removing metallic iron and associated materials from a moving hearth comprising:
   a. a moving hearth capable of supporting aggregate comprising metallic iron material, slag, and carbon-bearing material; and
   b. a moving belt positioned between a magnetic device and the moving hearth, with the magnetic device being capable of removing magnetic material from the aggregate; and
   c. a drum being positioned transverse to the aggregate on the moving hearth and supporting the belt moving in a continuous loop capable of moving magnetic material counter to the direction of travel of the moving hearth, the magnetic device being positioned within the drum.

58. The system according to claim 57, where the drum further comprises a cooling jacket capable of receiving a flow of coolant.

59. A system for removing metallic iron and associated materials from a moving hearth comprising:
   a. a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material;
   b. a moving belt positioned between a magnetic device and the moving hearth, the moving belt being positioned transverse or along the direction of travel of the hearth, the magnetic device being capable of removing magnetic material from the aggregate and the moving belt being capable of moving the removed
magnetic material transverse or along the direction of travel of the moving hearth; and

c. a collector positioned to receive removed magnetic material from the moving belt.

60. The system according to claim 59, where the velocity of the moving belt is in a range of about 100 to about 400 feet per minute (about 30 to about 120 meters per minute).

61. The system according to claim 59, further comprising:
   an impact plate adjacent to the moving belt, where the moving belt is capable of impacting the metallic iron material against the impact plate to separate metallic iron material from slag and other associated material.

62. A system of removing metallic iron and associated materials from a moving hearth comprising:
   a moving hearth supporting aggregate comprising metallic iron material, slag, and carbon-bearing material; and
   a plow capable of selective removal from the moving hearth of a regulated amount of aggregate while leaving other aggregate on the moving hearth if desired when the hearth moves beneath the plow.

63. The system according to claim 62, where the plow comprises:
   a plow edge and an adjacent inclined surface positioned to remove aggregate from the moving hearth when the hearth moves beneath the plow; and
   a brush adjacent to the surface capable of moving aggregate along the surface of the plow to a conveying device to remove the removed aggregate.

64. The system according to claim 63, comprising a classifier capable of segregating the removed aggregate according to size positioned at an edge of the inclined surface and positioned such that classified particles smaller than a selected size return to the moving hearth.

65. The system according to claim 63, where the distance between the plow edge and the moving hearth is adjustable.
66. The system according to claim 63, where the brush is a rotary brush positioned above the surface.

67. A system of removing aggregate from a moving hearth comprising:
   a moving hearth comprising a plurality of sections capable of supporting aggregate comprising metallic iron material, slag, and carbon-bearing material; and
   a sweeper capable of selective removal of a regulated amount of aggregate from the moving hearth when the hearth moves beneath the sweeper.

68. A system according to claim 67, where the sweeper comprises a vacuum device capable of pulling aggregate from the moving hearth.

69. A system according to claim 67, where the sweeper removes at least selected aggregate from the moving hearth.

70. A system according to claim 67, where the sweeper removes at least selected aggregate from the front and rear portions of the moving hearth sections.