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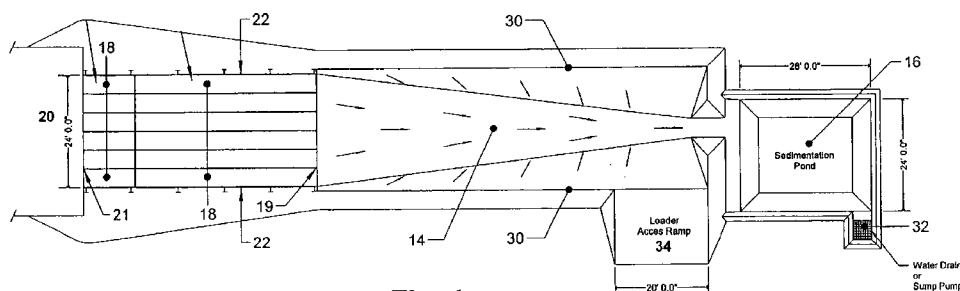


Fig. 1

(57) Abstract: An apparatus (10) and method for separating metal rich slag and metal poor slag are provided. A slag pot (20) is allowed to partially cool, agglomerating the metal in the pot. A portion of the partially cooled slag is poured down a first ramp (26), providing a metal poor slag. Optionally this slag is cooled with water. The remaining slag in the slag pot is poured down a subsequent ramp (30), resulting in a metal rich slag. Optionally, the latter step is repeated with any slag remaining in the slag pot (20).



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METHOD OF HANDLING, CONDITIONING AND PROCESSING STEEL SLAGS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of co-pending provisional patent application Serial No. 60/833,680 entitled "Method of Handling, Conditioning, and Processing Steel Slags," filed on July 27, 2006, the entire disclosure of which is incorporated by reference herein.

FIELD OF THE INVENTION

The present invention is directed toward the handling of slag generated in the process of steel melting, from the EAF (Electric Arc Furnace), AOD (Argon-Oxygen Decarburization) or converters' tap-hole, the conditioning of the slag to recover as much entrenched metal as possible, and generating an aggregate usable for civil construction, road building, etc. More specifically, the present invention covers the tilting, the cooling, the crushing and sizing of the slag, and also the processing of the slag to recover the metal in the slag.

BACKGROUND OF THE INVENTION

Steel production generates a by-product called slag. This by-product is generally formed by the additives added during the steel melting process, such lime, flux, and others, and also by the impurities from the raw materials used to make the steel. A limited quantity of metal is also entrenched in the slag.

In molten slag, the metal is typically in the form of small droplets. During the cooling of the slag, and depending upon the method of cooling used, the metal droplets tend to agglomerate and form bigger pieces of metal. As the metal density of these pieces becomes higher than the density of the molten slag, the metal tends to sink to the bottom of the slag pot.

Usually the slag is removed from the furnace by drilling a tap hole into the furnace and allowing the molten slag to drain from the furnace into a slag pot placed in front of the furnace through the tap hole. Once the tapping operation is completed, the slag pot is removed from the melt-shop and carried either on railroad cars, slag-pot carriers or specially designed vehicles to a slag dumping station. Different techniques are used to remove the slag from the slag pot. In some cases, the slag pot is left to cool down a certain period of time (typically from a few hours to a few days), or put into "pool," or the molten slag may be dumped into bunkers or a slag pit. In this later approach of dumping the molten slag into a bunker or slag pit, the slag might be left to cool, once again from a few hours to a few days. Once cooled, the slag is typically removed by a front-end loader or excavator and hauled away for further processing.

The cooled slag is generally processed through different stages, such as being crushed, grinded and/or handpicked to recover the metal present in the slag. Handpicking the metal is a procedure generally utilized for the coarser slag. The finer slag is processed such that the recovery of small pieces of metal is possible.

Once again, different techniques exist to process the finer fraction of slag. Some techniques grind the slag very fine (*e.g.*, 100% minus 250 microns). This technique allows for recovery of more than 98% of the metal from the slag. The remaining aggregate is a fine powder and few applications are available to recycle it. Other techniques use either magnetic or density separation. This will maintain the physical properties of the slag but the rate of recovery is low, typically at 50% to 65% metal recovery.

There is a growing trend in the steel industry to produce from slag an aggregate which is harmless for both the environment and human-beings, and that can also be used for construction works and other applications. This would reduce the amount of slag stockpiled and also reduce the risk of further environmental problems.

BRIEF DESCRIPTION OF THE INVENTION

An apparatus and method for separating metal rich slag and metal poor slag are provided. A slag pot is allowed to partially cool, agglomerating the metal in the pot. A portion of the partially cooled slag is poured down a first ramp, providing a metal poor slag. Optionally, this slag is cooled with water. The remaining slag in the slag pot is poured down a subsequent ramp, resulting in the separation of a metal rich slag. Optionally, the latter step is repeated with any slag remaining in the slag pot.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a top view of part of an exemplary apparatus for quick quenching and separating liquid slag. In the present invention, two or more of these apparatuses would be in close proximity to the slag pot, allowing the contents of the slag pot to be poured down each apparatus in turn, creating increasingly metal-rich slags; and

Fig. 2 is a cross-sectional view of the apparatus shown in Fig. 1 taken along line A-A.

DESCRIPTION OF THE INVENTION

The present invention is based on tapping the slag from the furnace into a slag pot. The slag pot is hauled to a dumping station. The slag must be liquid and kept hot (*i.e.*, molten) and the viscosity of the slag should be between determined parameters, as will be discussed hereafter. Additives, such as borax, etc., can be added to the slag pot to increase the heat and the viscosity of the slag. The time between the tapping of the slag from the furnace and transporting the molten slag to the dumping station is typically less than an hour, but a minimum period of time is required to allow the metal droplets to agglomerate and sink. During that time period, the metal droplets present in the slag will have time to sink to the

bottom of the slag pot, therefore agglomerating and creating bigger pieces of metal which will help in the metal removal process.

The slag pot is then presented to the dumping station. The dumping station should house at least two or more ramps, which may each be as shown in Figure 1 and described herein. At the end of each ramp, a horizontal elevated platform allows the vehicle with the slag pot to position itself for tilting. The elevated platform may be, for example 15-18 feet high. However, other heights are contemplated, as discussed below. The platforms may be of different heights. The slag pot will be tilted at the end of the platform onto a cooling bed consisting of a ramp having a predetermined angle of inclination (*i.e.*, slope). The ramp may be oriented at one continuous angle, or may be arranged such that it has various different angles as the ramp extends from the elevated platform to its end. Typically, the more molten the liquid slag is, the less of an angle the ramp should have to prevent the liquid slag from running down ramp too quickly. Thus, depending on the angle of the ramp, the viscosity of the molten slag should be adjusted so that there is sufficient time for it to cool and harden before reaching the end of the ramp.

The ramp will also have a minimum length to allow the slag to run down the ramp and cool before reaching the end. One length contemplated is 50 feet, but other lengths may be used and will generally depend on the viscosity and amount of liquid slag being cooled as well as the angle of the ramp. The viscosity of the slag should be such that it will cool before reaching the end of the ramp. The ramp should consist of steel plates with a specified thickness to avoid deformation caused by the high temperature of the liquid slag.

Spraying bars located on both sides of the ramp will spray water onto the liquid slag as it is dumped onto the ramp. The water helps to cool the slag as it runs down the ramp. Applying the quantity of water for a limited period of time is crucial to modify the physical characteristics expected (*i.e.*, turn the liquid slag into a crystalline form) and the quality of the

slag. In one form of the invention, it has been determined that it takes approximately 8 minutes for the liquid slag to cool and turn into a crystalline form as it is being quenched with water. During this 8 minute period, water is constantly applied to the liquid slag. However, other application periods are contemplated. For example, water may be applied for less than 8 minutes, for 4 minutes, 5 minutes, 6 minutes, 7 minutes, 9 minutes, 10 minutes, or greater than 10 minutes.

In accordance with the present invention, the tilting of the slag pot carrier is controlled. In one embodiment, a maximum of 75% to 80% of the slag will be tilted (*i.e.*, dumped onto the ramp) in the first step. The amount of slag tilted during the first step may be, for example, but is not limited to, between 70% and 85%, between 65% and 90%, or between 70% and 80%. The remaining slag (or an amount of the remaining slag, if more than two ramps are to be used) is tilted onto a separate ramp bunker located beside the first ramp. This second tilting may be processed in the same way as previously described for the first tilting, namely, applying water to the slag as it runs down the ramp to cool the slag and turn it into a crystalline form.

The second tilting typically accounts for 20% to 25% of the slag and will generally include 85% to 95% of the metal in the slag (again, other percentages are contemplated, and where two ramps are used the amount of slag in the second tilting will account for the balance of the molten slag left following the first tilting). Thus, the metal content in the first tilting should consist of between 5% to 15% of the metal in the slag. One skilled in the art will readily understand that the metal content percentages will vary depending upon the amount of metal that agglomerates and sinks to the bottom of the slag pot. Thus, the slag pot must be given a sufficient minimum period of time to allow the majority of the metal present to agglomerate and sink to the bottom of the slag pot. The present invention contemplates, however, that the first tilting will have a decisively lower metal content than the second tilting.

The slag tilt in the first instance, which is referred to herein as the "metal poor slag," is removed immediately after tilting/cooling and stockpiled. In a preferred embodiment, the metal poor slag is dumped in a building or under a roof.

The quenched slag is a porous, light greenish colored aggregate. For slag containing chrome (such as stainless steel slag), by shortening the cooling phase the process reduces the phase chrome hexavalent formation and therefore reduces environmental problems involved with processing stainless steel slag in particular.

The metal poor slag is later processed in a crushing-screening plant and reduced to a desired particle size of approximately 0-20 mm or 0-32 mm, or other sizes, according to various market requirements. The metal poor slag is first screened to remove the larger pieces of metal. During the crushing and sizing phase, a high-intensity magnet recovers free metallic particles in the slag and also mixed particles (pieces of metal with slag attached). This operation further reduces the metal content in the metal poor slag.

The slag tilt in the second instance is referred to herein as the "metal rich slag." After cooling, the metal rich slag is removed from the dumping area and may be processed through a wet-dressing plant. The wet-dressing plant generally consists of grinders, such as rod mills and ball mills, screw classifiers and high intensity magnet(s). The metal rich slag is typically ground to a size that is minus 1 mm. At the end of the process, a metallic concentrate is generated, usually in the fraction of 0 to 6 mm. This concentrate is typically between 93% and 96% metallic, though it may vary depending on the initial metal content of the slag. Additionally, the mixed particles recovered during the crushing and screening of the metal poor slag are also processed through the wet-dressing plant to increase the rate of recovery of the metal in the slag.

The final aggregate produced by the above-described process typically is 100% minus 250 microns in size and contains less than 0.020% of metal. As a result of the low metal content, the aggregate is generally environmentally safe.

It should be noted that although the handling of steel slag is described in various embodiments reported herein, the handling of other molten metal slags may also benefit from the processes and apparatuses reported herein.

Those skilled in the art will recognize that the operation of the slag pot may be controlled by computer, which may allocate slag dumps according to factors including the weight of the slag pot, calculation of slag density and composition, and the like.

A third aspect of the present invention is the contribution to a better environment. The metal poor slag which represents a large portion of the total slag generated by the mill can be marketed as aggregate for civil construction applications, and because of its special characteristics, such as porosity and stability, it is a perfect material for insulation, drainage material, and the like. The processed slag aggregate can be used as is or with a binding agent, such as cement, bituminous cement or various other kinds of binder.

The fine fraction of the processed slag can be utilized in many different applications, such as, but not limited to, as engineering material, light artificial aggregate, in the production of concrete bricks, pavers, pre-manufactured concrete pieces or structures, and so on.

One ramp apparatus that may be used in embodiments of the invention is described hereafter. It should be understood that multiple ramps should be present, to allow the metal rich slag and metal poor slag to be separated. If only two ramps are present, multiple slag pots may be emptied on each ramp before the slag is removed; this would allow all of the metal-rich slag from multiple slag pots to be accumulated on a single ramp, and all of the metal poor slag from those pots to be accumulated on another ramp. It should further be

understood that ranges and parameters given in the description of the ramps are exemplary and should be construed as alternatives to other ranges and parameters in this application.

Referring to Figs. 1-2, an exemplary apparatus for quick quenching liquid, or molten, slag is illustrated, shown generally at 10. The apparatus 10 generally includes a bay area 12 and a trough area 14. The liquid slag is cooled in the bay area 12 by the application of water under pressure, such that the cooled slag remains in the bay area 12. The trough area 14 receives the water running from the bay area 12 and directs it to a sedimentation pond 16, where the water can be recycled for further quenching or other applications.

The bay area 12 generally includes a plurality of steel slabs 18 which are installed side by side to form a flat surface. Liquid slag (not shown) is poured onto the steel slabs 18 for cooling, and thus the steel slabs 18 need to be able to withstand the high temperature of the liquid slag. The steel slabs 18 are oriented generally at an angle, with the low end 19 adjacent the trough area 14, such that the liquid slag and the water applied to the liquid slag run down the steel slabs 18 toward the trough area 14. In the exemplary form of Figs. 1 and 2, the bay area 12 is approximately 50 feet long and the trough area 14 is approximately 80 feet long. However, other lengths for these areas are contemplated.

A dumping platform 20 is provided at the high end 21 of the steel slabs 18. The dumping platform 20 is typically made of concrete, and may be approximately 4-10 feet high. However, other heights are contemplated. Liquid slag (not shown) is transported to the dumping platform 20 via trucks, slag pot carriers or other appropriate vehicles and poured onto the steel slabs 18 of the bay area 12. The poured liquid slag will spread out across the steel slabs 18 and run down toward the trough area 14 due to the angle of inclination of the steel slabs 18. To prevent the liquid slag from running off of the sides of the steel slabs 18, vertically oriented steel plates 22 are provided on opposite sides of the surface formed by the steel slabs 18. In the exemplary form of Figs. 1 and 2, the steel slabs 18 have a width of

approximately 24 feet across, which is typically sufficient to accommodate the poured liquid slag without resulting in excess slag at the edges. However, other widths for the steel slabs 18 are contemplated.

In one form, the steel slabs 18 have two different angles of inclination extending from the dumping platform 20 to the trough area 14. A first area, shown generally at 24, is adjacent the dumping platform 20 and includes a first angle of inclination, while a second area, shown generally at 26, extends to the trough area 14 and includes a second angle of inclination. As shown in Fig. 2, the first angle of inclination of the first area 24 is greater than the second angle of inclination of the second area 26. In this manner, liquid slag poured onto the steel slabs 18 is poured from the dumping platform 20 onto the first area 24. The liquid slag will begin to run toward the trough area 14 and spread generally evenly and thinly across the steel slabs 18. Once the liquid slag hits the second area 26, which is oriented at less of an angle, it will tend to run slower. The angle(s) of inclination of the steel slabs 18 should be chosen so that the liquid slag will stop running down the steel slabs 18 before it reaches the trough area 14. This aids in removing the slag since all of the cooled and crystalline slag will remain on the bay area 12, and also helps alleviate a hazardous condition since if the liquid slag would trap any water remaining in the trough area an explosion may occur.

In one embodiment, as shown Fig. 2, the angle of inclination of the first area 24 is approximately 17°, while the angle of inclination of the second area 26 is approximately 5°. However, these angles are for illustrative purposes only, and other angles of inclination are contemplated without departing from the spirit and scope of the present invention. For example, the steel slabs 18 may be oriented at one continuous angle, or may be arranged such that they have various different angles as they extend from the dumping platform 20 to the trough area 14. In one exemplary form of the present invention, the angle of inclination of the steel slabs 18 will tend to decrease as one moves away from the dumping platform 20 toward

the trough area 14. However, any configuration of angles of inclination of the steel slabs 18 may be implemented without departing from the spirit and scope of the present invention.

The only requirement is that the liquid slag spread out across the steel slabs 18 (a thin layer of liquid slag will cool more quickly) and run down toward the trough area 14, stopping before reaching the trough area 14. The angle(s) of inclination of the steel slabs 18 (*i.e.*, bay area 12) will depend on various factors, such as, but not limited to, the temperature and viscosity of the slag, as well as the amount of slag being quenched. Generally, a higher temperature slag will be more viscous than a lower temperature slag. Typically, the more molten (*i.e.*, more viscous) the liquid slag is the less of an angle the steel slabs 18 should have to prevent the liquid slag from running down the steel slabs 18 too quickly and possibly running off of the steel slabs 18 and into the trough area 14. The goal is to have the slag spread evenly and thinly across the steel slabs 18 and stop before reaching the end of the steel slabs 18. The steel slabs 18 (*i.e.*, bay area 12) should be made long enough so that the liquid slag stops running down the steel slabs 18 before reaching the trough area 14. As shown in Fig. 2, in one form, the bay area 12 is approximately 50 feet long. However, others lengths are contemplated and generally will depend on the temperature, viscosity and amount of liquid slag being cooled.

Once the liquid slag is poured onto the bay area 12 and spreads out across the surface formed by the steel slabs 18, it is hit with low pressure cold water via a water supply system 28. The water cools the liquid slag almost instantly (a thin layer of liquid slag will cool quicker than a thicker layer). As the liquid slag is quickly cooled, or quenched, using the low pressure water, it turns into a crystalline, or glass-like, form. Since the cooled, crystalline slag should be present on the steel slabs 18 on the bay area 12, it can be easily removed using a front-end loader or other similar vehicle.

As the slag hardens and turns into a granulate form, some dust may be generated. The water being applied to the liquid slag helps to eliminate dust from being transported into the air. Additionally, the spray bars and nozzles, which make up the water supply system 28, may be designed to contain the steam generated as the slag cools within the quenching area. For example, the spray nozzles used may apply a cone-like spray of water onto the liquid slag. Typically, the spray bars and nozzles will be positioned to spray water over the entire surface of the steel slabs 18, and thus over all of the liquid slag being cooled. The spray forms an umbrella over the slag trapping any steam generated. This trapped steam will cool and turn back into water. As a result, approximately 25-30% less steam may be generated in cooling the liquid slag. However, the spray bars and nozzles may also be configured such that no steam is contained during the quenching process. Additionally, the nozzles can be installed along each side of the steel slabs 18 spraying water toward the liquid slag.

Typically, the water applied to the liquid slag will be uniform in pressure and application. The present invention contemplates utilizing a low pressure water system (*e.g.*, between approximately 10-30 psi) to apply a high volume of water (*e.g.*, between approximately 800-2000 gallons/minute) in order to appropriately quench the liquid slag. The amount of water needed to thoroughly cool the liquid slag will depend on a number of factors, such as, but not limited to, the temperature, viscosity and amount of liquid slag being cooled (typically the temperature of the slag will decrease from the time it is tapped until the time it is brought to the platform to be quenched), the angle of the steel slabs 18, the thickness of the liquid slag as it runs down the steel slabs 18, the temperature of the water (the water used to cool the slag may become warmer if the water is being recycled for use), melt shop practices which may affect the viscosity of the slag, etc.

In order to determine the appropriate amount of water to use to cool the liquid slag, it is contemplated to first perform a "test run" of sorts and cool a batch of liquid slag applying

water at a rate of approximately 1200 gallons/minute for 10 minutes. The slag is then checked to determine if it has cooled all the way through and adjustments can be made to the amount of water applied and also to the angle of the steel slabs to determine optimum parameters for cooling the liquid slag. If the bottom of the slag next to the steel slabs 18 does not cool and turn crystalline, it will generally turn into a powdery form which is undesirable.

As the liquid slag cools and turns into a granulate form, the water which is applied to the liquid slag continues to run down the steel slabs 18 and is received at the trough area 14. Berms 30 are formed on either side of the trough area 14 and channel the water as it flows down the trough area 14 (*see* Fig. 1). The berms 30 may be formed of any material and, in one form, are formed of slag or fine aggregate or other similar material. The trough area may be virtually any length and, in one form as shown in Fig. 2, is 80 feet in length.

The sedimentation pond 16 is provided at an end of the trough area 14 and receives the water flowing down the trough area 14. A water drain or a sump pump 32 is provided which drains or pumps the water from the sedimentation pond 16, and may direct the water to an area where it can be recycled for further quenching or other applications. Typically, the drain/pump 32 will include a cover to prevent large debris from entering the drain/pump. It has been found that the water run off from the above-described quenching process is mostly clear and free of fine particles and, thus, the water may be recycled through a closed loop system and reused for further quenching with minimal mechanical and/or chemical treatment. The water from the quenched slag can also be directed to a unique pond or basin system where the water can be immediately pumped to the quenching spray bars. Depending on the frequency and volume of liquid slag that is being cooled down, a larger pond or basin system that overflows one after the other or a cooling tower can be used to help the water cool down before being re-used to help increase the effectiveness of the water.

After the liquid slag is cooled, it remains on the steel slabs 18. As previously mentioned, in order for the cooled slag to be easily removed, the length of the bay area 12 should be such that the slag stops moving before reaching the low end 19 of the bay area 12. A second batch of liquid slag may be poured on top of the already cooled slag, and quenched with low pressure cold water in the manner previously described. In this case, the duration of quenching will be set to ensure that enough heat remains in the slag and steel slabs 18 to burn off all remaining water and moisture before dumping another layer of liquid slag over the previous one. In one form, it is contemplated that the cooled slag and steel slabs 18 remain at a temperature of approximately 200-250 °F to burn off any excess water or moisture remaining before dumping an additional batch of slag on top for cooling. However, other temperatures may be utilized without departing from the spirit and scope of the present invention.

Cooling a number of batches of liquid slag on top of each other helps to reduce material handling costs, and a plurality of batches of liquid slag may be cooled on top of each other. Once a desired amount of slag has been cooled, it is removed from the steel slabs 18. A front-end loader, or other similar vehicle, accesses the trough area 14 via a loader access ramp 34. The front-end loader will drive up the trough area 14 and remove the cooled liquid slag from the steel slabs 18. The cooled liquid slag, which is in a granulated, or crystalline, form, may be used for a variety of purposes, including landfills, cementitious applications, or it may be further processed for other applications. In its crystalline form, the cooled slag generally has high cementitious and/or pozzolanic properties, making it particularly useful for cementitious applications.

As the water is sprayed onto the liquid slag, care is taken so that the water is applied with a uniform pressure and application. Thus, the spray bars and nozzles of the water supply system 28 should be design to uniformly spray the liquid slag with water at a constant

pressure and volume. Should water get under the hot liquid slag material, explosions may occur sending molten slag spraying into the air. Thus, care needs to be taken, and the spray bars and nozzles of the water supply system 28 designed, so that the low pressure water is applied uniformly over the liquid slag. While a preferred embodiment of the present invention contemplates spraying the liquid slag with a low pressure water, a high pressure water may also be used without departing from the spirit and scope of the present invention, as long as care is taken to not get water under the liquid slag. For example, the pressure of the water may be dictated by the specific nozzle design used.

It is imperative that the bay area 12 be totally clear of water, puddles of water and moisture before dumping the liquid slag thereon or an explosion may occur. Additionally, the trough area 14 should also be free of water or puddles of water in case the liquid slag runs off the bay area 12 and into the trough area 14.

The present invention has been described herein with reference to various ranges, which are exemplary only. One skilled in the art will understand that various modifications may be made to the inventive method and ranges without departing from the spirit and scope of the present invention.

I claim:

1. An apparatus for separating metal rich slag from metal poor slag, comprising:
at least two bay areas, each having an angled and generally flat surface provided between first and second ends, wherein the first end defines a high end and the second end defines a low end, such that liquid slag provided to a bay area adjacent to that bay area's first end will run down that bay area toward that bay area's second end; and

a water supply system provided for the bay areas, the water supply system applying water to the liquid slag on each bay area such that the liquid slag cools and turns into a crystalline form.

2. The apparatus of claim 1, further comprising a dumping platform provided adjacent the first end of the bay areas, wherein liquid slag is poured onto each bay area from the dumping platform.

3. The apparatus of claim 2, wherein said dumping platform is configured to receive a slag pot.

4. The apparatus of claim 3, wherein liquid slag is in said slag pot, and wherein said slag pot is configured to sequentially dump said liquid slag onto said bay areas.

5. The apparatus of claim 5, wherein said slag pot is configured to sequentially dump predetermined amounts of liquid slag into each of said bay areas.

6. The apparatus of claim 5, wherein there are two bay areas.

7. A method of separating liquid slag into fractions of metal rich slag and metal poor slag,, comprising the steps of:

providing at least two bay areas, each having an angled and generally flat surface provided between first and second ends, wherein the first end defines a high end and the second end defines a low end;

providing a slag pot containing liquid slag, wherein said liquid slag contains metal;

pouring an amount of liquid slag onto the bay area adjacent the first end of a first bay, such that the liquid slag spreads out across the bay area surface and runs down the first bay area toward the second end; and

applying water to the liquid slag on the first bay area such that the liquid slag cools and turns into a crystalline form, making a metal poor slag fraction;

pouring the remaining slag on the remaining bay areas adjacent to the first end of each of said remaining bay areas, such that the liquid slag spreads out across the bay area surface and runs down each bay area toward the second end of each remaining bay area; and

applying water to the liquid slag on the remaining bay areas such that the liquid slag cools and turns into a crystalline form, making one or more metal rich slag fractions.

8. The method of claim 7, wherein there are two bay areas.

9. The method of claim 8, wherein the first amount of slag poured to form the metal poor slag is between about 75% and 80% of the slag in the slag pot.

10. The method of claim 9, wherein the metal rich slag crystallized in the second bay comprises about 85% to about 95% of the metal initially present in the liquid slag.

11. The method of claim 7, further including the step of cooling said liquid slag prior to any pouring step.

12. The method of claim 11, wherein said cooling step lasts between about 5 minutes to about 30 minutes.

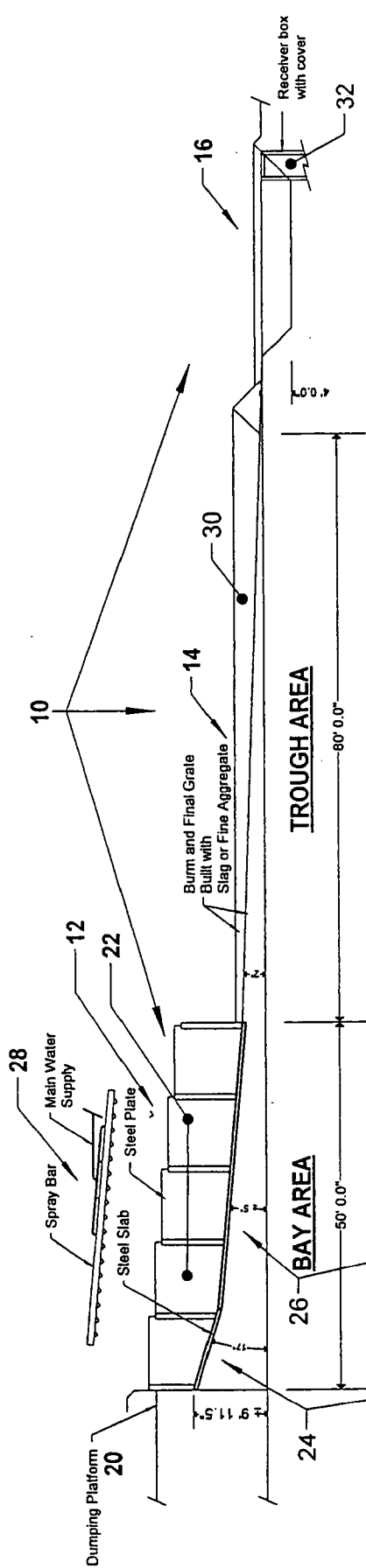


Fig. 2

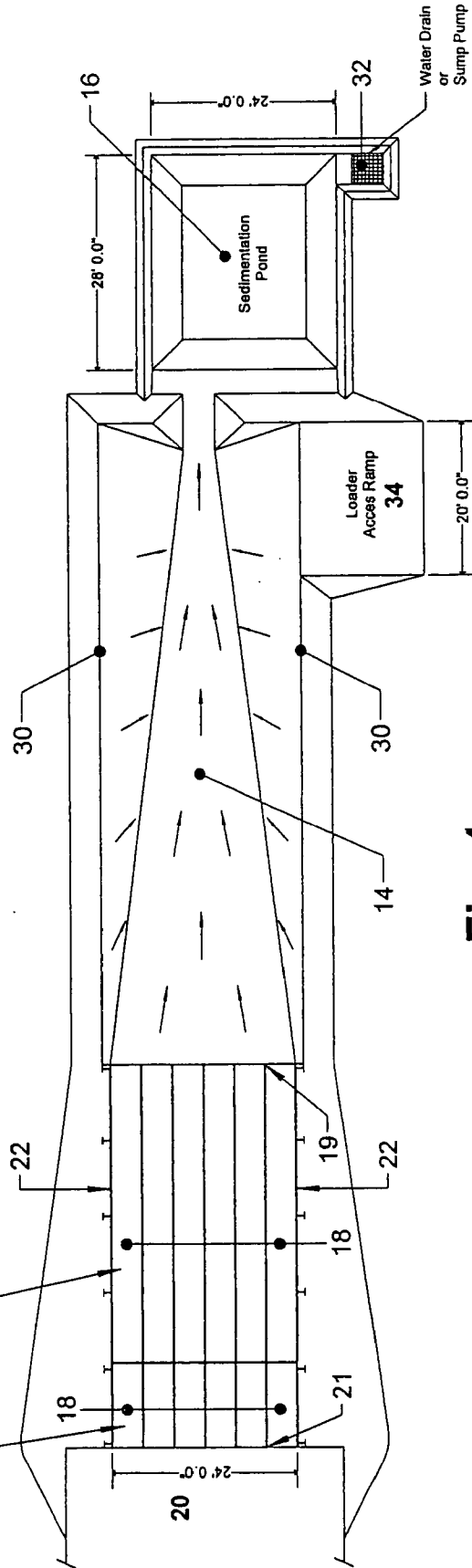


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US07/17001

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **C21B 3/04** (2006.01), **7/14** (2006.01)

USPC: 266/232

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 266/232

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2,223,569 A (LOHSE) 03 December 1940 (03.12.1940), figure 1.	1-12
A	US 4,212,666 A (KING et al) 15 July 1980 (15.07.1980), column 1 line 38 to column 2 line 48.	1-12
A	US 5,346,531 A (STREETS) 13 September 1994 (13.09.1994), figures 5 and 6.	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

15 May 2008 (15.05.2008)

Date of mailing of the international search report

12 JUN 2008

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