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(54) **Title:** ZINC PRECIPITATION SYSTEMS AND METHODS FOR THE EFFICIENT RECOVERY OF PRECIOUS METALS

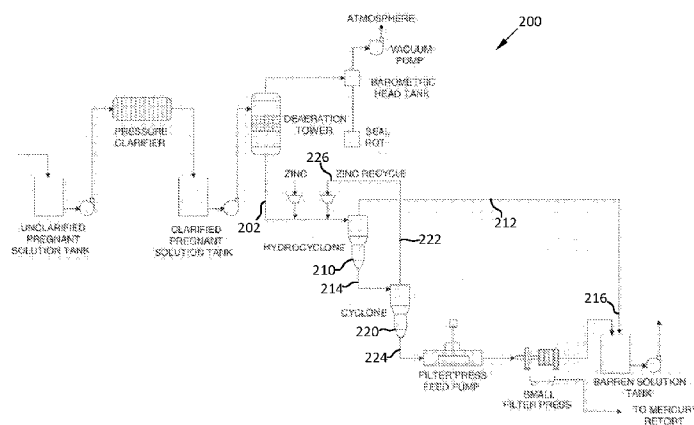


FIG. 4

(57) **Abstract:** A zinc precipitation circuit is disclosed. The circuit comprises a vessel configured to carry clarified pregnant solution comprising a dissolved precious metal, the vessel further comprising means for delivering zinc particles; a precipitate filter downstream of the vessel configured for solid-liquid separation; at least one classifier downstream of the vessel and upstream of the precipitate filter and further being configured to separate the zinc particles from other precipitates from the clarified pregnant solution; and, a recycle feed stream configured to deliver the zinc particles separated from other precipitates to the vessel. A method of recovering a precious metal via a zinc precipitation is also disclosed. The method comprises the steps of: providing zinc particles to a clarified pregnant solution; forming a precipitate by precipitating said precious metal from the clarified pregnant solution by virtue of the zinc particle addition; separating the zinc particles from other portions of the precipitate, thereby forming a concentrate of the precious metal; recycling the zinc particles separated out by using them for providing to the clarified pregnant solution; and, smelting the concentrate to recover the precious metal.



ZINC PRECIPITATION SYSTEMS AND METHODS FOR THE EFFICIENT RECOVERY OF PRECIOUS METALS

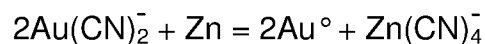
FIELD OF THE INVENTION

5 This invention relates to methods and systems for leaching gold and other precious metals from metal sulfide ores and concentrates and more particularly to methods and systems for improving the efficiency of Merrill-Crowe and other zinc precipitation operations.

10 BACKGROUND OF THE INVENTION

Following the discovery of gold's solubility in cyanide, it was discovered that passing the cyanide solution containing the dissolved gold through zinc chips caused the gold to precipitate out of solution. Early zinc precipitation systems simply used a wooden box filled with zinc chips, and although these systems
15 "worked", to an extent they were very inefficient, leaving much of the dissolved gold in solution.

The Merrill-Crowe process is essentially a separation technique for removing gold and/or other precious metals from a cyanide solution by zinc precipitation. It
20 is an improvement on the zinc box approach, and comprises a simple metathesis or cementation reaction:



It was initially discovered and patented by Charles Washington Merrill around
25 1900, and then later refined by Thomas B. Crowe, while working for the Merrill Company. In more recent years, electrowinning technologies have begun to replace this process; however, there are many Merrill-Crowe operations still in operation.

30 FIGS. 1 and 2 schematically illustrate the traditional Merrill-Crowe process. Unclarified pregnant solution formed after heap leaching is separated from the ore by methods such as filtration (e.g. horizontal leaf type clarifiers) and counter-current decantation (CCD). Afterwards, an extremely clear (i.e., "clarified")

pregnant solution is achieved by using pre-coated filters or other systems applied with diatomaceous earth. Design criteria for such filters and systems may vary depending on the turbidity of the unclarified pregnant solution. In some cases, two or more filters are used in parallel for redundancy, and/or so that one filter
5 may remain online while another "on deck" filter is being cleaned, pre-coated, and readied to go back online. Solids which are removed by the filters are typically of no value and are back-flushed to tails.

Oxygen is then removed from the clarified pregnant solution by passing the
10 solution through a vacuum de-aeration column where the clarified pregnant solution is percolated through a packing bed while under a vacuum. Flashing water vapor strips oxygen from the clarified pregnant solution forming a de-aerated pregnant solution. In some instances, special attention must be paid to eliminating air leaking into the column, which might decrease vacuum efficiency.
15 The de-aerated pregnant solution exits the bottom of the column, resulting in a very low net suction head on precipitate feed pumps. The precipitate feed pumps are generally carefully selected, so as to avoid cavitation and other tendencies to pull air back into the de-aerated pregnant solution. It should also be noted that these pumps will typically require a liquid seal in the packing area so that air does
20 not leak back into solution.

Zinc dust (e.g., sand-sized particles, chips, etc.) is added to the de-aerated pregnant solution at a constant rate, which, in turn, precipitates the gold, since the zinc has a higher affinity for cyanide ions than gold. If present, other precious
25 metals like silver and copper may also precipitate in the presence of the zinc. The addition of zinc typically involves the use of a zinc feeder with an auger and moving side walls (to avoid bridging). Using a cone-bottomed tank with a steady head tank for mixing solution (usually a cyanide solution) will assure that no air will inadvertently leak into the system. Generally speaking, zinc tends to be better
30 utilized with richer pregnant solutions, whereas weaker pregnant solutions may require more zinc and/or necessitate other recovery processes. In some instances, lead nitrate may be further provided to the system in order to "activate" the zinc; however, it must only be added in small amounts to prevent blinding of

zinc surfaces, which would disadvantageously prevent the precipitation of precious metals and result in lower recoveries. Moreover, excessive use of lead nitrate may form a lead hydroxide gel, which can gum up downstream filters. Variable-speed feeders may be used to deliver the zinc dust and/or lead nitrate, and are generally recommended.

The precipitate (gold concentrate mixed with zinc dust) is then filtered out of the solution (e.g., using precipitate filter feed pumps and one or more extremely large precipitate filters). Filters of any type, including plate and frame filters, drum filters, and belt filters may be used in the process; however, filter presses with recessed plates are generally the most common. Filter cake comprising the gold concentrate and zinc particles is collected in the chambers between the filter plates (which can be air blown to further remove moisture from within the cake). Then, the filter cake is eventually mixed with sulphuric acid (H_2SO_4) or, in some instances, sodium bisulfate (NaHSO_4), to dissolve the zinc in solution. This dissolving step essentially purifies the precipitate leaving just the gold concentrate in solid form. Typically, this dissolution step increases the concentration of gold from approximately 25-40 %/wt to approximately 35-55 %/wt. Dewatering of the zinc solution from the solid gold concentrate is typically done through the use of one or more extremely large secondary filters, and the remaining concentrate solids are collected for smelting into gold bullion. The bullion is sent to a refinery to remove the copper and silver. The specific process used in the refinery depends upon the number and types of impurities/other compositions in the gold bullion.

The extra steps involved with putting zinc into solution to separate it from surrounding gold solids, and then filtering to separate the gold concentrate from the zinc solution has several disadvantages. These disadvantages include increased cost, extra equipment (upwards of 80% more filtration area required), and a significantly greater plant footprint. For example, conventional Merrill-Crowe plants may require upwards of 40% floor space than the present invention. In particular, the number and sizes of filters needed in a typical Merrill-Crowe process can be quite impressive, especially in view of the fact that filters

generally account for more than 2/3 of total plant cost. Moreover, zinc is very difficult to dissolve out of solution once dissolved into solution. Traditionally, zinc dissolved in solution is conveyed to tailings ponds and disposed of, as the costs to recover the zinc are prohibitive.

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OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to reduce the amount of zinc consumption and also reduce the consumption of other reagents (e.g., H_2SO_4 ,
10 NaHSO_4) in conventional zinc-precipitation processes.

It is also an object of the present invention to significantly reduce the filter sizes required for typical zinc-precipitation processes.

15 Moreover, objects of the present invention include providing a method which might significantly reduce overall plant size for Merrill-Crowe-type operations.

Yet another object of the present invention is to provide a method for recovering gold and other precious metals which might significantly reduce overall plant
20 cost.

Moreover, an object of the present invention is to provide a more environmentally-friendly zinc precipitation process(es), which reduces or eliminates zinc disposal and requires less energy to operate.

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These and other objects of the present invention will be apparent from the drawings and description herein. Although every object of the invention is believed to be attained by at least one embodiment of the invention, there is not necessarily any one embodiment of the invention that achieves all of the objects
30 of the invention.

SUMMARY OF THE INVENTION

A method of recovering a precious metal via a zinc precipitation comprising the steps of: providing zinc particles to a clarified pregnant solution; forming a precipitate by precipitating said precious metal from the clarified pregnant solution by virtue of the zinc particle addition; separating the zinc particles from other portions of the precipitate, thereby forming a concentrate of the precious metal; recycling the zinc particles separated out by using them for providing to the clarified pregnant solution; and, smelting the concentrate to recover the precious metal. In some embodiments, separation of the zinc particles from other portions of the precipitate may be accomplished via classification. In some embodiments, classification may comprise solid-liquid separation or solid-solid separation. In some embodiments, said classification may comprise both solid-liquid and solid-solid separations. In some embodiments, the solid-liquid separation may be performed before the solid-solid separation. In some embodiments, the solid-liquid separation may be facilitated by a hydrocyclone. In some embodiments, the solid-solid separation may be facilitated by a cyclone. In some embodiments, the solid-solid separation may be facilitated by a panning device, such as a shaker table. In some embodiments, the step (d) of recycling may obviate the need for subsequent dissolving of the zinc particles downstream as conventionally done.

A zinc precipitation circuit is also disclosed. The circuit comprises a vessel configured to carry clarified pregnant solution comprising a dissolved precious metal, the vessel further comprising means for delivering zinc particles; a precipitate filter downstream of the vessel configured for solid-liquid separation; at least one classifier downstream of the vessel and upstream of the precipitate filter and further being configured to separate the zinc particles from other precipitates from the clarified pregnant solution; and, a recycle feed stream configured to deliver the zinc particles separated from other precipitates to the vessel. In some embodiments, the at least one classifier may comprise a solid-liquid separation device or a solid-solid separation device. In some embodiments, the at least one classifier may comprise both a solid-liquid separation device and a solid-solid separation device. In some embodiments, the solid-liquid separation

device may be situated upstream of the solid-solid separation device. In some embodiments, the solid-liquid separation device may be a hydrocyclone. In some embodiments, the solid-solid separation device may be a cyclone. In some embodiments, the solid-solid separation device may be a panning device, such as a shaker table. In some embodiments, the classifier may obviate the need for subsequent dissolving of the zinc particles downstream as conventionally done.

BRIEF DESCRIPTION OF THE DRAWING

FIGS. 1 and 2 are schematic representation of a typical Merrill-Crowe process; FIG. 3 shows a modified zinc precipitation process according to some embodiments of the invention; FIG. 4 shows another modified zinc precipitation process according to various aspects of the invention; and, FIG. 5 shows yet another zinc precipitation process according certain embodiments.

DETAILED DESCRIPTION OF THE INVENTION

The following description of the non-limiting embodiments shown in the drawings is merely exemplary in nature and is in no way intended to limit the inventions disclosed herein, their applications, or uses.

Turning now to FIG. 3, a zinc precipitation circuit 100 according to some embodiments is shown. The circuit 100 is unique in that it comprises one or more additional apparatus which are located downstream of the zinc precipitation step (where zinc particles are added to the de-aerated pregnant solution), and upstream the initial precipitate filtration step. The circuit 100 is also unique in that the zinc particles, which are added during the precipitation step, are advantageously recovered before filtration, and are recycled, obviating the need for their conventional subsequent dissolution in acid (FIG. 1).

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During the zinc precipitation step, zinc particles are added to de-aerated pregnant solution to form a product 104 comprising a zero-value barren de-aerated solution 112 (e.g., sodium hydroxide and/or sodium cyanide in aqueous

solution), and a valuable precipitate 114. The precipitate 114 may comprise both the previously-added zinc particles and also a number of precious metal-laden solids which may have precipitated out of the de-aerated pregnant solution. The circuit 100 further comprises a first separation step 110 (e.g., a hydrocyclone or other conventional means for liquid-solid separation), wherein barren de-aerated solution 112 (liquid fraction of product 104), is returned upstream to the leaching stage via delivery means 116 and recycled. Said delivery means 116 may be, for instance, piping with one or more inline pumps (not shown). By virtue of the first separation step 110, the valuable precipitate (solid fraction of product 104) is then sent to a second classification step 120. The second classification step 120 includes the sorting of solids and may be facilitated by any device which is configured to make separations based on particle density (e.g., one or more cyclones, reflux classifiers, mechanical panning devices such as vibrating shaker tables, and/or other devices such as those shown in U.S. Patent No. 7,963,398 which is incorporated by reference). At this second classification step 120, the lighter zinc particles 122 having a density of around 7.14 g/cm^3 are separated from the heavier precious metal particles which make up the valuable concentrate 124 (e.g., gold, which has a density of around 19.30 g/cm^3). The lighter zinc particles 122 are recycled back to the zinc precipitation step via delivery means 126. Delivery means 126 may include, for instance, a wet conveyor, a slurry pipe with a series of inline pumps, and/or a hopper (not shown). In some preferred embodiments, the heavier concentrate 124 may be sent directly to mercury retort 150 and then to smelting 160 without the need for the additional zinc dissolution and superfluous filtering steps shown in FIG. 1.

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FIG. 4 schematically shows a zinc precipitation circuit 200 according to certain embodiments. During zinc precipitation, zinc particles are added to a stream of de-aerated pregnant solution 202 to form a product comprised of a zero-value barren de-aerated solution 212 (e.g., sodium hydroxide and/or sodium cyanide in aqueous solution), and a valuable precipitate 214. The precipitate 214 may comprise both the previously-added zinc particles and precious metal-laden solids which may have precipitated out of the de-aerated pregnant solution 202. The circuit 200 further comprises a first separation device 210 (e.g., a

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hydrocyclone or other conventional means for liquid-solid separations), wherein barren de-aerated solution 212 (liquid fraction from the first separation device 210), is removed to a barren solution tank via delivery means 216. In some non-limiting embodiments, said delivery means 216 may comprise piping with one or more inline pumps (not shown). By virtue of the first separation device 210, the valuable precipitate 214 (solid fractions underflow of the first separation device 210) is then sent to a solid-solid classification device 220. In some non-limiting embodiments, the device 220 may comprise one or more devices which are configured to make separations based on particle density (e.g., cyclones, reflux classifiers, panning devices, vibration tables, and/or other means such as that shown and described in U.S. Patent No. 7,963,398). In the particular embodiment shown, the solid-solid classification device 220 comprises a cyclone separator which is fed by the low moisture underflow of the first separation device 210. At this classification stage 220, the lighter zinc particles 222 having a density of around 7.14 g/cm^3 are separated from the heavier precious metal particles which make up the valuable concentrate 224 (e.g., gold, which has a density of around 19.30 g/cm^3). The lighter zinc particles 222 are recycled back to the area where zinc precipitation takes place, and may be conveyed using any conventional delivery means 226 known in the art. In the particular embodiment shown, only a small filtering device such as a small filter press may be necessary to remove residual barren de-aerated solution 212 prior to the cake of concentrate 224 being sent to mercury retort and smelting. While the embodiment disclosed in FIG. 3 suggests no downstream zinc dissolution, it is contemplated that some small secondary dissolution and filtering operations may still be optionally provided in order to increase concentrate purity prior to smelting -- albeit on a much smaller scale and at a lesser cost to install/operate than what is currently required. The smaller scale and cost may be achievable due to less, nearly negligible amounts of un-recycled zinc particulate 222 leaving in the concentrate 224 which might inadvertently bypass the delivery means 226 and remain entrained in the concentrate 224.

FIG. 5 shows a similar zinc precipitation circuit to the one in FIG. 4, wherein a vibration table 320 may be used as the means for solid-solid classification. The

circuit 300 comprises means for zinc precipitation, wherein zinc particles are added to a stream of de-aerated pregnant solution 302 to form a product comprised of a zero-value barren de-aerated solution 312 (e.g., sodium hydroxide and/or sodium cyanide in aqueous solution), and a valuable precipitate 314. The precipitate 314 may comprise both the previously-added zinc particles and precious metal-laden solids which may have precipitated out of the de-aerated pregnant solution 302. The circuit 300 further comprises a first separation device 310 (e.g., a hydrocyclone or other conventional means for liquid-solid separations), wherein barren de-aerated solution 312 (liquid fraction from the first separation device 310), is removed to a barren solution tank via delivery means 316. In some non-limiting embodiments, said delivery means 316 may comprise piping with one or more inline pumps (not shown). By virtue of the first separation device 310, the valuable precipitate 314 (solid fraction underflow of first separation device 310) is then sent to a solid-solid classification device 320. In some non-limiting embodiments, the device 320 may comprise one or more devices which are configured to make separations based on particle density (e.g., cyclones, reflux classifiers, panning devices, vibration tables, and/or other means such as that shown and described in U.S. Patent No. 7,963,398). In the particular embodiment shown, the solid-solid classification device 320 comprises a shaker table, wherein underflow of the first separation device 310 is washed with flowing water and mechanically panned/sifted. At this classification stage 320, the lighter zinc particles 322 having a density of around 7.14 g/cm^3 are separated from the heavier precious metal particles which make up the valuable concentrate 324 (e.g., gold, which has a density of around 19.30 g/cm^3). The lighter zinc particles 322 are recycled back to the area where zinc precipitation takes place, and may be conveyed via any conventional delivery means 326 known in the art. For instance, one or more wet conveyors, slurry pipes, pumps, and/or hoppers (not shown) may be used as delivery means 326. In the particular embodiment shown, only a small filtering device such as a filter press may be necessary to remove residual barren de-aerated solution 312 prior to the cake of concentrate 324 being sent to mercury retort and smelting. While the embodiment disclosed in FIG. 3 suggests no downstream zinc dissolution as suggested in FIG. 1, it is contemplated that some small secondary dissolution

and filtering operations may still be provided at option, albeit on a much smaller scale and at a lesser cost to install/operate than what is currently required. The smaller scale and cost may be achievable due to less, nearly negligible amounts of un-recycled zinc particulate 322 leaving in the concentrate 324 - zinc which
5 might have inadvertently bypassed the delivery means 326 on account of system inefficiencies.

It should be known that the particular features, processes, and benefits which are shown and described herein in detail are purely exemplary in nature and should
10 not limit the scope of the invention. For example, while each embodiment may only show a single liquid-solid separation device 110, 210, 310 or solid-solid classification device 120, 220, 320, more than one device may be provided in series or parallel. Moreover, combinations of different types of liquid-solid separation devices and/or solid-solid classification devices may be
15 advantageously utilized. For example, a combination of both cyclone separators and shaker tables is not unforeseeable and may even be preferable for making finer cuts.

Although the invention has been described in terms of particular embodiments
20 and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from the spirit of or exceeding the scope of the claimed invention. Accordingly, it is to be understood that the drawings and descriptions herein are proffered by way of example to facilitate comprehension of the invention and should not be construed
25 to limit the scope thereof.

CLAIMS

1. A zinc precipitation circuit (200, 300) comprising:
 - (a) a vessel configured to carry clarified pregnant solution (202, 302)
5 comprising a dissolved precious metal, said vessel further comprising means for delivering zinc particles;
 - (b) a precipitate filter downstream of the vessel configured for solid-liquid separation;
 - (c) at least one classifier (210, 310; 220, 320) downstream of the vessel and
10 upstream of the precipitate filter and further being configured to separate the zinc particles from other precipitates from the clarified pregnant solution (202, 302);
and,
 - (d) a recycle feed stream (226, 326) configured to deliver the zinc particles (222, 322) separated from other precipitates to the vessel.
- 15 2. The circuit of claim 1, wherein the at least one classifier comprises a solid-liquid separation device (210, 310) or a solid-solid separation device (220, 320).
3. The circuit of claim 2, wherein the at least one classifier comprises both a
20 solid-liquid separation device (210, 310) and a solid-solid separation device (220, 320).
4. The circuit of claim 3, wherein the solid-liquid separation device (210, 310) is situated upstream of the solid-solid separation device (220, 320).
- 25 5. The circuit of claim 2, wherein the solid-liquid separation device (210, 310) comprises a hydrocyclone.
6. The circuit of claim 2, wherein the solid-solid separation device (220, 320)
30 comprises a cyclone.
7. The circuit of claim 2, wherein the solid-solid separation device comprises a panning device (320), such as a shaker table.

8. The circuit of claim 1, wherein the at least one classifier (210, 310; 220, 320) reduces or obviates the need for subsequent dissolving of the zinc particles downstream as conventionally done.

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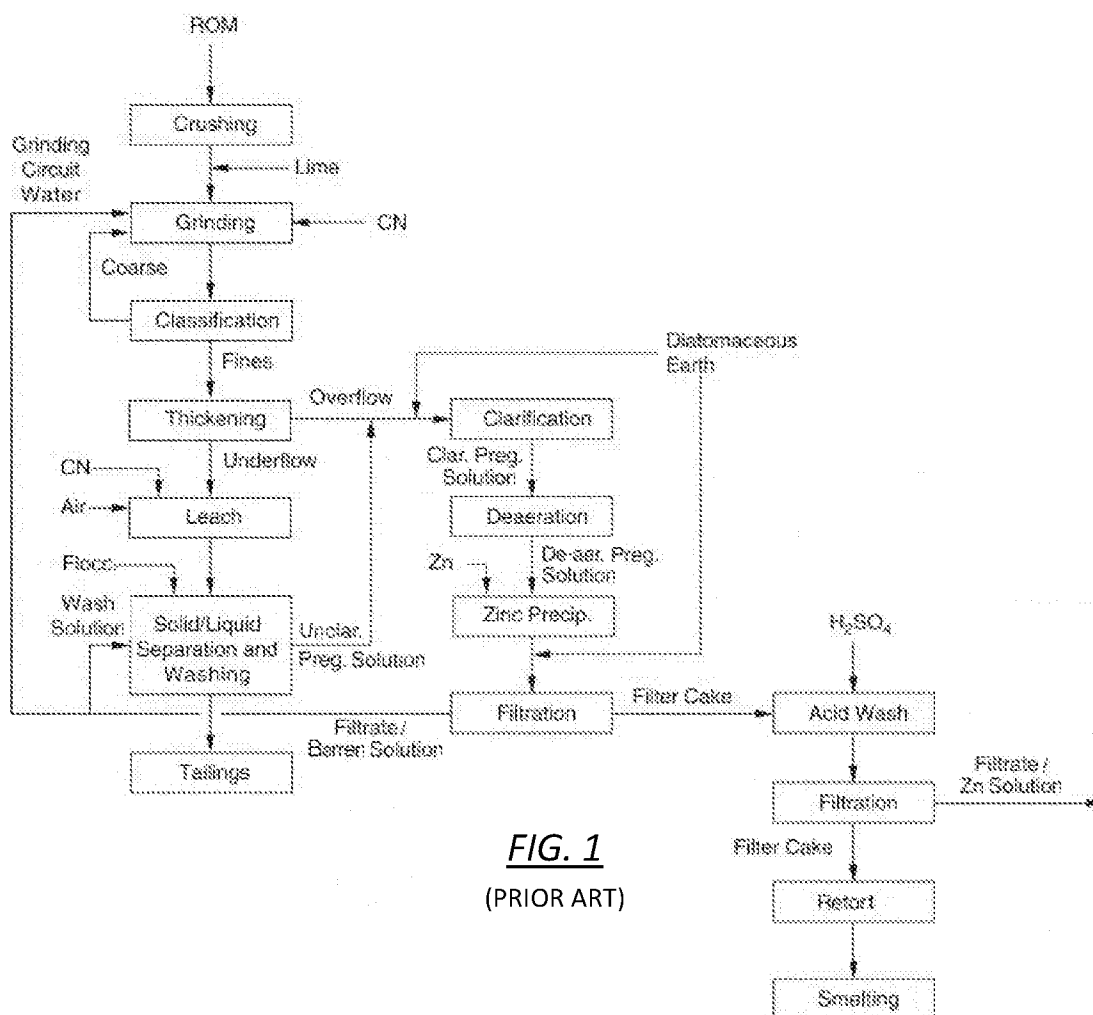


FIG. 1
(PRIOR ART)

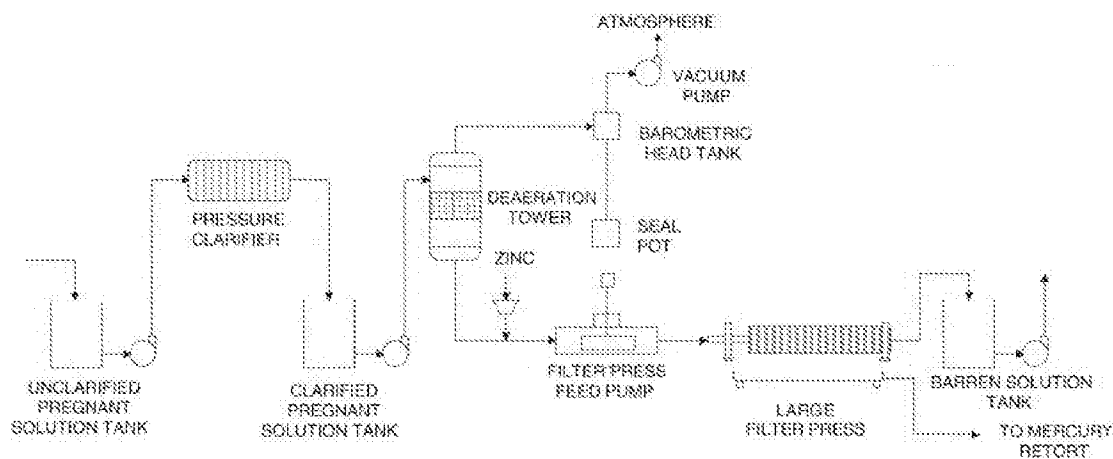


FIG. 2
(PRIOR ART)

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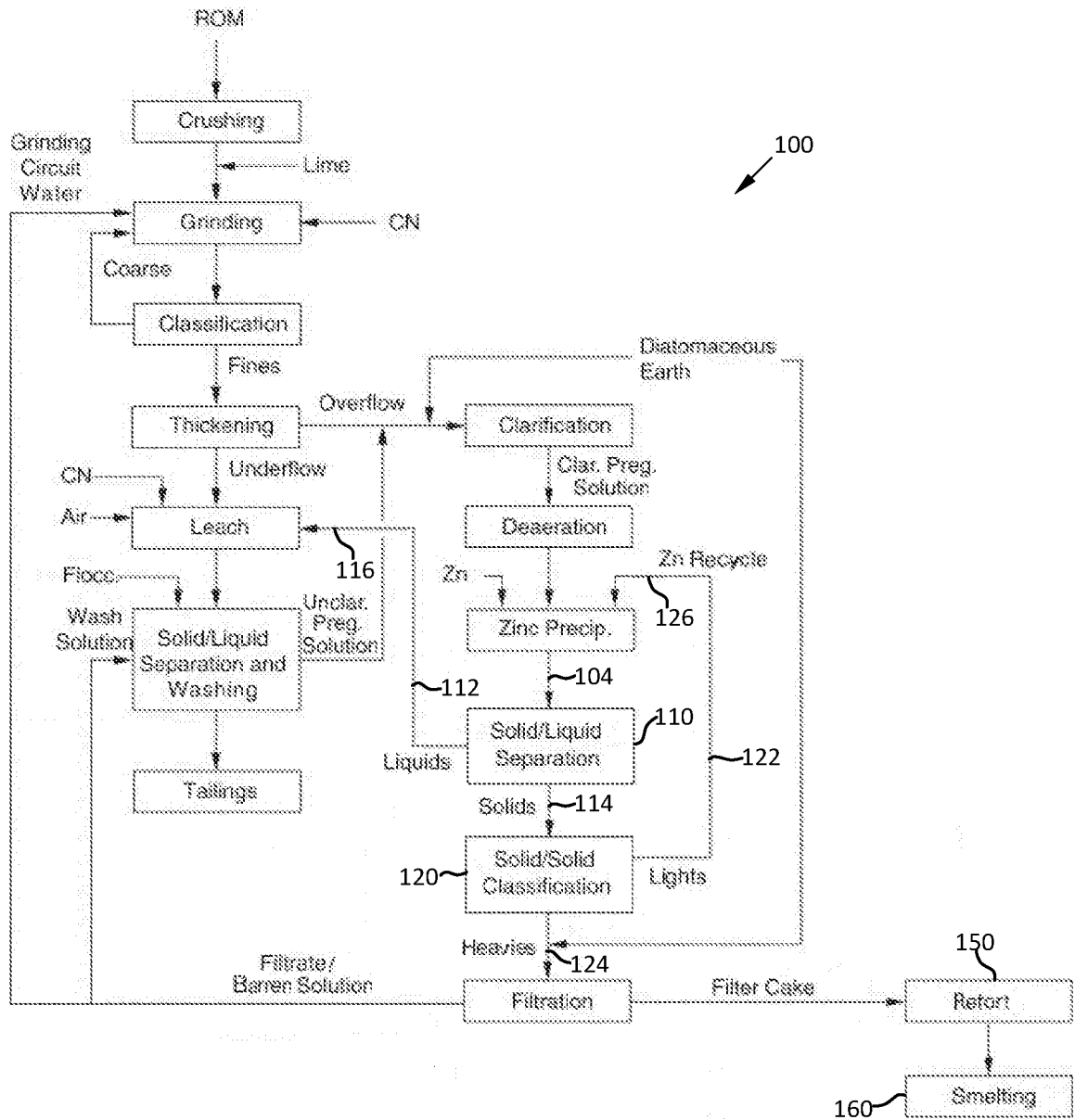
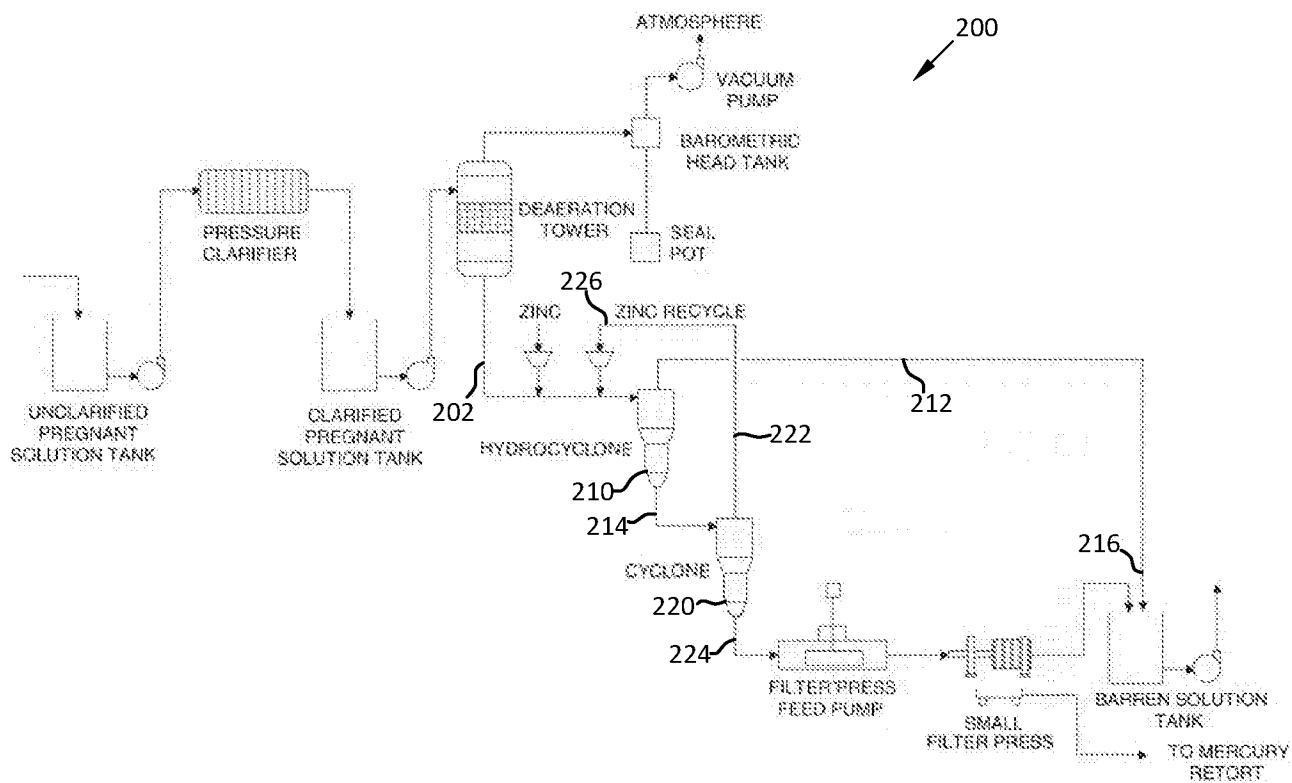
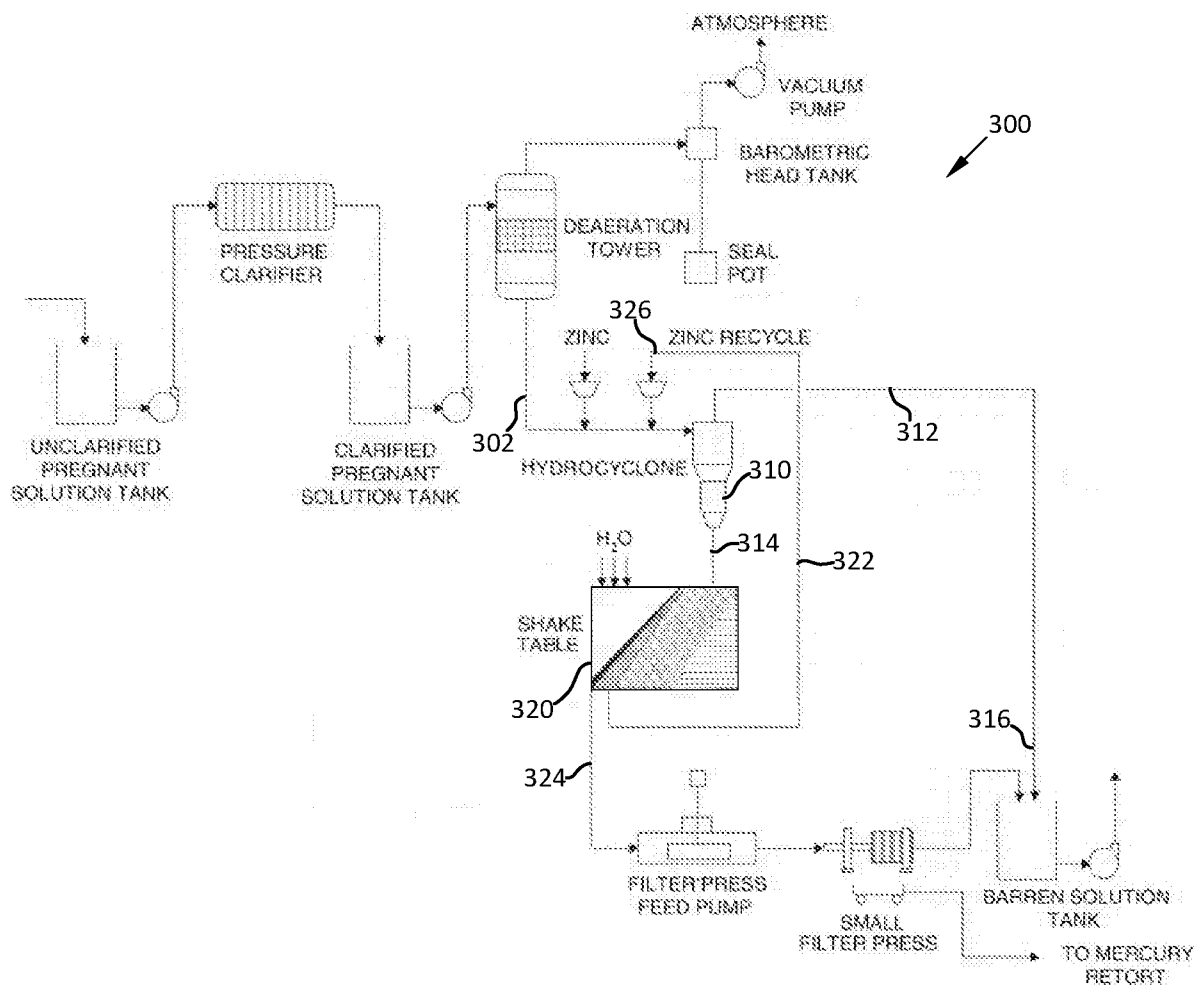


FIG. 3

**FIG. 4**

**FIG. 5**

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2013/050430

A. CLASSIFICATION OF SUBJECT MATTER

INV. C22B3/02 C22B11/02

ADD.

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)

C22B

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)

EPO-Internal, COMPENDEX, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 834 793 A (SCHNEIDER JOHN C [CA] ET AL) 30 May 1989 (1989-05-30) the whole document -----	1-8
X	WO 2012/103571 A1 (XSTRATA QUEENSLAND LTD [AU]; VOIGT PAUL BENJAMIN [AU]) 9 August 2012 (2012-08-09) the whole document -----	1-8
X	WO 93/01320 A1 (HOEFER DAWN ANNETTE [AU]) 21 January 1993 (1993-01-21) the whole document -----	1-8

☐

Further documents are listed in the continuation of Box C.

☒

See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

1 April 2014

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2013/050430

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4834793	A	30-05-1989	NONE	

WO 2012103571	A1	09-08-2012	CA 2825228 A1	09-08-2012
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