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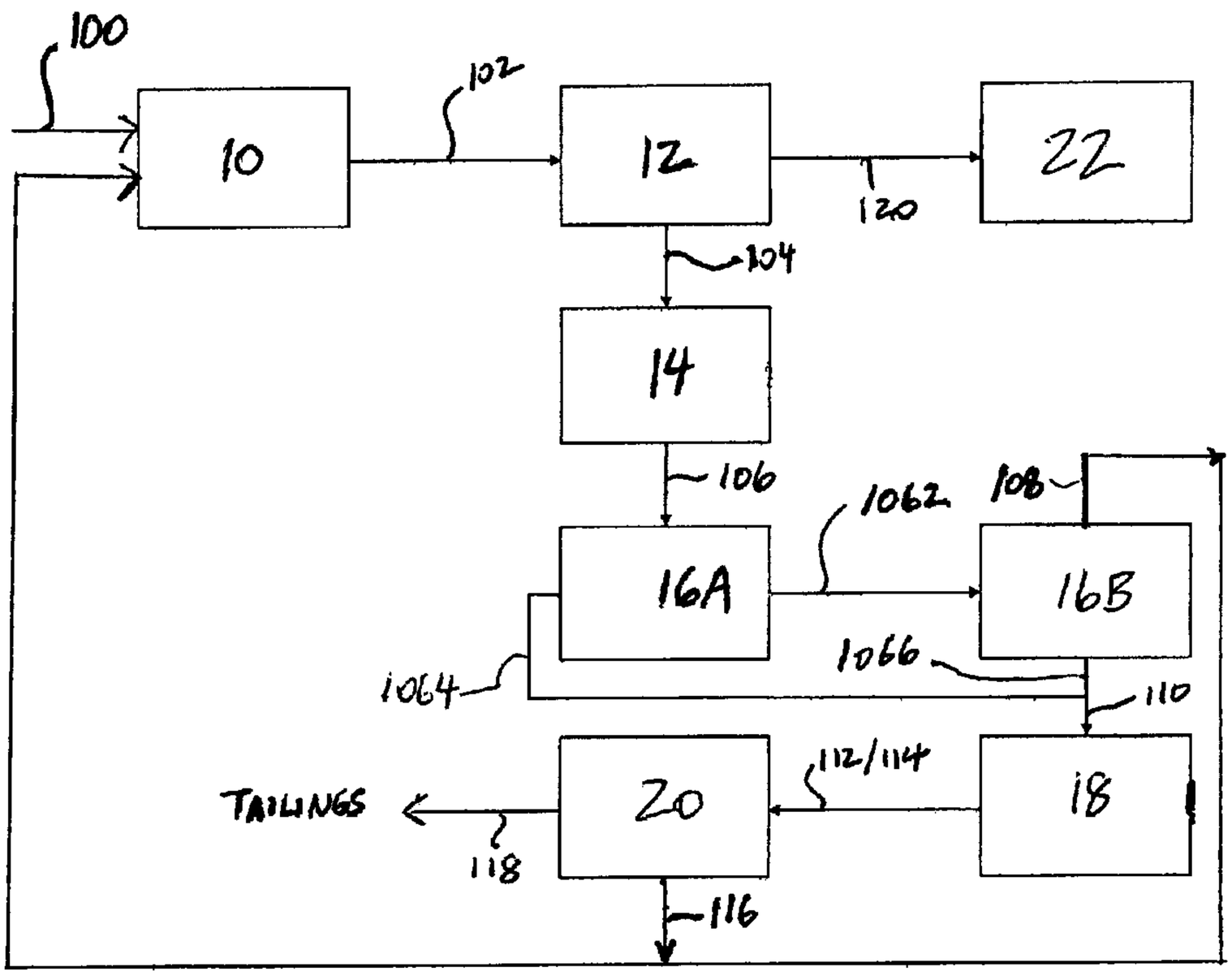
(54) Titre : RECUPERATION DE METAUX A PARTIR DE RESIDUS DE LIXIVIATION
(54) Title: RECOVERING METAL VALUES FROM LEACH RESIDUE



(57) Abrégé/Abstract:
There is also provided a method of treating a metalliferrous material. The method includes providing a metalliferrous material including nickel, cobalt, and iron. At least a fraction of the metalliferrous material is leached with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a reaction zone so as to effect production of a leachant including nickel sulphate, cobalt sulphate, and iron sulphate. The leachant is contacted with a reagent material in a reaction zone, wherein the reagent material is aqueous ammonia solution, so as to effect production of a reaction product including a product solution component and a solid residue component. The nickel and cobalt are concentrated in the product solution component, and the iron is concentration in the solid residue component.

ABSTRACT

There is also provided a method of treating a metalliferrous material. The method includes providing a metalliferrous material including nickel, cobalt, and iron. At least a fraction of the metalliferrous material is leached with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a reaction zone so as to effect production of a leachant including nickel sulphate, cobalt sulphate, and iron sulphate. The leachant is contacted with a reagent material in a reaction zone, wherein the reagent material is aqueous ammonia solution, so as to effect production of a reaction product including a product solution component and a solid residue component. The nickel and cobalt are concentrated in the product solution component, and the iron is concentration in the solid residue component.

RECOVERING METAL VALUES FROM A LEACH RESIDUE

FIELD OF THE INVENTION

[0001] This invention relates to the recovery of a metal value from a leach residue.

BACKGROUND OF THE INVENTION

[0002] Pressure leaching of sulphidic concentrates produces residues which often contain valuable minerals whose recovery is interfered with by the fact that such valuable minerals co-precipitate with non-valuable minerals or become occluded within gangue.

SUMMARY OF THE INVENTION

[0003] In one aspect, there is provided a method of treating a metalliferrous material. The method includes providing a metalliferrous material including at least one metalliferrous material-based target elemental metal and at least one metalliferrous material-based non-target elemental metal. At least a fraction of the metalliferrous material is solubilised so as to effect production of a solubilisation product including an intermediate operative solution, wherein the intermediate operative solution includes a solvent component and a solute component, and wherein the solute component includes at least one dissolved intermediate operative solution-based elemental metal comprising material, and wherein the at least one dissolved intermediate operative solution-based elemental metal comprising material includes at least one dissolved intermediate operative solution-based target elemental metal comprising material and at least one dissolved intermediate operative solution-based non-target elemental metal comprising material such that each one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based elemental metal comprising material and each one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based elemental metal comprising material, wherein each one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material includes at least one intermediate operative solution-based target elemental metal and wherein each one of the at least one intermediate operative solution-based target elemental metal is a one of the at least one metalliferrous material-based

target elemental metal of the metalliferrous material and is derived from the metalliferrous material, and wherein each one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material includes at least one intermediate operative solution-based non-target elemental metal and wherein each one of the at least one intermediate operative solution-based non-target elemental metal is a one of the at least one metalliferrous material-based non-target elemental metal of the metalliferrous material and is derived from the metalliferrous material, such that the intermediate operative solution includes at least one intermediate operative solution-based target elemental metal and at least one intermediate operative solution-based non-target elemental metal. Additionally, reagent material including at least one precipitation agent material and at least one complexing agent material is provided. Each one of the at least precipitation agent material is configured to react with at least one of the at least one dissolved intermediate operative solution-based elemental metal comprising material when the intermediate operative solution is contacted with the reagent material so as to effect production of at least one solid residue component-based elemental metal comprising solid material, such that any reaction of a dissolved intermediate operative solution-based target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and such that any reaction of a dissolved intermediate operative solution-based non-target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one

solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material. Each one of the at least complexing agent material is configured to react with at least one of the at least one dissolved intermediate operative solution-based elemental comprising material when the intermediate operative solution is contacted with the reagent material so as to effect production of at least one product solution component-based elemental metal comprising dissolved complex material, such that any reaction of a dissolved intermediate operative solution-based target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and such that any reaction of a dissolved intermediate operative solution-based non-target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based non-target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based non-target elemental metal comprising dissolved complex material includes at least one product solution

component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material. At least one operative dissolved intermediate operative solution-based target elemental metal comprising material is provided, wherein the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material, wherein each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is configured to react with at least one of the at least one precipitation agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and wherein each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is also configured to react with at least one of the at least one complexing

agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material. At least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is provided, wherein the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material, wherein each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is configured to react at least with at least one of the at least one precipitation agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue

component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material. The intermediate operative solution is contacted with the reagent material in a reaction zone, such that production of a product mixture is effected, wherein the product mixture includes a product solution component and a solid residue component, wherein the product solution component includes the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal and any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, and wherein the solid residue component includes any produced solid residue component target elemental metal comprising solid material-based target elemental metal and the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal. With respect to the product solution component, there is provided a respective molar quantity of each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal such that at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity is provided, and there is also provided a molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein the ratio of (A1) the sum of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity to (B1) the molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is defined by R1. With respect to the solid residue component, there is provided a molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal, and there is also provided a respective molar quantity of each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal such that at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is provided, wherein the ratio of (A2) the molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal to (B2) the sum of

the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is defined by R2. R1 is greater than R2.

[0004] In another aspect, there is also provided a method of treating a metalliferrous material. The method includes providing a metalliferrous material including at least one metalliferrous-based target elemental metal and at least one metalliferrous material-based non-target elemental metal, wherein the at least one metalliferrous material-based target elemental metal includes at least one of nickel and cobalt, and the at least one metalliferrous material-based non-target elemental metal includes iron. At least a fraction of the metalliferrous material is solubilised so as to effect production of a solubilisation product including an intermediate operative solution, wherein the intermediate operative solution includes at least one dissolved intermediate operative solution target element metal comprising material and at least one dissolved intermediate operative solution non-target elemental metal comprising material, wherein the at least one dissolved intermediate operative solution non-target elemental metal comprising material includes an iron-comprising material and wherein the non-target elemental of the iron comprising material is iron, and wherein. When the at least one of nickel and cobalt of the at least one metalliferrous material-based target elemental metal is nickel, the at least one dissolved intermediate operative solution target elemental metal comprising material includes a nickel-comprising material and wherein the target elemental metal of any nickel-comprising material is nickel. When the at least one of nickel and cobalt the at least one metalliferrous material-based target elemental metal is cobalt, the at least one dissolved intermediate operative solution target elemental metal comprising material includes a cobalt comprising material and wherein the target elemental metal of any cobalt comprising material is cobalt. When the at least one of nickel and cobalt of the at least one metalliferrous material-based target elemental metal is nickel and cobalt, the at least one dissolved intermediate operative solution target elemental metal comprising material includes nickel-comprising material and cobalt comprising material and wherein the target elemental metal of the nickel-comprising material is nickel and wherein the target elemental metal of the cobalt comprising material is cobalt. In this respect, the intermediate operative solution includes at least one operative intermediate operative solution-based target elemental metal, and the at least one operative intermediate operative solution-based target elemental metal is at least one of nickel and cobalt. The intermediate operative solution is

contacted with a reagent material in a reaction zone, wherein the reagent material is aqueous ammonia solution, so as to effect production of a reaction product including a product solution component and a solid residue component.

[0005] In another aspect, there is provided a method of treating a metalliferrous material,. The method includes providing an operative solution including a solvent component and a solute component, wherein the solute component includes at least one dissolved operative solution-based elemental metal comprising material, and wherein the at least one dissolved operative solution-based elemental metal comprising material includes at least one dissolved operative solution-based target elemental metal comprising material and at least one dissolved operative solution-based non-target elemental metal comprising material such that each one of the at least one dissolved operative solution-based target elemental metal comprising material is a one of the at least one dissolved operative solution-based elemental metal comprising material and each one of the at least one dissolved operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved operative solution-based elemental metal comprising material, wherein each one of the at least one dissolved operative solution-based target elemental metal comprising material includes at least one operative solution-based target elemental metal, and wherein each one of the at least one dissolved operative solution-based non-target elemental metal comprising material includes at least one operative solution-based non-target elemental metal, such that the operative solution includes at least one operative solution-based target elemental metal and at least one operative solution-based non-target elemental metal. A reagent material is provided including at least one precipitation agent material and at least one complexing agent material. Each one of the at least precipitation agent material is configured to react with at least one of the at least one dissolved operative solution-based elemental metal comprising material when the operative solution is contacted with the reagent material so as to effect production of at least one solid residue component-based elemental metal comprising solid material, such that any reaction of a dissolved operative solution-based target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one

reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one operative solution-based target elemental metal, and such that any reaction of a dissolved operative solution-based non-target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one operative solution-based non-target elemental metal. Each one of the at least complexing agent material is configured to react with at least one of the at least one dissolved operative solution-based elemental comprising material when the operative solution is contacted with the reagent material so as to effect production of at least one product solution component-based elemental metal comprising dissolved complex material, such that any reaction of a dissolved operative solution-based target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted

with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one operative solution-based target elemental metal, and such that any reaction of a dissolved operative solution-based non-target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based non-target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based non-target elemental metal comprising dissolved complex material includes at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is a one of the at least one operative solution-based non-target elemental metal. At least one operative dissolved operative solution-based target elemental metal comprising material is provided, wherein the at least one operative dissolved operative solution-based target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved operative solution-based target elemental metal comprising material is a one of the at least one dissolved operative solution-based target elemental metal comprising material, wherein each one of the at least one operative dissolved operative solution-based target elemental metal comprising material is configured to react with at least one of the at least one precipitation agent material, when the operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the operative

solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one operative solution-based target elemental metal, and wherein each one of the at least one operative dissolved operative solution-based target elemental metal comprising material is also configured to react with at least one of the at least one complexing agent material, when the operative solution is contacted with the reagent material, to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one operative solution-based target elemental metal. At least one operative dissolved operative solution-based non-target elemental metal comprising material is provided, wherein the at least one operative dissolved operative solution-based non-target elemental metal comprising material is included within the operative solution such that each one of the at least one operative dissolved operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved operative solution-based non-target elemental metal comprising material, wherein each one of the at least one operative dissolved operative solution-based non-target elemental metal comprising material is configured to react at least with at least one of the at least one precipitation agent material, when the operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal

comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one operative solution-based non-target elemental metal. The operative solution is contacted with the reagent material in a reaction zone, such that production of a product mixture is effected, wherein the product mixture includes a product solution component and a solid residue component, wherein the product solution component includes the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal and any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, and wherein the solid residue component includes any produced solid residue component target elemental metal comprising solid material-based target elemental metal and the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal. With respect to the product solution component, there is provided a respective molar quantity of each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal such that at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity is provided, and there is also provided a molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein the ratio of (A1) the sum of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity to (B1) the molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is defined by R1. With respect to the solid residue component, there is provided a molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal, and there is also provided a respective molar quantity of each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal such that at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is provided, wherein the ratio of (A2) the molar

quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental to (B2) the sum of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is defined by R2. R1 is greater than R2.

[0006] In another aspect, there is provided a method of treating a metalliferrous material. The method includes providing a metalliferrous material including nickel, cobalt, and iron. At least a fraction of the metalliferrous material is leached with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a leaching zone so as to effect production of a leachant including nickel sulphate, cobalt sulphate, and iron sulphate. The leachant is contacted with reagent material in a reaction zone, wherein the reagent material is aqueous ammonia solution, so as to effect production of a reaction product including a product solution component and a solid residue component.

BRIEF DESCRIPTION OF DRAWINGS

[0007] The system and method of the preferred embodiments of the invention will now be described with the following accompanying drawings:

[0008] Figure 1 is a schematic illustration of the experimental set-up of the H_2SO_4/SO_2 leach step for Example Nos. 1 and 2;

[0009] Figure 2 is a tabular summary of an assay of the feed residue, leach residue, and leach solution in Example No. 1;

[0010] Figure 3 is a schematic illustration of the experimental set-up of the air/ammonia precipitation of iron step for Example Nos. 1 and 2;

[0011] Figure 4 is a tabular summary of assays of reaction solutions, collected at regular intervals from the reactor, and final residue from the air/ammonia precipitation of iron step in Example No. 1;

[0012] Figure 5 is a tabular summary of assay results of solids from oxygen/ammonia leach of residue from H_2SO_4/SO_2 leach of lamellae thickener underflow residue in Example No. 1;

[0013] Figure 6 is a x-ray diffraction analysis of the residue from the ammonia leach of residue from the H_2SO_4/SO_2 leach of lamellae thickener underflow residue in Example No. 1;

[0014] Figure 7 is an x-ray diffraction analysis of an exemplary metalliferrous material, illustrating its composition;

[0015] Figures 8, 9 and 10 are flowsheets of exemplary embodiments of the invention;

[0016] Figures 11 and 12 are x-ray diffraction analyses of exemplary solid residues formed after contacting the intermediate operative solution (the leachate from the reductive leach) with aqueous ammonia solution;

[0017] Figure 13 is a tabular summary of the experimental results for the treatment of a relatively low metal sulphide concentration-comprising metalliferrous material feed in Example No. 2;

[0018] Figure 14 is a tabular summary of the experimental results for the treatment of a relatively high metal sulphide concentration-comprising metalliferrous material feed in Example No. 2; and

[0019] Figure 15 is a tabular summary of assays from various steps in the treatment of a relatively low metal sulphide concentration-comprising metalliferrous material feed in Example No. 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0020] There is provided a method 10 of recovering at least one target elemental metal from a metalliferrous material. Flowsheets illustrating exemplary embodiments of this method are provided as Figures 8, 9 and 10.

(A) PROVIDING A METALLIFEROUS MATERIAL

[0021] There is provided a metalliferrous material 104 including at least one metalliferrous material-based target elemental metal and at least one metalliferrous material-based non-target elemental metal.

[0022] For example, at least a fraction of the metalliferrous material 104 is an agglomerate and at least one of the at least one metalliferrous material-based target elemental metal is occluded within the agglomerate.

[0023] For example, the at least one metalliferrous material-based target elemental metal includes at least one of nickel (Ni) or cobalt (Co), and the at least one metalliferrous material-based non-target elemental includes iron (Fe).

[0024] In some embodiments, the metalliferrous material 104 includes quantities of nickel, cobalt and iron. In such cases, for example, the metalliferrous material 104 includes between 10 weight % to 20 weight % nickel, based on the total weight of the metalliferrous material 104, and between 5 weight % and 10 weight % cobalt, based on the total weight of the metalliferrous material 104, and between 15 weight % and 35 weight % iron, based on the total weight of the metalliferrous material 104. As a further example, the metalliferrous material 104 includes between 11 weight % to 15 weight % nickel, based on the total weight of the metalliferrous material 104, and between 6 weight % and 7 weight % cobalt, based on the total weight of the metalliferrous material 104, and between 25 weight % and 32 weight % iron, based on the total weight of the metalliferrous material 104. For example, at least a fraction of the nickel provided in the metalliferrous material 104 is in the form of nickel sulphide, nickel sulphate and/or nickel ferrite, at least a fraction of the cobalt provided in the metalliferrous material 104 is in the form of at least one of cobalt ferrite, cobalt sulphide, cobalt sulphate, and/or cobalt oxide, and at least a fraction of the iron provided in the metalliferrous material 104 is in the form of goethite. As a further example, with respect to nickel, nickel is occluded within the metalliferrous material 104.

[0025] An x-ray diffraction analysis, of an exemplary metalliferrous material 104, illustrating its composition, is provided in Figure 7.

[0026] In some embodiments, each one of the at least one metalliferrous material-based target elemental metal includes a respective molar quantity such that at least one molar quantity of metalliferrous material-based target elemental metal is provided in the metalliferrous material 104, and each one of the at least one metalliferrous material-based non-target elemental metal includes a respective molar quantity such that at least one molar quantity of metalliferrous

material-based non-target elemental metal is provided in the metalliferrous material 104. The ratio of the sum of the at least one molar quantity of metalliferrous material-based target elemental metal to the sum of the at least one molar quantity of metalliferrous material-based non-target elemental metal is between 0.3 and 1.2. For example, the ratio is 0.7. In some embodiments, the at least one metalliferrous material-based target elemental metal is one of nickel and cobalt, and the at least one metalliferrous material-based non-target elemental metal is iron. In some embodiments, the at least one metalliferrous material-based target elemental metal is nickel and cobalt, and the at least one metalliferrous material-based non-target elemental metal is iron.

[0027] For example, with respect to the metalliferrous material 104, at least a fraction of the metalliferrous material 104 is derived from a precursor metalliferrous material source. The precursor metalliferrous material source includes at least one precursor metalliferrous source-based target elemental metal and at least one precursor metalliferrous material source-based non-target elemental metal. For example, the precursor metalliferrous material source is an ore, a concentrate, or any other metal-comprising material.

[0028] For example, with further respect to the precursor metalliferrous material source, the precursor metalliferrous material source is a sulphide concentrate. For example, the precursor metalliferrous material source in the form of a sulphide concentrate includes between 35 weight % to 55 weight % nickel, based on the total weight of the precursor metalliferrous material source, and between 1 weight % and 15 weight % cobalt, based on the total weight of the precursor metalliferrous material source, and between 1 weight % and 2.5 weight % iron, based on the total weight of the precursor metalliferrous material source. As a further example, the precursor metalliferrous material source in the form of a sulphide concentrate includes between 52 weight % to 55 weight % nickel, based on the total weight of the precursor metalliferrous material source, and between 6.8 weight % and 7.3 weight % cobalt, based on the total weight of the precursor metalliferrous material source, and between 1.3 weight % and 1.5 weight % iron, based on the total weight of the precursor metalliferrous material source. In some embodiments, the precursor metallifferous material also includes between 1.5 weight % to 2 weight % zinc, based on the total weight of the precursor metalliferrous material source, and between 0.1 weight % and 0.4 weight % copper, based on the total weight of the precursor

metalliferrous material source, and between 0.15 weight % and 0.25 weight % calcium, based on the total weight of the precursor metalliferrous material source, and between 0.1 weight % and 0.2 weight % silicon, based on the total weight of the precursor metalliferrous material source.

[0029] For example, with further respect to the precursor metalliferrous material source, the precursor metalliferrous material source includes nickel, cobalt, and iron, wherein each of nickel and cobalt is a precursor metallifferous material source-based target elemental metal, and wherein iron is a precursor metallifferous material source-based non-target elemental metal. The ratio of moles of nickel to moles of iron within the precursor metalliferrous material source is between 21.8 and 66.5. For example, the ratio of moles of nickel to moles of iron within the precursor metalliferrous material source is between 36.7 and 55.6. As a further example, the ratio of moles of nickel to moles of iron within the precursor metalliferrous material source is 44.2. The ratio of moles of cobalt to moles of iron within the precursor metalliferrous material source is between 2.50 and 7.07. For example, the ratio of moles of cobalt to moles of iron within the precursor metalliferrous material source is between 4.03 and 5.55. For example, the ratio of moles of cobalt to moles of iron within the precursor metalliferrous material source is 4.79.

[0030] For example, the precursor metalliferrous material source is conditioned such that any one of several characteristics of the precursor metalliferrous material source is modified to improve the suitability of the precursor metalliferrous material source for the leaching. Exemplary characteristics which could be modified include particle size and composition.

[0031] For example, the precursor metalliferrous material source is precursor metalliferrous material source particulate material, and the particle size of the precursor metalliferrous material source particulate material is characterized by an average D50 of 44 microns, as measured with a Horiba™ Analyzer. The surface area of the precursor metalliferrous material source particulate material is characterized by an average surface area of 2320 cm^2 / cm^3, measured with a Horiba™ Analyzer. For example, this average surface area is greater than 2400 cm^2 / cm^3.

[0032] For example, the precursor metalliferrous material source includes 55 weight % nickel, based on the total weight of the precursor metalliferrous material source source, and

includes 6 weight % cobalt, based on the total weight of the precursor metalliferrous material source, and includes 1 weight % iron, based on the total weight of the precursor metalliferrous material source, and the precursor metalliferrous material source is characterized by an average D50 of 60 microns, as measured with a Horiba™ Analyzer.

[0033] There is provided a process feed material 100 including the precursor metalliferrous material source. The process feed material 100 is leached with a preliminary treatment leachant in a preliminary leaching zone 10 to effect production of a preliminary operative product 102 including a preliminary operative solution and a preliminary operative solid residue. The preliminary operative solution includes at least one dissolved preliminary operative solution based target elemental metal, wherein at least one of the at least one dissolved preliminary operative solution-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal. At least a fraction of the preliminary operative residue is separated from the product to provide a separated preliminary operative solid residue. At least a fraction of the preliminary operative solution is separated from the preliminary operative product 102 to provide a product leachate 120 including the at least one dissolved preliminary operative solution-based target elemental metal. The product leachate 120 is then, in some embodiments, subjected to further treatment in a target metal recovery unit operation 22 to effect recovery of one or more target metals. For example, suitable processes for some embodiments of leaching of the process feed material are described in U.S. Patent No. 2,576,314.

[0034] In some embodiments, the process feed material 100, including the precursor metalliferrous material source, is leached with the preliminary leachant, wherein the leachant is an aqueous solution including 130 g/L of ammonia and 175 g/L ammonium sulphate. For example, the leaching is effected in the preliminary leaching zone 10, wherein the temperature of the preliminary leaching zone is between 240 °F and 250 °F, and the pressure within the preliminary leaching zone 10 is between 725 to 900 kPa.

[0035] The metalliferrous material 104 includes at least a fraction of the separated preliminary operative solid residue. Each one of the at least one metalliferrous material-based target elemental metal is a one of the at least one precursor metalliferrous material source-based

target elemental metal and is derived from the precursor metalliferrous material, and at least one of the at least one metalliferrous material-based non-target elemental metal is a one of the at least one precursor metalliferrous material source-based non-target elemental metal and is derived from the precursor metalliferrous material.

[0036] In some embodiments, prior to effecting solubilisation (described in further detail below) of at least a fraction of the metalliferrous material 104, the residue is washed with hot water in a filter to remove excess ammonium sulphate or ammonia. Such removal mitigates co-precipitation of ammonium sulphate with iron to form a ferrous sulphate / ammonium sulphate double salt during filtering of a solid residue from an intermediate product mixture after leaching of the metalliferrous material, as is described below. The filter which effects the filtering provides locations for seeding of the precipitation, and the precipitation may cause blinding of the filter. As well, removal of excess ammonia at this stage serves to reduce the amount of sulphuric acid used for neutralization.

(B) SOLUBILISING OF THE METALLIFERROUS MATERIAL

[0037] At least a fraction of the metalliferrous material 104 is solubilised so as to effect production of a solubilisation product. The solubilisation product includes an intermediate operative solution.

[0038] The intermediate operative solution includes a solvent component and a solute component. The solute component includes at least one dissolved intermediate operative solution-based target elemental metal comprising material and at least one dissolved intermediate operative solution-based non-target elemental metal comprising material. Each one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material includes at least one intermediate operative solution-based target elemental metal, and each one of the at least one intermediate operative solution-based target elemental metal is a one of the at least one metalliferrous material-based target elemental metal of the metalliferrous material 104 and is derived from the metalliferrous material 104. Each one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material includes at least one intermediate operative solution-based non-target elemental metal, and each one of the at least one intermediate operative solution-based non-target elemental metal is a one

of the at least one metalliferrous material-based non-target elemental metal of the metalliferrous material 104 and is derived from the metalliferrous material 104. In this respect, the intermediate operative solution includes at least one intermediate operative solution-based target elemental metal and at least one intermediate operative solution-based non-target elemental metal.

[0039] For example, a one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material is cobalt (II) sulphate ($CoSO_4$). As a further example, a one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material is nickel (II) sulphate ($NiSO_4$). In some embodiments, the at least one dissolved intermediate operative solution-based target elemental metal comprising material includes cobalt (II) sulphate and nickel (II) sulphate. For example, a one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material is iron (II) sulphate ($FeSO_4$). In some embodiments, the intermediate operative solution includes cobalt (II) sulphate, nickel (II) sulphate, and iron (II) sulphate.

[0040] For example, the solubilisation of at least a fraction of the metalliferrous material 104 is effected by leaching of the metalliferrous material 104. In this respect, the metalliferrous material 104 is contacted with an operative leachant in an operative leaching zone 14. For example, the operative leachant is an aqueous solution. Contacting of the metalliferrous material 104 with the leachant effects production of a product mixture 106 including the intermediate operative solution and an intermediate solid residue. The intermediate solid residue includes that fraction of the metalliferrous material 104 which is not solvated within the intermediate operative solution after the metalliferrous material 104 has been subjected to the leaching.

[0041] In some embodiments, the operative leachant includes at least one reductant. In this respect, the contacting of the metalliferrous material 104 with the operative leachant effects reduction of at least one operative metalliferrous material-based non-target elemental metal such that at least one reduced metalliferrous material-derived non-target elemental metal is provided, and at least one of the at least one reduced metalliferrous material-derived non-target elemental metal is a component of at least one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material. Each one of the at least one operative

metalliferrous material-based non-target elemental metal is a one of the at least one metalliferrous material-based non-target elemental metal. The contacting of the metalliferrous material 104 with the leachant also effects reduction of at least one operative metalliferrous material-based target elemental metal such that at least one reduced metalliferrous material-derived target elemental metal is provided, and at least one of the at least one reduced metalliferrous material-derived target elemental metal is a component of at least one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material. Each one of the at least one operative metalliferrous material-based target elemental metal is a one of the at least one metalliferrous material-based target elemental metal.

[0042] In some embodiments, the metalliferrous material 104 includes an iron-comprising material, and at least one of (i) a cobalt-comprising material, and (ii) a nickel-comprising material, and the metalliferrous material 104 is contacted with an operative leachant, wherein the operative leachant is an aqueous solution including a reductant. For example, in such embodiments, at least a fraction of any nickel-comprising material includes nickel sulphide, and at least a fraction of any cobalt-comprising material includes cobalt sulphide. An example of a suitable operative leachant is an aqueous solution of sulphuric acid and sulphur dioxide.

[0043] In some embodiments, the metalliferrous material includes goethite (FeOOH), cobalt (III) oxide (ie. Co_2O_3), and nickel in a form sequestered in a goethite (FeOOH) matrix, and the metalliferrous material 104 is contacted with an aqueous solution of sulphuric acid and sulphur dioxide in an operative leaching zone, and the contacting effects production of at least one target elemental metal comprising material including at least one of cobalt (II) sulphate (ie. $CoSO_4$) and nickel (II) sulphate (ie. $NiSO_4$) and at least one non-target elemental metal comprising materials including iron (II) sulphate (ie. $FeSO_4$). In this respect, the production of cobalt (II) sulphate (ie. $CoSO_4$), and iron (II) sulphate (ie. $FeSO_4$), is effected in accordance with the following reactive processes:

$$Fe_2O_3(s + SO_2(aq) + H_2SO_4(aq) \rightarrow 2FeSO_4(aq) + H_2O\ (l)$$

$$Co_2O_3(s) + SO_2(aq) + H_2SO_4(aq) \rightarrow 2CoSO_4(aq) + H_2O\ (l)$$

[0044] With respect to the nickel (II) sulphate ($NiSO_4$), it is believed that, in some cases, the nickel (II) sulphate is present and occluded within the metalliferrous material, and is then freed from occlusion when the metalliferrous material is solubilised (for example, leached).

[0045] For example, with respect to the reaction mechanisms shown above, one (1) mole of sulphur dioxide and one (1) mole of sulphuric acid are required in order to effect the production of two (2) moles of iron sulphate. The same relationship holds true in effecting the production of the cobalt sulphate. The nickel in the metalliferrous material does not require any sulphuric acid or sulphur dioxide as the nickel (II) sulphate is originally present and occluded within the metalliferrous material and is then freed from occlusion upon solubilising (for example, leaching) of the metalliferrous material 104. An excess of acid is required to neutralize any ammonia that is entrained within the metalliferrous material 104 which is being leached. Also, a slight excess of sulphur dioxide is required to compensate for any losses to atmosphere.

[0046] For example, with respect to the operative leaching zone 14 in which the above-described contacting is effected, the operative leaching zone 14 is disposed at a temperature of 85 degrees Celsius and atmospheric pressure. It is anticipated that the reactions proceed faster at higher temperatures and pressures.

[0047] In some embodiments, the contacting of the metalliferrous material 104 with an operative leachant effects production of an intermediate product mixture 106 including the intermediate operative solution and an intermediate solid residue. In some embodiments, the filtering of the intermediate solid residue from the intermediate product mixture 106 is effected soon after the leaching is effected so as to mitigate against obstructions effected by post-precipitation of fine material, such as elemental sulphur. For example, with respect to the intermediate solid residue, the composition of the residue includes nickel sulphide, cobalt sulphide, silica, alumina, and iron sulphide.

[0048] In some embodiments, at least a fraction of the intermediate solid residue is recovered and recycled such that at least a fraction of the process feed material includes the recycled intermediate solid residue 108. For example, the recovered intermediate solid residue 108 is recycled to the preliminary leaching zone 10. In this respect, at least a fraction of the intermediate solid residue is separated from the intermediate product mixture 106 to provide the

recovered intermediate solid residue 108. For example, the separation is effected in at least one solid-liquid separation unit operation 16.

[0049] In some embodiments, the intermediate solid residue includes at least one intermediate solid residue-based target elemental metal comprising material, wherein each one of the at least one intermediate solid residue-based target elemental metal includes at least one intermediate solid residue-based target elemental metal, and each one of the at least one intermediate solid residue-based target elemental metal is a one of the at least one metalliferrous material-based target elemental metal and is derived from the metalliferrous material. In such embodiments, at least a fraction of the intermediate solid residue is recovered and recycled such that at least a fraction of the process feed material includes the recycled intermediate solid residue 108, and thereby also includes the at least one intermediate solid residue-based target elemental metal. For example, the recovered intermediate solid residue 108 is recycled to the preliminary leaching zone 10. In this respect, at least a fraction of the intermediate solid residue is separated from the intermediate product mixture 106 to provide the recovered intermediate solid residue. For example, the separation is effected in at least one solid-liquid separation unit operation 16.

[0050] In some embodiments, the intermediate solid residue includes at least one intermediate solid residue-based target metal sulphide, and each one of the at least one intermediate solid residue-based target metal sulphide is derived from the precursor metalliferrous material source. In this respect, the precursor metalliferrous material source includes at least one precursor metalliferrous material source-based target metal sulphide, wherein each one of the at least one precursor metalliferrous material source-based target metal sulphide includes a precursor metalliferrous material source metal sulphide-based target elemental metal, wherein the precursor metalliferrous material source metal sulphide-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal. The precursor metalliferrous material source is included in the process feed material 100 which is leached by the preliminary treatment leachant in the preliminary leaching zone 10. As described above, leaching of the process feed material 100 effects production of a preliminary operative product 102 including a preliminary operative solution and preliminary operative solid residue. In some embodiments, the preliminary leach solid residue

includes at least one preliminary operative solid residue-based target metal sulphide, wherein each one of the at least one preliminary operative solid residue-based target metal sulphide is a one of the at least one precursor metalliferrous material source-based target metal sulphide and is derived from the precursor metalliferrous material. Each one of the at least one preliminary operative solid residue-based target metal sulphide includes at least one preliminary operative solid residue target metal sulphide-based target elemental metal, wherein each one of the at least one preliminary operative residue target metal sulphide-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal. At least a fraction of the preliminary operative solid residue is separated from the preliminary operative product by at least one solid-liquid separation unit operation 12. For example, the at least one unit operation is a lamella thickener and filtration, and the separation is effected by the lamella thickener and filtration, in series. The metalliferrous material 104 includes at least a fraction of the separated preliminary operative solid residue. In this respect, the metalliferrous material 104 includes at least one metalliferrous material-based target metal sulphide, wherein each one of the at least one metalliferrous material-based target metal sulphide is a one of the at least one preliminary operative solid residue-based target metal sulphide and is also, therefore, a one of the at least one precursor metalliferrous material source-based target metal sulphide, and is derived from the precursor metalliferrous material. Each one of the at least one metalliferrous material-based target metal sulphide includes at least one metalliferrous material target metal sulphide-based target elemental metal which is a one of the at least one metalliferrous material-based target elemental metal (and which is also a one of the at least one precursor metalliferrous material source-based target elemental metal). In this respect, each one of the at least one intermediate solid residue-based target metal sulphide includes at least one intermediate solid residue target metal sulphide-based target elemental metal, and each one of the at least one intermediate solid residue target metal sulphide-based target elemental metal is a one of the at least one metalliferrous material target metal sulphide-based target elemental metal. In some of these embodiments, at least one of the at least one intermediate solid residue target metal sulphide-based target elemental metal is the same target elemental metal as a one of the at least one dissolved intermediate operative solution-based target elemental metal. At least a fraction of the intermediate solid residue is recovered and recycled such that at least a fraction of the process feed material includes the recycled intermediate solid residue 108, and thereby also includes the

at least one intermediate solid residue-based target metal sulphide. For example, the recovered intermediate solid residue 108 is recycled to the preliminary leaching zone 10. In this respect, at least a fraction of the intermediate solid residue is separated from the intermediate product mixture 106 to provide the recovered intermediate solid residue 108, and also to provide an operation feed 110, including the intermediate operative solution, which is then introduced to the reaction zone 18, as will be described in further detail below. For example, the separation is effected in at least one solid-liquid separation unit operation 16. In some of these embodiments, the at least one intermediate solid residue-based target metal sulphide of the recycled intermediate solid residue is at least one of nickel sulphide and cobalt sulphide.

[0051] In some embodiments, the metalliferrous material 104 includes a relatively high concentration of the at least one metalliferrous material based target metal sulphide. In some of these embodiments, this is attributable to a relatively high concentration of the at least one precursor metalliferrous material source-based target metal sulphide, and that an appreciable fraction of the at least one precursor metalliferrous material source-based target metal sulphide of the precursor metalliferrous material source remains unaffected by the leaching of the process feed material 100 in the preliminary leaching zone 10 (in some embodiments, this is referred to as "underleaching", and is an indication that the leaching zone 10 is being overfed) such that the preliminary leach solid residue whose production is effected by the leaching of the process feed material 100 includes a relatively high concentration of the at least one preliminary leach solid residue-based target metal sulphide, and this translates to a relatively high concentration of the at least one metalliferrous material based target metal sulphide. In those embodiments where the metalliferrous material 104 includes a relatively high concentration of the at least one metalliferrous material based target metal sulphide, the intermediate solid residue whose production is effected by the leaching of the metalliferrous material includes a relatively high concentration of the at least one intermediate solid residue-based target metal sulphide. In such cases, the separation of the at least a fraction of the intermediate solid residue from the intermediate product mixture is effected by at least one solid-liquid separation unit operation 16. For example, the separation is effected by a lamella thickener and filtration, in series. In some of these embodiments, when the metalliferrous material includes silica, the practising of these embodiments may effect an internal recycle of silica and, thereby, effect a build-up of silica which may be undesirable. This may, therefore, require intermittent bleeding of silica from the

process or an adjustment to the throughput of the process feed material 100 through the leaching zone 10. It is understood, however, that this underleaching (or "overfeeding") scenario is a rare situation, and when it does occur, steps are taken to correct the situation. Figure 8 is illustrative of the "underleaching" embodiments.

[0052] In some embodiments, the metalliferrous material 104 includes an intermediate concentration of the at least one metalliferrous material based target metal sulphide. In some of these embodiments, this is attributable to an intermediate concentration of the at least one precursor metalliferrous material source-based target metal sulphide, and that a fraction, intermediate to the relatively high fraction and the relatively low fraction, of the at least one precursor metalliferrous material source-based target metal sulphide of the precursor metalliferrous material source remains unaffected by the leaching of the process feed material 100 in the preliminary leaching zone 10 such that the preliminary leach solid residue whose production is effected by the leaching of the process feed material 100 includes an intermediate concentration of the at least one preliminary leach solid residue-based target metal sulphide, and this translates to an intermediate concentration of the at least one metalliferrous material based target metal sulphide. In those embodiments where the metalliferrous material 104 includes an intermediate concentration of the at least one metalliferrous material based target metal sulphide, the intermediate solid residue whose production is effected by the leaching of the metalliferrous material 104 includes an intermediate concentration of the at least one intermediate solid residue-based target metal sulphide. In such cases, the at least one unit operation 16 which effects separation of the at least a fraction of the intermediate solid residue from the intermediate product mixture includes flotation 16A. Flotation 16A is used in such cases in order to provide a more concentrated recovered intermediate solid residue fraction 108 for recycle to the preliminary leaching zone 10. The floatation 16A effects production of a floated concentrate 1062 and tailings material 1064. The floated concentrate 1062 includes an intermediate solid residue component and a liquid component. The intermediate solid residue component of the floated concentrate 1062 is at least a fraction of the intermediate solid residue of the intermediate product mixture 106. At least a fraction of the intermediate solid residue component of the floated concentrate 1062 (and, therefore, at least a fraction of the intermediate solid residue of the product mixture 106) is recovered and recycled such that at least a fraction of the process feed material 100 includes the recycled intermediate solid residue 108. In this respect, at least a

fraction of the intermediate solid residue component is separated from the floated concentrate 1062 in a solid-liquid separation unit operation 16B (such as a mechanical filtration unit operation) to provide the recovered intermediate solid residue 108, which is then recycled to the preliminary leaching zone 10, and also to provide a filtrate 1066 which is combined with the tailings material 1064 to form the operative feed 110 to the reaction zone 18. Figure 9 is illustrative of such embodiments.

[0053] In some embodiments, the metalliferrous material 104 includes a relatively low concentration of the at least one metalliferrous material based target metal sulphide. In some of these embodiments, this is attributable to a relatively low concentration of the at least one precursor metalliferrous material source-based target metal sulphide, and that an appreciable fraction of the at least one precursor metalliferrous material source-based target metal sulphide of the precursor metalliferrous material source is solubilised by the leaching of the process feed material 100 in the preliminary leaching zone 10 (in some embodiments, this is referred to as "overleaching", and is an indicator that the leaching zone 10 is being underfed) such that the preliminary leach solid residue whose production is effected by the leaching of the process feed material 100 includes a relatively low concentration of the at least one preliminary leach solid residue-based target metal sulphide, and this translates to a relatively low concentration of the at least one metalliferrous material based target metal sulphide. In those embodiments where the metalliferrous material 104 includes a relatively low concentration of the at least one metalliferrous material based target metal sulphide, the intermediate solid residue whose production is effected by the leaching of the metalliferrous material 104 includes a relatively low concentration of the at least one intermediate solid residue-based target metal sulphide. In some of these cases, it is not economically justifiable to effect separation of the at least a fraction of the intermediate solid residue from the intermediate product mixture and then effect its recycle to the preliminary leaching zone 10. In such cases, the intermediate product mixture 106 is provided as the operative feed 110 to the reaction zone 18 so as to effect contact between the intermediate operative solution and at least one reagent material system, as will be further described below. Figure 10 is illustrative of such embodiments.

[0054] In some embodiments, depending on the relative concentration of the at least one precursor metalliferrous material source-based target metal sulphide, any one of the

embodiments of the method illustrated in Figures 8, 9, and 10 is selected. In this respect, an indication of the relative concentration of the at least one precursor metalliferrous material source-based target metal sulphide is based upon a combination of a measured concentration of a one of the at least one metalliferrous material-based target elemental metal and a measured concentration of a one of the at least one metalliferrous material-based non-target elemental metal. In this respect, if the concentration of the metalliferrous material-based target elemental metal whose concentration is being measured is greater than a pre-determined value and the concentration of the metalliferrous material-based non-target elemental metal whose concentration is being measured is less that a predetermined value, this is an indication of a relatively high concentration of the metalliferrous material-based target metal sulphide, and an embodiment of the method illustrated in Figure 8 is selected. If the concentration of the metalliferrous material-based target elemental metal whose concentration is being measured is less than a pre-determined value and the concentration of the metalliferrous material-based non-target elemental metal whose concentration is being measured is greater than a pre-determined value, this is an indication of a relatively low concentration of the at least one metalliferrous material-based target metal sulphide, and an embodiment of the method illustrated in Figure 10 is selected. Otherwise, an embodiment of the method illustrated in Figure 9 is selected.

C. CONTACTING THE INTERMEDIATE OPERATIVE SOLUTION WITH AN OPERATIVE REAGENT, AND FACILITATING RECOVERY OF THE TARGET ELEMENTAL METAL

[0055] The intermediate operative solution is contacted with reagent material in the reaction zone 18.

[0056] In this respect, reagent material is provided in the reaction zone 18. The reagent material includes at least one precipitation agent material and at least one complexing agent material.

[0057] Each one of the at least precipitation agent material is configured to react with at least one of the at least one dissolved intermediate operative solution-based elemental metal comprising material when the intermediate operative solution is contacted with the reagent material so as to effect production of at least one solid residue component-based elemental metal

comprising solid material. For any reaction of a dissolved intermediate operative solution-based target elemental metal comprising material with a precipitation agent material, there is effected production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material. For any reaction of a dissolved intermediate operative solution-based non-target elemental metal comprising material with a precipitation agent material, there is effected production of at least one solid residue component-based non-target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material.

[0058] Each one of the at least complexing agent material is configured to react with at least one of the at least one dissolved intermediate operative solution-based elemental comprising material when the intermediate operative solution is contacted with the reagent material so as to effect production of at least one product solution component-based elemental metal comprising dissolved complex material. For any reaction of a dissolved intermediate

operative solution-based target elemental metal comprising material with a complexing agent material, there is effected production of at least one product solution component-based target elemental metal comprising dissolved complex material, wherein each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material. For any reaction of a dissolved intermediate operative solution-based non-target elemental metal comprising material with a complexing agent material, there is effected production of at least one product solution component-based non-target elemental metal comprising dissolved complex material, wherein each one of the at least one product solution component-based non-target elemental metal comprising dissolved complex material includes at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material.

[0059] There is also provided at least one operative dissolved intermediate operative solution-based target elemental metal comprising material. The at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative

dissolved intermediate operative solution-based target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material. Each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is configured to react with at least one of the at least one precipitation agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material. Each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is also configured to react with at least one of the at least one complexing agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material, wherein each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, and such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material.

[0060] There is also provided at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material, wherein the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material. Each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is configured to react at least with at least one of the at least one precipitation agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based non-target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material.

[0061] The intermediate operative solution is contacted with the reagent material in the reaction zone 18, such that production of a product mixture is effected. The product mixture includes a product solution component and a solid residue component. The product solution component includes the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal and any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal. The solid residue component includes the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal and the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal.

[0062] With respect to the product solution component, there is provided a respective molar quantity of each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal such that at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity is provided. There is also provided a molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal. The ratio of (A1) the sum of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity to (B1) the molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is defined by R1.

[0063] With respect to the solid residue component, there is provided a molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal. There is also provided a respective molar quantity of each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal such that at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is provided. The ratio of (A2) the molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal to (B2) the sum of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is defined by R2.

[0064] R1 is greater than R2. For example, R1/R2 is greater than 1000. As a further example R1/R2 is greater than 100,000. As a further example, R1/R2 is greater than 1,000,000.

[0065] In some embodiments, the contacting of the intermediate operative solution with the reagent material in the reaction zone effects,:

(i) reaction of each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based non-target elemental metal comprising solid material, wherein each one of the at least

one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material ; and

(ii) reaction of each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material with at least one of the at least one complexing agent material to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material, wherein each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material;

such that the product solution component includes the at least one produced product solution component-based target elemental metal comprising dissolved complex material, and the solid residue component includes the at least one produced solid residue component-based non-target elemental metal comprising solid material.

[0066] In some embodiments, the contacting of the intermediate operative solution with the reagent material in the reaction zone 18 effects circumstances wherein there is provided a material propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to effect reaction with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material

[0067] In some embodiments, the contacting of the intermediate operative solution with the reagent material in the reaction zone 18 effects circumstances wherein there is provided a material propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to effect reaction with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is

derived from the metalliferrous material, and wherein there exists a material propensity for at least one of the at least one produced solid residue component-based target elemental metal comprising solid material to co-precipitate with at least one of the at least one solid residue component-based non-target elemental metal comprising solid material.

[0068] In some embodiments, the contacting of the intermediate operative solution with the reagent material in the reaction zone 18 effects circumstances wherein there is provided a material propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to effect reaction with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material. There exists a material propensity for at least a fraction of the at least one solid residue component-based target elemental metal comprising solid material to become occluded within an agglomerate of the solid residue component.

[0069] In some embodiments, there is insubstantial propensity for at least one of the at least one at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material to react with any one of the at least one complexing agent when the intermediate operative solution is contacted with the reagent material. For example, there is insubstantial propensity for each one of the at least one at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material to react with any one of the at least one complexing agent when the intermediate operative solution is contacted with the reagent material.

[0070] In some embodiments, the contacting of the intermediate operative solution with the reagent material in the reaction zone effects reaction of each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material. Each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material. In this respect, the solid residue component includes the at least one solid residue component-based target elemental metal comprising solid material. Also, in this respect, there is provided a respective molar quantity of each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal such that at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal molar quantity is provided, and wherein the molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental is the sum of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal molar quantity, such that the ratio, R2, is defined as the ratio of (A2) the sum of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal molar quantity to (B2) the sum of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity.

[0071] For example, in those embodiments (which are described immediately above) where the contacting of the intermediate operative solution with the reagent material in the reaction zone effects reaction of each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, at least one of the at least one produced solid residue component-based target elemental metal comprising solid material is co-precipitated with at least one of the at least one solid residue component-based non-target elemental metal comprising solid material. As a further example, the solid residue component includes the at least one solid residue component-based target elemental metal comprising solid material, and at least a fraction of the solid residue component includes an agglomerate, and at least a fraction of the at least one solid residue component-based target elemental metal comprising solid material is occluded within the agglomerate.

[0072] Figures 11 and 12 are x-ray diffraction analyses of exemplary solid residue components which are produced after contacting the intermediate operative solution (including dissolved nickel, cobalt, and iron materials) with the at least one reagent system (aqueous ammonia solution).

[0073] In some embodiments, with respect to the reagent material, the ratio of (i) moles of the at least one complexing agent material to (ii) moles of the at least one precipitation agent material is controlled above a predetermined value. For example, the ratio of (i) moles of the at least one complexing agent material to (ii) moles of the at least one precipitation agent material is greater than 700.

[0074] In some embodiments, there is provided a respective molar quantity of each one of the at least one operative intermediate operative solution-based target elemental metal in the reaction zone such that at least one operative target elemental metal molar quantity is provided in the reaction zone. There is also provided a respective molar quantity of each one of the at least one complexing agent material in the reaction zone such that at least one complexing agent molar quantity is provided in the reaction zone. In the reaction zone, the ratio of (A) the sum of the at least one complexing agent molar quantity to (B) the sum of the at least one operative

target elemental metal molar quantity is at least 5:1. For example, the ratio is at least 6:1. As a further example, the ratio is at least 8:1.

[0075] In some embodiments, the reagent material is at least one reagent material system, wherein each one of the at least one reagent material system includes a respective at least two material states, wherein a fraction of each one of the at least one reagent material system is disposed in a one of the respective at least two material states and another fraction of each one of the at least one reagent material system is disposed in another one of the respective at least two material states, and wherein, for each one of the at least one reagent material system, the one of the respective at least two material states includes a precipitation agent material and the another one of the respective at least two material states includes a complexing agent material, such that the at least one reagent material system provides at least one precipitation agent material and at least one complexing agent material. For each one of the at least one reagent material system, transformation between the one of the respective at least two material states and the another one of the respective at least two material states is effected in response to a driving force provided for effecting thermodynamic equilibrium between the one of the respective at least two material states and the another one of the respective at least two material states. An example of such a reagent material system is an aqueous ammonia solution. In this respect, the precipitation agent material for a one of the material states of the aqueous ammonia solution is hydroxide ion (OH^-), and the complexing agent of another one of the material states of the aqueous ammonia solution is ammonia (NH_3).

[0076] In some embodiments, the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is at least one of cobalt (II) sulphate ($CoSO_4$) and nickel (II) sulphate ($NiSO_4$). In such embodiments, the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is iron (II) sulphate ($FeSO_4$). At least a fraction of the intermediate operative solution of such embodiments is contacted with reagent material in a reaction zone. In this respect, for example, the reagent material is aqueous ammonia solution, wherein the complexing agent material is ammonia (NH_3) and the precipitation agent material is hydroxide ion (OH^-). Ammonia and hydroxide ion are disposed in the following equilibrium in aqueous solution:

$$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$$

[0077] The contacting effects production of a product mixture including a product solution component and a solid residue component. When an operative dissolved intermediate operative solution-based target elemental metal comprising material in the reaction zone is cobalt (II) sulphate ($CoSO_4$), the solution product includes $Co(NH_3)_6SO_4$. When an operative dissolved intermediate operative solution-based target elemental metal comprising material in the reaction zone is (II) sulphate ($NiSO_4$), the solution product includes $Ni(NH_3)_6SO_4$. Each one of $Co(NH_3)_6SO_4$ and $Ni(NH_3)_6SO_4$ is a product solution component-based target elemental metal comprising dissolved complex material. The reactive processes which effect the production of each one of $Co(NH_3)_6SO_4$ and $Ni(NH_3)_6SO_4$ respectively proceed in accordance with the following reactive processes:

$$CoSO_4(aq) + 6NH_3(aq) \rightarrow Co(NH_3)_6SO_4(aq)$$

$$NiSO_4(aq) + 6NH_3(aq) \rightarrow Ni(NH_3)_6SO_4(aq)$$

[0078] With respect to the iron sulphate, in some embodiments, substantially none of the iron forms an ammonia complex when the intermediate operative solution is contacted with reagent material in a reaction zone.

[0079] As mentioned above, the contacting also effects production of a solid residue component. The solid residue component includes at least one produced solid residue component-based non-target elemental metal comprising solid material, and, in this case, the at least one produced solid residue component-based non-target elemental metal comprising solid material is ferrous hydroxide ($Fe(OH)_2$). The reactive process which effects production of ferrous hydroxide ($Fe(OH)_2$) is as follows:

$$FeSO_4(aq) + 2NH_4OH(aq) \rightarrow Fe(OH)_2(s) + (NH_4)_2SO_4(aq)$$

[0080] There is also a propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to react with the precipitation agent material to effect production of a solid residue component-based target elemental metal comprising solid material. When an operative dissolved intermediate operative

solution-based target elemental metal comprising material in the reaction zone is cobalt (II) sulphate ($CoSO_4$), the cobalt (II) sulphate includes a propensity to react with the hydroxide ion of the ammonia solution to effect production of a solid residue component-based target elemental metal comprising solid material in the form of cobalt hydroxide ($Co(OH)_2$), in accordance with the following reactive process:

$$CoSO_4\,(aq) + 2NH_4OH\,(aq) \rightarrow Co(OH)_2\,(s) + (NH_4)_2SO_4\,(aq)$$

[0081] When an operative dissolved intermediate operative solution-based target elemental metal comprising material in the reaction zone is nickel (II) sulphate ($NiSO_4$), the nickel (II) sulphate includes a propensity to react with the hydroxide ion of the ammonia solution to effect production of a solid residue component-based target elemental metal comprising solid material in the form of nickel hydroxide ($Ni(OH)_2$), in accordance with the following reactive process:

$$NiSO_4\,(aq) + 2NH_4OH\,(aq) \rightarrow Ni(OH)_2\,(s) + (NH_4)_2SO_4\,(aq)$$

[0082] In some embodiments, when the at least one solid residue component-based target elemental metal comprising solid material (for example, at least one of cobalt hydroxide and nickel hydroxide) is produced, the at least one solid residue component-based target elemental metal comprising solid material co-precipitates with the solid residue component-based non-target elemental metal comprising solid material (for example, in the form of $Fe(OH)_2$). Also, in some embodiments, when the at least one solid residue component-based target elemental metal comprising solid material (for example, at least one of cobalt hydroxide and nickel hydroxide) is produced, the at least solid residue component-based target elemental metal comprising solid material is occluded within an agglomerate, wherein the agglomerate primarily comprises the solid residue component-based non-target elemental metal comprising solid material (for example, in the form of $Fe(OH)_2$). If sufficient concentration of complexing agent material (for example, in this case, ammonia) is provided uniformly throughout the reaction zone, the co-precipitation or the occlusion is at least mitigated. In such cases, even if the solid residue component-based target elemental metal comprising solid material is produced, if there is sufficient ammonia concentration in the immediate vicinity where the solid residue component-based target elemental metal comprising solid material is produced, the solid residue

component-based target elemental metal comprising solid material is likely to convert to a respective product solution component-based target elemental metal comprising dissolved complex material before becoming occluded within an agglomerate and before co-precipitating with the iron hydroxide. In order to mitigate against sub-zones (within the reaction zone) of low ammonia concentration, the reaction is subjected to mixing, such as turbulent mixing, so as to facilitate uniformity of sufficient ammonia concentration throughout the reaction zone, and thereby provide conditions whereby any produced solid residue component-based target elemental metal comprising solid material is quickly converted to a product solution component-based target elemental metal comprising dissolved complex material (for example, $Co(NH_3)_6SO_4$ and/or $Ni(NH_3)_6SO_4$), before there is an opportunity to occlude the produced solid residue component-based target elemental metal comprising solid material in an agglomerate and before there is an opportunity for the produced solid residue component-based target elemental metal comprising solid material to co-precipitate with the solid residue component-based non-target elemental metal comprising solid material.

[0083] In some embodiments, in order to also mitigate against the co-precipitation or occlusion of at least one of the cobalt hydroxide and the nickel hydroxide, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion in the reaction zone is controlled above a predetermined value. For example, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is at least 700.

[0084] In some embodiments, in order to also mitigate against the co-precipitation or occlusion of at least one of the cobalt hydroxide and the nickel hydroxide, the concentration of aqueous ammonia in the reaction zone is at least 180 grams per litre.

[0085] In some embodiments, in order to also mitigate against the co-precipitation or occlusion of at least one of the cobalt hydroxide and the nickel hydroxide, there is provided a respective molar quantity of each one of the at least one intermediate operative solution-based target elemental metal in the reaction zone 18 such that at least one target elemental metal molar quantity is provided in the reaction zone 18 (if cobalt and nickel are the only target metal, then there are two values, and one value is the number of moles of cobalt in the reaction zone, and the second value is the number of moles of nickel in the reaction zone), and the ratio of moles of

aqueous ammonia in the reaction zone to the sum of the at least one target elemental metal molar quantity in the reaction zone (if cobalt or nickel is the only target elemental metal, then this value is the number of moles of cobalt or nickel in the reaction zone, and if both cobalt and nickel are target elemental metals, then this value is the sum of the number of moles of cobalt and the number of moles of nickel) is at least 5:1. For example, this ratio is at least 6:1. As a further example, this ratio is at least 8:1.

[0086] For example, with respect to the contacting of the intermediate operative solution with the reagent material in the reaction zone 18, the reaction zone 18 is disposed in a reaction vessel, and the reagent material is flowed into the reaction vessel to effect the contacting of the intermediate operative solution with the reagent material in the reaction zone 18. In this manner, the reagent material is replenished within the reaction zone 18 to maintain a pre-determined minimum concentration of ammonia in the reaction zone 18.

[0087] For example, after the contacting with the reagent material to effect production of the product mixture 112, the product mixture 112 is then contacted with an operative reagent to react with at least one of the at least one solid residue component-based non-target elemental metal comprising solid material to effect production of a treated product mixture 114 including at least one converted solid residue component-based non-target elemental metal comprising solid material, wherein each one of the at least one converted solid residue component-based non-target elemental metal comprising solid material includes faster settling characteristics relative to the at least one solid residue component-based non-target elemental metal comprising solid material from which the respective one of the at least one converted solid residue component-based non-target elemental metal comprising solid material is derived.

[0088] For example, the operative reagent includes oxygen (O_2), and the oxygen reacts with the produced ferrous hydroxide ($Fe(OH)_2$) to produce ferric oxide (Fe_2O_3) in accordance with the following reaction mechanism:

$$2Fe(OH)_2(s) + \tfrac{1}{2}O_2(aq) \rightarrow Fe_2O_3(s) + 2H_2O(l)$$

[0089] The produced ferric oxide (Fe_2O_3) is, in general, in the form of larger particles than the ferrous hydroxide ($Fe(OH)_2$) which is subjected to the reactive process to produce the

ferric oxide. In this respect, the produced ferric oxide is easier to separate from the intermediate mixture product by mechanical filtration than is the ferrous hydroxide. As well, the ferric oxide is more stable than the ferrous hydroxide in air.

[0090] For example, the oxygen is introduced into the reaction zone 18 by flowing a mixture of ammoniated air into the reaction zone 18 of the reaction vessel. For example, the composition of the ammoniated air mixture is sufficient such that ammonia is not significantly depleted within the reaction zone so as to compromise the desired conversion of any one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to a respective at least one product solution component-based target elemental metal comprising dissolved complex material.

[0091] For example, with respect to contacting of the intermediate operative solution with the reagent material in the reaction zone 18, this is effected at room temperature and atmospheric pressure.

[0092] In some embodiments, at least a fraction of the product solution component is recovered from the product mixture 112, and is subjected to further treatment to effect recovery of at least one of the at least one product solution component-based target elemental metal comprising dissolved complex material. In this respect, for example, at least a fraction of the product solution component is separated from the product mixture 112 in at least one sold-liquid separation unit operation 20 (for example, the solid-liquid separation unit operation 20 is a mechanical filtration unit operation) to thereby provide a recovered product solution component 116 and also provide tailings 118. The recovered product solution component 116 includes the at least one product solution component-based target elemental metal comprising dissolved complex material. In some embodiments, the recovered product solution component 116 is recycled to the leaching zone 10 and thereby forms at least a fraction of the process feed material 100. In such cases, the respective at least one target elemental metal of each one of the at least one product solution component-based target elemental metal comprising dissolved complex material of the recovered product solution component 116 remains solvated within the leaching zone 10 and is discharged from the leaching zone 10 in the product leachate 120 and is then

subjected to further treatment in the target metal recovery unit operation 22 to effect recovery of the one or more target metals.

D. EXAMPLES

[0093] Embodiments of the present invention will be described in further detail with reference to the following non-limitative examples.

Example No. 1

(a) Solubilization of metalliferrous material: H_2SO_4/SO_2 Leach

[0094] 1600 grams wet filter cake (53.4% moisture), the composition of which is specified in Table 1, prepared from a lamellae thickener underflow were combined with 1600 mls of water in a 3.8 liter titanium lined batch autoclave. The autoclave was equipped with a recirculation loop into which sulphur dioxide gas could be injected. The recirculation loop was also equipped with Oxidation-reduction potential ("ORP") and pH electrodes. The autoclave was also set up so as to allow injection of concentrated sulphuric acid (See Figure 1).

[0095] The autoclave was sealed and the circulation loop was started at a flow rate of approximately 350 mls/min. Sulphur dioxide gas was injected into the recirculation loop at a rate of approximately 275 to 300 mls/min. Sulphuric acid was injected into the autoclave so as to maintain a pH of 1.8. The ORP and pressure in the autoclave were monitored. In a typical reaction, the ORP would decrease from about 400 mV to 40 mV and the pressure in the autoclave would rise to about two (2) psig. The reaction time was in the order of 100 minutes.

[0096] The pressure rise was taken as an indication that the reaction was complete and further addition of sulphur dioxide and sulphuric acid were discontinued. The contents of the autoclave were then filtered. At this stage, filtration proceeded significantly faster than the original filtration to produce the cake used in the initial charge.

[0097] At this stage, samples of the solids and the solution were collected and submitted for analysis. The assay results are shown in Figure 2.

(b) Contacting of Intermediate Operative Solution with Reagent: Air/Ammonia Precipitation Of Iron

[0098] 825 mls of solution from the H_2SO_4/SO_2 leach were then collected and added over a period of 5 minutes to rapidly stirred 675 millilitres of aqueous ammonia solution (164 g/L NH_3). This ensured that there is always an excess of ammonia present in the reactor. Ammoniated air was prepared by passing air through a solution of 110 g/L aqueous ammonia. As the ammonia in the aqueous ammonia depleted it was topped up by the addition of 30 millilitres of concentrated ammonium hydroxide solution every 30 minutes. The ammoniated air was sparged into the blend of H_2SO_4/SO_2 leach solution and the aqueous ammonia solution (see Figure 3). The air addition was maintained for 5.5 hours during which time the ORP increased from –641 to –30 mV. The provided air effects conversion of ferrous hydroxide to goethite, which is relatively more stable in air and easier to filter than ferrous hydroxide. The typical molar ratio of ammonia to total metals at the end of the process was about 8 and the ammonium sulphate concentration was approximately 88 g/L.

[0099] The air was discontinued and the slurry was filtered. The assay results are shown in Figure 4. As was the case with the residue from the leach step, the product slurry filtered faster than the original slurry from the lamellae thickener underflow.

(c) Oxygen/Ammonia Leach Of Residue From Reduction Leach

[00100] The residue from the first H_2SO_4/SO_2 leach can be fed to a second ammonia leach circuit, thereby effecting recycling of the H_2SO_4/SO_2 leach residue. A leach test was performed on pooled sample of residues from two reduction leaches of lamellae thickener underflow solids. The assays of the feed solids and the leach residues are shown in Figure 5. Extraction calculations, using an iron tie, show that the majority of the nickel and cobalt are leachable. An XRD analysis of the residue shows that it is primarily quartz and nickel oxide (see Figure 6). Since it is unlikely that the nickel oxide was formed in either the reduction leach of the ammonia leach there is a strong chance that it originated with the feed into the refinery.

Example No. 2

[00101] This example is illustrative of the fact that the subject method can be easily adapted to changes in the composition of the pre-cursor metalliferrous material source. Changes in the composition of the precursor metalliferrous material source and, therefore, the metalliferrous material, can have an impact on the mass balance of the process. This is because there are two paths by which some of the target elemental metals (eg. nickel and cobalt) can be recovered. If the target elemental metal is sulphidic, then it is not solubilized when the metalliferrous material is leached with the aqueous reductant and, therefore, is recovered by recycling the leach residue to the step which effects leaching of the process feed material (including the precursor metalliferrous material source). If the target elemental metal is oxidic, it is recovered by leaching the metalliferrous material with an aqueous reductant.

[00102] Experiments were conducted using the experimental set-up for Example 1, using a metalliferrous material with a relatively low metal sulphide content and a metalliferrous material with a relatively high metal sulphide content. The table in Figure 13 illustrates that when there are relatively few metal sulphides in the metalliferrous material being leached (as evidenced by an iron content of 33%) there are relatively high recoveries of the target elemental metals through solubilization (see column entitled "Extraction to Reductive Leach Solution"). On the other hand, when the metal sulphide content is relatively high in the metalliferrous material (see the table in Figure 14), the overall recoveries of the target elemental metals through solubilization drops off substantially (see column entitled "Extraction to Reductive Leach Solution"), but a significant fraction of the target elemental metals in the metalliferrous material report to the residue arising from the leaching of the metalliferrous material. In the experiment with relatively high metal sulphide content metalliferrous material, the concentrations of the nickel and cobalt in the residue from the leaching of the metalliferrous material are, respectively, 29.8% and 5.75%. This indicates that the residue is rich in unleached metal sulphides. The leaching of the residue using ammonia solution effects extraction of the target metal sulphides, as illustrated in the column entitled "Extraction in Ammonia Leach of Residue" in the table of Figure 14, and contributes to a relatively high overall recovery of the target elemental metals (see column "Overall Recovery").

[00103] The table in Figure 15 illustrates assays for both the original metalliferrous material feed to the reductive leach process along with the assays of the reductive leach solution

and the solution (ie. the "iron precipitation solution") produced during the step where the reductive leach solution is contacted with the at least one reagent system (to effect iron precipitation) for a metalliferrous material feed with low metal sulphide content.

[00104] The assays of the final residue to tailings solids show that overall the solids discharged to tailings are substantially depleted in nickel and cobalt.

[00105] In some embodiments, the iron precipitation reaction may be similar enough to that in some existing ammonia leach plants with respect to deportment of impurities that no further processing is required for removal of impurities such as manganese and chromium.

[00106] It will be understood, of course, that modifications can be made in the embodiments of the invention described herein without departing from the scope and purview of the invention as defined by the appended claims.

CLAIMS:

1. A method of treating a metalliferrous material, comprising:

providing a metalliferrous material including at least one metalliferrous material-based target elemental metal and at least one metalliferrous material-based non-target elemental metal;

solubilising at least a fraction of the metalliferrous material so as to effect production of a solubilisation product including an intermediate operative solution, wherein the intermediate operative solution includes a solvent component and a solute component, and wherein the solute component includes at least one dissolved intermediate operative solution-based elemental metal comprising material, and wherein the at least one dissolved intermediate operative solution-based elemental metal comprising material includes at least one dissolved intermediate operative solution-based target elemental metal comprising material and at least one dissolved intermediate operative solution-based non-target elemental metal comprising material such that each one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based elemental metal comprising material and each one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based elemental metal comprising material, wherein each one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material includes at least one intermediate operative solution-based target elemental metal and wherein each one of the at least one intermediate operative solution-based target elemental metal is a one of the at least one metalliferrous material-based target elemental metal of the metalliferrous material and is derived from the metalliferrous material, and wherein each one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material includes at least one intermediate operative solution-based non-target elemental metal and wherein each one of the at least one intermediate operative solution-based non-target elemental metal is a one of the at least one metalliferrous material-based non-target elemental metal of the metalliferrous material and is derived from the metalliferrous material, such that the intermediate operative solution includes at least one

intermediate operative solution-based target elemental metal and at least one intermediate operative solution-based non-target elemental metal;

providing reagent material including at least one precipitation agent material and at least one complexing agent material;

wherein each one of the at least precipitation agent material is configured to react with at least one of the at least one dissolved intermediate operative solution-based elemental metal comprising material when the intermediate operative solution is contacted with the reagent material so as to effect production of at least one solid residue component-based elemental metal comprising solid material, such that any reaction of a dissolved intermediate operative solution-based target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and such that any reaction of a dissolved intermediate operative solution-based non-target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is

contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material;

and wherein each one of the at least complexing agent material is configured to react with at least one of the at least one dissolved intermediate operative solution-based elemental comprising material when the intermediate operative solution is contacted with the reagent material so as to effect production of at least one product solution component-based elemental metal comprising dissolved complex material, such that any reaction of a dissolved intermediate operative solution-based target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and such that any reaction of a dissolved intermediate operative solution-based non-target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based non-target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based non-target elemental metal comprising dissolved complex material includes at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is produced by the at least one reaction

effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material;

providing at least one operative dissolved intermediate operative solution-based target elemental metal comprising material, wherein the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based target elemental metal comprising material, wherein each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is configured to react with at least one of the at least one precipitation agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and wherein each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is also configured to react with at least one of the at least one complexing agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising

dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material;

providing at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material, wherein the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved intermediate operative solution-based non-target elemental metal comprising material, wherein each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is configured to react at least with at least one of the at least one precipitation agent material, when the intermediate operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material;

contacting the intermediate operative solution with the reagent material in a reaction zone, such that production of a product mixture is effected, wherein the product mixture includes a product solution component and a solid residue component, wherein the product solution component includes the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal and any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, and wherein the solid residue component includes any produced solid residue component target elemental metal comprising solid material-based target elemental metal and the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal,

such that, with respect to the product solution component, there is provided a respective molar quantity of each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal such that at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity is provided, and there is also provided a molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein the ratio of (A1) the sum of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity to (B1) the molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is defined by R1;

and such that, with respect to the solid residue component, there is provided a molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal, and there is also provided a respective molar quantity of each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal such that at least one produced solid residue component non-target elemental metal molar quantity is provided, wherein the ratio of (A2) the molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal to (B2) the sum of the at least one produced solid residue component non-target

elemental metal comprising solid material-based non-target elemental metal molar quantity is defined by R2;

wherein R1 is greater than R2.

2. The method as claimed in claim 1, wherein R1/R2 is greater than 1000.

3. The method as claimed in claim 1,

wherein the contacting of the intermediate operative solution with the reagent material in the reaction zone effects,:

(i) reaction of each one of the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based non-target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one intermediate operative solution-based non-target elemental metal and is derived from the metalliferrous material;

(ii) reaction of each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material with at least one of the at least one complexing agent material to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material, wherein each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one

reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material;

such that the product solution component includes the at least one produced product solution component-based target elemental metal comprising dissolved complex material, and the solid residue component includes the at least one produced solid residue component-based non-target elemental metal comprising solid material.

4. The method as claimed in claim 3,

wherein the contacting of the intermediate operative solution with the reagent material in the reaction zone effects circumstances wherein there is provided a material propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to effect reaction with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material.

5. The method as claimed in claim 3,

wherein the contacting of the intermediate operative solution with the reagent material in the reaction zone effects circumstances wherein there is provided a material propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to effect reaction with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and wherein there exists a material propensity for at least one of the at least one produced solid residue component-based target elemental metal comprising solid material to co-precipitate with at least one of the at least one solid residue component-based non-target elemental metal comprising solid material.

6. The method as claimed in claim 3,

wherein the contacting of the intermediate operative solution with the reagent material in the reaction zone effects circumstances wherein there is provided a material propensity for each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material to effect reaction with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal

comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material, and such that the solid residue component includes the at least one solid residue component-based target elemental metal comprising solid material, and wherein there exists a material propensity for at least a fraction of the at least one solid residue component-based target elemental metal comprising solid material to become occluded within an agglomerate of the solid residue component.

7. The method as claimed in claim 3,

wherein the contacting of the intermediate operative solution with the reagent material in the reaction zone effects reaction of each one of the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material with at least one of the at least one precipitation agent material to effect production of at least one solid residue component-based target elemental metal comprising solid material, wherein each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the intermediate operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one intermediate operative solution-based target elemental metal and is derived from the metalliferrous material;

such that the solid residue component includes the at least one solid residue component-based target elemental metal comprising solid material;

and such that there is provided a respective molar quantity of each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal such that at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal molar quantity is provided, and wherein the molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental is the sum of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal molar quantity, such that the ratio, R2, is defined as the ratio of (A2) the sum of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal molar quantity to (B2) the sum of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity.

8. The method as claimed in claim 7,

wherein at least one of the at least one produced solid residue component-based target elemental metal comprising solid material is co-precipitated with at least one of the at least one solid residue component-based non-target elemental metal comprising solid material.

9. The method as claimed in claim 7,

such that the solid residue component includes the at least one solid residue component-based target elemental metal comprising solid material, and wherein at least a fraction of the solid residue component includes an agglomerate and wherein at least a fraction of the at least one solid residue component-based target elemental metal comprising solid material is occluded within the agglomerate.

10. The method as claimed in claim 7, wherein there is insubstantial propensity for at least one of the at least one at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material to react with any one of the at least one complexing agent when the intermediate operative solution is contacted with the reagent material.

11. The method as claimed in claim 1, wherein at least a fraction of the metalliferrous material is an agglomerate and at least one of the at least one metalliferrous material-based target elemental metal is occluded within the agglomerate.

12. The method as claimed in claim 1, wherein the at least one metalliferrous material-based target elemental metal includes at least one of nickel and cobalt, and the at least one metalliferrous material-based non-target elemental metal includes iron.

13. The method as claimed in claim 12, wherein the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is a dissolved intermediate operative solution-based target elemental metal comprising material whose target elemental metal is one of nickel and cobalt.

14. The method as claimed in claim 12, wherein the at least one operative dissolved intermediate operative solution-based target elemental metal comprising material is: (i) a dissolved intermediate operative solution-based target elemental metal comprising material whose target elemental metal is cobalt, and (ii) a dissolved intermediate operative solution-based target elemental metal comprising material whose target elemental metal is nickel.

15. The method as claimed in claim 13 or 14, wherein the at least one operative dissolved intermediate operative solution-based non-target elemental metal comprising material is a dissolved intermediate operative solution-based non-target elemental metal comprising material whose non-target elemental metal is iron, and wherein the metalliferrous material is contacted with a reductant to effect the solubilisation of at least a fraction of the metalliferrous material.

16. The method as claimed in claim 15, wherein the reagent material is aqueous ammonia solution, wherein the complexing agent material is aqueous ammonia and the precipitation agent material is aqueous hydroxide ion.

17. The method as claimed in claim 16, wherein, in the reaction zone, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is controlled above a predetermined value.

18. The method as claimed in claim 15, wherein the reductant is an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide, wherein the reagent material is

aqueous ammonia solution, wherein the complexing agent is aqueous ammonia and the precipitation agent is aqueous hydroxide ion, and wherein, in the reaction zone, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is controlled above a predetermined value.

19. The method as claimed in claim 16, wherein, in the reaction zone, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is at least 700.

20. The method as claimed in claim 16, wherein the concentration of aqueous ammonia in the reaction zone is at least 180 grams per litre.

21. The method as claimed in claim 16,

wherein the at least one operative intermediate operative solution-based target elemental metal is at least one of nickel and cobalt, and wherein there is provided a respective molar quantity of each one of the at least one operative intermediate operative solution-based target elemental metal in the reaction zone such that at least one operative target elemental metal molar quantity is provided in the reaction zone, and wherein, in the reaction zone, the ratio of moles of aqueous ammonia to the sum of the at least one operative target elemental metal molar quantity is at least 5:1.

22. The method as claimed in claim 21, wherein the ratio is at least 6:1.

23. The method as claimed in claim 21, wherein the ratio is at least 8:1.

24. The method as claimed in claim 16, further comprising:

providing a process feed material;

leaching the process feed material in a preliminary leaching zone to effect production of a preliminary leach product including a preliminary leach solution and a preliminary leach solid residue, wherein the preliminary leach solution includes at least one dissolved preliminary operative solution-based target elemental metal;

separating at least a fraction of the preliminary leach solid residue from the preliminary leach product, such that the metalliferrous material includes at least a fraction of the separated preliminary leach solid residue fraction;

wherein the process feed material includes a precursor metallifferrous material source;

and wherein the precursor metalliferrous material source includes at least one precursor metalliferrous material source-based target elemental metal and at least one precursor metalliferrous material source-based non-target elemental metal, and wherein each one of the at least one metalliferrous material-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal and at least one of the at least one metalliferrous material-based non-target elemental metal is a one of the at least one precursor metalliferrous material source-based non-target elemental metal;

and wherein the precursor metalliferrous material source includes at least one precursor metalliferrous material source-based target metal sulphide, wherein each one of the at least one precursor metalliferrous material source-based target metal sulphide includes at least one precursor metalliferrous material source target metal sulphide-based target elemental metal, wherein each one of the at least one precursor metalliferrous material source target metal sulphide-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal;

and wherein the metalliferrous material includes at least one metalliferrous material-based target metal sulphide, and each one of the at least one metalliferrous material-based target metal sulphide is a one of the at least precursor metalliferrous material source-based target metal sulphide and includes at least one metalliferrous material target metal sulphide-based target elemental metal which is a one of the at least one precursor metalliferrous material source-based target elemental metal;

and wherein the contacting of the metalliferrous material with an operative leachant effects production of an intermediate product mixture including the intermediate operative solution and an intermediate solid residue, wherein the intermediate solid residue includes at least one intermediate solid residue-based target metal sulphide, wherein each one of the at least one

intermediate solid residue-based target metal sulphide is a one of the at least one metalliferrous material-based target metal sulphide, and wherein each one of the at least one intermediate solid residue-based target metal sulphide includes at least one intermediate solid residue target metal sulphide-based target elemental metal which is a one of the at least one metalliferrous material-based target elemental metal;

separating at least a fraction of the intermediate residue from the intermediate product mixture to provide a separated intermediate solid residue; and

recycling the separated intermediate solid residue to the preliminary leaching zone.

25. The method as claimed in claim 24, wherein the leaching of the process feed material is effected by contacting the process feed material with an aqueous solution comprising ammonia and ammonium sulphate.

26. The method as claimed in claim 25, wherein the at least one intermediate solid residue-based target elemental metal comprising metal sulphide is at least one of nickel sulphide and cobalt sulphide.

27. The method as claims in claim 26, wherein at least one of the at least operative dissolved intermediate operative solution-based target elemental metal of the intermediate operative solution is the same target elemental metal as a one of the at least one intermediate solid residue target metal sulphide-based target elemental metal.

28. The method as claimed in claim 26, wherein at least one of the at least one dissolved preliminary operative solution-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal.

29. The method as claimed in claim 1, wherein the metalliferrous feed is contacted with an operative leachant to effect the solubilisation of at least a fraction of the metalliferrous material.

30. The method as claimed in claim 29, wherein the operative leachant is an aqueous solution.

31. The method as claimed in claim 1, wherein at least a fraction of the intermediate product solution is separated from the intermediate product mixture.

32. The method as claimed in claim 1, wherein, the ratio of (i) moles of the at least one complexing agent material to (ii) moles of the at least one precipitation agent material is controlled above a predetermined value.

33. The method as claimed in claim 1, wherein, the ratio of (i) moles of the at least one complexing agent material to (ii) moles of the at least one precipitation agent material is greater than 700.

34. The method as claimed in claim 1,

wherein there is provided a respective molar quantity of each one of the at least one operative intermediate operative solution-based target elemental metal in the reaction zone such that at least one operative target elemental metal molar quantity is provided in the reaction zone;

and wherein there is provided a respective molar quantity of each one of the at least one complexing agent material in the reaction zone such that at least one complexing agent molar quantity is provided in the reaction zone;

and wherein, in the reaction zone, the ratio of (A) the sum of the at least one complexing agent molar quantity to (B) the sum of the at least one operative target elemental metal molar quantity is at least 5:1.

35. The method as claimed in claim 34, wherein the ratio is at least 6:1.

36. The method as claimed in claim 34, wherein the ratio is at least 8:1.

37. The method as claimed in claim 1, further comprising:

providing a process feed material, wherein the process feed material includes a precursor metalliferrous material source, and wherein the precursor metalliferrous material source includes at least one precursor metalliferrous material source-based target elemental metal and at least one precursor metalliferrous material source-based non-target elemental metal, and wherein each one

of the at least one metalliferrous material-based target elemental metal is a one of the at least one precursor metalliferrous material source-based target elemental metal and at least one of the at least one metalliferrous material-based non-target elemental metal is a one of the at least one precursor metalliferrous material source-based non-target elemental metal;

leaching the process feed material in a preliminary leaching zone to effect production of a preliminary leach product including a preliminary leach solution and a preliminary leach solid residue; and

separating at least a fraction of the preliminary leach solid residue from the preliminary leach product such that the metalliferrous material includes at least a fraction of the separated preliminary leach solid residue;

and wherein the contacting of the metalliferrous material with an operative leachant effects production of an intermediate product mixture including the intermediate operative solution product and an intermediate solid residue, wherein the intermediate solid residue includes at least one intermediate solid residue-based target elemental metal comprising solid material, wherein each one of the at least one intermediate solid residue-based target elemental metal comprising solid material includes at least one intermediate solid residue-based target elemental metal, and wherein each one intermediate solid residue-based target elemental metal is a one of the at least one metalliferrous material-based target elemental metal;

and wherein at least a fraction of the intermediate solid residue is separated from the intermediate product mixture and recycled to the preliminary leaching zone such that the process feed material includes the recycled intermediate solid residue.

38. A method of treating a metalliferrous material, comprising:

providing a metalliferrous material including at least one metalliferrous-based target elemental metal and at least one metalliferrous material-based non-target elemental metal, wherein the at least one metalliferrous material-based target elemental metal includes at least one of nickel and cobalt, and the at least one metalliferrous material-based non-target elemental metal includes iron;

solubilizing at least a fraction of the metalliferrous material so as to effect production of a solubilisation product including an intermediate operative solution, wherein the intermediate operative solution includes at least one dissolved intermediate operative solution target element metal comprising material and at least one dissolved intermediate operative solution non-target elemental metal comprising material, wherein the at least one dissolved intermediate operative solution non-target elemental metal comprising material includes an iron-comprising material and wherein the non-target elemental of the iron comprising material is iron, and wherein,

when the at least one of nickel and cobalt of the at least one metalliferrous material-based target elemental metal is nickel, the at least one dissolved intermediate operative solution target elemental metal comprising material includes a nickel-comprising material and wherein the target elemental metal of any nickel-comprising material is nickel;

and when the at least one of nickel and cobalt the at least one metalliferrous material-based target elemental metal is cobalt, the at least one dissolved intermediate operative solution target elemental metal comprising material includes a cobalt comprising material and wherein the target elemental metal of any cobalt comprising material is cobalt;

and when the at least one of nickel and cobalt of the at least one metalliferrous material-based target elemental metal is nickel and cobalt, the at least one dissolved intermediate operative solution target elemental metal comprising material includes nickel-comprising material and cobalt comprising material and wherein the target elemental metal of the nickel-comprising material is nickel and wherein the target elemental metal of the cobalt comprising material is cobalt;

such that the intermediate operative solution includes at least one operative intermediate operative solution-based target elemental metal, and the at least one operative intermediate operative solution-based target elemental metal is at least one of nickel and cobalt;

and

contacting the intermediate operative solution with a reagent material in a reaction zone, wherein the reagent material is aqueous ammonia solution, so as to effect production of a reaction product including a product solution component and a solid residue component.

39. The method as claimed in claim 38, wherein solubilisation of at least a fraction of the metalliferrous material is effected by contacting the metalliferrous material with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a leaching zone.

40. The method as claimed in claim 39, wherein,

when the at least one of nickel and cobalt of the at least one metalliferrous material-based target elemental metal is cobalt, the contacting of the metalliferrous material with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a leaching zone effects production of the intermediate operative solution, wherein the intermediate operative solution includes cobalt sulphate and iron sulphate,

and when the at least one of nickel and cobalt of the at least one metalliferrous material-based target elemental metal is nickel, the contacting of the metalliferrous material with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a leaching zone effects production of the intermediate operative solution, wherein the intermediate operative solution includes nickel sulphate and iron sulphate;

and when the at least one nickel and cobalt of the at least one metalliferrous material-based target elemental metal is cobalt and nickel, the contacting of the metalliferrous material with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a leaching zone effects production of the intermediate operative solution, wherein the intermediate operative solution includes nickel sulphate, cobalt sulphate, and iron sulphate.

41. The method as claimed in claim 40, wherein,

when the intermediate operative solution includes nickel sulphate and iron sulphate, the contacting of the intermediate operative solution with the reagent material effects production of the reaction product, wherein the reaction product includes $Ni(NH_3)_6SO_4$ and ferrous hydroxide;

and when the intermediate operative solution includes cobalt sulphate and iron sulphate, the contacting of the intermediate operative solution with the reagent material effects production of the reaction product, wherein the reaction product includes $Co(NH_3)_6SO_4$ and ferrous hydroxide;

and when intermediate operative solution includes nickel sulphate, cobalt sulphate and iron sulphate, the contacting of the intermediate operative solution with the reagent material effects production of the reaction product, wherein the reaction product includes $Ni(NH_3)_6SO_4$, $Co(NH_3)_6SO_4$, and ferrous hydroxide.

42. The method as claimed in claim 41, wherein, in the reaction zone, the aqueous ammonia solution includes aqueous ammonia and aqueous hydroxide ion, wherein the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is controlled above a predetermined value.

43. The method as claimed in claim 42, wherein, in the reaction zone, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is at least 700.

44. The method as claimed in claim 42, wherein the concentration of aqueous ammonia in the reaction zone is at least 180 grams per litre.

45. The method as claimed in claim 42,

wherein there is provided a respective molar quantity of each one of the at least one operative intermediate operative solution-based target elemental metal in the reaction zone such that at least one operative target elemental metal molar quantity is provided in the reaction zone,

and wherein, in the reaction zone, the ratio of moles of aqueous ammonia to the sum of the at least one operative target elemental metal molar quantity is at least 5:1.

46. A method of treating a metalliferrous material, comprising:

providing an operative solution including a solvent component and a solute component, wherein the solute component includes at least one dissolved operative solution-based elemental metal comprising material, and wherein the at least one dissolved operative solution-based elemental metal comprising material includes at least one dissolved operative solution-based target elemental metal comprising material and at least one dissolved operative solution-based non-target elemental metal comprising material such that each one of the at least one dissolved operative solution-based target elemental metal comprising material is a one of the at least one dissolved operative solution-based elemental metal comprising material and each one of the at least one dissolved operative solution-based non-target elemental metal comprising material is a

one of the at least one dissolved operative solution-based elemental metal comprising material, wherein each one of the at least one dissolved operative solution-based target elemental metal comprising material includes at least one operative solution-based target elemental metal, and wherein each one of the at least one dissolved operative solution-based non-target elemental metal comprising material includes at least one operative solution-based non-target elemental metal, such that the operative solution includes at least one operative solution-based target elemental metal and at least one operative solution-based non-target elemental metal;

providing reagent material including at least one precipitation agent material and at least one complexing agent material;

wherein each one of the at least precipitation agent material is configured to react with at least one of the at least one dissolved operative solution-based elemental metal comprising material when the operative solution is contacted with the reagent material so as to effect production of at least one solid residue component-based elemental metal comprising solid material, such that any reaction of a dissolved operative solution-based target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the intermediate operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one operative solution-based target elemental metal, and such that any reaction of a dissolved operative solution-based non-target elemental metal comprising material with a precipitation agent material effects production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target

elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one operative solution-based non-target elemental metal;

and wherein each one of the at least complexing agent material is configured to react with at least one of the at least one dissolved operative solution-based elemental comprising material when the operative solution is contacted with the reagent material so as to effect production of at least one product solution component-based elemental metal comprising dissolved complex material, such that any reaction of a dissolved operative solution-based target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one operative solution-based target elemental metal, and such that any reaction of a dissolved operative solution-based non-target elemental metal comprising material with a complexing agent material effects production of at least one product solution component-based non-target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based non-target elemental metal comprising dissolved complex material includes at least one product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one product solution component non-target

elemental metal comprising dissolved complex material-based non-target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is a one of the at least one operative solution-based non-target elemental metal;

providing at least one operative dissolved operative solution-based target elemental metal comprising material, wherein the at least one operative dissolved operative solution-based target elemental metal comprising material is included within the intermediate operative solution such that each one of the at least one operative dissolved operative solution-based target elemental metal comprising material is a one of the at least one dissolved operative solution-based target elemental metal comprising material, wherein each one of the at least one operative dissolved operative solution-based target elemental metal comprising material is configured to react with at least one of the at least one precipitation agent material, when the operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based target elemental metal comprising solid material and each one of the at least one solid residue component-based target elemental metal comprising solid material includes at least one solid residue component target elemental metal comprising solid material-based target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one solid residue component target elemental metal comprising solid material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component target elemental metal comprising solid material-based target elemental metal is a one of the at least one operative solution-based target elemental metal, and wherein each one of the at least one operative dissolved operative solution-based target elemental metal comprising material is also configured to react with at least one of the at least one complexing agent material, when the operative solution is contacted with the reagent material, to effect production of at least one product solution component-based target elemental metal comprising dissolved complex material and each one of the at least one product solution component-based target elemental metal comprising dissolved complex material includes at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal, wherein at least one reaction is effected when the

operative solution is contacted with the reagent material, such that at least one product solution component target elemental metal comprising dissolved complex material-based target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal is a one of the at least one operative solution-based target elemental metal;

providing at least one operative dissolved operative solution-based non-target elemental metal comprising material, wherein the at least one operative dissolved operative solution-based non-target elemental metal comprising material is included within the operative solution such that each one of the at least one operative dissolved operative solution-based non-target elemental metal comprising material is a one of the at least one dissolved operative solution-based non-target elemental metal comprising material, wherein each one of the at least one operative dissolved operative solution-based non-target elemental metal comprising material is configured to react at least with at least one of the at least one precipitation agent material, when the operative solution is contacted with the reagent material, to effect production of at least one solid residue component-based non-target elemental metal comprising solid material and each one of the at least one solid residue component-based non-target elemental metal comprising solid material includes at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal, wherein at least one reaction is effected when the operative solution is contacted with the reagent material, such that at least one solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is produced by the at least one reaction effected when the operative solution is contacted with the reagent material, wherein each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal is a one of the at least one operative solution-based non-target elemental metal;

contacting the operative solution with the reagent material in a reaction zone, such that production of a product mixture is effected, wherein the product mixture includes a product solution component and a solid residue component, wherein the product solution component includes the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal and any produced product solution

component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, and wherein the solid residue component includes any produced solid residue component target elemental metal comprising solid material-based target elemental metal and the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal,

such that, with respect to the product solution component, there is provided a respective molar quantity of each one of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal such that at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity is provided, and there is also provided a molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal, wherein the ratio of (A1) the sum of the at least one produced product solution component target elemental metal comprising dissolved complex material-based target elemental metal molar quantity to (B1) the molar quantity of any produced product solution component non-target elemental metal comprising dissolved complex material-based non-target elemental metal is defined by R1;

and such that, with respect to the solid residue component, there is provided a molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental metal, and there is also provided a respective molar quantity of each one of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal such that at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is provided, wherein the ratio of (A2) the molar quantity of any produced solid residue component target elemental metal comprising solid material-based target elemental to (B2) the sum of the at least one produced solid residue component non-target elemental metal comprising solid material-based non-target elemental metal molar quantity is defined by R2;

wherein R1 is greater than R2.

43. The method as claimed in claim 42, wherein R1/R2 is greater than 100,000.

44. A method of treating a metalliferrous material, comprising:

providing a metalliferrous material including nickel, cobalt, and iron;

leaching at least a fraction of the metalliferrous material with an aqueous solution including dissolved sulphuric acid and dissolved sulphur dioxide in a leaching zone so as to effect production of a leachant including nickel sulphate, cobalt sulphate, and iron sulphate;

contacting the leachant with reagent material in a reaction zone, wherein the reagent material is aqueous ammonia solution, so as to effect production of a reaction product including a product solution component and a solid residue component.

45. The method as claimed in claim 44, wherein, in the reaction zone, the aqueous ammonia solution includes aqueous ammonia and aqueous hydroxide ion, wherein the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is controlled above a predetermined value.

46. The method as claimed in claim 44, wherein, in the reaction zone, the ratio of moles of aqueous ammonia to moles of aqueous hydroxide ion is at least 700.

47. The method as claimed in claim 44, wherein the concentration of aqueous ammonia in the reaction zone is at least 180 grams per litre.

45. The method as claimed in claim 44,

wherein there is molar quantity of each one of nickel and cobalt in the reaction zone to define a total target elemental metal molar quantity in the reaction zone,

and wherein, in the reaction zone, the ratio of moles of aqueous ammonia to the total target elemental metal molar quantity is at least 5:1.

46. The method as claimed in claim 1, wherein R1/R2 is greater than 100,000.

Figure 1: Simplified Diagram of Experimental set up for H_2SO_4/SO_2 Leach

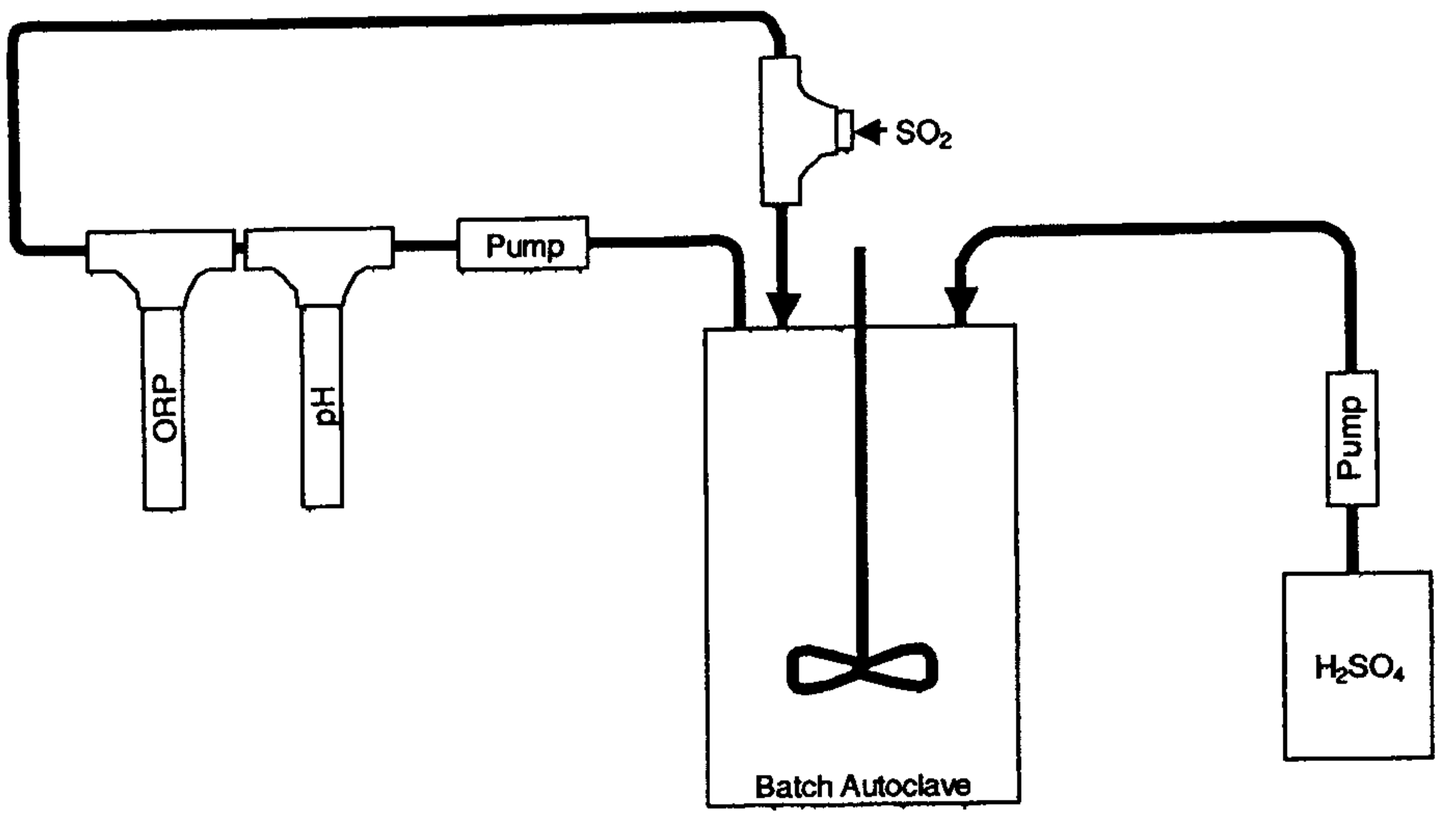
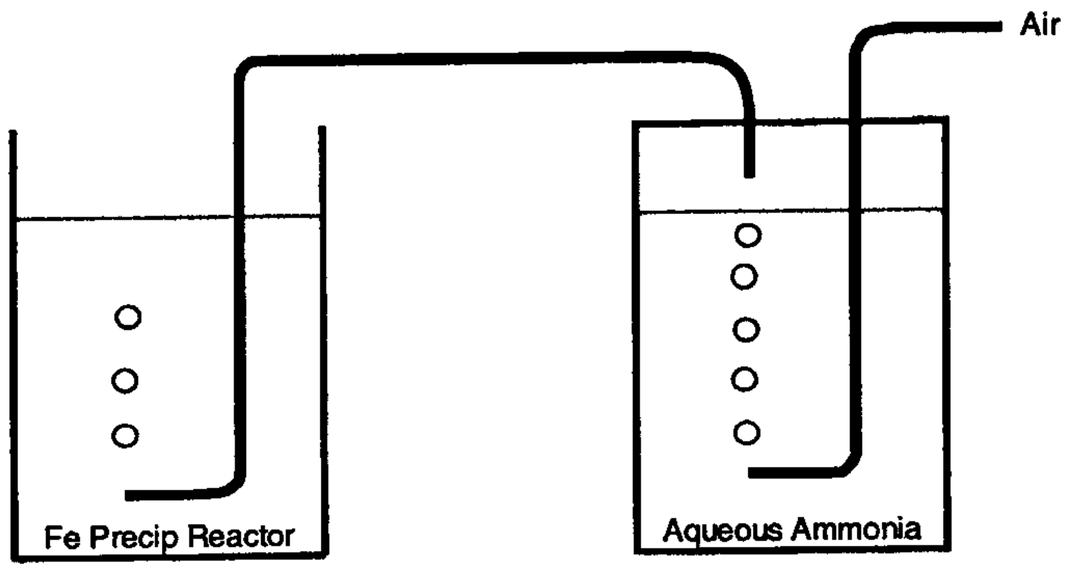


Figure 3: Simplified Diagram of Experimental set up for Fe Precipitation



Tabular Summary of

Assays of Feed Residue, Leach Residue and Leach Solution

	Feed (%)	Digest Residue (%)	Digest Liquor (g/L)
Ni	22.0	36.8	23.7
Co	11.8	13.6	17.6
Cu	0.11	0.321	0
Fe	22.1	1.63	53.9
Zn	0.68	0.313	1.52
Si	1.42	3.81	0.57
Cr	0.44	0.178	0.955
Cd	0.00	0.021	0.57
Mg	0.19	0.241	0.396
Mn	0.12	0.036	0.284
Al	0.37	0.408	0.742
Ca	0.13	0.125	0.178
S Total	12.9	32.2	58.9
Moisture	53.4	67.5	#N/A
SG (22 ºC)	#N/A	#N/A	1288

FIGURE 2

Tabular Summary of

Assays of Reaction Solutions and Final Residue from Ammonia/Air Precipitation of Leach Solution.

	Solution Assays (g/L)					Residue
	60 min	120 min	180 min	240 min	Final	%
Ni	13.5	13.9	13.8	13.5	13.4	0.958
Co	7.23	7.33	6.89	6.2	6.33	5.74
Cu	0	0.02	0	0	0	0
Fe	0	0.00889	0.00614	0.00001	0	42.8
Zn	0.844	0.848	0.836	0.822	0.805	0.145
Si	0	0	0	0	0	0.577
Cr	0	0	0	0	0	0.791
Cd	0	0	0	0	0	0.021
Mg	0.032	0.026	0.023	0	0	0.29
Mn	0.00638	0.0042	0.00646	0.00433	0.00189	0.228
Al	0	0	0	0	0	0.55
Ca	0.092	0.076	0.063	0.031	0	0.213
S Total	32.3	32.8	32.7	32.7	32.4	1.25
NH_3	43.9	41.0	43.0	47.9	47.5	NA
MR	7.06	6.45	6.93	8.10	8.03	NA
$AmSO_4$	85.1	86.0	86.9	89.1	87.8	NA

FIGURE 4

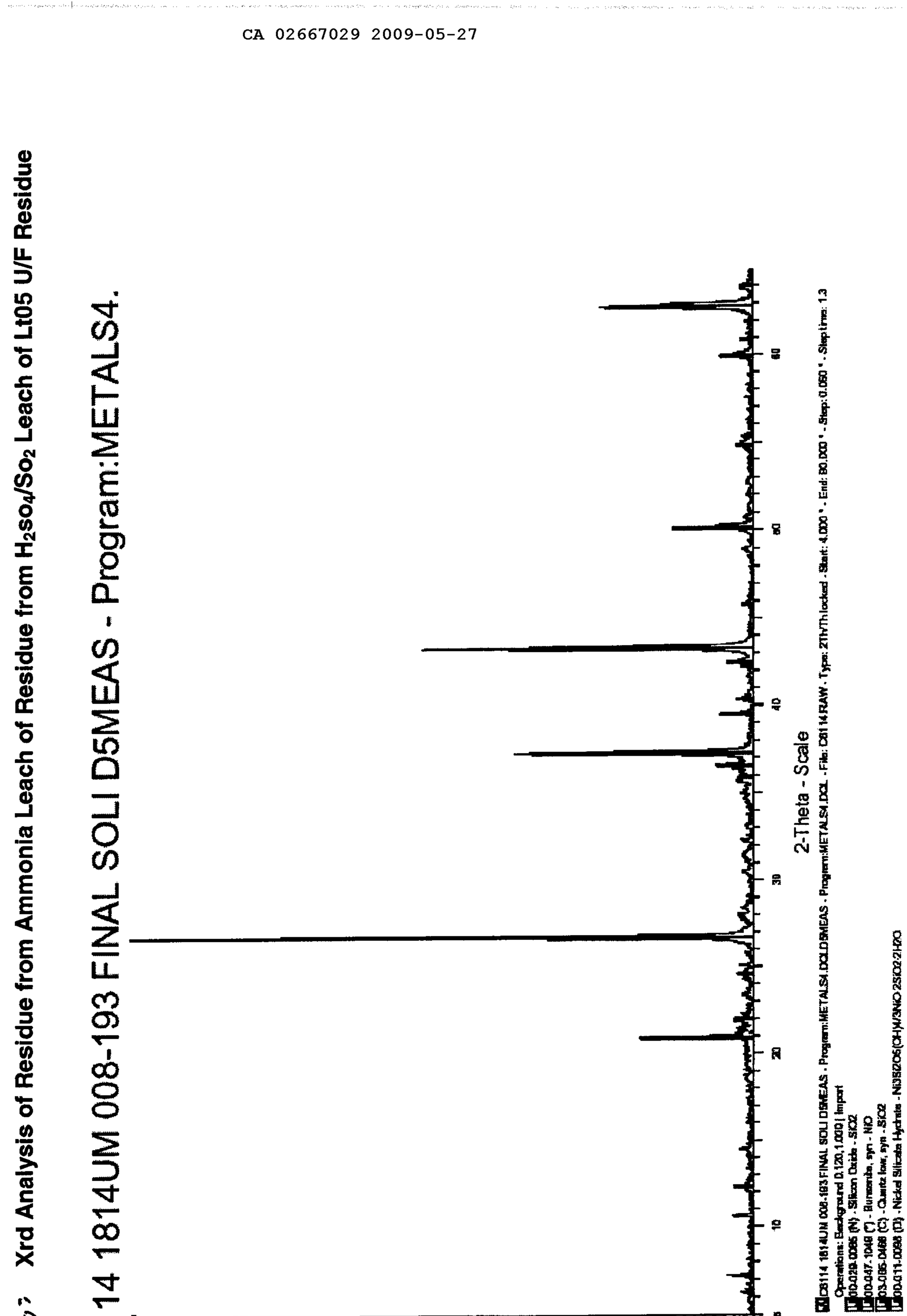
Tabular Summary of

Assay Results of Solids from Oxygen/Ammonia Leach of Residue from H_2SO_4/SO_2 Leach of Lamellae Thickener Residue.

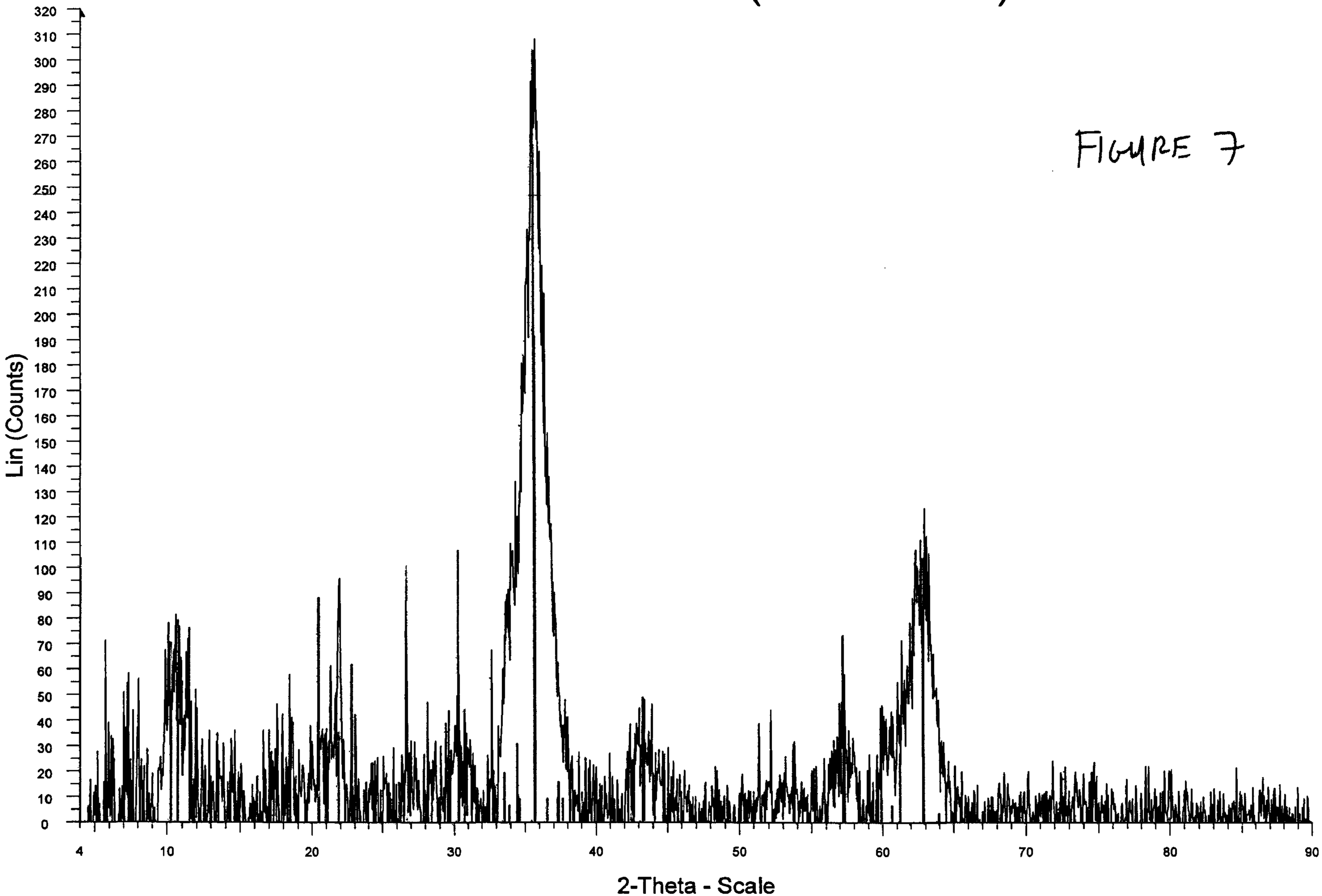
Solids Assays			Extractions based on	
	Feed	Dx	Fe	Si
Ni	39.3	16.8	90.3	89.1
Co	11.9	2.38	95.4	94.9
Cu	0.248	0	100	100
Fe	1.96	8.61	NA	-11.7
Zn	0.261	0.252	78.0	75.5
Si	3.94	15.5	10.4	NA
S Total	33.1	2.27	98.4	98.3

FIGURE 5

Figure 63 Xrd Analysis of Residue from Ammonia Leach of Lt05 U/F Residue



2FDX Frac Head Mar (S08034376)



2FDX Frac Head Mar (S08034376) - File: L7560.RAW - Type: 2Th/Th locked - Start: 4.000 ° - End: 90.000 ° - Step: 0.050 ° - Step time: 5. s - Temp.: 25 °C (Room) - Time Started: 2 s - 2-Theta:
Operations: Background 0.457,1.000 | Import

00-046-1045 (*) - Quartz, syn - SiO_2 - Hexagonal - WL: 1.5406

00-039-1346 (*) - Maghemite-C, syn - Fe_2O_3 - Cubic - WL: 1.5406

00-010-0325 (I) - Trevorite, syn - $NiFe_2O_4$ - Cubic - WL: 1.5406

00-040-0215 (N) - Iron Nickel Carbonate Hydroxide Hydrate - $Ni_{0.75}Fe_{0.25}(CO_3)_{0.125}(OH)_2 \cdot 0.38H_2O$ - Rhombo.H.axes - WL: 1.5406

00-012-0209 (D) - Diadochite - $Fe_2(PO_4)(SO_4)(OH) \cdot 5H_2O$ - Triclinic - WL: 1.5406

FIGURE 7

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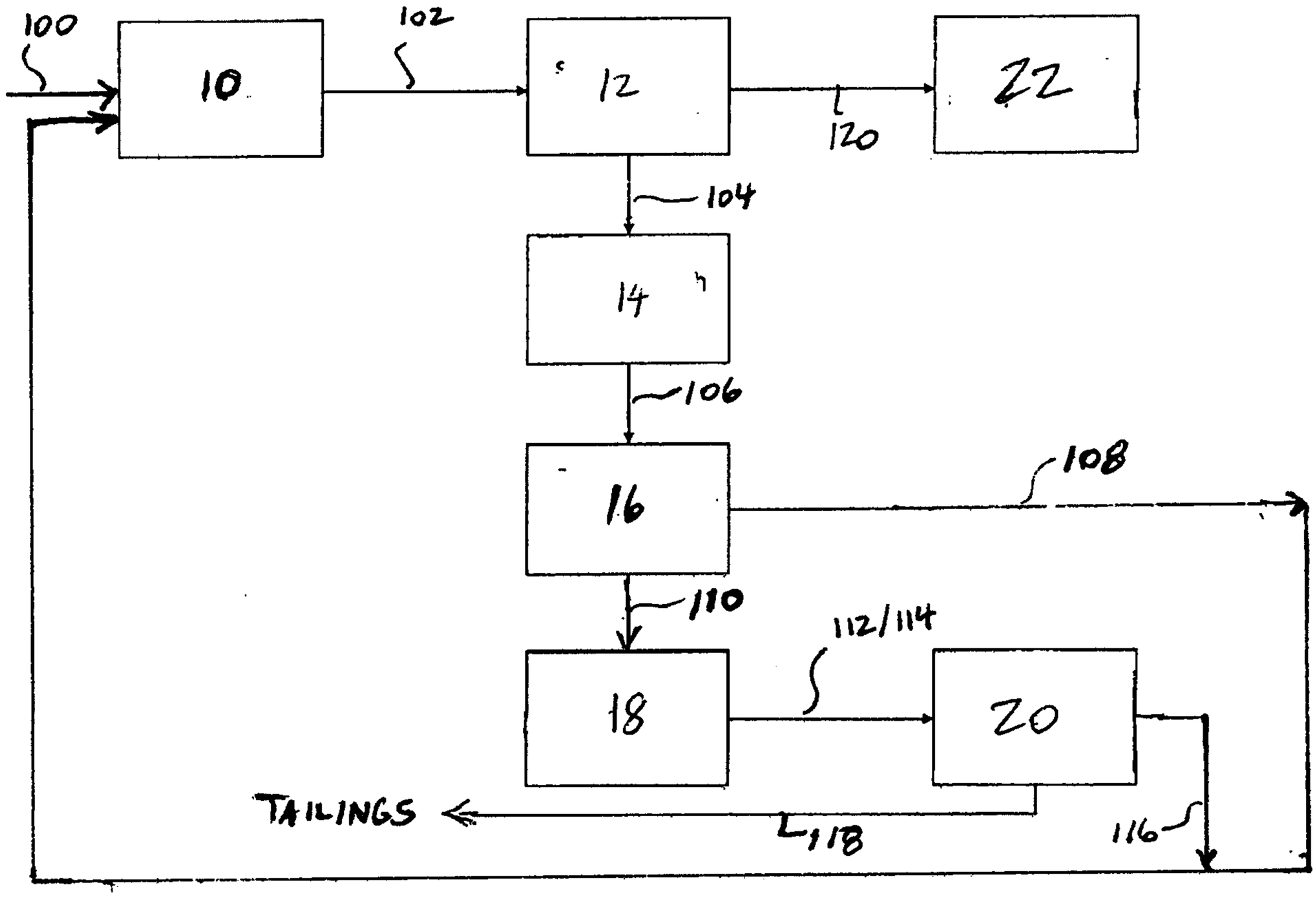
100
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102
12
22
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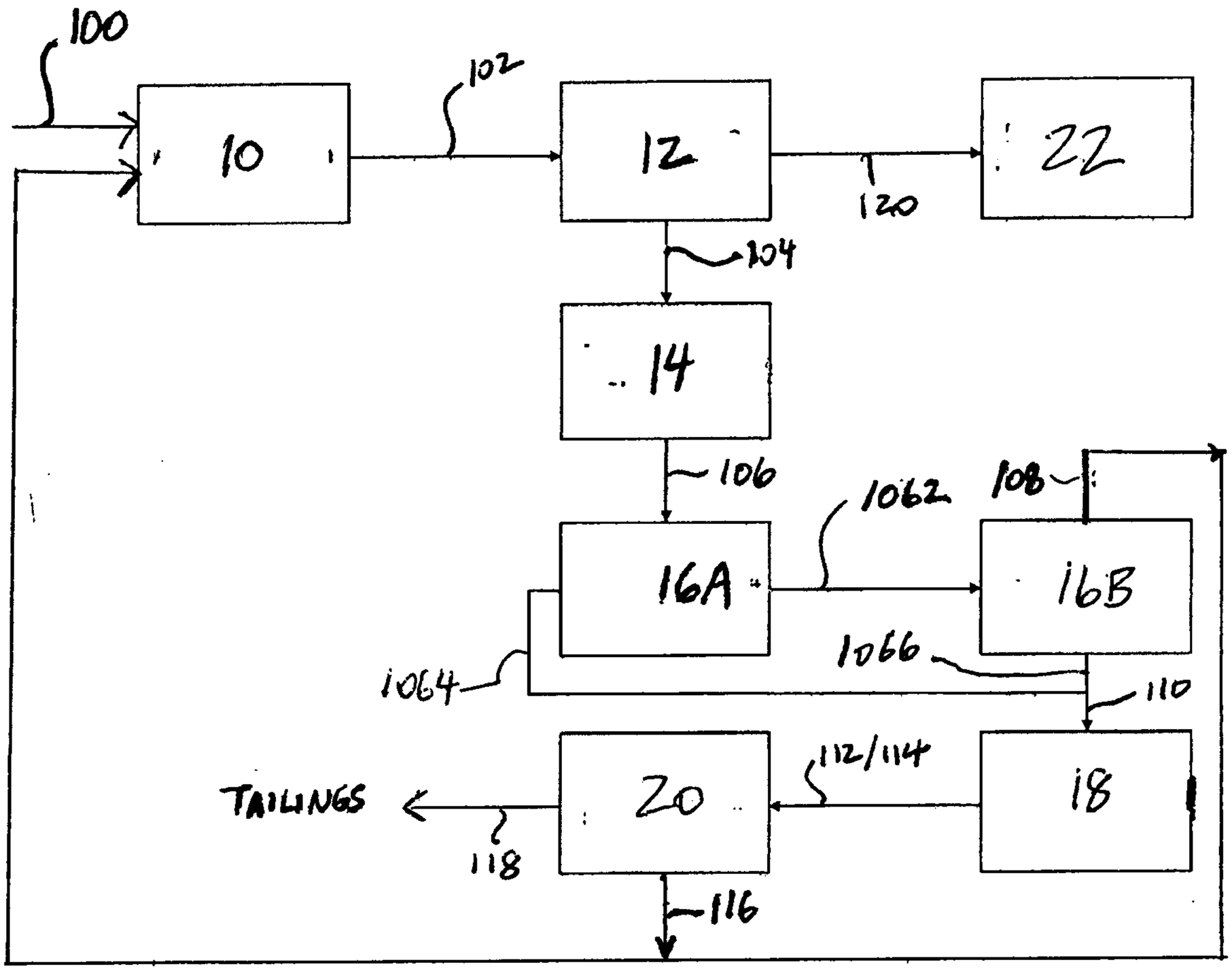
106
16
108
110
18
112/114
20
TAILINGS
118
116
10

FIGURE 8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16B
1064
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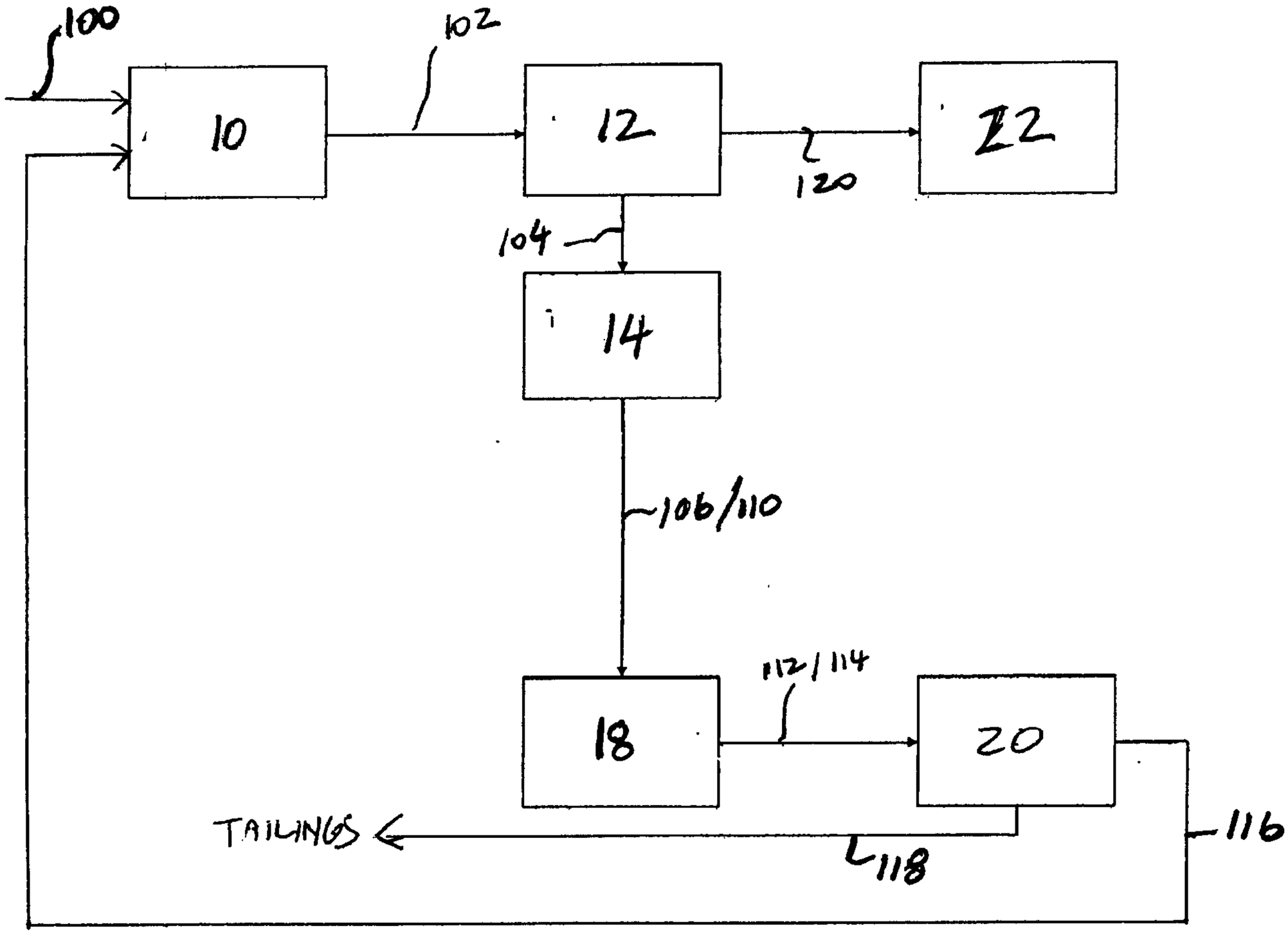
TAILINGS
20
118
116

FIGURE 9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TAILINGS
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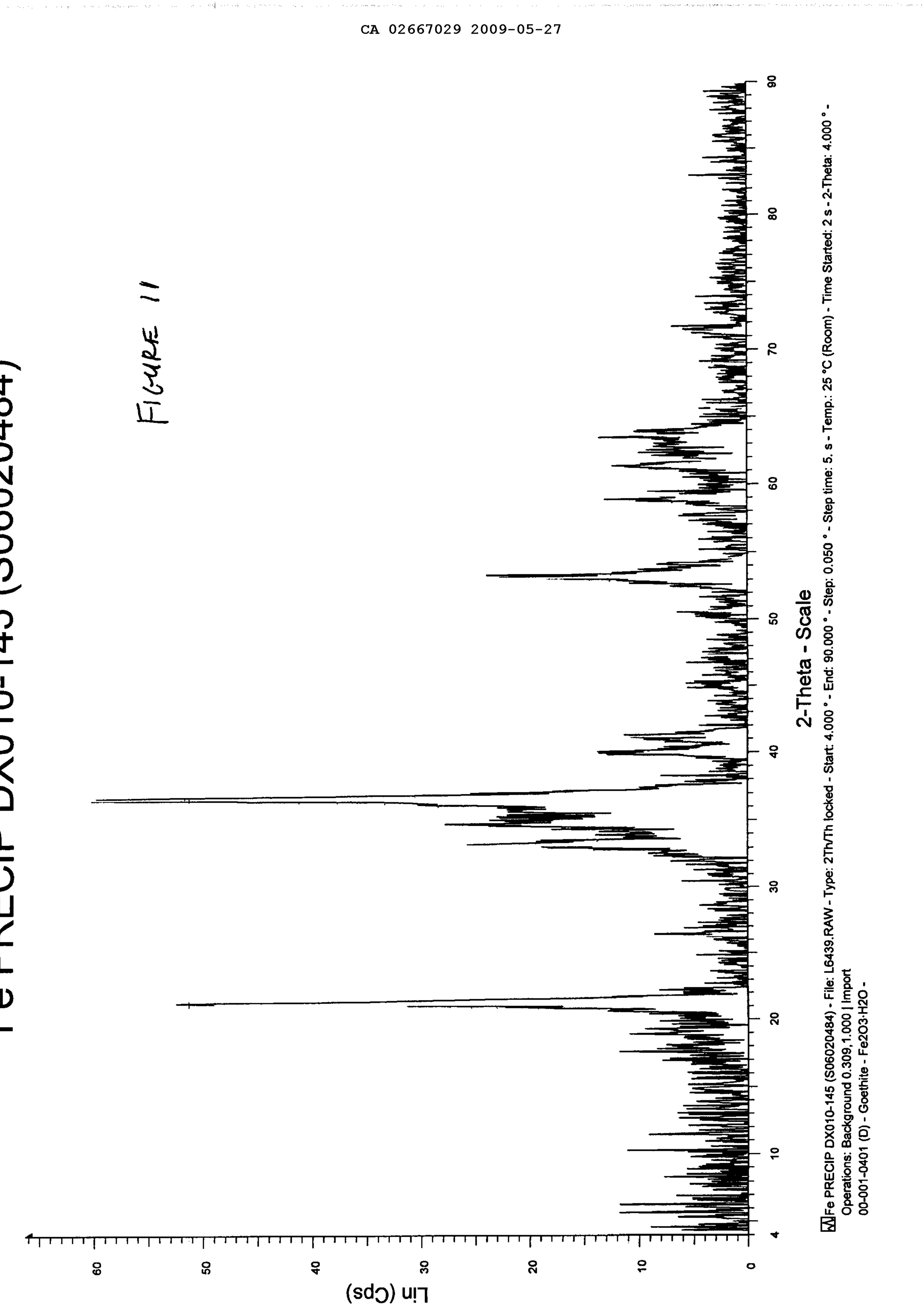
FIGURE 10

FIGURE 11


Fe PRECIP DX010-145 (S06020484)
Lin (Cps)
2-Theta - Scale
Fe PRECIP DX010-145 (S06020484) - File: L6439.RAW - Type: 2Th/Th locked - Start: 4.000 ° - End: 90.000 ° - Step: 0.050 ° - Step time: 5. s - Temp.: 25 °C (Room) - Time Started: 2 s - 2-Theta: 4.000 °
Operations: Background 0.309,1.000 | Import
00-001-0401 (D) - Goethite - Fe2O3·H2O -

C6770 010-123 FE PRECIP DX D5MEAS - Program:METALS4.DQ

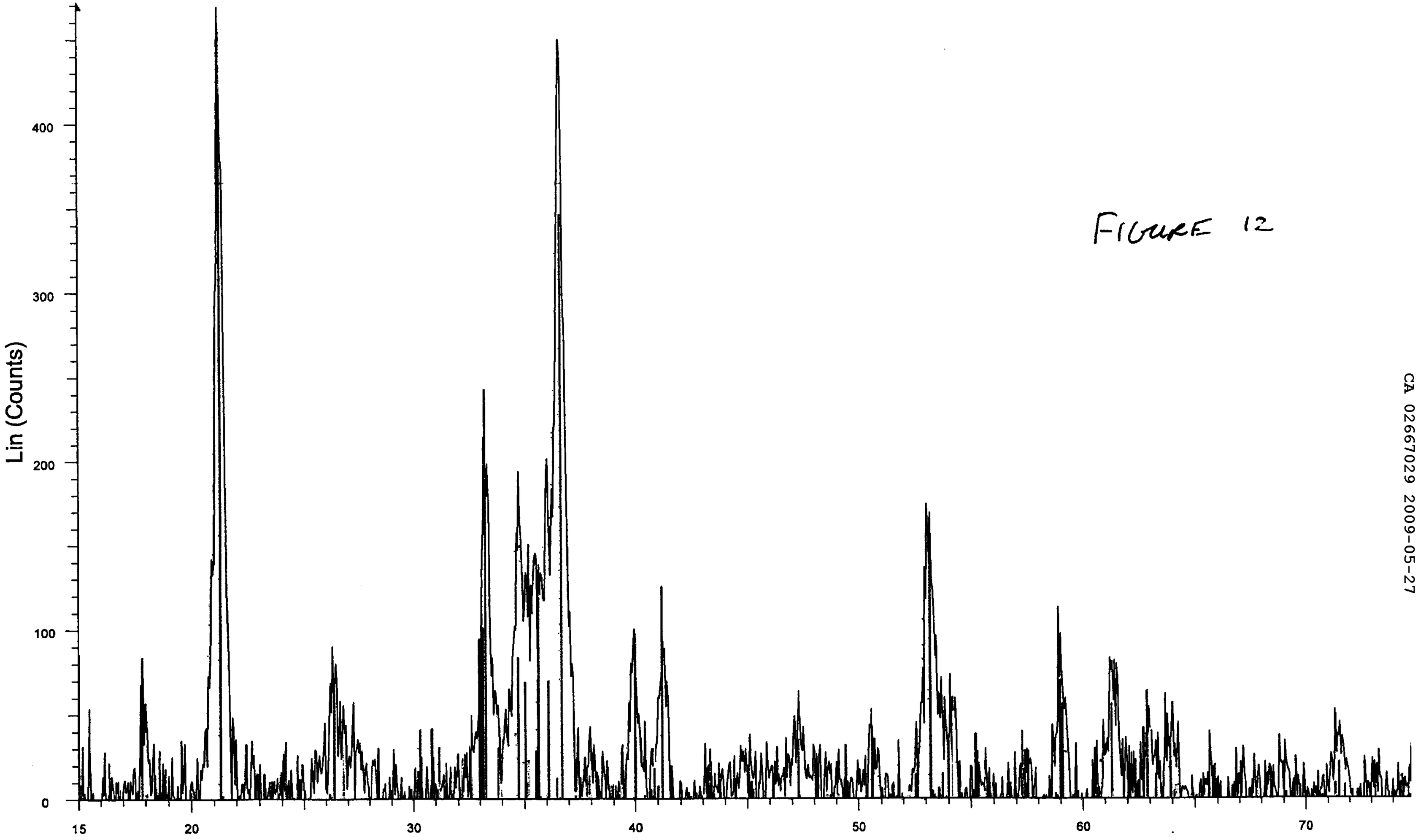


FIGURE 12

C6770 010-123 FE PRECIP DX D5MEAS - Program:METALS4.DQLD5MEAS - Program:METALS4.
Operations: Background 1.000,1.000 | Import
00-029-0713 (I) - Goethite - FeO(OH) - Orthorhombic - a 4.60800 - b 9.95600 - c 3.02150 - 4 - 138.618 -
00-040-1139 (I) - Iron Oxide - beta''-Fe2O3 - Hexagonal - a 5.92000 - b 5.92000 - c 35.69000 - 1083.23
00-024-0072 (D) - Hematite - Fe2O3 - Rhombo.H.axes - a 5.03800 - b 5.03800 - c 13.77200 - 6 - 302.72
00-022-0346 (Q) - Iron Hydroxide - Fe(OH)3 - Cubic - a 8.37000 - b 8.37000 - c 8.37000 - 586.376 - alph
00-039-0238 (I) - Iron Oxide - beta-Fe2O3 - Cubic - a 9.40400 - b 9.40400 - c 9.40400 - 831.645 - alpha
00-002-1165 (D) - Iron Oxide - delta-Fe2O3 - Hexagonal - a 5.10000 - b 5.10000 - c 4.42000 - 2 - 99.56
00-032-0469 (D) - Iron Oxide - Fe2O3 - Cubic - a 9.39300 - b 9.39300 - c 9.39300 - 16 - 828.730 - alpha
00-024-0081 (D) - Maghemite-C, syn - gamma-Fe2O3 - Cubic - a 8.35000 - b 8.35000 - c 8.35000 - 10 -
00-001-0662 (D) - Iron Oxide Hydrate - beta-FeOOH -

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Figure 13

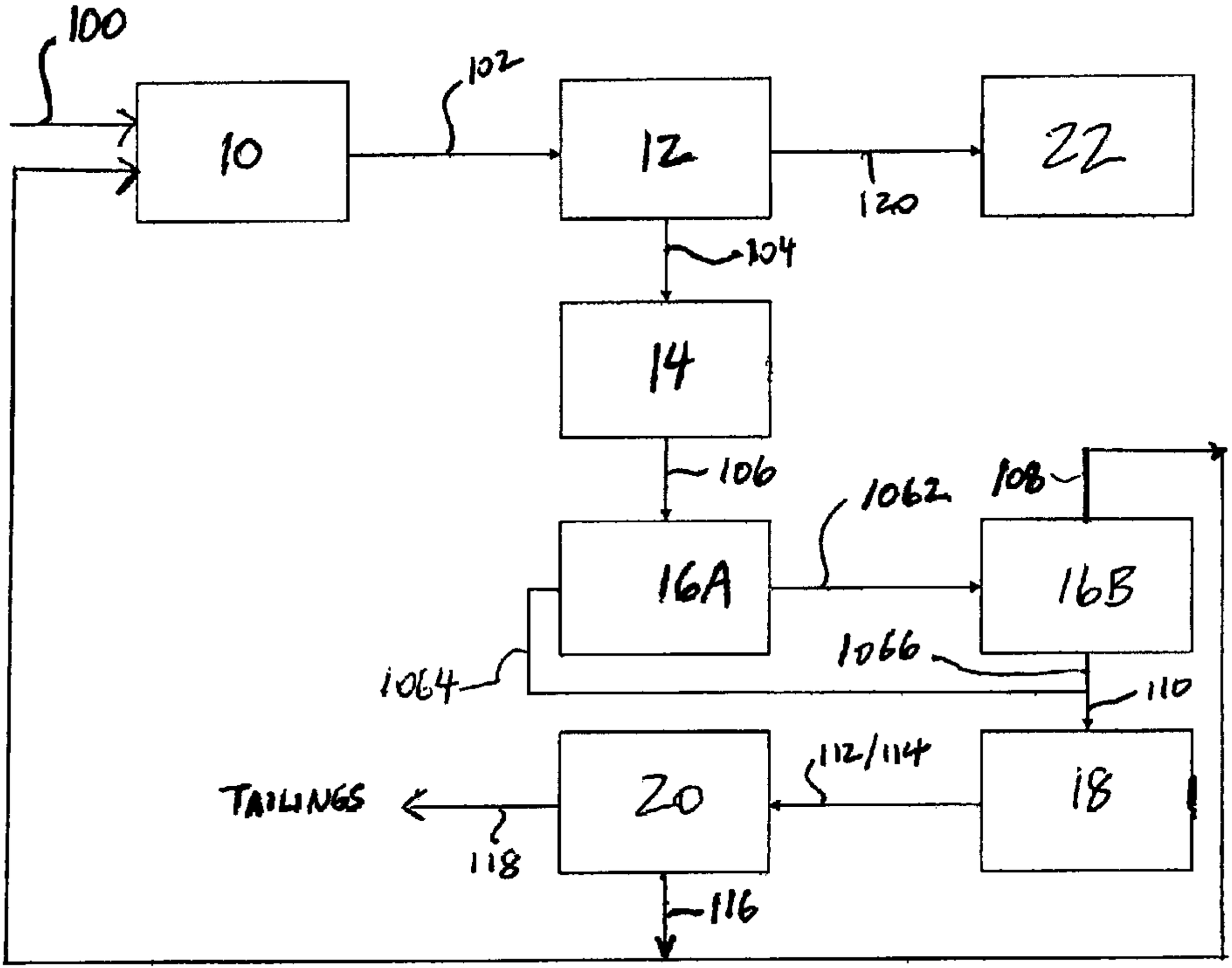
Table 1: Results for Low Sulphide Feed				
	Assay in feed (%)	Extraction to Reductive Leach solution	Recovery to Fe precipitation Solution	Overall Recovery
Ni	10.9	98.1	84.0	82.4
Co	6.13	99.6	76.7	76.4
Fe	33.2	98.6	0.0	0.0

Figure 14

Table 2: Results for High Sulphide Feed					
	Assay in feed (%)	Extraction to Reductive Leach solution	Extraction in Ammonia Leach of residue	Recovery to Fe precipitation Solution	Overall Recovery
Ni	18.8	30.5	89.7	97.0	91.9
Co	5.83	56.6	95.2	79.6	86.4
Fe	22.2	94.9	0	0	0

Figure 15

Table 3: Assays from various steps in treatment of low Sulphide Solids				
	Solids Assays (weight %)		Solution Assays (g/L)	
	Feed	Final residue to tailings	Reductive Leach Solution	Iron Precipitation Solution
Ni	10.9	2.2	21	6.63
Co	6.13	1.81	11.9	3.55
Cu	0.02	<.02	<0.02	<0.02
Fe	33.2	41.0	62.7	<0.05
Zn	0.51	0.10	0.98	0.33
Si	1.88	2.22	0.54	<0.1
Cr	3.30	4.05	5.7	<0.05
Cd	<.02	<.02	<0.02	<0.02
Mg	0.57	0.66	0.52	<0.02
Mn	0.27	0.33	0.52	<0.02
Al	1.22	1.39	1.47	<0.05
Ca	0.00	0.09	0.12	<0.02
S	1.35	1.79	73.9	24.4


100
10
102
12
120
22
104
14
106
1062
108
16A
16B
1066
1064
110
112/114
TAILINGS
20
18
118
116