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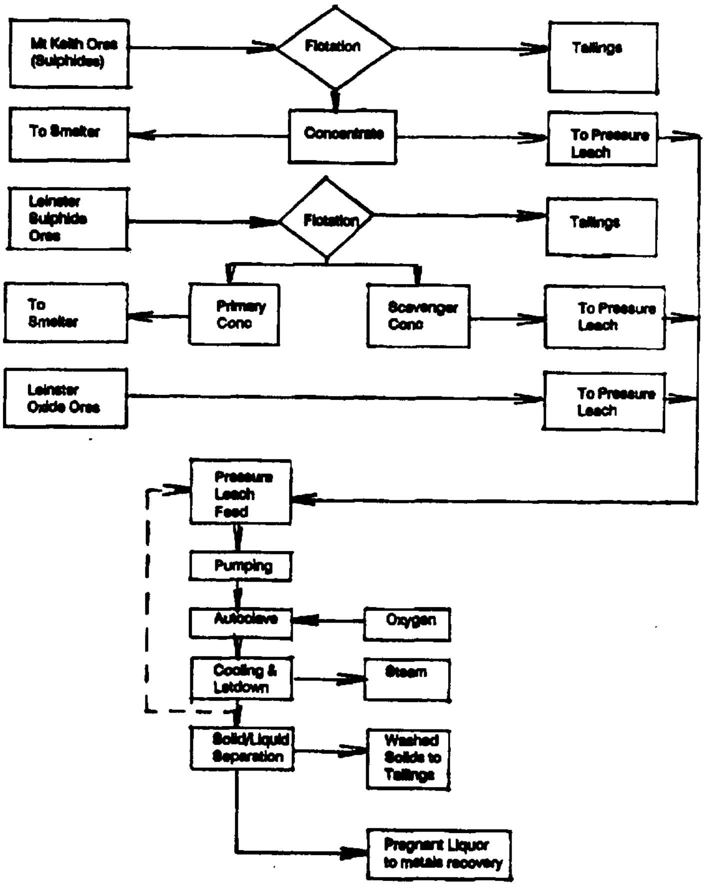
(54) Title: MINERAL PROCESSING

(57) Abstract

A method for leaching a mixed feed containing a plurality of metal values in an autoclave by oxidising sulphur components in the feed to produce sulphuric acid *in-situ*. The feed components are selected to give an appropriate acid balance on oxidation. The slurry resulting from the leach is neutralised and metals are removed by processes such as electrowinning, cyanidation, solvent extraction etc. after the slurry has been subjected to a solid/liquid separation step.



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TITLE: MINERAL PROCESSING

FIELD OF THE INVENTION

The present invention relates to mineral processing. More particularly the invention relates to the processing of a feed material containing oxidised metals together with a metal sulphide containing feed component by pressure oxidation leaching to facilitate the recovery of metal values therefrom.

BACKGROUND OF THE INVENTION

At present it is usual for one type of feed material to be processed independently of other types of feed materials. In cases where mixed ore bodies occur it is common to treat different parts of the ore body by different methods. This may require physical separation of feed materials prior to treatment.

Sulphide containing ores are typically processed by roasting and/or smelting to oxidise some or all of the sulphidic component to facilitate subsequent extraction of metal values. For example, nickel sulphide ores are typically processed by smelting and refining techniques. These techniques may be complemented by an initial concentrating step prior to smelting to increase the metal content of the smelter feed.

However, it is well known that the typical base metal sulphide smelting process is energy inefficient due to incomplete oxidation of the minerals and inherent heat losses to off gases, slag and product. Further, smelting of sulphidic ores and concentrates generates sulphur dioxide which is a major environmental problem if released to atmosphere. Process complexity is substantially increased if the sulphur gases are for example captured by incorporating a sulphuric acid plant to eliminate the sulphur dioxide emissions to the natural environment.

Smelting of oxide ores, for example laterite ores containing metal values such as nickel, chromium, iron and cobalt, requires very high temperatures for phase separation to produce ferro nickel, and high MgO levels for optimum slag and power consumption. Alternatively low MgO oxide ores require processing via acid pressure leaching requiring the separate manufacture of sulphuric acid to be supplied to the pressure leaching reactor.

The current smelting and refining techniques for processing sulphide ores and concentrates are restricted by the need to limit magnesium oxide levels in ores and concentrates and/or arsenic contents and/or selenium contents. A further inefficiency is the high loss to the slag of cobalt values from smelted nickel cobalt ores and concentrates. Similar process and metal value recovery limitations can be encountered in the processing of other metal sulphide ores and concentrates.

Moreover, in cases where oxide and sulphide ores occur in close proximity to one another, separate processing has generally been required. This may involve physical separation of feed materials prior to treatment. Separate processing also requires considerable additional resources which may preclude the establishment of separate processing facilities, such as at Leinster in Western Australia where sulphide and oxide ores containing nickel, cobalt, copper, zinc, gold and other metal values occur in the same ore body or nearby. Separate processing facilities generally involve lower efficiency leading to higher costs.

We now believe that a feed containing metal oxides and metal sulphides can be processed together by oxidising the sulphidic material in the feed to generate an acidic environment in-situ which leaches metal values from the oxidic components of the feed. Simultaneously metal values may be released from the sulphidic material into solution and/or remain in the oxidised solids in a form amenable to further treatment. This facilitates the treatment of a mixed feed containing a variety of metal values.

DISCLOSURE OF THE INVENTION

The present invention accordingly provides in one preferred embodiment a method for the treatment of a plurality of metal values in a feed containing sulphide and oxide components, the method including the step of oxidising the sulphide component in the feed at elevated temperature and pressure to generate an acid environment in-situ in which metal values from the sulphide and the oxide components are taken into solution and/or report to the solid phase in a form amenable to further treatment.

The present invention also provides in another preferred embodiment a method for the extraction of a plurality of metal values from a feed containing sulphide and oxide components, the method including the step of subjecting the feed in an aqueous environment to elevated temperature and pressure sufficient to oxidise the sulphide component in the feed to form an acid environment in-situ, wherein metal values from the sulphide and the oxide components are taken into solution in the acid phase and optionally also report to the solid phase in a form amenable to further processing, the method also including the further step of recovering metal values by subsequent recovery from the liquid phase and optionally the solid phase.

The present invention may be advantageously applied to feeds containing a variety of feed components including oxide and sulphide ores, concentrates and waste liquors, slags and tailings from other processes which contain metal values. Most preferably the present invention is applicable to feeds containing multiple base and/or precious metal values, ie feeds which contain three or more different base and/or precious metal values and which also contain sulphide and oxide components.

The term "metal values" is used herein to include metals not being impurities whether present in metallic, compound, mixed or other metal bearing forms.

The feed used in accordance with the present invention should contain sulphide and oxide components but may include other sulphur containing feed components such as sulphur itself, sulphur mattes and sulphur concentrates. The sulphide and oxide components of a feed used in accordance with the present invention may be found in a single ore body or may be provided by a blended feed from multiple sources. Accordingly the present invention may be advantageously applied, for example, by mixing a predominantly sulphide ore (which may or may not contain oxide components) with a predominantly oxide ore (which may or may not contain sulphide components) to form a mixed feed for use in accordance with the invention.

The sulphide and oxide components of a feed used in accordance with the invention generate an acidic environment in the aqueous medium of the reaction vessel. It is convenient for the acid to be expressed in terms of sulphuric acid equivalent. It is to be appreciated however that the acidic environment is unlikely to consist solely of sulphuric acid (H_2SO_4).

For example, the method provided by the present invention may also be advantageously applied in the presence of halide ions, for example, chloride ions. Such ions may be introduced into the reaction vessel from the feed materials themselves. Another potential source of halide ions such as chloride ions is the water supply which may include, for example, seawater or hyper saline water from aquifiers.

The reaction can be expected to occur more quickly and/or give higher extraction levels in the presence of chloride ions. This may be attributed to the chloride ions favouring the generation of hydrochloric acid in the reaction environment. While it is convenient to refer herein to chloride ions as represented by hydrochloric acid it is to be appreciated that the acidic environment is unlikely to consist solely of hydrochloric acid (HCl).

The feed used in accordance with the present invention may contain a variety of metal values and/or impurities including but not limited to nickel, cobalt, zinc, magnesium, copper, chromium, uranium, thorium and related radioactive elements, lead, rhodium, cadmium, vanadium, gallium, gold, silver, platinum and related precious metals.

The invention is particularly applicable to feeds containing a plurality of metal values. The invention is preferably applied to a feed containing three or more different values. Such a multiple metal feed may be found in a single deposit. It is also envisaged that a mixed feed may be prepared by blending or mixing two or more feed components each containing one or more metal values. Accordingly, the present invention may, for example, be applied to a mixed feed containing components from one or more separate ore bodies. The metal values in each component of a mixed feed may be the same as or different from the metal values in each other component of the mixed feed.

The treatment at elevated temperature and pressure according to the present invention may be carried out in an autoclave or other pressure vessel. However, other vessels capable of withstanding the temperatures, pressures and reaction conditions involved may also be used in accordance with the invention.

The treatment method provided by the present invention involves the use of elevated temperatures and pressures. For rapid reaction rates the method provided by the present invention should preferably be operated at temperatures of at least 180°C. Based on current practical materials of construction and the desire for the fastest practical reaction time, the presently preferred temperature range is 180-280°C with a range of 200 to 220°C being particularly preferred. Equipment for use in accordance with the present invention is preferably designed on the desired temperature plus an oxygen over pressure allowance of up to 10 atmospheres. Preferably the method provided by the present invention is carried out with oxygen overpressures in the range of 2 to 8 atmospheres.

For example, if dealing with an oxide feed ore containing multiple metals, particularly nickel and including copper, cobalt and zinc, the preferred temperature is typically about 250°C or higher for maximising the recovery of multiple metal values. For most base metals processing temperatures in the region of 180-220°C can be expected to be generally acceptable. Temperature, pressure, acid concentration and retention time all affect metal yields. Each mix of oxides and sulphides is preferably optimised to achieve a preferred balance in the recovery, temperature, acid level, time and pressure relationships.

The feed components fed to the reaction vessel should be present in proportions suitable to achieve a balance between acid generating materials and acid consuming materials such that the leach discharge is controlled to a desired acid condition (gm/litre of free acid). This may require supplementary addition of acid, acid producing or acid consuming materials.

For example, the acid condition in autoclave discharge is most preferably approximately 30-40 g/l free acid as H_2SO_4 for lateritic ores which can contain chromium, cobalt, nickel and magnesium values. By having a mixture of acid generating and acid consuming materials within the autoclave, localised high concentrations of acid should be avoided. Such localised high concentrations of acid give rise to undesirable scaling effects.

As may be appreciated by the skilled reader, complex reactions can be expected to occur in the reaction vessel at the elevated temperatures and pressures which may be employed in accordance with the present invention. Variations in feed materials also influence the anticipated reactions. Moreover, in the acidic environment involved, compounds may dissociate and a variety of ions, some of which may be unstable, can be expected to occur. Accordingly the following example reactions are to be understood to be non-limiting and included for illustrative purposes only.

Examples of some non-limiting simplified nett reactions that consume acid and which may occur in performing a method provided by the present invention include:

$MgSiO_3 + H_2SO_4 = MgSO_4 + SiO_2 + H_2O$

$Al_2O_3 + 3\ H_2SO_4 + 3\ H_2O = Al_2(SO_4)_3 .\ 6\ H_2O$

$MgCO_3 + H_2SO_4 = MgSO_4 + H_2O + CO_2$

$NiO + H_2SO_4 = NiSO_4 + H_2O$

Examples of some non-limiting simplified nett reactions that produce acid and which may occur in performing a method provided by the present invention include:

$4\ CuFeS_2 + 17\ O_2 + 4\ H_2O = 4\ CuSO_4 + 2\ Fe_2O_3 + 4H_2SO_4$

$4\ FeS + 9\ O_2 + 4\ H_2O = 2\ Fe_2O_3 + 4\ H_2SO_4$

$2\ S + 3\ O_2 + 2\ H_2O = 2\ H_2SO_4$

The feed material used in accordance with the present invention may also be adjusted to achieve a heat balance between exothermic an endothermic heats of reaction. The heat contents of the feed and exit streams from the reaction should be such that external heat energy requirements or cooling requirements in the leach system are autogenous or minimised with or without heat energy recycle from the reaction vessel discharge products to the feed materials.

Simultaneous acid and heat balances are obtainable but in many circumstances, heat recovery and recycle or supplementary cooling maybe required. The method of achieving this is influenced by equipment requirements and operating conditions required. The process control is preferably driven by either the acid balance or the heat balance.

The feed components may be pre-blended in the desired ratios and pumped into the reaction vessel as an aqueous slurry. However, other handling and charging techniques are also envisaged within the scope of the present invention. These may include, for example, operation of a batch autoclave.

In addition to the feed containing multiple metal values the feed being preferably introduced as a slurry or slurries, other materials which may be added to the reaction vessel include water, oxygen, other oxidants, acid (if required) recycled leach solids discharge (after cooling) for reactor cooling as or if required, and steam for any required heating.

The reaction times required to achieve oxidation of the sulphidic components in the feed and leaching of metal values into the liquid or solid phases are typically in the range of 0.5-2.0 hours.

After treatment in accordance with the present invention, the metal values in a mixed feed may be contained in either the liquid phase or the solids phase or both depending upon the nature of the feed and the metals being extracted. The reaction product is typically discharged in the form of a slurry which may require pH adjustment to facilitate recovery of individual metals in downstream processing. The pH required for subsequent processing is dependent upon the metals to be recovered and the process to be employed for extraction of the desired metals from the liquid and/or solids streams. Known methods for such pH adjustment may be employed in accordance with the present invention.

In one approach the pH may be kept relatively low (say about 2) during which time copper may be extracted by means such as solvent extraction. Subsequently, pH may be raised to remove iron eg. by precipitation at pH 3.5 to 4. Remaining valuable metals may be recovered after iron removal, for example by solvent extraction. This subsequent recovery of metals may be carried out in a series of steps involving increasing pH.

The form of downstream processing suitable for recovery of metal values is dependent upon the nature of the metal values to be extracted. A wide variety of recovery techniques including but not limited to resin-in-pulp, solvent-in-pulp, precipitation, electrowinning, solvent extraction and leaching such as cyanidation followed by carbon-in-pulp or carbon-in-leach extraction and physical techniques are all envisaged within the scope of the present invention. Hydroxamic acids which can exhibit very high levels of extraction of the desired metal ions into the solvent and can have the ability to operate over a wide pH range, ie in acidic and basic conditions, may be suitable for multiple metal extraction.

The treatment and extraction methods provided by the present invention provide a number of advantages over known prior art methods in that multiple sulphidic and oxide feed components can be processed through the one facility without any need for separation and that feed materials that are not generally considered economic for metal extraction may become economic for processing in accordance with the present invention. Further, feed materials not amenable to conventional processing such as high MgO and/or high arsenic sulphidic or oxide feeds may become economically treatable in accordance in the present invention. Also the cobalt in nickel smelter slags can be recovered and may become economically treatable in accordance with the present invention.

The methods provided by the present invention also facilitate the separation of desired metal values from undesired impurities. For example, desired metal values may be separated by selective extraction from solution of desired metal values from undesired impurities, or by separation of desired metal values taken into solution from undesired impurities such as arsenic which report to the solid phase.

The energy expenditure for process heating in the reaction vessel may be minimised or eliminated by use of the methods provided by the present invention and the invention may obviate the need for an acid production plant or the purchase of acid in a majority of circumstances where the sulphur balance in the feed is correctly proportioned while at the same time avoiding sulphur dioxide production requiring subsequent processing.

The present invention is further described in the following non-limiting examples of preferred embodiments which are based on empirical and theoretical considerations and are illustrative of the way in which the invention may be applied in practice.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a block diagram of a simplified flow sheet for Example 1;

FIGURE 2 is a block diagram of a simplified flow sheet for Example 2; and

FIGURE 3 is a block diagram of a simplified flow sheet for Example 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1:

A mixture of Leinster Oxide Ores, Leinster Secondary Concentrate and Mt Keith Concentrate may be formulated whereby the acid consuming constituents of the mixture balance with the acid producing constituents and a heat balance is achieved without heat recovery or supplementary heating. This may optionally include recycle of cooled leach discharge to leach feed for control of the heat balance.

The Leinster Oxide Ore is a mixed nickel oxide/silicate ore from the Leinster area of Western Australia and the Leinster Secondary Concentrate is a concentrate formed from multiple metal sulphide ore containing nickel, cobalt, copper, gold, zinc, etc also from the Leinster area of Western Australia. The Mt Keith Concentrate is a similar multiple metal sulphide ore, however the Concentrate includes a high magnesia concentration which may cause difficulty in smelting by prior art methods. The Mt Keith deposit is also in Western Australia.

A feed comprising a mixture of Leinster Oxide Ore, Leinster Secondary Concentrate and Mt Keith Concentrates is in this example embodiment introduced at ambient temperature into an autoclave by pumping in an aqueous slurry.

Oxygen is admitted into the autoclave to oxidise the sulphides generating an acid environment and to also oxidise the iron from sulphide minerals such as pentlandite, pyrrhotite and pyrite through to hematite. Multiple metals are released into solution generating acid ions which leach the oxide metal values into solution and the sulphur forms sulphate ions. Acid is consumed by magnesia minerals to form magnesium sulphate. Other acid consuming reactions include alunite and jarosite formation.

In this example, the preferred leach temperature is approximately 210-240°C with retention time at 0.75 to 1.5 hours and at a leach density of 35 to 45% solids and at an acid concentration of approximately 40g/l H_2SO_4. Leach discharge is preferably flash cooled in one or more stages to ambient pressure and to temperatures below boiling point.

Flash cooled leach discharge is then further cooled as necessary. The slurry then reports to solid liquid separation. The pregnant acid liquor is neutralised to approximately pH4 using limestone and/or lime. The solids from neutralisation (in slurry form) are preferably recycled to solid liquid separation feed. (The pH adjustment could be done direct on the part cooled, or cooled leach discharge slurry).

The neutralised pregnant liquor is clarified then subjected to a solvent extraction stage to remove elements such as copper before being subjected to further stages for selective extraction of nickel, cobalt, zinc etc. The loaded organics are in each case, preferably stripped with sulphuric acid. Cobalt, copper, zinc and/or manganese may be recovered from their respective strip liquor or rejected. Nickel may be recovered from its respective strip liquor.

A block diagram of a simplified flow sheet for this example of one possible use of the methods provided by the present invention for the recovery of nickel values from mixed nickel sulphide and nickel oxide ores is included herein as FIGURE 1.

<u>Example 2:</u>

In Western Australia, the following materials are currently produced

- Nickel Oxide
- Auriferous Pyrite
- Convertor Slag

These nickel oxides can be high in silica (40 to 60% SiO_2) and contain more than 1% Ni and approximately 0.1% Co.

Very substantial production of gold in Kalgoorlie, Western Australia requires processing of both refractory and free milling pyritic auriferous ores. Refractory ores are floated and then the concentrate is roasted, cyanided and gold recovered via CIP/CIL techniques.

Free milling auriferous ores are floated and then the concentrate is cyanided direct with gold being recovered via CIP/CIL. Some residual gold remains in the pyrite after cyanidation. After gold recovery, the cyanided pyrite is currently rejected to tailings.

Nickel matte from the Kalgoorlie (Western Australia) flash smelter is upgraded in convertors, and the convertor slag is returned to the flash furnace because of its nickel content. Convertor slag contains high levels of cobalt but this is largely unrecovered as it eventually passes out in the high volume flash furnace slag which reports to waste.

A mixed feed of nickel oxide, auriferous pyrite and convertor slag may be fed to an autoclave and processed in accordance with the present invention as set out in the flowsheet included herein as FIGURE 2.

In this preferred embodiment of the present invention the nickel oxide ore is used as the acid sink and as a source of nickel and cobalt. The refractory auriferous pyrites is used as an in-situ energy and acid source and in doing so the need to roast is eliminated. There is an environmental advantage in that sulphur no longer reports to atmosphere as sulphur dioxide.

Gold from the pyrites is eventually recovered from washed autoclave discharge solids via the well known CIP/CIL techniques. Cyanided free milling pyrite is added to the autoclave as a further source of an in-situ energy and acid which results in the recovery of further gold. This source of pyrite is presently discharged to tailings dams.

Convertor slag may be added as a source of nickel and cobalt. The slag may have some energy value from encapsulated matte/sulphides but will be largely neutral in respect to being an acid consumer.

Specific conditions for autoclave operation depend on the composition of each of the feed components and which one is to contribute most in the way of metal values. A typical set of operating conditions for the mix of nickel oxide, auriferrous pyrite and convertor slag is as follows:

35% solids in feed slurry
230°C
3 atmospheres of oxygen overpressure
1.5 hours retention time
40 g/l free acid expressed as H_2SO_4

At these conditions 90 to 95% of nickel in the laterite can be expected to be leached together with 92 to 96% of the cobalt. Cobalt extracted from slag into solution should be in the order of 95 to 98%. Residual gold left in the solids phase after cyanidation will be typically 1 g/t less than if the auriferrous pyrite was cyanided directly. Pressure oxidised auriferous pyrite is more amenable to cyanidation than direct cyanidation of auriferrous pyrite.

Example 3

In the north of Western Australia, copper is produced by Western Mining Corporation at its Nifty Operation from oxide ore via Heap Leach and solvent extraction/ electrowinning. Sulphide deposits occurring at depth below the oxide copper ores, contain copper in the primary ore body as chalcopyrite. These sulphide deposits have not yet been exploited due to present unattractive terms received for direct concentrate sales and the deposits being of insufficient size to support construction and operation of a smelter.

Close by to Nifty at Telfer, market tonnages of copper sulphide concentrates containing gold are produced from ores mined primarily for gold with the concentrate being a byproduct which is at present sold.

Copper concentrate from Nifty and copper/gold concentrate from Telfer may be sent to Leinster and pressure oxygen leached in conjunction with Leinster nickel oxide ores in accordance with the invention to produce nickel, cobalt, copper and/or zinc and/or gold etc. Close by to Leinster at Yeelirrie, there occurs a large calcrete uranium ore body. The calcrete reacts very readily with cold dilute acid and could be used in lieu of limestone for acid neutralisation purposes outside of the leach autoclave. Uranium could therefore also be produced and this also applies to the EXAMPLE NO. 1.

Specific conditions for autoclave operation depend on the composition of each of the feed components and which one is to contribute most in the way of metal values. Typical autoclave conditions for the mixture of Nifty copper sulphide concentrate, Telfer copper sulphide/gold concentrate and Leinster metal oxide ore are as follows:

45% solids in feed slurry
210°C
7 atmospheres of oxygen overpressure
1 hour retention time
30g/l free acid expressed as H_2SO_4

Under these conditions 97 to 98% of more of the total copper can be expected to leach into solution. More than 95% of the nickel can be expected to leach into solution. Gold recovery from cyanidation of the autoclave discharge solids should be in excess of 96%.

Advantages of combining the Nifty and Telfer concentrates, together with the Leinster metal oxide ore to form a feed in accordance with the present invention include:

- Allows the Nifty sulphide ore body to be brought into production (Nifty oxide ores will be depleted well before Nifty sulphides are depleted but nevertheless, a combined Nifty sulphide and Nifty oxide ores pressure leach could be contemplated. Nifty currently imports acid for its heap leach operations).
- Allows Leinster to exploit more of the metal oxide ores of that area.
- Some of the Yeelirrie calcrete can be used in lieu of limestone resulting in some uranium production.

A block flowsheet for the process of EXAMPLE NO. 3 is included herein as FIGURE 3.

While it has been convenient to describe the invention herein in relation to particularly preferred embodiments, it is to be appreciated that other constructions and arrangements are also considered as falling within the scope of the invention. Various modifications, alterations, variations and/or additions to the constructions and arrangements described herein are also considered as falling within the ambit and scope of the present invention.

CLAIMS

1. A method for the treatment of a plurality of metal values in a feed containing sulphide and oxide components, the method including the step of oxidising the sulphide components in the feed at elevated temperature and pressure to generate an acid environment in-situ in which metal values from the sulphide and the oxide components are taken into solution and/or report to the solid phase in a form amenable to further treatment.

2. A method according to claim 1 wherein the feed contains a plurality of metal values selected from the group comprising nickel, cobalt, zinc, magnesium, copper, chromium, uranium, thorium and related radioactive elements, lead, rhodium, cadmium, vanadium, gallium, gold, silver, platinum and related precious metals.

3. A method according to claim 2 wherein the feed is introduced into a treatment vessel in the form of one or more aqueous slurries.

4. A method according to claim 2 wherein the sulphide and oxide components of the feed are derived from a single ore body.

5. A method according to claim 2 wherein the feed contains three or more different metal values.

6. A method according to claim 2 wherein the feed includes a high proportion of magnesium.

7. A method according to claim 2 wherein the feed includes magnesium oxide, magnesium silicate or magnesium carbonate.

8. A method according to claim 2 wherein the oxide component of the feed includes a nickel laterite.

9. A method according to claim 8 wherein the nickel laterite is a high magnesium oxide nickel laterite.

10. A method according to claim 8 wherein the sulphide component of the feed includes nickel sulphide.

11. A method according to claim 2 wherein the feed comprises a mixture formulated such that the acid consuming materials of the mixture balance with the acid generating materials of the mixture to produce a leach discharge which is controlled to a desired acid condition.

12. A method according to claim 11 wherein the acid condition in the discharge falls within the range 30g/l to 40g/l free acid as H_2SO_4.

13. A method according to claim 10 wherein the feed comprises a mixture of a nickel oxide ore and a concentrate formed from a multiple metal sulphide ore which is formulated to provide that the acid consuming materials of the

mixture balance with the acid producing materials and heat balance is achieved without heat recovery or supplementary heating.

14. A method according to claim 2 wherein said method is applied in the presence of halide ions.

15. A method according to claim 14 wherein halide ions are added to the feed as sea water or hyper saline water from an aquifier.

16. A method according to claim 2 wherein the treatment is carried out at a temperature within the range 180°C to 280°C.

17. A method according to claim 16 wherein the temperature falls within the range 180°C to 220°C.

18. A method according to claim 16 wherein the temperature falls within the range 200°C to 220°C.

19. A method according to claim 16 wherein the oxide components contain nickel and the treatment is carried out at a temperature about 250°C.

20. A method according to claim 16 wherein the oxide components contain multiple metals and the treatment is carried out at a temperature about 250°C.

21. A method according to claim 2 wherein the treatment is carried out with oxygen overpressures in the range of 2 to 8 atmospheres.

22. A method according to claim 2 wherein the treatment is carried out for a period of 0.5 to 2 hours.

23. A method for the extraction of a plurality of metal values from a feed containing sulphide and oxide components, the method including the step of subjecting the feed in an aqueous environment to elevated temperature and pressure sufficient to oxidise the sulphide component in the feed to form an acid environment in-situ, wherein metal values from the sulphide and the oxide components are taken into solution in the acid phase and optionally also report to the solid phase in a form amenable to further processing, the method also including the further step of recovering metal values by subsequent recovery from the liquid phase and optionally the solid phase.

24. A method according the claim 23 wherein the further step of recovering metal values uses one or more recovery techniques selected from the group comprising resin-in-pulp, solvent-in-pulp, precipitation, electrowinning, solvent extraction and leaching techniques.

25. A method according to claim 24 wherein a series of solvent extraction steps is used for extracting individual metal values.

26. A method according to claim 25 wherein iron in solution is precipitated from the liquid phase prior to recovering metal values.

27. A method according to claim 24 wherein the solid and liquid phases from the initial treatment step are in the form of a slurry which is subjected to a solid/liquid separation step to form a solids stream and a liquor stream and wherein the further step of recovering metal values is applied to recover metal values from the liquor stream and/or the solids stream.

28. A method according to claim 21 wherein at least one of the feeds contains arsenic which principally reports to the solid phase.

29. A method according to claim 24 wherein the feed includes nickel smelter slag.

30. A method according to claim 21 wherein the feed includes convertor slag or flash furnace slag.

31. A method according to claim 23 wherein the reaction conditions and feed compositions are blended to ensure that substantially no sulphur dioxide is emitted by the reaction, and all acid required for the reaction is generated in-situ.

32. A method according to claim 23 wherein the feed includes nickel oxide, auriferous pyrite and convertor slag.

33. A method according to claim 23 including the following steps:

(a) forming a flotation concentrate of copper sulphide ore;

(b) mixing the concentrate with a copper/gold concentrate, nickel oxide ores and water to form a slurry;

(c) reacting the slurry with oxygen in an autoclave at temperatures in excess of 180°C and oxygen overpressures in excess of 2 atmospheres to produce a reacted slurry mix;

(d) subjecting the mix to a solid/liquid separation to provide a solid stream and an acidic liquid stream;

(e) recovering gold from the solid stream by cyanidation;

(f) electrowinning copper metal from the acidic liquid stream;

(g) neutralising the acid liquid stream;

(h) separating any solids from the neutralised liquid stream to produce a pregnant liquor; and

(i) recovering nickel from the pregnant liquor.

34. A method according to claim 33 wherein the neutralisation step is carried out by mixing a uranium calcrete ore with the acid liquid stream and nickel and uranium are recovered from the pregnant liquor by solvent extraction.

35. A method for the extraction of a plurality of metal values from a feed including a flotation concentrate of refractory auriferous pyritic ore, a concentrate of free milling auriferous pyritic ore which has been leached by cyanidation, convertor slag and nickel oxide ores, said method including the steps of:

(a) mixing the feeds and forming an aqueous slurry thereof;

(b) reacting the slurry with oxygen in an autoclave at temperatures in excess of 180°C and oxygen overpressures in excess of 2 atmospheres to produce a reacted slurry mix;

(c) subjecting the mix to a solid/liquid separation to provide a solid stream and a pregnant liquor;

(d) recovering gold from the solid stream by cyanidation; and

(e) recovering nickel and cobalt from the pregnant liquor.

36. A method for the extraction of a plurality of metal values from a feed including a flotation concentrate of a multiple metal sulphide ore, a scavenger concentrate of a flotation concentrate of a sulphide ore and a nickel oxide containing ore, said method including the steps of:

(a) mixing the feed and forming a slurry thereof;

(b) reacting the slurry with oxygen in an autoclave at temperatures in excess of 180°C and oxygen overpressures in excess of 2 atmospheres to provide a reacted slurry mix;

(c) subjecting the mix to a solid/liquid separation to provide a tailings stream and a pregnant acid liquor;

(d) partially neutralising the acid liquor to provide neutralised solids and neutralised liquor;

(e) separating the neutralised solids and neutralised liquor;

(f) recycling the neutralised solids to the slurry reacting in the autoclave; and

(g) recovering metal values from the neutralised liquor.

37. A method according to claim 36 wherein the reaction temperature in the autoclave is between 210°C and 240°C, the density of slurry being leached in the autoclave is 35% to 45% solids and the retention time in the autoclave is 0.75 to 1.5 hours.

38. A method according to claim 36 wherein the acid concentration in the autoclave is approximately 40g/l H_2SO_4.

39. A method according to claim 36 wherein the pH of the neutralised liquor is approximately 4.

40. A method according to claim 36 wherein the pH of the neutralised liquor is controlled to facilitate the recovery of individual metals from the neutralised liquor in stepwise fashion.

41. A method according to claim 36 wherein the pH of the neutralised liquor is initially low to facilitate copper recovery after which the pH is increased to facilitate recovery of other metals.

42. A method according to claim 40 wherein the pH of the neutralised liquor is initially about 2 at which pH copper is recovered, after which pH is raised to remove iron and recover other metals.

43. A method according to claim 36 wherein the neutralised liquor is subjected to solvent extraction to remove copper after which it is subjected to further stages for selective extraction of nickel, cobalt, zinc and any other metals in the neutralised liquor.

44. A method according to claim 36 wherein limestone and/or lime is used to neutralise the acid liquor.

45. A metal which has been recovered from a feed in accordance with the method of claim 23.

46. A method according to claim 16 wherein the temperature falls in the range 220°C to 260°C.

FIGURE 1

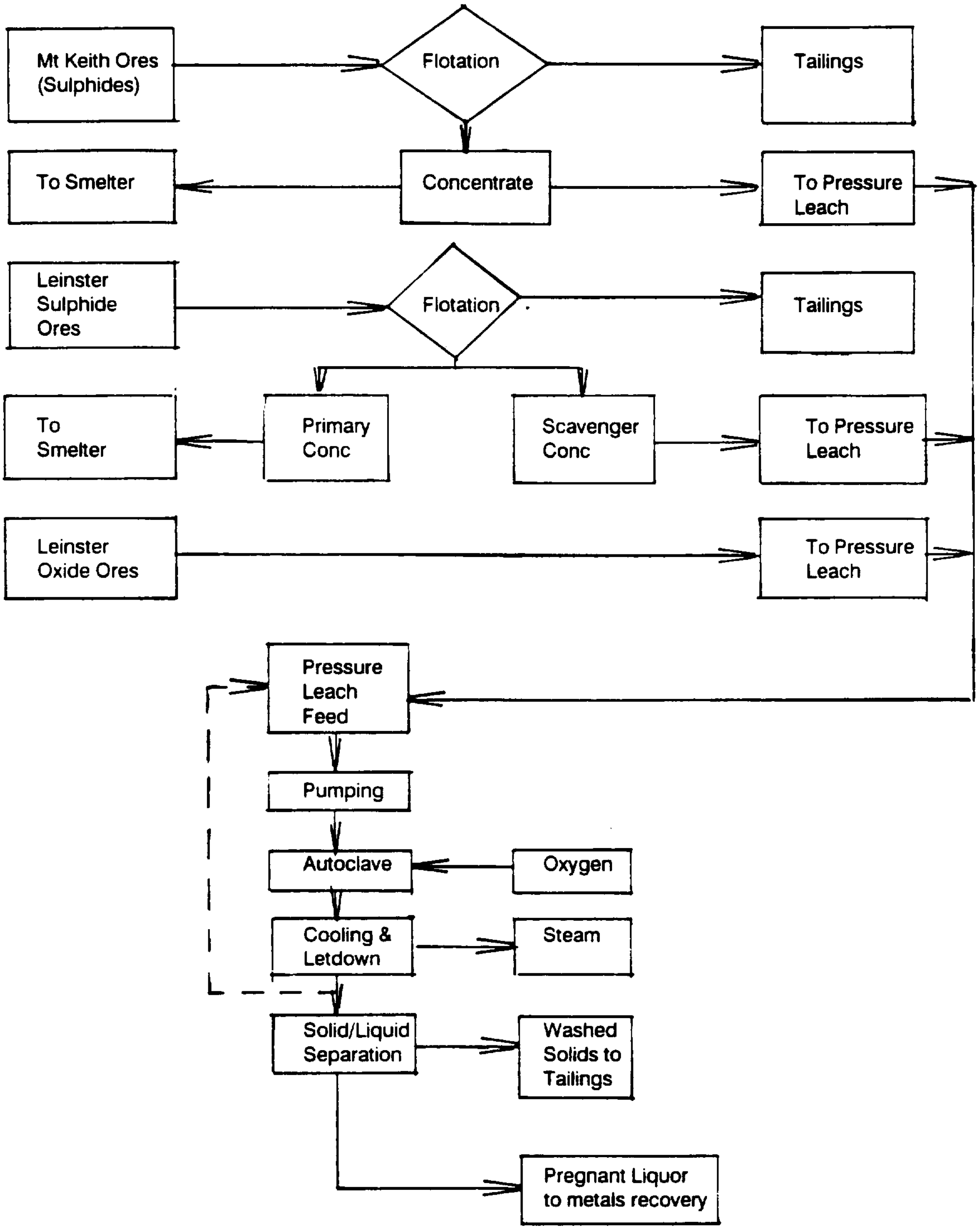

Mt Keith Ores (Sulphides)
Flotation
Tailings
To Smelter
Concentrate
To Pressure Leach
Leinster Sulphide Ores
Flotation
Tailings
To Smelter
Primary Conc
Scavenger Conc
To Pressure Leach
Leinster Oxide Ores
To Pressure Leach
Pressure Leach Feed
Pumping
Autoclave
Oxygen
Cooling & Letdown
Steam
Solid/Liquid Separation
Washed Solids to Tailings
Pregnant Liquor to metals recovery

FIGURE 2

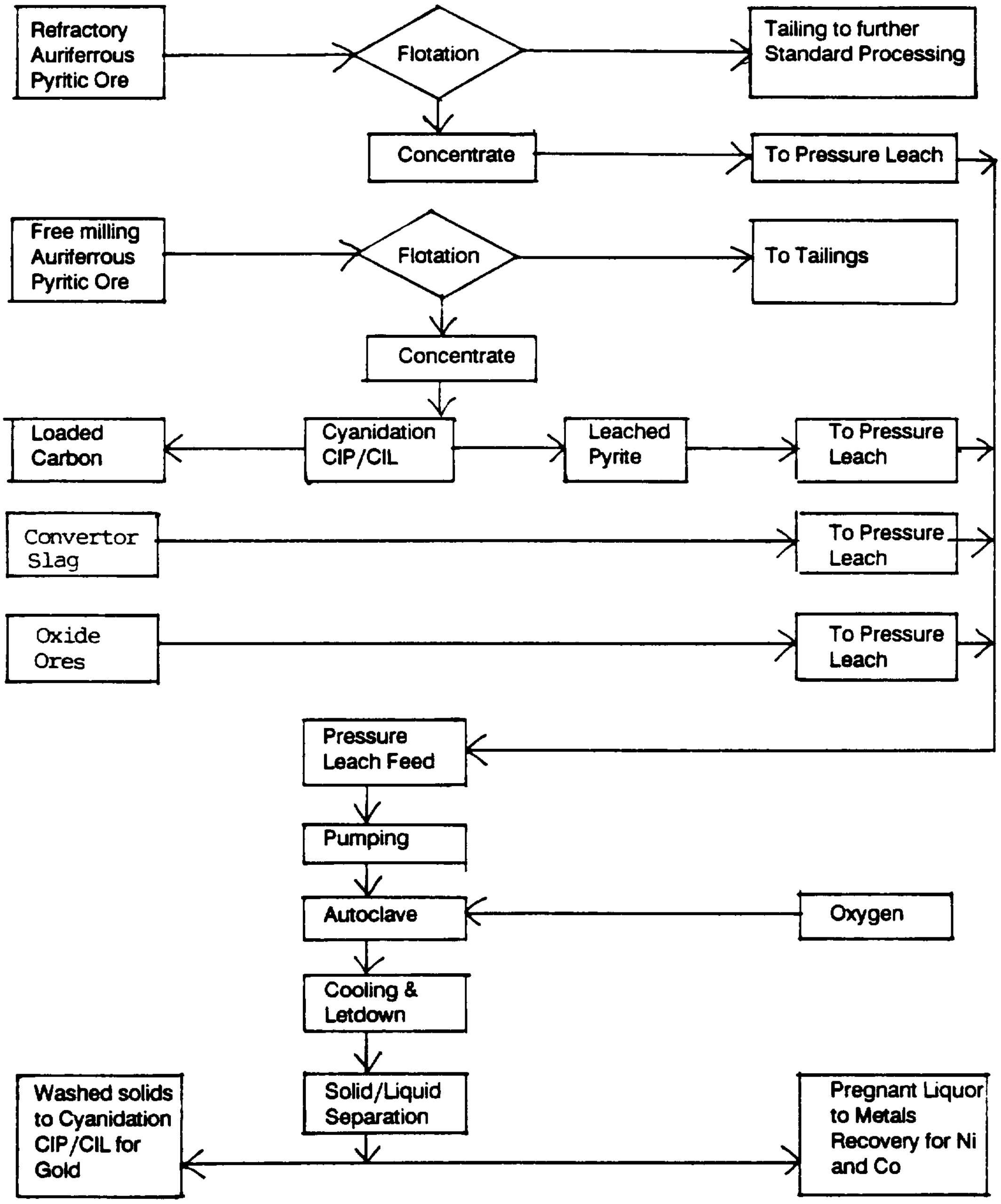
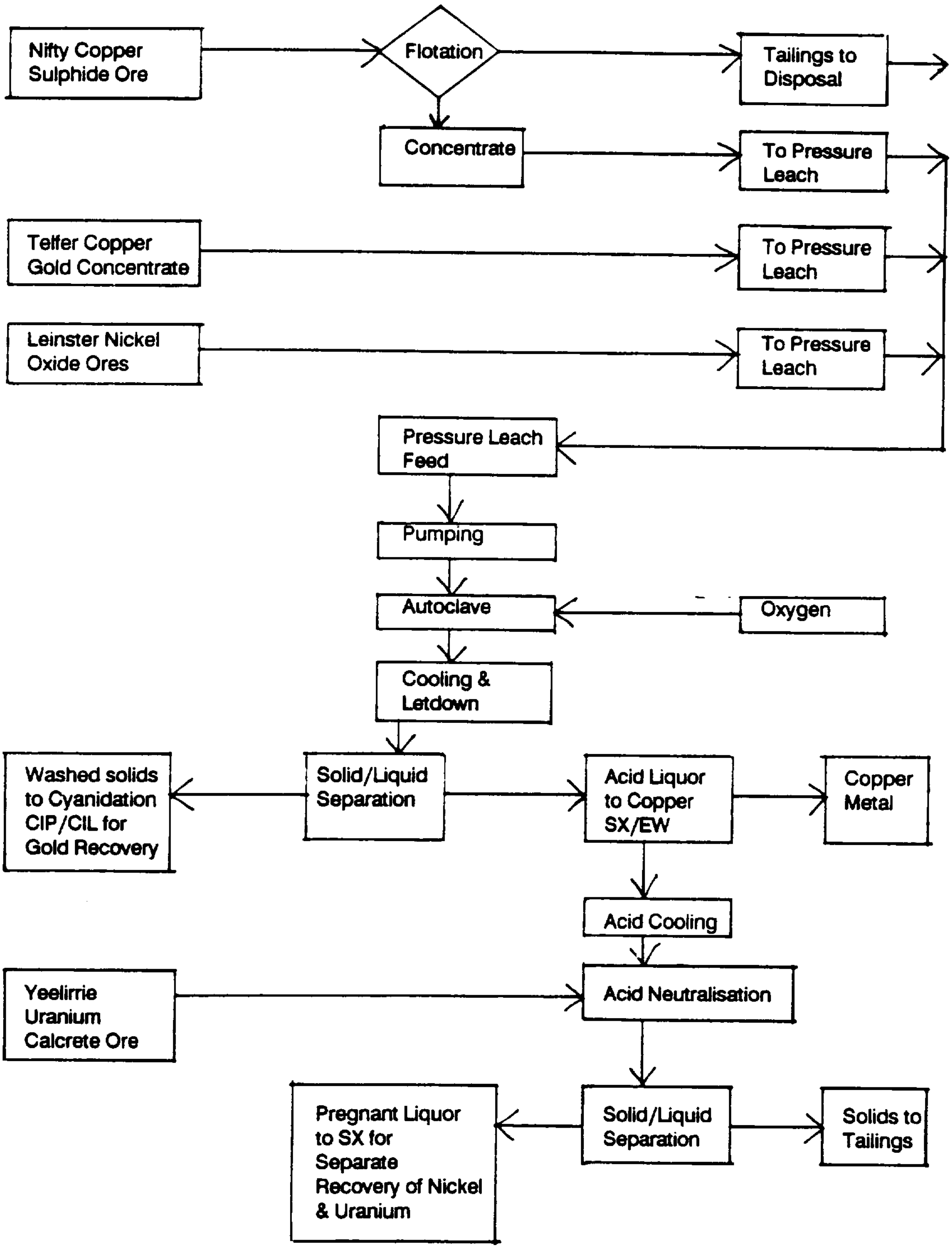

Refractory Auriferrous Pyritic Ore
Flotation
Tailing to further Standard Processing
Concentrate
To Pressure Leach
Free milling Auriferrous Pyritic Ore
Flotation
To Tailings
Concentrate
Loaded Carbon
Cyanidation CIP/CIL
Leached Pyrite
To Pressure Leach
Convertor Slag
To Pressure Leach
Oxide Ores
To Pressure Leach
Pressure Leach Feed
Pumping
Autoclave
Oxygen
Cooling & Letdown
Solid/Liquid Separation
Washed solids to Cyanidation CIP/CIL for Gold
Pregnant Liquor to Metals Recovery for Ni and Co

FIGURE 3


Nifty Copper Sulphide Ore
Flotation
Tailings to Disposal
Concentrate
To Pressure Leach
Telfer Copper Gold Concentrate
To Pressure Leach
Leinster Nickel Oxide Ores
To Pressure Leach
Pressure Leach Feed
Pumping
Autoclave
Oxygen
Cooling & Letdown
Washed solids to Cyanidation CIP/CIL for Gold Recovery
Solid/Liquid Separation
Acid Liquor to Copper SX/EW
Copper Metal
Acid Cooling
Yeelirrie Uranium Calcrete Ore
Acid Neutralisation
Pregnant Liquor to SX for Separate Recovery of Nickel & Uranium
Solid/Liquid Separation
Solids to Tailings

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00573

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^6: C22B 3/06 // C22B 11:00, 23:00, 19:00, 26:22, 15:00, C22B 34:32, 60:02, 13:00, 17:00, 34:22, 58:00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC C22B 3/00, 3/06, 11/00, 13/00, 15/00, 17/00, 19/00, 11/04, 13/04, 15/08, 17/04, 19/22, 23/00, 26/22, 34/22, 34/32, 58/00, 23/04, 60/02, 45/00, 39/00, 61/04, 55/00, 61/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT and JAPIO: IPC marks and (PRESSUR: and LEACH;) or AUTOCLAV:

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4548794 A (LOWENHAUPT et al) 22 October 1985 Whole document	1-46
A	US 4472359 A (PIETSCH et al.) 18 September 1984 Whole document	1-46
A	GB 2108480 A (SHERRITT GORDON MINES LIMITED) 18 May 1983 Whole document	1-46

☒ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
19 December 1995

Date of mailing of the international search report
21 December 1995

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C (Continuation)	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	AU 30893/84 B (CALIFORNIA NICKEL CORPORATION) 24 January 1985 Whole document	1-46
A	EP 100237 A (SHERRITT GORDON MINES LIMITED) 08 February 1984 Whole document	1-46
A	EP 96499 A (SHERRITT GORDON MINES LIMITED) 21 December 1983 Whole document	1-46
A	Derwent Abstract Accession No. 65614 E/31, Class M25, SU 870475 A (GIPRONIKEL RES INST) 7 October 1981 Abstract	1-46
A	US 4084961 A (CALDON) 18 April 1978 Whole document	1-46
A	GB 1189957 A (UNION CARBIDE CANADA LIMITED) 29 April 1970 Whole document	1-46

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 95/00573

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4548794	AU	30891/84	JP	60075536	BR	8403655
		PH	20875	FR	2549492	YU	1296/84
		GR	82205				
US	4472359	AU	80939/82	ZA	8201298	CA	1179510
		DE	3107368				
GB	2108480	AU	88583/82	ZA	8207078	CA	1173655
		FR	2515688				
EP	100237	AU	17108/83	GR	78633	CA	1212242
		IN	159988	DE	3378342	JP	59056537
		ES	524478	NO	832724	FI	832621
		US	4832925	ZA	8305316		
EP	96499	AU	14690/83	CA	1195846	DE	3367619
		ES	522853	FI	831751	GR	78815
		IN	159335	JP	59016940	NO	831947
		US	4443253	ZA	8303604		

END OF ANNEX