(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 December 2004 (09.12.2004)

PCT

(10) International Publication Number
WO 2004/106561 A1

(51) International Patent Classification[7]: C22B 3/06, 3/08, 3/46, 15/00

(21) International Application Number: PCT/AU2004/000738

(22) International Filing Date: 3 June 2004 (03.06.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2003902803 3 June 2003 (03.06.2003) AU

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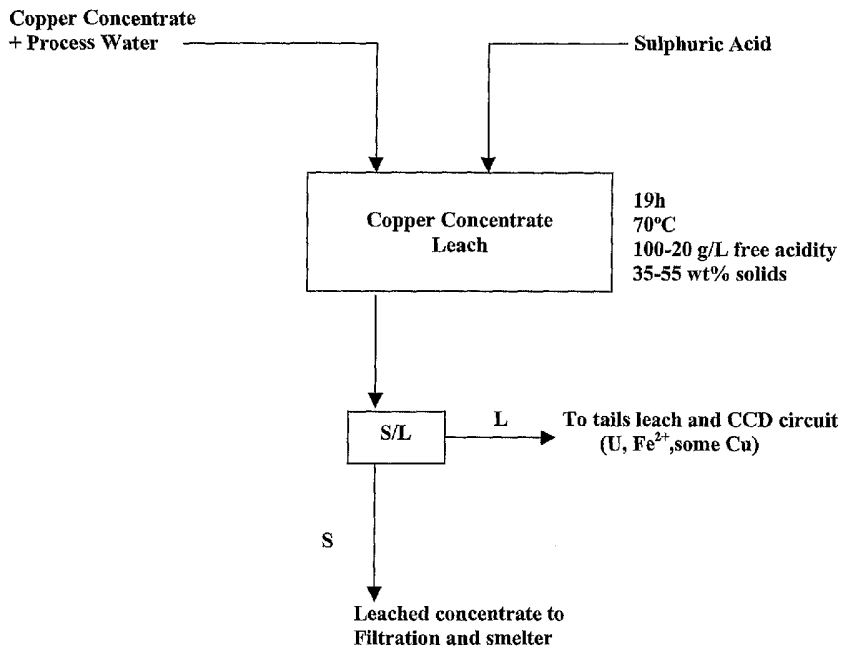
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,

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(54) Title: PROCESS OF UPGRADING A COPPER CONCENTRATE



(57) Abstract: According to the present invention there is provided a process for upgrading a copper concentrate suitable for smelting, the concentrate including gangue material containing any one or more of iron, uranium, aluminium, silicon or compounds thereof, the concentrate also including at least one of chalcopyrite and bornite, the process including the stages of: a) leaching at least a portion of the gangue material from the concentrate using an acid solution; and b) reacting chalcopyrite or bornite in the concentrate with ionic copper in a metathesis reaction that replaces iron with copper in the chalcopyrite or bornite and forms copper sulphide minerals.

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MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PROCESS OF UPGRADING A COPPER CONCENTRATE

Field of the Present Invention

The present invention relates to a hydrometallurgical process for upgrading a copper concentrate.

Background of the Invention

The present invention has been made to enable continued treatment of an ore body such as the ore body at Olympic Dam Operations in South Australia despite the grade and mineralogy of the ore being mined changing over time.

At present run-of-mine ore at Olympic Dam Operations is ground and concentrated in flotation vessels to produce a copper concentrate. Copper concentrate can have a particle size distribution with 80 weight percent passing 20-75 microns. The concentrate includes various copper sulphide minerals including chalcocite (Cu_2S), chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4) as well as gangue material, which includes compounds containing any one or a combination of iron, uranium, aluminium, and silicon.

It is expected that the relative proportions of the copper sulphide minerals in the ore body, and thus in the concentrate will change over time as the ore body is further developed. Specifically, it is expected that the proportion of chalcocite in the concentrate will reduce and the proportion of the chalcopyrite in the concentrate will increase over time. This will result in the production of a lower grade concentrate having a lower Cu:Fe and a lower Cu:S ratio. This is of fundamental importance in smelting.

According to present practice, the concentrate, which is fed to the smelter at Olympic Dam Operations undergoes an initial treatment to recover uranium and to at least partially remove hematite and other gangue

material using a sulphuric acid leach stage. Although hematite is normally considered difficult to leach using sulphuric acid, under suitable conditions hematite is dissolved to produce a ferrous sulphate solution. Thus, one apparent option to adjust the Cu:Fe ratio is to adjust the acidity of the leach to remove more hematite. However, the oxidation-reduction potential (ORP) of the leaching slurry also increases as acidity increases and some copper minerals would be more susceptible to dissolution and thus would also be removed from the concentrate if the leach conditions were changed. However, the Cu:S ratio is not changed by increased hematite dissolution.

An alternative process for upgrading low grade copper concentrate to maintain the Cu:S and Cu:Fe ratio within acceptable limits for smelting is therefore needed.

Summary of the Invention

According to the present invention there is provided a process for upgrading a copper concentrate suitable for smelting, the concentrate including gangue material containing any one or more of iron, uranium, aluminium, silicon or compounds thereof, the concentrate also including at least one of chalcopyrite and bornite, the process including the stages of:

a) leaching at least a portion of the gangue material from the concentrate using an acid solution; and

b) reacting chalcopyrite or bornite in the concentrate with ionic copper in a metathesis reaction that replaces iron with copper in the chalcopyrite or bornite and forms copper sulphide minerals.

An advantage provided by the present invention is that soluble ionic copper can react with chalcopyrite and bornite to form relatively insoluble copper sulphide minerals and thereby add to the amount of copper in the concentrate.

Although it is possible that stages a) and b) can be carried out concurrently, it is preferred that stages

a) and b) be carried out consecutively.

It is also possible that stage b) occur before stage a) or at least begin before stage a).

It has been found that acid leaching gangue material according to stage a) of the process of the present invention can create conditions in which the concentrate is upgraded by a series of redox reactions. In particular, during the acid leaching of stage a), it is possible that conditions may be created in which bornite and/or chalcopyrite are oxidised to copper sulphide minerals and thereby increase the ratio of copper to iron in the concentrate. For example, the oxidation of bornite to produce copper sulphide minerals may occur in stage a) without the addition of a reductant according to the following two half reactions.

Reaction 1

$Cu_5FeS_4 \rightarrow 4CuS + Fe^{2+} + Cu^{2+} + 4e^-$

Reaction 2

$Cu_5FeS_4 \rightarrow 3CuS + Cu_2S + Fe^{2+} + 2e^-$

Reaction 1 suggests the copper may be dissolved during stage a), however, the following half reaction involving the reduction of bornite suggests that any available copper ions are reacted to produce a copper sulphide precipitate.

Reaction 3

$Cu_5FeS_4 + 3Cu^{2+} + 4e^- \rightarrow 4Cu_2S + Fe^{2+}$

In the instance when stage a) involves the dissolution of hematite, ferric and sulphate ions are produced. Depending on the mineralogy of the concentrate being upgraded, ferric ions are a relatively strong oxidant and have a propensity to be reduced to ferrous ions in accordance with the following half reaction.

Reaction 4

$Fe^{3+} + e^- \rightarrow Fe^{2+}$

However, as can be seen from reactions 1 and 2, the oxidation of bornite produces in addition to copper sulphide minerals, ferrous and cuprous ions. The rate at which reaction 4 can occur depends on the products of reaction 1, 2 and 4. The rate of dissolution of hematite is also affected by the rate at which reaction 4 can occur.

In order to favour the dissolution of hematite, a reductant can be supplied to stage a) to facilitate the reduction of the ferric ions which in turn facilitates the dissolution of hematite.

Although it is possible that different types of reductants may be supplied to stage a), it is preferred that the reductants be any one or a combination of sulphur dioxide, sodium sulphite, or elemental iron.

Ionic copper can be supplied to stage a) which reacts with bornite and/or chalcopyrite to produce copper sulphide minerals by way of reduction and/or metathesis reactions. Ionic copper may be added to stage a) with or without the addition of a reducing agent. In the instance when ionic copper and a reductant are added to stage a), chalcopyrite may be reduced to produce a copper sulphide mineral in accordance with the following half reaction.

Reaction 5

$CuFeS_2 + 3Cu^{2+} + 4e^- \rightarrow 2Cu_2S + Fe^{2+}$

In the event that ionic copper is supplied to stage a) without the addition of a reductant, the dissolution of hematite is likely to reduce on account of the reduced availability of electrons to reduce ferric ions to ferrous ions.

In the event that ionic copper is supplied to

stage a) during acid leaching without the addition of a reductant, ionic copper is likely to react with bornite and/or chalcopyrite in a metathesis reaction.

An overall redox reaction in which no additional reductants and/or ionic copper are added to stage a) may be represented by the following reaction.

Reaction 6

$$Cu_5FeS_4 + Fe_2O_3 + 3H_2SO_4 \rightarrow 3CuS + Cu_2S + 3FeSO_4 + 3H_2O$$

It is preferred that the acid solution used in stage a) be a sulphuric acid solution. Accordingly, stage a) produces a solid phase from which iron oxides (eg hematite) and other gangue material have been partially or wholly removed and a liquid phase containing ferrous, uranium and other ions.

It is preferred that the concentration of sulphuric acid range from 20 to 100 g/L.

In the situation in which stages a) and b) occur consecutively, it is preferred that the liquid and solid phases produced in stage a) be at least partially separated in a solid/liquid separator prior to the concentrate being further processed according to stage b).

It is preferred that stage a) be carried out at a temperature > 70°C. Generally speaking, the amount and rate at which gangue material, particularly hematite, is leached from the concentrate increases as the temperature increases.

It is preferred that the acid solution and the concentrate in stage a) form a slurry whereby the proportion of solids in the slurry ranges from 35 to 60%.

It is preferred that the concentrate be subjected to leaching in stage a) for at least 10 hours.

It is even more preferred that the concentrate be subjected to leaching in stage a) for a period ranging from 10 to 25 hours.

It is preferred that the oxidation-reduction

potential (ORP) of the slurry in stage a) be < 380 mV and in stage b) be < 300mV. The ORP value is reported with reference to Ag/AgCl and 3M KCl.

The term "metathesis reaction" throughout this specification means a type of exchange reaction in which cations, preferably provided by a copper sulphate solution, react with chalcopyrite or bornite minerals to form relatively insoluble copper sulphide minerals including: covellite, chalcocite, digenite or derivatives thereof.

The copper sulphide minerals formed by metathesis have a tendency to form on the outer surfaces of copper iron sulphide mineral particles in the concentrate.

It is preferred that the metathesis reaction in stage b) be based on a reaction between copper sulphate and chalcopyrite or bornite.

It is preferred that the copper sulphate be in the form of a solution.

Two examples of metathesis reactions involving copper sulphate (provided from an external source) and chalcopyrite and bornite are as follows:

Reaction 7

$$3Cu_5FeS_4 + 6CuSO_4 + 4H_2O \rightarrow 5Cu_{1.8}S + 6Cu_2S + 3FeSO_4 + 4H_2SO_4$$

Reaction 8

$$3CuFeS_2 + 6CuSO_4 + 4H_2O \rightarrow 5Cu_{1.8}S + 3FeSO_4 + 4H_2SO_4$$

It is preferred that a reducing agent be added to stage b). It has been found that slightly reducing conditions enhance the substitution of copper ions for iron ions in the lattice of chalcopyrite and bornite minerals (ie. increase the metathesis reaction rate).

Examples of possible reducing agents include sodium sulphite (Na_2SO_3), sodium metabisulphite ($Na_2S_2O_5$), sulphur dioxide (SO_2), hydrogen and iron.

However, it is preferred that the reducing agent

be in the form of sulphur dioxide.

When stages a) and b) are carried out concurrently, one of the advantages of a reducing agent is that it can facilitate the dissolution of gangue material such as hematite and create conditions conducive to metathesis reactions.

An example of a metathesis reaction involving chalcopyrite and copper sulphate carried out in the presence of a reducing agent (SO_2) is as follows;

Reaction 9

$$Cu_5FeS_4 + 2SO_2 + 4H_2O + 3Cu^{2+} \rightarrow 4Cu_2S + 6H^+ + 2HSO_4^- + Fe^{2+}$$

It will be appreciated by those skilled in the art of the invention that an embodiment of the present invention may involve carrying out stages a) and b) concurrently whereby both leaching of gangue material and precipitation of copper sulphide minerals occurs simultaneously.

According to an alternative embodiment, stage a) can be carried out before stage b) so that in essence leaching of gangue material from the concentrate proceeds the production of a copper sulphide mineral. However as explained previously, it is possible that redox reactions may to some extent convert bornite and/or chalcopyrite into copper sulphide minerals during stage a).

According to yet another embodiment, stage b) may be carried out prior to stage a). Furthermore, when ionic copper is added to the concentrate to facilitate metathesis reactions prior to acid leaching, it is possible that a reductant may also be added to stage b) to facilitate a reduction of bornite and/or chalcopyrite to other copper sulphide minerals. Reaction 5 is an example of a half reaction in which bornite and/or chalcopyrite is reduced to a copper sulphide mineral.

Brief Description of the Drawings

A detailed description of a copper concentrate upgrading process according to a prior art process and the preferred embodiment of the invention will now be described with reference to:

Figure 1 which is a flowsheet of a copper concentrate treatment process presently in use at Olympic Dam Operations in South Australia;

Figure 2 which is a flowsheet of a copper concentrate upgrading process according to a preferred embodiment of the present invention;

Figures 3 to 5 which are flowsheets of copper concentrate upgrading processes according to alternative embodiments of the present invention; and

Tables 1 and 2 provide details of a total of 23 trials carried out on a concentrate presently available at Olympic Dam Operations and a concentrate expected to be produced in the future.

Detailed Description

The upgrading process shown in Figure 1 is a single stage leaching process presently in use at Roxby Downs mine. The materials fed to the leaching process comprise a copper concentrate slurry and sulphuric acid. The copper concentrate is prepared from a run-of-mine ore that has been ground and then concentrated in froth flotation vessels (not illustrated).

Upon completion of the leaching stage, the slurry is transferred to a solid/liquid separator. The upgraded concentrate can then be supplied to a smelter via other unit operations such as driers as necessary. The liquid from the separator contains ferrous sulphate, uranium compounds and possibly small amounts of soluble copper that may be further processed in the tails leaching circuit within the copper refining plant at Olympic Dam Operations.

In contrast, the process of the preferred

embodiment shown in Figure 2 is essentially a two stage process. A copper concentrate slurry comprising approximately 50 to 55% solids initially undergoes a sulphuric acid leaching stage to remove gangue material. The acid leaching stage may also involve redox reactions to assist the upgrading of concentrate.

The concentrate is then transferred to a copper precipitation stage involving metathesis reactions resulting from contacting the concentrate with a copper sulphate solution and carried out in the presence of a reducing agent. The metathesis reactions involve the conversion of solid chalcopyrite and bornite particles to solid compounds containing higher concentrations of copper and sulphur.

The process also includes solid/liquid separation after each stage for separating liquid and upgraded concentrate.

The slurry concentrate is treated in the leaching stage for a period of approximately 20 hours and at an elevated temperature of approximately 85°C. The sulphuric acid solution mixed with the slurry is supplied to produce an acid concentration in the leach solution ranging from 20-100 g/L.

The oxidation-reduction potential (ORP) of the slurry is of the order of 300mV, wherein the potential is in reference to Ag/AgCl and 3M KCl.

The acidity in the leaching step is maintained initially at 100 g/L but allowed to decrease about half way through the leach time to a lower concentration of 20 g/L. The ORP is dependent on the acid addition and the mineral composition of the concentrate.

The reaction kinetics under normal operating conditions are such that the concentrate is upgraded by at least partial dissolution of gangue material in the concentrate. The gangue material includes iron oxide compounds and uranium containing compounds.

In addition, the dissolution of iron oxide such

as hematite produces ferric ions that readily reduce in accordance with reaction 4. Reaction 4 takes place in association with reactions 1 and 2 and thereby converts bornite to insoluble copper sulphide minerals by way of redox reactions.

A reductant may be added to the leach stage for reducing ferric ions to ferrous ions and thereby increase the dissolution of hematite.

In addition, ionic copper may also be added to the leaching stage to convert bornite and/or chalcopyrite to copper sulphide minerals in accordance with reactions 3 and 5.

Figure 3 is a flowsheet in which iron leaching and copper precipitation are carried out simultaneously in a single stage. In particular a copper concentrate, sulphuric acid, and a soluble copper solution are supplied to the single stage to facilitate the dissolution of iron and produce a copper sulphide mineral from bornite and/or chalcopyrite by metathesis and redox reactions. A reductant is also supplied to assist in the reduction of ferric ions to ferrous ions and thus the dissolution of iron oxide material. The reductant also creates reducing conditions that favour the formation of the copper sulphide minerals by way of the redox and metathesis reactions. An upgraded solid phase is then separated from the liquid phase in a separator.

Figure 4 is a flowsheet in which both iron leaching and copper precipitation are carried out simultaneously in a first stage followed by copper precipitation in a second stage. The first stage is the same as flow sheet shown in Figure 3. The liquid and solid phases formed in the first stage are then separated and the solid phase further processed in a second stage that involves metathesis reactions driven by an ionic copper solution and reductant. An upgraded solid phase is then separated from the liquid phase in a further separator.

Figure 5 is a flowsheet in which copper precipitation involving metathesis and redox reactions occurs in a first stage followed by an iron leaching in a second stage. Copper concentrate, a soluble copper solution and a reductant are supplied to a first stage. The solid and liquid phases formed in the first stage are then separated and the solid phase treated in a second stage with sulphuric acid to leach iron. An upgraded solid phase is then separated from the liquid phase in a further separator.

Table 1 provides the results of 16 trials, of which trials 1 to 13 are upgrading processes carried out on a concentrate expected to be produced from ore mined at Olympic Dam Operations in the future ("future concentrate") and trials 14 to 16 are upgrading processes carried out on the concentrate presently available at Olympic Dam Operations ("present concentrate").

Table 1 includes data that shows the proportions of copper and iron in the feed concentrate, the liquid phase, and the upgraded concentrate, and the conditions under which the trials were conducted.

The upgrading processes in trials 6 to 13 were carried out in accordance with the present invention. However, unlike the preferred embodiment described above in relation to Figure 2, the upgrading processes in trials 6 to 13 were carried out so that the leaching and precipitation stages occurred concurrently. The upgrading processes conducted in the other trials 1 to 5 and 14 to 16 were carried out in accordance with the prior art and involved a leaching stage without soluble copper addition for metathesis of bornite (< 100°C).

An operating condition that had a notable impact on the leaching stage of both present and future concentrates was the temperature at which the leaching stage was operated. Specifically for the trials that only involved leaching without precipitation (trials 1 to 5 and 14 to 16), the percentage of the copper in the upgraded

solid phase was noticeably higher when the trials were conducted at higher temperatures.

In the case of trials 7 and 8 moderate amounts of an aqueous solution containing copper sulphate were added to the slurry in an attempt to facilitate copper precipitation into the concentrate and to create conditions in which precipitation of copper compounds may occur by means of metathesis reactions. However, although copper was precipitated in these trials, the proportion of copper in the upgraded solids was not as high as that achieved in comparable trials 1 and 4 where no soluble copper was added. This is attributed to the higher iron extraction in trials 1 and 4. This suggests that the addition of an aqueous copper solution to the leaching stage has a detrimental effect on the dissolution of iron compounds from the concentrate.

This leads to a conclusion that preventing the dissolution of copper and creating conditions that encourage the precipitation of copper by metathesis reactions may be less feasible when the leaching and copper precipitation stages are carried out concurrently when an aqueous solution of copper sulphate is used as the exchange reactant and when the ORP is high.

Trials 9, 10 and 12 involved the addition of a reducing agent in the form sodium sulphite and trials 9 and 10 also involved the addition of an aqueous copper solution for the purposes of precipitating dissolved copper. Precipitation of soluble copper was 52%, 95% and 100% in trials 9, 10 and 12.

Table 2 provides the results of 7 trials numbered 17 to 23, all of which are upgrading processes carried out on a concentrate expected to be produced from ore mined at Olympic Dam Operations in the future. Trials 17 to 21 were carried out in accordance with the flowsheet shown in Figure 2, namely an iron leaching stage followed by copper precipitation stage.

Trials 22 and 23 were carried out in accordance

with the flowsheet shown in Figure 5, namely a copper precipitation stage followed by an iron leaching stage.

The results of the trials show that the optimal process for upgrading the concentrate involves a 2 stage process in which gangue material leaching and copper precipitation are carried out at different optimum conditions.

A summary of the optimal process operating conditions for a flowsheet shown in Figure 2 is as set out below:

Stage 1 - Leach stage

Temperature:	> 80 °C
Acidity:	100 g acid per L for 8-12 h
Duration:	12 - 24 h
Slurry density:	> 50 wt% solids
ORP:	< 380 mV

Stage 2 - Copper precipitation stage

Temperature:	> 70 °C
Acidity:	> 20 g acid per L
Duration:	> 5 h
Slurry density:	> 50 wt% solids
ORP:	< 300 mV
Reductant:	sodium sulphite
Copper Concentration:	< 100 g Cu per L

Many modifications may be made to the preferred embodiment of the present invention described above without departing from the spirit and scope of the invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for upgrading a copper concentrate suitable for smelting, the concentrate including gangue material containing any one or more of iron, uranium, aluminium, silicon or compounds thereof, the concentrate also including at least one of chalcopyrite and bornite, the process including the stages of:

a) leaching at least a portion of the gangue material from the concentrate using an acid solution; and

b) reacting chalcopyrite or bornite in the concentrate with ionic copper in a metathesis reaction that replaces iron with copper in the chalcopyrite or bornite and forms copper sulphide minerals.

2. The process according to claim 1, wherein acid leaching gangue material according to stage a) creates conditions in which redox reactions produce copper sulphide minerals from bornite and/or chalcopyrite.

3. The process according to claim 2, wherein bornite and/or chalcopyrite are oxidized to copper sulphide minerals.

4. The process according to claim 2, wherein ionic copper is supplied to stage a) which reacts with bornite and/or chalcopyrite to produce copper sulphide minerals by way of reduction reactions or metathesis reactions.

5. The process according to claim 4, wherein a reducing agent is supplied to stage a) so that the reducing agent and ionic copper react with bornite and/or chalcopyrite in a reduction reaction to produce copper sulphide minerals.

6. The process according to claim 5, wherein the

reductant supplied to stage a) also reduces ferric ions which in turn facilitates an increased rate of dissolution of iron oxide gangue material.

7. The process according to claim 6, wherein the reductant is any one or a combination of sulphur dioxide, sodium sulphite, or elemental iron or sodium metabisulphite.

8. The process according to any one of claims 1 to 7, wherein the acid solution used in stage a) is a sulphuric acid solution.

9. The process according to claim 8, wherein the concentration of sulphuric acid solution ranges from 20 to 100 g/L.

10. The process according to any one of claims 1 to 9, wherein stages a) and b) are carried out consecutively.

11. The process according to claim 10, wherein liquid and solid phases produced in stage a) are at least partially separated in a solid/liquid separator prior to the concentrate being further processed according to stage b).

12. The process according to claims 1 to 11, wherein stage a) is carried out at a temperature > 70°C.

13. The process according to any one of claims 1 to 12, wherein the acid solution and the concentrate in stage a) form a slurry whereby the proportion of solids in the slurry ranges from 35 to 60%.

14. The process according to any one of claims 1 to 13, wherein the concentrate be subjected to leaching in stage a) for at least 4 hours.

15. The process according to claim 13, wherein the concentrate is subjected to leaching in stage a) for a period up to 25 hours.

16. The process according to claim 10 or 11, wherein the oxidation-reduction potential (ORP) of the slurry in stage a) is < 380 mV and in stage b) is < 300mV with reference to Ag/AgCl and 3M KCl.

17. The process according to any one of claims 1 to 16, wherein stage b) is carried out at a temperature greater than 100°C if chalcopyrite is present in the concentrate.

18. The process according to any one of claims 1 to 17, wherein the ionic copper is supplied in the form of a copper sulphate solution.

19. The process according to any one of claims 1 to 18, wherein a reducing agent is supplied to stage b) to enhance the substitution of copper ions for iron ions in chalcopyrite and/or bornite minerals.

20. The process according to claim 19, wherein the reducing agent supplied to stage b) is in the form of sulphur dioxide.

21. A plant for upgrading a copper concentrate suitable for smelting, the concentrate including gangue material containing any one or more of iron, uranium, aluminium, silicon or compounds thereof, the concentrate also including at least one of chalcopyrite and bornite, the plant including one or more than one vessel in which the following stages may be carried out simultaneously, consecutively or disjunctively:

a) leaching at least a portion of the gangue

material from the concentrate using an acid solution; and

b) reacting chalcopyrite or bornite in the concentrate with ionic copper in a metathesis reaction that replaces iron with copper in the chalcopyrite or bornite and forms copper sulphide minerals.

22. The plant according to claim 21, wherein acid leaching gangue material creates conditions in which redox reactions produce copper sulphide minerals from bornite and/or chalcopyrite.

23. The plant according to claim 22, wherein bornite and/or chalcopyrite are oxidized to copper sulphide minerals.

24. The plant according to claim 22, wherein ionic copper is supplied to the or each vessel which reacts with bornite and/or chalcopyrite to produce copper sulphide minerals by way of reduction reactions or metathesis reactions.

25. The plant according to claim 24, wherein a reducing agent is supplied to the or each vessel so that the reducing agent and ionic copper react with bornite and/or chalcopyrite in a reduction reaction to produce copper sulphide minerals.

26. The plant according to claim 25, wherein the reductant supplied to the or each vessel also reduces ferric ions which in turn facilitates an increased rate of dissolution of iron oxide gangue material.

27. The plant according to claim 26, wherein the reductant is any one or a combination of sulphur dioxide, sodium sulphite, or elemental iron or sodium metabisulphite.

28. The plant according to any one of claims 21 to 27, wherein the acid solution used in stage a) is a sulphuric acid solution.

29. The plant according to claim 28, wherein the concentration of sulphuric acid solution ranges from 20 to 100 g/L.

30. The plant according to any one of claims 21 to 29, wherein stages a) and b) are carried out consecutively.

31. The plant according to claim 30, further including a solid/liquid separator for separating the liquid and solid phases produced in stage a) prior to the concentrate being further processed according to stage b).

32. The plant according to claims 21 to 31, wherein stage a) is carried out at a temperature > 70°C.

33. The plant according to any one of claims 21 to 32, wherein the acid solution and the concentrate in stage a) form a slurry whereby the proportion of solids in the slurry ranges from 35 to 60%.

34. The plant according to any one of claims 21 to 23, wherein the concentrate is subjected to leaching in stage a) for at least 4 hours.

35. The plant according to claim 33, wherein the concentrate is subjected to leaching in stage a) for a period up to 25 hours.

36. The plant according to claim 30 or 31, wherein the oxidation-reduction potential (ORP) of the slurry in stage a) is < 380 mV and in stage b) is < 300mV with reference to Ag/AgCl and 3M KCl.

37. The plant according to any one of claims 21 to 36, wherein stage b) is carried out at a temperature greater than 100°C if chalcopyrite is present in the concentrate.

38. The plant according to any one of claims 21 to 37, wherein the ionic copper is supplied in the form of a copper sulphate solution.

39. The plant according to any one of claims 21 to 38, wherein a reducing agent is supplied to stage b) to enhance the substitution of copper ions for iron ions in chalcopyrite and/or bornite minerals.

40. The plant according to claim 39, wherein the reducing agent supplied to stage b) is in the form of sulphur dioxide.

41. An upgraded concentrate produced by the process or plant described above in any one of the preceding claims.

FIGURE 1

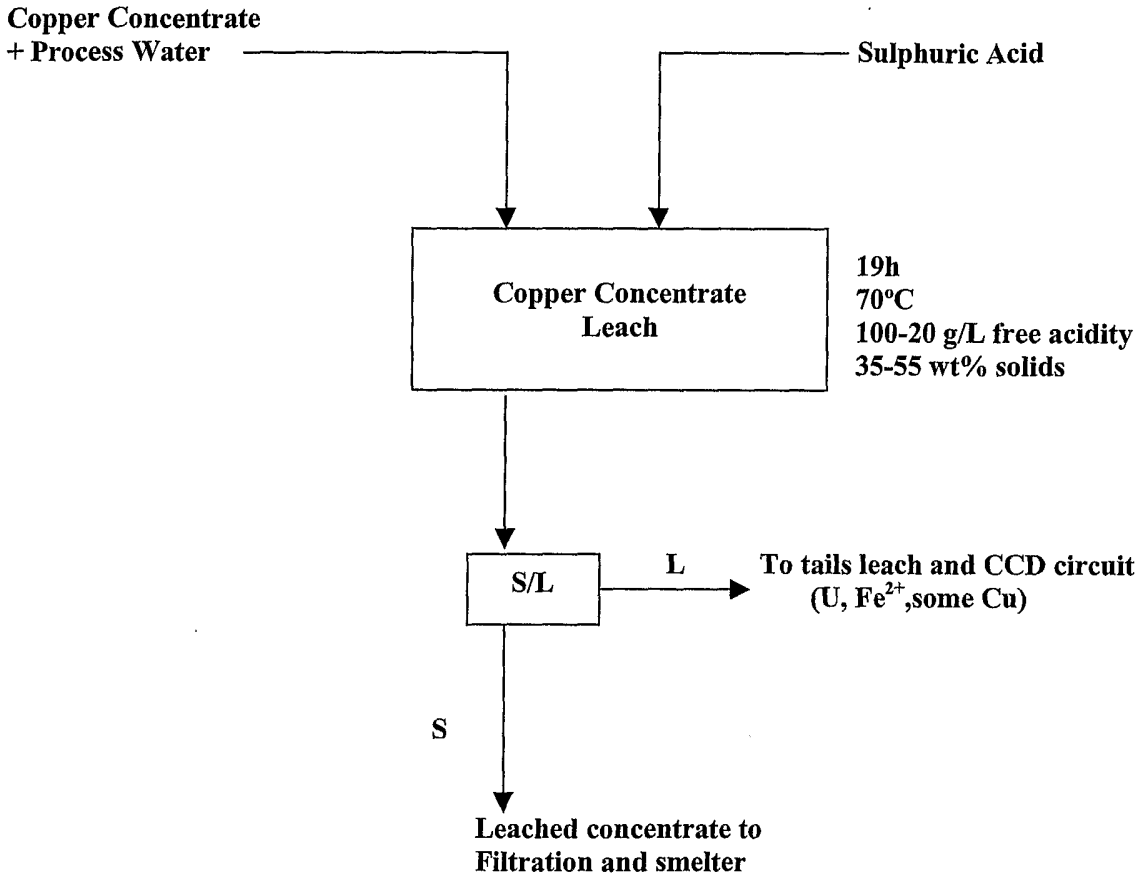

Copper Concentrate
+ Process Water
Sulphuric Acid
Copper Concentrate
Leach
19h
70°C
100-20 g/L free acidity
35-55 wt% solids
S/L
L
To tails leach and CCD circuit
(U, Fe2+,some Cu)
S
Leached concentrate to
Filtration and smelter

FIGURE 2

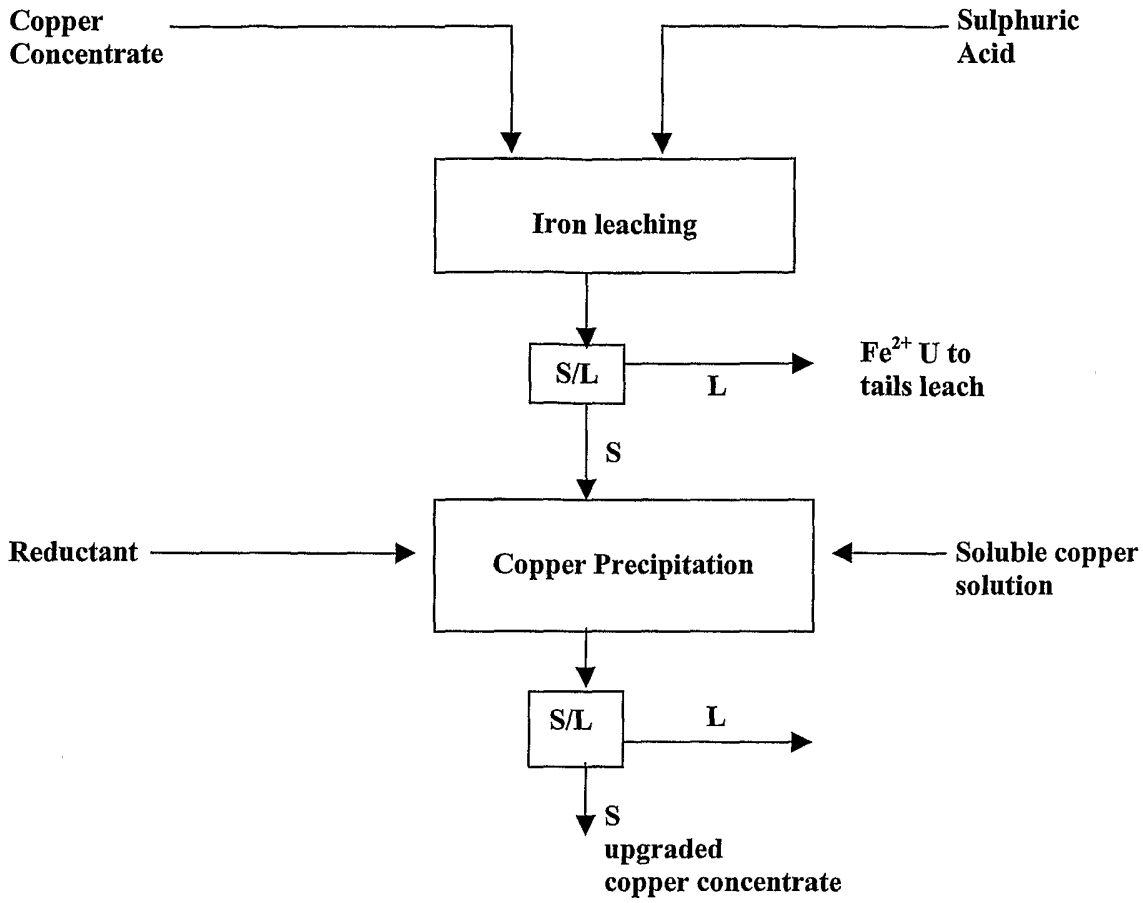


FIGURE 3

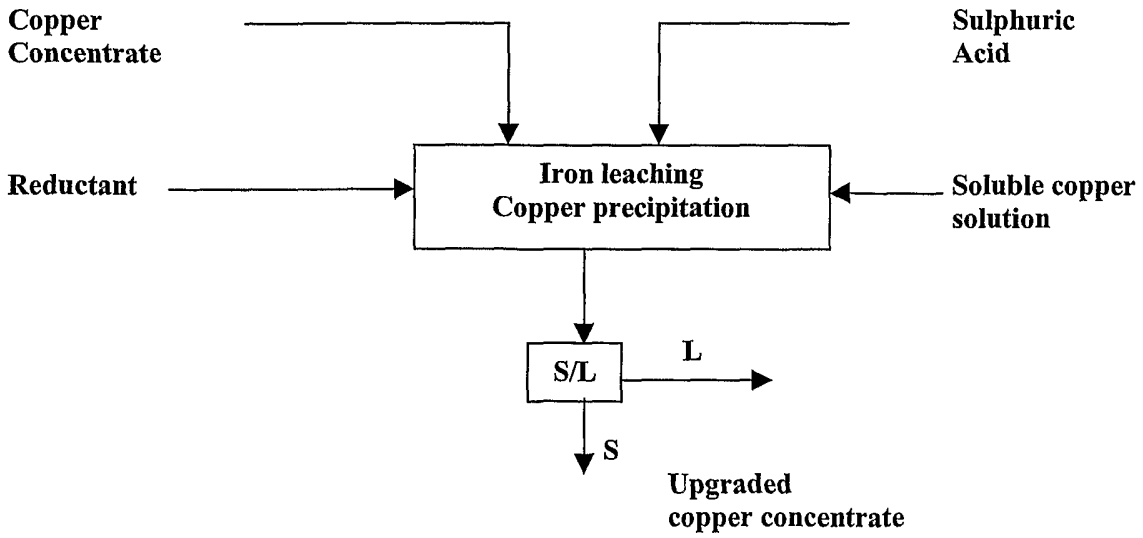


FIGURE 4

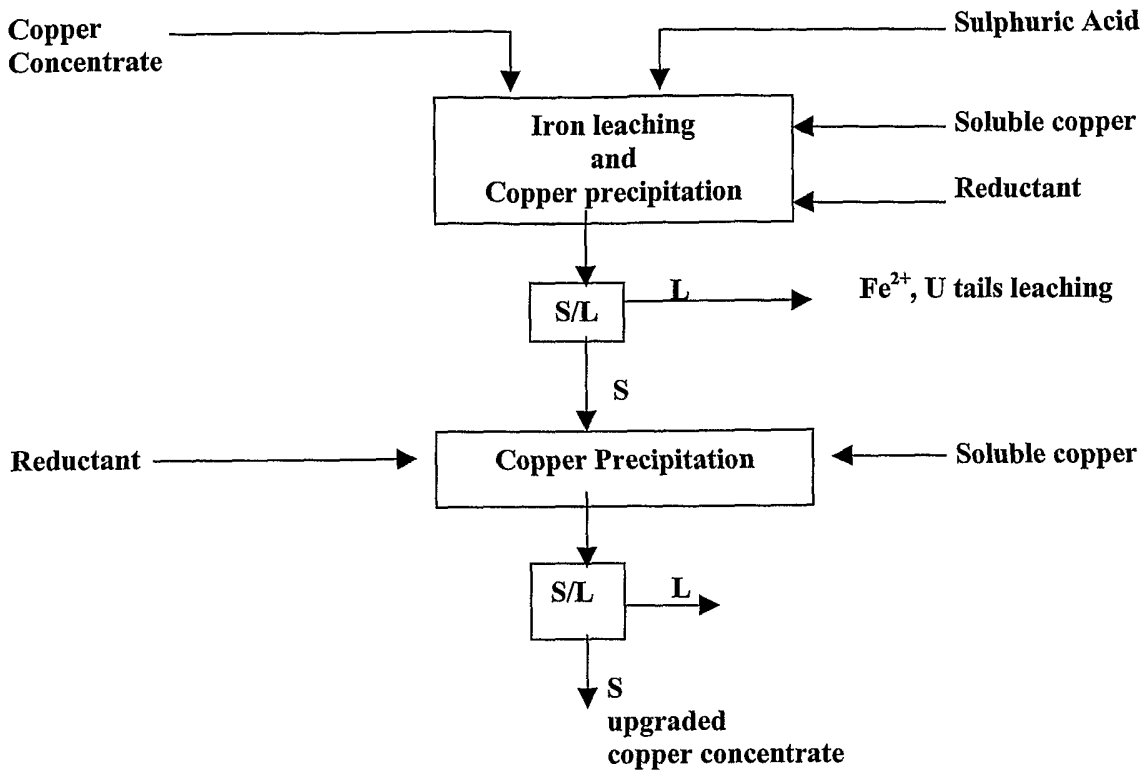


FIGURE 5

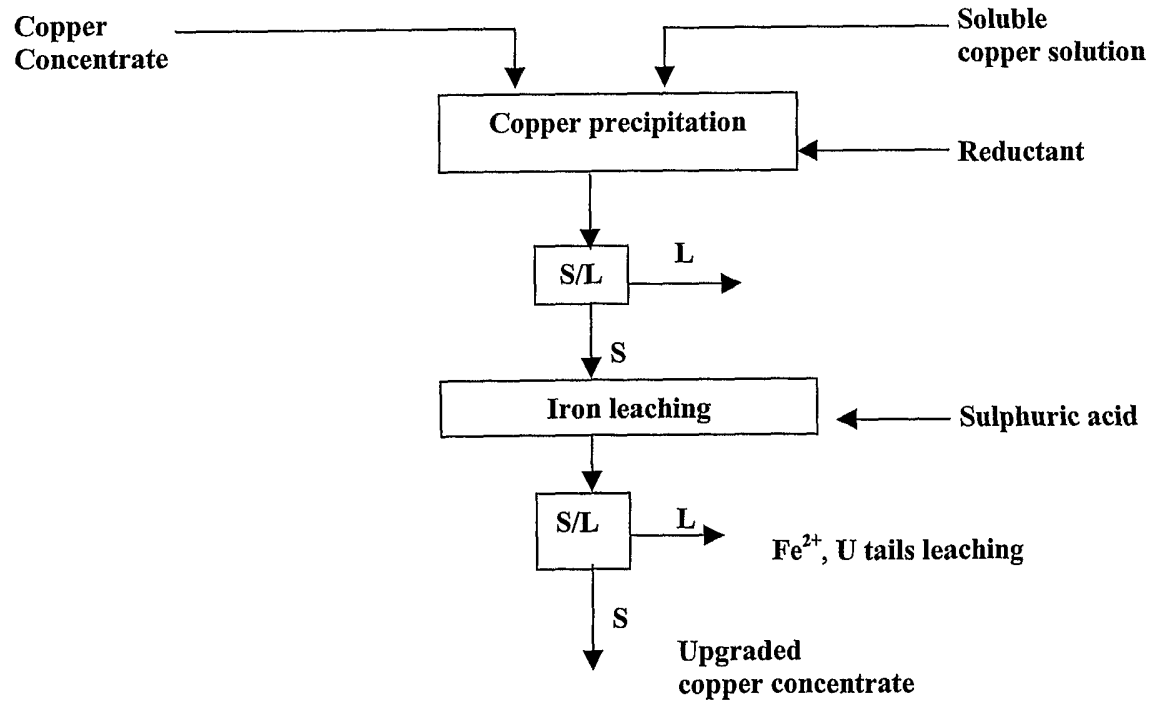


TABLE 1

Summary of Copper Concentrate Leaches

Operating Conditions								Feed Concentrate (%)		Extract (%)		Acid Consumption	Cu Deposition		Upgraded Concentrate Residue (%)	
Trial No.	Temp (°C)	Solids (%)	Leach Time (h)	Cu added (g/L)	Acid (g/L)	Na_2SO_3	ORP time avg. (mV)	Cu	Fe	Cu	Fe	kg H_2SO_4 /t feed conc.	% of Cu_{aq}*	% of Cu_s in Con**	Cu	Fe
1	70	50	21	0	100	No	335	37.3	25.2	4.5	32.0	179			43	20
2	85	50	22	0	100	No	308	38.1	24.2	2.1	47.4	308			47	16
3	70	35	12	0	100	No	315	37.5	25.0	3.8	30.7	168			43	20
4	70	35	21	0	100	No	319	37.5	25.0	4.4	36.4	256			44	19
5	90	35	12	0	100	No	320	37.5	25.0	3.7	45.0	312			45	17
6	50	50	21	5	100	No	315	37.3	25.2	2.0	18.1	149			40	22
7	70	50	21	5	100	No	334	37.3	25.2	3.5	24.9	210			42	21
8	70	35	21	5	100	No	329	37.5	25.0	4.5	32.1	215			43	19
9	70	26	22	12	100	Yes	303	37.1	25.2	0	37.1	167	52	5	46	18
10	70	34	22	19	100	Yes	293	38.1	24.2	0	32.9	295	95	9	46	19
11	85	47	23	37	100/20	No	316	38.0	25.5	0.0	32.3	13	79	7	45	20
12	85	47	23	37	100/20	Yes	243	38.0	25.5	0.0	36.6	39	100	9	47	18
13	85	47	21	37	100/20	No	344	37.9	25.1	0.0	21.2	20	38	3	43	21
14	70	50	21	0	100	No	307	47.7	20.3	1.7	32.6	133			53	15
15	80	50	21	0	100	No	297	47.7	20.3	0.8	44.3	197			55	13
16	90	50	21	0	100	No	204	47.7	20.3	0.0	56.1	233			57	11

Footnote:

*Percentage of added soluble copper that reports to the concentrate

** Soluble copper that reports to the concentrate as a percentage of the copper in the feed concentrate

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TABLE 2

Summary of Copper Concentrate Leaches

Conditions									Feed Concentrate		Extraction (%)		Acid Cons.	Reduct. Cons.	Cu Deposition		Final concentrate	
Trial No.	T (°C)	Solids (%)	Time (h)	Stage 2 Cu_{aq} g/L	Cu aq (% of Cu in Con.)	Acid in Fe leach (g/L)	Reductant	ORP at End of stage 1/ Stage 2 (mV)	Cu (%)	Fe (%)	Cu	Fe	kg H_2SO_4 /t feed con.	kg reduct. /t feed con.	% of Cuaq*	% of Cu in Con**	Cu end stages 1/2 (%)	Fe end stages 1/2 (%)
17	90/85	51/34	20/32	38	14	100-27	SO_2	212/312	38.5	24.1	0/0	43/54	232	436	83	11	47/52	17/13
18	90/70	51/45	20/31	41	9	100-23	Na_2SO_3	205/250	38.5	24.1	0/0	44/49	249	117	102	9	47/50	17/14
19	90/50	50/44	20/31	41	9	100-26	Na_2SO_3	201/266	38.5	24.1	0/0	45/48	242	88	65	6	48/49	17/15
20	90	49/41	23/29	51	12	40	Fe(s)	205/-28	40.0	24.0	0/0	50/56	345	38	100	12	49/53	14/13
21	85	51/25	12/24	62	38	100-40	Na_2SO_3	262/302	35.7	25.8	0/0	40/49	180	205	62	24	44/52	20/16
22	90	53	8/30	59	11	50 stage 2	None	357/321	39.6	25.2	0/0	13/41	133	-	92	10	43/47	22/17
23	90	53	2/29	59	11	50 stage 2	Na_2SO_3	140/251	39.6	25.2	0/0	16/51	167	42	100	11	45/51	21/14

Footnote:

* Percentage of added soluble copper that reports to the concentrate.

** Soluble copper that reports to the concentrate as a percentage of the copper in the feed concentrate

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2004/000738

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: C22B 3/06, 3/08, 3/46, 15/00

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 (IPC 7) C22B 3/06, 3/08, 3/46, 15/00 & (IPC 4) C22B 3/00, 15/08

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI: (IPC 7) C22B 3/06, 3/08, 3/46, 15/00; (IPC 4) C22B 3/00, 15/08; & keywords: copper, chalcopyrit+, bornit+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4290865 A (BACZEK ET AL) 22 September 1981 Whole document	1-12, 14, 18-34, 38-41
X	US 4256553 A (BACZEK ET AL) 17 March 1981 Whole document	1-11, 18-31, 38-41
A	US 4341742 A (CLARK ET AL) 27 June 1982 Whole document	1-41
A	US 3957602 A (JOHNSON ET AL) 18 May 1976 Whole document	1-41

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search
24 June 2004

Date of mailing of the international search report
20 JUL 2004

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2004/000738

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3985555 A (SHIRTS ET AL) 12 October 1976 Whole document	1-41
A	US 5993635 A (HOURN ET AL) 30 November 1999 Whole document	1-41
A	WO 85/03952 A (CHEMINOR A/S) 12 September 1985 Whole document	1-41

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2004/000738

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	4290865	CA	1164219	US	4359376		
US	4256553	CA	1156050				
US	4341742	AR	225839	AU	70753/81	BE	890636
		CA	1177653	ES	8301454	FR	2491450
		GB	2099411	PH	16857	WO	8201197
		ZA	8106902	ZM	8381		
US	3957602	NONE					
US	3985555	NONE					
US	5993635	AU	49331/96	BG	101980	CA	2215963
		EP	0815270	IN	187985	NZ	303107
		PL	322364	WO	9629439	ZA	9602223
WO	8503952	AU	40681/85	EP	0214324	NO	844505
		US	4671945				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX