Title: PRODUCING CALCIUM CYANIDE AT A MINE SITE USING EASILY TRANSPORTABLE STARTING MATERIALS

Abstract: The present invention is a method by which the mine can obtain a supply of calcium cyanide for use in its leaching operations. Specifically, one preferred method within the scope of the invention involves producing hydrogen cyanide directly at a mine site using formamide as a starting material. Alternative methods of producing hydrogen cyanide at the mine site using easily transportable starting materials, such as methanol and urea, are disclosed. The hydrogen cyanide is neutralized at the mine site with slaked lime (Ca(OH)_2) to form the calcium cyanide.
PRODUCING CALCIUM CYANIDE AT A MINE SITE USING
EASILY TRANSPORTABLE STARTING MATERIALS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 60/661,182, filed March 11, 2005.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to producing cyanide for mining applications. More specifically, the present invention relates to producing cyanide for mining applications at the mining site using starting materials that are readily transportable.

[0003] Aqueous solutions of cyanide anions (or “cyanide”) are used extensively in the mining industry as a mechanism for extracting precious metals, such as gold and silver, from the earth. Generally, these aqueous cyanide solutions contain sodium cyanide, potassium cyanide, or cyanide salts of other alkali metals. Although miners have tried to find other means of winning the gold from the ores, cyanide extraction continues to be the only cost-effective mining technique. Accordingly, it is believed that cyanide will remain the material of choice for precious metal mining.

[0004] Cyanide mining is usually accomplished in either a heap leaching or vat leaching operation. In these leaching operations, ore is contacted with a basic, dilute solution of cyanide. The solutions of cyanide typically have a concentration of less than 1000 ppm. In these basic conditions, the cyanide will react with the solid metal and oxygen in the air to form a soluble, aqueous complex, which is generally in the form of [Ag(CN)₂]⁻ or [Au(CN)₂]⁻. Once the leaching process is completed, the aqueous complex of the precious metal is then collected and concentrated so that the precious metal may be extracted and reduced into its metallic state. The cyanide used in the leaching process is also recycled for further leaching and/or disposed of in accordance with governmental regulations. During the process, some cyanide oxidizes and some is lost for further use.

[0005] Today the majority of the precious metal mining industry receives its cyanide for these mining processes either in the form of a liquid solution or in the form of dry sodium cyanide briquettes. The briquettes are generally manufactured in large integrated chemical manufacturing sites. Several main producers of alkali cyanide worldwide are:
(1) E.I. du Pont de Nemours and Company (which has cyanide facilities in Memphis, Tennessee and Texas City, Texas);
(2) Degussa AG (a German company that has cyanide facilities in Wessling, Germany); and
(3) Tae Kwang Industrial Co., Ltd. (Seoul, South Korea);
(4) Tongsuh Petrochemical Corporation, Ltd., (Seoul, South Korea); and
(5) Australian Gold Reagents Pty. Ltd., (Kwinana, Western Australia).

Generally, the product of choice for precious metal mines using the cyanide leaching process is sodium cyanide (NaCN). This product is usually manufactured from the neutralization of hydrogen cyanide (HCN) and caustic soda (NaOH). The HCN is produced either on purpose (primarily through the Andrussov Process or BMA Process) or from the reaction to produce acrylonitrile (in which one of the byproducts of this reaction is HCN). There is some production of hydrogen cyanide from other processes, but this is limited and is generally not a source for NaCN. Once formed, the NaCN is then dried and made into briquettes to assist in shipping the product over greater distances. However, if the NaCN is produced close to the mine site, the product of choice for the mine is usually a 30% solution of NaCN.

To produce HCN through the Andrussov Process, the raw materials are natural gas (methane, CH₄) and ammonia (NH₃). These gasses are reacted at elevated temperatures (2000°F) over a platinum-rhodium catalyst. The reaction is endothermic requiring the addition of heat. The reaction essentially involves the ammoxidation of methane, e.g. partial oxidation affected by the addition of oxygen (air). HCN is produced in this reaction as one of the products.

In some instances this HCN product is separated from the other product gases by first removing ammonia (using either a sulfuric acid scrubber or phosphoric acid). The HCN is then absorbed into water, which is distilled to obtain pure HCN. Upon removal of undesired impurities, like ammonia, carbonates, formates, etc. the HCN can be used in other downstream manufacturing processes including the production of NaCN which is dried. In other applications the HCN product gases are contacted directly with caustic soda to produce a NaCN solution. A NaCN solution is produced when the purchasing mine is within a distance suitable for freight logical shipping of the solution rather than a dry NaCN product, such as in the gold fields of Australia, South Africa, Uzbekistan, China and/or the United States.
[0009] When the acrylonitrile process is used to produce HCN, the HCN is essentially a byproduct of the acrylonitrile. However, in order to comply with current environmental/safety regulations, the manufacturing plant must treat and/or dispose of this HCN. Thus, these plants often choose to convert the HCN into NaCN and sell this additional product to the mining industry.

[0010] Despite the market for cyanide, there are growing concerns in the mining industry that supplies of cyanide will not be available at a commercially viable price in the future. It is anticipated that older facilities and technology currently used to manufacture hydrogen cyanide will become obsolete, thereby reducing the amount of HCN that is currently being produced and sold. Thus, the overall cost of cyanide is expected to increase in the future.

[0011] Cyanide is defined as an extremely hazardous chemical. In fact, in the public’s view, the use of cyanide is considered a threat to the environment and a possible tool for the use of terrorists. In the United States, some railroads will not transport cyanide. It is becoming more difficult to ship cyanide internationally. Exporting manufacturers must currently obtain export licenses from governmental agencies which define legitimate end users and location of use. Many international mining operations are concerned that future restrictions/regulations may restrict shipping cyanide across the oceans, shipping cyanide through ports in less developed regions of the world, and/or transporting cyanide over poorly maintained and/or less-traveled roads. Such additional restrictions will make shipping cyanide prohibitively expensive (or even impossible) and may jeopardize the commercial viability of existing or future mines.

[0012] Even with developed countries, there is a strong movement from lobbyists to decrease the use of cyanide in mines. Although it is expected that these lobbyists will mandate additional safeguards on mines, an outright ban of cyanide is not expected. However, there are certain states in the United States that have outlawed under certain conditions the use of cyanide, namely Wisconsin and Montana. Other states restrict the use of cyanide for new mining operations. If additional states follow this course, cyanide mining of precious metals will become a commercial impossibility.

[0013] Finally, there is a perceived likelihood in the mining industry that the traditional large manufacturers of cyanide may seek to exit the cyanide market. ICI and FMC, both previous manufacturers of cyanide, have already left the market. There are some possible reasons why cyanide manufacturers may desire to stop their cyanide production. First, cyanide manufacturing may not be considered a core business element of some large
manufacturers. Second, cyanide manufacturers are concerned about the safety, security and environmental hazards regarding cyanide. Specifically, these producers are concerned that they may be held liable if a disaster regarding cyanide ever occurred. Also, many producers seem to believe that cyanide is becoming a “commodity” chemical. Typically, chemicals are either classified as being a “specialty” product or a “commodity” product. As a chemical moves from being a specialty chemical to a commodity, the large, technologically-innovative companies often exit the market for this product so that they can focus their efforts on new products with higher profit margins. Thus, it should not be surprising if these large producers begin to slowly exit the cyanide market.

[0014] Given the present climate regarding cyanide, it would be advantageous for mines to find a new source for alkali cyanide that is commercially viable in the long-term. It would also be advantageous to provide a method for mines to obtain alkali cyanide without having to endure the difficulties associated with transporting alkali cyanide, including future risk of government prohibition of cyanide transportation. Such a method and process is disclosed herein.

BRIEF SUMMARY OF THE INVENTION

[0015] This invention provides a method by which a supply of cyanide is produced directly at a precious metal mine. This supply of cyanide may then be used by the mine in its leaching operations to extract the precious metal from the earth. The ability to produce cyanide at the mine site may provide the mine with long-term stability and/or commercial advantage. It may act as a type of “insurance” against future cyanide supply disruption and thereby protect the substantial investment associated with the mining operation. Because mining operations typically have a short lifespan of about 8-10+ years, a controlled supply of cyanide would be very desirable.

[0016] Generally, the mine will manufacture the supply of cyanide using starting materials that are readily available and easily shipped. As used herein, the term readily available means that the starting materials are commercially available and not subject to special or restrictive government regulation of control and handling. As used herein, the term easily shipped means the starting materials may be shipped through conventional and commercially available shipping means without special or restrictive government regulation of the shipping. In one presently preferred embodiment, the starting material is formamide which can be decomposed into HCN and water. Other starting materials may also be used. Once the HCN
has been formed, the producer will then neutralize the HCN with an inorganic base to produce a supply of cyanide anions. In some embodiments, the preferred inorganic base will be lime (CaO) or slaked lime (Ca(OH)$_2$) because this product is much lower cost compared to NaOH, readily available, and is often already used by the mine in other processes. Thus, when reacted with lime or slaked lime, the cyanide will be in the form of dissolved Ca(CN)$_2$.

**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

**[0017]** In order that the manner in which the above-recited and other features and advantages of the invention are obtained will be readily understood, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

**[0018]** Figure 1 is a flow diagram of a method of producing a supply of calcium cyanide at the mine site according to the present invention;

**[0019]** Figure 2 is a flow diagram of another method of producing a supply of calcium cyanide at the mine site according to the present invention;

**[0020]** Figure 3 is a flow diagram of another method of producing a supply of calcium cyanide at the mine site according to the present invention;

**[0021]** Figure 4 is a flow diagram of a method of mining precious metals that uses calcium cyanide that was produced at the mine site;

**[0022]** Figure 5 is a schematic flow diagram of a process for producing a supply of calcium cyanide; and

**[0023]** Figure 6 is a schematic flow diagram of a process for producing a supply of calcium cyanide similar to the process of Figure 5, but with recycle stream of the produced calcium cyanide to increase its concentration.

**DETAILED DESCRIPTION OF THE INVENTION**

**[0024]** The presently preferred embodiments of the present invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout. It will be readily understood that the components of the present invention, as generally described and illustrated in the figures herein, could be arranged and designed in a
wide variety of different configurations. Thus, the following more detailed description of the embodiments of the method of the present invention, as represented in Figures 1 through 6 is not intended to limit the scope of the invention, as claimed, but is merely representative of presently preferred embodiments of the invention.

[0025] Referring now to Figure 1, a method 120 of the present invention is illustrated in a flow diagram. The method 120 represents a method that allows a precious metal producer to manufacture cyanide directly at the mine site. Such on-site production of cyanide may provide the mine with long-term stability, commercial viability, and/or other advantages. For example, in some embodiments, this on-site production of cyanide may provide the mine with long-term stability in that the mine’s cyanide supply no longer depends upon manufacturers that might exit the marketplace. Likewise, such production of cyanide may give the mine more stability in that its cyanide supply is not influenced by difficulties in shipping cyanide which may develop throughout the world. Finally, such on-site production of cyanide may also reduce the mine’s operating costs in that the mine will no longer be forced to pay shipping costs, taxes, fees, and/or other charges that may be associated with cyanide transportation. This includes elimination of the hazards associated with shipping cyanide to a mine site. As a result, this method of on-site cyanide production may provide significant advantages.

[0026] The method 120 includes the step of obtaining 122 a supply of formamide (HCONH₂). Formamide is a relatively expensive chemical that is commercially available in liquid form from a variety of sources including the BASF Aktiengesellschaft company located in Ludwigshafen, Germany, the Kemira Oyj Industrial Chemicals company located in Helsinki, Finland, and other small producers. Formamide is much less hazardous and is subject to far fewer restrictions than is cyanide. Presently formamide is not viewed as a terrorist threat and may be shipped throughout the world without much difficulty.

[0027] Once the supply of formamide has been obtained, the supply of formamide may be decomposed 124 at the mine site to produce a quantity of HCN. As used herein, the term “at the mine site” refers to any location that is associated within a nominal distance to a precious metal mine. Thus, in some of the presently preferred embodiments, this phrase means that the decomposing and neutralizing steps of the method 120 are accomplished either on the same property and/or on property that is proximate or contiguous with the parcel from which the precious metals are being extracted. In some cases, there may be multiple mining
operations within a few miles. In such cases, there may be only one facility to manufacture the cyanide that supports the multiple mining operations.

[0028] In general, the heterogeneous catalytic reaction step that converts the formamide into HCN is relatively straightforward.

$$\text{HCONH}_2(g) \rightarrow \text{H}_2\text{O}(g) + \text{HCN}(g)$$

The reaction takes place in the vapor phase at elevated temperature and low pressures and it is essentially quantitative. The exact methods and processes by which this reaction may occur are described in U.S. Patent No. 4,693,877 entitled "Cleavage of Formamide to give Hydrocyanic Acid and Water." This patent, which is now expired, is expressly incorporated herein by reference.

[0029] Further information and descriptions of the conversion of formamide into HCN are described in the following patents and book excerpts:

- U.S. Patent No. 2,042,451;
- U.S. Patent No. 2,529,546;
- U.S. Patent No. 2,534,000;
- U.S. Patent No. 2,604,380;
- U.S. Patent No. 3,702,887;
- U.S. Patent No. 4,745,207;
- U.S. Patent No. 4,693,877;
- German Patent No. DE 476,662;
- German Patent No. DE 477,437;
- German Patent No. DE 498,733;
- German Patent No. DE 561,816;
- German Patent No. DE 944,547;
- German Patent No. DE 1,000,796;
- German Patent No. DE 1,211,612;
- German Patent No. DE 2,445,168; and.

[0030] Each of the above-referenced patents, as well as the above-cited treatise, is expressly incorporated herein by reference. While some of the above-referenced documents
or patents describe the decomposition of formamide on a micro-scale, these reactions can be easily scaled for large-quantity, industrial applications.

[0031] Once the formamide has been decomposed to form the quantity of HCN, the HCN may then be neutralized at the mine site to produce an aqueous solution of calcium cyanide, step 126. The aqueous solution of calcium cyanide may then be diluted or concentrated for use in the mining operations. In general, this processing step may involve one of more of the following steps:

- contacting the HCN gas with a solution or slurry of slaked lime (Ca(OH)₂) to produce the aqueous solution of calcium cyanide;
- diluting the formed cyanide solution to concentrations that are appropriate for the mine’s leaching processes (such as 1000 ppm, etc.).

[0032] Figure 5 contains a general schematic representation of a process 150 of producing calcium cyanide from the decomposition of formamide. As shown in Figure 5, a supply of formamide 152 is provided to a vaporizer 154 which vaporizes the formamide. The formamide stream 156 passes through a heat exchanger 158 to heat the formamide to a temperature suitable for the catalytic decomposition reaction which occurs in a catalytic contactor 160. The formamide is decomposed into hydrogen cyanide gas and water vapor. These gases 162 are introduced into a contactor 164 together with calcium hydroxide 166, slaked lime, to neutralize the HCN and form Ca(CN)₂. The neutralized product stream 168 is introduced into a separator 170 to which a vacuum pump 172 is connected for removal of gases 174. The separator 170 includes a liquid barrier 176 is permeable to gases, but not liquids. The aqueous solution of Ca(CN)₂ product stream 178 is then recovered.

[0033] In some applications, it may be desirable to concentrate the Ca(CN)₂ thus formed. Figure 6 contains a general schematic representation of a process 180 similar to process 150 except that a portion of the aqueous solution of calcium cyanide is recycled back to the contactor for further contact with HCN gas. The aqueous solution of Ca(CN)₂ product stream 178 is passed through a heat exchanger 182 to capture heat from the product stream 178. The concentrated aqueous solution of Ca(CN)₂ 184 is removed for use at the mine site. Additional Ca(OH)₂ 186 may be added to the recycle stream 188, as needed, to react with the HCN. Barren stream 190 may also be added to the recycle stream 188. The barren stream 190 usually contains a small amount of aqueous cyanide. Recycling the barren stream in this manner may allow the aqueous cyanide to be efficiently used. Some fresh water may be added to the recycle stream or the barren stream 190 may be replaced by a fresh water stream.
However, fresh water usually contains dissolved carbonate which may react with calcium to form calcium carbonate, a scaling problem. The barren stream 190 would have less dissolved carbonate than fresh water, reducing any calcium carbonate scaling problem.

[0034] As noted above, lime or slaked lime is the inorganic base for converting the HCN into a slurry or solution of calcium cyanide (Ca(CN)_2). Lime may be converted to slaked lime by contact with water in a slaker. As is known in the art, lime comprises primarily calcium oxide, but it may contain measurable amounts of other compounds including silica, alumina, and/or other metal cations including magnesium, iron, etc. Thus, when lime or slaked lime is used as the inorganic base, the main product will be calcium cyanide; however, given the other ingredients in lime, there may be measurable quantities of other impurities containing magnesium, iron, silica, alumina, etc. The presence of such impurities is not detrimental to the applications proposed herein. In fact, the ability to use an inorganic base, like lime, of lower purity and cost is a distinct advantage in accordance with the invention.

[0035] Lime is a presently preferred inorganic base because it is substantially less expensive than caustic soda (NaOH) or other inorganic bases. Generally, caustic soda is often not produced in areas close to the mine and thus, caustic soda must be shipped long distances as a 50% aqueous solution or in some cases as flaked caustic soda. Such shipping can be prohibitively expensive. On the other hand, lime is generally produced locally (i.e., in areas close to the mine) and is substantially cheaper to ship and purchase. In fact, many mines will already have a supply of lime or slaked lime on-hand because lime is often added to the leaching solution to ensure that the leaching solution maintains a pH range of about 9 to about 10.5. Lime is also often used to neutralize effluent from autoclave or roasting processes at the mine. In this manner, the lime needed to neutralize the HCN may already be available at the mine site.

[0036] It should also be noted that the reaction equipment necessary to produce the calcium cyanide directly at the mine site could be further designed as a pre-fabricated product. In other words, the reaction equipment used to produce the cyanide may be manufactured and assembled using readily available parts and fittings, and then shipped (via freight, skids, etc.) to the mine site. Once this pre-fabricated reaction equipment arrives, it may be quickly set up and used by the producer to manufacture the calcium cyanide. Moreover, when the producer finishes its cyanide production, the reaction equipment could then be sold or shipped off to another mine, etc.
[0037] Because of the simplicity of the formamide decomposition process described above, the reaction processing equipment may be easily scaled to meet desired production requirements. In addition, the reaction processing equipment is relatively simple to operate. This will be particularly advantageous when operated in remote locations where skilled labor is expensive and not widely available.

[0038] Referring now to Figure 2, a flow diagram of a second method 220 of the present invention is illustrated. The method 220 again represents a method that allows cyanide to be produced directly at the mine site. As noted above, this production of the cyanide at the mine site may provide the mine with significant advantages.

[0039] Unlike the method 120 outlined above, the first step in the method 220 involves obtaining 222 the starting materials for the Andrussov process for producing HCN. As described above, these starting materials include natural gas and ammonia. However, because these starting materials may not be readily available at the mine site or may be expensive and/or difficult to ship, methanol (CH₂OH) and urea (CO(NH₂)₂) may be used as the starting materials. Method 240, shown in Figure 3, is substantially the same as method 220, except that obtaining step 242 replaces step 222. Step 242 includes obtaining a supply of methanol and urea at the mine site as starting materials to prepare HCN. Other embodiments may also be made in which the starting materials are a combination of some of the above-mentioned reagents such as natural gas and urea or methanol and ammonia.

[0040] Urea is available in large quantities and it is used as a fertilizer throughout the world. It is shipped and handled as a non-hazardous material. Methanol is also a commodity chemical in the world and can be shipped easily. Neither urea nor methanol is known to be a terrorist threat.

[0041] Urea is known to decompose into ammonia. For example, U.S. Patent Nos. 5,252,308, 2,797,148 and 3,718,731 describe ways in which urea may be decomposed into ammonia. These patents are incorporated herein by reference and show the methods/reaction conditions by which these reactions may take place.

[0042] Again, once the proper starting materials have been obtained, the next step in the method 220 is to react 224 the starting materials at the mine site to form a quantity of HCN. Such reactions are known in the art. For example, information regarding the reaction of ammonia and methanol to produce HCN is also known. Methanol along with propylene and ammonia are currently used to produce HCN over catalysts at lower temperatures as part of the process for forming acrylonitrile (which forms HCN as a byproduct). In these reactions,
excess ammonia is reacted with methanol to produce a greater amount of HCN. As is known in the art, such reactions may involve both fixed and fluidized beds operating at lower temperatures. In fact, the following patents, which are all incorporated herein by reference, teach specific information that may be useful in performing the reaction of ammonia/urea with methanol/methane to produce HCN:

- U.S. Patent No. 5,158,787;
- U.S. Patent No. 3,911,089;
- U.S. Patent No. 4,485,079;
- U.S. Patent No. 5,288,473;
- U.S. Patent No. 3,716,496;
- U.S. Patent No. 3,988,359;
- U.S. Patent No. 4,511,548;
- GB Patent No. 718112;
- GB Patent No. 913836;
- Japanese Patent No. JP 78-35232; and
- German Patent No. DE 1,143,497 (no oxygen present).

Once the supply of HCN has been formed, the next step is to neutralize 226 the HCN at the mine site to produce the calcium cyanide. The processes for the step 226 are similar and/or identical to the methods and processes associated with the processing step 126 described above in conjunction with Figure 1. For the sake of brevity, however, this discussion will not be repeated; rather, the reader may simply examine the previous disclosure for more information.

It should also be noted that lime is not widely used as the inorganic base of choice for the Andrusow process due to the possibility that some of the calcium cations (or other metal cations) will react with carbon dioxide and form a calcium carbonate precipitate (or some other type of precipitate). Moreover, Ca(CN)₂ has not been a desirable alkali cyanide because it cannot be dried and formed in briquettes, unlike NaCN. In addition, Ca(CN)₂ can only be concentrated to about 15-17% by weight, which is substantially more dilute than concentrated NaCN solutions. Thus, shipping costs for Ca(CN)₂ are significantly greater than shipping costs for NaCN. Another reason Ca(CN)₂ is not a desirable alkali cyanide because it decomposes readily at higher temperatures and higher concentrations than NaCN. As a result,
cyanide manufacturers have generally avoided making Ca(CN)₂. However, according to the present invention, the ability to manufacture an aqueous Ca(CN)₂ solution directly at a mine site, as needed for direct use, eliminate the foregoing disadvantages.

[0045] Referring now to Figure 4, a flow diagram of a different method 320 of the present invention is illustrated. The method 320 is a method for mining precious metals using calcium cyanide. The first step of this method involves producing 322 the calcium cyanide at the mine site using at least one starting material. This producing step may be accomplished using either the methods 120, 220, 240 outlined above. Accordingly, the starting material(s) may be formamide, methane and ammonia, methanol and urea, etc.

[0046] The next step in the mining process 320 is to leach 324 the ore with the cyanide solution. The way in which such leaching may be performed is known in the art. Once this leaching 324 has been done, the pregnant solution is then collected 326. The pregnant solution is the solution that is gathered after the leaching has been accomplished. This pregnant solution will contain a quantity of precious metal ions bound to cyanide anions as an aqueous complex. Again, the precise methods/processes for gathering this pregnant solution are well known in the art and are currently being practiced at all precious metal mines that use cyanide.

[0047] Finally, the last step 328 in the method 320 is recovering the precious metal from the pregnant solution. The exact method for recovering 328 the precious metal will depend on a variety of factors including cost, availability of reagents, etc. Of course, all of these specific methods/steps associated with recovering the precious metal are well known in the mining industry and fall within the scope of the present invention.

[0048] The present invention may be embodied in other specific forms without departing from its structures, methods, or other essential characteristics as broadly described herein and claimed hereinafter. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.
CLAIMS:

1. A method for producing an aqueous solution of calcium cyanide directly at a mine site, the method comprising:
   obtaining a supply of formamide at the mine site;
   reacting the formamide at the mine site to produce a quantity of hydrogen cyanide;
   and
   contacting the quantity of hydrogen cyanide at the mine site with slaked lime to produce a supply of calcium cyanide.

2. The method according to claim 1 wherein the slaked lime comprises primarily calcium hydroxide.

3. The method according to claim 1 further comprising the step of diluting the calcium cyanide to concentrations that may be used in at the mine site in at least one mining operation.

4. A method for producing an aqueous solution of calcium cyanide directly at a mine site, the method comprising:
   obtaining a supply of ammonia at the mine site;
   obtaining a supply of methanol at the mine site;
   reacting the ammonia and methanol at the mine site to produce a quantity of hydrogen cyanide; and
   contacting the quantity of hydrogen cyanide at the mine site with slaked lime to produce a supply of calcium cyanide.

5. The method according to claim 4 wherein the ammonia is obtained by decomposing urea.

6. The method according to claim 4 wherein the slaked lime comprises primarily calcium hydroxide.

7. The method according to claim 4 further comprising the step of diluting the calcium cyanide to concentrations that may be used in at the mine site in at least one mining operation.
8. A method of mining precious metals using a calcium cyanide solution comprising:
    producing the calcium cyanide solution at a mine site from at least one starting
material;
    leaching an area of interest at the mine site with the cyanide solution;
    collecting a pregnant solution which contains a quantity of precious metal ions bound
    to cyanide anions as an aqueous complex; and
    recovering the precious metal ions from the pregnant solution.

9. The method of mining according to claim 8 wherein the producing step comprises
decomposing formamide to form hydrogen cyanide and neutralizing the hydrogen cyanide
with slaked lime to form the calcium cyanide solution.

10. The method of mining according to claim 8 wherein the producing step comprises
creating the cyanide solution using methanol and urea as the starting materials.

11. The method of mining according to claim 8 wherein producing step comprises
producing a quantity of hydrogen cyanide that is then converted into a solution of calcium
cyanide using lime or slaked lime.

12. A method for producing calcium cyanide directly at a mine site, the method
comprising:
    obtaining a supply of the starting materials at the mine site for use in an Andrussov
process for producing hydrogen cyanide;
    reacting the starting materials at the mine site to produce a quantity of hydrogen
    cyanide; and
    processing the quantity of hydrogen cyanide at the mine site to produce a supply of
calcium cyanide.

13. The method according to claim 12 wherein the processing step is accomplished by
contacting the hydrogen cyanide with slaked lime to produce the calcium cyanide.
120

Obtain a Supply of Formamide at a Mine Site

122

Decomposing the Supply of Formamide at the Mine Site to Produce a Quantity of HCN

124

Neutralizing the HCN at the Mine Site with Lime to Produce an Aqueous Solution of Calcium Cyanide

126

Figure 1
220

Obtaining the Starting Materials for the Andrussov Process

222

Reacting the Starting Materials at the Mine to Produce a Quantity of HCN

224

Neutralizing the HCN at the Mine Site with Lime to Produce a Solution of Calcium Cyanide

226

Figure 2
Obtaining a Supply of Methanol and Urea at the Mine Site

Reacting the Starting Materials at the Mine to Produce a Quantity of HCN

Neutralizing the HCN at the Mine Site with Lime to Produce a Solution of Calcium Cynide
Producing a Solution of Calcium Cyanide Directly at the Mine Site

Leaching the Ore with a Solution of the Calcium Cyanide

Collecting the Pregnant Solution which Contains a Quantity of Precious Metal Ions Bound to Cyanide Anions as an Aqueous Complex

Recovering the Precious Metal Ions from the Pregnant Solution

Figure 4
Figure 5
Figure 6
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC: C01C 3/08(2006.01);C01G 7/00(2006.01);C01G 5/00(2006.01)

USPC: 423/29,376,379
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S.: 423/29, 376, 379

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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<tbody>
<tr>
<td>X</td>
<td>US 5,356,474 A (DIEHL et al) 09 August 1994 (9-8-1994), see col. 10, lines 35-53.</td>
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<td>9-11</td>
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<td>Y</td>
<td>US 1,596,119 A (POINDEXTER, JR) 17 August 1926 (17-8-1926), see page 1, line 5 to page 2, line 51.</td>
<td>1-7, 9-13</td>
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<td>Y</td>
<td>US 4,485,079 A (BRAZDIL, JR, et al) 27 November 1984 (27-11-1984), see col. 1, lines 8-47.</td>
<td>4-7, 10</td>
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<tr>
<td>Y</td>
<td>US 3,702,887 A (SENNENWALD et al) 14 November 1972 (14-11-1972), see col. 1, line 16 to col. 2, line 24.</td>
<td>1-3, 9</td>
</tr>
<tr>
<td>Y</td>
<td>US 6,743,407 A (SCHAEPER et al), 01 June 2004 (1-6-2004), see col. 1, line 13 to col. 4, line 51.</td>
<td>12, 13</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

See patent family annex.

Date of the actual completion of the international search
20 June 2006 (20.06.2006)

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