THE USE OF STAINLESS AND OTHER HIGH PERFORMANCE ALLOYS IN HYDROMETALLURGICAL PROCESS PLANTS FOR THE RECOVERY OF METALS

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1. INTRODUCTION

Hydrometallurgical processes are being increasingly used for the recovery of metals such as nickel, cobalt, copper, gold and zinc. This is good news for the stainless steel industry, as the often highly corrosive conditions in hydrometallurgical plants require the use of significant quantities of stainless steel and high-nickel alloys.

2. HYDROMETALLURGICAL PROCESS TRENDS

2.1 TREATMENT OF NICKEL/COBALT LATERITES BY THE PAL PROCESS

The outstanding development in the nickel industry in the last decade is the construction of three new pressure acid leaching (PAL) plants in Western Australia for the treatment of nickel/cobalt laterites. Traditionally laterites have been processed by smelting to produce ferronickel or matte for further refining. A few reduction roast-ammonia leach plants have been built for lower grade laterites for which smelting is uneconomic. However, this process has only been able to achieve nickel recoveries in the range of 75-85%, and cobalt recoveries of 35-45%. Only one previous PAL plant has been installed. This is the Moa Bay operation in Cuba, initially established by Freeport in the late fifties, and subsequently taken over by the Cubans shortly after commissioning. Moa Bay is still operating, now with the involvement of Sherritt who process the sulphide product at their refinery in Canada. The PAL process was subjected to extensive further development by Amax and Nical in the USA in the seventies and eighties, though neither development proceeded through to a commercial scale operation. However, these developments, together with the advent of pressure oxidation operations for gold, zinc and uranium recovery, and the development of new solvent extraction technology, provided a platform for the launch of the Bulong, Murrin Murrin and Cawse projects in WA. The key attractions of the PAL process are high recoveries of both nickel and cobalt, the absence of the energy consuming pre-drying step needed for the smelting and reduction roast routes, the potentially lower operating cost and applicability to a wider range of ores.

The front end of each of the three new WA PAL plants is similar, and can be viewed as a modernised version of Moa Bay. All three utilise titanium clad autoclave construction to accommodate process water of varying levels of salinity, which did not occur at Moa. The main differences between the three lie in the downstream process flowsheet, which varies markedly. Because of the huge investment, there was a strong incentive to use proven process route for Murrin Murrin. Thus, precipitation of a mixed sulphide was adopted, as at Moa Bay; however an on-site refinery was included. Cawse, as the late starter, plumped for the precipitation of mixed hydroxides followed by on-site refining via ammonia leaching, solvent extraction (SX) and electrowinning. This utilised process “building blocks” proven in other operations, and offered the best opportunity for a fast-track schedule. On the other hand, the pioneer Bulong project had the longest development period, which allowed time to optimise the process route. This is the most innovative of the three, and involves the application of sequential SX directly to the pressure leach solution in order to minimise cost. The three process routes are depicted in Figure 1,2 and 3.

The PAL process involves leaching in strong sulphuric acid solution at about 250^{0}C and elevated pressure in autoclaves, which are served by large preheating and pressure let-down systems. These are followed by extensive solid/liquid separation and product recovery facilities, which treat the resulting leach slurry at temperatures typically between 40 and 100^{0}C. These extremely aggressive conditions, aggravated in the WA operations by the use of saline process water, present major materials of construction challenges. Materials utilised for the autoclaves and associated preheating and let-down systems include titanium clad steel, brick lining, high-nickel alloys and tantalum. For the subsequent facilities, high-nickel alloys, stainless steels, rubber linings, HDPE, FRP, other plastics and polymer concrete are typically used. Factors affecting material selection include capital cost, availability of supply, maintenance time and costs, and safety. The presence of chloride in solution, as in the WA plants, is another major issue, which can significantly affect the choice of materials. Larger operations, such as Murrin Murrin, will likely include on-site acid plants, as the by-product energy can be used to reduce operating costs.

The new PAL plants have experienced difficult commissioning periods and relatively slow ramp-up. However, the processes have basically worked and it appears that product quality targets will be achieved. The Cawse operation has been the most trouble free, and has achieved design capacity. Although "the jury is still out" as far as operating costs are concerned, expansions are being planned, and a number of new projects are pressing on with detailed feasibility studies. In time honoured fashion, the next projects are expecting to benefit from the experiences of the existing plants. At their presentation at the ALTA Nickel/Cobalt 2000 conference, Inco stated that most of the future increase in nickel production will come from laterite PAL operations. Inco themselves are currently operating a major demonstration PAL operation for their Goro project in New Caledonia. New PAL developments include Ravensthorpe, NiWest, Marlborough, Syerston and Young in Australia, Ramu in PNG, and Weda Bay in Indonesia, plus others in New Caledonia, Africa and the Philippines.

2.2 PRESSURE OXIDATION OF SULPHIDE ORES AND CONCENTRATES

Pressure oxidation is already a well-established technology, with successful commercial operations for the treatment of gold, zinc and uranium sulphide ores and concentrates. Based on these successes, significant efforts are being made to extend the technology to other sulphides such as copper and nickel. Driving forces include environmental concerns with smelting, the desire of small and medium sizes miners to produce metals instead of relying on toll smelters, and the treatment of impure and/or low grade concentrates unsuitable for smelting. Reflecting the interest and the need, a number of development programs are underway, some of which have reached pilot and demonstration scale. Examples include the Mt Gordon, CESL, Activox, Dynatec and NSC processes, which operate under various process conditions. In the case of copper, the Mt Gordon and NSC process have already been commercialised, in Australia and the USA respectively, while the CESL process is reported to be close to commercialisation after extensive pilot and demonstration plant campaigns. For nickel, the Activox process is in the final stages of piloting for projects in Africa, Inco is reported to be testing pressure oxidation for their Voisey's Bay project in Canada, while the Platsol process is being piloted for the Northmet polymetallic project in the USA. A typical flowsheet for copper recovery is shown in Figure 4.

Pressure oxidation involves the use of oxygen under pressure in autoclaves to break down the metal sulphides and liberate the metals for subsequent recovery. The solutions in the autoclaves are generally acidic and corrosive, and in some processes contain significant chloride. Temperatures are in the range of 100-230^{0}C, depending on the type of process and the characteristics of the feed material. In the case of gold, the autoclave discharge is neutralised prior to cyanidation, so that the corrosive conditions are confined to the autoclave system. However, in the other applications, the downstream process steps are also carried out in corrosive conditions, so that most of the operations require corrosion resistant materials. Depending on temperature, pressure and solution, the materials used in the autoclave system include brick lining, titanium, high-nickel alloys and stainless steels. For the rest of the facilities, typical materials include stainless steels, high-nickel alloys, rubber lining, HDPE, FRP, other plastics and wood.

Successful treatment of chalcopyrite in particular, which is the main source mineral for the world's copper, could lead to a proliferation of pressure oxidation plants in the future.

2.3 BIO-OXIDATION OF SULPHIDE ORES AND CONCENTRATES

Bio-oxidation is also well established for treating sulphidic gold concentrates, and the first plant for cobalt recovery is in the early stages of operation in Kilembe in Uganda treating tailings from a former copper operation. The process is also a competitor with pressure oxidation for the future treatment of copper and nickel sulphides. Major development programs are being undertaken by Bactech/Mintek and Billiton, both of whom have run successful pilot plant operations for the treatment of copper and nickel feedstocks and are pressing on strongly towards commercialisation. As with pressure oxidation, successful commercialisation for the treatment of chalcopyrite concentrates would open up a potentially large market. A typical flowsheet for copper recovery is given in Figure 5. On another front, Pacific Ore are piloting a bio-oxidation heap leaching process at Titan Resources' Radio Hill nickel/copper facility in WA. Promising results have been recently announced, and negotiations are reported to be in progress with WMC and other parties interested in applying the technology. If successful, it could open the dor to the treatment of extensive low grade nickel sulphide resources currently uneconomic with existing technology.

From the materials point of view, these processes involve the processing of sulphuric acid solutions containing a variety of impurities at temperature varying from ambient up to about 80^0C, at atmospheric pressure. Chloride contents are generally low compared with some of the pressure oxidation processes.

2.4 CHLORIDE LEACHING PROCESSES

A chloride/sulphate leaching process has been in operation at Pasminco's Pt Pirie lead operation for many years, recovering copper from a copper/lead matte. Recently the process has been considered for the treatment of copper sulphide ores and concentrates. For example, pilot scale testwork has been reported for Leadstar's Labuk project in East Malaysia. In another development, Intec have undertaken extensive campaigns with their demonstration plant in Sydney using their innovative chloride leaching process. Again, the target is chalcopyrite concentrates. They are reported to be aggressively pursuing opportunities for the first commercial application. This development has been supported by a consortium of major copper companies. The flowsheet is illustrated in Figure 6. As with previous attempts to develop chloride processes for copper production, materials selection is a crucial issue. The fact that no autoclaves are involved in the above processes is an advantage.

Chloride leaching also features strongly in the current push for new magnesium metal projects in Australia. A prominent example is the Kunwarrara project in Queensland, for which a demonstration scale plant has been operated.

2.5 COPPER HEAP LEACHING

Since the early nineteen seventies, there has been an explosion of copper heap leaching operations, particularly in the USA and Chile. From relatively small beginnings, they have grown ever larger in size. One of the main reasons is the relative ease in which high grade cathode copper can be produced at the mine site by the application of solvent extraction and electrowinning, SX/EW. A major advance in this technology was the successful development of the direct deposition of copper cathodes onto stainless steel plates by MIM in Queensland, and later by Kidd Creek in Canada. In recent years, heap leaching/SX/EW has been successfully extended to copper secondary sulphide ores, which has significantly widened the opportunities for new projects. A typical flowsheet is shown in Figure 7.

Apart from the significant amount of stainless required for the EW plates, stainless and high-nickel alloys are used in other areas of the operation such as pumps, piping, mixer-settlers, tanks, filters and heat exchangers. In some operations, the leach solutions contain chloride, which may require higher alloys. Competitive materials include HDPE, FRP and other plastic linings.

The MIM and Kid technologies were actually first developed for copper electrorefining, and have gone on to become standard in the industry, with numerous large scale operations. As with heap leach/SX/EW, electrorefineries widely use stainless and other alloys for corrosive solutions.

3. THE FUTURE?

Although nothing is ever certain, many of the hydrometallurgical trends reviewed above are likely to continue, thus opening up new opportunities for stainless steels and other alloys. Of course there will be strong competition from other materials such as plastics, and, for the more extreme applications, titanium and tantalum. History has indicated that there is usually a balance, which means that the stainless industry should be ensured of a healthy portion of the business. This will be assisted by the industry continuing to be pro-active in developing appropriate new alloys, providing useful corrosion and fabrication data to potential users, and, of course, by being cost competitive.

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Fig 1.
Simplified Bulong Flowsheet

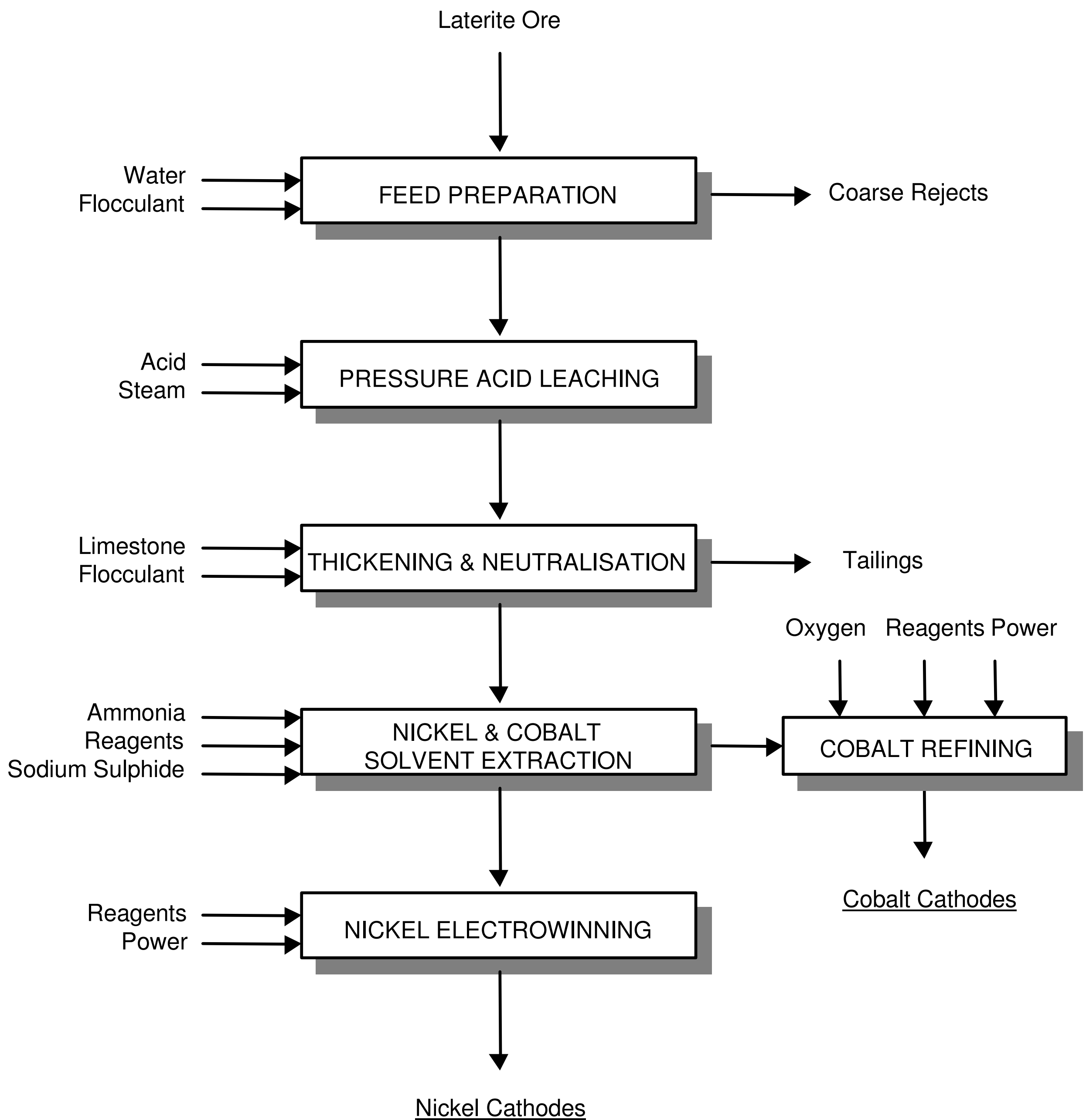


Fig 2.
Simplified Murrin Murrin Flowsheet

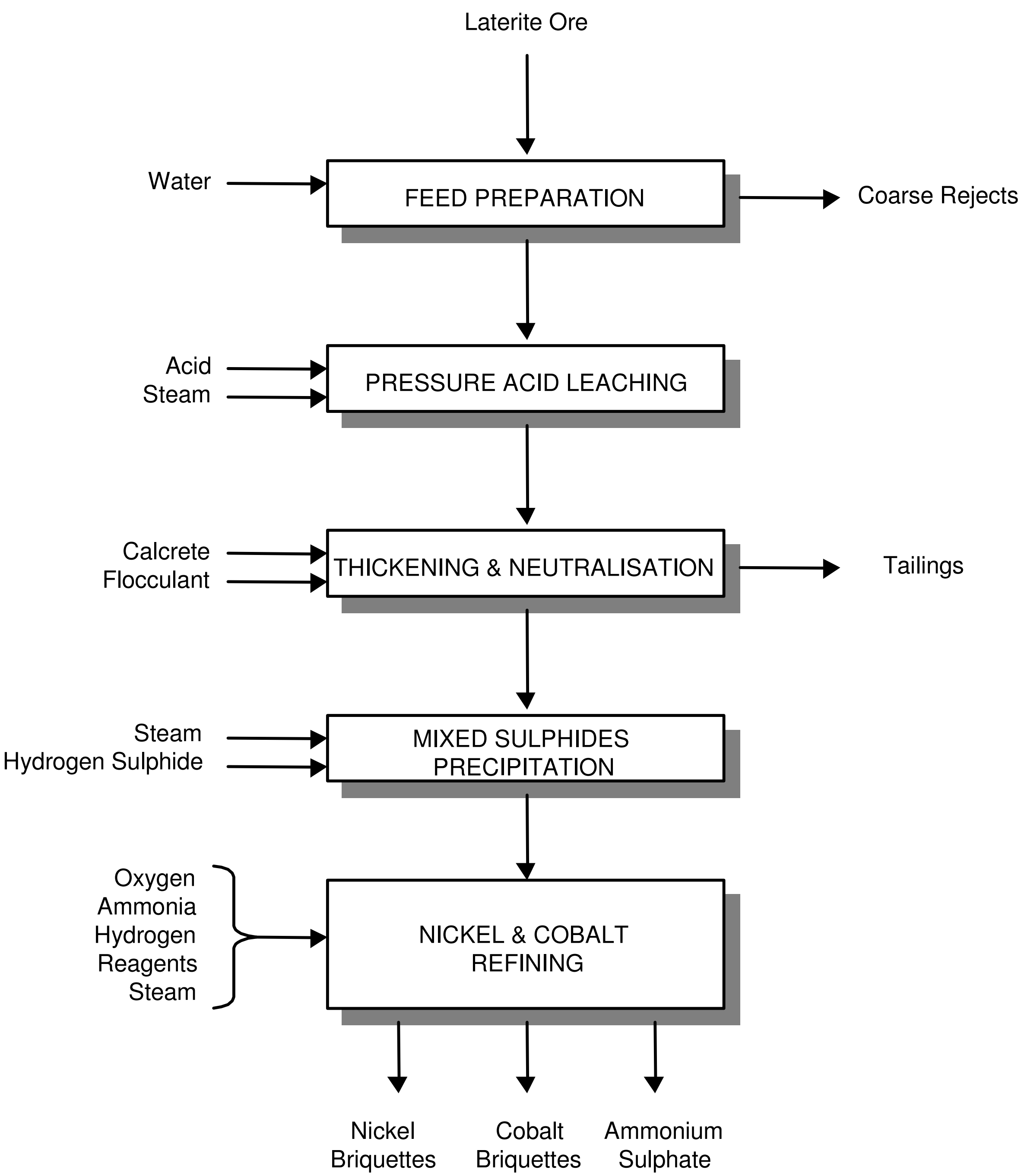


Fig 3.
Simplified Cawse Flowsheet

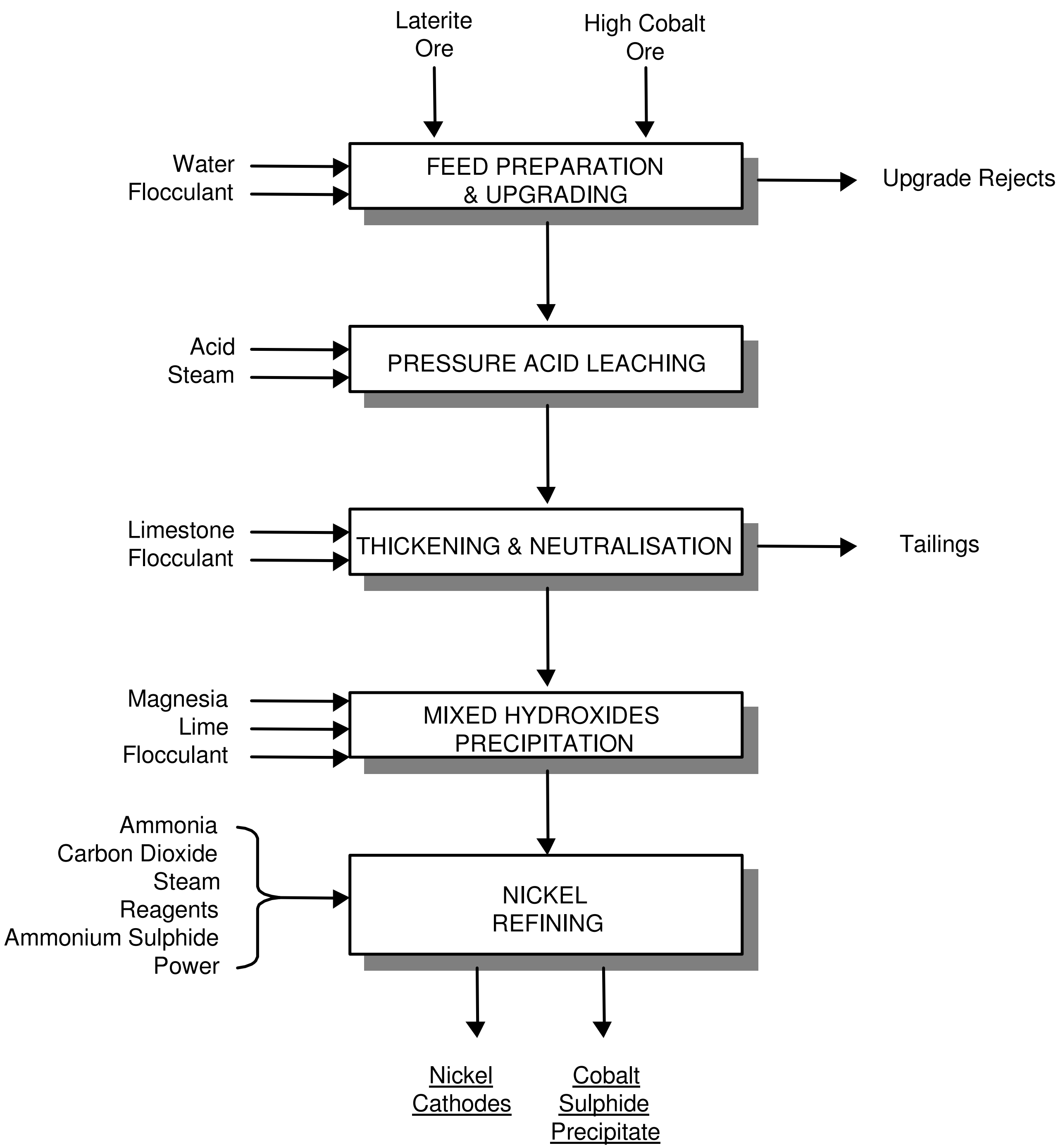


Fig. 4

High Pressure Oxidation Flowsheet

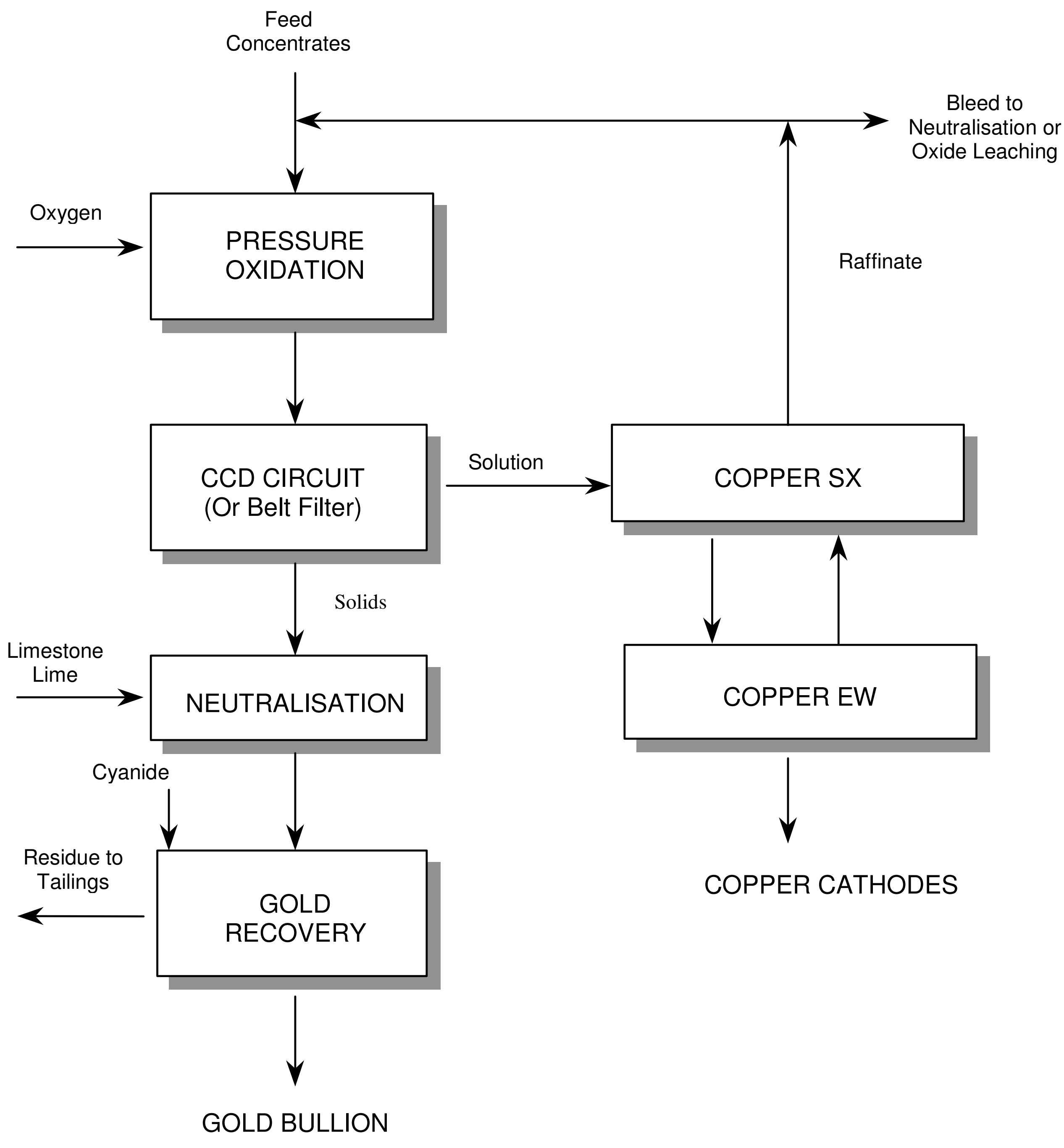


Fig. 5 Bio-Oxidation Process Flowsheet

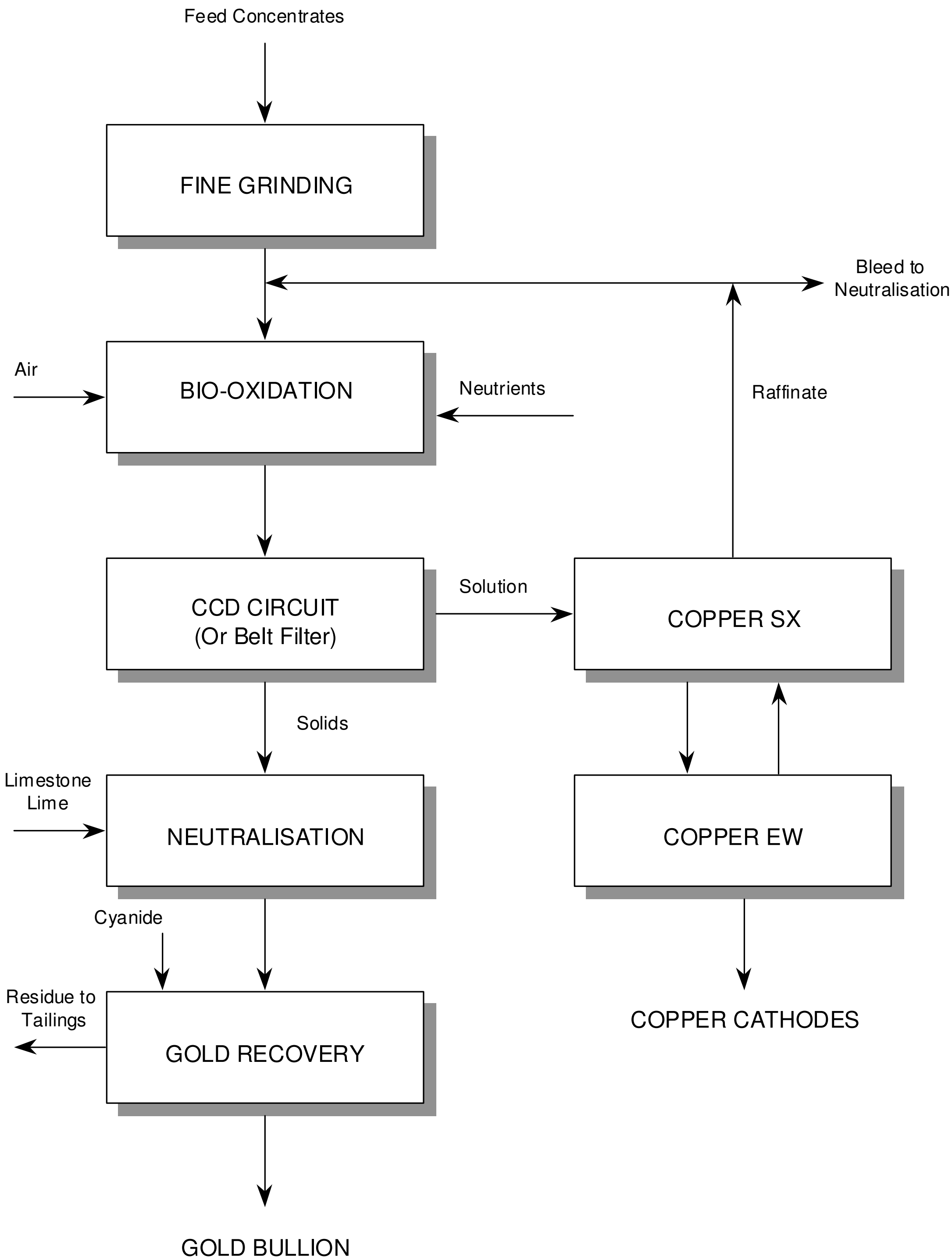


Fig. 6 Intec Process Flowsheet

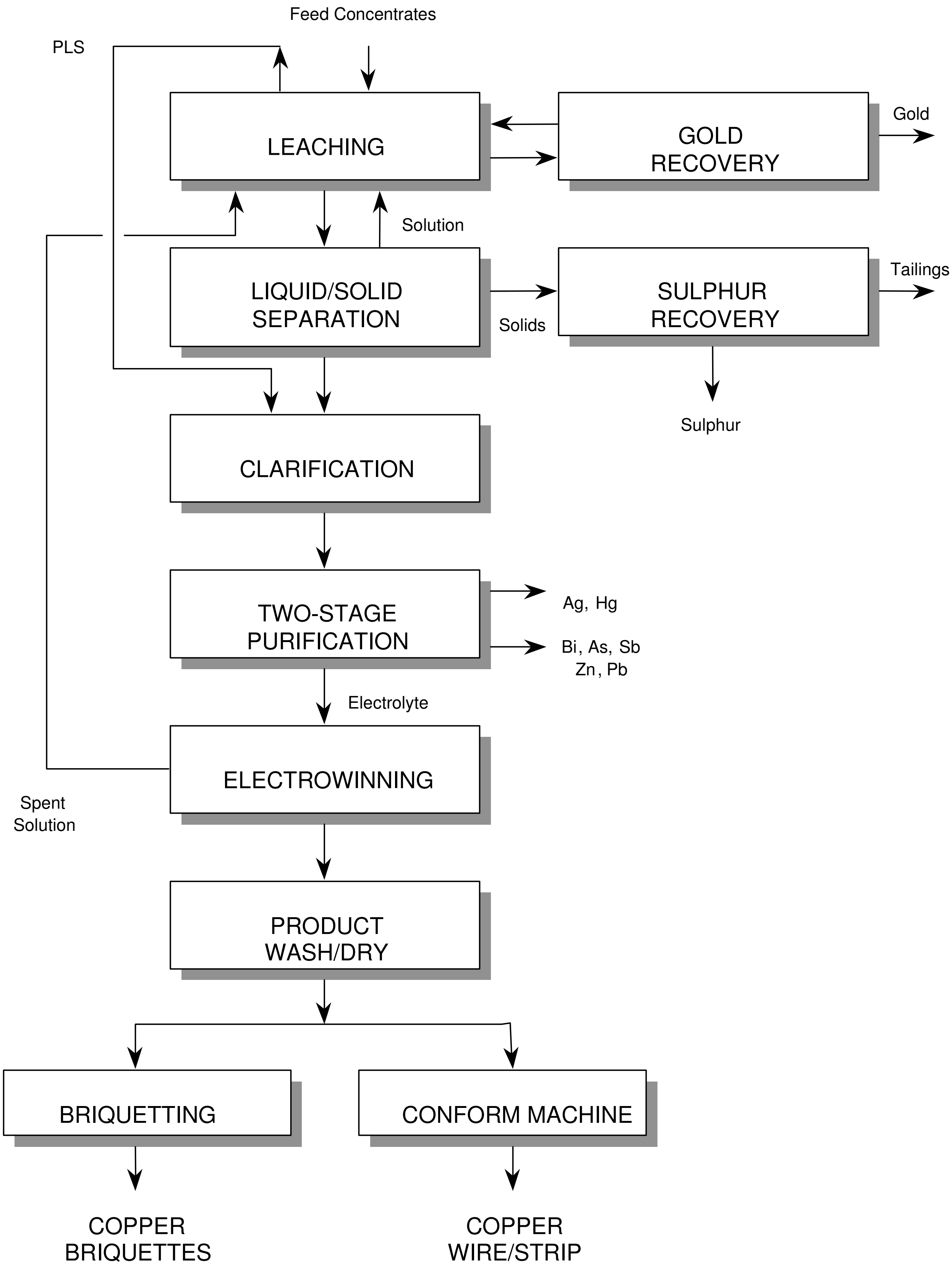
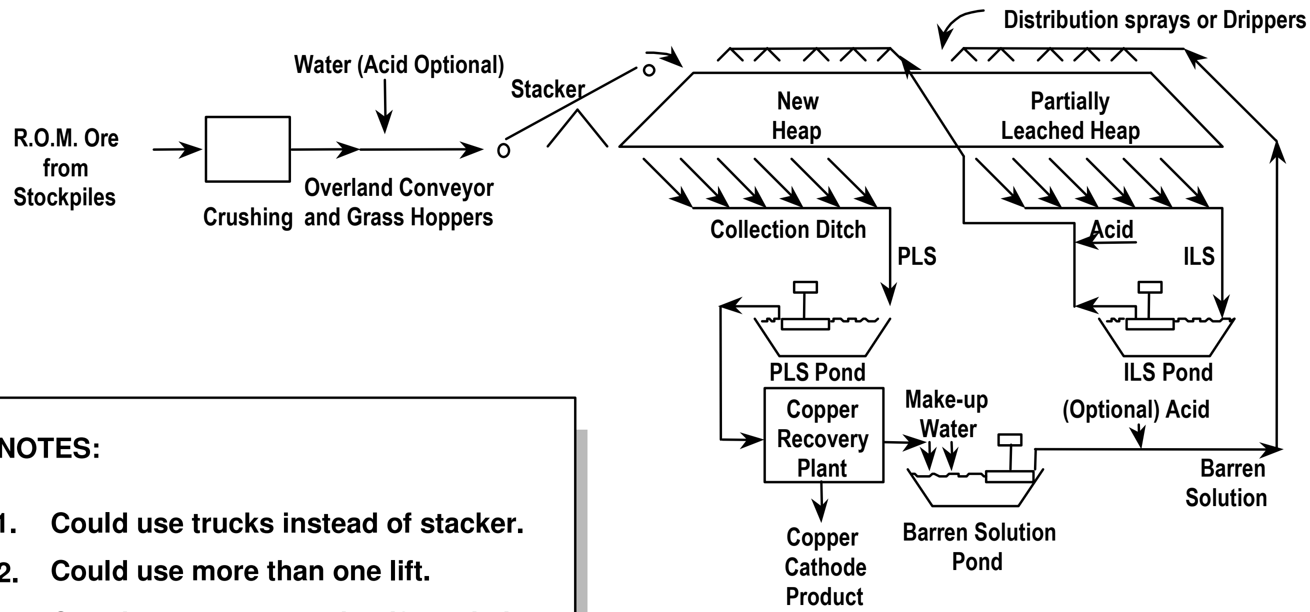


FIG. 7 Typical Heap Leaching Flowsheet



NOTES:

1. Could use trucks instead of stacker.
2. Could use more than one lift.
3. Could use agglomeration if needed.
4. Copper recovery plant includes SX/EW