# Cleaning Copper and Ni/Co Slags: The Technical, Economic, and Environmental Aspects

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In today's nonferrous-metal smelting processes, in which slags with an elevated metal content are generated, slag cleaning is a necessity because of the obvious economic implications. This particularly applies to highly priced metals and for custom smelters, which have to ensure that they recover at least the metals that were paid for.

Besides these economic reasons, consideration must also be given to the environmental aspect of slag quality. Even if the metal content and/or price does not economically warrant its recovery, slag cleaning might be justified to generate an environmentally stable slag, which may be valorized for applications, such as road construction and cement production, rather than disposed of as a hazardous waste material. A number of different test procedures have been developed and adopted in several countries as criteria for the hazardousness of waste materials (e.g., the U.S. toxic characteristic leaching procedure test or the German S4-elution test), which may give conflicting results as to the qualification of the waste material.

Several processes have been developed and commercially applied to clean metallurgical slags, either as part of the smelting process or as post-treatment for dumped slags containing metal values, that before could not be treated either for metallurgical reasons or because of economic incentives. These include pyrometallurgical processes by settling (copper), reduction to matte or alloy (copper, nickel, and cobalt) and fuming (zinc, lead, and tin), as well as the beneficiation process by milling and flotation of slowly cooled slag (copper).

Metals in slags are encountered either as a dispersed phase (in the form of matte or metal) or as a dissolved species (in the form of sulfide or oxide).[1] Oxidic dissolved species are prevalent in slags from processes involving high-grade mattes.[2,3] From dispersed species, such as entrained matte particles, metals such as copper and nickel can be recovered from slag by settling, if entrained particles are not too finely dispersed.

Electric furnaces are most frequently encountered in copper smelting;[4] however, other furnaces, such as the Ausmelt-developed, oil-fired furnace at the Chinese Houma smelter[5] and the Teniente-developed Horno de Limpieza de Escoria furnace,[6,7] are being used for copper-slag cleaning, the latter after injection of a reductant for the recovery of copper from more oxidized slags.

The flotation of slowly cooled slags after suitable milling is another process very frequently encountered for the recovery of sulfide copper from copper slags, particularly from copper converting.[4] The process provides a higher copper recovery but, besides its more elevated investment cost,[1] the hurdles associated with the handling of slowly cooled slags and the disposal of the slag flotation tailings must be faced. Furthermore, slowly cooled crystalline slags are questionable with regard to their environmental stability.[8] Therefore, the process is better suited for application in association with integrated mining/smelting operations. This process and others for copper-smelter slag cleaning are encountered in Chile; an update of the Chilean operations is presented here by S. Demetrio et al.[7] The new Rönnskär copper smelting operation[9] also cleans the flash-smelter slags by flotation at its Boliden concentrator. The high-zinc slags from electric furnaces and the copper-converter slags are treated by fuming for zinc recovery and settling of copper matte in an electric furnace.

Whereas nickel follows copper in converting to a large extent,[10] cobalt follows iron and invariably reports to the converter slags or to the smelter slags if converter slags are returned to the smelter. From these, cobalt can be recovered as an alloy[11] or a matte[12] by reducing smelting in an electric furnace. Considerable activity has been reported by Avmin in Zambia[13] to recover cobalt from copper-smelting slags (according to a process developed by Mintek[11]) and by OMG in the Republic Congo.[14,15] A new development in slag cleaning copper, nickel, and cobalt is the Ausmelt process,[16] which is a smelting/reduction process to matte/metal using top-submerged lance technology followed by a short settling period for metal phase separation.

To decrease cobalt losses in slags from Cu-Ni smelting, processes have been developed that are aimed at separating iron prior to the converting step. This is achieved in the Falconbridge process, in which iron and sulfur are partially oxidized by roasting as a first step, followed by reducing smelting to matte in an electric furnace as described in Reference 17. In the recently implemented DON process[18,19] by Outokumpu, nickel concentrates are flash smelted to a high-grade matte low in iron, which is further treated by hydrometallurgical processing.[20] The smelter slags are reduced in an electric furnace to recover the metal values, particularly the cobalt, in a low-grade sulfur-deficient matte, which joins the high-grade matte for further processing. The cobalt losses with the discard electric-furnace slag are lowered to about 30 percent, as compared to 50 percent, when using the conventional circuit of flash melting and converting.

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