

THE INDUSTRIAL APPLICATION OF PLASMAS TO METALLURGICAL PROCESSES

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ABSTRACT

The plasma decomposition of molybdenite concentrate to molybdenum and sulphur is used to illustrate the industrial application of plasmas to metallurgical processes. The selection of this application was based on a preliminary techno-economic assessment, whose conclusion was that the most promising industrial applications would be found in high added-value refractory metals, alloys, and compounds, the production of which involves high temperatures, and a complex series of steps by existing conventional techniques. A brief review is made of the few plasma metallurgical processes presently practiced, as well as those in an advanced state of development.

The early development program concentrated on the injection of molybdenite into large-volume plasmas, but it was found that the requirements for very high sulphur elimination (lower than 0.15% S in the product) and low specific energy consumption, necessary for a viable industrial process, could not be achieved. Recent work has, therefore, centered on the use of direct current transferred arcs, which appear to offer the most promising approach to the design of commercial reactors for this application.

The industrial development program has been continually complemented by fundamental university research on the reaction kinetics, particle heat and momentum transfer, and most recently, investigations of the diagnostics and properties of transferred arcs, which are described in detail. Briefly summarized, the results permit the calculation of the fraction of the total energy fed to the arc going to (a) cathode cooling, (b) radiation from the arc to the reactor walls and roof, and (c) absorbed by the anode, as a function of the operating variables: current, arc length and volumetric flowrate of the plasmagen sheath gas surrounding the cathode tip (or, more exactly, its velocity). The complex energy transfers occurring at the anode were analyzed in detail.

It was found that the energy used for cathode cooling was invariably small, and almost independent of current and arc length. On the other hand, the total voltage drop was a strong function of the arc length and a weak function of the current. By varying the operating conditions (mainly arc length and sheath gas velocity past the cathode tip) the fraction of the total energy supplied to the arc radiated to the walls could be varied from 30% to 65%.

It was also found that most of the energy transferred to the anode by the arc was released over a small area varying between 1.5 and 2.5-cm diameter, depending on the current and arc length.

A process flowsheet and the results of an economic assessment for a commercial plant are presented to show the relative cost breakdown between key process units, in particular the plasma generator/reactor and material/gas handling systems. The sensitivity of costs to factors such as scale of operation, specific energy consumption and electricity prices, raw materials, gas recycle versus once-through disposal, and product recovery is illustrated. It is concluded that, while the plasma generator/reactor may be the technical heart of the overall process, industrial development programs must consider the capital and operating costs of a complete plant including peripheral equipment, product marketing, as well as the duration, cost and risk associated with the development project. This demonstrates the importance of preparing comprehensive flowsheets and economic assessments in the early stages of the industrial development of a plasma process.