The State of Nonferrous Extractive Metallurgy

H. H. Kellogg

If we wish to understand the state of nonferrous extractive metallurgy — that is, where the technology stands at present, and how it is likely to change — we should first consider a number of broad societal issues that confront the industry. These issues may tell as much about trends in metallurgical processing as do technological considerations. To illustrate and emphasize these societal influences I have found it useful to think about the changes that have taken place since I began teaching extractive metallurgy at Columbia University, 35 years ago.

Fundamental to the understanding of these 35 years is the huge growth of the metal industries, worldwide, as illustrated in Table I. More than twice as much copper and zinc has been produced during my tenure at Columbia than in all recorded history prior to 1946. For aluminum, a relatively new metal that has experienced rapid growth, the record is even more dramatic — 17 times more metal produced between 1946 and 1980 than in all the years before 1946. Yearly production of lead has doubled, that of copper and zinc has nearly tripled, and that of aluminum has increased eleven-fold since 1950. The U.S. Bureau of Mines predicts the course of metal demand to the year 2000, and their latest forecasts are for continued growth in world primary metal demand at annual rates that range from 5.5% for aluminum to 2.0% for zinc.

RESOURCES, ENERGY, THE ENVIRONMENT

With such exponential growth in metal production it is not surprising that industry has recently faced problems of a broad societal nature that seemed not to exist in 1946. No metal industry in 1946 was hampered by shortages and high prices of fuels, nor was government regulation of environmental matters of any importance, and, with few exceptions, there were still abundant nonferrous ores of good grade. Now, after passage of 35 years, and production of the huge quantities of metal shown in Table I, these three factors — energy, environment, and mineral resources — are uppermost in the minds of industry planners, and are beginning to force fundamental changes in our mineral technology.

This natural triad of forces, illustrated in Figure 1, is inherent in the nature of metal production. Two-way interactions occur along each path of the triangle: to mine and produce metals one must have mineral resources and energy, and some environmental changes are inevitable; it is equally true that to produce useful energy requires mineral resources and environmental changes; finally, to protect the environment, or to undo environmental damage requires energy and mineral resources.

These interactions were just as valid in 1946 as they are today, and will be 100 years from now. They are intrinsic interactions whose strength can be influenced by man's actions, but they cannot be eliminated either by technology or by governmental policy. Today we feel the forces of energy, environment, and resources on the metal industry, but did not in 1946, because our huge production of metals over the past 35 years has depleted many of our high-grade mineral resources, and because vast increases in all kinds of industrial activity (including the metal industry) have begun to deplete our stock of cheap fossil fuels and to pour unacceptable amounts of pollutants into our air, water, and soil.

As a young professor at Columbia in the late 1940s and early 1950s, I was excited by potential improvements in metal extraction technology that could result from application of modern science and engineering. I confidently expected sweeping changes in conventional nonferrous technology — a technology mostly inherited from the 19th century. But, with a few exceptions, these changes didn't come in the 1950s, or in the 1960s; it was not until the 1970s that technologic change began to invade the nonferrous metal industry. I had to wait 20 years to see significant introduction of new technology because, in 1950, although the technological ideas were available, the pressure to introduce new technology was not. The metal industry is both conservative and capital-intensive; it requires an overwhelming incentive to move it toward new technology. It was not until the 1970s that the forces of energy, environment, and mineral resources provided the climate where technologic change became inescapable. The strength of these forces can only increase as the century draws to a close, and I expect to see even more rapid introduction of new technology in the years ahead.

The Low-Technology Profile

Another characteristic of the metal-producing industries requires clarification before proceeding to discussions of new technology. Compared to the electronics or aerospace industries, the metal industries are distinctly "low technology." Metal pro-
dution began centuries ago as a useful art, handed down from generation to generation by skilled practitioners. Scientific understanding of metallurgical processes grew slowly during the 19th century and more rapidly in this century, but even today much of our practical process knowledge remains empirical. Metal production is "low technology" in part because its practice predates scientific knowledge.

The "low-technology" profile of extractive metallurgy reflects, however, the nature of its task as much as it does the state of our scientific understanding. An industrial plant that processes 2000 tons per day of copper concentrate, producing 500 tons of copper, 1800 tons of sulfuric acid, and 1400 tons of slag each day, by its very nature must be designed to handle bulk materials by technology that will always appear crude alongside that of a plant producing fine electronics or aerospace vehicles. The task, by its very nature, is a low-technology task. As long as the industrialized world wishes to produce bulk quantities of a limited number of metals, it seems inevitable that secondary metal production requires only 5-40% of the energy for primary metal; consider that secondary metal production saves an equivalent amount of scarce mineral resources; consider that secondary metal production from scrap avoids many serious environmental problems associated with primary metal production, such as the disposition of sulfur from sulfide concentrates.

Increased recycle of post-consumer scrap is both inevitable and desirable, but will entail its own complement of technological problems. Today we recycle only limited amounts of impure aluminum scrap because we possess no means to remove such impurities as copper, iron, silicon, and other elements during secondary processing. We can only meet product specifications for secondary aluminum by limiting our intake of impure scrap, and diluting this either with clean scrap or primary aluminum. Even with iron and steel scrap we must limit the intake of tramp elements, such as copper, tin, and nickel, in order to produce saleable metal. Clearly, we will need new technology for removal of impurities from impure aluminum, zinc, and iron scrap if we are to successfully recycle larger quantities of such materials.

**TECHNOLOGICAL TRENDS**

The broad societal forces, so far discussed, provide the potential for significant changes in extraction technology—changes needed to conserve energy, to protect the environment and worker health, to cope with low-grade and complex mineral raw materials, and to make possible increased recycle of impure, post-consumer scrap. It remains to consider the technological opportunities for