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MOLYBDENUM RECYCLING IN THE UNITED STATES IN 1998

By John W. Blossom

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ABSTRACT

This report describes the flow of molybdenum in the United States in 1998 with emphasis on the extent to which molybdenum was recycled. Molybdenum was mostly recycled from products of molybdenum-bearing steels and superalloys, with some molybdenum products recovered specifically for their high molybdenum content. In 1998, 8,000 metric tons (t) of molybdenum was estimated to have been recycled, and the recycling rate was calculated to be 33 percent, with recycling efficiency at about 30 percent.

INTRODUCTION

The materials flow of molybdenum, as shown in figure 1, describes molybdenum supply and demand factors for the United States in 1998 in order to illustrate the extent of molybdenum recycling and to aid in identifying recycling trends. Knowledge of recycling trends is increasingly important because use of scrap promotes conservation of natural resources and enhances the sustainability of primary production for a cleaner environment. Definitions of specialized terms used in characterizing recycling of metals are given in the appendix. Most data used in this report are derived from U.S. Bureau of Mines and U.S. Geological Survey Minerals Yearbooks. Other estimates, such as that for old and new scrap generated, are based on these data. Some figures, such as unrecovered old scrap, are remainders.

Molybdenum is a refractory metallic element used principally as an alloying agent in steels, cast irons, and superalloys to enhance hardenability, strength, toughness, and wear and corrosion resistance. Primarily added in the form of molybdc oxide or ferromolybdenum, it is frequently used in combination with chromium, columbium (niobium), manganese, nickel, tungsten, or other alloy metals to achieve desired metallurgical properties. The versatility of molybdenum has assured it a significant role in contemporary technology and industry, which increasingly requires materials that are serviceable under ever increasingly higher stresses, greater temperature ranges, and more corrosive environments. Moreover, molybdenum finds significant usage as a refractory metal and in numerous chemical applications, including catalysts, lubricants, and pigments. The variety of uses for molybdenum materials, few of which afford acceptable substitutions, has resulted in a demand that is expected to grow at a greater rate than most other ferrous metals. Figure 1 shows the domestic flow of molybdenum in 1998 with the flow of recycled molybdenum shown in detail.

DISTRIBUTION OF MOLYBDENUM

Almost all molybdenum is recovered from low-grade deposits containing the mineral molybdenite (MoS_2). Deposits mined primarily for molybdenum provide 65 percent to 70 percent of U.S. output and about 45 percent of world output. The remainder is obtained mainly as a byproduct from mining large, low-grade porphyry copper deposits. Molybdenum ores generally grade 0.2 weight percent to 0.5 weight percent molybdenite; copper ores from which byproduct molybdenum is recovered contain 0.02 weight percent to 0.08 weight percent molybdenite.

Distribution of molybdenum reserves and productive capacity is concentrated in a few countries of the world. In 1998, world mine output was an estimated 135,000 metric tons (t) (molybdenum contained in concentrate), of which the United States, Canada, and Chile provided 65 percent. An estimated 1.5 percent of world output came from Russia.

The same four countries possess about 85 percent of the estimated 12 million metric tons (Mt) of molybdenum in the world reserve base. The reserve base for the top four countries, by contained molybdenum, is: United States, 5,400,000 t; Chile, 2,500,000 t; China, 1,000,000 t; and Canada, 910,000 t. Russia estimates its reserve base to be 360,000 t. These five countries, led by the United States, are expected to continue as the principal mine producers in the 21st century. Although exploration for new sources is likely to be successful in other areas, the aforementioned countries probably have the greatest potential for future additions to reserves and, ultimately, to mine output (Blossom, 2001).

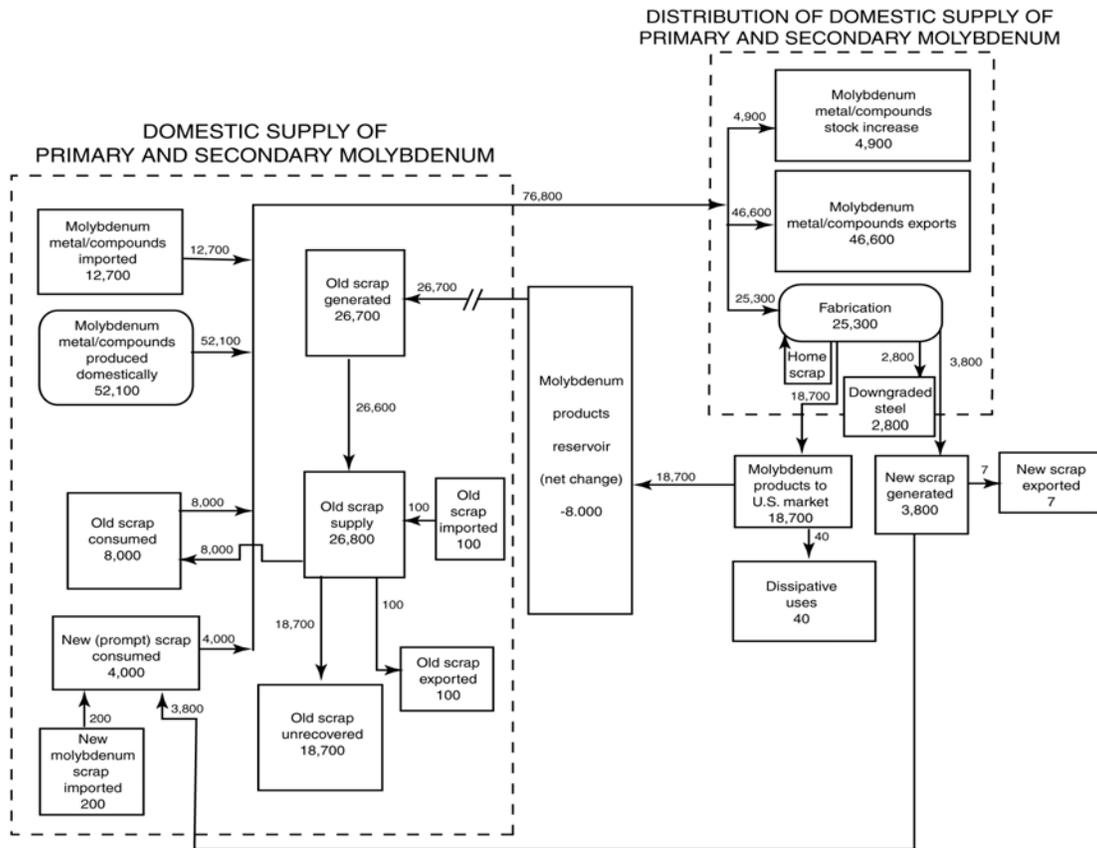


Figure 1. U.S. molybdenum materials flow in 1998 (metric tons, molybdenum content)

As a result of the concentration of production capacity, international trade in molybdenum materials consists primarily of exports from the United States, Canada, and Chile to industrialized nations that lack mine production. The major importers are the countries of Western Europe and Japan. The United States has exported about one-half of its mine output in recent years, mostly as concentrate or oxide, and currently supplies about 45 percent of the molybdenum consumed in other market-economy countries. Because U.S. producers have a viable molybdenum scheme made up of a strong reserve base, and mining and marketing plans, the United States is expected to continue as a leading supplier of molybdenum to the world market (Blossom, 2002).

Salient molybdenum scrap statistics are based on the molybdenum content of steel, catalyst, and superalloy scrap. In 1998, about 26,700 t of molybdenum was recovered from molybdenum-bearing old scrap. About 8,000 t of molybdenum valued at about \$70 million was recycled (table 1). The old scrap recycling efficiency was calculated to be about 30 percent and the recycling rate was about 33 percent. Molybdenum contained in new scrap consumed was about 4,000 t.

Table 1. Salient statistics for U.S. molybdenum scrap in 1998
 [Values in metric tons of contained molybdenum, unless otherwise specified]

Old Scrap:	
Old scrap generated ¹	26,700
Old scrap consumed ²	8,000
Value of old scrap consumed	70 million
Old scrap recycling efficiency ³	30 percent
Old scrap supply ⁴	26,800
Unrecovered old scrap ⁵	18,700
New scrap consumed ⁶	4,000
New-to-old scrap ratio ⁷	33:67
Recycling rate ⁸	33 percent
U.S. net imports of scrap ⁹	190
Value: U.S. net imports of scrap	\$1.8 million

¹Molybdenum content of products theoretically becoming obsolete in the United States in 1998. It excludes dissipative uses.

²Molybdenum content of products which were recycled in 1998.

³(Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imported plus any old scrap stock decrease or minus any old scrap stock increase).

⁴Old scrap generated plus old scrap imported plus old scrap stock decrease.

⁵Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

⁶Including prompt industrial scrap but excluding home scrap.

⁷Ratio of quantities consumed, expressed as a percentage ratio.

⁸Fraction of the molybdenum supply that is scrap on an annual basis. It is defined as consumption of old plus consumption of new scrap divided by apparent supply (see appendix); measured in weight and expressed as a percentage.

⁹Trade in scrap is judged to be about equally divided between old and new scrap. Net exports are exports of scrap minus imports of scrap.

GEOLOGIC OCCURRENCE OF MOLYBDENUM

The average crustal abundance of molybdenum is 1 to 2 parts per million (ppm). Molybdenum does not occur in nature in its free or native state but is found only chemically combined with other elements. Molybdenite (MoS_2), a lead-gray metallic mineral that characteristically occurs in thin, tabular, commonly hexagonal plates and also disseminated as fine particles, is the only molybdenum mineral of commercial importance. It has a specific gravity of 4.6 to 4.7, a hardness of 1 to 1.5, a greasy feel, and it soils the fingers. Superficially, it resembles graphite, for which it commonly has been mistaken (Blossom, 1985; King and others, 1973).

Wulfenite (PbMoO_4), a molybdate of lead, is a metallic mineral of variable color. The mineral has a resinous or adamantine luster, a hardness of 2.75 to 3, a specific gravity of 6.5 to 7, and a white streak. It generally occurs in well-formed crystals, chiefly square and tabular. Deposits are found almost entirely in veins, mostly in the oxidized parts of lead deposits. Occurrences of wulfenite are numerous, but none are of economic importance. Powellite-scheelite [$\text{Ca}(\text{Mo}, \text{W})\text{O}_4$] is a calcium molybdate-tungsten solid solution series; tungsten may substitute up to 10 percent of molybdenum. Primarily hydrothermal, powellite and scheelite occur in veins and skarns and are not alteration products of molybdenite. Powellite-scheelite is nearly always impure; it has a hardness of 3.5, a specific gravity of 4.3, and varies in color from dirty white to gray, straw yellow, greenish yellow, pale greenish blue, and brown. Powellite is found with scheelite, and this association helps to identify the mineral because it fluoresces a golden yellow. Ferrimolybdate ($\text{Fe}_2\text{Mo}_3\text{O}_{12}\cdot 8\text{H}_2\text{O}$) is a very soft, hydrous mineral of distinctive canary-yellow color; it is an oxidation product of molybdenite and pyrite. It occurs as fine, needle-like crystals and has a hardness of 1.5 and a specific gravity of 2.99 to 4.5. Other molybdenum minerals include chillagite, ilsemannite, koechlinite, lindgrenite, eosite, and jordisite (King and others, 1973).

Types of Deposits.—Molybdenum deposits are of five geologic types: (1) porphyry or disseminated deposits, including stockworks and breccia pipes in which metallic sulfides are dispersed through relatively large volumes of hydrothermally altered and fractured rock; (2) contact-metamorphic zones and tactite bodies of silicated carbonate-bearing rocks, such as limestone, dolostone, and carbonate-bearing shale, adjacent to intrusive granitic rocks; (3) quartz veins; (4) pegmatites and aplite dikes; and (5) bedded deposits in sedimentary rocks.

The first three genetic-type deposits are hydrothermal in origin and represent nearly all the identified molybdenum resources currently mined in the world. In hydrothermal deposits, metallic minerals are precipitated from high-temperature aqueous fluids either by changes in temperature and pressure or by evaporation of the liquid. Minerals are deposited in the cracks, cavities, or interstices of the host rock. Intrusive rocks, with which the metallic minerals are genetically related, range from intermediate to felsic in composition and include porphyritic intrusions, dioritic, quartz monzonitic, and granitic

composition (Bookstrom, 1999). Metallization commonly takes place both in the host intrusive and in the surrounding or overlying country rock. The Climax and Henderson deposits in Colorado and Questa deposit in New Mexico are examples of such hydrothermal molybdenum stockwork deposits.

Most of the porphyry copper deposits in the Western United States contain small quantities of molybdenite disseminated with the copper minerals through large bodies of granite rock. The chief minerals are chalcopyrite and chalcocite, with pyrite and small amounts of other sulfides, including molybdenite also in the composition. In addition, minor amounts of other base-metal minerals, specular hematite, fluorite, and secondary silicate minerals are present. Chalcocite replaces pyrite and chalcopyrite in the zone of secondary enrichment. The copper-to-molybdenum ratio ranges from about 10:1 to perhaps 150:1, generally increasing inward and downward within the porphyry copper system.

Small quantities of molybdenite are widely distributed in lime-silicate deposits along the contacts between granitic intrusive rocks and lime-rich sedimentary rocks. Molybdenite is commonly associated with scheelite, bismuthinite, or copper sulfides in zones of silicated limestone near granitic intrusive rocks. The only domestic production from this type of mineralization has been as a byproduct from the Pine Creek tungsten deposit in California. The mineral deposit originated by replacement of the carbonate rock.

Magmatic hydrothermal fluid also is involved in formation of pegmatites and aplites. In pegmatites, fluid and crystals coexist. Growth of large crystals is prompted by slow crystal nucleation and rapid ionic diffusion to crystal growth sites. Aplites form by "pressure quenching" of magma in response to rapid loss of aqueous fluid. In both pegmatites and aplites, MoS₂ deposition involves interactions between magma, crystals, and magmatic-hydrothermal fluid. Pegmatites are coarsely crystalline and consist almost exclusively of quartz and feldspar. Molybdenite occurs as an accessory mineral, and the individual crystals are generally large and usually euhedral. Many pegmatites contain apatite, beryl, cassiterite, columbite, ilmenite, magnetite, rutile, wolfram, and zircon. The average grade of these types of deposits is low; hence, they are not important potential producers of molybdenum. Pegmatite-type deposits that contain disseminated molybdenum associated with bismuth were mined in Val d'Or and Preissac in Quebec, Canada (King and others, 1973).

Molybdenum minerals occur in coal, shale, phosphorite, lignitic sandstone, and some arkosic sandstone. A small quantity of molybdenum has been recovered from uraniferous lignites in North Dakota and South Dakota, but output from these sources ceased in 1968.

Molybdenum is obtained from primary molybdenum mines and from byproduct copper and tungsten mines.

Countries that produced molybdenum in 1998 were: Armenia, Canada, Chile, China, Iran, Kazakhstan, Mexico, Mongolia, Peru, the Republic of Korea, Russia, the United States, and Uzbekistan (Blossom, 2001).

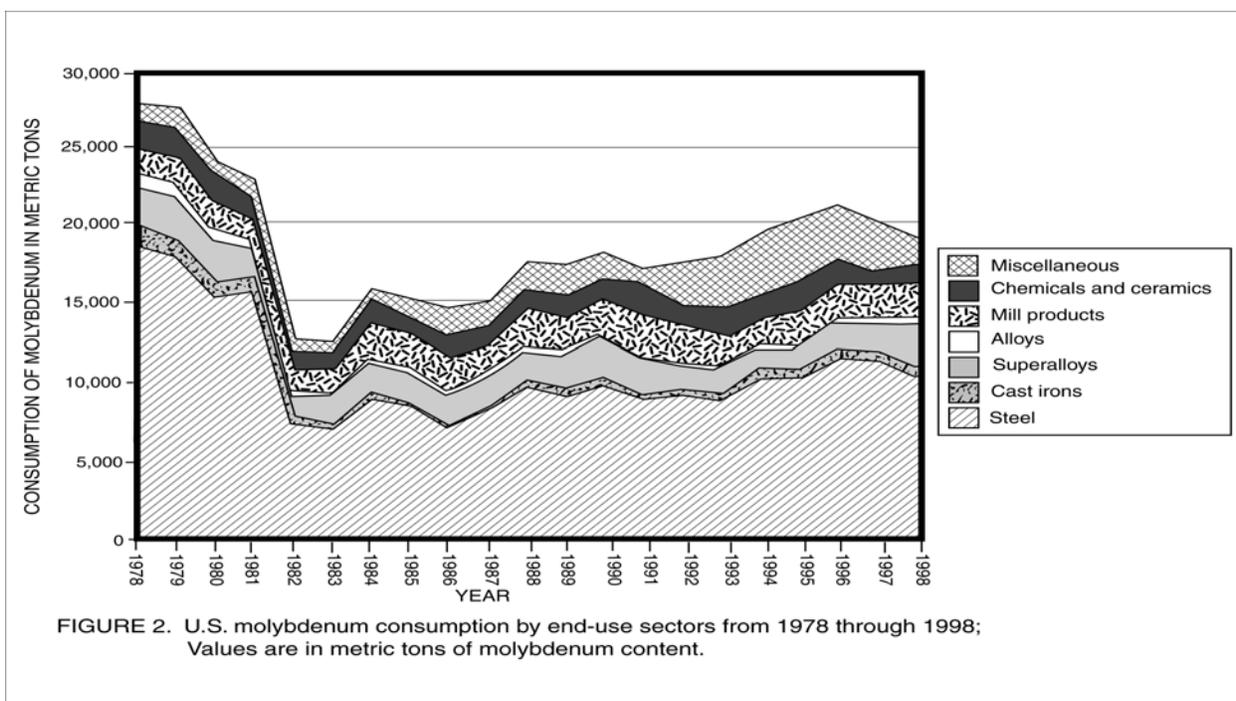
SOURCES OF MOLYBDENUM FROM SCRAP

Molybdenum is recycled as a component of ferrous scrap comprising home, new, and old scrap. Home or mill scrap is generated within the steel mill during production of iron and steel. Old scrap includes metal articles that have been discarded after serving a useful purpose. Because of the wide variety of chemical and physical characteristics, old scrap often requires significant preparation. The molybdenum component is identified, but in most cases the scrap is selected for other elements that it contains. If additional molybdenum is required in the melt in making steel, new (primary) molybdenum oxide or ferromolybdenum, which are products derived from ore, are added.

When the valuable metals or compounds have been recovered, molybdenum catalysts are changed to an environmentally acceptable state, so that catalysts do not become solid waste. These metals may be used again in other end uses or reused in catalysts.

Pure and alloyed molybdenum metal and compound scrap from chemical plants, furnaces, trimmings from fabrication processes, and unuseable fabricated items comprise new scrap and reenter into the flow, usually through the melt process.

Alloy and stainless steel are major sources of molybdenum-bearing scrap. While molybdenum is not recovered separately from scrap steel and superalloys containing it, recycling of these alloys is significant, and the molybdenum content is reused. Some of the molybdenum content that is recycled, however, may be effectively downgraded in alloys, where it is tolerated but not essential.



OLD SCRAP GENERATED

As shown in figure 1, the starting point for molybdenum scrap flow through processing is old scrap generated, which is the amount of molybdenum that became obsolete in 1998 and is estimated to be 26,700 t. This was the old scrap supply available to industry; it was estimated based on the lifetimes of products in which molybdenum is used, which ranged from 10 to 60 years, with an estimated average of 20 years. Some scrap is lost to the environment and some is unrecoverable. In 1998, industry used an estimated 8,000 t of old scrap, while 100 t was exported and 18,700 t was unrecovered. Figure 2 shows changes in end-use patterns from 1978 to 1998; these changes will result in changes in the mix of end uses of old scrap generated in the future.

NEW SCRAP

New scrap consumed in 1998 was estimated to be 3,800 t to 4,000 t, of which most was domestically generated, with about 200 t imported. The new-scrap-to-old-scrap consumption ratio during 1998 was 33:67. New scrap consisted mainly of trimmings from fabrication processes, such as stamping and recycling of unuseable fabricated items. New scrap may also be produced in the manufacture of another commodity product, such as the tungsten filament used in light bulbs. In its manufacture, the filament is twisted around a tiny molybdenum rod. The rod is then dissolved in acid and shipped for recycling as a sludge.

DISPOSITION OF MOLYBDENUM SCRAP

Old scrap consists mainly of molybdenum-bearing steel, which includes carbon, alloy, and stainless steel, and so may have been used in many applications. The steel grades with the highest percentages of molybdenum are in the alloy and stainless steel categories. The highest volume of production, however, is in carbon steel. This scrap, which is derived from demolition of buildings, bridges, and other structures and junked cars and manufacturing equipment, is sold to scrap dealers. Molybdenum catalysts, sometimes in relatively pure form and sometimes contained in sludges, usually are sold by chemical processors to small specialized catalyst recycling plants.

RECYCLING EFFICIENCY FOR OLD SCRAP

The relation between the amount of scrap that is theoretically available for recycling and what is actually recovered and reused is called recycling efficiency. Old scrap recycling efficiency during 1998 was estimated to be 30%. Because data were not available, stock changes were not taken into account. Recycling efficiency is not expected to increase significantly because molybdenum scrap competes with new materials, which are readily available and tend to suppress some molybdenum-bearing scrap prices, thereby limiting scrap recycling and, consequently, recycling efficiency. Additionally, much molybdenum-bearing scrap, such as stainless steel scrap, is usually purchased for other metal content, so its collection usually is dependent on the prices of other commodities, such as chromium and nickel.

INFRASTRUCTURE OF THE MOLYBDENUM SCRAP INDUSTRY

Steel mills and foundries that require ferrous molybdenum-bearing scrap and superalloy melt shops that require pure molybdenum scrap are supplied by brokers and scrap collectors and processors. (See “Iron and Steel” chapter in this series.) Other types of scrap from spent catalyst and metal-laden solutions, such as those generated in the production of light bulb filaments, must be processed to comply with environmental requirements. Brokers bring scrap buyers and sellers together on a scrap transaction and receive a fee for this service. Consumers use brokers to procure scrap; processors use their services to market their scrap. Brokers purchase scrap without having storage or processing facilities for a particular client buyer or sometimes without any certainty of finding a buyer offering a favorable price and profit. The scrap recycling infrastructure in the United States causes its recycling rate to be equal to and, in most cases, exceed that of other industrialized countries, and the rate is much higher than that of lesser developed countries.

Amlon Metals Inc., with headquarters in New York, N.Y., was founded about 1950 and provided reclamation services worldwide. The company recycled about 200,000 metric tons per year of metal-bearing materials and provided documents, sampling, transport, and certification of recycling materials. Their focus is on about 10 metals, including molybdenum, and catalysts are a significant portion of their business. Hi-Temp Specialty Metals in Willingboro, N.J., processed molybdenum turnings, electrodes, chips, and wire. INMETCO, in Ellwood City, Pa., converted about 63,000 t of molybdenum-bearing secondary material, including electric-arc furnace dust, spent catalyst, mill scale, and grinding swarf, into about 24,000 t of iron-chromium-nickel ingots with 1.1 percent molybdenum content; so the molybdenum recycled from this source alone was about 264 t (Cassidy, 2001).

PM Recovery in New Castle, Pa., specialized in processing molybdenum-bearing nickel and cobalt-based grindings, turnings, and off-specification ingot. Kalumetals, Inc., in Latrobe, Pa., used a batch-process furnace to produce molybdenum oxide, and Langeloth Metallurgical in Pittsburgh, Pa., used some secondary material in its molybdenum oxide roasters (Cassidy, 2001).

PROCESSING OF MOLYBDENUM SCRAP

Using a variety of equipment, scrap dealers collect and process scrap into a physical form and chemical composition that can be consumed. The type and size of equipment they use depends on the types and volume of scrap available in the area and the requirements of their customers. The largest and most expensive piece of equipment is the shredder. The shredder can fragment discarded objects into first-size pieces; shredded metals, glass, rubber, and plastic are segregated before shipment. Hydraulic shears, which have cutting blades of chromium-nickel-molybdenum alloy steel for hardness, slice heavy pieces of plate, chemical piping, and structural steel into chargeable pieces. Baling presses are used to compact scrap into manageable bundles, thereby reducing scrap volume and shipping costs. Scrap dealers must carefully sort the scrap they sell, and consumers must purchase scrap that does not contain unacceptable levels of undesirable elements.

Old and new molybdenum scrap consumed or recycled during 1998 was about 12,000 t (4,000 t new and 8,000 t old). Appliances, bicycles, and other molybdenum-bearing steel are shredded for recycling. More than 1,500 scrap yards process steel from construction and demolition sites by shearing, shredding, and baling.

Fabrication of new products produces new scrap that is chemically and physically relatively clean and of known chemical composition. For this reason, most scrap consumers prefer new scrap to old scrap. Preparation of new scrap is usually limited to cutting, cleaning, and baling prior to rapid transport back to the consumer for recycling. Processes used may include calcining, drying, leaching, precipitation, and various means of separation. Some processing may be sub-contracted for sludge-like material, dusts, catalysts, solutions, and grindings. Hi-Temp Specialty Metals processed molybdenum turnings, electrodes, chips, and wire by crushing and abrading the material in a ring mill to remove oxide films in preparation for vacuum melting by others. A roasting process was used by INMETCO and Langeloth Metallurgical at their Ellwood City and Pittsburgh, Pa., facilities, respectively (Cassidy, 2001).

SUMMARY AND OUTLOOK FOR MOLYBDENUM RECYCLING FLOW

Consumption of molybdenum and the growth or decline of the scrap industry depends directly on the health of the specialty and carbon steelmaking industries. Most regions of the world will see a marked increase in steel consumption during the next 5 years, according to the International Iron and Steel Institute (American Metal Market, 2000). In the United States, a steadily increasing population and a growing economy in the long term should assure that demand for steel products and the scrap used to make them will also increase. Steel and scrap consumption will increase as Federal funding of highway and bridge projects increases and will require structural and reinforcement bar products. The use of steel framing is increasing in construction of multifamily developments, retirement homes, and single-family residences. A thriving industry is also dependent on plentiful inexpensive energy. As energy costs rise, the demand for some steel applications may be affected, but demand for pipe and tubular goods used in the oil and gas industry will increase for new drilling and refining projects (Fenton, 2001, p. 5).

The electric-arc furnace (EAF) consumes mostly scrap to make steel. The EAF contribution to total steel production has risen dramatically over the past 30 years, and the amount of EAF-produced steel should continue to increase, perhaps at a rate of 4 percent per year during the next decade (Steel Times International, 2000). The EAF may be the primary steel production method in the world by 2010 (Forster, 1999). The use of EAF has increased in minimills from small units limited in use for specialty steel production to the large-capacity furnace used to produce a wide range of steels, including flat product sheet and plate, long product bars, structural shapes, tubulars, and wire (Recycling Today, 1998). EAF steel comprised nearly 50 percent of all steel produced in the United States in 1998 through 2000 (Fenton, 2002).

The availability of scrap and operating and capital cost advantages have made EAF growth possible. Relocations and establishments of new minimills in areas of increasing population growth and manufacturing activity in the Southern and Western States, and away from the traditional "Rust Belt" States, have, to a large extent, satisfied demand for construction steel products and products used by the oil and gas industry. The EAF process is flexible in its material requirements, and plants can also operate with considerable flexibility in making various products depending on market requirements (Worden, 2000). EAF steelmaking will continue to grow because of the capital and operating cost advantages relative to those of the basic-oxygen furnace (BOF), the increasingly wide range of steel products that it makes, and its environmental cleanliness. The use of the EAF is the most effective way of reducing carbon dioxide emissions, and less energy is needed to melt scrap than to smelt ore. Use of EAFs will increase as minimills are built, and EAFs may replace more operating BOFs (Katrak and others, 1999).

Ferrous alloy scrap will remain the most important raw material used. Increasing availability from domestic producers of direct-reduced iron and hot-briqueted iron will be a factor in dampening this trend toward greater scrap usage, spurred by increasing need for low-residual element feedstocks for the production of high-quality flat steel and special-bar-quality steels required to compete in the higher end markets.

Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals of the alloys in which molybdenum is found, such as iron, nickel, and chromium. While large quantities of molybdenum will continue to be consumed in downgraded form in steelmaking, molybdenum will continue to be recycled in this manner. As long as the value of molybdenum remains relatively low, scrap metal is not likely to be sought for its molybdenum content. Therefore, recycling rates and efficiency are not likely to change significantly in the near term.

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APPENDIX—DEFINITIONS

apparent consumption. Primary plus secondary production (old scrap) plus imports minus exports plus adjustments for Government and industry stock changes.

apparent supply. Apparent consumption plus consumption of new scrap.

dissipative use. A use in which the metal is dispersed or scattered, such as paints or fertilizer, thus making it exceptionally difficult and costly to recycle.

home scrap. Scrap generated as process scrap and consumed in the same plant where it was generated.

new scrap. Scrap produced during the manufacture of metals and articles for both intermediate and ultimate consumption, including all defective finished or semifinished articles that must be reworked. Examples are borings, castings, clippings, drosses, skims, and turnings. New scrap includes scrap generated at facilities that consume old scrap. Included as new scrap is prompt industrial scrap—scrap obtained from a facility separate from the recycling refiner, smelter, or processor. Excluded from new scrap is home scrap—scrap that is generated as process scrap and used in the same plant.

new-to-old-scrap ratio. New scrap consumption compared with old scrap consumption, measured in weight and expressed as a percentage of new plus old scrap consumed (for example 40:60).

old scrap. Scrap including (but not limited to) metal articles that have been discarded after serving a useful purpose. Typical examples of old scrap are electrical wiring, lead-acid batteries, metals from shredded cars and appliances, silver from photographic materials, spent catalysts, tool bits, and used aluminum beverage cans. This is also referred to as post-consumer scrap and may originate from industry or the general public. Expended or obsolete material used dissipatively, such as paints and fertilizer, is not included.

old scrap generated. Molybdenum content of products theoretically becoming obsolete in the United States in the year of consideration, excluding dissipative uses.

old scrap recycling efficiency. Amount of old scrap recovered and reused relative to the amount available to be recovered and reused. Defined as (consumption of old scrap (COS) plus exports of old scrap (OSE)) divided by (old scrap generated (OSG) plus imports of old scrap (OSI) plus a decrease in old scrap stocks (OSS) or minus an increase in old scrap stocks), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{OSE}}{\text{OSG} + \text{OSI} + \text{decrease in OSS or - increase in OSS}} \times 100$$

old scrap supply. Old scrap generated plus old scrap imported plus old scrap stock decrease.

old scrap unrecovered. Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

price. Unit value of contained molybdenum in molybdenum oxide was used in calculating total value of contained metal in scrap.

recycling. Reclamation of a metal in useable form from scrap or waste. This includes recovery as the refined metal or as alloys, mixtures, or compounds that are useful. Examples of reclamation are recovery of alloying metals (or base metals) in steel; recovery of antimony in battery lead; recovery of copper in copper sulfate; even the recovery of a metal where it is not desired but can be tolerated, such as tin from tinplate scrap that is incorporated in small quantities (and accepted) in some steels, only because the cost of removing it from tinplate scrap is too high and tin stripping plants are too few. In all cases, what is consumed is the recoverable metal content of scrap.

recycling rate. Fraction of the apparent metal supply that is scrap; on an annual basis. It is defined as (consumption of old

scrap (COS) plus consumption of new scrap (CNS)) divided by apparent supply (AS), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{CNS}}{\text{AS}} \times 100$$

scrap consumption. Scrap added to the production flow of a metal or metal product.