MOLYBDENUM

By John F. Papp

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Molybdenum is a refractory metallic element used principally as an alloying agent in steel, cast iron, and superalloys to enhance hardenability, strength, toughness, and wear and corrosion resistance. To achieve desired metallurgical properties, molybdenum, primarily in the form of molybdic oxide or ferromolybdenum, is frequently used in combination with or added to chromium, columbium, manganese, nickel, tungsten, or other alloy metals. The versatility of molybdenum in enhancing a variety of alloy properties has ensured it a significant role in contemporary industrial technology, which increasingly requires materials that are serviceable under high stress, expanded temperature ranges, and highly corrosive environments. Moreover, molybdenum finds significant use as a refractory metal in numerous chemical applications, including catalysts, lubricants, and pigments. The variety of uses for molybdenum materials, few of which afford acceptable substitution, has resulted in demand that is expected to grow at a greater rate than that of most other alloying metals. Distribution of molybdenum reserves and productive capacity was concentrated in a few countries of the world. World mine output was estimated to be 130,000 metric tons (t) (molybdenum contained in concentrate), of which, in descending order of production, the United States, Chile, China, Peru, Mexico, and Canada provided 92%. These countries also possessed about 90% of the estimated 12 million metric tons (Mt) of molybdenum in the world reserve base.

Production

Domestic production data for molybdenum were derived by the U.S. Geological Survey by means of three separate voluntary surveys. These surveys are Molybdenum Ore and Concentrate (annual), Molybdenum Concentrate (monthly), and Molybdenum Products and Molybdenum Concentrates (monthly). Surveys are sent to all operations that produce molybdenum ore and products. All eight operations to which surveys were sent responded, representing 100% of the U.S. production shown in table 1.

In 2001, U.S. mine production of molybdenum concentrate was 37,600 t, a decrease from 40,900 t in 2000. World mine production of molybdenum concentrate decreased to 130,000 t in 2001 from 133,000 t in 2000. U.S. share of world production was 29% in 2001 compared with 31% in 2000. Compared with that of the previous year, net production of molybdenum products decreased by 4,000 t in 2001 (tables 1, 2, 7, 8).

Cappa (2001) described the major molybdenum deposits in Colorado (Climax, Henderson, and Mount Emmons) and their geologic history, discovery, and development. The Climax deposit was developed before World War II when demand for hardened steel was increasing. Mining at the Henderson deposit started in 1976.

Molybdenum is produced as a byproduct of copper production at the Sierrita and Bagdad Mines in Arizona and at the Chino Mine in New Mexico. Phelps Dodge Corp. announced reduced copper production at these mines, which will cause reduced molybdenum production (The TEX Report, 2002).

Consumption

In 2001, consumption of molybdenum concentrate was 33,300 t, a decrease of 500 t compared with that of 2000. Domestic mine production of molybdenum concentrate was roasted, exported for conversion, or purified to lubrication-grade molybdenum disulfide. Technical-grade molybdic oxide consumption decreased by about 18% in 2001 compared with that of 2000. Oxide was the chief form of molybdenum used by industry, particularly in stainless and alloy steel, cast iron, and superalloys. In 2001, ferromolybdenum comprised 33.3% of the molybdenum-bearing forms used to make steel compared with 32.7% in 2000. However, ferromolybdenum comprised 54% of the molybdenum-bearing forms used to make steel, a 2% increase from that of 2000. Some of the oxide, however, was converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder (tables 1, 3).

Stocks

In 2001, producer plus consumer industry stocks were 10,700 t, a decrease of 700 t compared with those of 2000. Inventories of molybdenum in concentrate at mine and plant increased by about 180 t. Producer stocks of molybdenum in such products as oxide, ferromolybdenum, molybdate, metal powders, and other types decreased by about 240 t. Consumer stocks of molybdenum contained in various materials decreased by 1,180 t compared with those of 2000. Stocks of 10,700 t represented about a 34-week supply. Supply is calculated as reported stocks divided by annual consumption (tables 1, 3).

Prices

Prices are from Platts Metals Week and are in U.S. dollars per kilogram of contained molybdenum. The time-average prices were MoX, $5.196, and FeMo, $6.850.

Foreign Trade

In 2001, molybdenum exports collectively contained about

31,200 t of molybdenum and were valued at $163 million. (Molybdenum contents of exports were estimated assuming the molybdenum content of molybdenum oxide exports to be 66.7%.) Molybdenum imports collectively were valued at $93 million (tables 4-6).

World Review

Capacity.—As of December 31, U.S. rated capacity for mines and mills was estimated to be 70,000 tons per year of contained metal. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate based on the physical equipment of the plant and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity included operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Reserves.—U.S. molybdenum reserve base was estimated to be 5.4 Mt, about 45% of world molybdenum reserve base. About 90% of U.S. reserves was in large porphyry or disseminated deposits mined or anticipated to be mined primarily for molybdenum; these deposits were in Alaska, Colorado, Idaho, Nevada, New Mexico, and Utah. Other molybdenum sources contribute insignificantly to U.S. reserves.

Most Canadian reserves of molybdenum are in British Columbia. Other Canadian reserves were associated with molybdenum and copper-molybdenum porphyry deposits in British Columbia and with minor sources in New Brunswick and Quebec.

Molybdenum reserves in Central America and South America were associated mainly with large copper porphyry deposits. Of several such deposits in Chile, the Chuquicamata and El Teniente deposits were among the world's largest and accounted for 85% of molybdenum reserves in Chile. Mexico and Peru had substantial reserves. La Caridad deposit in Mexico was a large producer. Numerous other copper porphyries that may contain recoverable quantities of molybdenum have been identified in Central America and South America. Many of these deposits were being actively explored and evaluated and could substantially add to reserves in the future. Reserves of molybdenum in China and the Commonwealth of Independent States were estimated to be substantial, but definitive information about the current sources of supply or prospects for future development in these two areas was lacking.

Environment

Molybdenum is an essential plant and animal nutrient; however, ruminants have a narrow range between nutritional deficiency and toxicity. Neunhäuserer and others (2001) reported on the remediation of 200 hectares of pasture that were polluted with molybdenum of industrial origin after grazing cattle were affected. They tried phytoremediation and reducing molybdenum in the forage. At highly contaminated sites, molybdenum was removed from the ecosystem. At less severely contaminated sites, molybdenum in the soil was immobilized. The Urad Mine in Colorado closed in 1974 after 60 years of mining, leaving 234 acres (94.7 hectares) of tailings to be reclaimed. Margolis and others (2001) reported that planting high-altitude grass and shrubs in biosolids and wood chips covering waste rock spread over the site to provide stability worked well.

Outlook

Because of abundant resources and adequate production capacity in China, Chile, the United States, and other countries, the future requirement for molybdenum should be readily met by the world producers. The principal use for molybdenum will continue to be in chemicals and catalysts and as an additive in steel manufacturing in general, most importantly alloy and stainless steel. Strong growth in production of stainless steel and superalloys can be expected in the near term with generally healthy economic conditions over the next few years.

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TABLE 1
SALIENT MOLYBDENUM STATISTICS 1/

(Metric tons of contained molybdenum, unless otherwise specified)

		1997	1998	1999	2000	2001
United States:						
Concentrate:						
Production		60,100	53,300	42,400	40,900 r/	37,600
Shipments		32,100	52,100	42,800	35,500 r/	37,000
Value, shipments	thousands	$406,000	$200,000	$251,000	$184,000 r/	$192,000
Reported consumption		24,300	35,900	34,500	33,800	33,300
Imports for consumption		6,330 r/	6,570 r/	6,390 r/	6,120 r/	6,010
Stocks, December 31:						
Concentrate, mine and plant		3,660	6,270	4,580	4,030	4,210
Product producers 2/		6,500	7,780	5,340	5,360	5,600
Consumers		1,150	2,170	2,070 r/	2,050 r/	868
Total		11,300	16,200	12,000	11,400	10,700
Primary products:						
Production		48,000	57,200	39,800	42,900	40,300
Shipments		25,900	38,000	39,000	34,600	32,600
Reported consumption		20,000	18,800	18,700	18,300 r/	16,200
World, mine production		139,000 r/	136,000 r/	129,000 r/	133,000 r/	130,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes technical and purified molybdic oxide, briquets, ferromolybdenum, phosphomolybdic acid, molybdenum disulfide, molybdic acid, ammonium molybdate, sodium molybdate, calcium molybdate, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF MOLYBDENUM PRODUCTS IN THE UNITED STATES 1/

(Metric tons of contained molybdenum)

	Metal powder		Other 2/		Total	
	2000	2001	2000	2001	2000	2001
Received from other producers	2	--	16,100	17,100	16,100	17,100
Gross production during year	5,180	5,120	37,700	35,200	42,900	40,300
Molybdenum products used to make other products	3,000	4,340	20,200	20,300	23,200	24,600
Net production	2,190	771	17,500	14,900	19,700	15,700
Shipments	730	771	33,900	31,900	34,600	32,600
Producer stocks, December 31	259	259	5,100	5,340	5,360	5,600

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes ferromolybdenum, molybdic oxides, phosphomolybdic acid, molybdenum disulfide, molybdic acid, ammonium molybdate, calcium molybdate, sodium molybdate, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

TABLE 3
U.S. REPORTED CONSUMPTION, BY END USES, AND CONSUMER STOCKS OF MOLYBDENUM MATERIALS 1/

(Kilograms, contained molybdenum)

End use	Molybdic oxides	Ferro-molyb-denum 2/	Ammonium and sodium molybdate	Molyb-denum scrap	Other	Total
2000:						
Steel:						
Carbon	W	347,000	--	--	21,800	369,000 r/
High-strength low-alloy	638,000 r/	137,000 r/	--	--	303,000	1,080,000 r/
Stainless and heat-resisting	3,070,000	485,000	--	--	108,000 r/	3,660,000
Full alloy	1,850,000 r/	2,100,000 r/	--	--	48,600 r/	4,000,000 r/
Tool	1,020,000	398,000	--	--	57,300 r/	1,470,000
Total	6,570,000 r/	3,470,000 r/	--	--	539,000 r/	10,600,000 r/
Cast irons (gray, malleable, ductile iron)	W	515,000 r/	--	--	27,000	542,000 r/
Superalloys	865,000	W	--	(3/)	1,020,000 r/	1,890,000 r/
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	41,500	--	--	916	42,400
Other alloys	W	63,300	--	--	102,000 r/	165,000 r/
Mill products made from metal powder 4/	W	--	--	--	1,880,000 r/	1,880,000 r/
Cemented carbides and related products 5/	--	--	--	--	154	154
Chemical and ceramic uses:						
Pigments	W	--	241,000	--	W	241,000
Catalysts	985,000	--	W	--	W	985,000
Other	W	--	--	--	W	W
Miscellaneous and unspecified uses:						
Lubricants	--	--	278,000 r/	--	-- r/	278,000 r/
Other	572,000 r/	51,100	1,080,000	--	21,600	1,730,000 r/
Grand total	9,000,000 r/	4,140,000 r/	1,600,000 r/	--	3,600,000 r/	18,300,000 r/
Stocks, December 31	932,000 r/	202,000 r/	39,700	19,900	855,000	2,050,000 r/
2001:						
Steel:						
Carbon	322,000	382,000	--	--	21,800	725,000
High-strength low-alloy	520,000	116,000	--	--	218,000	854,000
Stainless and heat-resisting	2,060,000	267,000	--	--	164,000	2,490,000
Full alloy	1,280,000	1,690,000	--	--	31,200	3,000,000
Tool	1,030,000	384,000	--	--	59,100	1,470,000
Total	5,210,000	2,840,000	--	--	494,000	8,540,000
Cast irons (gray, malleable, ductile iron)	W	417,000	--	--	27,000	444,000
Superalloys	1,060,000	W	--	(3/)	1,250,000	2,320,000
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	37,800	--	--	638	38,500
Other alloys	W	57,900	--	--	102,000	159,000
Mill products made from metal powder 4/	W	--	--	--	1,910,000	1,910,000
Cemented carbides and related products 5/	--	--	--	--	172	172
Chemical and ceramic uses:						
Pigments	W	--	238,000	--	W	238,000
Catalysts	1,030,000	--	W	--	W	1,030,000
Other	W	--	--	--	W	W
Miscellaneous and unspecified uses:						
Lubricants	--	--	255,000	--	181,000	435,000
Other	116,000	53,500	891,000	--	13,800	1,070,000
Grand total	7,420,000	3,400,000	1,380,000	--	3,980,000	16,200,000
Stocks, December 31	505,000	167,000	30,700	11,300	154,000	869,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other" of the "Miscellaneous and unspecified uses" category. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes calcium molybdate.
3/ Included with "Other" of "Superalloys" category.
4/ Includes construction, mining, oil and gas, and metal working machinery.
5/ Includes ingot, wire, rod, and sheet.

TABLE 4
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS No.	2000 Quantity (metric tons)	2000 Value (thousands)	2001 Quantity (metric tons)	2001 Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Belgium		37	$206	22	$343
Brazil		2	21	20	63
Canada		711	4,940	673	4,630
Germany		--	--	--	--
Japan		188	1,880	177	1,310
Mexico		191	1,040	48	296
United Kingdom		1	8	--	--
Other		55	473	1	14
Total		1,190	8,560	940	6,660
Molybdates all, contained weight:	2841.70.0000				
Australia		5	64	6	49
Brazil		2	45	1	10
Canada		475	2,240	305	1,250
China		(2/)	12	--	--
Colombia		2	17	--	--
Honduras		2	22	2	10
Japan		202	1,850	297	1,810
Korea, Republic of		44	324	5	37
Mexico		30	1,380	249	4,150
Netherlands		251	1,080	210	990
Singapore		17	91	1	6
Taiwan		16	106	(2/)	14
Thailand		1	19	--	--
Venezuela		8	49	--	--
Other		22	225	109	1,330
Total		1,080	7,530	1,180	9,670
Ferromolybdenum, contained weight: 3/	7202.70.0000				
Australia		1	16	1	8
Canada		920	4,980	442	3,960
China		--	--	12	169
Japan		95	3,420	--	--
Korea, Republic of		4	37	1	11
Mexico		214	1,470	50	565
Venezuela		--	--	--	--
Other		(2/)	12	124	1,730
Total		1,230	9,940	629	6,440
Powder, gross weight:	8102.10.0000				
Brazil		7	263	7	220
Canada		3	123	4	132
France		3	58	4	143
Germany		51	1,430	30	758
India		2	124	2	71
Italy		10	294	(2/)	5
Japan		31	612	117	2,050
Mexico		3	115	1	23
Spain		7	188	6	164
Sweden		40	919	6	129
Switzerland		(2/)	3	(2/)	7
Taiwan		88	1,530	36	668
United Kingdom		3	113	2	48
Other		52	1,170	4	108
Total		300	6,940	219	4,520

See footnotes at end of table.

TABLE 4--CONTINUED
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS No.	2000 Quantity (metric tons)	2000 Value (thousands)	2001 Quantity (metric tons)	2001 Value (thousands)
Molybdenum unwrought, gross weight:	8102.91.0000				
Australia		--	--	17	$191
Brazil		--	--	12	118
Canada		19	$364	12	197
China		39	616	--	--
France		1	30	--	--
Germany		35	408	45	586
Japan		4	57	17	180
Korea, Republic of		7	263	6	220
Mexico		6	108	(2/)	21
Netherlands		16	253	--	--
Sweden		1	26	2	37
United Kingdom		68	1,030	184	3,610
Other		32	392	39	614
Total		228	3,550	334	5,770
Molybdenum wrought, gross weight:	8102.92.0000				
Brazil		1	42	--	--
Canada		23	713	37	1,070
France		2	210	17	550
Germany		7	361	3	174
India		1	99	1	84
Italy		(2/)	10	--	--
Japan		63	3,820	109	5,310
Korea, Republic of		2	180	1	127
Mexico		1	90	1	87
Netherlands		(2/)	11	(2/)	27
United Kingdom		76	3,440	73	3,180
Other		9	636	17	995
Total		185	9,610	259	11,600
Wire, gross weight:	8102.93.0000				
Argentina		(2/)	23	(2/)	10
Belgium		9	355	4	261
Brazil		13	645	16	662
Canada		3	249	3	256
France		7	368	21	642
Germany		15	850	25	1,340
Hungary		44	3,710	51	2,410
India		22	1,010	17	806
Indonesia		10	427	--	--
Italy		2	89	10	427
Japan		5	318	1	112
Korea, Republic of		8	406	3	269
Mexico		1	136	2	326
South Africa		(2/)	17	(2/)	5
Spain		1	52	8	432
Sweden		2	73	7	351
Taiwan		(2/)	8	--	--
United Kingdom		1	83	1	120
Other		7	478	8	348
Total		150	9,300	177	8,770

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Ferromolybdenum contains about 60% to 65% molybdenum.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS OF MOLYBDENUM ORE AND CONCENTRATES (INCLUDING ROASTED AND OTHER CONCENTRATES), BY COUNTRY 1/

	2000		2001	
Country	Quantity (metric tons of contained molybdenum)	Value (thousands)	Quantity (metric tons of contained molybdenum)	Value (thousands)
Australia	31	$374	147	$2,290
Belgium	5,120	21,100	3,380	12,300
Brazil	31	386	30	279
Canada	1,420	6,240	650	3,200
Chile	35	263	12	148
China	795	1,540	201	204
Germany	672	3,080	512	2,110
India	1	10	294	1,610
Italy	90	754	95	458
Japan	3,100	16,800	1,700	10,400
Korea, Republic of	16	243	29	320
Mexico	62	238	764	3,310
Netherlands	8,780	37,700	13,500	51,100
Sweden	454	2,720	--	--
United Kingdom	2,910	11,400	6,210	20,500
Other	100	774	299	1,820
Total	23600	104000	27800	110000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MOLYBDENUM 1/

		2000			2001		
Item	HTS No.	Gross weight (metric tons)	Contained molybdenum	Value (thousands)	Gross weight (metric tons)	Contained molybdenum	Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	6,900	4,340	$25,700	9,470	6,000	$32,700
Molybdenum ore and concentrates, other	2613.90.0000	3,440	1,780	9,610	10	12	70
Molybdenum oxides and hydroxides	2825.70.0000	1,210	NA	7,200	1,010	NA	5,370
Molydates of ammonium	2841.70.1000	2,280	1,310	11,800	2,740	1,610	14,300
Molydates all others	2841.70.5000	332	236	1,130	318	113	1,000
Molybdenum orange	3206.20.0020	1,620	NA	7,110	1,120	NA	5,050
Ferromolybdenum	7202.70.0000	8,310	5,310	34,700	5,580	3,580	21,000
Molybdenum powders	8102.10.0000	137	125	3,590	172	163	3,280
Molybdenum unwrought	8102.91.1000	16	16	314	25	24	258
Molybdenum waste and scrap	8102.91.5000	475	466	5,590	775	714	7,030
Molybdenum wire	8102.93.0000	17	NA	876	17	NA	1,040
Molybdenum other	2613.10.0000	7	NA	1,560	14	NA	1,870
Total		24,700	13,600	109,000	21,200	12,200	93,000

NA Not available.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 7
MOLYBDENUM-PRODUCING MINES IN THE UNITED STATES IN 2001

State and mine	County	Operator	Source of molybdenum
Arizona:			
Bagdad	Yavapai	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated.
Morenci	Greenlee	do.	Do.
Sierrita	Pima	do.	Do.
Colorado, Henderson	Clear Creek	do.	Molybdenum ore, concentrated.
Idaho, Thompson Creek	Custer	Thompson Creek Metals Co.	Do.
New Mexico, Questa	Taos	Molycorp, Inc.	Do.
Utah, Bingham Canyon	Salt Lake	Kennecott Utah Copper Corp.	Copper-molybdenum ore, concentrated.

TABLE 8
MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained molybdenum)

Country 3/	1997	1998	1999	2000	2001 e/
Armenia e/	1,800	2,500	2,800 r/	3,100 r/	3,300
Canada	8,223 r/	8,469 r/	6,250	6,830	7,000
Chile	21,339	25,298	27,370 r/	33,200 r/	33,000
China e/	33,300	30,000	29,700	28,800 r/	28,200
Iran e/	600	1,400	1,600	1,600	1,600
Kazakhstan	100 e/	100 e/	155 r/	215 r/	225
Kyrgyzstan	NA	225 e/	250	250 e/	250
Mexico	4,842	5,949	7,961	6,886	7,000
Mongolia	2,000 r/	2,000 r/ e/	1,910 r/	1,335 r/	1,450
Peru	3,835	4,344	5,470	7,190	7,500
Russia e/	2,000	2,000	2,400	2,400	2,600
United States	60,100	53,300	42,400	40,900 r/	37,600 4/
Uzbekistan e/	500	500 r/	500 r/	500 r/	500
Total	139,000 r/	136,000 r/	129,000 r/	133,000 r/	130,000

e/ Estimated. r/ Revised. NA Not available.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 13, 2002.
3/ In addition to the countries listed, North Korea, Romania, and Turkey are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.
4/ Reported figure.