

MOLYBDENUM

By John W. Blossom

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. To achieve desired metallurgical properties, molybdenum, primarily in the form of molybdc 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 has ensured it a significant role in contemporary industrial technology, which increasingly requires materials that are serviceable under higher stresses, greater temperature ranges, and more corrosive environments. Moreover, molybdenum finds significant usage 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 a demand that is expected to grow at a greater rate than most other ferrous metals.

Distribution of molybdenum reserves and productive capacity is concentrated in a few countries of the world. World mine output was estimated at 140,000 metric tons (molybdenum contained in concentrate), of which the United States, China, Chile, Russia, and Canada, in descending order, provided 90%. These five countries, led by the United States, are expected to continue to be the principal mine producers for the rest of this century. These countries also possess about 90% of the estimated 12 million metric tons of molybdenum in world reserve base.

Domestic production data for molybdenum are derived by the U.S. Geological Survey (USGS) 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 11 operations to which surveys were sent responded, representing 100% of the total U.S. production shown in table 1.

Domestic mine production of molybdenum concentrate increased to 60,900 tons of contained molybdenum, compared with 54,900 tons in 1996. This production was about 43% of world production. World mine production of molybdenum concentrate increased from a total of 133,000 tons in 1996 to 140,000 tons. Net production of molybdenum products increased 2,300 tons in 1997. (*See tables 1, 2, and 3.*)

Consumption

Consumption of molybdenum concentrate decreased by 200 tons compared with that of 1996. Domestic mine production of molybdenum concentrate was either roasted, exported for conversion, or purified to lubrication-grade molybdenum disulfide. The consumption in 1997 of technical-grade molybdc oxide decreased about 12% from that of 1996. Oxide is the chief form of molybdenum used by industry, particularly in stainless and alloy steel, cast irons, and superalloys. Some of the material is, however,

converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder. (*See tables 1 and 4.*)

Stocks

Total industry stocks, which include those of producers and consumers, increased by 1,470 tons of contained molybdenum. Inventories of molybdenum in concentrate at producer locations increased by about 1,190 tons. Producer stocks of molybdenum in products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, increased by about 720 tons. Domestic end-use consumer stocks of molybdenum contained in various materials decreased 460 tons from that of 1996. Inventories of 11,400 tons represented about a 30-week supply, as measured by reported consumption.

Prices

Prices are from Platt's Metals Week (1997) and are in U.S. dollars per kilogram of contained molybdenum. At the beginning of 1997, the prices were molybdenum concentrates (MoCons), \$4.960; molybdc oxide (MoX), \$9.480; and ferromolybdenum (FeMo), \$11.464. At the beginning of the second quarter, the prices were MoCons, \$4.960; MoX, \$9.976; and FeMo, \$12.125. At the start of the third quarter, the prices were MoCons, \$4.960; MoX, \$9.976; and FeMo, \$11.905. At the start of the fourth quarter, the prices were MoCons, \$4.960; MoX, \$9.535; and FeMo, \$11.795. At the end of the fourth quarter, the prices were MoCons, \$4.960; MoX, \$8.157; and FeMo, \$11.133. The average prices were MoCons, \$4.960; MoX, \$9.457; and FeMo, \$11.721.

Foreign Trade

Exports of molybdenum in concentrate and in molybdc oxide were about 27% higher than in 1996; molybdenum concentrate exports were about 95% of domestic mine production. About 96% of reported exports went to Belgium, Chile, China, Japan, Mexico, the Netherlands, and the United Kingdom. The calculated molybdenum content of all exports was about 61,900 tons. Total value of exports increased from \$302 million in 1996 to \$356 million in 1997.

About 21,600 tons of molybdenum in various forms were imported into the United States, about 900 tons more than in 1996. Total value of all forms of molybdenum imported increased from \$134 million in 1996 to \$137 million. In terms of value, the major form imported was ore and concentrates, roasted. (*See tables 5, 6, and 7.*)

World Review

Capacity.—As of December 31, 1997, the rated capacity for

mines and mills was 165,000 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 includes 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.—With a reserve base of molybdenum estimated at 5.4 million tons, the United States has 45% of the world molybdenum reserve base. About 90% of U.S. reserves is in large porphyry or disseminated deposits mined, or anticipated to be mined, primarily for molybdenum; these deposits are 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 are 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 are associated mainly with large copper porphyry deposits. Of several such deposits in Chile, the Chuquicamata and the El Teniente deposits are among the world's largest and account for 85% of total reserves in Chile. Mexico and Peru have substantial reserves. The La Caridad deposit in Mexico is 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 are 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 are estimated to be substantial, but definitive information about the current sources of supply or prospects for future development in the two countries is lacking.

Outlook

The world demand for molybdenum contained in alloy and

stainless steel and also for chemicals/catalysts is expected to increase about 5% in 1998. It is estimated that the demand in 1999 will be about the same as in 1998.

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¹Prior to January 1996, published by the Bureau of Mines.

TABLE 1
SALIENT MOLYBDENUM STATISTICS 1/

(Metric tons of contained molybdenum unless otherwise specified)

	1993	1994	1995	1996	1997
United States:					
Concentrate:					
Production	36,800	46,800	60,900	54,900	60,900
Shipments	39,200	46,000	61,700	57,900	59,100
Value thousands	\$165,000	\$284,000	\$651,000	\$456,000	\$406,000
Reported consumption	13,800	17,200	25,500	24,500	24,300
Imports for consumption	3,400	2,280	5,570	5,480	6,330
Stocks, December 31:					
Concentrate, mine and plant	11,200	5,510	5,390	2,470	3,660
Product producers 2/	6,150	3,940	4,820	5,780	6,500
Consumers, by end use	2,480 r/	2,040 r/	2,170 r/	1,680 r/	1,220
Total	19,800 r/	11,500	12,400	9,930 r/	11,400
Primary products:					
Production	22,700	31,100	46,000	46,300	48,000
Shipments	16,000	21,400	24,000	24,100	25,900
Reported consumption, by end use	17,700	19,100	19,900	20,900 r/	20,000
World: Mine production	99,200 r/	112,000	142,000 r/	133,000 r/	140,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes technical and purified molybdc oxide, briquets, ferromolybdenum, phosphomolybdic acid, molybdenum disulfide, molybdc 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)

	1996		1997		1996		1997	
	Metal powder		Other 2/		Total		Total	
Received from other producers	--	--	4,140	3,710	4,140	3,710	4,140	3,710
Gross production during year	4,830	4,290	41,500	43,700	46,300	48,000	46,300	48,000
Molybdenum products used to make other products	2,850	2,280	21,000	21,000	23,900	23,300	23,900	23,300
Net production	1,970	2,000	20,400	22,700	22,400	24,700	22,400	24,700
Shipments	481	469	23,600	25,500	24,100	25,900	24,100	25,900
Producer stocks, December 31	223	202	5,560	6,300	5,780	6,500	5,780	6,500

1/ Data are rounded to three significant digits; may not add to totals shown.

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

TABLE 3
MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained molybdenum)

Country 3/	1993	1994	1995	1996	1997 e/
Armenia e/	500	500	1,500 r/	1,800 r/ 4/	1,800
Canada	9,700	10,250	9,113	8,789 r/	7,540 p/
Chile	14,899	15,949 r/	17,889	17,415 r/	17,900
China e/	18,300	21,400	33,000 r/	29,600 r/	32,000
Iran	700 r/	670 r/	560 r/	560 r/ e/	600
Kazakstan e/	600	534 r/ 4/	400 r/	400 r/	400
Korea, Republic of	--	2	--	-- e/	--
Mexico	1,705	2,610	3,883 r/	4,211 r/	4,300
Mongolia	2,050	2,100	1,830	2,200	1,992 4/
Peru	2,980	2,765	3,411	3,711	3,835 4/
Russia e/	10,300	7,700	8,800	8,500	8,500
United States	36,800	46,800	60,900	54,900 4/	60,900
Uzbekistan e/	700	700	500	500	500
Total	99,200 r/	112,000	142,000 r/	133,000 r/	140,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 12, 1998.

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.

TABLE 4
U.S. REPORTED CONSUMPTION, BY END USES, AND CONSUMER STOCKS OF MOLYBDENUM MATERIALS 1/

(Kilograms, contained molybdenum)

End use	Molybdc oxides	Ferro molyb- denum 2/	Ammonium and sodium molybdate	Molyb- denum scrap	Other	Total
1996:						
Steel:						
Carbon	866,000 r/	324,000 r/	--	--	76,500	1,270,000 r/
High-strength low-alloy	470,000	377,000	--	--	--	848,000 r/
Stainless and heat-resisting	3,460,000	342,000 r/	--	--	77,600	3,880,000
Full alloy	2,660,000 r/	1,540,000	--	--	W	4,200,000 r/
Tool	1,080,000	89,600	--	--	32,200	1,200,000
Unspecified steel	W	96,600 r/	--	--	(3/)	96,600 r/
Total	8,540,000	2,770,000	--	--	186,000	11,500,000
Cast irons (gray, malleable, and ductile iron)	177,000	834,000 r/	--	--	27,800	1,040,000 r/
Superalloys	W	57,000	--	(4/)	1,130,000 r/	1,180,000 r/
Alloys (other than steels, cast irons, and superalloys):						
Welding materials (structural and hard-facing)	--	88,700	--	(3/)	2,970 r/	91,700 r/
Other alloys	W	W	--	--	73,800	73,800
Mill products made from metal powder 5/	--	W	--	--	2,160,000 r/	2,160,000 r/
Cemented carbides and related products 6/	--	--	--	--	--	--
Chemical and ceramic uses:						
Pigments	W	--	W	--	--	W
Catalysts	1,700,000	--	W	--	W	1,700,000 r/
Other	W	--	(3/)	(3/)	35,100 r/	35,100 r/
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	270,000	270,000 r/
Other	1,290,000 r/	67,700 r/	1,130,000	--	346,000 r/	2,830,000 r/
Grand total	11,700,000 r/	3,820,000 r/	1,130,000	--	4,230,000 r/	20,900,000 r/
Stocks, December 31, 1996	541,000	236,000	38,300	32,100	834,000	1,680,000
1997:						
Steel:						
Carbon	626,000	307,000	--	--	76,500	1,010,000
High-strength low-alloy	586,000	293,000	--	--	--	879,000
Stainless and heat-resisting	3,410,000	455,000	--	--	90,000	3,950,000
Full alloy	2,400,000	1,990,000	--	--	W	4,390,000
Tool	1,010,000	88,700	--	(7/)	W	1,100,000
Unspecified steel	W	W	--	--	W	W
Total	8,030,000	3,140,000	--	--	167,000	11,300,000
Cast irons (gray, malleable, and ductile iron)	180,000	803,000	--	--	W	982,000
Superalloys	W	W	--	(4/)	1,180,000	1,180,000
Alloys (other than steels, cast irons, and superalloys):						
Welding materials (structural and hard-facing)	--	66,600	--	(8/)	2,470	69,000
Other alloys	--	W	--	--	75,900	75,900
Mill products made from metal powder 5/	--	--	--	--	2,250,000	2,250,000
Cemented carbides and related products 6/	--	--	--	--	W	W
Chemical and ceramic uses:						
Pigments	W	--	W	--	--	W
Catalysts	971,000	--	W	--	W	971,000
Other	W	--	--	--	27,300	27,300
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	287,000	287,000
Other	1,140,000	164,000	1,290,000	--	255,000	2,850,000
Grand total	10,300,000	4,170,000	1,290,000	--	4,240,000	20,000,000
Stocks, December 31, 1997	761,000	202,000	52,400	35,000	172,000	1,220,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Other" of the "Miscellaneous and unspecified uses" category.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes calcium molybdate.

3/ Revised to zero.

4/ Included in "Other:" "Superalloys" category.

5/ Includes ingot, wire, rod, and sheet.

6/ Includes construction, mining, oil and gas, metal working machinery.

7/ Included in "Other:" "Tool" category.

8/ Included in "Other:" "Welding materials (structural and hard-facing)" category.

TABLE 5
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS NO.	1996		1997	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Belgium		45	\$398	37	\$194
Brazil		--	--	2	22
Canada		848	5,820	647	4,770
Germany		--	--	14	173
Japan		582	4,780	333	2,990
Mexico		79	1,060	59	478
Netherlands		210	1,860	--	--
United Kingdom		21	77	62	403
Other		1	3	82	626
Total		1,790	14,000	1,240	9,650
Molybdates all, contained weight:	2841.70.0000				
Argentina		(2/)	3	--	--
Australia		11	135	5	42
Brazil		3	54	6	123
Canada		395	2,290	255	1,300
China		21	191	2	83
Colombia		16	100	10	73
Honduras		2	26	3	35
Japan		159	1,610	184	1,870
Korea, Republic of		70	668	39	609
Mexico		68	349	107	399
Netherlands		260	1,590	1,150	2,910
Singapore		8	49	162	1,440
South Africa		18	115	(2/)	3
Taiwan		80	194	5	50
Thailand		211	175	1	45
Venezuela		(2/)	10	30	85
Other		15	50 r/	68	617
Total		1,340	7,620	2,030	9,680
Ferromolybdenum, contained weight: 3/	7202.70.0000				
Australia		--	--	1	9
Canada		420	2,900	463	5,890
Japan		214	1,870	56	4,270
Korea, Republic of		3	40	3	65
Malaysia		62	252	--	--
Mexico		192	1,610	104	1,440
Singapore		89	3,220	--	--
Spain		1	17	--	--
Taiwan		--	--	11	717
Venezuela		1	12	2	12
Other		3	3	38	602
Total		985	9,930	678	13,000
Powder, gross weight:	8102.10.0000				
Brazil		3	102	14	508
Canada		5	171	5	118
France		11	330	22	611
Germany		9	555	10	420
India		32	1,110	11	393
Italy		(2/)	46	(2/)	3
Japan		74	2,930	24	616
Mexico		3	149	4	138
Spain		2	131	7	200
Sweden		4	130	22	378
Switzerland		--	--	2	68
Taiwan		4	94	126	2,950
United Kingdom		6	430	9	226
Other		57	2,080	6	161
Total		210	8,260	262	6,790

See footnotes at end of table.

TABLE 5--Continued
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS NO.	1996		1997	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Molybdenum unwrought, gross weight:	8102.91.0000				
Australia		9	\$219	9	\$211
Austria		12	191	(2/)	3
Brazil		30	510	(2/)	3
Canada		26	698	18	421
China		52	650	--	--
France		23	404	29	442
Germany		38	665	5	93
India		23	390	10	221
Japan		324	2,800	30	651
Korea, Republic of		--	--	1	33
Mexico		6	52	(2/)	7
Netherlands		39	214	10	189
Sweden		(2/)	16	2	48
United Kingdom		13	266	14	84
Other		6	29	18	240
Total		601	7,110	146	2,650
Molybdenum wrought, gross weight:	8102.92.0000				
Brazil		3	119	(2/)	20
Canada		24	859	29	958
France		8	493	3	391
Germany		3	394	3	315
India		1	447	5	204
Italy		(2/)	42	(2/)	8
Japan		74	4,750	81	4,090
Korea, Republic of		8	634	4	433
Mexico		1	137	1	133
Netherlands		4	181	1	181
United Kingdom		47	2,420	22	1,320
Other		12	500	15	597
Total		185	11,000	164	8,650
Wire, gross weight:	8102.93.0000				
Argentina		(2/)	45	1	82
Belgium		(2/)	17	(2/)	18
Brazil		32	1,640	25	1,080
Canada		1	69	(2/)	47
France		14	806	11	662
Germany		19	1,280	13	875
Hungary		36	4,030	56	5,450
India		9	587	24	1,240
Indonesia		2	110	3	204
Italy		8	443	7	391
Japan		14	1,160	6	665
Korea, Republic of		8	472	8	472
Mexico		1	137	2	179
Netherlands		--	--	(2/)	7
South Africa		1	60	1	57
Spain		1	67	(2/)	32
Sweden		9	450	9	344
Taiwan		5	293	5	243
United Kingdom		5	349	1	129
Other		9	280	9	47
Total		174	12,300	181	12,200

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Ferromolybdenum contains about 60% to 65% molybdenum.

Source: Bureau of the Census.

TABLE 6
U.S. EXPORTS OF MOLYBDENUM ORE AND CONCENTRATES (INCLUDING ROASTED
AND OTHER CONCENTRATES), BY COUNTRY 1/

(Metric tons)

Country	1996		1997	
	Quantity (contained molybdenum)	Value (thousands)	Quantity (contained molybdenum)	Value (thousands)
Australia	61	\$588	219	\$1,070
Belgium	12,400	48,200	14,300	67,300
Brazil	20	138	53	321
Canada	268	1,880	556	3,790
Chile	6,990	35,400	6,450	23,500
China	1,290	4,480	313	1,040
Germany	505	2,800	845	3,560
India	59	262	--	--
Italy	384	2,370	322	2,090
Japan	5,140	31,900	5,840	44,600
Korea, Republic of	10	135	2	24
Mexico	5,500	22,700	6,060	25,400
Netherlands	5,890	36,600	15,600	84,500
Sweden	473	4,190	925	6,480
United Kingdom	6,010	40,100	5,610	28,300
Other	26	131	150	1,280
Total	45,000	232,000	57,200	293,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF MOLYBDENUM 1/

Item	HTS No.	1996			1997		
		Gross weight (metric tons)	Contained molybdenum	Value (thousands)	Gross weight (metric tons)	Contained molybdenum	Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	8,090	5,460	\$41,300	8,100	5,040	\$48,600
Molybdenum ore and concentrates, other	2613.90.0000	36	21	173	2,420	1,290	8,810
Molybdenum oxides and hydroxides	2825.70.0000	1,160	NA	8,850	1,420	NA	11,200
Molybdates of ammonium	2841.70.0000	665	368	5,360	848	456	6,580
Molybdates all others	2841.70.5000	83	36	506	240	156	1,320
Molybdenum orange	3206.20.0000	1,840	NA	5,710	1,760	NA	6,480
Mixtures of inorganic compounds	3823.90.3400	--	--	--	--	--	--
Ferromolybdenum	7202.70.0000	7,870	4,960	55,100	5,840	3,640	36,700
Molybdenum powders	8102.10.0000	125	110	3,470	77	68	2,570
Molybdenum unwrought	8102.91.1000	91	84	2,380	326	301	4,890
Molybdenum waste and scrap	8102.91.5000	693	640	9,720	536	527	8,670
Molybdenum wire	8102.93.0000	2	NA	320	4	NA	475
Molybdenum other	8102.99.0000	4	NA	1,060	7	NA	1,170
Total		20,700	NA	134,000	21,600	NA	137,000

NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.