

# MOLYBDENUM

By John W. Blossom

**Domestic survey data and tables were prepared by Barbara J. McNair, statistical assistant, and the world production table was prepared by Ronald L. Hatch, international data coordinator.**

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 molybdc oxide or ferromolybdenum, is frequently used in combination with or added to chromium, columbium (niobium), 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 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 substitutions, has resulted in a 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 135,000 metric tons (molybdenum contained in concentrate), of which, in descending order of production, the United States, China, Chile, Canada, and Mexico provided 91%. These five countries were expected to continue to be the principal mine producers for the rest of this century. These countries also possessed about 90% of the estimated 12 million tons of molybdenum in the world reserve base. [All units are metric tons of contained molybdenum unless otherwise noted.]

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 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 decreased to 53,300 tons of contained molybdenum, compared with 60,900 tons in 1997. In 1998, U.S. production was about 39% of world production. World mine production of molybdenum concentrate decreased to 135,000 tons in 1998 from 140,000 tons in 1997. Net production of molybdenum

products increased by 9,200 tons in 1998. (See tables 1, 2, and 7.)

## Consumption

Consumption of molybdenum concentrate increased by 11,800 tons compared with that of 1997. Domestic mine production of molybdenum concentrate was roasted, exported for conversion, or purified to lubrication-grade molybdenum disulfide. Technical-grade molybdc oxide consumption decreased by about 4% in 1998 compared with that of 1997. Oxide was the chief form of molybdenum used by industry, particularly in stainless and alloy steel, cast iron, and superalloys. Some of the oxide was, however, converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder. (See tables 1 and 3.)

## Stocks

In 1998, producer plus consumer industry stocks increased by 4,800 tons of contained molybdenum compared with those of 1997. Inventories of molybdenum in concentrate at producer locations increased by about 2,610 tons. Producer stocks of molybdenum in products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, increased by about 1,280 tons. Consumer stocks of molybdenum contained in various materials increased by 950 tons compared with those of 1997. Stocks of 16,200 tons represented about a 45-week supply. Supply is calculated as reported stocks (table 1) divided by annual consumption (table 3).

## Prices

Prices are from Platt's Metals Week (1998) and are in U.S. dollars per kilogram of contained molybdenum. At the beginning of 1998, the prices were molybdenum concentrates (MoCons), \$4.960; molybdc oxide (MoX), \$8.370; and ferromolybdenum (FeMo), \$11.240. At the beginning of the second quarter, the prices were MoCons, \$7.820; MoX, \$9.520; and FeMo, \$11.680. At the start of the third quarter, the prices were MoCons, \$6.880; MoX, \$8.700; and FeMo, \$11.130. At the start of the fourth quarter, the prices were MoCons, \$5.670; MoX, \$6.720; and FeMo, \$10.030. At the end of the fourth quarter, the prices were MoCons, \$4.692; MoX, \$5.897; and

FeMo, \$8.322. The annual average prices were MoCons, \$4.620; MoX, \$5.870; and FeMo, \$8.320.

## Foreign Trade

Exports of molybdenum in concentrate and in molybdic oxide were about 27% lower than those of 1997; molybdenum concentrate exports were about 78% of domestic mine production. About 91% of reported exports of concentrates went to Belgium, Chile, Japan, Mexico, the Netherlands, and the United Kingdom. The calculated molybdenum content of all exports was about 46,200 tons. Total value of exports decreased from \$356 million in 1997 to \$272 million in 1998.

The United States imported about 12,700 tons of molybdenum contained in various materials, which was about 1,200 tons more than those imported in 1997. Total value of all forms of molybdenum imported decreased to \$131 million from \$137 million in 1997. In terms of value, the major form imported was ore and concentrates, roasted. (See tables 4, 5, and 6.)

## World Review

**Capacity.**—As of December 31, 1998, the rated capacity for mines and mills was estimated to be 150,000 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.**—With a reserve base of molybdenum estimated to be 5.4 million tons, the United States had 45% of the 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 total 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 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 countries was lacking.

## Outlook

The world demand for molybdenum contained in alloys, including stainless steel nonferrous alloys, and in chemicals/catalysts was expected to be about the same in 1999 and 2000 as in 1998.

## Reference Cited

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## SOURCES OF INFORMATION

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<sup>1</sup>Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1  
SALIENT MOLYBDENUM STATISTICS 1/

(Metric tons, of contained molybdenum, unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Concentrate:					
Production	46,800	60,900	54,900	60,900	53,300
Shipments	46,000	61,700	57,900	59,100	50,500
Value thousands	\$284,000	\$651,000	\$456,000	\$406,000	\$200,000
Reported consumption	17,200	25,500	24,500	24,300	35,900
Imports for consumption	2,280	5,570	5,480	6,330	6,570
Stocks, December 31:					
Concentrate, mine and plant	5,510	5,390	2,470	3,660	6,270
Product producers 2/	3,940	4,820	5,780	6,500	7,780
Consumers, by end use	2,130 r/	2,220 r/	1,650	1,220	2,170
Total	11,600 r/	12,400	9,900	11,400	16,200
Primary products:					
Production	31,100	46,000	46,300	48,000	57,200
Shipments	21,400	24,000	24,100	25,900	38,000
Reported consumption, by end use	19,100	19,900	20,900	20,000 r/	19,000
World: Mine production	108,000 r/	136,000 r/	126,000 r/	139,000 r/	135,000 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, phosphomolybdc 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)

	Metal powder		Other 2/		Total	
	1997	1998	1997	1998	1997	1998
Received from other producers	--	--	3,640 r/	5,460	3,640 r/	5,460
Gross production during year	4,290	4,470	43,700	52,800	48,000	57,200
Molybdenum products used to make other products	2,280	2,200	21,000	21,200	23,300	23,400
Net production	2,000	2,270	22,700	31,600	24,700	33,900
Shipments	469	622	25,500	37,300	25,900	38,000
Producer stocks, December 31	202	199	6,300	7,580	6,500	7,780

r/ Revised.

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

2/ Includes ferromolybdenum, molybdc oxides, phosphomolybdc acid, molybdenum disulfide, molybdc 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 molybdenum 2/	Ammonium and sodium molybdate	Molybdenum scrap	Other	Total
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	--	--	27,900	4,420,000 r/
Tool	1,010,000	88,700	--	(3/)	18,800	1,120,000 r/
Total	8,030,000	3,140,000	--	--	213,000 r/	11,400,000 r/
Cast irons (gray, malleable, ductile iron)	180,000	806,000 r/	--	--	28,600	1,010,000 r/
Superalloys	W	W	--	(4/)	1,180,000	1,180,000
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	39,500 r/	--	(5/)	416 r/	39,900 r/
Other alloys	--	W	--	--	78,000 r/	78,000 r/
Mill products made from metal powder 6/	--	--	--	--	2,250,000	2,250,000
Cemented carbides and related products 7/	--	--	--	--	156	156
Chemical and ceramic uses:						
Pigments	W	--	W	--	--	W
Catalysts	971,000	--	W	--	W	971,000
Other	W	--	--	--	29,200 r/	29,200 r/
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	285,000 r/	285,000 r/
Other	1,140,000	191,000 r/	1,290,000	--	179,000 r/	2,800,000 r/
Grand total	10,300,000	4,170,000	1,290,000	--	4,240,000	20,000,000
Stocks, December 31, 1997	761,000 r/	202,000	52,400	35,000	172,000	1,220,000
1998:						
Steel:						
Carbon	503,000	280,000	--	--	39,600	822,000
High-strength low-alloy	505,000	146,000	--	--	--	651,000
Stainless and heat-resisting	3,060,000	664,000	--	(8/)	89,300	3,810,000
Full alloy	2,260,000	2,010,000	--	--	27,900	4,290,000
Tool	650,000	87,800	--	(3/)	19,400	757,000
Total	6,970,000	3,190,000	--	--	176,000	10,300,000
Cast irons (gray, malleable, ductile iron)	241,000	843,000	--	--	27,700	1,110,000
Superalloys	981,000	W	--	--	1,220,000	2,200,000
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	37,700	--	--	375	38,100
Other alloys	W	96,000	--	--	79,600	176,000
Mill products made from metal powder 6/	--	--	--	--	2,410,000	2,410,000
Cemented carbides and related products 7/	--	--	--	--	93	93
Chemical and ceramic uses:						
Pigments	W	--	W	--	--	W
Catalysts	967,000	--	W	--	W	967,000
Other	W	--	--	--	29,400	29,400
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	231,000	231,000
Other	11,800	84,400	1,170,000	--	179,000	1,440,000
Grand total	9,170,000	4,250,000	1,170,000	--	4,350,000	18,900,000
Stocks, December 31, 1998	873,000	393,000	46,700	19,300	839,000	2,170,000

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/ Included in "Other" of "Tool" category.

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

5/ Included in "Other" of "Welding materials" category.

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

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

8/ Included in "Other" of "Stainless and heat-resisting" category.

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

Product and country	HTS No.	1997		1998	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Belgium		37	\$194	42	\$420
Brazil		2	22	--	--
Canada		647	4,770	559	4,190
Germany		14	173	3	26
Japan		333	2,990	308	2,430
Mexico		59	478	68	407
United Kingdom		62	403	19	103
Other		82	626	98	768
Total		1,240	9,660 r/	1,100	8,340
Molybdates all, contained weight:	2841.70.0000				
Australia		5	42	25	87
Brazil		6	123	3	25
Canada		255	1,300	453	2,380
China		2	83	--	--
Colombia		10	73	7	38
Honduras		3	35	2	34
Japan		184	1,870	383	2,000
Korea, Republic of		39	609	36	205
Mexico		107	399	33	234
Netherlands		1,150	2,910	377	1,770
Singapore		162	1,440	196	4,290
South Africa		(2/)	3	--	--
Taiwan		5	50	6	46
Thailand		1	45	--	--
Venezuela		30	85	60	166
Other		68	617	13	116
Total		2,030	9,680	1,590	11,400
Ferromolybdenum, contained weight: 3/	7202.70.0000				
Australia		1	9	2	21
Canada		772 r/	5,890	915	5,760
Japan		207 r/	4,270	99	2,380
Korea, Republic of		4 r/	65	2	31
Mexico		176 r/	1,440	151	1,200
Taiwan		17 r/	717	--	--
Venezuela		2	12	--	--
Other		67 r/	602	227	1,990
Total		1,250 r/	13,000	1,400	11,400
Powder, gross weight:	8102.10.0000				
Brazil		14	508	11	358
Canada		5	117 r/	5	176
France		22	610 r/	21	656
Germany		10	419 r/	14	515
India		11	392 r/	15	402
Italy		(2/)	3	--	--
Japan		24	616	22	700
Mexico		4	138	--	--
Spain		7	200	13	439
Sweden		22	377 r/	52	967
Switzerland		2	67 r/	(2/)	8
Taiwan		126	2,950	133	3,130
United Kingdom		9	226	1	67
Other		6	161	34	1,230
Total		262	6,790	321	8,650

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.	1997		1998	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Molybdenum unwrought, gross weight:	8102.91.0000				
Australia		9	\$211	13	\$722
Austria		(2/)	3	--	--
Brazil		(2/)	3	--	--
Canada		18	421	13	301
China		--	--	8	108
France		29	442	21	369
Germany		5	93	14	146
India		10	221	12	272
Japan		30	651	8	201
Korea, Republic of		1	33	--	--
Mexico		(2/)	7	5	51
Netherlands		10	189	12	184
Sweden		2	48	(2/)	16
United Kingdom		14	84	59	635
Other		18	240	16	196
Total		146	2,650	181	3,200
Molybdenum wrought, gross weight:	8102.92.0000				
Brazil		(2/)	20	(2/)	6
Canada		29	958	30	895
France		3	391	1	411
Germany		3	315	7	590
India		5	204	(2/)	51
Italy		(2/)	8	1	77
Japan		81	4,090	54	2,980
Korea, Republic of		4	433	3	166
Mexico		1	133	4	270
Netherlands		1	181	(2/)	6
United Kingdom		22	1,320	25	1,420
Other		15	597	8	335
Total		164	8,650	133	7,200
Wire, gross weight:	8102.93.0000				
Argentina		1	82	(2/)	47
Belgium		(2/)	18	(2/)	32
Brazil		25	1,080	18	731
Canada		(2/)	47	1	113
France		11	662	30	1,270
Germany		13	875	17	1,020
Hungary		56	5,450	45	2,540
India		24	1,240	26	1,230
Indonesia		3	204	3	187
Italy		7	391	3	186
Japan		6	665	29	1,660
Korea, Republic of		8	472	10	522
Mexico		2	179	1	338
Netherlands		(2/)	7	2	66
South Africa		1	57	(2/)	61
Spain		(2/)	32	2	98
Sweden		9	344	7	252
Taiwan		5	243	5	410
United Kingdom		1	129	(2/)	85
Other		9	47	13	184
Total		181	12,200	212	11,000

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

(Metric tons)

Country	1997		1998	
	Quantity (contained molybdenum)	Value (thousands)	Quantity (contained molybdenum)	Value (thousands)
Australia	219	\$1,070	82	\$539
Belgium	14,300	67,300	4,470	23,000
Brazil	53	321	60	475
Canada	556	3,790	731	4,120
Chile	6,450	23,500	6,840	20,400
China	313	1,040	423	829
Germany	845	3,560	461	1,640
India	--	--	9	200
Italy	322	2,090	449	2,280
Japan	5,840	44,600	4,410	31,300
Korea, Republic of	2	24	9	115
Mexico	6,060	25,400	4,220	19,900
Netherlands	15,600	84,500	12,800	68,700
Sweden	916 r/	6,460 r/	894	4,870
United Kingdom	5,610	28,300	5,480	31,000
Other	150	1,280	362	1,640
Total	57,200	293,000	41,700	211,000

r/ Revised.

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

Source: Bureau of the Census.

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

Item	HTS No.	1997			1998		
		Gross weight (metric tons)	Contained molybdenum	Value (thousands)	Gross weight (metric tons)	Contained molybdenum	Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	8,100	5,040	\$48,600	8,020	5,090	\$39,700
Molybdenum ore and concentrates, other	2613.90.0000	2,420	1,290	8,810	2,710	1,480	7,810
Molybdenum oxides and hydroxides	2825.70.0000	1,420	NA	11,200	1,180	NA	9,610
Molybdates of ammonium	2841.70.0000	848	456	6,580	1,240	684	8,980
Molybdates all others	2841.70.5000	240	156	1,320	192	113	982
Molybdenum orange	3206.20.0000	1,620 r/	NA	5,880 r/	2,050	NA	7,950
Ferromolybdenum	7202.70.0000	5,840	3,640	36,700	7,690	4,830	44,000
Molybdenum powders	8102.10.0000	77	68	2,570	110	103	3,210
Molybdenum unwrought	8102.91.1000	326	301	4,890	145	137	2,110
Molybdenum waste and scrap	8102.91.5000	536	527	8,670	296	292	4,080
Molybdenum wire	8102.93.0000	4	NA	475	6	NA	500
Molybdenum other	8102.99.0000	7	NA	1,170	8	NA	1,650
Total		21,400 r/	11,500	137,000	23,700	12,700	131,000

r/ Revised. NA Not available.

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

Source: Bureau of the Census.

TABLE 7  
MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained molybdenum)

Country 3/	1994	1995	1996	1997	1998 e/
Armenia e/	500	1,500	1,800 4/	1,800	2,500
Canada	10,250	9,113	8,789	7,612 r/	7,991 p/ 5/
Chile	15,949	17,889	17,415	21,339 r/	25,298 4/ 5/
China e/	21,400	33,000	29,600	33,300 r/	30,000 5/
Iran	670	560	560 e/	600 e/	600
Kazakhstan e/	100 r/	75 r/	100 r/	100 r/	100
Korea, Republic of e/	2	--	--	--	--
Mexico	2,610	3,883	4,210 r/	4,842 r/	5,949 4/ 5/
Mongolia	2,066 r/	1,822 r/	2,201 r/	1,992	2,000 4/
Peru	2,765	3,411	3,711	3,835	4,344 4/
Russia e/	4,000 r/	3,000 r/	2,000 r/	2,000 r/	2,000
United States	46,800	60,900	54,900	60,900 r/	53,300 4/
Uzbekistan	500 r/	400 r/	500	500 e/	500
Total	108,000 r/	136,000 r/	126,000 r/	139,000 r/	135,000

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, 1999.

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.

5/ Correction of figure from 1998 Minerals Yearbook, Volume I, made on February 15, 2001.