

BISMUTH

By Robert D. Brown, Jr.

In Nebraska, the sole domestic producer of primary bismuth recovered it as a byproduct of lead refining in the first half of 1997. On June 30, the refinery was permanently shut down. In November, the last stocks of bismuth held in the National Defense Stockpile (NDS) were sold and the United States became completely dependent on foreign suppliers. The largest foreign producers of refined bismuth were, in order of importance, Mexico, Peru, Belgium, and China. Following several years of increase or decrease of 5% or so, world mine production rose more than 16% in 1997. World refinery production, however, remained unchanged.

About 43% of bismuth was used in pharmaceuticals and chemicals; 39%, in bismuth alloys; 16%, as metallurgical additives; and 2%, in other uses. Total domestic demand in 1997 was about the same as that in 1996. Only a small amount of bismuth was obtained by recycling old scrap.

In recent years, several new uses for bismuth have been developed as nontoxic substitutes for lead in various applications. These include the use of bismuth in brass plumbing fixtures, ceramic glazes, crystalware, fishing sinkers, lubricating greases, pigments, and solders. Bismuth is the leading candidate for replacing lead in applications that have an environmental impact, such as shot used in waterfowl hunting. This is the only application showing a consistent, significant increase in demand as a substitute for lead. The use of bismuth as a replacement for lead in free-machining plumbing brasses has begun to increase.

The average New York dealer price for bismuth fell to \$3.50 per pound for 1997. This was the second year of moderate decline following 2 years of significant increases. The value of bismuth consumed domestically was slightly less than \$12 million.

Legislation and Government Programs

The Defense Logistics Agency (DLA), which administers the NDS, sold all 191.5 metric tons of bismuth remaining in the stockpile at the beginning of 1997. The last bismuth in the stockpile was sold in November.

After a number of years of conditional approval, the U.S. Fish and Wildlife Service granted final approval of the use of 97% bismuth/3% tin shot for waterfowl hunting. This approval was granted on the basis of testing by the Bismuth Cartridge Council, which determined that spent bismuth shot was not toxic when ingested by waterfowl. Bismuth-tin shot is the leading alternative to steel shot, which replaced lead for waterfowl hunting several years ago (U.S. Fish and Wildlife Service, 1997).

The driving force for conversion to plumbing alloys that contain bismuth rather than lead is the Safe Drinking Water Act (Public Law 104-182). This law, first passed in 1986 and amended in 1996, requires that all pipes, fixtures, solders, and fluxes used for the installation or repair of facilities providing water for human consumption be lead free by August 6, 1998.

Production

ASARCO Incorporated, the only domestic producer of primary bismuth, ceased production in 1997. Asarco stopped refining lead at its Omaha, NE, plant on June 1, 1996. The processing of byproduct materials, including bismuth, continued at the plant until June 1997 (ASARCO Incorporated, 1997). The company agreed to remediate the property for use as a park. To avoid disclosing company proprietary information, production data are not published by the U.S. Geological Survey (USGS).

Some firms recovered bismuth from fusible alloy scrap, but secondary production data are not available. It was estimated that secondary production provided 5% or less of the domestic supply.

Consumption

Domestic consumption data are collected by the USGS through a voluntary canvass. Of the 45 firms that received the consumption survey form in 1997, 71% responded. The respondents accounted for an estimated 85% of the bismuth consumed in the United States. The amount used by the nonrespondents was estimated on the basis of reports from prior years or information from other sources. Consumption in the category of bismuth alloys had the largest increase in 1997, whereas chemical usage had the largest decrease. For the first time in recent years, chemical uses accounted for less than one-half of the bismuth used domestically. The best known chemical use is that of bismuth subsalicylate, the active ingredient in over-the-counter stomach remedies. Other bismuth pharmaceuticals are used to treat burns and stomach ulcers and in veterinary applications. Other bismuth chemical compounds are used for widely varying applications—from pearlescent pigments in cosmetics and paints to superconductors.

In table 2, bismuth metal use is categorized as bismuth alloys, metallurgical additives, and other. One class of bismuth alloys comprises the fusible (low-melting-point) alloys—combinations of bismuth and other metals, such as cadmium, gallium, indium, lead, and tin. Applications for these alloys include holding lenses or other parts for machining or grinding, solders, fire sprinkler triggering mechanisms, and fuel tank safety plugs. Also included in bismuth alloys is the metal used to produce shot for waterfowl hunting; the use of this 97% bismuth/3% tin shot has increased steadily since 1994.

Bismuth is added in small percentage amounts to aluminum, copper, and steel alloys to improve machinability. It is also used in malleable iron to prevent the formation of graphite flakes.

Interest remained high in using bismuth as a nontoxic substitute for lead in several applications. Bismuth oxide has been replacing lead oxide in the fire assaying of precious metals; lead in ceramic glazes; and lead and steel in shotgun pellets.

Research and development continued on the use of bismuth

(often in combination with selenium) to replace lead in plumbing brasses. Although this strategy appeared to be the most promising metallurgical approach to meeting more stringent tap water standards in the United States, bismuth consumption for this application was just beginning to increase.

There was a drive to replace lead additions generally, such as the lead added to steel to provide greater machinability. One major domestic steel company began to offer a bismuth-containing substitute for the leaded alloy nearly 20 years ago. Others have yet to move away from the cheaper lead additions (Ozols, 1997).

Prices

The domestic dealer price for commercially pure bismuth, published in Platt's Metals Week, averaged about \$3.50 per pound for the year, representing a 4% (\$0.15) decrease after a 5% decrease in 1996. The price was \$3.30 per pound at the beginning of 1997, having gradually decreased nearly \$1.00 per pound in 1996. The price fell to \$3.20 per pound during the first quarter, rose sharply during the second quarter to \$3.90, but fell steadily during the second half of the year to \$3.33 per pound at yearend. This final decline indicated expectations of adequate world supply despite the termination of production in the United States.

Foreign Trade

Total imports increased significantly (46% by weight and 32% by value) in 1997, with increases from all major suppliers. Of the 14 supplying countries, the 5 largest—Belgium, Mexico, the United Kingdom, Peru, and China—in descending order, accounted for 94% of the total. Exports increased (36% by weight and 30% by value) in 1997, but remained small (about 9% by weight and 17% by value) compared with imports.

World Review

World supply appeared to be adequate for 1997. During the first half of the year, Mexico, Peru, and the Republic of Korea stopped supplying bismuth to the world market just when trader activity had begun to increase. This precipitated a sharp price increase in the middle of the second quarter (Mining Journal, 1997a). Adequacy of supply, however, became apparent in the third quarter as Peru and China were willing to sell at low prices (Mining Journal, 1997b). This dampened any price recovery despite the lack of any further supply of bismuth from the United States.

Bismuth is usually recovered as a byproduct of lead or tungsten production. The Tasna Mine in Bolivia, which was closed in 1985, has been the world's only significant potential source of bismuth as a principal product. The new owners, Corriente Resources Inc. of Vancouver, Canada, and potential partner Sidech, S.A., of Belgium continued to make plans for the reopening of the mine. Corriente reported the mine's reserves to be 500,000 tons grading 1.47% bismuth and 1.28% copper, with credits for gold, silver, and tungsten. Corriente also purchased a

nearby smelter that it planned to convert from zinc to bismuth/copper production. This acquisition would eliminate costly exportation of concentrates for smelting. The company expected the mine to produce from 900 to 1,000 metric tons per year of bismuth and 10,000 to 15,000 troy ounces per year of gold. It projected a requirement for a steady price of \$4.00 per pound of bismuth to start up. China's capability to provide more than 1,000 tons per year to the world market and its apparent willingness to sell at low prices, however, complicated the prospects for a fairly permanent price increase until demand for new applications reaches higher levels (Tice, 1997).

Current Research and Technology

Corriente Resources and Sidech reportedly are developing a lance furnace process for the coproduction of bismuth, copper, and minor metals. If successful, this approach would lower the effective cost of bismuth production by the gain of credits for the other metals recovered (Tice, 1997).

Researchers from several academic, industrial, and Government laboratories reported on various approaches to obtaining lead-free solders for electronic applications. This work was driven by the negative environmental impact of lead-containing alloys for the same uses. Systems studied included tin-bismuth, tin-zinc-bismuth, tin-silver-bismuth, tin-bismuth-indium, and tin-bismuth-antimony. This research included potential applications in computers and communications, as well as in spacecraft and air and ground transportation (Mahidhara and others, 1997).

Outlook

Demand for bismuth in recent years has been steady rather than growing; it has not increased as rapidly as anticipated earlier. Significant increases in demand for new applications, except for shot for waterfowl hunting, still appear to lie in the future. Nonetheless, the long term outlook is for growth, especially as development and introduction of nontoxic replacements for lead continues.

Because bismuth is most often a byproduct of lead, a rapid increase in supply is unlikely, especially as the total production of lead remains fairly flat, with a large and increasing fraction of lead demand satisfied by recycling. Bismuth supply could be augmented by the resumption of production at the Tasna Mine in Bolivia, the world's only mine where the principal product would be bismuth.

References Cited

- ASARCO Incorporated, 1997, Annual report 1996: New York, ASARCO Incorporated, NY, 45 p.
- Mahidhara, R.K., and others, eds, 1997, Design and reliability of solders and solder interconnects: Warrendale, PA, The Mining, Metals, and Materials Society, no. 3546, 372 p.
- Mining Journal, 1997a, Minor metals in April: Mining Journal, v. 328, no. 8429, May 16, p. 399.
- 1997b, Minor metals in August: Mining Journal, v. 329, no. 8445, September 5, p. 201.
- Ozols, Victor, 1997, Cold finished bar—Some customers say get the lead out: American Metal Market, v. 105, no. 34, February 19, p. 9A.

Tice, Kelly, 1997, A mine's tale—Taking care of bismuth: American Metal Market, v. 105, no. 174, September 9, p.1.

U.S. Fish and Wildlife Service, 1977, Approval of bismuth-tin shot as non-toxic for waterfowl and coots hunting: Federal Register, v. 62, no. 12, January 31, p. 4873-4876.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Bismuth. Ch. in Minerals Commodity Summaries, annual.¹

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

Bismuth. Ch. in Minerals Yearbook, annual.¹

Bismuth. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Bismuth. Mineral Industry Surveys, quarterly.¹

Other

Bismuth. Ch. in Mineral facts and problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT BISMUTH STATISTICS 1/

(Metric tons)

	1993	1994	1995	1996	1997
United States:					
Consumption	1,300	1,490	2,150	1,520	1,530
Exports 2/	70	160	261	151	206
Imports for consumption	1,330	1,660	1,450	1,490	2,170
Price, average, domestic dealer, per pound	\$2.50	\$3.25	\$3.85	\$3.65	\$3.50
Stocks, December 31, consumer	323	402	390	122	213
World:					
Mine production (metal content) 3/	3,550 r/	3,340 r/	3,400 r/	3,610 r/	4,210 e/
Refinery production 3/	4,390 r/	4,180 r/	3,970 r/	4,340 r/	4,400 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Comprises bismuth metal and the bismuth content of alloys and waste and scrap.

3/ Excludes the United States.

TABLE 2
BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1996	1997
Chemicals 2/	855	655
Bismuth alloys	401	593
Metallurgical additives	231	252
Other	35	31
Total	1,520	1,530

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

2/ Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.

TABLE 3
U.S. EXPORTS OF BISMUTH METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY 1/

Country	1996		1997	
	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)
Argentina	137	\$11	960	\$10
Australia	197	5	21	10
Belgium	65,500	\$220	36,900	81
Bermuda	--	--	180	10
Brazil	50	6	--	--
Canada	59,500	1,410	120,000	1,760
China	--	--	684	6
Dominican Republic	1,150	35	1,290	45
Finland	472	4	--	--
France	5,380	77	2,450	19
Germany	497	38	1,300	95
Grenada	--	--	717	6
Guatemala	14,200	16	--	--
Hong Kong	--	--	166	14
Ireland	227	9	1,500	33
Israel	--	--	2,230	19
Korea, Republic of	63	18	--	--
Malaysia	--	--	103	3
Mexico	51	4	218	19
Netherlands	209	7	4,980	44
Singapore	144	8	4,900	79
Switzerland	2,220	20	--	--
Taiwan	--	--	72	11
Thailand	45	4	--	--
United Kingdom	596	44	27,500	250
Total	151,000	1,930	206,000	2,510

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

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY 1/

Country	1996		1997	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Belgium	584,000	\$4,690	691,000	\$5,320
Canada	80,800	675	99,400	789
China	151,000	1,180	161,000	1,160
France	--	--	32	10
Germany	498	104	114	21
Hong Kong	15,800	128	--	--
Japan	1,680	90	600	25
Macao	--	--	20,000	128
Malaysia	--	--	4,270	31
Mexico	453,000	3,380	601,000	3,870
Netherlands	--	--	161	7
Peru	19,500	164	163,000	1,150
Spain	--	--	100	1
Switzerland	--	--	19	3
United Kingdom	189,000	1,090	425,000	27,700
Total	1,490,000	11,500	2,170,000	15,200

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

Source: Bureau of the Census.

TABLE 5
BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	Mine					Refinery				
	1993	1994	1995	1996	1997	1993	1994	1995	1996	1997
Belgium e/	--	--	--	--	--	950	900	800	800	800
Bolivia	--	--	121	348 r/	350 e/	7	36	19	28 r/	60 e/
Bulgaria e/	40	40	40	40	40	40	40	40	40	40
Canada 3/	144	129	187	150 r/	183 p/	--	--	--	--	--
China e/	740	610	740	610 r/	600	1,050	850	800	800	800
Italy e/	-- 4/	--	--	--	--	15 r/	5	5	5	5
Japan 5/	149 e/	152 e/	177 e/	169 e/	168 e/	497	505	591	562 r/	560
Kazakstan e/	130 r/	45 r/	120 r/	115 r/	115	180 r/ 4/	84 r/ 4/	166 4/	160	160
Korea, Republic of e/ 5/	5	--	--	--	--	5 4/	--	--	--	--
Mexico 6/	908	1,047 r/	995	1,070 r/	1,642 p/	650 e/	836 r/	924	957 r/	990 p/
Peru	1,300 r/	1,210 r/	900 r/	1,000 e/	1,000 e/	937	877 r/	581 r/	939 r/	940 e/
Romania e/	40	40	40	40	40	35	35	35	35	35
Russia e/	60 r/	40 r/	50 r/	50 r/	50	9	9	10	10	10
Serbia and Montenegro e/	5 4/	5	5	5	5	10 4/	(7/) 4/	(7/) 4/	(7/)	(7/)
Tajikistan e/	16	12	11	5	5	--	--	--	--	--
United States	W	W	W	W	W	W	W	W	W	W
Uzbekistan e/	10	10	10	11	11	--	--	--	--	--
Total	3,550 r/	3,340 r/	3,400 r/	3,610 r/	4,210	4,390 r/	4,180 r/	3,970 r/	4,340 r/	4,400

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

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

2/ Table includes data available through May 11, 1998. Bismuth is produced primarily as a byproduct of other metals, mostly lead; Bolivia is the sole producer of primary bismuth.

3/ Figures listed under mine output are the metal content of concentrates produced.

4/ Reported figure.

5/ Mine output figures have been estimated based on reported metal output figures.

6/ Refined metal includes Bi content of imported smelter products.

7/ Less than 500 kilograms. Production in kilograms: 1994--88; 1995--86; 1996--100 (estimated); and 1997--not available.