BISMUTH

By Robert D. Brown, Jr.

Domestic survey data and tables were prepared by Carolyn F. Crews, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

U.S. bismuth consumption increased 4% during 2000, compared with that of 1999. Consumption increased in all sectors: bismuth alloys, chemicals and pharmaceuticals, and metallurgical additives. In 2000, all primary bismuth consumed in the United States was imported. The only domestic refinery, in Nebraska, produced bismuth as a byproduct of lead refining until July 1997. The last stocks of bismuth held in the national defense stockpile (NDS) were sold that same year. The largest foreign producers of refined bismuth were Belgium, China, Mexico, and Peru.

Domestically, about 42% of bismuth was used in bismuth alloys, 40% in pharmaceuticals and chemicals, 16.5% as metallurgical additives, and 1.5% for other uses (table 2). 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 included the use of bismuth in brass plumbing fixtures, ceramic glazes, crystalware, fishing sinkers, lubricating greases, pigments, and solders. Bismuth was a leading candidate for replacing lead in applications that have an environmental impact, such as shot used for waterfowl hunting. Another newly developed use was in galvanizing to improve drainage of galvanizing alloys. Poor drainage causes galvanizing alloy to accumulate in corners and angles as well as bridge small holes and thin channels, which requires extra cleaning of the workpiece. Lead additions improve the drainage properties of galvanizing alloys. Zinc-bismuth alloys have the same drainage properties as zinc-lead alloys without the toxicity of lead (Gagné, 2000).

In 2000, the average New York dealer price for bismuth decreased from $3.85 per pound to $3.70 per pound (table 1). This reversed increases in 1998 and 1999, but the average price was still the second highest in 5 years. The value of bismuth consumed domestically in 2000 was about $17.4 million, the same as for 1999.

Legislation and Government Programs

The Defense Logistics Agency, which administers the NDS, sold the final 85 metric tons (t) of bismuth in the stockpile on November 4, 1997.

The conversion to plumbing alloys that contain bismuth rather than lead is driven by the Safe Drinking Water Act Amendments of 1996 (Public Law 104-182). This law bans lead from all fixtures, fluxes, pipes, and solders used for the installation or repair of facilities providing water for human consumption after August 1998.

The U.S. Environmental Protection Agency announced new standards for dangerous levels of lead on painted indoor surfaces, in dust, and on bare soil where children play. These new standards will provide new and uniform benchmarks on which to base remedial action to be taken to safeguard the public from exposure to lead. The standards, which affect Federal agencies, and State, local, and tribal governments, could further the use of bismuth as a lead substitute (U.S. Environmental Protection Agency, 2000).

The Copper Development Association has changed the name of its alloys, introduced in 1995 as SeBiLOY (containing selenium and bismuth), to Envirobrass to highlight the significant environmental and health benefits of the alloys to manufacturers and consumers. Envirobrass I and II contain a mixture of bismuth and selenium substituted for lead in red

Bismuth in the 20th Century

In 1900, the United States produced 200 metric tons of bismuth ore, all mined in Colorado, primarily bismuth carbonate from Lake County. The ore averaged about 7% bismuth and had a value of about $9 per ton, based on bismuth content. The ore also contained gold and silver, increasing its price to $70 per ton. The world's supply and pricing of metallic bismuth were closely controlled by Johnson Matthey and Co., Ltd., of England and the Government of Saxony, which today is a State of Germany. Supply was much greater than demand. Imports of bismuth totaled 82 tons valued at $250,000. A small amount of bismuth was imported in medical preparations. The main use for bismuth was in the manufacture of low-melting-point alloys for electric fuses, safety plugs for steam boilers, solders, amalgams, and baths for steel tempering. Most of these alloys contained various combinations of lead, tin, and cadmium with bismuth. In 1906, the Betts process for refining lead bullion became the major source of bismuth; since then bismuth has been known as a byproduct metal.

In 2000, U.S. consumption of bismuth was more than 2,000 tons; bismuth alloy consumption was 890 tons, chemical and pharmaceutical uses accounted for 860 tons, and metallurgical additives plus other uses reached approximately 380 tons. New uses included replacement for lead associated with environment or public health concerns (such as in fishing sinkers, waterfowl shot, and plumbing fixtures), weather resistant paints, and hot dip galvanizing. Since 1997, when domestic production and national stockpile sales ended, the United States has been completely dependent on imports for primary bismuth; only a relatively small amount of bismuth is recycled in the country. The world's leaders in refinery production in 2000 were Belgium, China, Mexico, and Peru. Although a myriad of new uses increased world bismuth demand during the 20th century, adequate reserves indicated that supply would be sufficient for future needs.

brasses used for water meters, valves, and plumbing fixtures. A new alloy, Envirobrass III, is a lead-free yellow brass for permanent mold casting (Payne, 2000).

The Danish Minister for Environment and Energy announced that the country would prohibit lead in several products where it can be replaced. The ban takes effect in 2001 and has the goal of reducing lead consumption by one-third in the next few years (Mining Journal, 2000a).

Production

ASARCO Inc., formerly the only U.S. producer of primary bismuth, ceased production on June 30, 1997. Some domestic firms continued to recover secondary bismuth from fusible alloy scrap in 2000, but secondary production data were not available. Secondary production was estimated to be no more than 5% of domestic supply during the year.

Consumption

Domestic bismuth consumption data are collected by the U.S. Geological Survey through a voluntary survey. Of the 40 firms that received the consumption survey in 2000, 70% responded. The respondents accounted for an estimated 75% of the bismuth consumption 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.

Bismuth consumption in 2000 was estimated to be 2,130 t, a 4% increase from that of 1999 (table 1). There were small or moderate increases in each sector: bismuth alloys, chemical and pharmaceutical uses, and metallurgical additives in 2000. Chemical uses, comprising most of the bismuth consumed in earlier years, accounted for less than one-half of the bismuth used domestically for the fourth successive year; in 2000, it was supplanted for the first time as the leading sector of consumption. 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, intestinal disorders, and stomach ulcers; veterinary applications are important as well. Bismuth nitrate is the initial material used for the production of most other bismuth compounds. Other bismuth chemical and compound uses include applications ranging from superconductors to some pearlescent pigments in cosmetics and paints.

Bismuth metal is used primarily as an alloy and metallurgical additive (table 2). 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 included fuel tank safety plugs, holders for lens grinding and other articles for machining or grinding, solders, and sprinkler triggering mechanisms. Also, the metal used to produce shot for waterfowl hunting is categorized as a bismuth alloy.

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

There remains considerable interest 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 and in ceramic glazes, and bismuth replaces lead as well as steel in shotgun pellets. In fact, one area of steady increase since 1994 has been the use of bismuth alloy cartridges for waterfowl hunting; the alloy has been 97% bismuth and 3% tin.

Bismuth also has been the primary candidate of researchers seeking substitutes to replace lead in products that traditionally have contained lead, such as plumbing fixtures and solders. Alloys that use bismuth (often in combination with selenium) to replace lead in plumbing brasses are in regular production. This strategy appears to be a promising metallurgical approach to meeting more stringent tapwater standards in the United States. Although bismuth use in water meters in particular has increased, growth in bismuth consumption as a metallurgical additive remained somewhat sluggish in 2000.

There has been an effort to replace lead in other applications as well. For example, bismuth has been a substitute for the lead added to steel to provide greater machinability. A major domestic steel company began to use a bismuth-containing substitute for the leaded alloy nearly 20 years ago. Nevertheless, although bismuth has been successful in replacing lead in various applications, it has been challenged as a lead substitute by tungsten and tin (Cusack, 1999).

Prices

The domestic dealer price for commercially pure bismuth, published by Platt's Metals Week, averaged about $3.70 per pound in 2000, representing a 4% ($0.15) decrease after 4% and 3% increases in 1999 and 1998, respectively (table 1). The price was $4.30 per pound at the beginning of 2000, after fluctuating between $3.15 and $4.65 during 1999. The price fell steadily (except for one increase in March) for almost three quarters during 2000, falling to $3.23 per pound in September. Then it began a fairly rapid increase, reaching $4.00 per pound and holding there until the end of the year. In recent years, bismuth price has cycled between lows of around $3.00 per pound and highs of about $4.00 per pound (Mining Journal, 2000c); this remained true for the year 2000. A major underlying factor for the apparent $4.00 ceiling continued to be the large amount of bismuth normally available from China at lower prices (Mining Journal, 2000d). The long decline during most of the year was attributed to the resumption of supply from Mexico, and the rapid increase in the last quarter was attributed to a brief reduction of supplies from China (Ryans Notes, 2000).

Trade

Total bismuth imports increased significantly—15% by weight in 2000 (table 4). The large increase in the amount received from Mexico (86%) represents a return to normal; in 1999, bismuth production in Mexico was limited by pollution concerns.

Exports nearly doubled by weight and more than doubled by value in 2000 (table 3). The largest increases were to Germany, Mexico, and the United Kingdom.

World Review

World refinery production increased, easing concerns over supply and contributing to the downturn in prices (table 5). Production remained relatively low in Peru owing to continued use of high silver and gold concentrates in favor of high bismuth-bearing concentrates (Mining Journal, 2001).

On February 28, 2000, the Mexican environmental authority lifted restrictions on production by Industrias Peñoles, S.A., that had been affected to decrease lead pollution. This returned nearly 600 t of metal to the world bismuth market (Metal Bulletin, 2000).

Usually, bismuth is recovered as a byproduct of lead or tungsten production. The world's only significant potential source where bismuth could be the principal product is the Tasna Mine in Bolivia, which was closed in 1985 and is now for sale (Doorn, 2000). Corriente Resources Inc. of Vancouver and the state mining corporation Corporación Minera de Bolivia had planned to reopen the mine, but low prices delayed the startup. Possible byproducts or coproducts available from Tasna include copper, gold, and tungsten (Mining Journal, 1999).

Bismuth is to be a major coproduct from the new NICO Mine of Fortune Minerals, Ltd., in Northwest Territories, Canada. The deposit also contains cobalt, copper, and gold (Fortune Minerals, 2000).

In Bolivia, the newly private Vinto tin smelter was reopened by Allied Deals Corp. of the United Kingdom. In addition to tin, the smelter has a capacity of 30 tons per year (t/yr) of bismuth (Mining Journal, 2000b).

A new smelting unit at the Hunan Shizhuyuan Non-Ferrous Metal Mine, China's largest bismuth producer, was expected to increase bismuth production from 350 t/yr to more than 400 t/yr (American Metal Market, 2000). Almost 500 t, however, was produced by yearend (Metal Bulletin, 2001).

Current Research and Technology

The use of bismuth oxide additions in electronic ceramics increased, especially in Japan. The additions enhance the electronic properties of ferrites and ceramic capacitors (Roskill's Letter from Japan, 2001).

In applications such as thermal fuses and soldering, bismuth alloy wires as small as 1 millimeter in diameter are needed. A unique process is used to produce these wires. In traditional ingot casting or cold mold continuous casting, solid metal makes contact with the mold over a considerable area. The resulting friction between mold and wire causes the solidification structure normally expected: a structure that is very brittle bismuth in spite of its softness. By using a heated mold at just above the solidification temperature of the alloy, the wire is not solid until it begins to exit the mold. This can result in extremely ductile wires, which are very useful in the applications mentioned (Soda and others, 2000).

More than 100,000 t of steel have been successfully galvanized using a new galvanizing-alloy-containing bismuth. This alloy is the conventional zinc-nickel alloy used for reactive steels with the addition of 1.8% tin and 0.5% bismuth without special processing adjustments. The higher fluidity and wetability of the new galvanizing alloy results in lower consumption of zinc, better surface appearance, less dross, and less finishing required after galvanizing. A bonus is that the bath is maintained about 100° C lower than the conventional bath, resulting in a 2% reduction in energy consumption. Traditionally, lead additions have been used in many plants to produce similar results as well as to obtain a large grain size in the coating. The new procedure, however, yields as good or better results with a lead-free process (Beguin and others, 2000). A new zinc-bismuth alloy can replace the equivalent leaded alloy with good resulting properties. There is greater fluidity and better drainage of zinc (Gagné, 2000). This alloy, without nickel, is used for ordinary steels.

Yellow bismuth vanadate is a major component of a yellow pigment blend for hot-melt road markings and paints. The resulting markings have very good heat resistance, do not fade, and meet applicable transportation regulations for color and reflectance. Traditional paints for this purpose use lead and hexavalent chromium pigments. Both of these are toxic to plants and animals. The new blend is lead- and chrome-free and thus is free from environmental regulation (Gooding and Delaney, 2000).

Outlook

The long-range outlook for bismuth indicates that demand will probably grow, especially in new applications and as the development of nontoxic bismuth substitutes for lead continues. The use of bismuth in plumbing fixtures and shot for ammunition is still increasing in the United States and in Europe. A partial ban on lead has been announced in Denmark. In Japan and elsewhere, however, the increase in substitution for lead has been slow because the applicable environmental regulations are less stringent (Roskill's Letter from Japan, 1999).

Bismuth is usually a byproduct of lead; a significant near term increase in supply, therefore, is unlikely, especially because total world production of lead will remain relatively stable with a large and increasing fraction of lead demand satisfied by recycling. Nevertheless, a global shortage of bismuth is not anticipated. Despite any increase in world demand, Chinese supplies can be expected to help keep the bismuth market stable (Mining Journal, 2001).

It appears that low prices, due to the nearly constant availability of Chinese bismuth or to the general deflationary trend for metals during the past decade, are the limiting factor to bismuth supply (Carnak, 1999). Usually, more bismuth appears in the market whenever prices increase.

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

Country	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)
Bahamas, The	735	$8	5,400	$11
Belgium	742,000	5,790	832,000	6,870
Canada	108,000	827	120,000	829
China	556,000	4,080	426,000	3,290
Finland	--	--	1	3
Germany	1,490	64	56,600	475
Italy	400	19	--	--
Japan	3,260	165	6,830	347
Korea, Republic of	--	--	14	4
Mexico	277,000	1,880	516,000	3,940
Netherlands	19,500	202	409	10
Peru	6,810	60	20,400	155
Spain	200	2	420	5
Switzerland	86	3	--	--
United Kingdom	391,000	2,220	430,000	3,180
Total	2,110,000	15,300	2,410,000	19,100

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

Source: U.S. Census Bureau.

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

(Metric tons)

Country	Mine 1996	Mine 1997	Mine 1998	Mine 1999	Mine 2000 e/	Refinery 1996	Refinery 1997	Refinery 1998	Refinery 1999	Refinery 2000 e/
Belgium e/	--	--	--	--	--	800	800	700	700	700
Bolivia	348 r/	684 r/	941 r/	709 r/ e/	740	28	55	44	57 r/	60
Bulgaria e/	40	40	40	40	40	40	40	40	40	40
Canada 3/	150	196 r/	219	311	202	--	--	--	--	--
China e/	610	550	240	400	400	750	760	820	1,300	1,300
Italy e/	--	--	--	--	--	5	5	5	5	5
Japan 4/	169 e/	165 e/	144 e/	135 e/	155	562	550	479	481 r/	518
Kazakhstan e/	115	115	115	130	130	50	50	50	55	55
Mexico 5/	1,070	1,642	1,204	548 r/	1,000	957	990	1,030	412 r/	900
Peru	1,000 e/	1,000 e/	1,000 e/	1,000 e/	1,000	939	774	832 r/	705 r/	744
Romania e/	40	40	40	40	40	35	35	35	35	35
Russia e/	50	50	35	50	50	10	10	7	10	10
Serbia and Montenegro e/	5	5	5	2	2	(6/)	(6/)	(6/)	(6/)	(6/)
Tajikistan e/	5	5	5	5	5	--	--	--	--	--
United States	W	W	W	W	W	W	W	--	--	--
Total	3,600 r/	4,490 r/	3,990 r/	3,370 r/	3,760	4,180	4,070	4,040 r/	3,800 r/	4,370

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.
1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through May 11, 2001. 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/ Mine output figures have been estimated based on reported metal output figures.
5/ Refined metal includes Bi content of imported smelter products.
6/ Less than 500 kilograms. Production in kilograms: 1996--100 (estimated); 1997-2000--not available.