Background Report Reference

AP-42 Section Number: 12.15

Background Chapter: 2

Reference Number: 8

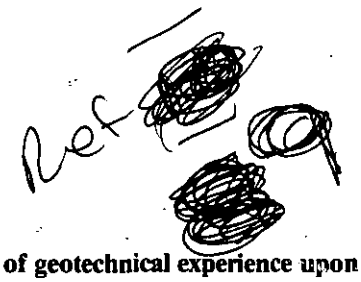
Title: Mineral Commodity Summaries, Lead

Woodbury, W.D.

US Dept. of Interior, Bureau of Mines

1992

LEAD



By William D. Woodbury

Mr. Woodbury is a physical scientist with the Branch of Nonferrous Metals. He had 25 years of geotechnical experience upon becoming the Bureau's lead specialist in 1982. Domestic survey data were prepared by P. Wiser and S. Hays, Nonferrous Data Section. International data tables were prepared by C. Jacarepaqua and A. Wilkes, International Data Section.

The year 1989 will be remembered within the lead industry, worldwide, as one of many records and accomplishments in several sectors. Most significantly, it was very profitable as the world price was sustained at high levels throughout the year, averaging the highest since 1981, and the fourth highest ever. Spot shortages of premium grades developed, and at yearend reported total metal stocks held by world producers, consumers, merchants, and the London Metal Exchange (LME) represented only about 3 weeks of demand.

In the United States, production at secondary lead smelter-refineries and consumption of lead for storage batteries established record highs. Recovery from old scrap also set a new record. Total primary refinery production was about the same as that in 1988. However, the Nation's oldest and largest lead smelter-refinery established record

TABLE 1

SALIENT LEAD STATISTICS

(Metric tons unless otherwise specified)

	1985	1986	1987	1988	19
United States:					
Production:					
Domestic ores, recoverable lead content	413,955	339,793	311,381	384,983	410
Value thousands	$174,008	$165,150	$246,720	$315,222	$356
Primary lead (refined):					
From domestic ores and base bullion	422,650	348,217	336,471	371,348	379,034
From foreign ores and base bullion	71,353	22,071	37,139	20,739	17,421
Secondary lead (lead content)	615,695	624,769	710,067	r736,401	808,589
Exports (lead content):					
Lead ore and concentrates	9,987	4,380	8,764	20,902	[1]57,038
Lead materials, excluding scrap	37,322	19,778	13,586	29,077	[1]43,837
Imports for consumption:					
Lead in ore and concentrates	2,649	4,604	873	20,606	[1]5,122
Lead in base bullion	760	142	10,827	4,046	[1]5,782
Lead in pigs, bars, reclaimed scrap	134,521	143,511	192,260	155,893	[1]116,358
Stocks, Dec. 31:					
Primary lead[2]	84,502	20,400	21,608	15,398	15,623
At consumers and secondary smelters	93,130	83,824	88,586	r89,865	82,741
Consumption of metal, primary and secondary	1,148,298	1,125,521	1,230,373	r1,245,170	1,283,234
Price: Metals Week average, delivered, cents per pound	$19.07	$22.05	$35.94	$37.14	$39.35
World:					
Production:					
Mine thousand metric tons	r3,431.2	r3,334.9	3,428.8	p3,414.4	e3,394.9
Refinery[3] do.	r3,356.7	r3,192.6	3,204.2	p3,239.5	e3,253.8
Secondary refinery do.	r2,283.8	r2,359.3	2,517.6	p2,615.7	e2,648.9
Price: London Metal Exchange, pure lead, cash average, cents per pound	$17.84	$18.43	$26.99	$29.73	$30.63

e Estimated. p Preliminary. r Revised.

[1] Because of the implementation of the Harmonized Tariff System in Jan. 1989, import and export categories for 1989 are not necessarily comparable with those in previous years.

[2] American Bureau of Metal Statistics Inc.

[3] Primary metal production only. Includes secondary metal production where inseparably included in country total.

U.S Dept. of the Interior
Bureau of Mines, 89

production and output-per-worker levels, while simultaneously setting record-low injury rate and air pollutant emissions levels. Domestic mine production increased significantly, primarily because of a large mine coming on-stream in Alaska. As a result, the United States became a significant net exporter of lead concentrates for the first time, virtually all to Canada.

World mine production decreased marginally from that of 1988, and on a recoverable basis was 54% of demand. World secondary refinery production reached a record 2.65 million metric tons, and world demand increased for the seventh consecutive year, setting a record for the third consecutive year.

LEGISLATION AND GOVERNMENT PROGRAMS

In a major ruling by the Environmental Protection Agency (EPA) in September, in response to a court-ordered deadline, primary lead smelter slags were one of five mineral processing wastestreams conditionally retained in the Bevill exclusion from Federally regulated hazardous materials rules under the Resource Conservation and Recovery Act (RCRA), part B, as amended. This ruling was expected to be retained when final rules are promulgated, by court-ordered agreement, in January 1991. However, process wastewater was not retained in the exemption. The latter is only a fraction in volume of the former, however, and can be recycled effectively with best available technologies (BAT) at a cost estimated by EPA to be 0.1% to 0.2% of the 1988 value of refined metal shipments.

In a related matter, the EPA proposed in December that lead-acid batteries be prohibited from processing at Municipal Waste Combustors (MWC's) as part of an overall requirement that 25% of all recyclable materials entering the systems be salvaged. The regulation will be finalized in 12 months under MWC regulations.

At the state level, an historic occurrence with significant impact was the passage in Missouri of a new law, which, for the first time, regulates mine tailings. The industry-backed rules established a permit and fee system for lead, zinc, and iron ore tailings, set forth reclamation standards for closure, and established a trust fund administered by the State for reclaiming the tails when currently active mines permanently close. The new law is known as the Metallic Minerals Waste Management Act of 1989. In Colorado, ASARCO Inc. reached an agreement with the State and EPA on a remediation program for a portion of the Leadville Superfund site.

STRATEGIC CONSIDERATIONS

Because of its pervasive worldwide use in the transportation, communications, and electronics industries, primarily for electric power storage, lead is a strategic and critical commodity. The National Defense Stockpile holds 525,000 metric tons of lead against a goal of 998,000 tons.

Except for mines in Missouri, Morocco, and the Republic of South Africa, primary supply of lead is closely interrelated, as a result of geologic occurrence, with zinc and silver. All of these metals are recovered from the same ore in most producing countries. A strategic consideration with potentially wide-ranging impact on domestic supply resulting from these coproduct-byproduct relationships arose in 1989. This was a result of emerging and innovative environmental control strategies that are discussed later. One aspect of the pollution prevention concept, known as source reduction, could entail severe reduced allowances for the use of virgin, i.e. primary, materials in the manufacture of potentially harmful or hazardous products. In the worst-case scenario, elimination of certain products from the market place could be considered.

Implemention of such a strategy on virgin lead use in the United States could impact the domestic supply of several other metals. An analysis of domestic mine production in 1988, before a large new base and precious metal mine opened in Alaska, indicates that 23% of U.S. total zinc mine production came from a coproduct relationship with lead. These same mines also produced 100% of the bismuth, 7% of the silver, and 23% of the cadmium. Because cadmium reports with the zinc concentrates, the balance came from zinc mines in which lead is strictly a byproduct outside of Alaska. The zinc mines also were a small and only domestic source of germanium. Estimates for 1990, when the huge Red Dog zinc-lead-silver mine in Alaska is in production, are that the lead-zinc-silver coproduct relationship will supply 97% of the lead, 55% of the zinc and cadmium, and 30% of the silver. Also, as byproducts, these same mines are expected to supply all of the bismuth and indium, and about 80% of the germanium mined in the United States.

ISSUES

Because lead, its oxides, and some other lead compounds are highly toxic, especially to infants and children, whether inhaled or ingested, lead was selected during the year by the EPA for a comprehensive, highly publicized, study effort throughout the whole agency. This effort, known as The Lead Pollution Prevention Program (P4), was scheduled for completion in 1992, and involves almost all program offices in the EPA. The objective is to develop a comprehensive, cross-media (air-land-water) policy to minimize or eliminate human exposure to lead or its compounds where epidemiological evidence warrants. The new lead policy is to be framed in the context of pollution prevention rather than waste minimization, but still could utilize improved command-and-control techniques to achieve parts of the objective, including more timely, predictable, and realistic enforcement practices. The new lead policy, when finally determined, could serve as a model for tackling other major health risk problem areas as the Nation moves toward a uniform environmental code during the rest of this century. It is intended by EPA that the lead producing and consuming industries, as well as environmental and health organizations, be solicited for input and kept continuously apprised of developments during the information gathering, study, and policy framing periods. The Bureau of Mines was expected to be intimately involved with both the industrial sectors and EPA during development of the P4 program.

PRODUCTION

Mine Production

The increase in domestic mine output was exclusively from Missouri, Idaho, and a large new silver-zinc mine in Alaska. The reopening of The Doe Run Co.'s Brushy Creek Mine, closed since 1985, supplemented declining production elsewhere in Missouri. The Greens Creek Mine on Admiralty Island, AK, a joint venture of RTZ Corp. PLC (53%), Hecla Mining Co. (28%), CSX Corp. (12.6%), and Exalas Resources Inc. (6.3%), opened in February. Cominco Alaska Inc.'s planned November opening for the Red Dog Mine in the region of Kotzebue, AK, was delayed because of technical problems in the mill startup. Nine operating mines in Missouri, including Brushy Creek, plus six other mines shown on table 4, produced all but about 2,400 tons of the domestic recoverable mine output. The nine mines in Missouri accounted for 89% of the year's total. On the basis of lead in concentrates, the industry performed at only 62% of capacity (table 15) because of decreasing primary demand.

The Doe Run Co. of St. Louis, MO, the Nation's largest lead producer, operated three mine and mill divisions in Southeastern Missouri: Buick, Fletcher, and Viburnum. To take advantage of continuing high copper and zinc prices, Doe Run increased the total ore milled by 6% to 4.3 million tons, according to the annual report to stockholders of The Homestake Mining Corp., a 42.5% owner of Doe Run. This resulted in production levels of 228,000 tons of lead in concentrates, 49,000 tons of zinc concentrate, and 70,000 tons of copper concentrate. Average metal grades of the ore hoisted by Doe Run in 1989 were 5.6% lead, 0.9% zinc, and 0.6% copper. Total reserves at yearend were reported by Homestake to be 66.3 million tons, graded at 5.0% lead, 0.9% zinc, and 0.3% copper.

Asarco operated two mine and mill complexes in Southeastern Missouri, which together increased the ore milled by 40% compared with that of 1988, according to the company's annual report to stockholders. Contained lead increased by 20,700 tons, but declined by 2,000 tons at the Leadville, CO, mine operated by Asarco on a 50% equity share basis. At yearend, Asarco had the captive domestic capacity to supply all the lead concentrates required by its Glover, MO, smelter, and about one-half of the company's overall requirements. In 1984, the company's mines supplied only 5% of the company's needs, according to Asarco.

The Magmont Mine at Bixby, MO, a joint venture of Dresser Industries Inc. and Cominco American Inc., the operator, was the Nation's third largest producing lead mine in 1989. However, because of dwindling reserves and lowered average ore grades, production declined nearly 10% from 1988 to 63,000 tons of contained lead in concentrates. According to Cominco Ltd.'s annual report to stockholders, the average concentrate grade actually increased from 77.5% to 77.9%. During the year, emphasis was on mining in the area of the large 1986 groundfall, and pillar extraction exceeded that in other areas of the mine. Surface drilling yielded no additional reserves, and planning for shutdown within the next 2 or 3 years was begun. The average grade of lead ore hoisted was 6.8% compared with 7.2% in 1988, although zinc and copper grades remained at 1.0% and 0.3%, respectively.

At Cominco Alaska Inc.'s Red Dog Mine in Alaska, final assembly of the mill modules, trial runs, and commissioning of the equipment continued through December for official startup in early 1990. Construction of the port and storage facilities 52 miles away was also essentially completed. At yearend, Cominco had spent $317 million on the mine and mill complex and $170 million on the road and port facilities. The latter were financed by the State of Alaska through the Alaska Industrial Development and Export Authority. In addition, Cominco will pay an annual

TABLE 2

MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY STATE

(Metric tons)

State	1985	1986	1987	1988	1989
Alaska	—	—	—	—	W
Arizona	581	W	—	W	W
Colorado	W	W	W	W	W
Idaho	33,707	9,951	W	W	W
Illinois	W	W	W	W	W
Missouri	371,008	319,900	W	353,194	366,931
Montana	846	W	W	8,266	W
Nevada	(1)	—	—	W	—
New Mexico	W	10	W	W	W
New York	W	W	W	W	W
South Dakota	—	—	—	—	4
Tennessee	W	—	W	W	W
Total	413,955	339,793	311,381	384,983	410,915

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Less than 1/2 unit.

TABLE 3

MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY MONTH

(Metric tons)

Month	1988	1989
January	27,771	33,553
February	28,231	31,323
March	36,080	34,840
April	32,720	33,996
May	30,346	34,885
June	32,540	36,401
July	30,424	33,509
August	36,340	38,992
September	33,157	34,601
October	34,446	35,379
November	31,098	33,116
December	31,830	30,320
Total	384,983	410,915

TABLE 4

TWENTY-FIVE LEADING LEAD-PRODUCING MINES IN THE UNITED STATES IN 1989, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of lead
1	Buick	Iron, MO	The Doe Run Co.	Lead-zinc ore.
2	Fletcher	Reynolds, MO	do.	Do.
3	Magmont	Iron, MO	Cominco American Inc.	Do.
4	West Fork	Reynolds, MO	ASARCO Incorporated	Do.
5	Sweetwater	do.	do.	Do.
6	Viburnum No. 29	Washington, MO	The Doe Run Co.	Do.
7	Casteel[1]	Iron, MO	do.	Copper-lead ore.
8	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Lead-zinc ore.
9	Viburnum No. 28	Iron, MO	The Doe Run Co.	Copper-lead ore.
10	Greens Creek	Admiralty Island, AK	Greens Creek Mining Co.	Zinc ore.
11	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Do.
12	Leadville Unit	Lake, CO	ASARCO Incorporated	Lead-zinc ore.
13	Sunnyside	San Juan, CO	Washington Mining Co.	Do.
14	Bunker Hill	Shoshone, ID	Bunker Hill Mining Co. (U.S.) Inc.	Zinc ore.
15	Sunshine	do.	Sunshine Mining Co.	Silver ore.
16	Balmat	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
17	Butte Hill	Silver Bow, MT	New Butte Mining Co. Inc.	Lead-zinc ore.
18	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co.	Fluorspar.
19	Great Eastern	Park, CO	J. T. Lamping	Lead ore.
20	Coeur	Shoshone, ID	ASARCO Incorporated	Silver ore.
21	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
22	Camp Bird	Ouray, CO	Royal Camp Bird Inc.	Gold ore.
23	Mission	Pima, AZ	ASARCO Incorporated	Copper ore.
24	Gold King	San Juan, CO	Gold King Consolidated Inc.	Lead-zinc ore.
25	Center	Grant, NM	Mount Royal Mining & Exploration	Gold ore.

[1]Includes Brushy Creek Mill.

toll fee to the State, as well as maintenance costs.

Primary Smelter-Refinery Production

According to Homestake's annual report, the Doe Run smelter-refinery at Herculaneum, MO, produced a record 216,758 tons of refined lead as a result of improved institutional and processing control systems, yielding a record high of 1.82 tons per manshift. This was accomplished simultaneously with setting a new safety performance record of a ratio of 1.1 lost-time injuries per 200,000 manhours, compared with a national average of 7.9, according to the National Bureau of Labor Statistics. The facility, which includes a strip lead manufacturing plant, also achieved the lowest average employee blood levels ever recorded at the site, and for the first time achieved 1.1 micrograms (μg) of particulate lead emissions per cubic meter of air against the National Ambient Air Quality Standard (NAAQS) of 1.5 μg per cubic meter on an annual basis.

According to the Asarco annual report, the company produced 172,600 tons of refined lead in 1989, slightly less than in 1988 and 1987. Nearly two-thirds of the total was produced at the Glover, MO, smelter-refinery, and the balance at the Omaha, N. ery, which received bullion f East Helena, MT, smelter. The Omaha plant also produced lead from purchased old and new scrap in 1989. Construction of a completely enclosed unloading, handling, and ore storage facility to mitigate environmental problems continued throughout the year at East Helena.

Secondary Smelter-Refinery Production

Domestic secondary production increased appreciably for the fourth consecutive year, achieving the highest level ever, as the industry performed at 87% of capacity, the same rate as in 1988. In spite of two closures during the year, there was a net increase in capacity of 80,000 tons from yearend 1988, a net result of one large new plant coming on-stream late in the year, several expansions, and two downgradings. Total annual secondary rated capacity for refined lead and lead alloys at yearend was estimated by the Bureau of Mines to be 930,000 tons, representing 42 companies and 50 plants, with individual capacities ranging from less than 1,000 tons per year to 120,000 tons per year. The 10 largest operated 18 plants, representing 89% of the total capacity and accounting for 86% of the production. Twenty-three small producers, including Asarco, with annual capacities averaging 1,000 tons, produced mainly specialty alloys for such uses as solders, brass or bronze ingots, and bearing metals. The most significant event of the year relative to plants was the opening of the first large new secondary smelter-refinery since 1981, that of Exide Corp. at Muncie, IN, on the site of the former Bergsoe-Boliden plant, which closed in 1983. This was a major accomplishment in light of present day environmental requirements.

During the year, Doe Run entered the secondary market by purchasing scrap batteries and tolling them elsewhere. Except for the necessary RCRA part B permit to store hazardous materials, Doe Run acquired all the necessary environmental permits for building and operating a proposed Tonolli-Engitec CX "clean technology" plant at its Buick smelter in Boss, MO. However, it expected to move forward with the project in 1990. RSR Corp. also did not break ground on any of its three proposed new

TABLE 5

REFINED LEAD PRODUCED AT PRIMARY REFINERIES IN THE UNITED STATES, BY SOURCE MATERIAL[1]

(Metric tons unless otherwise specified)

Source material	1985	1986	1987	1988	1989
Refined lead:					
From primary sources:					
Domestic ores and base bullion	422,650	348,217	336,471	371,348	379,034
Foreign ores and base bullion	71,353	22,071	37,139	20,739	17,421
Total	494,003	370,288	373,610	392,087	396,455
Calculated value of primary refined lead[2] thousands	$207,689	$180,004	$296,026	$321,039	$343,932

[1] Total refined lead: American Bureau of Metal Statistics Inc.; domestic and foreign ores: Bureau of Mines calculations.
[2] Value based on average quoted price.

TABLE 6

STOCKS AND CONSUMPTION OF NEW AND OLD LEAD SCRAP IN THE UNITED STATES, BY TYPE OF SCRAP

(Metric tons, gross weight)

Type of scrap	Stocks, Jan. 1	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
1988						
Smelters, refiners, others:						
Soft lead[1]	1,855	28,548	—	28,721	28,721	1,682
Hard lead	567	5,717	—	6,093	6,093	191
Cable lead	854	3,699	—	3,668	3,668	885
Battery-lead plates	28,584	812,343	—	819,470	819,470	21,457
Mixed common babbitt	95	1,853	—	1,833	1,833	115
Solder and tinny lead	1,776	20,861	—	20,425	20,425	2,212
Type metals	172	1,808	—	1,877	1,877	103
Drosses and residues	5,232	59,372	60,559	—	60,559	4,045
Total	39,135	934,201	r60,559	r882,087	942,646	30,690
1989						
Smelters, refiners, others:						
Soft lead[1]	1,682	31,260	—	31,914	31,914	1,028
Hard lead	191	8,585	—	8,585	8,585	191
Cable lead	885	9,517	—	9,381	9,381	1,021
Battery-lead plates	21,457	923,777	—	922,651	922,651	22,583
Mixed common babbitt	115	2,071	—	1,990	1,990	196
Solder and tinny lead	2,212	19,680	—	20,057	20,057	1,835
Type metals	103	1,728	—	1,725	1,725	106
Drosses and residues	4,045	66,314	67,934	—	67,934	2,425
Total	30,690	1,062,932	67,934	996,303	1,064,237	29,385

r Revised.
[1] Includes remelt lead from cable sheathing plus other soft lead scrap processing.

"clean technology" plants announced in November 1988, but preliminary design and expansion details for the Indianapolis, IN, facility were completed by a consulting engineering firm.

In litigation actions, EPA officially declared the Nesquehoning, PA, plant site of Tonolli Corp., closed since 1985, a priority superfund site, and listed many U.S. battery manufacturers as potentially responsible parties (PRP's) liable for cleanup costs. In November, the Department of Labor proposed fines exceeding $2 million for Interstate Lead Co. of Leeds, AL, for "blatant" blood lead and air level violations. If upheld, it would be the eighth stiffest Occupational Safety and Health Administration (OSHA) fine in history. The company was appealing at yearend.

CONSUMPTION

Domestic consumption of lead was the highest since 1979 as lead-acid storage battery manufacturers used more than 1 million tons for the first time. Automotive starting-lighting-ignition (SLI) battery shipments, including exports, exceeded 80 million units for the second consecutive year. The industrial-traction and specialty battery sectors also recorded significant gains. However, lead oxides used for glass, paint, ceramics, and other chemicals, which had been the second largest use for lead on a metal equivalent basis, declined for the fifth consecutive year. This was more than offset by a significant increase in lead use for bullets and shot, the latter including use at nuclear plants. Use of sheet lead in construction and cable lead sheathing in communications also increased, the latter by 40% compared with that of 1988.

Demand for lead in industrial and traction batteries, which includes uninterruptible power supply (UPS) designed to ensure constant voltage for large computer systems at hospitals, banks, communications networks, etc., and standby power supply (SBS) for emergency lighting and some telephone systems, was estimated by the Bureau of Mines to be 174,000 tons. This was an increase of 12% over that of 1988, and represents a record high. About one-third of that was for traction batteries, i.e., electric vehicles, including in-plant fork lifts and underground mine equipment. The UPS

TABLE 7

SECONDARY METAL RECOVERED[1] FROM LEAD AND TIN SCRAP IN THE UNITED STATES

(Metric tons)

	Lead	Tin	Antimony	Other	Total
1988					
Refined pig lead[2]	367,055	—	—	—	367,055
Refined pig tin[3]	—	r545	—	—	r545
Lead and tin alloys:					
Antimonial lead	331,341	902	13,866	736	346,845
Lead-base babbitt	1,439	112	162	(4)	1,713
Solder	19,487	3,619	141	(4)	23,247
Type metal	973	70	139	(4)	1,182
Other alloys, including cable lead	1,852	29	24	—	1,905
Total	355,092	4,732	14,332	736	374,892
Tin content of chemical products	—	W	—	—	W
Grand total	722,147	r5,277	14,332	736	r742,492
1989					
Refined pig lead[2]	411,976	—	—	—	411,976
Refined pig tin[3]	—	563	—	—	563
Lead and tin alloys:					
Antimonial lead	360,570	952	13,657	725	375,904
Lead-base babbitt	1,523	116	178	(4)	1,817
Solder	16,732	3,225	128	(4)	20,085
Type metals	936	46	137	(4)	1,119
Other alloys, including cable lead	2,141	30	9	—	2,180
Total	381,902	4,369	14,109	725	401,105
Tin content of chemical products	—	W	—	—	W
Grand total	793,878	4,932	14,109	725	813,644

r Revised. W Withheld to avoid disclosing company proprietary data.
[1] Most of the figures herein represent actual reported recovery of metal from scrap.
[2] Includes remelt lead.
[3] Includes remelt tin.
[4] Included with "Antimony" to avoid disclosing company proprietary data.

market was expected to continue to increase as it is applied to smaller networked computer systems. There was also about 35,000 tons of lead used in 1989 for specialty batteries for aircraft and military applications.

STOCKS

Metal stocks at domestic primary refineries at yearend were essentially the same as a year ago, but those held by consumers declined nearly 10%. Therefore, total domestic metal stocks were at the lowest level since 1968, and reflected the worldwide tight supply-demand situation as depicted in table 17. This worldwide sensitive balance kept the world price relatively high throughout the year, which essentially has been the case since May of 1987. Stocks of lead and antimonial lead metal in the market economy countries (MEC's) reporting to the International Lead and Zinc Study Group (ILZSG), including those on the LME, were approximately 378,000 tons at yearend, only about 6% of total world demand, and 60,000 tons lower than at yearend 1988.[1] Stocks in LME warehouses declined nearly 40,000 tons to only 23,000 tons at yearend. The centrally planned economy countries (CPE's) do not report lead stock levels.

PRICES

The North American producers' price quotations, including major secondaries, which were listed in a range of 42 to 42.5 cents per pound in early December 1988, dropped to 40 cents in early January 1989, and continued to drop through April, according to Metals Week. From a low of 35 cents per pound, which held from March 2 through April 27, quotes rose steadily through August before settling in a range of 42 to 44 cents from August 31 through October 31. The range broadened to 41 to 44 cents on November 1, before dropping to 38 to 40 cents during December. Monthly average cash prices on the LME paralleled the movement in the United States through April, but dropped more slowly, which

TABLE 8

LEAD RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons)

	1988r	1989
KIND OF SCRAP		
New scrap:		
Lead-base	42,013	47,129
Copper-base	3,256	e3,600
Tin-base	5	3
Total	45,274	50,732
Old scrap:		
Battery-lead plates	623,033	678,702
All other lead-base	56,989	67,755
Copper-base	11,105	e11,400
Tin-base	—	—
Total	691,127	757,857
Grand total	736,401	808,589
FORM OF RECOVERY		
As soft lead	367,055	411,976
In antimonial lead	331,341	360,570
In other lead alloys	23,639	21,040
In copper-base alloys	14,361	e15,000
In tin-base alloys	5	3
Total	736,401	808,589
Value[1] thousands	$602,962	$701,465

e Estimated. r Revised.
[1] Value based on average quoted price of common lead.

TABLE 9

U.S. CONSUMPTION OF LEAD, BY PRODUCT

(Metric tons)

SIC code	Product	1988	1989
	Metal products:		
3482	Ammunition: Shot and bullets	52,708	62,940
	Bearing metals:		
35	Machinery except electrical	425	W
36	Electrical and electronic equipment	(1)	W
371	Motor vehicles and equipment	5,152	1,683
37	Other transportation equipment	457	W
	Total bearing metals	6,034	2,586
3351	Brass and bronze: Billets and ingots	9,994	9,610
36	Cable covering: Power and communication	16,170	22,605
15	Calking lead: Building construction	1,618	1,831
	Casting metals:		
36	Electrical machinery and equipment	r1,333	524
371	Motor vehicles and equipment	(1)	W
37	Other transportation equipment	13,474	3,395
3443	Nuclear radiation shielding	1,065	W
	Total casting metals	r15,872	16,175
	Pipes, traps, other extruded products:		
15	Building construction	11,193	8,856
3443	Storage tanks, process vessels, etc.	(2)	962
	Total pipes, traps, other extruded products	11,193	9,818
	Sheet lead:		
15	Building construction	14,009	15,900
3443	Storage tanks, process vessels, etc.	(2)	(2)
3693	Medical radiation shielding	3,449	5,087
	Total sheet lead	17,458	20,987
	Solder:		
15	Building construction	3,985	3,909
341	Metal cans and shipping containers	848	762
367	Electronic components and accessories	4,824	4,092
36	Other electrical machinery and equipment	3,052	2,029
371	Motor vehicles and equipment	6,355	6,217
	Total solder	19,064	17,009
	Storage batteries:		
3691	Storage battery grids, post, etc.	r514,694	552,308
3691	Storage battery oxides	r454,964	459,847
	Total storage batteries	r969,658	1,012,155
371	Terne metal: Motor vehicles and equipment	2,324	2,286
27	Type metal: Printing and allied industries	(3)	(3)
34	Other metal products[4]	5,290	4,564
	Total metal products	r1,127,383	1,182,566
	Other oxides:		
285	Paint	W	W
32	Glass and ceramics products	W	W
28	Other pigments and chemicals	W	10,074
	Total other oxides	62,524	57,984
2911	Gasoline additives	(5)	(5)
	Miscellaneous uses	55,263	42,684
	Grand total	r1,245,170	1,283,234

r Revised. W Withheld to avoid disclosing company proprietary data; included in appropriate totals.
[1] Included with "Other transportation equipment" to avoid disclosing company proprietary data.
[2] Included with "Building construction" to avoid disclosing company proprietary data.
[3] Included with "Other metal products" to avoid disclosing company proprietary data.
[4] Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, and fishing weights.
[5] Included with "Miscellaneous uses" to avoid disclosing company proprietary data.

caused the spread with the U.S. average to decrease from 9.6 cents per pound in January to 7.2 cents in May. The price and spread then rose slowly through October to the year's high of 34 cents per pound, the spread again reaching 9.6 cents. The LME price then took a sharp dip in November, as it did in the United States, but more so, resulting in the high spread of the year of 9.9 cents per pound. However, in December the LME rose slightly, which reflected Asian and European spot shortages of premium metal, and the spread with the average U.S. price reached the lowest of the year, 6.7 cents per pound.

The North American producer price is a delivered price in the United States. Normally, a North American producer price of 5 cents per pound above the LME to cover the tariff, insurance, ocean freight, and delivery would stimulate importation. However, the worldwide tight supply-demand balance (table 17) and occasional spot shortages of premium metal (99.99% plus), resulted in the lowest net metal domestic imports since 1982, a recession year. The average U.S and LME prices were the highest since 1980, when they were 42.5 and 41.2 cents per pound, respectively. The United States was a net pig metal exporter of 75,000 tons in that year.

TABLE 10

U.S. CONSUMPTION OF LEAD, BY MONTH[1]

(Metric tons)

Month	1988r	1989
January	98,725	111,493
February	99,320	104,013
March	107,655	106,962
April	102,222	104,901
May	106,821	108,154
June	106,492	107,353
July	95,051	98,856
August	105,332	111,328
September	105,881	107,532
October	113,441	114,945
November	106,254	108,339
December	97,976	99,358
Total[2]	1,245,170	1,283,234

r Revised.
[1] Monthly totals include monthly reported consumption plus the prorated monthly distribution for companies that report on an annual basis only.
[2] Includes lead that went directly from scrap to fabricated products.

TABLE 11

U.S. CONSUMPTION OF LEAD IN 1989, BY STATE[1]

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	50,326	39,330	10,383	—	100,039
Florida	5,516	7,225	1,126	—	13,867
Georgia	31,798	5,858	—	—	37,656
Illinois	30,063	45,589	2,072	1,005	78,729
Kansas	20,530	16,105	11,829	—	48,464
Louisiana	6,750	3,508	1,574	—	11,832
Maryland	143	—	—	—	143
Michigan	16,415	11,046	267	—	27,728
Missouri	11,321	16,834	—	—	28,155
New York	15,892	5,048	13,428	—	34,368
Ohio	23,295	15,667	2,937	257	42,156
Pennsylvania	84,814	33,810	30,543	1,709	150,876
Tennessee	6,111	9,317	2,885	—	18,313
Texas	89,337	17,111	4,527	—	110,975
Alabama and Mississippi	18,767	—	—	2,222	20,989
Arizona and Colorado	256	176	58	—	490
Arkansas and Oklahoma	3,970	11,204	247	—	15,421
Delaware and New Jersey	44,856	7,036	3,159	248	55,299
Indiana and Kentucky	230,777	41,406	14,595	599	287,377
North Carolina and South Carolina	43,142	27,201	9,000	—	79,343
Connecticut, Massachusetts, Rhode Island	4,953	3,202	48	32	8,235
District of Columbia, Virginia, West Virginia	58	493	2,167	—	2,718
Idaho, Oregon, Washington	15,151	8,177	1,519	—	24,847
Maine, New Hampshire, Vermont	7,754	6,081	—	21	13,856
Iowa, Minnesota, Nebraska, Wisconsin	23,956	28,683	17,939	780	71,358
Total	785,951	360,107	130,303	6,873	1,283,234

[1] Includes lead that went directly from scrap to fabricated products.

TABLE 12

U.S. CONSUMPTION OF LEAD IN 1989, BY CLASS OF PRODUCT[1]

(Metric tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	67,637	71,161	24,740	6,873	170,411
Storage batteries	623,156	287,140	101,859	—	1,012,155
Other oxides	57,984	—	—	—	57,984
Gasoline additives	W	—	—	—	W
Miscellaneous	37,174	1,806	3,704	—	42,684
Total	785,951	360,107	130,303	6,873	1,283,234

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1] Includes lead that went directly from scrap to fabricated products.

The domestic prices for lead oxides were based on the selling price plus conversion charges for pig lead in a given period. Premium adjustments were also made by individual producers to reflect differences in manufacturing techniques, freight considerations, quality, and packaging requirements or other factors. According to American Metal Market, the quoted premiums for litharge ranged from 2 cents to 10 cents per pound in 1989, averaging about 6 cents for bags or drums in truckload lots, and 8 to 15 cents, averaging about 11 cents per pound, for 97% red lead. The premiums for leady litharge ("Bulk Battery") ranged from 1 cent to 4 cents per pound, and averaged about 2 cents.

WORLD REVIEW

According to the ILZSG statistics, consumption of soft lead and antimonial lead in the MEC's was a record 4.43 million tons in 1989, exceeding the previous high set in 1988 by about 70,000 tons.[2] Estimated world consumption of lead in all forms during 1989 increased for the seventh consecutive year to just under 6 million tons, and exceeded the 1988 previous record by more than 100,000 tons (table 17). The world demand growth since 1982 has averaged just over 2% per year, primarily because of steadily increasing SLI, UPS, SBS, traction, and load levelling battery systems. Estimated world total refinery production in 1989, including that from recycled scrap, increased only slightly from that of 1988. The production deficit shown in table 17 resulted in a continuing drawdown of world stocks, occasional spot shortages of premium metal, and sustained high prices worldwide. At yearend, supply and demand continued in delicate balance because of technical problems at smelters in Canada and Italy, mine production problems in Australia, and labor, political unrest, and sabotage in Peru.

Five new lead-producing mines came on-stream in 1989, and two small silver mines with byproduct lead were known to have closed during the year. As a result, there was 150,000 more tons of capacity operating at yearend than yearend 1988. This was the largest year-to-year increase in many years, accord-

TABLE 13

STOCKS OF LEAD AT CONSUMERS AND SECONDARY SMELTERS IN THE UNITED STATES, DECEMBER 31

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1985	50,475	36,374	5,770	511	93,130
1986	47,589	30,442	5,524	269	83,824
1987	55,278	27,959	5,185	164	88,586
1988	50,850	r34,108	4,756	151	r89,865
1989	48,836	29,068	4,598	239	82,741

r Revised.

TABLE 14

AVERAGE MONTHLY AND ANNUAL QUOTED PRICES OF LEAD[1]

(Cents per pound)

Month	1988		1989	
	North American producer price	London Metal Exchange	North American producer price	London Metal Exchange
January	38.00	30.21	40.17	30.62
February	34.85	29.71	37.01	28.17
March	34.00	29.39	35.07	26.69
April	34.00	29.41	35.02	27.55
May	34.57	30.27	36.34	29.15
June	36.30	30.68	39.15	30.16
July	36.50	28.06	40.29	31.32
August	36.52	27.25	41.75	31.81
September	38.41	27.63	43.63	33.00
October	39.15	29.68	43.63	34.07
November	41.38	31.33	41.26	31.39
December	42.02	33.12	38.89	32.22
Average	37.14	29.73	39.35	30.63

[1] Metals Week. Quotations for the United States on a nationwide, delivered basis. LME cash average.

ing to ILZSG, including reopenings and expansions. The largest of the new mines opened in 1989 were the Greens Creek silver-zinc mine in Alaska (12,000 tons of lead capacity) and the Hilton Mine in Australia (20,000 tons) which was integrated into the Mount Isa project in Queensland. The largest reopening was Doe Run's Brushy Creek Mine in Missouri, and the largest expansion (additional 38,000 tons) was at the Hellyer Mine on Tasmania. There were no permanent primary smelter-refinery closings in 1989. In Europe, a small rotary furnace was added to the Gailitz plant in Austria, and in Italy, Nuova Samim expanded its refinery at San Gavino by 20,000 tons. In Canada, Cominco Ltd. brought its new, larger, replacement QSL smelter on-stream.

Australia

The increase in mine production during 1989 was almost completely attributable to the new Hilton Mine coming on-stream, the Hellyer expansion project of Aberfoyle Ltd., and a full year's production from the Cadjebut open pit in Western Australia owned by BHP Minerals (58%) and Billiton Australia (42%). An expansion of the Cadjebut Mine, from 7,500 tons per year to 16,000 tons per year for lead, and from 41,000 tons per year to 65,000 tons per year for zinc, was started late in the year. Increased production from Hellyer began in March and, when at capacity, was expected to produce a million tons of ore yielding 50,000 tons of lead and 110,000 tons of zinc per year. Reserves are 16.2 million tons grading 13.0% zinc and 6.8% lead, according to Aberfoyle.

Production from the integrated Mount Isa and Hilton operations of MIM Holdings Ltd. (MIM) will raise annual output from 180,000 to 200,000 tons of lead, and from 200,000 tons to 250,000 tons of zinc. The Hilton region 20 kilometers north of Mount Isa, Queensland, is envisaged as MIM's long-term source of lead-zinc-silver, gradually replacing the mine at Mount Isa. A resource of 100 million tons was indicated, including 49 million tons of proven and probable reserves, with grades similar to the Mount Isa Mine. Deposits of similar magnitude have been discovered nearby at North Hilton, making it one of the world's largest lead-zinc-silver regions.

Also in Queensland, a decision was announced early in 1989 to proceed with development of the Thalanga zinc-lead-copper-silver-gold deposit. The project is a joint venture between the operating company, Pancontinental Mining Ltd. (50%), Outokumpu Australia Pty. Ltd. (25%), and Agip Australia Pty. Ltd. (25%). The latter's share was secured from Outokumpu during a reorgan-ization of the partnership. Reserves total 5.2 million tons grading 10.2% zinc, 3.1% lead, and 2.4% copper. At full production in 1991, when an underground decline is scheduled to replace the open pit, output is expected to reach 48,000 tons per year of zinc, 13,000 tons per year of lead, 10,000 tons per year of copper, and 33 tons per year of silver. This group continued study of a deposit at Lady Loretta near Mount Isa, publishing reserves of 6.5 million tons grading 18.8% zinc and 9.2% lead. Agip is a wholly owned subsidiary of Agip of Italy, owned by the state organization ENI, which also owns SAMIM, Italy's largest lead and zinc metal producer.

In exploration activity, MIM reached an agreement with the Northern Territory government for an 18-month drilling program, to be completed by the end of 1990, to establish the viability of mining the MacArthur River deposit. Resource estimates at yearend were 227 million tons of ore averaging 9.2% zinc and 4.1% lead. The company believes that technical problems with separating

TABLE 15

WORLD PRIMARY PRODUCTION CAPACITY

(Thousand metric tons)

	1988[r]			1989		
	Mine	Smelter	Refinery	Mine	Smelter	Refinery
North America:						
Canada	355	205	230	370	230	230
Mexico	210	300	320	210	300	320
United States	655	515	595	680	515	595
Other	10	—	—	10	—	—
Total	1,230	1,020	1,145	1,270	1,045	1,145
South America:						
Peru	205	115	110	210	115	110
Other	80	140	140	85	140	140
Total	285	255	250	295	255	250
Europe:						
Belgium	—	90	125	—	90	125
Bulgaria[e]	100	130	120	100	130	120
France	2	190	150	2	190	150
Germany, Federal Republic of	7	190	250	7	190	250
Italy	18	115	80	18	115	100
Poland	50	90	90	50	90	90
Spain	92	85	85	92	85	85
U.S.S.R.[e]	550	635	675	550	635	675
United Kingdom	—	50	160	—	50	160
Yugoslavia	115	155	155	116	155	155
Other	220	145	110	220	150	110
Total	1,154	1,875	2,000	1,155	1,880	2,020
Africa:						
Morocco	74	65	65	74	65	65
Namibia	40	75	75	40	75	75
South Africa, Republic of	102	—	—	102	—	—
Other	24	30	15	24	30	15
Total	240	170	155	240	170	155
Asia:						
China[e]	350	200	190	350	200	190
Japan	30	270	285	30	270	285
Korea, North[e]	85	90	70	85	90	70
Other	100	95	150	100	95	150
Total	565	655	695	565	655	695
Oceania: Australia	516	445	235	575	445	235
World total	3,990	4,420	4,480	4,100	4,450	4,500

[e] Estimated. [r] Revised.

the extremely fine-grained ore can be overcome with modern autogenous direct smelting techniques. Also in the Northern Territory, the Woodcutters Joint Venture operated by Nicron Resources Ltd. completed the first full year of underground operation. Proven and probable reserves were further extended to 1.27 million tons grading 13.8% zinc and 6.4% lead. Additional drilling at depth outlined another 3 million tons of similar grades, and studies were undertaken to determine the viability of further development at the open pit-underground project.

Brazil

Companhia Paraibuna de Metais created a new subsidiary to produce high-grade lead for specialty batteries from the lead and silver residues of their electrolytic primary zinc refinery in Minas Gerais. The new company, Companhia de Chumbo e Prata do Espirito Santo (CHESA), planned to produce 24,000 tons per year at a new plant in the State of Santo by 1991. The parent company also was expected to begin construction in 1990 of a new QSL lead smelter and electrolytic refinery. The project was expected to take 3 years to complete, have a capacity of 45,000 tons per year, and to process mostly imported Peruvian concentrates. The State of Parana closed the 19,000-tons-per-year primary lead refinery of Plumbum S.A. Mineração e Metalurgia in October until process effluent filtration equipment is installed at discharge points.

Canada

Mine production of lead declined significantly in 1989 through a combination of technical difficulties, natural events, and labor problems. Cutback in hoisting capacity at Brunswick Mining and Smelting Corp. Ltd.'s Number 12 Mine in New Brunswick was a result of a shaft-deepening project. Also in New

TABLE 16

WORLD RESOURCES, 1989

(Million metric tons)

	Reserves	Reserve base[1]
Australia	14	26
United States	11	22
U.S.S.R.[e]	10	15
Canada	7	13
China[e]	6	9
Mexico	3	4
South Africa, Republic of	2	5
Total	53	94
Bulgaria[e]	2	3
Korea, North[e]	2	3
Peru	2	3
Yugoslavia	2	3
Total	8	12
Other	9	14
Grand total	70	120

[e] Estimated.

[1] The Reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).

Source: International Lead Zinc Study Group, Bureau of Mines estimates, and other published sources.

Brunswick, East-West Caribou Mining Ltd. suspended production at the Caribou Mine in July to develop additional reserves, presently estimated at 15 million tons grading 11% lead and zinc combined. In July, Curragh Resources Inc. lost production temporarily at the Faro Mine, the nation's largest, in the Yukon Territory because of loss of power caused by forest fires. At Cominco Ltd.'s Sullivan Mine in British Columbia, the nation's second largest lead producer, production declined significantly because of increasing ore depth and processing problems, and cancellation of the miner's bonus formula, according to the Government's Mineral Policy Sector annual report.

In exploration and development during the year, Hudson Bay Mining and Smelting Co. Ltd. completed an expansion at its Chisel Lake Mine in Manitoba that was expected to increase lead output by 5,000 tons per year. In August, Noranda Inc. and Brunswick Mining and Smelting reopened their Heath Steel Mine near Bathurst, New Brunswick, which had been shut down since 1983. The three separate ore bodies contain 4 million tons of reserves grading 6.3% zinc and 2.5% lead. Also in New Brunswick, Marshall Minerals Corp. continued work on its Restigouche project in the north. East-West Caribou Mining planned to process the ore from the mine, which had about 1.1 million tons of reserves grading 7.71% zinc and 5.96% lead. In Nova Scotia, Westminer Canada Ltd. started work on reopening the Gays River Mine, closed by Esso Minerals Canada in 1982, at a production of 10,000 tons per year lead and 15,000 tons per year zinc. Reserves were about 1.5 million tons grading 10% zinc and 6.2% lead.

At midyear, Banco Español de Credito of Spain agreed to sell a 20% interest in Asturiana de Zinc S.A. to Curragh in exchange for a 5% share of Curragh plus a 15% interest in their Cirque deposit in northern British Columbia. That project, with 30 million tons of reserves grading 8.6% zinc and 3.5% lead, was expected to come on-stream in 1992 at 25,000 tons per year of lead.

France

Peñarroya agreed to sell its remaining lead-zinc-silver leases in France and Belgium to Nicron Resources of Australia. Remaining reserves are about 350,000 tons grading 6.5% zinc and 3.5% lead with the potential of an additional 1 million tons. Nicron will exercise the options and start production pending confirmation by exploratory drilling.

Greece

Financial problems forced the state-owned Hellenic Mining and Metallurgical Co. of Laurium S.A. (EMMEL) to close the rebuilt 20,000-tons-per-year primary smelter-refinery in June. At yearend, EMMEL had no immediate plans to reopen the facility, but late in the year the Government formed a board to examine its options.

Italy

Nuova Samim and Metallgesellschaft (MG) of the Federal Republic of Germany (FRG) agreed to merge their secondary lead activities. The two Italian plants had a capacity of 80,000 tons per year, and the German plant at Braubach, which installed the Italian Tonolli CX process in 1988 with Tonolli, had a capacity of 40,000 to 50,000 tons-per-year. In September, Nuova Samim's large primary smelter at Porto Vesme, Sardinia, was shut down because of technical problems. The Russian designed Kivcet plant had been in operation since early 1987. A planned expansion for 1990 was therefore accelerated to increase the capacity by 25% to 100,000 tons per year by midyear 1990, when the smelter was expected to reopen after correction of the problems.

Japan

Nippon Mining Co. Ltd. planned to develop a new mine on Hokkaido over the next 4 years. The deposit reportedly had reserves of 3 million tons grading 13% lead and 15% zinc with traces of indium.

Morocco

A large new underground zinc-lead-copper-silver mine was under development at Hajar by Companie Minière des Guemassa to be in full production by 1992 at about 16,000 tons per year for lead.

Saudi Arabia

The National Industrialization Corp. announced plans to construct the nation's first secondary lead smelter, capacity about 12,000 tons per year, near Jeddah. Startup is scheduled for early 1991. Late in the year, a group of Saudi private investors announced plans to construct a 25,000-tons-per-year plant near Riyadh, with MG of the FRG to be a 25% equity shareholder.

TABLE 17

WORLD SUPPLY AND DEMAND

(Thousand metric tons)

Year	Mine production	Primary demand[1]	Apparent consumption		Stock changes (ILZSG)	Refinery production	Production surplus/deficit
1978	3,395			5,595	−71	5,524	
1979	3,472			5,650	+62	5,712	
1980	3,470	60%		5,364	+66	5,430	+91
1981	3,366			5,337	−7	5,330	
1982	3,448			5,174	+41	5,215	
1983	3,357			5,303	−19	5,284	
1984	3,269			5,582	−113	5,469	
1985	3,431	57.5%	2% per	5,587	+54	5,641	
1886	3,335		year	5,633	−81	5,552	−181
1987	3,429		avg.	5,679	+43	5,722	
1988[p]	3,414	55%	growth	5,855	−5	5,855	
1989[e]	3,395			5,963	−60	5,903	
Total	40,781	58%		66,727	−90	66,637	[2] −90

[e] Estimated. [p] Preliminary.

[1] Recoverable content (95%) of mine production (lead in concentrates) divided by apparent consumption.

[2] Yearend stocks 1977 = 468; yearend stocks 1989 = 378 (estimated; producer, consumer, merchant, LME).

Spain

The nation's largest secondary lead producer, S.E. del Acumulador Tudor, doubled the capacity of its smelter at San Esteban de Gormaz from 20,000 tons per year to 40,000 tons per year to replace the yearend closing of its 15,000-tons-per-year plant at Zaragoza. Boliden Mineral AB of Sweden announced the significant discovery of a very large lead-zinc deposit, Los Frailes, near its Aznalcollar Mine, acquired from the Spanish company APIRSA in 1987. An estimated 50 million tons of ore grading 14% lead and zinc would make it one of Europe's largest base metal mines when developed. Pending further drilling, production could begin as early as mid-1992.

Tunisia

The Office National des Mines (ONM) and its partner, MG of the FRG, were studying the closed Bougrine Mine for possible reopening at depth. Deeper reserves are estimated to be 6 million tons grading 12% zinc and 6% lead. If approved, the mine could be on-stream within 3 years, producing 100,000 tons per year of lead and zinc concentrate. A lead-zinc deposit was discovered in the state of Kaf, estimated to contain 4 million tons of reserves, as a result of a joint-venture exploration program with BRGM of France.

United Kingdom

Britannia Refined Metals (BRM), a subsidiary of MIM of Australia, announced plans to acquire Chloride Metals' 30,000-tons-per-year secondary lead plant at Wakefield, West Yorkshire. In addition, BRM started to replace its 30,000-tons-per-year plant at Northfleet, Kent, utilizing MIM's revolutionary Isasmelt process, the first outside of Australia, and the first secondary application of the process. The process was developed with Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO). The new smelter was scheduled for completion by mid-1991 at an increased capacity of 40,000 tons per year.

CURRENT RESEARCH

Recent and ongoing research relative to lead and its uses have focused

TABLE 18

LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY[1]

(Thousand metric tons)

Country[2]	1985	1986	1987	1988[p]	1989[e]
Algeria[e]	3.8	3.6	3.6	3.6	3.6
Argentina	28.6	26.9	26.1	28.5	28.0
Australia	498.0	447.7	489.1	465.5	[3]495.0
Austria	[r]6.1	[r]4.7	5.2	2.3	2.0
Bolivia	6.2	3.1	9.0	12.5	[3]15.7
Brazil	[r]17.0	[r]13.6	11.6	14.3	14.6
Bulgaria[e]	95.0	95.0	97.0	97.0	97.0
Burma	21.9	18.2	27.1	16.7	12.0
Canada	268.3	349.3	413.7	368.4	[3]275.0
Chile	2.5	1.5	.8	1.4	1.4
China	[e]200.0	227.0	252.0	312.0	330.0
Colombia	.1	.2	.2	([4])	.1
Congo (Brazzaville)	1.5	[e]1.4	1.4	1.8	1.4
Czechoslovakia	2.7	2.9	[e]2.8	[e]2.8	2.8
Ecuador[e]	.2	.2	.2	.2	.2
Finland	2.4	2.0	[r e]2.9	[r e]1.9	1.8
France	2.5	2.5	2.2	2.0	1.1
Germany, Federal Republic of	20.5	16.7	18.8	14.3	7.8
Greece	19.8	20.9	20.6	[e]20.0	20.0
Greenland	17.8	16.2	20.5	23.1	20.0
Honduras	21.2	12.6	5.0	16.9	10.0
Hungary[e]	.7	—	—	—	—
India	27.1	37.6	36.7	30.5	32.0
Iran[e]	[3]21.6	21.6	21.6	21.6	22.0
Ireland	34.6	36.4	33.8	32.5	32.1
Italy	15.6	11.1	12.0	16.5	17.0
Japan	50.0	40.3	27.9	22.7	18.6
Kenya[e 5]	[r].6	[r].6	[r].5	[r].6	.6
Korea, North[e]	110.0	110.0	110.0	110.0	110.0
Korea, Republic of	9.7	11.9	14.0	14.5	[3]12.9
Mexico	[r]206.7	[r]182.7	177.2	171.3	[3]163.0
Morocco	106.8	76.2	75.7	72.2	67.3
Namibia	34.6	37.5	33.0	32.1	34.0
Nigeria[e]	.3	.1	[3].1	.1	.1
Norway	3.6	3.4	3.1	2.8	3.2
Peru	201.5	194.4	204.0	149.0	[3]192.2
Poland	51.3	42.5	48.8	[r e]49.0	47.0
Romania[e]	[r]30.0	[r]34.3	[r]36.3	[r]30.2	[3]37.7
South Africa, Republic of	98.4	97.8	93.6	90.2	[3]78.2
Spain	85.6	79.6	83.2	[r e]74.9	74.1
Sweden	[r]75.9	88.9	90.4	[e]91.0	89.0
Thailand	19.7	26.3	23.5	29.5	32.0
Tunisia	2.5	1.9	3.5	[e]3.5	3.5
Turkey[6]	9.8	10.4	9.5	[r e]11.0	14.8
U.S.S.R.[e]	440.0	440.0	440.0	440.0	440.0
United Kingdom	4.0	[r].6	.7	1.2	.8
United States	424.4	353.1	318.7	394.0	[3]419.3

See footnotes at end of table.

TABLE 18—Continued

LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY[1]

(Thousand metric tons)

Country[2]	1985	1986	1987	1988[p]	1989[e]
Yugoslavia	115.1	114.6	106.7	103.3	100.0
Zambia[6]	15.0	14.9	14.5	r e15.0	14.0
Total	r3,431.2	r3,334.9	3,428.8	3,414.4	3,394.9

[e] Estimated. [p] Preliminary. [r] Revised.
[1] Table includes data available through June 13, 1990.
[2] In addition to the countries listed, Uganda may produce lead, but available information is inadequate to make reliable estimates of output levels.
[3] Reported figure.
[4] Less than 1/2 unit.
[5] Reported for 1987 and 1988 as galena (not further specified), assumed 78% Pb.
[6] Pb content of ore.

TABLE 19

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
Argentina:					
Primary	15.1	15.7	16.2	r e16.0	16.0
Secondary	13.6	15.0	16.0	e16.0	16.0
Total	28.7	30.7	32.2	r e32.0	32.0
Australia:					
Primary	200.1	156.2	201.7	168.0	177.0
Secondary[e]	15.6	14.8	15.0	15.0	15.0
Total[e]	215.7	171.0	216.7	r183.0	2192.0
Austria:					
Primary	10.0	6.0	6.8	9.0	8.8
Secondary	15.5	19.0	16.0	16.0	15.2
Total	25.5	25.0	22.8	25.0	24.0
Belgium:					
Primary	75.3	64.5	71.1	83.2	80.0
Secondary	39.0	33.8	36.9	43.3	46.0
Total	114.3	98.3	108.0	126.5	126.0
Bolivia: Primary	.2	.2	.2	.4	2.2
Brazil:					
Primary	29.8	32.7	29.8	29.5	234.2
Secondary	51.8	52.0	58.4	68.7	255.4
Total	81.6	84.7	88.2	98.2	289.6
Bulgaria:[e]					
Primary	98.0	97.0	98.0	98.0	95.0
Secondary	18.0	17.0	17.0	17.0	10.0
Total	116.0	114.0	115.0	115.0	105.0
Burma: Primary	9.6	5.4	4.0	4.4	3.5
Canada:					
Primary	173.2	169.9	139.5	179.5	150.0
Secondary	68.4	87.7	91.2	89.9	83.0
Total	241.6	257.6	230.7	269.4	233.0

See footnotes at end of table.

strongly on improve
acid battery, throu
applications, in terms of
ity, dependability, and manufactur
marketing economics.

Research performed in 1989 by Fuji Electrochemical Co. of Japan (FDK) and Isuzu Motors Ltd. of Japan, which was 38% owned by General Motors Corp. of Detroit, led to the development of a quick-charging automotive "battery" with a storage capacity 30 to 50 times greater than conventional SLI's. Commercial production was targeted for 1992. The capacitor-structured "battery," with internal resistance as low as one-hundredth of a double layer capacitor in terms of power accumulation capacity per cubic volume, can recover electric power in less than 30 seconds, with accumulation potential 10,000 times that of conventional capacitors. Individual coin-size cells can be linked in series or parallel circuitry on any irregular area, such as a car roof or bumper, for solar charging as a "key-off" or accessory supply, or to recharge a dead SLI battery. Other potential applications would be electric cars, home and industrial supplemental or load-levelling power supply, and aerospace. A coin-size cell can store power of 1 volt and 30 watts.[3]

In contract work performed for NASA's Jet Propulsion Laboratory (JPL), tile-like positive electrode squares with improved adhesion were developed to reduce flaking on the positive faces of bipolar plates, common after repeated charge-discharge cycles in conventional lead plates. This new segmented structure prevents defects from spreading across the structure. The plate body is made of fiberglass coated with conductive fluoride-doped tin oxide in epoxy resin. Lead dioxide paste, reinforced with the same conductive fibers, is then applied to the formed recesses after conditioning the body surface to improve adhesion. The negative side of the plate is then built up from epoxy and graphite, lead foil, and lead paste supported by a glass scrim.[4]

Also for JPL, performance of a conventional lead and litharge positive plate was improved from 25% to 40% efficiency to 65% to 68% efficiency by increasing the porosity of the active paste material. This was accomplished by covering the conventional grid with lead

sulfate paste blended with tin oxide-coated glass fibers. The lead sulfate, which has a large molecular volume, increases in density during charging, opening additional pores. Ironically, lead sulfate buildup and subsequent sloughing is a cause for shorting out and failure in conventional lead-acid battery construction. In preliminary tests the new cell was deeply discharged and recharged more than 2,000 times without fading.[5]

A patent was issued during the year on a range of synthetic polymeric materials exhibiting an electrochemical ionic semiconductivity previously known only in living organisms. These materials greatly enhance ion selectivity with no change in resistivity when used as plate separators in a battery system. Because they also essentially eliminate nonionic transfer, they control the mobility within electrolytes of all metals, facilitating their use as electrodes in virtually all metal-metal secondary battery systems also. Known generically as EPM materials, they can be used as electrolytic cells for the extraction of metal ions from process effluents, as nonporous breathable coatings for protective clothing or bandages, or even as a synthetic skin in burn treatment.[6]

A comprehensive coverage of lead-related investigations and an extensive review of current world literature on the extraction and uses of lead and its products, including batteries, were published in quarterly issues of Leadscan, Lead Development Association, London, United Kingdom.

OUTLOOK

Although overall domestic consumption of lead has grown at an average rate of about 3% per year since 1985, this rate is not expected to be sustained, primarily because of institutional factors. As the Nation pays increased attention to pollution prevention mentality instead of the present strategy of waste minimization through command and control techniques, some end uses of lead will certainly be curtailed or eliminated entirely by legislation or regulation. One of the pollution prevention strategies known as source reduction will most likely reduce the use of lead in nongrowth markets such as solders; paints and coatings (already

TABLE 19—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
China:[e]					
Primary	170.0	200.0	200.0	200.0	220.0
Secondary	40.0	40.0	40.0	45.0	50.0
Total	210.0	240.0	240.0	245.0	270.0
Colombia: Secondary[e]	3.0	4.0	4.0	4.0	3.5
Cyprus: Secondary[e]	(3)	(3)	(3)	(3)	—
Czechoslovakia: Secondary	21.4	23.6	26.0	26.0	26.0
Denmark: Secondary	4.5	.6	—	—	
Finland: Secondary	4.4	1.2	[r]1.2	[e]2.0	2.0
France:					
Primary	133.6	132.0	138.8	146.5	147.0
Secondary	90.0	98.4	107.1	109.2	108.0
Total	223.6	230.4	245.9	255.7	255.0
German Democratic Republic:[e]					
Primary	19.2	15.5	17.1	19.2	18.2
Secondary	[r]35.8	[r]29.0	[r]32.0	[r]35.8	33.8
Total	55.0	[r]44.5	[r]49.1	[r]55.0	52.0
Germany, Federal Republic of:					
Primary	181.0	182.1	167.6	176.6	182.0
Secondary	175.3	184.5	172.8	168.5	168.0
Total	356.3	366.6	340.4	345.1	350.0
Greece: Primary	13.7	19.3	2.7	[r e]5.0	5.0
Guatemala: Secondary	.1	.1	.1	.1	[2].2
Hungary: Secondary[e]	.1	.1	.1	.1	.1
India:					
Primary	15.6	19.9	20.7	18.8	19.0
Secondary	[e]10.0	11.3	12.1	14.0	15.0
Total	[e]25.6	31.2	32.8	32.8	34.0
Iran: Secondary[e]	7.5	8.0	10.0	10.0	10.0
Ireland: Secondary	9.0	10.2	9.6	[e]10.0	10.0
Italy:					
Primary	[r]29.5	[r]29.3	62.3	72.2	72.5
Secondary	96.7	[r]101.7	111.4	111.6	112.0
Total	[r]126.2	[r]131.0	173.7	183.8	184.5
Jamaica: Secondary[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	233.7	232.7	218.8	217.7	[2]207.7
Secondary	133.3	128.7	119.5	122.3	[2]124.6
Total	367.0	361.4	338.3	340.0	[2]332.3
Kenya: Secondary[e]	2.0	[r]2.0	[r]2.0	[r]2.0	1.0
Korea, North: Primary[e]	95.0	95.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary	11.0	32.1	52.5	[r]46.0	36.8
Secondary	9.2	27.5	30.0	[r]44.0	44.1
Total	20.2	59.6	82.5	[r]90.0	80.9
Malaysia: Secondary	14.6	13.8	11.8	[e]12.4	12.5

See footnotes at end of table.

TABLE 19—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
Mexico:					
Primary	r203.0	r182.0	177.0	168.1	2160.9
Secondary[e]	31.0	33.0	235.0	35.0	35.0
Total[e]	r234.0	r215.0	212.0	203.1	195.9
Morocco:					
Primary	59.5	60.0	62.5	e62.5	62.5
Secondary[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	61.5	62.0	64.5	64.5	64.5
Namibia: Primary	38.5	40.0	40.6	44.4	45.0
Netherlands: Secondary[e]	25.0	33.0	35.7	39.5	40.0
New Zealand: Secondary[e]	6.0	4.0	23.6	3.0	5.0
Nigeria: Secondary	.8	1.0	.3	e.5	.5
Pakistan: Secondary[e]	1.0	1.0	2.0	2.0	2.0
Peru:					
Primary	81.9	66.4	71.3	53.6	70.0
Secondary[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	86.9	71.4	76.3	58.6	75.0
Philippines: Secondary[e]	7.0	7.0	7.0	7.0	7.0
Poland:					
Primary[e]	61.1	63.3	64.5	r61.0	61.0
Secondary[e]	26.2	25.0	25.0	r36.0	20.0
Total	87.3	88.3	89.5	r97.0	81.0
Portugal: Secondary[e]	7.0	6.0	6.5	6.5	6.5
Romania:[e]					
Primary	38.6	36.0	233.2	r38.0	45.0
Secondary	10.0	15.5	10.0	10.0	15.0
Total	48.6	51.5	r43.2	r48.0	60.0
South Africa, Republic of: Secondary	32.8	40.5	38.3	37.4	236.0
Spain:					
Primary	112.8	88.0	71.4	r e68.8	75.0
Secondary	43.3	42.0	51.3	r e52.0	50.0
Total	156.1	130.0	122.7	r e120.8	125.0
Sweden:					
Primary	43.2	r49.2	61.2	e60.0	58.0
Secondary	25.9	r27.8	30.2	e30.0	28.0
Total	69.1	r77.0	91.4	e90.0	86.0
Switzerland: Secondary	2.0	r2.5	2.5	1.5	1.4
Taiwan: Secondary[e]	r48.7	53.5	r66.4	r67.3	67.2
Thailand: Secondary	7.5	9.1	11.4	15.6	16.0
Trinidad and Tobago: Secondary[e]	2.0	2.0	1.8	1.8	1.8
Tunisia:					
Primary	2.0	2.2	e2.2	e2.2	2.2
Secondary[e]	.5	.5	.5	.5	.5
Total[e]	2.5	2.7	2.7	2.7	2.7

See footnotes at end of table.

eliminated in interior house paints); ceramics; gasoline additives; containers or other packaging, including inks or dyes, especially where food is concerned; and cosmetics. Some reduction of lead per battery unit can also be anticipated as the technology continues to advance. As a result, U.S. annual growth in lead demand will probably fall within an average range of 0.5% to 1.0% per year in the decade of the 90's as the storage battery sector becomes even more dominant. The lower average growth rate can certainly be expected if source reduction is applied to the ammunition sector, currently the second largest end use. The higher growth rate could be attained if lead-acid batteries for peak-power, load-levelling applications become widely accepted for households and commercial facilities.

World demand for lead, including the United States., has grown at an average rate of about 2% through 1989 since the low recession year of 1982 (table 17). Lower growth domestic demand, which is currently about 21% of the total, will undoubtedly lower the overall growth rate somewhat in the future. However, storage battery use in all applications will undoubtedly grow faster in the rest of the world than in the United States as some poorer nations increase their living standards as they grow with the world economy. It is estimated that currently about 60% of world demand is for batteries, compared with about 80% in the United States alone, and is forecast to reach about 70% by the end of the decade as the rest of the world's supply-demand pattern is rationalized by environmental concerns. Therefore, the most probable world growth until the end of the century is forecast to average about 1.5% per year.

The attendant worldwide production outlook is interrelated with anticipated structural changes discussed in the following section. Because of large capital demand and high costs associated with environmental concerns, large production surpluses in the near term are not likely. High realized producer prices are critical to profitably amortizing the large improvement expenditures anticipated over the next 10 years. However, this will continue to be partially subjected to developing situations in zinc and silver markets because of the geo-

TABLE 19—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
Turkey:[e]					
Primary	6.5	7.0	7.0	7.3	9.8
Secondary	2.5	2.6	3.0	3.7	1.0
Total	r9.0	r9.6	10.0	r11.0	10.8
U.S.S.R.:[e]					
Primary	r485.0	r485.0	r475.0	r447.0	455.0
Secondary	265.0	270.0	275.0	280.0	280.0
Total	r750.0	r755.0	r750.0	r727.0	735.0
United Kingdom:					
Primary	148.1	156.1	137.5	172.2	160.0
Secondary	179.1	172.5	200.7	201.6	200.0
Total	327.2	328.6	338.2	373.8	360.0
United States:					
Primary	494.0	370.3	373.6	392.1	396.5
Secondary	615.7	624.8	710.2	736.4	808.6
Total	1,109.7	995.1	1,083.8	1,128.5	1,205.1
Venezuela: Secondary[e]	18.0	16.0	17.0	18.5	17.0
Yugoslavia:					
Primary	r60.0	r75.0	76.4	70.9	78.0
Secondary	40.0	r38.0	36.0	e39.0	41.0
Total	r100.0	r113.0	112.4	109.9	119.0
Zambia: Primary	8.9	6.6	8.0	6.4	7.0
Grand total of which:	r5,640.5	r5,551.9	5,721.8	5,855.2	5,902.7
Primary	r3,356.7	r3,192.6	3,204.2	3,239.5	3,253.8
Secondary	r2,283.8	r2,359.3	2,517.6	2,615.7	2,648.9

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 13, 1990. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates *(primary) or scrap* (secondary), and include the lead content of antimonial lead, but exclude, to the extent possible, simple remelting of scrap.

[2] *Reported* figure.

[3] Revised to zero.

logic relationships of the three metals in the primary production sector.

Complex multinational, multifaceted realignments and restructuring, including divestitures, among world lead producers and product manufacturers are expected to continue through the rest of the century. The reasons, whether market-driven, technology-driven, environmentally driven, or combinations thereof, are discussed in the following section.

BACKGROUND

Industry Structure

Since the development of the last major lead-producing region in 1968, the first year of significant production from the Viburnum Trend in Southeast Missouri, large-scale structural changes have occurred worldwide in both the producing and consuming sectors of the lead industry. Most apparent, as illustrated in table 17, is the decline in primary demand, which has accelerated downward in recent years and is expected to continue this trend at a similar rate into the next century. The milestone year was 1984 when world mine production dropped to a 15-year low. As the world economy pulled out of recession, resource recycling was emphasized as world demand accelerated. A proliferation of new secondary plants has appeared together with expansion of capacity at older plants and environmental concerns for improved performance forcing technologic retrofitting. This was especially noticeable by 1988 when world supply and demand were almost in balance (table 17). However, at yearend 1989, world metal stocks were extremely low relative to demand as world demand again outstripped production, as was the case in 1986. Although world secondary refinery production was an estimated record 2.65 million tons in 1989, mine production was estimated to be about the same level as 1978, in spite of significant increased production from new mines and increasing productivity at some old mines, especially in China.

Although increasing worldwide environmental awareness will continue to force an increasingly greater share of demand to be supplied from secondary sources, this will not alleviate the tight supply problem, regardless of the rate of recycling increase, without a considerable revolutionary (as opposed to evolutionary) technology shift. Basically, this will require electrowinning and/or eletrorefining to obtain premium metal (99.99% plus), the occasional spot shortages of which have led to market "tightness" in the fourth quarters of 1988 and 1989. Conventional primary smelters fed by virgin ores can achieve this, especially with electrorefining (nearly 99.999%), but the best on average that conventional secondary smelter refineries can achieve is 99.985% purity. Premiums for the purer product have kept average prices artificially high the past 2 years. Eventually, a rationalization of worldwide environmental codes will alleviate this problem by forcing optimum recycling in conjunction with clean technology reprocessing.

Ironically, the demand for high-purity lead has been fed by evolutionary changes in the worldwide demand pattern itself and not simply the volume increase. Original equipment automotive batteries and some large UPS system batteries that are continuously on-line as voltage regulators and not subject to drawdown are more amenable to the use of high-purity calcium lead alloys. This is especially critical for the mass-production automobile industry. Replacement "hybrid" type low antimonial lead batteries, which are superior in electrical charge recovery cyclability but are more expensive to make, can carry a premium not associated with the cost of buying a new car. However, because of the greater volume

necessary (5 out of 6 in the United States) compared with the original equipment battery market, discounts can often offset this to the consumer, especially when the market is saturated.

What all this has led to in recent years is a massive worldwide restructuring and rationalization of the industry. In some cases retrenchment; in others vertical integration, often through multi-national mergers, especially on the primary side; in still others, lateral merging for more flexible marketing; and, in other cases, joint ventures, divestiture, or expansion depending on capital availability and its cost or simple conviction or lack thereof to remain competitive under continuously changing and evolving conditions.

One of the best examples of multinational restructuring through mergers on the primary side to increase vertical integration for some parties, facilitate cash-flow for investment for others, and ensure flexible marketing for all involved Asarco, one of the two remaining domestic primary lead metal producers. According to its 1989 annual report, Asarco, which is essentially a custom smelting company, has substantial interests in three of the world's major mining companies: an 18.7% stake in MIM of Australia, a 52.3% ownership of Southern Peru Copper Corp. (SPCC), and a 34% holding in Mexico Desaraollo Industrial Minero, S.A. de C.V. (MEDIMSA). MIM, which in return has a 24.9% interest in Asarco, is a partially integrated producer of copper, silver, gold, lead, zinc, and coal. SPCC operates two large copper mines and a copper smelter in Peru. MEDIMSA is a holding company for several, not necessarily integrated, companies in Mexico engaged in the mining, milling, smelting and refining of nonferrous metals, including the large integrated copper producer Mexicana de Cobre, S.A. de C.V. All these associated companies accounted for about 11% of the market economy countries' mine production of copper, 17% of silver, 14% of lead, and 10% of zinc in 1989, according to Asarco. In addition, MIM owns a secondary lead plant in Taiwan, and Asarco is presently considering reentering that sector in the United States, representing lateral integration within one commodity, following the leadership of Doe Run. Other examples would be SAMIM's involvement in both primary and secondary sectors in Italy, with MG of the FRG as previously discussed, and Brittania Metals in the United Kingdom, a subsidiary of MIM.

The total merger of Peñarroya of France with Preussag AG of the FRG in late 1987 into Metaleurop is an example of multilayer restructing and merger on a grand scale. In late 1989, MG, in an attempt to expand its base production and raw material reserves on a global scale, hiked its share in MIM from 4% to 10.5%. MIM has a 3% interest in MG and a 9% interest in Cominco Ltd. of Canada, one of the world's leading base metal producers, in which MG has a 37% share through its Canadian holding company, Metall Mining Co. Ltd. Mitsubishi Mining and Smelting Co. Ltd. of Japan also has a small interest in Cominco, and they jointly own and operate a primary lead smelter that also utilizes secondary feed at Noashima called Mitsubishi Cominco Smelting Co. Ltd.

In the United States, there are two prime examples of divestiture in recent years, as both AMAX Inc. and Kennecott have gotten out of the lead business because of environmental risks and uncertain future markets. AMAX's interests, the Buick Mine and Boss Smelter-refinery, were eventually folded into The Doe Run Co. along with its partner, the Homestake Lead Mining Co. of Missouri. The interests of Kennecott's Ozark Lead Co. were acquired by Asarco.

Doe Run's pending lateral movement into the secondary sector utilizing "clean processing technology" will allow them market flexibility by, ironically, reopening the Buick conventional refinery only. Pyrometallurgical refineries can be made environmentally sound by retrofitting, not yet proven for conventional smelters, and extremely doubtful if stricter emission standards are applied. However, by combining the two processes, Doe Run will be better able to compete in the antimonial lead market, almost exclusively the domain of secondary producers in the United States. RSR Corp., which is about equal to Doe Run in lead production, on the other hand has chosen to convert to electrowinning with electrorefining of the metallic portion of the scrap to penetrate the premium market, now controlled by the primary producers in the United States.

On the consuming side, in the battery sector, multinational mergers and joint-producing ventures have also become common in recent years as new automated manufacturing technologies and new environmental codes spread rapidly, requiring increasing new capital investment. Recent examples of this in the United States have been Dunlop of Australia's acquisition of Chloride Inc., a former U.S. subsidiary of the Chloride Group of the United Kingdom, to form Pacific Chloride Inc., and then acquiring GNB Inc., the Nation's third largest battery company, renamed Pacific Dunlop Inc. Exide Corp., the Nation's largest battery manufacturer, has formed joint ventures with Yuasa Electric Storage Battery Co. Ltd., one of Japan's largest, to manufacture batteries for Japanese car manufacturers in the United States and also to manufacture replacement motorcycle batteries. The joint-venture plant at Reading, PA, adjacent to Exide's large secondary smelter-refinery-plastics complex, is the Nation's largest motorcycle battery plant, according to Exide.

Costs

In 1987 the Bureau of Mines investigated the domestic primary and secondary lead smelting and refining industries to determine the economic impacts of then existing and proposed environmental, health, and safety regulations. The impacts were assessed in terms of capital and operating costs for existing and alternative smelting-refining technologies. For the primary sector, the estimated capital cost to rehabilitate the three Missouri smelter-refineries by replacing the present sinter plant-blast furnace operations with dryers, flash smelting, continuous drossing, and double-contact acid plants was estimated to be $1,000 per annual ton of capacity, or $400 million 1987 dollars. The estimated capital expenditure for a single 400,000 ton replacement "green field" flash smelter in Missouri, optimally located, was estimated to be $750 per annual ton of capacity, or $300 million 1987 dollars. That plant would incorporate all BAT, including total ambient ventilation, and collection of airborne particulates from all plant areas. A second option analyzed was that for three QSL-type bath furnaces at a single location, estimated capital cost about the same as that for

rehabilitation of the existing three separate plants. Over 90% of the costs in all three scenarios were attributed to the requirements for improved airborne particulate (on-site and offsite) and SO_2 emission controls.

The average investment cost required for the 24 secondary plants processing batteries in 1987 to achieve existing regulatory compliance was estimated to average $124 per annual ton of plant capacity for those studied. An average additional cost of about $400 per annual ton of capacity was estimated and would be required to meet the most probable new lead NAAQS of 0.5 $\mu g/m^3$. The latter cost was purely an estimate based on secondary industry responses to the Bureau of Mines for probable equipment requirements.

None of the foregoing estimates imply that investing the necessary capital expenditures would guarantee full compliance with all EPA, OSHA, or State requirements, in either the primary or secondary sectors.

With respect to basic operating costs only, the Bureau found that in 1987, these averaged 22 cents per pound for the secondary plants studied and 20.8 cents for the primary plants, allowing for 11.9 cents per pound byproduct credits in the latter case. After including taxes, capital recovery, and a 15% discounted cashflow return on investment, total costs were 23.1 cents and 23.8 cents, respectively.

Raw material feed costs, in recoverable metal terms, averaged 14.2 cents per pound for the primary plants and were assumed to be 9 cents for the secondary plants. Regulatory costs for these plants, on average, were 2.75 cents for primary and 3 cents for secondary at that time, but none of the plants in either sector were in full compliance with all EPA and OSHA or State regulations. An additional average cost per plant to meet the then existing regulations would have been 5.5 cents per pound for the primaries, only by complete rehabilitation, and 3.8 cents for the secondaries, requiring extensive retrofitting. The additional 5.5 cents for the primary case allowed for an additional (to 11.9 cents) estimated attendant 0.7 cent per pound increase in the deductible byproduct credit because of improved recovery (12.6 cents). Total required upgrading to meet the existing 1987 regulations, including taxes and return on investment, would have resulted in total average costs of 29.3 cents per pound for the primaries and 27.2 cents for the secondaries. Updating these costs to 1989 would require an additional average of 3 to 5 cents per pound in recoverable metal feed costs for secondary plants because of higher prices for battery scrap during 1988 and 1989. On the primary side, however, the mine and mill average costs have probably decreased at captive mines as a result of improved productivity, resulting in a slight reduction of raw material feed costs to the smelters. Some additional retrofitting costs at the smelters since 1987 were probably offset by improved productivity resulting primarily from institutional changes at Doe Run, discussed earlier.

It was estimated by the Bureau in 1987 that an additional average retrofit operating cost of at least 2 cents per pound on top of the capital requirements would be necessary for secondary plants to meet a probable NAAQS of 0.5 $\mu g/m^3$. The proposed revised drinking water standard, which will directly impact plant discharges and process effluents, could double that additional cost or more. For primary plants, it is virtually certain that neither total rehabilitation nor new BAT plants, flash or bath, could meet such a NAAQS revision. It was estimated in 1987 that a new flash plant would operate at 28.2 cents per pound, including capital recovery and return on investment and discounting improved byproduct recovery credits of 12.8 cents per pound. The comparable figure estimated for a new bath plant (QSL-type), was 29.4 cents. Although the latter has an inherent lower functional processing cost as the feedstock does not have to be dried, the capital recovery costs included are estimated to be 1.7 cents per pound greater than that for a flash plant (Outokumpu-type).[7]

---

[1] International Lead and Zinc Study Group (London). Lead and Zinc Statistics. ILZSG Mon. Bull., v. 30, No. 9, Sept. 1990, p. 18.

[2] Page 33 of work cited in footnote 1.

[3] American Metal Market. Apr. 18, 1990.

[4] NASA Tech. Briefs. Apr. 1990, p. 22.

[5] ———. May 1990, p. 34.

[6] Advanced Battery Technology. July 1989, p. 5.

[7] Isherwood, R. J., Smith, R. C., Kiehn, O. A., and Daley, M. R. Impact of Existing and Proposed Regulations on the Domestic Lead Industry. BuMines OFR 55-88, Aug. 1988, 33 pp.

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Lead. Ch. in Mineral Commodity Summaries, annual.
Lead. Ch. in Mineral Facts and Problems, 1985 Edition.
Lead. Mineral Industry Surveys, monthly.
Minerals Today, bimonthly.

Other Sources

ABMS Non-Ferrous Metal Data.
American Metal Market (daily paper)
Engineering and Mining Journal.
International Lead and Zinc Study Group (ILZSG), special reports.
International Lead Zinc Research Organization. (ILZRO).
Lead Industries Association Inc.
Metal Bulletin (London).
Metals Week.
Mining Congress Journal.
Mining Engineering.
Mining Journal (London).
Mining World.
Skillings' Mining Review.
World Metal Statistics (World Bureau of Metal Statistics, Birmingham, United Kingdom)
World Mining.