ANTIMONY

By Howard Masters, Lambert Metals, UK

Having tripled in price during 2002 after years in the doldrums, the antimony market weakened in 2003 only to recover again during the first half of 2004. The cause of these fluctuating prices can be traced back to July 2001 when an accident occurred at Longquan Mining Co in Nandan County, Guangxi Province, China. More than 80 people were killed and led the central government to crack down on unsafe and mostly illegal mining practices in the region and, later on, in the rest of the country. The net effect of these enforced mining restrictions in China, which typically supplies more than 80% of the world's antimony, has been to reduce supplies of antimony concentrates. As to how serious these shortages are, given that world demand remains depressed, is unclear, leaving the market uncertain and susceptible to swings in price.

Antimony ores are mined and then beneficiated and processed into antimony metal or oxide, a white powder. Chemical-grade ore is that which is sufficiently pure to be used directly in producing trioxide, chloride or other industrial chemical compounds. The most significant of the antimony compounds, antimony trioxide, is employed as a flame retardant in an organic solvent applied to textiles, plastics, building materials, adhesives, rubber, pigments, paper etc.

The uses of antimony in non-metal products include: in enamels for plastics, metal and ceramics; as a decolourising and refining agent in glass; in stabilisers and plastics; in pigments in paints and ceramics; in vulcanising agents; in ammunition primers; and fireworks.

Most commercial grades of antimony trioxide contain between 99.20% and 99.50% Sb, with varying amounts of impurities such as arsenic, iron and lead. Commercial suppliers offer various grades of antimony trioxide based on the relative tinting strength of their product which is related to average particle size. In general, the tinting strength increases as the particle size decreases.

The commercial metallic products are generally semi-circular shaped ingots (regulus), plates, broken pieces, granules and cast cake. Other forms are powder, shot and single crystals.

Antimony is rarely used alone and is usually alloyed with other metals such as lead and zinc. These alloys are used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, type-metal, ammunition and pewter.

International trade is in the form of ores, concentrates, trioxide and metal in various grades from pure to high and antimonial Lead. Trading is on a large

scale as resources are concentrated in developing countries such as China, whereas consumption of refined products is mostly in the more industrialised Western countries.

The most common form of metal produced by smelting is minimum, 99.65% Sb regulus material on which most world prices for metal are based. The price for this standard regulus as quoted by *Metal Bulletin (MB)* on an 'in warehouse' Rotterdam basis, was US$2,750-3,050/t at the beginning of the year, but these levels were being encouraged by speculative interests and were much higher than the actual prices being traded. As a consequence the quotation slipped down to US$2,250-2,500/t by the end of January, only to recover a little, being encouraged by the disruption to supplies caused by the Chinese New Year, back to US$2,550-2,650/t by mid-April. From this point on, however, the quotation reduced as a result of poor demand, particularly from the northern hemisphere during the summer months, down to a low for the year of US$2,100-2,200/t in mid-November. More speculative interest at the year-end saw the quote finish the year at US$2,250-2,300/t and continue upwards in the early part of 2004 back towards the US$3,000/t level.

Principal identified world resources are in China, Bolivia, Mexico, South Africa, US, Russia and other Former Soviet Union (FSU) countries. Total reserves are estimated at around 4 Mt (reserve base) of which about 2 Mt are considered to be recoverable (reserves) (Table 1).

Primary supply

Despite its reduced output, China remained dominant, producing around 80% of world primary output. The next largest contribution came from South Africa with some 5%, about the same as the combined production of Russia and the countries of the Commonwealth of Independent States (CIS).

China's output of antimony concentrates has decreased by 49% since 2001 (Table 2) but, despite this, production of refined antimony units dropped by only 24% in the same period to 101,564 t, implying that stocks built up during decades of over-production are diminishing, with the output of metal contained in concentrates significantly less (about 42%), than the amount of refined antimony being produced. China is, however, now also importing antimony ores from countries such as Russia, Kazakhstan, Tajikistan and Australia.

Chinese production is split between state-run plants and the private sector. The three main provinces for mining and production of antimony are Guangxi, Hunan and Yunnan. Since the Nandan closure, Hunan has taken over from Guangxi as the main producing province and now provides 70% of Chinese concentrate output, although its production of refined antimony up until November had only increased by 1.84% on 2002 at 58,841 t. In Guangxi and Yunnan, however, production reduced by 35.11% to 28,016 t and 12.9% to 7.715 t respectively. With world consumption currently estimated at only around 110,000 t and dropping, the market appears well balanced.

The big question is the level of Chinese consumption. This is estimated at 25,000 t for 2003 of which about 44% was consumed for plastic flame-

retardants, 20% for alloys and 12% for polyester and fibre. For 2003, the government allocated export quotas for 67,000 t, which have been reduced to 65,700 t for 2004. This leaves more than sufficient production for domestic use although smuggling of material, particularly through Vietnam, continues. If China's economy continues growing at its current rate this balance could well change.

The Chinese Ministry of Land and Resources (MLR) initiated an investigation in April as a pre-emptive measure to avoid further disasters such as those that had happened in Nandan County. As a result, up to 60 small-scale antimony mines and smelters in Hunan Province were supposedly earmarked for closure and, according to reports, the Ministry started closing mines and blowing up smelters around the city of Lengshuijiang in central Hunan, the province's main antimony-mining area in mid-June. Output at the state-owned Hsikwangshan Twinkling Star, the world's largest antimony trioxide producer with a 37,000 t/y capacity, was not affected although production for 2003 was down by about 10% to around 25,000 t of metal and trioxide combined, as a result of flooding during the early part of the year. The company runs two main mining zones, North and South, covering 100 sq km^2 and operates four smelters, three producing antimony and one zinc. Concentrate production from the mines declined by 18% in 2003 leaving 8% of total output made up by outside purchases. Hunan Dongang antimony works, similarly, has its own mine but was also running below its capacity of 10,000 t/y of mostly trioxide, with 2003 production only expected to be 4,000 t.

The largest concentration of antimony production in China has always been, up until the past few years, in Guangxi Province where there was a proliferation of small privately-owned mines. Many of these have been closed since the accidents but, as in Hunan, the main state-owned mines and smelters remained in operation. The Luizhou China Tin Group has two antimony smelting plants both located in Jinchengjiang using concentrates from their own mines. In September the company resumed mining at its No. 101 and 102 ore bodies located at Gaofeng, and was also looking to develop No. 105 directly below No. 100, which was closed permanently after the Nandan disaster. This, however, only represents about 20% of the output before the closures and production at another mine (Tongken) has decreased owing to poorer grade ore now being mined. As a consequence, China Tin was only running at about 50% of its 15,000 t/y capacity of refined antimony during 2003, as was another state-run smelter in Hechi, which has a 10,000 t/y capacity.

Nanfang, one of the largest privately-owned smelters in Guangxi, has a 20,000 t/y capacity for antimony but was producing only around 350 t/mth and stopped production altogether in June owing to a shortage of concentrates. Production could restart within two months if sufficient raw materials were to be sourced. In the meantime, plans for a new 8,000 t/y plant to produce trioxide went ahead with the completion of the first 4,000 t/y phase scheduled for the end of August. The state-owned Naning smelter was also due to close its 4,000 t/y capacity in June despite an earlier US$3.6 million investment in environmental upgrades to reduce pollution. The project raised emission

standards to among the highest in China and there were plans to switch to smelting aluminium.

In August 2003, the MLR issued regulations to enforce and control production of various resources in China, including antimony. Unlicensed mining activities and companies that wasted the country's natural resources, ignored safety and environmental legislation or violated industry policies would be closed.

Despite all of this, many mines and smelters continued in operation throughout China, with provinces such as Chongqing, which, although only a small producer, increased output of refined antimony by 33% up to August. Also, in January 2004 China's customs statistics showed antimony concentrate output for that month to be 2,496 t up by 53% compared with the same period in 2003. Output in Hunan Province was the highest at 1,200 t, and output from Guangxi was 998 t, up 128%. These figures may just be a blip but do show that the production capacity still exists.

After China, the most significant production used to come from the Kadamjay antimony combine in Kyrgyzstan, which, with a capacity of 12,000 t/y, supplied nearly 90% of Soviet-produced antimony. After the collapse of the USSR the plant became part of the State concern, Kyrghyzaltyn, and restricted finance caused the combine to lose its links with traditional ore concentrate suppliers in other countries principally Tajikistan, Uzbekistan and Russia. Production was temporarily suspended at the end of 2002 and in the autumn of 2003 the combine was withdrawn from the Kyrgzaltyn structure to become a joint-stock company free to trade independently.

Production in 2003 was only 1,309 t, a decline of 13.5% from 2002. With new state funding, production of 3,600 t is being targeted for 2004. Much will depend upon Kadamjay's ability to obtain concentrates for which it is now in competition with the Chinese. New ore supplies have been identified in Russia and the plant is improving its technology for processing lower-grade local ores, including a reasonably close, newly discovered deposit of gold-antimony at Nichkesu. However, funds are still lacking for this mine development. The plant was the subject of several failed privatisation efforts during 2003. Most recently it was reported that Russian interests may buy the plant as part of a larger debt-reduction programme by the Kygyz Government for money owed to Russia.

A potential solution to the raw-material supply problems came from Tajikistan in early 2004. Although the Anzobsky dressing works, the major concentrate provider to Kadamzhay, is not state run the Tajik Government, through its industry ministry, announced it would put pressure on the company to increase its supplies to enable the smelter to operate at full capacity. Last year the Kyrgyzstan firm received just over 1,800 t of antimony concentrate from Anzob. In Russia, Sarylakh-Surma has been granted an export quota for 2004 of 8,500 t of antimony concentrates containing gold and silver, which will also be ideal for Kadamjay if it is not outbid by China.

South Africa's only antimony producer is the Consolidated Murchison mine located in the Murchison greenstone belt near Gravelotte in Northern Province. Owned by the Metorex Mining group, it supplies about 8% of world demand. Operations are based upon proved and probable reserves totalling 1.7 Mt averaging 2% Sb, with a further 8.5 Mt of mineral resources estimated averaging 2.5% Sb. In 2003, development was focused on deepening the Beta shaft to give access to reserves at depth, and to commissioning a new and third shaft, which was scheduled to increase output in 2003 above the 9,570 t of concentrates containing 58-59% Sb mined in the previous year. Most of this production is exported to Mexico where Great Lakes Chemicals, the world's largest producer of flame retardants, has concentrated its production in recent years.

In Australia, the Hillgrove mine in New South Wales was re-opened in March after going into receivership in early 2002. Work began on the site to prepare it for a resumption of production with the first priority being to repair the existing equipment. Permission was also sought from the NSW Government to build a new tailings facility at the mine but legal problems developed between the new owners and those responsible for re-opening the mine. By early 2004, production had still not restarted when ownership changed hands again. There are currently inferred resources estimated at 29,000 t of antimony but future plans are based more on developing gold production. Also in Australia, AGD Mining continued exploration of its Costerfield gold-antimony project in Central Victoria. The Augusta zone is located 1-2 km from the company's treatment plant and has resources of 290,000 t averaging 6.2% Sb. In May further samples showed that the eastern lode of the deposit contains most of the antimony in a range of 8.6% to 32.5% Sb.

Mining in Turkey is nowadays reduced to concentrates containing 18-20% Sb yielding only about 500-600 t/y of metal, most of which is sold locally.

In Peru, production of antimony is only as a by-product by non-ferrous metals producer Doe Run but the company did plan to increase output in 2003 to 696 t, which would be an increase of 122% on 2002, and even further in 2004, to 842 t.

The Beaver Brook antimony mine near Gander in Newfoundland, Canada, is among the world's largest undeveloped antimony deposits, which, once in full production, could supply up to 5% of the world's annual demand. The mine has been kept under care-and -maintenance since the operations were suspended in 1998-99 as a result of low world antimony prices. However, in September 2003, VVC Exploration Corp acquired all the assets and plans to restart production in 2004. The Beaver Brook antimony project was developed between 1994-98. Antimony was discovered in mineralised zones outlined through approx 25,000 m of drilling which developed a resource estimated to be some 1.04 Mt at an average grade of 4.32% Sb.

There was no domestic mine production of antimony in the US in 2003. For many years the Sunshine mine in Kellogg, Idaho, was the only mine producing antimony in the US but it closed in 2001 after operating at a loss for

many years. In May 2003, Sterling Mining Co agreed to lease the mine for 15 years with an option to buy. However, it remains unclear if there are any plans to resume antimony production, which was only ever as a by-product off the more important silver mining. In early 2004, Great Lakes Chemical Corp and Laurel Industries, part of Occidental Petroleum Corp, agreed to combine their antimony businesses in Mexico under a joint venture whereby Laurel Industries will close its antimony oxide operation based in Texas by the end of the year.

With the closure of AMSPEC Chemical Co in New Jersey in 2002 and the transfer of Laurel Industries' operations from Texas to Mexico, the only remaining US producer of primary antimony metal and oxide will be United States Antimony Corp (USAC) based in Montana, which has 50% ownership of a mine and processing properties in Mexico. USAC produces antimony oxide as a flame retardant; sodium antimonite for glass; antimony metal for ordinance, bearings and lead alloys; and a variety of other products. The company also recycles many antimony products which otherwise are taken to designated landfill sites.

Secondary supply

Secondary antimony was recovered mostly in alloy form at lead smelters, and antimony production from domestic source materials in the US was derived almost entirely from the recycling of lead-acid batteries.

Traditionally, the bulk of secondary antimony has been recovered as antimonial Lead, most of which was generated and then also consumed by the battery industry. However, changing trends in that industry in recent years have caused lesser amounts of secondary antimony to be produced and recycling now only supplies a minor portion of demand.

Stockpiles

Stockpiles have been an important source of antimony, especially the US National Defence Stockpile which, for many years, has been making available up to 5,000 short tons annually, mostly for US consumers, although not all the offerings have been taken up in recent years owing to poor demand. However, at the start of the fiscal year in October 2002, only 2,618 short ton were left unsold and by July 2003 the supplies were finally exhausted with the last sonale. Some quantities were also seen in Europe from FSU stockpiles but these stockpiles, too, are now believed to be mostly exhausted.

Outlook

World production of antimony is continuing to reduce but during 2003 most major consuming countries maintained a trend towards lower demand. In the US, for example, which, along with Japan and Korea, are the major markets, imports in 2003 dropped to a total of 25,400 short ton for combined ore and concentrate, metal and oxide against 28,500 short ton in 2002.

Continued mining restrictions in China may cause higher market prices again but if they were to rise too high then substitution could occur. Compounds of chromium, tin, titanium, zinc and zirconium substitute for antimony chemicals

in paint pigments and enamels. Combinations of cadmium, calcium, copper, selenium, strontium, sulphur and tin can be used as substitutes for hardening Lead. Selected organic compounds and hydrated Aluminium oxide are widely accepted substitutes as flame-retardants.

Currently, antimony-based catalysts account for around 90% of usage worldwide as they represent a low-cost good quality option. The bulk of polyethylene terephthalate (PET) used in the production of drinking bottles uses antimony catalysts but these are under regulatory pressure. In March, Toyobo in Japan announced it had developed an aluminium-based catalyst that was cheaper and did not discolour PET and, in October, Mitsui Chemicals unveiled a new titanium catalyst that it would start using at its plant in Indonesia where the company now makes regular PET resins that are not heat-resistant. Its new plant in Thailand, due to come on stream in 2004, will start by using an antimony-based catalyst but plans to switch over to titanium soon afterwards.

Also, early in 2004, the Japanese manufacturing giant Tejin Group was nearing completion of its development work on a titanium catalyst for PET, having already developed one for polyester fibres that targets substitution of antimony-based catalysts. In Japan, however, germanium has been the dominant base for catalysts for bottle-grade PET for the past 20 years because they are heat resistant and can endure sterilisation.

Any increase in demand for antimony would appear to depend upon the flame- retardant sector where annual growth is predicted to be 4% over the next five years. Major producers Albermarle Corp and Great Lakes Chemicals are confident about the outlook as increasing environmental, health and safety requirements, especially in developing economies such as China, come into effect. In February, Great Lakes added a fifth antimony oxide production line at its Reynosa facility in Mexico, boosting capacity by 20%. Great Lakes' antimony trioxide is used as a synergist, along with brominated flame-retardants, in flame-retardant polymer formulations widely used in electrical and electronic applications. It is also an effective flame-retardant in high- performance PVC applications.

One interesting development was that as semiconductor manufacturers widen their search for materials that can improve on the performance of silicon chips, Korean company Samsung Electronics announced in July that it had developed a new chip based on germanium-antimony-telluride. The chip has been developed for 'Phase-change' random access memory chips (PRAMS), which can process data faster than flash memory chips and unlike silicon are non-flammable. When the chips are commercialised it is expected that they will find applications in mobile telephones and digital cameras. Samsung Electronics and Intel Corp are leading the move to PRAMS and are expected to commercialise the chips by 2005.

China has so far been able to make up its shortfall of antimony concentrates by processing both stockpiled and imported material, but the closure of a number of smelters suggest that this situation is coming to an end. If the

antimony concentrate production figures are to be believed it cannot be long before more smelters close due to a shortage of feed. There are limited sources available outside China although there have been indications that mining activity in China can be increased.

The shortage of antimony concentrates, plus the tightening markets for antimony metal and trioxide, has so far not impacted on prices as demand for antimony and end products has been poor. Despite an improvement worldwide in consumer confidence in 2003 there is little possibility of demand increasing sufficiently to lead to a severe shortage of material.

Tables next page.

Table 1: World primary production, reserves and reserve base (antimony content)

Antimony	Production (t/y)		Reserves (t)	Reserve Base (t)
	2002	**2003**		
US	-	-	80,000	90,000
Bolivia	2,000	2,400e	310,000	320,000
China	118,000r	101,564	790,000	2,400,000
Russia	5,000	4,500e	350,000	370,000
South Africa	5,650r	6,700	34,000	250,000
Tajikistan	2,000	1,500	50,000	150,000
Other countries	2,000	2,000e	150,000	330,000
World total	**134,650r**	**118,664**	**1,764,000**	**3,910,000**

e - Estimated
r - Revised
Source: US Geological Survey Mineral Commodity Summaries January 2004 much of which contains estimated figures. Accordingly adjustments have been made where more accurate information has been obtained.

Table 2: Chinese antimony production 2001 – 2003

Production (t)	2001	2002	Annual % change	2003	Annual % change	% change 2001-03
Concs. (Antimony Units)	82,000	62,400	-24%	42,401	-32%	-49%
Refined Antimony Units	134,000	118,000	-12.1%	101,564	-14%	-24%

Source: National Bureau of Statistics, China.