Antimony

By Howard Masters

China continues to dominate the world antimony market and ever since a string of fatal mining accidents in the Nandan mining region of Guangxi Province in July 2001 led to the closure of many mines, the balance between supply and demand for antimony has been slowly shifting, from a surplus to a possible shortage. World consumption, however, has either declined or completely disappeared in almost all applications over the past 30 years, with the major exception of demand for antimony trioxide. This is used mainly as a flame retardant, and this application has been growing steadily. As a result, the market remained relatively stable throughout 2004 although by the middle of 2005 there were signs that the restrictions on supply were beginning finally to have an effect.

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 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 in 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.

Metallic 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* on an ‘in warehouse’

Rotterdam basis, was US$2,250.00-2,300.00/t at the beginning of 2004 but fears of shortages, encouraged by the possibility of disruption to shipments during the Chinese New Year, pushed prices higher during the first quarter, to US$2,900-3,000/t at the end of March 2004. The quotation slowly slipped back down to US$2,500-2,600/t by mid July as the summer months approached, only to recover sharply during August on news of severe flooding in the main antimony-mining areas of China, to a high quotation for the year of US$3,100-3,200/t. From this level, the price fluctuated in a narrow range, ending the year at US$2,750-2,850/t. Prices remained fairly stable through the first half of 2005, only to move even higher in July and August, to US$3,600-3,700/t as a result of further flooding in China and speculative pressure from producers and traders, who claimed that the problems in China were restricting the production of good-quality material.

The principal identified world resources of antimony are in China, Bolivia, Mexico, South Africa, the 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) (See Table 1).

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

	Mine production		Reserves	Reserve base
	2003	**2004[e]**		
US	-	-	80,000	90,000
Bolivia	2,300	2,600	310,000	320,000
China	101,564	83,000	790,000	2,400,000
Russia	4,500[e]	3,000	350,000	370,000
South Africa	5,300	5,300	44,000[r]	200,000[r]
Tajikistan	1,800	2,500	50,000	150,000
Other countries	2,200	2,000	150,000	330,000
World total	117,664	98,400	1,774,000	3,860,000

[e] - Estimated
[r] - Revised
Source:- US Geological Survey Mineral Commodity Summaries January 2005 much of which contains estimated figures. Accordingly adjustments have been made where more accurate information has been obtained.

Despite its reduced output, China remained dominant, providing around 80% of world mine output in 2004. 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).

Chinese production is split between state-run plants and the private sector. The main province for mining and production of Antimony was Guangxi but since the Nandan closures Hunan Province has become the most important followed by Yunan and Guizhou. Reliable statistics are impossible to obtain from China as even official figures vary according to the different bodies issuing them. Overall mine production capacity is estimated as up to 150,000

t/y but in the years prior to the Nandan closures actual production was generally either side of 100,000 t/y. The Nandan mines were the largest producers in China, with around 50,000 t/y of contained antimony. The loss of output from Nandan has been mostly made up by increased production in other areas and imports of concentrates from the CIS, Canada and Australia, estimated in 2004 at around 30,000 t, up from 27,000 t in 2003.

The state-owned Hsikuangshan Mining Administration based in Hunan Province is the world's largest single producer and has a capacity of 30,000 t/y of metal and antimony trioxide combined. The Zhazixi antimony mine, also in Hunan, is a typical medium-sized producer with a capacity of 3,000 t/y of metal and 5,000 t/y of oxide.

In Guangxi, the largest companies are Huan Dong Metal Materials Plant and Liuzhou China Tin Group. The latter controls two key smelters, Jing Chengjiang and Hechi Metallurgy and Chemistry Factory. Ore production in Guangxi was largely from a multitude of small family-owned mines that sold to the smelters but these mines have mostly been closed.

In mid 2004, it was announced that the state-owned Minmetals Group would henceforward be the sole entity permitted to exploit antimony from the Nandan mines although it may be some years before production of high-quality concentrate restarts.

Flooding continues to be a source of problems for antimony producers throughout southern China. During 2004, the Hsikwangshan North and South, Zhazixi and Banxi mines were all disrupted by heavy rain. Officials at Hsikwanghsan have also expressed concerns regarding long-term shortages as China's metal-in-concentrate market tightens owing to domestic reserve depletion.

Despite all these problems, according to China's National Bureau of Statistics total output for the eight-month period to August 2005 actually increased, by 10.5% to 89,118 t. During the same period, antimony concentrate production also rose, by 7.1% year-on-year, to 51,210 t.

Another big unknown is the level of Chinese domestic consumption, reported to have been around 40,000 t in 2004, up from 25,000 t in 2003. Export quotas for 2004 were reduced slightly to 65,700 t but statistics issued by China's General Administration of Customs showed exports during the year only totalled 21,487.70 t down 15% on the previous year. For the first six months of 2005, however, 17,525.30 t were reported. This apparent increase may well be the result of the government's crackdown on smuggling, which has been widespread. As an example, China's customs reported 1,060 t of antimony ingot exported to the US in the first five months of 2004 but this was nearly 50% below the 1.578 t of Chinese antimony reported by US customs as being imported during the same period. Similarly, Chinese figures showed 3,007 t exported to Japan in the first half of 2004 against Japanese customs figures of 4,042 t.

Export rebates were cut by the Chinese Government in May 2005, from 13% to 8%. If anything, this would encourage smuggling and it certainly gave a boost to prices, at least in the short term, as Chinese exporters looked to compensate for their losses. The Chinese Government's stated intention, however, is to cut back on unnecessary production of some metals as it struggles to deal with power shortages. In August 2005, the State Council announced it would impose quotas later in the year on the exploitation and export of several metals, including antimony, with the objective of controlling total output, optimising the industry structure, enhancing environmental protection and easing the energy squeezes. The policy is also designed to encourage reorganisation and combination to form industry giants and restrict illegal exploitation and excessive exports.

Details for the quotas would be worked out later in the year but, with export licences currently issued every year for 60,000-70,000 t, it can be seen that as exports are currently running at only some 50-60% of this figure, restrictions would have to be severe for there to be any positive results from such a policy.

Outside China, mine production comes mostly from Consolidated Murchison Ltd, South Africa's only antimony producer (with gold as a by-product), and is managed by mid-tier mining company Metorex Ltd. For several years, the mine's profitability has been affected by Chinese sales of metal and oxide depressing the international market.

In 2004, the mine in Northern Limpopo Province moved from profitability to operating loss as a result of low prices, the strengthening of the rand and underperformance in terms of both volume and grade.

Although the grade at the Beta Shaft area was higher than the average in 2003, tonnage declined owing to pillars being left in low-grade areas previously defined as payable reserves. In-stope development at Beta Shaft has increased, resulting in an increased development-to-stoping ratio. The grade at Alpha Shaft declined in 2004 and work in low-grade stopes was halted, resulting in a decline in total production. Monarch Shaft performed at about the same volume and grades as the previous year

Murchison's total tonnage milled declined from 550,000 t in 2003 to 475,000 t in 2004, partly because of under-production from Beta and Alpha Shafts but mainly as a result of the slowing of the open-pit section. The antimony head grade increased to 1.29% Sb but overall recovery declined and metal sales decreased accordingly. The mine sold 520,976 mtu (metric tonne units) of antimony in 2004 (2003: 551,352 mtu). Remaining resources, calculated in accordance with Samrec standards, indicate a remaining life of about seven years, to be extended by five years should the Monarch Shaft be deepened.

The most significant producing country after China used to be Kyrgyzstan, where antimony resources are found in nine main deposits, two of them are large (Kadamdzhai and Khaidarkan) both with more than 100,000 t of contained metal; seven are average size (Tereksai, Kassan, Abshir,

Savoyardy, Chaarat, Sharkratma and Murlau) each with more than 30,000 t. The Kadamdzhai Antimony Combine (KAC) is the only enterprise in the CIS that produces metallic antimony and has the capacity to produce 25,000 t/y of metal but in 2004 KAC only produced 320 t.

Kadamdzhai was commissioned in 1936 but since the collapse of the USSR production has sunk to record lows, owing to lack of finance, causing the combine to lose its traditional sources of ore and concentrates, principally Tajikistan and Russia. After several failed privatisation attempts, the combine was finally sold in June 2005 to the Kazakstan ATF-Invest Bank, which has promised to pay off all debts and invest in the plant. For the project to be successful, the new owners will have to redevelop concentrate supplies, and this could be difficult now that they are being diverted to China to offset the shortages arising there.

In Australia, re-opening of the Hillgrove mine in New South Wales continued to be discussed, and AGD Mining Ltd carried out further exploration at the Costerfield gold-antimony project in central Victoria. However, no significant antimony production has yet been reported from either project. In September 2004, Republic Gold Ltd reported that it had discovered a significant antimony mineral deposit at its Northcote site in Queensland. Drilling has revealed antimony sulphate, with a head grade ore of 2.5% Sb. This could be converted into concentrates in what is believed to be in saleable quantities.

In Latin America, Bolivia used to be a significant producer but the dominance of China has considerably reduced its output, despite the fact that mining still holds a pivotal place in the Bolivian economy. However, in the first four months of 2005, output climbed by 23% compared with the same period in 2004, to 1,399 t.

In Peru, antimony is produced as a by-product by Doe Run and output is believed to have reached 850 in 2004, which would be an improvement on the 606 t produced in 2003.

Mexico increased its production last year, by 37%, to 595 t.

In North America, a drilling programme was started in March 2004 by VVC Exploration Corp, the new owner of the Beaver Brook antimony mine near Gander in Newfoundland, Canada. Fill-in drilling at the main zone, and additional exploration drilling of the western extension, would complete the mine planning at one of the world's largest antimony deposits. Mining at Beaver Brook was suspended in 1998 owing to low world antimony prices. If put back into full production, VVC believes the mine could supply up to 5% of the world's annual demand; it would be North America's only producing antimony mine. US production of primary antimony ceased in early 2001, when the Sunshine silver mine in Idaho (which produced antimony as a by-product) closed down.

Antimony production from domestic source materials in the US during 2004 was derived entirely from the recycling of lead-acid batteries and supplied

only a minor portion of estimated US consumption. United States Antimony Corp (USAC) is now the only remaining producer of antimony products in the US. USAC processes ores supplied by 50%-owned Mexi Mine in Mexico, although it also recycles antimony products that would otherwise be taken to landfill sites. Great Lakes Chemical Corp and Laurel Industries Inc combined their antimony businesses with effect from May 1, 2004. Laurel Industries is part of the chemical operations of Occidental Petroleum Corp and, under the JV agreement, manufacturing has been consolidated into Great Lakes' facility in Reynosa, Mexico. Laurel's operation at Laporte, Texas, has been closed.

Despite the dearth of antimony mining in North America, the US is one of the world's major consuming markets.

Demand

Antimony metal is extensively used worldwide to harden and increase the mechanical strength of lead, particularly for use in wet-cell batteries. Consequently, some tonnages are recovered during recycling of antimonial lead. However, very little of the antimony trioxide used in flame retardants is recovered.

During 2004, most major antimony-consuming countries experienced a continuing trend towards lower demand in virtually all consumption categories. This can partly be attributed to higher antimony prices encouraging substitution. 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 in flame retardants but generally perform less well than antimony.

In the US, which along with Japan and Korea, provide the major markets, imports in 2004 dropped to an estimated total of 24,400 short tons for combined ore and concentrate, metal and oxide, against 26,700 st in 2003. World production of antimony continued to reduce during 2004 and if the restrictions on mining in China continue and lead to higher market prices for antimony, substitution would be further encouraged.

Antimony-based catalysts account for around 90% of usage worldwide as they represent a low-cost, good-quality option. In January 2005, however, Teijin Ltd in Japan announced that it will scale up its production of polyethylene terephthalate (PET) produced with titanium-based catalysts rather than using catalysts based on antimony, germanium or rare earths. At present, Teijin is producing about 7,000 t/y of PET, but intends to raise output to 16,000 t/y within the year. The company has been marketing the product to Europe for use in beverage bottles, fibres and films.

Because it is inert, titanium is being used increasingly in medical applications such as hip replacements, artificial joints and teeth, and last year the US Food and Drug Administration (FDA) approved its use in a new mesh device for

hernia repair. Teijin maintains, therefore, that a titanium catalyst for the production of PET food containers and wraps is preferable to other catalysts.

One problem in using titanium is its tendency to give a yellow tinge to the resin, an undesirable feature for a consumer plastic, but Teijin has now been able to correct this and predicts that this breakthrough will signal the end of PET catalysts based on antimony, germanium and rare earths.

Tokyo based Hitachi Maxell has developed a bismuth-coupling-material (BCM) phase-change recording film, which enables recording on rewritable DVDs to be accomplished more than four times faster than currently available alternatives.

Phase change film is traditionally composed from antimony-tellurium-based alloys such as those containing germanium, antimony and tellurium; or silver and indium. The BCM film consisting of bismuth, germanium and tellurium allows both high- and low-speed recording, such as 5 times and 2 times DVD-RAMs.

The future of antimony, therefore, would appear to depend upon the flame-retardant sector where demand in the US alone is expected to rise by 3.6% annually, to approximately 5,000 t in 2008. Gains in usage will be concentrated in more specialised antimony trioxide and magnesium hydroxide formulations, as well as in brominated and phosphorus compounds; alumina trihydrate (the largest volume product) will exhibit less rapid growth.