Platinum Group Metals

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INTRODUCTION

The term "platinum group metals" (PGMs) refers to six closely related metals generally found together: platinum (Pt), palladium (Pd), rhodium (Rh), ruthenium (Ru), iridium (Ir) and osmium (Os). These "noble" metals possess unusual qualities such as high melting points and chemical inertness and, most importantly, exceptional catalytic properties, even under conditions of severe temperature and corrosion.

Industrial demand for PGMs in the market economy countries for 1995 and 1996 was estimated at:

	1995	1996[e]
	(tonnes)	
Platinum	145.3	142.8
Palladium	189.7	190.0
Rhodium	14.3	13.0
Iridium	1.6	2.0
Ruthenium	9.8	10.7
Osmium	. .	. .

Source: Johnson Matthey.
. . Not available; [e] Estimated.
Note: Data have been converted from troy ounces to tonnes.
One tonne = 32 150.7 troy oz.

These data understate total demand, as they are net of material recovered from recycling (except for autocatalysts). Industrial demand for platinum (i.e., not including investment sales or exports to China) for 1996 in the market economy countries is estimated at 135.5 t, up slightly from 134.5 t in 1995.

The principal uses for platinum and rhodium are in catalysts, especially autocatalysts, which account for about 40% of industrial demand for platinum and about 75% of demand for rhodium in market economy countries. Electrical, autocatalyst and dental uses account for over 90% of the demand for palladium.

Japan is the leading industrial consumer of both platinum and palladium, while lagging behind both Europe and North America in the much smaller rhodium market. Considering platinum, palladium and rhodium together, Japan is the leading industrial consumer with a 37% share, while North America and Europe account for 29% and 23% respectively of the 338.5 t of demand in 1996 (unchanged from 1995).

The supply of primary PGMs from market economy countries, plus Russian exports but excluding stock movements, was estimated at:

	1995	1996[e]
	(tonnes)	
Platinum	155.2	150.9
Palladium	197.2	186.0
Rhodium	13.6	14.4

Source: Johnson Matthey.
[e] Estimated.
Note: Data have been converted from troy ounces to tonnes.

The Republic of South Africa (RSA) and the Russian Republic are by far the major producers of PGMs. Canada and the United States, with much smaller outputs, are second-rank producers. In Canada and Russia, PGMs are by-products of nickel production, although both Canada and the United States each have a single mine producing PGMs as the main product. Inco is the largest PGM producer outside of South Africa and the Russian Republic. The relative shares of primary output of the leading producers in 1996 were:

	Platinum	Palladium	Rhodium
		(%)	
Republic of South Africa	71	30	77
Russia (exports)	19	60	19
Total	90	90	96

Source: Natural Resources Canada, calculated from data of Johnson Matthey.

Russian PGM production is a State secret. It is widely accepted that much of the Russian exports since 1990 have been from stockpiles, in the order of 50% of total exports in the last two years.

The prices of platinum and palladium are determined daily in a number of markets; London, New York and Tokyo are the principal markets for platinum and palladium. Johnson Matthey issues prices daily for platinum, palladium, rhodium, iridium and ruthenium. Various publications list prices for rhodium.

The average London prices for the three principal PGMs were (in US$/troy oz):

	1995	1996e
	(US$/troy oz)	
Platinum	424.20	397.21
Palladium	151.32	128.12
Rhodium	446.19a	295.78a

Source: *Metals Bulletin*.
e Estimated.
a Average of high and low European Free Market price.

CANADIAN DEVELOPMENTS

Primary PGM output in Canada declined from 1995 to 1996 despite increased nickel production and increased output from Canada's sole primary PGMs mine. Canadian PGM data show the PGM content in nickel-copper mattes exported by Canadian smelters plus the recoverable PGM content in concentrates exported. While Canadian export statistics do not show the exports of contained PGMs in the matte exported to Norway, these data are incorporated into the PGM production data for Canada as shown in the following table:

Year	Canadian PGM Production1
	(tonnes)
1990	11.12
1991	11.12
1992	11.31
1993	11.82
1994	13.42
1995	16.07
1996e	13.48

Source: Natural Resources Canada.
e Estimated.
1 Recoverable tonnage from primary sources.

In addition to primary PGM output, Canadian non-ferrous producers recover considerable amounts of PGMs by recycling domestic and imported post-consumer materials. Obsolete autocatalysts, industrial catalysts, electronics, telecommunications equipment and other post-consumer materials are the main sources of post-consumer items that contain sufficient PGMs to warrant recovery.

Canada has one producer with PGMs as the principal product and two producers of by-product PGMs. North American Palladium Ltd. operates the Lac des Iles open-pit PGM mine in northern Ontario. Inco Limited and Falconbridge Limited recover PGMs as by-products of their nickel-copper operations. Inco's Sudbury, Ontario operation is the source of the majority of Canada's primary PGM output. A small portion of Inco's PGMs comes from its Manitoba operations. Ontario accounts for the vast majority of Canada's primary PGM production.

In Sudbury, Inco is proceeding with the development of the McCreedy East mine and completing detailed exploration and evaluation of the Victor deposit. Both deposits contain higher-than-average precious metal content of 13.4 g/t and 7.6 g/t respectively.

Canadian PGM production is expected to increase in the future for two reasons. First, output from Lac des Iles should rise following de-bottlenecking and the increase in crushing capacity completed in 1996. Second, Canadian nickel production is expected to rise as Falconbridge's Raglan property comes on stream. The Raglan deposit, which contains somewhat more PGMs per tonne than does the ore from Sudbury, is scheduled to begin production in December 1997.

Both Inco and Falconbridge ship contained PGMs to refining facilities in Europe for final recovery. Falconbridge sends its PGMs, contained in a copper-

nickel matte, to the company's Nikkelverk refinery in Norway. These contained PGMs in the matte are not reported in Canadian export data. Nikkelverk also processes primary materials from other primary and secondary sources. Nikkelverk's capacity has recently been increased to handle additional material from Raglan and elsewhere.

Inco's platinum refinery in Acton, United Kingdom, processes both primary and secondary materials, and also toll refines PGMs. Inco's deliveries of PGMs from primary sources, mostly Canadian, between 1993 and 1995 were:

	1993	1994	1995
		(tonnes)	
Platinum	3.6	3.5	4.1
Palladium	4.8	3.9	4.8
Rhodium	0.4	0.3	0.3

Source: Inco Limited annual reports.

Canada's PGM mine operated by Lac des Iles Mines Ltd. is located 80 km northwest of Thunder Bay, Ontario. The operation began mining in December 1993. North American Palladium Ltd., formerly Madeleine Mines Ltd. until June 1993, owns Lac des Iles, which itself was incorporated in 1991.

As of the end of 1995, the probable ore reserves of the Roby Zone totalled 6 Mt grading 6.7 g/t PGMs in the ratio of 14:1 palladium:platinum (Pd:Pt). The C Zone's probable reserves were 2.1 Mt grading 4.1 g/t PGMs in the ratio of 9:1 Pd:Pt. The total reserves will supply 2700 t/d for 11 years, equivalent to 7.5 years from the Roby Zone and 3.5 years from the C Zone. Nine of the eleven years of ore reserves were categorized as probable ore reserves as of the end of 1995.

Two pits, the Roby Zone and C Zone, are presently being mined. The ultimate pit for the Roby Zone is designed at 610 m x 365 m by 245 m deep, targeted at 7.2 Mt of ore. The Roby Zone ore may continue to a depth of 460 m or more, and an additional 0.58 Mt of ore could be mined using underground methods. The C Zone pit design envisages an ultimate depth of 150 m.

Ore grades were improving by the third quarter of 1996 but, due to mine development, the mined ore was still running at below reserve averages. Increasing ore grades and tonnage are expected in 1997.

During 1996, various projects to increase operating efficiency were completed, including a 65-km power line, new crushing facilities, and improvements in the mill. The company expected that crushing costs will decline by 50% to about C$2.50/t and power costs decrease from 13¢/kWh to less than 3¢/kWh. Lac des Iles production has been:

Year	Palladium	Platinum	Gold
		(kg)	
1994	1 836	117	108
1995	2 385	156	150
1996[a]	1 308	92	86

Source: North American Palladium Ltd.
[a] Data for nine months.

In addition to PGMs and gold, Lac des Iles produces small quantities of copper and nickel. Lac des Iles concentrates are shipped to Falconbridge Limited in Sudbury for processing, with the final recovery of the metals occurring at Falconbridge's Nikkelverk refinery in Norway.

Both Inco and Falconbridge also recover PGMs from scrap and secondary materials, including autocatalysts. At the Horne smelter in Quebec, Noranda Inc. processes electronics and telecommunications equipment to obtain significant amounts of palladium and platinum.

WORLD DEVELOPMENTS

South Africa and Russia are the leading producers of PGMs. The United States and Canada are the third and fourth largest producers of primary PGMs, but their combined output is less than 10% of world PGM production. Zimbabwe will become an important producer of PGMs, starting in 1997, with good potential to increase production substantially. Finland, Japan, the former Yugoslavia, Ethiopia, Colombia, Zimbabwe, Uzbekistan and Australia each produced less than 1% of world PGM production in 1996. Primary PGMs are also produced in the People's Republic of China, associated with the approximately 40 000 t/y of nickel production from the Jinchuan Nickel Corporation.

Generally, only South African orebodies were exploited principally for their PGM values in 1996. Elsewhere, PGMs are the by-products of the mining of other metals (usually nickel); however, the Lac des Iles mine in Canada and the Stillwater mine in the United States are PGM mines. For example, the Russian Norilsk complex produces almost all of the country's PGMs and produced most of the 251 000 t of reported nickel production in Russia in 1995. In addition, it also produces very significant amounts of copper and cobalt.

Platinum Supply

Primary platinum supplies available to market economy countries declined slightly in 1996, mostly due to a decline in Russian exports. Primary output in the Western World was estimated at 150.9 t, compared to 155.2 t in 1995.

In addition, Johnson Matthey estimated that 11.5 t of platinum were recovered from the recycling of autocatalysts in 1996, up from 10.4 t in 1995.

South Africa is the largest platinum producer delivering 104.8 t to markets in 1995 and an estimated 106.4 t in 1996. South Africa's PGM output is derived almost exclusively from three reefs located in the Bushveld Complex, namely the Merensky Reef, the UG2 Reef and the Plat Reef. In addition to the PGMs from the Bushveld Complex, minor amounts of PGMs (less than 0.5% of total production) are recovered from the processing of copper ores at the Palabora mine and the gold deposits of the Witwatersrand Basin.

Each reef in the Bushveld Complex has a different ratio of PGMs. The estimated in-situ content of two of these reefs is: Merensky, 3.43 g/t platinum, 1.98 g/t palladium and 0.19 g/t rhodium; and UG2, 2.66 g/t platinum, 1.71 g/t palladium and 0.44 g/t rhodium.

It is estimated that about two thirds of the in-situ PGMs are recovered on average for sale as metal. The Plat Reef is more variable than the Merensky or UG2 reefs with contents varying between 7 and 27 g/t total PGMs.

Gencor Ltd. is the second largest producer of platinum in South Africa; through Impala Holdings Ltd. (Implats) it owns significant shares of Impala Platinum Ltd., Barplat Investment Ltd. and Messina Ltd. Implats operates two mining complexes – Bafokeng North and Wildebeestfontein South. It holds a 27% equity share and profit participation in Lonrho's Eastern Platinum Limited and Western Platinum Limited as the result of a merger of its Karee mine and Middelkraal reserves with Western Platinum in 1989. Impala and the Bafokeng tribe did not resolve a dispute about royalties owed. The tribe had challenged the validity of an agreement negotiated between a trustee for the tribe and Impala; the tribe sought a 25-33% increase in royalties.

Lonrho Plc, headquartered in London, is the third largest platinum producer in South Africa, producing about 17% of the country's PGMs. It owns Western Platinum Limited and Eastern Platinum Limited, with Implats having an equity share in both operations. Lonrho's reserves are being sought by the two largest South African producers, Impala Platinum Holdings Ltd. (Implats) and Anglo American Platinum Corporation Ltd. (Amplats).

In 1995, Gencor Ltd. sought European Commission approval for a planned merger of the platinum operations of Implats with those of Lonrho Plc to give Implats access to Lonrho's shallower reserves. In 1996, following its investigation, the European Commission blocked the proposed merger on the grounds that the merger would have lessened competition by creating a duopoly in the platinum market.

Anglo American Corporation of South Africa Ltd. controls the world's largest platinum operations through Amplats, producing about half of South Africa's PGM production. Amplats produced nearly 50 t of platinum in fiscal year 1995/96, managing Rustenburg Platinum Holdings Ltd., Potgietersrsrust Platinum Ltd. (PPRust) and Lebowa Platinum Mines Ltd. Rustenburg Platinum operates three deep underground mines on the western rim of the Bushveld Complex: the Rustenburg Section, the Union Section, and the Amandelbult Section, as well as some small pits. PPRust and Lebowa each operate one mine, the PPRust mine being an open pit. Rustenburg was the site of a serious labour dispute in 1996 that resulted in a production loss of about 3.1 t of platinum.

In March 1996, Anglo announced its purchase of 5.9% of Lonrho Plc's shares with first right of refusal for another 18.5% of Lonrho's shares. Despite a warning by the European Commission against taking control of Lonrho because of concerns about competition in the platinum market, Anglo later increased its shareholding in Lonrho to 28%, making it the largest single shareholder. The European Commission and Anglo later began talks about Anglo's role in Lonrho, and these talks had not been resolved by the end of the year.

Anglo American Corporation is a large shareholder in Gold Fields of South Africa Ltd., which in turn is a major shareholder in Northam Platinum Ltd. Northam's PGM mine has lost money since its start-up in 1992. Northam produces less than 5% of South Africa's PGMs.

Russia

Russia is the second largest producer of platinum. Russian exports of platinum have increased significantly since 1989, as shown below. Exports in 1996, already down slightly from 1995, were still 3.8 times that of the export level of 1986.

It is widely accepted that sales from stockpiles have allowed Russian exports to sustain such high levels since the late 1980s. Speculation is that perhaps half of the recent export levels, or about 17 t/y, were released from the stockpile. Most of the remainder (i.e., estimated at about 17-23 t/y) came from the RAO Norilsk Nickel operation, the most important Russian PGM producer.

Norilsk Nickel's Siberian operation is a nickel-copper operation with by-product PGMs. It is thought that Norilsk's PGM grades vary between 45 and 340 g/t. No other comparable PGM producers are known to

exist in the former Soviet Union, although there is some placer recovery of platinum in Russia. At sites ranging from the Urals to the Kamchatka Peninsula, placer operations recover in the order of 5-6 t/y of platinum.

PGM output and the size of the stockpile are state secrets. Observers have used nickel production as a proxy for indications of PGM output. Official Russian nickel production data, of which Norilsk is the most important producer, shows that nickel production increased from 212 000 t in 1994 to 251 000 t in 1995, and was running at 6% below 1995 levels for the first nine months of 1996. It has been speculated that PGM output from Norilsk declined from 1990 to 1993, but then recovered somewhat in 1995 due to increased throughput and increases in PGM grades.

Norilsk faces many challenges in trying to maintain production levels. The operation needs investment to modernize, to address environmental problems, and to maintain an adequately developed reserve base. Norilsk faces its traditional problems due to an isolated location and the harsh climate that increases shipping difficulties for its principal products: nickel and copper. Uncertainty associated with the restructuring of the Russian economy has been compounded by the purchase of 38% of its shares by Uneximbank Bank in 1995 and ensuing changes in senior personnel.

Year	Russian Platinum Exports
	(tonnes)
1986	9.0
1987	12.4
1988	13.7
1989	16.2
1990	22.4
1991	34.2
1992	23.3
1993	21.2
1994	31.4
1995	39.8
1996[e]	34.2

Source: Johnson Matthey.
[e] Estimated.
Note: Data have been converted from troy ounces to tonnes.

United States

In the United States, Stillwater Mining Company increased its production, mill head grade and reserves in 1996. Its production increased to 1.8 t of platinum and 6.1 t of palladium, up 16% from 1995. Stillwater plans to double mine output. Even at that rate, the smelter will still have excess capacity. The company conducted tests on secondary materials in 1996 and may increase smelter throughput with secondary feed. The PGM-bearing matte from the Stillwater smelter is shipped to Belgium for final refining.

Zimbabwe

Zimbabwe continues its emergence as an increasingly important factor in the PGM world. The Broken Hill Pty. Co. Ltd. and Delta Gold N.L. own the Hartley platinum mine in Zimbabwe, which began mine production at the end of 1996; the mill has also been commissioned. The cost of the mine, mill and smelter exceeded original budget estimates of US$264 million by US$23 million. The mine is scheduled to reach an operating rate of 90 000 t/m by September 1997, and then to reach its full operating rate of 180 000 t/m 12 months later. Smelter commissioning was under way at the end of 1996. PGMs and gold will be refined in the United Kingdom. Proven reserves are 51 Mt grading 2.64 g/t platinum, 1.8 g/t palladium, 0.21 g/t rhodium, 0.47 g/t gold, and some nickel and copper. About 115 Mt of additional ore have been indicated but classified as a "resource." At full production the operation is designed to process 2.16 Mt/y of ore to yield 4.7 t of platinum, 3.4 t of palladium, 0.4 t of rhodium, 0.7 t of gold, as well as some nickel, copper and cobalt. Twenty years of various categories of reserves have been identified at relatively shallow depths of 100-500 m.

The possibility of doubling Hartley's output has been planned. Much of the infrastructure was designed to support such an option. Doubling its production capacity would cost an estimated US$100 million. In addition, there is the possibility of a joint venture with the Mhondoro prospect owned by BHP and Delta Gold. Such a joint venture could increase total production from the Mhondoro-expanded Hartley complex to about 6 Mt/y of ore. Other candidates for future development include the Ngezi Platinum Area and the Selous Platinum Area, both owned 100% by Delta. Grades and tonnage at the Ngezi prospect are said to be similar to those at Hartley.

The state-owned Zimbabwe Mining & Smelting Co. (Pvt) Ltd. produced about 0.4 t of platinum in 1996 during trial mining operations. Its planned operating rate is 300 000 t/y of ore, with plans to increase the rate to 750 000 t/y. Much of the infrastructure was designed to support such an expansion.

Platinum Recycling

Recycled PGMs are commodities that compete with primary material. Platinum and other PGMs are recovered from a variety of post-consumer scrap and other sources. Used industrial catalysts, electronic scrap, jewellery sweepings, autocatalysts and

telecommunications equipment are important sources of PGMs. In Johnson Matthey's extensive reviews of the PGM industry, demand in each sector except autocatalysts is net of recycling, thus indicating the primary metal requirements.

Primary Palladium Supply

The primary palladium supply to market economy countries declined in 1996 due to reduced sales from Russia. Unlike platinum, South Africa is not the premier palladium producer; Russian exports provide over twice the amount of palladium to market economy countries than does South African production. Primary palladium supply to market economy countries (including Russian exports) was estimated at 186.0 t in 1996 compared to 197.2 t in 1995.

In addition, Johnson Matthey estimates that 3.6 t of palladium were recovered from the recycling of motor vehicle catalysts in 1995. This rose to an estimated 4.2 t in 1996. Secondary palladium is recovered from nonferrous facilities in Finland, Belgium, South Africa, Sweden, Japan, the United States and Canada.

Primary Rhodium Supply

The supply of primary rhodium to market economy countries increased in 1996 by 6% to an estimated 14.4 t. South Africa is the largest rhodium producer. Russian exports are the second most important source of supply to market economy countries.

Dependence on South Africa and Russia is even higher for rhodium than for platinum or palladium. Over three quarters of the rhodium supply to market economy countries originates in South Africa, with an additional 19.5% coming from Russian exports.

Higher prices for rhodium in the early 1990s (over US$5000/oz) caused producers to seek to maximize rhodium output and spurred consumers to seek cheaper substitutes. Even though prices have declined by 90% from the high levels of the early 1990s, the output of rhodium has not plummeted because rhodium is a by-product of platinum and palladium production.

CONSUMPTION AND USES

PGMs are used in a wide variety of applications in pure form, in alloys with other PGMs, or are alloyed with other metals. The diversity of their uses reflects their varied and unique attributes. The qualities of PGMs include:

- chemical inertness,
- resistance to corrosion,
- high-temperature oxidation resistance,
- very good ability to catalyze chemical reactions,
- high melting point,
- high strength at elevated temperatures,
- low coefficient of thermal expansion,
- stable thermo-electric properties,
- good mechanical durability, and
- stable electrical contact resistance.

The four largest industrial consuming sectors for platinum and palladium were electrical, 73.2 t; autocatalysts, 111.5 t; jewellery, 63.5 t; and dental (palladium only), 40.7 t.

An additional 7.3 t of platinum were removed from available supply by investments. Net stock changes resulted in 2.5 t of platinum going into stocks, while 4 t of palladium came out of stocks.

Platinum and palladium are the most widely used of the PGMs. In 1996 they accounted for 40% and 53% respectively of a total industrial PGM demand of 358.6 t.

Platinum Consumption

Japan is the leading industrial consumer of platinum, taking about 43% of industrial demand. Industrial demand in North America and Western Europe accounts for 22% and 20% respectively of total industrial demand in market economy countries.

Japan is a distinctly different market from Europe and North America with a different pattern of platinum demand. In Japan, the major use for platinum is in jewellery. Japanese jewellers accounted for 79% of the 58 t of Japanese industrial demand in 1996. In contrast, in Western Europe and North America, autocatalysts are the largest consumption sector of platinum, accounting for 60% of the net industrial demand in each of the two regions. Autocatalysts and jewellery together account for about 76% of industrial platinum demand in market economy countries.

Other industrial uses include glass-making, and use in the chemical and petroleum industries.

Autocatalysts

Automobile emission limits were first legislated in the United States in the late 1960s. The emission limits were progressively tightened and oxidation catalysts were required to meet air pollution control limits. By 1983 all new light-duty gasoline-powered vehicles in the United States were fitted with three-way catalysts. In the autocatalyst, platinum efficiently transforms hydrocarbons (HC) and carbon monoxide (CO) in the exhaust gases to more benign substances, while rhodium is most efficient at handling oxides of nitrogen (NO_x). Palladium can handle all three pollutants, but less efficiently than either platinum or rhodium.

Other countries have adopted emission controls modelled on those of California. Canadian emission regu-

lations were implemented in 1987. European regulations required new cars with gasoline engines to have catalytic scrubbers as of 1993. Industrializing nations have also introduced regulations as their motor vehicle density increased. The demand for autocatalysts is forecast to continue to rise as regulations ratchet down emission limits and as the number of jurisdictions regulating emissions increases.

The composition of autocatalysts varies according to prices for the various PGMs, the composition of the fuel, the regulated limits, and the service life of components. Southeast Asia and other areas with gasolines that have significant amounts of sulphur or lead inhibit the use of catalysts richer in less expensive palladium. In North America, Ford Motor Company opted to equip most of its vehicles with palladium-rich autocatalysts. In Europe, moves to palladium-richer catalysts for gasoline engines have been somewhat offset by the need for platinum catalysts to control emissions from diesel engines.

Clean Diesel Technologies Inc. patented a platinum fuel additive for use with diesel fuels. The platinum additive reduces hydrocarbon, carbon monoxide and particulate emissions. The platinum in the additive is not recoverable.

Jewellery

In 1996, Japanese jewellers consumed more platinum (46 t) than did the total net demand for autocatalysts in market economy countries (45.1 t). The platinum industry has promoted the consumption of jewellery through the "Platinum 1000" concept. Such jewellery is almost pure platinum (exceeding 99% by weight) and, because it is a softer alloy, the jewellery is generally heavier. Other markets for platinum jewellery are much smaller than the Japanese one.

Other Platinum Consumption

All other uses of platinum are relatively minor compared to autocatalysts and jewellery. Chemical uses and petroleum refining make use of platinum to increase the speed and efficiency of chemical reactions. The electronics industry uses platinum in substrates in the manufacture of computer hard disks. The glass industry uses platinum in the manufacture of glass fibres, drawing on platinum's corrosion resistance and strength.

One minor application that currently shows promise for increased future consumption is the manufacture of fuel cells. Fuel cells generate power by combining oxygen and hydrogen, yielding water and energy as products. Various technologies are being investigated; the two most popular technologies are the phosphoric acid fuel cell (PAFC) and the proton exchange membrane fuel cell (PEM).

The first commercial fuel cell to run on renewable fuel began operating at a landfill in the United States in mid-1996. The 200-kW PAFC from International Fuel Cells Corp. will use the methane generated from the landfill to provide heat and electricity for an estimated 18 months.

The PEM fuel cells have a higher power-to-weight ratio than the PAFCs do, and are therefore more suitable for motor vehicles.

Ballard Power Systems Inc., located in British Columbia, signed a number of contracts in 1996 to supply PEM fuel cells. Ballard will supply two 250-kW power plants for field trials with GPU Inc. of the United States, and two test plants to Howaldtswerek-Deutsche Werfte, a German submarine builder. In February, Ballard signed a C$2 million research contract with Honda Motor Co. Ballard has arrangements with three other automakers, two German and one Swedish, to test its fuel cells. Transit buses powered by Ballard fuel cells will begin testing in 1997 in Vancouver and Chicago, joining the ones presently on trial in Los Angeles.

Investment Offtake

Japan is the leading buyer of platinum for investment purposes. Platinum bars and coins are a form of investment to hedge against inflation or a means to speculate against platinum prices. However, as platinum is also an industrial metal like silver, material previously taken off the market for investment can later appear as feed for industrial demand. In 1996, investment is estimated to have amounted to 7.3 t, or 5.4% of industrial demand. In 1995, investment amounted to 10.7 t.

The Royal Canadian Mint's sales of platinum Maple Leaf coins in 1996 were about 2.1 t, up from 0.98 t in 1995. Increased export sales were responsible for some of the higher demand.

The U.S. Mint received authorization in 1996 to issue platinum Eagle coins. These are expected to be available in the first quarter of 1997, to be followed by a larger bullion issue for the investment market.

Palladium Consumption

Japan's dominance as the leading consumer of palladium has eroded in the last decade. In the late 1980s, Japan consumed about 50% more palladium than did North America and about 2.5 times more than Europe. By 1996, the estimated shares of demand by Japan and North America were about equal, while Europe accounted for almost one quarter of demand in market economy countries. The reason for the accelerating demand in North America has been the use of palladium in autocatalysts; net demand in this sector in North America has risen almost ninefold since 1986 to 36.2 t.

Similar to platinum, the pattern of Japanese demand for palladium differs from that in Western Europe

and North America. In Japan, the major use for the 65.8 t of palladium used in 1996 was in electrical applications, representing about 59% of Japanese industrial demand. In North America and Europe, which used 65 t and 45.9 t respectively, just over half of their industrial demand for palladium is accounted for by use in autocatalysts. On a worldwide basis, autocatalysts are the leading consuming sector for palladium, slightly edging out the electrical sector. The sectorial net industrial demand (excluding investment offtake) in 1996 for market economy countries was estimated at 65.9 t for electrical, 40.7 t for dental, 66.4 t for autocatalysts, 6.2 t for jewellery and 6.2 for other.

Palladium usage in the electrical sector has increased along with the rapidly rising demand for electronic goods such as personal computers, mobile phones and video cameras. The newer generations of electronic equipment also use more multi-layered ceramic capacitors (MLCC) that contain palladium. While nickel has made limited inroads into this use, palladium still provides superior performance and ease of manufacture. Declining palladium contents in individual components have been somewhat offset by increased MLCC use.

The third largest use for palladium is in dental alloys, orthodontic devices and prosthodontic devices. Other industrial uses for palladium include industrial catalytic applications, pharmaceutical and nitric acid production, petroleum refining, and jewellery.

Autocatalysts have been described above in the section on platinum.

Rhodium Consumption

Unlike platinum or palladium, Japan did not dominate the much smaller rhodium market of 13 t in 1996. Both North America and Western Europe consumed more rhodium in 1996 than did Japan. Autocatalysts account for over 85% of rhodium consumption in market economy countries.

Small amounts of rhodium were used in the chemical, electrical and glass industries. In these applications, rhodium is used with other PGMs to produce an alloy with enhanced physical or catalytic properties.

Consumption of other PGMs

Ruthenium and iridium demand is much lower than the demand for platinum or palladium. Estimated demand in 1996 for ruthenium was 10.7 t, and for iridium was estimated at about 2.0 t. Demand data for osmium are not available.

Ruthenium has a variety of uses; the most newsworthy in 1996 was its use as a catalyst in the Kellogg Advanced Ammonia Process. The use of ruthenium instead of iron as a catalyst permitted lower operating pressures, which in turn saves power costs. Other applications include its use in the manufacture of chlorine and caustic soda.

Half of the demand for iridium comes from the electochemical sector. Iridium-ruthenium alloys have been used instead of ruthenium for electrodes in chlor-alkali plants. Iridium has also displaced rhodium catalysts used to make acetic acid. Other uses include minor amounts in autocatalysts used with direct fuel-injection engines and in electrolytic cells to produce sodium chlorate.

MARKETS AND PRICES

The average annual prices of the major PGMs over the past three years were provided in the introduction. Table 3 shows average monthly prices for the three major PGM metals for the past three years. Figure 1 shows the daily London AM fix for platinum from 1992 to 1996.

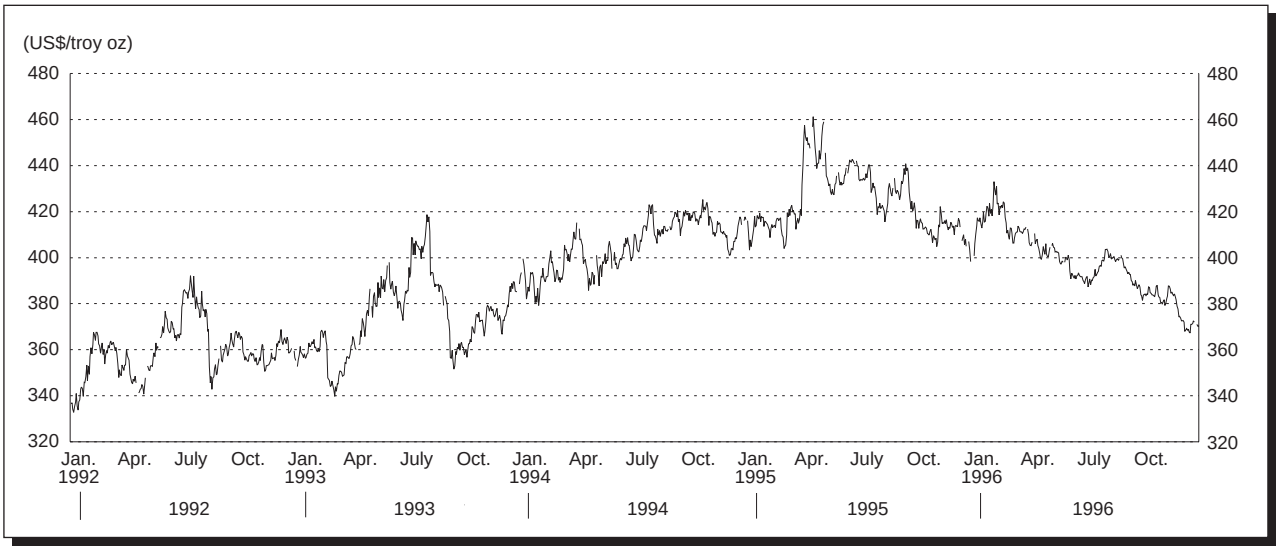
Platinum prices appear to have been caught in the down-draft of declining gold prices during the latter part of 1996. Palladium prices were better supported due to their larger component of industrial usage bolstered by moves to palladium-rich autocatalysts, and by their relative lack of exposure to changes in investment demand. Rhodium prices continued to languish in the range of $220-$230/oz at the end of 1996, the legacy of past producer decisions to maximize rhodium output when prices were high and consumer decisions to substitute away from rhodium.

OUTLOOK

Canadian PGM production is largely a function of nickel production but, over time, nickel producers can shift the PGMs-to-nickel ratio. Canadian PGM production is forecast to increase as Canadian nickel production rises due to output from the new Raglan operation. In addition, output from Lac des Iles is expected to increase as mine production increases and capital expenditures are made to debottleneck the mill.

A large proportion of Canada's PGM production is produced as the by-product of other metals. By-production from Canada and Russia is less sensitive to PGM prices than is production from the United States or South Africa. In some applications, such as autocatalysts, demand is fairly price insensitive in the short to medium term. An autocatalyst containing, for example, about 1.5 g of platinum and 0.3 g of rhodium would cost an automaker about $20 for the PGMs, based on average 1996 prices. Since this catalyst is essential to selling the car, automakers would pay multiples of this price to avoid an inability to sell the entire vehicle; therefore, PGM demand for autocatalysts is fairly insensitive to price in the short term.

Figure 1
Platinum Prices, London AM Fix, 1992-96



Source: Natural Resources Canada, based on various sources including *Reuters* and *Metals Week*.

In certain other applications, PGMs are more susceptible to substitution. Other metals can substitute in certain industrial catalytic or electronic applications. These industrial applications can be more immediately threatened with substitution when PGM prices increase. Jewellery and investment purchases are more sensitive to prices, although this sensitivity is tempered by investors who are unwilling to take a loss when prices decline sharply and by those with sentimental attachment to jewellery.

With the potential for supply disruptions in South Africa and Russia in the short to medium term, the possibility of spectacular price increases cannot be ruled out. In the event of major supply disruptions with the potential to be sustained, speculative demand would compound price increases since no other producers have the capacity to fill a void left by severe shortfalls in either Russian or South African production.

Over the next few years, the state of the Russian PGM stockpiles will be an important question. Once thought to be capable of sustaining only a few years of increased exports over the "normal" levels of the late 1980s, they have proven to be more substantial. At present, speculation is that they may only last a few more years. The actual size of the stockpiles and the strategy that is followed to phase out sales as stock levels decline will be important determinants for the prices of palladium and platinum.

While the primary platinum market can only react slowly to price changes because of the inertia of mining layouts and smelting/refining technology, in contrast, the secondary market for PGMs can react more quickly. This ability could be compromised by regulations that treat used autocatalysts and other secondary forms of PGMs as "hazardous wastes." While the Basel Convention has the potential to seriously disrupt international trade in certain secondary PGMs, the bulk of secondary PGM trade amongst OECD countries is covered by a March 1992 OECD Decision.

Autocatalysts should remain a dependable market for PGMs in the medium to long term. The market for emissions control technology will grow as vehicle numbers increase, emission limits decrease, and the service life of components is extended. While gasoline and diesel engines will continue to be used in most motor vehicles, the use of PGMs, especially platinum and rhodium, in autocatalysts will remain a secure source of demand. Some increased efficiencies in PGM use in autocatalysts can be expected but, as of yet, no substitutes appear to be sufficiently advanced to threaten the use of PGMs in autocatalysts. There is room for inter-PGM substitution, as low lead and low sulphur levels in gasolines permit the substitution of platinum by palladium in some catalysts.

However, as the use of autocatalysts becomes more widespread, increasing amounts of PGMs will be recovered from scrapped vehicles. Once the population of vehicles equipped with PGM catalysts is sufficiently large and widespread, then the rate of demand for primary PGMs will slow. Primary PGMs would then be needed only to make up for losses in recycling, for net new internal combustion vehicle registrations, and for increased PGM loadings per vehicle to meet new standards.

In the long term, as zero emission vehicles (ZEVs) become more widespread, fewer catalysts would be required on the world's motor vehicle fleet. While the fuel cell has the potential to become the power source for ZEVs, so do many other competing technologies such as lead-acid batteries, the aluminum battery, nickel hydrides and others.

A very large above-ground inventory of platinum exists that could be mobilized by a spectacular price increase. As was the case with silver, when prices rise above certain levels, despite the potential for further price increases, temptation results in even heirlooms being brought in for melting. Since 1980, the estimated cumulative investment sales amount to over 160 t of platinum, or over one year of current demand. Jewellery sales since 1980 represent an estimated reservoir exceeding 620 t of platinum, or over four years of current primary demand.

Price Outlook

Due to the narrow production base for PGMs, their prices are more volatile than those of the major industrial base metals such as iron and steel, copper or aluminum. The most significant factors affecting prices are whether labour or political events interfere with PGM output in Russia or South Africa, the size of the Russian PGM stockpile and the degree to which it will be drawn down, and the rate of economic growth worldwide which affects demand for PGMs.

As demonstrated in the latter part of 1996, the price of gold can play an important role in platinum prices. Gold is an important competitor for platinum for investment and jewellery demand. However, predicting gold prices is also difficult and, hence, using it to predict platinum prices poses a problem.

In the medium and longer term, Zimbabwe's role as a PGM supplier is likely to become more pronounced. It appears that Zimbabwe has considerable potential PGM reserves at shallower depths, making them cheaper to exploit. Future Zimbabwean production will relieve some of the pressure on prices.

With major uncertainties overshadowing PGM prices, it is very difficult or impossible to forecast prices with a reasonable degree of accuracy. Cost pressures, especially labour costs, in South Africa may be expected to push prices higher over time unless productivity increases continue. Eventually, the Russian stockpile will be depleted, unless production from Norilsk is higher than any observers speculate, and the supply void created by decreased Russian exports will push prices higher until new capacity can be brought on stream or until markets are lost to lower-priced substitutes. Perhaps a price of US$400-$450/oz, in 1996 dollars, at the 1996 value of the U.S. dollar relative to Special Drawing Rights of the International Monetary Fund, can be considered a base trend around which prices will oscillate. But, as noted, there is plenty of potential for spectacular price rises and much volatility.

Notes: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 70. (2) Information in this review was current as of January 31, 1997.

TARIFFS

Item No.	Description	Canada			United States	EU	Japan[1]
		MFN	GPT	USA	Canada	MFN	GATT
26.16	Precious metal ores and concentrates						
2616.90.00.30	Platinum group	Free	Free	Free	Free	Free	Free
71.10	Platinum, unwrought or in semi-manufactured forms, or in powder form						
	Platinum:						
7110.11	Unwrought or in powder form	Free	Free	Free	Free	Free	Free
7110.19	Other	Free	Free	Free	Free	0.4%-1.6%	Free-2.4%
	Palladium:						
7110.21	Unwrought or in powder form	Free	Free	Free	Free	Free	Free
7110.29	Other	Free	Free	Free	Free	0.8%	Free-2.4%
	Rhodium:						
7110.31	Unwrought or in powder form	Free	Free	Free	Free	Free	Free
7110.39	Other	Free	Free	Free	Free	0.8%	Free-2.4%
	Iridium, osmium and ruthenium:						
7110.41	Unwrought or in powder form	Free	Free	Free	Free	Free	Free
7110.49	Other	Free	Free	Free	Free	0.8%	Free-2.2%
71.12	Waste and scrap of precious metal or of metal clad with precious metal						
7112.20	Of platinum, including metal clad with platinum but excluding sweepings containing other precious metals	Free	Free	Free	Free	Free	Free
71.15	Other articles of precious metal or of metal clad with precious metal						
7115.90.10.20	Crucibles of platinum	Free	Free	Free	Free	3.8%	2.2%
7115.90.90.30	Other of platinum	8.7%	5%	Free	Free	3.8-6%	2.2%

Sources: Customs Tariff, effective January 1997, Revenue Canada; Harmonized Tariff Schedule of the United States 1997; The "Bulletin International des Douanes," Journal No. 14 (18th Edition), European Union, 1995-1996, "Conventional" column; Customs Tariff Schedules of Japan, 1996.
[1] GATT rate is shown; lower tariff rates may apply circumstantially.

TABLE 1. PLATINUM METALS, SHIPMENTS AND TRADE, 1994-96

Item No.		1994		1995		1996p	
		(kilograms)	($000)	(kilograms)	($000)	(kilograms)	($000)
SHIPMENTS[1]							
	Platinum, palladium, rhodium, ruthenium, iridium	13 422	144 538	16 068	181 996	14 234	146 203
EXPORTS							
2616.00	Precious metal ores and concentrates						
2616.90.83	Platinum group metals content						
	United Kingdom	7 325	71 744	10 320r	94 106r	8 686	75 593
	Total	7 325	71 744	10 320r	94 106r	8 686	75 593
7110.11	Platinum unwrought or in powder form						
	Germany	–	–	–	–	150	2 758
	Japan	86	1 534	374	6 576	126	2 211
	United States	169	2 874	110	854	27	430
	United Kingdom	–	–	82r	1 546r	–	–
	Argentina	–	–	155	1 150	–	–
	Total	255	4 408	721r	10 126r	303	5 399
7110.19	Platinum in other semi-manufactured forms						
	United States	68	1 264	145r	2 718r	633	11 377
	United Kingdom	–	–	–	–	33	488
	Portugal	–	–	–	–	8	56
	Other countries	42	648	107	2 037	–	–
	Total	110	1 912	252r	4 755r	674	11 921
7110.21	Palladium unwrought or in powder form						
	United States	1 680	11 333	2 554r	17 650r	3 286	20 319
	United Kingdom	3 901	25 439	1 132r	8 086r	340	1 903
	France	243	1 650	243	1 750	–	–
	Total	5 824	38 422	3 929r	27 486r	3 626	22 222
7110.29	Palladium in other semi-manufactured forms						
	United States	24	254	180r	1 461r	325	3 885
	Portugal	–	–	–	–	3	22
	Other countries	24	105	88	441	–	–
	Total	48	359	268r	1 902r	328	3 907
7110.31	Rhodium unwrought or in powder form						
	Germany	–	–	–	–	30	464
	United Kingdom	–	–	2	42r	–	–
	Total	–	–	2	42r	30	464
7110.39	Rhodium in other semi-manufactured forms						
	United States	–	–	1	12	...	4
	Total	–	–	1	12	...	4
7110.41	Iridium, osmium and ruthenium unwrought or in powder form						
	United States	...	3	...	2	–	–
	Total	...	3	...	2	–	–
7110.49	Iridium, osmium and ruthenium in other semi-manufactured forms						
	United States	–	–	–	–	...	9
	United Arab Emirates	43	3	–	–	–	–
	Total	43	3	–	–	...	9
7112.20	Waste and scrap of platinum, including metal clad with platinum, except sweepings containing other precious metals						
	United States	158r	2 709	207r	3 435r	257	4 796
	United Kingdom	12r	215	78r	1 443	134	2 221
	Germany	26r	852	–	–	13a	308
	Switzerland	–	–	–	–	94	74
	Total	196r,a	3 776	285r,a	4 878r	498a	7 399
7115.90	Other articles of precious metal or of metal clad with precious metal						
	United States	312	3 127	375r	3 751r	167	1 670
	United Kingdom	285	76	41	3	1	11
	Other countries	–	1	1 250	571	46	4
	Total	597	3 204	1 666r	4 325r	214	1 685

TABLE 1 (cont'd)

Item No.		1994		1995		1996p	
		(kilograms)	($000)	(kilograms)	($000)	(kilograms)	($000)
IMPORTS[2]							
2616.00	Precious metal ores and concentrates						
2616.90.00.30	Platinum group metal content						
	United States	1	16	–	–	...	1
	Guyana	...	1	–	–	–	–
	Total	1	17	–	–	...	1
7110.11	Platinum unwrought or in powder form						
	South Africa	4 207	76 633	5 852r	110 416r	5 165	91 309
	United Kingdom	321	4 619	64	1 386	315	2 933
	United States	507	8 199	271r	5 085r	95	1 730
	Russia	593	11 044	104	1 835	37	533
	Other countries	24	424	–	–	11	90
	Total	5 652	100 919	6 291r	118 722r	5 623	96 595
7110.19	Platinum in other semi-manufactured forms						
	Russia	1 613	29 077	1 270r	24 048r	1 922	34 420
	United States	480	8 176	392r	5 088r	250	4 674
	South Africa	...	2	61	1 165	81	1 470
	Switzerland	25	298	57r	749r	17	255
	Chile	–	–	–	–	10	199
	Canada	–	–	...	3	3	99
	Other countries	116	1 910	29	445	3	67
	Total	2 234	39 463	1 809r	31 498r	2 286	41 184
7110.21	Palladium unwrought or in powder form						
	United Kingdom	692	3 911	385r	2 741r	387	2 215
	United States	140	981	121r	730r	68	344
	Russia	103	729	19	130	28	176
	Saudi Arabia	–	–	–	–	13	58
	South Africa	249	1 855	114r	753r	908	44
	Other countries	154	793	–	3	–	–
	Total	1 338	8 269	639r	4 357r	1 404	2 837
7110.29	Palladium in other semi-manufactured forms						
	United States	930	7 354	901r	8 823r	836	8 049
	United Kingdom	169	1 068	995r	6 974r	1 218	7 451
	Germany	145	1 367	71	629	259	3 044
	Russia	159	1 031	230r	1 564r	219	1 280
	Switzerland	64	417	72r	535r	58	563
	Mexico	–	–	–	–	1	210
	Other countries	–	–	78	522	3	20
	Total	1 467	11 237	2 347r	19 047r	2 594	20 617
7110.31	Rhodium unwrought or in powder form						
	Russia	184	6 344	249r	6 341r	227	3 458
	United Kingdom	45	1 795	1	22	...	10
	South Africa	79	1 730	41r	715r	...	10
	Other countries	5	237	–	42	...	4
	Total	313	10 106	291r	7 120r	227	3 482
7110.39	Rhodium in other semi-manufactured forms						
	Russia	11	320	–	–	55	1 245
	United States	3	123	1	27	1	30
	United Kingdom	5	180	–	–	...	5
	Other countries	–	1	...	1	–	–
	Total	19	624	1	28	56	1 280
7110.41	Iridium, osmium and ruthenium unwrought or in powder form						
	United States	1	9	...	3	1	17
	South Africa	–	–	–	–	2	13
	Other coutries	1	8	1	10	...	3
	Total	2	17	1	13	3	33
7110.49	Iridium, osmium and ruthenium in other semi-manufactured forms						
	United States	3	33	4	58r	2	33
	United Kingdom	8	81	4	63	1	9
	Germany	–	–	–	–	...	...
	Total	11	114	8	121r	3	42

TABLE 1 (cont'd)

Item No.		1994		1995		1996p	
		(kilograms)	($000)	(kilograms)	($000)	(kilograms)	($000)
IMPORTS (cont'd)							
7112.20	Waste and scrap of platinum, including metal clad with platinum, except sweepings containing other precious metals						
	United States	591 256	6 879	301 472r	3 581r	225 496	3 339
	Cuba	130	1 886	236	1 529	228	2 900
	France	–	–	–	–	3 170	457
	Costa Rica	–	–	–	–	151	340
	Mexico	6 421	1 564	207 554	2 794	31	128
	Other countries	53	311	38	124	–	–
	Total	597 860	10 640	509 300r	8 028r	229 076	7 164
71.15	Other articles of precious metal or of metal clad with precious metal						
7115.90.10.20	Crucibles of platinum						
	United States	585	15 121	890r	19 688r	882	21 454
	Argentina	–	–	–	–	10	172
	Other countries	–	–	2	80	1	11
	Total	585	15 121	892r	19 768r	893	21 637
7115.90.90	Other						
7115.90.90.30	Of platinum						
	United States	123	1 013	153r	1 316r	260	970
	Canada	4	33	33	247	–	–
	Other countries	. . .	7	. . .	1	. . .	4
	Total	127	1 053	186r	1 564r	260	974

Sources: Natural Resources Canada; Statistics Canada.
– Nil; . . . Amount too small to be expressed; p Preliminary; r Revised.
a Under review by Statistics Canada.
1 Platinum metals, content of concentrates, residues and matte shipped for export. 2 Imports from "other countries" may include re-imports from Canada.
Note: Numbers may not add to totals due to rounding.

TABLE 2. CANADA, PLATINUM METAL SHIPMENTS, 1980-96

	kilograms	$000
1980	12 776	159 088
1981	11 902	136 186
1982	7 105	82 253
1983	6 965	79 180
1984	10 369	133 467
1985	10 534	141 396
1986	12 190	193 730
1987	10 930	181 849
1988	12 541	190 914
1989	9 870	141 730
1990	11 123	189 423
1991	11 123	150 155
1992	11 311	130 204
1993	11 819	123 610
1994	13 422	144 538
1995	16 068	181 996
1996p	14 234	146 203

Source: Natural Resources Canada.
p Preliminary.

TABLE 3. PRINCIPAL PGM PRICES, 1993-96

Month	Platinum AM	Palladium AM	Rhodium European Free Market
	(US$/oz)	(US$/oz)	(average US$/oz)
1993			
Jan.	359	110	1 769
Feb.	359	110	1 634
Mar.	350	106	1 349
Apr.	369	115	1 150
May	385	120	904
June	384	127	816
July	403	139	769
Aug.	393	137	851
Sept.	362	121	931
Oct.	368	130	1 014
Nov.	375	128	1 052
Dec.	383	125	999
1994			
Jan.	388	124	901
Feb.	394	132	800
Mar.	400	133	724
Apr.	397	134	675
May	398	136	608
June	401	137	794
July	411	146	774
Aug.	412	152	847
Sept.	417	153	791
Oct.	419	155	722
Nov.	413	157	677
Dec.	410	154	630
1995			
Jan.	414	156	596
Feb.	414	157	557
Mar.	416	163	469
Apr.	449	170	463
May	437	161	528
June	438	159	527
July	433	155	491
Aug.	425	150	411
Sept.	430	144	346
Oct.	413	173	348
Nov.	413	134	322
Dec.	410	132	271
1996			
Jan.	416	130	272
Feb.	421	139	331
Mar.	411	138	329
Apr.	404	137	324
May	401	132	326
June	393	129	324
July	393	132	315
Aug.	400	127	315
Sept.	390	122	298
Oct.	384	118	247
Nov.	382	117	235
Dec.	371	117	227

Source: *Metal Bulletin.*