

# PLATINUM-GROUP METALS

By Henry E. Hilliard

Six metals, (platinum, palladium, rhodium, iridium, ruthenium, and osmium) make up the platinum group metals (PGM). Of the six metals, platinum and palladium are the most important commercially. PGM are used as catalysts in the automotive, chemical, and petroleum refining industries. PGM are also used in the electrical and electronic, dental and medical, and jewelry industries.

Although the metals of the group generally are found together, minable deposits of the PGM are very rare. Often, the PGM are byproducts of the mining of some other metal, usually nickel or copper. The major PGM mining countries are, in order of importance, South Africa, Russia, Canada, and the United States.

Identified world PGM resources at yearend 1996 were estimated at 100 million kilograms. The reserve base was estimated at 66 million kilograms and reserves at 56 million kilograms. Of the reserve base and the reserves, South Africa had nearly 90% of each; Russia had 9% and 11%, respectively; and the United States had 1% and 0.4%, respectively.

In the United States, the Stillwater Mine, in Montana, accounts for nearly all domestic primary PGM production. Production at the Stillwater Mine, consisting primarily of palladium and platinum, increased in 1996, reflecting the progress made in the company's 4-year plan to increase ore production from 336,000 metric tons per year to more than 660,000 tons per year by mid-1997. In 1995, the Stillwater Mine produced 1,590 kilograms of platinum and 5,260 kilograms of palladium; while in 1996, the mine produced nearly 1,840 kilograms and 6,100 kilograms of platinum and palladium, respectively (Stillwater Mining Company, 1997). Among the accomplishments in 1996 were the commissioning of the 530-meter shaft adjacent to the concentrator for hoisting miners, materials, and development waste, and construction and commissioning of a base metal refinery adjacent to the smelter. The new refinery, with a capacity of nearly 4,000 tons, uses the Sherritt Process to enrich the smelter product by dissolving contained nickel and copper using sulfuric acid. Although the Stillwater Mining Co. concentrates and smelts the ore from the Stillwater Mine locally, the company shipped the resulting PGM-bearing matte to one domestic and one foreign refinery for further processing.

The remaining domestic primary PGM production were byproducts of the refining of primary copper; they were recovered from anode slimes at two copper refineries in Texas and Utah. In addition to the small amount of byproduct production, about 20 refiners, located primarily on the east and west coasts, recovered PGM from scrap material. Other companies located throughout the United States collected scrap

materials, such as catalysts and PGM-bearing solutions, and processed them to increase the grade. These upgraded secondary materials were then sold to refiners. Most companies specialized in refining or upgrading a particular type of scrap. Because of their high value, PGM are routinely recovered from petroleum catalysts, chemical catalysts, automobile catalysts, glass fiber bushings, electronic scrap, laboratory equipment, dental materials, and jewelry. PGM were sold by at least 90 processors and dealers, largely in the Northeast.

The principal domestic use of PGM was in the catalytic converters of automobiles and light trucks, where they reduce the carbon monoxide, unburned hydrocarbons, and nitrogen oxides in exhaust gases to tolerable levels. Other automotive applications include oxygen sensors and certain types of spark plugs, both of which used small quantities of platinum.

The nonautomotive applications of PGM were numerous. The petroleum refining industry used PGM, principally platinum, in reforming, cracking, and isomerization reactions. Other PGM catalyst applications include the syntheses of nitric acid and hydrogen cyanide using platinum and rhodium, and the production of hydrogen peroxide using palladium. PGM catalysts were also used to produce a variety of organic chemicals.

Electronic applications for PGM include the production of thick-film resistors using ruthenium, the production of thick-film conductors using palladium, and the use of platinum "targets" for sputtering thin films on circuit boards. Platinum-rhodium alloys were used in thermocouples for precise temperature measurement.

In addition, platinum, rhodium, and palladium were used in the "bushings" through which textile (continuous filament) glass fiber is extruded.

The Engelhard average price for unfabricated platinum decreased from \$425.32 per troy ounce for 1995 to \$398.17 per ounce for 1996. Similarly, the Engelhard average price for palladium decreased from \$153.46 for 1995 to \$130.41 for 1996. For 1996, the Engelhard average price for iridium was \$74.00; for rhodium, \$308.80; and for ruthenium, \$47.56. In 1995, the average prices were \$74.14, \$464.66, and \$26.72 per ounce for iridium, rhodium, and ruthenium, respectively.

Platinum stocks held by the New York Mercantile Exchange (NYMEX) increased to 2,844 kilograms at yearend 1996 from 1,188 kilograms at yearend 1995. NYMEX yearend palladium stocks rose to 3,064 kilograms from 2,149 kilograms. Stocks of PGM held by the Federal Government in the National Defense Stockpile remained unchanged from the previous year, and at yearend 1996 consisted of 14,100 kilograms of platinum, 39,300 kilograms of palladium, and 920 kilograms of iridium.

The United States remained dependent on imports of PGM. For the period 1992-96, the United States imported more than 318,000 kilograms of platinum. Of this amount, South Africa supplied approximately 60%, the United Kingdom 10%, and Russia 9%. During the same period, the United States imported more than 500,000 kilograms of palladium. The major source countries were Russia, 42%; South Africa, 22% and the United Kingdom, 11%. All unwrought and semimanufactured PGM can be imported duty free.

Although platinum, palladium, and rhodium are so efficient in automotive catalysts that they have no competitive substitutes, the percentage of each metal used in the catalyst can be varied. Silver and gold are alternatives for platinum and palladium in many end uses, including electrical and electronic applications, jewelry, and dental applications.

### World Review

Johnson Matthey estimated that world demand for platinum, nearly 152 tons, was essentially unchanged in 1996 (Johnson Matthey, 1997). Although platinum use in automotive catalysts declined owing in part to a shift by some manufacturers to palladium-rich catalysts, the decline was more than offset by the estimated increase in demand for platinum in the form of small investment items, for jewelry, and for petroleum catalysts. Similarly, the world demand for palladium in 1996, as estimated by Johnson Matthey, also remained essentially unchanged from that of 1995. Increased demand for palladium for automotive catalysts was more than offset by lower demand for electrical applications.

**South Africa.**—South Africa remained the world's largest PGM producer, accounting for 80% of platinum production and 44% of palladium production. Essentially all of South Africa's PGM output was produced by 10 mines, 9 of which are underground operations, mining the Bushveld Complex. The Bushveld Complex, and the Stillwater Complex in the United States, are the only deposits in the world mined primarily for their PGM content.

**Other.**—Canada and Russia are the other major producers of

PGM. For both countries, PGM are byproducts of their nickel operations, primarily in the Sudbury District of Canada, and the Noril'sk-Talnakh region of Russia.

### Outlook

Given the strong demand for a cleaner environment, worldwide demand for PGM is expected to grow moderately over the next few years. Many countries already require the use of catalytic converters for controlling emissions from gasoline-powered automobiles, and other countries are expected to adopt these requirements. Although both platinum and palladium are used in catalytic converters, in the short-term, platinum is expected to remain the dominant metal, owing primarily to the need to use up to three times as much palladium to obtain the desired emissions reduction. Domestically, moderate growth for PGM demand is also expected over the next few years as increasingly stringent standards for automobile emissions are adopted.

### References Cited

Johnson Matthey PLC., 1997, *Platinum 1997*: Johnson Matthey PLC., London, England, 52 p.  
Stillwater Mining Co., 1997, *Stillwater annual report 1996*: 42 p.

### SOURCES OF INFORMATION

#### U.S. Geological Survey Publications

Platinum-Group Metals. Ch. in *Mineral Commodity Summaries*, annual.<sup>1</sup>

Platinum-Group Metals. *Precious Metals Mineral Industry Surveys*, monthly.<sup>1</sup>

Platinum-Group Metals. Ch. in *Minerals Yearbook*, annual.<sup>1</sup>

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<sup>1</sup>Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1  
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF PLATINUM GROUP METALS IN 1996 1/

(Kilograms)

Country	Ores and concentrates	Waste and scrap	Refined					
			Platinum	Palladium	Rhodium	Iridium	Osmium Ruthenium	
<b>Imports:</b>								
Australia	--	107	389	--	304	--	--	--
Belgium	--	146	2,300	8,760	--	--	--	--
Canada	--	251	2,170	3,610	(2/)	(2/)	--	(2/)
Chile	--	5	80	--	--	--	--	--
China	--	--	70	1,230	--	--	--	--
Colombia	--	50	544	--	--	--	--	--
France	--	324	43	121	122	1	--	5
Germany	--	195	4,190	2,810	232	53	--	414
Hong Kong	--	172	--	--	--	--	--	--
India	--	--	--	70	19	--	--	--
Ireland	--	--	--	205	--	--	--	--
Italy	--	5	187	247	8	1	--	(2/)
Japan	--	151	259	4,400	43	--	--	--
Mexico	101	222	16	3	2	--	--	--
Netherlands	--	808	54	(2/)	--	1	--	4
Norway	--	--	281	2,270	21	--	--	--
Russia	1,860	172	10,600	83,100	1,970	--	--	922
South Africa	--	126	42,900	24,100	6,020	1,130	(3/)	13,200
Switzerland	--	--	3,100	4,920	80	58	--	201
United Kingdom	--	1,910	8,320	9,890	835	565	--	828
Other	--	411	296	174	--	--	--	--
<b>Total</b>	<b>1,960</b>	<b>5,060</b>	<b>75,800</b> 4/	<b>146,000</b>	<b>9,650</b>	<b>1,810</b>	<b>(3/)</b>	<b>15,600</b>
<b>Exports:</b>								
Australia	--	--	48	49	--	4	5/	
Belgium	--	1,050	2,770	5,550	--	(2/)		
Canada	8	168	418	927	(2/)	3	5/	
Chile	--	--	48	1	--	--		
Finland	--	--	545	--	--	--		
France	--	20	351	392	1	--		
Germany	40	1,050	1,420	1,580	18	18	5/	
Hong Kong	4	(2/)	319	179	6	4		
Ireland	--	--	310	213	76	(2/)		
Israel	--	--	--	177	(2/)	--		
Italy	--	22	135	506	(2/)	4	5/	
Japan	7	924	1,960	2,300	6	20	5/	
Korea, Republic of	3	(2/)	1,930	983	70	13	5/	
Malaysia	--	--	452	7	--	--		
Mexico	5	1	42	4,380	--	4	5/	
Netherlands	--	129	127	4,130	(2/)	10	5/	
Singapore	--	--	31	463	--	--		
South Africa	4	--	--	163	--	--		
Sweden	--	145	69	148	--	1	5/	
Switzerland	238	--	127	522	(2/)	(2/)		
Taiwan	--	--	48	1,780	(2/)	2		
United Kingdom	152	5,110	1,360	2,080	10	26	5/	
Uruguay	--	--	55	--	--	--		
Venezuela	--	1	107	--	(2/)	--		
Other	26	18	78	193	--	15	5/	
<b>Total</b>	<b>487</b>	<b>8,640</b>	<b>12,700</b>	<b>26,700</b>	<b>187</b>	<b>122</b>	<b>5/</b>	

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Data withheld pending verification by the Bureau of the Census.

4/ Of this amount, 2,070 kilograms was in the form of platinum coins.

5/ Includes osmium and ruthenium.

Source: Bureau of the Census.

TABLE 2  
PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country 3/	1992	1993	1994	1995	1996 e/
<b>Platinum:</b>					
Australia e/ 4/	100	100	100	100	100
Canada e/ 5/	4,800	5,000	6,000	9,320 r/	8,260
Colombia	1,956	1,722 r/	1,084 r/	973 r/	669 6/
Ethiopia e/	1	--	--	--	--
Finland e/	60	60	60	60	60
Japan 7/	629	661	691	730 r/	850
Russia e/	28,000	20,000	15,000	18,000	18,000
Serbia and Montenegro	19	10	10 e/	10 e/	10
South Africa e/ 5/	94,900	109,000	114,000	118,000	117,000
United States e/ 8/	1,650 r/	2,050 r/	1,960 r/	1,590 r/	1,840
Zimbabwe	9	4	7	10 e/	10
<b>Total</b>	<b>132,000</b>	<b>139,000</b>	<b>139,000</b>	<b>149,000 r/</b>	<b>146,000</b>
<b>Palladium:</b>					
Australia e/ 4/	400	400	400	400	400
Canada e/ 5/	5,800	6,000	7,000	5,950 r/	5,270
Finland e/	100	100	100	100	100
Japan 7/	986	1,183	1,277	2,174 r/	2,300
Russia e/	70,000	50,000	40,000	48,000	48,000
Serbia and Montenegro	130	72	50	50 e/	50
South Africa e/ 5/	41,000	48,000	47,800	49,400	48,900
United States e/ 8/	5,440 r/	6,780 r/	6,440 r/	5,260 r/	6,100
Zimbabwe	19	11	17	20 e/	20
<b>Total</b>	<b>124,000</b>	<b>113,000</b>	<b>103,000</b>	<b>111,000 r/</b>	<b>111,000</b>
<b>Other platinum-group metals:</b>					
Canada e/ 5/	1,310	1,440	1,970	803 r/	712
Russia e/	6,000	4,000	3,000	3,600	3,600
South Africa e/ 5/	17,000	19,000	22,100	22,800	22,500
<b>Total</b>	<b>24,300</b>	<b>24,400</b>	<b>27,100</b>	<b>27,200 r/</b>	<b>26,800</b>
<b>Grand total</b>	<b>280,000</b>	<b>276,000</b>	<b>269,000</b>	<b>287,000 r/</b>	<b>284,000</b>

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 29, 1997. Platinum-group metal production by Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

3/ In addition to the countries listed, China, Indonesia, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan.

4/ Platinum-group metals recovered from nickel ore processed domestically. Platinum-group metals extracted from exported ores are believed to be included in the production figures for Japan and may be included in figures for other receiving countries.

5/ Country reports only total of platinum-group metals produced. Figures for constituent metals are estimates.

6/ Reported figure.

7/ Production derived entirely from imported ores.

8/ Estimates for the Stillwater Mine from published sources. A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.