Palladium

Autocatalyst

After five years of rapid growth in demand for palladium in autocatalysts, last year saw a reduction in purchasing by the auto industry. Demand fell by 4 per cent to 5.65 million oz as auto makers responded to the higher prices by adjusting their levels of stock. In contrast, actual consumption of palladium in catalysts fitted to cars and trucks manufactured in 2000 rose by 24 per cent, to meet increasingly stringent emissions legislation throughout the world.

It now seems clear that in both 1998 and 1999 some auto makers anticipated substantial growth in their consumption of palladium to meet increasingly tough standards for hydrocarbons. They responded by purchasing large quantities of the metal for future use and to protect themselves against increases in price and potential long term market shortages. They may also have been concerned by the delays in shipments of palladium from Russia that had occurred in the early months of 1997 and 1998.

The policies auto makers adopted towards inventories in 2000 are more difficult to assess. We believe that in the first half of the year some of the major North American auto makers responded to the high price of palladium by drawing down stocks built up in the preceding two years. After reaching a peak of $800 in February, the price retreated during the March to May period, and users may have been lulled into believing that substantial quantities of Russian metal would be sold throughout the rest of the year. However, Russian shipments remained erratic and it was not until mid September that significantly more metal became available. Despite increased shipments by Almaz in the period to the end of November, the price continued to rise steadily. We believe that this was at least partly caused by auto companies purchasing metal to replenish stocks run down in the first half of the year. With the Russian state treasury Gokhran indicating that it planned to sell no pgm in 2001, auto makers (and other users) may have moved to ensure they had adequate stocks for the following year.

It is clear that, because of their strategic nature, policies towards holding stocks vary between companies and are difficult to quantify precisely. Overall, we estimate that palladium inventories held by auto companies declined by about 340,000 oz in 2000, after increases of nearly 2 million oz over the two previous years. Whatever their views towards stocks, the response by auto makers worldwide to the record levels of the palladium price in the latter half of 2000 is clear - they wish to reduce their dependence on the metal if at all possible. This is likely to result in larger quantities of platinum and rhodium being used in future, although palladium seems certain to remain an important component of autocatalysts due to its ability to control hydrocarbon emissions.

In Europe, tighter Stage III emissions regulations came into force for all new models from January 2000 and applied to all cars produced from January 2001. Most manufacturers in Germany were already fitting catalysts designed to meet Stage III standards in advance of the due date, encouraged by domestic tax incentives. With the new standards in force, incentives to meet Stage IV levels of emissions are now available and a number of manufacturers are already standardising on catalysts that will meet these, even stricter, regulations.

Palladium Demand: Autocatalyst
'000 oz

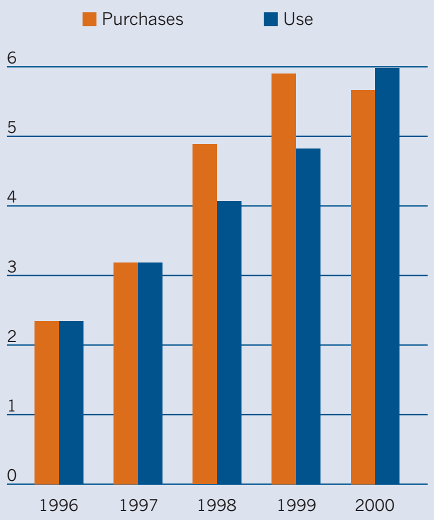
	1999	2000
Europe	1,530	1,920
Japan	600	505
North America	3,490	2,800
Rest of the World	260	425
Total	**5,880**	**5,650**
Autocatalyst recovery	**(195)**	**(230)**

Most auto makers in Europe are adding more palladium to catalysts designed to meet the Stage III and Stage IV limits. As a result, European demand for palladium in autocatalysts in 2000 rose by 25 per cent to 1.92 million oz. Plans to increase palladium loadings were put in place before the sharp increase in price experienced last year. As a result, many auto makers, worried about the increased cost of emissions control systems, are now seeking to minimise their use of the metal, either through thrifting of total pgm loadings, or by substituting some of the palladium with platinum and rhodium.

The use of palladium in autocatalysts fitted to cars manufactured in Japan also rose in 2000; exports to the USA grew by 7 per cent and more palladium was required to meet the US LEV standards in that country. Tighter legislation also came into operation in Japan, with the introduction in October 2000 of Japanese Low Emission Vehicle (JLEV) standards, but manufacturers appear to have added

Smoptech palladium catalysts are based on a novel fibre support

Palladium Autocatalyst Demand 1996-2000
Million oz



platinum rather than palladium to their catalysts to comply with the new domestic regulations. There was no repeat of the stock building that occurred in 1999 and overall purchases of palladium by the auto industry in Japan declined 16 per cent to 505,000 oz.

In addition to the JLEV standards, the Japanese Environmental Agency has put forward for government consideration a set of technical guidelines for even tougher emissions limits. These suggest further reductions in permitted emissions of HC and NOx of between 25 per cent and 75 per cent from the JLEV rules. Compliance with these suggested standards is at present voluntary, but a number of auto makers have launched models that meet the new proposals and have highlighted their compliance in promotional advertising for the new vehicles.

Despite poor sales in the last two months of the year, the North American market for cars and light-duty trucks grew by 3 per cent overall in 2000. Imports increased strongly but domestic production levels were 2 per cent down on the 1999 level. The proportion of vehicles manufactured to LEV standards rose and this led to higher palladium consumption to meet the tighter HC emission levels demanded by these regulations.

In the Rest of the World, demand for palladium grew by 63 per cent last year to 425,000 oz. In Mexico, production of cars and trucks rose by 25 per cent: as about three quarters of these vehicles were destined for North America there was a substantial growth in palladium demand for catalysts to meet the LEV standards north of the border. Demand also expanded in Brazil and Argentina as economic activity continued its gradual recovery from the crash of 1997. In Asia, the South Korean auto industry, despite undergoing painful restructuring, boosted exports by 11 per cent and this led to higher demand for palladium. In addition, Korea introduced its own LEV legislation in January 2000.

Autocatalyst Recovery

The amount of palladium recovered in 2000 from scrapped autocatalysts rose by 18 per cent to reach 230,000 oz. About two thirds of this metal was recovered from catalytic converters removed from vehicles that had been scrapped in North America. Although an extensive network exists in the USA to collect used converters and extract the pgm-bearing contents, most of the metal was finally refined outside the country, in Europe, Japan, Canada and South Africa.

The greatly increased quantities of palladium used by the auto industry since the middle of the 1990s can be expected to lead to a substantial growth in recovery from scrapped autocatalysts in due course. However, the average life of cars in most regions of the world is 8-10 years and, although the quantities of palladium recovered are increasing, it will be another 4-5 years before they are comparable with the amounts of platinum that are recovered from auto recycling.

Chemical

Demand for palladium in the chemical industry rose by 20,000 oz to 260,000 oz in 2000.

Sales of palladium process catalysts remained strong, but consumption of palladium in the nitric acid industry continued its gradual decline.

In Europe, there were significant sales of palladium for a catalyst used in the production of vinyl acetate monomer, a chemical that is widely employed in the manufacture of polymers, resins, films and laminates. In contrast, demand for palladium process catalysts in North America declined in comparison with 1999, when there were significant purchases of palladium for an intermediate process in the production of artificial fibres.

Demand for palladium process catalysts in the Rest of the World is principally for bulk petrochemicals such as purified terephthalic acid (PTA). Investment in the production of PTA - a feedstock used in the manufacture of packaging materials and artificial fibres - has been the mainstay of palladium demand in this region for several years. During 2000, new plants were built in several countries in Asia and the Middle East, while there were also capacity expansions at a number of existing sites. Further investment in this process is expected to take place this year.

In the nitric acid industry, where palladium catchment gauze is used to capture platinum lost from the catalyst, high metal prices are leading to a gradual

Palladium Demand: Chemical
'000 oz

	1999	2000
Europe	65	95
Japan	20	20
North America	75	65
Rest of the World	80	80
Total	**240**	**260**

erosion of palladium demand. In the USA, most nitric acid plants operate at high pressures and the industry has largely abandoned the use of catchment because of the increased cost of palladium. In other regions plants generally operate at low or medium pressures, which require fewer catchment gauzes. Companies here have generally retained the use of catchment systems, but in some cases have reduced the number of gauzes and settled for slightly lower platinum recoveries.

Dental

During 2000, it was the dental sector in which high palladium prices had their most significant negative impact. Demand was down by 26 per cent to 820,000 oz - the lowest figure for 17 years. The use of palladium alloys decreased worldwide, with the sharpest declines occurring in the USA and Germany. In comparison, there was a more modest fall in consumption in Japan.

The Japanese market is generally less price sensitive than other countries, because treatment using the Kinpala alloy, which contains 20 per cent palladium, qualifies for a subsidy under the state health insurance scheme. However, demand is not entirely insulated from price movements, because the level of subsidy does not necessarily reflect the current cost of alloy components. Although the government now revises reimbursement rates twice a year, there is a time lag of several months before the adjustment takes place. In an environment of rising prices, such as existed in 2000, repayment levels may fall below the intrinsic metal value of the alloy, temporarily discouraging its use.

Japanese demand has also been affected by changes in the state health insurance scheme introduced in 1999, requiring patients to make higher contributions to their medical care. In last year's depressed economic climate, this triggered a decline in attendance at dental practices and a reduction in the number of reconstructive dental procedures. These factors contributed to a decline of 14 per cent in the use of palladium dental alloys in Japan last year.

Elsewhere, the rising palladium price has triggered a rapid shift to alternative products. In Europe, where the use of palladium dental alloys is concentrated in Germany, demand plunged by 44 per cent last year, as the impact of high dollar prices was exacerbated by a weak euro. In North America, palladium consumption fell by one third. Dental laboratories are switching from palladium to high gold and, especially in Europe, base metal alloys; in addition, technical improvements are encouraging the greater use of metal-free materials such as porcelain.

Palladium Demand: Dental
'000 oz

	1999	2000
Europe	180	100
Japan	545	470
North America	350	230
Rest of the World	35	20
Total	**1,110**	**820**

Electronics

During 2000, palladium continued to lose market share to base metals in the manufacture of multi-layer ceramic capacitors (MLCC). Despite this, the increase in production of MLCC was such that demand for palladium in electronics actually increased last year. But the high price of palladium has made its future in this sector less secure.

Manufacturers of MLCC increased their output by 47 per cent in 2000 to 620 billion units, and to achieve this result needed to utilise fully all their production capabilities. As a result, although the proportion of MLCC containing palladium electrodes fell, from 62 per cent in 1999 to 46 per cent last year, the amount of palladium consumed in this application rose by 5 per cent to 1.82 million oz. The need for more MLCC was driven by buoyant markets for mobile phones and other consumer electronic products. There was especially strong demand for capacitors in more complex cellular phones, especially the WAP (wireless application protocol) models used for internet communications.

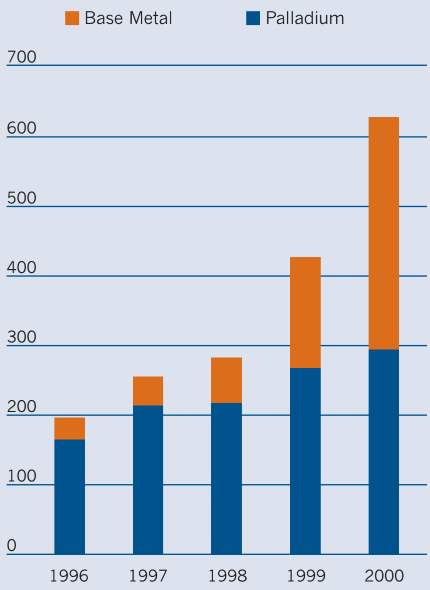
Over the last decade the electronics industry has experienced several severe fluctuations in consumer demand and manufacturing activity. In late 2000 and, even more so, in the first quarter of 2001 there have been clear indications that the rate of increase in demand for electronic goods has peaked. In particular, sales of the newer WAP phones are likely to expand much more slowly than had been anticipated; virtually all manufacturers have reported a slowdown in sales growth and instituted cutbacks in production. It also seems clear that manufacturers of components for mobile phones and other electronic devices have entered the current phase of declining activity with substantial inventories. We therefore expect production of MLCC to fall significantly in 2001.

Developments in technology in

Palladium Demand: Electronics
'000 oz

	1999	2000
Europe	255	265
Japan	980	990
North America	405	465
Rest of the World	350	420
Total	**1,990**	**2,140**

MLCC Production by Electrode Type 1996-2000
Billions



recent years have resulted in comparable performance of palladium and nickel based MLCC for most applications. The slowdown in the electronics industry will give MLCC makers the opportunity to concentrate on producing cheaper nickel based products rather than those containing precious metals and consequently their demand for palladium is likely to decline sharply this year.

MLCC production accounts for over 80 per cent of demand for palladium in electronics, and is sensitive to price since the palladium content of the MLCC is a significant proportion of the materials cost. This is less so for other applications in the sector, such as hybrid integrated circuits (HIC) and the plating of lead frames, and demand for these uses is not expected to change significantly. However, in its application in the plating of connectors, palladium is in competition with gold, having originally been introduced as a cheaper alternative to the then more highly priced yellow metal. With the reversal of the relative prices of the metals over the last two to three years, several users are considering returning to gold plating, and some have already done so.

The recovery of palladium from old scrap is an important component of net demand in electronics. Although there is pressure to increase recycling for environmental reasons, the success of miniaturisation and thrifting programmes in recent years has resulted in the grades of precious metal in electronic scrap falling significantly. The amount of palladium recovered in 2000 is estimated to have been around 340,000 oz worldwide, some 15 per cent lower than in the preceding year.

Other

The use of palladium in other applications fell sharply in 2000, largely due to the sale back to the market of metal recovered from petroleum refining catalysts. There was also a decline in demand from the jewellery sector, as fabricators in Japan and China adopted platinum alloys with lower palladium contents.

In the petroleum sector, palladium's principal use is in catalysts for hydrocracking. This process can utilise either base metals or palladium, the choice depending on a number of technical considerations as well as the cost of the catalyst itself. For example, palladium is more durable in some circumstances, and also gives gasoline with a higher octane value, whereas base metal catalysts produce more middle distillate products such as diesel and jet fuel.

Palladium Demand: Other
'000 oz

	1999	2000
Europe	75	65
Japan	115	110
North America	60	15
Rest of the World	95	70
Total	**345**	**260**

Several US refineries have recently taken the decision to adopt base metal catalysts in place of palladium. During 2000, this trend was accelerated by rising palladium prices, with some companies changing catalysts more quickly than originally planned in order to recover the metal and sell at high prices. As a result, demand from the petroleum refining industry was negative last year.

Consumption of palladium by the jewellery industry fell by around 15 per cent last year. Demand was affected by a sharp decline in the fabrication of platinum jewellery in Japan, and by the adoption of platinum jewellery alloys with a lower palladium content in China. This was offset to some extent by the increased use of white gold worldwide in order to meet consumer demand for inexpensive white jewellery; many white gold alloys contain palladium as a whitening agent.

In Japan, platinum jewellery has traditionally been made using alloys containing 10 or 15 per cent palladium. In recent years there has been a move towards materials with a higher platinum content, especially in the bridal market, and this trend continued last year. Palladium demand was also affected by a decline in sales of platinum chain, which is typically fabricated from Pt850 alloys. Some manufacturers have started to experiment with lower-content palladium alloys, containing cheaper metals such as silver and copper in place of some of the palladium.

The Chinese platinum jewellery industry has also made extensive use of alloys containing 10 per cent palladium. However, manufacturers are now moving towards Pt950 as a result of new regulations governing the purity of platinum jewellery, which were introduced in September 2000. High palladium prices are also encouraging the adoption of alloys containing alternative metals.

Automotive Emissions Legislation in California

It was pollution in the city of Los Angeles that first gave birth to the control of emissions from road vehicles and, ultimately, to the introduction of autocatalysts in 1975. Much of the world has followed this initiative by introducing limitations on allowable emissions, but California has continued to lead the way in driving standards forward in the search for cleaner air.

History

The first reported episode of smog formation in Los Angeles occurred as early as 1943 but it was not until 1966 that auto tailpipe emission standards for hydrocarbons (HC) and carbon monoxide (CO) were adopted in California, the first such standards in the world.

Initial emissions regulations were met by engine modifications, but in 1975 the first two-way (or oxidation) catalytic converters came into use as part of the Motor Vehicle Emission Control Program of the California Air Resources Board (CARB). They were followed a year later by the first three-way catalytic converters, to control HC, CO and nitrogen oxides (NOx).

Some Key Dates in Californian Emissions Control

1947 California passes Air Pollution Control Act
1960 Motor Vehicle Pollution Control Board established in California
1967 Federal Act allows California to set its own emissions standards
1968 Inaugural meeting of California Air Resources Board (CARB)
1975 First catalytic converters come into use in California
1990 CARB approves Low and Zero Emissions Vehicles standards
1998 CARB approves LEV II emissions standards
1999 California Fuel Cell Partnership formed
2001 ZEV mandate for 2003 confirmed

Low Emissions Vehicle (LEV) Program

In 1990, CARB approved standards for Low and Zero Emissions Vehicles that would apply from 1994 to 2003. These were based upon the progressive introduction of four classes of vehicles, each with increasingly stringent emissions requirements:

- **TLEV** transitional low emissions vehicles
- **LEV** low emissions vehicles
- **ULEV** ultra low emissions vehicles
- **ZEV** zero emissions vehicles

Currently, auto makers are required to comply with a Fleet Average NMOG (Non-Methane Organic Gas) standard, which is tightened each model year. In the period to 2003, manufacturers may certify vehicles in any combination of the LEV categories in order to satisfy this standard.

LEV II Program

CARB approved new proposals in November 1998, referred to as LEV II, for a strengthening of the regulations from 2004. The new standards will require light trucks, including sports utility vehicles (SUVs), pick-ups and small vans, as well as some vehicles currently in the medium duty class, to meet the same emissions standards as passenger cars. A further significant ruling is that diesels will be subject to the same standards as gasoline powered vehicles.

Other requirements of the LEV II program are that auto makers must reduce fleet average emissions levels each year through to 2010; NOx standards for low and ultra-low emissions vehicles will be reduced by 75 per cent from the LEV level; and durability standards will be extended from 100,000 to 120,000 miles. The program also permits credits for vehicles that achieve near-zero emissions, such as fuel cells, hybrids and cars meeting a new super ultra low emissions vehicle (SULEV) standard.

Zero Emissions Vehicles (ZEV)

As part of its 1990 LEV Program, CARB mandated that 2 per cent of passenger cars produced and offered for sale in California in 1998 by the seven major auto manufacturers should be zero emissions vehicles. This percentage was to rise gradually and reach 10 per cent in 2003, but the mandate was modified in 1996 to eliminate the 1998-2002 requirement.

The 1998 LEV II program introduced a system whereby manufacturers could meet up to 60 per cent of the ZEV requirement through the sales of partial zero emissions vehicles (PZEVs), with five PZEVs being sold in place of each ZEV required. The emissions criteria for a PZEV were the same as for a SULEV except that the durability requirement was extended from 120,000 to 150,000 miles.

In August 2000 an extensive review of the ZEV program was published. Subsequently, in January 2001, CARB voted to keep the ZEV mandate in place, although the rules were revised to reduce the number of pure ZEV required in the period to 2006, while raising the minimum ZEV requirement to 16 per cent in 2016.

TLEV, LEV, ULEV and ZEV Standards for Passenger Cars

Class	NMOG g/m	CO g/m	NOx g/m
TLEV	0.156	4.200	0.600
LEV	0.090	4.200	0.300
ULEV	0.055	2.100	0.300
ZEV	zero	zero	zero

based on 100,000 miles durability