

Cobalt: Policy Options for a Strategic Mineral

**Special Study
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STRATEGIC MINERAL**

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PREFACE

Cobalt is a metal used in U.S. aerospace and defense industries. At present it is not produced in the United States. It has been one of the metals purchased for the strategic stockpile. Vulnerability of the United States to shortfalls in the supply of cobalt and other minerals and materials is a concern of both the Congress and the Administration. Hearings have been held before the Senate Committee on Banking, Housing, and Urban Affairs to consider subsidizing domestic cobalt production.

The Congressional Budget Office (CBO) has prepared this analysis in response to a request from the Senate Committee on Commerce, Science, and Transportation. In keeping with CBO's mandate to provide objective analysis, the report makes no recommendations.

The paper was written by Robert J. Barbera of CBO's Natural Resources and Commerce Division, under the supervision of David L. Bodde and Everett M. Ehrlich. The author would like to thank Paul Bugg, Patricia Devine, Thomas Gunther, and Stanley Miller, who provided valuable comments on earlier drafts. Scott Sibley, Mineral Commodity Specialist at the Bureau of Mines, was helpful in locating data on cobalt. The paper was edited by Francis Pierce, and typed and prepared for publication by Deborah Dove.

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SUMMARY

The vulnerability of the United States to disruptions in the supply of imported materials considered essential to industrial production has been of concern to policymakers throughout the post-World War II era. Cobalt is a prime example of such a "strategic mineral." Cobalt alloys are important to a number of U.S. industries, especially aerospace and defense, and short-run opportunities for substitution are limited. The bulk of the world's supply of cobalt originates in central Africa (primarily Zaire and Zambia, which hold 64 percent of the world's known cobalt reserves), a politically unstable region. At present, the United States produces no cobalt. Thus, aside from cobalt stockpiles and the recycling of used materials, the United States is completely dependent on imports. This gives rise to two kinds of vulnerability. The first is essentially military in nature: the possible need to wage a war in the absence of foreign supplies of cobalt. The second is economic: the effect on the economy of a disruption in foreign supply with an attendant sudden increase in price. The fourfold price increases during the late 1970s, and the worldwide scramble for cobalt supplies at that time, have given prominence to this second kind of vulnerability.

THE CURRENT FEDERAL POSITION

The strategic stockpile, created to provide sufficient quantities of metals and materials for essential production during war, is below its current goals for many materials. In March 1981, the Administration initiated the purchase of 5.2 million pounds of cobalt for the stockpile--the first major purchase in 20 years. Taking a different approach, the Department of Defense announced in early 1982 that it was exploring the possibility of offering subsidies to U.S. mining companies to initiate production from otherwise uneconomic domestic cobalt ores. Congressional concern about possible cutoffs of cobalt imports prompted hearings before the Senate Banking Committee in October of 1981 focused on whether U.S. dependence on imports would justify subsidization of domestic production.

ANALYSIS

This paper examines in detail both the future demand for cobalt in the United States and the potential for cobalt supply shortfalls. The analysis suggests that, although significant disruptions in the supply of cobalt are a

possibility throughout the 1980s, the existence of the strategic stockpile ensures that their consequences would be limited to the increased financial costs faced by cobalt users. No major loss to the national economy would be likely.

U.S. Cobalt Demand

Cobalt is usually employed as an alloy with other metals where it imparts qualities such as heat resistance, high strength, wear resistance, and superior magnetism to the materials that are formed. U.S. consumption of cobalt in 1980 totaled about 17 million pounds, divided among alloys for jet engines and stationary gas turbines, permanent magnets for electrical equipment, machinery, and nonmetallic applications.

Increases in Cobalt Prices and Resulting Demand Effects. During the late 1970s, cobalt prices rose from \$5.50 per pound to \$25.00 per pound; spot prices were recorded as high as \$50.00; and cobalt was in short supply. The tight market resulted from a combination of factors: military conflict in Zaire, expanding industrial economies, and a change in U.S. stockpile policy. The price increases had significant effects on U.S. cobalt demand, precipitating searches for substitutes, improved conservation, and increased recycling from scrap.

Over the 1977-1979 period, these adjustments accounted for an estimated 19 percent reduction in what would otherwise have been the demand for cobalt. The experience was, for consumers of cobalt, a vivid illustration of the potential for future cobalt price swings and supply shortfalls. Accordingly, many U.S. industry efforts to identify cobalt substitutes continue, in spite of recent price declines. As of May 1982, cobalt's price had fallen to \$12.50 per pound.

Future Problems in the Cobalt Market

Demand for cobalt is extremely difficult to forecast because of the mineral's specialized applications. Year-to-year fluctuations in cobalt use are often dramatic. Given the high levels of activity expected in a number of industrial sectors that traditionally use cobalt, in particular aerospace and electronics, estimates of about 30 million pounds of cobalt use by 1990 appear reasonable, although the further development of cobalt substitutes could appreciably reduce this estimate. More importantly, the development of substitutes would reduce U.S. vulnerability to supply shortfalls.

Cobalt and Direct Military Conflicts. U.S. involvement in a direct military conflict could conceivably result in a shutoff of cobalt supplies to

the United States. Thus some contingency plan that will supply cobalt for defense purposes appears warranted.

Economic Vulnerability to Nonmilitary Shortfalls. Concentration of the world's cobalt reserves in central Africa suggests that the threat of price increases and supply disruptions will continue throughout this decade.

Significant adjustment to a supply disruption is possible. Private inventories and in-pipeline supplies would provide an initial buffer. Suppliers of cobalt unaffected by the political disturbance could also be expected to increase their output. Scrap recovery would also increase. Substitution possibilities exist for a number of cobalt uses, and some have already been applied; the price rises attending a shortfall should accelerate their introduction. These adjustments and others appear to be sufficient to limit the effects of supply shortfalls largely to the payment of higher prices for cobalt and its substitutes.

Potential Effects on the U.S. Economy. The financial costs of higher cobalt prices, although potentially devastating to particular cobalt users, appear inconsequential to the economy as a whole. Although severe shortfalls could generate tenfold price increases, these would amount to less than \$2 billion in a \$3 trillion economy, and the value of imports would be less than 5 percent of the costs of U.S. petroleum imports from OPEC countries in 1981.

POLICY OPTIONS

The Strategic Stockpile for Wartime Use

The Strategic and Critical Materials Stockpiling Act of 1946 requires that stockpiling of cobalt be done in sufficient quantities to provide supplies necessary for military, industrial, and essential civilian needs for the fighting of a three-year war. Executive agencies have translated this directive into a stockpile goal for cobalt of 85.4 million pounds, about one-half of which has been stockpiled so far.

As previously noted, the costs of shortfalls to the United States are likely to be quite limited in peacetime. Nonetheless, the possibility of a cutoff of cobalt supplies in wartime justifies some contingency plan for defense purposes. The strategic stockpile, given current cobalt prices, is probably the least expensive solution. The government recently purchased cobalt at \$15 per pound for the stockpile, a price significantly below the estimated \$25 cost for domestically produced ores. Moreover, the protec-

tion afforded by stockpiled cobalt extends beyond the mandatory three years, since domestic ore bodies could be brought on-line within that time and greatly extend the years of protection afforded by the stockpile.

Finally, the recent development of significant substitutes for cobalt suggests that the stockpile goal may be in need of reevaluation. Any reduction in the goal would reduce the cost of the stockpile.

Alternative Policies

A number of alternatives to the present policy are conceivable:

- o A separate "economic stockpile" that could be drawn upon to moderate cobalt price swings;
- o Subsidies to induce domestic ore production;
- o Increased federal funding for research and development to expand the supply of cobalt and its substitutes;
- o Expanded access to public lands for the location and development of domestic ore; and
- o Accelerated development of ocean mining to tap the vast stores of cobalt contained in marine manganese nodules.

Any of these alternatives would afford a certain degree of protection against supply hazards--but each would entail some cost.

An economic stockpile, designed to moderate the impact of cobalt price increases to U.S. users of cobalt, would be an expensive form of protection in relation to the limited nature of the costs to the United States associated with such increases. The same would be true of subsidies for domestic ore production.

Increased research and development efforts could enable U.S. consumers of cobalt to substitute other metals, and also expand cobalt supply possibilities. Judgments about the appropriate level for research and development funding are always difficult to assess. In any event, it is noteworthy that substitution of other metals helped to mitigate the impact of the 1977-1979 price increases.

It does not appear that cobalt's strategic importance should be a major consideration in decisions relating to public lands or accelerated ocean mineral development.

Concern about U.S. reliance on foreign supplies of cobalt is part of a more far-reaching anxiety over several dozen minerals--including chromium, platinum, manganese, and bauxite--that are considered essential to U.S. production of goods and services but not produced domestically in quantities adequate to meet U.S. needs. They are termed "strategic and critical" minerals because of the precariousness of their availability and their critical role in U.S. manufacturing.^{1/} Because U.S. industry, in particular jet engine manufacturers, depends so heavily on imported cobalt, and because the world's reserves are concentrated in a very few politically unstable nations, concern has arisen over possible disruptions in supply. Military strategists assume the worst case in which all air and shipping lanes would be blocked and no cobalt would reach American shores. There is also growing concern about nonmilitary cutoffs of cobalt supplies by cartel actions or political upheavals in major producing nations. Many observers also see the possibility of episodic rises in the price of cobalt such as occurred in the late 1970s.

Cobalt and Its Uses in U.S. Industry

Cobalt is a hard, brittle, metallic element found in association with nickel, silver, lead, copper, and iron ores and resembling nickel and iron in appearance. Its most common use is in alloys to which it imparts qualities such as heat resistance, high strength, wear resistance, and superior magnetism.^{2/} Major end-products include jet engine parts, permanent magnets, cutting tools, and pigments.^{3/} World production is estimated to have been 66 million pounds in 1980.^{4/} U.S. primary demand totaled 16 million pounds for that year, representing about 24 percent of world

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1. A more extensive examination of the issues surrounding strategic minerals will be made in a CBO study to be published in the near future.
 2. Scott Sibley, Cobalt, Mineral Commodity Profiles, Bureau of Mines (1977), p. 1.
 3. Ibid., p. 1.
 4. Bureau of Mines, Mineral Commodity Summaries, 1982, p. 37.

production.^{5/} The dominant source is central Africa, in particular Zaire. In 1979, Zaire produced over 53 percent of the world's cobalt.^{6/}

Current U.S. Policy

Cobalt has been identified as "strategic and critical" by the federal government since the inception of stockpiling under the Strategic and Critical Materials Stockpiling Act of 1946. The appropriate size of the cobalt stockpile has, however, been the subject of much debate. Significant purchases occurred throughout the 1950s but in 1973, under the Nixon Administration, a general change in stockpile policy reduced the goal for cobalt by 70 percent and subsequently millions of pounds of cobalt were sold. In late 1976, the Ford Administration effectively reversed the decision of the Nixon Administration and established a new cobalt goal of 85.4 million pounds, which is currently about 49 percent filled.

U.S. manufacturers keep stores of cobalt on hand, typically enough for four to six months of consumption. Some recycling of cobalt also occurs; recent recycling levels have been equal to about 7 percent of U.S. consumption. There is no U.S. production at present, so that primary U.S. demand (consumption not met through recycling) must come from drawing down stocks or importing.

Subsidies to promote domestic cobalt production--which is uneconomic under current market conditions--were recently a subject of hearings before the Senate Banking Committee.^{7/} Cobalt was one of many ores subsidized under the Defense Production Act Supply Expansion Program during the Korean War.

Expanded access to public lands for exploration and development, a goal of the present Administration, has been justified in part on the need for strategic minerals. Administration officials have also suggested that their rejection of the Law of the Sea Treaty was due in part to the strategic

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5. Primary demand measures the apparent consumption of cobalt minus that met by recycling scrap. Data from Bureau of Mines.
 6. Bureau of Mines, Mineral Commodity Summaries, 1982, p. 201.
 7. Defense Production Act and the Domestic Production of Cobalt, Hearings before the Senate Committee on Banking, Housing, and Urban Affairs (October 26, 1981).

importance of ocean minerals and the unfavorable terms afforded U.S. mining companies interested in such development.

Plan of the Paper

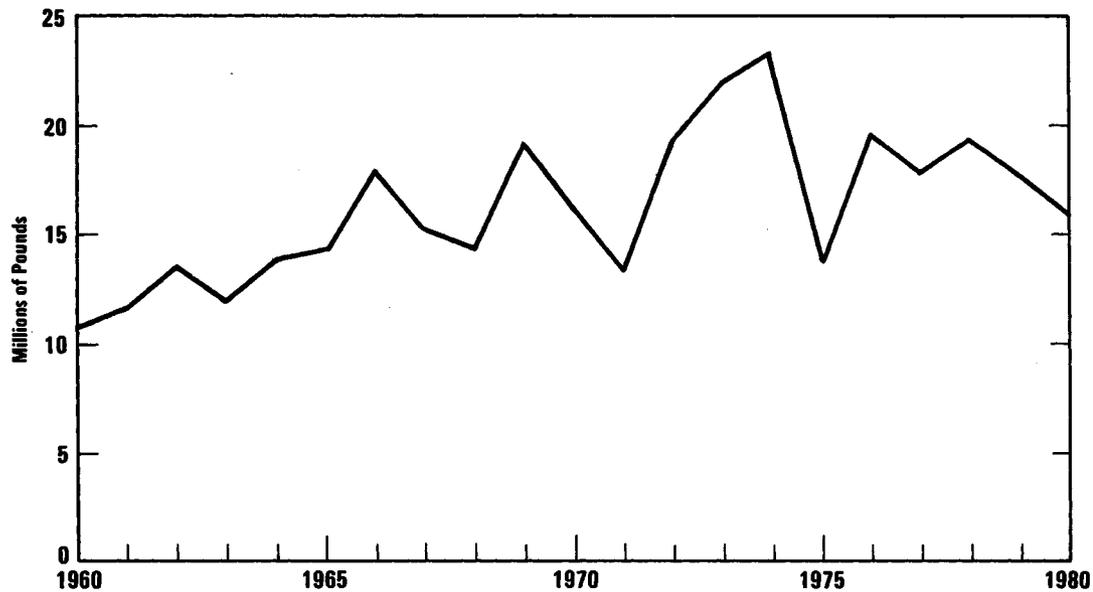
Are government cobalt stockpiles, cobalt production subsidies, and expanded lands access justified on strategic grounds? An answer to this question depends on the degree to which the United States is exposed, at any time, to cobalt supply shortfalls, and the extent to which such shortfalls are attended by significant economic, political, or military costs. Chapter II analyzes the U.S. demand for cobalt and the degree to which price increases in the past have motivated the different end users to reduce or eliminate cobalt consumption. Chapter III assesses the supply picture for both the United States and the world. Chapter IV projects demand and supply trends through 1990. It also surveys potential disruptions in supply and the market adjustments they would entail. The final chapter examines some policy options.

CHAPTER II. ANALYSIS OF COBALT DEMAND

This chapter presents the results of an analysis of the demand for cobalt, based upon data compiled by the Bureau of Mines in the 1960s and 1970s. The analysis suggests that cobalt price increases motivate significant substitution of other materials over time.

The demand for cobalt has shown an upward trend over the past 20 years, although use fluctuated greatly from year to year (see Figure 1). Growth in cobalt use reflects, in part, the metal's high-temperature properties, which became increasingly important during the 1960s and the 1970s for jet engine production, where the trend has been to hotter operating temperatures. On the other hand, throughout this period significant substitution for cobalt occurred in the production of magnets. Additionally, growth in the U.S. economy has been shifting toward the service

Figure 1.
U. S. Primary Demand for Cobalt, 1960-1980



SOURCE: Congressional Budget Office based on data from U.S. Bureau of Mines.

and high technology sectors, where cobalt has limited application. As a result, the use of cobalt should grow less rapidly than the economy in coming years.^{1/}

Table 1 presents five-year averages of the demand for cobalt in relation to gross domestic product (cobalt intensity-of-use). From 1960 to 1975, a slight downward trend is apparent. In the 1976 to 1980 period, however, the intensity-of-use of cobalt drops appreciably. This relatively large drop in cobalt's intensity-of-use clearly reflects the significant price increases that occurred during this period, as depicted in Figure 2.

TABLE 1. COBALT INTENSITY-OF-USE, 1961-1980

| Period | Average Primary Demand for Cobalt ^{a/} (millions of pounds) | Gross Domestic Product ^{b/} (billions of 1971 dollars) | Cobalt Intensity-of-Use (thousands of pounds of consumption per billion dollars of real gross domestic product) |
|-----------|--|---|---|
| 1961-1965 | 13.1 | 773 | 16.9 |
| 1966-1970 | 16.6 | 942 | 17.6 |
| 1971-1975 | 18.3 | 1,122 | 16.3 |
| 1976-1980 | 18.0 | 1,684 | 10.7 |

SOURCE: CBO calculations.

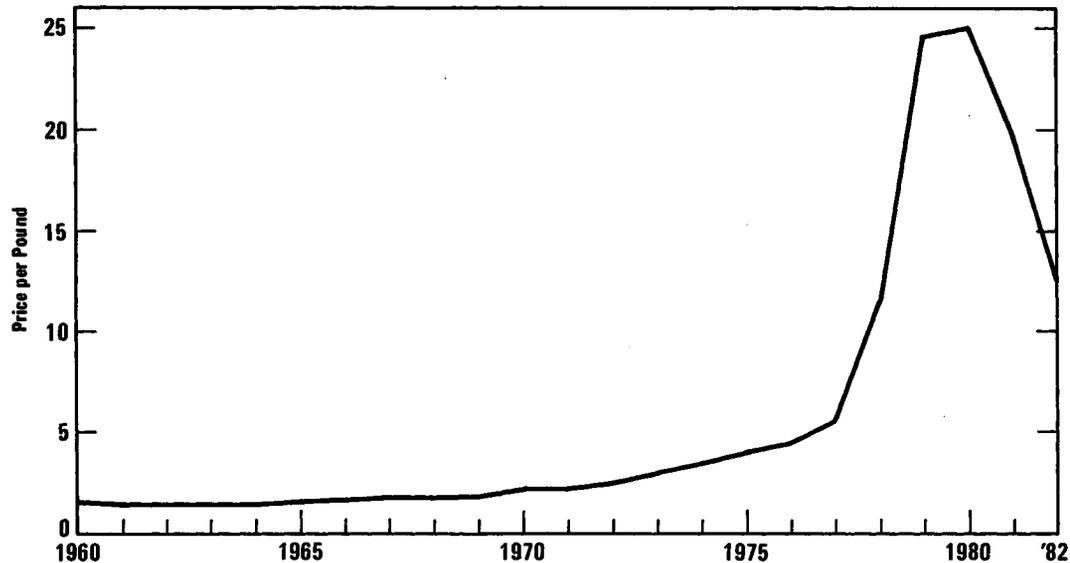
- a. Bureau of Mines data.
- b. Economic Report of the President.

The Recent Price History of Cobalt and U.S. Market Responses

From 1977 through 1979, the price per pound of imported cobalt rose from approximately \$5.50 to approximately \$25.00; spot prices as high as \$50.00 per pound were recorded, and cobalt was in short supply. These price

1. Wilfred Malenbaum, World Demand for Raw Materials in 1985 and 2000, University of Pennsylvania (1978), pp. 44-49.

Figure 2.
Cobalt Prices in the U. S. Market, 1960-1982



SOURCE: Congressional Budget Office, based on data from U.S. Bureau of Mines.

Note: The cobalt price for 1982 is the May price.

increases were fueled by war in the Shaba region of Zaire, which, although only shutting down cobalt production for a short time, caused increases in worldwide private stockpiling. A simultaneous peaking of cobalt use in many Western nations, and the cessation of cobalt sales from the U.S. strategic stockpile (see below), allowed Zaire, the world's primary supplier and acknowledged price setter, to execute this substantial price increase. Since then, substitution of other materials for cobalt as well as worldwide recession have driven the price down again. Estimates of the quantitative relationship between price increases and consumption of cobalt are presented in the next section. Substitution for cobalt is evidently possible for many applications, and over time higher prices can effectively motivate such substitutions.

The Response of Major Cobalt End Uses to Price Changes

Cobalt is primarily employed in jet engine (or gas turbine) construction, in electrical components, machinery production, and in a number of

nonmetallic applications (see Table 2). Although consumption is generally insensitive to moderate price changes in the short run, a careful examination of each of these end uses reveals that users do respond to price, particularly over the long run. Table 3 gives the representative price

TABLE 2. COBALT END USES (In percent of total use)

| Use | 1976-1980 Average |
|---|----------------------|
| Air and Surface Engines | 25 |
| Electrical Components (Magnets) | 23 |
| Machinery (Machine Tools, Construction Machinery) | 17 |
| Nonmetallic Uses | |
| Paints | 15 |
| Chemical catalysts | 10 |
| Ceramics | 8 |
| Miscellaneous | 2 |

SOURCE: Bureau of Mines.

TABLE 3. REPRESENTATIVE COBALT LONG-RUN PRICE ELASTICITIES BY END USE

| Use | Price Elasticities |
|--|-----------------------|
| Jet Engines (Gas Turbines) | -0.17 |
| Electrical Components (Magnets) | -0.41 |
| Machines (Machine Tools, Construction Machinery) | -0.27 |
| Nonmetallic Uses | |
| Paints | -0.63 |
| Chemical catalysts | -0.10 |
| Ceramics | -0.37 |
| Weighted Average | -0.32 |

SOURCE: CBO econometric modelling results.

elasticity of demand for each end use. The overall long-run elasticity of demand for cobalt is estimated to be approximately -0.32. This means that a 1.0 percent increase in the price of cobalt would cause use to drop by 0.32 percent. Levels of cobalt recycling also respond to price. As Table 4 indicates, pre-1976 scrap levels never exceeded 2.5 percent of U.S. cobalt consumption; the 1980 level was over 6.9 percent.

TABLE 4. COBALT SCRAP RECYCLING

| Year | Percent of Total Consumption | Thousand Pounds |
|--------------|------------------------------|-----------------|
| 1960 to 1976 | 2.4 | 330 |
| 1977 | 2.8 | 507 |
| 1978 | 5.1 | 1,036 |
| 1979 | 6.2 | 1,170 |
| 1980 | 6.9 | 1,181 |

NOTE: These statistics reflect the recent increases in scrap recycling motivated by cobalt price increases. Limited reporting, however, tends to render these numbers underestimates. (See Considerations in Choice of Form for Materials for the National Stockpile, National Materials Advisory Board, National Research Council, Publication NMAB-378, 1982.)

Gas Turbines. Cobalt-bearing superalloys are employed in jet engine production for aircraft, and for gas turbine engines used for both electric power generation and gas pipelines. During the 1976-1980 period, cobalt primary demand for this end use averaged about 4.6 million pounds.^{2/} Cobalt use in this sector traditionally has been considered very insensitive to price changes, due to the high temperature properties that cobalt bearing alloys exhibit, and to the limited importance of the cost of cobalt metal in alloys when contrasted to the cost of a jet engine.^{3/} Econometric analysis of cobalt use confirms that consumption in this end use is relatively insensitive

2. Primary demand for this end-use category is calculated as apparent consumption for this end use minus 60 percent of scrap cobalt.
3. In 1982 a military engine retailed for \$3-4 million. Its cobalt content was around 900 pounds. Even at \$100 per pound, the cost of cobalt in the engine would be less than 3 percent of the engine's price.

to price changes as compared to the other end uses. Moreover, price-related adjustments occur in this sector relatively slowly. The short-run (one-year) elasticity of demand is estimated to be -0.03 , and the long-run (six-year) elasticity of demand -0.17 .^{4/}

Magnets. A second major use of cobalt involves the production of magnets for electrical components, primarily alnico (aluminum-nickel-cobalt alloy) magnets used in electric motors, loudspeakers, car radios, and television speakers. Cobalt price increases in the late 1950s resulted in the substitution of cobalt-free ceramic magnets for alnico magnets in many loudspeakers. An average primary demand of 4 million pounds of cobalt was registered by this sector over the 1976-1980 period.^{5/}

Econometric modeling of cobalt use in this sector reveals a strong response to price changes due to the availability of substitutes. The best-fit explanatory equation estimates a short-run elasticity of demand of -0.12 , and a long-run elasticity of demand of -0.41 .

Machinery. Cobalt alloys are also used in machine tools and construction machinery. The average primary demand for cobalt for this end use was 3 million pounds for the 1976-1980 period.^{6/} Cobalt is used in cemented carbide alloys as a "metal matrix," or cement, in production of high-strength (often tungsten carbide alloy) cutting tools. These cemented carbides are often used to produce drilling bits in mining and drilling operations. Econometric modeling efforts reveal a long-run demand elasticity for cobalt in this end use of -0.27 .

Nonmetallic Applications. Cobalt is used in a number of nonmetallic applications. Oil-based paints use cobalt oxide additives to reduce drying time. Cobalt is employed as a catalyst in the petrochemical industry. Cobalt also has a wide variety of uses in ceramic glass production. For the 1976-1980 period, primary demand for cobalt averaged 2.7 million pounds for paints, 1.8 million pounds for catalysts, and 1.5 million pounds for

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4. Neither of these elasticities, however, was statistically significant at the 90 percent confidence level.
 5. Calculated as apparent consumption for this end use, minus 15 percent of scrap.
 6. Calculated as apparent consumption for this end use, minus 20 percent of scrap.

ceramics and glass.^{7/} Econometric modeling efforts indicate that the use of cobalt is relatively sensitive to price in both paints and ceramics, but its use as a catalyst is not. Estimates for the demand elasticities for these end uses are summarized in Table 5.

TABLE 5. REPRESENTATIVE DEMAND ELASTICITIES FOR NON-METALLIC COBALT APPLICATIONS

| | Short-Run Elasticity | Long-Run Elasticity |
|-----------|-------------------------|------------------------|
| Paints | -0.25 | -0.63 |
| Catalysts | -0.04 | -0.10 |
| Ceramics | --a/ | -0.37 |

NOTE: See Appendix A.

- a. No estimate of short-run elasticity for ceramics was made (see Appendix A).

Examples of End Use Adjustments

As the previous section detailed, most of cobalt's end uses show a long-run sensitivity to price. The large and sustained increases in price during the 1977 to 1979 period not unexpectedly reduced the demand for cobalt. A careful review of the recent history of each of these end uses shows how conservation and substitution efforts brought about the adjustments.

The use of cobalt for jet engines is insensitive to price in the short run. Accordingly, and in light of the simultaneous surge in demand for all air and surface jet engines during the 1975-1979 period, it is not surprising that these years witnessed a significant increase in cobalt consumption for this end use in spite of the 1977-1979 price explosion. Nevertheless, the 1977-1979 experience motivated a number of actions in this sector. Efforts

7. Calculated as apparent consumption of each end use, minus 2 percent of scrap for paints and 1.5 percent of scrap each for catalysts and ceramics.