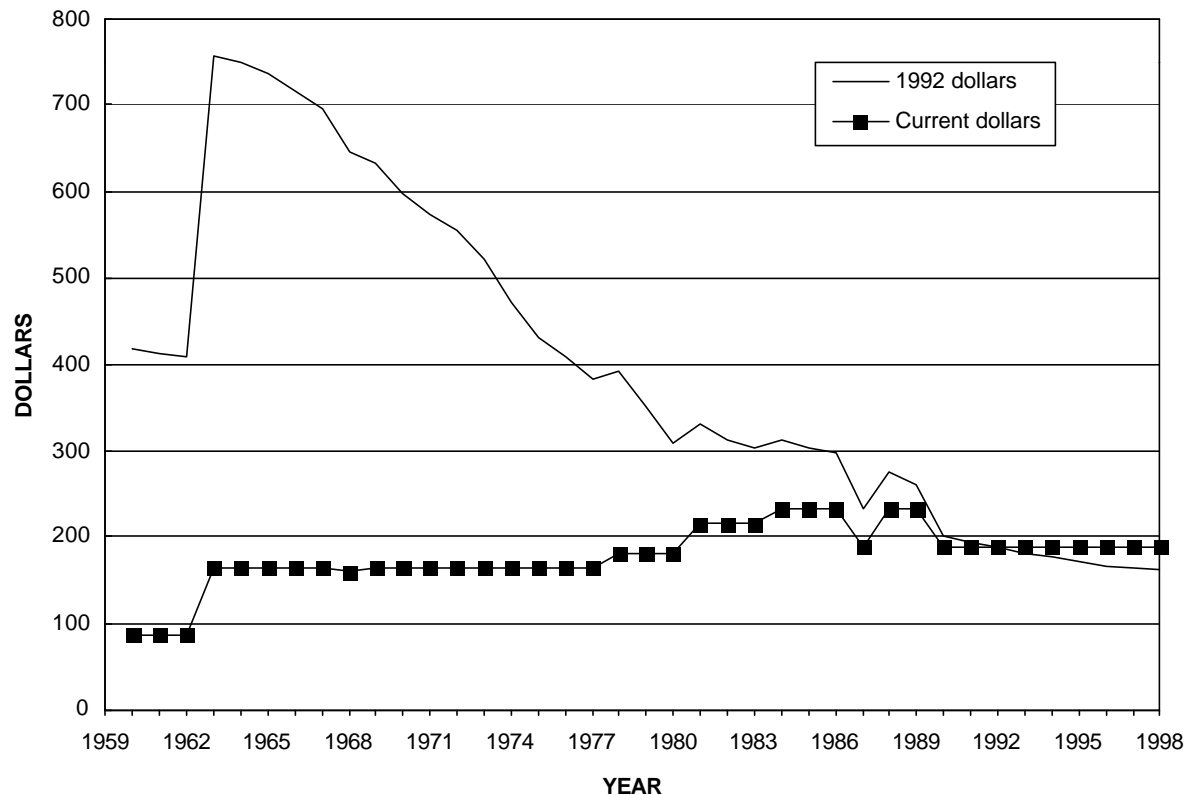


### Yearend Hafnium Sponge Metal Price (Dollars per kilogram)



### Significant events affecting hafnium prices

1950	The decision to use hafnium-free zirconium in nuclear reactors
1951	The decision to use hafnium in nuclear reactor control rods
1979-81	Economic recession high inflation

In 1923, hafnium was discovered when Dirk Coster and George Charles von Hevesey separated it from zirconium. Anton Eduard van Arkel and Jan Hendrik de Boer first produced metal 2 years later by using the crystal bar process—hafnium tetrachloride passed over a tungsten filament (van Arkel and de Boer, 1925). Hafnium and zirconium occur together in the ore mineral zircon. Until the 1940's, fractional crystallization of zirconium-hafnium compounds was used to produce limited quantities of hafnium oxide and metal powder. In 1948, hafnium metal powder was

quoted at \$32 per gram (\$32,000 per kilogram). Because of the high costs associated with this technique, a more-economical means was sought. Development of improved methods to separate the two elements began in the 1940's. In 1949, the price of hafnium metal powder dropped to \$22 per gram (\$22,000 per kilogram). That same year, Carbide & Chemicals Corp., Oak Ridge, TN, developed a liquid-liquid solvent extraction technique to remove hafnium from zirconium; technology that had grown out of the Manhattan Project (Powell, 1961). Commercial production of hafnium

arose from the need to produce hafnium-free zirconium metal for use in nuclear reactors. In 1950, a decision was made to use zirconium in the prototype land-based *Nautilus* nuclear reactor for future use in submarines (Wilson and Staehle, 1960, p. 1). In 1951, hafnium was selected as the material to be used in the reactor's control rods.

Hafnium was an expensive laboratory metal in 1945 when development work on an improved magnesium-reduction process (Kroll process) began at the U.S. Bureau of Mines' (USBM) Northwest Electrodevelopment Experiment Station in Albany, OR (Etherington, Dalzell, and Lillie, 1955, p. 2). A pilot plant to produce zirconium metal by using the Kroll process began operating in 1947 and was expanded in 1949, 1950, and twice in 1951 (Kroll, 1937; Kroll, Schlechten, and Yerkes, 1946; Kroll, Schlechten, and others, 1947; Kroll, Anderson, and others, 1948). It was not until 1951, however, that the USBM facility produced several kilograms of hafnium metal grading 28% hafnium and the balance zirconium. By yearend 1951, the USBM produced 3,916 kilograms (8,634 pounds) of hafnium oxide that was used to produce 1,395 kilograms (3,075 pounds) of hafnium sponge (Smith and Stephens, 1960, p. 84).

Hafnium's commercial availability coincided with the expiration of U.S. Department of Defense contracts for nuclear reactors in 1962. The price remained stable at about \$165 per kilogram (\$75 per pound) for 15 years, and the continued availability of the metal resulted from the growth and development of the commercial nuclear industry.

U.S. demand for hafnium declined in the 1990's as no new orders for nuclear reactors were placed. Demand is primarily for replacement parts and control rods in existing nuclear reactors and as an alloying agent in certain superalloys.

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**Yearend Hafnium Sponge Metal Price**  
(Dollars per kilogram<sup>1</sup>)

Year	Price	Year	Price	Year	Price	Year	Price
1959	NA	1969	165.35	1979	181.88	1989	231.49
1960	88.18	1970	165.35	1980	181.88	1990	187.39
1961	88.18	1971	165.35	1981	214.95	1991	187.39
1962	88.18	1972	165.35	1982	214.95	1992	187.39
1963	165.35	1973	165.35	1983	214.95	1993	187.39
1964	165.35	1974	165.35	1984	231.49	1994	187.39
1965	165.35	1975	165.35	1985	231.49	1995	187.39
1966	165.35	1976	165.35	1986	231.49	1996	187.39
1967	165.35	1977	165.35	1987	187.39	1997	187.39
1968	159.84	1978	181.88	1988	231.49	1998	187.39

NA Not available

<sup>1</sup> Prices are an average of a range, converted from pounds.

Source: American Metal Market.