

The Magnesium Industry in Transition

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Abstract. Dow Chemical dominated the magnesium industry for decades but ultimately exited in 1998. This article considers the evolution of the industry and Dow's decision to divest.

Key Words: Capacity, dominant firm, exit, limit pricing, magnesium.

I. Introduction

Few economists are familiar with the industrial history of magnesium, the lightest metal in commercial use. For much of the twentieth century, the Dow Chemical Company dominated world production of magnesium and maintained a position of near-monopoly in the United States. To deter entry when commercial demand for magnesium began to grow appreciably in the 1960s, Dow employed a remarkable range of tactics, including announcements of excess capacity, limit pricing, and sophisticated price discrimination.² Moreover, Dow's production efficiency, honed through decades of experience, was widely recognized. Yet by the end of the century Dow's advantages had eroded, and significant entry occurred in the US and especially abroad. Faced with growing import competition, falling prices, and a storm-damaged plant, Dow exited the industry in November 1998.

This article describes the evolution of the magnesium industry and its current status.³ It begins with an overview of magnesium's uses and production methods, and concludes with an assessment of Dow's exit decision.

Magnesium's Applications and Markets

Initially used as a pyrotechnic material in bombs and flares, magnesium now has diverse applications. These include "structural" uses in aerospace, automotive, and other products that take advantage of magnesium's light weight.⁴ Additional applications exploit magnesium's extensive chemical properties. About half of all magnesium produced today is added to aluminum alloys to enhance their characteristics. Magnesium's single largest use is in aluminum "flip-top" cans, where about 2.5% magnesium content is essential.

Unlike other metals that trade on a global market at a reasonably uniform price, the markets for magnesium have been fragmented. For many years magnesium producers such as Dow were able to

¹ I thank Ken Corts and Deborah Kramer for helpful comments. This article gives interpretations of Dow Chemical's actions, and I retain full responsibility for errors.

² These tactics are considered in detail in Lieberman (1983, 1998).

³ Extensive information on the magnesium industry can be obtained from the US Geological Survey web site, <http://minerals.usgs.gov/minerals/pubs/commodity/magnesium/>. Kenney (1979) provides historical perspective.

⁴ Magnesium's density is 112 pounds per cubic foot, compared with 175 pounds for aluminum and 449 pounds for steel.

maintain price discrimination, facilitated by sizable US import tariffs.⁵ Tariff reductions have curtailed the scope for such practices, leading to a more uniform market. The US duty on imported magnesium ingot fell from 40% in the 1960s to 8% by the mid-1980s, with most imports from Canada and Israel now fully exempt.

Production Technology

There are two principal methods for making magnesium: the thermic process and the electrolytic process. Small-scale producers have generally utilized the thermic process in which dolomite, an abundant ore, is heated until magnesium vapor is given off. Entry is relatively easy for this technology, which has low capital cost but high operating costs. Prior to the rationalization of world magnesium tariffs, most major developed countries had at least one thermic plant.

Electrolytic plants are capable of attaining lower average total cost than thermic plants. Dow was a pioneer in the development of electrolytic technology. In the electrolytic process, an electric current is applied through magnesium chloride obtained from underground brine or sea water. While the electrolytic process for magnesium is similar to the standard Hall process for making aluminum, cost-efficient operation of a magnesium plant has required a considerable amount of tacit engineering knowledge. In recent years, however, know-how has become more widespread as foreign producers have gained experience and process improvements developed in the former Soviet Union have become available for license. With technology less of a barrier, access to cheap energy has become more important, thus favoring plant locations outside the United States.

II. Industry Evolution

Early Growth Driven by Wartime Demand

Wartime surges in demand shaped the magnesium industry during the first half of the twentieth century. Prior to 1915 Germany was the world's sole source of magnesium. With the British blockade of Germany during World War I, seven magnesium plants were built in the United States, although only those of Dow Chemical and the American Magnesium Company (AMC) were commercially significant.

The end of World War I led to a drastic decline in the demand for magnesium. All of the magnesium plants in the US were shut down except for those operated by Dow and by AMC, which became a subsidiary of Alcoa. In 1927 Dow and AMC signed a patent cross-licensing agreement, and they set up an arrangement that granted AMC the right to purchase magnesium from Dow at a significant discount from the market price. Dow then expanded capacity, and AMC closed its plant. Dow thus became the only US magnesium producer from 1928 until the outbreak of World War II.

By 1938, the eve of World War II, the four major magnesium-producing countries were Germany with 12,000 tons per year capacity, Britain with 5,000 tons per year capacity, the US (Dow) with 3,300 tons per year capacity, and France with 2,500 tons per year capacity. During World War II, magnesium production capacity expanded enormously throughout the world. German capacity reached a peak of 34,000 tons through the expansion of existing facilities. Furthermore, as the war progressed, the Germans built new magnesium plants in Austria and Norway.

⁵ To utilize excess capacity in the 1960s, for example, Dow sold magnesium to buyers in Germany at a discount of up to 40% off the US market price. Moreover, magnesium alloys with elastic demand were often priced at a discount by Dow.

Wartime expansion of magnesium production in the US started in 1940 when Dow doubled the capacity of its Midland, Michigan, plant and started construction of a new plant in Freeport, Texas. During 1941-1943, fifteen new magnesium plants were built in the United States, thirteen by the US government. Dow operated only one of these government-owned plants (at Velasco, Texas, not far from the Freeport plant). By the end of the war the US production capacity for magnesium increased by a factor of nearly *one hundred*, to 291,000 tons per year.⁶

Postwar Developments

After the war, production of magnesium decreased drastically. US production fell from a peak of 184,000 tons in 1943 to only 5,300 tons in 1946. Germany was prohibited from producing magnesium. Moreover, most of the German plants were located in what became the Soviet zones of Germany and Austria. The Russians dismantled the plants and took them back to the USSR.

As the war ended, Dow closed its original plant at Midland because of improved economies at its Freeport, Texas plant. All of the government plants were closed by November 1945. Thus, Dow's Freeport plant remained the only plant in the US producing magnesium after the war. Post-war US magnesium production rose very modestly from 5,300 tons in 1946 to 15,700 tons in 1950, which was significantly below the 18,000 ton capacity of the Freeport plant.

The Korean War revived magnesium production. Dow increased the capacity of its Freeport plant to 24,000 tons per year. Seven government-owned magnesium plants were reactivated and by the end of 1951 were producing at 70% of capacity. Overseas, Norsk Hydro Elektrisk (a private company with majority ownership by the Norwegian government) began reconstruction of the German-built plant at Heroya, Norway, at 12,000 tons per year capacity in 1950.

After the Korean War demand for magnesium decreased, and virtually all the US government-owned magnesium plants were again shut down except the Velasco, Texas, plant operated under lease by Dow. The US government established a public auction to sell the Velasco facility, which was by far the most efficient of the magnesium plants built by the government during World War II. Prior to the auction, Dow operated the Freeport and Velasco plants at capacity to build a magnesium stockpile. Dow proved to be the sole bidder for the Velasco plant, which was subsequently closed for four years as Dow drew inventories down.

While Dow dominated the post-war production of magnesium in the US and worldwide, an important constraint on Dow's pricing was the existence of a US government-owned stockpile amassed for emergency wartime use. At its peak, this government stockpile contained enough magnesium to supply all US consumption for several years or more. The government made periodic sales from the stockpile, which was gradually depleted and eventually terminated in 1975.

Entry Deterrence by Dow

In 1958 a new entrant, Alabama Metallurgical Corporation (Alamet), began construction of a new 6,000-ton-per-year thermic plant, partly to serve the market for high-purity magnesium, which Dow was unable to supply. By the mid-1960s, several firms announced their intention to enter into magnesium production, attracted by magnesium's growth potential and by prospective refinements in

⁶ The outbreak of war in Europe did not prevent the application of antitrust law in the United States. In 1941 the Justice Department charged Dow, Alcoa, and I. G. Farben of Germany with price-fixing and the use of patent cross-licensing to monopolize magnesium production in the US. The companies pleaded no contest and signed a consent decree that called for compulsory patent licensing and the dissolution of prior patent agreements.

process technology. In addition, the major aluminum producers were known to be considering entry into magnesium.

Presumably, Dow recognized that significant entry would have made magnesium more of a commodity, which would have reduced Dow's margins and ability to price discriminate. Dow undertook a series of sophisticated actions and announcements to deter these potential entrants:

- Dow committed to a six-year "price incentive program" of gradual price cuts to buyers in the aluminum alloying industry. The details of this program were designed to deter entry by the technologically-advanced aluminum makers, such as Alcoa. Dow could have cut price immediately but chose instead to commit to a schedule of time-phased reductions. By doing so, Dow minimized its revenue loss while still sending a credible signal on its likely production costs.
- For other buyers Dow continued its policy of pricing magnesium ingot slightly below the production cost of a thermic plant. This limit pricing policy was reinforced by periodic announcements of excess capacity and efficiency gains, which signaled the potential for price cuts if large-scale entry occurred. For example, in 1965 Dow announced a series of incremental capacity expansions obtained by improving the electrolytic cells at its plants. One year later Dow reported that it was reactivating large amounts of idle capacity at the Freeport plant. And in 1967 Dow announced construction of a new magnesium plant located in the Pacific Northwest. Dow built part of this plant but then put construction on hold.

Thus, Dow announced excess capacity, signaled low costs, and contractually guaranteed low prices to a targeted set of buyers. These deterrence tactics, which have been considered at some length in the economics literature,⁷ appear to have forestalled large-scale entry into the US magnesium industry in the 1960s. Two start-ups entered the industry but soon encountered serious technical problems with their plants. Moreover, by the end of the decade, Alamet closed its small thermic plant after years of marginal results.⁸ Thus, by the early 1970s Dow found itself once again the sole producer of magnesium in the United States.

Dow's Strategic Shift

The early 1970s were a turning point for Dow. The firm shifted from its "limit-pricing" strategy, designed to maintain Dow's position as the dominant magnesium producer, to a "skim pricing" type of strategy intended to maximize more immediate returns. (Figure 1 plots the price of magnesium ingot from the 1950s through the 1990s.) Dow ended its "price incentive program" in 1971, raising the price paid by the aluminum companies from 30.25 cents to 36.25 cents per pound. By the following year, growth in US demand had absorbed all of Dow's excess production capacity. Dow's ability to raise prices was constrained briefly by wage and price controls imposed by the US government. When these controls were lifted in 1974, Dow responded by doubling the price of

⁷ See, for example, Spence (1977), Dixit (1980), Bulow *et al.* (1985) and Lieberman (1987) on excess capacity; Gaskins (1971), Milgrom and Roberts (1982) and Harrington (1986) on limit pricing; and Aghion and Bolton (1987) on contractual barriers to entry. While Dow's behavior may seem consistent with theories on the use of excess capacity as an entry deterrent, it is important to note that Dow exploited capacity built by the government during World War II. Dow understood how to use excess capacity as a strategic weapon but never built such capacity when required to pay the full investment cost.

⁸ Following Alamet's exit, the US market for high-purity magnesium was supplied by imports.

magnesium ingot, followed by additional price hikes. In part, such price increases were needed to cover the post-OPEC rise in energy costs. But the pattern suggests that Dow was now striving to maximize short-term profitability while cutting back on investment in the magnesium business. For example, in 1972 Dow sold its magnesium research library to Battelle Laboratories and transferred magnesium R&D staff to other business units. Dow's production capacity peaked in the 1970s and then declined as the firm chose not to expand or even renew its existing facilities.

Responding to these developments, Alcoa entered the magnesium industry, opening a plant in Washington state in 1976. NL Industries, one of the announced entrants of the 1960s, struggled with its technologically-troubled plant at the Great Salt Lake. AMAX, Inc., acquired this plant in 1980, brought it to design capacity, and then sold it to Magnesium Corporation of America (MCA). Yet despite the entry of these two large-scale magnesium producers in the United States, Dow's skim pricing strategy seems to have been comparatively successful. The inflation-adjusted US market price of magnesium held at historically high levels for more than a decade. Moreover, Dow's share of US capacity remained above 60%, even though the firm's world market share steadily declined.

The Rise of Imports

Dow's position weakened considerably in the 1990s. Tariff reductions, expansions by foreign producers, and the fall of communism made the magnesium market more global and increased the pressure on magnesium prices in the United States. Norsk Hydro, the world's second largest magnesium producer and a major refiner of aluminum, opened a large-scale magnesium plant in Canada in early 1990.⁹ Much of the plant's output was exported to the United States, where magnesium prices fell sharply. MCA filed an anti-dumping suit, which blocked further imports from Canada until the mid-1990s. Concurrently, the disintegration of the Soviet Union in 1991 led to an intensification of competition in the world magnesium market. Magnesium producers in the former Soviet states of Russia, Ukraine and Kazakhstan turned to exports as means of generating hard currency. Average US prices dropped significantly in 1992, and a two-tier pricing system was established, with import prices below the transaction prices charged by US producers. In 1994, MCA initiated further anti-dumping actions against shipments from Russia, the Ukraine and China. With the cessation of US imports from these countries, as well as from Canada, prices rose substantially in 1995.

With the resolution of the dumping investigations by the U.S. International Trade Commission, imports resumed in 1996 from Russia and Canada. This led to an immediate drop in prices, followed by continued price reductions over the next few years. The US became a net importer of magnesium, and by 1997 imports had grown to exceed Dow's annual production capacity. The trend was forecast to continue for the foreseeable future, as new entrants announced plans for additional large-scale magnesium plants in Australia, Canada, the Netherlands, and elsewhere.

Dow's Exit

Beleaguered by imports and the erosion of its cost advantage, Dow's magnesium operations were further hit by natural catastrophe in 1998. Dow's remaining magnesium plant at Freeport, Texas, was struck by lightning in June and flooded by Hurricane Francis and other rainstorms in August and September. Dow declared a "force majeure" and then announced on November 20 that it was shutting the plant, effective immediately. This abrupt closure ended Dow's history of more than 80 years in the

⁹ Industry experts believed that this plant achieved cost efficiencies exceeding those of Dow.

magnesium industry, serving as the world's largest producer from World War II through the mid-1990s.

Dow's exit signaled the declining role of US producers in the increasingly global magnesium industry. The principal countries importing magnesium to the United States from 1995 to 1998 were Canada (52%), Russia (22%), China (12%) and Israel (5%). In 1999, the year after Dow's exit, the world's major magnesium producing nations were the United States (22% of world output), Canada (23%), China (16%), Russia (13%), Norway (9%) and Israel (6%). Norsk Hydro had emerged as the world's largest magnesium maker, with plants in Norway and Canada accounting for slightly less than one-fourth of world magnesium output. A quarter century earlier, Dow's world market share had been twice as great, and Dow was the sole producer in the United States, from which it exported heavily. Assuming that many of the announced magnesium plants are completed by new entrants around the world, this trend toward globalization and declining concentration should continue through the early part of the twenty-first century.

III. Conclusions

The history of the magnesium industry illustrates the rise and fall of a dominant firm, a process that has been documented for many industries (e.g., Rosenbaum, 1998). Factors leading to Dow's success have been common among dominant firms: early entry, cost efficiency, and strategic deterrence behavior. What seems unusual about magnesium, though, is that Dow appears to have made a conscious choice to relinquish its position. This strategic shift occurred in the early 1970s, when Dow began to "harvest" its magnesium business rather than invest beyond its Texas plants. Dow switched from a "limit pricing" strategy designed to deter entry, to a "skim pricing" type of strategy that ultimately sacrificed the firm's viability as a magnesium producer.

Why did Dow make such a choice? Unlike Dow, other dominant firms have opted to expand preemptively in related industries (e.g., DuPont in titanium dioxide (Ghemawat, 1984) and Alcoa in aluminum prior to 1945). One potential explanation is that Dow's cost advantage was not sustainable. Dow's production process benefited from years of incremental improvements but was not fundamentally different from the technology potentially available to others. (DuPont, by comparison, had pioneered a more differentiated process for titanium dioxide.) Moreover, Dow's cost advantage was due in part to simple economies of scale. Dow was the only magnesium producer with electrolytic plants of efficient scale in the decades following the Second World War. Given modest demand for magnesium during peacetime and a potential global market fractured by tariffs, there were no opportunities for entry of another efficient-scale plant until the US market expanded sufficiently in the 1960s. Later, as demand grew and tariffs fell, such plants could be sited in many locations around the world.

Constraints relating to "economies of scope" may also have made continued expansion unattractive for Dow. Dow's cost advantage arose partly from economies specific to the Texas plant complex where Dow's magnesium process utilized byproducts from other chemical operations. Such advantages could not be easily replicated at other sites, and the supply of byproducts may have limited Dow's ability to expand internally. Moreover, while Dow may have enjoyed economies of scope in magnesium production, on the marketing side magnesium had little in common with Dow's core chemical businesses. Magnesium was thus a potential candidate for divestiture as Dow sought to focus and restructure its operations in the 1980s and 1990s.¹⁰ At the same time, price hikes on magnesium

¹⁰ In the early 1990s Dow unsuccessfully sought a buyer for the Freeport plant.

provided cash flow in a period of transition that was difficult for Dow and for the chemical industry generally.

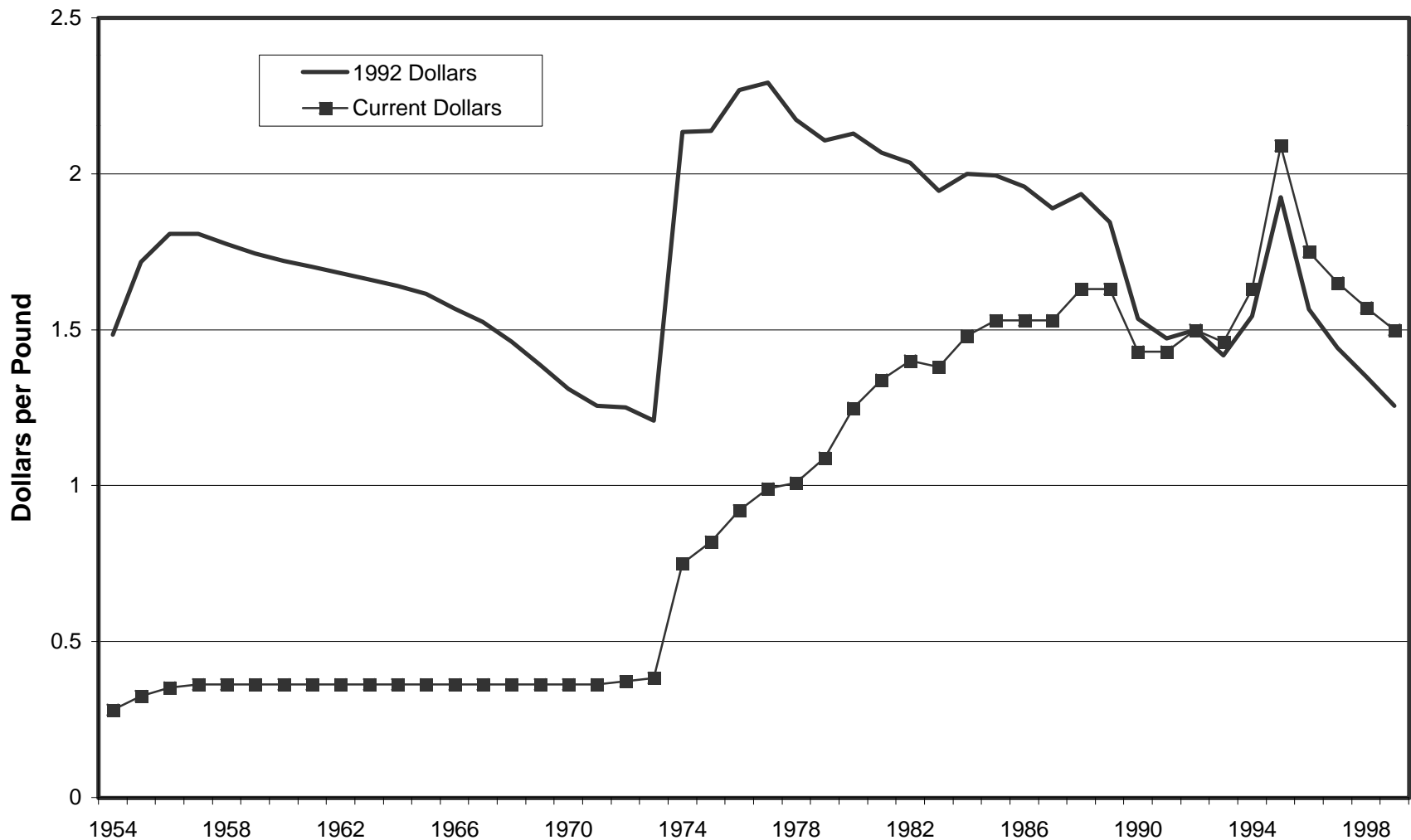
Continued expansion in magnesium would also have risked antitrust scrutiny. Alcoa's policy of aggressive capacity expansion was condemned by Judge Learned Hand in his Supreme Court ruling against that company in 1945. Similar investments by Dow to maintain dominance would surely have attracted Justice Department attention in the 1970s.

Thus, many factors contributed to Dow's decision to divest. Taken as a whole, Dow's actions and the industry's evolution show how dominant positions can erode in capital-intensive, homogeneous product industries where technological change takes place relatively slowly. Over a period of decades, the forces of demand growth, tariff reduction, and technology diffusion have transformed magnesium from a specialty material with a dominant producer into a commodity product with a competitive global market. While such trends toward globalization and declining concentration can be seen in many industries, seldom do we observe such a dramatic decline by a dominant firm.

REFERENCES

- Aghion, P. and P. Bolton (1987). "Contracts as a Barrier to Entry," *The American Economic Review* 77(3): 388-401.
- Bulow, J., J. Geanakoplos and P. Klemperer (1985). "Holding Idle Capacity to Deter Entry," *The Economic Journal* 95: 178-182.
- Dixit, A. (1980). "The Role of Investment in Entry-Deterrence." *The Economic Journal* 90: 95-106.
- Gaskins, D. (1971). "Dynamic Limit Pricing: Optimal Pricing Under Threat of Entry." *Journal of Economic Theory*.
- Ghemawat P. (1984). Capacity Expansion in the Titanium Dioxide Industry. *The Journal of Industrial Economics* XXXIII: 145-163
- Harrington, J. E. (1986). "Limit Pricing when the Potential Entrant is Uncertain of Its Cost Function," *Econometrica* 54(2): 429-438.
- Kenney, G. B. (1979). *An Analysis of the Energy Efficiency and Economic Viability of Expanded Magnesium Utilization*, Garland Publishing, New York.
- Lieberman, M. B. (1983). "The U.S. Magnesium Industry (A), (B), and (C)," Stanford University, Graduate School of Business, case S-BP-231.
- Lieberman, M. B. (1987a). "Excess Capacity as a Barrier to Entry: An Empirical Appraisal." *Journal of Industrial Economics* 35(June): 607-627.
- Lieberman, M. B. (1998). "Dow Chemical and the Magnesium Industry." In D. I. Rosenbaum, ed., *Market Dominance*, Praeger, Westport, CT.
- Milgrom, P., and D. J. Roberts (1982). "Predation, Reputation, and Entry Deterrence." *Journal of Economic Theory* 27(2): 280-312.
- Rosenbaum, D. I., ed. (1998). *Market Dominance: How Firms Gain, Hold, or Lose It and the Impact on Economic Performance*, Praeger, Westport, CT.
- Spence, A. M. (1977). "Entry, Capacity, Investment and Oligopolistic Pricing." *The Bell Journal of Economics* 8: 534-44.

Figure 1: Price of Magnesium Ingot



Source: US Geological Survey, *Metal Prices in the United States through 1998*. (Yearend price of 99.8% purity ingot, updated) .