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UPDATE ON EPA'S MAGNESIUM INDUSTRY PARTNERSHIP FOR CLIMATE PROTECTION

SCOTT C. BARTOS

U.S. ENVIRONMENTAL PROTECTION AGENCY

Introduction

The magnesium industry commonly uses sulfur hexafluoride (SF₆) to prevent the rapid oxidation and burning that occurs when the molten metal directly contacts air. Many companies apply a cover gas of dilute SF₆ mixed with dry air and/or carbon dioxide (CO₂) to maintain a protective layer on the molten metal surface. SF₆, an odorless and nontoxic gas, has been the industry standard for melt protection for more than 20 years. However, the continued emission of this long-lived, extremely potent greenhouse gas is a costly business practice with long term environmental impacts. While the annual amount of SF₆ released to the atmosphere is small in comparison to other greenhouse gases, each year's emissions accumulate and its environmental impact will persist for generations due to the chemical's 3,200 year atmospheric lifetime. Recent measurements indicate SF₆ concentrations in the atmosphere have grown approximately seven percent per year since 1978.¹ Scientific evidence indicates that emissions of greenhouse gases to the atmosphere are warming the earth's surface and changing the planet's climate system.² Scientists predict more frequent severe storms and droughts, increases in respiratory and infectious diseases, and rising sea levels will accompany climate disruption.

Leading magnesium producers and casting companies are working with the U.S. Environmental Protection Agency (EPA) to alleviate the global environmental threat of climate change. EPA is very proud to cooperate with the magnesium industry through the SF₆ Emission Reduction Partnership for the Magnesium Industry and the International Magnesium Association (IMA) to reduce greenhouse gas emissions. These voluntary initiatives are guiding research of new technologies, promoting environmental stewardship, and providing a valuable forum to freely exchange technical information. Significant progress has been made to identify and implement SF₆ emission reduction strategies since the partnership's inception.

Protecting the Climate

The U.S. magnesium industry and its products are protecting the climate both directly and indirectly. Sixteen U.S. companies (see Table 1) have volunteered to work with EPA to reduce emissions of SF₆ as partners in the SF₆ Emission Reduction Partnership for the Magnesium Industry. These environmental champions are leading the effort to reduce direct emissions of an important process chemical, SF₆, that is also a long-lived greenhouse gas.

¹M. Maiss and C. Brenninkmeijer, Atmospheric SF₆, Trends, Sources and Prospects, *Environmental Science & Technology* Vol. 32, No. 20, Oct. 1998.

² Intergovernmental Panel on Climate Change, Third Assessment Report, Climate Change 2001: The Scientific Basis, 2001.

In addition to the industry's efforts to reduce the direct emissions of SF₆, magnesium used to produce lightweight automotive parts allows for the construction of more fuel efficient vehicles and thus an indirect benefit for the environment. Lighter, more efficient vehicles provide superior performance, reduce imports of foreign oil, save money, and make the air cleaner. The magnesium industry's direct and indirect contributions to climate protection are a one-two punch for environmental protection.

Table 1. SF₆ Emission Reduction Partnership for the Magnesium Industry*	
Acme Die Casting	Magnesium Aluminum Corporation
Chicago White Metal Casting	Magnesium Corporation of America
Consolidated Foundries - Pomona	Magnesium Products of America
CONTECH Metal Forge Division of SPX Corporation	Northern Diecast
Del Mar Die Casting	Northwest Alloys
Diversified Diemakers	Product Technologies
Hyatt Die Cast & Engineering Corporation	Spartan Light Metal Products
Lunt Manufacturing	Wyman-Gordon Investment Castings

*As of January 1, 2002

SF₆ – Potent Greenhouse Gas

Historically, the industry controlled molten metal oxidation by applying solid salt fluxes or a sulfur dioxide (SO₂) based cover gas. While these techniques will prevent oxidation, they also introduce performance and safety compromises. Salt fluxes are corrosive, reduce product yield and quality, and present a solid waste disposal problem while SO₂ is toxic to humans and tends to condense upon and corrode steel equipment and facility structures. Compared to other methods of protection, SF₆ is relatively easy to use, presents no significant hazards to workers, results in fewer impurities in the product melt, and avoids the generation of large quantities of sludge.

From an environmental perspective, the primary concern with SF₆ is its high global warming potential (GWP), estimated to be 23,900 over a 100-year time horizon. The GWP provides a relative ranking of the ability of a specific greenhouse gas to trap heat in the atmosphere as compared to the most abundant anthropogenic greenhouse gas, CO₂. CO₂ has a GWP₁₀₀ equal to 1.

EPA and the Magnesium Industry Collaborate for Climate Protection

EPA consulted with magnesium industry representatives in summer 1998 to develop the SF₆ Emission Reduction Partnership for the Magnesium Industry. The partnership's memorandum of understanding (MOU) was finalized in 1999 following careful review and revision by industry representatives and EPA. The MOU describes the roles and responsibilities of the participants. EPA assists its partners to develop and analyze SF₆ emission control strategies and publicizes the partners' achievements. Partner companies agree to investigate and implement strategies to reduce emissions using a pollution prevention hierarchy to guide their search. Partners track their achievements using reporting software and inventory methods consistent with the Intergovernmental Panel on Climate Change's (IPCC) Good Practice guidance. On an annual basis, partners submit reports that estimate the use and emissions of SF₆ for the preceding year.

EPA welcomed 12 magnesium industry Charter Partners at the Earth Technologies Forum held in September 1999 in Washington, DC. The 16 current member companies represents 100 percent of U.S. primary production and approximately 80 percent of U.S. magnesium casting operations. The Partnership is open to all firms in the magnesium industry, and EPA expects participation to continue growing in 2002.

Following the pollution prevention hierarchy, the partnership has made significant progress towards identifying and adopting the most cost effective and environmentally friendly emission reduction technologies. The pollution prevention hierarchy guides companies to seek to reduce pollution as far upstream in the manufacturing process as is possible.

The magnesium industry's foremost trade organization, the International Magnesium Association (IMA), is an important ally to EPA in helping to implement the SF₆ partnership. To protect sensitive company specific data, the IMA has volunteered to receive and store the partners' annual reports. EPA meets with the IMA to compile the submitted data and produce the partnership's annual report. In 2000, the IMA initiated a ground breaking research program to identify viable chemical substitutes for SF₆ and SO₂. The association solicited technical support from outside research facilities, selecting a Norwegian group, SINTEF, to screen technically feasible protective cover gas alternatives. EPA proudly supports this proactive global industry initiative led by the IMA.

2000 Results

The partnership's total SF₆ emissions for 2000 are approximately 99,300 kg, a 14% decrease from 115,000 kg in 1999. But, the total emissions alone do not provide a complete picture of the partnership's successes because the total emissions are directly related to the industry's production activity in any given year. For example, when business is good, the industry will produce/cast more metal and require proportionately more cover gas. When addressing emissions from a growing or fluctuating industry sector, an "intensity" unit of measurement is preferred to total emissions because the intensity values (e.g. usage) should not expand or contract with economic activity. Therefore, the partnership compares individual companies' usage rates (kg SF₆/tonne of Mg) to evaluate their progress

(see figures 1 and 2). The partnership's average usage rate (both primary producers and casting companies) in 2000 is 9.3% lower than in 1999; a significant accomplishment in just one year.

EPA and the partner companies have worked together to develop and improve an electronic reporting tool that provides an efficient and consistent inventory method and helps assure good data quality.

SF₆ Usage Rates - Primary Producers (U.S. and International)

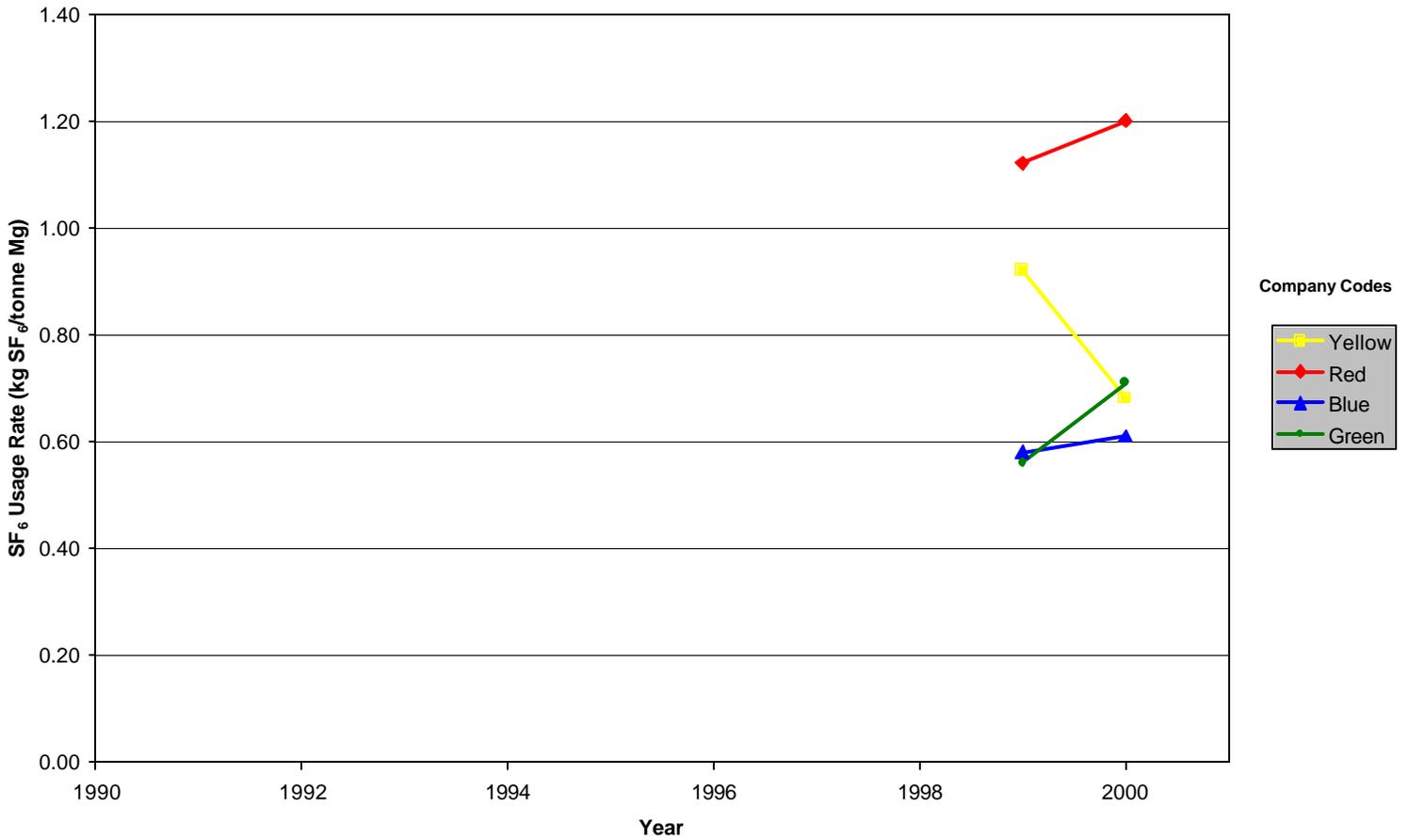


Figure 1.

Partnership SF₆ Usage Rates - Die Casting

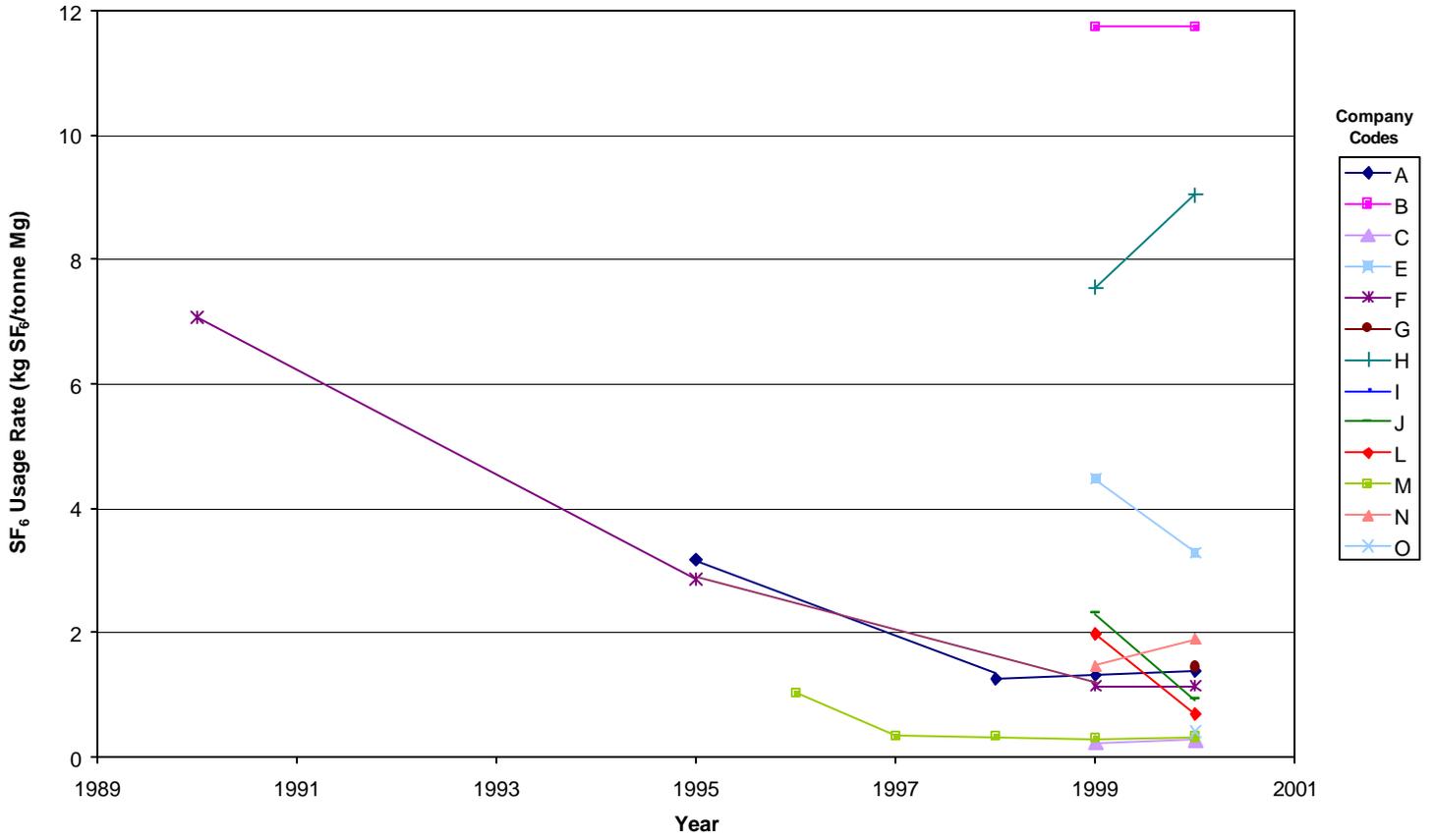


Figure 2.

SF₆ Emission Reduction Technologies

The SF₆ Emission Reduction Partnership for the Magnesium Industry has catalyzed numerous global industry initiatives to identify and implement pollution prevention strategies. Alternatives for reducing SF₆ emissions that are now being investigated fall into three general categories: practices that optimize SF₆ use and containment, chemicals that can be used as substitutes for SF₆, and technologies that capture and recycle SF₆. Specific processes that fall within each category have been demonstrated. A large number of partner companies have optimized SF₆ handling equipment and gas management by adopting good housekeeping practices that improve controls on cover gas distribution, tighten furnace enclosures, and minimize SF₆ loss during operation. Operators are exercising greater care in supplying the low concentrations of SF₆ to the melt that are recommended for proper operation and protection of molten magnesium.

Several alternative chemicals are being investigated for use. Sulfur dioxide (SO₂), an old industry standard, is being used throughout Hydro Magnesium's operations and in several other casting facilities, as a stop-gap measure to reduce SF₆ emissions until other more environmentally friendly technologies are successfully tested and commercialized. Sulfur dioxide provides effective protection of molten magnesium, but it is toxic and of concern for use in the workplace.

The most promising and well coordinated industry effort to identify alternative melt protection is being led by the International Magnesium Association and its Ad Hoc Committee on SF₆. This committee is composed of representatives from IMA, several magnesium casting firms, EPA, and an automobile manufacturer. The committee selected a research proposal from SINTEF, The Foundation of Scientific and Industrial Research at the Norwegian University of Science and Technology, to evaluate alternative cover gases for protection of molten magnesium. The study, in its second year, is evaluating several alternative chemicals including a fluoroketone provided by 3M. Air Products and Chemicals is considering providing a new candidate chemical to the study as well. Based on SINTEF's early results regarding the solubility of fluorine in molten magnesium, the investigators are evaluating the viability of bubbling fluorine up from the bottom of the melt or supplying fluorine to the melt in solid form (e.g., iron fluoride).

The Cooperative Research Centre for Cast Metals Manufacturing (CAST) in Australia is conducting research and development to find a suitable substitute gas for SF₆. Using the concept that the addition of fluorine into the magnesium oxide surface film is the key mechanism for preventing oxidation of molten magnesium, CAST developed a patented process that uses the hydrofluorocarbon gas 1,1,1,2-tetrafluoroethane, otherwise known as HFC-134a.

HFC-134a does not completely eliminate global warming concerns, as it has a relatively high GWP₁₀₀ of 1,300 but shorter atmospheric lifetime of 14 years. HFC-134a has been used with alloys AM-60, AZ91, AZ31, pure magnesium, and an experimental rare earth-containing magnesium metal.

Reportedly, some gas distribution modifications are needed to accommodate a conversion from SF₆.³

Brochot, the French producer of magnesium casting systems, has also developed an innovative cover gas substitute to SF₆. The company has developed a new casting wheel with the intent of minimizing surface oxidation when melting magnesium and magnesium alloys. The design reduces metal turbulence and the surface area subject to oxidation. In addition, Brochot has replaced SF₆ with a patented gas mixture containing CO₂, argon, and xenon.^{4,5}

Two membrane techniques are being investigated for use in capturing SF₆ from the gas stream exiting the furnace; one has been tested in pilot scale at Magnesium Corporation of America (MagCorp) in Utah. Air Liquide developed the Floxal SF₆ Recycle Process, a system reportedly capable of capturing SF₆ in low concentrations from hooded magnesium furnaces and concentrating the gas to concentrations appropriate for reuse on site at the magnesium facility. MagCorp and Air Liquide formed a partnership to develop and test this technology. The pilot-scale experiment demonstrated the technology's ability to reduce an ingot casting machine's SF₆ consumption by 41 percent via in-house SF₆ recycling.

Carbon Membranes, Ltd. is developing a second separation membrane technology. They describe their technology as a tailor-made carbon molecular sieve membrane (CMSM) that operates in the same generic fashion as Air Liquide's, i.e., SF₆ is separated from the hood exhaust and recycled to the magnesium melt surface. SF₆-bearing exhaust from the magnesium melt surface is captured and transported to a membrane process to separate, purify, and compress SF₆ to higher concentrations. The recovered SF₆ gas is reused for melt protection.

Conclusion

The objective of EPA's voluntary partnership with magnesium producers and casting companies is to reduce or eliminate emissions of SF₆ where **cost effective** and **technically feasible**. The individual Partner companies determine when such emission reduction efforts are cost effective and feasible to adapt to their operations.

³ Ricketts, N.J. and S.P. Cashion. Hydrofluorocarbons as a Replacement for Sulphur Hexafluoride in Magnesium Processing. Cooperative Research Centre for Cast Metals Manufacturing (CAST). Paper presented at EPA's Conference, SF₆ and the Environment: Emission Reduction Strategies; San Diego, CA. November 2-3, 2000.

⁴ Brown, R.E. Improved Magnesium Casting. In *Light Metal Age*, Vol. 58, p. 64. August 2000.

⁵ USGS. Mineral Industry Surveys, Magnesium in the Third Quarter 2000. U.S. Department of the Interior, U.S. Geological Survey, November 2000.

The magnesium industry's diligence and international coordination are uncovering many viable technologies to reduce SF₆ emissions. Some are available today and others are just over the horizon. It is clear that the magnesium industry is well positioned to make significant contributions to global climate protection. The industry's lightweight products will enable the automotive and aerospace industries to design and build the next generation of highly efficient transportation. EPA is proud to work with the magnesium industry and help foster its advances by supporting technology evaluations, recognizing partners' achievements, and promoting efficient information sharing.