Building a Bridge for Climate Protection: U.S. EPA and the Magnesium Industry

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Introduction

When producing and casting magnesium, sulfur hexafluoride (SF_6) is commonly used as a cover gas for the molten metal. SF_6 gas prevents the rapid surface oxidation (and possible burning) of the liquid metal when it comes into direct contact with air, by forming a protective film of fluorine-containing magnesium oxide (MgO). SF_6 is a colorless, odorless, non-flammable, non-toxic, and extremely stable man-made gas that was first synthesized in 1902. It became commercially available in 1940, and has been used by the magnesium industry for more than 20 years.

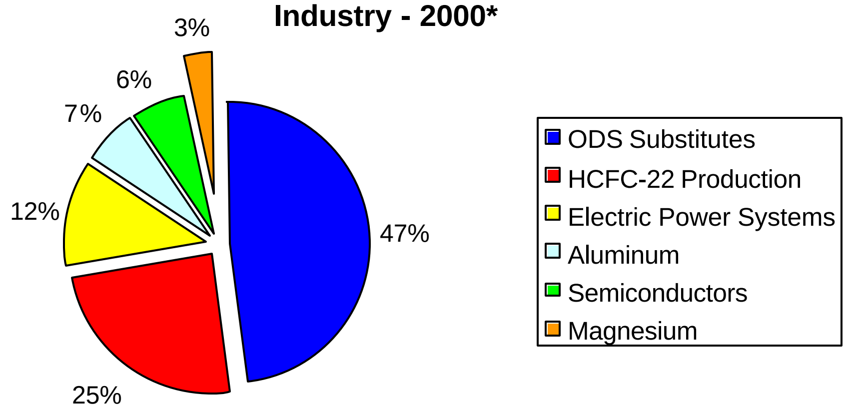
In 1999 global sales of SF_6 to the magnesium industry, excluding Russia and China, were approximately 170 metric tonnes (Smythe, 2000). SF_6 is an extremely potent greenhouse gas, with an atmospheric lifetime of 3,200 years. Consequently, it will accumulate in the atmosphere and its effect on the climate will be felt by many future human generations. This characteristic is highlighted by recent measurements that have identified an increase in atmospheric SF_6 concentrations of approximately 7 percent per year since 1978 (Maiss and Brenninkmeijer, 1998).

The industry is uniquely positioned to help address the global climate challenge, both directly and indirectly. The U.S. magnesium industry has joined with the U.S. Environmental Protection Agency (EPA) to develop a voluntary partnership to reduce SF_6 emissions. The partnership provides a forum to educate, assist and recognize industry efforts to reduce SF_6 emissions. Furthermore, magnesium's unique physical and mechanical properties have expanded its opportunities in electronics and automotive applications. Specifically, magnesium-based products are highly recyclable, with typically less than 5 percent material waste; and they allow for the manufacture of lighter, more fuel-efficient vehicles with lower associated CO_2 emissions.

Climate Impact of SF6

Until the mid-1990s, SF_6 use as a cover gas for melt protection was considered a safe environmental resource. It replaced the use of sulfur dioxide (SO_2) and solid salt fluxes, which are both toxic and corrosive. However, recent studies have shown that SF_6 is an extremely powerful greenhouse gas with the global warming potential of 23,900 times that of carbon dioxide (IPCC, 1995). Figure 1 illustrates the relative contribution of SF_6 to high GWP greenhouse gas emissions from industrial processes in the U.S. The magnesium industry accounts for approximately 3 percent of the total emissions from industrial processes. While this contribution may seem small, it can not be ignored given the rapid growth in demand for magnesium and magnesium cast parts and the extremely long atmospheric lifetime of this synthetic chemical.

Figure 1. Relative Contribution of SF_6 From U.S. Mg Industry - 2000*



**As compared to all U.S. sources of PFCs, HFCs, and SF_6.*

SF_6 Emission Reduction Partnership for the Magnesium Industry

In 1999, EPA and the magnesium industry officially launched the SF_6 Emission Reduction Partnership. The partnership's primary objective is to reduce or eliminate SF_6 emissions via cost effective and technically feasible means. Companies formalize a relationship with EPA by signing the Memorandum of Understanding (MOU). The MOU, which was established and developed in collaboration with the industry, outlines the roles and responsibilities of each party. Companies are responsible for tracking and reporting annual SF_6 usage, sharing information on successful mitigation strategies, and optimizing their production processes to reduce SF_6 usage. EPA is responsible for recognizing partners' achievements, serving as a clearinghouse for technical information and assisting partners to identify and implement cost effective emission reduction strategies.

Currently, the partnership includes 16 companies, and represents 100 percent of U.S. primary production and approximately 80 percent of U.S. magnesium casting operations. Table 1 provides a list of the current partners.

Table 1.
SF_6 Emissions Reduction Partnership for the Magnesium Industry – Current Partners (as of January 1, 2002)

Partner Companies
Acme Die Casting
Chicago White Metal Casting
Consolidated Foundries – Pomona
CONTECH Metal Forge Division of SPX Corporation
Del Mar Die Casting
Diversified Diemakers
Hyatt Die Cast & Engineering Corporation
Lunt Manufacturing
Magnesium Aluminum Corporation
Magnesium Corporation of America
Magnesium Products of America
Northern Diecast
Northwest Alloys[a]
Product Technologies
Spartan Light Metal Products
Wyman-Gordon Investment Castings

[a]*Ceased Mg production in October 2001.*

An important ally in implementing the partnership is the International Magnesium Association (IMA). The IMA has volunteered to receive and archive partner-specific confidential data. Partners estimate SF_6 reductions by using methods that follow IPCC Good Practice guidance (IPCC, 2000), i.e., all SF_6 consumed is emitted to the atmosphere. Based on this framework, EPA developed a software application that ensures the consistent estimation of SF_6 use and emissions among member companies.

The software application enables partners to estimate SF_6 usage by two methods, i.e., inventory or container tracking. The inventory method estimates SF_6 usage by developing a mass balance of SF_6 use throughout the year, i.e., new purchases, beginning and end of year quantities in storage. The container tracking method identifies and tracks, by date, the receipt, content, and dispatch of each SF_6 container that is brought on site. After completion, these reports are submitted to the IMA. EPA uses this information to develop the partnership's annual report and to estimate the magnesium sector's annual greenhouse gas emissions as committed by the U.S. under the United Nations Framework Convention on Climate Change.

Partnership Results and Best Practices

Between 1999 and 2000, program members reported a reduction in total SF_6 emissions of approximately 14 percent (i.e., 16,000 kg of SF_6). Table 2 provides an overall summary of average emissions from primary production and die casting facilities combined. The emission rate is defined as the quantity of SF_6 consumed per tonne of magnesium processed.

Table 2.
Partnership Average Emission Rates for 1999 and 2000

Year	1999	2000	Percent Change
Average Emission Rate[a] (kg SF_6/tonne of Mg)	2.3	2.0	- 13%

[a]*Averages are **not** production weighted.*

The reductions reflect partner efforts to improve SF_6 handling strategies, and implement new technologies to improve process efficiencies. These results are a significant achievement, and illustrate the commitment of member companies to the voluntary partnership.

EPA's partners have approached the need for greater environmental stewardship in different ways. Many partners have attempted to improve the efficiency of their cover gas system by tightening furnace enclosure hoods, or by improving controls for the distribution of low concentration SF_6 gas to the molten magnesium. For example, one partner has installed a system to automatically match the flow rate of SF_6 to the casting machine magnesium throughput. Consequently, if production quantities decline, the amount of SF_6 consumed by the cover gas system will automatically reduce. Also, another partner, using ambient air as a carrier gas, has upgraded its air drying system allowing it minimize moisture and therefore the amount of SF_6 required to adequately protect the melt.

Furthermore, MagCorp in partnership with Air Liquide has conducted a pilot-scale study into the use of SF_6 recycling systems. The study was implemented to test Air Liquide's Floxal recycling process, which uses a molecular filtration system to recover SF_6 from the process exhaust stream, for reuse within the facility. Results have proved successful, in that the Floxal recycling system has typically recovered greater than 90 percent of the SF_6 from the exhaust stream. Magcorp expects this capture/recycle technology will allow it to reduce SF_6 emissions by 45 percent (Tripp et. al, 2000).

Partnership Program Goals

As part of EPA's responsibility to assist partners in identifying cost effective and technically feasible practices, EPA is involved in several initiatives to enhance the understanding of the melt protection process, and to communicate this understanding to a wider audience. These key initiatives include: 1) research to develop alternative cover gases for SF_6 and SO_2 that are economically and environmentally viable; and 2) measurement program that aims to determine specific SF_6 emission levels from magnesium production and casting operations.

1. SF_6 Substitution Research

EPA and IMA are sponsoring a three year study to research alternate cover gases for SF_6. The research was initiated in 2000, and is being conducted by a partnership between SINTEF Materials Technology and the Norwegian Institute of Science and Technology (NTNU).

Currently, several gases have been evaluated by benchmarking against SF_6. These include, Boron Trifluoride (BF_3), Xenon/Argon/CO_2-based gas (supplied by Brochot, a French casting equipment manufacturer), 1,1,1,2-tetrafluoroethane (HFC-134a), hydrofluoroethers (HFE 7100 and HFE 7200), and a fluoroketone (FK). 3M has supplied the HFE and FK compounds. Furthermore, Air Products and Chemicals are expected to supply a new gas, sulphuryl fluoride (SO_2F_2), to the SINTEF SF_6 substitute study for testing during 2002.

Preliminary results have indicated that all gases performed well compared to SF_6. HFE 7100 has provided the best results thus far when assessed based on fire quenching and oxidation prevention abilities, however, the tests indicate the evolution of significant quantities of hydrogen fluoride (HF). When toxicity and greenhouse gas issues are taken into account, the FK gas produces the best overall results. It is predicted to have a global warming impact that is approximately 99.95 percent lower than SF_6 (Milbrath and Owen, 2000).

In addition to this basic research, investigators have also identified the presence of residual fluorine in the molten metal. Consequently, further tests will be conducted to assess the viability of dissolving fluorine into the melt in solid form, and thus improving the efficiency of the protection process. These tests will also address concerns regarding the impact of an increased fluorine concentration on metal quality and characteristics.

2. SF_6 Measurement Campaign

Currently, magnesium industry SF_6 emissions are estimated using methodology based on IPCC guidance. This methodology, consistent with J.D. Hanawalt's early work with SF_6 based melt protection, assumes 100 percent of the SF_6 used is emitted to the atmosphere (Hanawalt, 1972). However, expert opinion hypothesizes that some form of SF_6 destruction, via chemical reaction, occurs during the melt protection process. Consequently, if inventories are developed using IPCC guidelines, SF_6 emissions may be overestimated. Since the extent of destruction is unknown, EPA's measurement initiative represents a strategy that will quantify the destruction rates of SF_6, and identify and measure breakdown products. Results of the program could provide a basis for making recommendations to revise current IPCC methodology.

Conclusion

The magnesium partnership forms an integral part of the voluntary approach recently highlighted by President Bush in his new U.S. Global Climate Change Policy. Currently, the partnership accounts for a significant percentage of U.S. primary production and die casting capacity. The partnership is providing a valuable forum for the sharing of information on new research initiatives and successful mitigation strategies as well as a mechanism for the industry to document emission reduction efforts. The partner-reported SF_6 emissions reductions illustrate the success of the program to protect the climate through collaborative government and industry initiatives.

The magnesium industry is uniquely positioned to meet the current global climate challenge. Current research is identifying new process technologies and compounds that will improve the industry's environmental performance reduce its dependence on SF_6. Furthermore, since magnesium is a highly recyclable and lightweight metal, it's increasing use in automobile components enhances the production of more fuel-efficient vehicles with lower associated CO_2 emissions.

Literature

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