4.3.5 ELECTRIC POWER SYSTEMS AND MAGNESIUM: SUBSTITUTES FOR SF_6

Technology Description

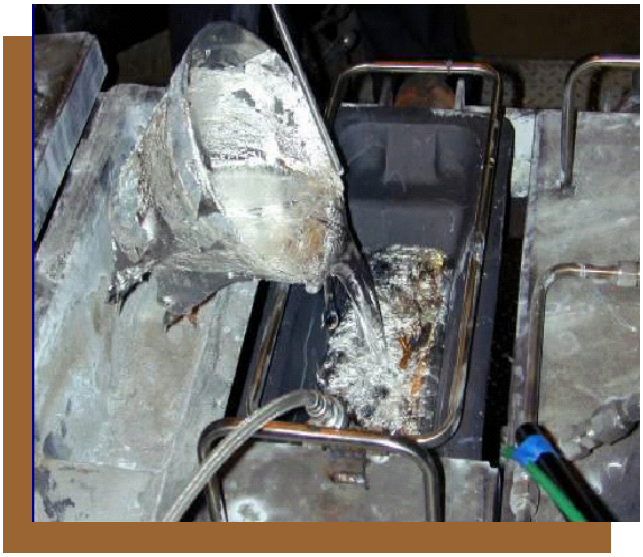

Figure 1. Molten Mg with SF_6 cover gas.

Figure 2. Molten Mg without protective cover gas.

Electric Power Systems: Sulfur hexafluoride (SF_6) is a favored insulating agent for high-voltage electric power system equipment because of its dielectric strength and arc-suppression capabilities. Use of other insulating media has been researched and some have been used, especially in medium- and low-voltage applications. Historically, several other media were used (e.g., air, vacuum, oil) before the advent of SF_6, some of which remain in use today in certain applications.

Magnesium Industry: Magnesium metal producers and casters use SF_6 mixed with dry air and/or CO_2 as a cover gas to prevent oxidation and burning of the molten metal. About 5% to 20% of the SF_6 is believed to react with the metal surface, preventing oxidation, while the remainder escapes to the atmosphere. The magnesium casting machine operators need to have access to the surface of the magnesium melt. Therefore, a tightly sealed system is difficult to engineer and maintain. Recognizing that some gas will escape, a highly attractive technology option involves use of a gas other than SF_6 with better environmental characteristics. The challenge is to isolate a substitute with low or no global-warming potential that satisfies the magnesium industry's melt protection performance and safety requirements.

System Concepts

- Electric power systems: Purchase/use equipment that relies on insulating agents other than SF_6.
- Magnesium casting: Use a gas for magnesium melt protection that avoids the global-warming concerns associated with SF_6.

Representative Technologies

- Electric power systems: Existing insulating agents other than SF_6 include oil, air, or vacuum insulation; but SF_6 is the predominant choice for high-voltage applications. Despite extensive research efforts, no single gaseous compound has been isolated that serves as a substitute for SF_6 in high-voltage applications. SF_6 remains the insulating medium of choice. Gas mixtures, however, have been used successfully, including mixtures of SF_6/N_2 or SF_6/CF_4 in cold-weather applications.
- Magnesium casting:
  - HFC-134a: The Cooperative Research Centre for Cast Metals Manufacturing (CAST) in Australia is conducting research and development to find a suitable substitute gas for SF_6. Based on the concept that the addition of fluorine into the magnesium oxide surface film is the key mechanism for preventing oxidation of molten magnesium, CAST has developed a process that uses the hydrofluorocarbon gas 1,1,1,2-tetrafluoroethane, otherwise known as HFC-134a.

- SO_2: Sulfur dioxide provides effective protection of molten magnesium, but its toxicity presents a concern for use in the workplace.
- IMA Study / SINTEF: The International Magnesium Association (IMA) established an Ad Hoc Committee on SF_6 composed of representatives from IMA, several magnesium casting firms, 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.
- Novec 612™: 3M™ has commercialized a fluorinated ketone, $C_3F_7C(O)C_2F_5$ (Novec 612™) as a substitute for SF_6.

Technology Status/Application

- Electric power systems: At least one utility is known to use SF_6/N_2 and SF_6/CF_4 gas mixtures for circuit breakers used in cold weather, at transmission and sub-transmission voltage levels (i.e., 500 kV and below).
- HFC-134a and Novec 612™ are reported to provide good molten metal protection in magnesium production and die-casting applications.

Current Research, Development, and Demonstration

RD&D Goals

- To find substitutes for SF_6 that have comparable insulating and arc quenching properties in high-voltage applications and/or protect molten magnesium – and significantly less or no global-warming potential.

RD&D Challenges

- Electric power systems: To date, no widely applicable alternatives have been found for SF_6. The primary RD&D challenge is to find an acceptable insulating medium for high-voltage applications.
- Magnesium casting:
  - Characterizing chemical and physical mechanisms that govern protection of molten magnesium through use of cover gas.
  - Selecting effective gas substitutes that not only guard against magnesium burning, but also minimize emissions of greenhouse gases or other pollutants of concern.
  - Isolating the best methods of gas distribution to overcome the potential disturbances associated with magnesium melt turbulence and temperature.

RD&D Activities

- EPA and the magnesium industry are working in a voluntary partnership to eliminate SF_6 emissions.
- Magnesium casting: SINTEF and CAST continue their work with alternative gases and HFC-134a. Based on their findings regarding the solubility of fluorine in molten magnesium, SINTEF is researching the viability of bubbling a fluorine-bearing gas through the melt or adding fluorine in a solid matrix, such as iron fluoride.
- The Electric Power Research Institute (EPRI) is investigating a solid-state current limiter that may lead to future equipment designs that do not require SF_6 insulation.

Recent Progress

- Electric power systems: Gas mixtures, as discussed above, have been used successfully in cold-weather applications.
- Magnesium producers and casting firms report promising results from early production-scale trials of alternative fluorinated cover gases.

Commercialization and Deployment Activities

- If a substitute gas is found, commercialization and deployment are not expected to represent hurdles. Gas mixtures appear to be readily available to potential users in cold regions where they are applicable.

Market Context

- Electric Power Systems: Circuit breaker equipment used in high-voltage electricity transmission and distribution.
- Magnesium Industry: All magnesium production and casting firms that use SF_6 for magnesium melt protection.