Handling and Use of Sulfur Dioxide for Magnesium Melt Protection

SF₆ and the Environment: Emission Reduction Strategies
November 2-3, 2000
Without Proper Protection, Molten Magnesium Will Evaporate and Burn

- Due to its high vapor pressure, magnesium will evaporate from an unprotected molten magnesium surface
- In an atmosphere of air/oxygen, magnesium vapor will react or burn, forming oxides
- This reaction will generate heat and thereby increase the evaporation, thus accelerating the burning

![Diagram showing the process of magnesium burning with oxygen and heat generation.](image-url)
A US patent from 1934 cited several gases, including SF$_6$, BF$_3$, and SO$_2$.

A combination of salt-based fluxes and SO$_2$ was commonly used until the introduction of SF$_6$.

R&D in the late 60's and 70's formed the basis for using SF$_6$ as melt protection in magnesium melting and casting.

During the late 70's and 80's most producers and die casters adopted SF$_6$ in production.

SF$_6$ was considered a major improvement for the working environment in the magnesium industry, since SO$_2$ is both toxic and corrosive.
Using $\text{SO}_2$ for Melt Protection

✓ Proven and reliable technology
  ➤ More than 50 years experience in Europe
  ➤ Recent experience in North America and Japan
  ➤ Concentration and flow parameters established
  ➤ Compatible mixing and furnace equipment available
Using \textit{SO}_2\textsubscript{2} for Melt Protection

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✓ No global warming
  ➤ Establishes superiority for magnesium in Life Cycle Analysis
SO\textsubscript{2} Creates a Life Cycle Advantage for Magnesium Components

Life Cycle Study of Cross Car Beams

Reference: Opel/Hydro Magnesium
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✓ Disadvantages
  ▶ Toxic (2 ppm occupational exposure limit in 8 hr)
  ▶ Potential acidic precipitation \((\text{H}_2\text{SO}_4)\)
Casting of Ingots Requires

Melt Surface Protection

Liquid Metal

Melt Protection

Cooling Hood

Casting Belt

Ingot Molds

Propane Burner
Hydro Magnesium Systematically Reduced SF₆ Usage in Ingot Casting Lines

CO₂-eq. [kg/kg Mg]
Hydro Magnesium Plants Are Replacing SF$_6$ with SO$_2$
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✓ Implementation of SO$_2$
  ➢ "Tightening" furnaces and casting equipment to minimize the use of sulfur dioxide
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✓ Implementation of SO$_2$
  ➢ "Tightening" furnaces and casting equipment to minimize the use of sulfur dioxide
  ➢ Developing established procedures for safe gas management
  ➢ Verifying that sulfur dioxide can be used for effective melt protection while still achieving an acceptable and safe working environment
Magnesium Diecasting Requires Protection of the Melt Surface
Hydro Magnesium Approach for Diecasting

- Encourage diecasters to consider $SO_2$
- Developed a gas mixing unit for air-sulfur dioxide
Gas Mixing Unit
Manifold for Gas Distribution
**Design Data for Gas Distribution**

- **Distance between metal level and lid/gas manifold**
  - 100-150 mm

- **Size of gas supply and distribution manifold**
  - 1.0-1.5 cm² (internal diameter of 12-15 mm)

- **Total outlet area**
  - 0.15-0.30 cm² (20-40 outlets of 1 mm diameter)

- **Recommended gas flow**
  - Approximately 10 Nl/min (gas outlet velocity of 5-10 m/s)
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Continuing education - papers/presentations
- Use of SF₆ in the Magnesium Industry - An Environmental Challenge (1996)
- Protection of Molten Magnesium from Oxidation (1996)
- Gas Protection of Molten Magnesium Alloys; SO₂ as a Replacement for SF₆ (1996)
- Diecaster Bulletin (1997)
- Progress to Eliminate SF₆ as a Protective Gas in Magnesium Die Casting (1998)
- Use of SO₂ as Protection Gas in Magnesium Diecasting (2000)
## Cost Impact

**SF₆ vs. SO₂**

<table>
<thead>
<tr>
<th></th>
<th>SF₆</th>
<th>SO₂</th>
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<tbody>
<tr>
<td>Number of machines</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Running operation</td>
<td>[days / year]</td>
<td>300</td>
</tr>
<tr>
<td>Running operation</td>
<td>[hours / day]</td>
<td>24</td>
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<tr>
<td>Flow rate of gas to each machine</td>
<td>[NI / min]</td>
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<tr>
<td>Concentration of gas</td>
<td>[%]</td>
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<tr>
<td>Price</td>
<td>[NOK / kg]</td>
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</tr>
<tr>
<td>Volume / weight</td>
<td>[NI / kg]</td>
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<tr>
<td>Consumption of gas</td>
<td>[kg / year]</td>
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<tr>
<td>Cost / year</td>
<td>[NOK]</td>
<td>91500</td>
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</tbody>
</table>
Environmental Impact

![Graph showing CO2-equivalents (kg/kg Mg) vs. % die casting yield* for SF₆ and SO₂ cast operations.]

(*component weight/shot weight)
✓ Sulfur dioxide is toxic
  ➢ Occupational exposure limit of 2 ppm
  ➢ Odor detectable at 0.1-0.3 ppm
  ➢ Safe practice record established
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Sulfur dioxide contributes to acid rain
- Use determined by local agencies
- Related to annual consumption (50-500 kg/yr)
- Dependent on operating environment