Strategy to Reduce and Replace Emissions of SF_6 in Magnesium Operations

SF_6 and the Environment: Emission Reduction Strategies
November 2-3, 2000

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The Industry Continues to Focus on the Reduction of SF_6 Emissions

- Reduced consumption of SF_6
  - ✓ Improved smelting and casting equipment
  - ✓ Training of operators and managers
  - ✓ Sharing of R&D results and "Best Practice"

    International Magnesium Association Technical Report: Recommended Practices for the Conservation of Sulfur Hexafluoride in Magnesium Melting Operations (1998)
- Recycling SF_6 from the casting process off-gases
  - ✓ Suppliers of SF_6 are working to develop recycling based on membrane and/or adsorption technologies

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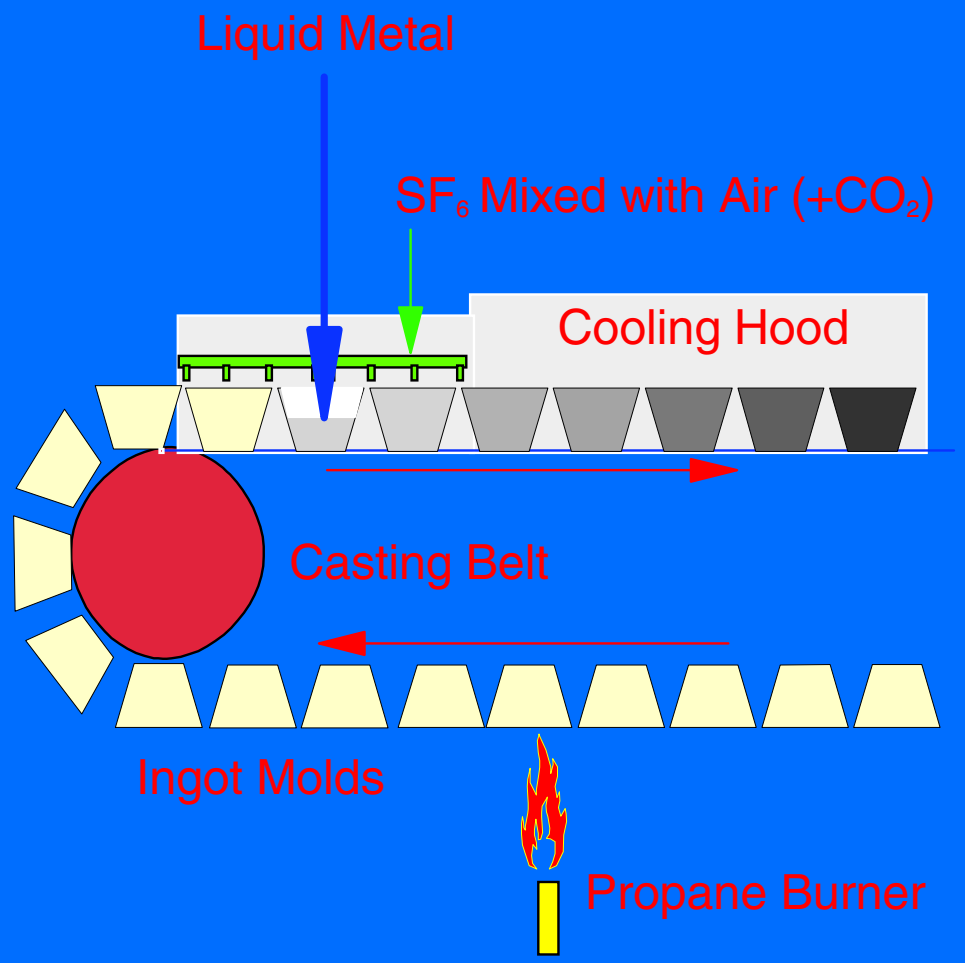
Greenpeace Position

- ✓ HFC/PFC/SF_6 emissions present a real danger
- ✓ Alternatives exist in virtually all applications
- ✓ SF_6 should immediately be banned globally

Casting of Ingots Requires Melt Surface Protection



SF_6 emissions are typically 0.4-1.0 kg/ton of Mg ingots produced

Reduction at Hydro Magnesium

- ✓ Step 1 - awareness
  - Training
  - Discipline
  - Detection
  - Costs
- ✓ Step 2 - reduction of existing limitations
  - Determine lowest usable values
  - Tightening of system components
  - Computer modeling of convection, drafts, etc.
  - Extensive attention to casting stations
- ✓ Step 3 - continuing cooperation
  - Norwegian and Canadian governments
  - Competitors through IMA

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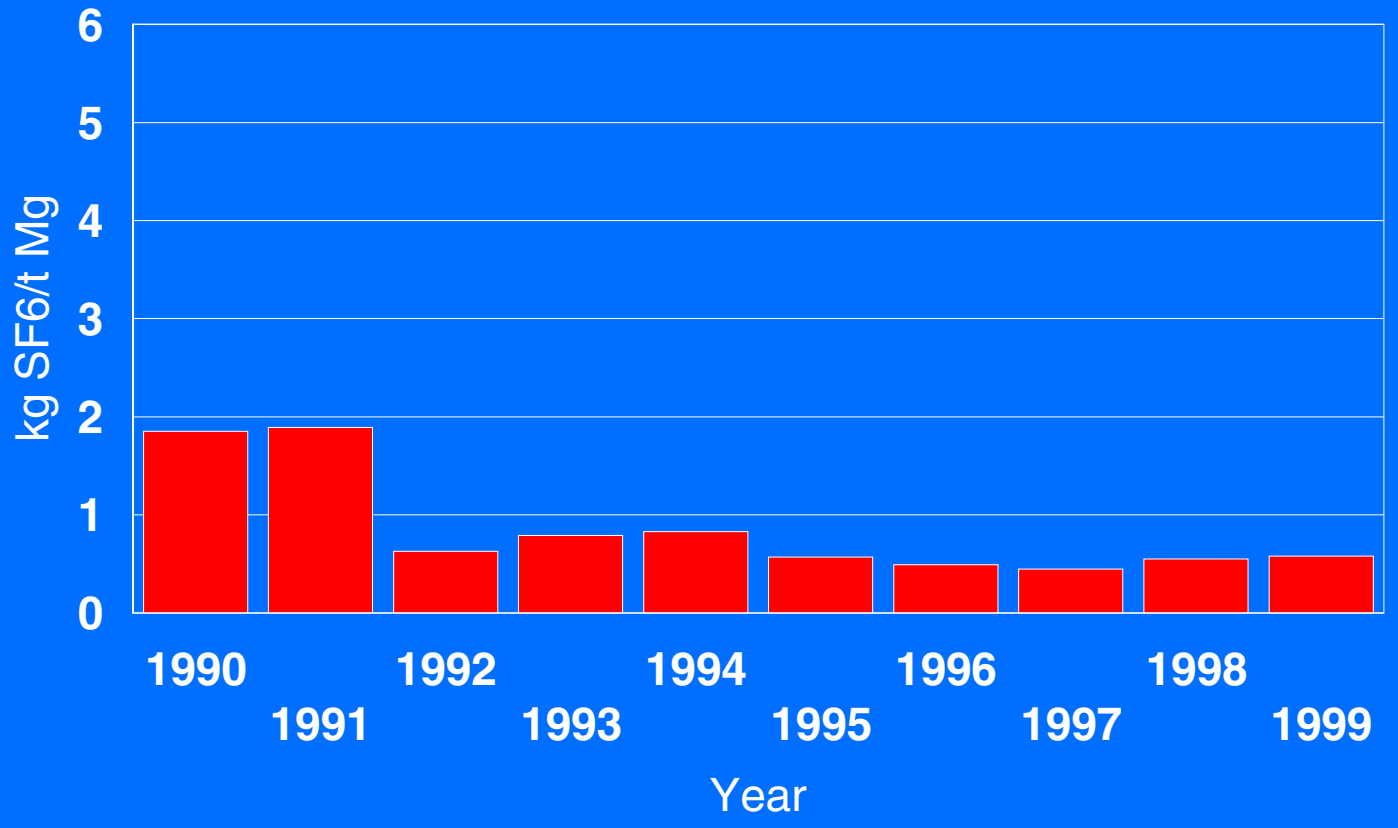
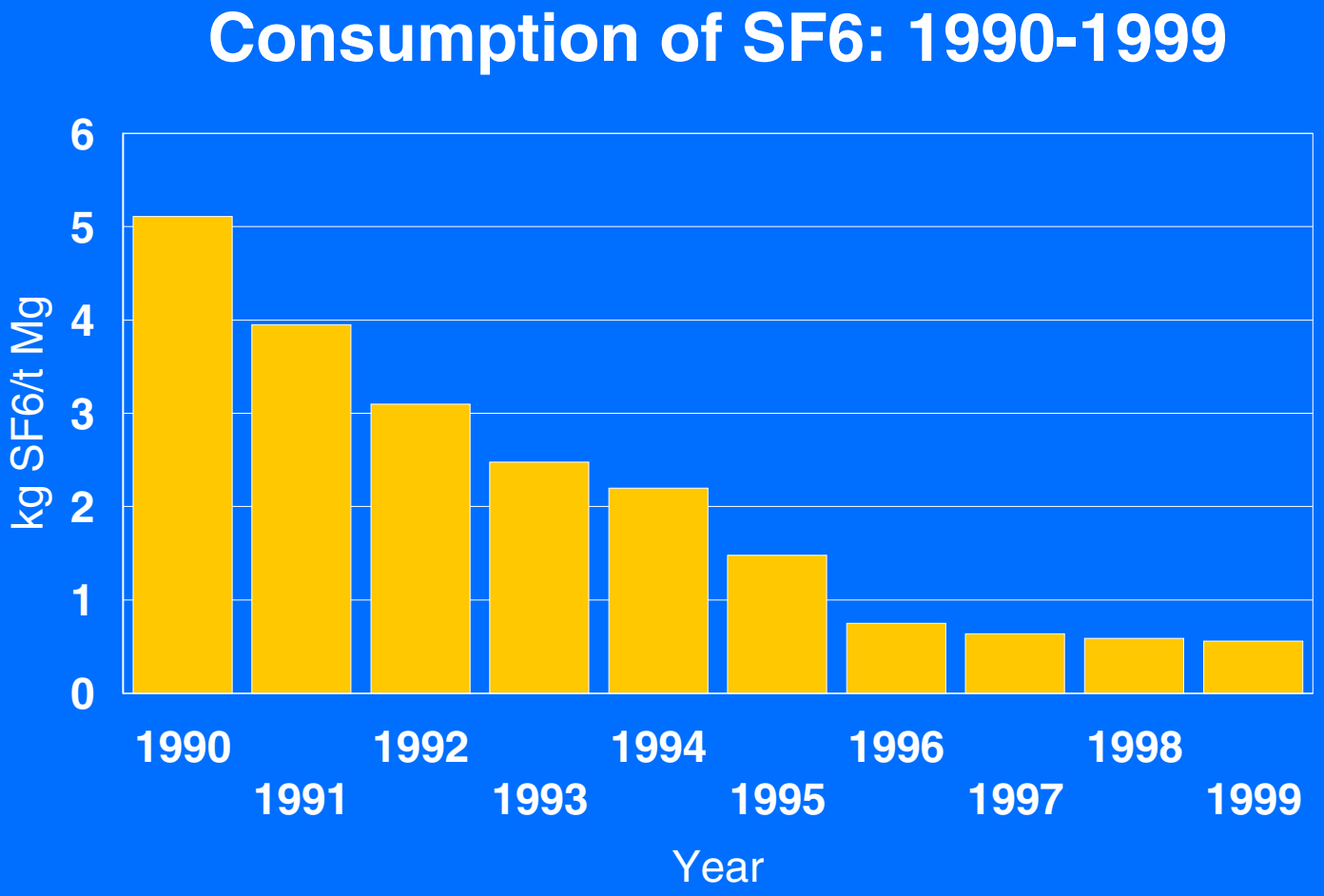
Hydro Magnesium Melt Protection Gas Usage (HMN)

Consumption of SF6: 1990-1999

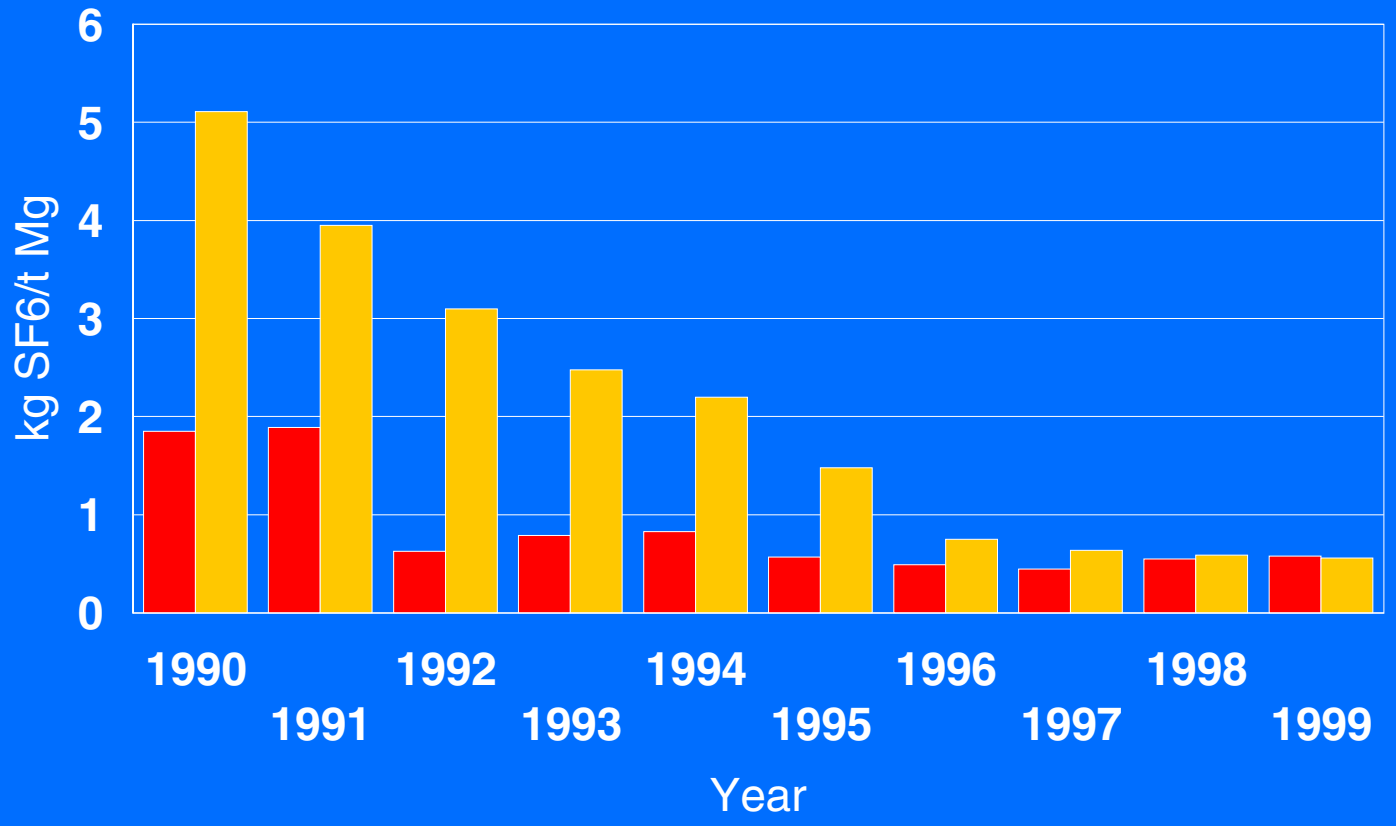


Hydro Magnesium Melt Protection Gas Usage (HMC)



Hydro Magnesium Melt Protection Gas Usage (HMC, HMN)

Consumption of SF6: 1990-1999



High Pressure Diecasting Is the Preferred Fabrication Process

Interior Parts
Seat Components
Instrument Panel/Knee Bolster
Steering Column Comp.
Steering Wheel
Brake & Clutch Pedal Bracket
Airbag Retainer
Pedal Bracket
Radio Heat Sink/Frame
Radio/HVAC Cover
Sunroof Comp.
Mirror Bracket
Headlight Retainer
Liftgate Inner
Inner Door Frame
Support Pillars
Grill Reinforcement
Radiator Support

Exterior
Engine Hood
Roof Panels
Rear Deck Lid
Wheels

Engine Parts
Cyl. Head Cover
Intake Manifold
Oil Pump Housing
Accy. Dr. Bracket
Electrical Connector
Oil Pan
Engine Block

Drivetrain Parts
Man. Trans. Housing
4WD Transfer Case
Automatic Transmission Housing

Present Applications
Projected Applications

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Hydro Magnesium Approach for Diecasting

- Assisted in sulfur hexafluoride reduction
  - Protection of Molten Magnesium from Oxidation at Diecasters (1996)
  - Diecaster Bulletin (1997)
- Encouraging diecasters to evaluate SO_2
  - Developed a gas mixing unit for air-sulfur dioxide
  - Offering in-plant trials to demonstrate safe handling
  - Gas Protection of Molten Magnesium Alloys; SO_2 as a Replacement for SF_6 (1996)
  - Progress to Eliminate SF_6 as a Protective Gas in Magnesium Diecasting (1998)
  - Use of SO_2 as Protection Gas in Magnesium Diecasting (2000)

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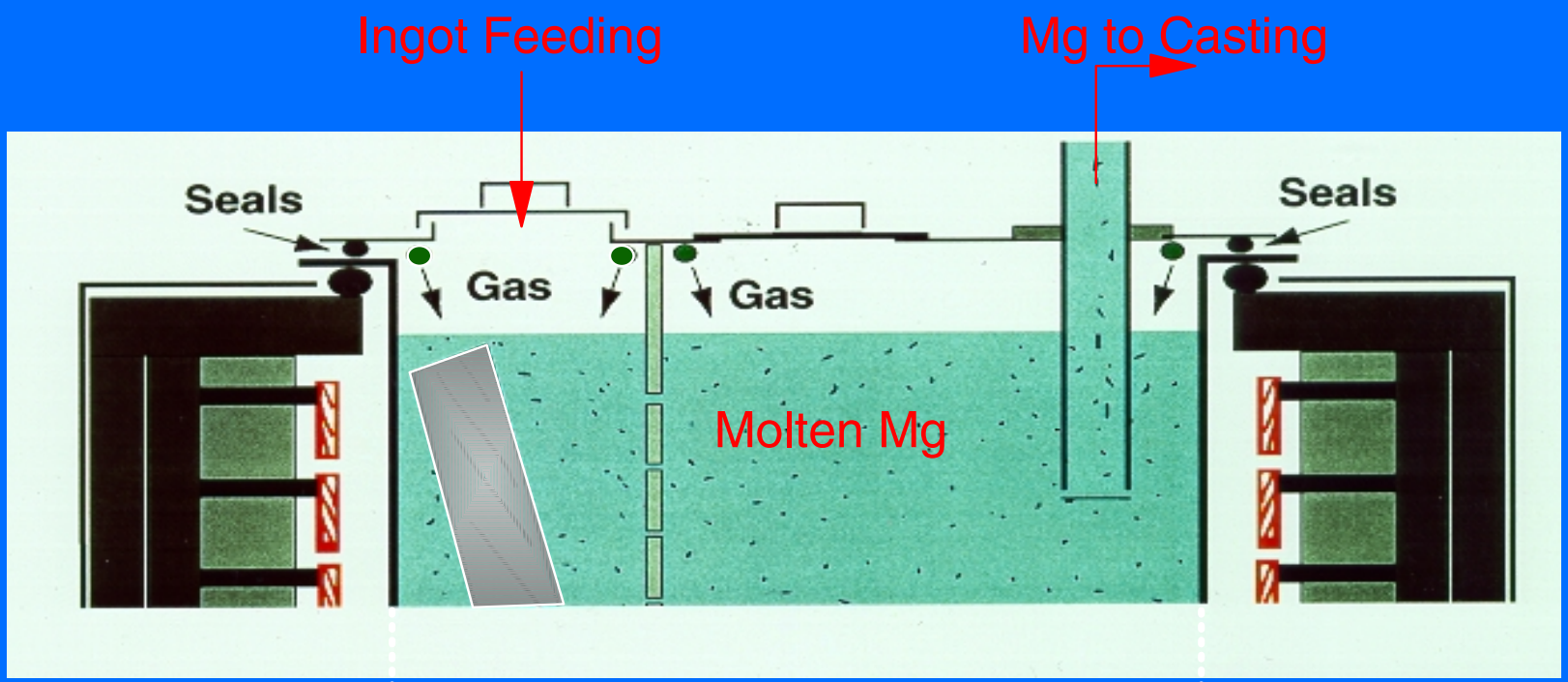
Magnesium Diecasting Requires Protection of the Melt Surface



The total SF_6 emissions are typically 1.0-2.5 kg/ton of diecast components, including ingot production, diecasting process, and recycling of process scrap

Sulfur Hexafluoride Reduction

- Important factors
  - Gas mixing unit for stable conc. is a prerequisite
  - Crucibles with high volume to surface area preferred
  - Well-tightened furnace lids and hatches
  - Horizontal sliding hatches/locks for ingot feeding
  - Minimize gas volume over furnace
  - Keep metal level as constant as possible
  - Dry air (<0.1 wt. pct. humidity) is necessary
  - Gas tube system designed for efficient distribution

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Using 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
- No global warming
  - Establishes superiority for magnesium in Life Cycle Analysis
- Cost-effective solution
- Disadvantages
  - Toxic (2 ppm occupational exposure limit for 8 hrs working)
  - Potential acidic precipitation

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Alternatives to SF_6 and SO_2 Under Development

- Hatch patented "MagShield" system
  - Technology based on the gas BF_3, produced in situ, mixed with air
  - BF_3: LC_{50} = 1180 mg/m³/4h, classified as highly toxic
  - SO_2: LC_{50} = 2520 mg/m³/4h, classified as toxic
- Australian patent application
  - HFC-134a: LC_{50} = 1500 g/m³/4h, assumed to be non-toxic
  - HF generation is a concern
- Brochot patent
  - Using a mixture of 70% CO_2, 20% Ar, and 1% Xe plus air
  - Assumed to be non-toxic, but limited effectiveness

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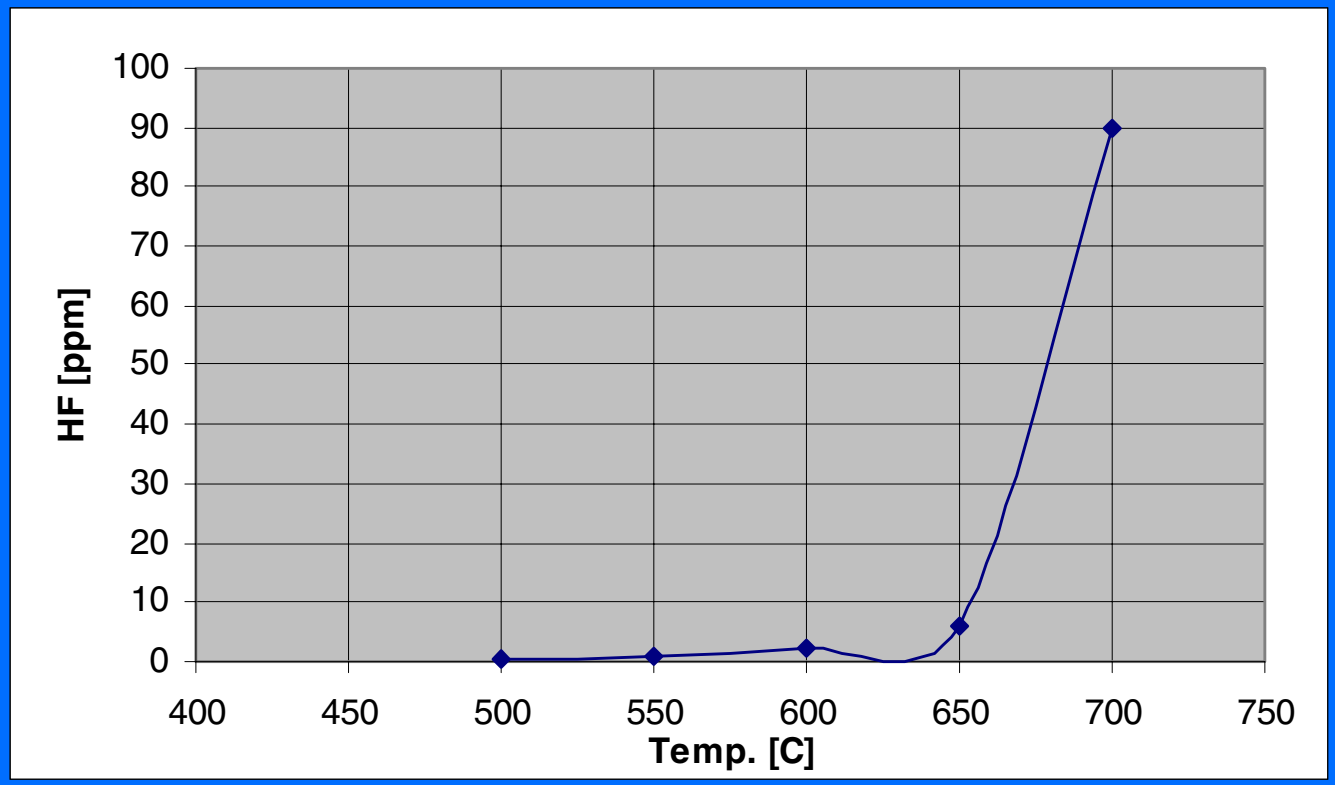
Evolution of HF from HFC-134a with Increasing Melt Temperature



Outlook for Other Gases

- ✓ Argon as a cover gas
  - Inert; thus no reaction with Mg
  - Evaporation of unreacted Mg results in condensation of a highly reactive dust
  - Subsequent entrance of air generates an explosion
- ✓ Melt protection with nitrogen
  - Reacts with Mg vapor to form nitrides
  - Likely ammonia generation
- ✓ Other candidates have been identified, but are also significant global warmers

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European Initiatives

- European Commission activities
  - Approximately 120 casting companies
  - Workshop on policy measures for climate gases
  - Continued focus for SF_6 is to reduce emissions
  - Move toward replacement with SO_2
  - Introduced idea of "green taxes" on CO_2-equivalents
- Voluntary agreements under consideration: feasibility outside Europe considered unlikely
- Conferences to reduce non-CO_2 emissions in industrialised countries and establish global co-operation for emissions reduction
- SFT has established a maximum limit for SF_6 emissions from Hydro Magnesium's primary plant in Norway

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