Development of 3™ Novec™ 612 Magnesium Protection Fluid as a Substitute for SF_6 over Molten Magnesium

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Protection of Molten Mg

Molten salt fluxes protected melts, but contamination results in increased corrosion and low metal recovery

Sulfur and SO_2 have been used for protection of molten Mg without added corrosion

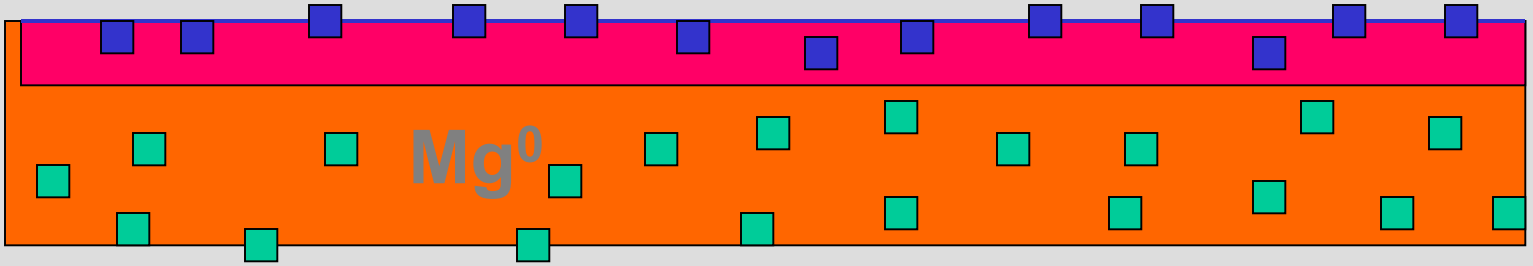
-1934, Reimers patented use of fluorine containing materials such as HF, BF_3, SiF_4, SbF_5, IF_5, PF_5, SO_2F_2, NF_3, or SF_6

-1970-79 Fruehling started and Couling continued work to show SF_6 was effective

-1998-2001 Cashion and SINTEF/Hydro workers described the surface films on Mg produced under SF_6 cover gases

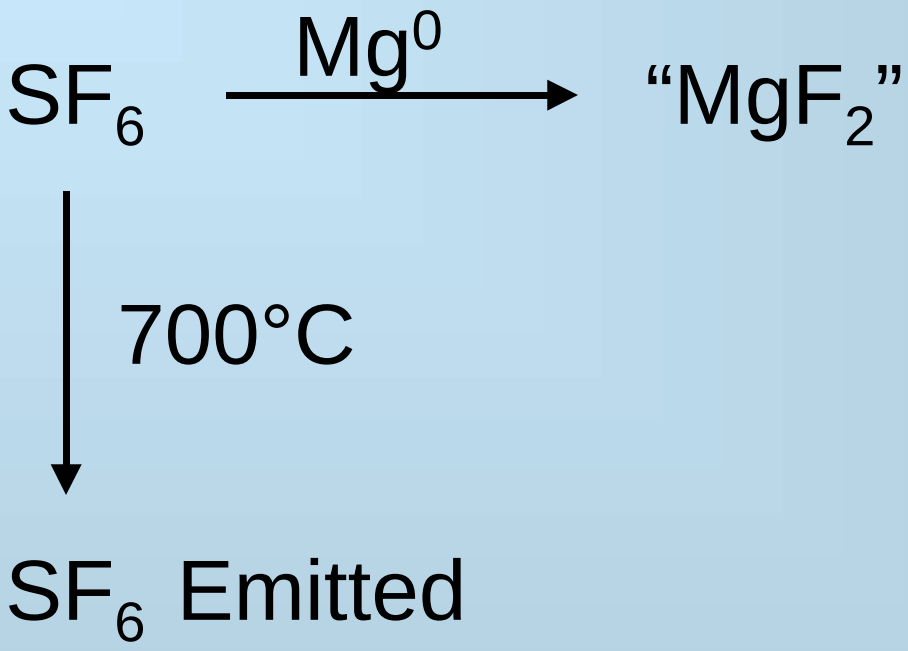
SF_6 Protection of Molten Mg

$Mg^0 + O_2 \longrightarrow MgO$



$Mg^0 + SF_6 \longrightarrow$ "MgF_2"

SF_6 Reactions over Mg?



Global Warming Potentials

Compound	Lifetime (yrs)	GWP (100 Yr ITH)
CO_2	100-150	1
SF_6	3200	22,200

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C_6F_{14}	3200	9,000	

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CF_3CH_2F	13.6	1,600	HFCs
CF_3CHF_2	32.6	3,800	
CHF_3	243	14,800	

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$C_3F_7C(O)C_2F_5$	**0.014**	**~1**	**FKs**

Fluorinated Ketone Physical and Environmental, Safety and Health Properties

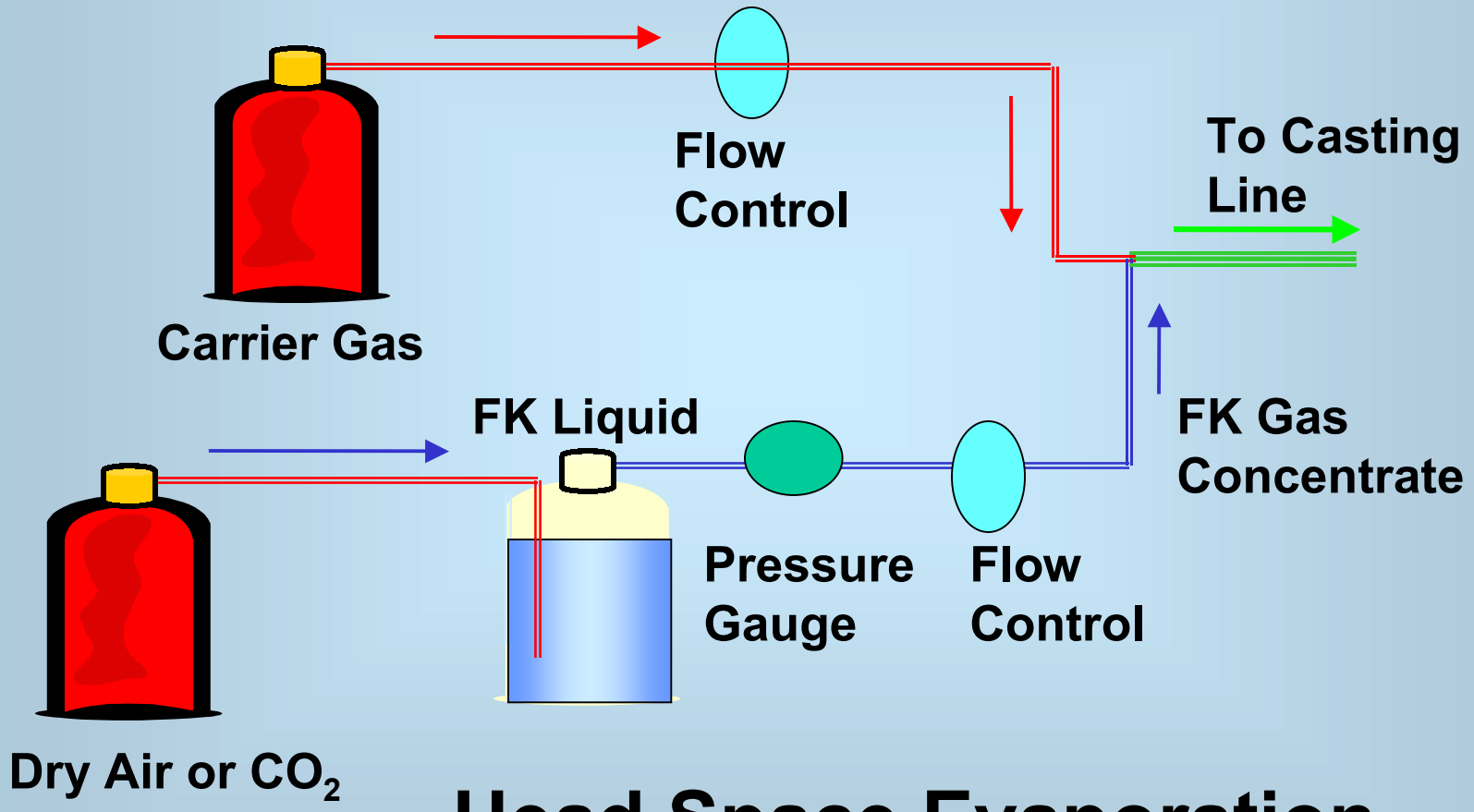
Physical Properties	
Boiling Point °C	49
Freezing Point °C	-108
Viscosity, liquid @ 20°C, cSt	0.042
Vapor Pressure @ 20°C, kPa	32.6
Liquid Density @ 20°C, g/mL	1.61
Gas Density @ 80°C - 1 Atm, g/mL	0.011

EHS Properties	
Atmospheric lifetime, days	<10
Global Warming Poteintial	~1
Flash Point	None
PEL, ppmV	150
Acute LC50, ppmV	>100,000

Environmental

- Novec^{TM} 612 : GWP = 1, Non-ozone depleting, short atmospheric lifetime (1 week)
- Degraded in sunlight to CO_2, HF and TFA
- Fully registered in Europe, US, Canada, Australia with no restrictions
- Registration in Japan early 2003

Liquid to Gas System to Generate Cover Gas System



Head Space Evaporation

Novec™ 612 Applications Experience

Tested over pure Mg, AM-50, RZ-5, AJ-52, AZ-91

With dry air, CO_2, N_2, Ar or mixtures as the carrier gas

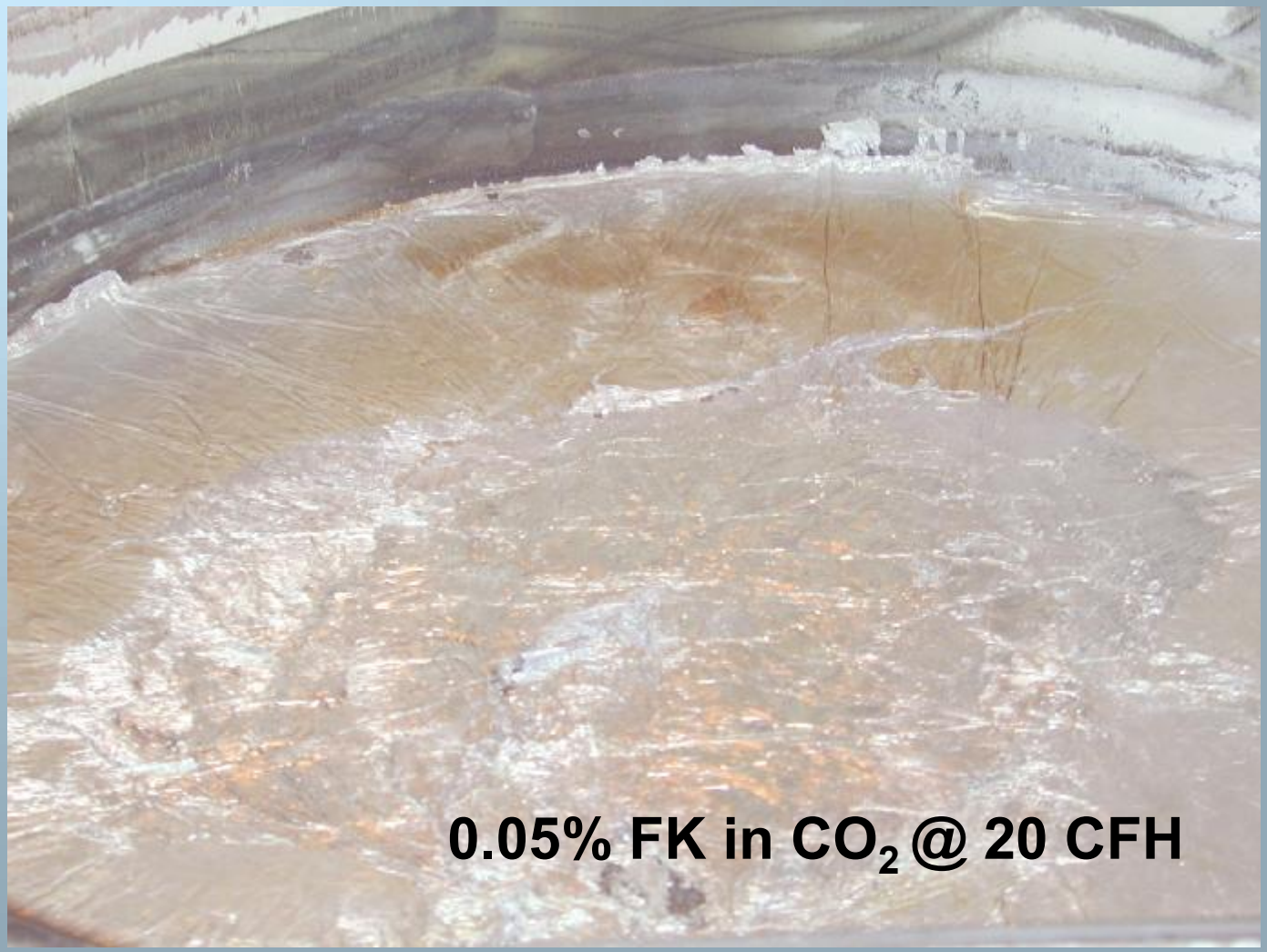
At melt temperatures from 650 to 790 °C

In 3 to 500 kg furnaces with melt areas of 0.008 to 0.5 m^2

For open casting (ingots and sand casting) and die casting

Pilot Scale Furnace

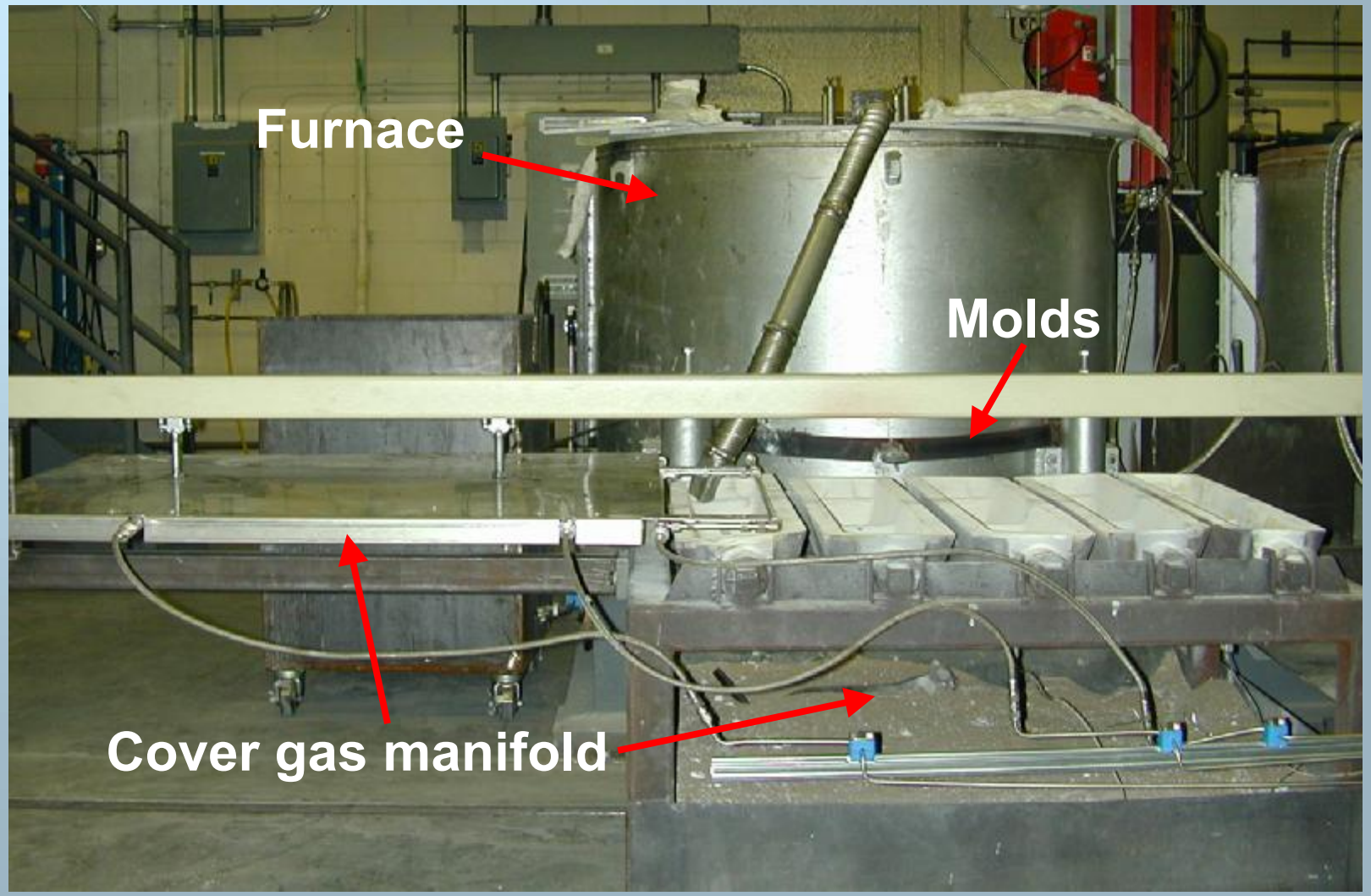
Surface of AM-50 in 80 kg Crucible



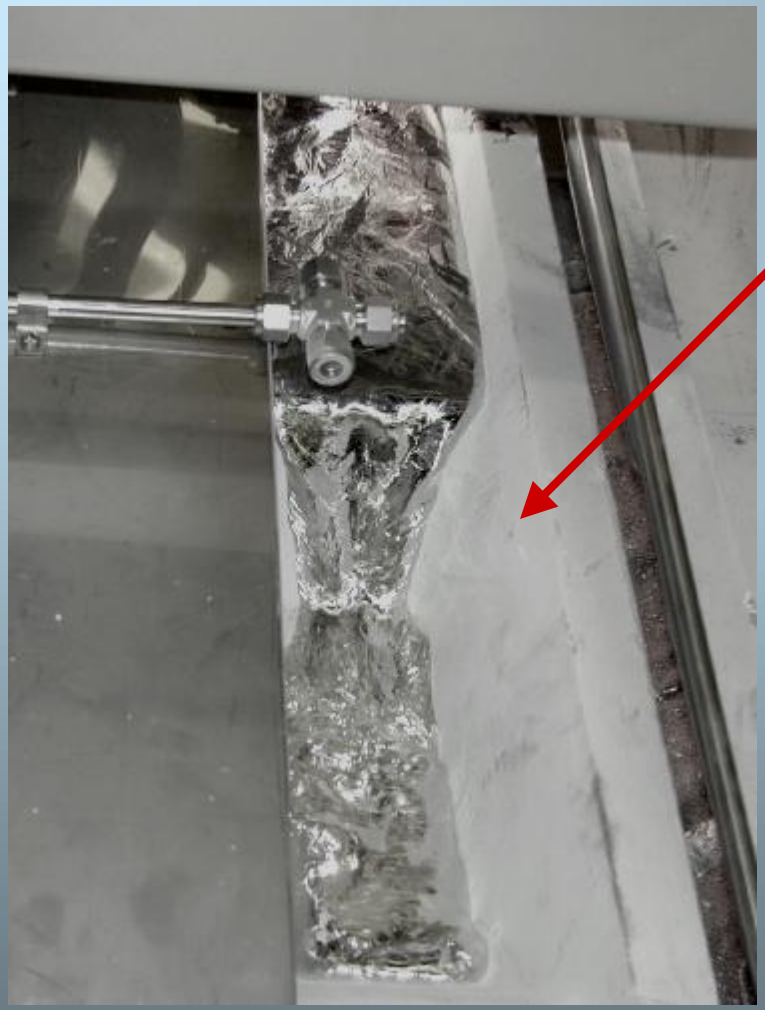
Hand casting of AM-50

Under 500 ppmV of FK in CO_2 @ 30 CFH

Ingot Casting Setup



Ingot mold filling with pumped molten Mg

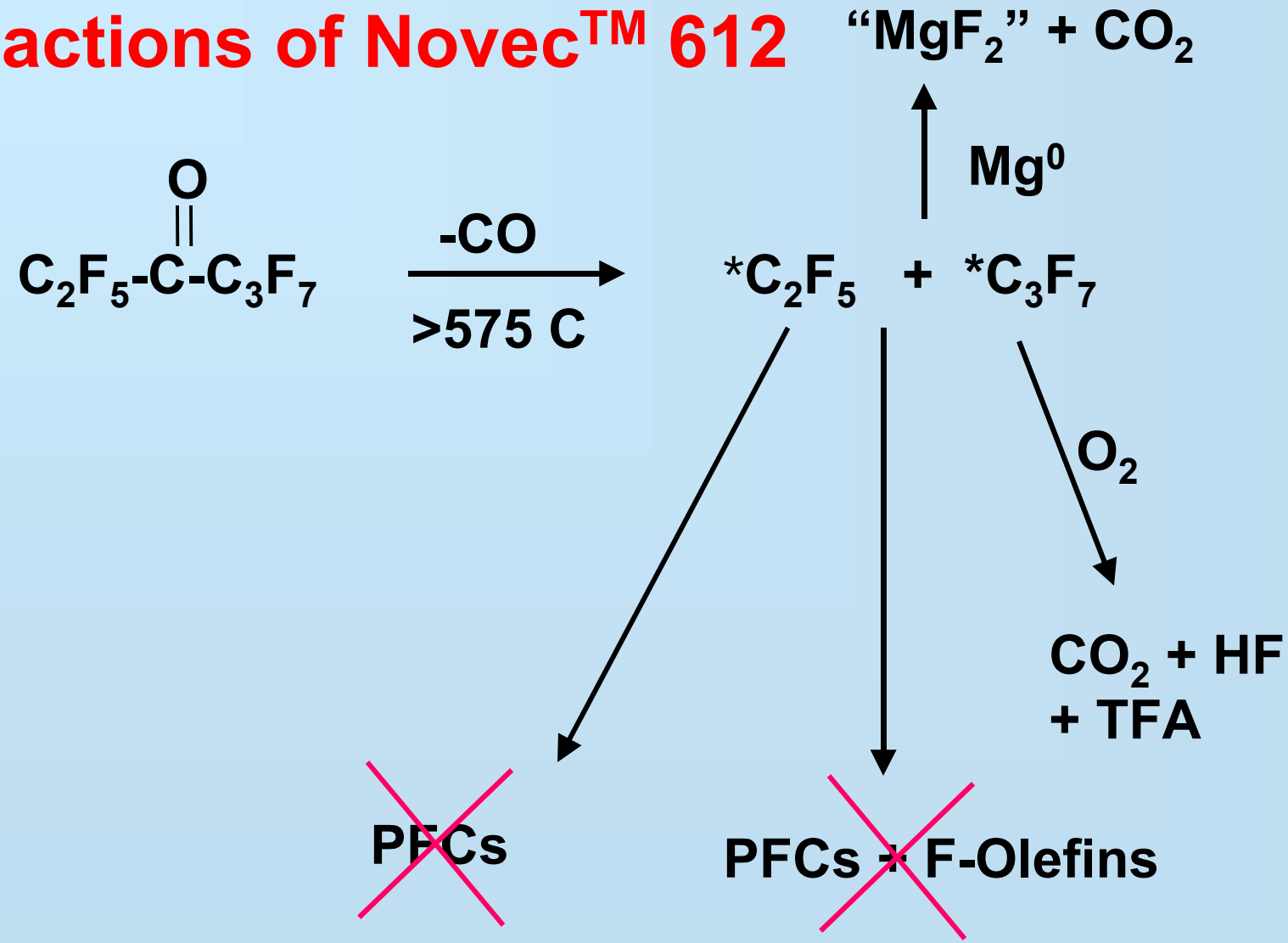


Under 750 ppmV FK in CO_2
@ 90 CFH

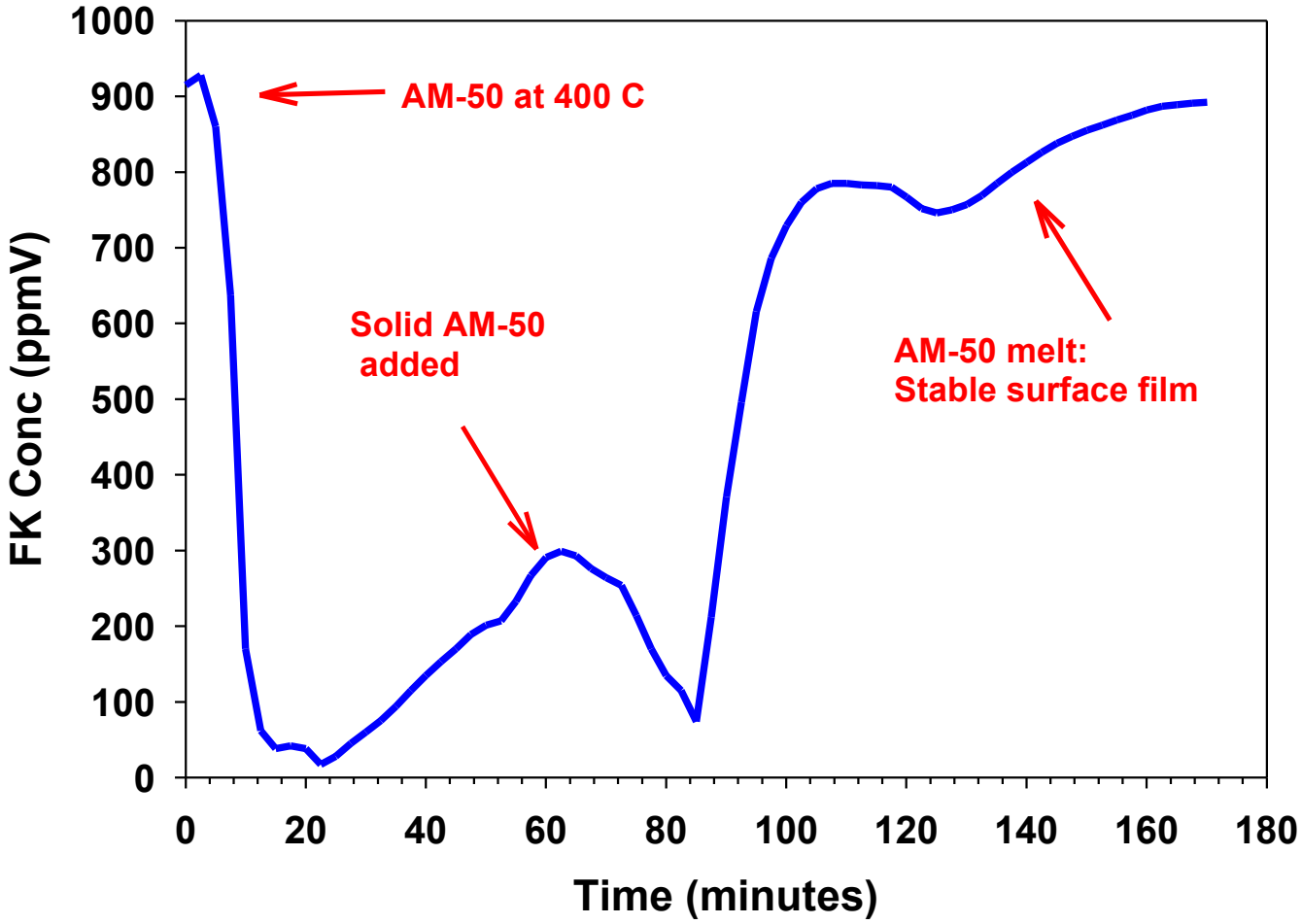
Protection Summary

- Mg protection similar to that produced by SF_6 (Operators' Comments)
- Protected at lower conc and flow rates
  - SF_6 (0.2 to 2.0%)
  - Novec^{TM} 612 (0.025 to 0.1%)
- Spot oxidation/fires extinguished with higher flow rates of Novec^{TM} 612
- Protected all casting operations tested

Reactions of Novec™ 612



Initial Melt of AM-50 Ingots
Novec 612™ Conc vs Time



Emissions from Casting Trials

	Conditions			Gas Analysis			
Alloy	**FK Conc (ppmV)**	**Flow Rate (CFH)**	**Ingot Quality**	**FK found ppmV**	**PFIB Found ppbV**	**PFC Found ppmV**	**HF Found ppmV**
AM-50	500	30	Good	4	Not Det	-	10
AM-50	250	30	Marginal	1	Not Det	-	-
Pure Mg	750	90	Good	4	Not Det	Not Det	-
Pure Mg	1000	90	Good	14	Not Det	Not Det	-
Pure Mg	500	20	Poor	9	Not Det	Not Det	-

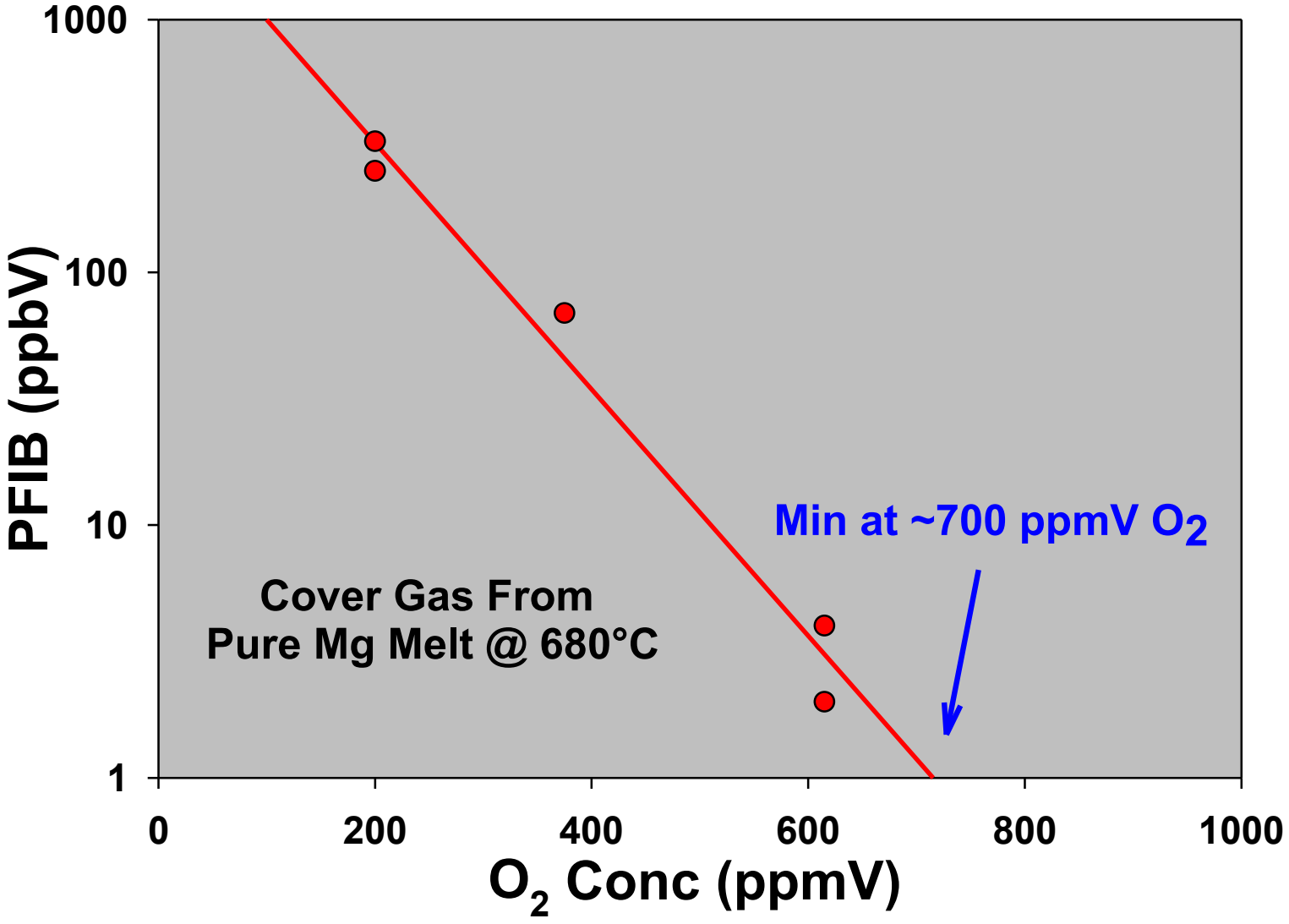
CO_2 as carrier gas

Composition In Furnace

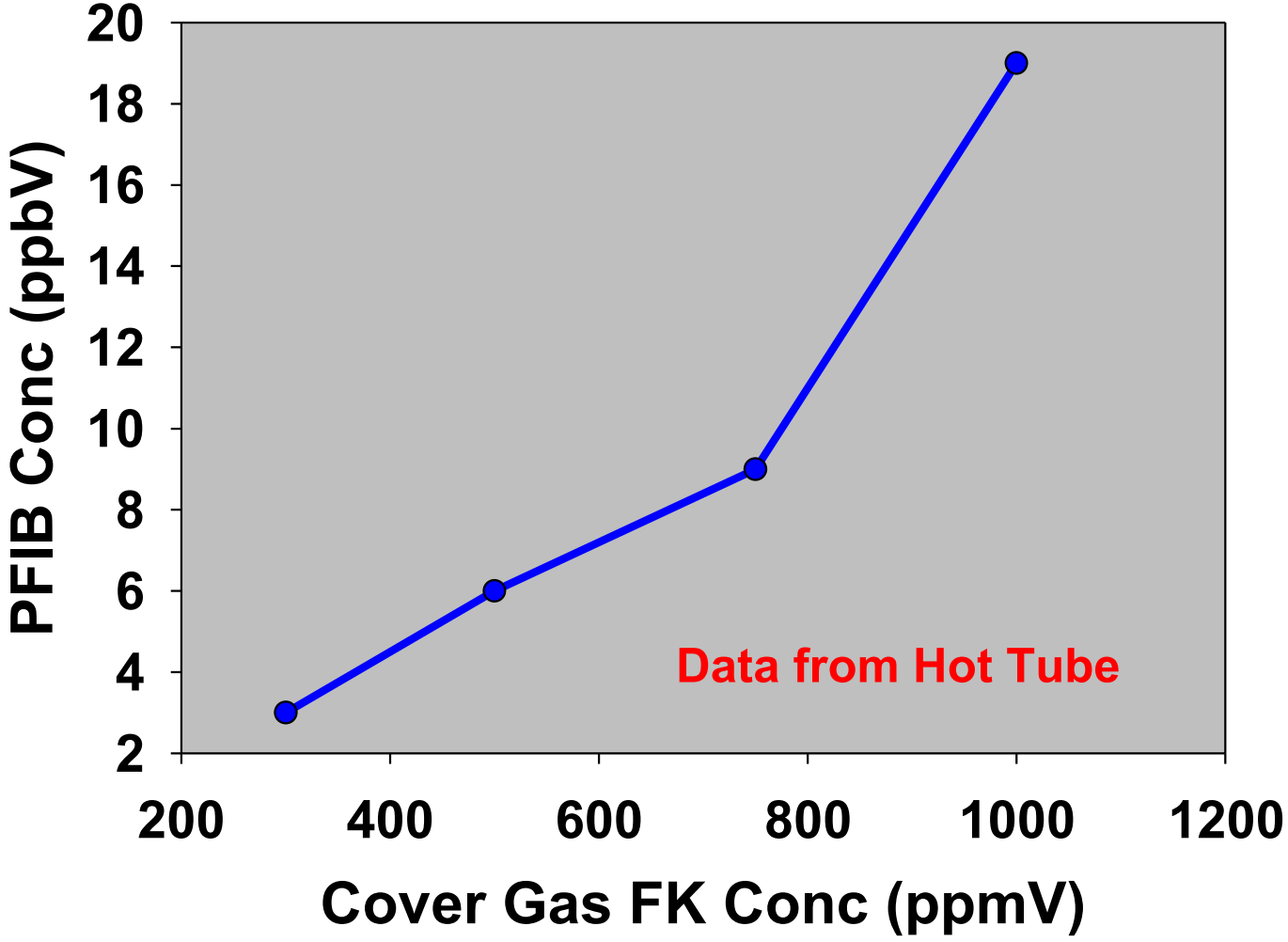
	Conditions				Gas Analysis		
Alloy	**Melt Temp (°C)**	**FK Conc (ppmV)**	**Flow Rate (CFH)**	**Furnace Protection**	**FK found ppmV**	**PFIB Found ppbV**	**PFC Found ppmV**
AM-50	680	1000	20	Good	894	204	-
AJ-52	720	1000	10	Good	164	26	322
Pure Mg	680	1000	20	Good	23	23	380
Pure Mg skimmed	680	1000	20	Good	1	Not Det	Not Det

CO_2 as carrier gas

Effect of O_2 Content of Cover Gas



Effect of FK Conc on PFIB Formation



Control of F-Olefin Production

- Oxygen in the cover gas mixture (1-5% air) for furnaces
- Use low concentration of FK (higher flow rates)
- Increase flow rate not concentration
- Don’t overprotect

Furnace Gas Composition over AM-50

AM-50 @ 680°C with 500 ppmV in CO2-5%air

Gas	Novec 612	PFC	F-Olefin	COF2	HF
Flow rate	Conc	Conc	Conc	Conc	Conc
2.5	22 ± 5	25 ± 7	ND	ND	84 ± 19
L/min	ppmV	ppmV			ppmV

From SINTEF Pilot Trials 9/2002

- Melt is over protected at these conditions
- HF generation is under study

Beta-site tests are underway

Testing at user sites to produce useful information on use conditions and performance.

Sites chosen to broaden application types and uses to confirm efficacy and refine designs of application equipment.

Continued Cooperation with IMA Program

Commercial Introduction

3™ Novec™ 612 Magnesium Protection Fluid

Phased Market Introduction 2003

North America, Europe, Japan

Full production in 1st Quarter 2003

Pilot supplies are available now

Technical Support for Conversions

Acknowledgement

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