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Hitachi Power Systems America, Inc.

BHK Babcock-Hitachi K.K.

McIlvaine Hot Topic Hour

Catalyst Selection

Presented by:

Stephen Guglielmo
SCR Product Manager
October 21, 2010

Outline

- Regulations and Market Drivers
- Catalyst Selection
- Latest Catalyst Developments

Regulations and Market Drivers

Federal Air Regulatory Drivers

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- Transport Rule 1 (CAIR replacement)
- Transport Rule II – (NOx)
- National Ambient Air Quality Standards (NAAQS)
  - SO_2, Ozone, PM
- New Source Performance Standards (NSPS)
- Maximum Achievable Control Technology (MACT)
- New Source Review (NSR) – i.e. consent decrees
- Clean Air Mercury Rule (CAMR)
- Greenhouse Gas Regulations/Legislation (GHG)

The U.S. has a Complicated Network of Overlapping Rules and Regulations for Emissions

Proposed Transport Rule – Issued July 6, 2010

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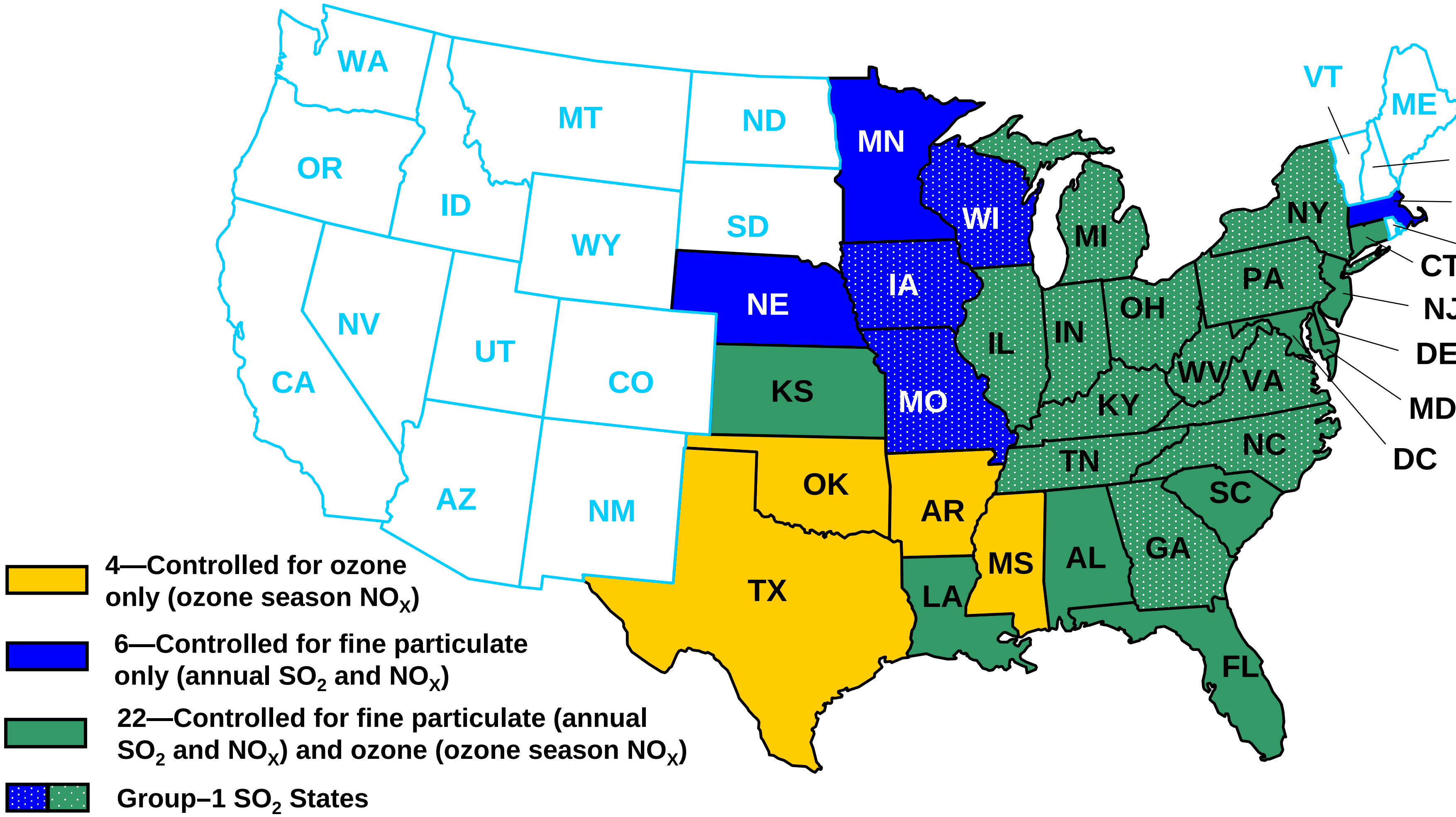
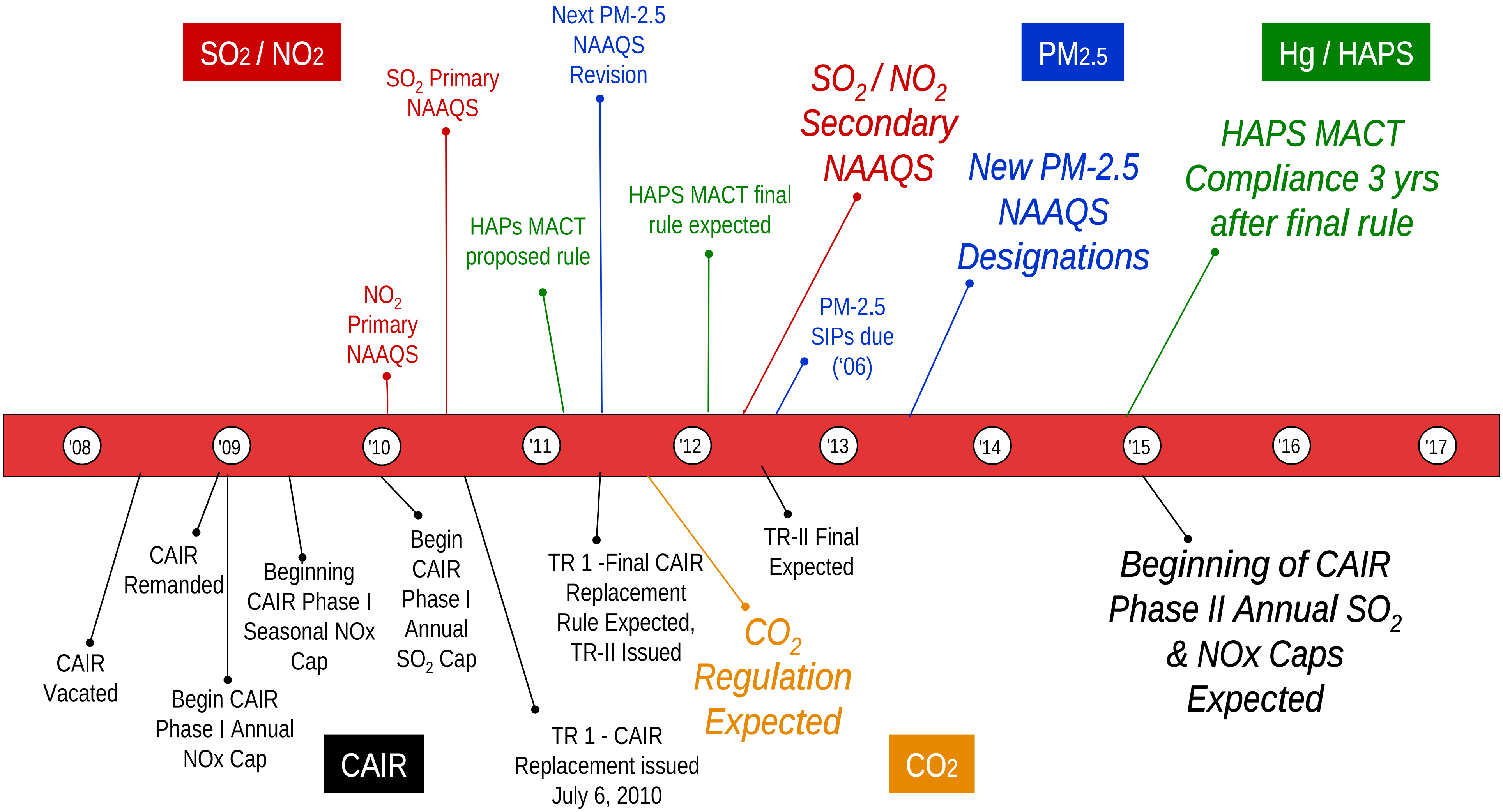


Source: IHS CERA.
Data Source: US EPA.
Notes: The 28 states subject to annual SO_2 standards are grouped into two tiers. The 15 dotted states above belong to the more stringent tier (Group–1) and are subject to a substantial increase in their SO_2 reduction requirement beginning in 2014. As compared to CAIR, the Transport Rule ozone season NO_x program would include Georgia, Kansas, Oklahoma, and Texas but exclude Iowa, Massachusetts, Missouri, and Wisconsin. Similarly, the Transport Rule annual SO_2 and NO_x programs would include Connecticut, Kansas, Massachusetts, Minnesota, and Nebraska but exclude Mississippi and Texas.

Proposed Transport Rules – Key Take Away's

- Transport Rule 1 (TR-1) will impact the existing coal market. Most at risk are some 30 gigawatts worth of units without SO_2 controls. Expect the heaviest hit states would be KY,OH,PA and WV
- TR-1 will end multi-state cap-and-trade programs to control sulfur dioxide (SO_2) and nitrogen oxide (NO_X) emissions
- TR-1 will not carry banked allowances forward
- TR- 2 proposal due in summer 2011 and final rule expected summer 2012 – will tighten NOx standards where TR-1 did not.
- 3 GW coal units already shut down, more to follow suit

Summary Timeline for Environmental Regulatory Requirements for the Utility Industry



How Will Catalyst Management Play a Role in Meeting These New Challenges by Regulation?

Catalyst Selection

Start From the Beginning….

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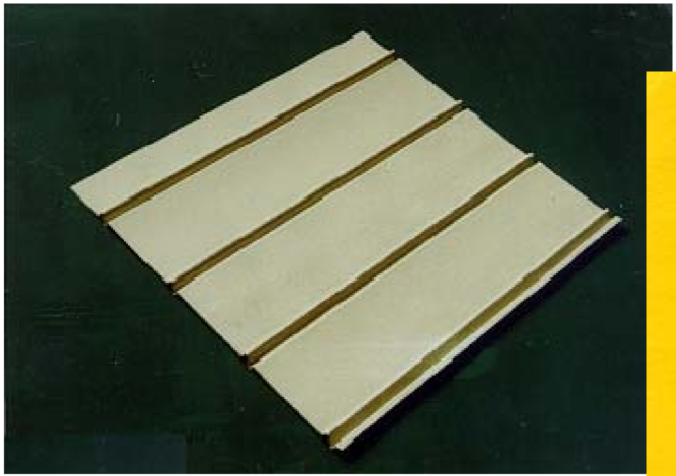
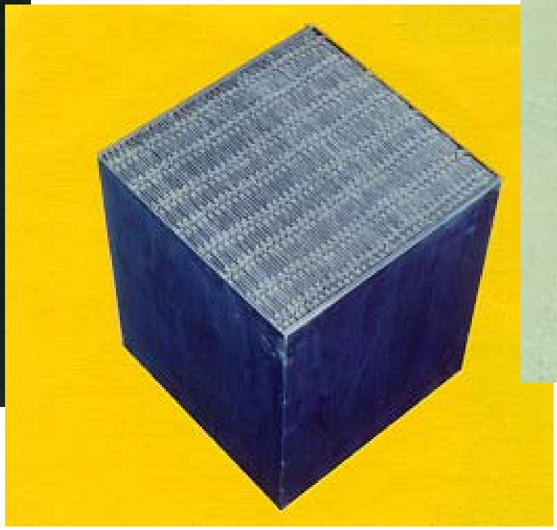
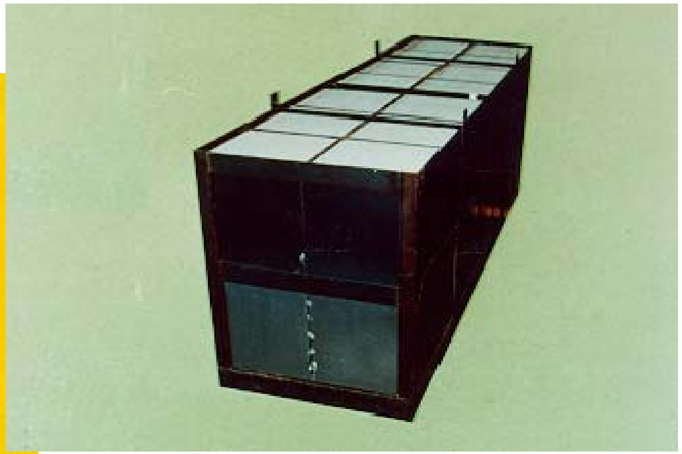
- Specifying the Correct Catalyst to Provide the Most Operational Flexibility and the Lowest Overall Lifecycle Cost:
  - What's your budget?
  - What kinds of fuel are you burning?
  - What is your outage cycle?
  - How does your unit operate?
  - How much NOx removal and/or K_0/K_e do you need?
  - What are your SO_2 to SO_3 conversion limitations?
  - What are your DP limitations?
  - What level of Hg oxidation do you need?
  - Future Regulations?
  - Other Considerations?

Available Options to Impact Performance

- Factors that impact catalyst performance and Cost:
  - Catalyst Pitch (Hydraulic Diameter)
  - Catalyst Volume/Height
  - Catalyst Formulation
  - Disposal of Spent Catalyst







Variation of Catalyst Pitch

	Catalyst Pitch (mm)				
	10	7	6	5.7	5.2
Catalyst Volume	Maximum ⟷ Minimum				
Pressure Loss	Minimum ⟷ Maximum				
Dust Plugging	Minimum ⟷ Maximum				
Note	Additional Catalyst Layer Required for Initial Installation	Fair for Application			Precaution for Pop- Corn Ash Required

Hydraulic Diameter

	PLATE	HONEYCOMB	CORRUGATED
Nominal Pitch, mm	5.7 (7.0)	6.9 (9.0)	6.5 (9.0)
a, mm	5.7 (7.0)	6.9 (9.0)	6.5 (9.0)
b, mm	62 (85)	6.9 (9.0)	6.5 (9.0)
D_h, mm	9.25 (11.7)	6.2 (8.0)	5.06 (7.0)
Difference vs. Plate	--	-33% (-14%)	-45% (-24%)

D_h = 4 x Cross Sectional Area (mm^2) / Perimeter (mm)

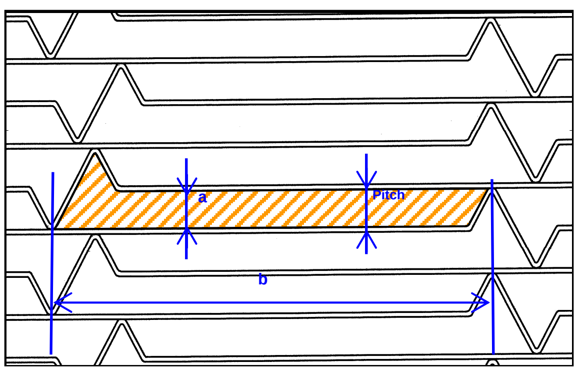
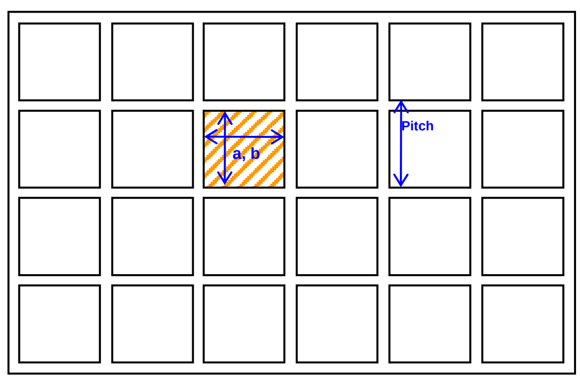
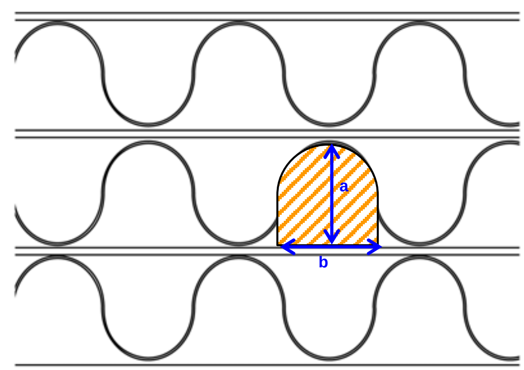


Plate type



Honeycomb type



Corrugated type

Typical Catalyst Deactivation Factors

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Deactivation Factor	Effect on Catalyst	Types of Fuel
Arsenic (As)	Deactivates Sites	Bituminous
Alkaline metals (K_2O, Na_2O)	Deactivates Sites	Biomass SBS
Phosphorus (P_2O_5)	Deactivates Sites	PRB Biomass
Iron (Fe_2O_3) Produced by catalyst wetting due to tube leakage etc.	Increase SO_2 conversion rate	Bituminous
Calcium (CaO)	Covers Active Sites	PRB
Ash Content / Silica	Erosion	Lignite
Vanadium	Increase SO_2 conversion rate	Pet Coke

Catalyst Disposal

- Plate type catalyst is the only catalyst that can be recycled.
- Recycling can be done by a steel mill for no cost to you.

Latest Catalyst Developments

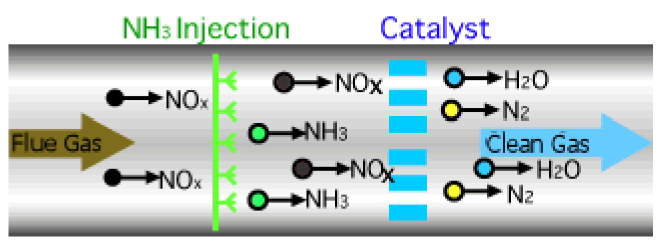
Extended Life Catalyst

CM Catalyst

Combines High NOx Reduction with:

- Longest Catalyst Life: ↓ Lifecycle Cost
- Low SO2 → SO3 Conversion: ↓ SO_3 Mitigation Consumption
- Excellent Hg Oxidation: ↓ Activated Carbon Consumption

Compared to Conventional Catalysts



Excellent DeNox performance and lower operating costs.

Characteristics of New CM SCR Catalyst

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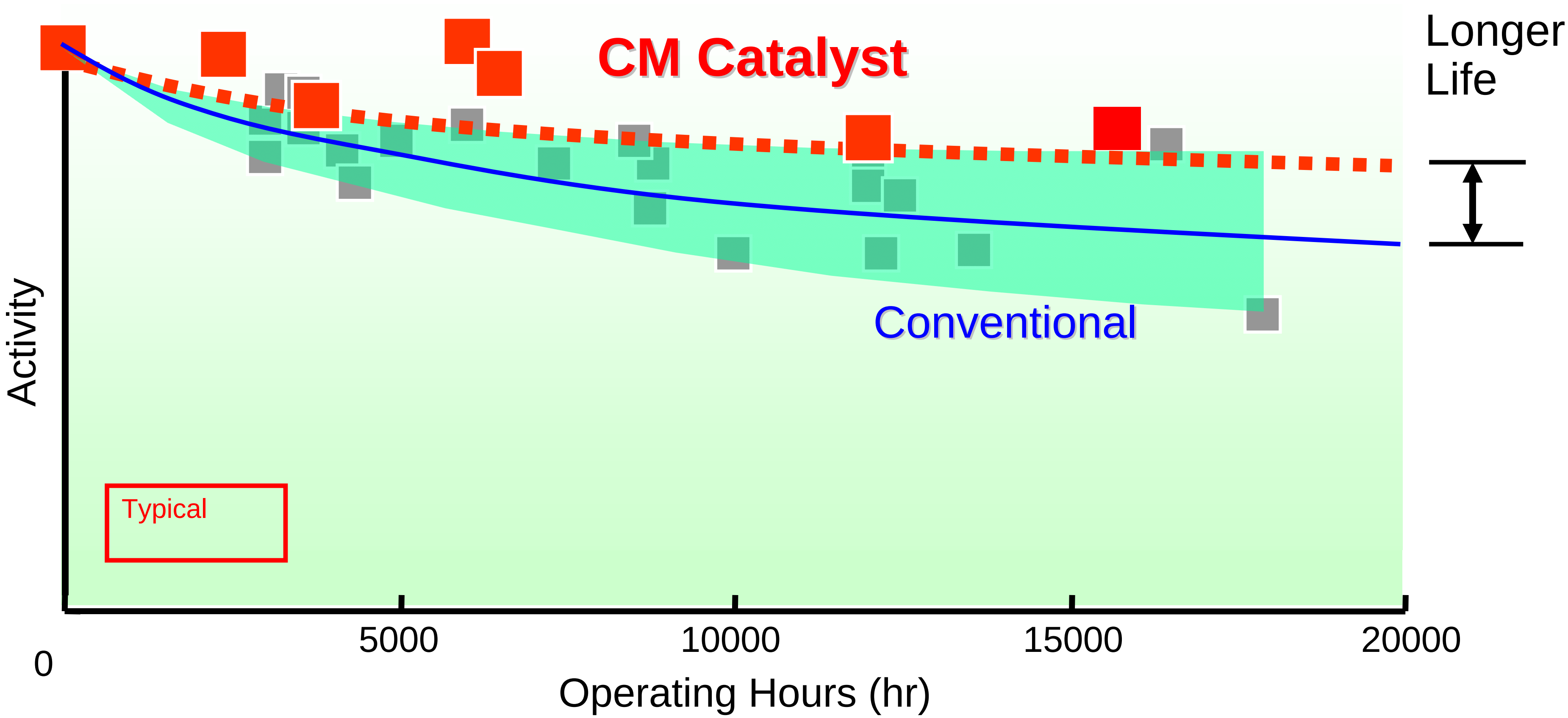
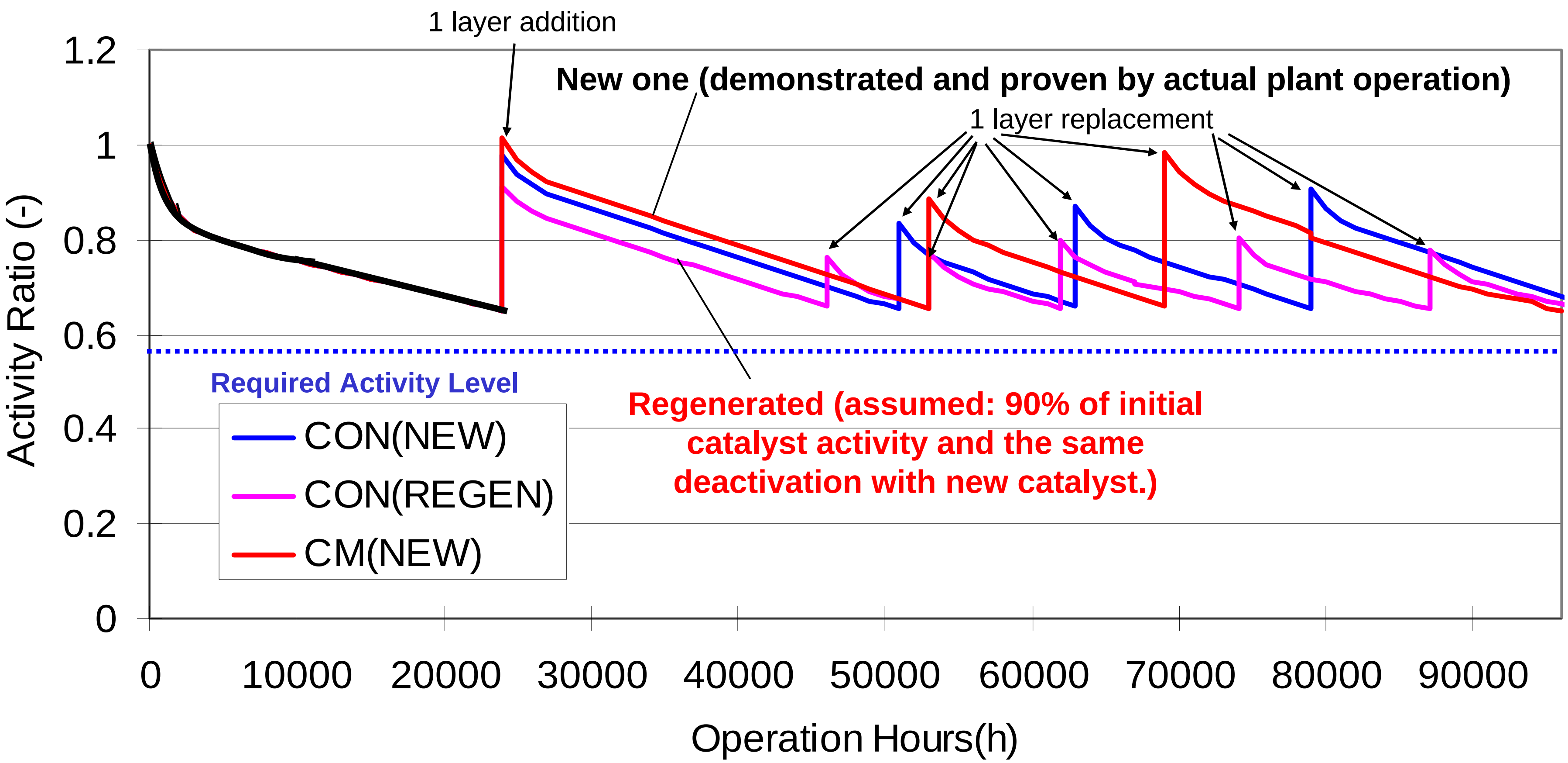


Newly developed CM catalyst deactivates slower than conventional or regenerated catalyst, therefore providing longer service life.

Economics of Regenerated vs. New CM Catalyst



Based on our experience, DeNOx activity of Regenerated catalyst is lower than that of new catalyst. Therefore, Regenerated catalyst has a shorter lifetime than new catalyst, if catalyst volume is constant and deterioration rate is the same for both cases. The economics should be evaluated for a long term operation prior to application of regenerated catalyst.

Catalyst Type	Required number of replacement for 12 years	Catalyst volume ratio to be replaced	Unit price	Total price for Catalyst	Removal & Installation cost
Conventional Unused	**4**	**Base:100 %**	**Base:100 %**	**Base:100%**	**4 Times**
Conventional Regenerated	**6**	**150 %**	**60 %**	**90%**	**6 Times**
New CM Unused	**3**	**75%**	**100%**	**75%**	**3 Times**

Based on the deactivation tendencies of CM catalyst vs. conventional or regenerated conventional, the extended life allows for longer time between catalyst change outs of catalyst, therefore making it more economical over the lifetime of the SCR.

Enhanced Mercury Oxidation Catalyst

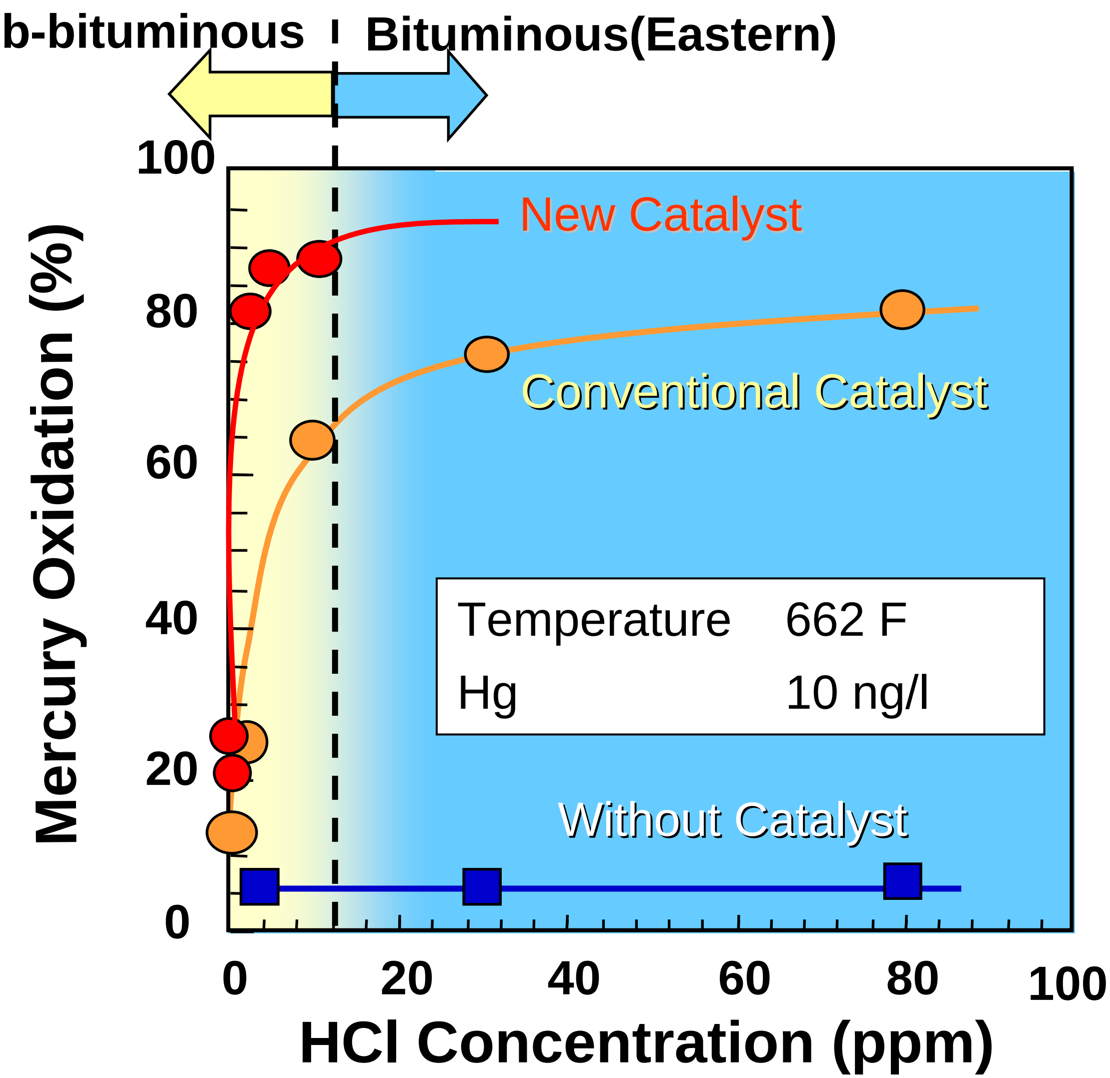
Mercury Oxidation Catalyst: TRAC®

(TRiple Action Catalyst)

- Equivalent performance to CM Catalyst but with enhanced mercury oxidation.
- Increased mercury oxidation rate of 90% at the SCR outlet.

Excellent DeNox performance and lower operating costs.

Characteristics of TRAC®



Typical Performance of TRAC®

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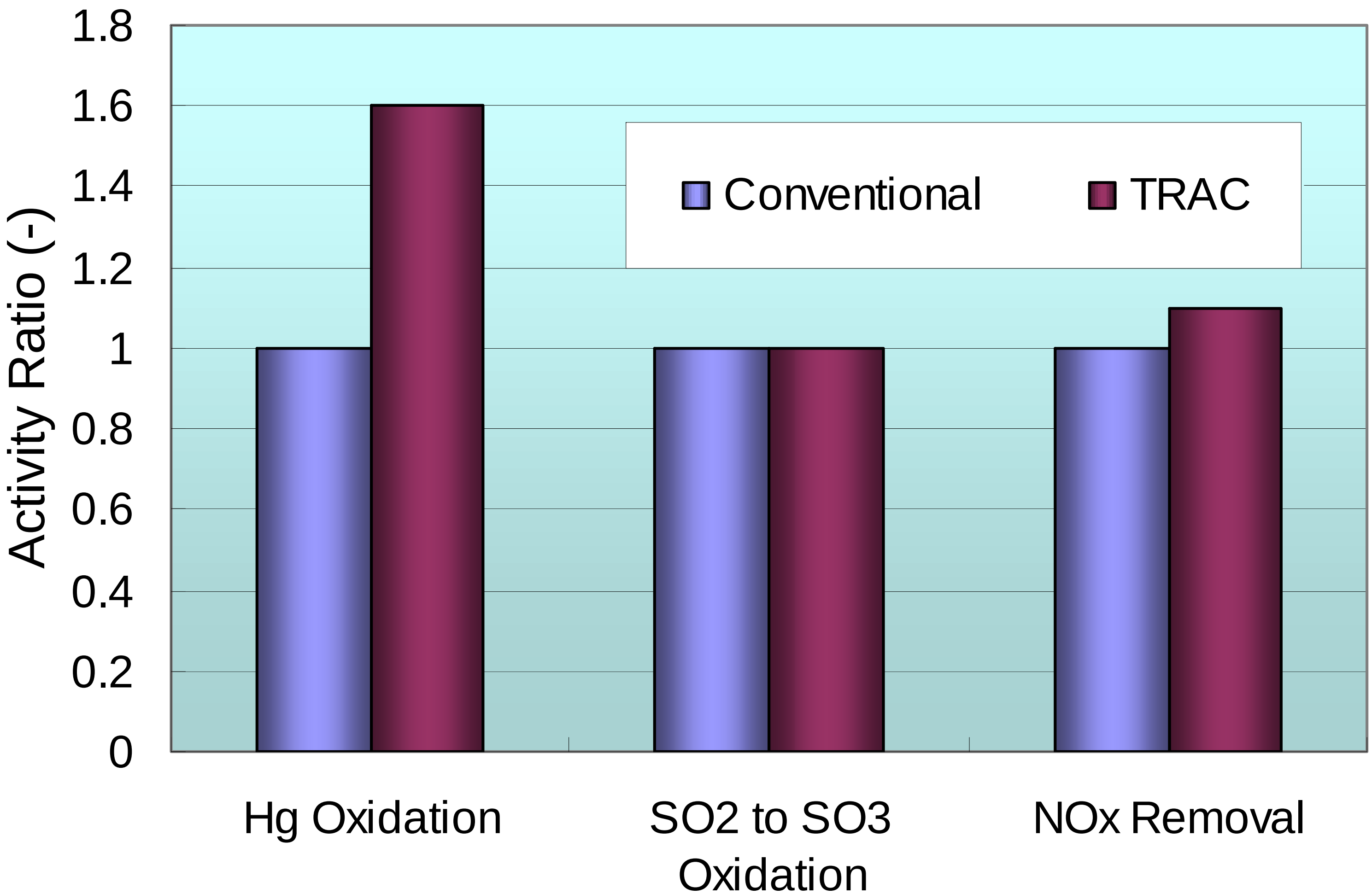
TRAC® – TRiple Action Catalyst*



Why Oxidize Mercury in the SCR?

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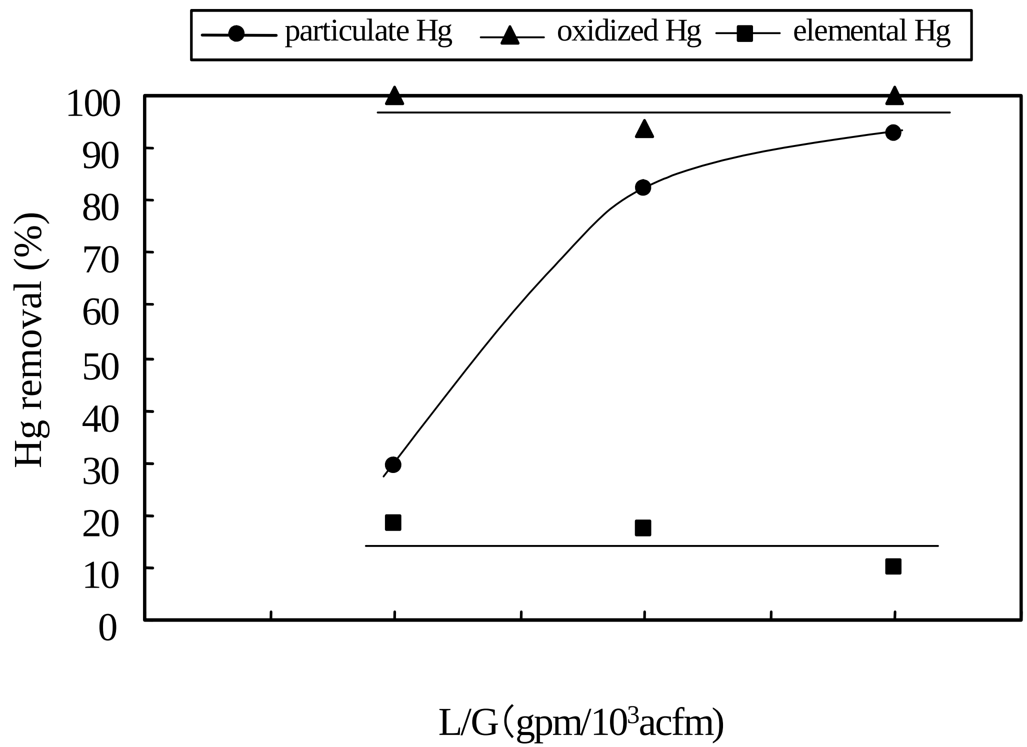
- **Co-Benefit**…Utilization of SCR to reduce NOx <u>and</u> oxidize Hg
- In Hitachi WFGD, removal of 90+% of the <u>oxidized mercury</u> can be achieved
- Hg Removal efficiency of Dry FGD System can be improved with more oxidized Hg
- **Significantly reduce** use of additives such as ACI



PRB Applications

(52% CaBr2 solution. @0.9$/lb basis)

	3 N/T Layers	Existing 2 Layers + TRAC® 1 Layer	TRAC® 3 Layers
Oxidized Hg (%) (W/O Br Injection)	41%	56%	71%
Br Concentration Expected for 90% oxidation	25 ppm	4 ppm	3 ppm
Halogen Cost	$0.18M / year	$0.03M / year	$0.02M / year

N/T = Non-TRAC® Catalyst

Flue gas temp. at SCR inlet: 741 Deg.F
After a half year operation

For PRB applications, some halogen injection may be required to achieve 90% mercury oxidation at AH outlet.

TRAC® is effective to reduce operation cost by lowering the amount of halogen injection required.

Eastern Bituminous Applications

	3 N/T Layers	2 N/T Layers + 1 TRAC®	3 Layers of TRAC®
ACI injection, # / MMACF	2.6	1.8	0
ACI Cost (Millions per year)	$2.6	$1.8	n/a
HG Oxidation(@ APH outlet), (%)	(90% removal)	95	95

N/T = Non-TRAC® Catalyst

For Bituminous applications, TRAC® is effective to reduce operation cost by lowering or even eliminating ACI injection.

Summary

- New regulations are creating new challenges for SCR operations. Hitachi continues to develop new solutions minimizing the operational impact to the unit providing the flexibility required.
- Newly developed CM and TRAC® catalysts can be applied for both PRB and E.B. coals.
- Both are able to achieve less than 0.25% of SO_2 / SO_3 oxidation rate per layer for E.B.
- Both reduce the need for sorbent injection for SO_3 mitigation.
- TRAC ® enhances Hg oxidation capability with 95% Hg oxidation possible at A/H outlet to avoid ACI for E.B. coal, and PRB with minimal or no Halogen Injection required.

Development continues thru Hitachi's R&D efforts to further enhance our SCR catalyst performance.

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Questions?

Stephen Guglielmo

908-605-2823

stephen.guglielmo@hal.hitachi.com

