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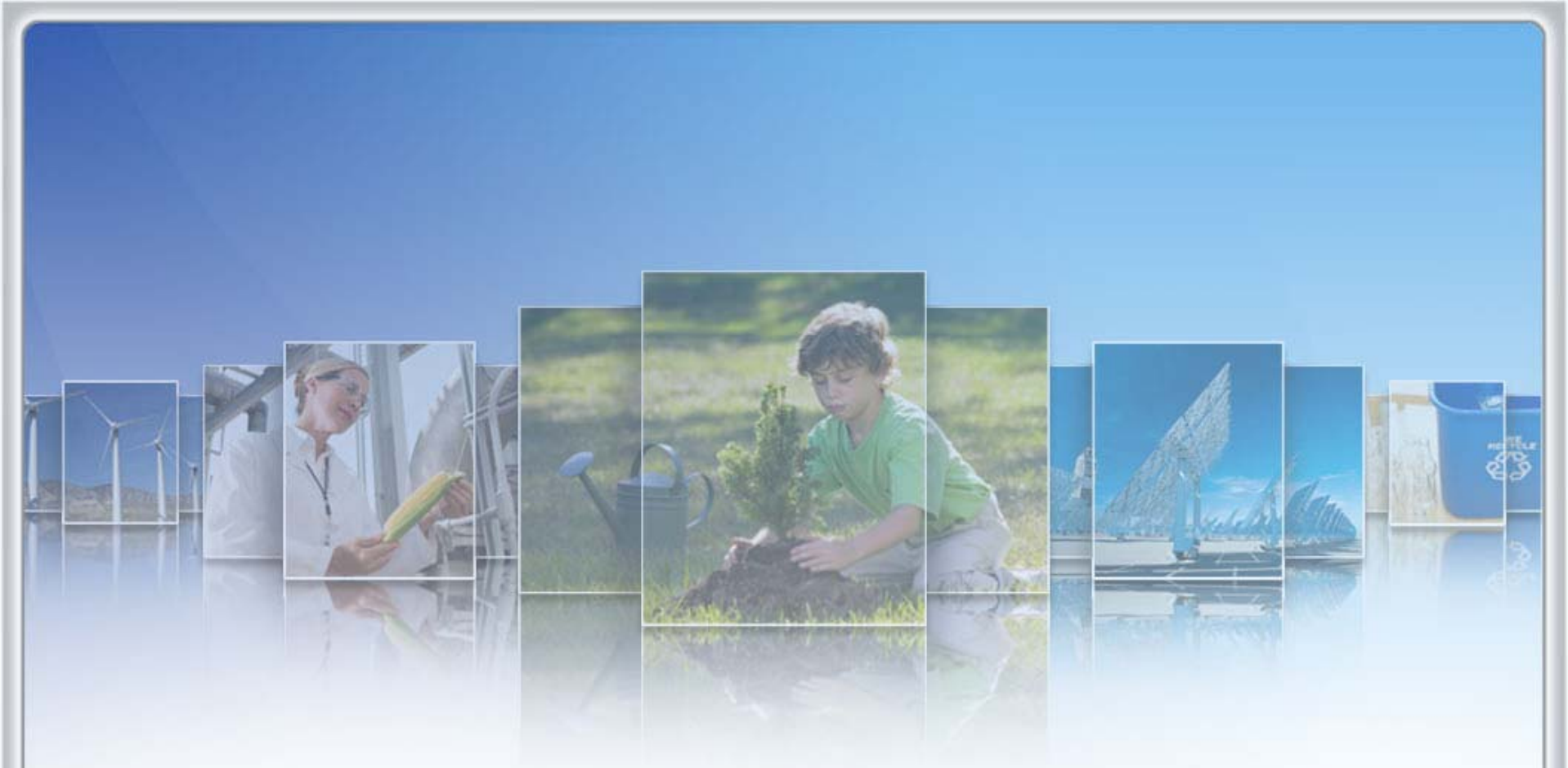

Enhanced Mercury Oxidization (EMO™)

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The Shaw Group
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EMO™ Overview / Refresher

- Injecting chemical: EMO™ chemical additives (HBr)
  - Mercury Oxidization: Hg(0) → Hg(2+)
  - Mercury Absorption/Adsorption: in existing FGD, or to add powdered activated carbon (PAC) or Trona/alkaline injection for the non-scrubbed systems
- Generally speaking, the Hg(0)/Hg(2+) ratio (native mercury oxidization) at the economizer outlet:
  - Bituminous: 50% Hg(0) / 50% Hg(2+)
  - Sub- Bituminous: 90% Hg(0) / 10% Hg(2+)
  - Lignite: 70% Hg(0) / 30%Hg(2+)
- To reach 90% or above on mercury emission reduction for any coal-fired application

8.6 lb/TBtu → 0.86 lb/TBtu

- Injection location and temperature: Economizer outlet (650°F)
- After Hg is oxidized, it will be bound with fly ash and scrubbed by the wet FGD, or for un-scrubbed systems, PAC or Trona injection

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Even Distribution Applying the Effective Chemical

EMO™ System

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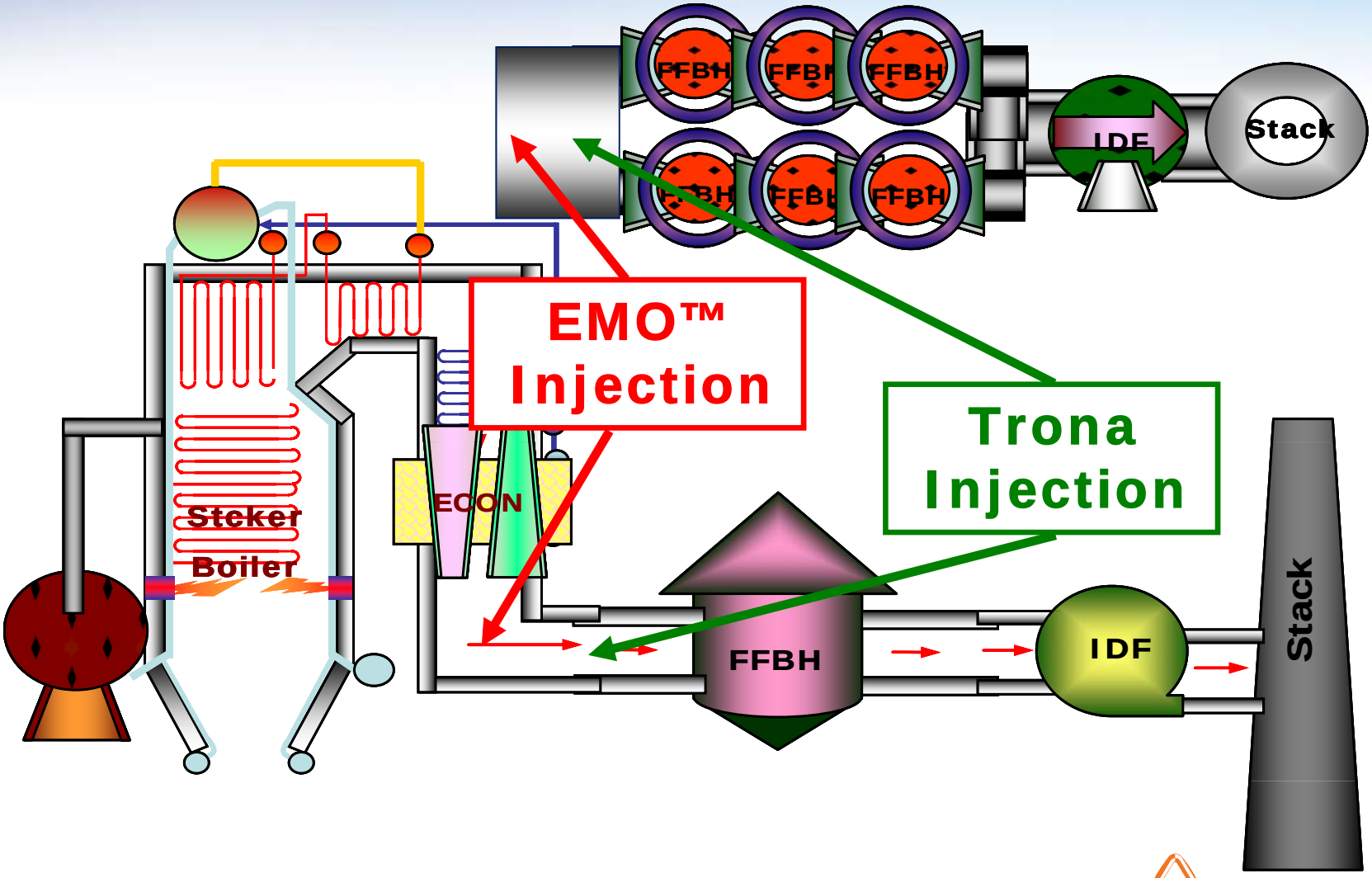
EMO™ Field Trial Unit Configuration



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First EMO™ Full Scale Data

- Sub-bituminous testing results
  - Stoker unit – 25 MW equivalent burning PRB
  - SNCR + fabric filter baghouse
- Testing performed
  - Baseline tests
  - Varying EMO™ chemical injection rates at the boiler outlet
  - Varying Trona injection rates at the baghouse inlet

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First EMO™ Field Demonstration (25 MW)

OHM Stack	2.66	3.05	3.10	3.47	2.66	3.05	3.25	3.43
OHM Stack (3% O2)	6.50	7.46	7.38	8.26	6.32	7.26	7.73	8.17
OHM Stack Hg (lb/TBtu by Fd)	5.34		5.91		5.18		5.83	
SO3 (ppmvd)	0.63		NA		NA		NA	
Boiler Steam Load (klb/hr)	149.2		149.4		149.4		149.4	
CPM (lb/hr)	283.4		215.7		202.0		191.2	
Stack Flow Rate (dscfm)	112,661		111,273		112,193		114,359	
Stack Flow Rate (mmscfh)	7.143		7.029		7.077		7.154	
Stack Flow Rate (mmacfh)	12.198		12.098		12.180		12.313	
NH3 Feed Rate (lb/hr)	122.1		184.3		150.0		150.0	
Trona Feed Rate (lb/hr)	0.0		0.0		250.0		350.0	
SO2 (ppmvd by Shaw CEMS)	27.6		27.5		6.1		5.3	
NOx (ppmvd by Shaw CEMS)	57.5		61.0		72.4		68.6	
NO2 (ppmvd by Shaw CEMS)	NA		5.4		5.4		5.4	
CO (ppmvd by Shaw CEMS)	14.5		14.3		15.7		16.2	
O2 (%vol-dry by Shaw CEMS)	13.58		13.38		13.38		13.38	
CO2 (%vol-wet by Shaw CEMS)	5.94		6.21		6.21		6.21	
Stack temp (°F)	445.1		452.3		452.3		452.3	
%Excess Air	177.2%		170.5%		170.5%		170.5%	
Stack Moisture (%vol)	5.37		5.01		4.87		4.09	
Hg(0)/ Hg(T) ratio at Stack	87.1%		89.3%		87.1%		94.6%	
APCD Hg Removal (ECON - Stack)	NA		NA		8.0%		-3.6%	

X Trona injection: (N/A)

✓ Baseline SO2: 27.6 lb/hr, post-Trona: 2.5 lb/hr, 95% R.E

X Baseline Hg emission: 5.6 lb/TBtu

X Average CPM: 200 lb/hr

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First EMO™ Field Demonstration (25 MW)

OHM Stack	1.38	1.63	1.47	1.74	1.41	1.69
OHM Stack (3% O2)	2.81	3.32	3.23	3.83	3.28	3.94
OHM Stack Hg (lb/TBtu by Fd)	2.37		2.73		2.81	
Appendix K Stack (µg/dscm)	1.85		1.97		1.99	
RD (OHM/App K)	6.2%		6.2%		8.2%	
CPM (lb/hr)	1.9		4.4		5.4	
Boiler Steam Load (klb/hr)	148.8		146.9		150.0	
Stack Flow Rate (dscfm)	116,711		115,592		116,257	
Stack Flow Rate (mmscfh)	7.359		7.304		7.351	
Stack Flow Rate (mmacfh)	12.585		12.552		12.600	
NH3 Feed Rate (lb/hr)	149.4		151.4		156.0	
EMO Concentration (%wt)	0.300		0.395		0.609	
EMO Feed Rate (lb/hr)	7.5		9.9		15.2	
Trona Feed Rate (lb/hr)	350.0		355.0		360.0	
SO2 (ppmvd by Shaw CEMS)	2.3		2.0		1.8	
NOx (ppmvd by Shaw CEMS)	54.6		54.8		51.7	
NO2 (ppmvd by Shaw CEMS)	2.0		2.1		0.3	
CO (ppmvd by Shaw CEMS)	18.7		17.7		13.8	
O2 (%vol-dry by Shaw CEMS)	12.09		12.75		13.22	
CO2 (%vol-wet by Shaw CEMS)	5.7		6.22		6.23	
Stack temp (°F)	446.4		450.8		448.4	
%Excess Air	125.8%		147.6%		164.4%	
Stack Moisture (%vol)	4.84		5.05		5.11	
Hg(0)/ Hg(T) ratio at Stack	84.5%		84.4%		83.2%	
APCD Hg Removal (ECON - Stack)	57.9%		51.5%		50.1%	

- ✓ Trona injection at 400˚F at 350 lb/hr, 30 lb/MMacf
- ✓ Baseline SO2: 27.6 lb/hr, post-Trona: 2.0 lb/hr, 95% R.E
- ✓ Baseline Hg emission: 5.5 lb/TBtu, post-Trona/EMO : 2.6 lb/TBtu, 58% R.E. at 0.2 GPH
- ✓ Average CPM: 200 lb/hr, post-Trona/EMO : 3.0 lb/hr, 97% R.E.

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HCl Emission Reduction Applying Trona

	HCl (lb/hr)	HCl (ppmvd)	HCl (lb/MMBtu)
Baseline	0.62	0.97	0.0026
	0.36	0.55	0.0014
	0.57	0.85	0.0024
Average	0.52	0.79	0.0021

Trona at 150 lb/hr, at 12.5 lb/Mmacf	0.07	0.10	0.0003
	0.07	0.11	0.0003
	0.07	0.11	0.0003
Average	0.07	0.11	0.0003
HCl Removal Efficiency	86%		

Trona at 250 lb/hr, at 20 lb/Mmacf	0.04	0.06	0.0002
	0.04	0.06	0.0002
	0.00	0.00	0.0000
Average	0.03	0.04	0.0001
HCl Removal Efficiency	94%		

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Second EMO™ Full Scale Data

- Sub-bituminous testing results
  - PC Unit - 660 MW equivalent burning PRB
  - SCR + electric-static precipitator
- Testing performed only on Duct A (one side)
  - Baseline tests
  - Varying EMO™ chemical injection rates at the SCR inlet
  - Varying Trona injection rates at the SCR outlet

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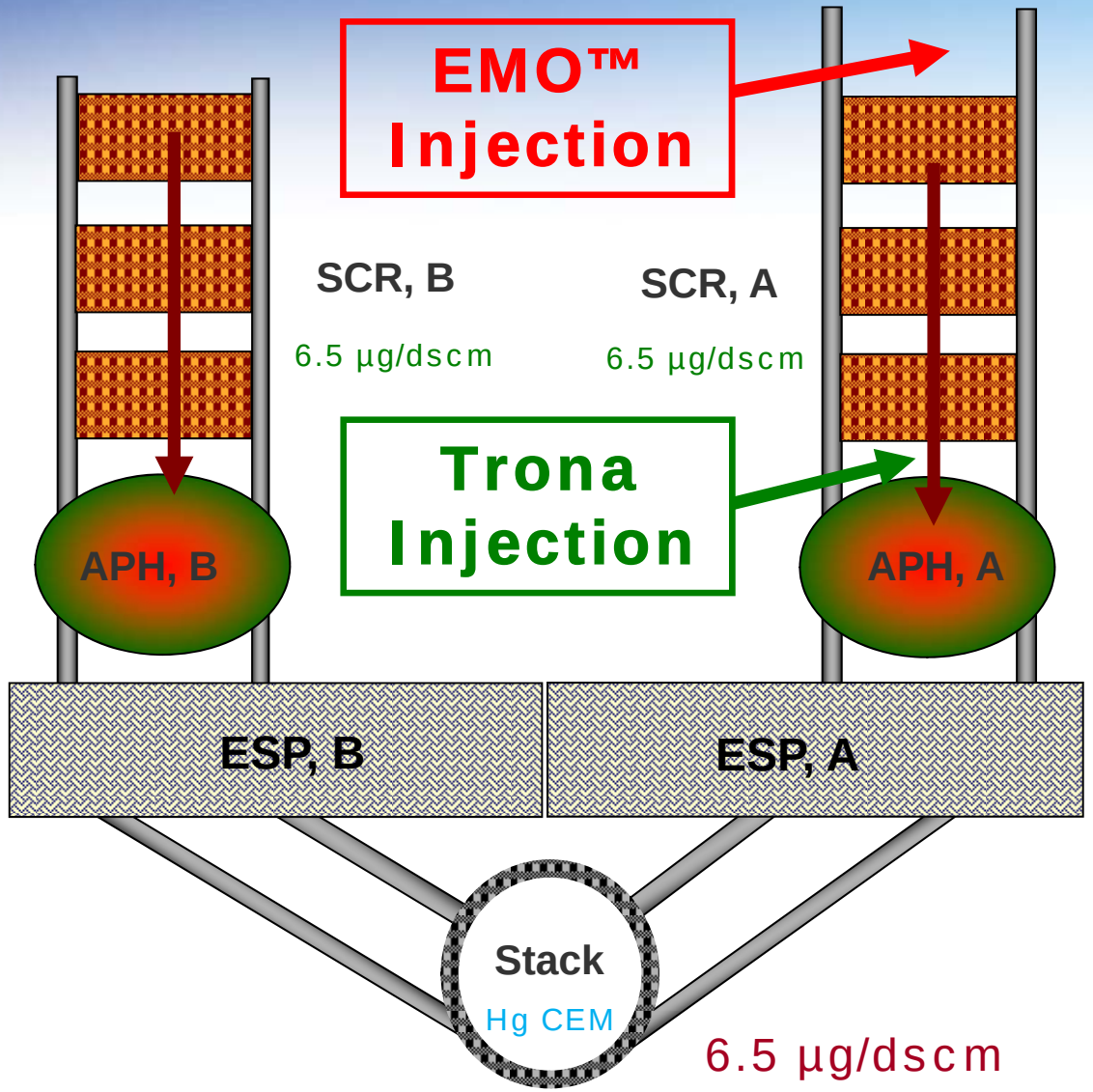
EMO™ Field Trial Unit Configuration



- The flue gas mercury level was determined to be around 6.5 µg/dscm with more than 95% of it existing in the form of elemental mercury, which was common for the PRB-fired application due to the low chlorine content in the PRB coal.

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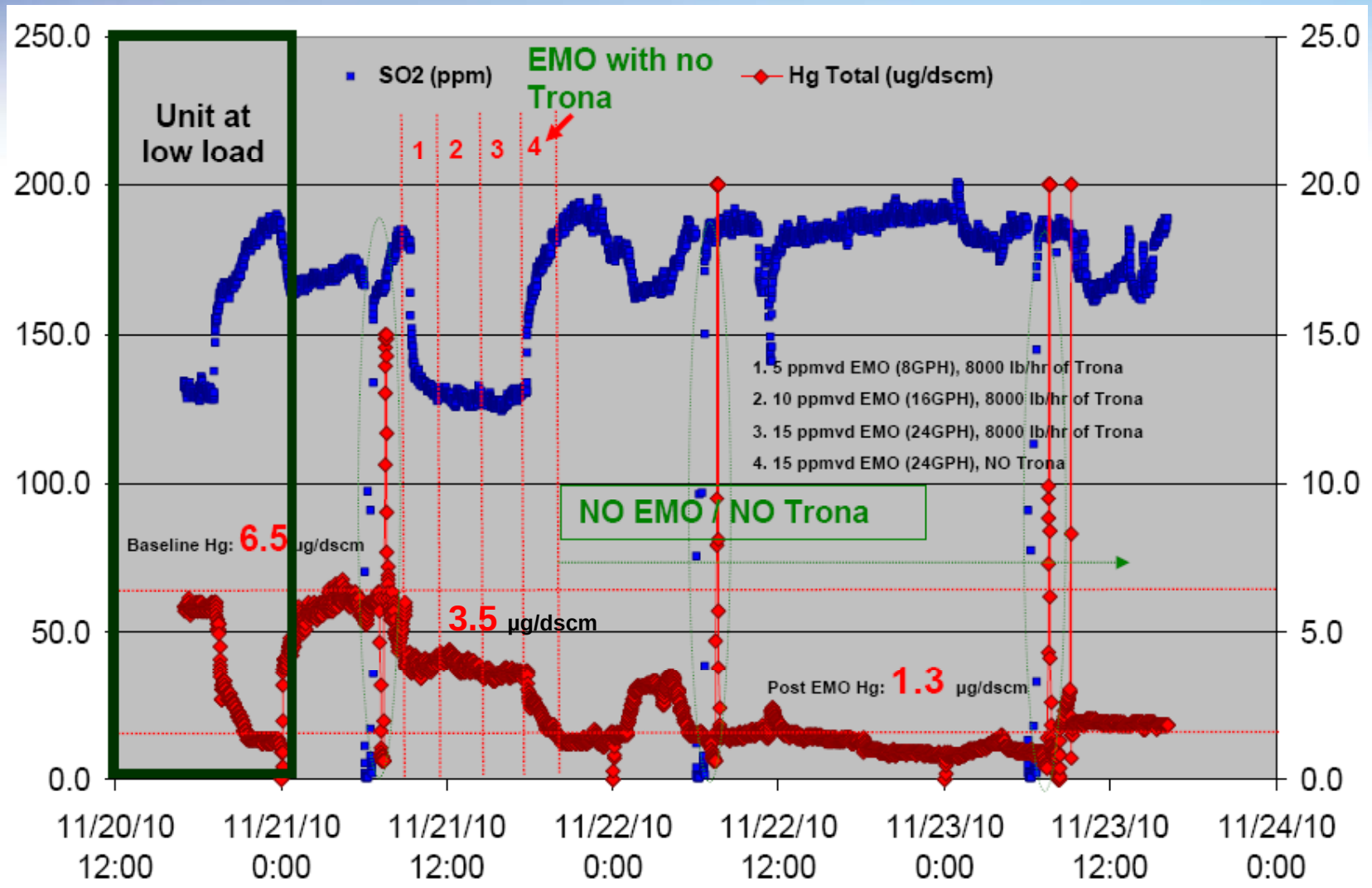
Result Overview – Hg/SO2 (Stack CEMs)



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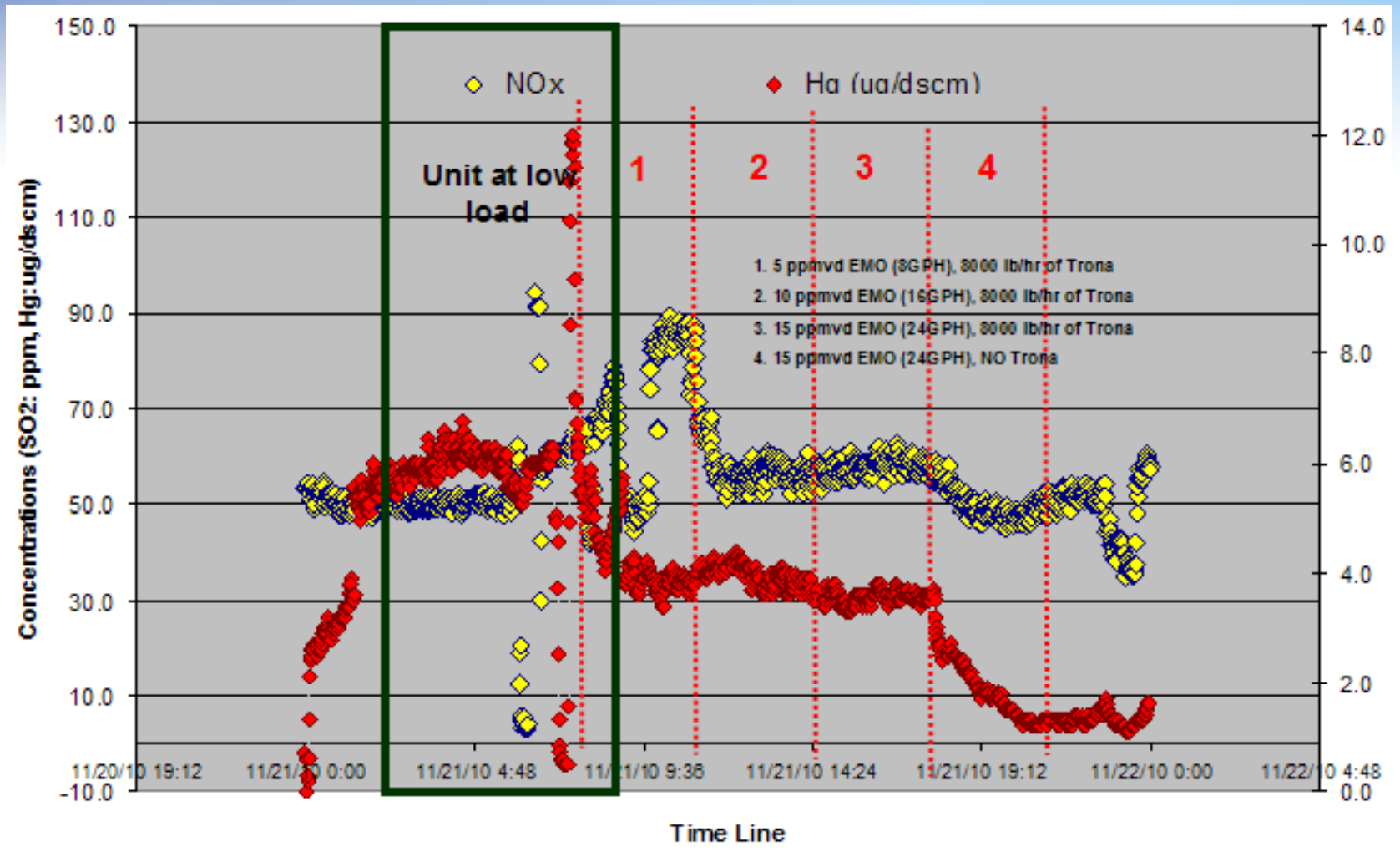
The Impact of EMO™ on NOx



During Run 4 (EMO™ only, no Trona), it was observed that EMO™ yielded no negative impact on NOx emission reduction.

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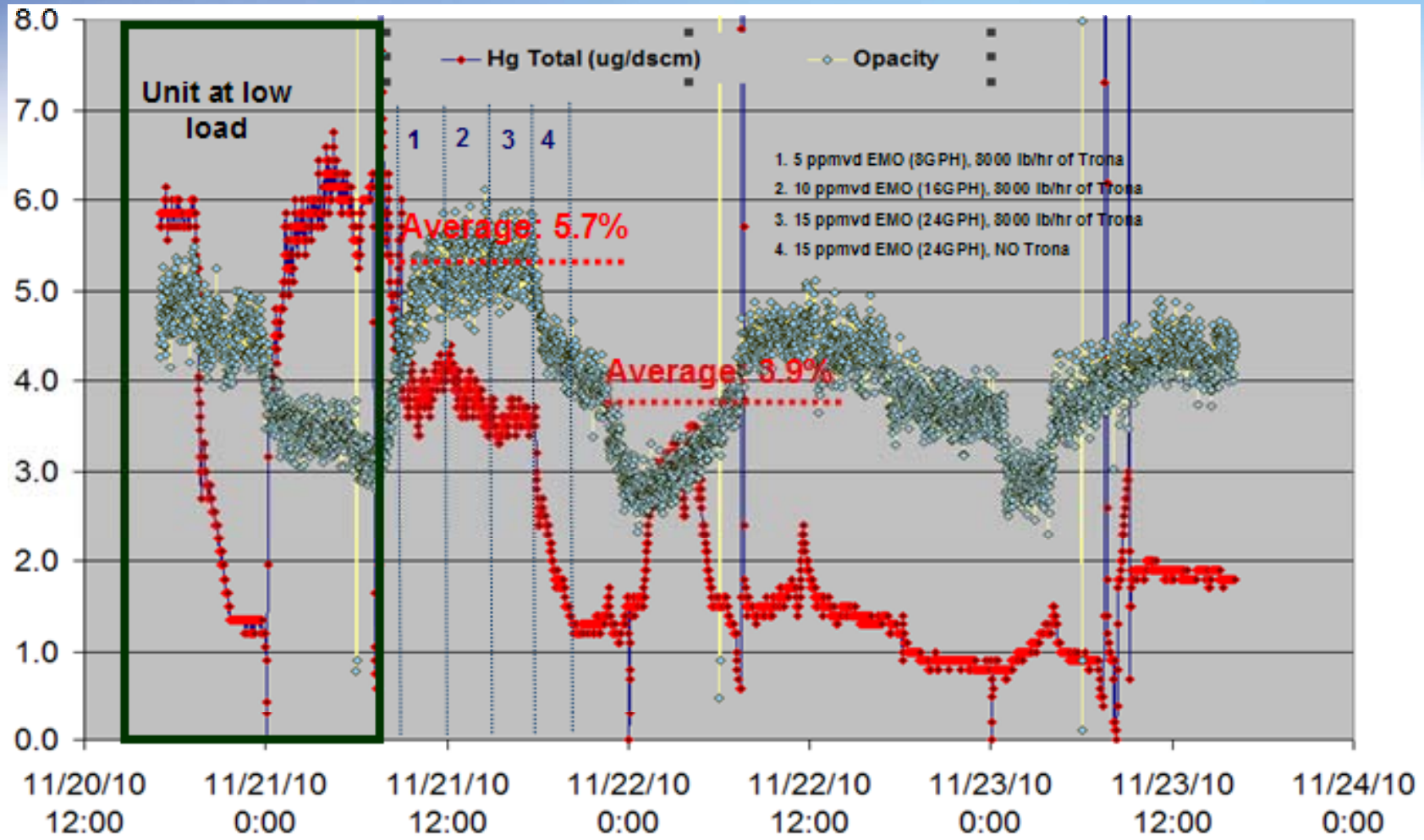
The Impact of EMO™ on Opacity



During Run 4 (EMO™ only, no Trona), while the Stack Hg reduction was observed to be above 95%, the Stack opacity was also observed to improve from 5.7% down to 3.9%

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Factors that Define this Technology

- Even chemical dispersion and complete mixture with the flue gas – Injection nozzles designed to control to desired residence time, and the proper cooling system to optimize system performance
  - Shaw EMO™ employs Shaw's liquid-spraying nozzle, pumping and the system cooling to optimize the system performance model
- Selection for the injection location – Combustion zone, post-combustion hot side/cold side
  - Shaw EMO™ suggests injection to be carried out at the economizer (680 °F – 850 °F) post-combustion zone which yields no impact to the fuel combustion processes
- Chemical properties/composition – HBr, Br_2, HCl, or Cl_2 where Cl_2 and Br_2 yield only little effect promoting Hg oxidization
  - Shaw EMO™ employs HBr as the injection additive which has been demonstrated as an effective chemical reagent promoting mercury oxidization
- Corrosion-resistance system construction and leakage free protection, material handling and transportation.

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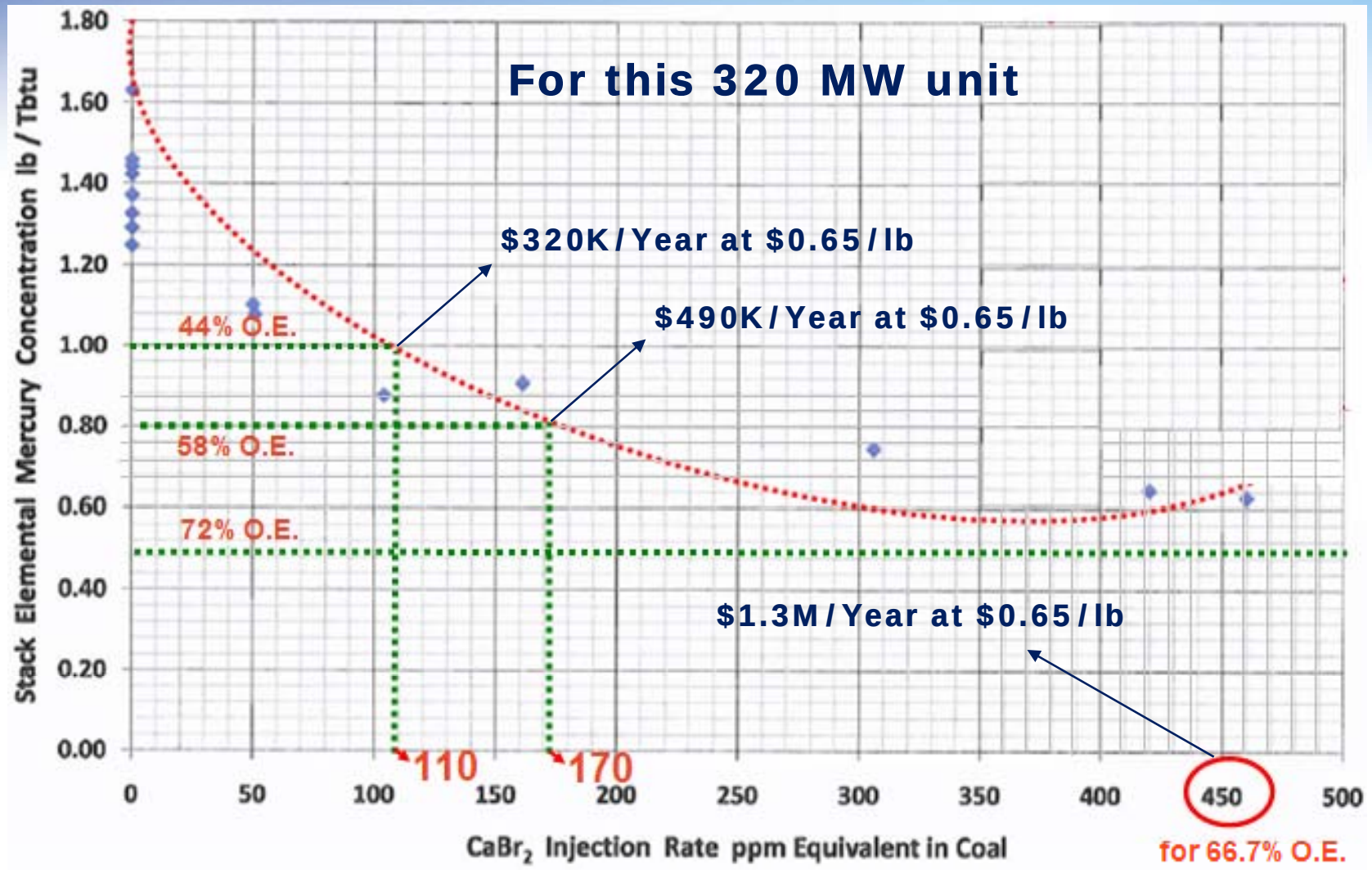
$CaBr_2$ Performance on Hg Oxidization



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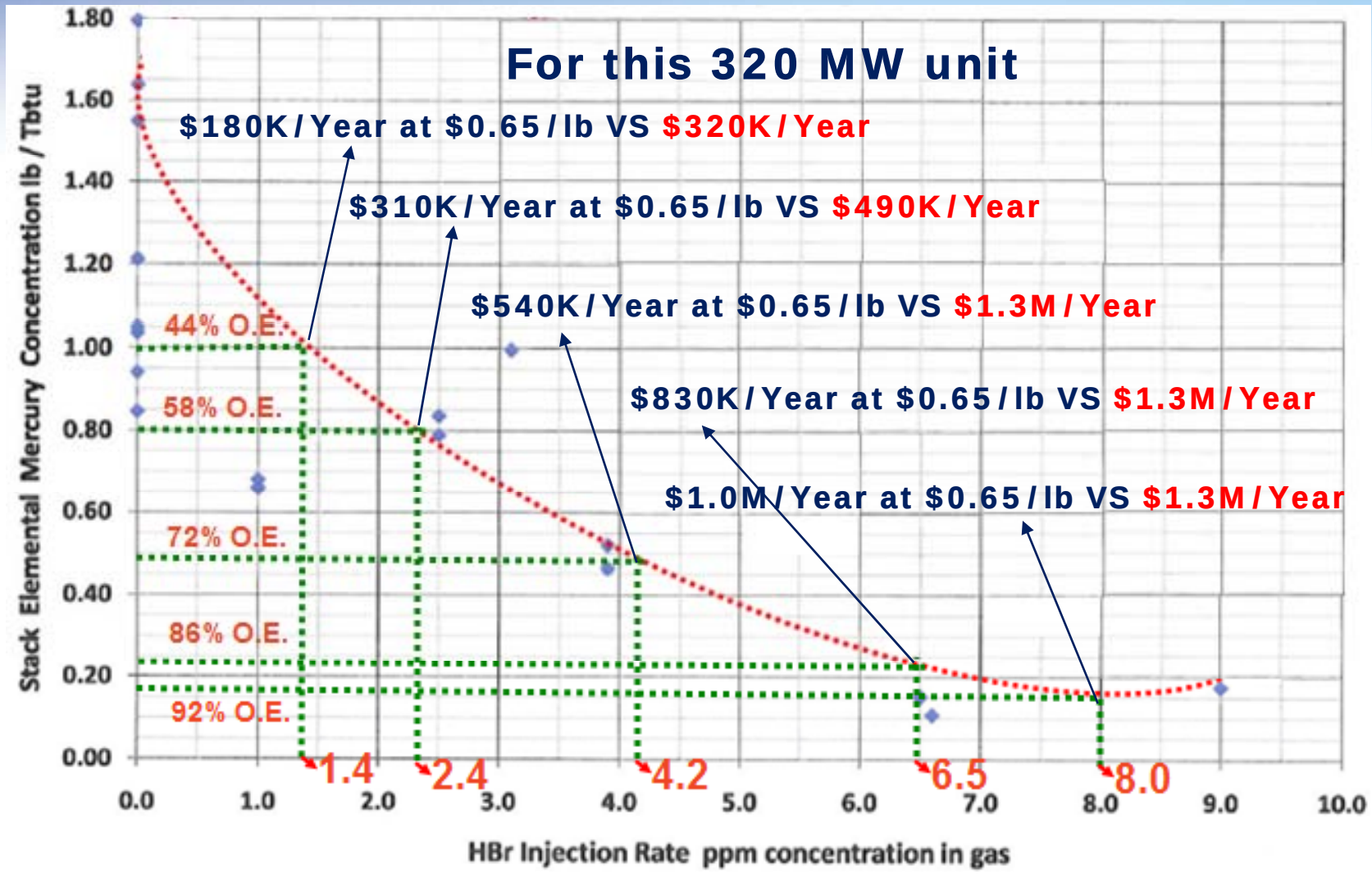
EMO™ Performance on Hg Oxidization



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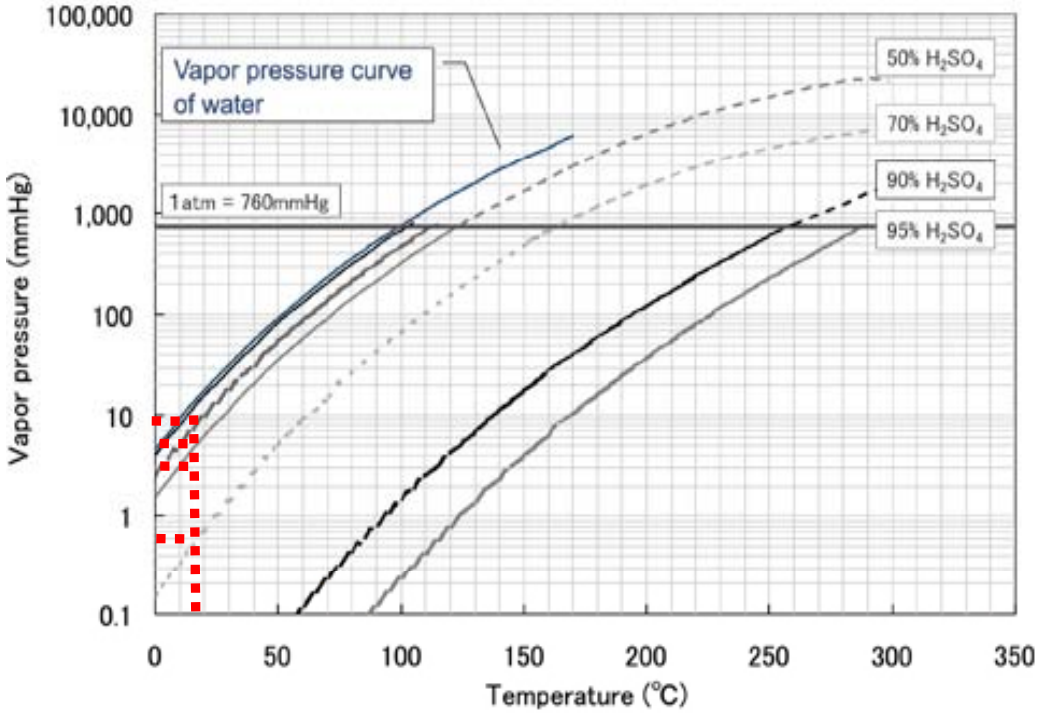
Long Term Corrosion Issues

- Acid gas dew point for SO3 : 270 to 290˚F (This is why flue gas temperature is kept above 300˚F - to prevent SO3 condensation)
- Boiling point of pure HBr is at -88˚F (This is a very low boiling point which indicates HBr exists in vapor phase at atmospheric pressure)



- Vapor pressure of pure HBr at 62˚F is 20 atm or 15,200 mmHg. Vapor pressure of pure HCl at 68˚F is 42 atm or 31,650 mmHg (Again, HBr exists in vapor phase at atmospheric pressure)

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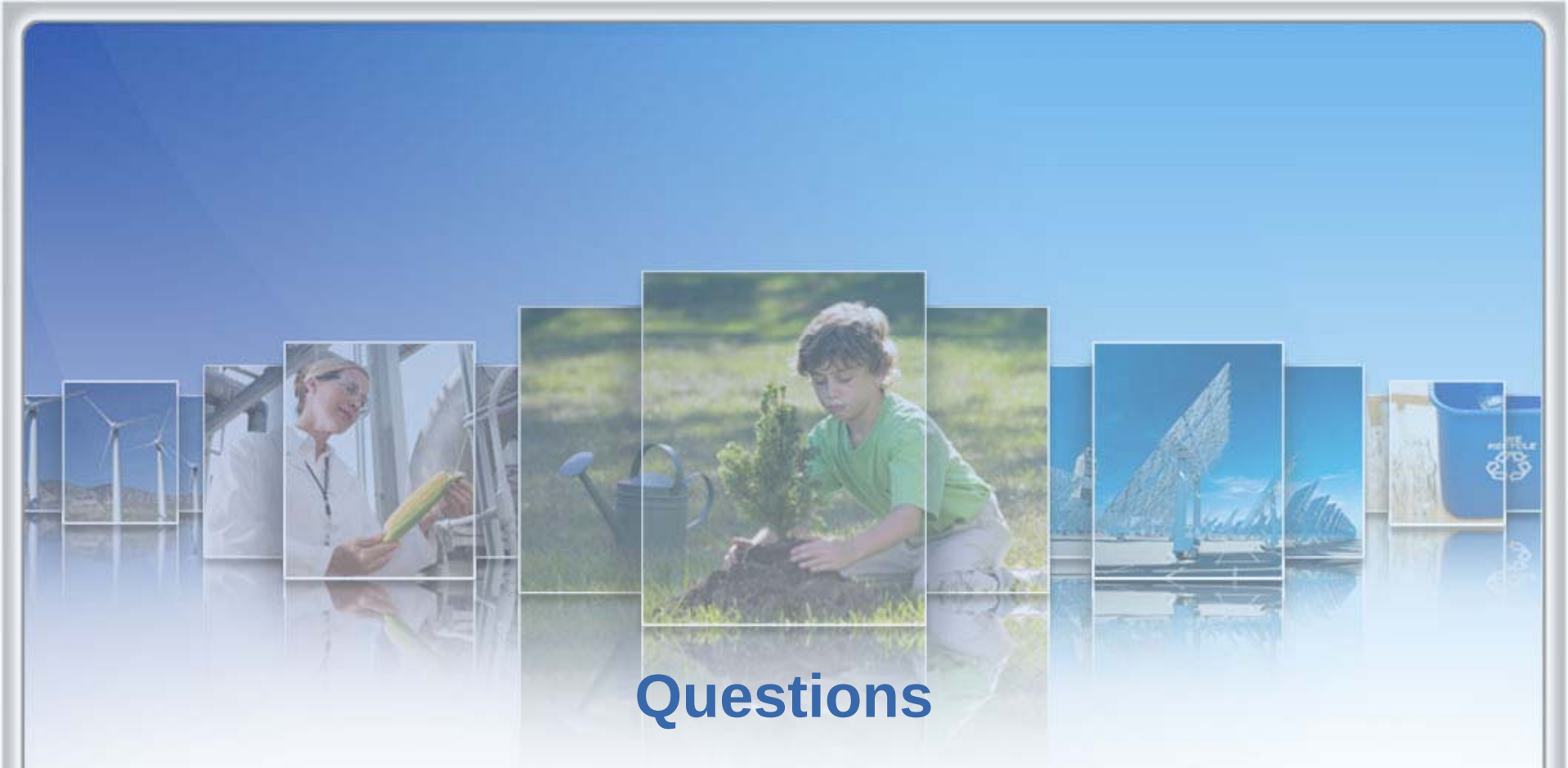

Questions

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