Cyclic Testing of a Long-Life Zinc-Ferrite Sorbent for Moving-Bed Reactors

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Introduction

- Coal gasifiers coupled with combined cycle power plants (IGCCs) are potentially the lowest cost source of baseload electricity
- Coal contains sulfur that is converted to H_2S in the gasifier
- The H_2S must be removed before the gases are fed to the gas turbine

Hot-Gas Cleanup

- It is better to remove the H_2S (as well as COS and CS_2) at high temperatures than to suffer the cost and inefficiencies involved with cooling the gases and removing sulfur at near-ambient temperature

Objective

- Design a regenerable sorbent that removes H_2S from hot reducing-gases
- Suitable for use in a moving-bed hot-gas cleanup system (for example, the G.E. Moving Bed System at the Tampa Electric Polk Power Station)

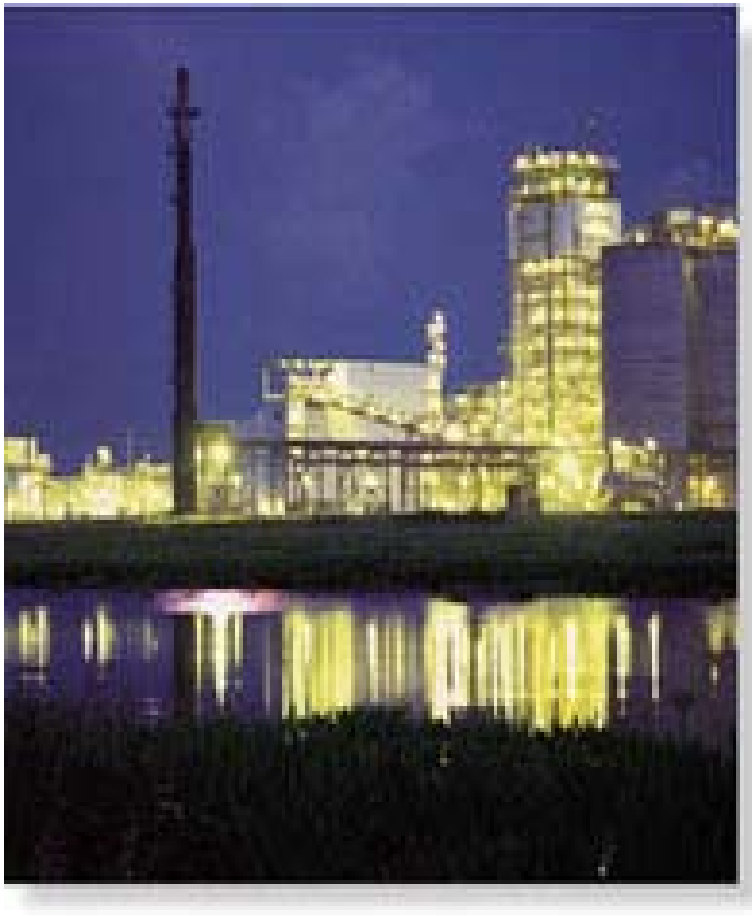
Polk County Plant

- A state-of-the-art integrated coal gasification combined-cycle (IGCC) power plant, Tampa Electric's Polk Power Station produces enough electricity to serve 75,000 homes.

- 250-megawatt IGCC facility is among the nation's cleanest, most efficient and most economical power generation units. The plant is a first-of-its-kind combination of two leading technologies.

- The first technology is called "coal gasification," which uses coal to create a clean-burning gas. The second technology is called "combined-cycle," which is the most efficient method of producing electricity commercially available today.

The plant combines coal with oxygen in the gasifier to produce the gaseous fuel. After processing, the clean coal gas is used in the combustion turbine to produce electricity.



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The TNT- MB Sorbent

- TDA and NORTON - Moving Bed
- Zinc Ferrite + Inert Binders
- Absorbs at 600ºF - 900ºF
  - Tenth absorption to breakthrough > 1 hour @ 600 ºF
  - Tenth absorption to breakthrough > 7 hours @ 900 ºF
- Regenerates at 700ºF in 4% O_2
- > 13 Lb (Sulfur) Per Ft^3 bed at design conditions

TDA Research

Previous Work On $ZnFe_2O_4$

- **GE Pilot Plant Run 2B > 1200°F Regeneration = *No Sulfate***
  - Cook et al. (1992) Twelfth Annual Gasification and Gas Stream Cleanup Systems Contractors Review Meeting
- **RTI: "Zinc Ferrite Sorbents Were Found to Be Limited to 550°C" (1022°F)**
  - Gangwal and Gupta (1991) Eleventh Annual Gasification and Gas Stream Cleanup Systems Contractors Review Meeting
- **RTI and SRI International: "Carbon Deposition Rate Exceeds the Rate of Removal by *Steam*, and Hence Carbon Is Likely to Accumulate on the Sorbent"**
  - Krishnan et al. (1991) *A Preliminary Study of Carbon Deposition on Zinc Ferrite Sorbents*, DOE/MC/25006-3057, contract AC21-88MC25006

TDA Research

Testing of TNT-MB

- **10-Cycle Tests without SO_2 at DOE-FETC-Morgantown (CRADA) completed, (114)**
  - Low Temperature Scoping Tests
  - 10 cycles at 7 atm regeneration
- **3 1/2-Cycle Scoping Tests with SO_2 completed at Institute of Gas Technology (IGT), (114)**
- **10-Cycle Low Temperature Sulfidation Tests without SO_2 at TDA completed, (298)**
  - 10 cycles at 7 atm regeneration
  - 600ºF - 700ºF Sulfidation Temperatures
- **25-Cycle Test at IGT completed, (298)**

Sulfidation Conditions

Simulated Texaco Gas Stream

- Carbon Monoxide : 35.8 %
- Hydrogen : 26.8 %
- Carbon Dioxide : 12.2 %
- Hydrogen Sulfide : 1.2 %
- Nitrogen : 5.9 %
- Water : 18.1 %
- Space Velocity : 2000 hr^{-1}
- Pressure : 20 atm

Regeneration Conditions

- Sulfur Dioxide : 8%-10%
- Nitrogen : 87%
- Oxygen : 4.0%
- Space Velocity : 2000 hr^{-1}
- Pressure : 7 atm
- Temperature : 700-1300 °F

Oxygen turned off at breakthrough, makeup with Nitrogen.

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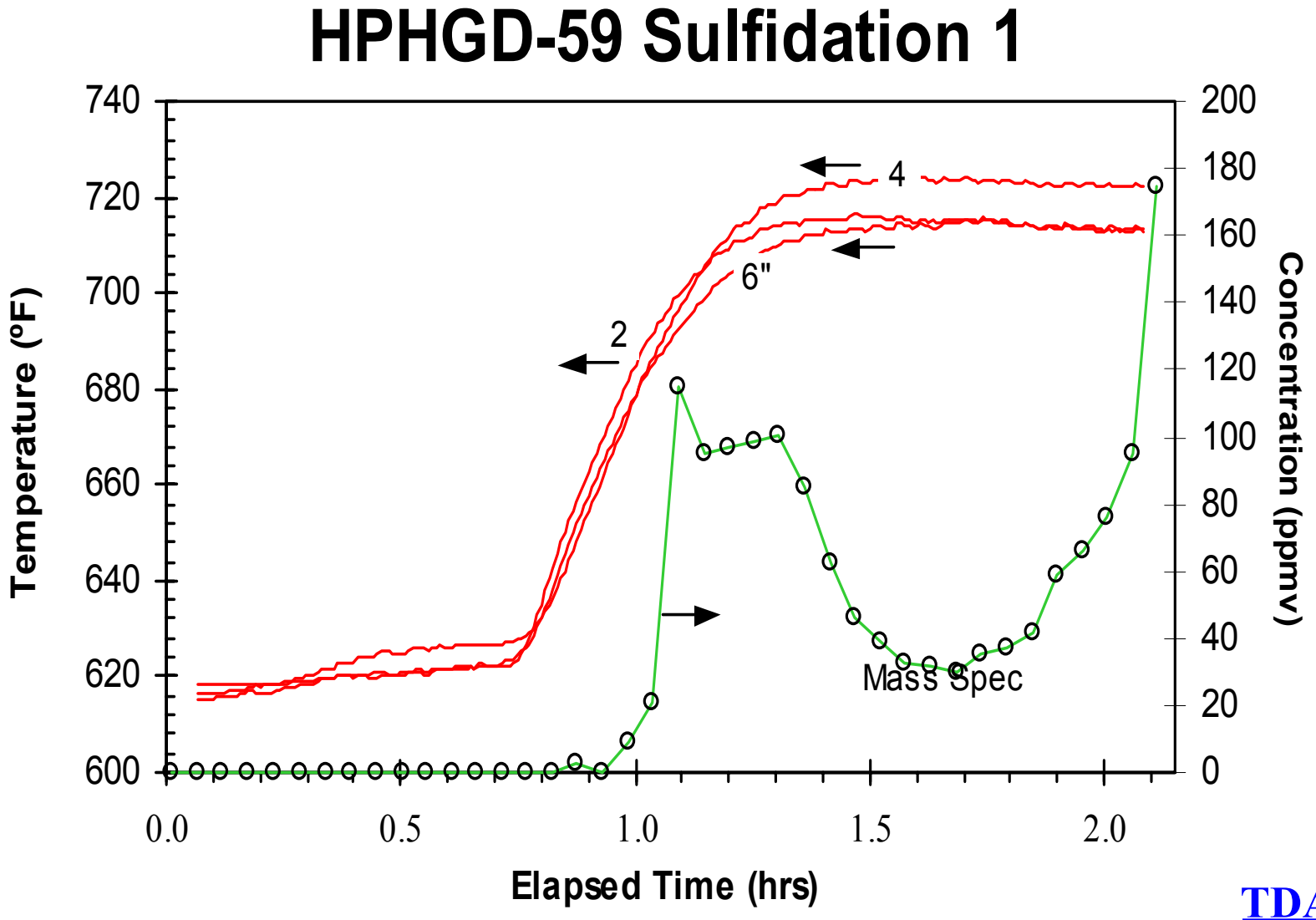
Low Temperature Absorption at 600/700ºF at FETC



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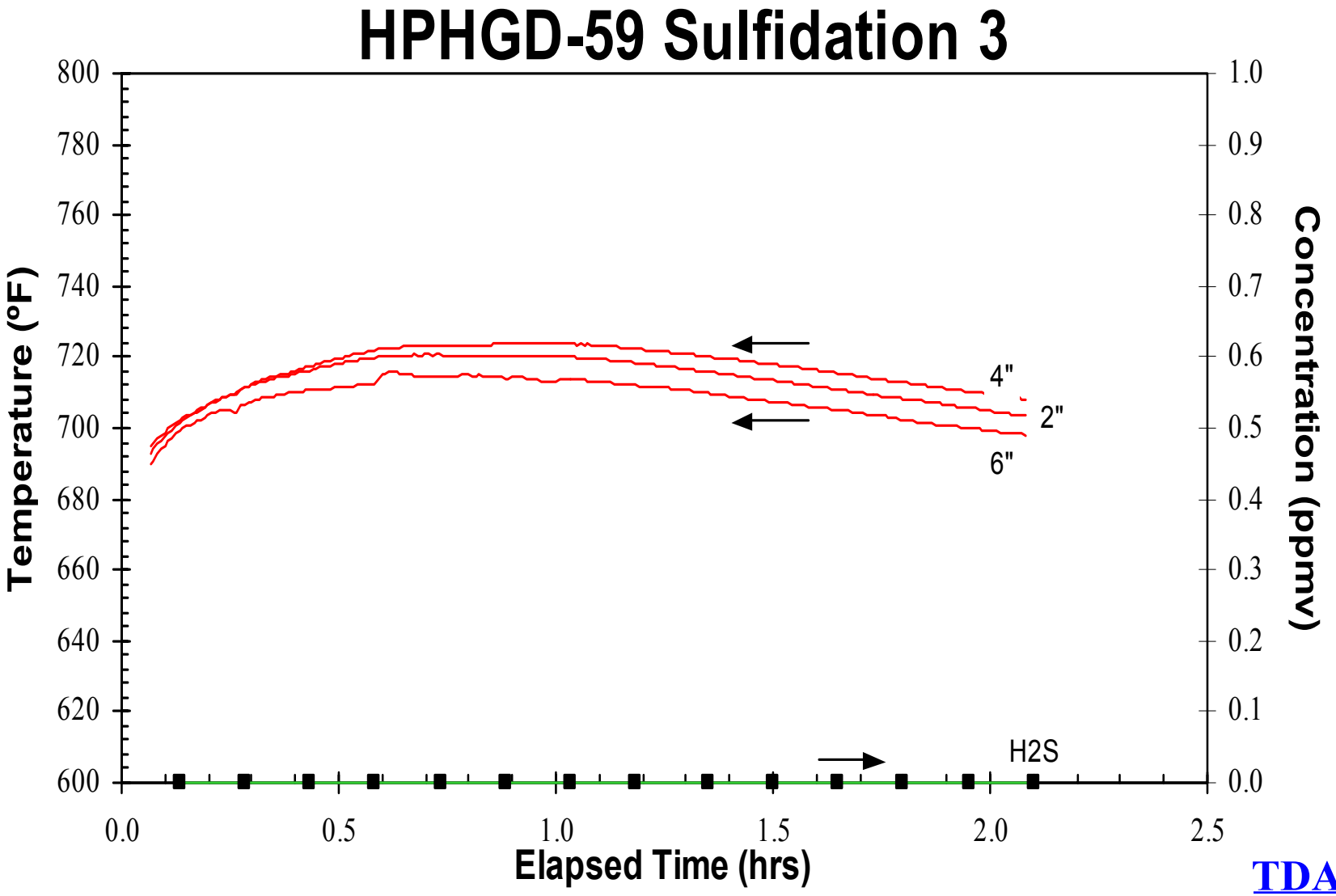
Low Temperature Absorption at 700ºF at FETC



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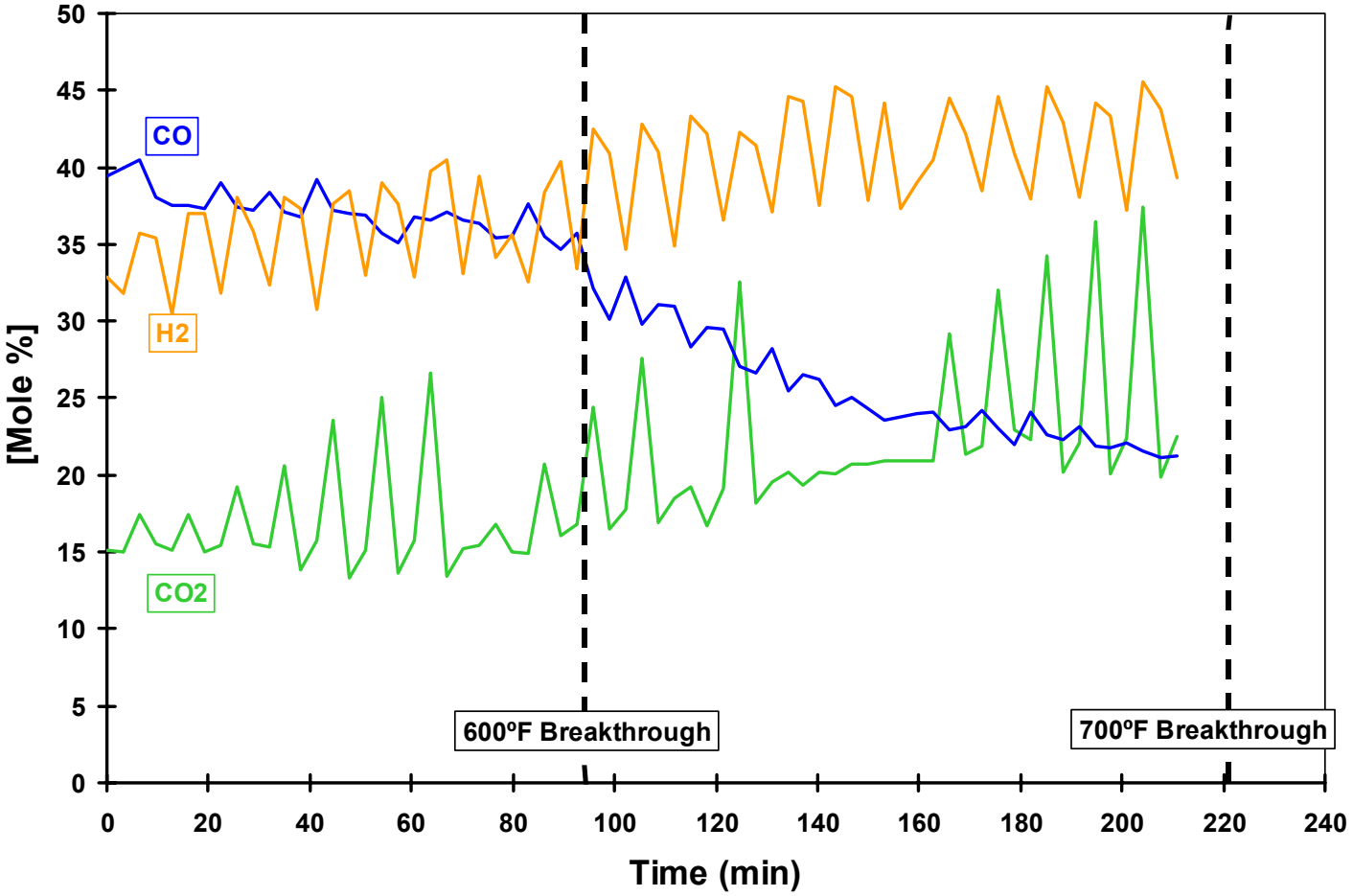
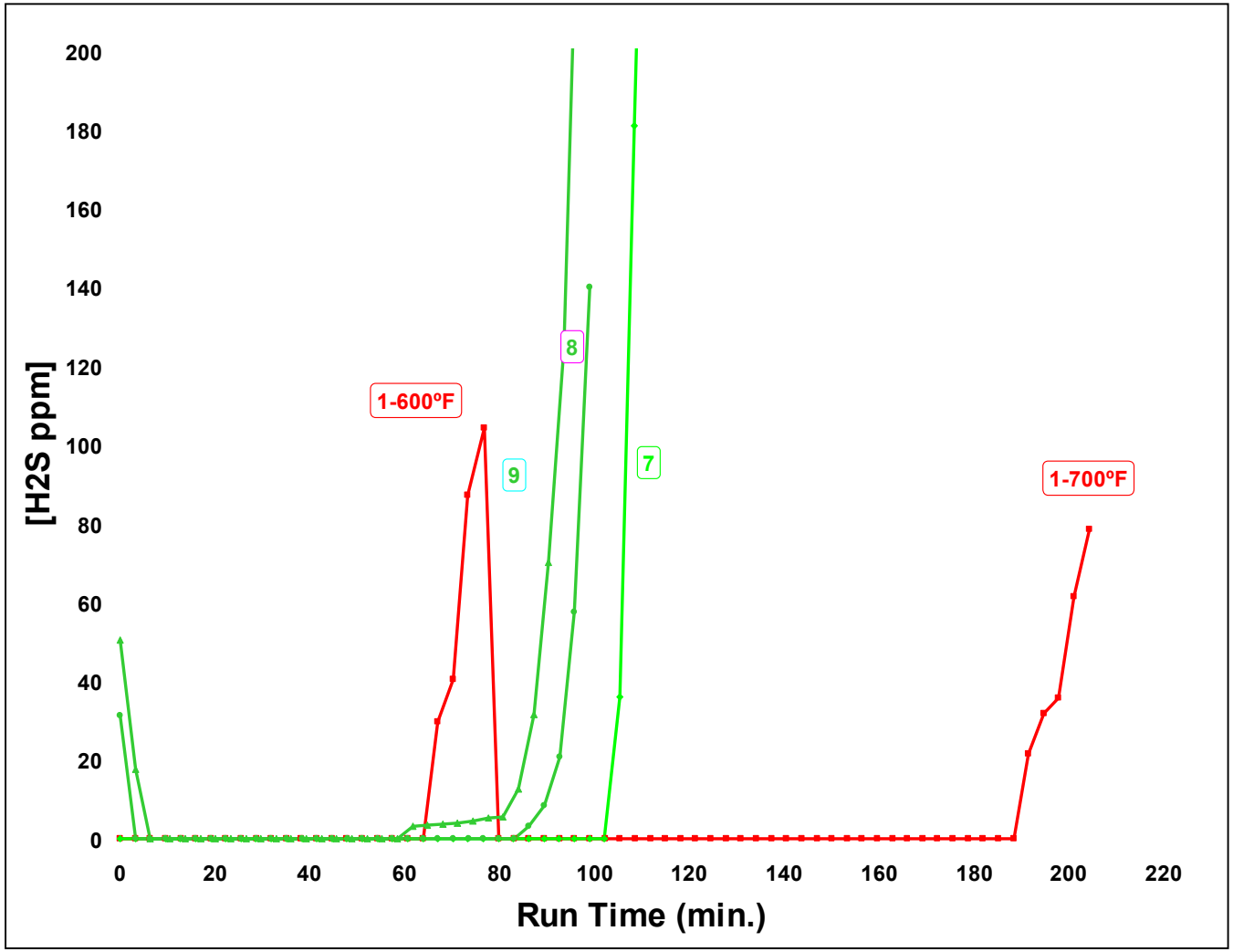
Dry Exit Gas Composition
600-700°F Sulfidation



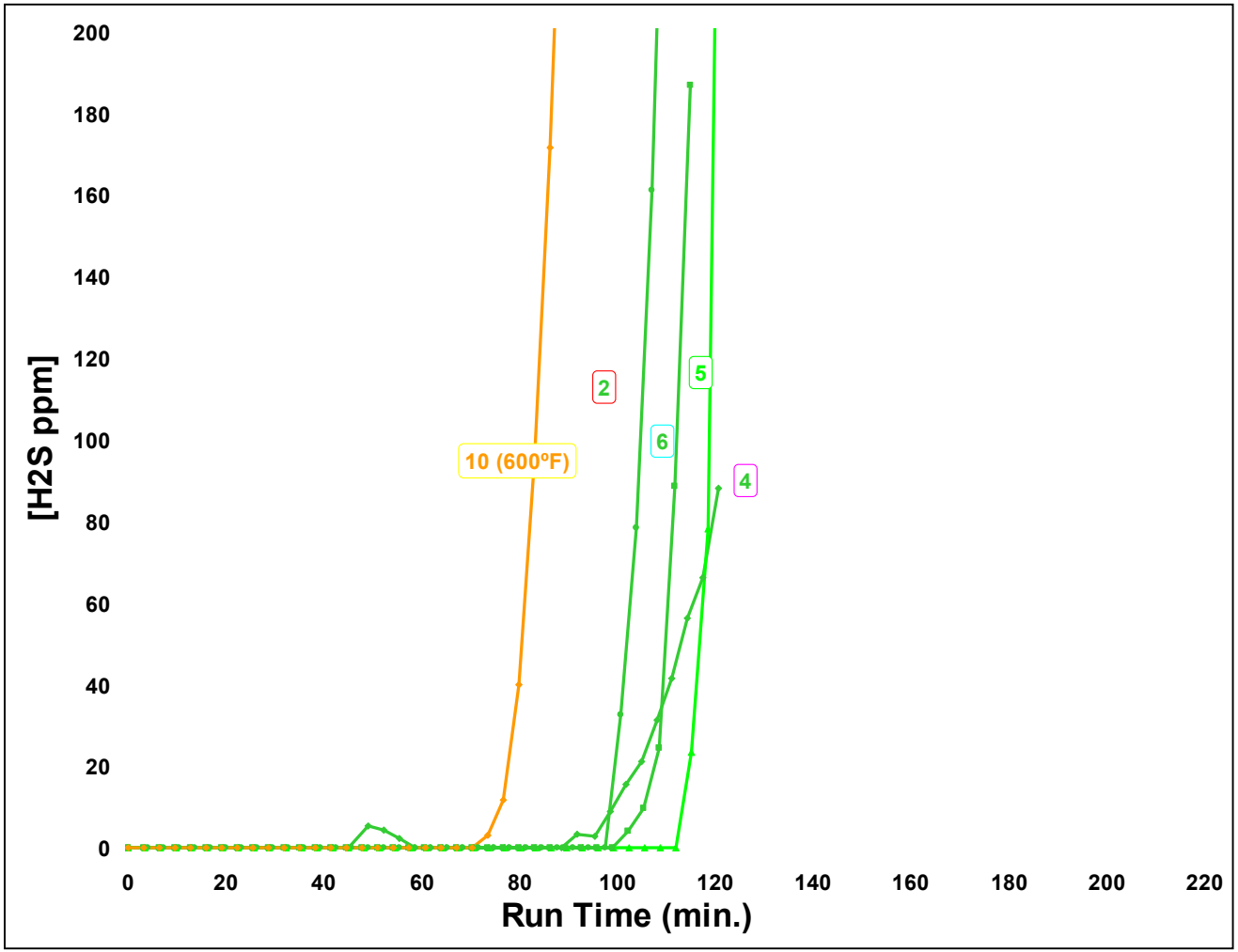
TDA Research

Low Temperature Breakthroughs at 650°F at TDA (17.5-19.5% H_2O)



TDA Research

Low Temperature Breakthroughs at 650ºF at TDA ($10.0-12.0\%\ H_2O$)



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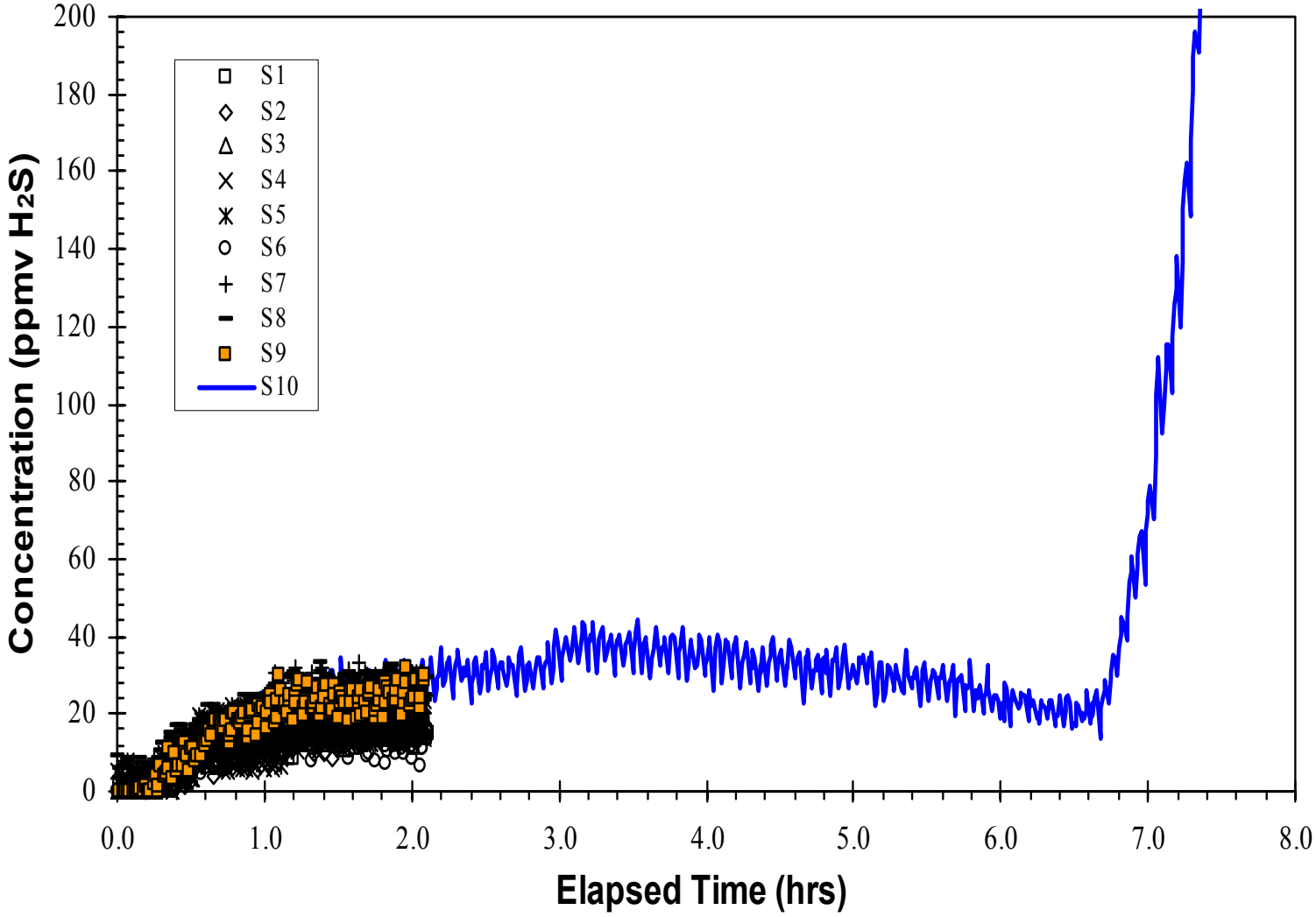
Breakthroughs at FETC at 900ºF (482ºC)



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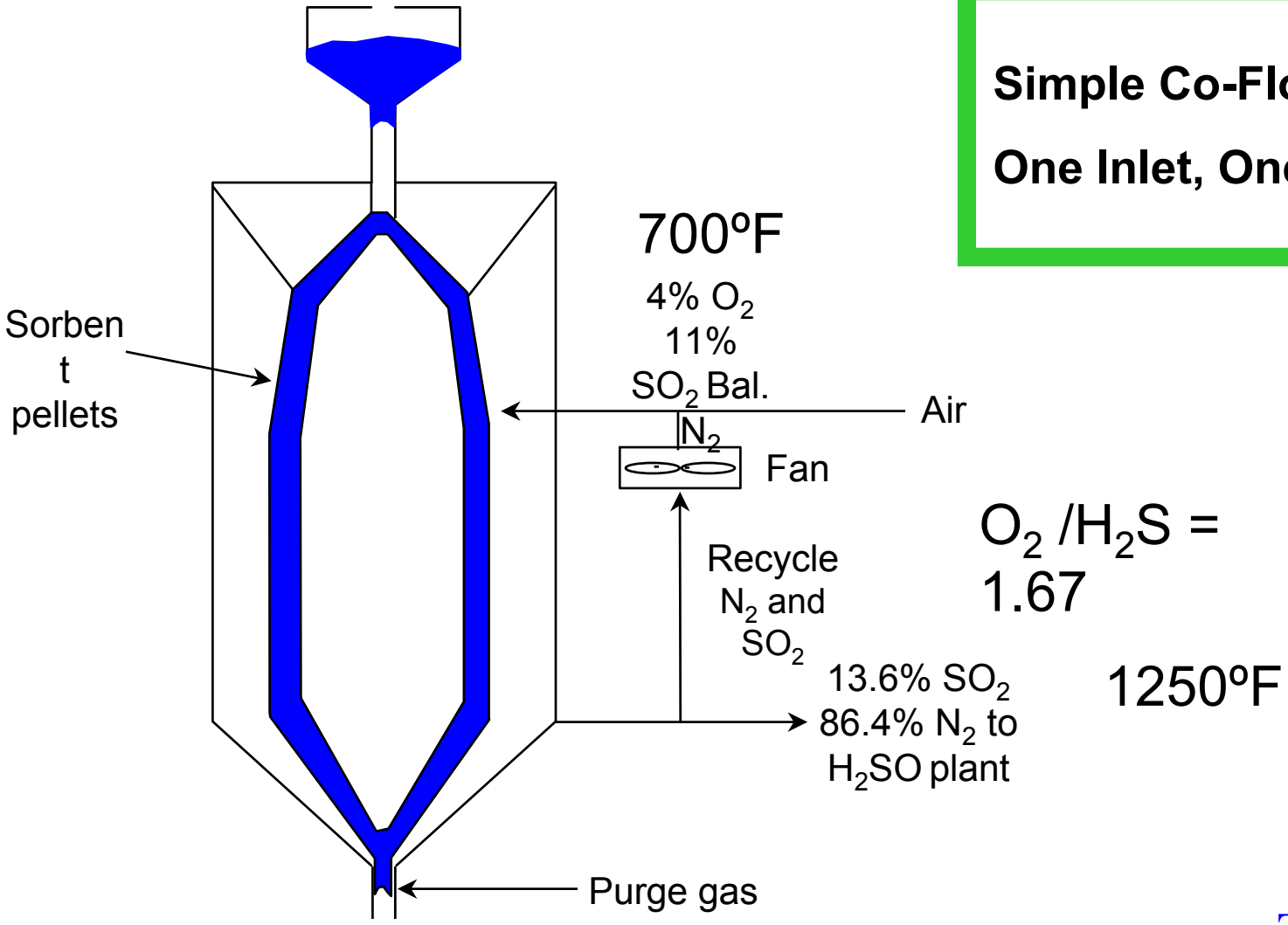
Regeneration of TNT-MB



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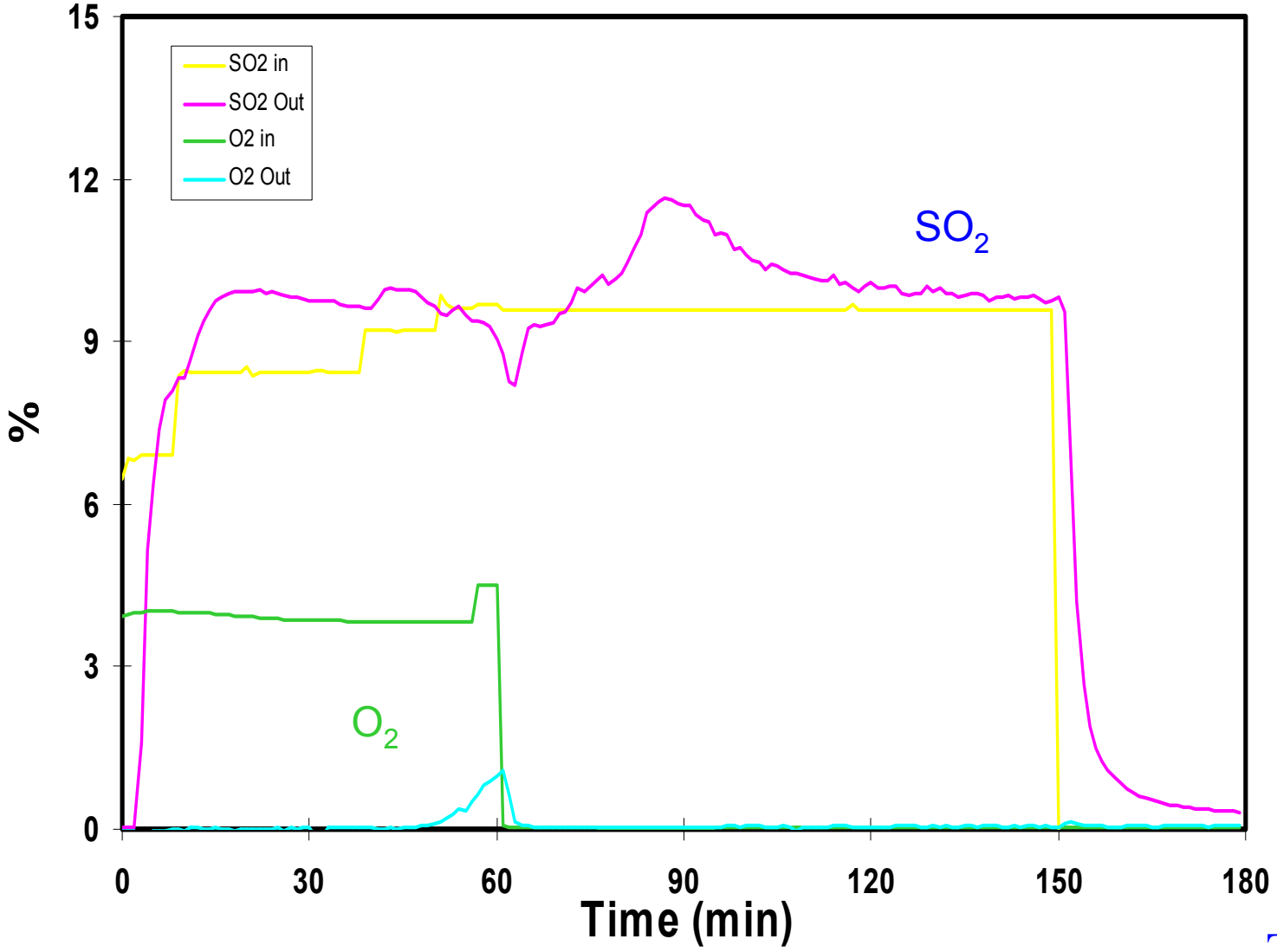
Regeneration at IGT, 5 atm
8-10% Inlet SO_2



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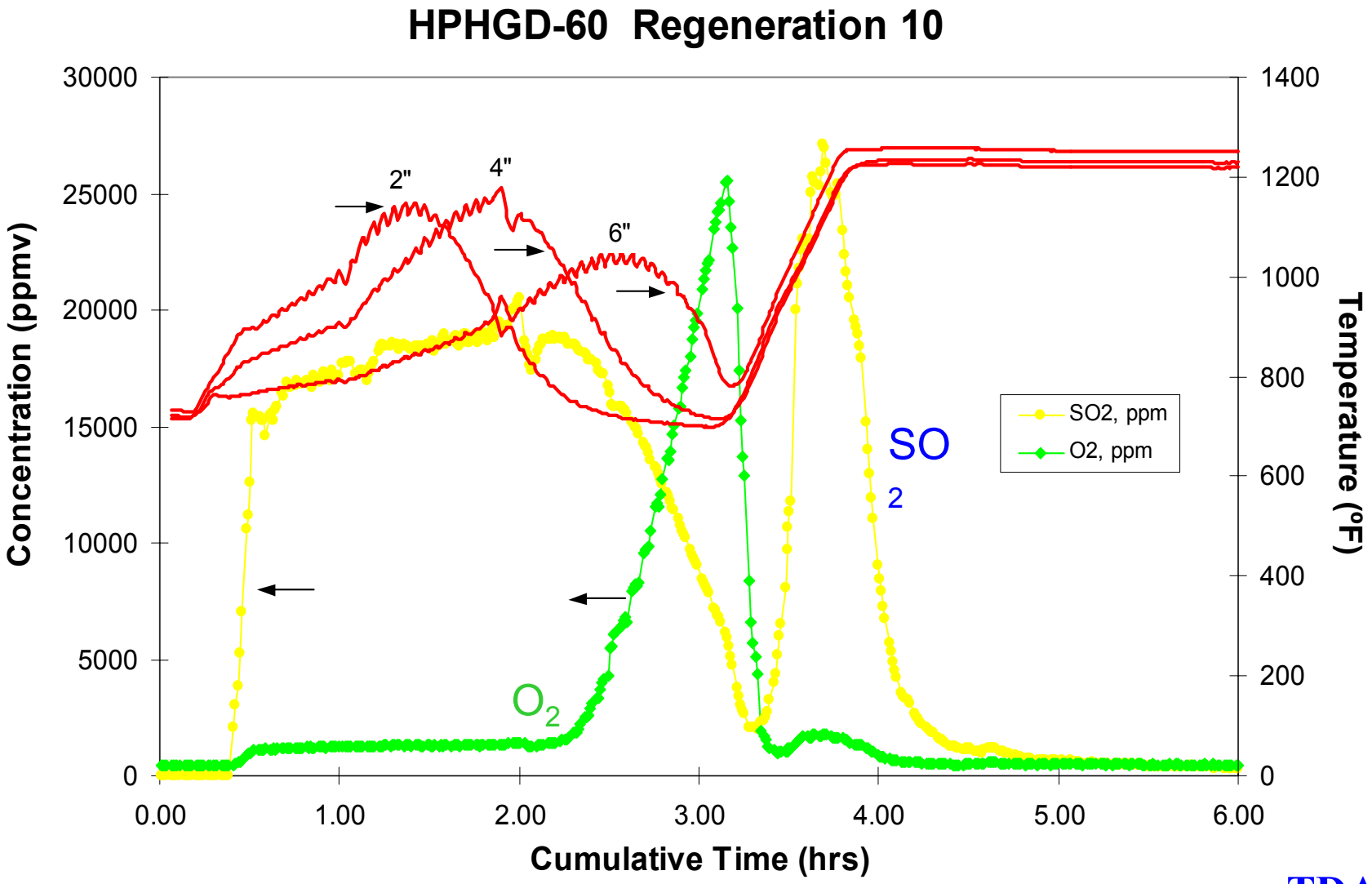
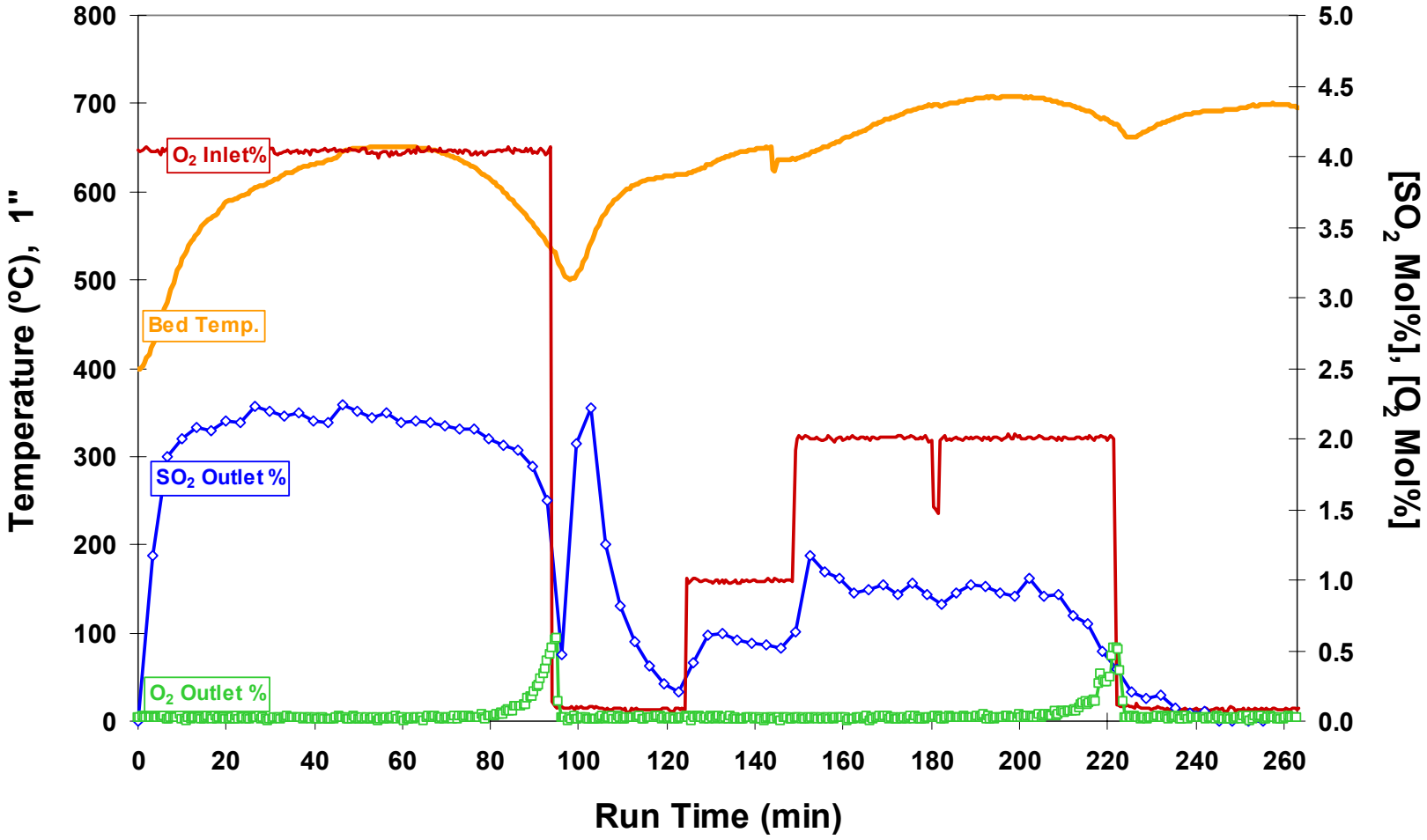
Regeneration at FETC, No Inlet SO_2



TDA Research

Regeneration at TDA, No Inlet SO_2



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Properties of Norton Produced TNT-MB Sorbent (114) 10-Cycle CRADA at FETC

Property	Fresh	4th Reg	5th Abs	10th Abs	10th Reg
Sulfur (wt%)	0.44	2.0	16.8	14.4	2.8
ASTM Attrition (wt.%)	1.8	1.3	1.1	NA	0.87 inlet 0.64 outlet
Sulfate Sulfur (wt%)	0.42	0.30	NA	0.07	0.27
Carbon (wt%)	NA	< 0.05*	0.05	< 0.5*	NA

900 ºF Sulfidations

4th Regeneration with 10% SO_2 at 2 - 3 ATM at TDA

5th Absorption at 20 ATM at TDA

10th Cycle at FETC: NO SO_2 in the inlet during regeneration.

*** Limit of Detection**

TDA Research

Properties of Norton Produced TNT-MB Sorbent (298)
10-Cycle Low Temperature Testing at TDA

	Attrition wt%	Crush Strength lbs.	Surface Area m^2/g	Porosity g/cc	Median Pore Diameter μm	Bulk Density lbs/ft^2	Sulfur wt%	Carbon wt%
As Sintered (TDA)	2.22	31.3	2.55	.2395	.3084	1.35		
As Sintered (Norton)	1.90	31.0	2.76	.2420	.3290	na		
10A - Inlet	1.99	33.4	2.30	.2309	.3093	1.48		
10A-Outlet	1.99	29.9	3.63	.1643	.3544	1.44		
10R - Inlet	1.63	30.4	2.55	.2175	.3296	1.38		
10R - Outlet	1.50	33.3	2.53	.2262	.3184	1.38		

600ºF - 700 ºF Sulfidations at TDA, No SO_2 in Regenerations

*** Limit of Detection**

TDA Research

Closure

- **TNT-MB is a NON-SPALLING Zinc Ferrite Sorbent**
- **TNT-MB Reduces Regenerator Size & Complexity**
  - Only one inlet
  - Half the current TECo regenerator used
  - Very high sulfur loadings make reduced sorbent circulation and/or reactor sizes possible in future moving beds
- **The Sorbent Retains Its Activity for Multiple Cycles**
  - 600ºF: > 1 hour breakthrough
  - 700ºF: > 3 hour breakthrough
  - 900ºF: > 7 hour breakthrough
- **Attrition Resistance Improves with Cycling**

Acknowledgments

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