MERCURY CONTROL TECHNOLOGIES FOR ELECTRIC UTILITIES BURNING LIGNITE COAL

Mercury Control Technology
R&D Program Review Meeting
August 12–23, 2003
National Energy Technology Laboratory
Pittsburgh, PA

John H. Pavlish
University of North Dakota
Energy & Environmental Research Center

EERC
Energy & Environmental Research Center

Project Goals

Develop, Test, and Demonstrate Sorbent-Based Technologies for Electric Utilities Burning Lignite Coal

- Increase the scientific understanding of mercury–flue gas interactions leading to more effective design of sorbents
- Test a range of sorbent-based technology options
- Determine and demonstrate optimum conditions for Hg capture using sorbents
- Field-demonstrate sorbent-based technology to prove and quantify effectiveness, performance, and cost

Approach

Phase I Bench-/Pilot-Scale Testing

- Lignite flue gas characterizations
- Bench-scale sorbent screening tests
- Pilot-scale control technology screening tests
- By-product analyses

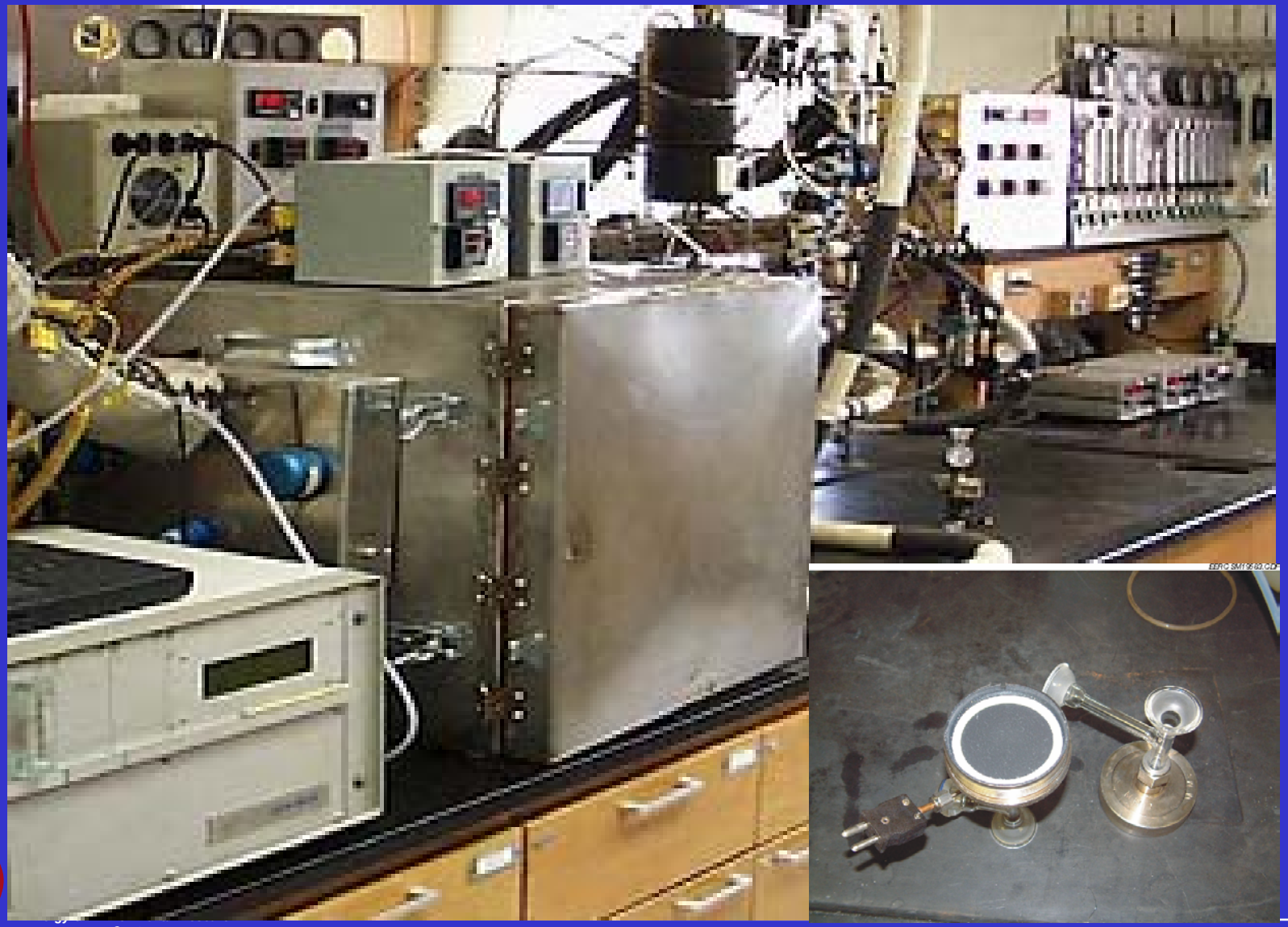
Phase II Full-Scale Testing/Demonstration

- Field demonstration
  - Select sorbent and technology option
  - Prepare site and install technology hardware
  - Evaluate sorbent effectiveness and impacts
  - Evaluate impact of design and process variables
  - Perform by-product analyses
  - Quantify effectiveness and cost

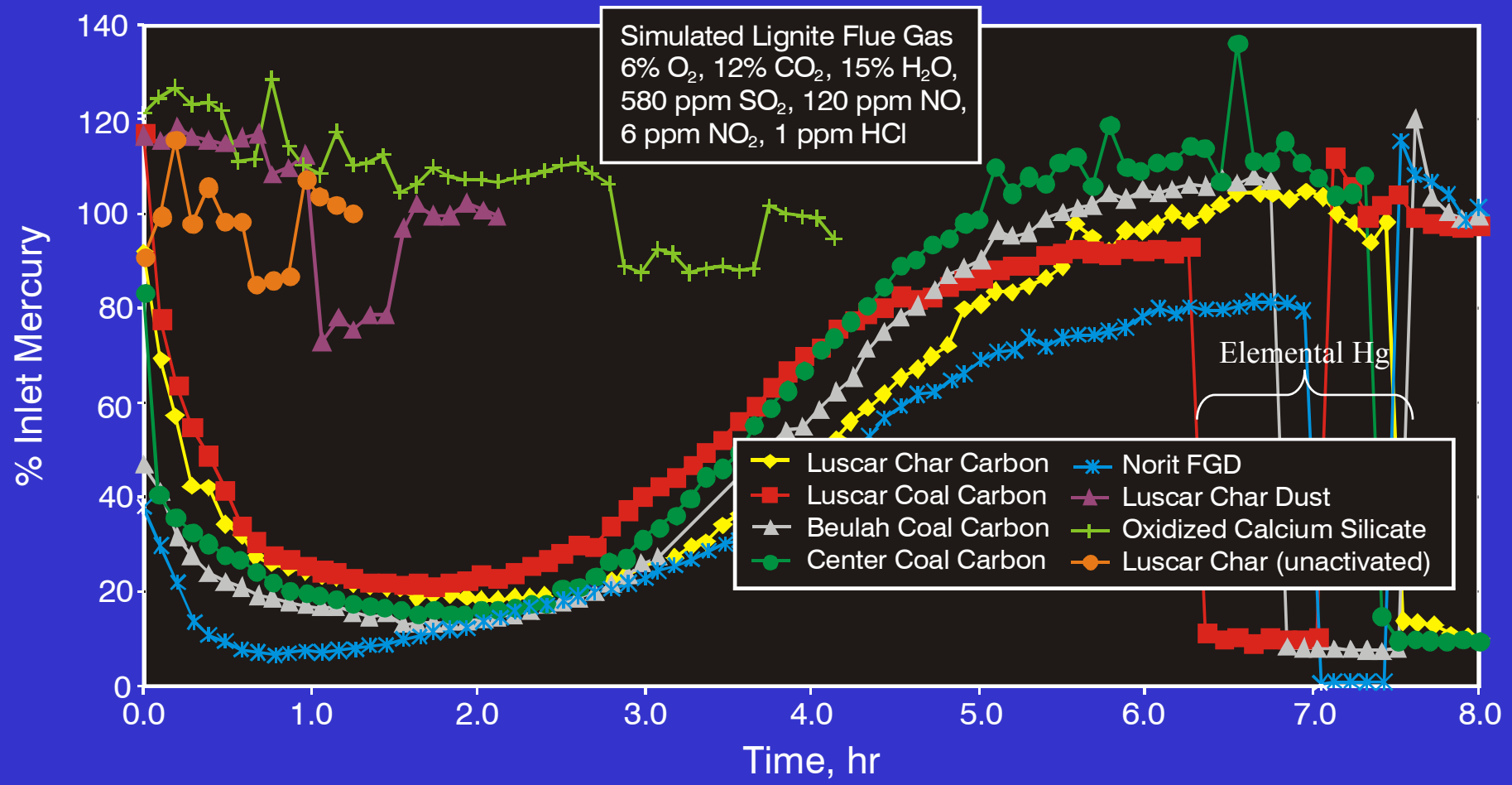
Bench-Scale Testing, Sorbents Tested

- Activated carbons were prepared from the following coals and chars:
  - Luscar coal
  - Luscar coal char
  - Center coal
  - Beulah–Zap coal
- Eight different sorbents were tested and screened under different test conditions.

EERC Mercury Bench-Scale System

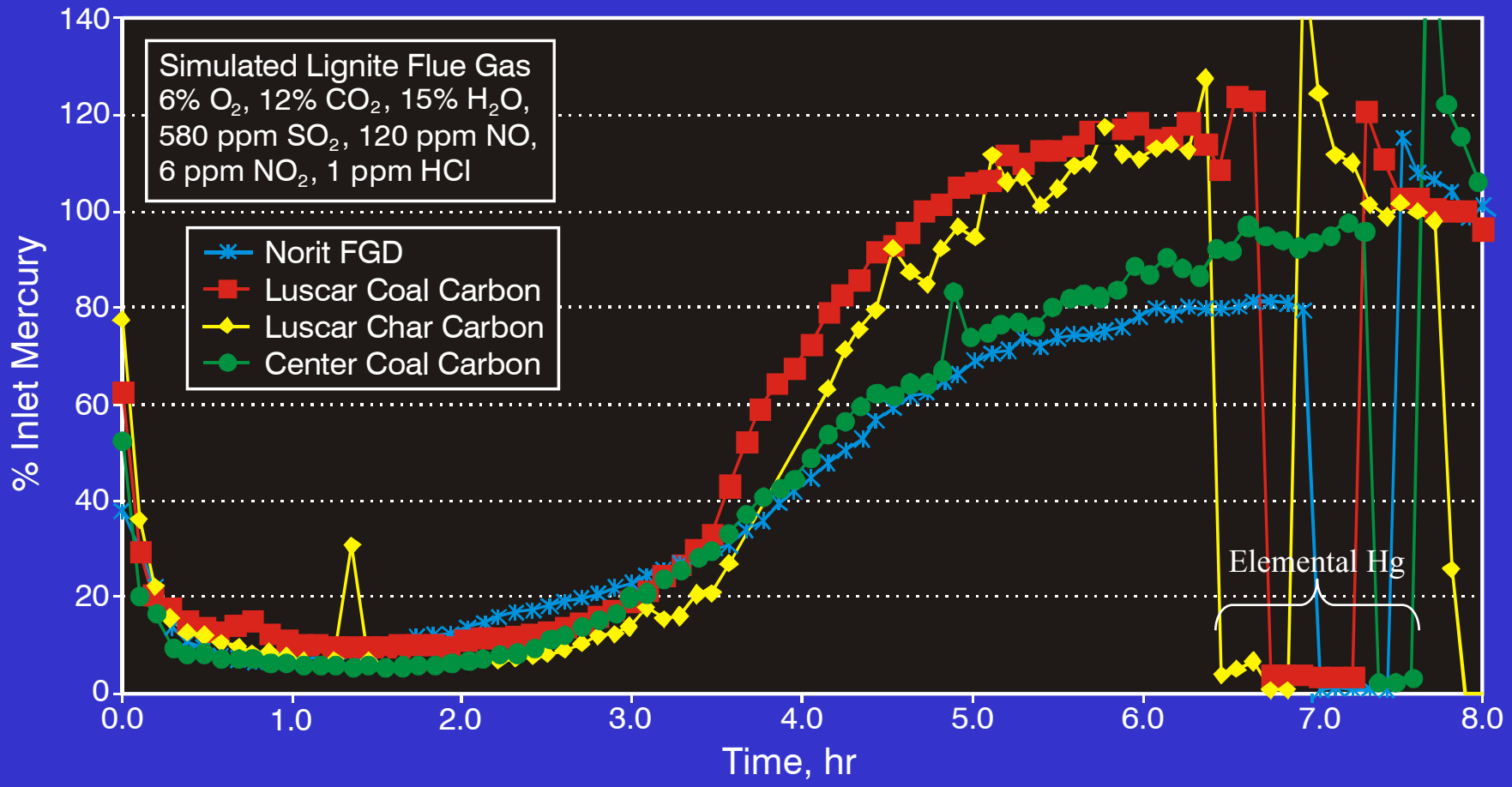


Bench-Scale, Fixed-Bed Tests (carbons activated at T1)



EERC
Energy & Environmental Research Center

Bench-Scale, Fixed-Bed Tests (carbons activated at T2)



Pilot-Scale (PTC) Testing

Pilot-Scale Test Parameters

- Coal
  - Poplar River (C1)
  - Freedom (C2)
- Sorbent type
  - Luscar char-derived (S1)
  - Norit FGD (S2)
- Sorbent loading
  - 0 to 25 lb/million acf
- Sorbent size
  - Fine ~ 5 micron
  - As-received, 15–20 micron
- Temperature
  - 300° and 400°F
- Bag material
  - GORE
  - Ryton
- Gas flow
  - Air-to-Cloth, 6 and 12
- Particulate control configuration
  - ESP only
  - ESP followed by fabric filter
  - Fabric filter only
  - *ADVANCED HYBRID*™ Filter

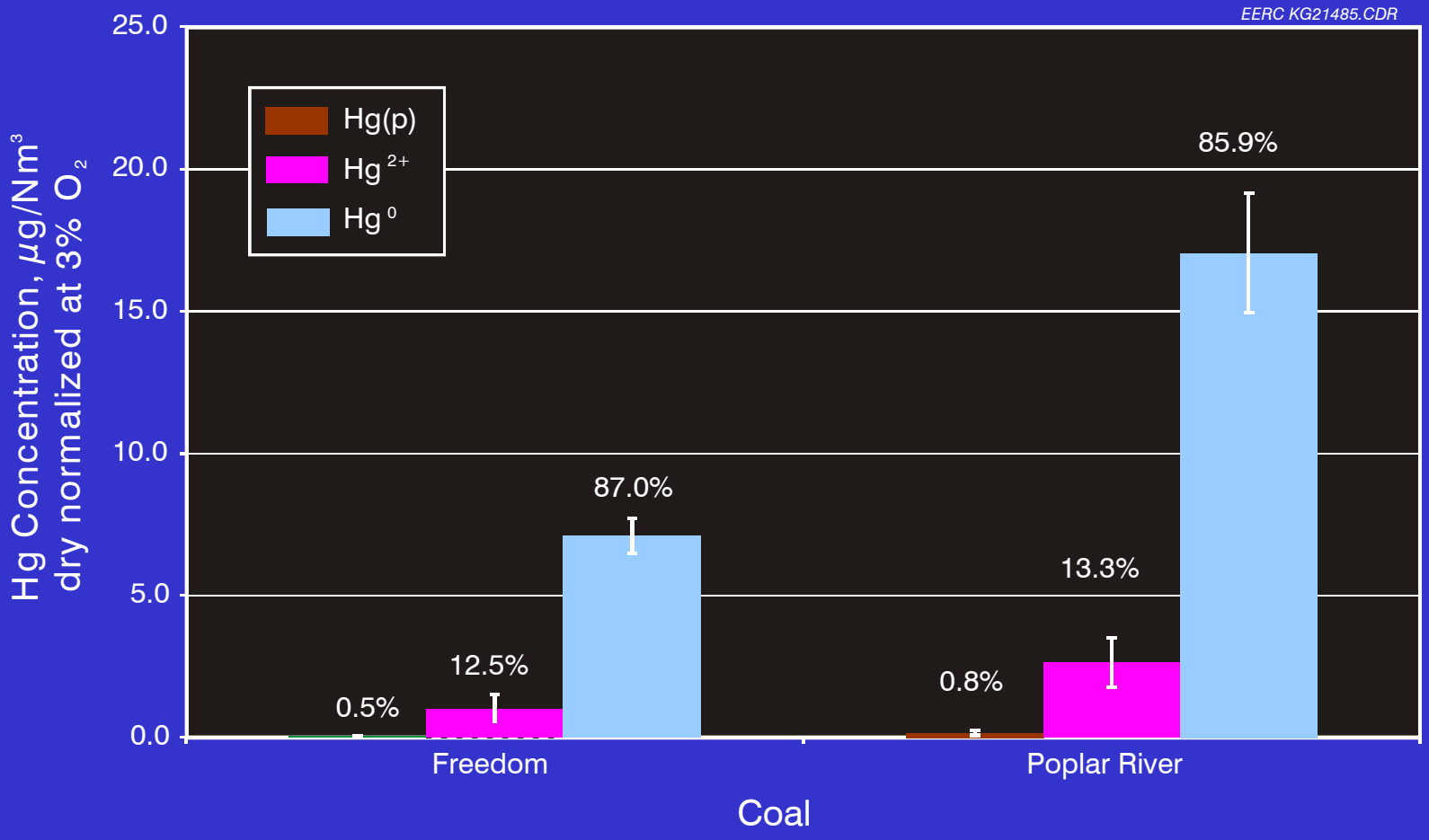
Performed over 60 tests

Characteristics of Test Coals, Moisture-Free Basis

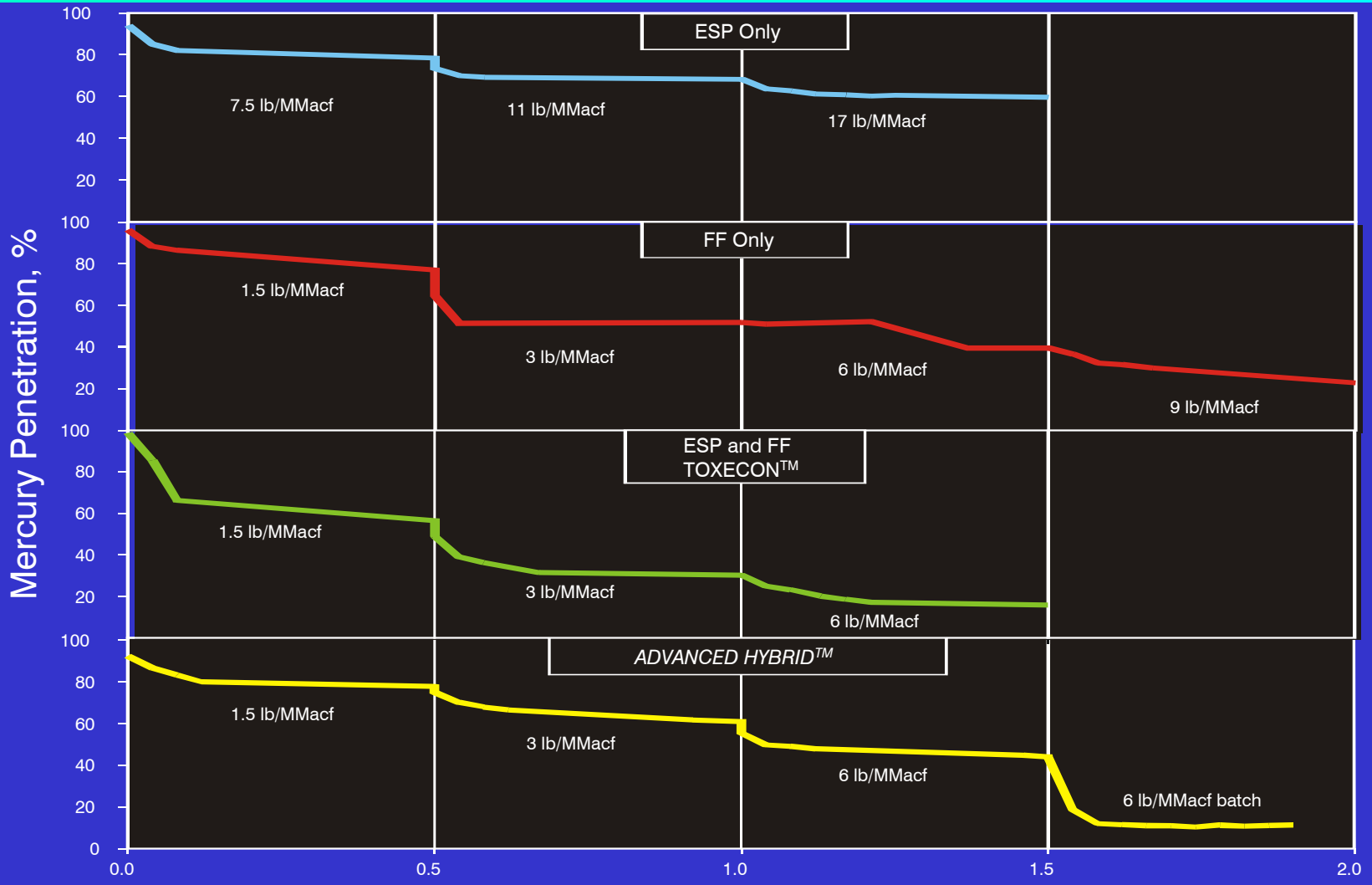
	Poplar River Coal							Freedom Coal		
	Moist. Free	Moist. Free	Moist. Free	Moist. Free	Moist. Free	Moist. Free	Average	Moist. Free	Moist. Free	Average
Proximate Analysis, %	6/7/2002	T 1	T 4	T12	T20	7/8/2002		6/7/2002	7/19/2002	
Moisture	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Matter	45.08	45.81	46.43	45.74	46.95	45.93	45.99	44.48	46.47	45.48
Fixed Carbon	34.49	33.30	32.57	33.32	33.74	34.94	33.73	41.69	42.92	42.31
Ash	20.43	20.89	21.00	20.94	19.31	19.13	20.28	13.83	10.61	12.22
Ultimate Analysis, %										
Hydrogen	3.61	3.37	3.35	0.00	3.46	3.60	3.48	3.83	4.01	3.92
Cabon	53.22	52.06	52.47	0.00	52.62	53.63	52.80	59.74	61.08	60.41
Nitrogen	0.85	0.81	0.80	0.00	0.80	0.80	0.81	1.01	1.02	1.02
Sulfur	0.70	0.95	1.00	0.85	0.96	0.90	0.90	0.79	0.92	0.86
Oxygen (IND)	21.19	21.92	21.38	0.00	22.85	21.94	21.86	20.80	22.36	21.58
Ash	20.43	20.89	21.00	20.94	19.31	19.13	20.28	13.83	10.61	12.22
Heating Value (Btu/lb)										
Btu	8428	8493	8507	8673	8843	8732	8613	9702	10276	9989
Mercury ppm (dry)	0.117	0.171	0.165	0.160			0.153	0.062	0.093	0.077
Chlorine ppm (dry)	11		24		23	18	19	18	21	20

Pilot-Scale Test Results

Inlet Mercury Speciation

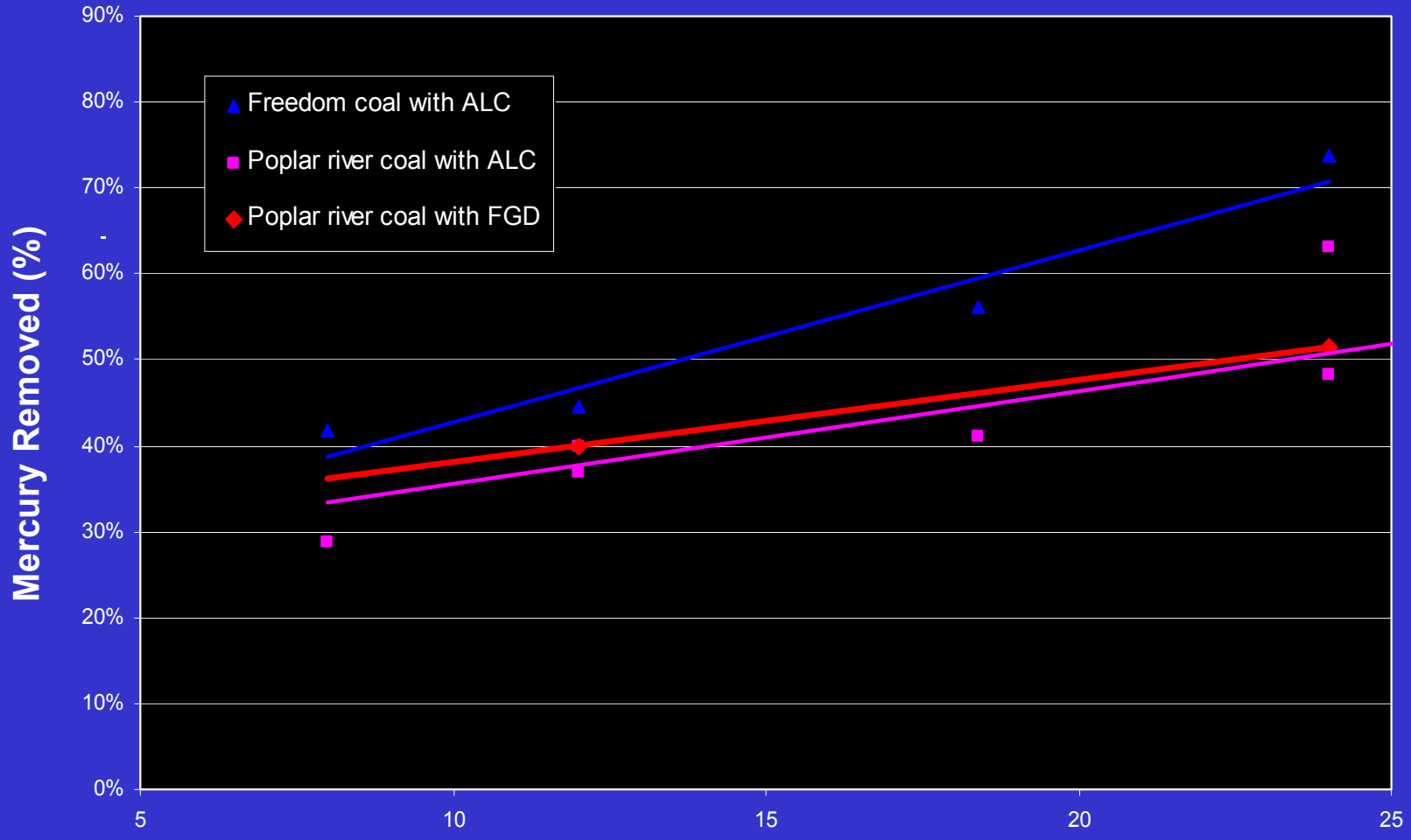


Sorbent Injection – Mercury Response Curves



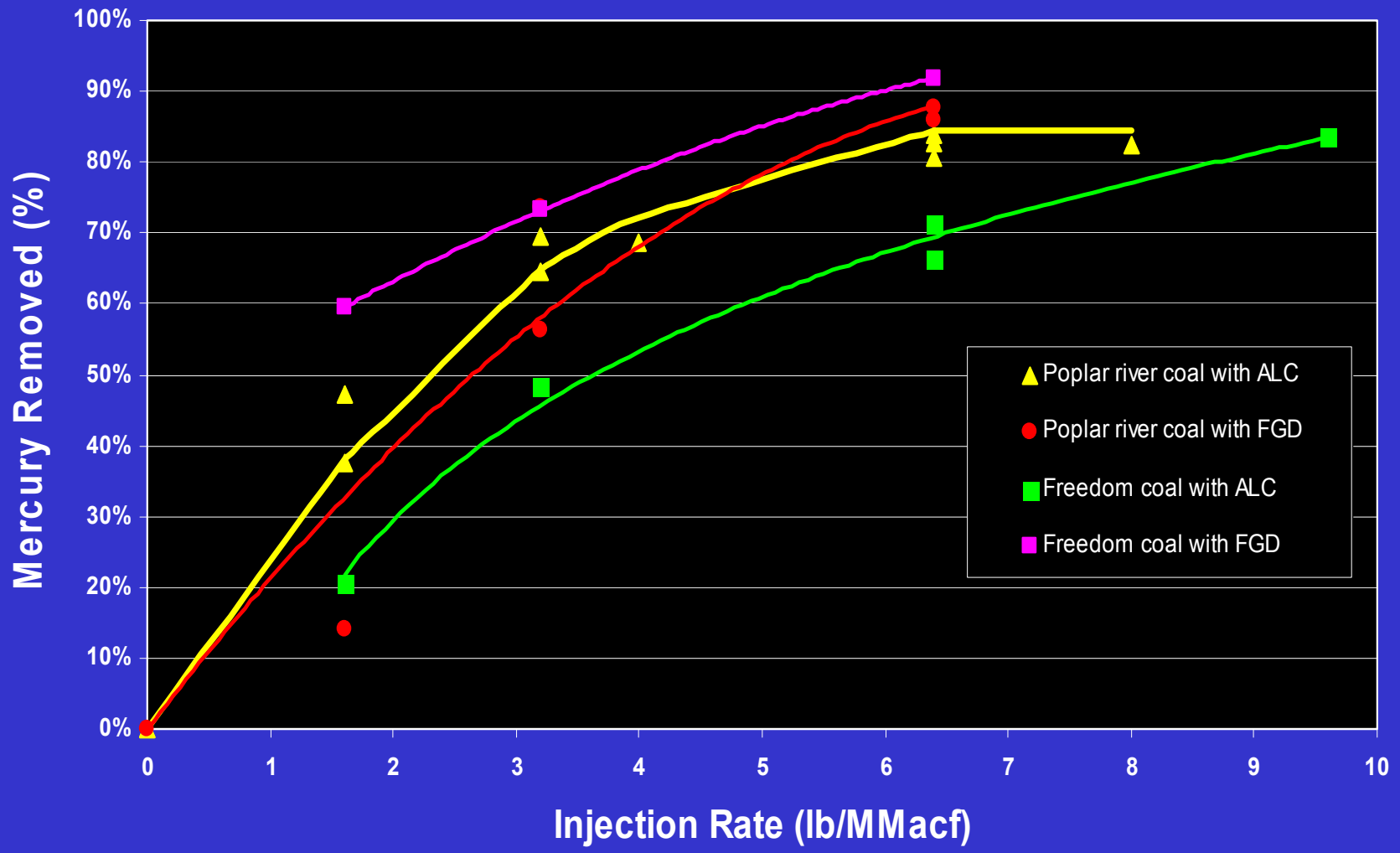
EERC
Energy & Environmental Research Center

ESP Only – Mercury Removal Efficiency for Poplar River and Freedom Coals with ALC and FGD, 300°F



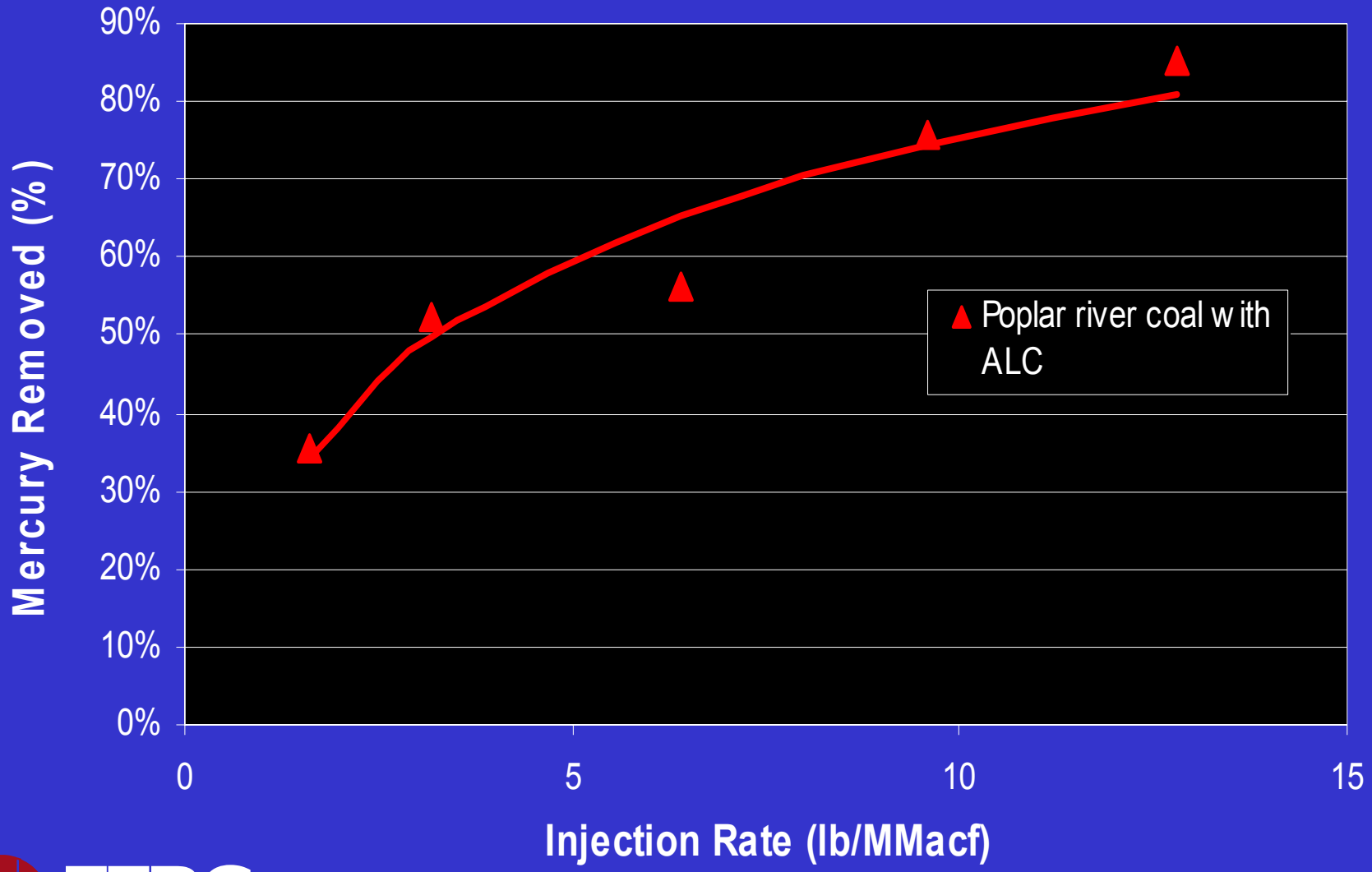
ALC: Activated Luscar Char
FGD: DARCO FGD (Norit)

ESP/FF – Mercury Removal Efficiency for Poplar River and Freedom Coals with ALC and FGD, 300°F

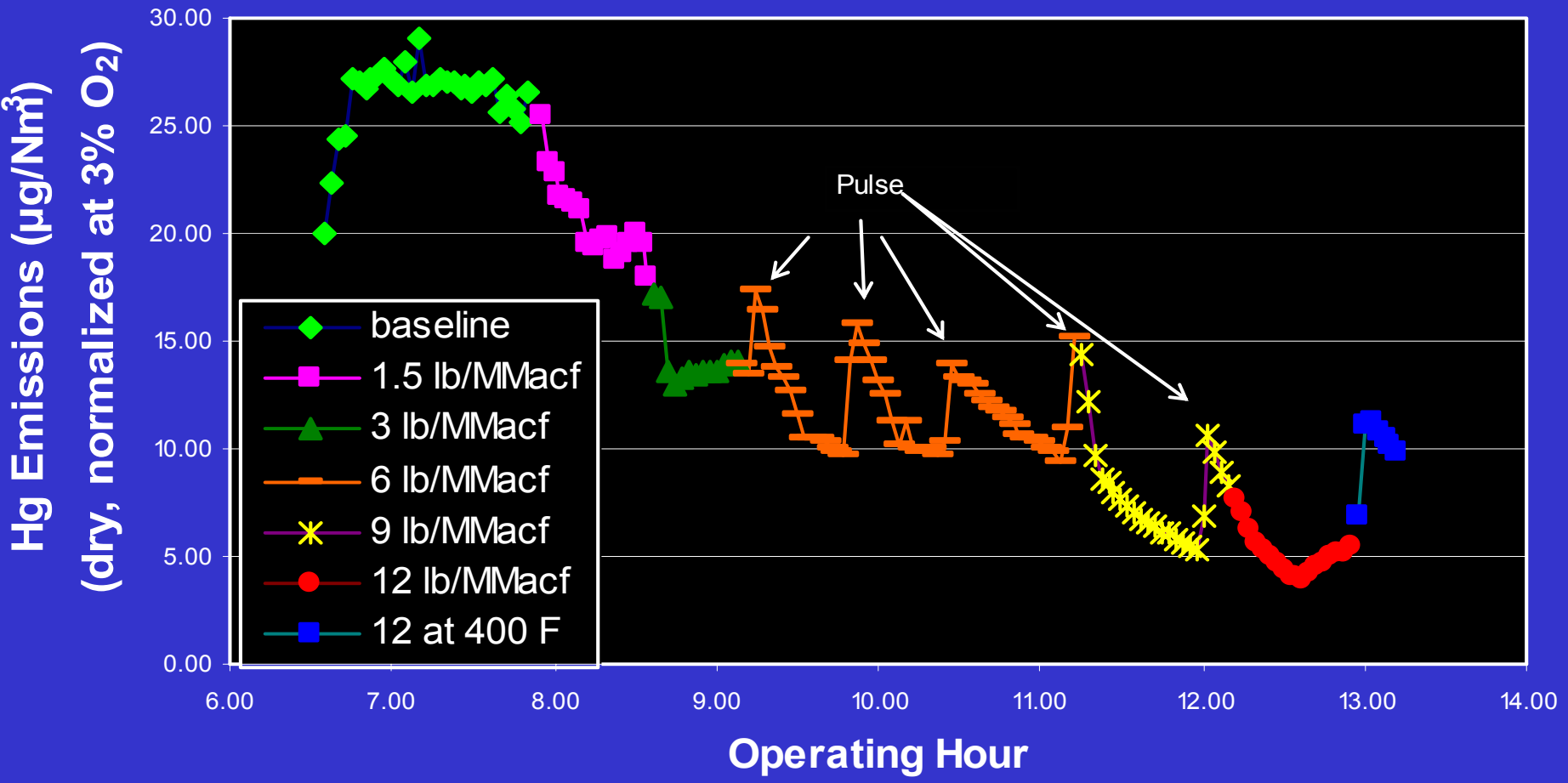


EERC
Energy & Environmental Research Center

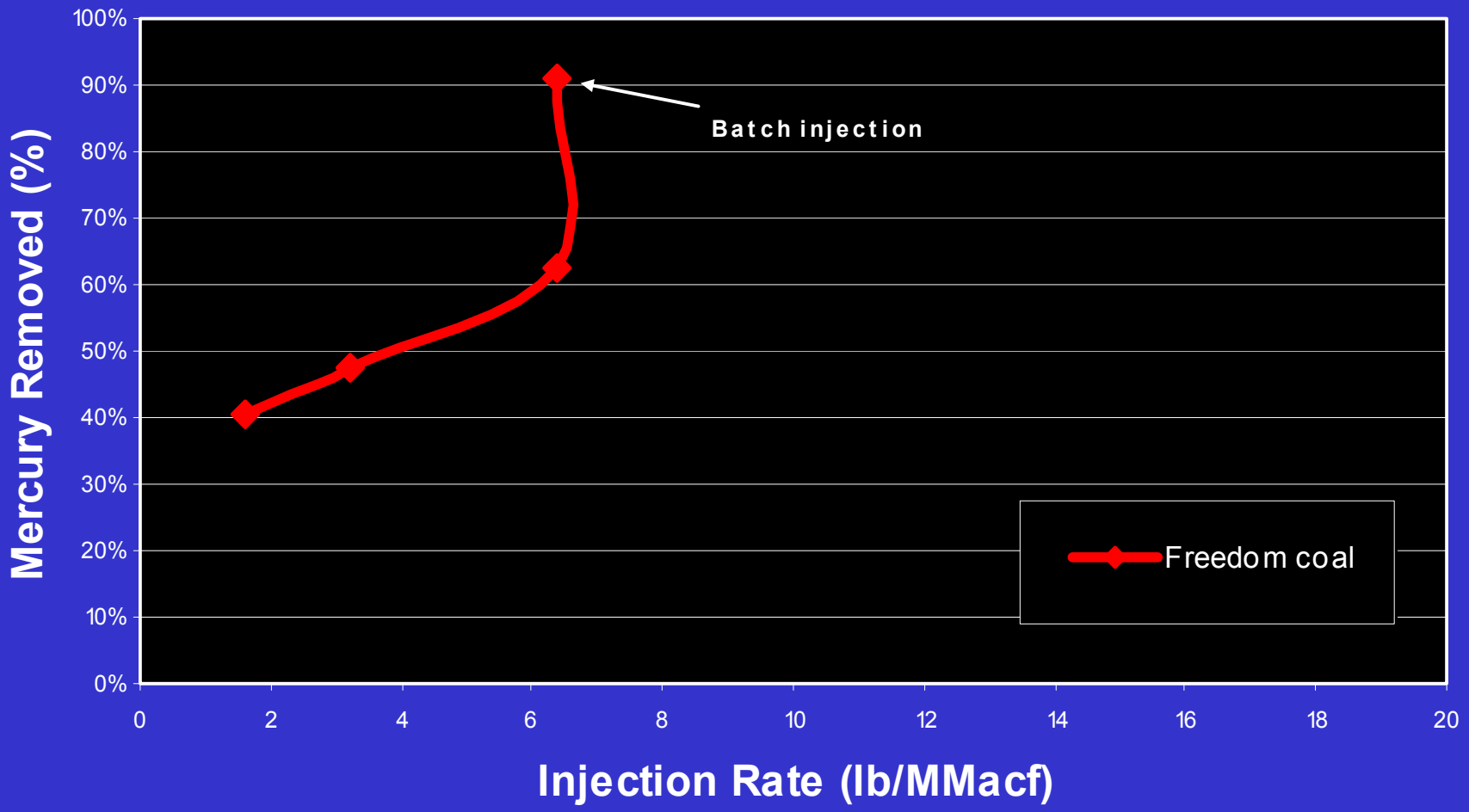
FF Only – Mercury Removal Efficiency for Poplar River Coal with ALC, 300°F



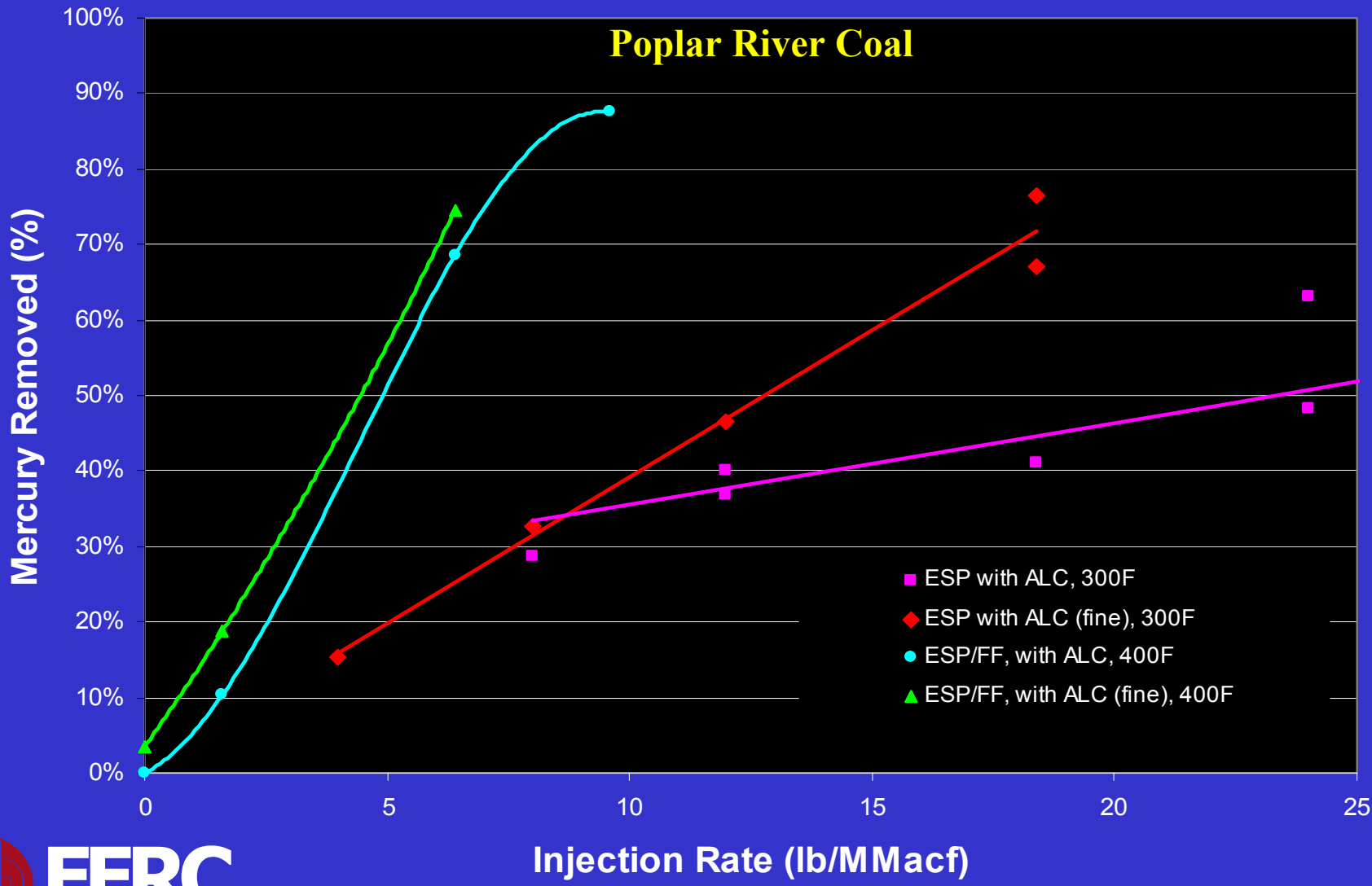
FF Only – Mercury Emission for Poplar River Coal with ALC, 300°F



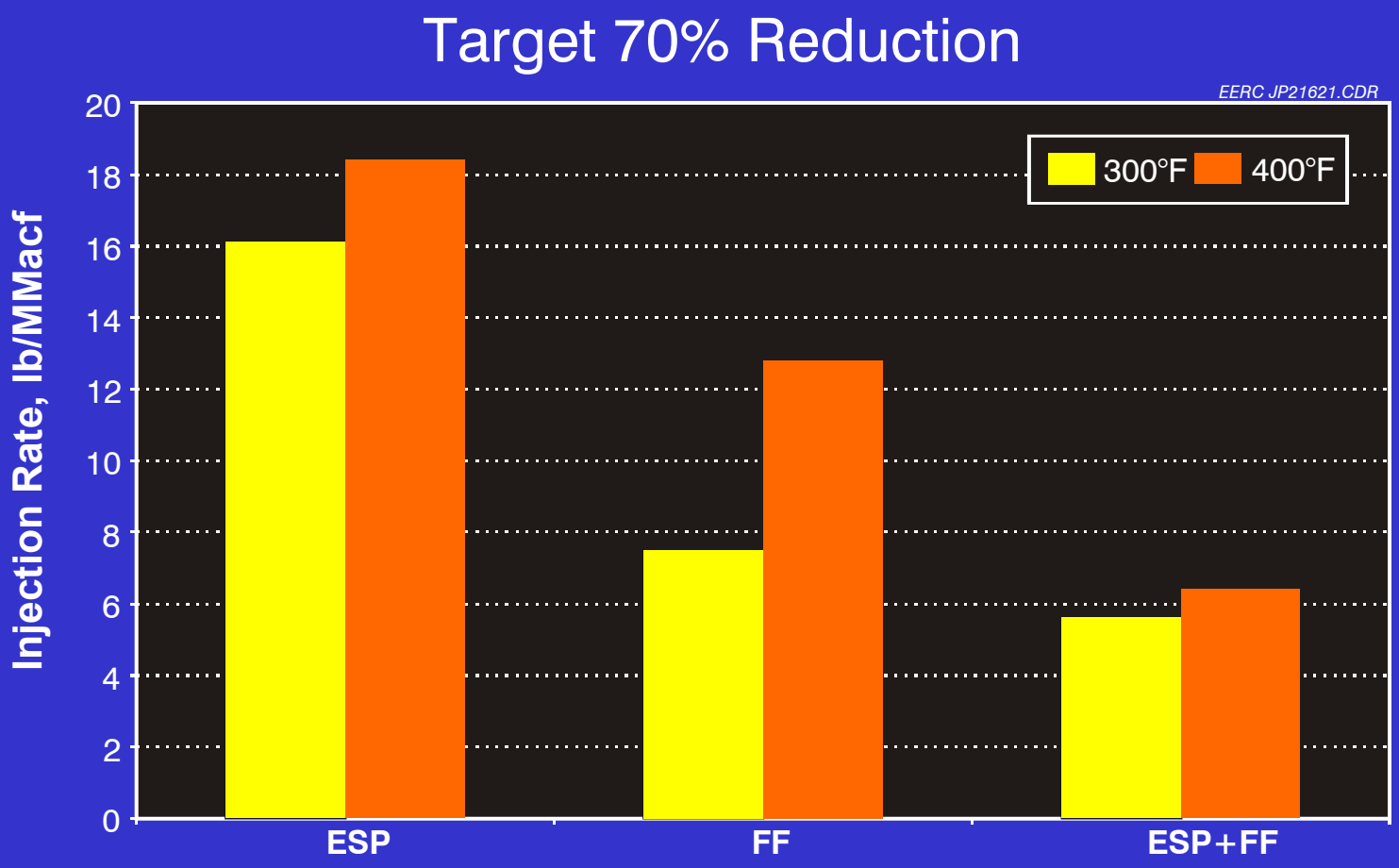
Advanced Hybrid™ – Mercury Removal Efficiency for Freedom Coal with ALC, 300°F



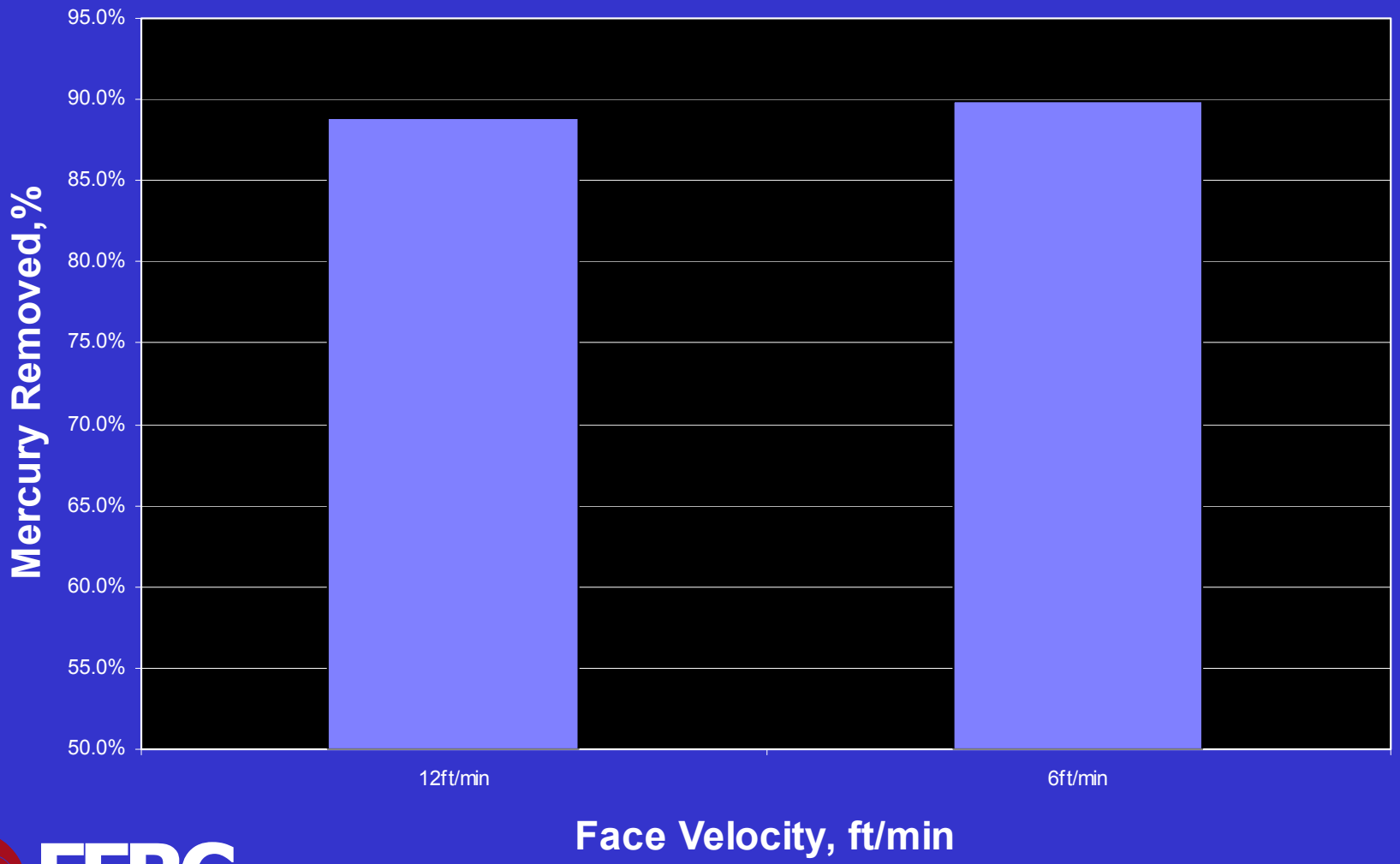
Effect of Sorbent Particle Size, As-received (~20µm) and Fine (~5µm)



Effect of Temperature

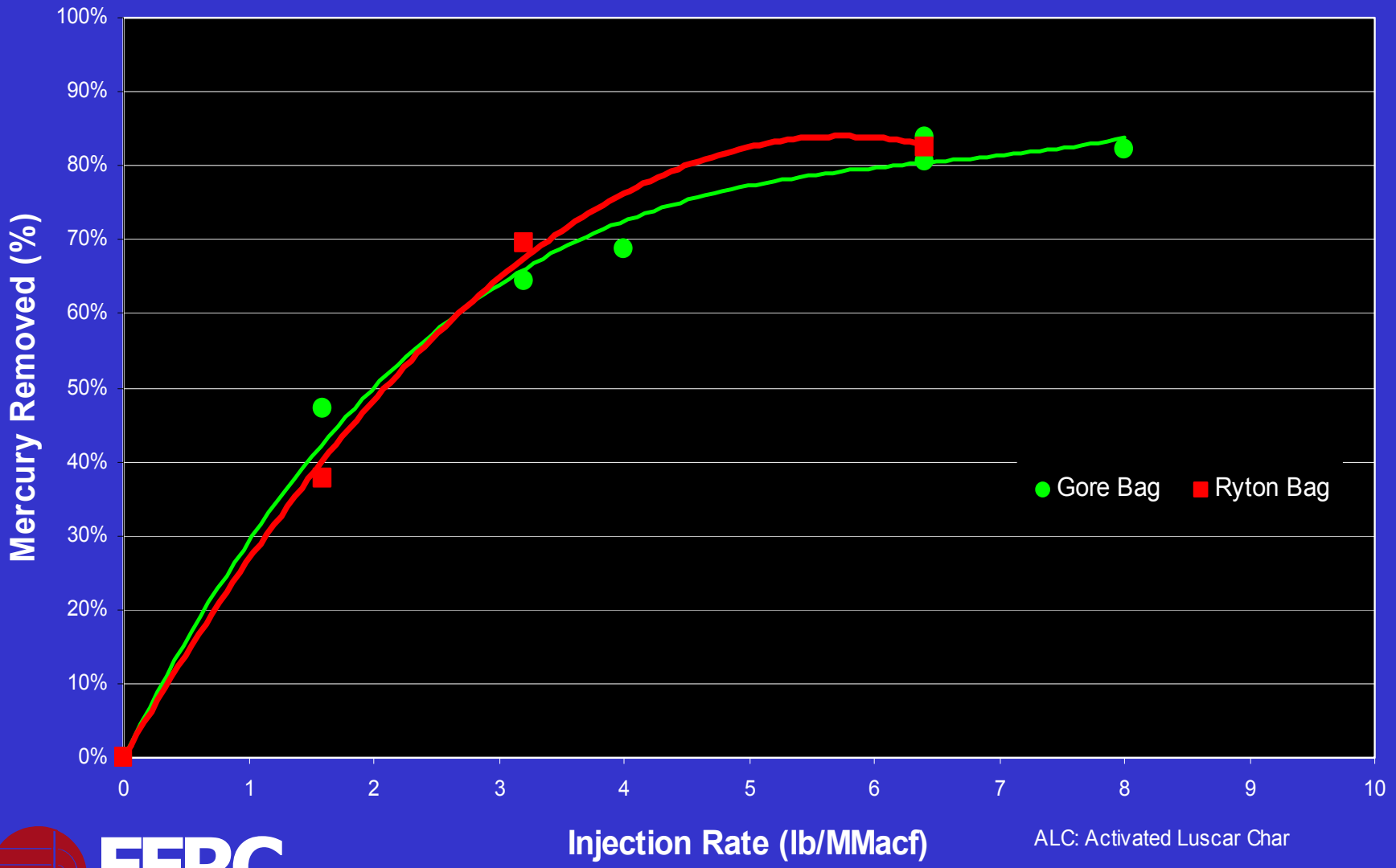


Effect of Gas Velocity, Poplar River Coal with ALC



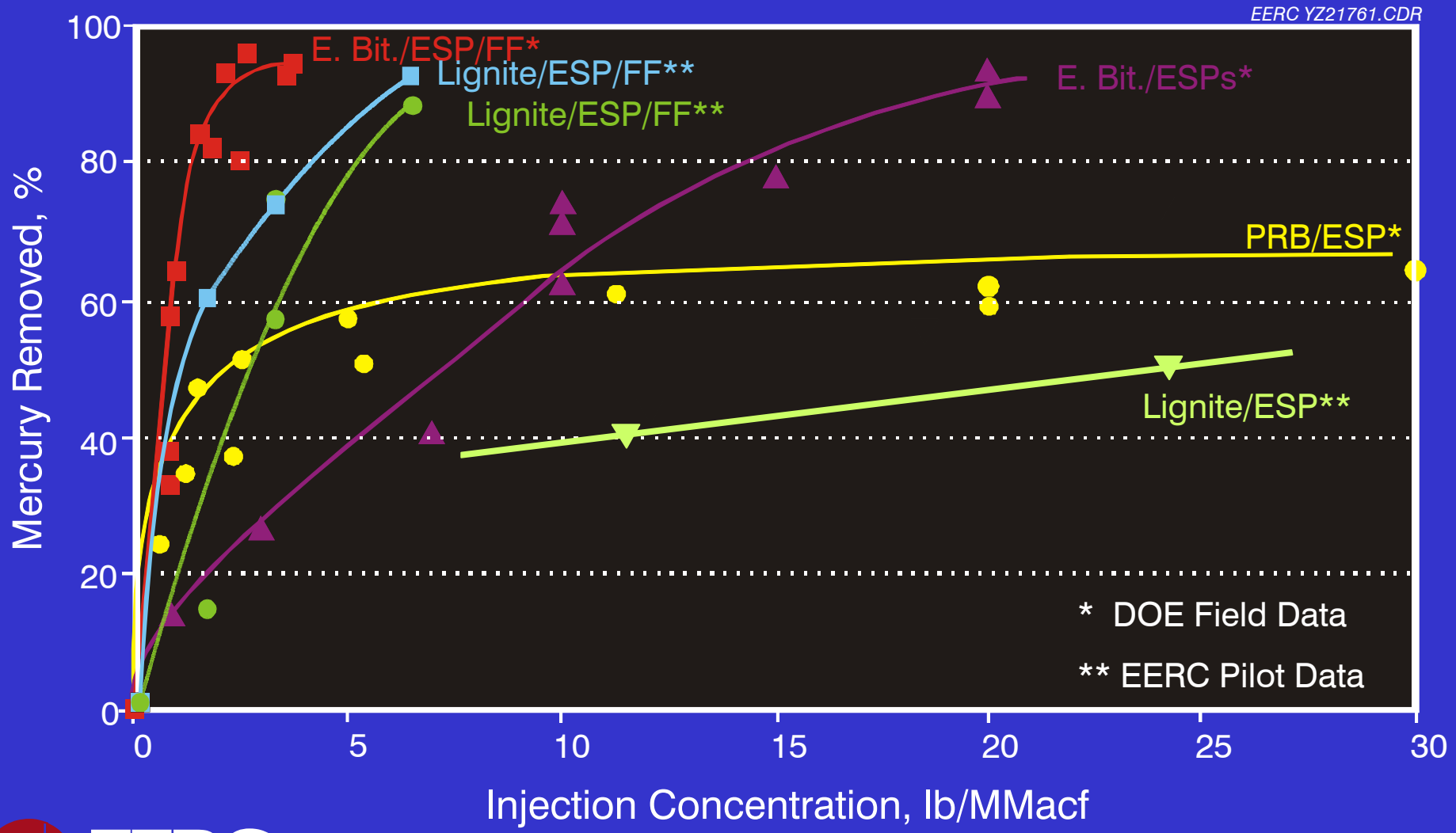
EERC
Energy & Environmental Research Center

Effect of Bag Material, Poplar River Coal with ALC



ALC: Activated Luscar Char

Mercury Removal Trends with Activated Carbon Injection



EERC
Energy & Environmental Research Center

Bench-Scale Conclusions

- Unactivated Luscar char and calcium silicate were ineffective in capturing or oxidizing mercury.
- Lignite-based carbons activated at 750°C required a 30- to 45-minute conditioning period in the simulated lignite flue gas before they exhibited good mercury capture.
- Lignite-based carbons activated at 800°C required a shorter, 15-minute conditioning period and captured gaseous mercury more effectively than those activated at 750°C.
- Luscar char activated at 750°C and DARCO FGD did not show a conditioning effect under acid-rich baseline flue gas.
- Mercury capacities of the Luscar char activated at 800°C ranged from 164 to 202 μg/g in the presence of the simulated lignite combustion flue gas.

Pilot-Scale Conclusions

- Speciation results were very similar for the Poplar River and Freedom coal flue gases at approximately:
  - Hg^0 = 85%, Hg^{2+} = 15%, Hg(p) <1%
- Production of unburned carbon during initial tuning of the combustion system promoted the formation of Hg^{2+} and/or Hg(p).
- Increasing injection rates and decreasing gas temperatures in all four particulate control devices significantly improved mercury removal.
- In general, the sorbents were slightly more effective at capturing mercury from the Freedom flue gas as compared to the Poplar River flue gas.

Pilot-Scale Conclusions (continued)

- The DARCO FGD and activated Luscar char provided good mercury capture showing similar results, with a few exceptions.
- Increasing flue gas temperatures from 300°F to 400°F generally required 10–20% more activated carbon. However, a much larger amount was required in some cases.
- Fine-particle-sized (~5 micron) sorbents provided mixed results, with some cases (notably ESP) showing improvement.
- The type of fabric filter material (Ryton versus Gore) did not significantly affect mercury capture.
- Fabric filter media (conventional and *ADVANCED HYBRID*™ filter) provide better flue gas-to-sorbent contact and thus showed better mercury removal relative to the ESP.

Pilot-Scale Conclusions (continued)

- Batch injection may be more effective than continuous, limited tests. More tests are needed to confirm this.
- Sorbent enhancements or methods to improve sorbent reactivity showed the potential to significantly enhance mercury removal for both lignite coals – more at AQIV.
- Mercury captured in Poplar River and Freedom coal fly ashes remained insoluble after 18-hour, 30-day, and 60-day tests.
- ACI data from full-scale units burning bituminous and subbituminous coal equipped with ESP and fabric filter devices generally provide better mercury removal efficiency at a given injection rate as compared to ACI pilot-scale results for lignite.
- Based on pilot-scale results, the cost of reducing mercury from plants burning lignite coal is expected to be higher compared to plants burning bituminous coals. Phase II of the project will provide more accurate performance and cost data.

Phase II, Field Testing/Demonstration

Proposed Site: Poplar River Power Station (SaskPower)

- Two units, commissioned in 1981 and 1983
- Unit 1 = 298 MW and Unit 2 = 294 MW
- ESPs for particulate control

Poplar River Power Station

- South-central Saskatchewan
- 10 km SE of Coronach

International Project
Participating Organizations

Canada

- Saskatchewan Power
- Environment Canada
- Ontario Ministry of the Environment
- Luscar Ltd.

United States

- Basin Electric Power Cooperative
- Minnkota Power Cooperative, Inc.
- Otter Tail Power Company
- EPRI
  - Great River Energy
  - Xcel Energy
  - Minnesota Power, Inc.
- North Dakota Industrial Commission
- U.S. Department of Energy