EERC Technology… Putting Research into Practice

National Center for Hydrogen Technology (NCHT)

NETL H_2-from-Coal Separations Project Reviews

April 29, 2008

Presentation Topics

- Overviews
  - EERC hydrogen activities
  - NCHT summary
  - Other related activities
- Hydrogen-from-coal activities

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Key EERC History and Experience

Over 50 years of experience with gasification technologies.

Over 50 years of experience in resource, product, and by-product management, including coal, ash, water, fuels, and chemicals.

Leading the nation's largest carbon sequestration partnership (Plains CO_2 Reduction Partnership).

Partnered with almost every major manufacturer of gasification systems in the world and many developers of liquefaction systems.

Experience working on technologies specifically related to producing liquid fuels from coal and other feedstocks.

Recognized as the world leader in understanding the operational challenges and opportunities associated with the inorganic components of coal and renewables.

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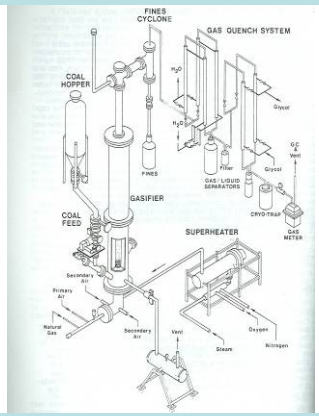
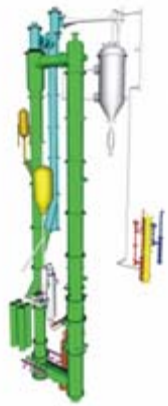
The EERC Has Worked in Gasification for over 50 years

Chronology of Gasification RD&D at the EERC



Catalytic Gasification/SOFC

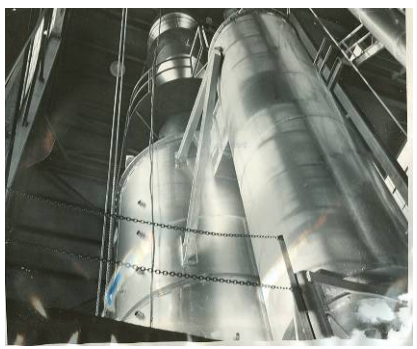
Transport Reactor Development Unit



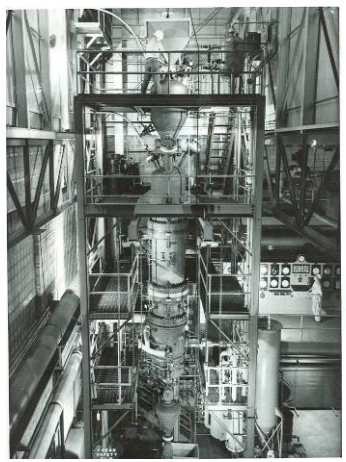
Year

1945 1955 1965 1975 1985 1995 2005

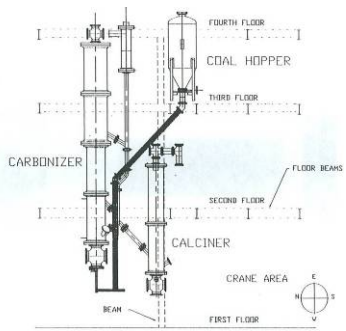
Annular Externally Heated Retort



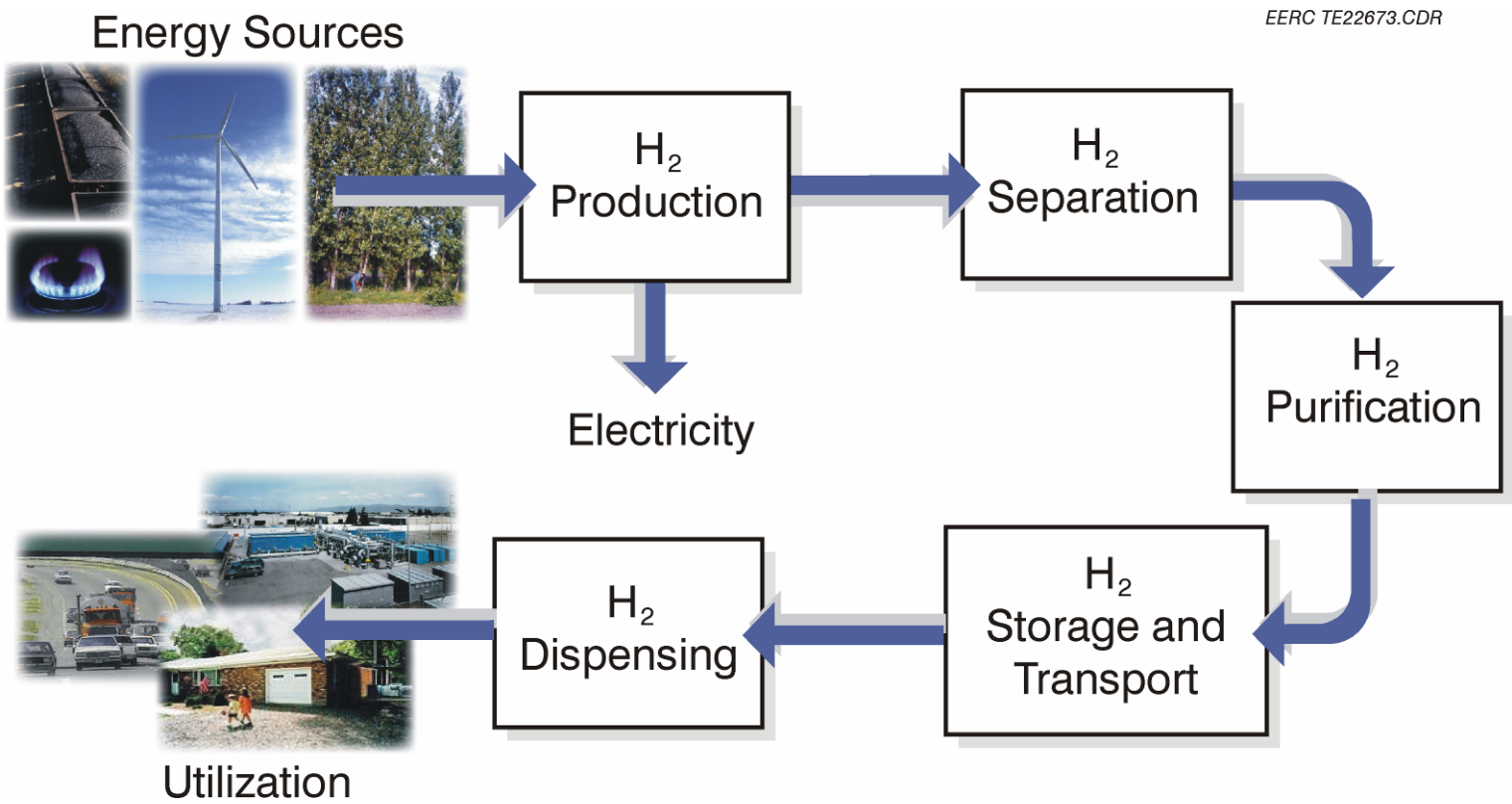
Slagging Fixed-Bed Gasifier



Mild Gasification



National Center for Hydrogen Technology (NCHT)



National Center for Hydrogen Technology

- Recent completion of new 15,000-ft^2 NCHT facility.
- Houses testing of technologies in hydrogen production, separation–purification, storage, and integrated fuel cells.
- Special materials lab for development of materials, advanced joining techniques, and application evaluations.
- Pilot systems: high-pressure fluidized-bed gasification system; pressurized lab-scale entrained-flow gasifier; Pratt & Whitney Rocketdyne (PWR) compact reformer; and other systems for developing hydrogen, alternative fuels, and fine chemicals.

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Production and Purification of Hydrogen from Heavy Feedstocks

- Team with Air Products and Chemicals, Inc., the world leader in the merchant supply of hydrogen.
- Develop a new concept for production and purification of hydrogen from coal and other heavy feedstocks.
- Phase 1
  - Design and fabricate laboratory adsorbent test system.
  - Generate proof-of-concept data.
- Phase 2
  - Design and fabricate fixed-bed test unit.
  - Evaluate stability of adsorbent using syngas feed from a coal gasifier

LaPorte Hydrogen/Carbon Monoxide/Syngas Plant

AIR PRODUCTS

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Portable Downdraft Gasifier (PDDG)

- Fixed-bed downdraft gasifier typically used for biomass gasification to produce heat and power.
- The unit operates at low pressure and provides gas filtration.

Operating parameters of EERC's 150-kW_e microgasifier

- 280 lb/hr of 6200 Btu/lb of hardwood and hemlock
- Average dry gas, 198 scfm
- 68.4% efficiency
- Diesel substitution at up to 80% of load ~ 100 hp
- H_2 16%, CO 18%, CO_2 12%, CH_4 3%, N_2 50%, O_2 1.5%, PM 30 mg/Nm_3, tar 250 ppm

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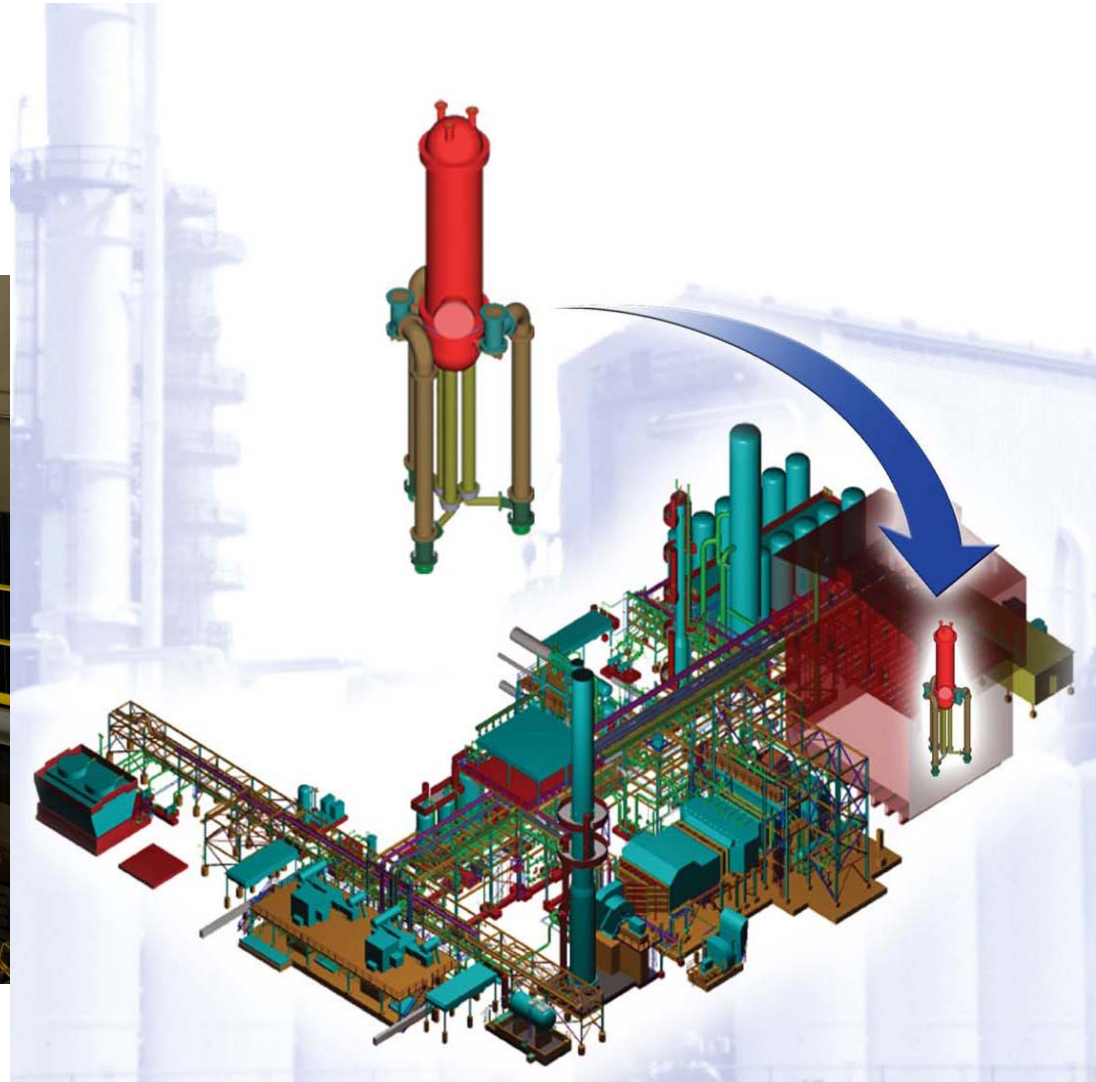
Activity 3.2 – PWR H_2 Generator – Compact Reformer for Industrial Hydrogen

Development of PWR's Hydrogen Generator Technology

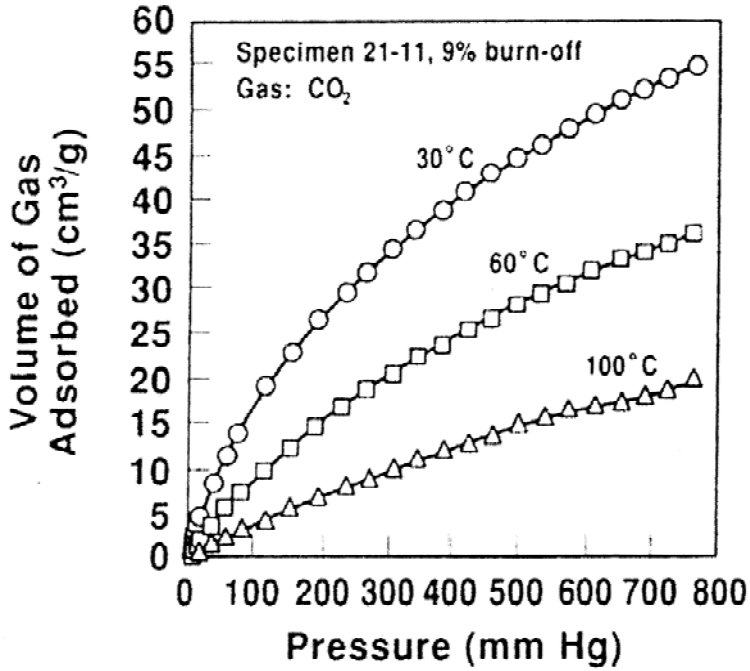
* Courtesy of Pratt & Whitney Rocketdyne



High-Density Activated Carbon for High-Pressure Hydrogen Purification

Electrical Swing Adsorption (ESA)

- ESA is very similar to the commercial process known as pressure swing adsorption, except that the composite is regenerated by passing a low-voltage current through it.
- Low-pressure ESA is being developed at Oak Ridge National Laboratory (ORNL) for purifying hydrogen gas streams.
- The EERC is working with ORNL to develop ESA for high-pressure applications using high-density activated carbons.



SGL CARBON GROUP

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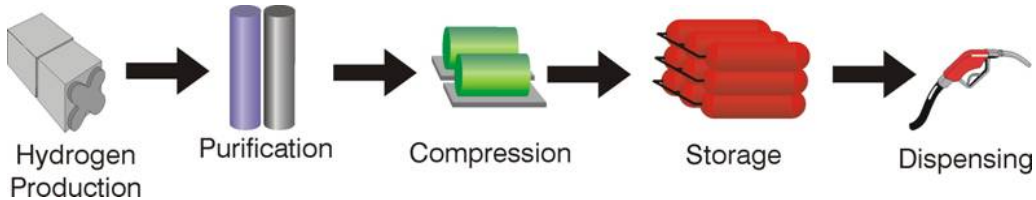
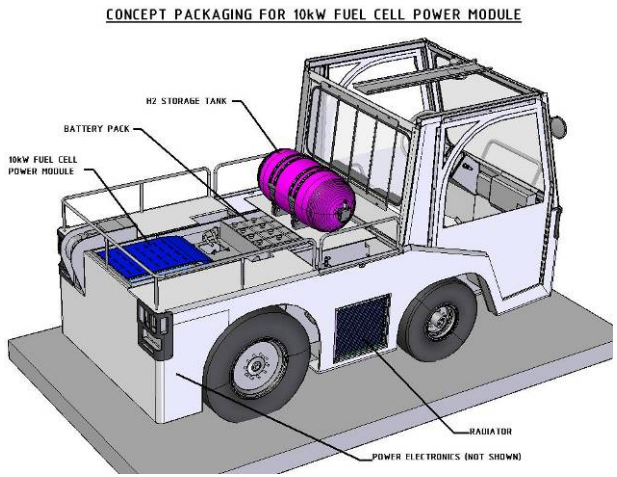
Integrated Demonstration of JP-8-Based Hydrogen Production and Use in Military Fuel Cell Electric Hybrid Vehicles Hydrogen Refueling

"Traditional" Concept





On-Demand High-Pressure Reforming Concept

ERDC US Army Engineer Research and Development Center

Construction Engineering Research Laboratory (CERL)

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ePower Synergies, Inc.

Grand Forks AFB Warriors of the North

2006 DOE H_2 COSTS
(not including H_2 production)

Tr[illegible]on
($4-$9/gge)

Compression, Storage, and Dispensing
($2–$3/gge)

Kraus Global
Dispenser

Up to 12,000 psi (875 bar)

~~@ 5000-psi (350 bar)~~
Delivery Pressure

HPWR eliminates
- **Hydrogen transportation.**
- **Hydrogen compression.**
- **Large-volume hydrogen storage.**

Department of Energy, Hydrogen Program, FY2006 Annual Progress Report

EERC Technology… Putting Research into Practice

Year 1 and 2 – Activity 1.2

Gasification of Lignites to Produce Hydrogen, Liquid Fuels, and Power

Steven Benson, Michael Jones, Michael Swanson, and Josh Stanislowski

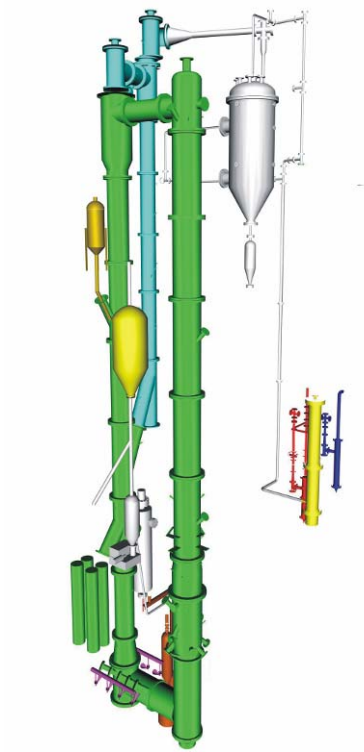
April 29, 2008

Gasification of Lignites to Produce Syngas for Hydrogen and Power Production

Project Goal

This project will provide key data on the feasibility of utilizing lignites to generate a hydrogen-rich fuel gas for the production of hydrogen, liquid fuels, chemicals, and power.

The results of this project will be available for integration with carbon management technology development activities related to gasification system platforms.



Pilot-Scale Transport Reactor (scale up to Wilsonville, Alabama, system)

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Objectives

- To conduct gasification testing of lignites to provide information on the opportunities and challenges to produce a hydrogen-rich fuel gas.
- To determine the ability to perform warm-gas cleanup for sulfur, particulate, alkali, halogens, ammonia, and other trace species to levels required upstream of low-temperature shift reactors and hydrogen separation systems and for meeting the requirements of fuel cell applications.
- To test hydrogen separation and removal technologies in order to produce a clean hydrogen stream and CO_2.

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Phase I Testing

- Sulfur
  - Transport-style gas–solid contactor enables continuous removal and regeneration
  - Packed bed used for sulfur polishing
- Water-gas shift
  - High-temperature catalyst
  - Low-temperature catalyst
- Mercury
  - Activated carbons with additives
- H_2/CO_2 separation/purification
  - H_2 separation membranes

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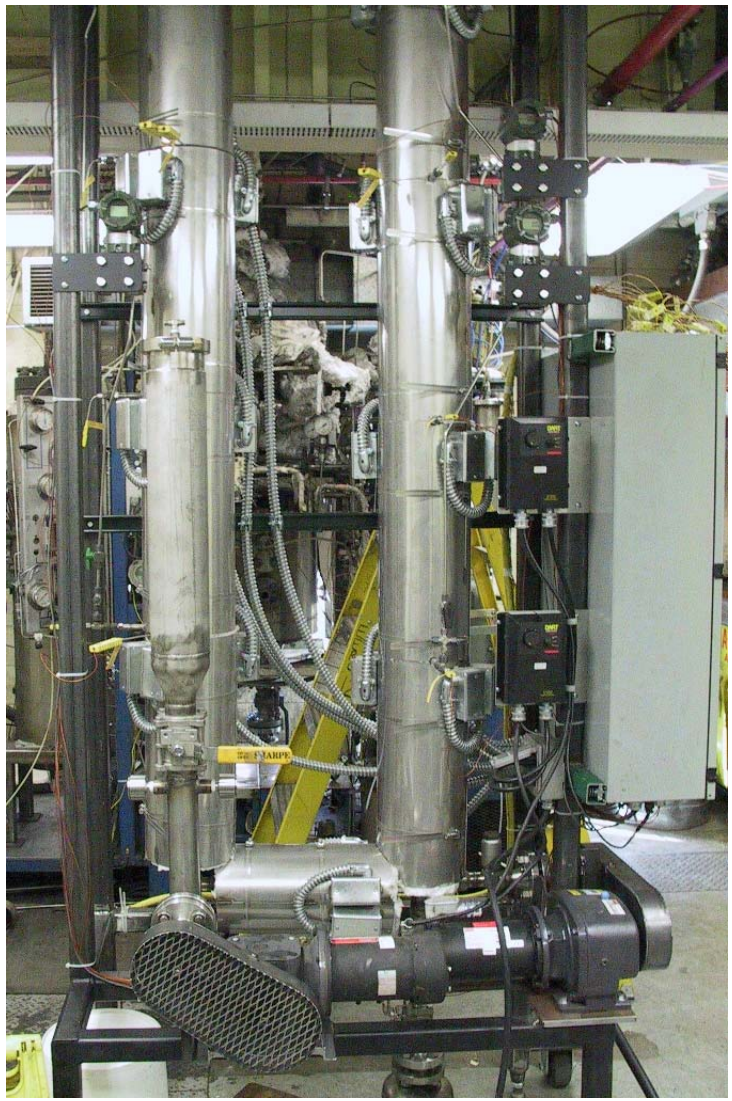
Sulfur Reactor



- Transport reactor for warm-gas sulfur removal has been constructed and tested, including cyclone for solids recycle.
- Utilized sorbent for shakedown testing and a commercial sorbent for sulfur capture testing.
- System inserted into the bench-scale system after the primary cyclone and before the hot-gas filter vessel (HGFV).

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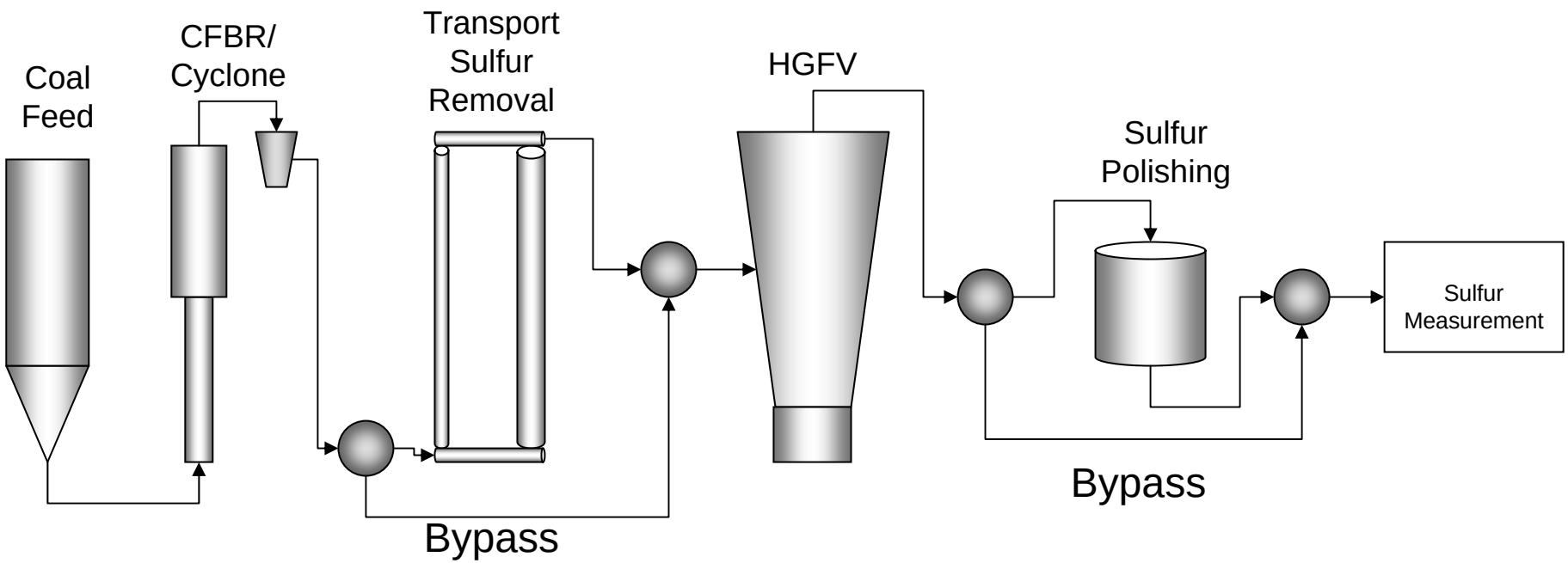
Sulfur Removal Process Scheme



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Parametric Test 2 Results – Oxygen-Blown Gasification Sulfur Removal Testing

Run	Temp °F	Recycle Rate	Drager, ppm	Yokogawa GC, ppm	% Removal
Baseline	N/A	N/A	1650	1690	
1	650	50%	6.5		99.53
2	800	75%	5.8		99.58
3	950	100%	5.6		99.59
4	800	75%	3.2		99.77
5	650	100%	1.8		99.87
6	800	75%	2		99.85
7	950	50%	3		99.78
Baseline	N/A	N/A	1100	988	
8	800	75%	3.3		99.76

- Similar removals seen in air-blown runs.

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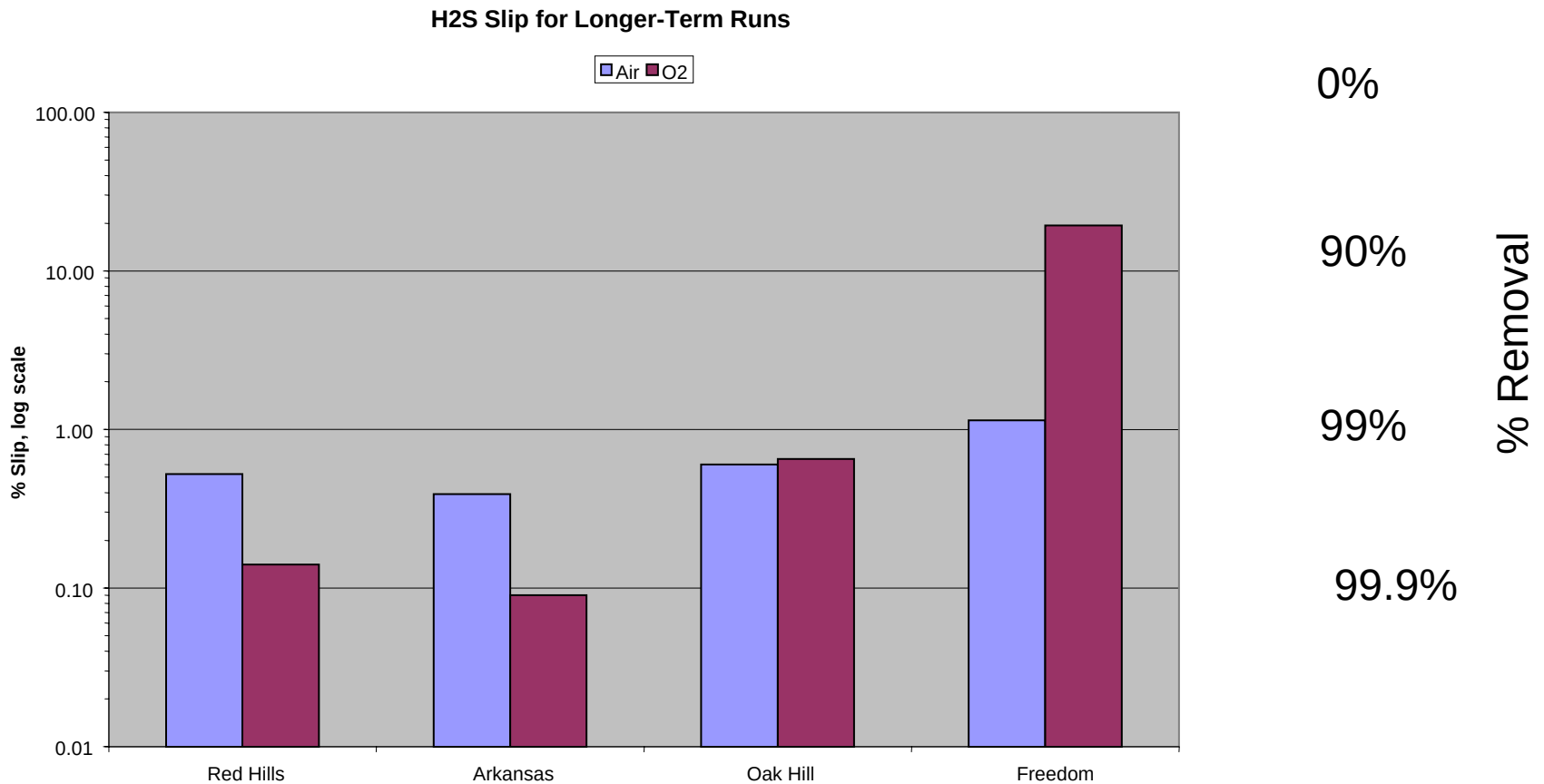
Longer-Term Sulfur Removal Results – Transport Reactor



- Achieved as low as 1.6 ppm H_2S
- Sulfur breakthrough occurred on the Freedom run

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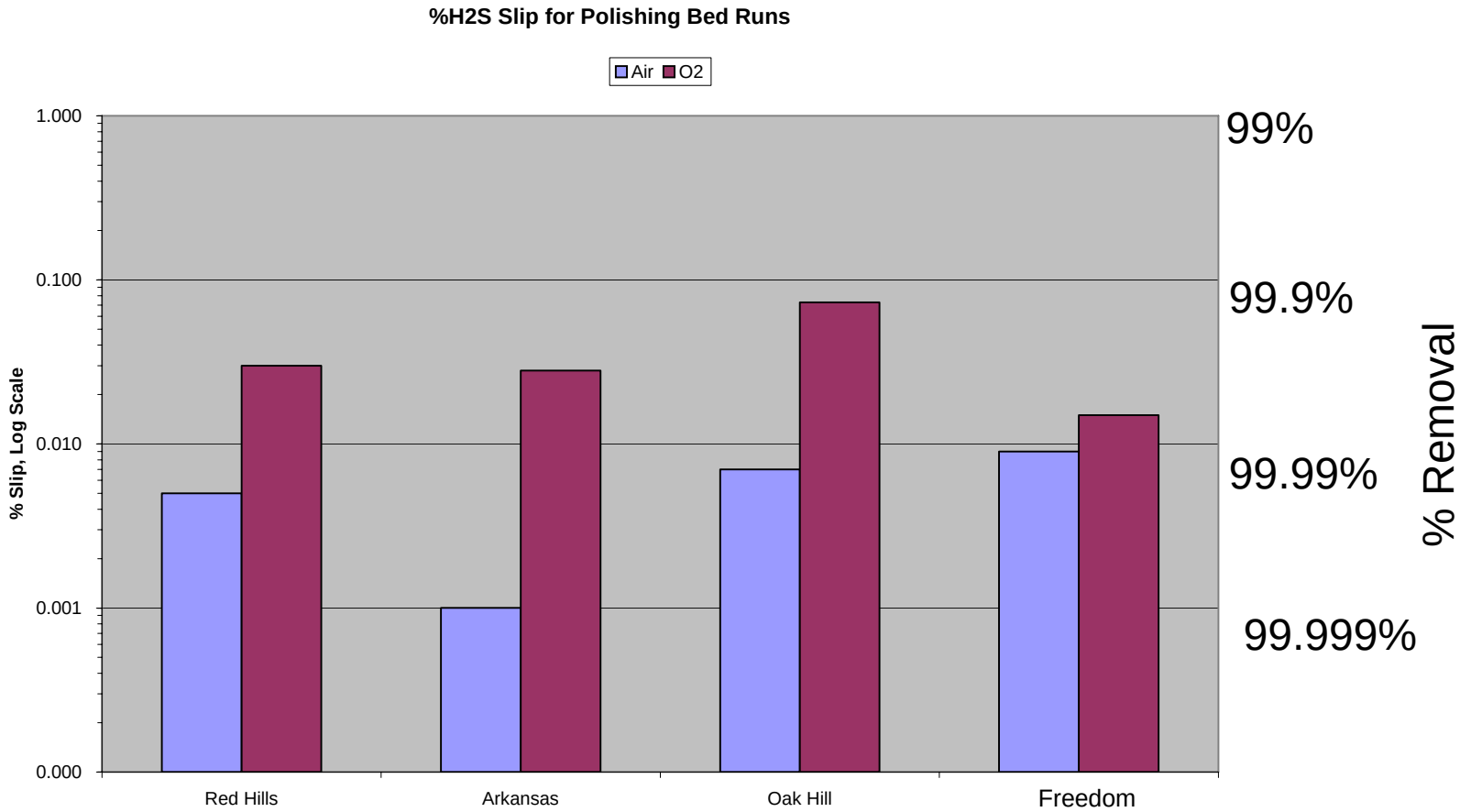
Sulfur Removal Results Polishing Bed



- Achieved as low as 0.01 ppm H_2S

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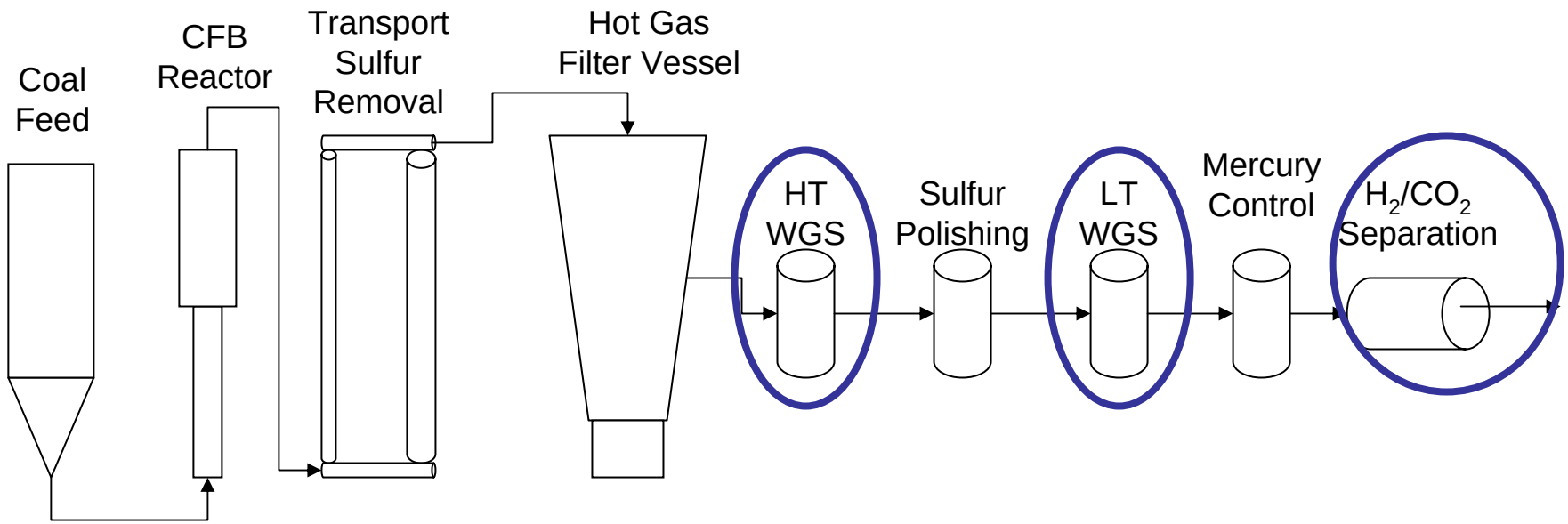
Water-Gas Shift and Hydrogen Separation



- High- and low-temperature water-gas shift catalyst to maximize hydrogen yields.
- Hydrogen separation membrane for warm-gas purification of hydrogen.

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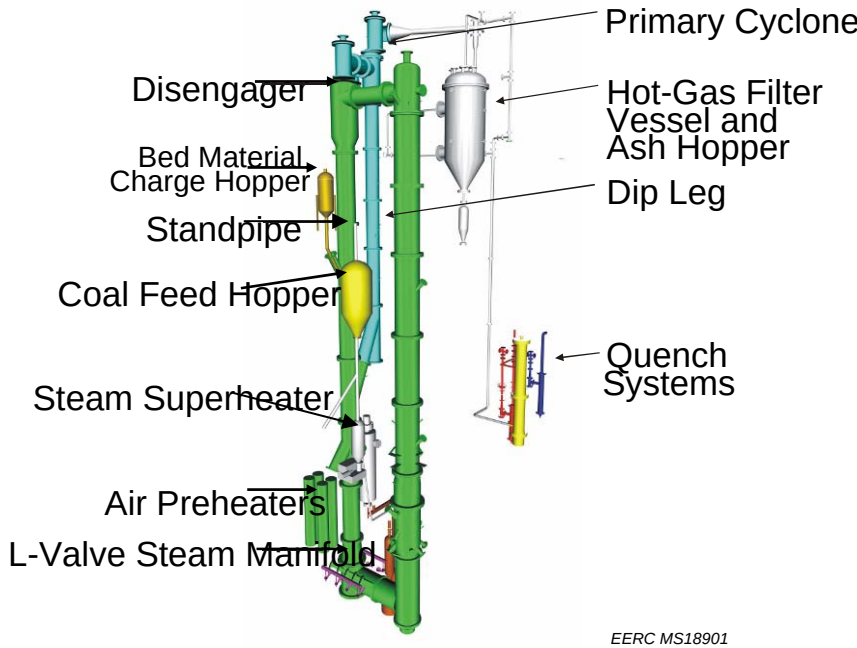
Future Project Objectives

- Characterize coal and develop test plan.
- Demonstrate the gasification performance of a selected lignite in a pilot-scale transport reactor.
- Demonstrate lignite gasification performance in a bench-scale entrained-flow gasifier.
- Make use of available skid-mounted bench-scale syngas cleanup equipment from the circulating fluidized-bed reactor (CFBR) for longer-term slipstream testing.
  - Sulfur reactor and sulfur packed bed
  - Water-gas shift catalyst
  - Hydrogen separation membrane
- Will test new filter elements in the HGFV.
- Testing a mercury and trace element removal skid.

EERC TRDU with L-Valve Modifications



Numerous opportunities to test hydrogen purification systems on this and related projects

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