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Development of a Coal-fired Oxygen Transport Membrane (OTM) Combustor

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Praxair, Inc.

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Overview

- Praxair has developed an OTM tube technology that can be used to generate oxygen in a combustion environment
- Praxair has successfully tested the OTM tubes with H_2, CO, and CH_4 fuels.
- University of Utah has successfully tested the OTM tubes with coal pyrolysis products.
- Future work is focused on operating OTM tubes with both coal pyrolysis and gasification products

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Outline

- Overview of Oxygen Transport Membranes (OTM)
  - Attributes/advantages of OTM tubes
  - Proposed application for power generation
- Coal-Based OTM Reactor
  - Design and Configuration
  - Technical Challenges
- Preliminary Coal Results
  - Experimental Procedures
  - Results
  - Future Work

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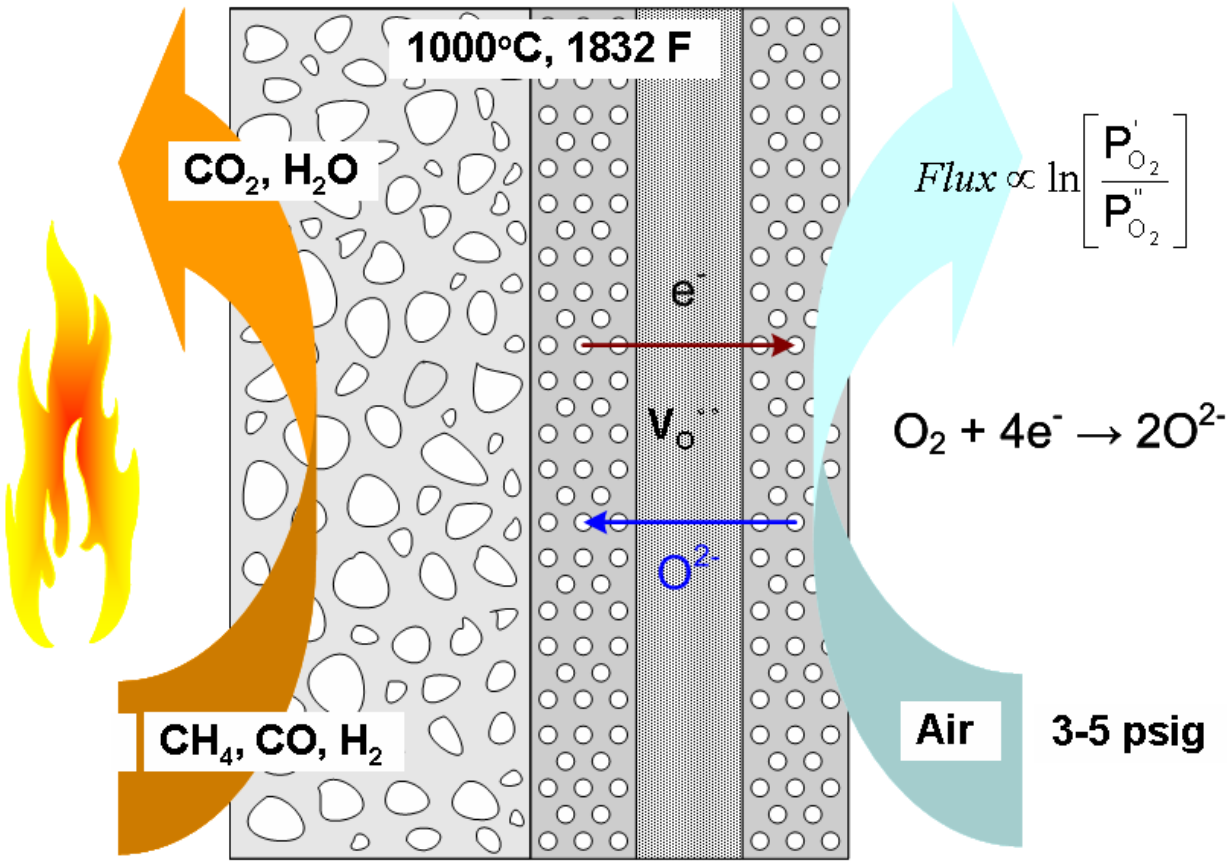
Oxygen Transfer Membrane (OTM)*



Oxy-Fuel Combustion Without Producing Oxygen

**Shah et al., "Oxycombustion on Oxygen Transport Membranes," 1st International Oxycoal Combustion Conference, Cottbus, Germany, Sept. 8-10, 2009*

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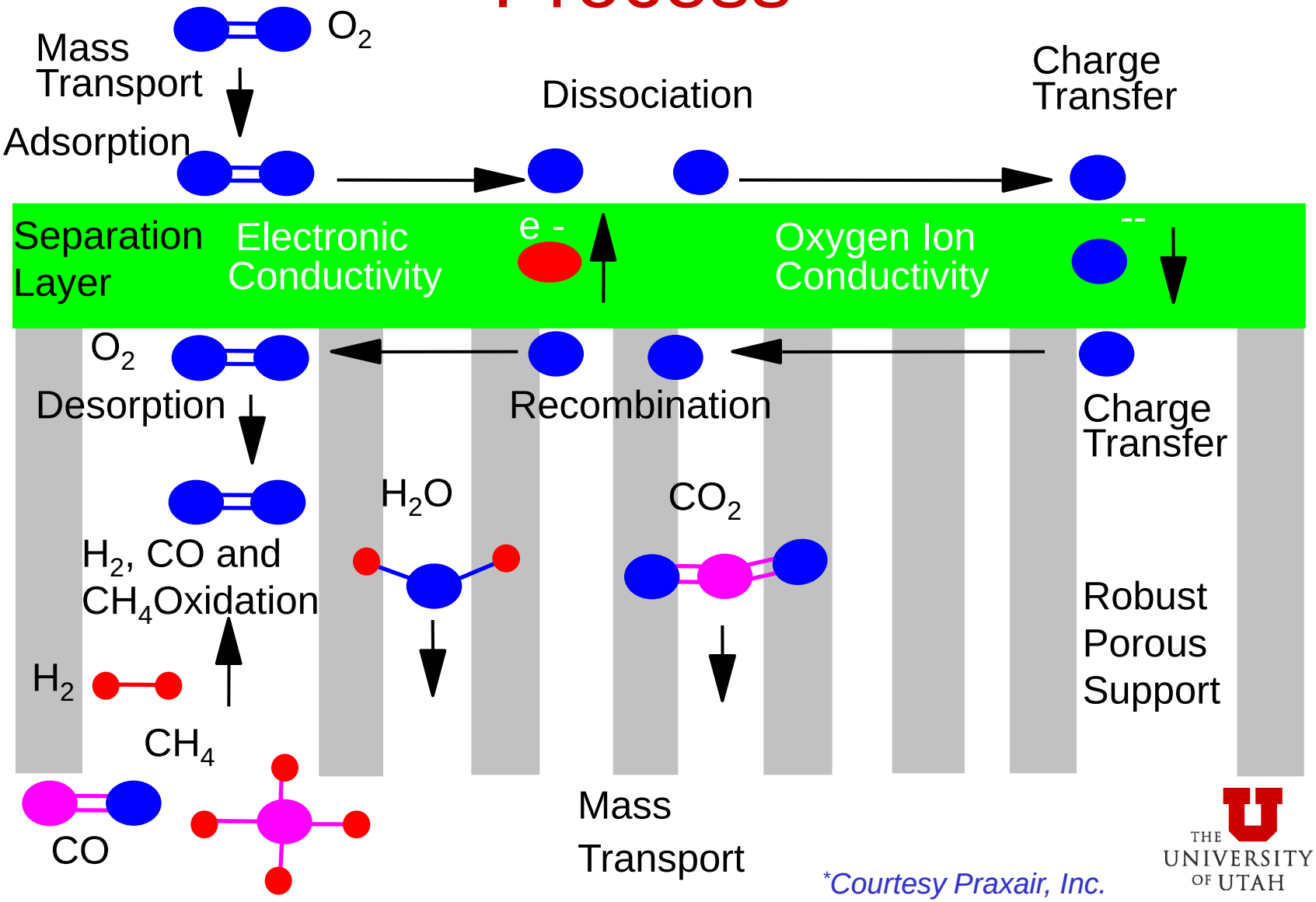
Overview of Oxygen Transport Process*



*Courtesy Praxair, Inc.

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Advantages of the Praxair OTM Tubes

- Allows for air separation to occur within the combustion chamber
- Oxygen is consumed at or near the membrane surface
  - provides a high partial pressure gradient across the membrane
- Input air does not need to be pressurized or preheated
- Step change in efficiency
  - >70% reduction in ASU power
- Enables zero-emission coal-fired power plant via advanced power cycle

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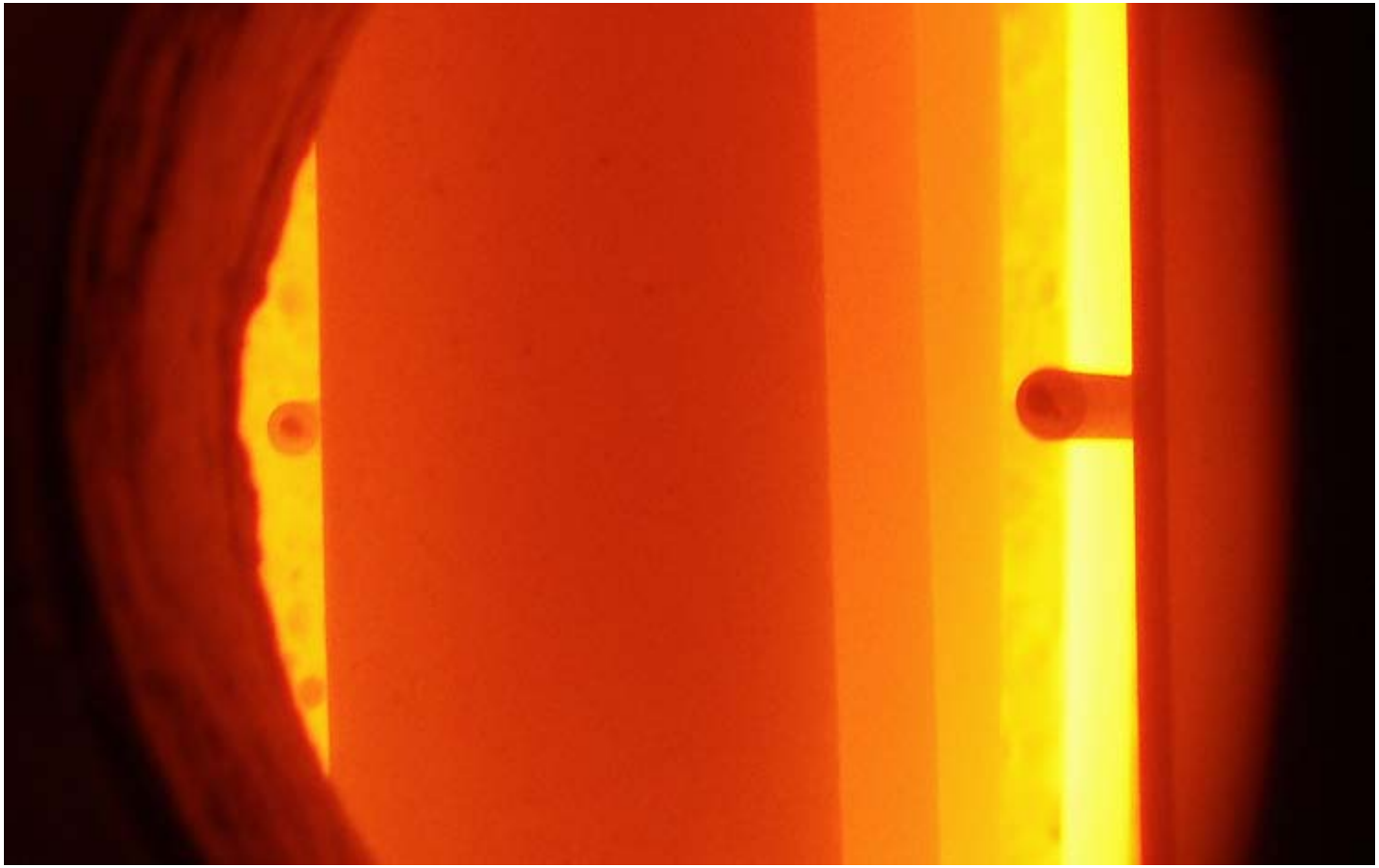
Operation of OTM Tubes on Natural Gas*



Shah et al., "Oxycombustion on Oxygen Transport Membranes," 1st International Oxycoal Combustion Conference, Cottbus, Germany, Sept. 8-10, 2009

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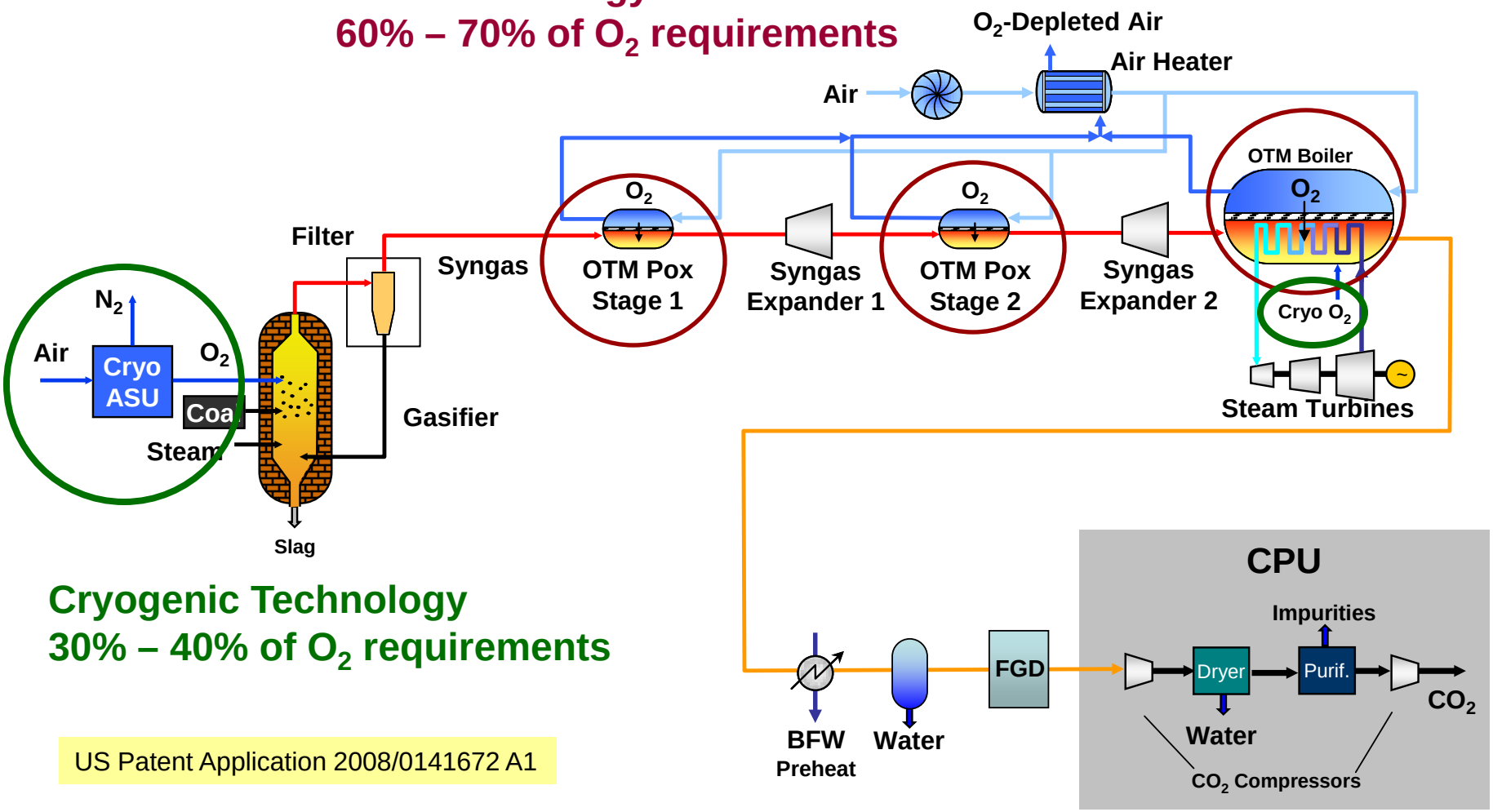
OTM Advanced Power Cycle

OTM Technology
60% – 70% of O_2 requirements



Cryogenic Technology
30% – 40% of O_2 requirements

US Patent Application 2008/0141672 A1

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University of Utah Coal-Based OTM Reactor Project Objectives

- Effectiveness of combustor design
- Capacity of the OTM tubes to react with coal volatiles and gasification products
- OTM tube fouling and deposition
- OTM tube robustness
- NO_X and SO_X emissions

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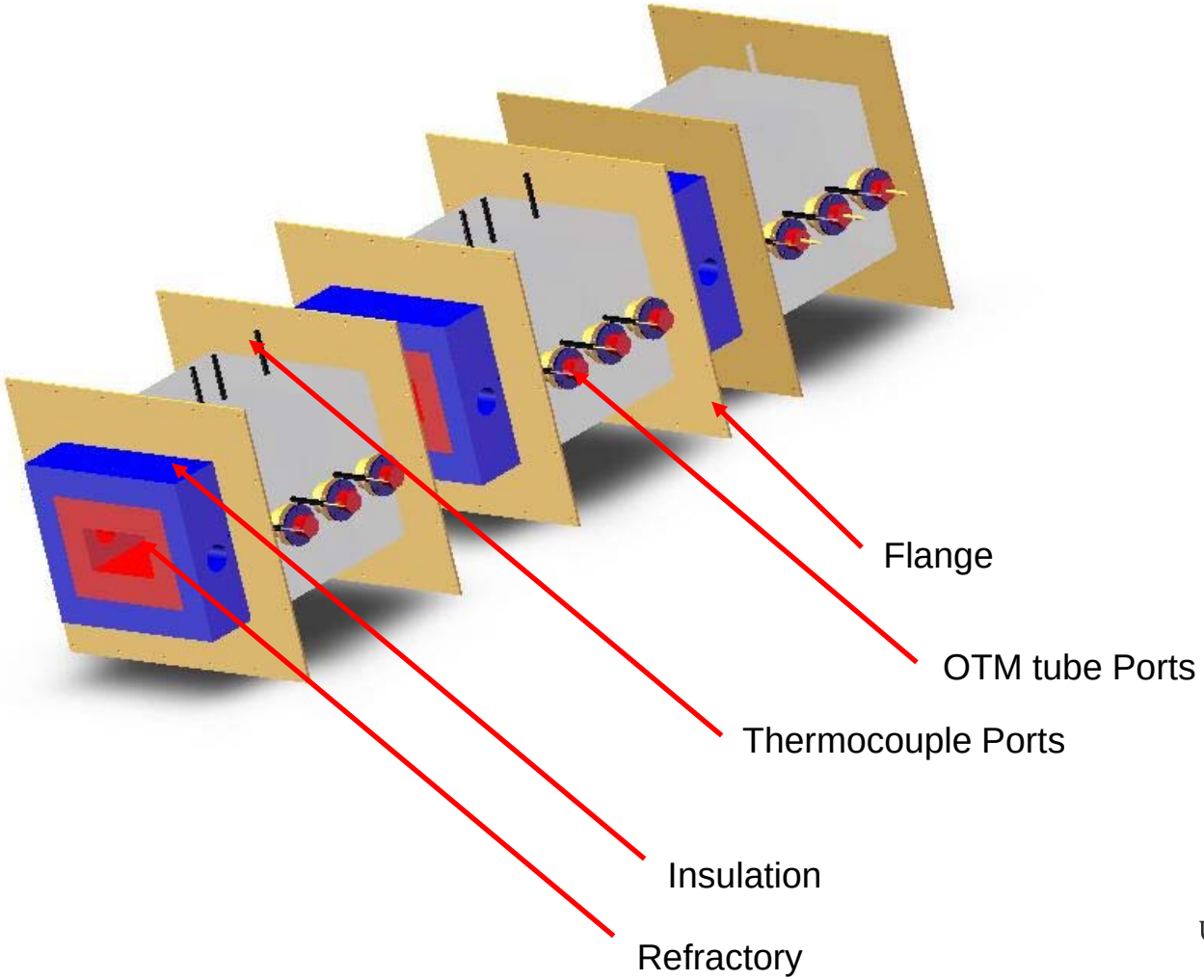
OTM-Coal Reactor Design



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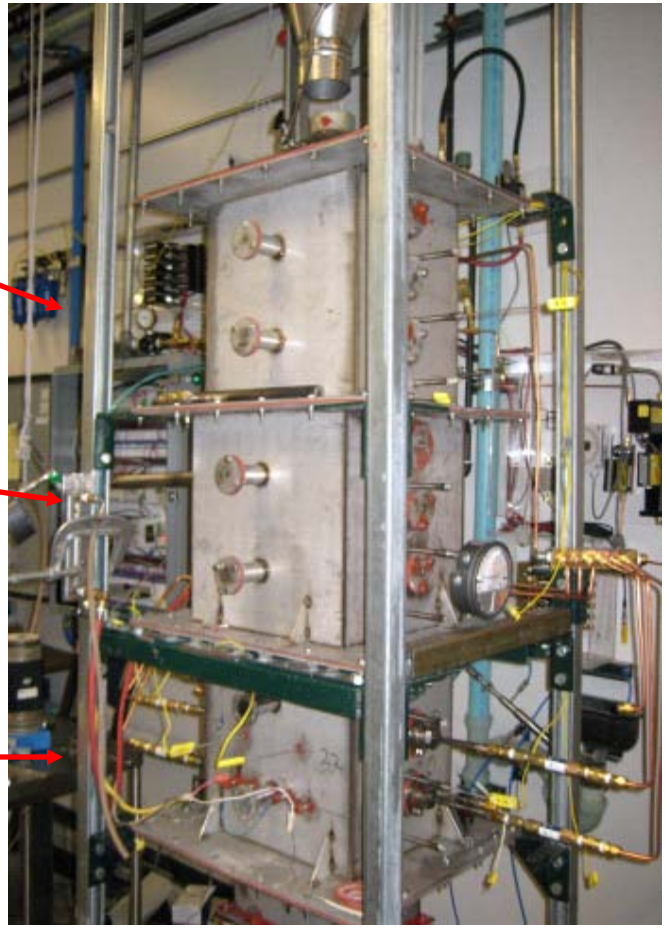
Completed Coal-Based OTM Reactor

Section 3:
Freeboard

Section 2:
OTM Tube
Zone

Section 1:
Particle Bed



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Reactor Configuration

1. Section 1 houses a bed of ceramic beads
   A. Coal is mixed with the ceramic beads to heat the coal and maintain uniform bed temperature.
   B. Coal pyrolysis and gasification occurs in the particle bed.
2. OTM tubes are placed in the second section above the bed
   A. Tubes react with coal volatiles and gasification products
3. Section three houses a natural gas torch
   A. Used to initially heat the reactor
   B. Serves as an afterburner for any unreacted fuel

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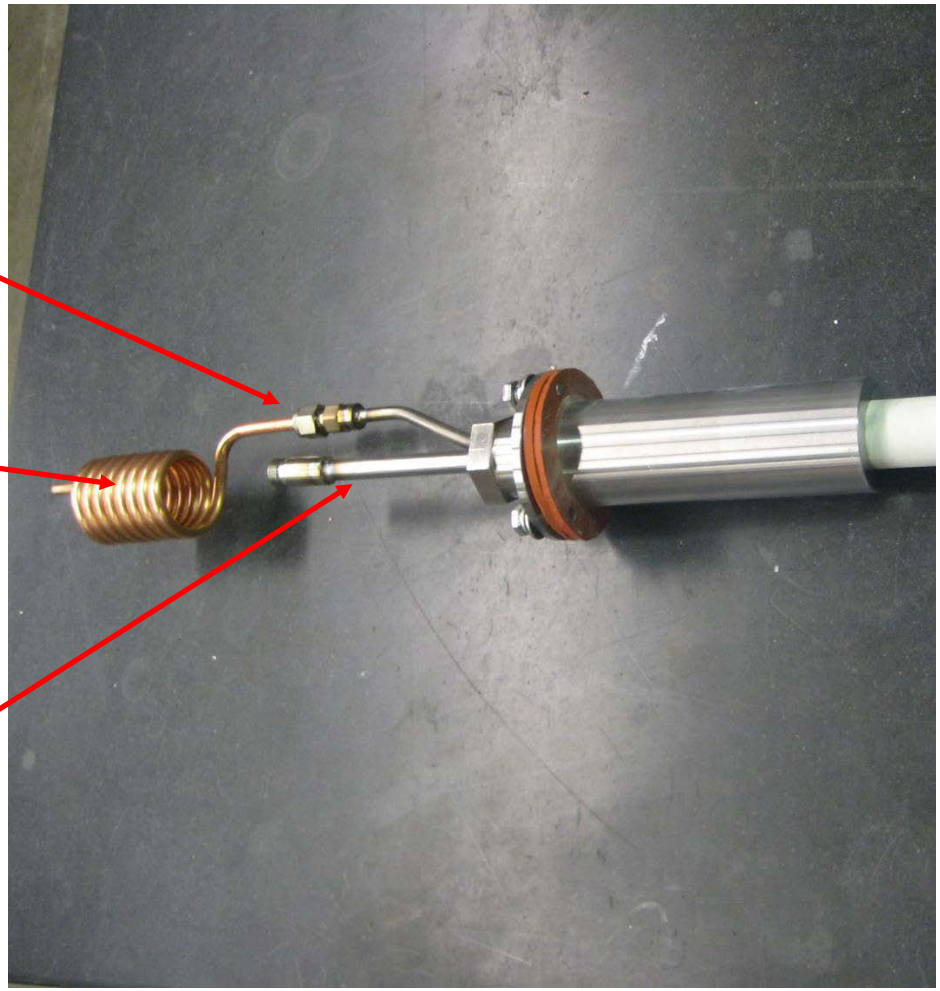
OTM Tube Loader System



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Heating the Coal-Based OTM Reactor

- The reactor initially needs to be preheated to the operating temperature of the OTM tubes
- Means of heating the reactor
  - Electric gas preheater
  - Heating panels located between the refractory and Insboard insulation
  - Natural Gas Torch
  - Hydrogen/air combustion in particle bed (during heatup only)
  - Coal (with auxiliary oxygen during heatup)

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Experimental Procedure for OTM Tests with Coal

- Heat OTM tubes to operating temperature using panel heaters and torch
- Heat particle bed using panel heaters and hydrogen/air mixture
- Begin adding Coal w/auxiliary oxygen introduced through bed
- Turn off Torch
- Turn off Hydrogen/Air
- Turn off Auxiliary Oxygen

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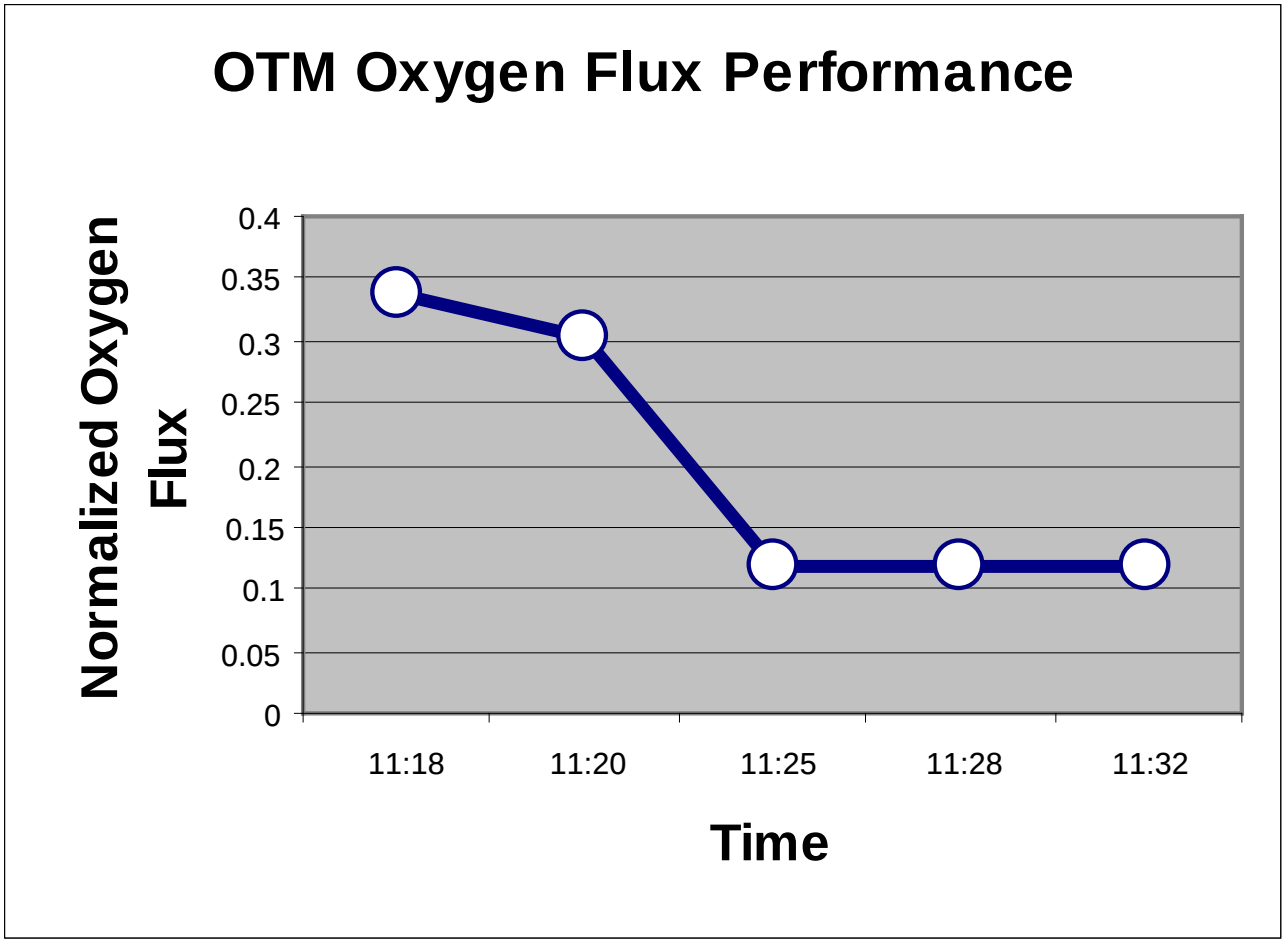
Preliminary Experimental Results: OTM Tube Oxygen Flux Performance



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Results of Preliminary Coal Experiments

- Successful operation of OTM tubes with coal pyrolysis products
- Limited oxygen fluxes through OTM tubes were measured
- High drop in oxygen fluxed observed when hydrogen gas was turned off
- Coal did not burn effectively with auxiliary oxygen use
  - did not prove to be a heat source
  - higher bed temperatures needed
- Higher wattage heaters needed to increase OTM tube and particle bed temperatures
  - OTM performance and volatile production will increase

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Future Work

- Increase operational temperatures of OTM tubes
- Increase particle bed temperatures such that coal char can be gasified effectively
- Develop sampling probe and modify reactor
  - will facilitate measurement of gas composition profiles

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