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Session: Clean Coal Burning Facilities

Demonstration of a Novel, Low-Cost Oxygen Supply Process and its Integration with Oxy-Fuel Coal-Fired Boilers

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Oxy-combustion is a leading option.... but cost of oxygen is a key factor to make economics viable

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- **Gasification applies only to new plants**
- **Oxy-combustion can be applied to both new plants and retrofits**

  - **450 MW Conesville Station evaluation (Carbon Sequestration Road-mapping Workshop - 2002)**
  - **AEP, OCDO, Alstom Power, NETL**

	Capital	Power Consumption
Boiler	36%	2%
ASU	33%	67%
CO_2 Treatment/Compression	17%	30%
Flue Gas Recycle,	14%	1%

Oxygen Production Options

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- **Cryogenic Air Separation (ASU) is current best technology for large capacity oxygen supply for oxy-combustion**
  - Mature technology; 95 - 99.9% Oxygen
  - Byproducts can be utilized to improve economics
  - Continued incremental improvements in performance and cost pursued.
  - A key change is the extension to larger capacity single train.
- **VPSA (not applicable as it is typically applied at smaller oxygen capacities)**
- **High temperature oxygen generation process options and their integration with oxy-combustion power plant (Emerging Technologies)**
  - Oxygen transport membranes
  - BOC's CAR (Ceramic Autothermal Recovery) Process

CAR (Ceramic Auto-thermal Recovery) Technology Overview

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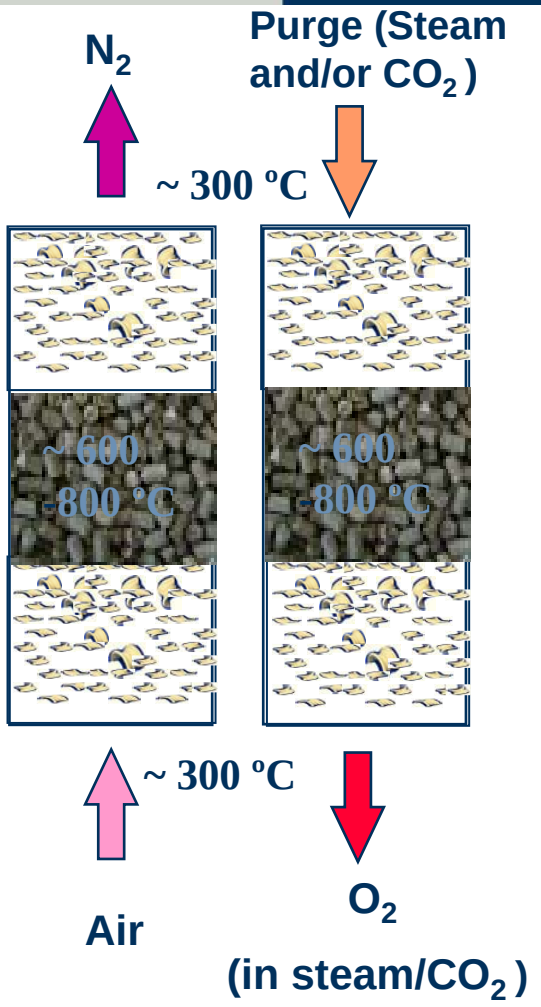
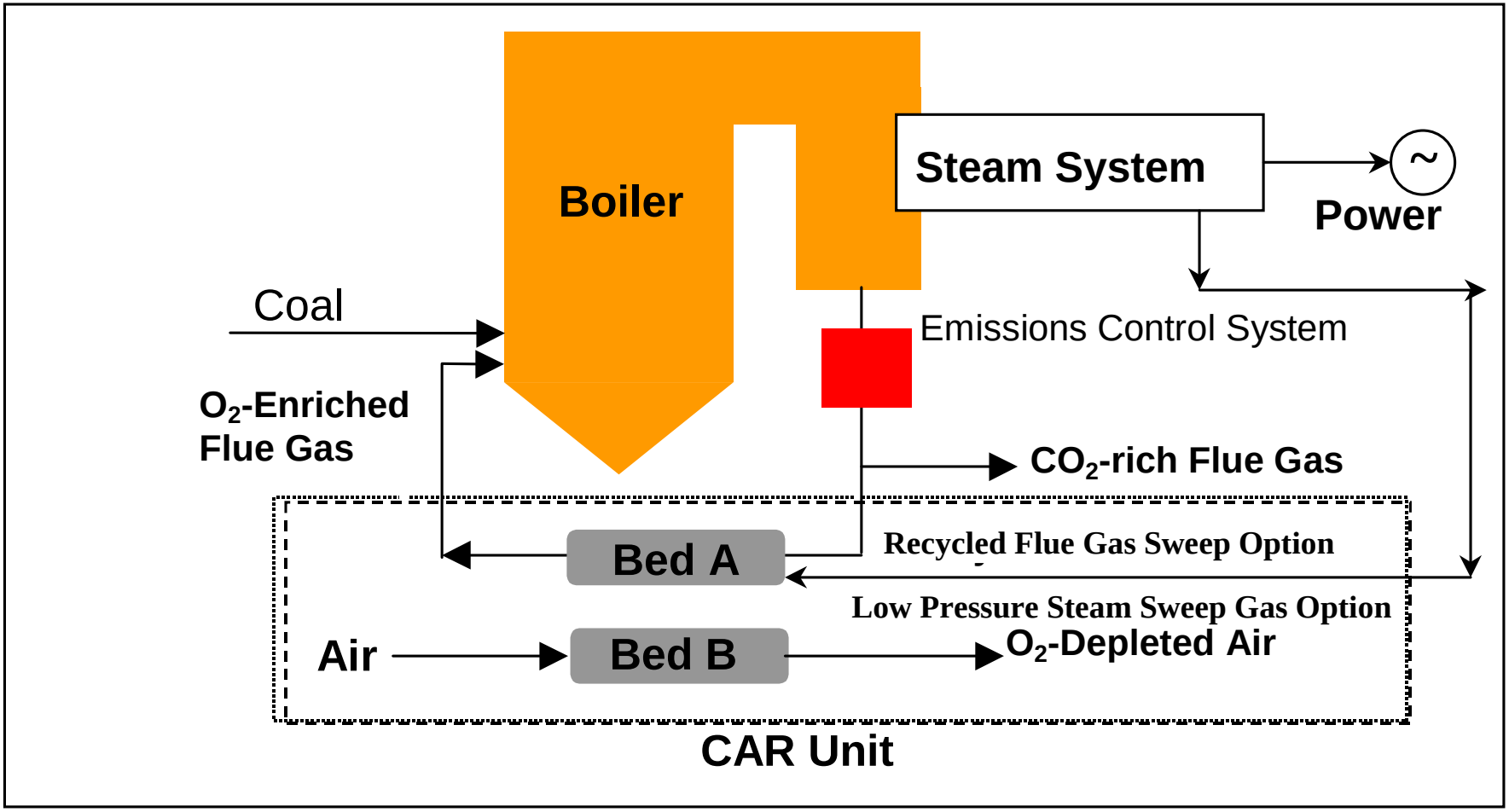
Process Features

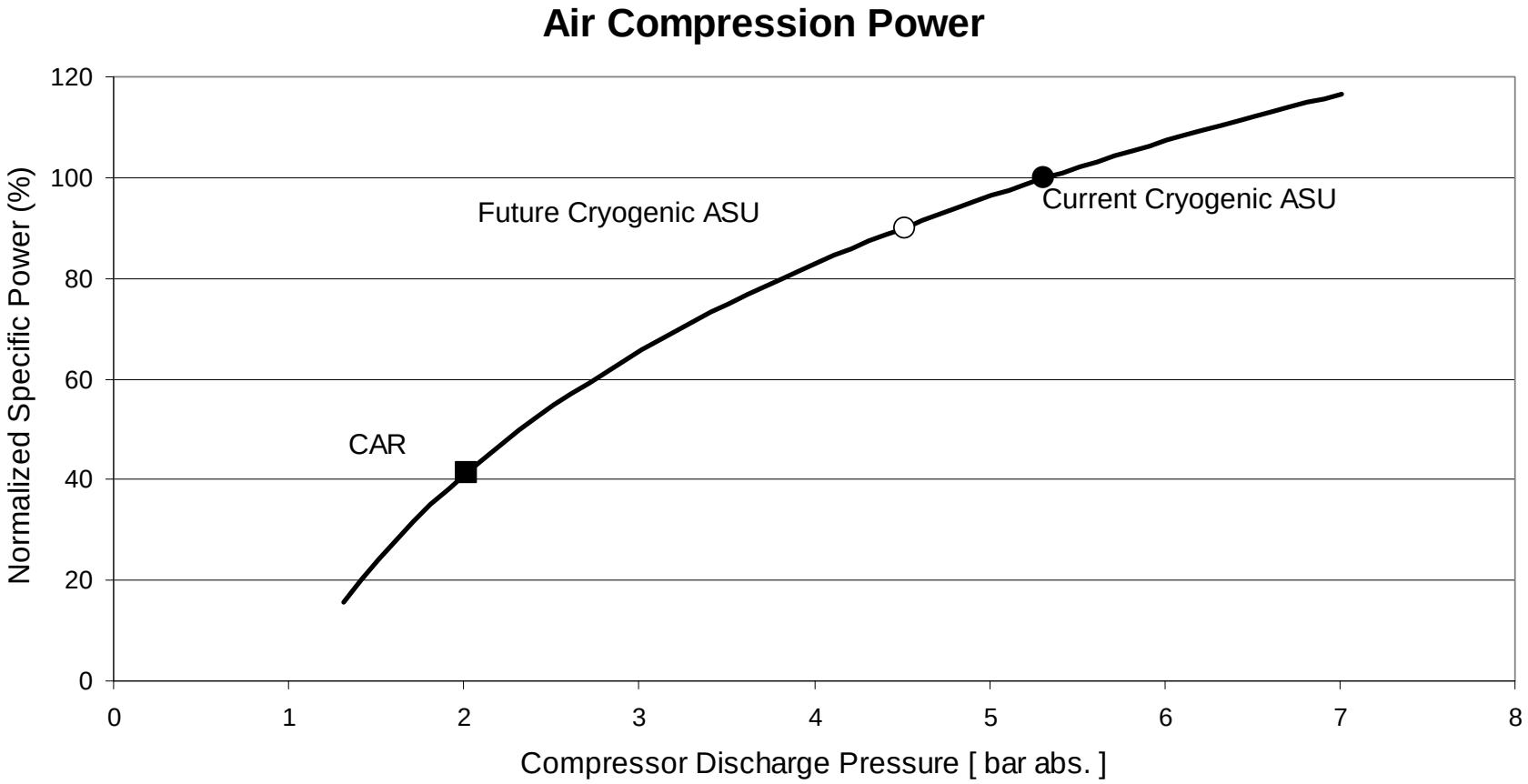
- Uses oxygen "storage" property of perovskites at high temperatures. Selective O_2 extraction from an O_2-containing gas stream, e.g. air
- Based on conventional pelletized materials
- Cyclic steady state process. Perovskite alternately exposed to feed air and regeneration gas flows.
- Partial pressure swing (using a sweep gas) enables production of an O_2-enriched stream
- Internal regenerative heat transfer



Schematic of CAR Unit Integrated with Coal Fired Boiler (Oxy-combustion)



Intrinsic Power Analysis (Limits)



- Advanced cryogenic air separation Cycles (e.g. multiple reboilers and internally heat integrated distillation) can operate down to ~ 3.6 bars but capital costs significantly increase
- CAR requires regeneration gas (50-70% of air flow at 1.6 bars) and heat source to compensate for heat losses

Demonstration of CAR Process Technology and its Integration with Oxy-fuel Coal Fired Boilers

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- Initial development of the CAR process using a process development unit was through a jointly sponsored research (JSR) project with Western Research Institute co-funded by DOE-NETL.

- Further development has been currently progressed under a DOE-NETL cooperative agreement with The BOC Group, Inc. as the prime contractor and WRI and Alstom Power Plant Laboratories, Windsor, CT as partners.

BOC ALSTOM WRI

Demonstration of CAR Process Technology and its Integration with Oxy-fuel Coal Fired Boilers: Project Objectives

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Phase 1 Objectives:

- Evaluate the performance of a 0.7 tons/day O_2 pilot-scale CAR system, when fully integrated with a pilot-scale coal combustor and determine the optimum operating conditions of this unit.
- Perform a techno-economic evaluation of a commercial-scale oxygen-fired power plant (retrofit option) that utilizes a CAR system to provide the oxygen.
- Perform long-duration tests on the CAR unit to determine long-term effects of the CAR bed materials.

Phase 2 Objectives:

- Design and construct a 10 ton/day O_2 pilot-scale CAR unit
- Evaluate the performance of the pilot-scale CAR unit when integrated with both a pulverized coal-fired and a CFB combustor.
- Refine the techno-economic study and develop a detailed commercialization plan.

CAR Process Development Unit: Process Diagram

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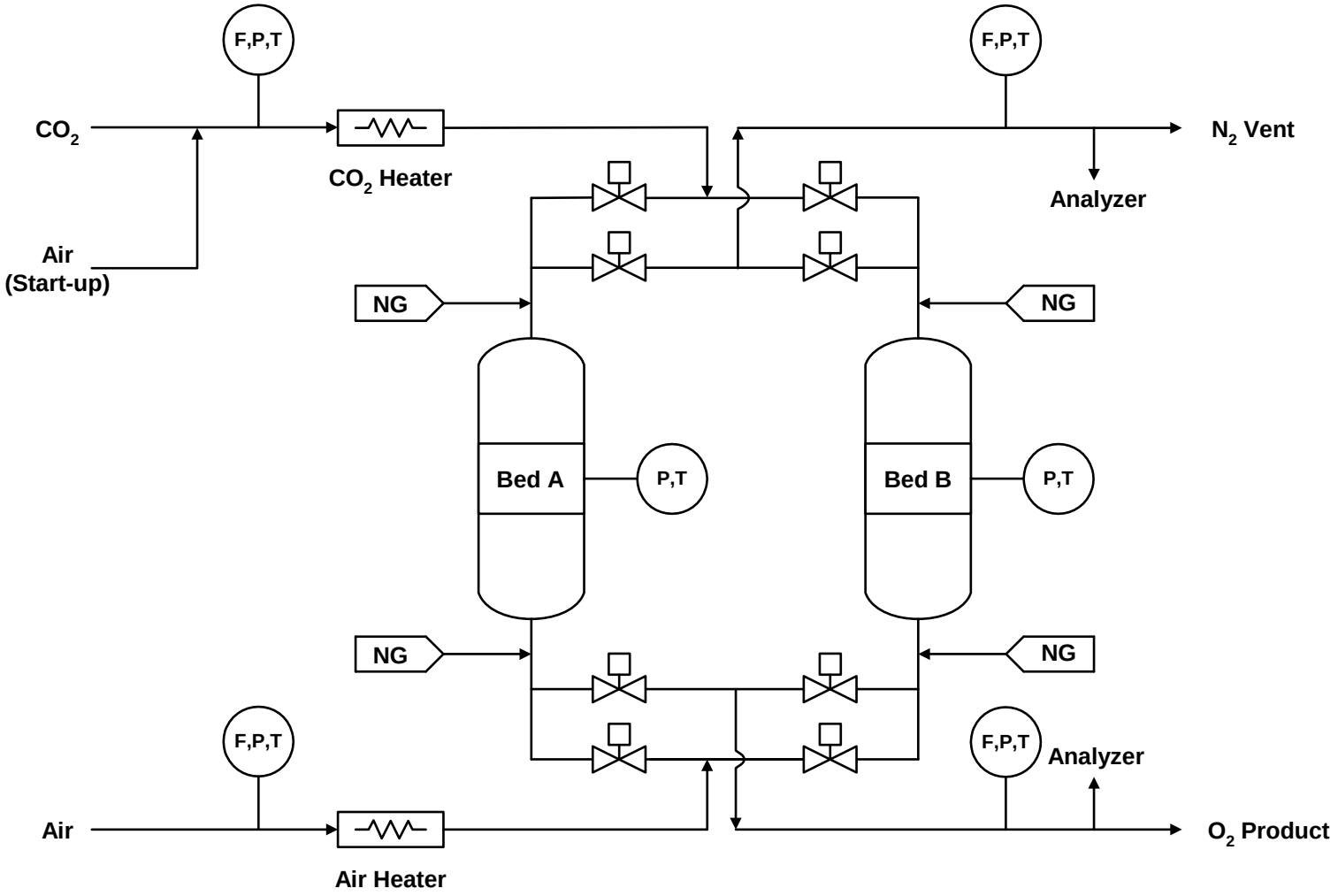

CAR Process Development Unit

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- 30 kg/hr (0.7 TPD) O_2 PDU
- 2-Bed Unit, 200 mm ID, 2.5 m length
- Cyclic steady state ops
- Automated control and data acquisition

CAR Process Development Unit Initial Start up

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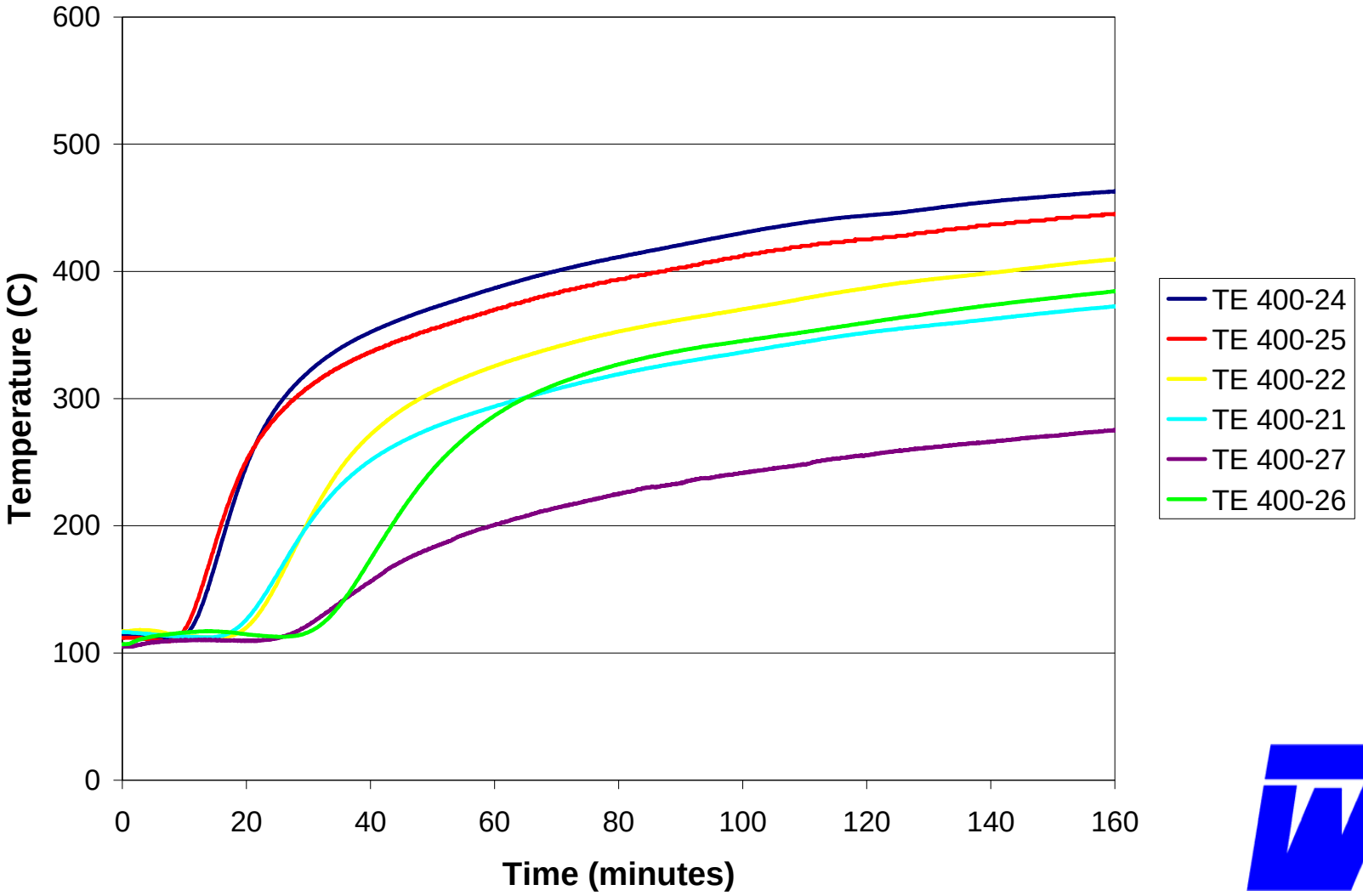
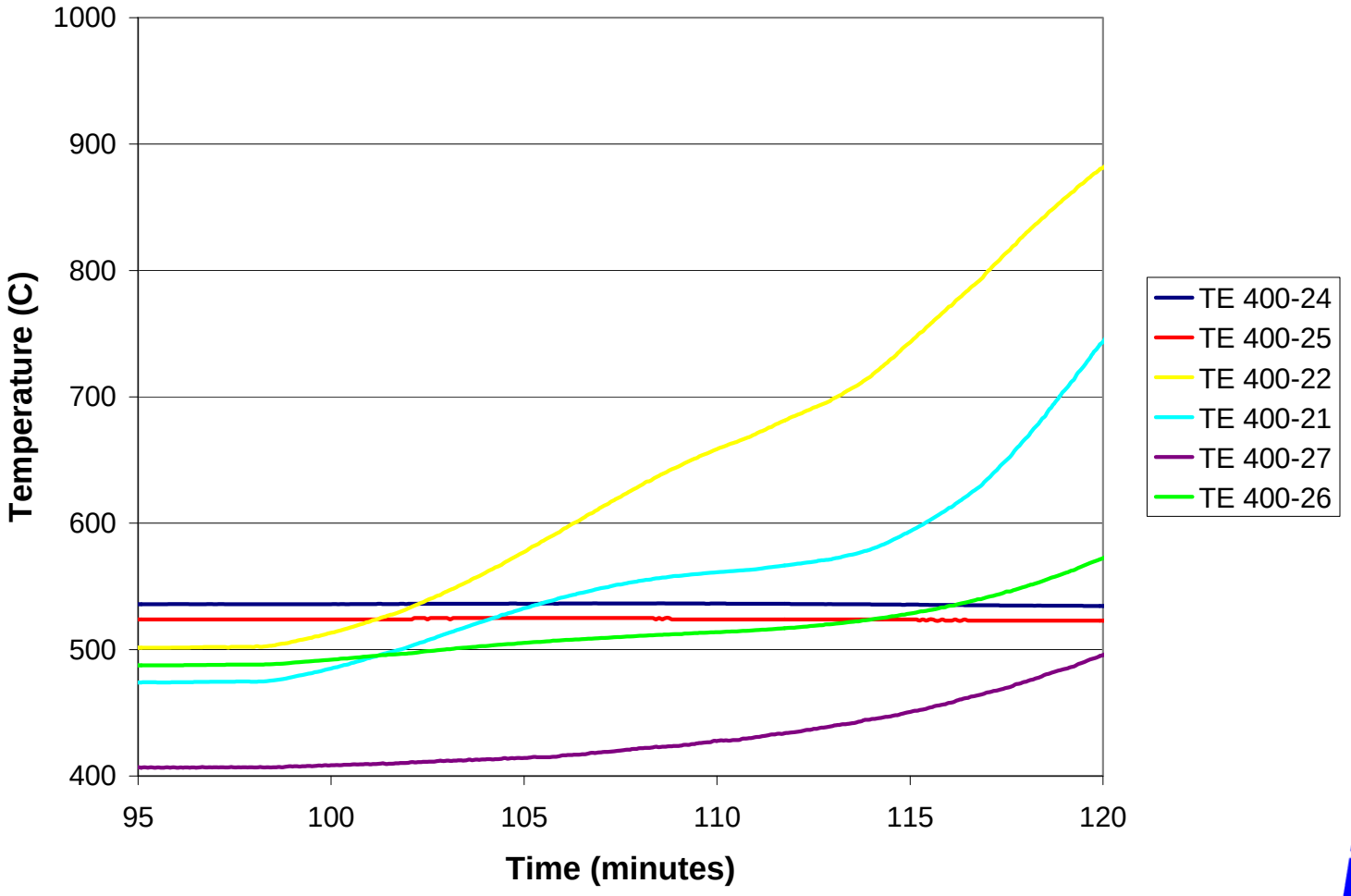
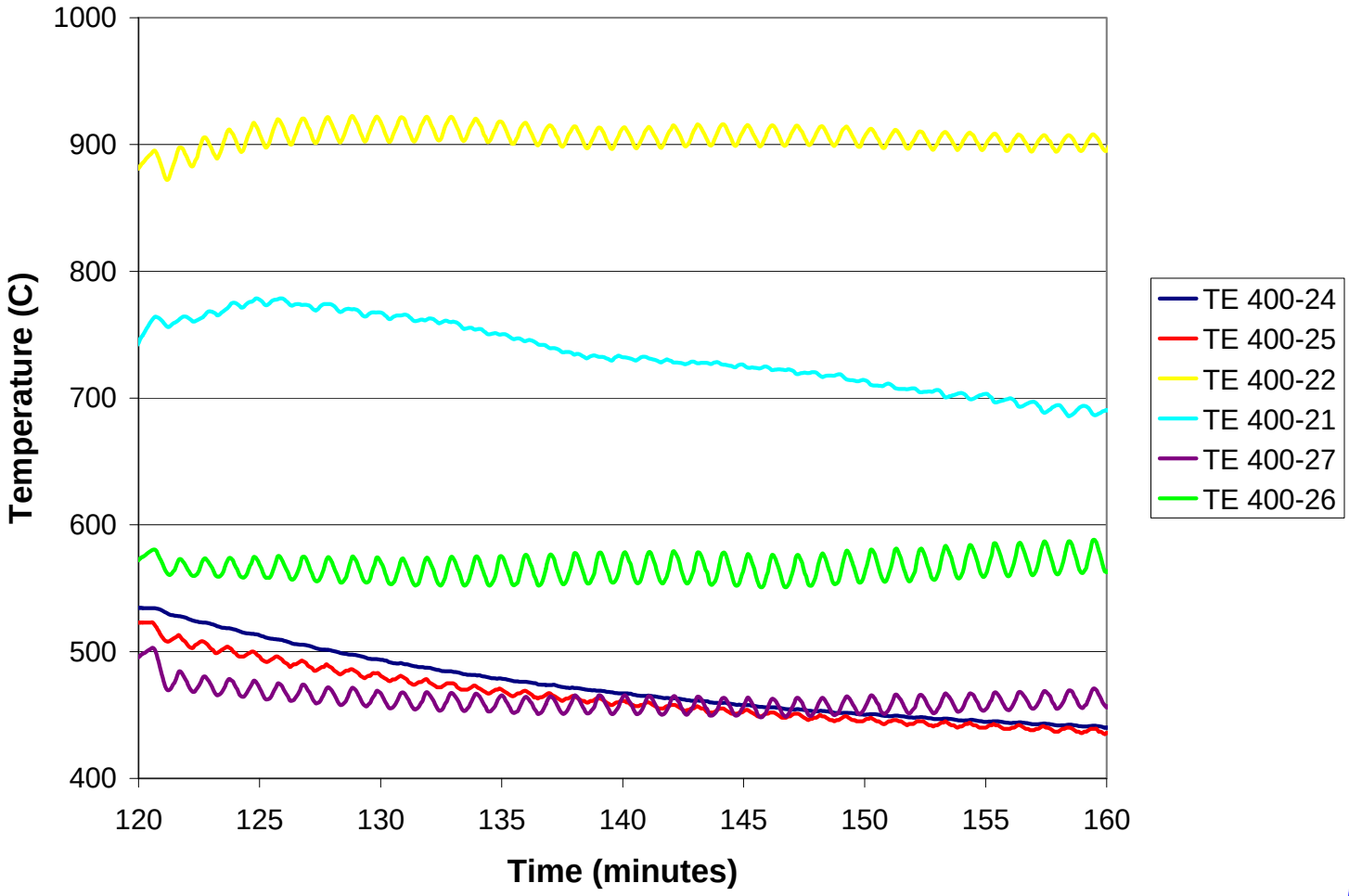


Methane Addition to Achieve Operating Bed Temperature



Temperature profile During Cycling



CAR Process Development Unit: Progress and Plans

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- Start up procedure confirmed using air heater and air flow to heat both beds to 450°C, followed by methane injection to bring both beds to high temperatures (~850°C - 900°C).
- Cycling initiated at high temperature using 30 to 60 second cycle periods using air flow from bottom and carbon dioxide from top of beds.
- Oxygen production and product gas mixture compositions determined.
- Optimization of cycle times and gas flow rates performed to improve bed temperature distribution and oxygen production.

CAR Process Development Unit: Technical Challenges to Meet Performance Target

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- Need to achieve uniform radial and axial temperature distribution in the perovskite bed
- Balancing the regeneration flow between heat transfer requirement and oxygen regeneration requirement (achieving desired oxygen concentration)
- Optimization of the perovskite bed zone and the heat transfer zones for a given material
- Demonstration of scale-up performance of perovskite materials

CAR PDU-CTF Integrated Testing with Flue Gas Recycle

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- Reference Oxyfuel Testing has been performed on the WRI's Combustion Test Facility

- Equipment design and procurement for integration has been completed. Installation is nearing completion.

- Integrated testing will involve flue gas used in the CAR PDU as sweep gas for O_2 regeneration.

250,000 BTU/hr balanced-draft system designed to closely replicate pulverized coal-fired utility boiler

WRI

Schematic of CAR-CTF Integration (Flue Gas as Sweep for the CAR Process)

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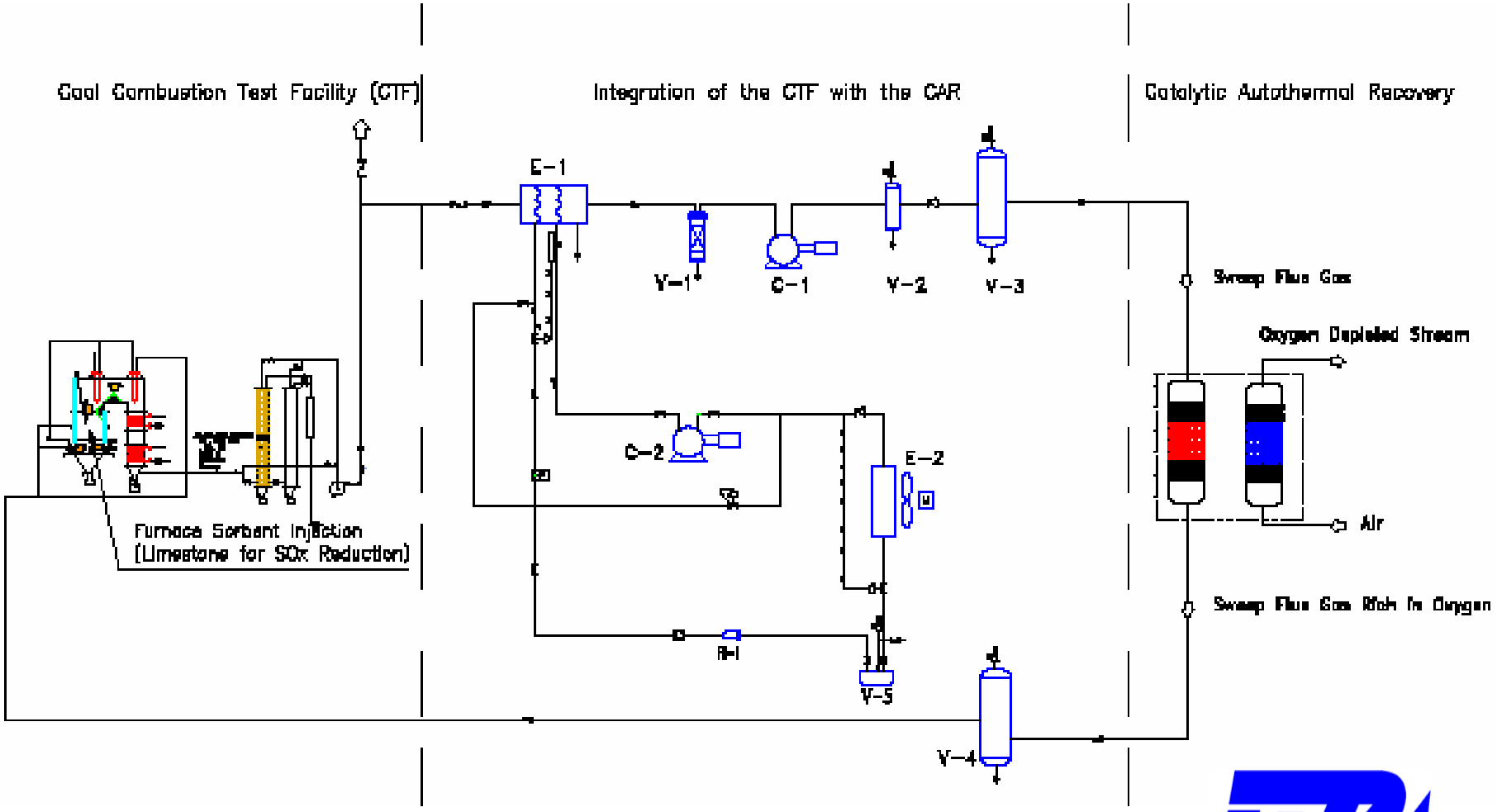

Flue Gas Exposure Tests on CAR Materials

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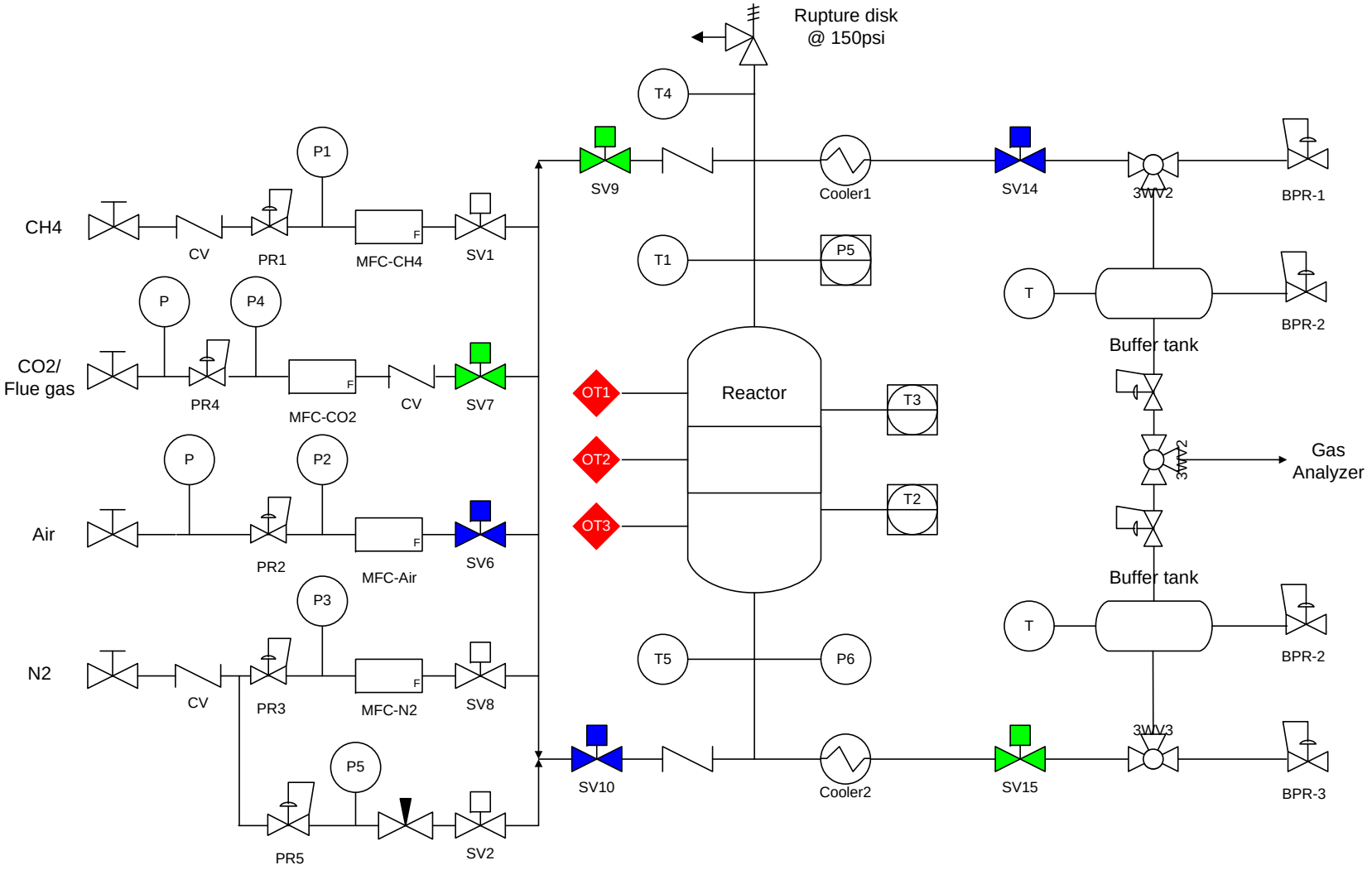
OBJECTIVES :

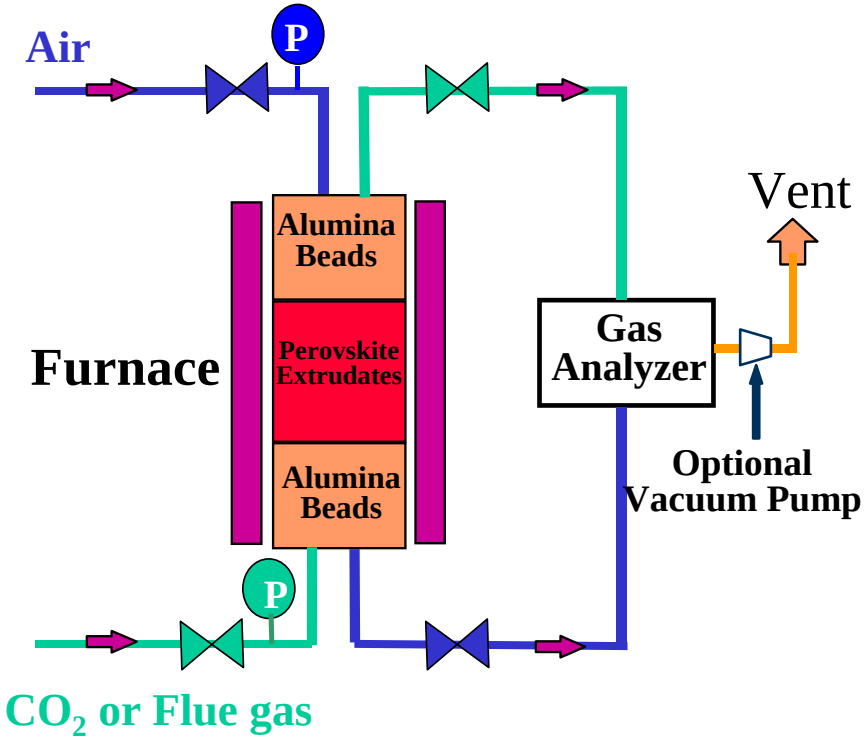
- Expose selected CAR perovskite materials in a small scale unit to the flue gas contaminants (SO_2, NOx, Hg etc) using a flue gas slip stream from the coal combustion test facility.

- Determine initial performance impact on the CAR materials to allow selection of a candidate for the CAR process development unit (0.7 tpd) integrated flue gas testing

CAR Small Scale Test Unit: Flow Schematic



CAR Small Scale Unit



- 1.5” ID x 6” packed height
- 200-400 grams perovskite sample
- Furnace helps maintain temperature
- Air flow for oxygen retention and storage
- Counter-current flows for CO_2 or recycle flue gas sweep/ regeneration option

Typical Cycle Sequence

	0									30									60
Bed A	O2 Retention									SR	Purge								

CAR Small Scale Unit

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Flue Gas Exposure Testing Schematic

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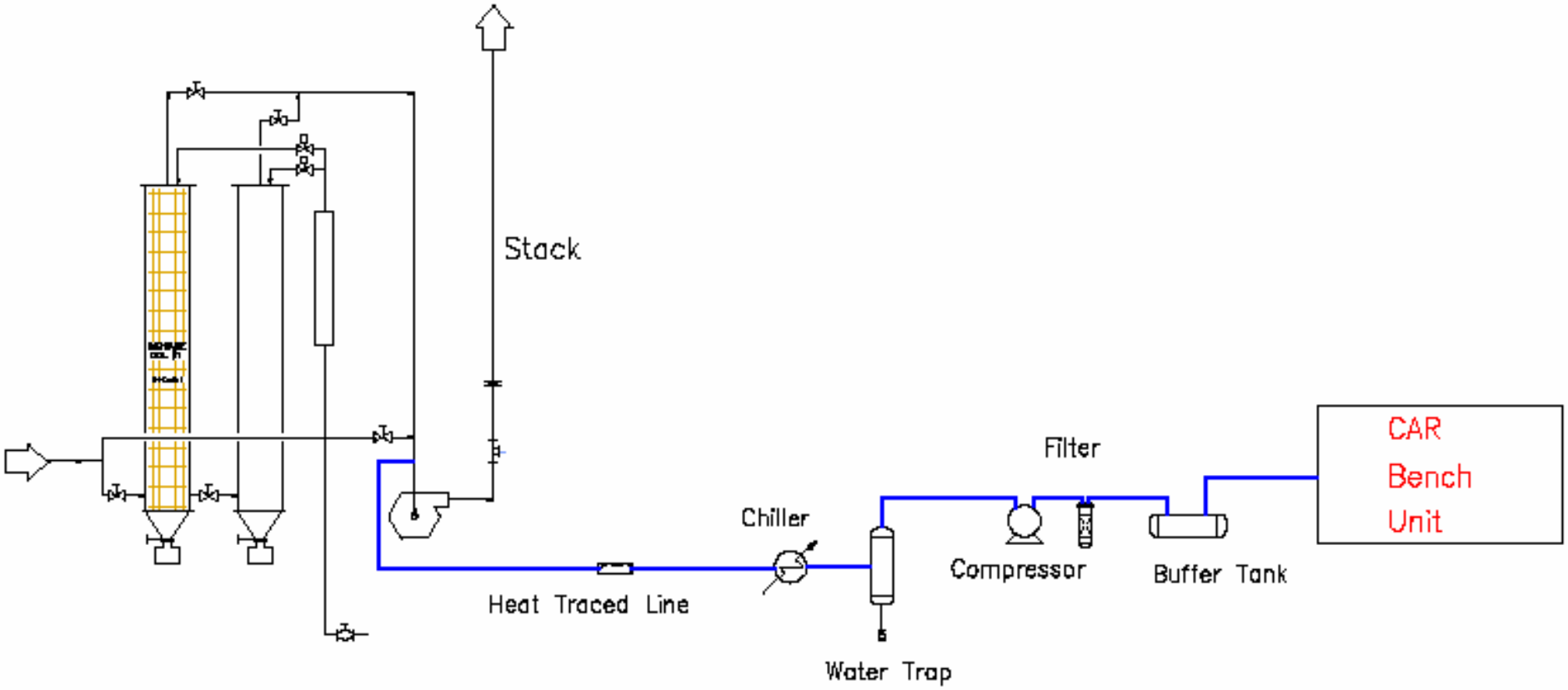

Preliminary Results and Observations

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- NO_X is released in the product stream from the small scale CAR unit

- SO_x is initially captured by the perovskite material, further testing is in progress to determine its distribution after material saturation. Characterization of the material following the contaminant exposure is planned after the testing is complete.

- Oxygen capacity on perovskite is affected, most likely by the reaction of SO_x with the material currently tested. Detailed assessment on the extent of capacity loss is currently in progress.

- Controlled testing of alternative perovskite material is planned to determine the material performance impact due to contaminant loading.

Concluding Remarks

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- Oxy-combustion is one of the leading option for coal-based power generation with CO_2 capture. Oxygen cost is a key factor affecting economics.

- Preliminary design and economic assessment of the CAR Process Technology for integrated high temperature O_2 generation in oxy-combustion shows that this approach offers promise for lowering capital cost and power consumption, if performance targets can be achieved.

- Perovskite material development for the CAR process has been progressed with European partners and has received funding under the EU 6th Framework program awarded to BOC Ltd, UK and European partners.

- A CAR process development unit has been fabricated and installed. Testing has been progressed for process validation and integrated oxy-combustion process testing with WRI's combustion test facility representing a coal-fired boiler. This project is supported by DOE-NETL through a cooperative agreement with The BOC Group, Inc. (Murray Hill, New Jersey) and partners. Based on success in this phase, plans have been developed for a pilot demonstration.

ACKNOWLEDGEMENTS

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