



NATIONAL ENERGY TECHNOLOGY LABORATORY



NETL's IGCC Dynamic Simulator Research and Training Center

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Outline of Presentation

- **Background & Motivation**
 - Benefits to Industry/CoalFleet
- **NETL IGCC DSR&T Center**
 - Project Overview, Schedule, and Current Status
- **NETL IGCC Dynamic Simulator**
 - Capabilities, Features, and Configuration
 - IGCC Reference Plant with CO₂ Capture
- **Future Plans**
 - Simulator Development, Testing, and Deployment
 - DSR&T Center: Research and Training Programs
- **Summary**

NETL IGCC Dynamic Simulator R&T Center

Enginomix Background

- **Modeling IGCC systems since 1982**
 - Off-Design IGCC systems modeling at Stanford University, 1981-86: based on Aspen with external FORTRAN unit models
 - Transient modeling of “Simplified IGCC” at GE R&D Center 1986-88
 - EPRI: web-based IGCC modeling project, based on IPSEpro
 - DOE: Off-design models of Polk and “generic” IGCC plant with IPSEpro
- **Original developer of GateCycle**
 - Design and off-design modeling of gas-turbine based power plants
 - Combined-cycle design/analysis software still in use at GE
- **Thermal & chemical systems modeling & economics**
 - IGCC & Biomass gasification with gas cleanup
 - Conventional coal boilers, flue-gas cleaning process design
 - Geothermal technologies (steam, ORC, Kalina)
 - Solar thermal cycle modeling
 - Advanced oxy-fueled combustion and GT cycles
- **Member ASME PTC 47 (Performance Test Code for IGCC)**

NETL IGCC Dynamic Simulator R&T Center

Motivation

- No operating commercial-scale IGCC-CCS systems
- Demonstrate integration of technologies (gasification, carbon capture and power generation)
 - critical need for education & experience with analysis, operation, and control
- DOE's restructured FutureGen approach aims to accelerate deployment of IGCC with carbon capture and storage (CCS)
- Proven advantages of developing and using dynamic simulation during early stages of complex project development



Polk IGCC Power Plant

NETL IGCC Dynamic Simulator R&T Center

Benefits to Industry

- Offer range of non-proprietary training courses on IGCC familiarization, operations, and control
- Present opportunity to license NETL's generic IGCC simulator for internal training purposes
- Provide a path for derivative works - reducing time, risk, and cost of developing plant-specific IGCC simulators
- Afford unique opportunity to collaborate with leading researchers from industry, academia, and government
- Encourage and train new generation of engineers in critically needed disciplines

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NETL IGCC Dynamic Simulator R&T Center

Project Overview

- **Mission**
 - “IGCC with CO₂ capture” research, demo, education, and training
- **Location**
 - Flagship research center at NETL
 - Training and education center at WVU’s National Research Center for Coal & Energy (NRCCE)
- **Operation**
 - NETL Institute for Advanced Energy Solutions (IAES)
 - Carnegie Mellon University
 - University of Pittsburgh
 - West Virginia University (WVU)
 - Collaboratory for Process & Dynamic Systems Research (CPDSR)
- **Funding**
 - DOE’s Fossil Energy Gasification Program



**NETL
Morgantown,
WV**

**NETL
IAES/
CPDSR**



**WVU/NRCCE
Morgantown,
WV**

NETL IGCC Dynamic Simulator R&T Center

Major Project Phases

- Phase I – Scoping Study (Complete: DOE/NETL-2008/1321)
- Phase II – Detailed Planning/Spec (Completed)
- Phase III – IGCC Dynamic Simulator Development (Starting)
- Phase IV – Acceptance Testing/Deployment at DSR&T Center
- Phase V – Establishment/Ongoing Support of DSR&T Center

	CY08				CY09				CY10			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Phase II			RFP	Award								
Phase III												
Phase IV												
Phase V												

NETL IGCC Dynamic Simulator R&T Center

Recently Completed Detailed Planning Phase

- **Identified and assembled collaboration team**
 - DOE/NETL, WVU, Enginomix, FCS, EPRI, CoalFleet funders
- **Completed market research survey**
 - Potential bidders (e.g., Software vendors, A&E firms)
 - Other interested parties (e.g., CoalFleet funders)
- **Identified IGCC reference plant**
 - Case #2 (IGCC w/ CO₂ Capture): DOE/NETL-2007/1281
- **Developed IGCC process descriptions and conducted independent technical review**
 - Enginomix & Fossil Consulting Services, Inc. (NETL) – prime contractors
 - Energy Resources Consultancy (NETL) – Jerry Henderson (Polk IGCC)
 - Gasification Solutions (NETL) – Carlo Wolters & Marco Kanaar
 - Gas Processing Solutions (EPRI) – Dan Kubek
- **Prepared functional specification for IGCC simulator**
- **Issued RFP through NETL Acquisitions**
- **NETL awarded contract - September 2008**

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NETL IGCC Dynamic Simulator

Capabilities and Features

- **Plant-wide IGCC dynamic simulator**
 - Generic IGCC plant fueled by coal and/or petroleum coke
 - Process-side (gasification and gas cleaning with CO₂ capture)
 - Power-block-side (combined cycle)
- **High-fidelity, real-time, dynamic simulation**
 - Adequate model fidelity to verify operating procedures and general plant transients
 - Slow (0.5X), real-time, and fast time (5-10X) performance modes
- **Full-scope training simulator**
 - Start-ups (cold, warm, hot), shutdowns, and load changes
 - Normal, abnormal, and emergency operating conditions
 - Response to fuel and ambient condition variations
 - Full DCS emulation and control strategy analysis
 - Instructor capabilities, scenarios, trending, snapshots, etc.

NETL IGCC Dynamic Simulator

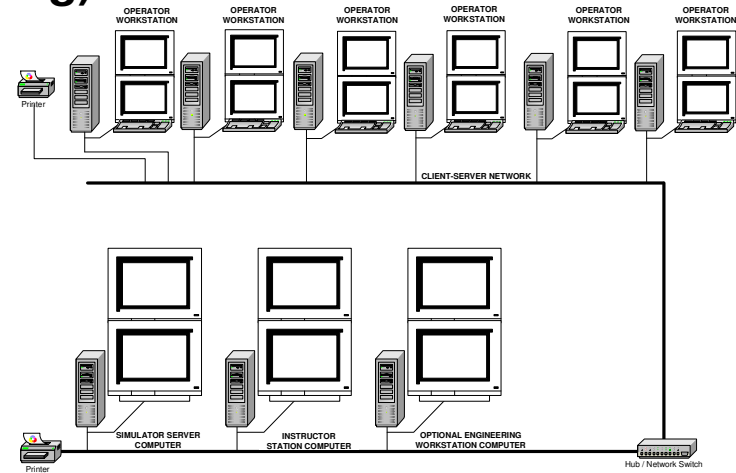
Capabilities and Features

- **Simulator Configuration**

- Single, integrated IGCC dynamic model
- Multiple, independent dynamic models consisting of, at a minimum, separate models for :
 - Coal/coke gasification with CO₂ capture
 - Gas-turbine-based, combined-cycle plant

- **Simulator Architecture (Minimum Config)**

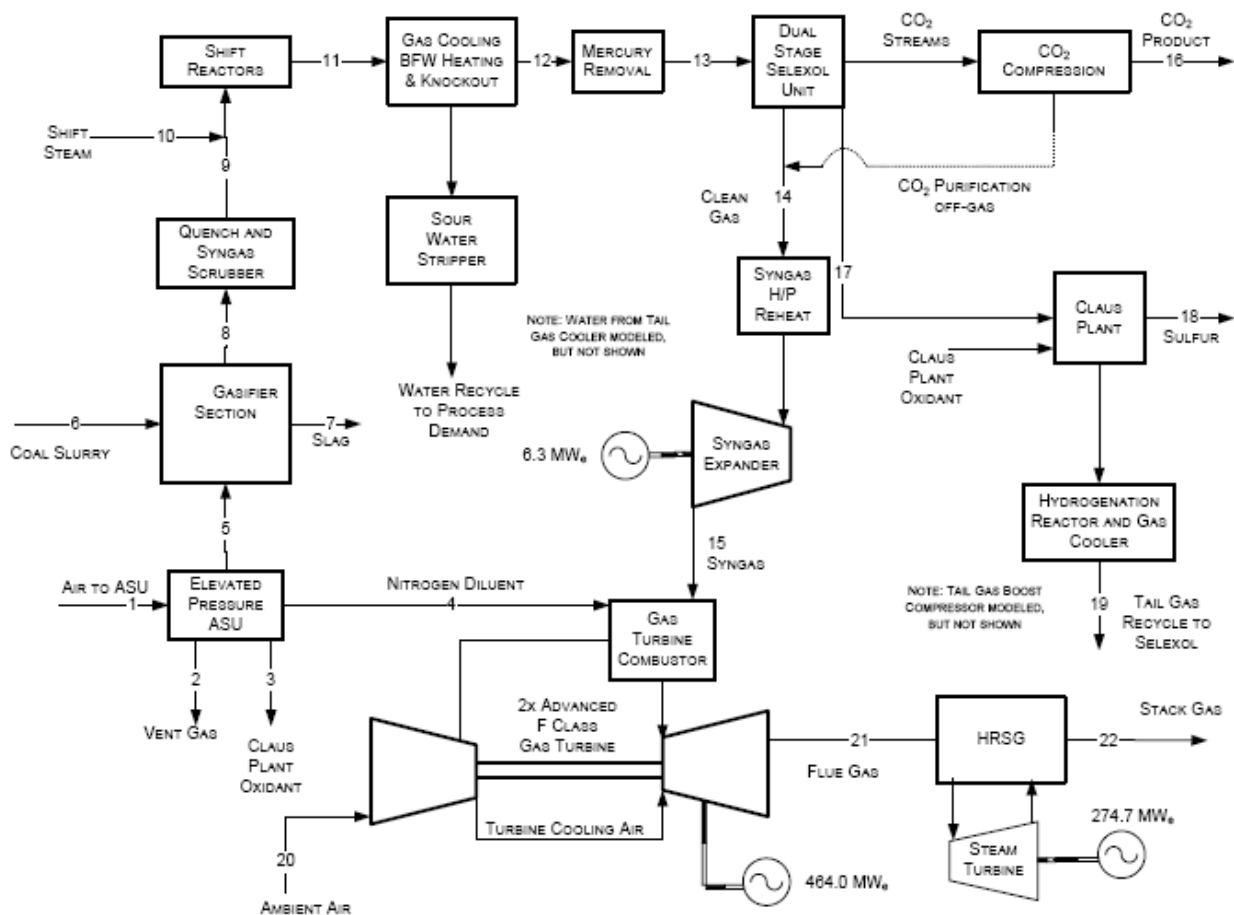
- Six operator workstations
- Simulator server computer
- Instructor station computer
- Optional engineering workstation computer
- Allows for the training of 12 people or more



**NETL IGCC Simulator Architecture
(Minimum Configuration)**

NETL IGCC Dynamic Simulator

IGCC Reference Plant with Carbon Capture



Source: Case #2 from DOE/NETL Report -2007/1281

NETL IGCC Dynamic Simulator

IGCC Reference Plant with Carbon Capture

Baseline Case	IGCC Case #2
Fuel	Illinois #6 Coal
Oxidant	95 vol% Oxygen
Gasifier	Slurry-Fed Entrained-Flow
H₂S Separation	Selexol 1st Stage
Sulfur Recovery	Claus Plant
CO₂ Separation	Selexol 2nd Stage
Gas Turbine	2 Adv. F Class (232 MW output each)
Subcritical Steam Cycle	1,800 psig/1,000°F/1,000°F
Power Output	746 MW gross (556 MW net)

“Cost and Performance Baseline for Fossil Energy Power Plants Study, Volume 1: Bituminous Coal and Natural Gas to Electricity,” National Energy Technology Laboratory, www.netl.doe.gov, August 2007.

NETL IGCC Dynamic Simulator

Process Descriptions

For detailed functional specification, process descriptions and control strategies were developed for key plant sections:

- Slurry Preparation
- Air Separation Unit
- Gasifiers
- Syngas Scrubbers
- Shift Reactors
- Gas Cooling, Medium Pressure (MP) and Low Pressure (LP) Steam Generation, and Knockout
- Sour Water Stripper
- Mercury Removal
- Selexol™ Acid Gas Removal System
- CO2 Compression
- Syngas Reheat and Expansion
- Claus Plant
- Hydrogenation Reactor and Gas Cooler
- Combustion Turbine (CT)-Generator Assemblies
- Heat Recovery Steam Generators (HRSGs) and Steam Turbine (ST)-Generator

“DOE/NETL IGCC Dynamic Simulator Research and Training Center, Volume 2: IGCC Process Descriptions,” DOE/NETL-2008/1324, June 30, 2008.

NETL IGCC Dynamic Simulator

Process Descriptions

- **Purpose**
- **Component List**
- **Overall Description of Process**
- **Modeling Expectations**
- **Controls and Instrumentation**
- **Malfunctions**
- **System Interconnections**
- **Startup Considerations**
- **References Used for Development**
- **Representative Process Schematic/P&ID**

“DOE/NETL IGCC Dynamic Simulator Research and Training Center, Volume 2: IGCC Process Descriptions,” DOE/NETL-2008/1324, June 30, 2008.

NETL IGCC Dynamic Simulator

Modeling Fidelity

PROCESS/SYSTEM NAME	High Fidelity Model	Limited Fidelity Model	Comments
Air Separation Unit	X		
Slurry Preparation	X	X	<i>Chemistry model may be limited fidelity</i>
Gasifiers	X	X	<i>Chemistry model may be limited fidelity</i>
Quench and Syngas Scrubbers	X	X	<i>Chemistry model may be limited fidelity</i>
Shift Reactors	X		
Gas Cooling, MP and LP Steam Generation and Knockout		X	
Sour Water Stripper		X	
Mercury Removal System		X	
Dual Stage Selexol Unit (AGR with CO₂ Capture)	X	X	<i>Chemistry model may be limited fidelity</i>
Syngas Reheat, Expansion, and Combustion	X	X	<i>Chemistry model may be limited fidelity</i>
CO₂ Compression	X		
Claus Plant	X		
Hydrogenation Reactor and Gas Cooler	X		

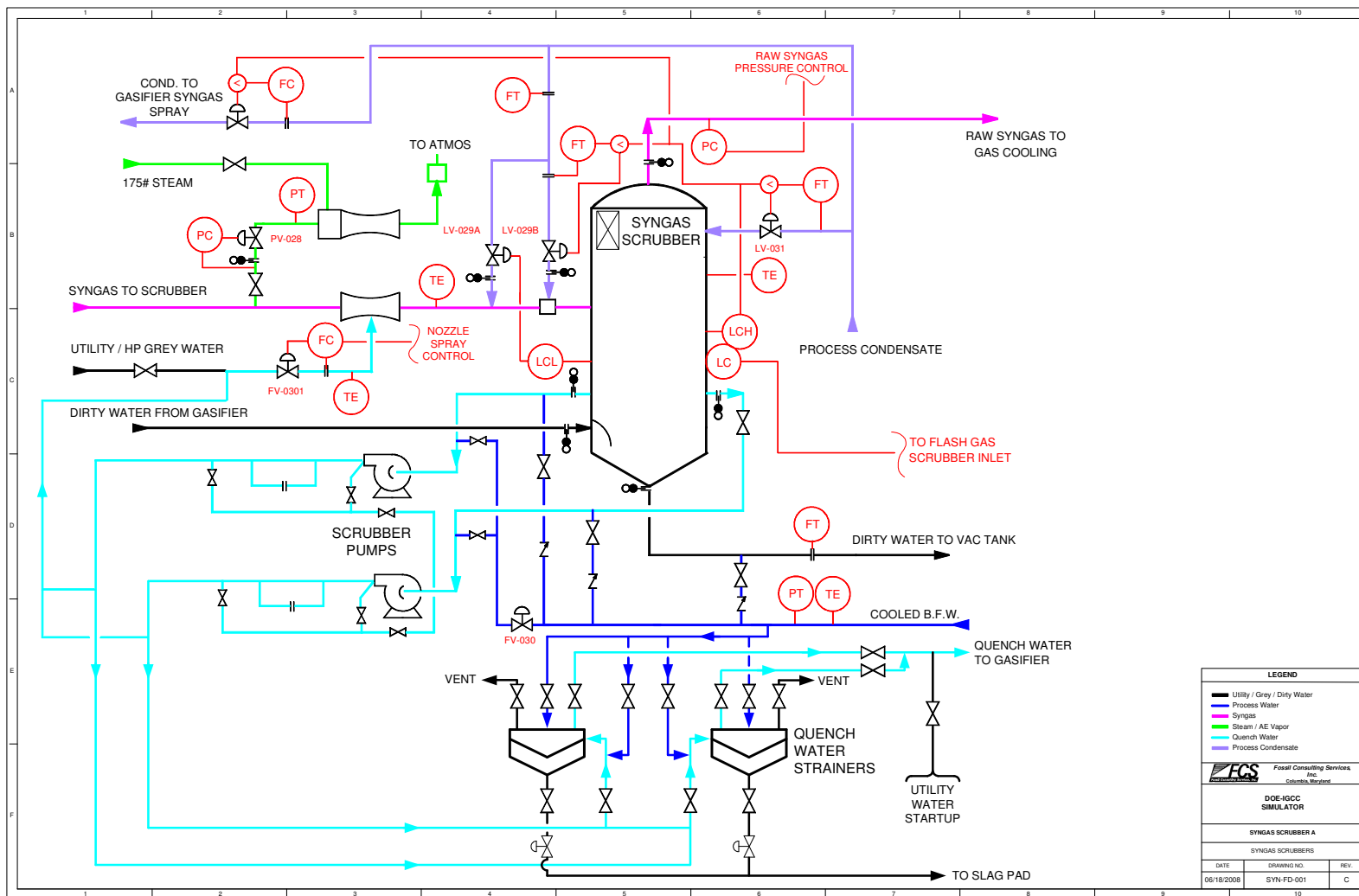
NETL IGCC Dynamic Simulator

Representative Malfunctions

SYSTEM	MALFUNCTIONS
Gasifiers	<ol style="list-style-type: none"> 1. <i>Ignition Failure</i> 2. <i>Ignition indication false positive</i> 3. <i>Gasifier feed control valve failures</i> 4. <i>Improper Coal / Air Ratio</i> 5. <i>Gasifier Emergency Shutdown</i> 6. <i>Slurry Charge Pump inlet or outlet valve</i> 7. <i>Hi/Lo RSC Drum Level problems including trips (Emergency Shutdown System)</i> 8. <i>Loss or low RSC Steam Drum Circulation Flow Trip (loss of circ pumps)</i> 9. <i>Injector cooling coil leak and or trip</i> 10. <i>RSC sump level trip</i>
Quench and Syngas Scrubber	<ol style="list-style-type: none"> 1. <i>Failure of Scrubber Pump</i> 2. <i>Improper Syngas Scrubber Level (High or Low)</i> 3. <i>Nozzle Scrubber Failure</i> 4. <i>Improper Nozzle Scrubber Spray</i> 5. <i>Quench Strainer Plugging</i>
Shift Reactors	<ol style="list-style-type: none"> 1. <i>Catalyst Exhaustion</i> 2. <i>Low Shift Reactor Inlet Temperature</i> 3. <i>Loss of, or Improper Feedwater Flow to the Shift Gas Reactors</i> 4. <i>Gas Piping / Component Leakage</i> 5. <i>Component Failures., eg improper output analyzers, malfunctioning of pumps</i> 6. <i>Process Control Failures (TBD), valve position indicators, control valve suddenly on manual</i>

NETL IGCC Dynamic Simulator

Representative Process Schematic



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NETL IGCC Dynamic Simulator

Development, Testing, and Deployment

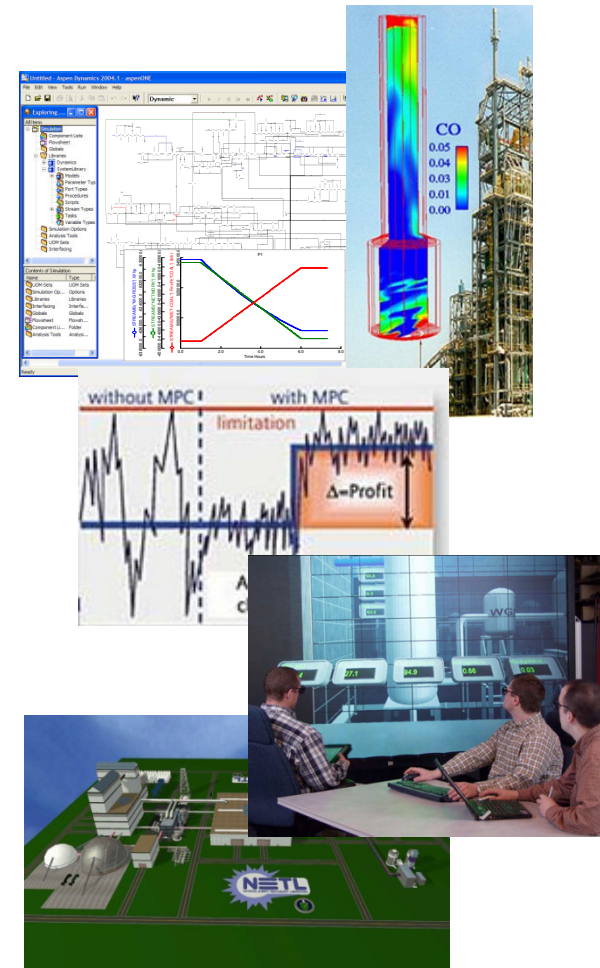
- **Phase III: Simulator Development**
 - 18 month development period
 - Monitor progress and evaluate completion of milestones and deliverables
 - Leverage participation of collaboration partners
- **Phase IV: Testing/Deployment at DSR&T Center**
 - Factory Acceptance Test
 - Leverage collaborator experience
 - Simulator personnel training including instructor training and engineer/modeler training
 - Deployment of simulator at NETL and WVU/NRCCE
 - Site Acceptance and Availability Tests

NETL IGCC Dynamic Simulator R&T Center *Training Program*

Potential Courses	Audience	Anticipated Length
IGCC Orientation for Engineers and Managers	Technical personnel investigating the feasibility of IGCC plants	3 Days to One week
Introduction to IGCC Operations	New or inexperienced IGCC operators	Two weeks
IGCC Operator Course	New or inexperienced IGCC operators	One week
Principle of IGCC Design and Operations for Engineers	Utility engineers who will be involved in the procurement, installation, design oversight and commissioning of IGCC plants	Two weeks
Combined Cycle Operations	Operators, supervisors and managers at combined cycle plants	One week
Gasification Process Operations	Operations personnel whose interest is in the gasification and carbon capture processes	One week

NETL IGCC Dynamic Simulator R&T Center *Research Program*

- **IGCC-CCS R&D Projects**
 - High-fidelity dynamic equipment modeling
 - Gasification
 - CO₂ capture
 - Advanced process control
 - Virtual plant simulation
 - VE-Suite
- **Future Simulator Projects**
 - Polygeneration plants
 - Gas turbine/fuel cell hybrids
 - Chemical looping systems
 - Additional gasifier technologies



NETL IGCC Dynamic Simulator R&T Center

References for Additional Information

- **Papers**

- Provost, G.T., M.R. Erbes, H.P. Stone, S.E. Zitney, R. Turton, J.N. Phillips, M. Quintrell, M. McClintock, and J. Marasigan, “Generic Process Design and Control Strategies used to Develop a Dynamic Model and Training Software for an IGCC Plant with CO₂ Sequestration,” To appear in *Proc. of the 25th Annual International Pittsburgh Coal Conference*, September 29 – October 2, Pittsburgh, PA (2008).
- Erbes, M.R. and S.E. Zitney, “Dynamic Simulation and Training for IGCC Power Plants,” *Proc. of the 23rd Annual International Pittsburgh Coal Conference*, September 25-28, Pittsburgh, PA (2006).

- **Presentations**

- M. Erbes, S. Zitney, and R. Turton, NETL IGCC Dynamic Simulator Research and Training Center Project, Accepted for presentation at 2008 Gasification Technologies Conference, Washington D.C., USA, October 5–8 (2008).
- Zitney*, S.E. and M.R. Erbes, “IGCC Dynamic Simulator and Training Center,” Presented at *Gasification Technologies 2006 Conference*, October 1-4, Washington, D.C. (2006).

- **NETL Reports**

- Fact sheet available on NETL web site (www.netl.doe.gov)
- DOE/NETL IGCC Dynamic Simulator Research and Training Center, Volume 2: IGCC Process Descriptions, DOE/NETL-2008/1324, June 30, 2008.
- DOE/NETL IGCC Dynamic Simulator Research and Training Center, Volume 1: Scoping Study, DOE/NETL-2008/1321, May, 2006.
- Cost and Performance Baseline for Fossil Energy Power Plants Study, Volume 1: Bituminous Coal and Natural Gas to Electricity, www.netl.doe.gov, DOE/NETL-2007/1281, August 2007.
- Developing NETL web pages for NETL IGCC DSR&T project

NETL IGCC Dynamic Simulator R&T Center

Summary/Benefits

- Satisfy industry need for education and experience with analysis, operation, and control of commercial-scale IGCC w/ carbon capture
- Provide NETL Collaboratory for Process & Dynamic Systems Research with a world-class IGCC research, training, and education resource
- Encourage and train a new generation of engineering students to enter into the field
- Serve as a focal point for collaborative IGCC research and development with universities, software and service providers, and the power and energy industries
- Accelerate development of advanced process and dynamic systems modeling technology to better achieve the aggressive goals for design, operability, and controllability of high-efficiency, zero-emission power plants



Thank You!

Questions?

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