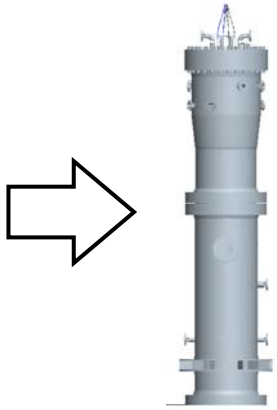
# Compact Gasification Development and Test Status



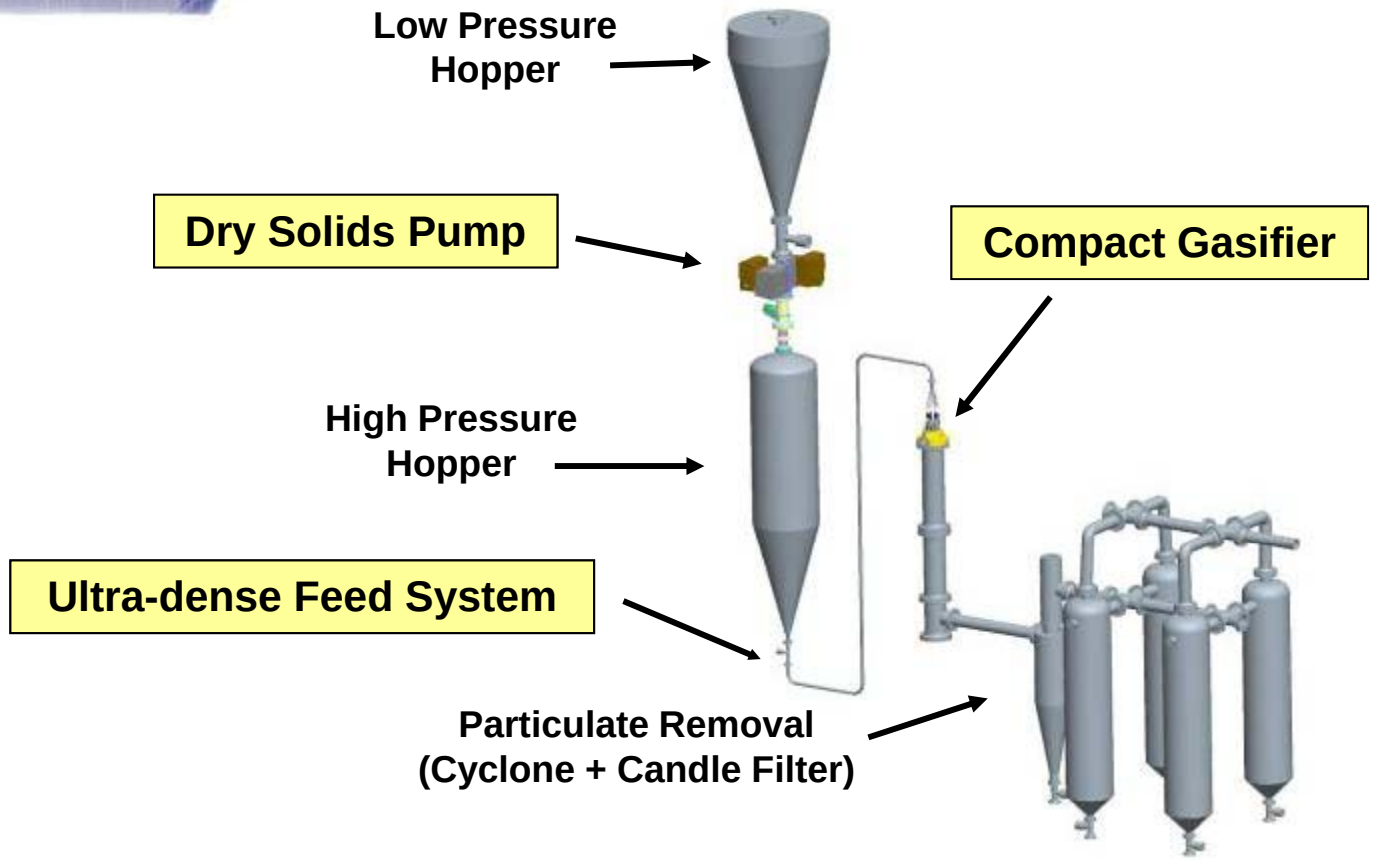
**Steve Fusselman**
**Gasifier Lead**

**Pratt & Whitney Rocketdyne**
**A United Technologies Company**

**GTC Annual Conference**
**October 2011**

**Leveraging 50 Years of Rocket Engine Experience to Reduce Cost and Improve Plant Performance**

# Key Design Features of the Compact Gasification System




- Yellow Items are Key Development Items
- Other Items are Commercially Available

# Gasifier Development Partners

- **PWR has teamed with ExxonMobil Research and Engineering (EMRE) to develop and commercialize the technology**
- **Alberta Innovates: Energy and Environment Solutions (EES) is cost-sharing definition of a demo plant for an Alberta location and funding tests with Alberta feedstock**
- **Zero Emission Energy Plants, Inc. (ZEEP) is a commercial launch customer with a global license for use of PWR technology in gasification plants**

# Pilot Plant Gasifier Test Program

Pratt & Whitney
A United Technologies Company

**Pilot Plant at the Gas Technology Institute**

- **Started Dec 2009**
- **18 tons per day**

**Injector**

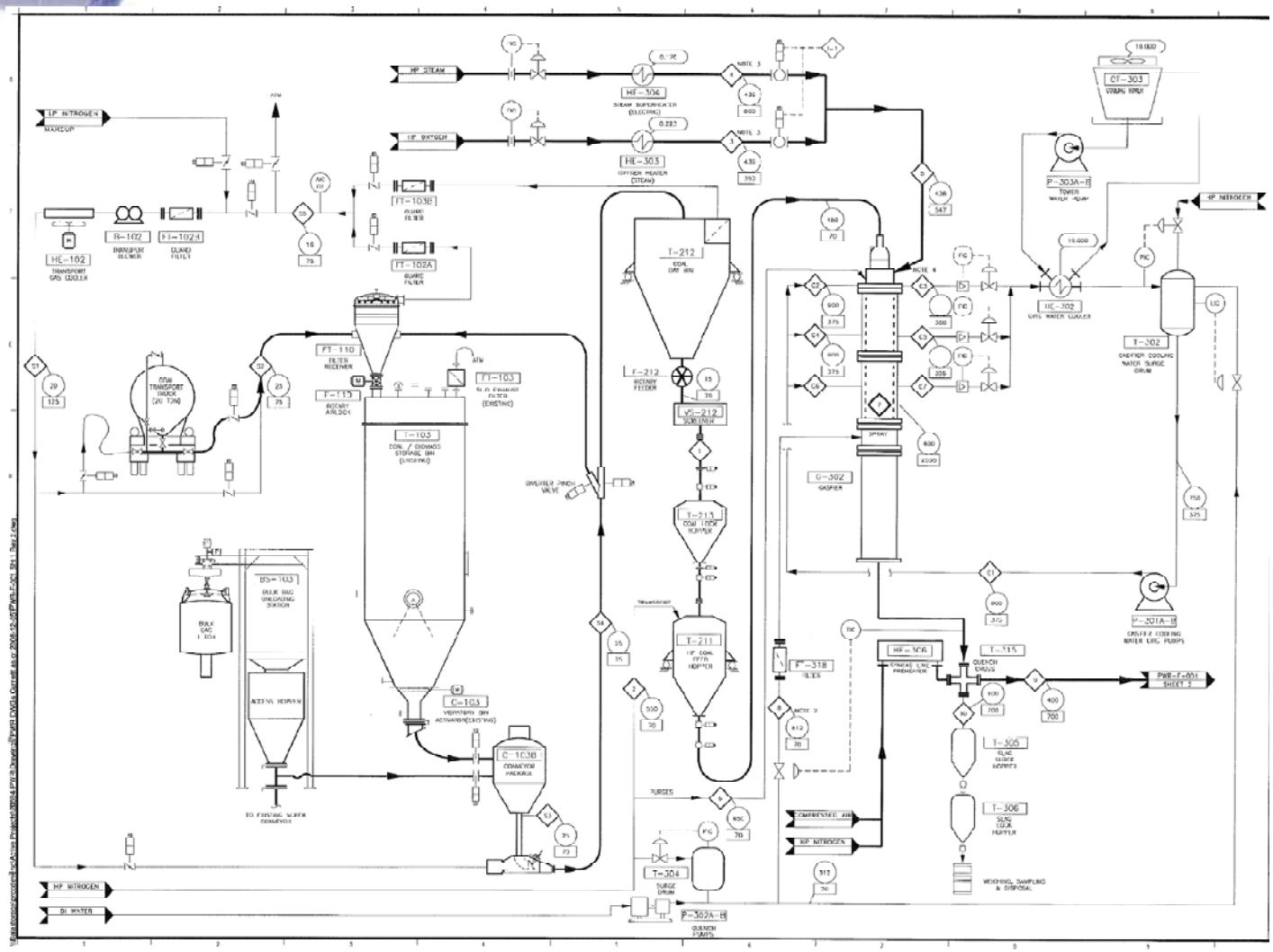
**Gasifier**

## Test Objectives Completed

- **Demonstrated performance**
  - **99% carbon conversion**
  - **High cold gas efficiency**
  - **Formed protective slag layer**
  - **Demonstrated particulate removal**
  - **Tested 4 feedstocks**
- **Verified operating environments**
- **Validated computer models**
- **Obtained preliminary life data**
- **Established operating procedures**

**764 hours Hot-Fire Testing through April 2011**

# Pilot Plant Gasifier Facility
# Process Flow Diagram



# Pilot Plant Gasifier Successfully Processed Range of Feedstocks

Pratt & Whitney
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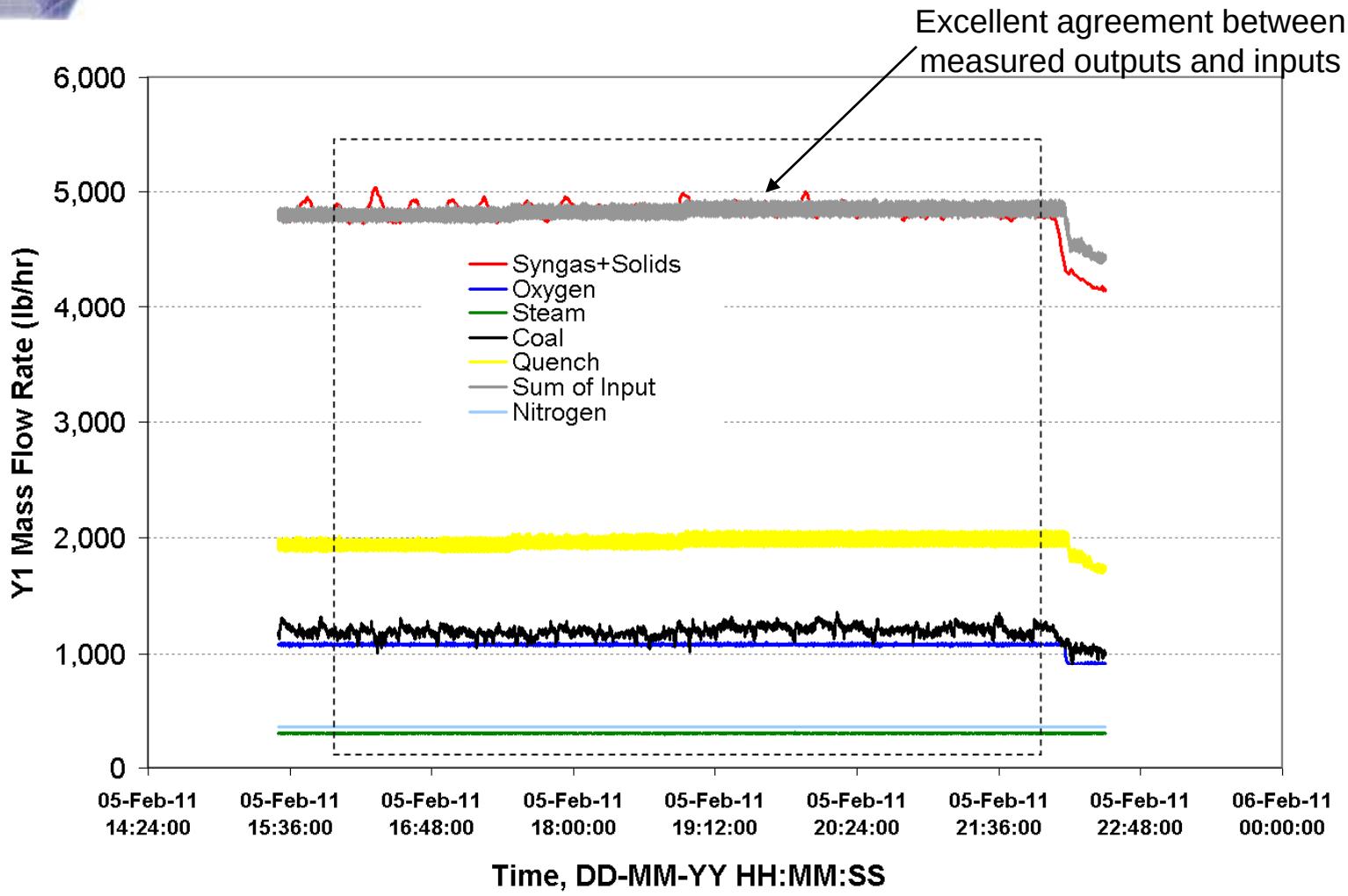
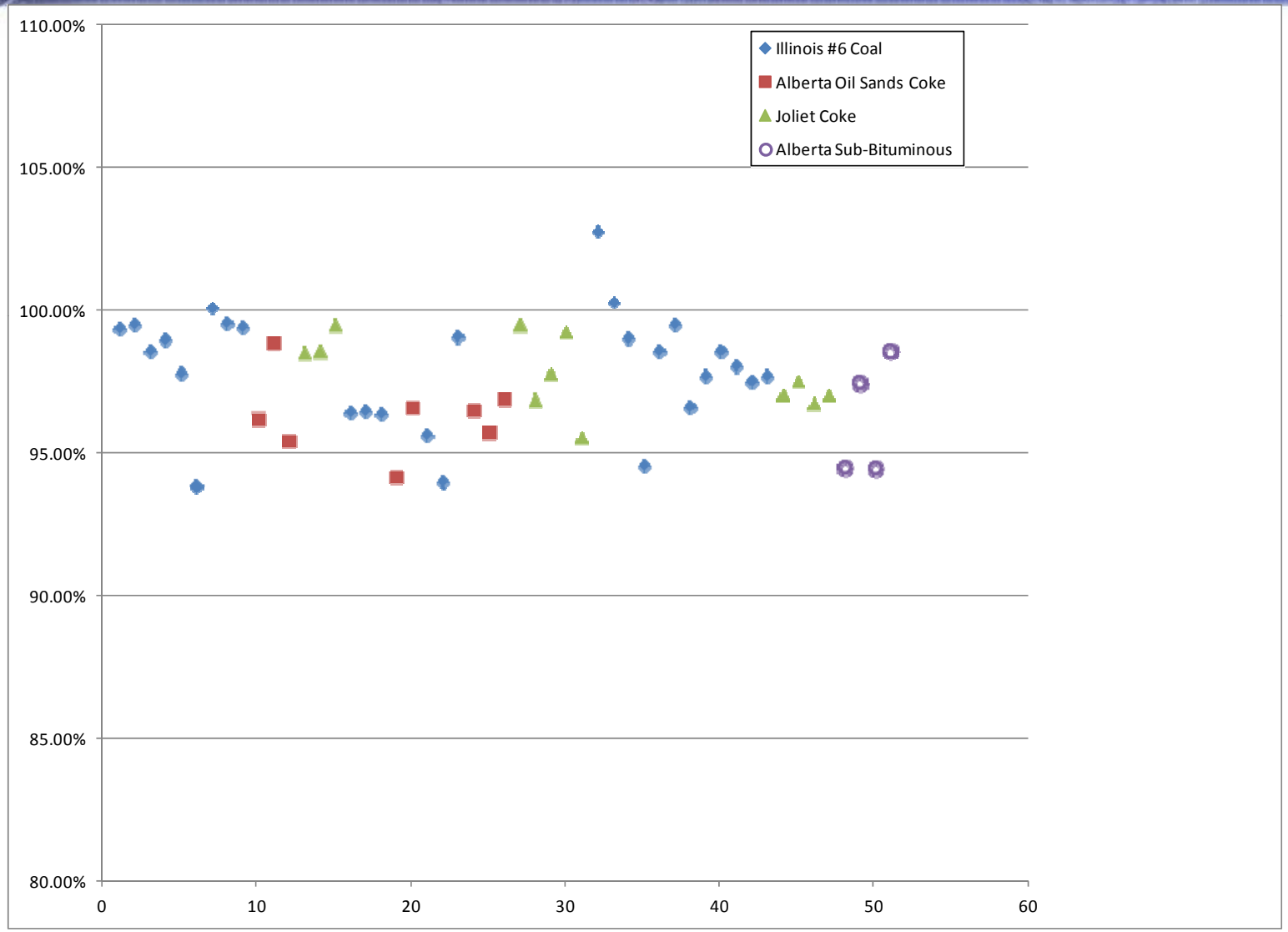
| | Illinois #6 Coal | Oil Sands Petcoke | Joliet Petcoke | Alberta sub-bit coal |
|---|---|---|---|---|
| Proximate Analysis (wet) | | | | |
| Moisture Content, % | 5.73 | 0.43 | 0.23 | 7.46 |
| Volatile Matter, % | 37.35 | 13.29 | 12.26 | 28.52 |
| Ash, % | 9.32 | 3.21 | 0.3 | 23.86 |
| Fixed Carbon, % | 47.6 | 83.07 | 87.21 | 40.16 |
| Total | 100 | 100 | 100 | 100 |
| Ultimate Analysis (dry) | | | | |
| Ash | **9.89** | **3.23** | **0.3** | **25.78** |
| C | 73.68 | 84.55 | 88.66 | 57.66 |
| H | 4.96 | 3.47 | 3.79 | 3.4 |
| N | 1.32 | 1.59 | 1.64 | 0.85 |
| S | 3.46 | 6.47 | 6.45 | 0.17 |
| O | 6.69 | 0.69 | 0 | 12.14 |
| Total | 100 | 100 | 100.84 | 100 |
| HHV, Btu/lb (dry) | 12,690 | 14630 | 15070 | 9869 |
| Slag Fluid Temp, °F | **2270** | **2660** | **2600** | **2656** |

**PWR gasifier technology successfully gasified very high ash content, high fluid temp Alberta sub-bituminous coal**

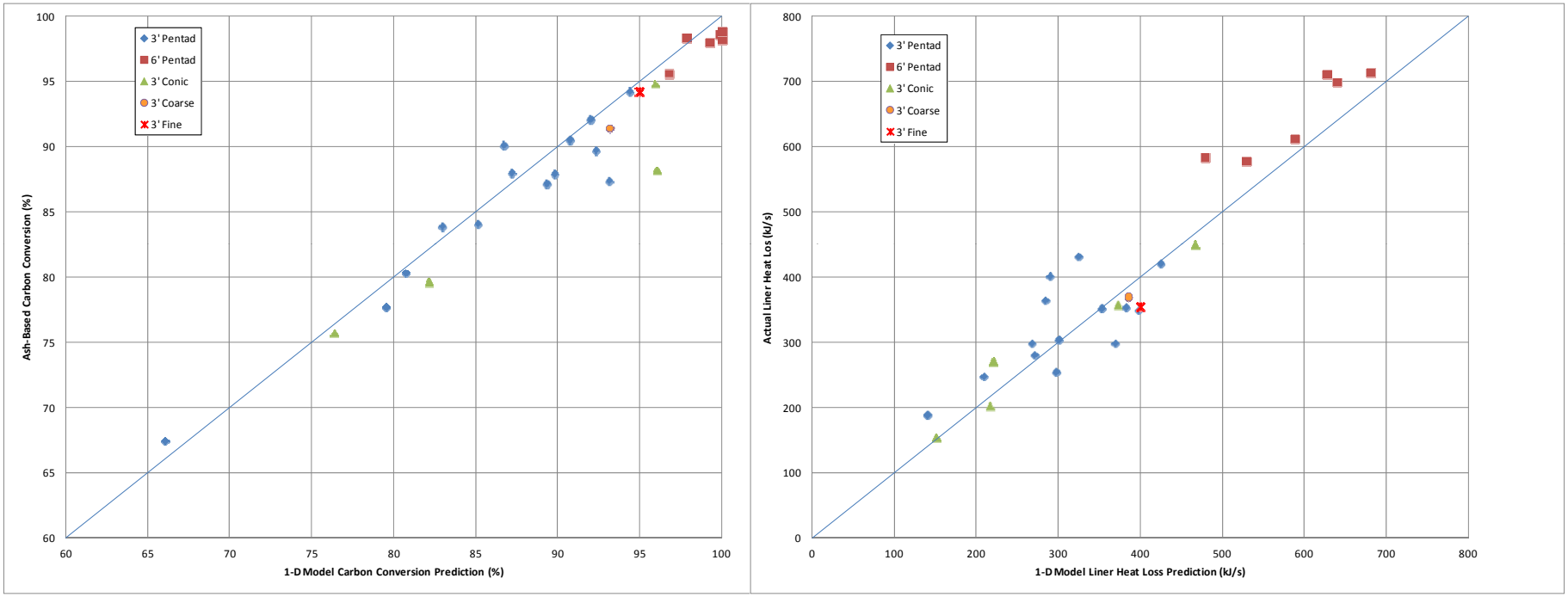
# Excellent Mass Balance Closure Typical Over 6-Hour Mass Balance Period



# Excellent Raw Mass Balance Data Observed Throughout Testing



# Pilot Plant Data Anchors Gasifier Models Over Wide Operating Range

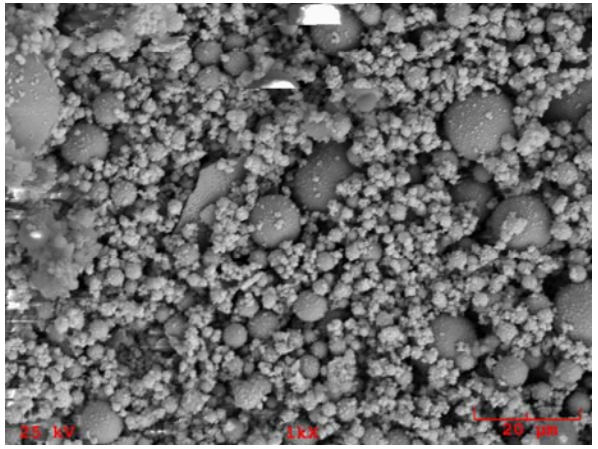



- **Models anchored to 53 operating points with 4 feedstocks**
- **1-D kinetic model for carbon conversion and heat load predictions**
- **CFD model as scale-up and design tool**
- **~0.1 sec residence time reactor - not optimized for high conversion**

# Protective Slag Layer Formed on Liner Surface

**Slag layer retained after 38 hours on low ash petcoke**
**(view looking down from gasifier injector)**

**Coarse slag from Alberta sub-bit**



**Alberta sub-bit cyclone fines (magnified 1000x)**

# Pilot Plant Gasifier Achieved Technical Objectives

Pratt & Whitney
A United Technologies Company

| Objective | Prediction | Results | Impact |
|---|---|---|---|
| Carbon Conversion | 90% (0.1 sec residence time) | 91% | Validates >99% conversion at commercial scale. |
| Heat Loss | < 3 MMBTU/hr | < 1 MMBTU/hr | Heat flux within design limits.<br>CGE benefit at comm'l scale. |
| Multiple Feedstocks Tested | 3 | 4 | Feedstock flexibility demonstrated on petcoke, bituminous, sub-bituminous. |
| Test Data Points | >27 | 53 | Supports CFD model validation. |
| Component Test Time | >400 hours | >400 hours liner<br>>700 hours injector | Slag layer formed.<br>Environments consistent with life goals. |
| Particulate Removal | | Non-leachable fines | Environmentally benign slag/fines streams. |
| Operations | | < 10 minute start-up time | Fast response.<br>Safety system demonstrated. |

# Results Validate PWR Compact Gasification System Benefits

Pratt & Whitney
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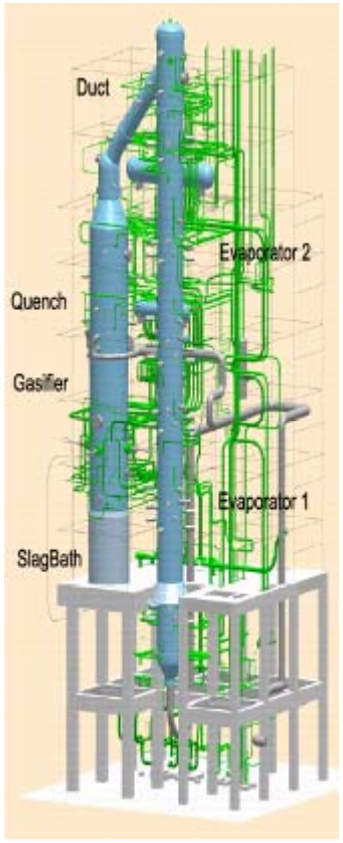
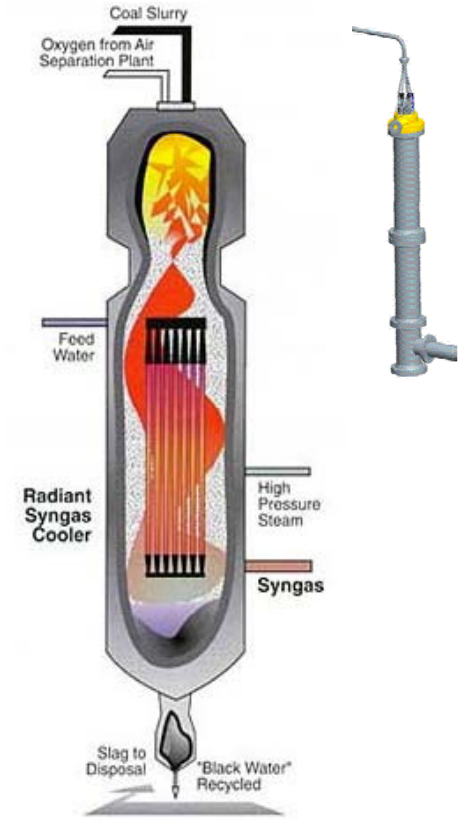
## Current Market Leaders




Source: Shell paper (2004)

## Compact Gasification System

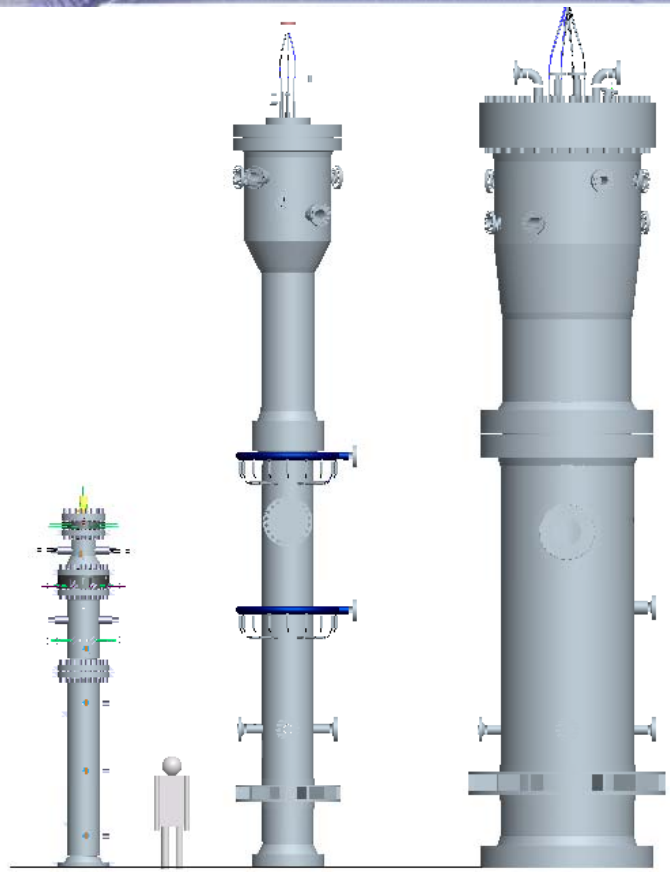



Source: DOE paper (2006)

- 90% size reduction (gasifier)
- 50% lower capex (gasification system)
- 2 yr burner, 10 yr liner life look feasible
  - Supports > 99% gasifier availability
- > 99% carbon conversion demonstrated
- +3-4% CGE vs. other dry feed gasifiers
- Dry feed system to gasify all ranks of coal, petcoke and biomass blends

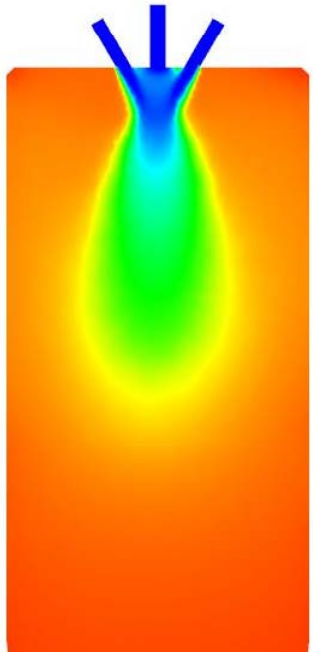
**Results validate 20%-25% cost of product reduction from NETL, Jacobs studies**

# Demonstration Plant Gasifier Design Is In Progress



**Pilot Plant 18 TPD** | **Demo Plant 400 TPD** | **Commercial Plant 3,000 TPD**

- **CFD design tool validated with pilot plant data**
- **Advancing demonstration plant gasifier design**



# Acknowledgement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- **However, the opinions, findings and conclusions expressed herein are those of the authors**


# Questions?