DRY SOLIDS PUMP
COAL FEED TECHNOLOGIES

DOE/NETL Cooperative Agreement DE-FE0012062

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Program Background

US Department of Energy (DOE) funded AR to develop:

- “A commercial solids pump as soon as possible”

Recognizing:

- Need for gasifier commercial solids pump capable of 500-1,000 PSI injection
  - To reduce capital cost of Integrated Gasification Combined Cycle, Coal-to-Chemical and Coal-to-Liquid gasification based plants

- GTC analysis shows significant gasification growth to 2030 and beyond
  - Electric utilities in EPRI “Coal Fleet” voted solids feeding as # 1 priority for successful commercialization of gasification plants
  - Opportunity represents several 100’s solids pumps

Target date for availability of commercial pumps around 2017
Program Objectives

Overall:
• Develop a solids pump that meets AR “Compact Gasifier” requirements
  - 1200 psi, 400 TPD (demonstration)
• Develop a solids pump meeting commercial gasification industry requirements
  - 500 psi, 600 TPD

Current Program:
• Design, develop, manufacture and test a prototype solids pump capable of “Commercial scale” feed rate
• Test prototype to allow design optimization for commercial solids pump

Future:
• Manufacture and supply a solids pump for commercial validation
• Commence production of solids pumps for commercial sale
Program Technical Approach

• Design prototype at “commercially defined” size
  - 400 TPD Nominal, 600 TPD Maximum
• Utilize commercial components to maximum extent possible
• Utilize a manufacturing integrator for ensuring machine produceability

• Evaluate and test with commercially selected and supplied feed-stocks:
  - Initially Illinois #6 and Powder River Basin coals,
  - Then lignite, Pet Coke and coal/biomass blends
Coal Feed Testing Program

To validate commercial-scale feeding system for gasifier demonstration plant

Feed Distribution System (Completed)
• Capability tested at 600 TPD (2010)

Solids pump (Underway)
- Discharge 400+ TPD at 1,200 psi
- Standard “Utility” grind PSD
  - Testing multiple feed-stocks

Ultra-dense flow transport (no plugging)
Flow splitters (uniform distribution)
Pump (accurate injection)
Pump Operation

- “Caterpillar” track moving walls forming parallel sided duct
- Operation based on “solids lock-up” physics which achieved coal injection into 1,000 PSI in prior DOE-funded tests
- Design uses “solids plug” gas seal also proven in prior DOE-funded research
- “Linear” concept offers advantages over rotary solids pump:
  - Higher energy efficiency
  - Simply scalable to large capacities
  - Feed material flexibility
Prototype Pump Configuration

- Hopper Flange
- Inlet Isolation Valve
- Mounting
- Microwave sensors
- Hydraulic Motors
- Fines Bins
- Outlet Pressure Vessel
- Outlet Isolation Valve
- Gasifier System Flange

Pump Weight: 50 MT
Pump Height 5.3 m
Pump Power 750 Kw (2 x 375 Kw)
Pump Internal Components

- System Pressure
- Coal Duct
- Wear Tiles
- Internal Strong-back
- Track Assemblies (2)
- Tensioner System
- Drive Sprocket
- Outlet Comprising:
  - Gas Seal Duct
  - Deconsolidation Zone
  - Gas Check Valve
Pump Manufacture & Installation
Pump Installed in EERC Test Stand
Prototype Testing

- Shake-down testing initiated 2012
  - Validated controls system and mechanical operation and characterization
  - Confirmed fundamental operating criteria
  - Identified performance limitations on certain components

- Modified select internal components for improved performance 2013
  - Fines sealing around moving components
  - Component clearance reductions for gas seal improvement
  - Fines clearing and removal system upgrades

- Pump start-up and operation procedures developed

- DOE contract concluded end 2013
Coal Feed Technologies, CFT Program

Follow-on CFT program agreed with DOE with completion late 2016

Target 500 hours of prototype operation addressing:

- Short-term testing at pressures up to 300 PSI
- Performance mapping tests to understand and control upset conditions
- Additional feedstock tests to validate pump operation with wider range of fuels
- Long duration testing at pressures up to 1200 PSI
- Define prototype component modifications for commercial pump design
CFT Program Prototype Testing

Testing undertaken to confirm:

- Pump loading and seal plug formation
- Seal plug permeability/leakage
- Feeding at 50 t/hour into 100 psi

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**III#6 - Plug Generation**

1 scfm Sparge Gas, 3.5 RPM/min - Target 40,000 ft-lbf

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**CTB-2b - 15 PSIG III#6 - 1 scfm Sparge Gas**

1 RPM/0.092 ft/sec - 40 Hz Blower Motor

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**HPTA-1-15-55-2 - Cut on Torque - 45 seconds short of Hopper Duration**

1 RPM/0.092 ft/sec - 40 Hz Blower Motor
CFT Prototype Operational Issues

Coal consolidation impacted by flow discontinuity

Coal accumulation on drive sprockets affects track trajectory

Tile-to-Tile Leak paths

Coal consolidation impacted by flow discontinuity

Coal accumulation on drive sprockets affects track trajectory

0 10 20 30 40 50 60 70 80 90 100

Scraper Strain (uin/in), Tensioner Pres (psig)

Ave Torque
East Corner Strain
East Center Strain
West Tensioner Pres

ETS-2 - 15 PSIG IIM6 - 1 scfm Sparge Gas
10994/0.003 ft/sec - 30 Hz Blower Motor

GTI
CFT Program Initial Results

Pump fundamentals demonstrated in CFT Prototype testing at EERC:
- Plug consolidation to density of 60 lb/ft\(^3\) repeatable
- Motor torque required – 80,000 ft-lbf
- Static plug sealed 300 psig for planned 30 minutes
- Dynamic extrusion against 55 psig for 27 minutes at 51 TPD

Coal plug delivered against gas pressure of 97 psig

Issues limiting prototype performance:
- Coal transition irregularities from dynamic to stationary zones disrupting seal
- Leakage between tiles and casing impacting track trajectory
- Plug generation beyond optimum location in flow path causing high torque

Prototype feed pressure capability and feed rate shown limited

The most effective solution to these challenges sought
Semi-scale Program

Prototype pump size, weight - has been a challenge for development:
- One year to design, build, install and test initial component modifications
- Development at full scale found schedule and cost prohibitive

Options to accelerate development evaluated:
- Small-scale pump built and tested successfully
- Semi-scale pump program selected, approx. 1/15th scale
- Design and SOA SLM manufacture undertaken
CFT Semi-scale Rig in Test

SLM Tiles and Outlet
CFT Semi-scale Initial Testing

Initial Tile-sidedwall Leakage Addressed by Side Seals and Vacuum Clearing Ports
CFT Semi-scale Initial Test Results

• Reliable coal flow into pump by active hopper confirmed at semi-scale
• Coal lock-up in active pump duct confirmed
• Consolidated and repeatable coal plug in outlet confirmed
• Drive system modification in work to allow low-speed track operation
• Second generation SLM tiles to improve seal performance in manufacture
• Additional SLM scraper configurations in manufacture
  - SLM allows low-cost manufacture of complex components quickly
• Data acquisition system sensor mod’s for lower than expected loads

• Commencing pressure testing (150 PSI max) shortly
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