DRY SOLIDS PUMP
Coal Feed Technologies
(DSP-CFT)

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Gasification Systems Project Review

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DSP-CFT Project Goals and Objectives

Overall Goals:

- **Develop an innovative high-pressure pump feed system**
- **Verify it will reduce CAPEX and OPEX of coal gasification plant for power production with carbon capture**
- **Support first of a kind commercially relevant demonstration in 2018**

Specific Objectives are:

1. Demonstrate high-pressure solids feed system operation with U.S. sub-bituminous and lignite coals

- **2. Install and test component upgrades to the subscale DSP that improve overall performance compared to the current full-scale prototype**

3. Perform a techno-economic study comparing the DSP feed system to a dry solids lock-hopper feed system

Milestones:

Deliver Illinois #6 into 150 psi with Subscale DSP ✓

Confirm low rank coal performance matches Ill#6 on Subscale DSP ✓

Deliver Illinois #6 into 500 psi pressure with full-scale DSP

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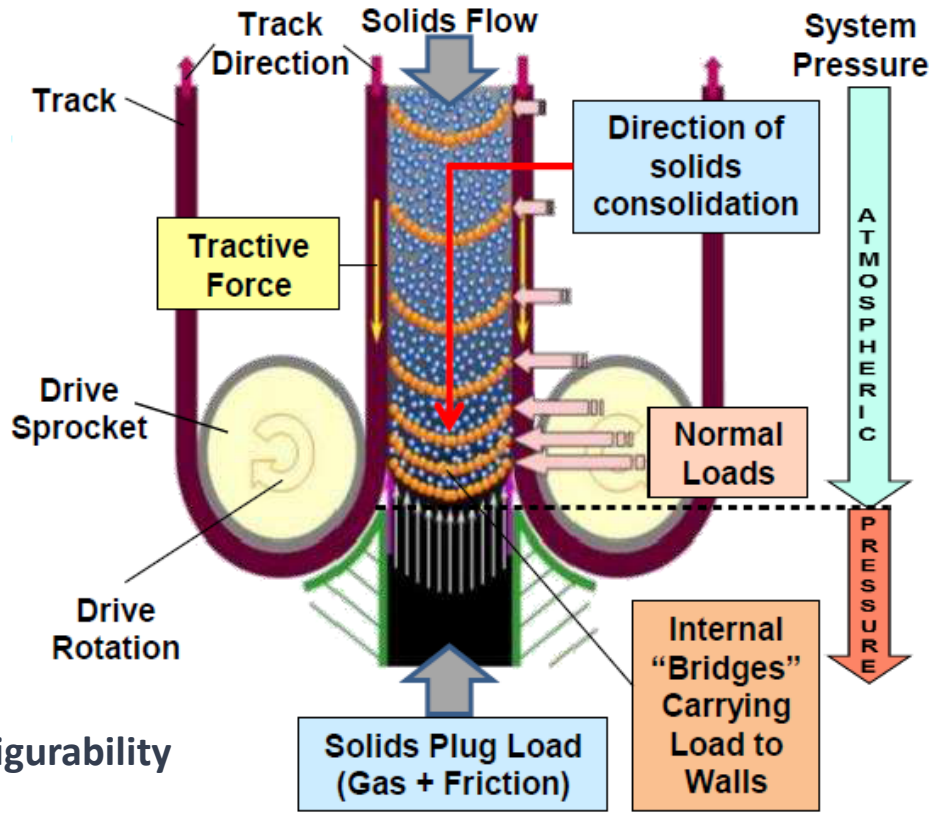
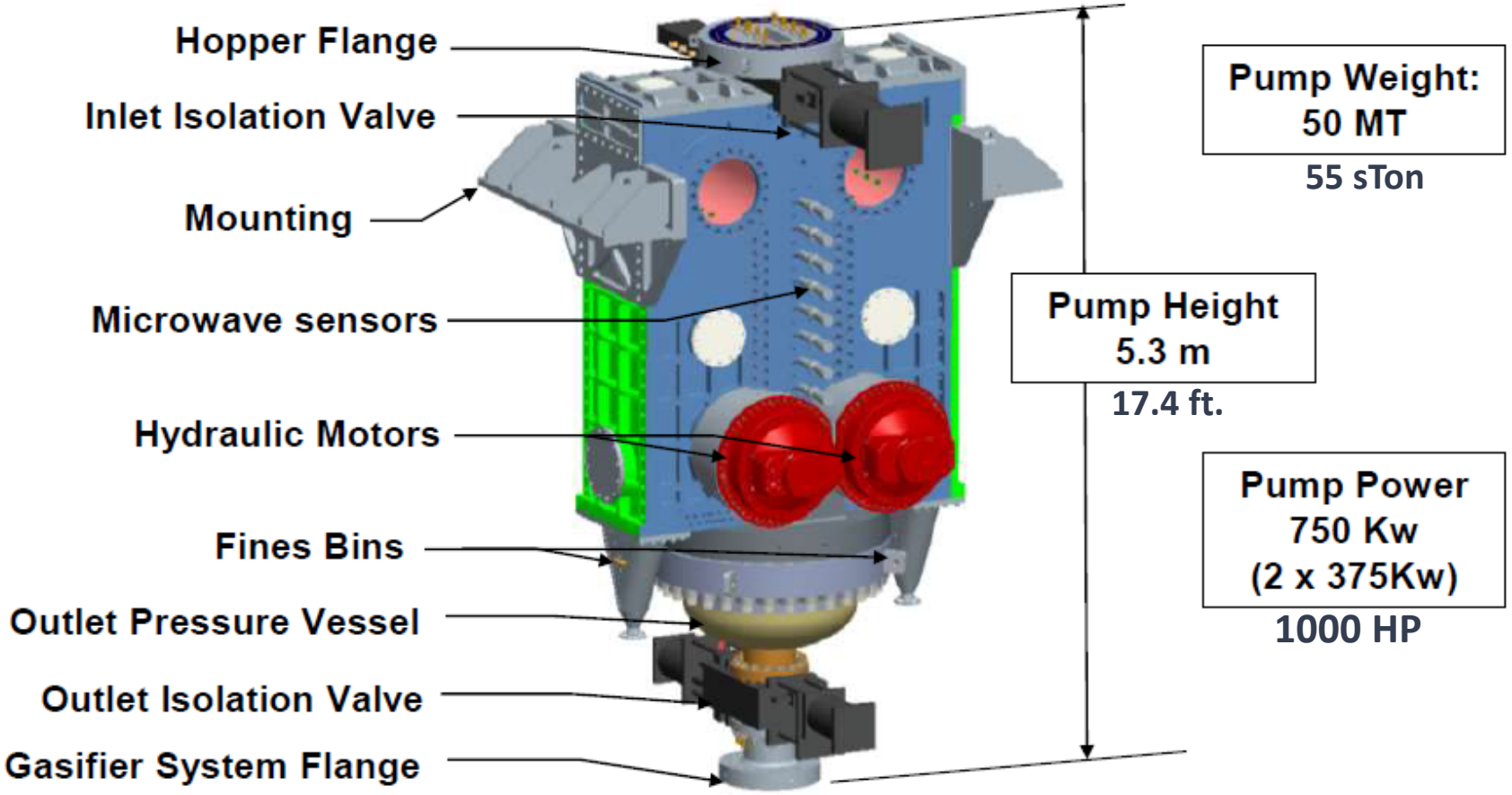
Prior DSP Program Objective and Concept

Develop a solids pump that meets "Compact Gasifier" commercial gasification industry requirements - 1200 psi, 400 TPD (demonstration), 500 psi, 600 TPD

- "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 through duct configurability

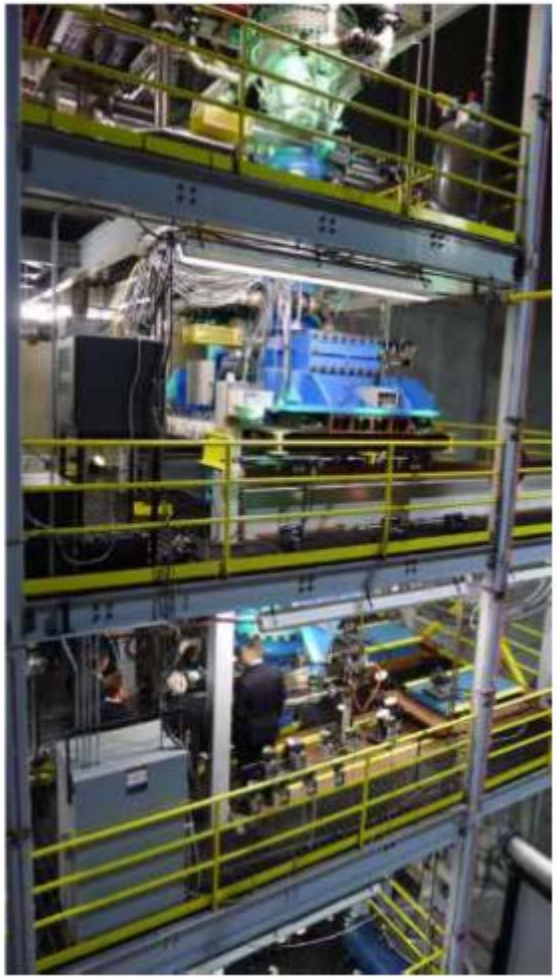


Full-scale Prototype DSP



Full-scale Prototype DSP Test Installation

Pump installed in the Test Stand



Full-scale Prototype DSP Testing Results

Pump fundamentals demonstrated in Prototype testing:

- 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 extrusion against gas pressure of 97 psig

Issues limiting prototype performance:

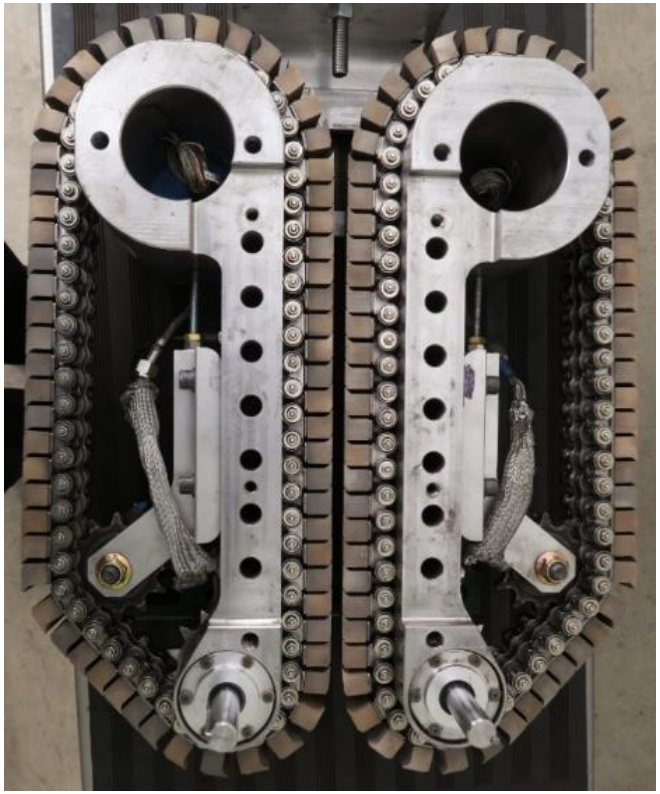
- Coal transition irregularities from dynamic to stationary zones disrupting seal
- Leakage between tiles and casing impacting track trajectory
- Plug generation beyond optimum location in flow path causing high torque

Prototype pump size, weight a challenge for development efficiency

Accelerate development using subscale DSP for DSP-CFT Program

Subscale DSP

- 1:7 Scale, duct size 2.135” x 0.415”, 62 tiles per belt
- .26-1.9 tiles/second operating speed



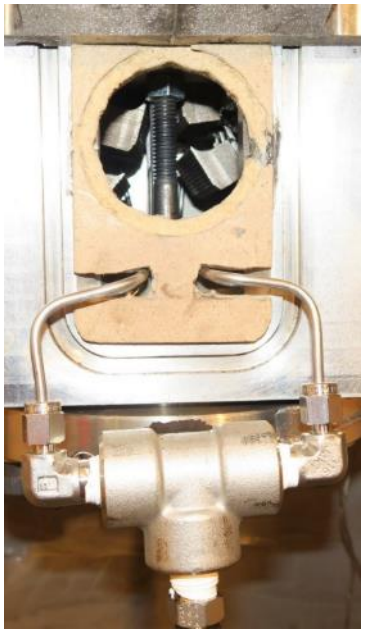
Subscale DSP Test Summary

- Successful testing of a variety of configurations undertaken with subscale unit
- All testing using Illinois #6 coal
- Subscale pump components optimized;
  - Inlet configurations
  - Active flow enhancements at inlet
  - Tiles arrangements and shape configurations
  - Outlet configurations
- Subscale pump design pressure limit of 150 psi consistently achieved
  - Able to increase efficiency by torque optimization
  - Design modifications for prototype identified and completed
- Subscale test results reported at this meeting last year
- Final subscale configuration then transferred to full-scale DSP
  - Full scale DSP upgrades in final assembly
- Low rank fuel types tested in Subscale DSP to evaluate possible impact to DSP configuration and performance
  - Sub-bituminous, lignite,
  - Anthracite, coal-biomass blends and biomass also run in subscale pump

Tile Cleaning Upgrades

- Small size of subscale components susceptible to fouling
  - Fines impact track trajectory, torque level
- Gas jets clear fines in-between tiles directly into vacuum





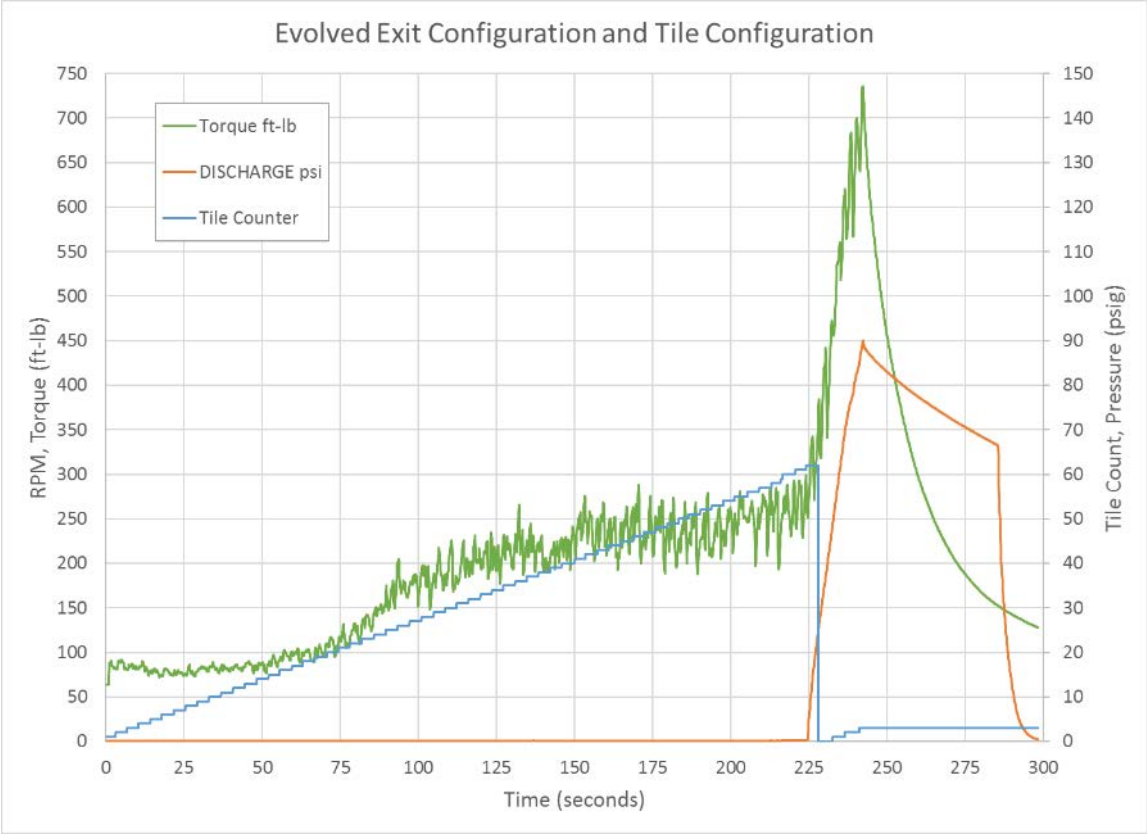

DSP Testing of Low Rank Coal

- Test matrix, objectives and fuel moisture content

Test	Fuel	Test Type	Moisture
A	So Co PRB Subbituminous	Plug formation/extrusion - no gas	12.1%
B	So Co PRB Subbituminous	Static pressure capability	
C	So Co PRB Subbituminous	Extrusion into gas pressure	
D	Genesee Subbituminous	Plug formation/extrusion - no gas	8.1%
E	Genesee Subbituminous	Static pressure capability	
F	Genesee Subbituminous	Extrusion into gas pressure	
G	Mississippi Lignite	Plug formation/extrusion - no gas	9.5%
H	Mississippi Lignite	Static pressure capability	
I	Mississippi Lignite	Extrusion into gas pressure	
J	North Dakota Lignite	Plug formation/extrusion - no gas	12.7%
K	North Dakota Lignite	Static pressure capability	
L	North Dakota Lignite	Extrusion into gas pressure	

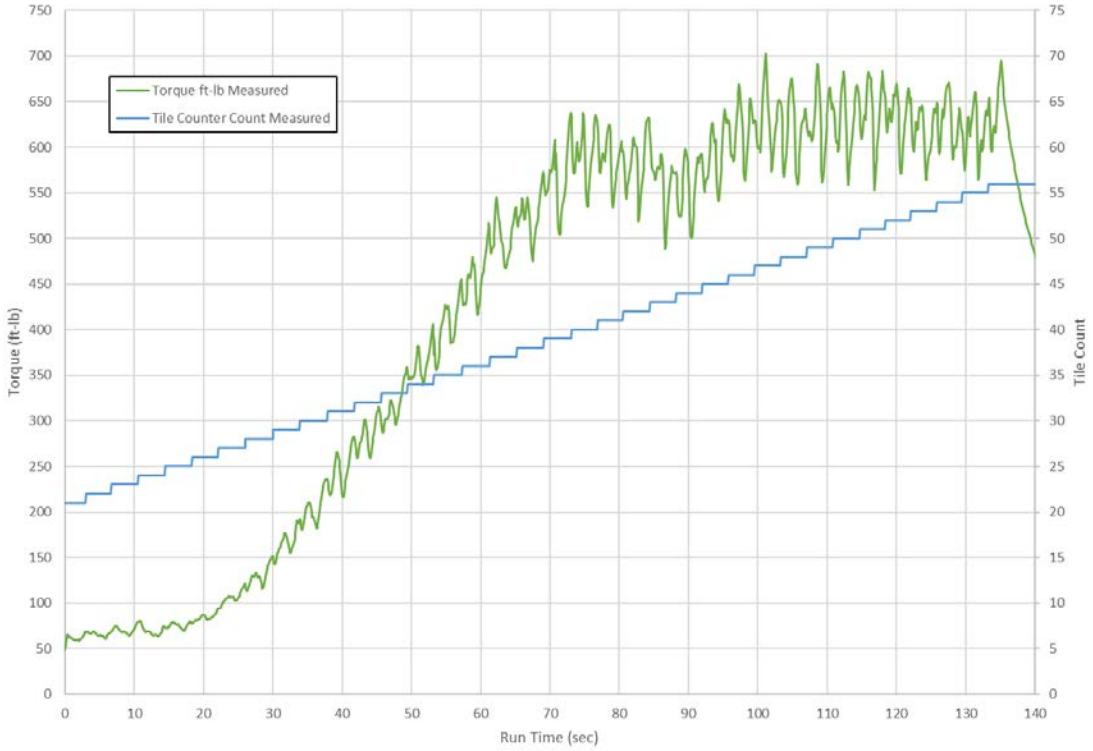
Illinois #6 Sub-bituminous

- **Re-baseline performance**



Southern Company PRB Subbituminous

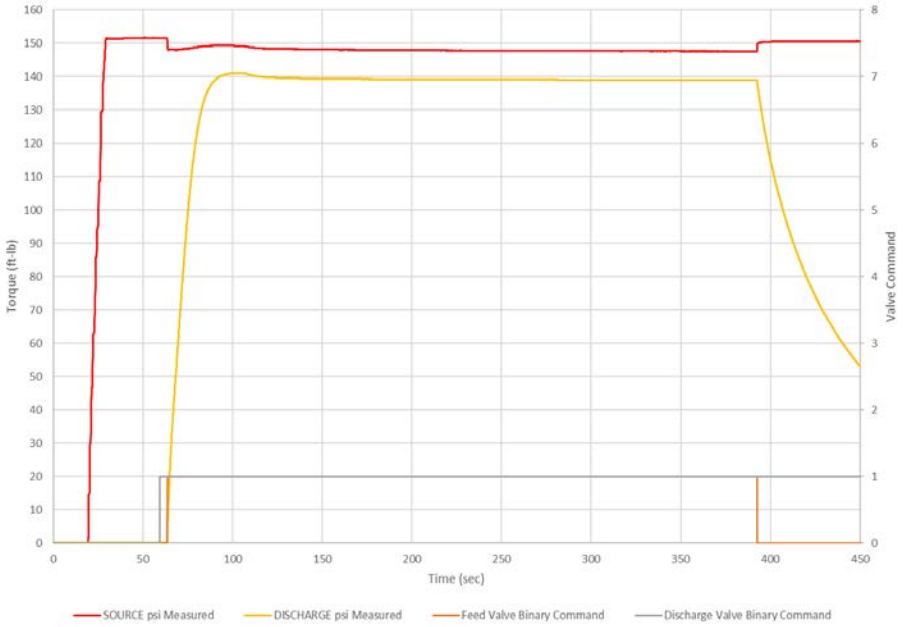
- **Plug formation plot**

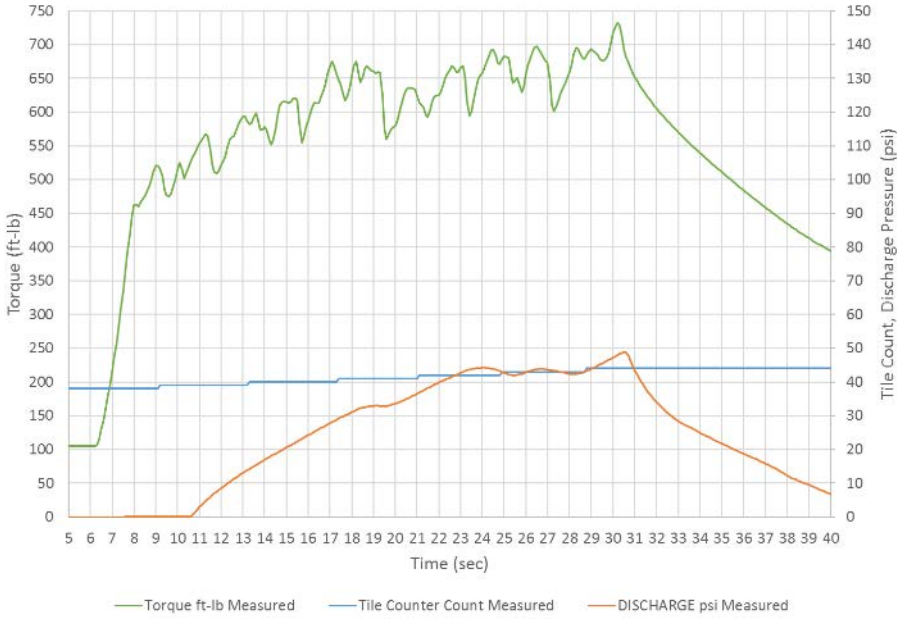


Coal at discharge

So. Co. PRB Subbituminous

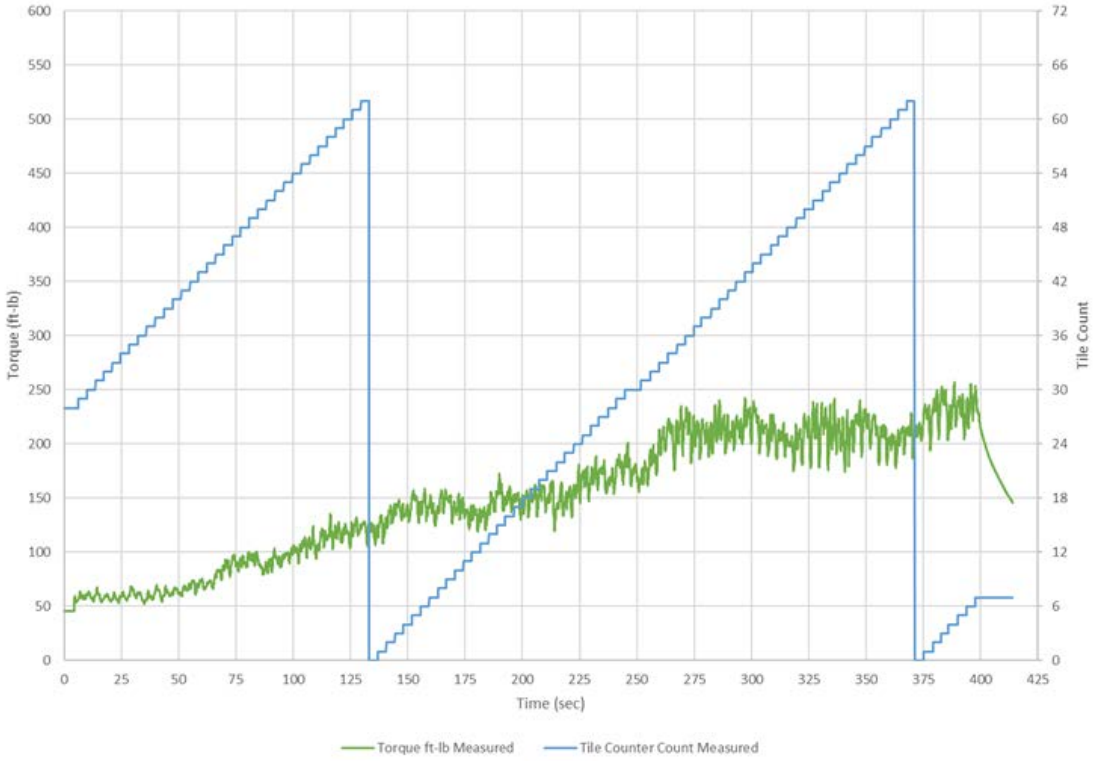
- **Static pressure and extrusion into pressure**





Genesee Subbituminous

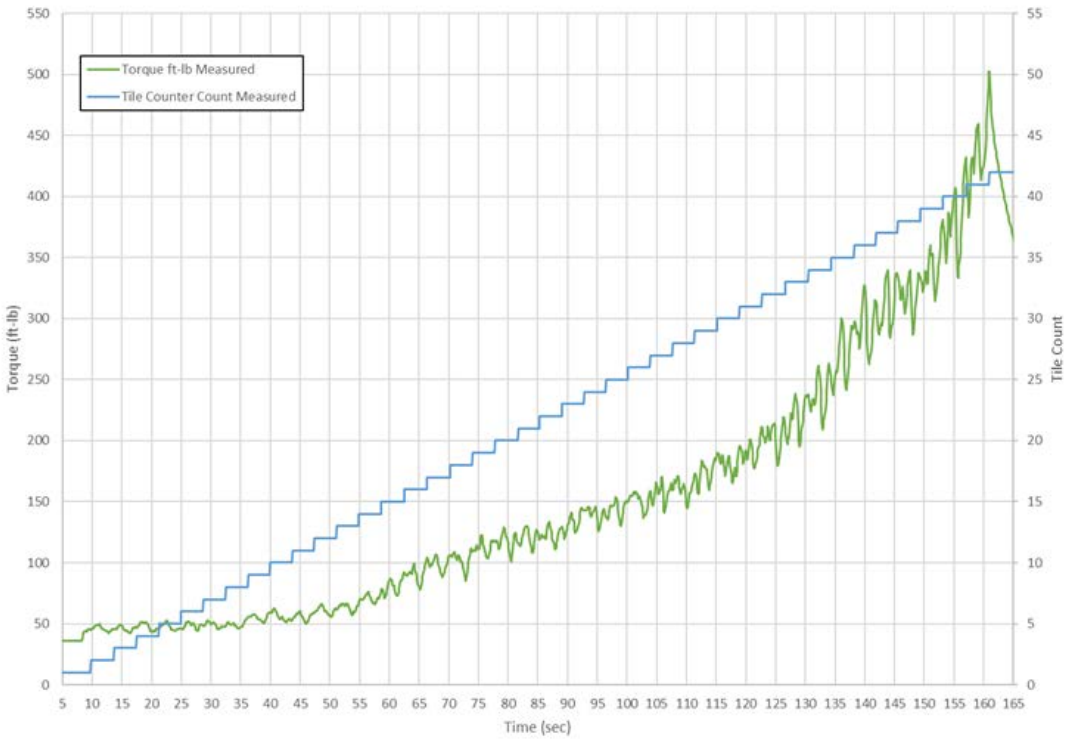
- **Plug formation**



Coal at discharge

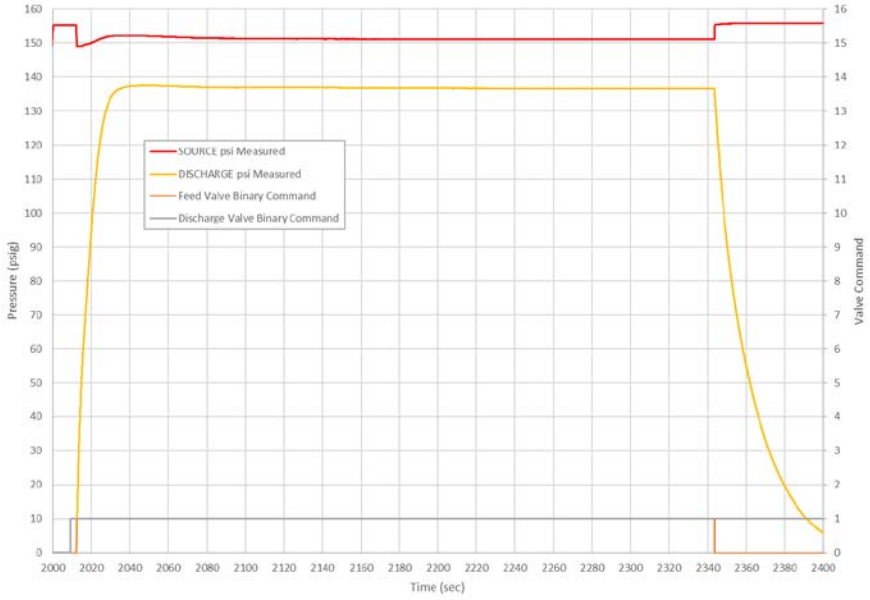
Genesee Subbituminous

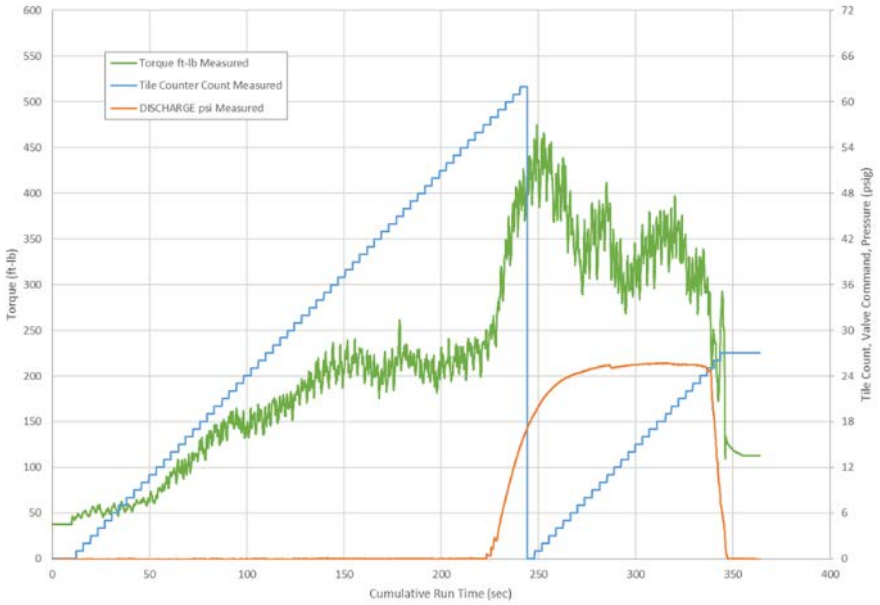
- **Mechanical back pressure used to raise torque to comparable levels for each fuel**



Genesee Subbituminous

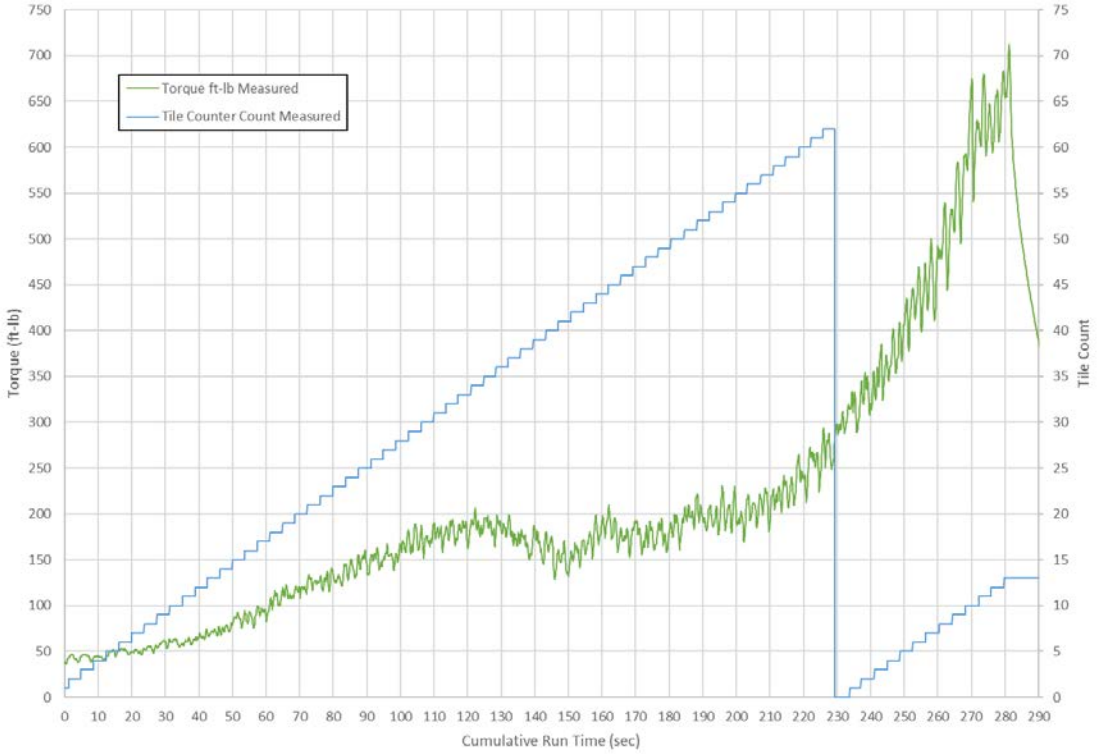
- Static pressure and extrusion pressure tests





Mississippi Lignite

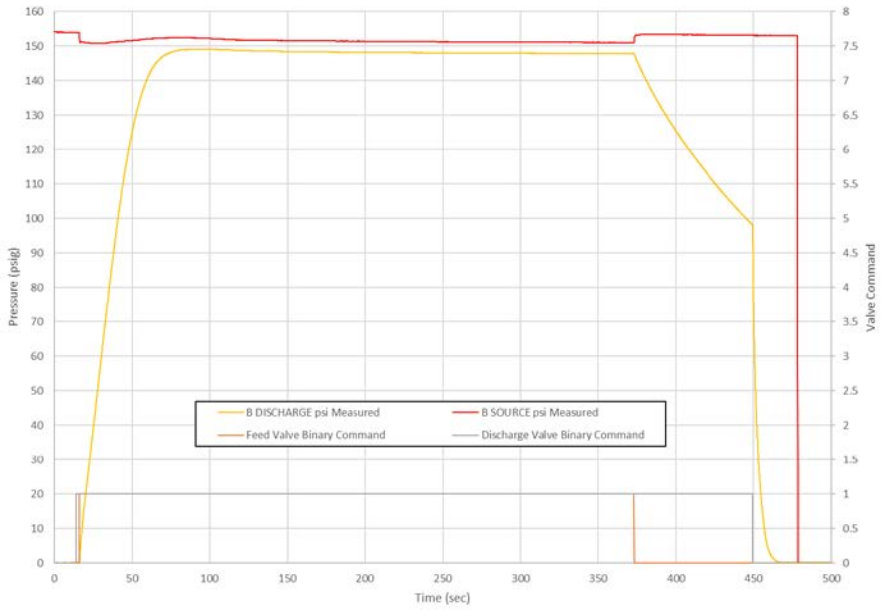
- **Plug formation then mechanical back pressure**

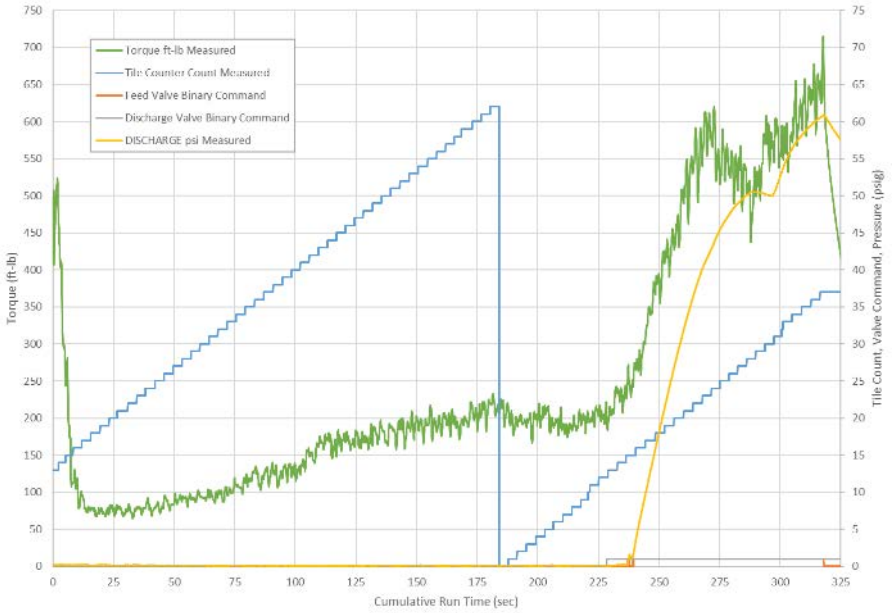


Coal at discharge

Mississippi Lignite

- Static pressure and extrusion pressure tests

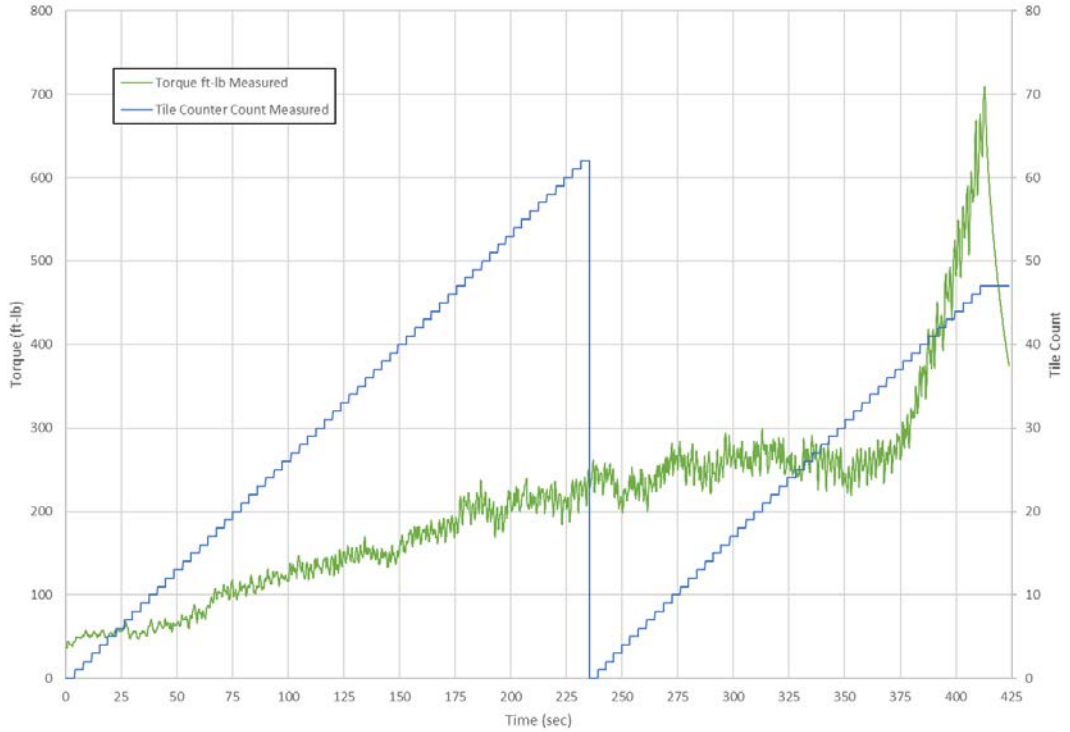




North Dakota Lignite

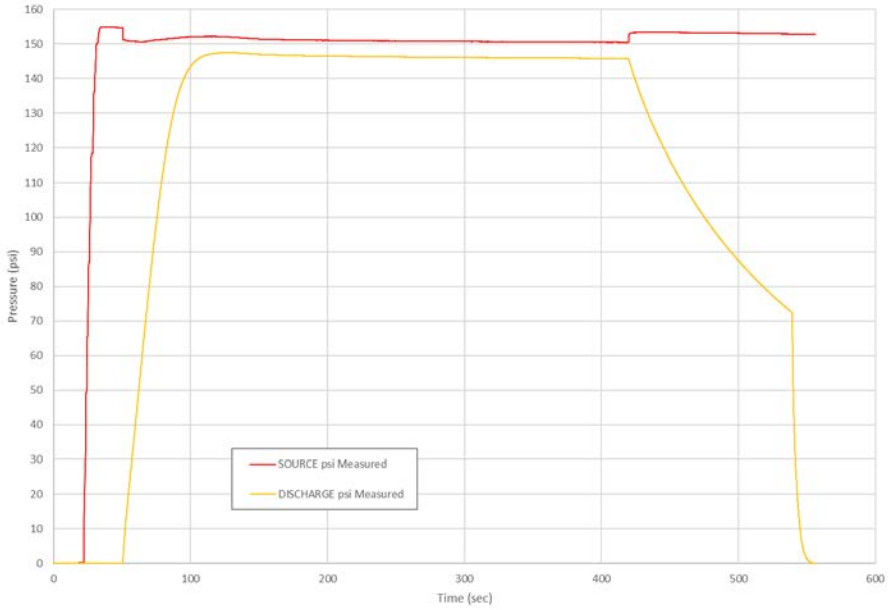
- **Plug formation then mechanical back pressure**

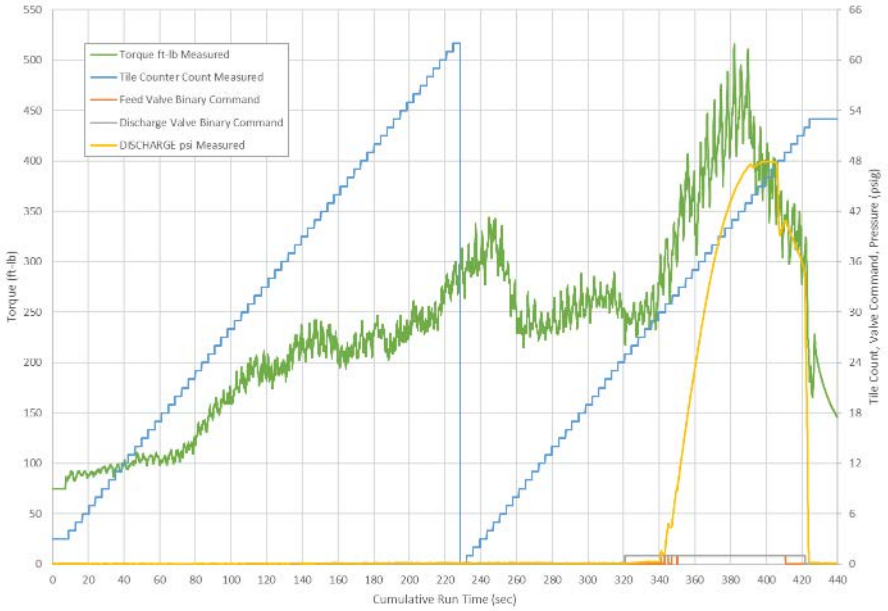
Coal at discharge



North Dakota Lignite

- **Static pressure and extrusion pressure tests**

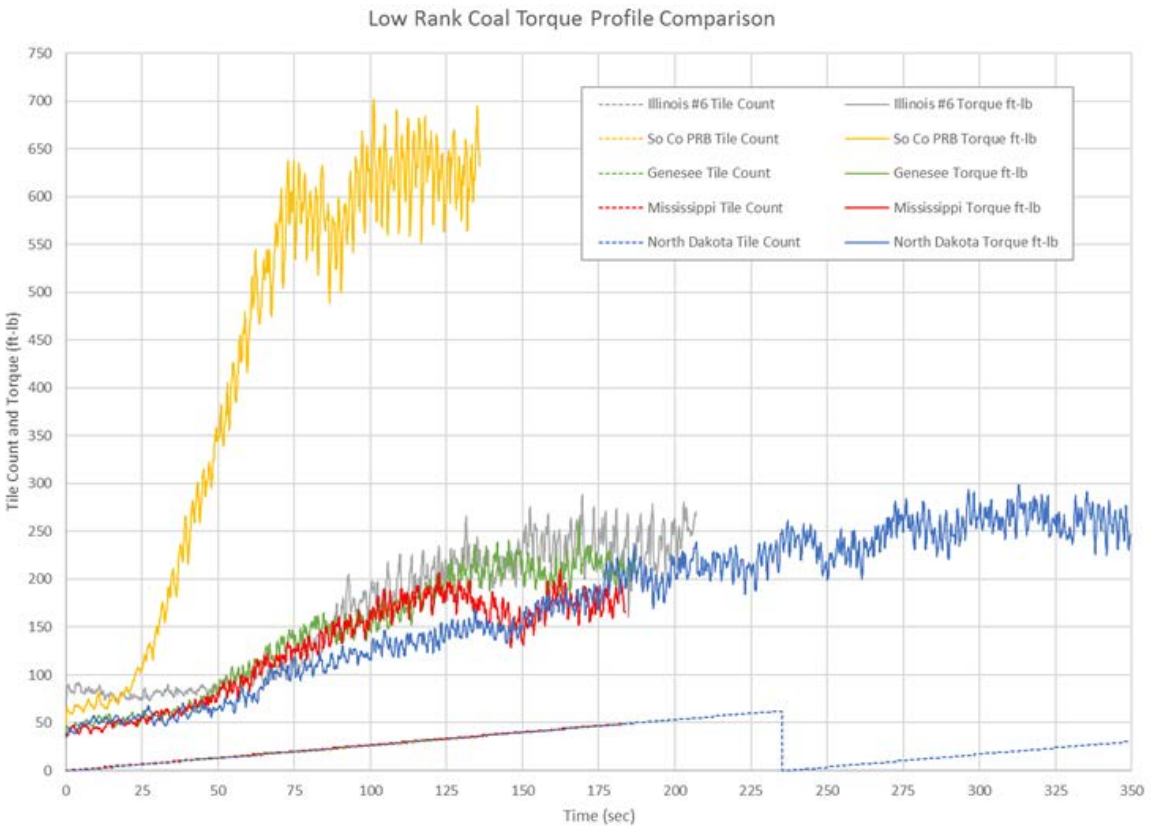




Sub-scale Low Rank Coal Test Summary

- Static pressure capability demonstrated with all fuels
- Steady state extrusion demonstrated with all fuels
  - Duration limited by pump cleanliness and torque capability
- Extruded into gas with all fuels
  - Highest pressure achieved 90 psi before tripping on torque
  - Longest was 31 tiles at 25 psi before leaking
- All tests utilized a single outlet configuration (optimized for Ill#6)
  - Modifying outlet would improve performance levels
  - Dynamic outlet control options available for addressing fuels variability

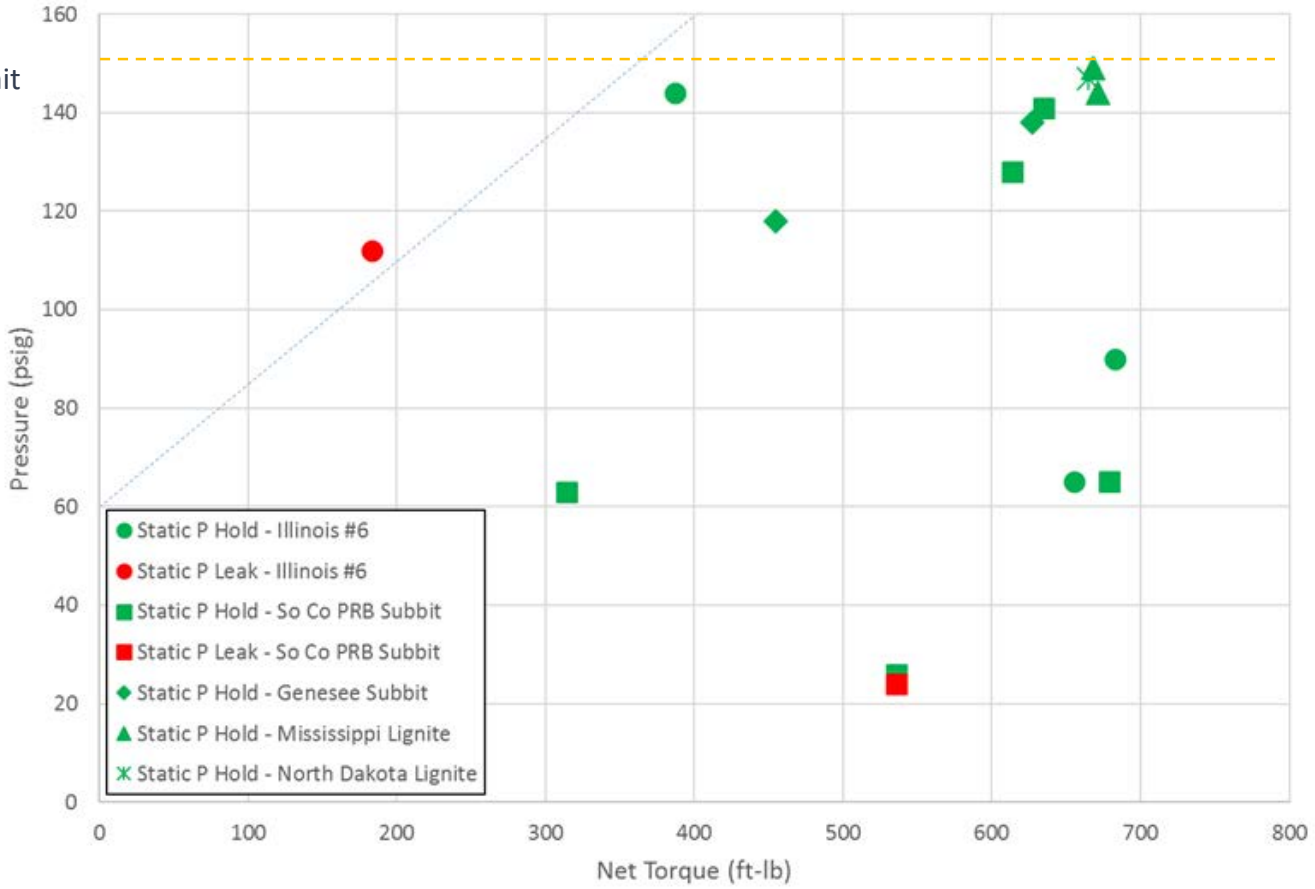
Free Extrusion Results



Fuel	Free Extrusion Torque (net ft-lb)
Illinois #6 Bituminous	195 (high variation)
So. Co. PRB Subbituminous	568, 565 (too wet?)
Genesee Subbituminous	164, 159
Mississippi Lignite	131, 140
North Dakota Lignite	216, 170

Static Pressure Results

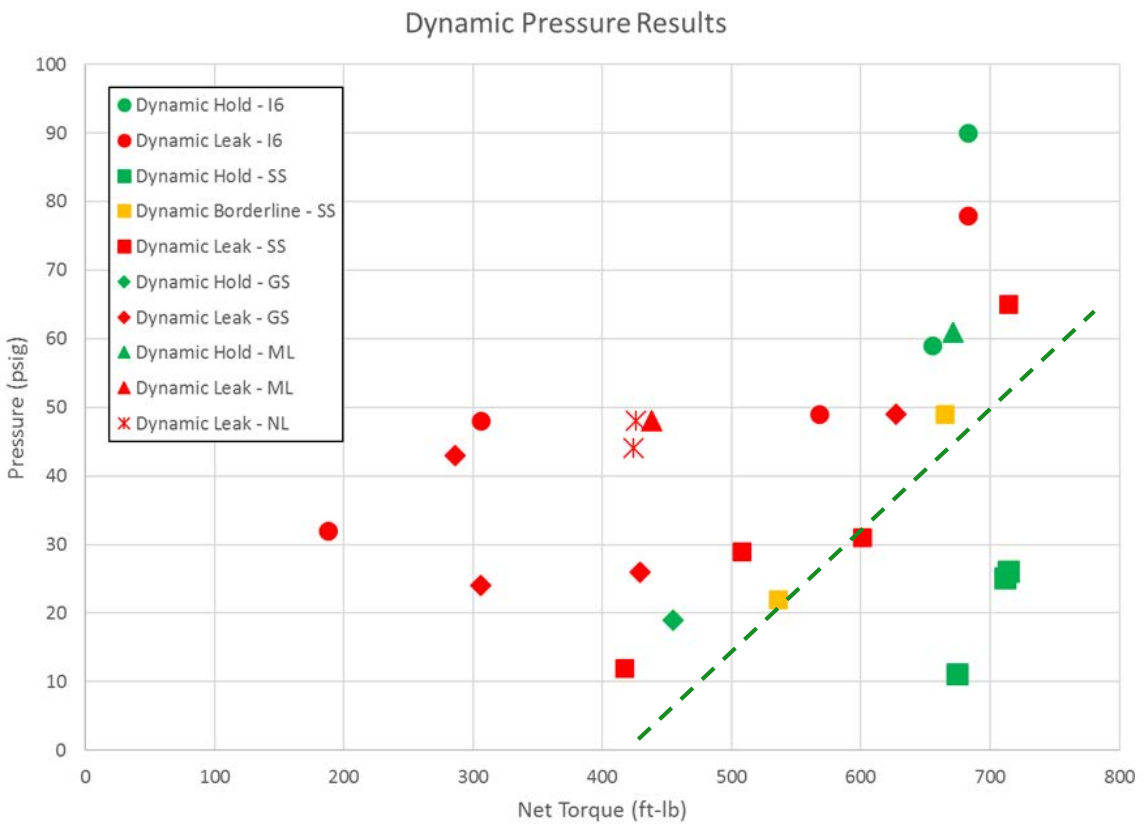
150 psig hardware limit



Includes data from the middle of extrusion runs/attempts, SEUD maybe incompletely filled or already leaked

Gas Extrusion Results

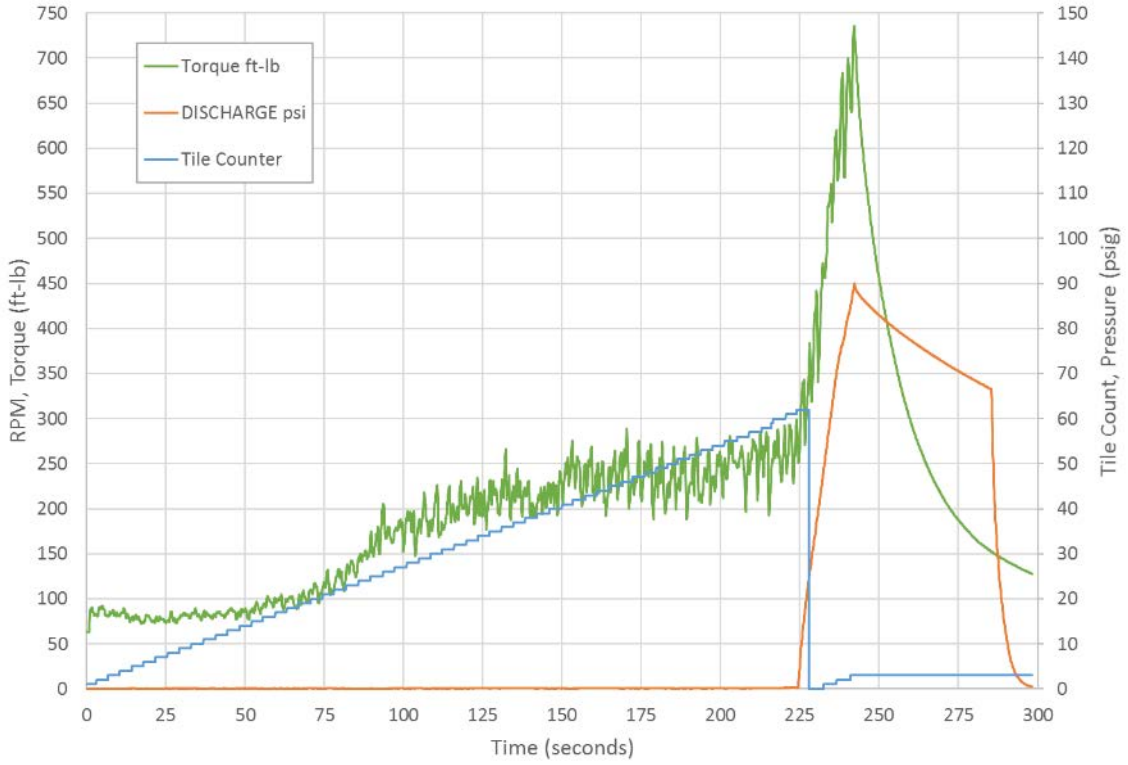
- **Still transient results based on either a trip or leak**
  - **Subscale machine is too torque limited**
  - **More torque allows more consolidation hence higher pressure**



Highest Pressure Gas Extrusion

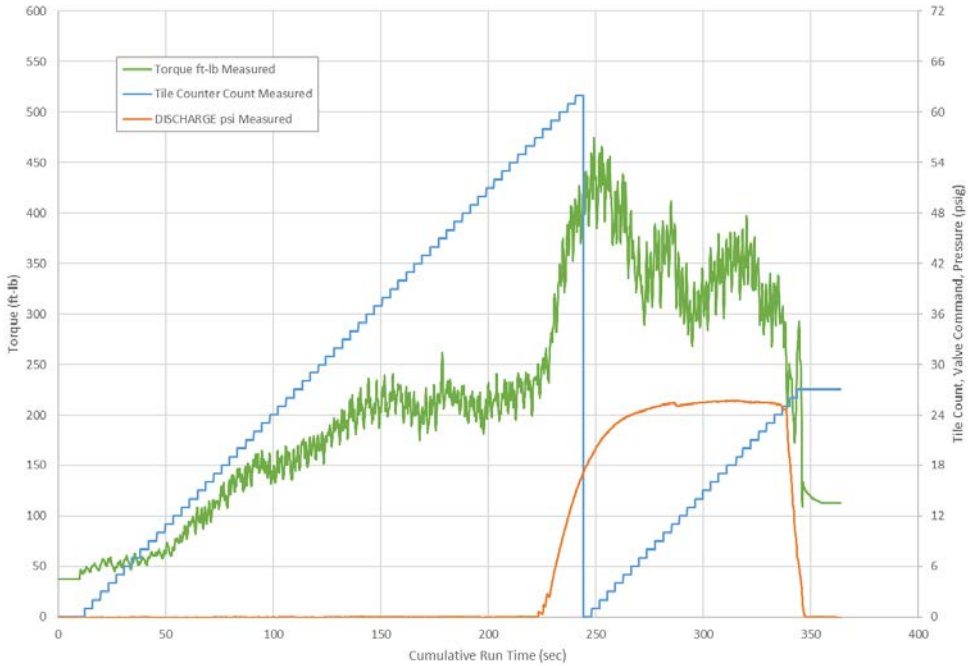
- **Illinois #6**

  - Plug form 240 ft-lb, 700 ft-lb trip at 90 psi



Longest Duration Gas Extrusion

- Genesee Subbituminous
  - Plug form 220 ft-lb, 31 tiles at 25 psig
  - Limited by ability to keep pump clean



Key Observations

- Outlet fill critical to pressure performance
- Diverging outlet magnifies pressures effect on torque
- Slippery/polished outlet surfaces reduce torque
- Lessons learned incorporated in full-scale DSP when possible

Full-scale DSP-CFT Upgrades

Tile Upgrades

Active Hopper Testing

DSP-CFT Program Status

- Subscale testing of proposed modified components - completed
- Low-rank fuel types evaluation in subscale DSP - completed
- Evaluation of prototype modifications and cost analysis - completed
- Manufacture of upgraded components for full-scale DSP - completed
- Modifications to test stand and full-scale DSP - April completion
- Testing on full-scale DSP - May 2018
  - Testing will use Ill #6 with 500 psi pressure target (hardware limited)
- Program to conclude - 3rd Quarter 2018

Acknowledgement

GTI wishes to thank the Department of Energy and the National Energy Technology Laboratory for their support of this program

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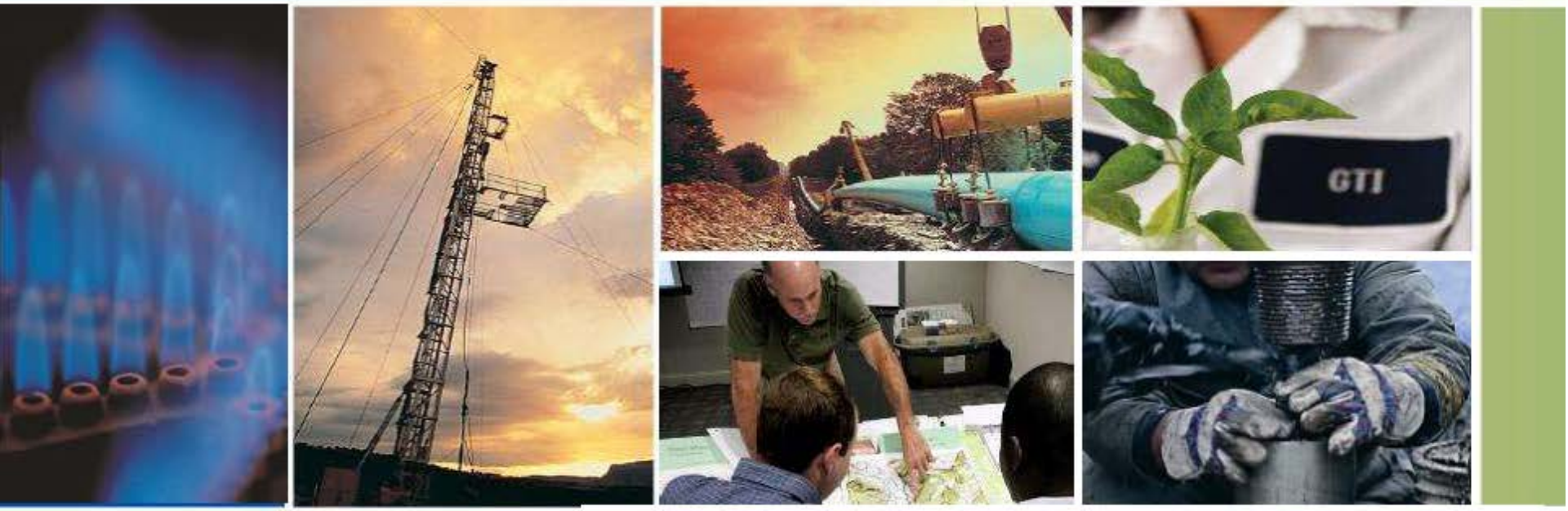
Turning Raw Technology into Practical Solutions



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