DRY SOLIDS PUMP
Coal Feed Technologies
(DSP-CFT)

Gasification Systems Project Review

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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 DSP that improve overall performance compared to the current prototype DSP
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 prototype

Presentation Outline

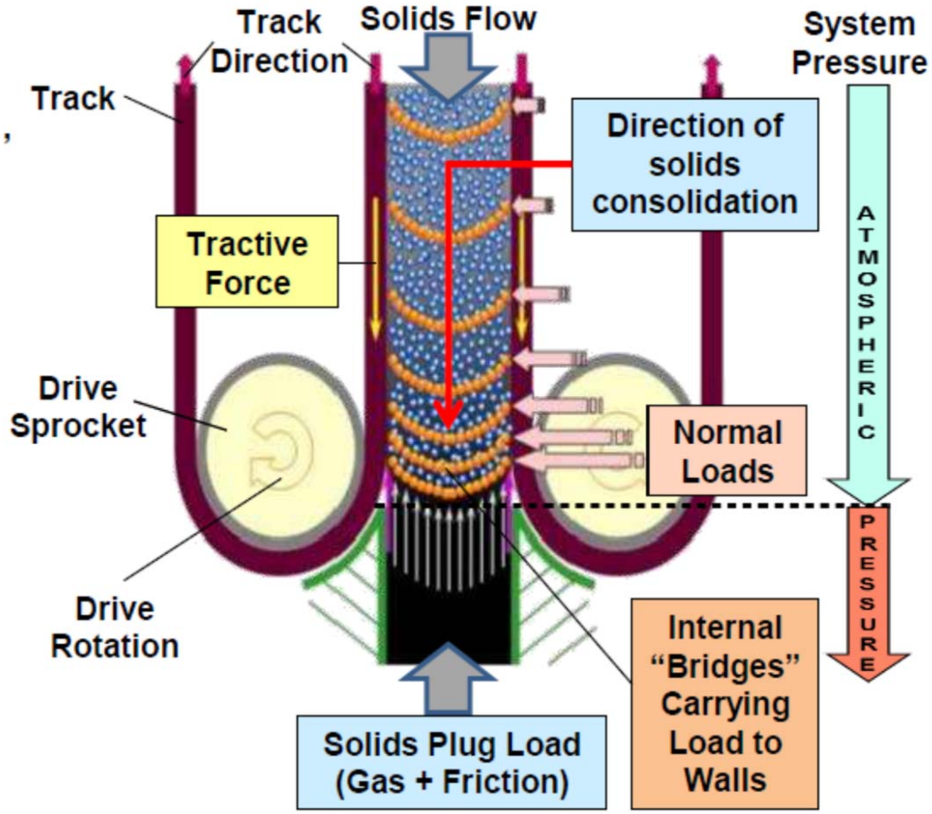
- Prior DSP Program description
- Prototype DSP testing and results
- DSP-CFT program
- DSP-CFT program subscale DSP
- Subscale DSP testing and results
- DSP-CFT program upgrades to prototype DSP

Note – IP development currently limits DSP configurations shown

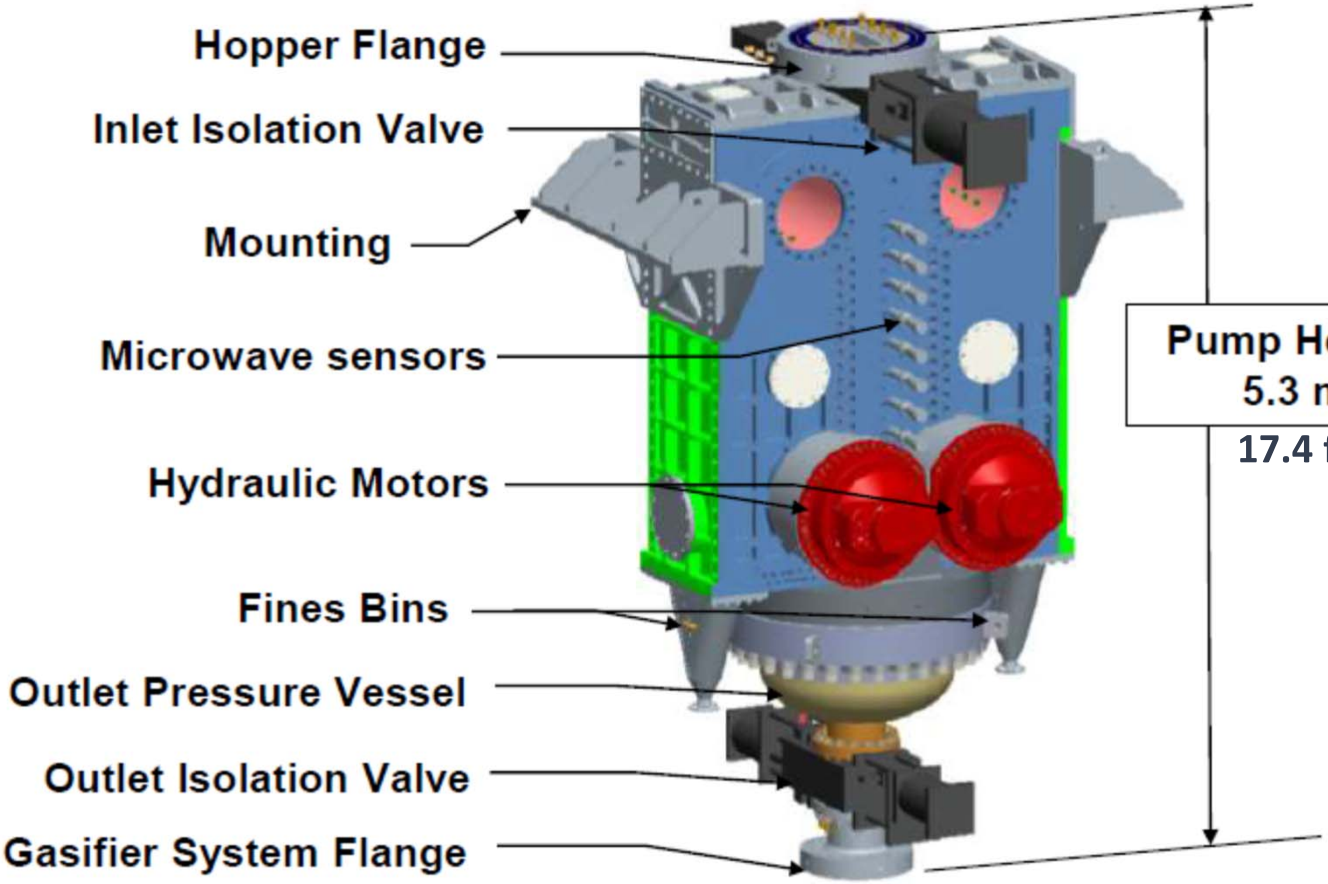
Prior DSP Program Objective and Concept

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



Prototype Dry Solids Pump



Pump Weight:
50 MT

55 sTon

Pump Height
5.3 m

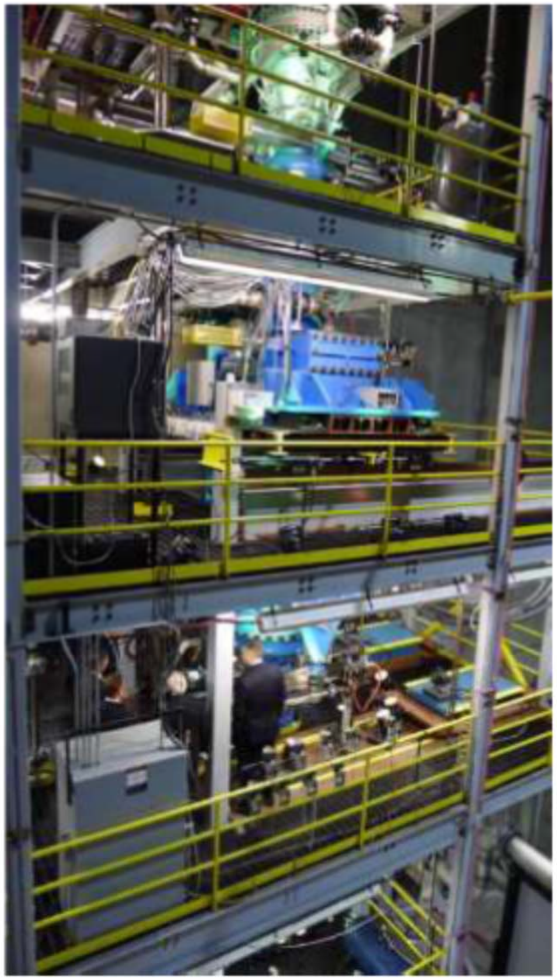
17.4 ft.

Pump Power
750 Kw
(2 x 375Kw)

1000 HP

Prototype DSP Installed in Test Stand

Pump installed in the Test Stand



Prototype 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:

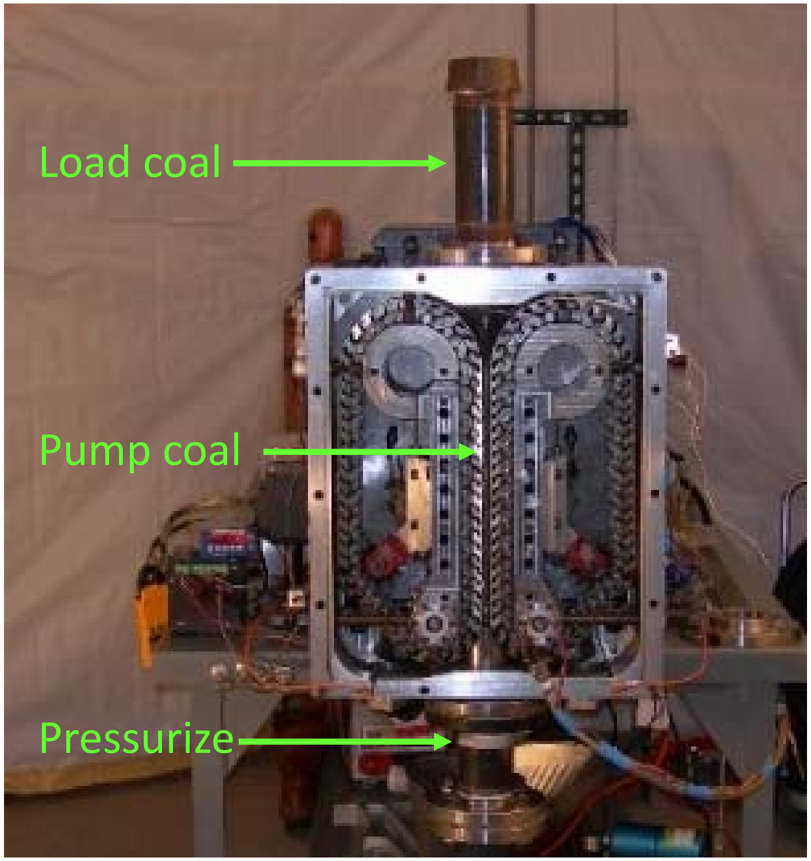
- Coal transition irregularities from dynamic to stationary zones disrupting seal
- Leakage between tiles and casing impacting track trajectory
- Plug generation beyond optimum location in flow path causing high torque

Prototype pump size, weight a challenge for development efficiency

Accelerate development using subscale DSP decided for DSP-CFT Program

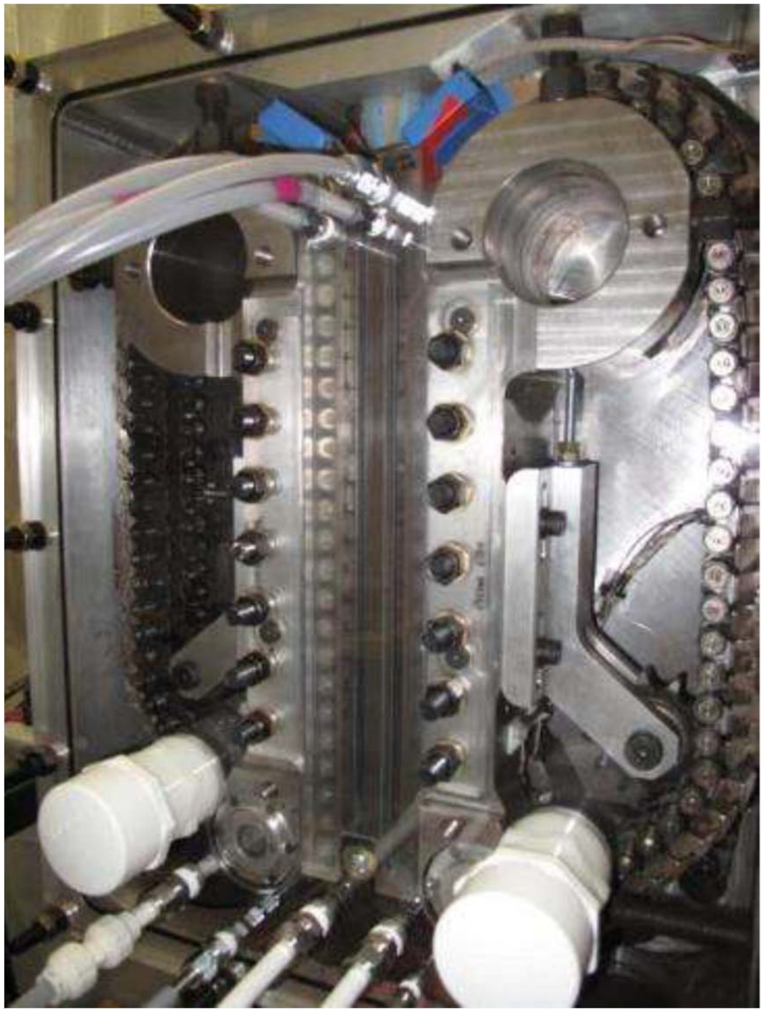
DSP-CFT Subscale Hardware/Instrumentation

- 1:7 Scale Machine
  - 2.14” x .42” working zone
  - 150 psig hardware limit
  - SLM manufacturing used
  - Active hopper developed
- Pump Data Collected
  - Motor RPM
  - Tile Counter
  - Torque
  - Internal load cells
  - Discharge pressure



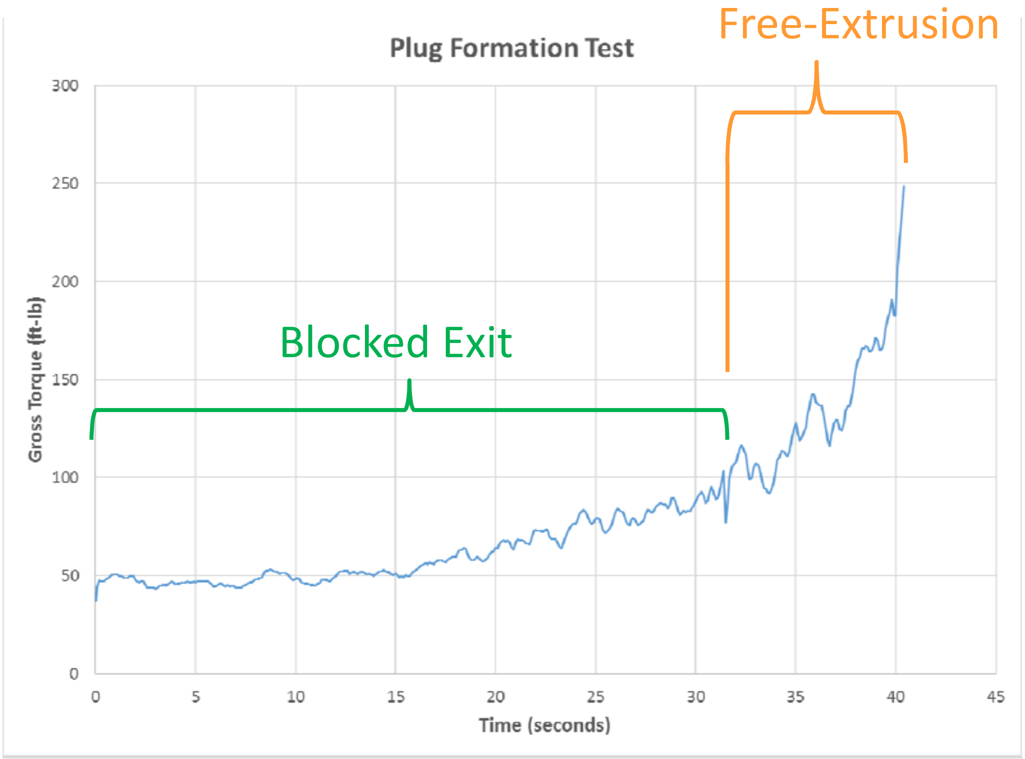
Subscale Configurations Evaluated

- Major features
  - 3 Exit configurations
- Minor features
  - Exit geometry/throttling
  - 3 Tile shapes
  - Tile orientation/alignment
  - Working zone shape/size
  - Fines management



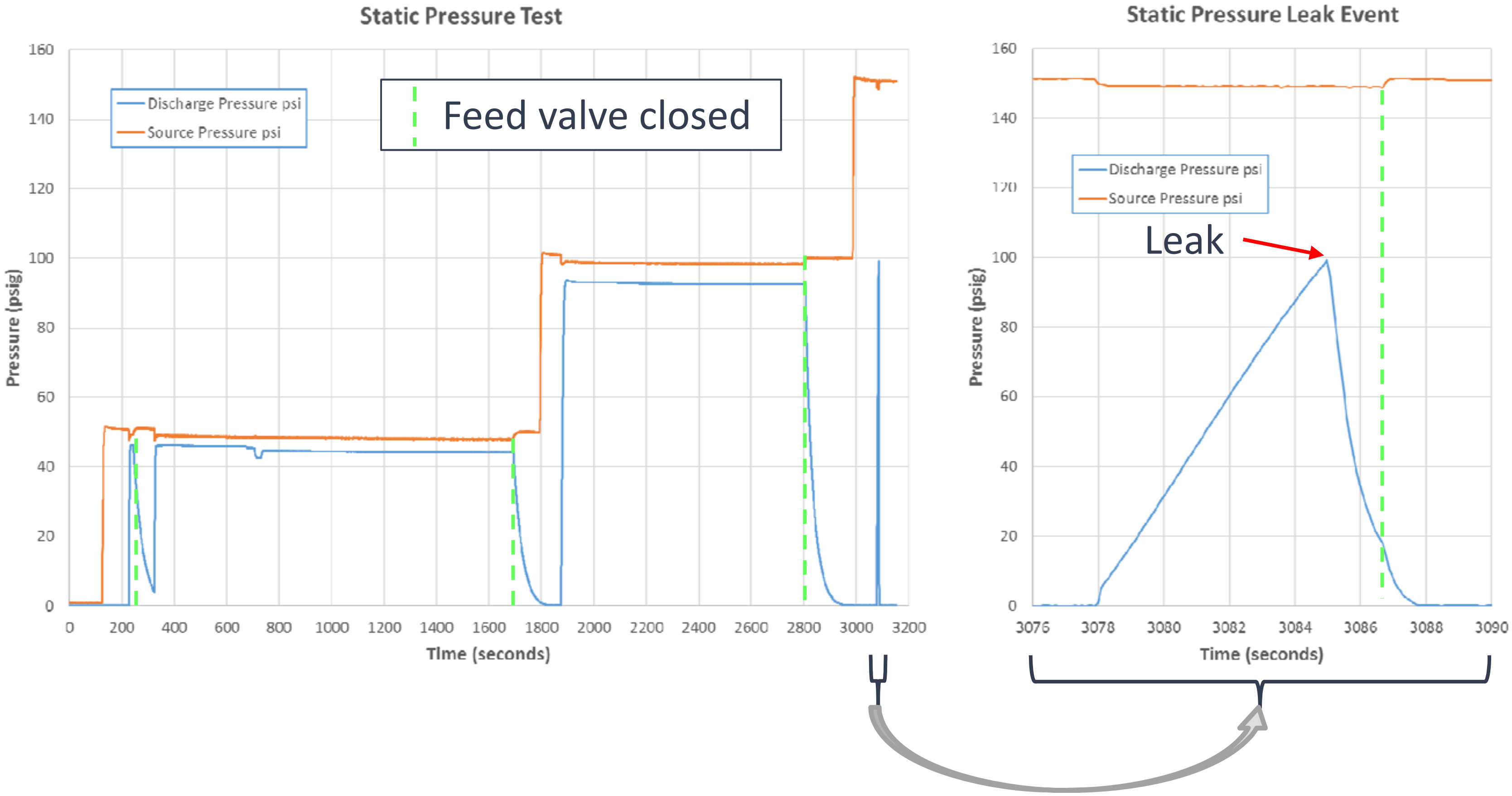
Subscale Testing – Plug Formation

- Run pump (with blocked exit if necessary) to form initial plug
- (Remove plug and) run pump to specified torque value



Subscale Testing – Static Pressure

> **Pump off, ramp and hold set discharge pressure**

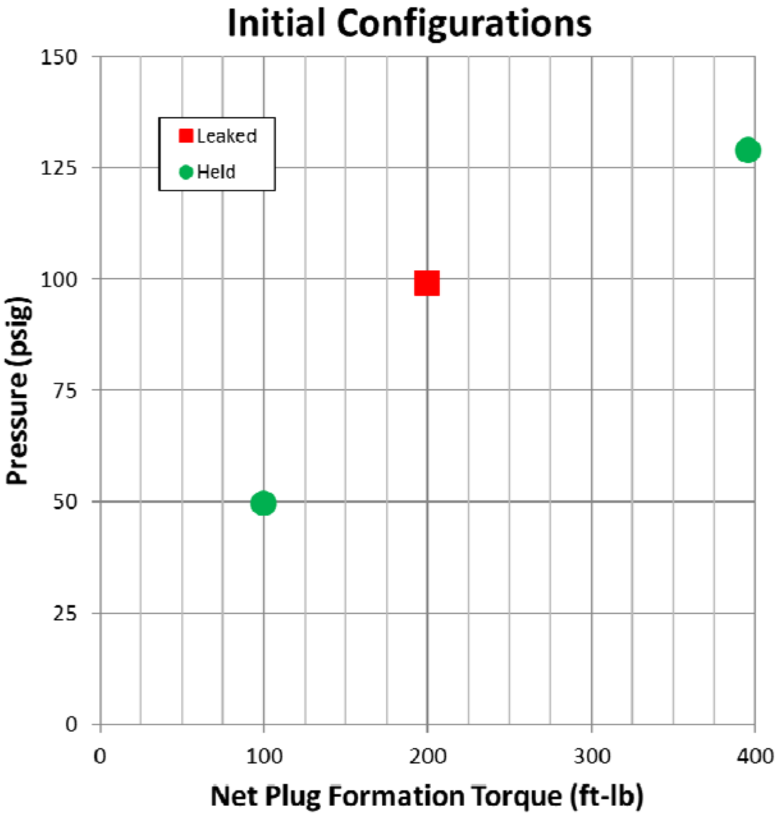


Feed valve closed

Leak

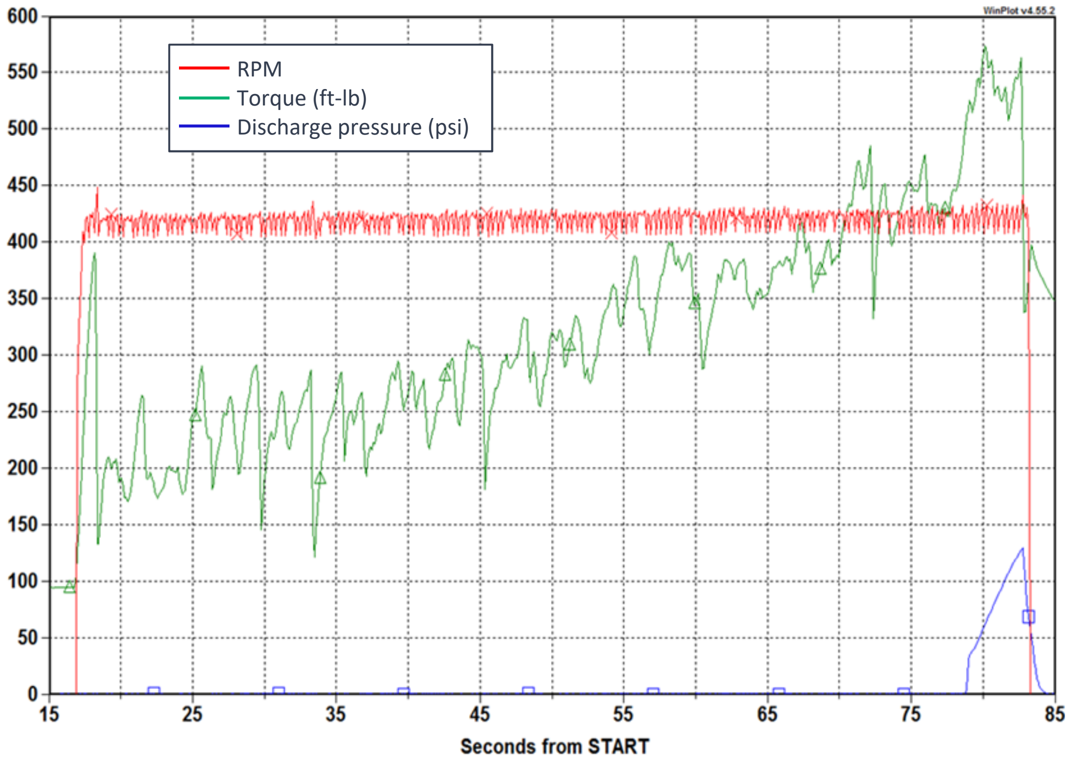
Static Pressure Capability

- Static pressure demonstrated up to hardware limit (150 psig)
- Capability trends with consolidation at gas interface
  - Consolidation roughly correlates with torque
- Exit configuration also has effect on capability
  - Longer exit geometry can seal better at lower consolidation



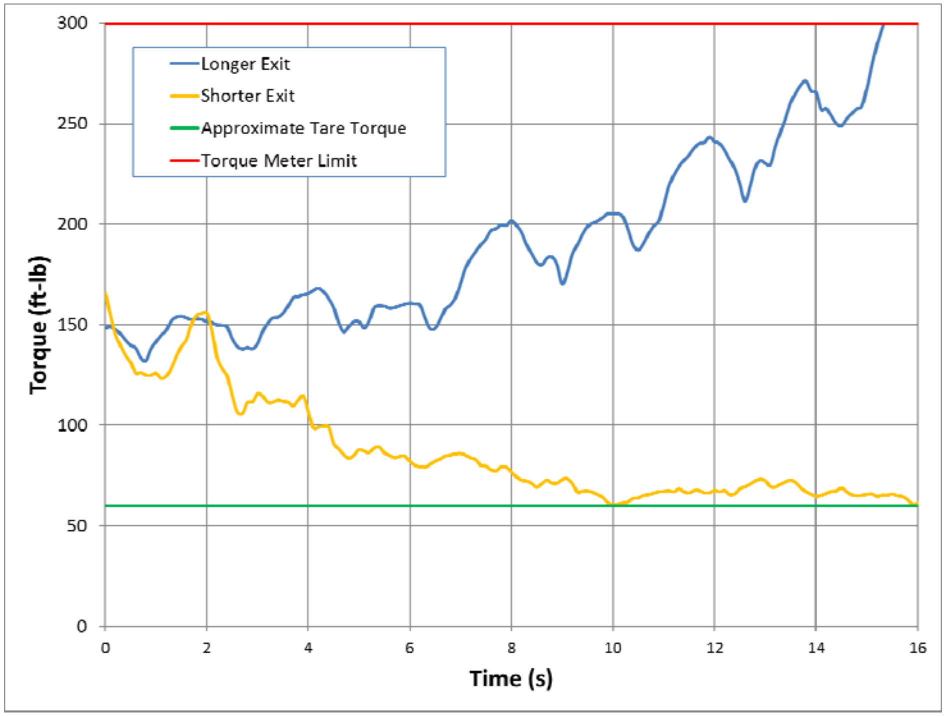
Subscale Testing – Extrusion Run

- While running pump, pressurize discharge after crossing torque threshold
  - Narrow window to apply gas pressure after torque threshold and before torque limit



Baseline (Prototype) Exit Configuration Results

- Torque either climbs (when exit sufficiently restrictive) or drops to tare value (when exit insufficiently restrictive)
  - Unable to find steady state torque with initial exit configuration geometry variations

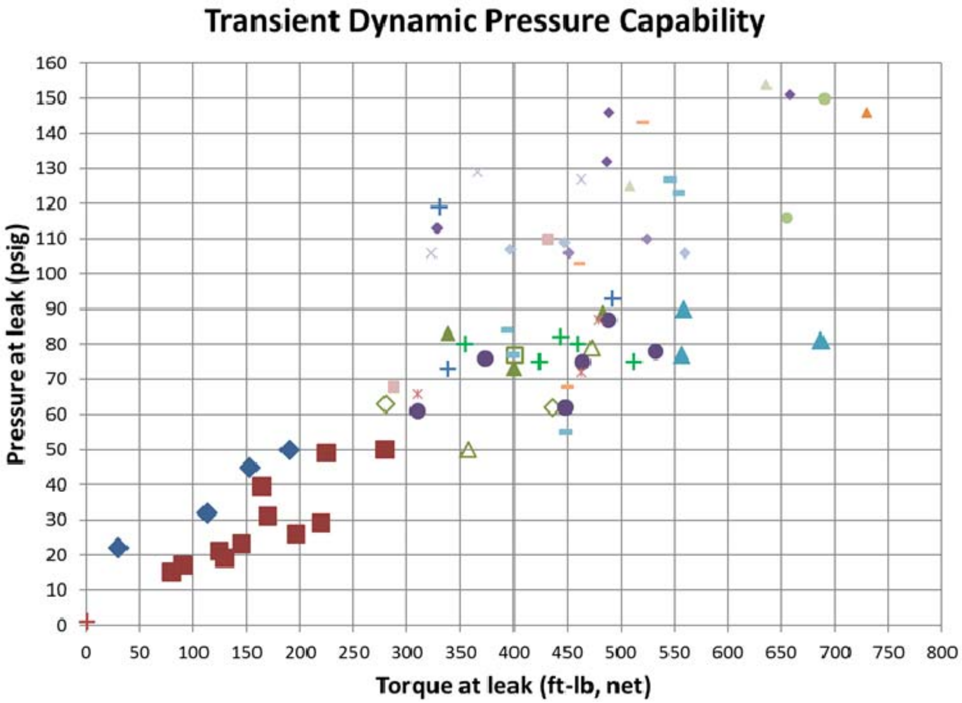


Baseline Extrusion Pressure Test Results

> Extrusion pressure capability trends with torque

> Relatively insensitive to minor variation of exit configuration

- For any individual configuration, variation test-to-test attributed mainly to inconsistent consolidation at the gas seal location

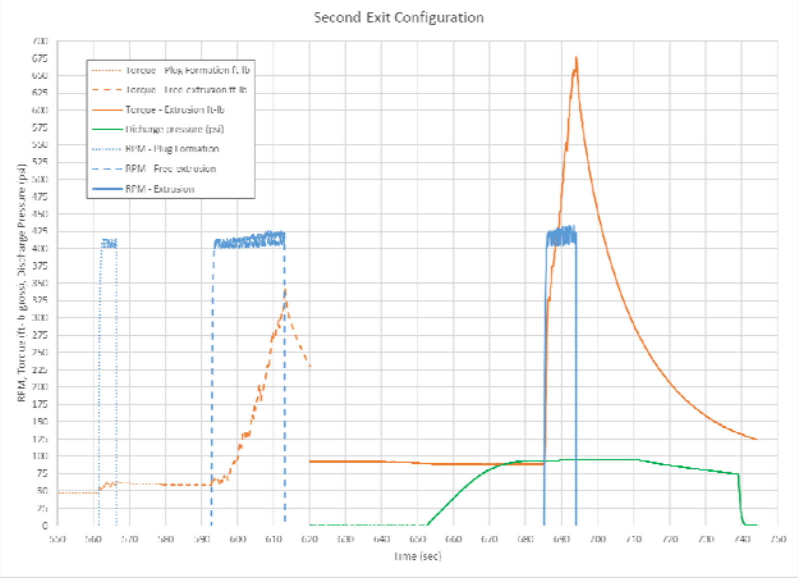


Key Observations for Baseline Configuration

- Subscale duplicated issues exhibited by prototype
- Fluidized fines control at loading critical to pump operation
- Inconsistent consolidation at gas seal interface unacceptable
  - High consolidation in one area drives torque requirement
  - Poor consolidation in another area provides leak path
  - Sensitive to small asymmetries in pump assembly
- Gas seal location may be sensitive to cyclical tile-exit interaction
- Moved to revised outlet configuration exit 2

Exit Configuration 2

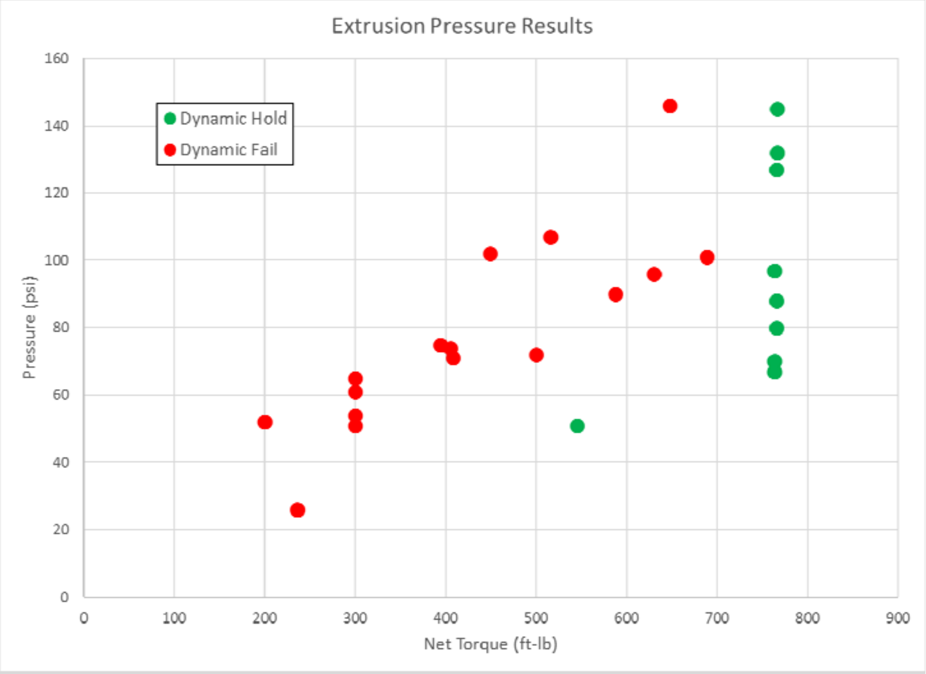
- Continued success demonstrating static pressure and extrusion pressure capability
- Unable to find steady state torque

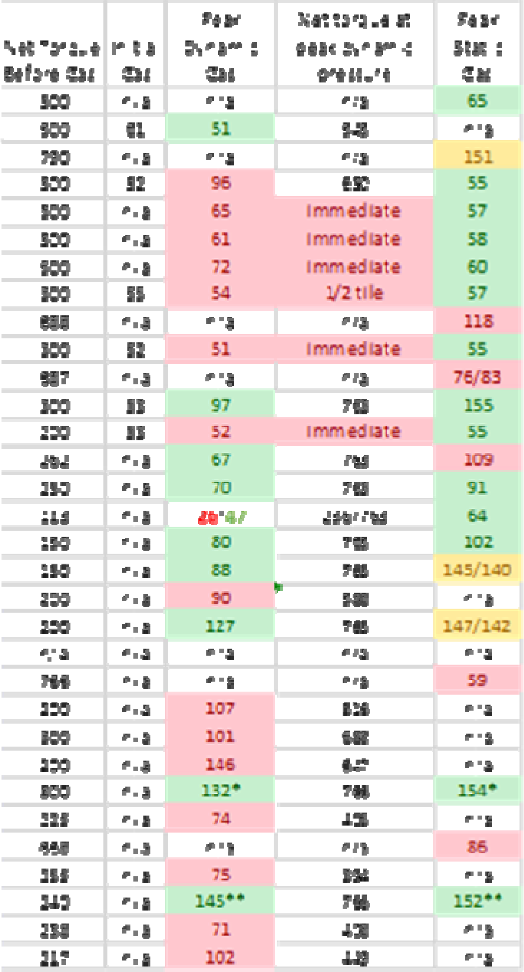


Exit Length	Throttle	Net plug formation torque (ft-lb)	Net free extrusion torque (ft-lb)	Net pressure extrusion torque (ft-lb)	Extrusion pressure (psi)	Static pressure (psi)
short	no	100	500	n/a	n/a	🟥 19
short	no	25	500	n/a	n/a	🟥 24
short	no	500	n/a	n/a	n/a	🟩 153
short	yes	5	500	n/a	n/a	🟥 36
long	no	10	500	n/a	n/a	🟩 152*
long	no	5	300	n/a	n/a	🟥 131
long	n/a	25	300	700	🟩 95	n/a
medium	no	10	300	n/a	n/a	🟥 27
medium	no	n/a	500	n/a	n/a	🟥 18.6
long	no	5	215	665	🟩 57	🟩 155
short	yes	5	300	n/a	n/a	🟥 41
short	yes	n/a	500	n/a	n/a	🟥 52
medium	yes	5	300	n/a	n/a	🟥 39
medium	yes	5	500	n/a	n/a	🟩 153
long	yes	5	300	n/a	n/a	🟥 113
long	yes	10	300	n/a	n/a	🟥 74
long	yes	30	625	n/a	n/a	🟥 56
long	yes	n/a	665	n/a	n/a	🟥 59
long	yes	n/a	630	n/a	n/a	🟩 153
	Key:	🟩 No Leak		🟥 Leak		

Exit Configuration 3

> **Pressure capability continues to trend with torque/consolidation**





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Key
Leak event
Small/steady leak
No Leak

Exit 3 Configuration Development

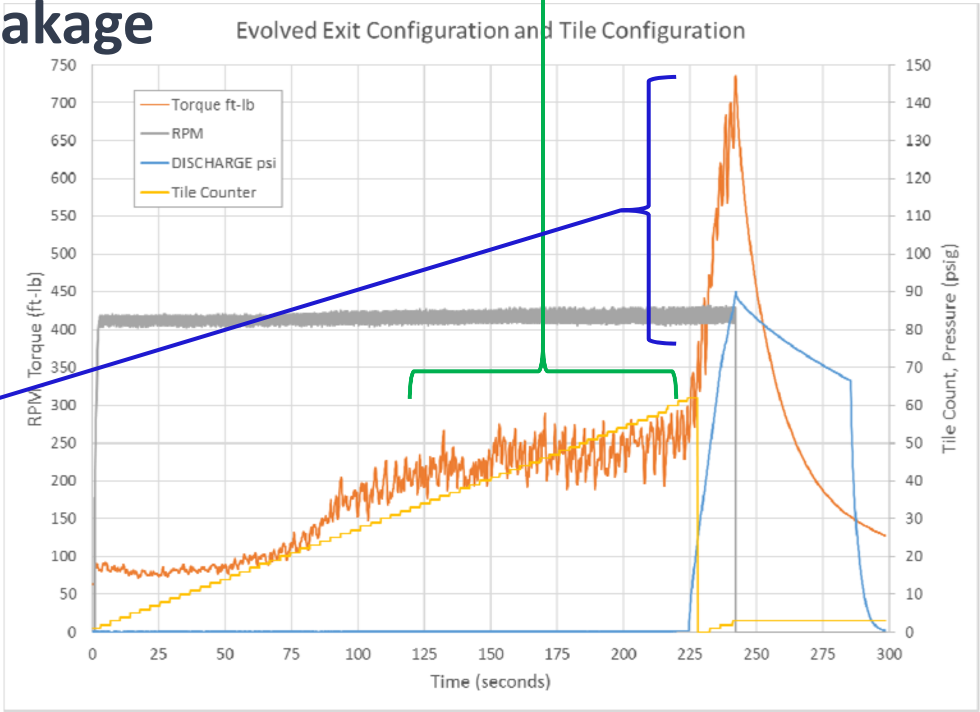
- Geometry/dimensions iterated to reduce steady state torque requirement while still providing gas seal mechanism
- Some geometry tested can amplify the effect of discharge pressure on torque required

Evolving Exit 3 Configuration

- Pressure capability continues to trend with torque/consolidation

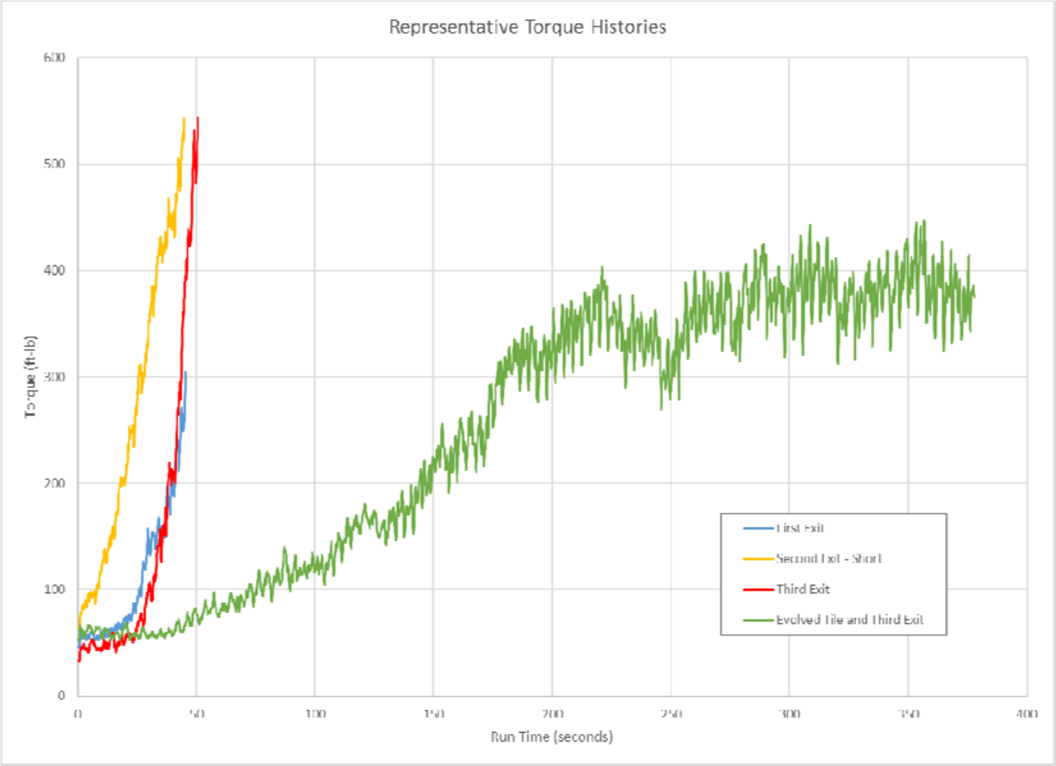
Final Exit with Revised Tile Configuration

- Achieved ***steady state***
- **Extrusion at 90 psig, no leakage**
  - **Features that reduce free-extrusion torque can amplify the effect of pressure on pump torque requirement**



Successful Development of Torque Reduction

- > **Design evolved until steady state operation achieved below pump torque limit**



Subscale Test Summary

- Successful testing of a variety of configurations undertaken with subscale unit
- 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 in development
- Final subscale configuration being transferred to prototype
- Low rank fuel types testing to begin shortly

Fuel Types for Evaluation

- The CFT program will evaluate low rank fuel types in the Subscale DSP
- Fuels will include Sub-bituminous coal and Lignite
- Pet Coke as well as biomass-coal blends may be tested schedule/budget permitting
- Objective to identify any fuel type impact on DSP operation and whether modifications are required for handling at commercial scale
- Determine feed system configuration for meeting each fuels characteristics and providing best overall DSP system performance
- Identify cost of DSP customization if required to handle low rank fuel specifications

DSP-CFT Prototype Program Status

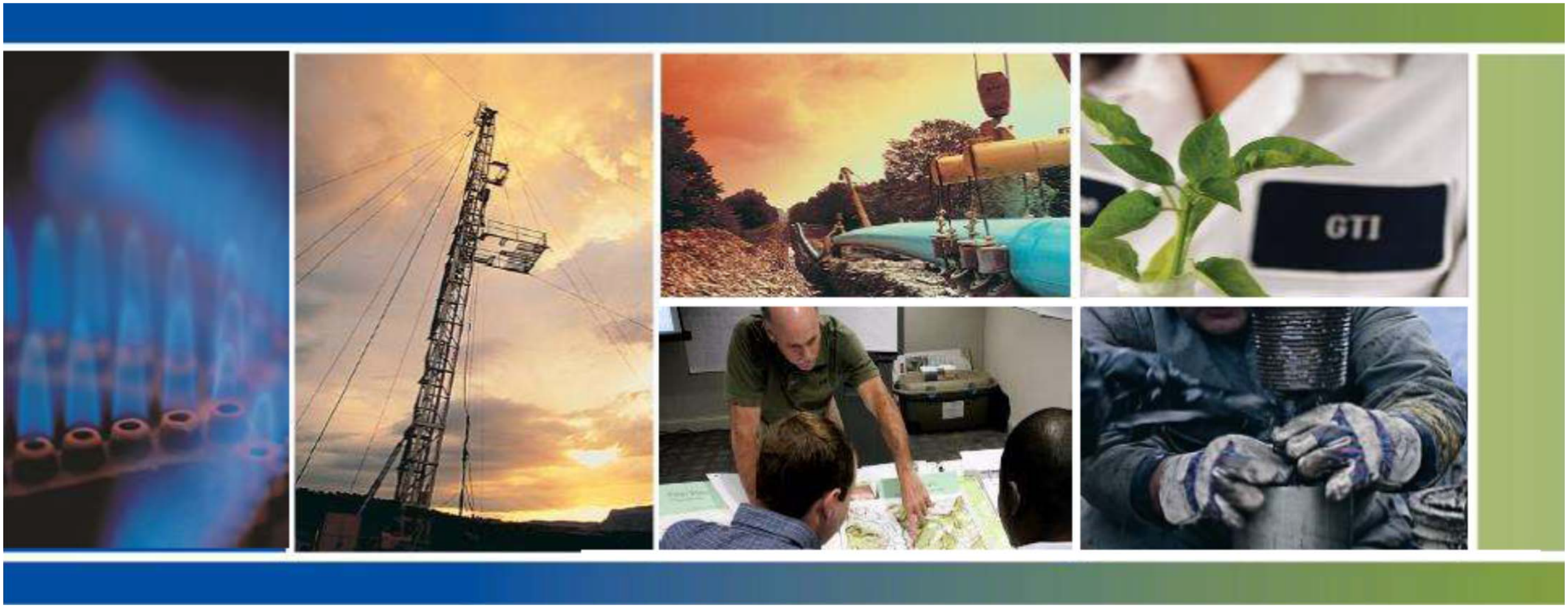
- Subscale testing of proposed modified components completed
- Low-rank fuel type evaluation commencing shortly
- Evaluation of prototype modifications and cost analysis complete
- Manufacture of prototype upgraded components in work
- Modifications to prototype required for component upgrades completed
- Testing on prototype to begin in 2nd Quarter 2017
- Program on track to conclude 3rd Quarter 2017

Acknowledgement

GTI Pump Test Team:
Joe Caravella
Harold Lacquement
Tom Emerson
Mike Kutin

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

Turning Raw Technology into Practical Solutions



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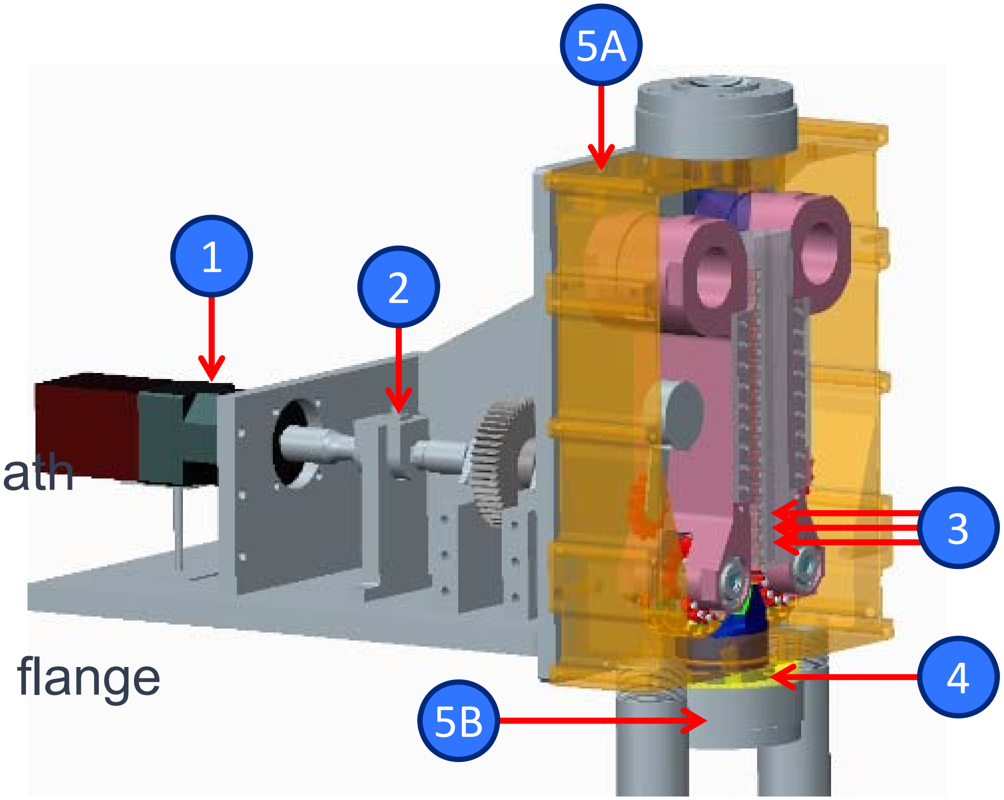
Back Up Charts (follow)

Subscale Instrumentation

1. Motor RPM
2. Torque
   - Upstream of gear split
3. Track load x 12
   - 3 load cells per roller path
4. Vertical load
   - 3 load cells around the flange
5. Gas pressure x 2
   - Case (A) and discharge (B)



Pneumatic System

> GN2 for static and extruding pressure tests