Wear-resistant Surface Technologies for Low-leakage NG Compressors

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Argonne National Laboratory
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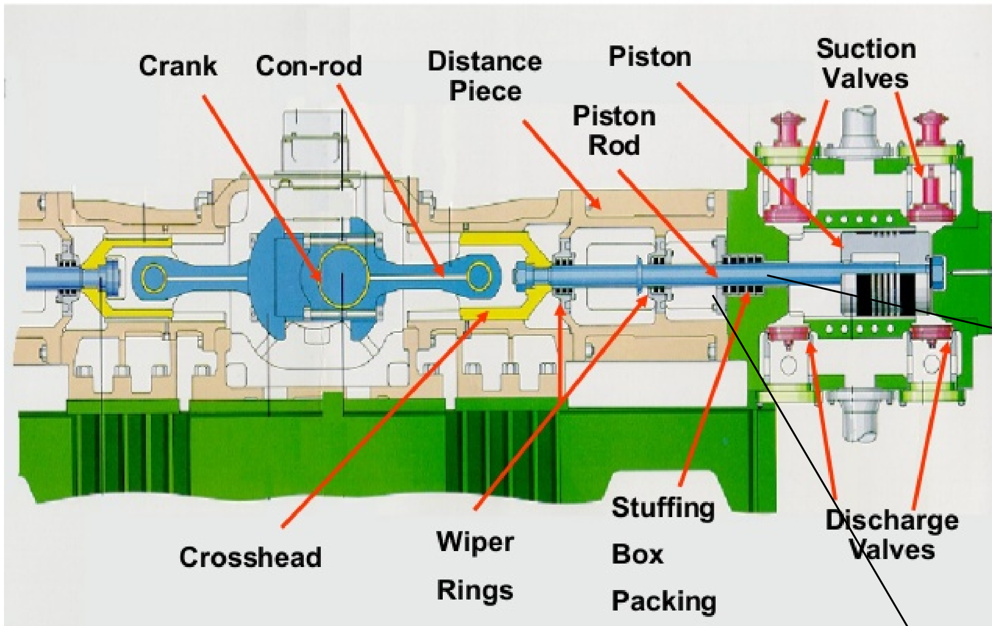
Project Objective

- US is the largest producer of natural gas (NG) which is projected to further increase by 44% through 2040.
- Methane emission through sealing surfaces of reciprocating compressors used in the supply chain is a major concern.
  - Pound for pound, the adverse impact of methane on climate change is 25 times greater than carbon dioxide
  - Estimates suggest that these compressors also consume huge amounts of energy (i.e., 2 quads in 2012 or about 2 percent of total U.S. energy use)
- Current compressor/sealing technology is more than 50 years old and methane leakage is largely due to the inability of current seal materials to provide long wear life and insure tighter sealing.
- **Objective:** To develop and implement self-lubricating, high-wear resistant materials, coatings, and surface treatments on sealing surfaces to mitigate natural gas emissions from the reciprocating compressor systems.

Problems with Existing Technologies

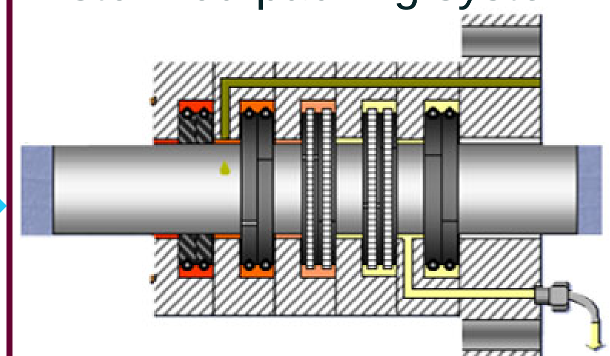
- High frictional heat and progressive wear of sealing surfaces of piston rod packing systems increase the gap through which natural gas escapes to environment.



Most common seal materials: Filled teflon (C-, MoS_2- and glass-filled) Polyetherether-ketone, bronze, ceramics, WC-spray coatings are also used

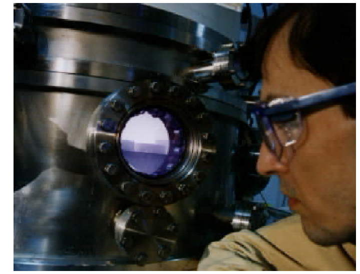
- The highest volume of gas loss is associated with wear of piston rod packing systems.

Piston rod packing system

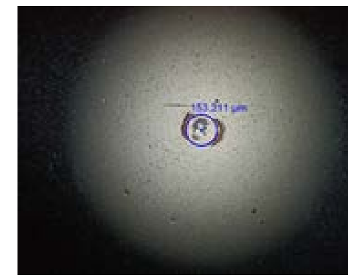


Technical Innovation

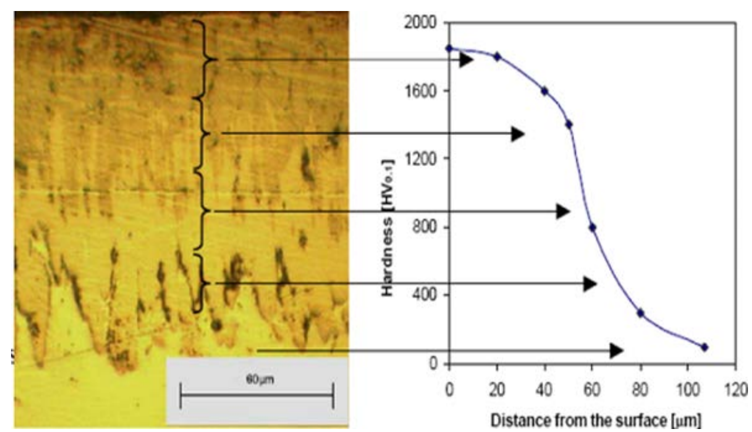
- **Near Frictionless Carbon (NFC)**: A form of amorphous hydrogenated diamondlike carbon (DLC) coating with friction coefficients to below 0.01. Thickness : 1-10 µm
- **Catalytically Active Nano Composite (NC) Coatings**: A new revolutionary coating technology that extracts DLC tribofilms from methane, in situ, and on demand to dramatically reduce wear.
- **Boriding:** A very-fast, efficient and green surface technology that produces very thick, hard and wear resistant boride layers on top to increase durability (should have much superior performance than tungsten carbide (WC) spray coatings used on rods)



No coating

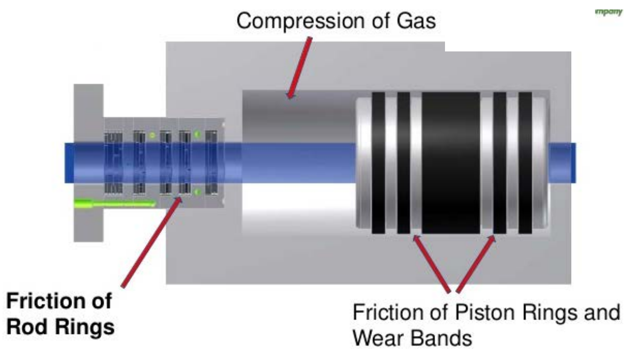


NC-coating



Technical Approach

- **Q1: Understanding of friction and wear problems with baseline seal materials and coatings**
  - Identify/understand root-causes of friction/wear problems in current compressor systems
  - Materials to be evaluated include polymers, bronze, WC, etc.
  - Evaluate seal contact configuration on friction and wear
- **Q2: Impact of Operating conditions (speed, temperature, lubrication, contact pressure)**
  - Baseline studies with existing seal materials
    - Determine the effects of reciprocating speed, ambient temperature, and sealing interface contact pressures on friction and wear of the current seal materials.
  - Surface chemical characterization to understand underlying mechanism.
  - Vast experience/knowledge in wear studies of materials in methane.

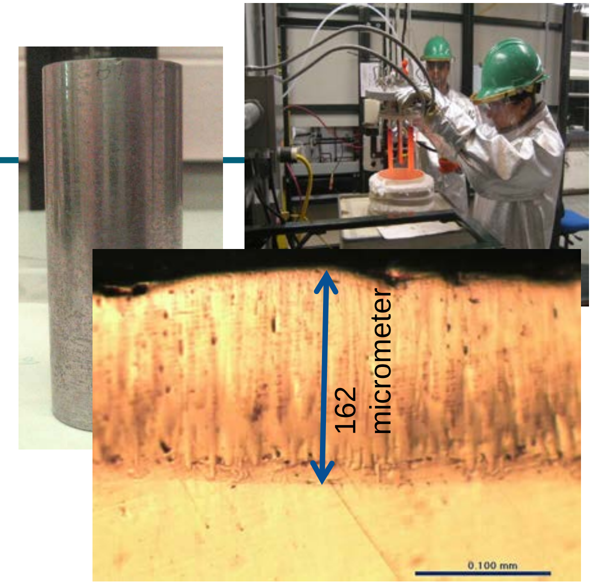


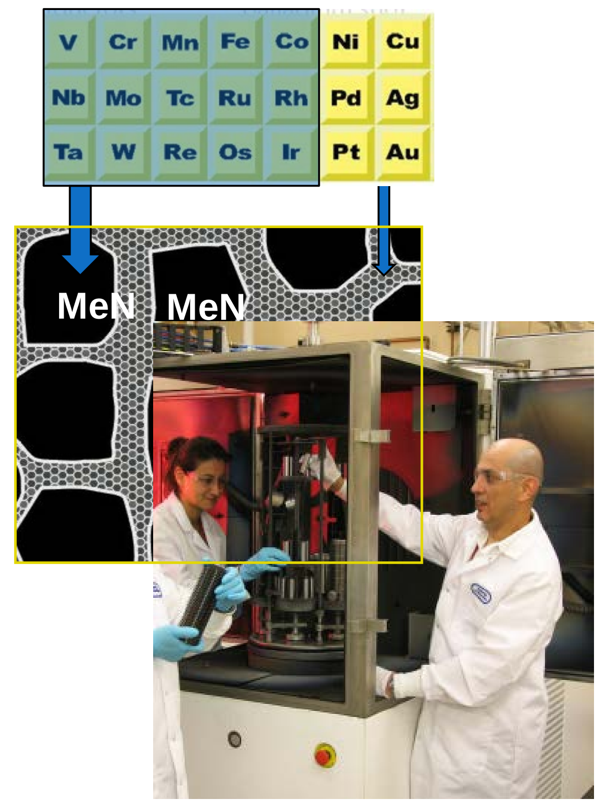
Most common material is filled PTFE (C-filled PTFE, glass-filled). PEEK, bronze, ceramics, WC-spray coatings are also used

Argonne's sealed methane tribometer

Technical Approach

- **Q3: Development/Optimization of Surface Treatment Technologies**
  - Develop and customize Argonne's coatings and boriding capabilities to provide superior friction and wear properties in intended sealing applications.
    - Ultra-fast boriding (which provides very thick and hard layers) will be employed on critical sealing surfaces to achieve greater wear performance against the selected seal materials.
    - Proven technology, transferred to industry, low risk.
- **Q4: Development/Optimization of Coating Technologies**
  - Optimize catalytically active nanocoatings to dramatically reduce wear in methane environments.
    - Further tailor these coating for the specific seal materials used in NG compressor applications.
  - Tailor nearly-frictionless carbon films for ultimate friction and wear control in methane
    - Provides some of the lowest wear and friction coefficients in methane and hence we will explore the potential of this coating in NG applications.
    - These technologies patented by Argonne, mature, proven, hence pose low risk in compressor applications





Transition and Deployment

- **Who Cares?** US Government/Agencies and other stakeholders involved in the production, delivery, storage, and use of natural gas
- **Who is the end user?** Natural gas compressor manufacturers and pipeline operators
- **How will they use it?** They will use coated/treated components from the licensee of Argonne technologies
- **Does it improve their mission/capabilities?** Yes, it will make them globally more competitive and compliant with EPA mandates
- **What is the commercialization approach?** Joint development, commercial viability (cost/benefit analysis), scale-up and deployment through licensing.
- **What is the technology sustainment model?** Drastically reducing methane emission through the use of home-grown/patented sustainable and transformational surface technologies. Leapfrogging 50 year old natural gas compressor technology to mitigate methane emission at its source.

Measure of Success

- Tribological studies have so far confirmed high friction and wear for reciprocating surfaces based on existing seal materials and coatings.
- Preliminary tests with Argonne's NFC coating showed unmeasurable wear in comparison to uncoated surfaces
- Successful development/deployment of Argonne's surface technologies will improve life, reduce parasitic energy losses, and most important, reduce methane emission
- Long-lasting ultra-low leakage through the piston rod packing system (positive impact on environment/climate change)
- Much lower friction between reciprocating surfaces (positive impact on energy efficiency)
- High wear life leading to higher durability/reliability (less maintenance cost through longer meantime between failures)
- Ultimately, leading to highly efficient low leakage compressor technology that can further enhance US leadership in the world market.

Project Management & Budget

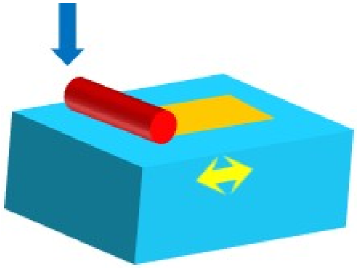
- **Project duration:** 2 years (September 2015 Award date, January 2016 start date)
- **Task 1.** Survey of friction/wear problems in natural gas compressors
  - Milestone: Comprehensive friction and wear data bases on existing seal materials and coatings (due 9/30/2016)
- **Task 2**. Design, development, and optimization of novel sealing surfaces
  - Milestone: Successfully developed and optimized surface and coating technologies providing much superior wear performance compared to baseline materials and coatings (due 9/30/2016)
- **Task 3**. Preliminary rig/compressor testing
  - Milestone: Successful demonstration of the viability of proposed surface technologies in rigs/component level testing.

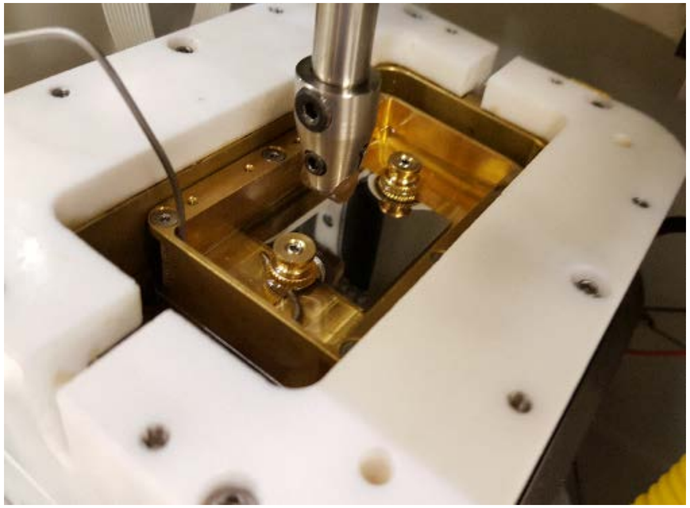
Total Project Budget	
DOE Investment	$700K/year
Cost Share	$0
Project Total	$700K/year

Methodology and Accomplishments

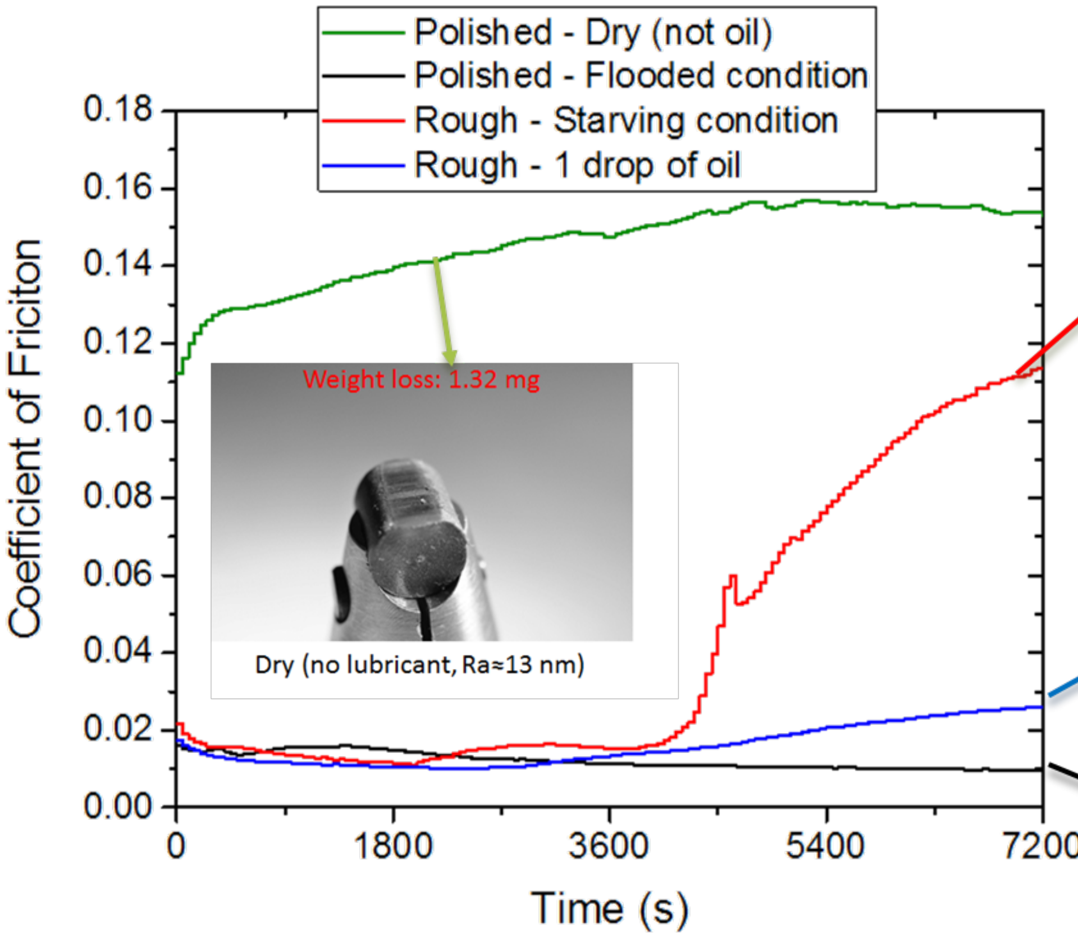
- Project tasks/milestones are on schedule
- Results:
  - Completed procurement of test materials, selection of seal contact geometry, configuration, test conditions
  - Completed baseline studies with representative seal materials.
  - Initiated tests with Argonne’s wear-resistant coatings

Reciprocating Tribo-tester





Validation of Test Methodology



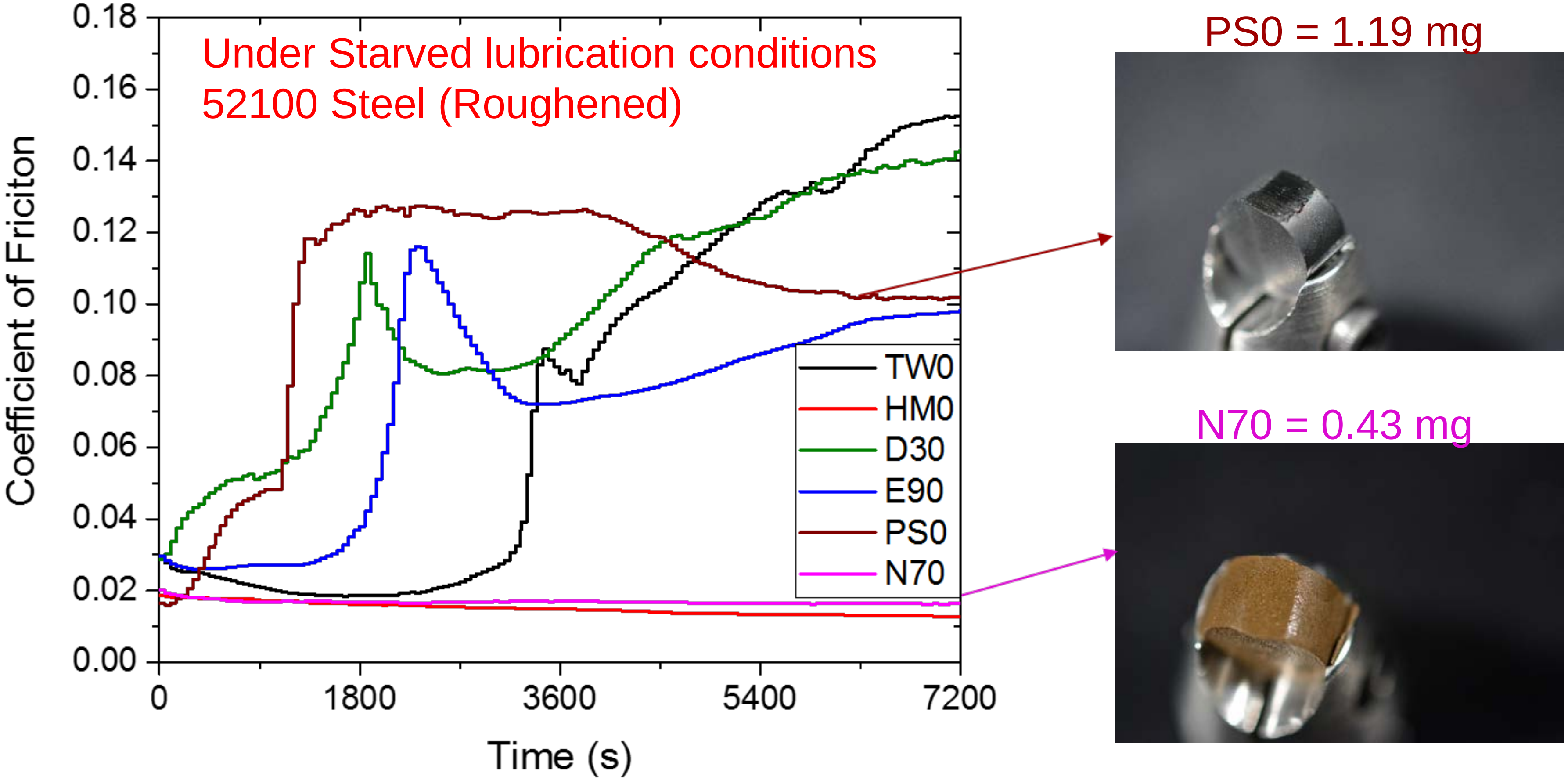
DTE SAE 100 – Starved –
(500 grit, Ra≈120 nm)

DTE SAE 100 – One drop
(500 grit, Ra≈120 nm)

DTE SAE 100 – Flooded, (Ra≈13 nm)

Comparison of friction and wear behavior of a glass and MoS_2-filled PTFE seal material under dry, starved, and fully-oil-lubricated test conditions.

Results: Friction and Wear Behavior



Representative Seal Materials

TWO (702)	**Glass, MoS2 filled PTFE**
HMO (711)	**Mineral MoS2 filled PTFE**
PSO (711)	**Carbon/Graphite filled PTFE**
E90 (783)	**Carbon fiber filled PTFE**
N70 (790)	**Carbon fiber filled PTFE with a modified polymer**
D30 (X-476)	**Dendritic bronze filled PTFE**
DHO (714)	**Bronze/MoS2 filled PTFE**

Comparison of friction and wear behavior of different Teflon (PTFE)-based seal material under starved-oil-lubrication conditions.