Wear-Resistant Surface Technologies for Low-Leakage NG Compressors

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Argonne National Laboratory
Project Period: 10/01/2015-09/30/2017

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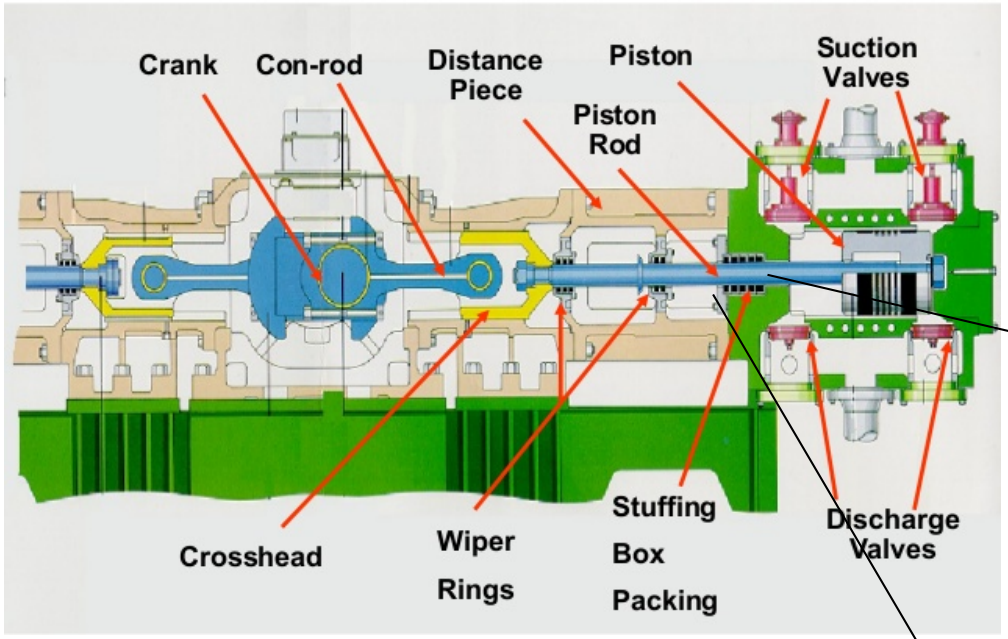
Project Objective

- Current compressor technology is more than 50 years old and methane leakage is a major problem
  - Traditional seal materials are unable to provide long wear life and to insure tighter sealing
  - Further, estimates suggest that these compressors consume huge amounts of energy (i.e., 2 quads in 2012 or about 2 percent of total U.S. energy use*)
- **Objective:** To develop and implement self-lubricating, high-wear resistant materials, coatings, and surface treatments on sealing surfaces to mitigate natural gas leakage from the reciprocating compressor systems.

* Data provided by the Energy Information Administration (EIA) indicate that the annual amount of natural gas used to transport natural gas through the pipeline system was about 0.7 quadrillion Btu. In addition to the pipeline natural gas use, compressors are used in the gathering and processing of natural gas, which is accounted for in the 1.4 quadrillion Btu of natural gas reported by EIA as "lease and plant fuel".

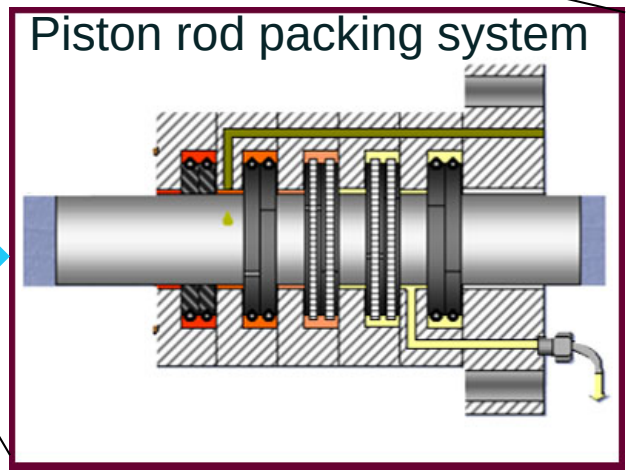
Technical Innovation

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



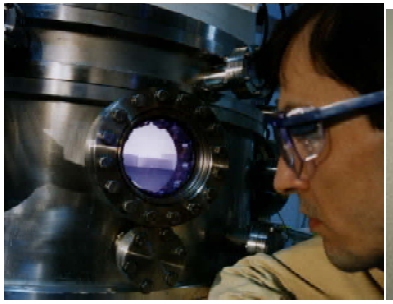
Most common seal materials: Filled teflon (C-, MoS_2- and glass-filled) Polyetherether-ketone, bronze, ceramics, WC-spray coatings are also used

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

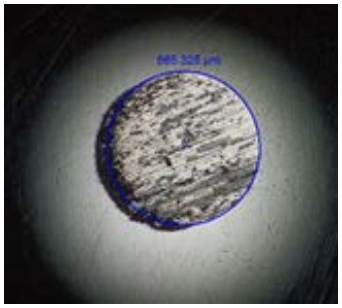


Technical Innovation

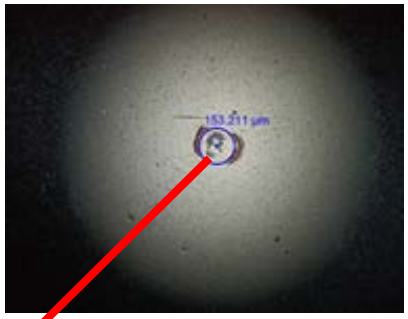
- **Near Frictionless Carbon (NFC)**: A form of amorphous hydrogenated diamondlike carbon (DLC) coating with friction coefficients to below 0.01. Thickness : 1-10 µm



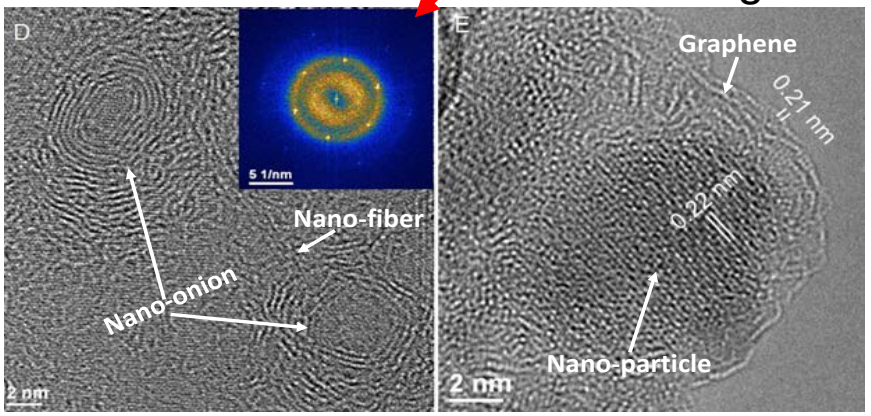
- **Catalytically Active Nano Composite (NC) Coatings**: A new revolutionary coating technology that extracts DLC tribofilms from methane, in situ, and on demand to dramatically reduce wear.



No coating

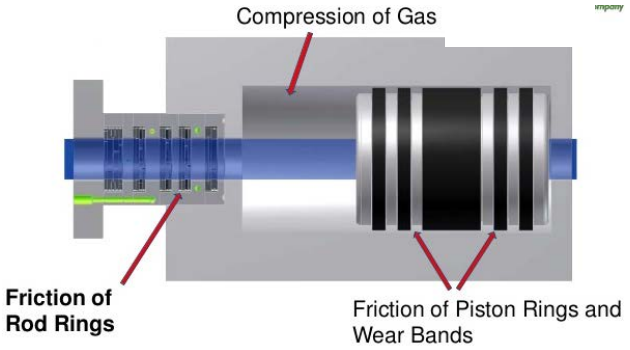


NC-coating



Technical Approach

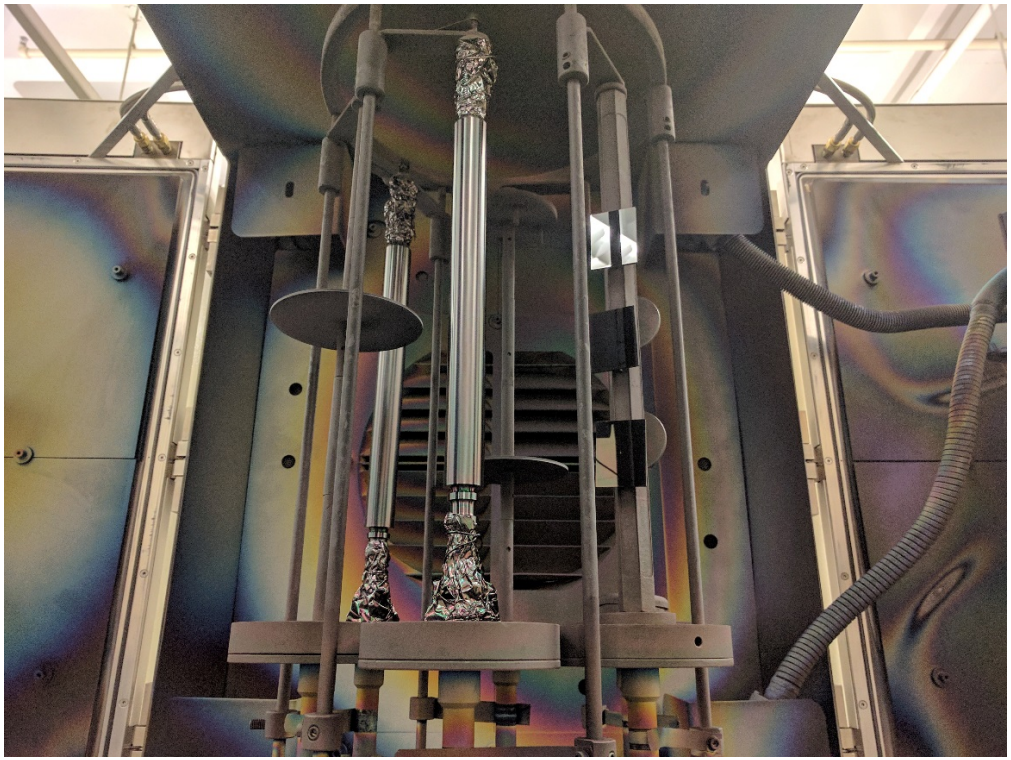
- **TASK 1: Assessment of friction/wear problems in NG compressors and baseline studies (Q1 and Q2)**
  - Identify/understand root-causes of friction/wear problems in current compressor systems and evaluate seal contact configuration on friction and wear
  - Baseline studies with existing seal materials
    - Determine the effects of reciprocating speed, ambient temperature, and sealing interface contact pressures on friction and wear of the current seal materials.
- **TASK 2: Development/Optimization of Surface Treatment Technologies (Q3 and Q4))**
  - Develop and customize Argonne's coatings and boriding capabilities to provide superior friction and wear properties in intended sealing applications.
  - Evaluation of commercially available seal materials rubbed against steel, diamond-like carbon (near frictionless) and catalytically active nanocomposite coating (VN-Cu)



Wear on Seal and Coating

Technical Approach

- **TASK 3: Assessment of long term friction/wear performance of down-selected seal-coating couples for NG compressors**
  - Long-term testing of selected test pairs (coatings and seals)
  - Coating of compressor components
  - Component level testing



Transition (beyond DOE assistance)

- **Who Cares?** US Government Agencies and industrial 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 establish coating facility or obtain directly from coating companies
- **Does it improve their mission/capabilities?** Yes, it will lead to higher durability/reliability (hence, lower maintenance cost) and reduce methane leakage.
- **What is the commercialization approach?** Joint development, scale-up and deployment through licensing.
- **What is the technology sustainment model?** Marked improvement of seal life/performance using transformational surface technologies. Mitigation of methane emission at its source.

Measure of Success

- Confirmed high friction and wear losses for existing seal materials and coatings.
- Tests with Argonne's nearly frictionless carbon coating showed unmeasurable wear in comparison to uncoated surfaces
- Catalytically active nano-composite coatings were also shown to dramatically reduce wear hence improve life.
- Both coatings have the capacity to enable long-lasting ultra-low leakage through the piston rod packing systems of NG compressors
- Much lower friction between reciprocating surfaces (positive impact on energy efficiency)
- Ultimately, leading to highly efficient low leakage compressor technology that can further enhance US leadership in the world market.

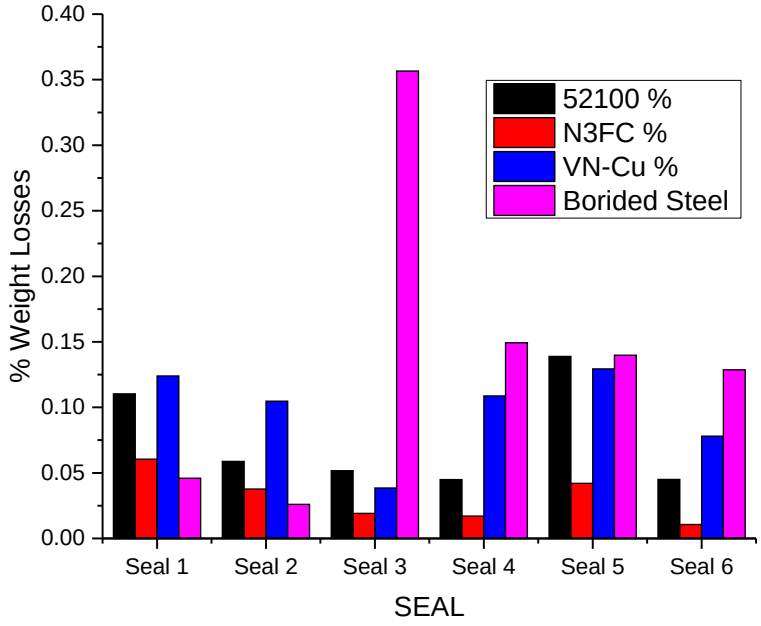
Project Management & Budget

- **Project duration:** 2 years (FY2016 and FY2017)
- **Task 1.** Survey of friction/wear problems in natural gas compressors
  - Milestone: Comprehensive friction and wear data bases on existing seal materials and coatings (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 (9/30/2016)
- **Task 3**. Preliminary rig/compressor testing
  - Milestone: Successful demonstration of the viability of proposed surface technologies in rigs/component level testing (due 9/30/2017)

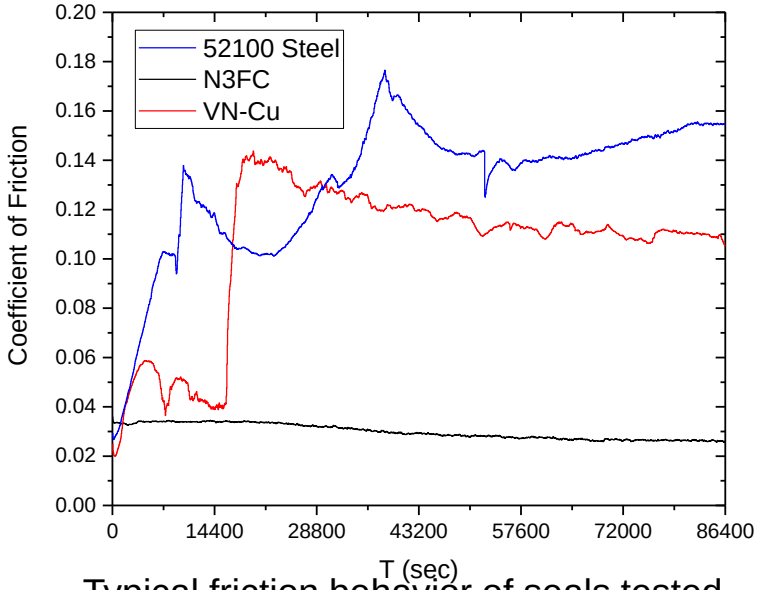
Total Project Budget	
DOE Investment	$700K/year
Cost Share	$0
Project Total	$1.4M

Results and Accomplishments

- Successful development, optimization, and application of NFC and catalytically-active nano-composite coatings on compressor rods for rig-testing.
- From now until the end of the project, the coatings will be subjected to long-duration compressor tests by our seal manufacturer partner (**Cook Compression**) at their test facilities.



Wear losses of seals tested against different surfaces.



Typical friction behavior of seals tested again steel, VN-Cu and N3FC.