H_2 Materials Compatibility of Low Cost, High Pressure, Polymer H_2 Dispensing Hoses

Kevin Simmons, PNNL (PM,Presenter), Kenneth Johnson, PNNL
Jennifer Lalli, NanoSonic (PI), William Harrison, NanoSonic (PM)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Pacific Northwest NATIONAL LABORATORY

NanoSonic Putting nanotechnology to work

Overview

Timeline
- Project Start Date: 1/15/2018
- Project End Date: 7/19/2018
- % Completed: 0%

Budget
- Total Project Budget: $60K
  - Total Federal Share: 50%
  - Total DOE Funds Spent:
    $0K (PNNL)
    $0K(NanoSonic)

New Start

Barriers
A. Lack of Hydrogen/Carrier and Infrastructure Options Analysis

I. Other Fueling Site/Terminal Operations

K. Safety, Codes and Standards, Permitting

Partners
- PNNL (Project Lab Lead)
- NanoSonic (PI)

Relevance

Objectives: To increase the safety and reliability of H2 hoses while low H2 permeation polymers and durable cryogenic composites to realize the H2@Scale objectives to reduce the cost of H2

- Provide scientific and technical basis to enable full deployment of H2 and fuel cell technologies by filling the critical knowledge gap for polymer performance in H2 environments for dispensing hoses
- Develop standard test protocol for dispensing hose materials under high pressure hydrogen and sub ambient temperatures
- Develop a better understanding of material performance under extreme conditions for improved life cycle performance and costs

Barriers	Project Impact
A. Lack of Hydrogen/Carrier and Infrastructure Options Analysis	Develop hose durability and reliability data for hydrogen compatibility guidance that will provide improved life-cycle costs for dispensing hoses
I. Other Fueling Site/Terminal Operations	Provide alternative dispensing hose options with lower costs and longer operational life
K. Safety, Codes and Standards, Permitting	Develop valuable test method that provide increased understanding of dispensing hose performance under extreme environmental conditions

Objectives

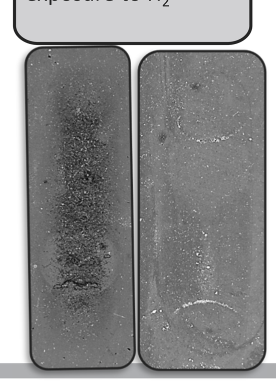
To determine the lifetime of NanoSonic H_2 hose polymer and composite constituents
- Testing material using time-temperature superposition (TTS) studies via dynamic mechanical analysis (DMA) under H_2
- Friction and wear resistance under in situ H_2 tribometry
- Multi-axis strain testing of composite materials under cryogenic conditions.

Project Tasks

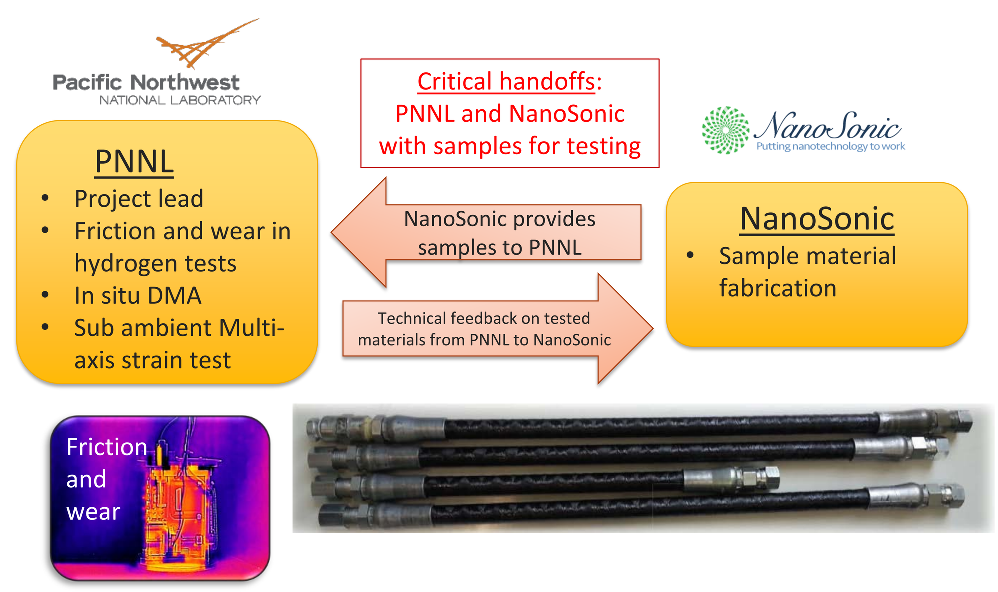
Task 1:
Technical Interchanges with NanoSonic
- Materials of interest developed by NanoSonic
- NanoSonic to provide PNNL with newly developed materials
- Interchange technical information

Task 2:
Cryogenic Multi-axis Strain Testing
Selection of relevant polymers
- Determining preliminary test parameters
- Conducting preliminary tests and establishing optimum conditions of operation

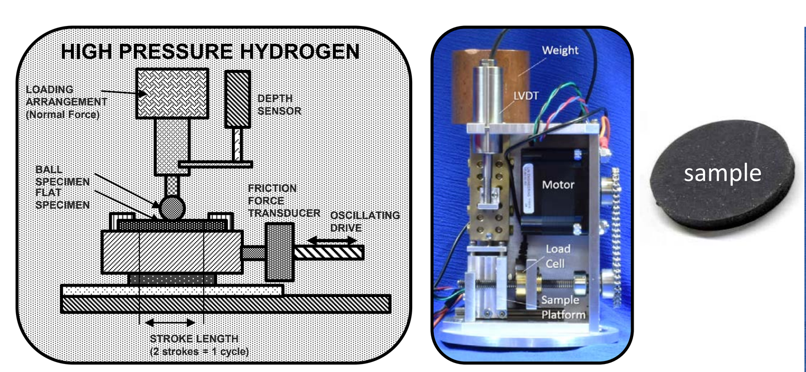
Task 3:
H2 Tribology and H2 DMA TTS for Polymer and Composite Lifetime Assessment
Baseline properties before and after exposure to H_2

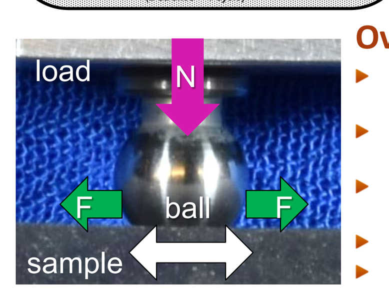


Work Flow

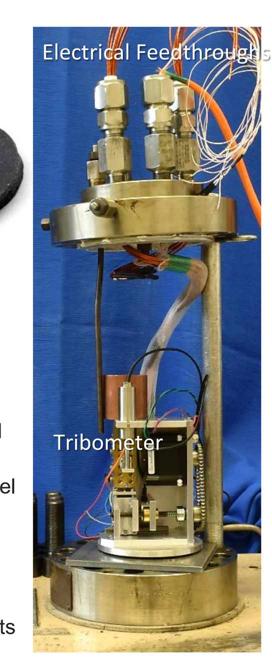


Approach
Overview of the Unique PNNL In Situ Tribometer



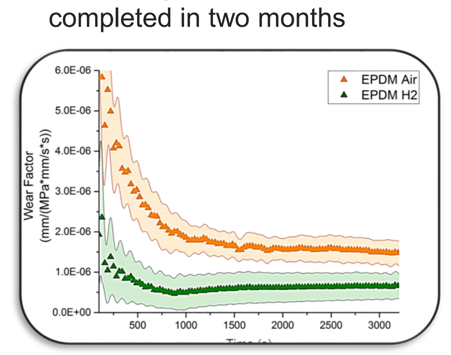


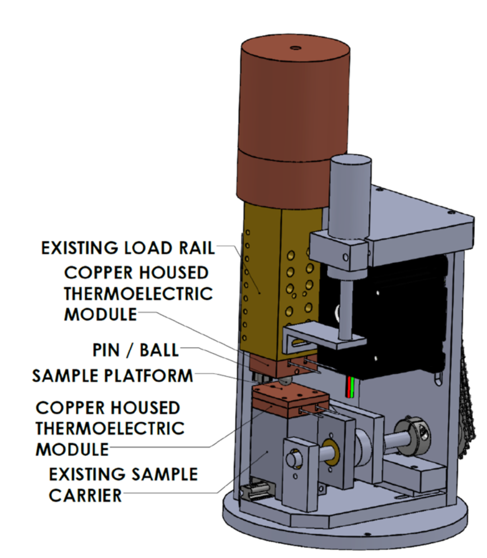
Overview of Tribometer
- Linear reciprocating adapted from ASTM G133
- Normal load (using weights) presses steel ball into moving sample
- Frictional force and vertical wear depth profiles measured in situ
- Pressures up to 5,000 psi hydrogen
- Ambient air and high pressure argon tests run for comparison



Approach
Novel In Situ Tribometer with In Situ Heating and Cooling

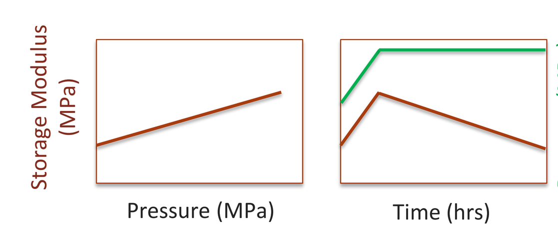
- Target temperatures above or below ambient (-40 to +85°C) for infrastructure applications
  - New design offers lower temperature range capability (-50 to +200°C)
  - New design expected to be completed in two months

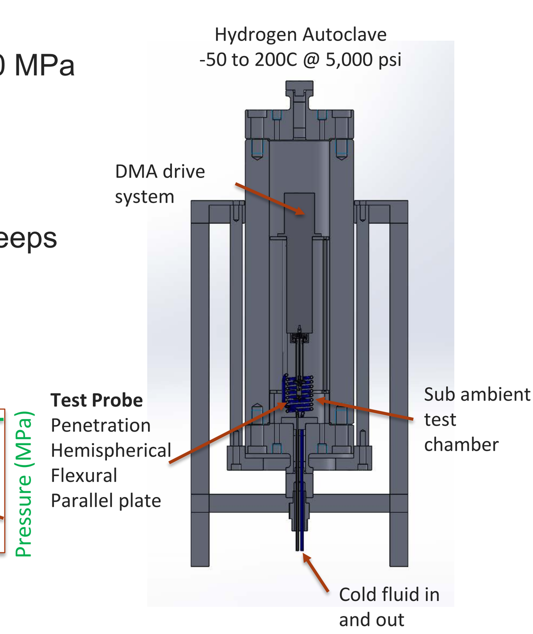




Approach
In situ Dynamic Mechanical Analysis

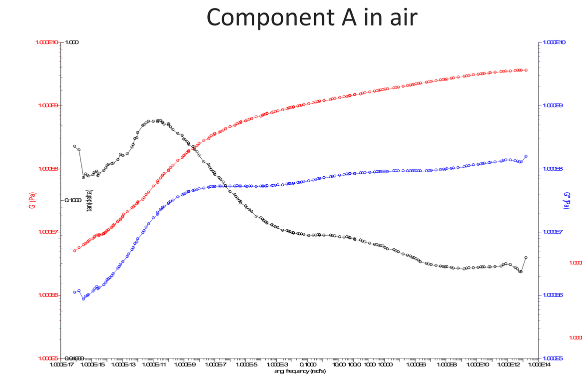
- Pressure range atmospheric to 30 MPa
- Frequency sweeps
- Creep and recovery
- Temperature range -50C to 125C
- Isothermal runs with pressure sweeps to investigate pressure effects on material with gas variable



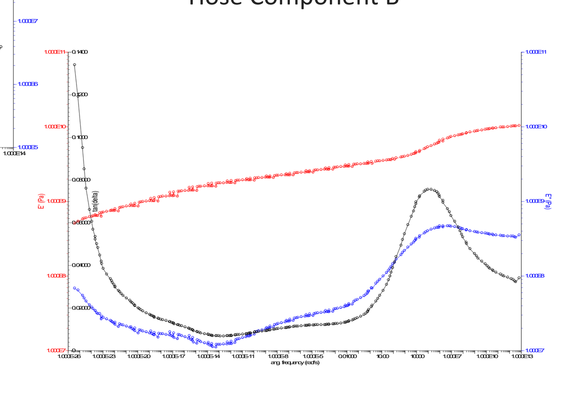


Accomplishments and Progress
In situ Dynamic Mechanical Analysis

DMA TTS Master Curve for NanoSonic H_2 Hose Component A in air

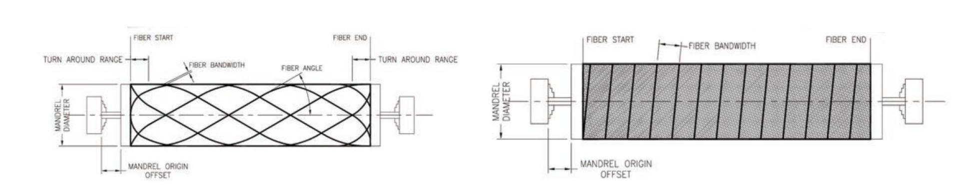


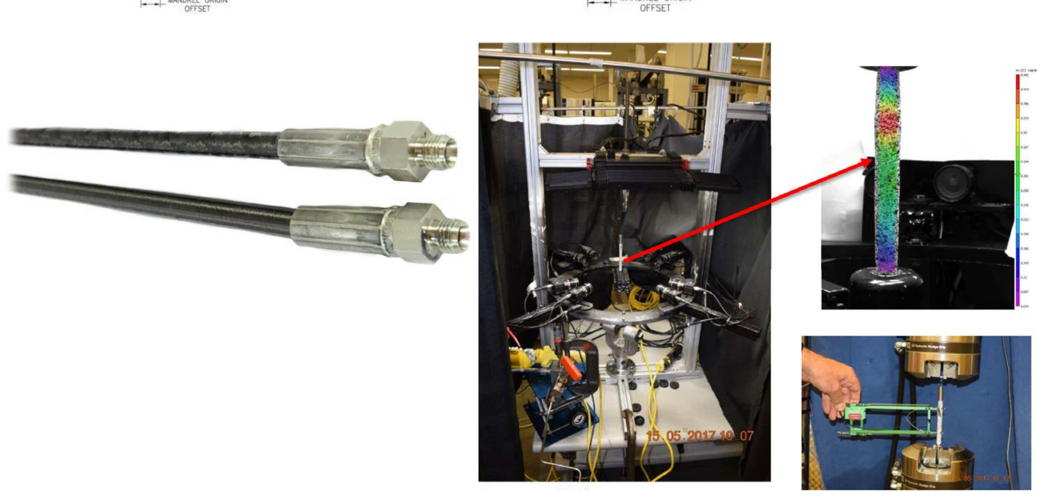
DMA TTS Master Curve for NanoSonic H_2 Hose Component B



DMA TTS Master Curve Baseline Developed

Approach
Composite In-plane Strain and Hose Testing





Accomplishment Summary
- New Start
- CRADA in place and materials being prepared by NanoSonic for PNNL

Response to previous year's reviewers' comments
- This project was not reviewed last year

Collaborative Activities

	Partner	Project Roles
	DOE	Sponsorship, Steering
Pacific Northwest NATIONAL LABORATORY	PNNL	Project Lead, Polymer Characterization, Wear and Tribological Studies, Mechanical Properties and High Pressure
NanoSonic	NanoSonic	Project Manager, Principal Investigator, Material Development, Material Fabrication, and Polymer Characterization

Remaining Challenges and Barriers

Challenges and Barriers	Mitigation
Hose Connections	Testing to understand deficiency in hose connections that will allow for connector design changes
Hose Liner Barrier Cold Gas Properties	Testing to develop material properties in cold gas hydrogen that will provide insight on material deficiency
Composite in-plane Strain Understanding	Develop an understanding of the composite material limitations for hoses and tanks that will provide a more predictable understanding

Proposed Future Work
- Remainder FY18
  - Tribology testing of NanoSonic hose barrier material at ambient conditions
  - Tribology testing of NanoSonic hose barrier material with in-situ argon exposure to 4000 psi
  - Tribology testing of NanoSonic hose barrier material with in-situ hydrogen exposure to 4000 psi
- FY19
  - In-situ Dynamic Mechanical Analysis (DMA) at 4000 psi in hydrogen and argon
  - Subambient testing at -40C in in-situ DMA at 4000 psi hydrogen and argon
  - In-plane strain testing on composite plates

Technology Transfer
- Industrial Collaborators
  - NanoSonic

Contacts

Kevin Simmons (PM)	☎: 509-375-3651	✉: kl.simmons@pnnl.gov
Ken Johnson	☎: 509-375-2241	✉: ki.johnson@pnnl.gov
Jennifer Lalli	☎: 540-626-6266	✉: jhlalli@NanoSonic.com
William Harrison	☎: 540-626-6266	✉: wharrison@NanoSonic.com