



POWERTECH LABS INC.

Materials Testing in Hydrogen Gas

Darren Bromley, P.Eng.

April 9th, 2013

Powertech

Overview

- About Powertech
- History in hydrogen industry
- Evolution of test equipment
- Current materials test equipment
- Challenges and limitations

About Powertech

Based in Surrey, British Columbia
Founded in 1979, with over 30 years of technical engineering expertise

World-class Technical Expertise
130 employees: technologists, professional engineers and PhDs

Large multidisciplinary laboratory facility
11 acre site; 200,000 sq. ft.; 19 labs)

Global customer base
300+ customers, including many Fortune 500

History in Hydrogen

- 1994 - requested by Ballard to investigate safety of using CNG cylinders for hydrogen
- Determined a lack of any standards – Powertech now:
  - Convener of ISO 15869 for Hydrogen tanks
  - Chair of U.S. HGV2 for Hydrogen tanks
  - Secretary of CSA B51 (first published hydrogen fuel tank standard in world)
  - Chair U.S HGV3.1 for H_2 vehicle components
  - Convener ISO 17268 for H_2 fill connectors

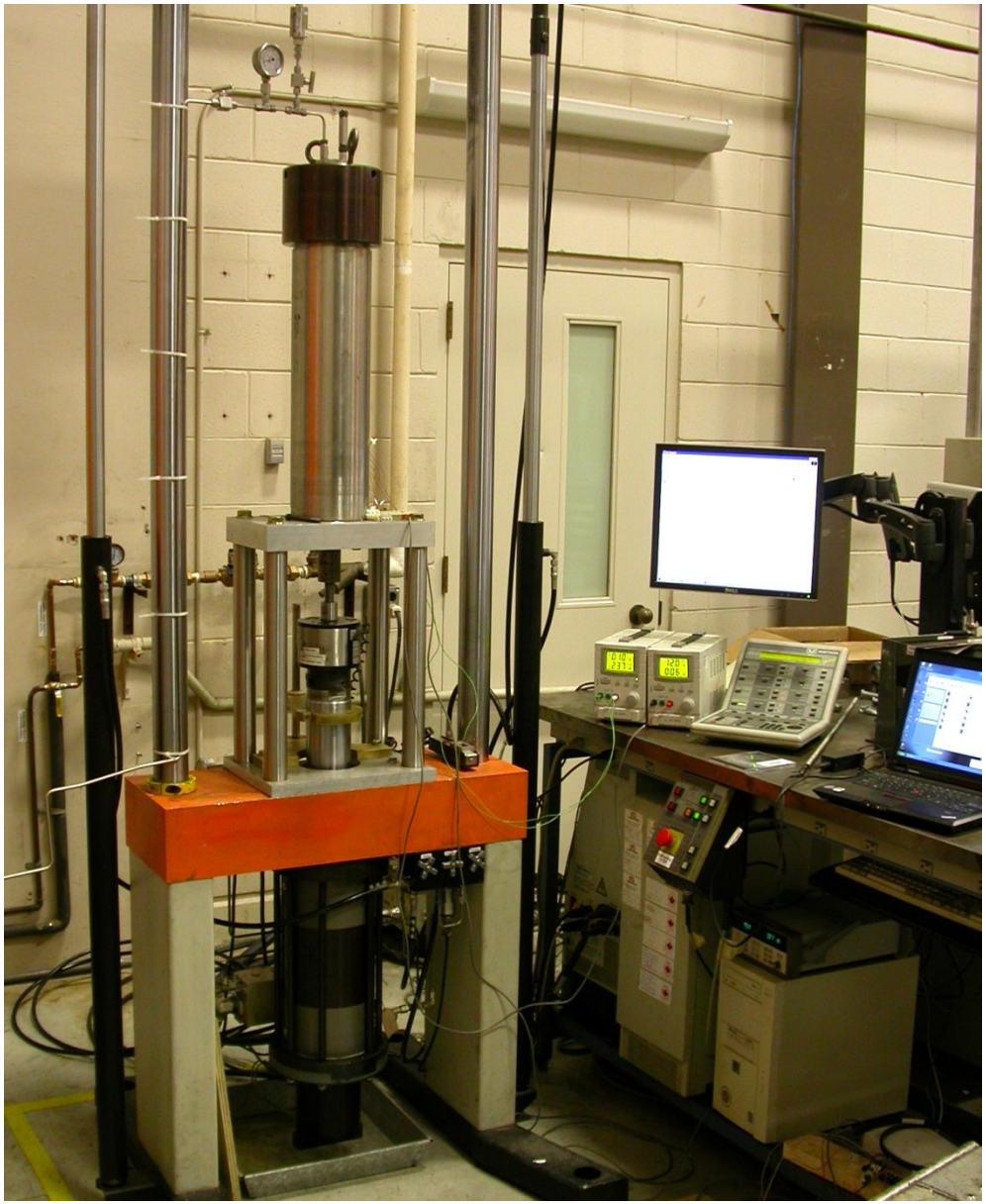
Hydrogen Test Facilities

Hydrogen Testing

- Perform certification testing of ALL high pressure components in a vehicle fuel system
  - Cylinders, solenoid valves, regulators, pressure relief devices, etc.
- Perform certification testing of ALL high pressure components in fuel stations
  - Storage vessels (design pressures up to 100 MPa), hoses, break-aways, flow meters, check valves, nozzles, connectors, etc.
- Perform design verification and safety testing of complete fuel systems, and complete vehicles
  - Extreme temperature fast filling, collision impact, vehicle fire, etc.

Hydro gen Test Chamber

- Instron servo-hydraulic test frame
- 10,000 psi limit
- Tests:
  - Fatigue life
  - Fatigue crack growth rate
  - Fracture toughness
  - Slow strain rate tensile

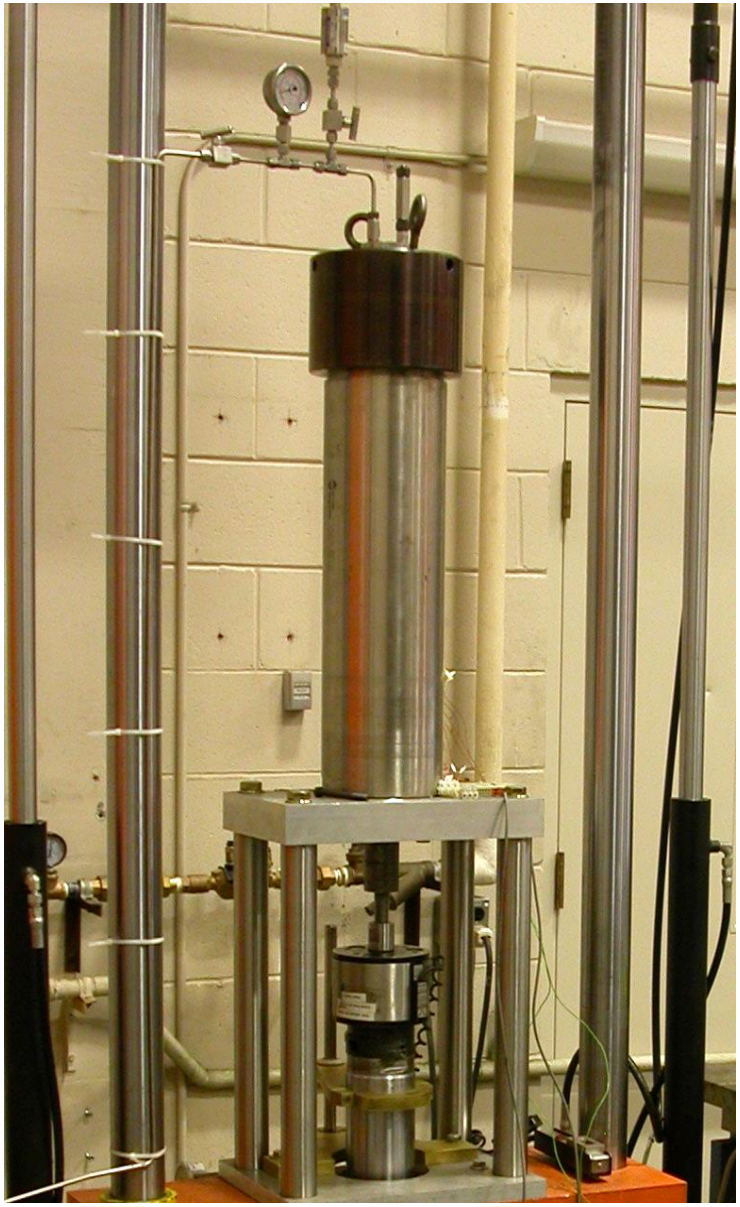


CONSTANT Evolution

- Multiple o-ring pull rod seals
  - SSRT: no problem
  - Fatigue: o-rings wore extremely fast
- Internal strain gauge based load cells
  - Signal drift, unstable readings
  - First attempt was non-vented (top cracked open)
- Alignment issues caused galling of pull rod
- Stacking Polypak seals caused collapse and extrusion
- Encountered pull rod seizing during attempt at low temperature test (difference of CTE)

Hydro gen Test Chamber

- Stellar pressure transducer
- Conax Buffalo 10-wire pass through
- External and internal load cells
- Eutectic pressure relief device
- Over-pressure relief valve



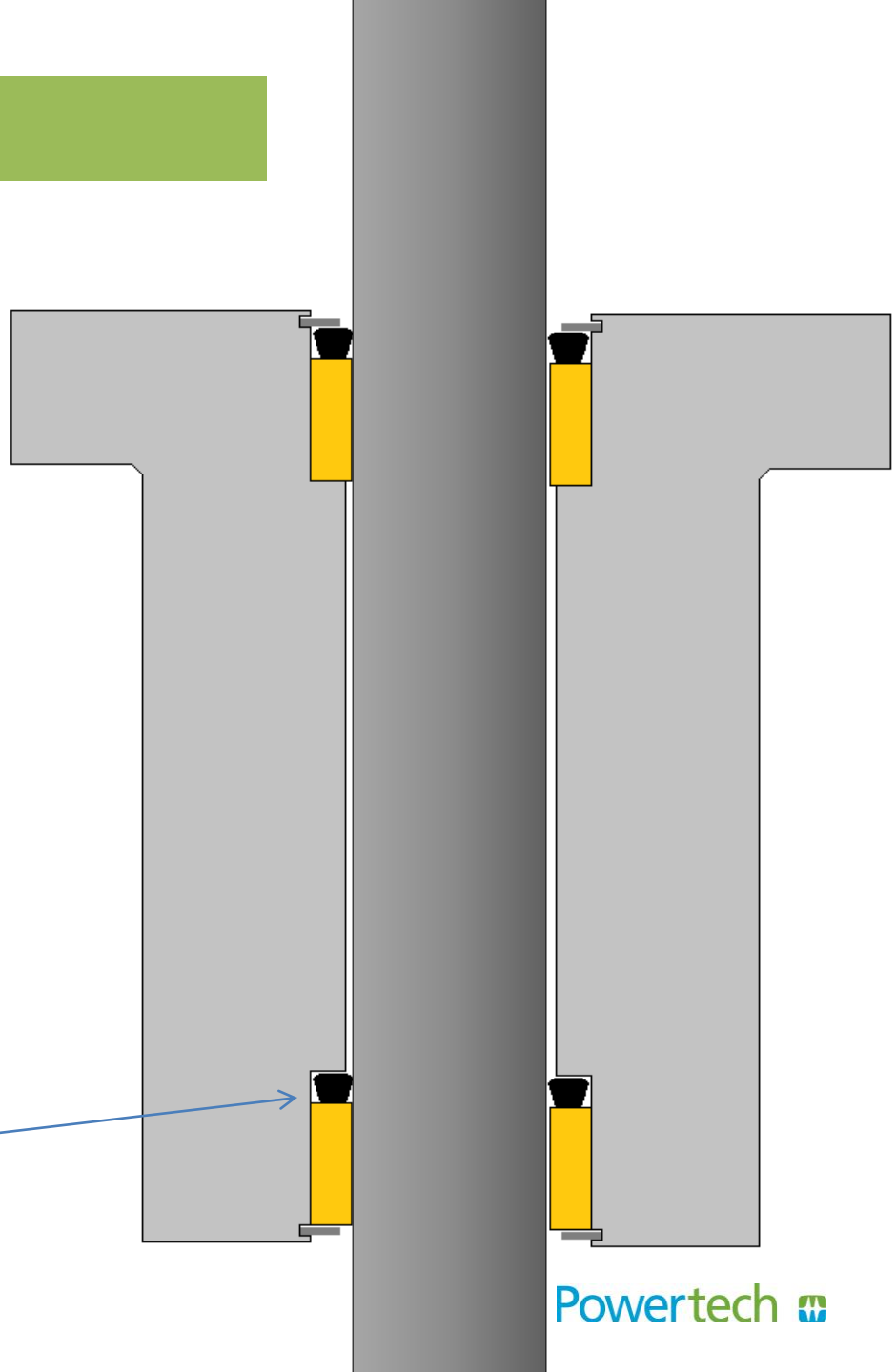
Elevated Temperature Tests

- Heat tape and insulation for elevated temperature tests
- Temperature control to +85°C

Powertech

Dynamic Sealing

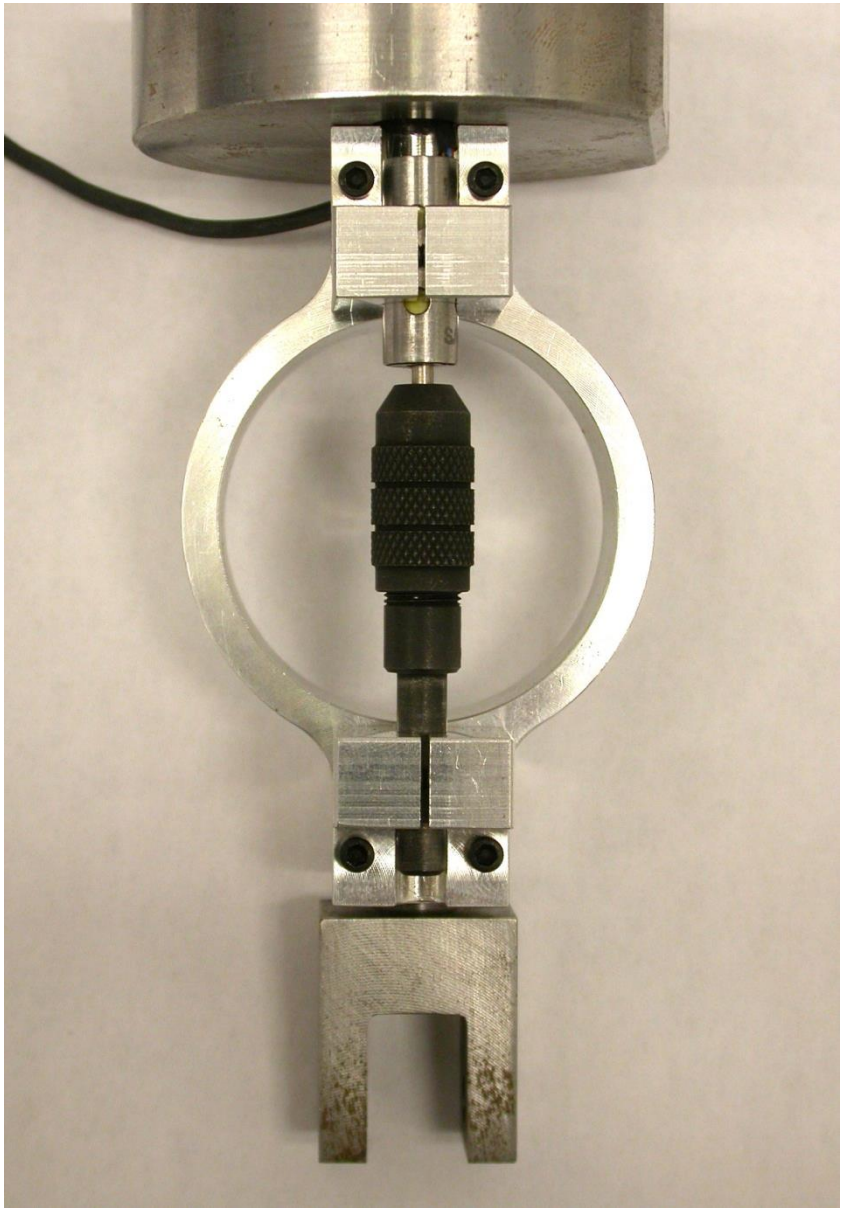
- Dynamic sealing insert into vessel bore
- Double Polypak piston seals backed by brass bushings
- Seals held by ring clips
- Polished pull rod made from Q&T 4130
- Plans to incorporate leak port



Powertech

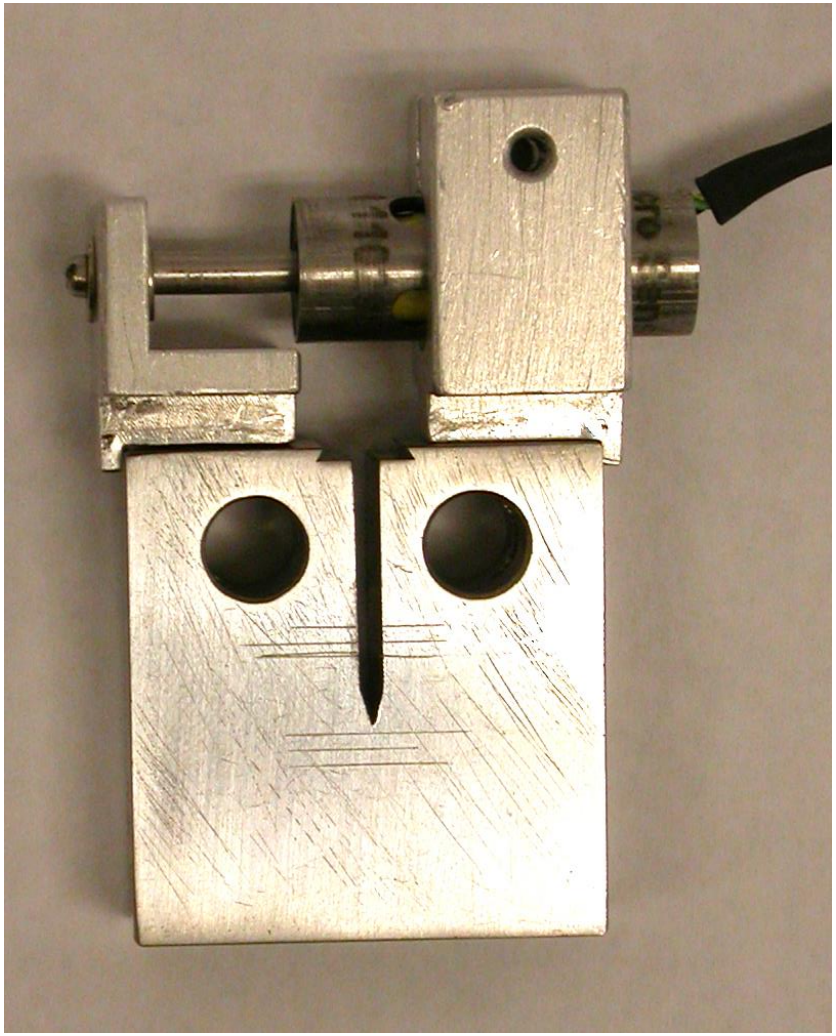
Internal Load Measurement

- Internal load measured using proving ring design
- Deflection of ring measured using vented Macro Sensors LVDT
- Numerical modeling used to design a variety of load capacities
- LVDT holders are transferred between them

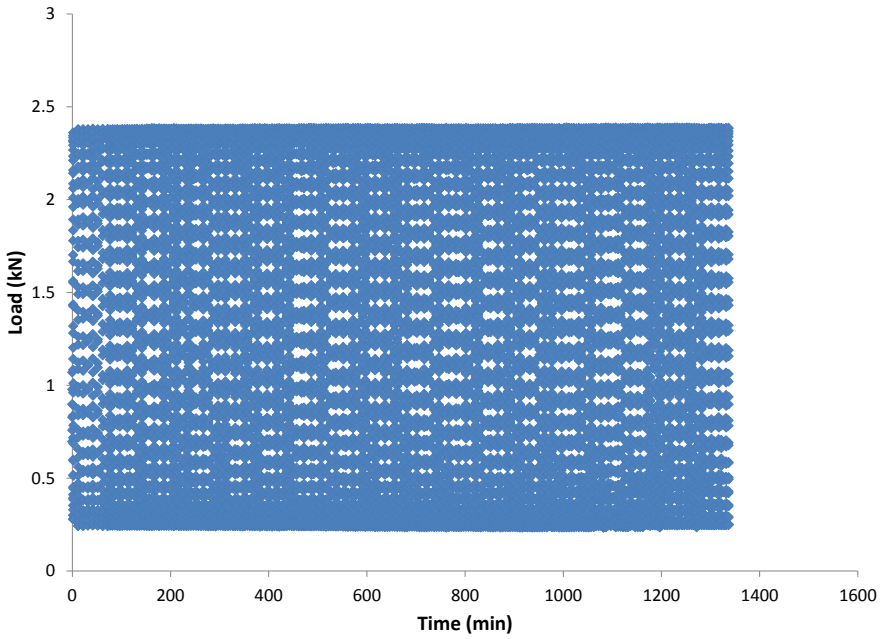


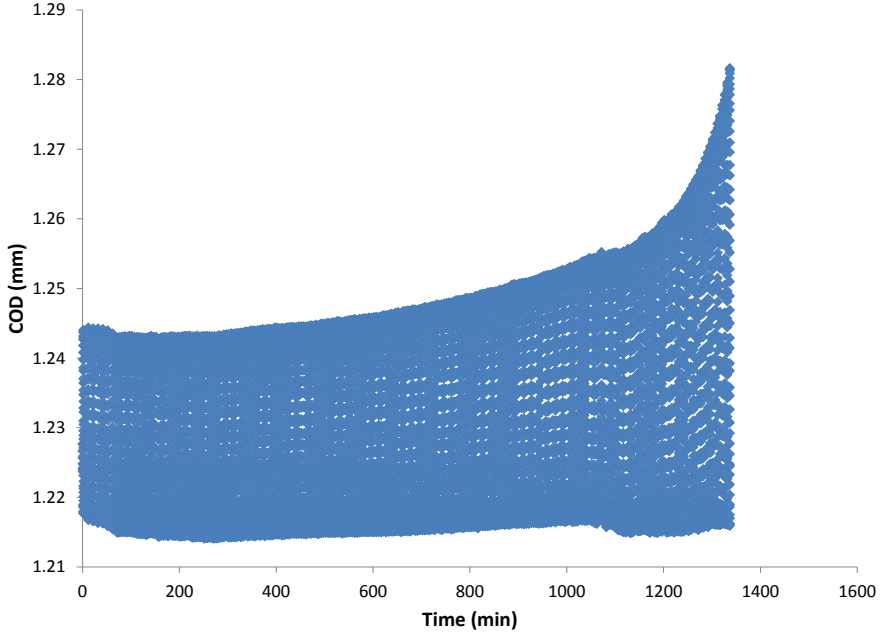
COD Gauge

- Crack opening displacement measured using vented LVDT
- LVDT is mounted to the specimen
- Load line COD is calculated using geometrical relationships



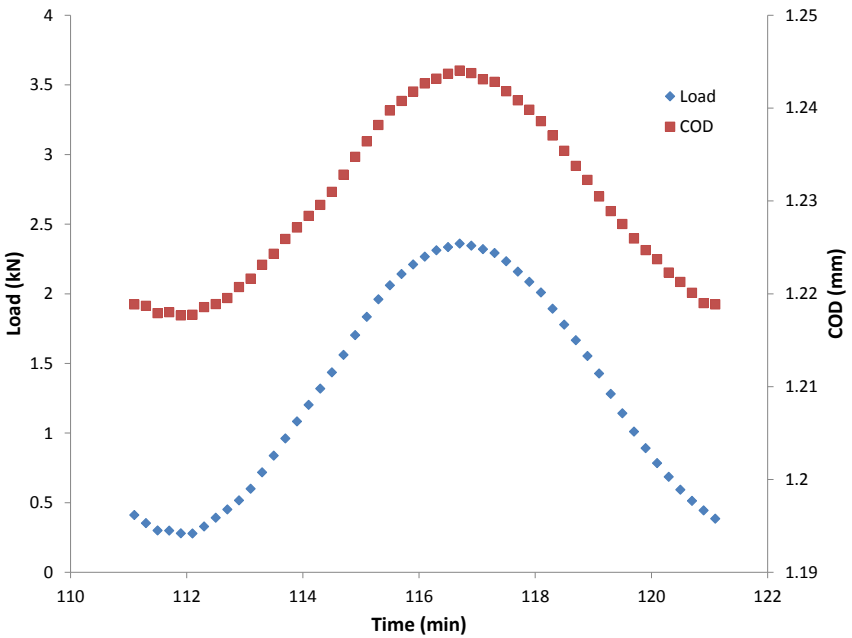
Sample Fatigue Test Data

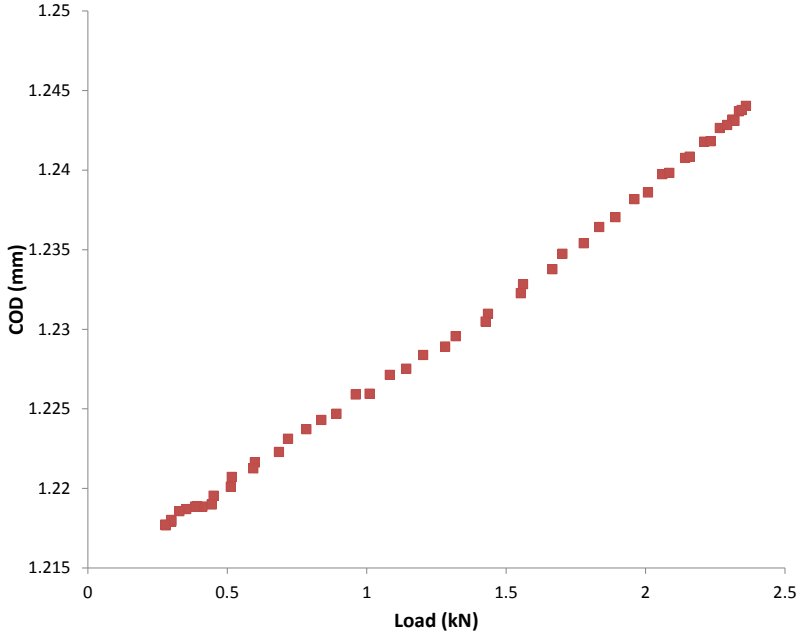




- Load and COD data for sample specimen
- Cycle frequency was 0.1 Hz, stress ratio was 0.1
- Data was recorded at 5 Hz for one full cycle every 5 minutes

Powertech

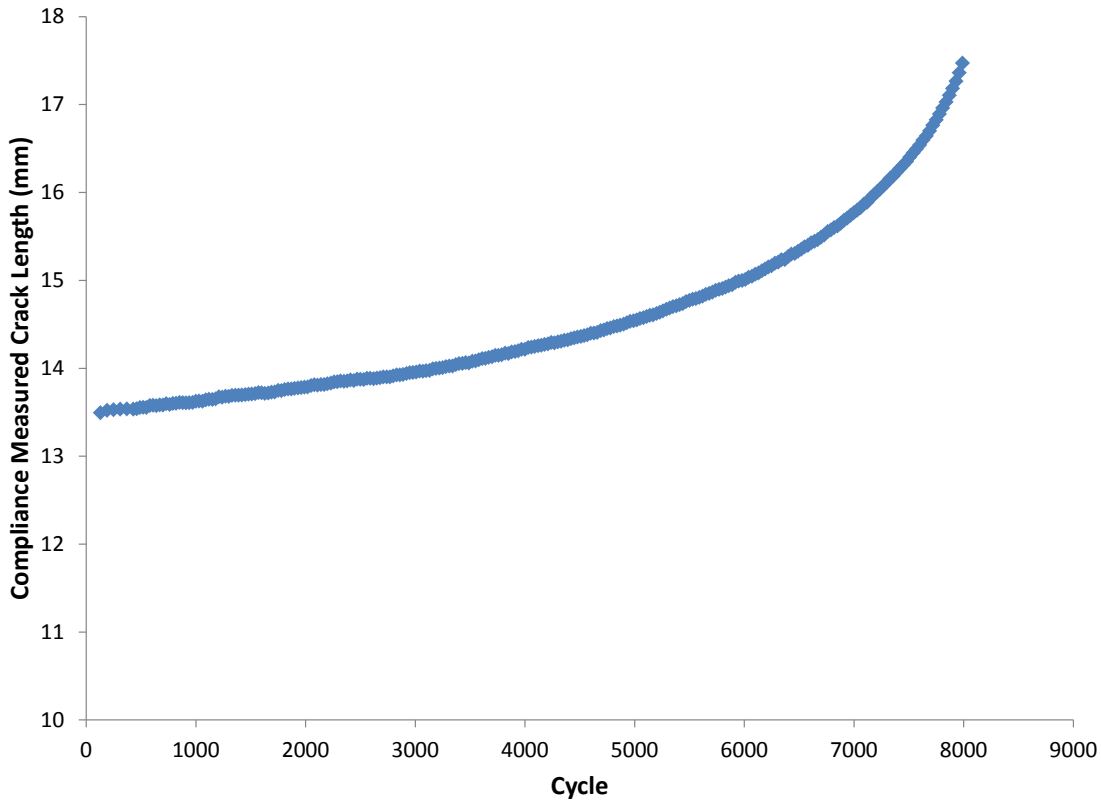




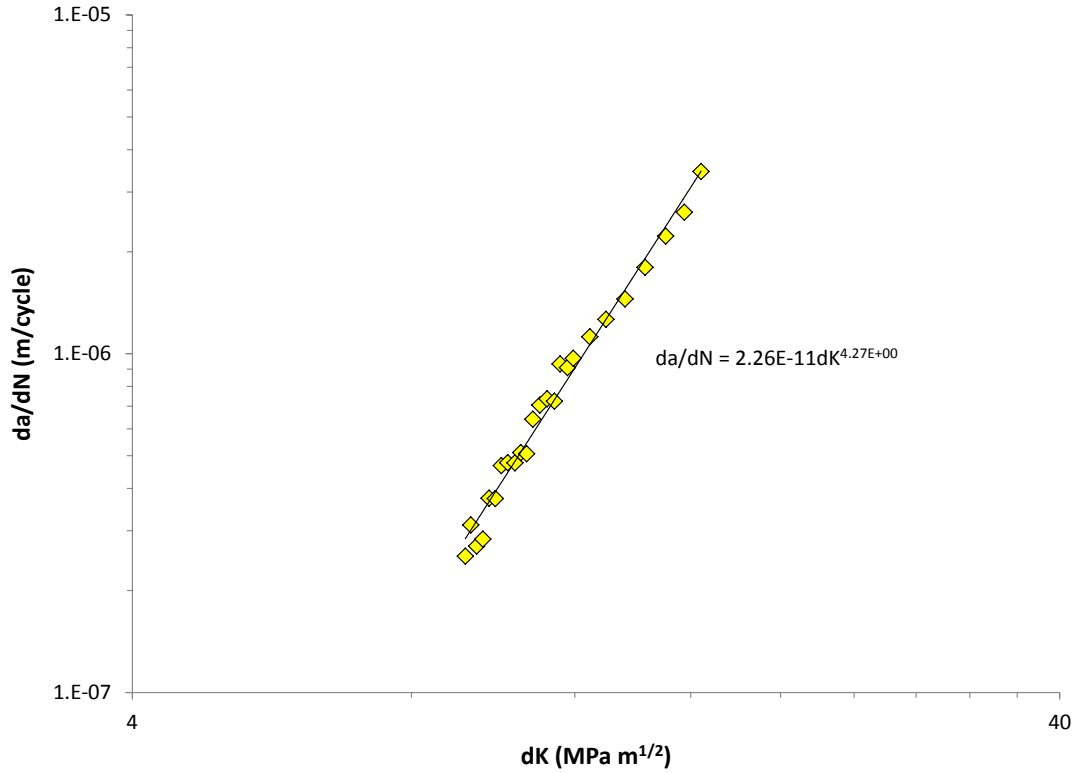
- Load and COD data for the first cycle
- Graph on left indicates accurate sine wave control
- Graph on right indicates negligible hysteresis, thus, favorable accuracy obtained from compliance measurements of crack length

Powertech

- Compliance calculation of crack length versus cycles
- Calculated crack lengths are very close to post-test measurements (<5%)
- Linearly adjusted to correspond to physical measurements



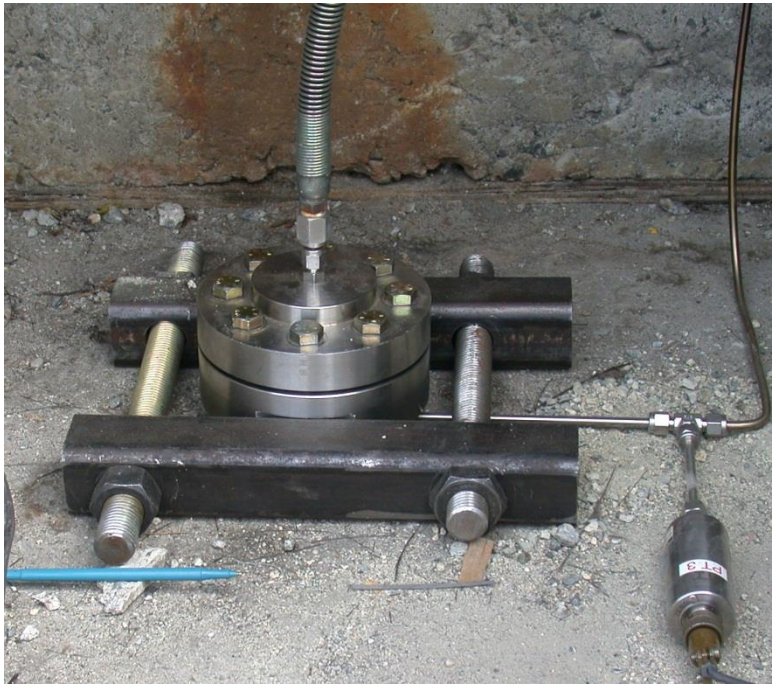
Powertech



- Resulting relationship between stress intensity amplitude and crack growth rate represented by the Paris Law

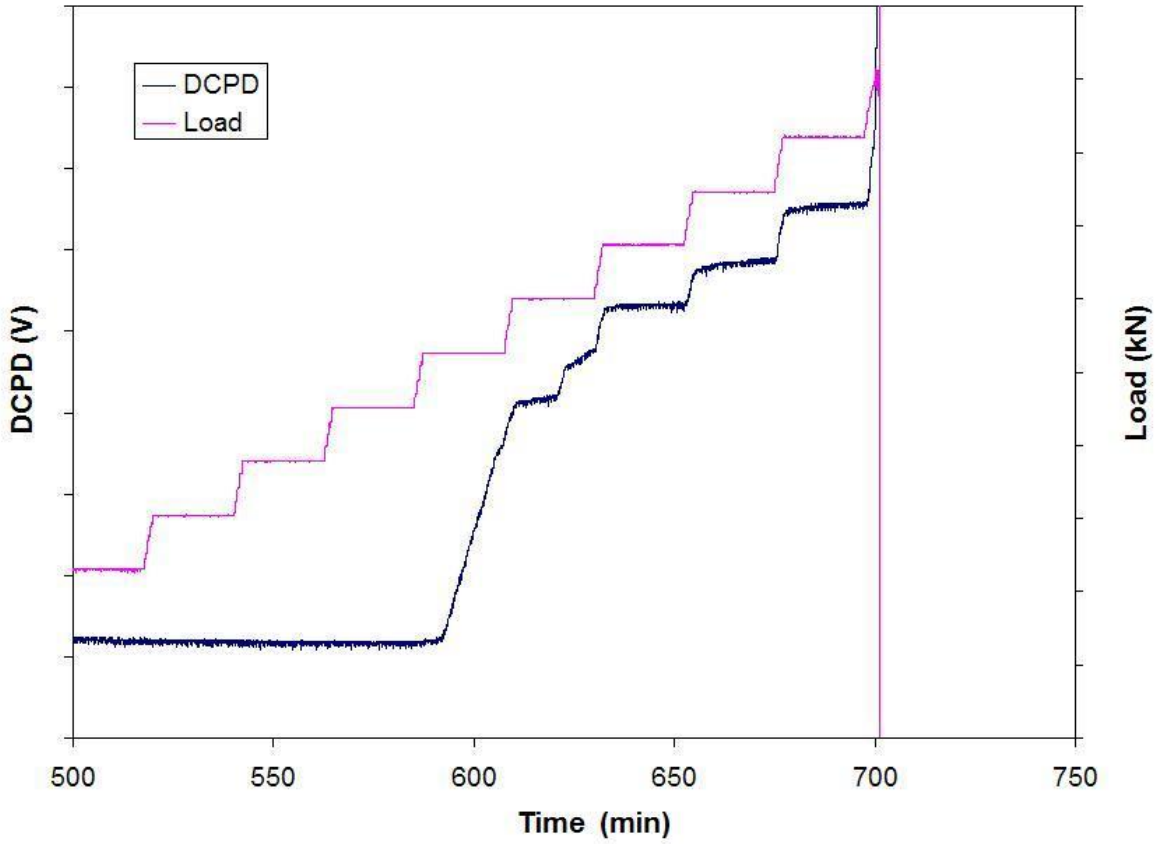
ISO 11114-4

- Method A, disk burst test
- Various pressure ramp rates
- Comparison of burst pressure between hydrogen and helium



ISO 11114-4

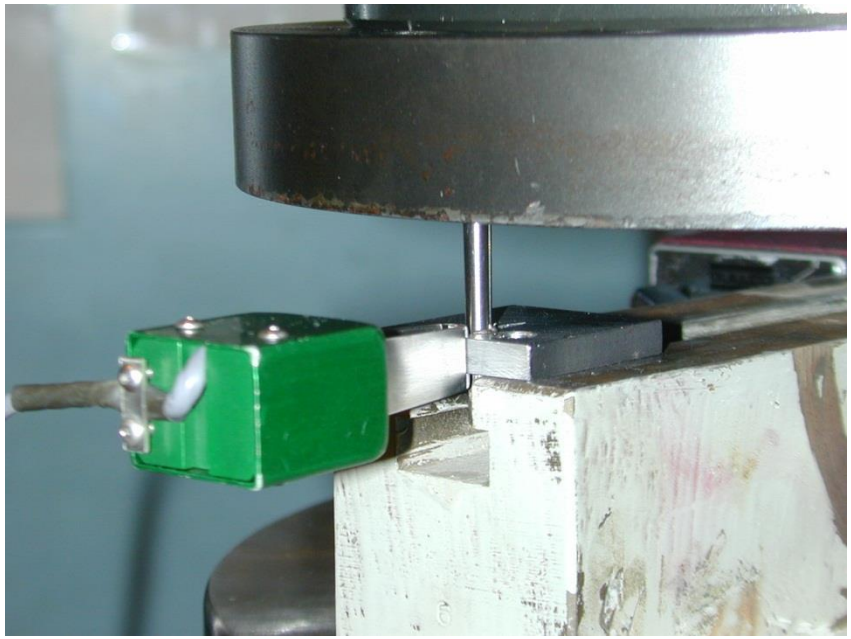
- Step load test to determine threshold for crack propagation



Powertech

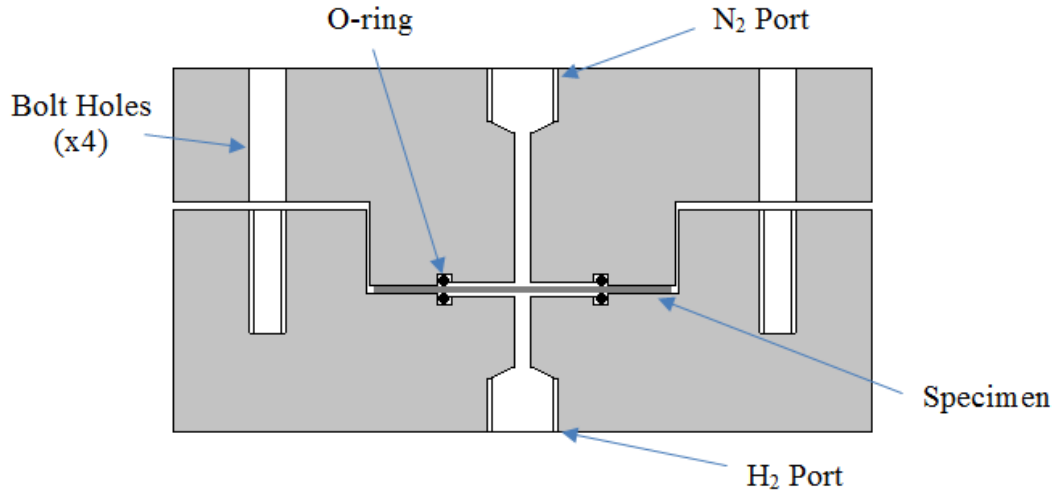
ISO 11114-4

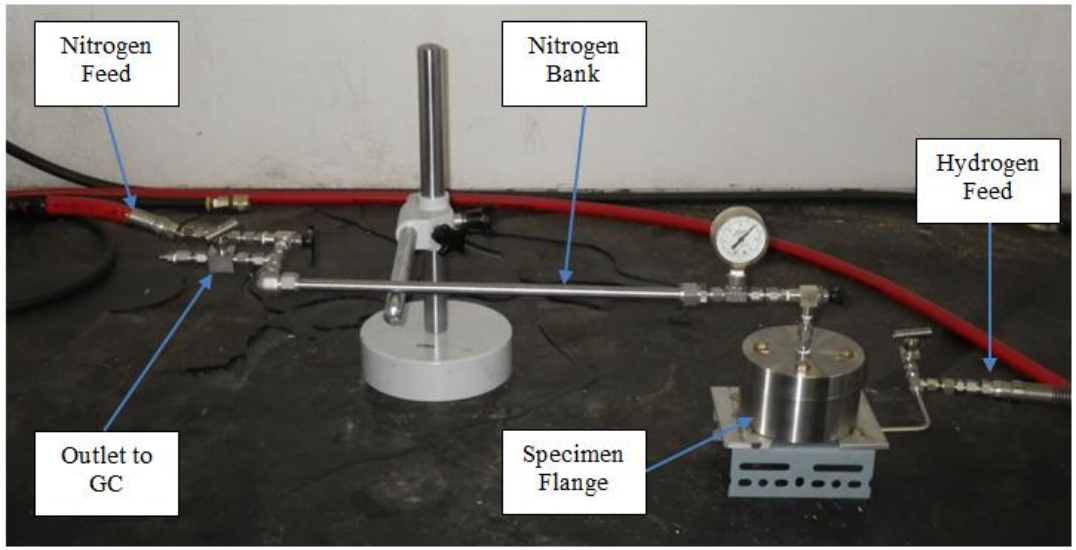
- Method C, sustained load
- CT specimens loaded with taper pin
- 1000 hours soaked in hydrogen
- Inspect for crack growth



Permeation Testing

- Thin disk of test material embedded in flange
- Hydrogen applied to one side of the specimen
- Nitrogen bank on the other
- Nitrogen bank sampled for hydrogen content at regular intervals

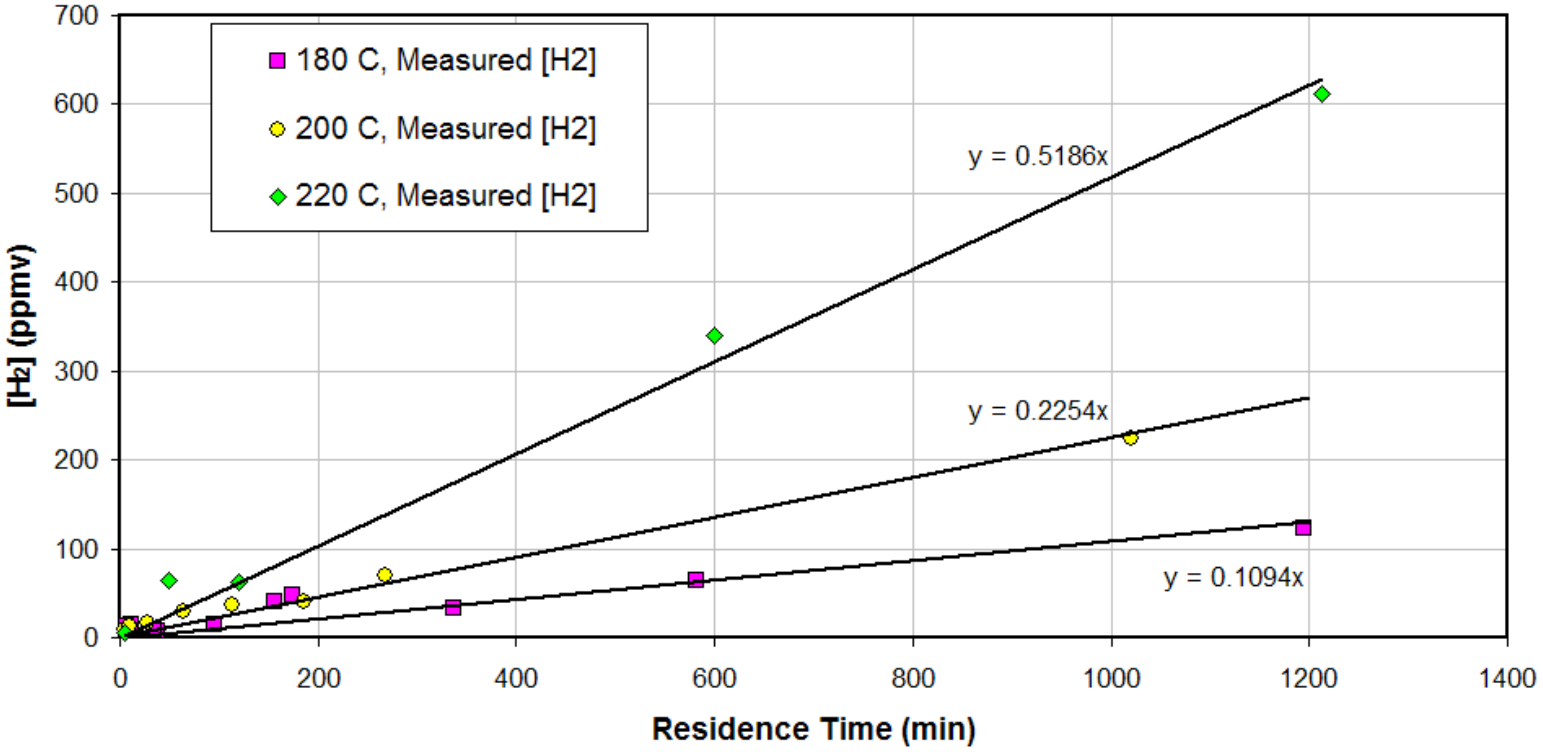




Powertech

Permeation Testing

- Measuring at multiple temperatures can reveal the permeability coefficient and activation energy



Powertech

Challenges and Limitations

- Low temperature testing
- Measurement of large crack opening displacements
- Fatigue testing using negative load ratios

Thank you!