

GTR Pressure Cycling Discussion GTR Meeting – 5th Informal Working Group

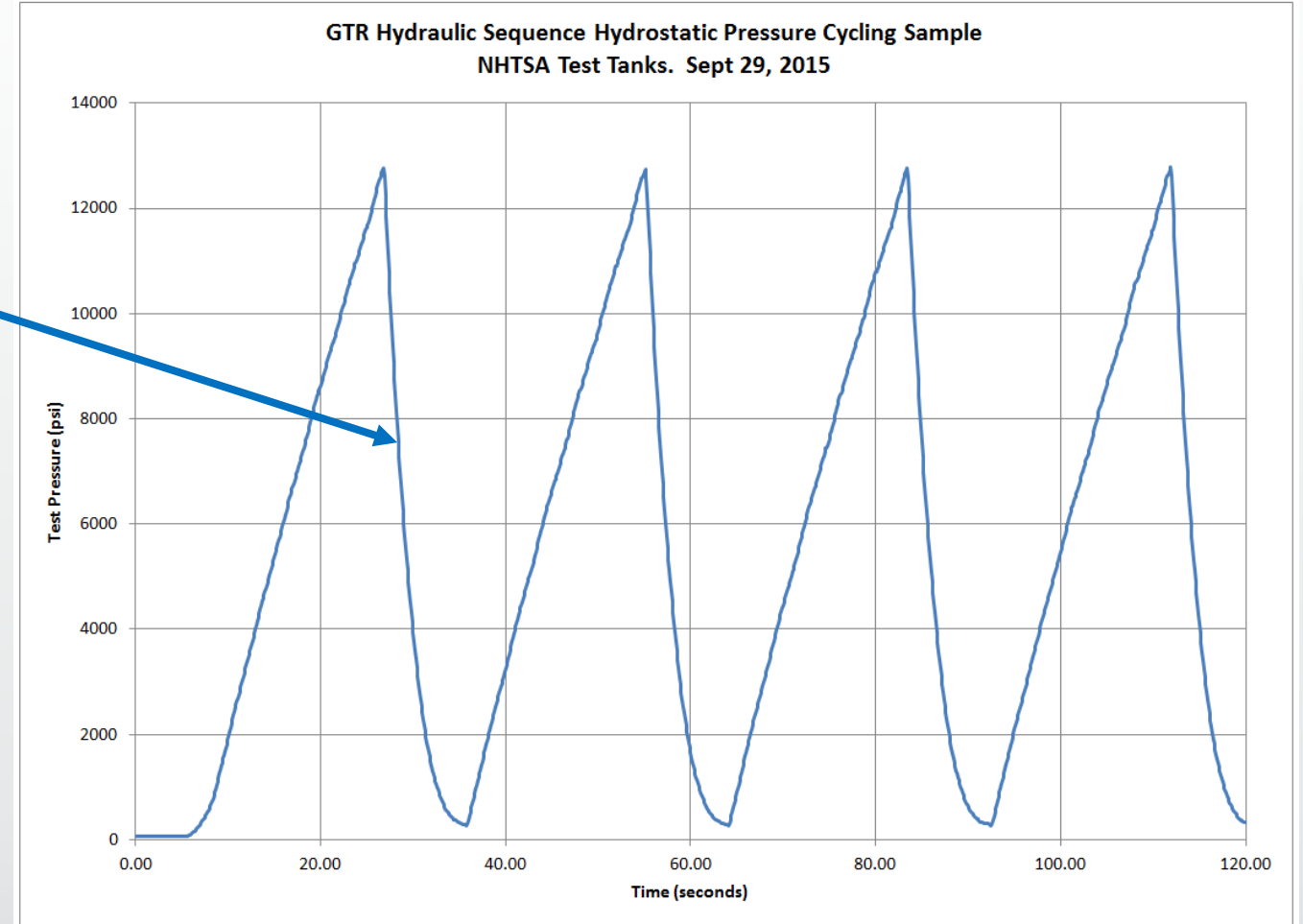
March 4th, 2019

Issue with GTR Pressure Cycle Test Procedure

- How do we prevent a validated tank design from failing an accelerated test procedure?
- Test Report: Hydrogen Container Performance Testing, UN GTR No. 13 Prepared For US Department of Transportation, National Highway Traffic Safety Administration.
- 3 Tank manufacturers provided tanks: 2 type IV and 1 type III.
- Quantum provided a 76L type IV (Manufacturer #2) which had an early leak in the baseline initial pressure cycle life and the ambient temperature pressure cycle tests.
- The issue is with the fast depressurization rates during the testing which cause strain-rate issues in the liner which are not representative of how the product is used in service.

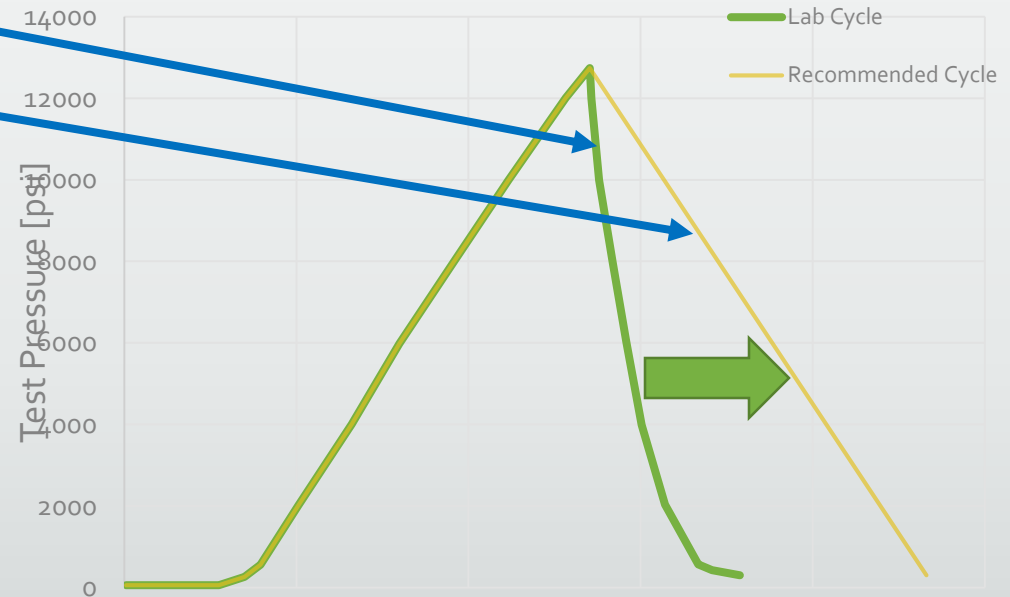
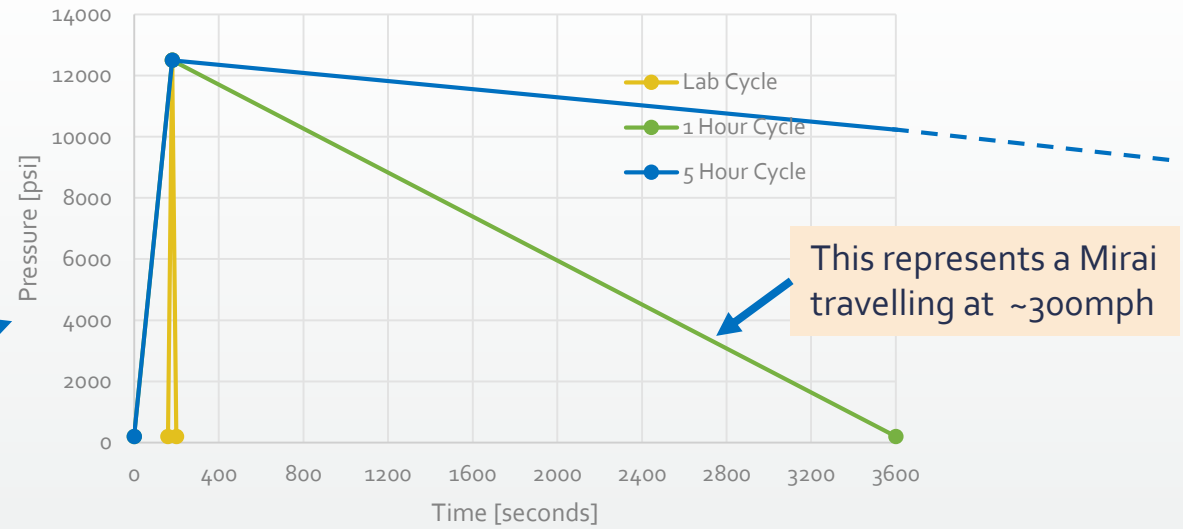
Pressure Cycle Profile

- The depressurization slope represents a rate of 2,500 psi/sec.
- The overall cycle rate of 2 cycles per minute used is not a concern, as long as the fluid temperature in the tank is controlled.



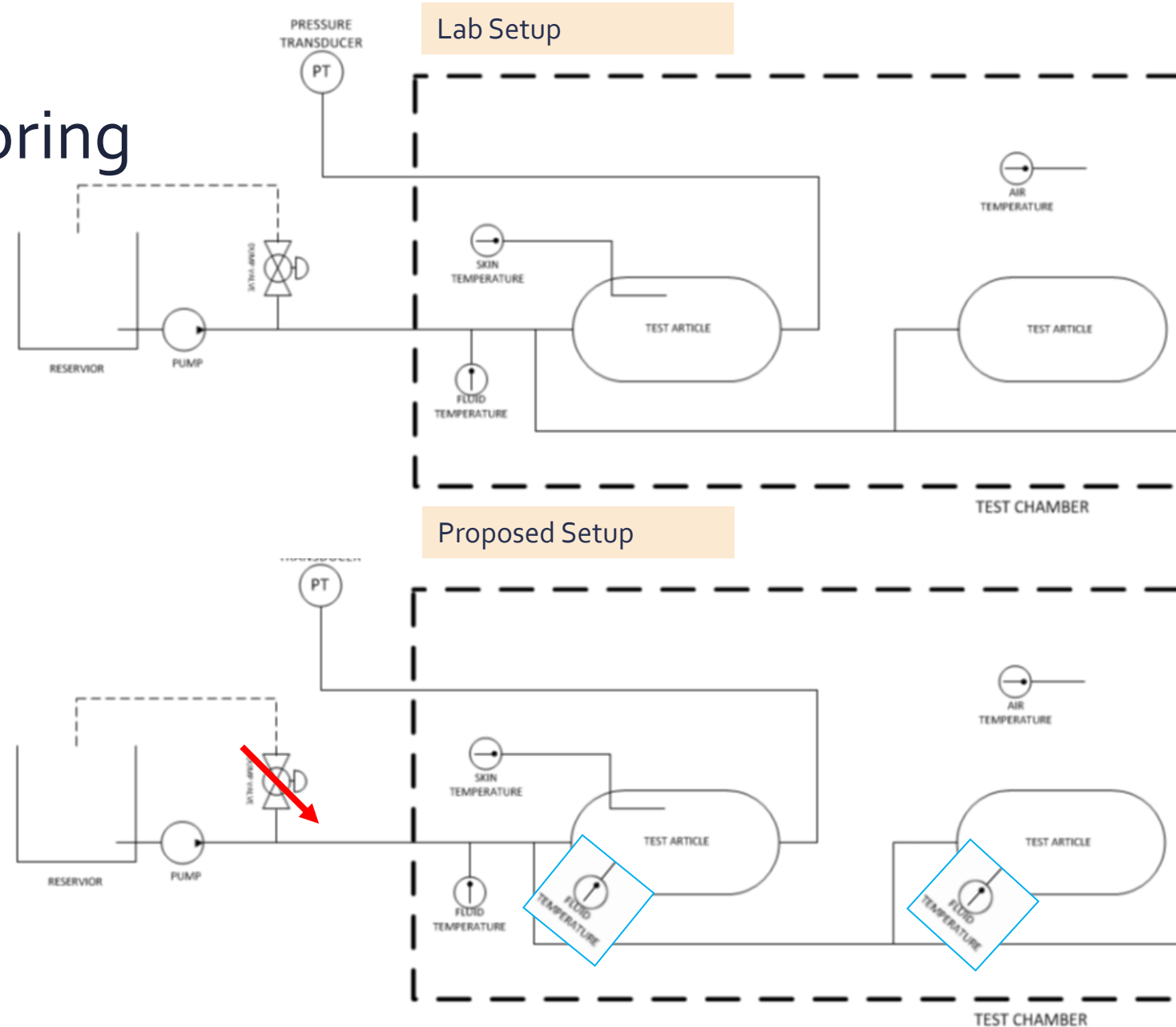
Pressure Cycle Profile

- One hour cycle (3 minute fast fill and 57 minute discharge) vs 5 hour cycle vs tested cycle
- Profile used during actual testing
- Recommended profile to minimize the effect of pressurization
 - Quantum controls the pressurization with a variable flow valve



Temperature Monitoring and Control

- The temperature of the fluid should be measured inside every tank common to the fluid port.
- The fluid inside the tank can see temperatures higher than the fluid measured before entering the tank
- The skin temperature will always be lower than the fluid in the tank being heated by the heat of compression.
- Quantum has seen in external lab testing where the temperature was so high that caused the water to boil.
- In this arrangement, due to tank #2 having over twice the volume of tanks #1 and #3, the tank would show increased effects of heat up due to fluid flow. Since tank #2 was not instrumented, the temperature inside the tank would be unknown.



The 76L tank was validated prior to this comparison test

- 70MPa H₂ tank designed for an OEM and tested to:
 - Ambient Temperature Pressure Cycle Test performed on 2 tanks from 2 to 88 MPa and stopped at 100,000 cycles each
 - Hydrogen Gas Cycle Test (1,000 cycles)
 - All EC-79 tests completed on this tank design
 - High risk segments of GTR testing were also performed during the development of this tank including:
 - SAE J2579 Durability (Hydraulic) Performance Test, which includes drop, surface damage, chemical exposure, high temp static pressure, extreme temp, and burst
 - High Temperature Permeation (+50°C) = 4.68 cc/hr/L with X-HDPE Rotomolded Liner

QUANTUM
TECHNOLOGIES

Development – Fatigue Cycling

Test Log No.: 3172-1 Serial No.: H12030762BT004
Test Date: 04/12/12 Part No.: 113052
Lot No.: BT

Test in accordance with: Test Log # 3172
Technician: Tung Nguyen

Service Pressure: 70 MPa
No. of cycles required: 100,000 Pressure Limits: 2.0 to 88 MPa
Date Completed: 05/20/12 No. of cycles completed: 100,000

Comments: The 76L 70 MPa H₂ Storage Tank successfully passed the 100,000 filled cycles without any visible signs of damage or leakage.

To be filled out by Test and Validation Group Only

Signature of Technician: *Tung Nguyen* Date: 05/20/12
Signature of Supervisor: *Bob Lake* Date: 6/4/12

Passed: Failed:

TUV Representative Witness: *Debra P. Pagan* Date: 05/23/2012
Required? Yes: No:

Serial No.: H12030762BT006
Part No.: 113052
Lot No.: BT

Pressure Limits: 2 to 88 MPa
No. of cycles completed: 100,000
ulic cycles.

Date: 06/27/2012

TÜV AMERICA
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Quantum Request to the GTR Committee

- How do we prescribe a test protocol to not fail a validated tank in accelerated testing?
- Quantum is requesting a modification to the wording in the GTR standard to refine the pressure profile and temperature controlling requirements:
 - Provide more uniform up/down ramp rates.
 - The temperature inside the tank is measured and controlled so that the tank does not see an over temperature condition.