Artificial Lift R&D Council

ALRDC

Gas Lift Valve Opening Behavior Observations during Dynamic Performance Testing per API 19G2, Annex G

Russell Burkey,
Southwest Research Institute

ALRDC Gas Lift Workshop
June 7th-11th 2021

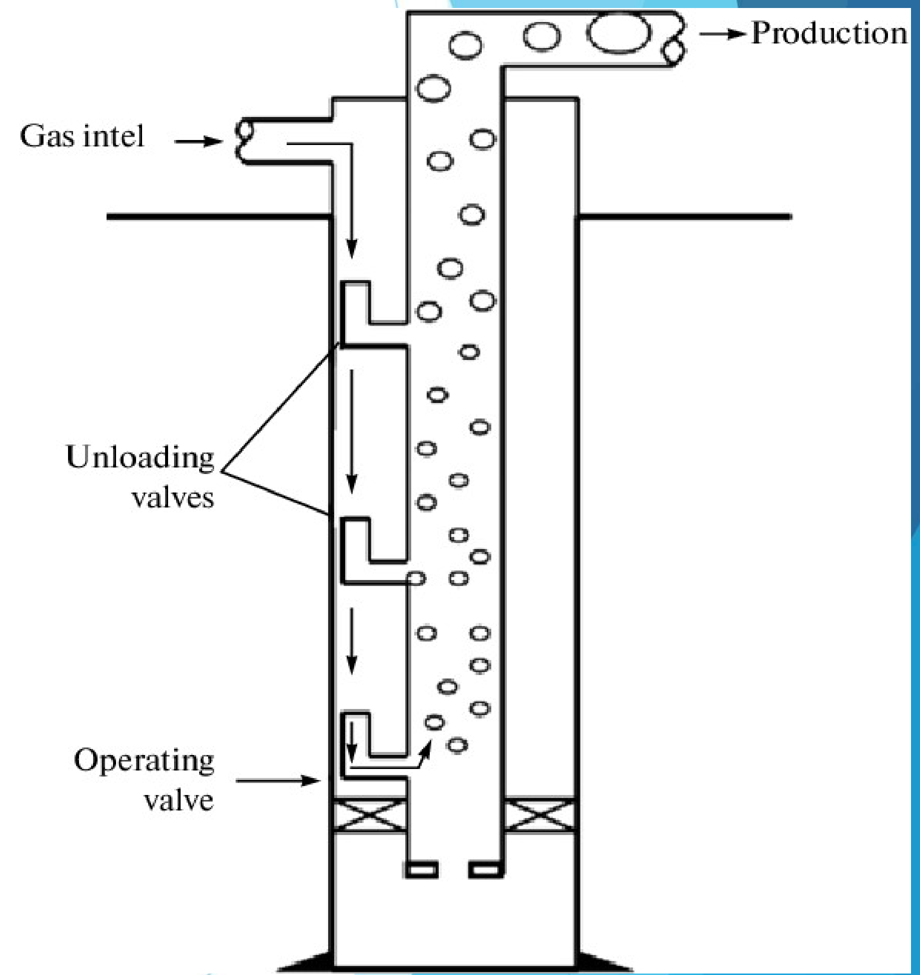
SwRI
SOUTHWEST RESEARCH INSTITUTE

Overview

- The Challenge
- Test, Test Facility Overview
- Opening Pressure Observations and Discussion
- Test Facility Revisit
- Closing Thoughts

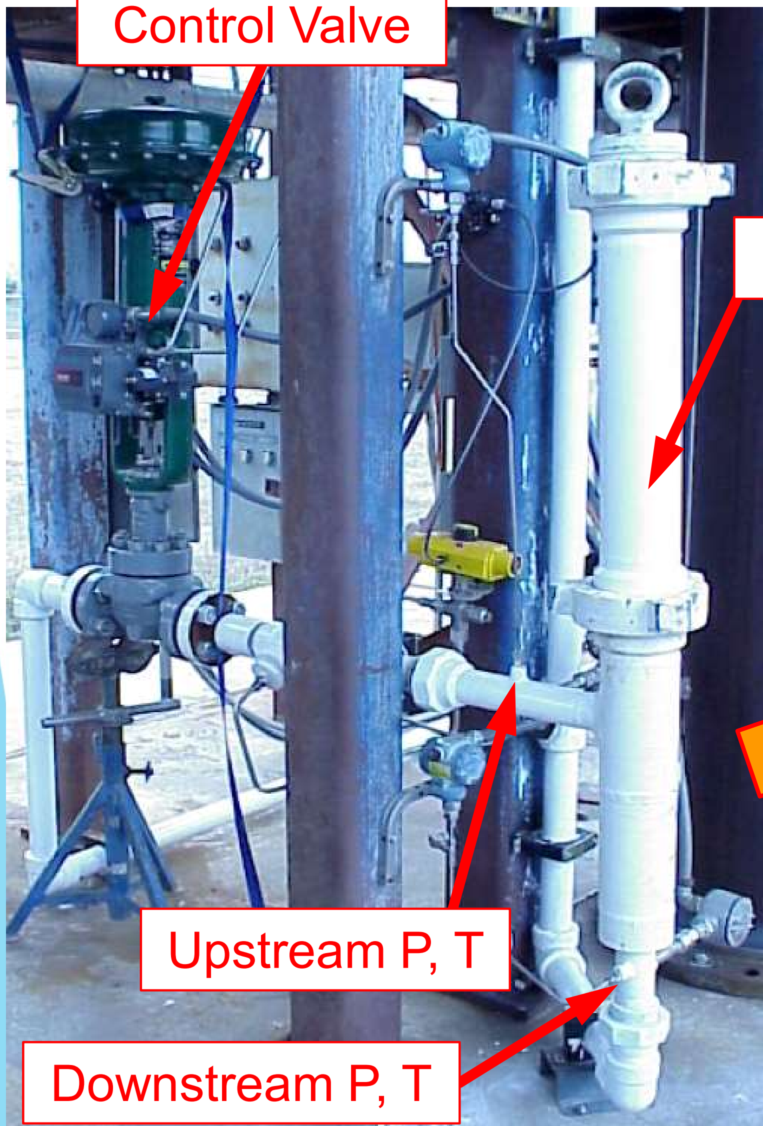
The Challenge

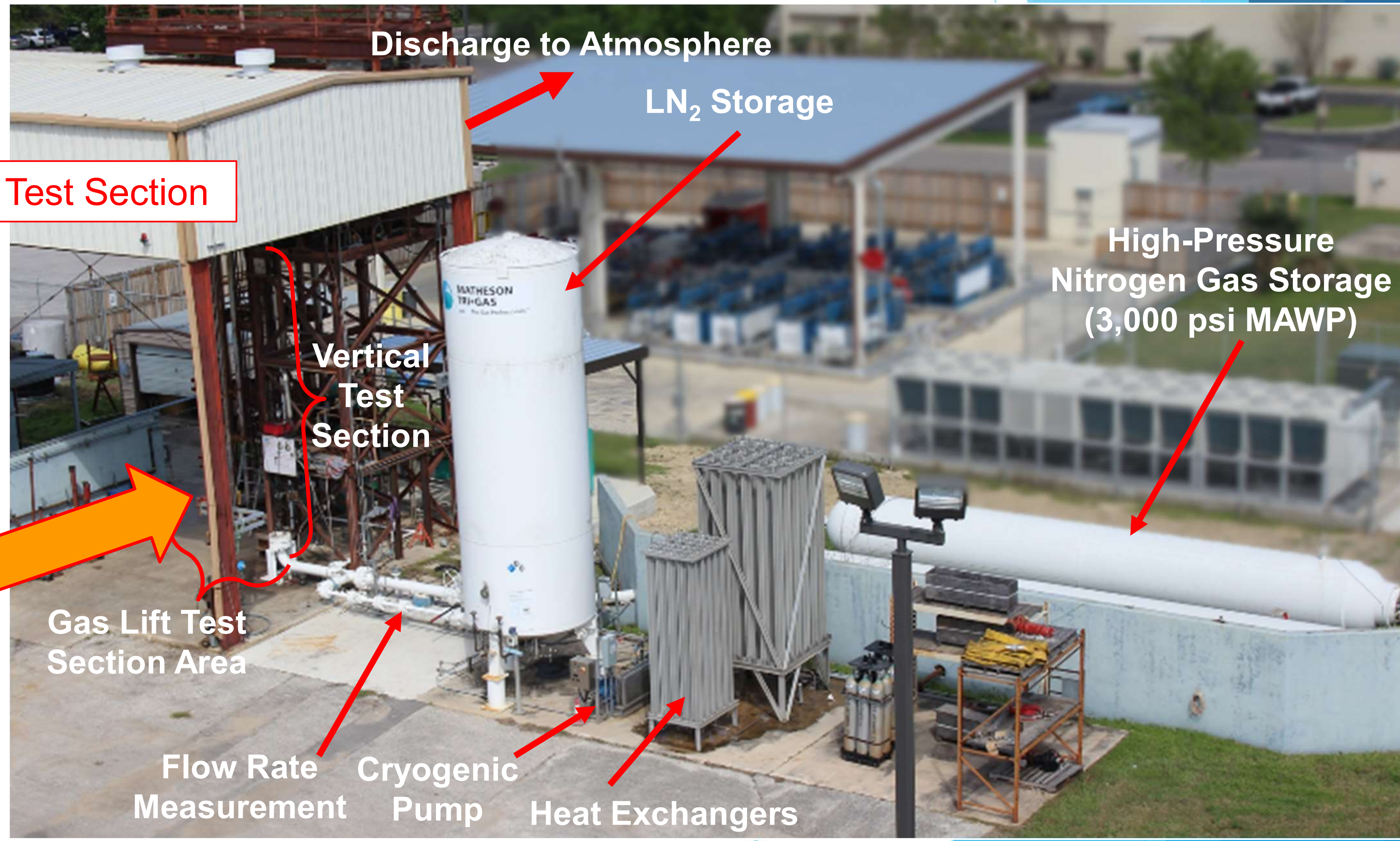
- GLV flow performance and opening/closing conditions critical to GL design and operation
- GLV design validation testing per API 19G2
  - Dynamic Performance Testing per Annex G.5 (Flow Performance Test)
  - IPO valves, gas charged bellows
  - Constant Injection Pressure Test (G.5.4)
  - Key results include Flow Coefficient (C_v) and Pressure Drop Ratio Factor ($R_{p.crt}$)
  - Includes measurement of GLV opening pressure (P_{voT}) pre- and post-test
  - Test commonly completed in a single-pass, blowdown type facility – API 19G4 Annex B
  - Prescribed 6 test runs completed in quick succession
  - Controlled P's and Q, **but flow test run is transient thermally…**
  - **Temperature Matters…Changes observed in opening pressure hypothesized to be related to cooling of the dome gas**



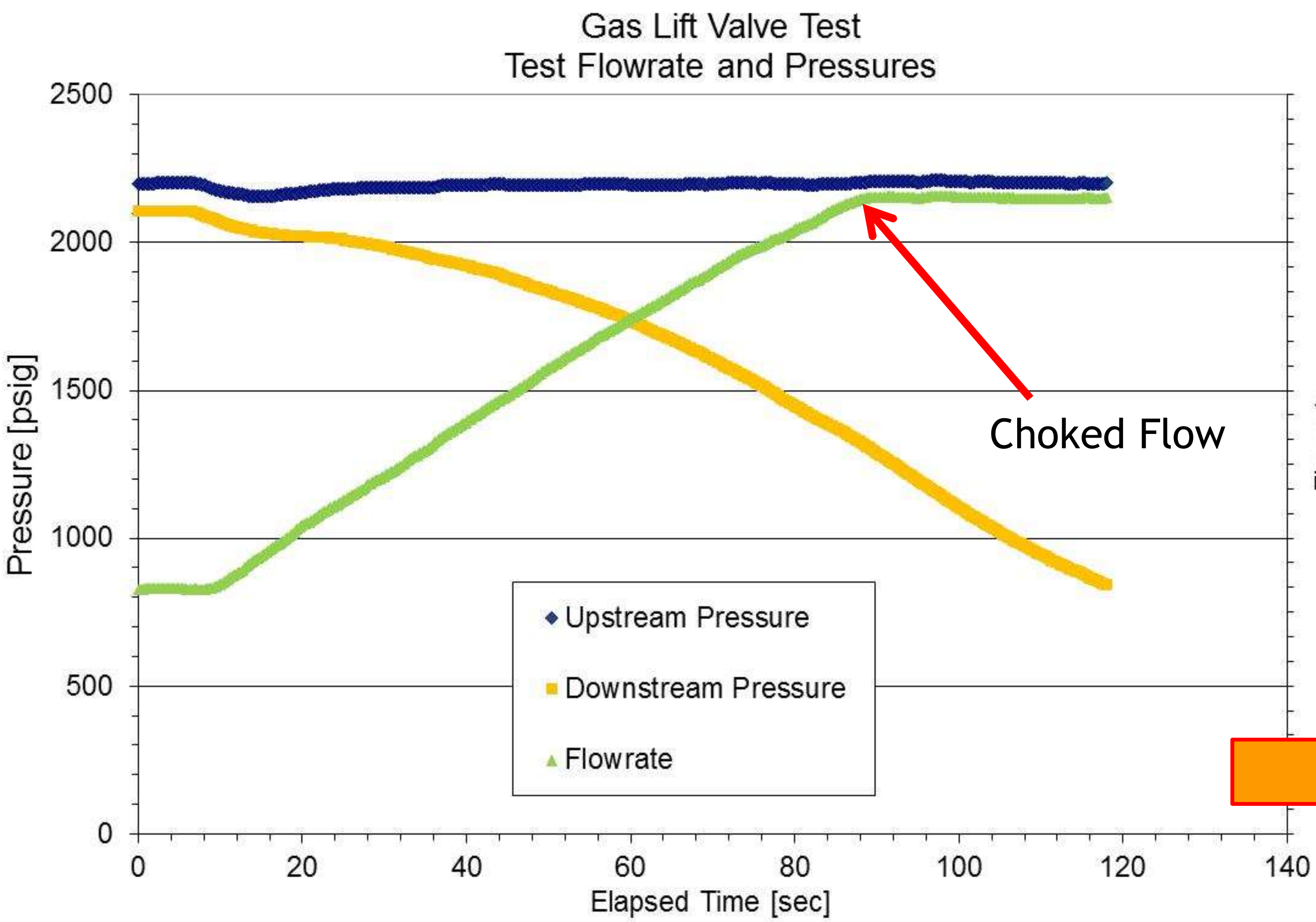
Artificial Lift R&D Council

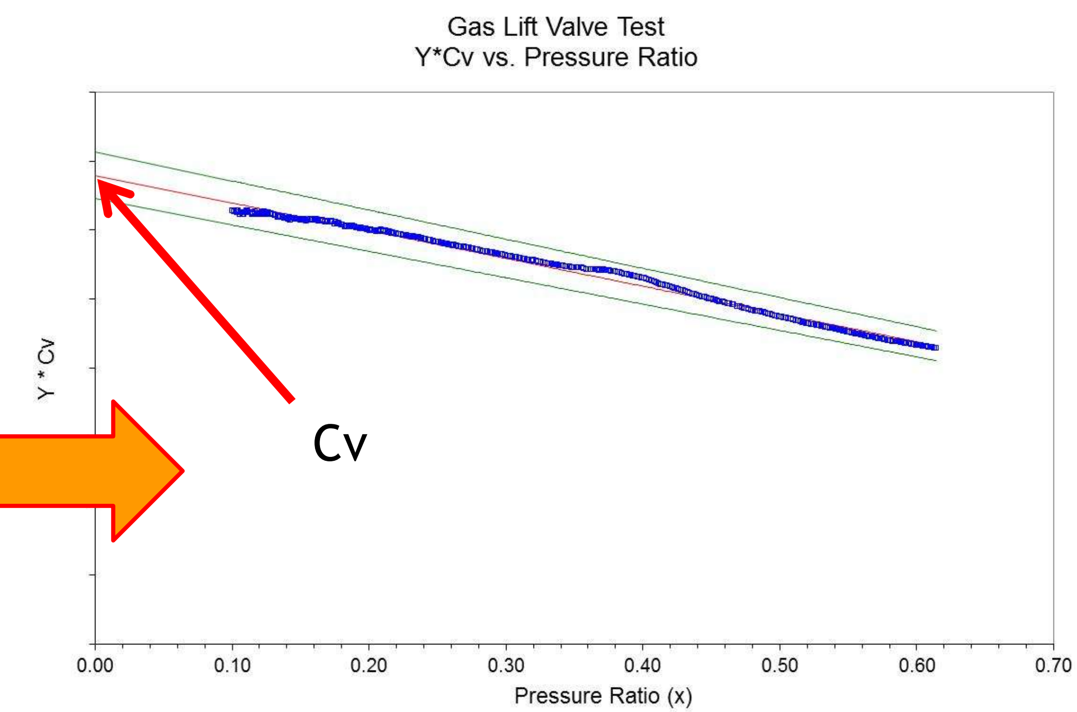
Test Facility Description





Typical Flow Test Data

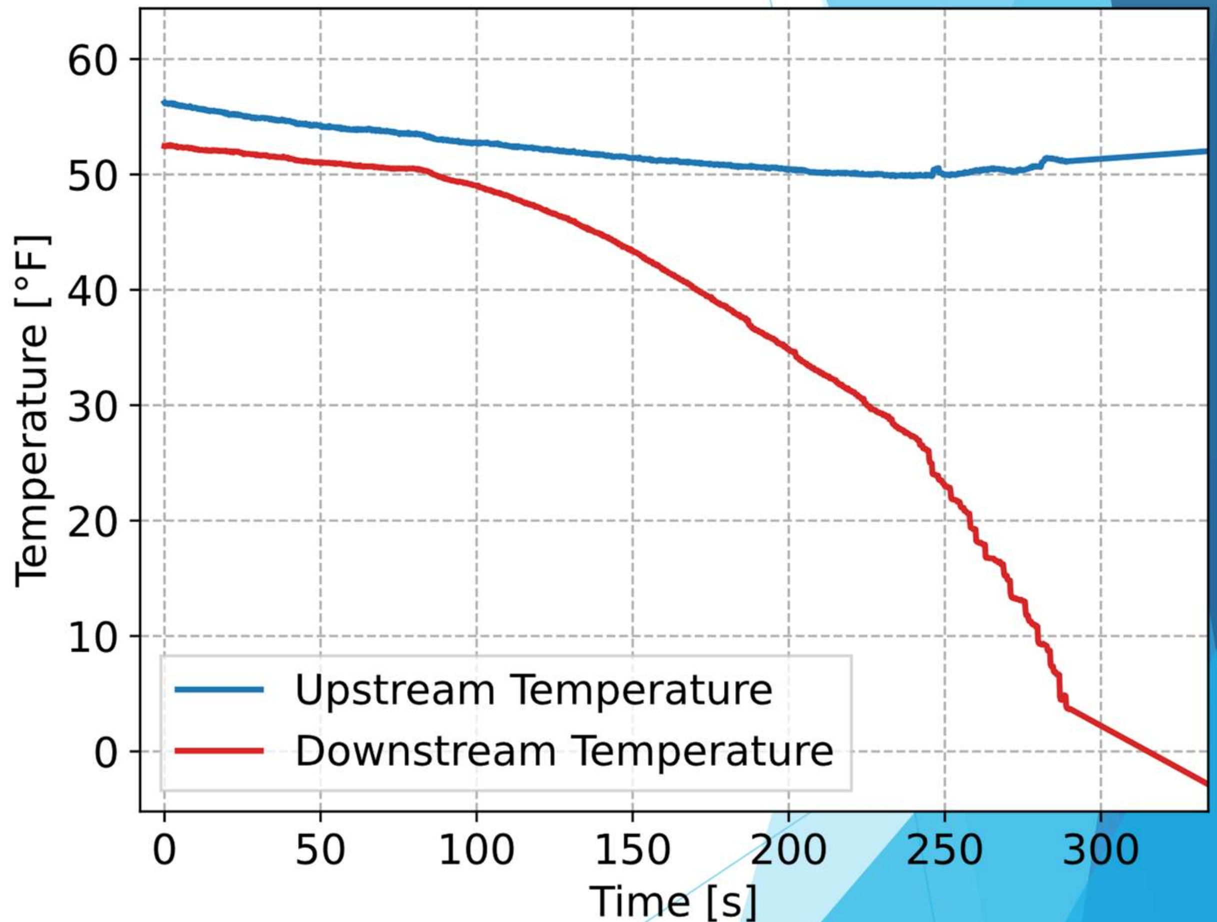




Valve Cooling Effect

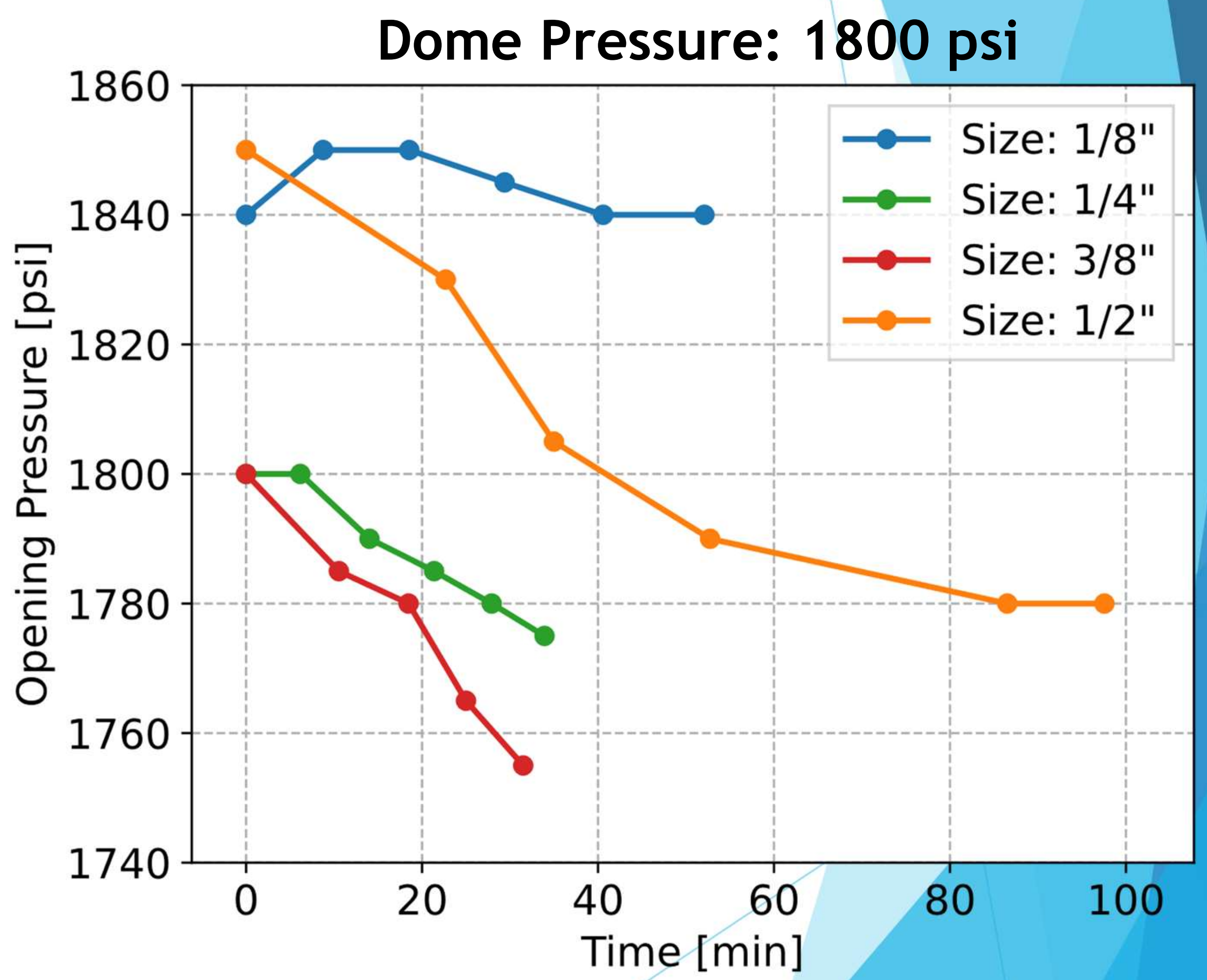
- Dynamic flow test is a **transient thermal** process
- The injected gas cools down as it is throttled through the valve port due to the **Joule-Thomson** effect
- Downstream of the valve, the gas can reach sub-zero temperature
- The cold gas cools the valve though convection
- The cooling is transferred to the dome gas by conduction through the valve body

Dome Pressure: 1800 psi, Port: ½”



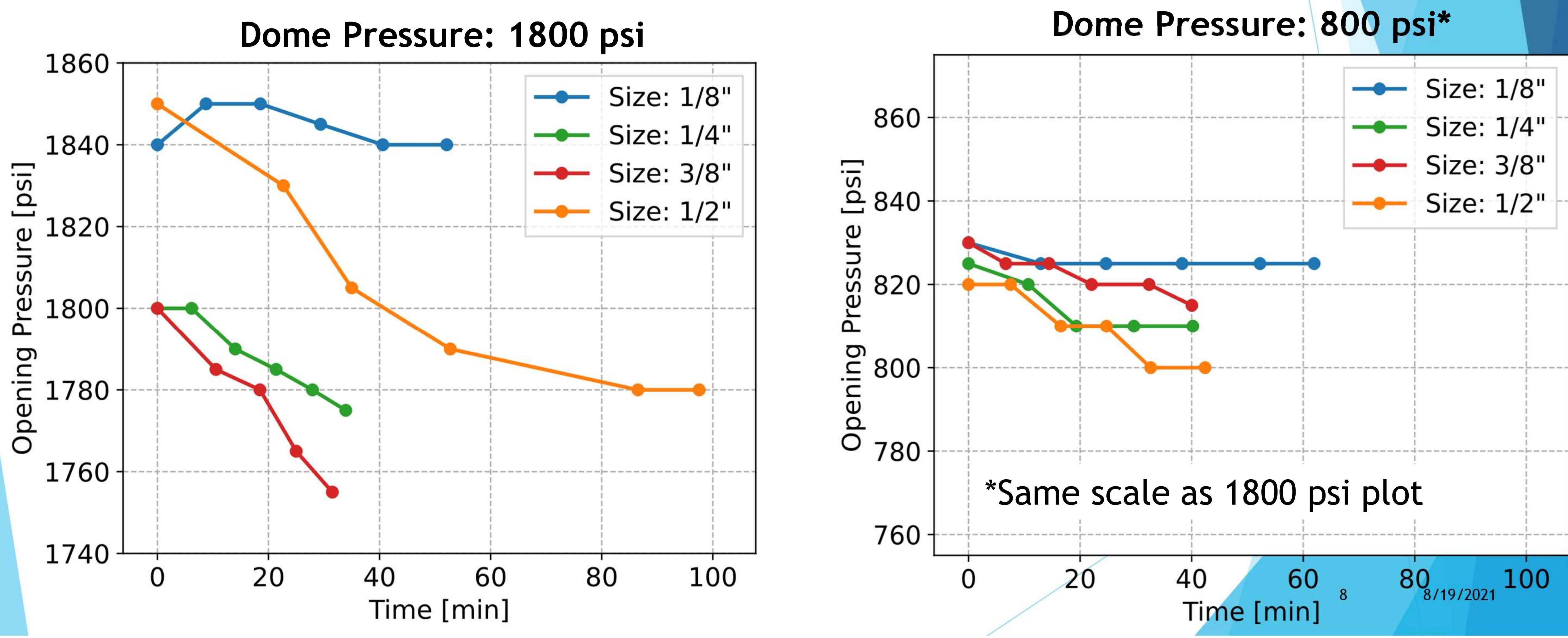
Change in Opening Pressure Observations

- Pre- and Post-test opening pressure (P_{voT}) plotted for each test run
- The opening pressure changes as each test run is completed
- The opening pressure can change by up 75 psi after 6 test runs
- Higher sensitivity observed during the larger port size tests
- Increased mass flow rates lead to more intense cooling



Change in Opening Pressure Observations

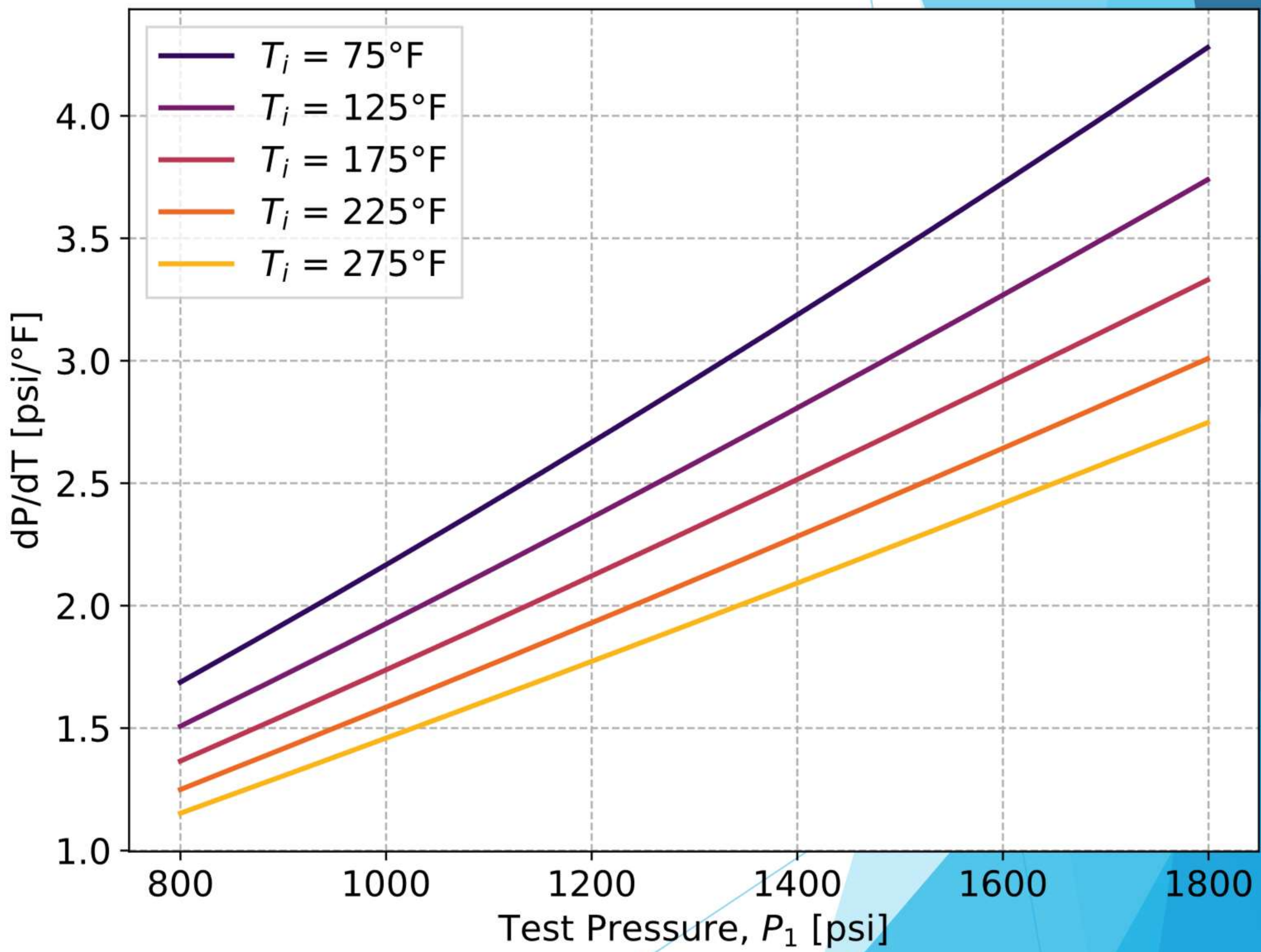
- Smaller OP changes observed for the lower dome pressure tests
- Lower mass flow rates lead to less intense cooling
- Decreased pressure sensitivity to temperature changes at lower pressure



Change in Opening Pressure Observations

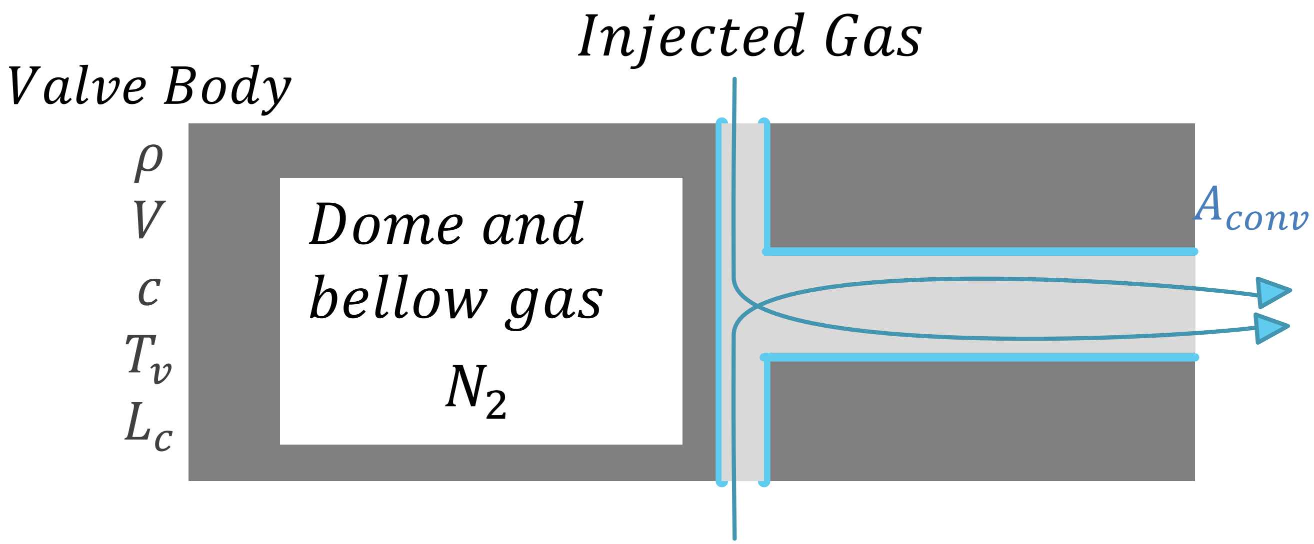
- Increased pressure sensitivity to temperature changes at higher pressure and lower temperature

$$\left.\frac{dP}{dT}\right|_{\rho=con} = \delta_{T_1,\,P_1}$$



Nitrogen Gas Data from REFPROP

Simple Heat Transfer Analysis – Lumped Capacitance



$$\rho V c \frac{dT_v}{dt} = -hA_{conv}(T_{v_0} - T_{gas}(t))$$

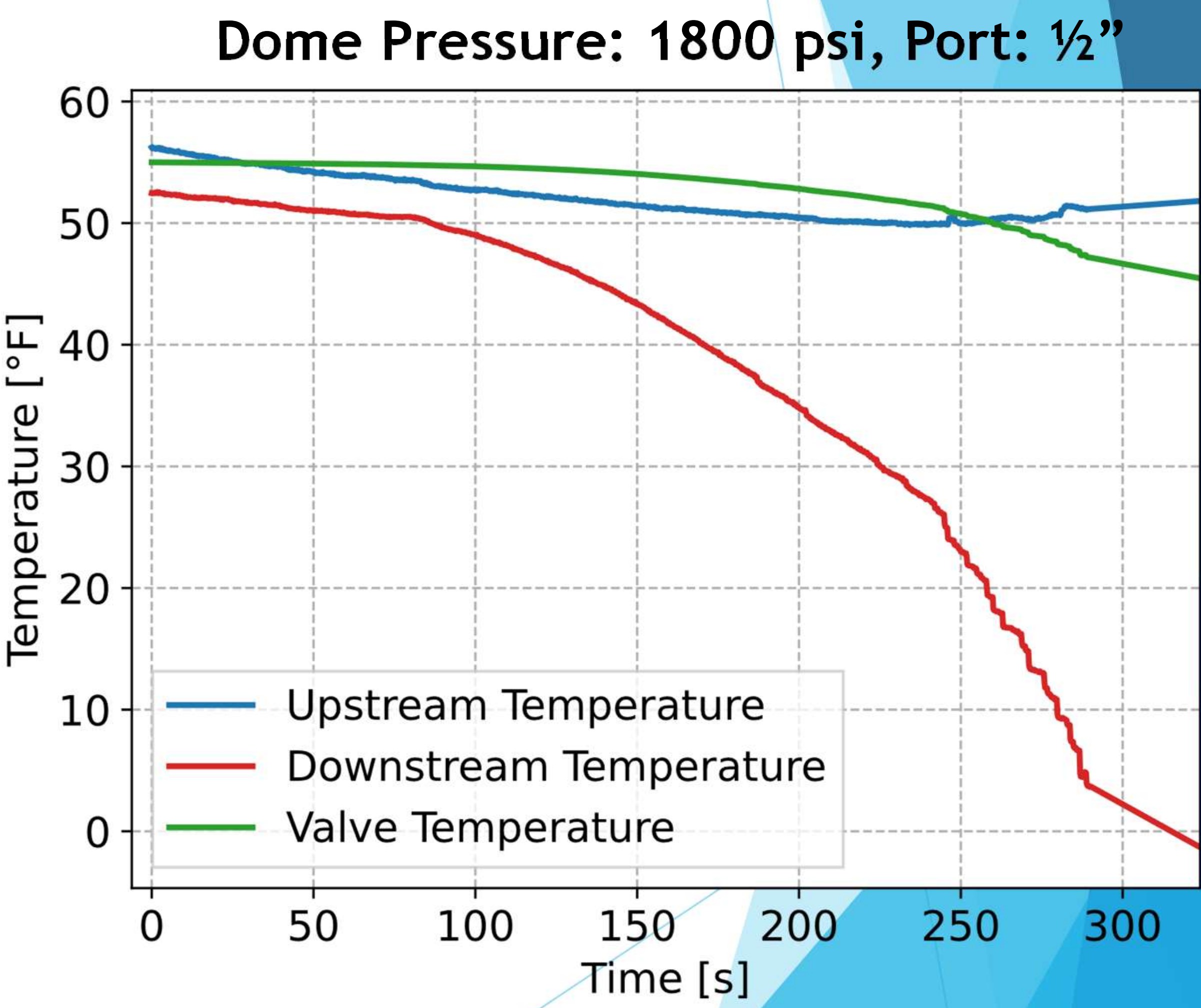
h = Convection HT Coefficient

A_{conv}= Internal Valve Area

- Perform a basic heat calculation to confirm that this convection cooling is the cause of the temperature drift
- The approach:
  - Highly simplified the valve geometry
  - Uses Petukhov correlation for internal flow to estimate h
  - T_{gas} assumed to be the measured downstream gas temperature
  - Models the valve body as a lumped thermal capacitance
  - Assumes the thermal mass of dome gas is negligible

Simplified Heat Transfer Analysis – Lumped Capacitance

- The model predicts that the valve cools down by approximately 10˚F
- The estimated temperature change is of the magnitude to explain the observed change in the pre- and post-test opening pressure
- Key takeaway: Flowing pressure drop and resulting cooling can affect valve behavior during test and in field application.
- Caveat: the Biot number > 1, so the lumped capacitance analysis has limited validity

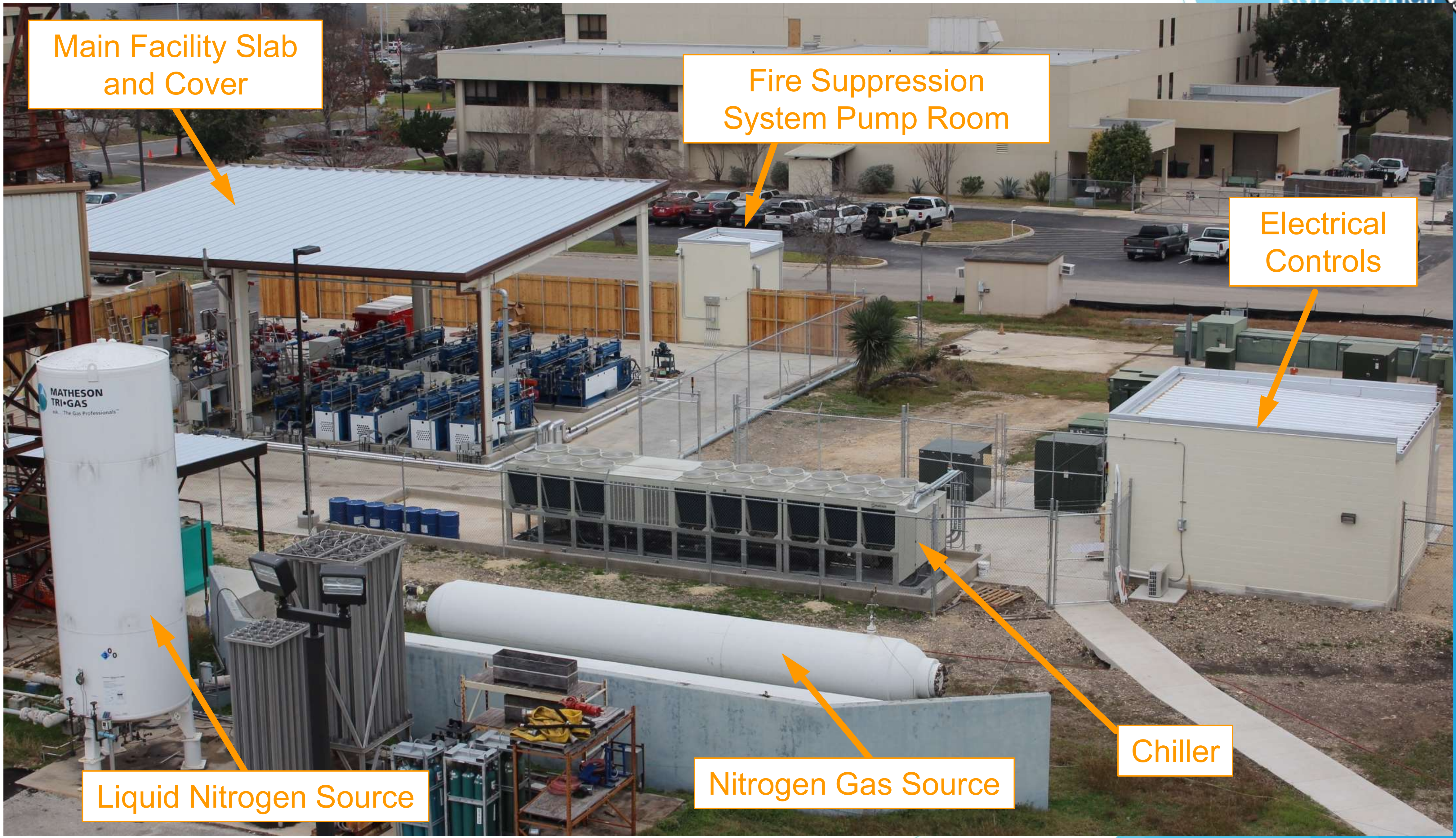


Test Facility Revisited

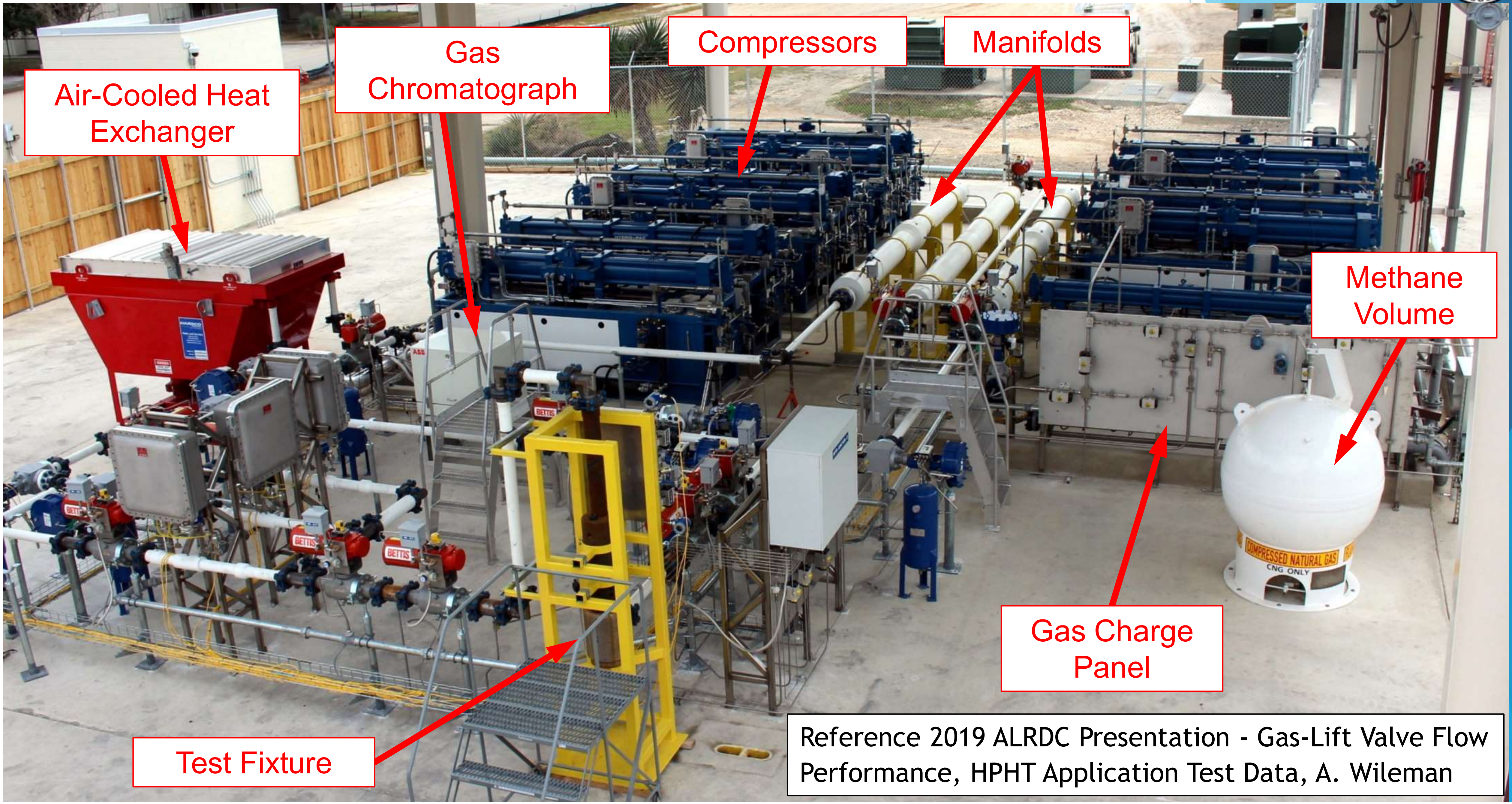
- Single-Pass, Blowdown
  - High Pressure Drop available
  - Valve Flow Performance Parameters (C_v, $R_{p.crit}$) applicable to well conditions
  - Relatively simple setup and operate
  - Quick test completion (6 test runs in hour(s))
  - Relatively low cost testing
- Challenges:
  - Transient Thermally
    - Lacks temperature control
    - Ambient to sub ambient test temperatures
  - Limited Flow Duration (dependent on flow rate)

- Recirculating
  - More field realistic P, T, Q conditions
  - Long, stable flow durations
  - Thermal steady state operation
    - Stable, elevated temperature operation
  - High Pressure, Wide pressure range
  - Match gas specific gravity
- Challenges:
  - Pressure drop through test article and facility limited by prime mover flow/DP characteristics
  - Longer test times (to achieve thermal steady state)
  - More complex system
  - Relatively higher cost testing

Recirculating Facility Review



Recirculating Facility Review



Reference 2019 ALRDC Presentation - Gas-Lift Valve Flow Performance, HPHT Application Test Data, A. Wileman

Artificial Lift R&D Council

Closing Thoughts

- Temperature Matters…
- Carefully Consider How Test Conditions Relate to Field Application
- Life is like an onion – many layers to peel off…
- Nothing is free – everything is a trade-off…

Acknowledgements

- Thank you very much!
  - Phil Glass, Southwest Research Institute
  - Luis Gutierrez, Southwest Research Institute
  - Angel Wileman, Southwest Research Institute

Questions…

Copyright

Disclaimer

The following disclaimer shall be included as the last page of a Technical Presentation or Continuing Education Course. A similar disclaimer is included on the front page of the Gas-Lift Workshop Web Site.

The Artificial Lift Research and Development Council and its officers and trustees, and the Gas-Lift Workshop Steering Committee members, and their supporting organizations and companies (here-in-after referred to as the Sponsoring Organizations), and the author(s) of this Technical Presentation or Continuing Education Training Course and their company(ies), provide this presentation and/or training material at the Gas-Lift Workshop "as is" without any warranty of any kind, express or implied, as to the accuracy of the information or the products or services referred to by any presenter (in so far as such warranties may be excluded under any relevant law) and these members and their companies will not be liable for unlawful actions and any losses or damage that may result from use of any presentation as a consequence of any inaccuracies in, or any omission from, the information which therein may be contained.

The views, opinions, and conclusions expressed in these presentations and/or training materials are those of the author and not necessarily those of the Sponsoring Organizations. The author is solely responsible for the content of the materials.

The Sponsoring Organizations cannot and do not warrant the accuracy of these documents beyond the source documents, although we do make every attempt to work from authoritative sources. The Sponsoring Organizations provide these presentations and/or training materials as a service. The Sponsoring Organizations make no representations or warranties, express or implied, with respect to the presentations and/or training materials, or any part thereof, including any warrantees of title, non-infringement of copyright or patent rights of others, merchantability, or fitness or suitability for any purpose.

Artificial Lift
R&D Council

Back-up Slides

Petukhov Correlation

$$\mathrm{Nu} = \frac{(\xi/8)\,\mathrm{Re}\,\mathrm{Pr}}{1.07 + 12.7(\xi/8)^{1/2}\,(\mathrm{Pr}^{2/3} - 1)}$$

$$\xi = (1.82 \log \mathrm{Re} - 1.64)^{-2}$$

- Petukhov, B.S., “Heat transfer and friction in turbulent pipe flow with variable physical properties,” Adv. Heat Transfer 6, 503-565 (1970).

Test Facility Description