GROUND-BASED CRYOGENIC LEAK TEST OF FITTINGS FOR CRYOGENIC FLUID MANAGEMENT

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Gabor Tamasy, Adam Swanger, Jared Sass, Angela Krenn, and Will Reaves

NASA Kennedy Space Center
KSC, FL 32899 USA

OUTLINE

- Background
- Objectives
- Test Hardware
- Test Results
- Summary
- Lessons Learned
- Recommendations

BACKGROUND (Initial Proof of Concept)

- Swagelok Vacuum Coupling Radiation (VCR) fittings are commonly used in cryogenic thermal vacuum work.
- Hardware developed in 2020 to evaluate the leak performance of pressurized VCR fluid fittings (¼, 1 inch) and seals (Silver-Plated Stainless Steel, Copper, Nickel).

Image

OBJECTIVES (Current testing)

- Incorporate hardware enhancements into the Thermal Vacuum (TVAC) test apparatus developed in 2020.
- Evaluate the performance of a statistically larger sample set of VCR fittings (¼, ½, and 1 inch) and seals (Stainless-Steel, Silver-plated Ni).

VCR TEST ARTICLE

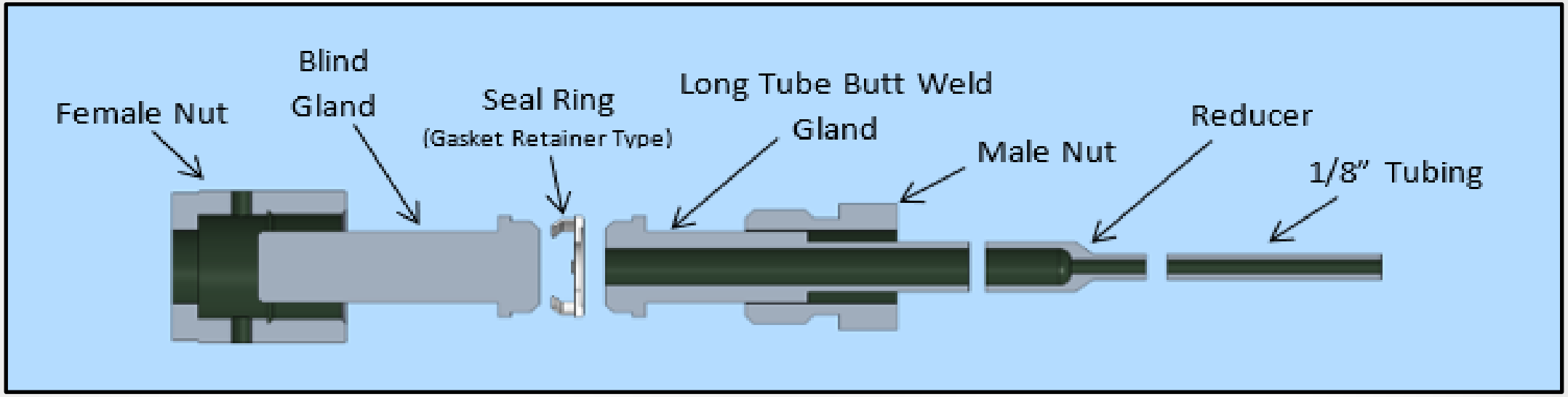
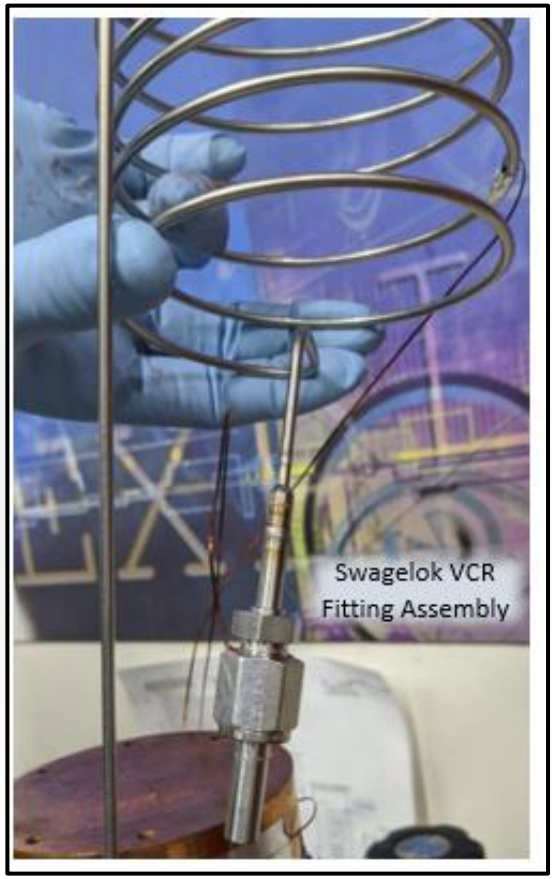


Image: NASA

VCR Fitting Test (Typical Test Article Setup)

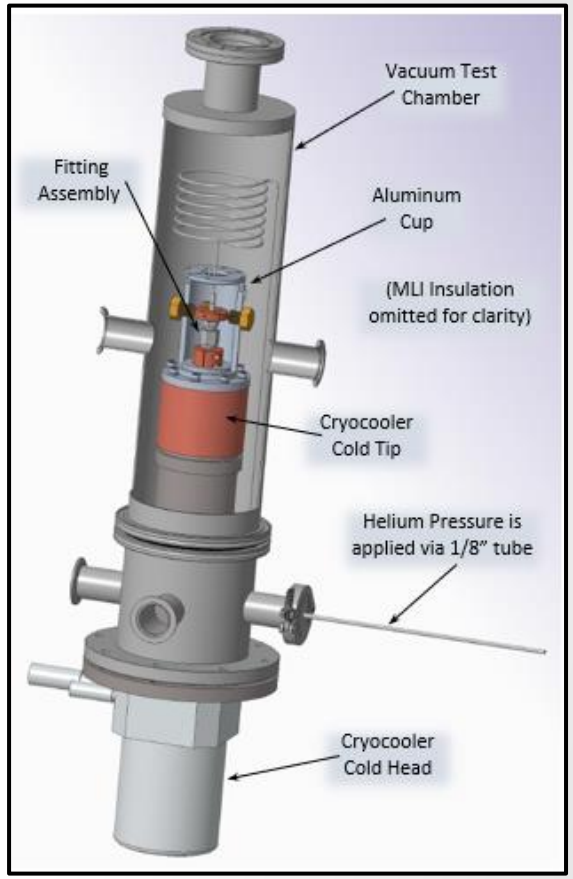
VCR FITTING TEST SETUP (Thermal Vacuum Chamber – TVAC)

- Chamber attached to Cryocooler and pumped down to vacuum
- Fitting pressurized with gaseous helium (GHe)
- Leaks into vacuum chamber measured with calibrated helium leak detector (Inside-out method)



Test fitting assembly prior to TVAC installation

Image: NASA



TVAC Chamber Cutaway

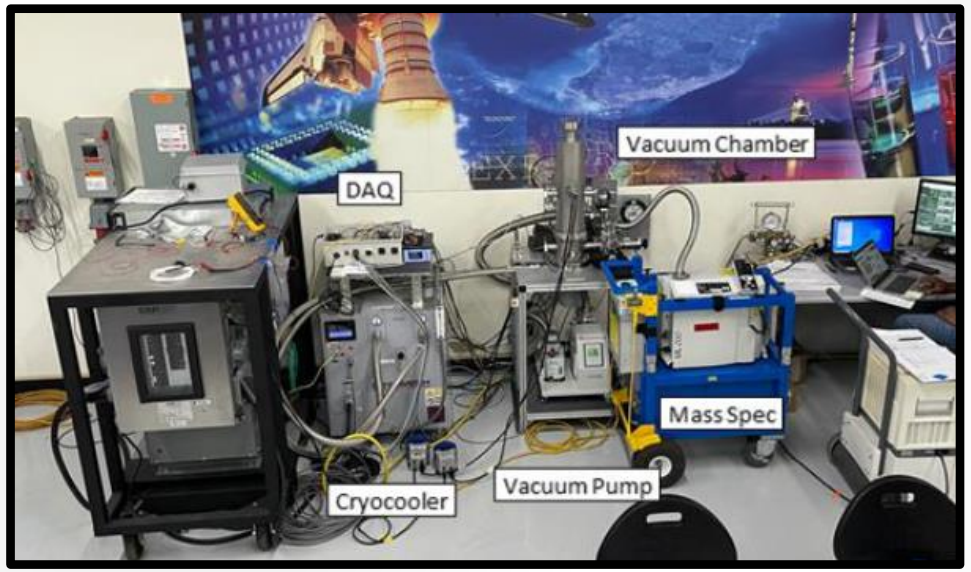
Image: NASA

HARDWARE ENHANCEMENTS (2022)

- Developed a LabView application to execute an automated series of leak measurement tests.
- Added solenoid-operated valves and an electronic pressure regulator to automatically control fitting pressurization and venting and vacuum system isolation.
- Implemented error handling of problems such as vacuum leak, high helium background, inadequate helium pressure, etc. to interrupt testing and await operator input.
- Implemented automated data collection and reporting.

VCR FITTING TEST SETUP (Overall Test Hardware)

- Internal Components
  - Cryocooler
  - Vacuum Pump
  - Helium Leak Detector (Mass Spectrometer)
  - Vacuum Test Chamber
  - Data Acquisition System (DAQ)
- External Components
  - Cryocooler Chiller
  - Helium K-Bottle w/ Electronic Regulator



Test Setup (Internal)

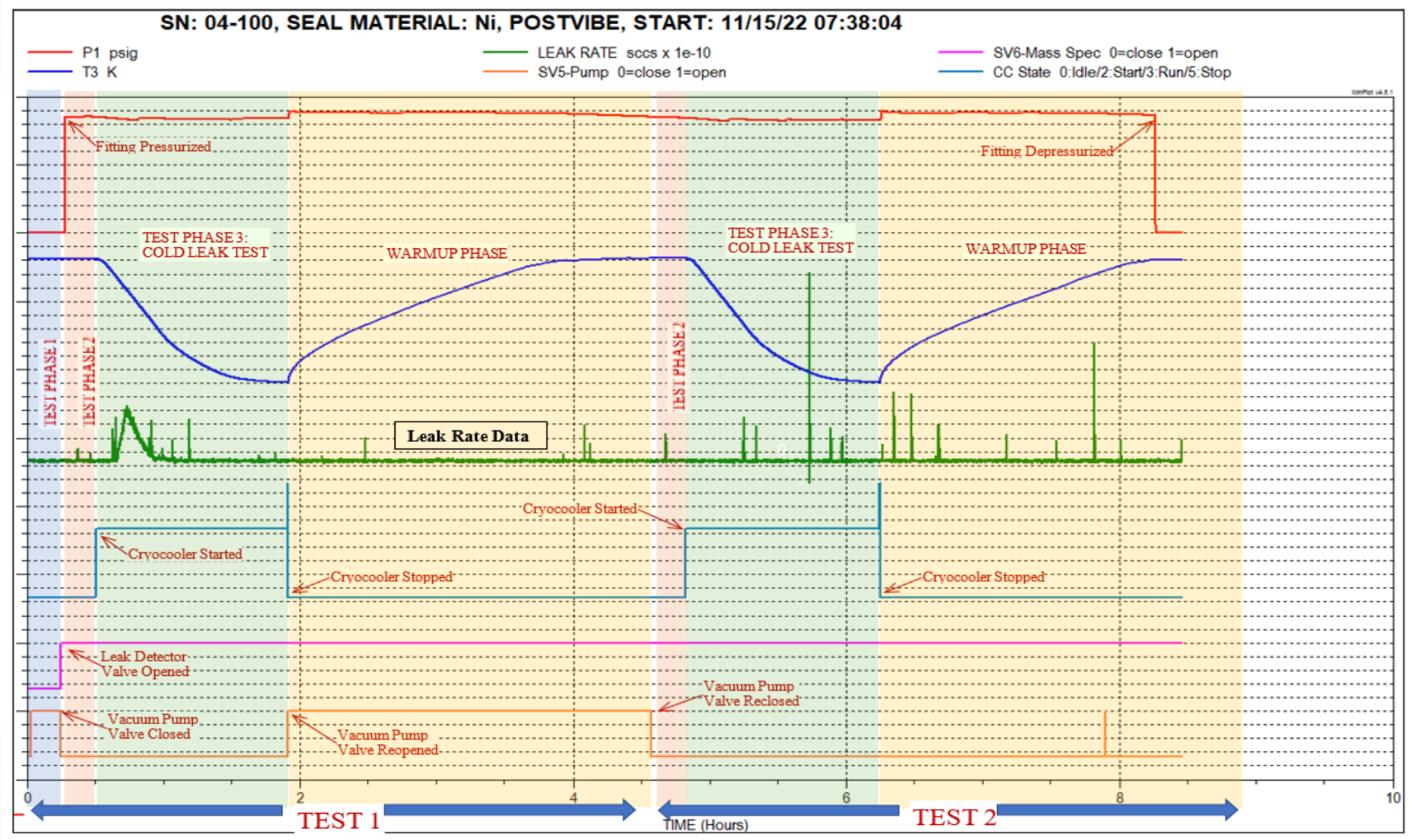
Image: NASA

Test Setup (External)

Image: NASA

THERMAL VACUUM (TVAC) TESTING

- **START OF COLD LEAK TEST**
  - Chamber evacuated
  - Fitting pressurized
  - Leak detector valve opened
  - Cryocooler started
  - Cryocooler stopped
- **END OF COLD LEAK TEST**
  - Warmup



Typical automated TVAC test, 2 ambient-cryo cycles

Image: NASA

VIBRATION TESTING

- Each fitting was exposed to launch-like dynamic conditions to determine whether the sealing capability would be compromised due to launch vibration.
- Performed on an Unholtz Dickey vibration shaker table at the KSC Vibration Test Laboratory (VTL) and based on ASTM F1387-19 S8 specifications.

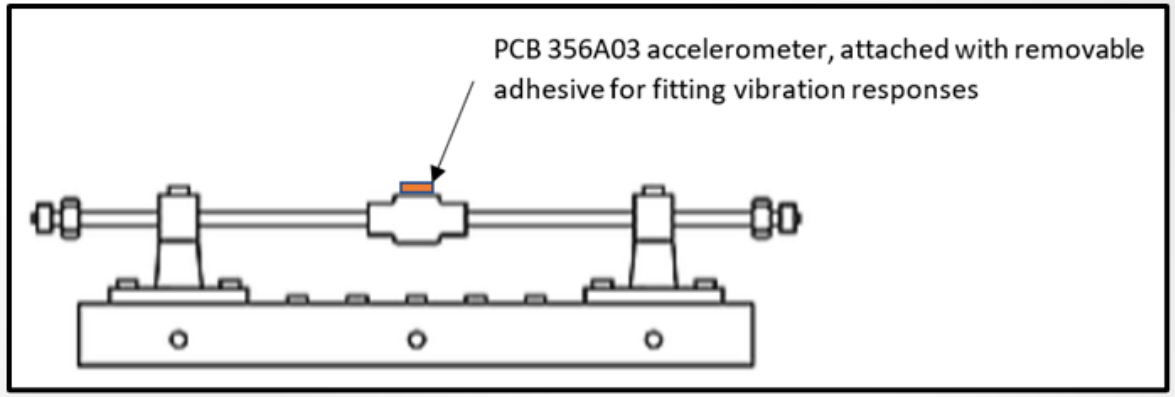


Image: NASA

ASTM F1387-19 Standard test setup

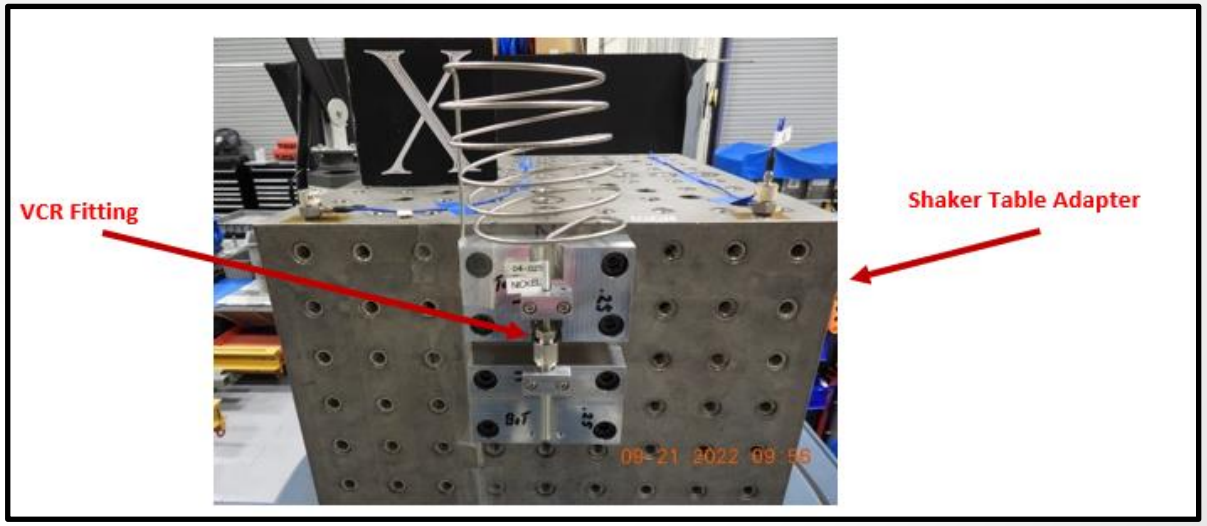


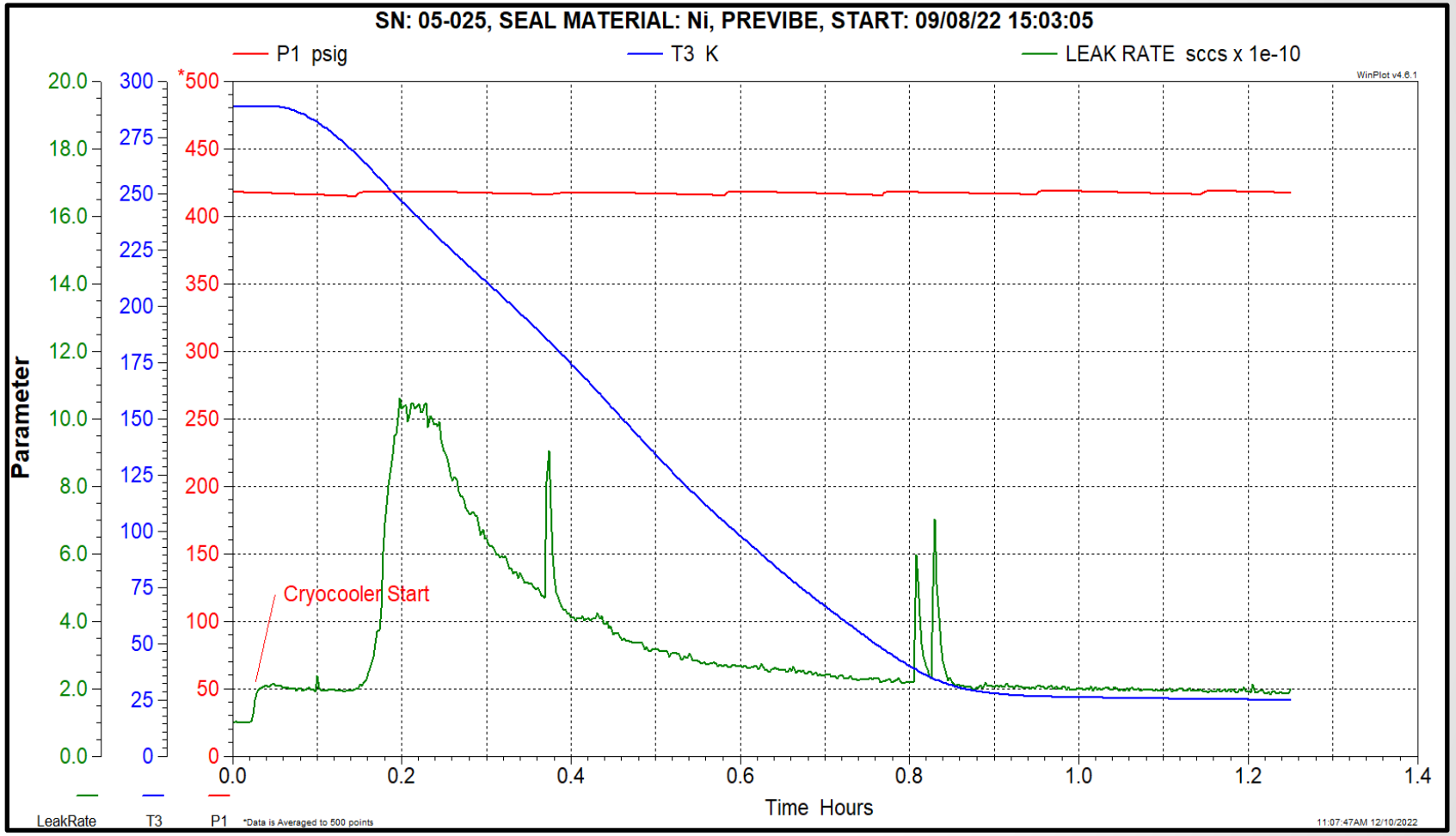
Image: NASA

Vibration Test Setup on VTL shaker table

RESULTS/FINDINGS

- ¼” Fitting
- Silver-Plated Nickel Seal
- Pre-Vibe Run

- **Pressure (P1)**
- **Temperature (T3)**
- **Leak Rate (max)**
  - **10.5 x 10^{-10} sccs**



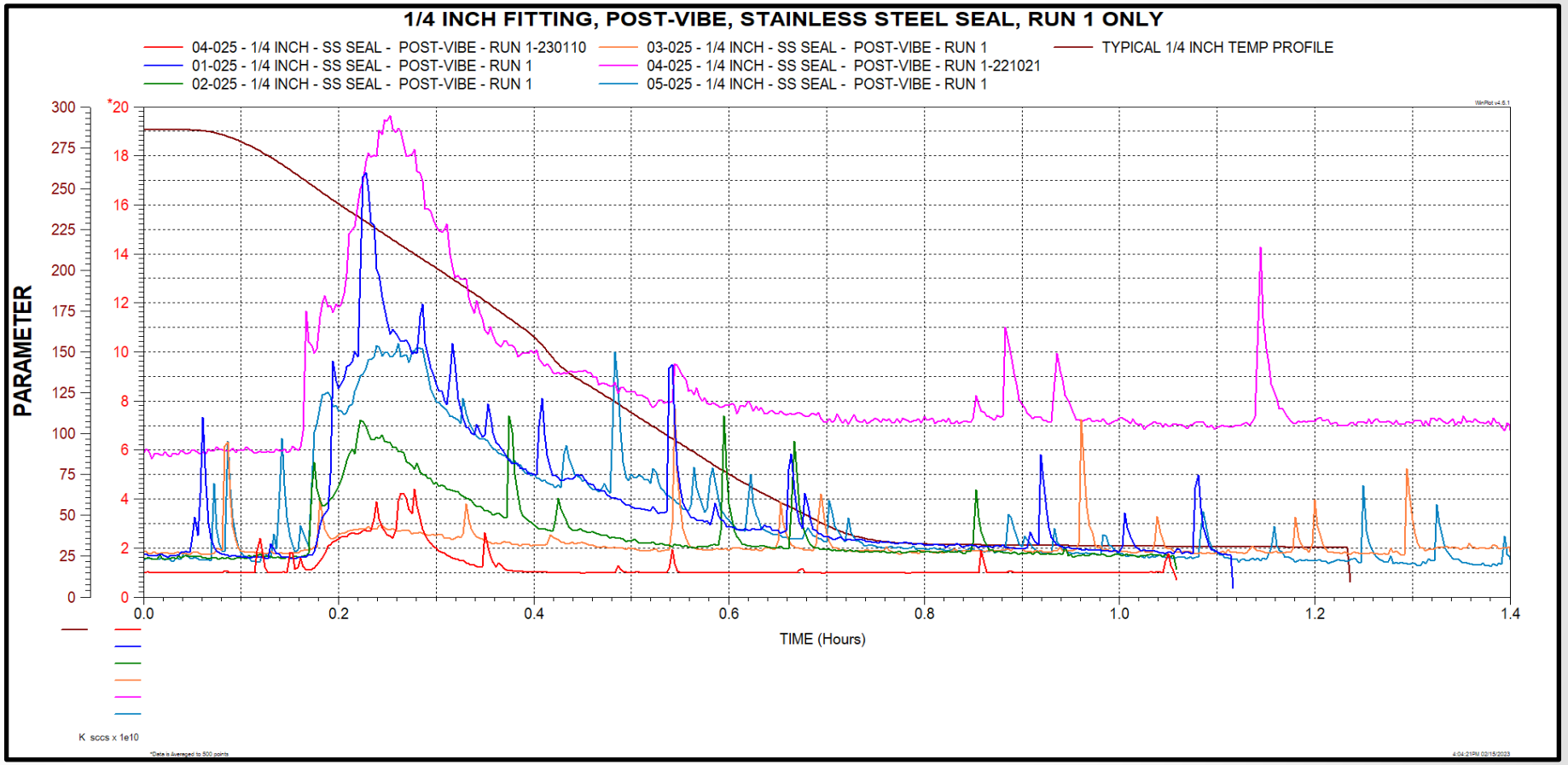
Representative TVAC data run

Image: NASA

RESULTS/FINDINGS

- ¼” Fittings (5)
- SS Seal
- Post-Vibe test

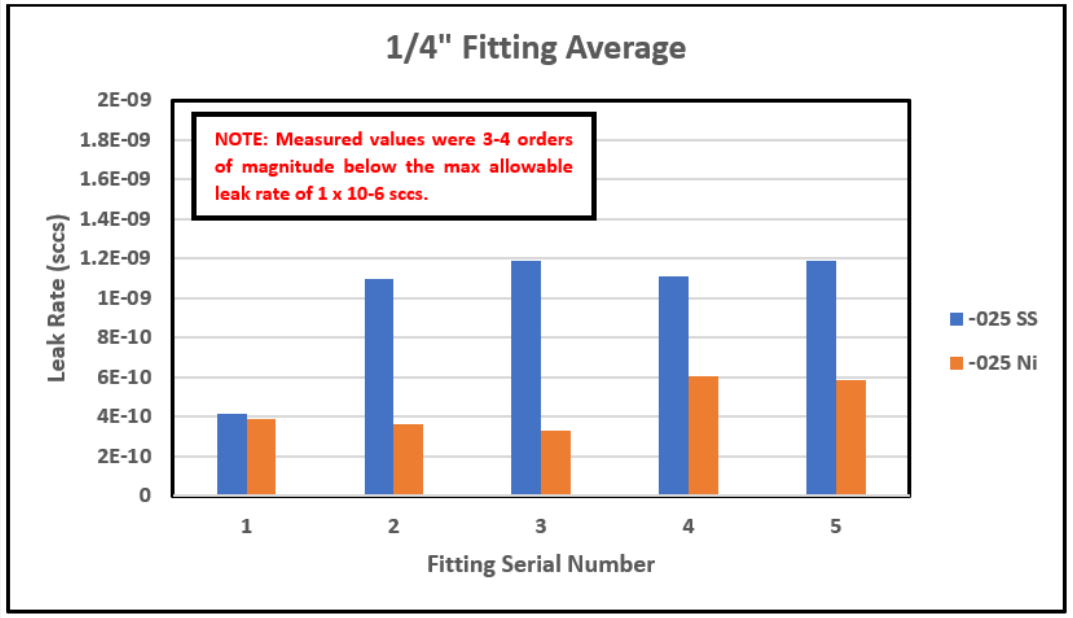
- Max observed leak rate: 19.6×10^{-10} sccs
- Max allowable leak rate: 1×10^{-6} sccs

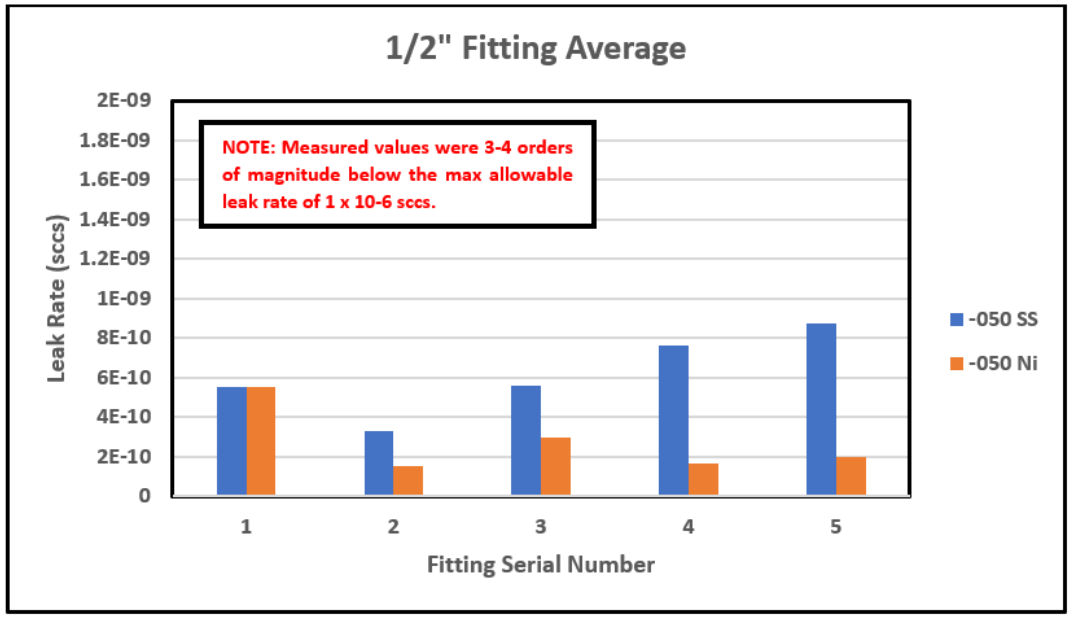


TVAC data run

Image: NASA

RESULTS/FINDINGS





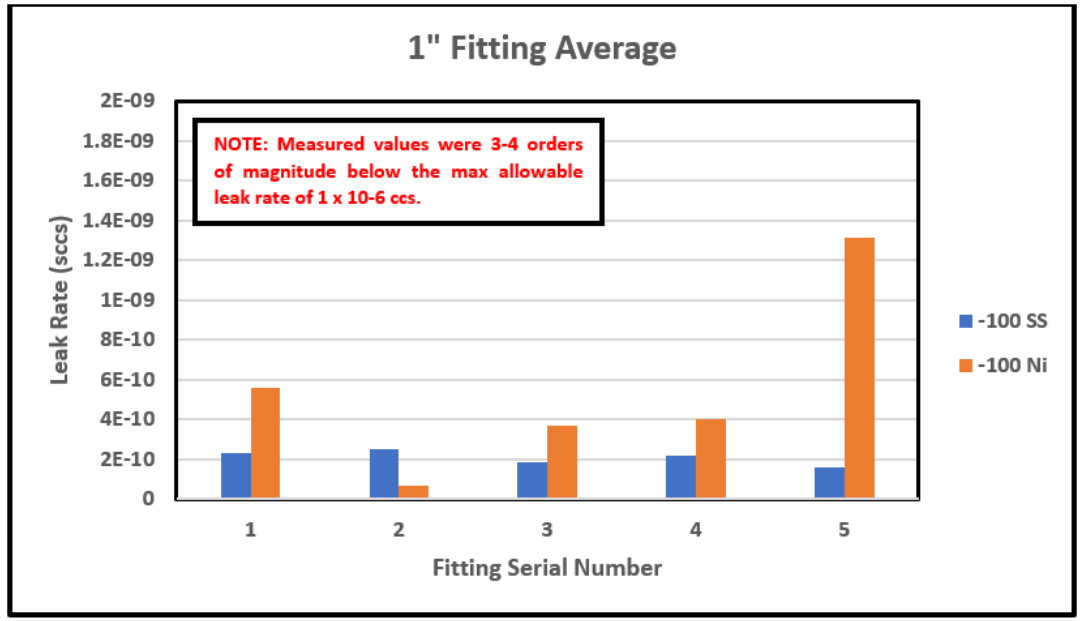


Image: NASA

Maximum Helium Leak Rate Comparisons (NOTE: Plotted values are the average of 4 tests: 2 pre-vibe and 2 post-vibe.)

SUMMARY

- The measured GHe leak rates for 30 fitting/seal-pair test samples were typically in the range of 10^{-9}-10^{-10} sccs during both Pre-Vibe and Post-Vibe TVAC cycles.
- The fittings remained leak tight at cryogenic temperature (20-30K)
- The fittings survived launch vibrations and remained leak-free under extreme thermal cycling.
- The Silver-plated Ni seals had lower leak rates, but the Stainless-Steel seals were more rugged.
- There were two deviations where damage to the Silver-plated Ni seal ring (scratches) during assembly resulted in a leaky fitting.

Image: NASA

LESSONS LEARNED

- Seal rings are delicate and must be handled with care during assembly.
    - There were 2 leaky fittings due to damaged/scratched seal rings. The test data for two fitting/seal pairs (½ inch Ni and 1 inch Ni) were inconsistent. Upon further examination, it was found that both seals contained scratches and imperfections that may explain the inconsistencies in the test data. Data from these fittings was discarded and not used in the final analysis.
- Data file labeling is very important for efficient tracking/sorting of large data sets.
- The sequence of operations is important and can affect the quality of measurements.

RECOMMENDATIONS

- Continue further testing to fully qualify the fittings per the ASTM F1387-19 and/or other relevant NASA specifications.
- Use the automated test setup to qualify other cryogenic fluid components.

Image: NASA

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Image: NASA

THANK YOU FOR YOUR ATTENTION!

QUESTIONS?