ELLIOTT TOOL TECHNOLOGIES

# Torq N' Seal® HX Plug
# Hydro / Helium Test Report

**10 August 2017**

## Abstract

Torq N' Seal® high pressure tube plugs (US Patent Numbers 6883547 & 9249916) have been used across a variety of industries and heat exchanger applications for over 35 years. These plugs create a mechanical contact seal that can withstand pressures in excess of **6,500 psi** and temperatures greater than 1,750°F, or higher depending on the alloy. Torq N' Seal® high pressure tube plugs are installed by hand using a 3/8" drive torque wrench and associated HEX driver attachment, eliminating the need for costly training and installation tools that competing tube plugs require. This saves costly man-hours during critical facility downtime without sacrificing safety or efficacy in heat exchanger maintenance or capacity reduction projects.

Comprehensive testing and analysis has been completed using Torq N' Seal® plugs to verify their efficacy in sealing heat exchanger tubes. These tests included high pressure up to **10,000 psi**; pressure cycling, prolonged service, and vibration at **6,500 psi**; thermal cycling and installation effects on adjacent tubes; and **helium testing up to $10^{-10}$ std cc/s**. Torq N' Seal® plugs have also been hydro tested by the US Naval Air Warfare Center and Ontario Hydro (the precursor to Ontario Power) to pressures in excess of **6,500 psi**.

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# Introduction

Heat exchanger tube plugging is used to take a heat exchanger tube out of service for two main reasons, leaking/ruptured tubes or capacity reduction. There are a variety of ways to plug a heat exchanger tube, but regardless of method the goals remain the same: Create a positive seal that will endure even the harshest conditions for the life of the heat exchanger, with a simple, safe, and cost-effective implementation designed to prevent damage to adjacent tubes and tube sheet ligaments.

The Torq N' Seal® heat exchanger tube plug is a solid one-piece thimble style plug that can be inserted into the tube sheet of a leaking tube and expanded with a standard 3/8" drive torque wrench (see Appendix A.1 & A.2). The plug will expand approximately 30 mils (0.030") to provide a positive mechanical contact seal. The Torq N' Seal® heat exchanger plug can be used in high or low-pressure applications such as feedwater heaters, moisture separator re-heaters, preheaters, condensers, coolers, fin-fan coolers, or any other tubed heat exchanger.

Permanent, positive sealing in excess of **6,500 psi** is achieved without special tooling or personnel training, exceeding the needs of even super-critical heat exchangers. The plug can be inserted to any depth of the tube sheet, providing flexibility to avoid severely corroded areas on the tube sheet face. The design enables rapid implantation and fit into tight areas adjacent to the tube sheet/shell joint interface, baffle plates, and internal dividers. The one-piece design enhances sealing characteristics by eliminating second potential leak paths common to design found in two-piece plugs. Torq N' Seal®'s wide sealing area contact zone ensures a positive seal while the gradual and symmetrical torque expansion eliminates thermal and mechanical shock to the tube sheet, commonly found with welding, impact due to hammering of tapered pins, and explosive insertion methods. Additionally, the patented design allows installation of plugs at the face and back side of the tube sheet to prevent intrusion of shell side corrosives. With single plugging techniques accomplished on the face of the tube sheet, corrosives can enter the void created in the tube sheet, thereby exacerbating erosion and corrosion of the tube sheet ligaments.

The Torq N' Seal® plug is snapped onto the hex capture driver and inserted into the tube ID, ensuring that the serrated sealing area is within the tube sheet. Applying the initial torque to the driver engages the anti-spin eccentric cam, locking the plug into the tube ID, thereby providing a torsional resistive force. As additional torque (in-lb) is exerted, the drive screw threads into the plug body, pressing the tapered expansion ferrule into the reverse taper of the plug. These tapered surfaces combine to generate an enormous radial expansion force, swaging the serrated sealing area into the tube wall (see Appendix A.3 & A.4). A permanent, positive mechanical contact seal in excess of **6,500 psi** is created.

Torq N' Seal® heat exchanger tube plugs meet or exceed all of the following manufacturing, design, and test specifications:

- ASME B31.3
- ASME Section VIII Division 1
- CSA B51
- CSA Z662

- TEMA
- CAN/CSA 285.0 6.1.6 Cat H
- ISO-9001:2008 Standards for
  - ASME Section VIII
  - API 660
  - Alberta (ABSA) 2017-01051
  - Ontario (TSSA) CRN# OA11184.5R2

## Basis for Test Pressures

Test pressures were selected based on the ASME Section VIII Division 1 and ASME B31.3 testing requirements for high pressure vessels and piping. ASME Section VIII Division 1 requires the minimum test pressure of pressure vessels to be 1.3 times the maximum allowable working pressure (MAWP) multiplied by the lowest stress ratio (LSR) of the materials from which the pressure vessel is fabricated. The LSR is the ratio of material yield strength at test temperature to material yield strength at operating temperature. There is no time limit specified for ASME Section VIII Division 1.
ASME B31.3 specifies a test pressure not less than 1.5 times the design pressure multiplied by Rr, where Rr is the equivalent of LSR in Section VIII Division 1. Pressure must be maintained for at least 10 minutes during visual inspection for leaks. ASME B31.3 was used to determine test pressure because it was the stricter of the two regulations.
Since Torq N' Seal® tube plugs are installed in a variety of heat exchanger applications, design pressure is a range more than a set value. As a result, the design pressure for testing was selected based on the single most demanding Torq N' Seal® application, supercritical coal power plants. In the phase diagram of water there is a point, which occurs at 705°F/3,208 psi, called the critical point of water. Here liquid water and steam become indistinguishable. Increasing the temperature and pressure above the critical point pushes steam into the supercritical range. Many of the large pulverized coal power plants in existence today produce supercritical steam and have an efficiency of a little more than 40 percent, such as the 600-MW John W. Turk Jr. power plant in Arkansas.

The design pressure selected for testing was 4,200 psi, as this is among the highest design pressures for ultra-supercritical coal boilers in operation today. By meeting the most demanding potential application of Torq N' Seal® plugs, this design pressure provides a safety/performance factor of several times relative to more typical installations. Multiplying by 1.5 times, in order to meet the ASME B31.3 high pressure piping test requirements, gives a test pressure of 6,300 psi. Even these relatively high pressures are so far below the yield strength of the Torq N' Seal® plug materials being tested that yield strength effects were negligible. For instance, minimum yield strength for carbon steel is greater than 50,000 psi.

**Thus, the standard test pressure was set at 6,500 psi**, used for the prolonged service, temperature cycling, pressure cycling, and vibration testing. The high-pressure test was completed at **10,000 psi.** Again, these values were specifically selected to confirm a factor of safety and performance well beyond that required by relevant codes for even the most stringent Torq N' Seal® applications.

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## Testing Procedures and Results

A variety of tests have been conducted to prove the efficacy of Torq N' Seal® heat exchanger tube plugs. The test parameters were designed to demonstrate the service of Torq N' Seal® plugs to relevant code in the most demanding potential applications. These tests include: High pressure testing to 10,000 psi; Prolonged service testing at 6,500 psi for 4 days (96 hours) followed by a high-pressure test to 10,000 psi; Thermal cycling between 100°F and 600°F; Pressure cycling between 0 psi and 6,500 psi; Vibration testing at 6,500 psi; Installation effect on adjacent tubes and tube sheet ligaments; Helium testing up to $10^{-10}$ std cc/s.

Torq N' Seal® plugs were inserted into test fixtures (see Appendix A.5) of inner diameter 0.500" made from Carbon Steel and 316 Stainless Steel. The plugs were size 0.490" to 0.510" and installed based on the manufacturer's recommended installation torque using a 1/4" HEX driver coupled with a 3/8" drive torque wrench. Plug materials tested were Carbon Steel and 316 Stainless Steel. After installation, a measurement was made from the top of the plug to the beginning of the tube on the test fixture using a digital caliper accurate to 1/1000th of an inch. The test fixture was placed over a dry surface where leaking would be immediately apparent. Water was the medium, pressurized by a hydraulic pump (see Appendix A.6).

### High Pressure

The test fixture was pressurized from 0 psi to 10,000 psi over the course of 1 minute (see Appendix A.7 & A.8). Observations for leakage were made continuously during pressurization. Upon reaching a pressure of 10,000 psi, the valve was closed, the pressure on the pump and hose were released, and the test fixture was left for 10 minutes. After 10 minutes, the pressure was recorded and observations for leakage were made, then the valve was opened to relieve pressure back to the reservoir. After pressure was relieved, a measurement was made of the plug location using digital calipers.

The test fixture showed no signs of leakage anywhere in the system throughout the course of the experiment. Pressure did not drop during the 10-minute observation period. The measurement of plug location showed no difference from the original measurement, indicating the plug had not moved within the test fixture.

### Prolonged Service

The test fixture was pressurized from 0 psi to 6,500 psi over the course of 1 minute. Observations for leakage were made continuously during pressurization. Upon reaching a pressure of 6,500 psi, the valve was closed. Pressure on the pump and hose was relieved and disconnected from the test fixture. The test fixture was left under pressurization for 4

days (96 hours). Observations for leakage were made periodically over the course of the experiment. After 4 days, the pressure was recorded and final observations for leakage were made. The hose and pump were reconnected and the valve was opened, relieving pressure back to the reservoir. Then, the test fixture was pressurized again up to 10,000 psi over the

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course of 1 minute to verify plug efficacy after extended, high demand service. Pressure was held for 10 minutes then relieved back to the reservoir. Plug location was recorded.

The test fixture showed no signs of leakage anywhere in the system throughout the course of the experiment. Pressure did not change during the 4-day (96 hour) observation period. Plug and test fixture achieved 10,000 psi after observation period with no leakage or pressure drop. Plug location showed no change between the pre and post-test measurements, indicating the plug had not moved within the test fixture.

## Thermal Cycling

A band heater was wrapped around the OD of the test fixture (see Appendix A.9) at the far end of the plug. The test fixture was pressurized from 0 psi to 2,500 psi over the course of 1 minute. Observation for leakage were made continuously during pressurization and the remainder of the test. Upon reaching a pressure of 2,500 psi, the valve was closed. Pressure on the pump and hose was relieved. The band heater was turned on and temperature at the seal location was measured using an IR thermometer as the test fixture was heated to a maximum temperature of 600°F, which took approximately 15 minutes. Then the band heater was turned off and the test fixture was allowed to cool to 100°F, which took approximately 11 minutes. The test fixture was heated and cooled a total of 10 times (see Appendix A.10). Then the pressure was relieved back to the reservoir and a measure of plug location was taken.

The test fixture showed no signs of leakage in the system throughout the course of the experiment. Start and finish pressures showed no change. Plug location showed no change between the pre and post-test measurements, indicating the plug had not moved within the test fixture.

## Pressure Cycling

Observations for leakage were made throughout the course of the experiment. The test fixture was pressurized from 0 psi to 6,500 psi over the course of 1 minute. Then pressure was relieved to the reservoir (atmospheric pressure) almost immediately. The test fixture was pressurized and relieved a total of 10 times (see Appendix A.11). After the final cycle, pressure was relieved to the reservoir and a measure of plug location was taken.

The test fixture showed no signs of leakage in the system throughout the course of the experiment. Plug location showed no change between the pre and post-test measurements, indicating the plug had not moved within the test fixture.

## Vibration

Observations for leakage were made throughout the course of the experiment. The test fixture was pressurized from 0 psi to 6,500 psi over the course of 1 minute. Upon reaching a

pressure of 6,500 psi, the valve was closed. Pressure on the pump and hose was relieved and disconnected from the test fixture. The test fixture was affixed to a pneumatic vibrator

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rated at 60 Hz and a maximum displacement of 0.05”. The test fixture was subjected to vibration for 10 minutes. The test fixture was then removed from the pneumatic vibrator and reconnected to the hose and pump. After recording the final pressure, the valve was opened to relieve pressure back to the reservoir. A measurement of plug location was taken.

The test fixture showed no signs of leakage in the system throughout the course of the experiment. There was no pressure drop evident during the test and no change between start and end pressures. Plug location showed no change between the pre and post-test measurements, indicating the plug had not moved within the test fixture.

### Effects on Adjacent Tubes and Tube Sheet Ligaments

A mock tube sheet made of Admiralty Brass was fabricated for this experiment. Small length copper tubes were rolled into the tube sheet. The ID of the test location and every adjacent tube were taken, as was the center-to-center distance between each adjacent tube and the test location using a digital caliper. A stainless-steel plug was selected, intended to amplify any deformation relative to a standard Torq N’ Seal® installation which would recommend an Admiralty Brass plug. The plug was installed based on the manufacturer’s recommended installation torque. The same ID and center-to-center measurements were taken.

The measurements showed negligible change after installing the plug in the test location. This indicated that the plug did not deform the tube sheet, nor did it have any impact on adjacent tubes.

### Helium Testing

Two types of helium (He) testing were completed, for certification and further details see pages 14 and 15 after the Appendix. First, the test fixture was pressurized to 15 psi with helium tracer gas (80% He, 20% air). An STX radiodetector probe, sensitive to $10^{-4}$ std cc/s, was positioned outside the fixture at the exposed end of the tube. No helium was detected over a 3 hour period.

In the second test, the Torq N Seal® test fixture was evacuated to a near full vacuum and Helium (He) was applied to the Torq N Seal Plug end of the fixture. A Leybold Mass Spectrometer was used to detect any helium in-leakage up to a threshold of $10^{-10}$ std cc/s. There was no leakage detected throughout the course of the experiment.

## Conclusion

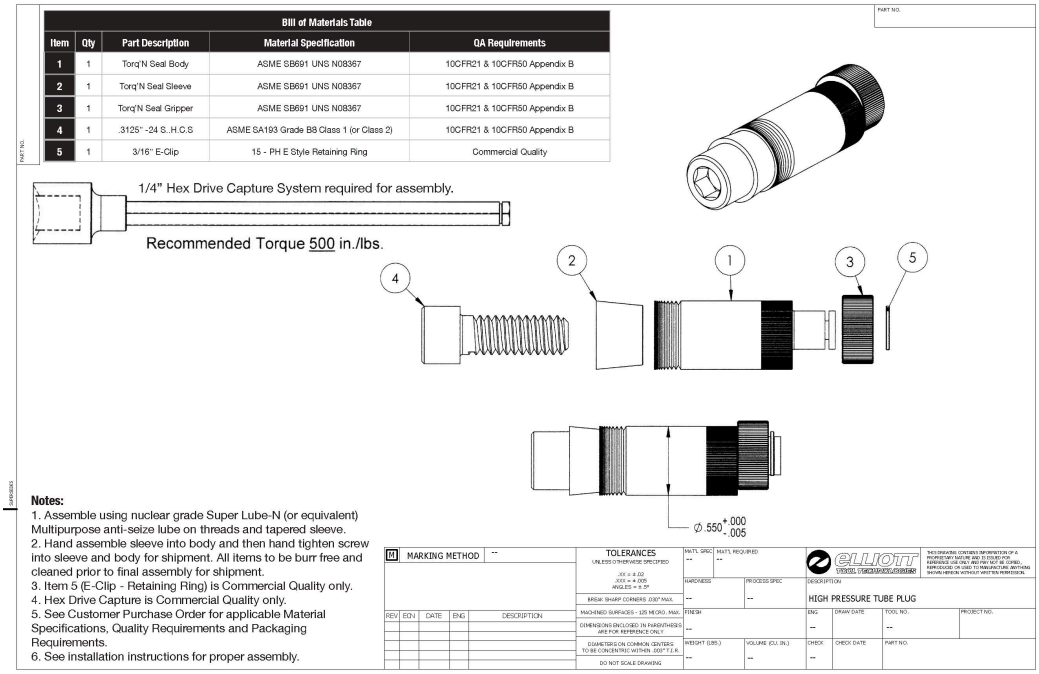
Torq N’ Seal® heat exchanger tube plugs met all of the test requirements described in the previous section. No meaningful leakage, plug displacement, or pressure release was detected under any of the testing scenarios, as listed below:

- High pressure in excess of 10,000 psi
- Prolonged service at 6,500 psi, followed by pressurization to 10,000 psi
- Thermal cycling between 100°F and 600°F
- Pressure cycling between 0 psi and 6,500 psi
- Vibration of 100 Hz and 0.10” displacement at 6,500 psi

• No discernible deformation of adjacent tubes or tube sheet ligaments during installation
• Helium testing up to 10-10 std cc/s (300 yr detection rate) with no leakage

Torq N' Seal® heat exchanger tube plugs meet or exceed all relevant pressure vessel codes and requirements (ASME B31.3, ASME Section VIII Division 1, etc). 6,500 psi was specifically selected to meet code for the most demanding possible installations, thus demonstrating their suitability for any heat exchanger tube plugging application.

## Appendix



| Bill of Materials Table | | | | |
|---|---|---|---|---|
| Item | Qty | Part Description | Material Specification | QA Requirements |
| 1 | 1 | Torq'N Seal Body | ASME SB691 UNS N08367 | 10CFR21 & 10CFR50 Appendix B |
| 2 | 1 | Torq'N Seal Sleeve | ASME SB691 UNS N08367 | 10CFR21 & 10CFR50 Appendix B |
| 3 | 1 | Torq'N Seal Gripper | ASME SB691 UNS N08367 | 10CFR21 & 10CFR50 Appendix B |
| 4 | 1 | .3125" -24 S..H.C.S | ASME SA193 Grade B8 Class 1 (or Class 2) | 10CFR21 & 10CFR50 Appendix B |
| 5 | 1 | 3/16" E-Clip | 15 - PH E Style Retaining Ring | Commercial Quality |



Figure A.1 Torq N' Seal® Assembly Drawing

Figure A.2 Assorted Torq N' Seal® Plugs and HEX Drivers

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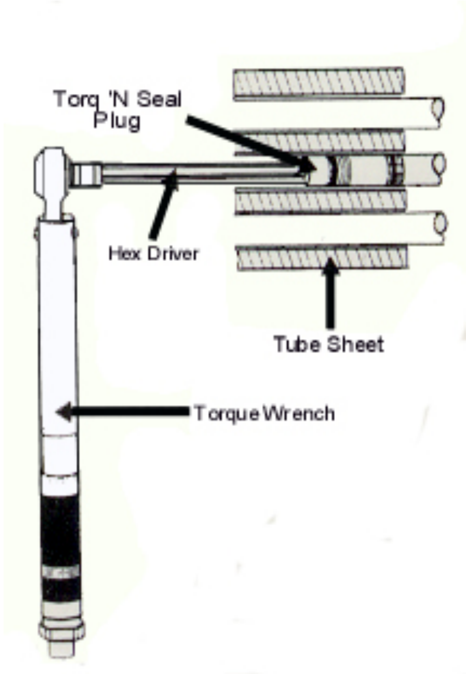
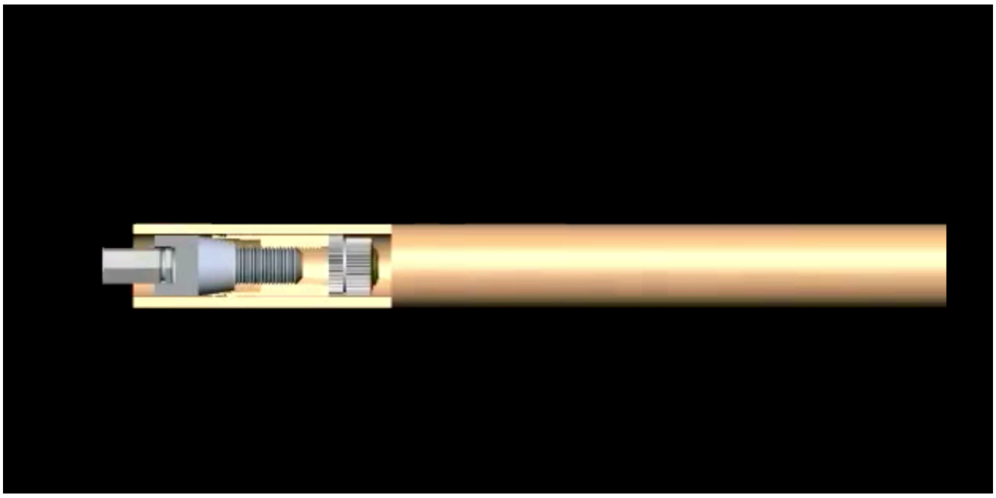



Figure A.3 Torq N' Seal® Installation Drawing



https://youtu.be/pY2kkFbgrok

Reference A.4 Torq N' Seal® Installation Video

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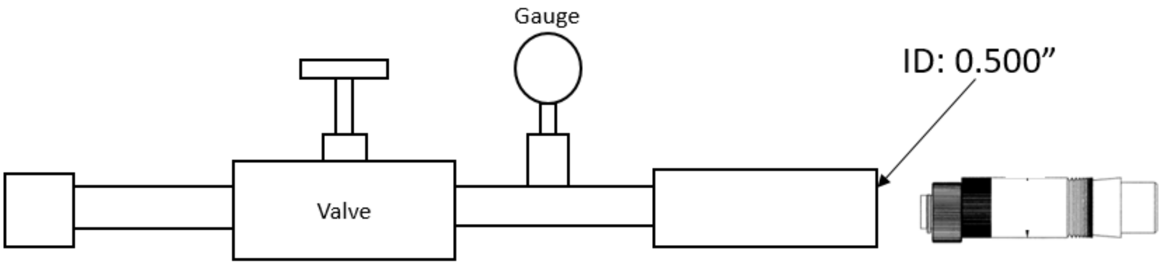


Figure A.5 Torq N’ Seal® Hydro Test Fixture Diagram

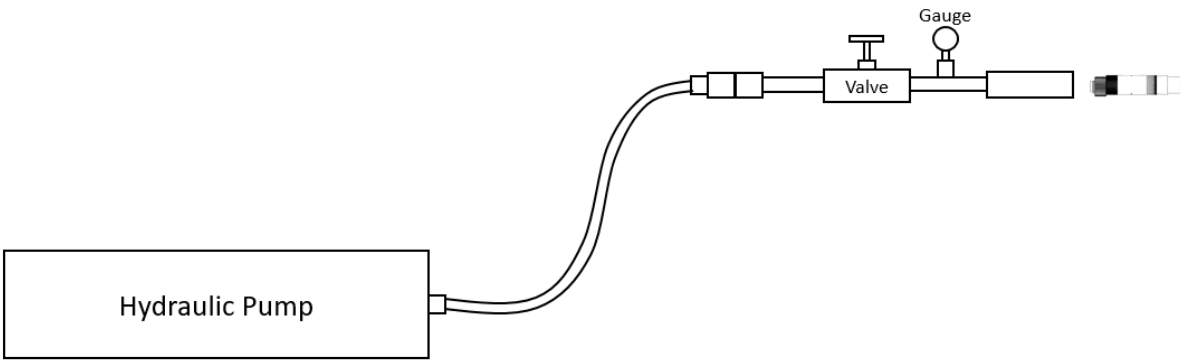


Figure A.6 Torq N’ Seal® Hydro Test System Diagram



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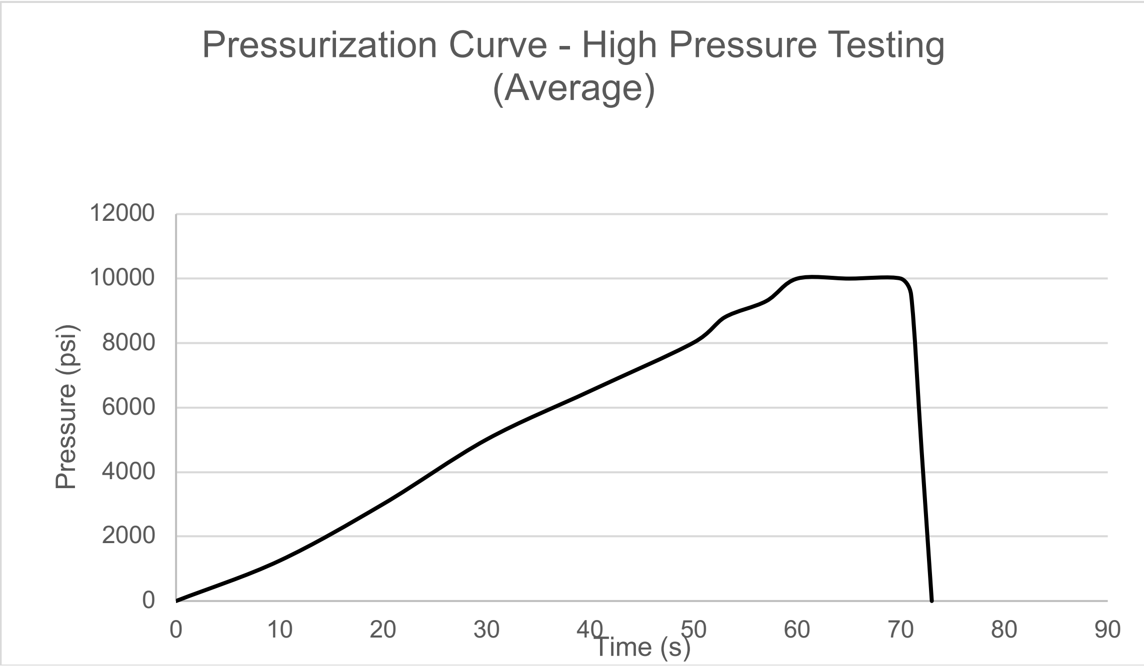


Figure A.7 High Pressure Test Results


Figure A.8 High Pressure Test Picture

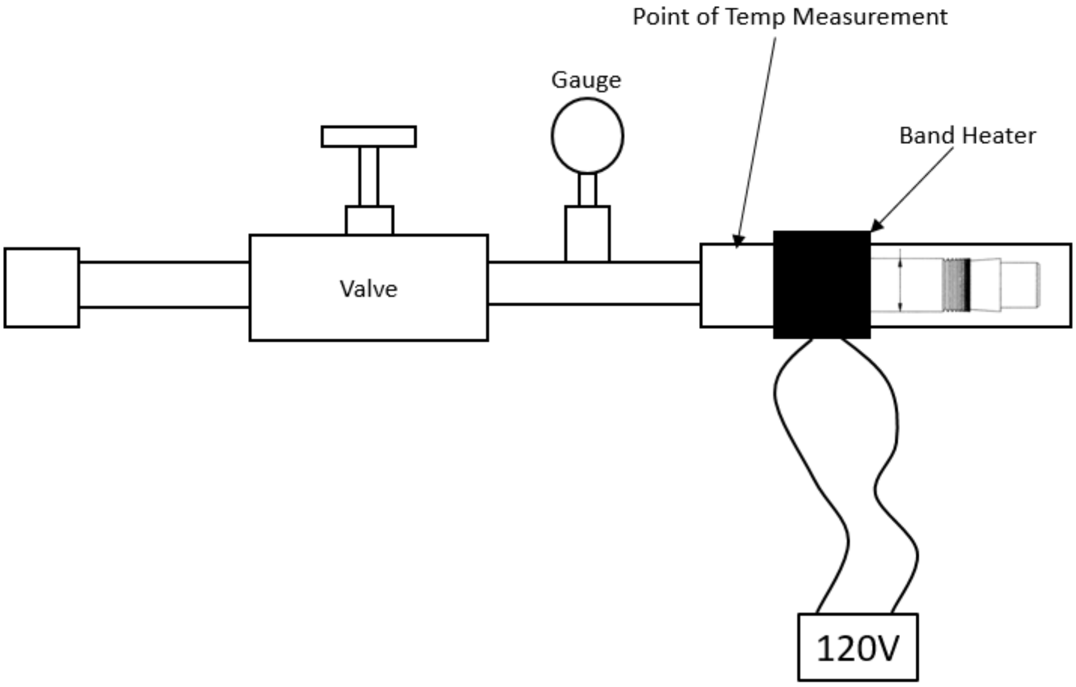


Figure A.9 Thermal Cycling Test Fixture Diagram

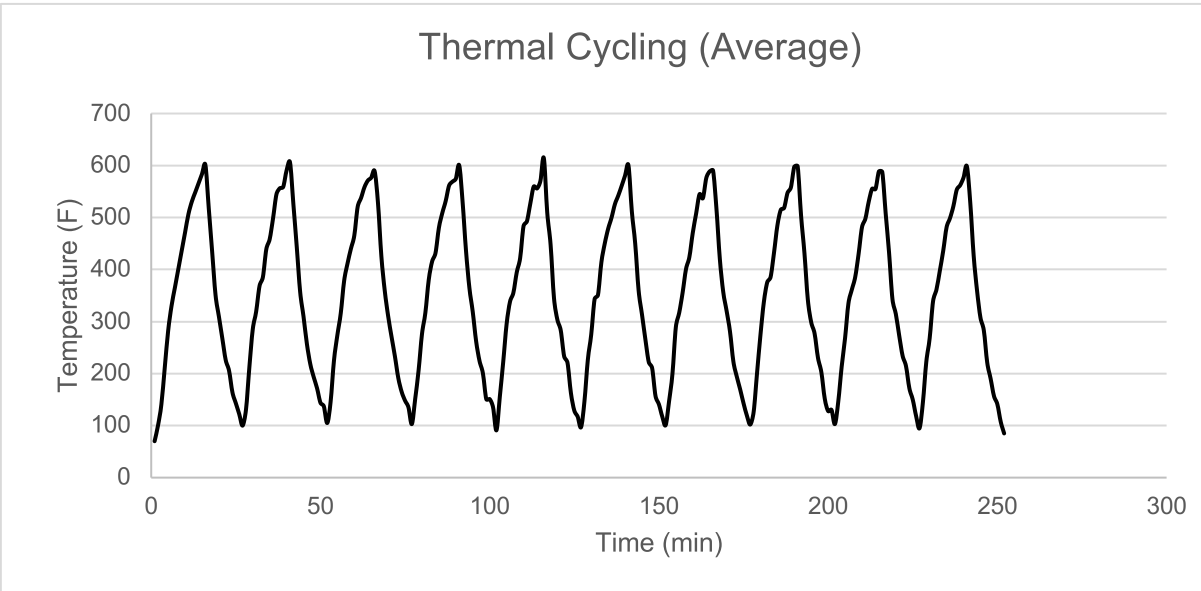


Figure A.10 Thermal Cycling Test

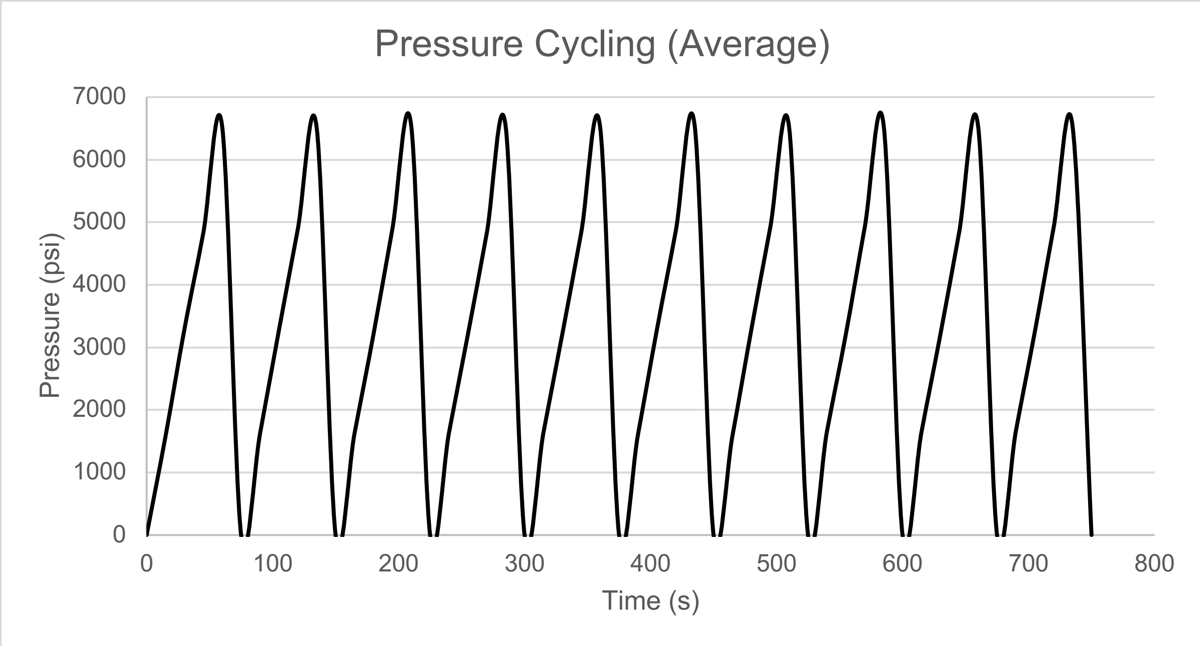


Figure A.11 Pressure Cycling Test



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# Torq N Seal® Plug Helium (He) Test
# 10 Aug. 2017

Testing was done in accordance with the **ASME SE-432** Specification utilizing both mass spectrophotometer and radiodetector type leak detectors for Helium (He), measuring steady-state leak rate.

Tracer gas leak testing is a simple and highly-efficient method of leak detection that provides high sensitivity as well as increased accuracy and repeatability. This method is used for testing parts with very low leak rates that are outside the range for conventional air-flow pressure decay and mass flow, or to replace bubble test methods. Tracer gas testing uses escaping tracer gas to identify micro-leaks in the range of $1x10^{-4}$ to $1x10^{-10}$ std. cc/s.

Per **ASME SE-432**, leak detection methods can be subdivided into a tracer mode and a detector probe mode. The tracer mode procedure is used when the system is evacuated and the tracer gas (He) comes from a source located outside the system. The detector probe mode is used when the system is pressurized with the tracer gas (He) and testing is done at atmospheric pressure. Usually the tracer probe technique is more rapid because the gas reaches the detector at a higher concentration, despite any streaming effects.

In general, leakage measurement procedures involve covering the whole of the suspected region with tracer gas (He), while establishing a pressure differential across the system by either pressurizing with a tracer gas or by evacuating the opposite side. The presence and concentration of the tracer gas on the lower pressure side of the system are determined and then measured.

- **Helium Pressure Test- Detector Probe Method (Shell-side Simulation)**
  The Torq N Seal® test fixture was pressurized with 15 psi (1 Atm.) of Helium (80% He/ 20% Air) for 3 hours. An STX Radiodetector was used to detect any leakage of He.
  - **Results: No leakage @ $10^{-4}$ std. cc/s, 3 hour detection rate**
  - Interpretation: Helium pressure (15 psi) was applied to the back side (Eccentric locking wheel side) of the Torq N Seal® Plug with no leakage being detected for 3 hours simulating a potential shell-side leak path.
- **Helium Vacuum Test- Tracer Method (Tube-side Simulation)**
  The Torq N Seal® test fixture was evacuated to a near full vacuum and Helium (He) was applied to the Torq N Seal Plug end of the fixture. A Leybold Mass Spectrometer was used to detect any leakage from an A2LA accredited and ISO 17025:2005 certified testing facility, ensuring that the strictest controlled calibration procedures were followed. These standards are provided with traceable calibration certificiates, including the N.I.S.T and ANSI/NCSL Z540.1-1994.
  - **Results: No leakage @ $10^{-4}$ std. cc/s, 300 year detection rate**
  - Interpretation: Near full vacuum was applied to the back side (Eccentric locking wheel side) of the Torq N Seal® Plug with tracer gas (He) applied to the front end (Capscrew/Installation Side) of the Torq N Seal Plug with no leakage being detected simulating a potential tube-side leak path (UHV Test Report 11581).


*Torq N Seal® Helium Test Fixture*