

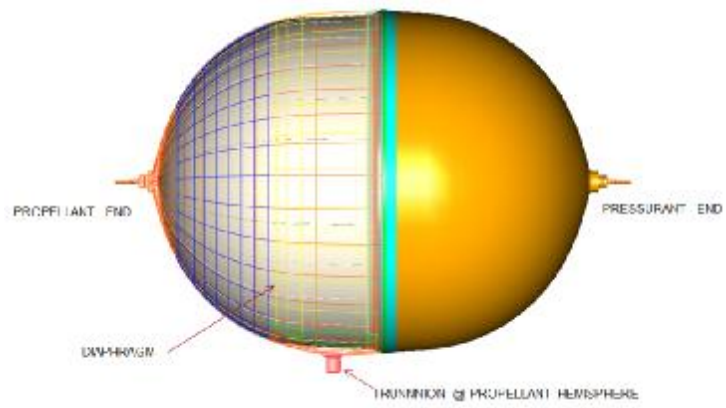
# QUALIFICATION ENVIRONMENTS

FOR

## PROPELLANT TANK

Orbital ATK P/N 80557

**ATK P/N 80557**



**Table 1: P/N 80557 Propellant Tank Specifications**

<b>Parameters</b>	<b>Requirements</b>
Operating Pressure	350 psig
Proof Pressure	525 psig
Burst Pressure	>700 psig
Total Internal Volume	29,340 in <sup>3</sup> (481 liters) minimum
Qualification Tank Volume	29,498.9 in <sup>3</sup> (483.6 liters)
Material of Construction	The 80557 Propellant Tank is an assembly consisting of titanium domes with cylinder section, and incorporating an elastomeric diaphragm.
Membrane Thickness	0.041" (1.04 mm)
Vacuum Capability	Tested to 0.2 torr (actual 0.198 torr)
Tank Mount(s)	Mounting is provided by a side pin and flex plates on polar bosses.
Tank Weight	Required tank mass is 69 lb <sub>m</sub> , Actual tank mass, including bearing and shear plates, is 68.39 lb <sub>m</sub> Actual tank mass is 65.65 lb <sub>m</sub>
Shell Leakage	<1x10 <sup>-6</sup> std cc/sec He max
Failure Mode	Burst

80557-1 was subjected to the following qualification tests:

<b>DETAIL REQUIREMENTS</b>
Pre-assembly Inspection & Test
Post-assembly Inspection & Test
Examination of Product
Mass Measurement
<b>PRESSURE TESTING</b>
Volumetric Capacity Measurement
Proof Pressure Test
Volumetric Capacity Measurement
Internal (Diaphragm) Leak Test**
Negative Pressure Capability Test**
External Leak Test
Proof Pressure Cycling
MEOP Pressure Cycling
System Priming Test
Differential Pressure, Mass Flow Rate & Expulsion Efficiency
Weld Quality Inspection (X-ray & Dye Pen)
Visual & Dimensional Inspection
<b>VIBRATION TESTING: SINE &amp; RANDOM (DRY &amp; WET)</b>
General Requirements
Vibe Test Procedure
Preparation for Shipment
<b>POST-VIBE TESTING</b>
Internal (Diaphragm) Leak Test**
Negative Pressure Capability Test**
Volumetric Capacity Measurement
Proof Pressure Test
Volumetric Capacity Measurement
Differential Pressure, Mass Flow Rate & Expulsion Efficiency
External Leak Test
Weld Quality Inspection (X-ray & Dye Pen)
<b>COMPLETION OF QUAL TESTING</b>
Mass Measurement
Final Visual & Dimensional Inspection
Burst Pressure Test & Inspection

**The following tests are listed in the document:**

- 1) Pressure Cycle Log
- 2) Proof Pressure Test
- 3) Negative Pressure Test
- 4) External Leak Test
- 5) Proof Pressure Cycles
- 6) MEOP Pressure Cycles
- 7) System Priming Test
- 8) Differential Pressure & Mass Flow Rate
- 9) Vibration Test Data & Natural Frequencies
- 10) Burst Pressure Test

# Pressure Cycle Log

Date	Test Title	Fluid Medium	Spec Pressure	Actual Pressure	No. of Cycles	Time at Pressure	Test Engineer/Technician Signature	Dept.
5/14/13	PROOF PRES.	DI H <sub>2</sub> O	535.2 <sup>+14</sup>	541	1	5 MIN 3 SEC	<i>[Signature]</i>	70
5/17/13	INT LEAK	HE	120 <sup>+10</sup>	125	1	45 MIN	<i>[Signature]</i>	70
5/20/13	EXT LEAK	HE	356.8 <sup>+10</sup>	358	1	45 MIN	<i>[Signature]</i>	70
5/22/13	PROOF CYCLE	DI H <sub>2</sub> O	538.1 <sup>+10</sup>	536-541	18	9 MIN	<i>[Signature]</i>	70
5/24/13	MEDP CYCLE	DI H <sub>2</sub> O	555.8 <sup>+10</sup>	556-559	50	25 MIN	<i>[Signature]</i>	70
5/29/13	SYS PRIME, DIFF PRES, EXHAUSTION	GN2	290.3 <sup>+10</sup>	297	1	1 HR	<i>[Signature]</i>	70
6/13/13	INT LEAK	HE	120 <sup>+10</sup>	126	1	45 MIN.	<i>[Signature]</i>	70
6/14/13	PROOF PRES.	DI H <sub>2</sub> O	535.2 <sup>+/-10</sup>	540	1	5 MIN.	<i>[Signature]</i>	70
6/14/13	DIRE. PRES, MASS FLOW RATE, EXHAUSTION	GN2	100- 285	179	1	1 HR.	<i>[Signature]</i>	70
6/19/13	EXT LEAK	HE	356.5 <sup>+10/-0</sup>	360	1	30 MIN	<i>[Signature]</i>	70
6-18-13	BURST TEST	H <sub>2</sub> O	714.3 <sup>+10</sup>	716	1	18 SEC.	<i>[Signature]</i>	70
6-18-13	" "	"		914	-	-	<i>[Signature]</i>	70

## **Pre-Proof Volume Determination**

### **Pre-Proof Volumetric Determination**

The tank pre-proof test volume was determined by the weight of water method described in paragraph 4.2.1 of ATK QTP 50-000779. The internal volume was determined to be 29,498.9 in<sup>3</sup>, meeting the minimum requirement of 29,340 in<sup>3</sup>.

## Proof Pressure Test

### Proof Pressure Test

The tank proof pressure test was performed per ATK QTP 50-000779, paragraph 4.2.2. The actual proof pressure recorded was a temperature-adjusted 541 psig for a test period of 5 minutes and 3 seconds. Nominal proof pressure of the Qual Tank is 525 psig at 35 °C. Three LVDT's were used to measure axial and radial growth as a function of pressure as recorded on Data Sheet D for reference only as requested by the customer. There were no anomalies observed during and after testing and there was no visible deformation to the tank.

Below is proof pressure test tank growth data.

### **Proof Pressure Test: (\*Data for Reference Only)**

	Pressure (T °F)	LVDT 1 Axial (in)	LVDT 2 Radial – Trunnion Side (in)	LVDT 3 Radial – Opposite Trunnion 1 (in)
(1) Growth at 105 psig	105	.001	.001	.021
(2) Growth at 173 psig	173	.002	.001	.035
(3) Growth at 285 psig (Launch Pressure)	285	.004	.003	.056
(4) Growth at 350 psig (MEOP)	350	.005	.005	.068
(5) Growth at 525 (psig) (Proof Nominal)	541	.011	.010	.102
(6) Growth at 0 psig after Proof	0	.002	-.001	-.001



## Negative Pressure Test

### Negative Pressure Capability Test

The Negative Pressure Capability Test, aka Vacuum-rating Test, was performed per ATK QTP 50-000779, paragraph 4.2.5. The vacuum system met the 0.2 Torr requirement and the external shell did not exhibit any deformation or damage after being held below the required vacuum level for the five (5) minute test period. There were no anomalies observed during and after testing and the testing did not deviate from the test procedure requirements. Results are recorded on Data Sheet F.

Below is negative pressure test data.

	ACTUAL	REQUIRED VALUE
1. Verify Tank is Dry	Yes/No	Dry
2. Specimen Pressure	.190 Torr <sup>psia</sup>	0.2 Torr (0.00386 psid)
5. Test Duration	5 minutes	5 +1/-0 (min)
6. Visual Inspect for Damage	PASS Pass/Fail	Pass

## **External Leak Test**

### **External Leakage Test**

The external leakage test was performed per ATK QTP 50-000779, paragraph 4.2.6. After the chamber sensitivity was stabilized per the test requirements, the tank was subjected to a vacuum chamber pressure below 20 microns, and a test pressure of 358 psig which is within testing tolerance of the temperature-adjusted MEOP (356.8 psig). The observed leakage rate was  $3.39 \times 10^{-9}$  scc/sec, meeting the required rate of  $1.0 \times 10^{-6}$  scc/sec of GHe maximum. Following the test, the tank was visibly inspected and there were no visible damage to the tank. The Max / Min thermocouple reading was not recorded on Data Sheet G because at the time a thermocouple was not available for the test in the configuration needed for the new Leak Test. This is a low risk issue for helium leak testing as the (de-)pressurization rate is controlled to less than 20 psi / sec.

## **Proof Pressure Cycles**

### **Proof Pressure Cycle**

The tank was cycled between ambient and a temperature-adjusted proof pressure of 533.7 +10/0 psig for eighteen (18) cycles per ATK QTP 50-000779 paragraph 4.2.7. The tank was held at proof pressure for a minimum for thirty (30) seconds for each cycle. Linear Voltage Displacement Transducers (LVDT's) were used to measure axial and radial growth as a function of pressure as recorded on an appendix to Data Sheet H. There were no anomalies observed during and after testing and there was no visible damage to the tank.

## **MEOP Pressure Cycles**

### **MEOP Pressure Cycle**

The tank was cycled between ambient and temperature-corrected MEOP of 355.8 +5/-0 psig for fifty (50) cycles per ATK QTP 50-000779 paragraph 4.2.8, as recorded on Data Sheet I. The tank was held at MEOP pressure for a minimum of thirty (30) seconds for each cycle. The tank was held overnight with a minimum pad pressure of 20 psig until cycling continued the next day, a standard and acceptable practice during extended duration pressure cycling tests. Linear Voltage Displacement Transducers (LVDT's) were used to measure axial and radial growth as a function of pressure as recorded on an appendix to Data Sheet I. There were no anomalies observed during and after testing and there was no visible damage to the tank.

## **System Priming Test**

### **System Priming Test**

The tank was pressurized and then exposed to empty lines via a fast acting valve to simulate system priming per ATK QTP 50-000779, paragraph 4.2.9. The tank was loaded with 992 lbs (95% fill fraction) of de-ionized water. The tank was then pressurized to a temperature-adjusted MEOP (297 psig meets 290.3 +10/-0 at 75 °F). The DI water was then expelled at a rate of 4.3 gallons per minute for 6 seconds meeting the spec requirement. There were no anomalies observed during and after testing and there was no visible damage to the tank.

## Differential Pressure & Mass Flow Rate

### Differential Pressure and Mass Flow Rate

The pre-vibration differential pressure and mass flow rate test was conducted per ATK QTP 50-000779, paragraph 4.2.10. The tank was pressurized initially to 250 psig prior to the five flow rate tests shown in Table 2 where the recorded pressure drops from Data Sheet E are summarized. The expulsion efficiency was calculated to be 100% meeting the 99% minimum requirement with test pressures of 168-250 psig meeting the 100-285 psig range requirement.

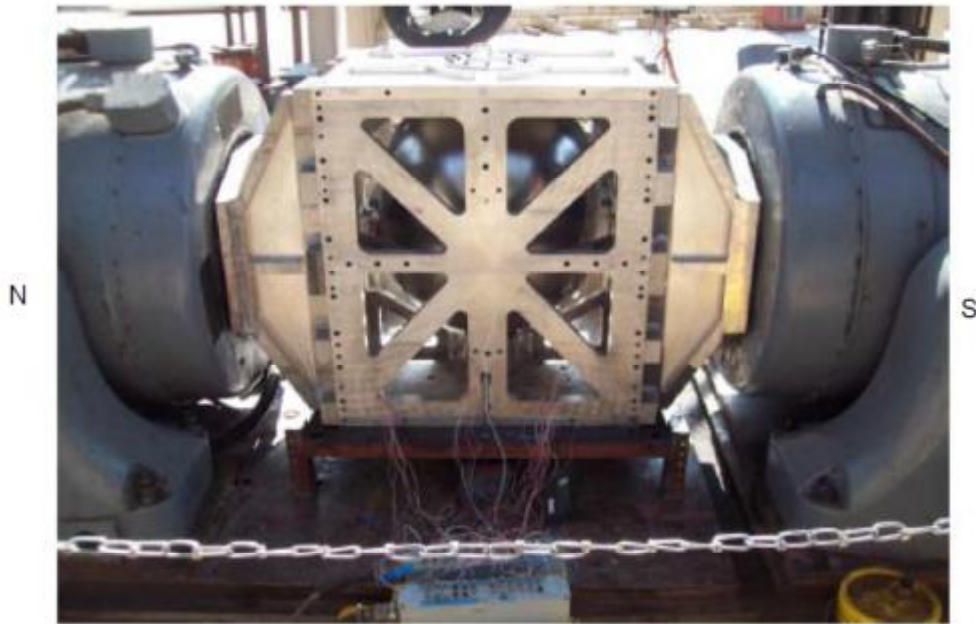
**Table 2:** Differential Pressure Test Summary

<b>Greater than 95.5% Fill fraction to Start</b>		
<b>GPM</b>	<b>PSID</b> <i>after 5 minutes</i>	<b>PSIG</b>
<b>0.80</b>	0.2	250-180
<b>1.59</b>	0.35	180-176
<b>2.28</b>	0.5	176-176
<b>2.39</b>	0.5	176-172
<b>4.30</b>	0.85	172-168



## Vibration Test Data

X-axis vibration test setup



Y-axis vibration test setup



## Z-axis vibration test setup



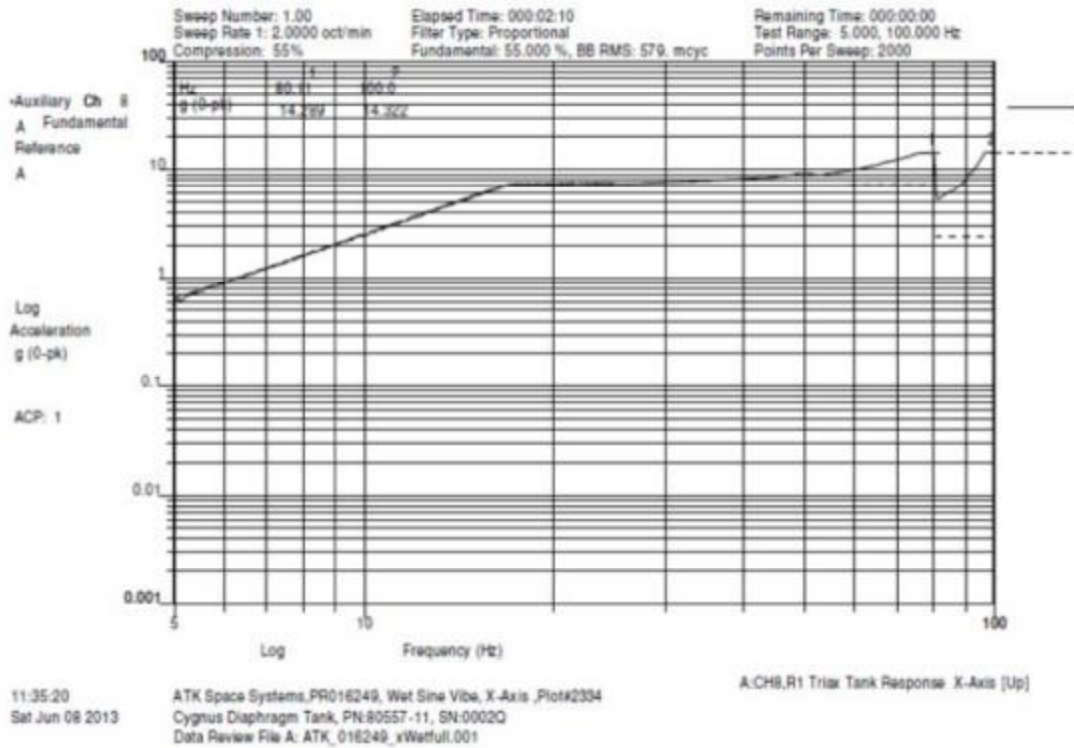
Natural Frequencies:

**Table 3:** Natural Frequencies: FEA vs. Wet Sine Vibe vs. Spec Requirements

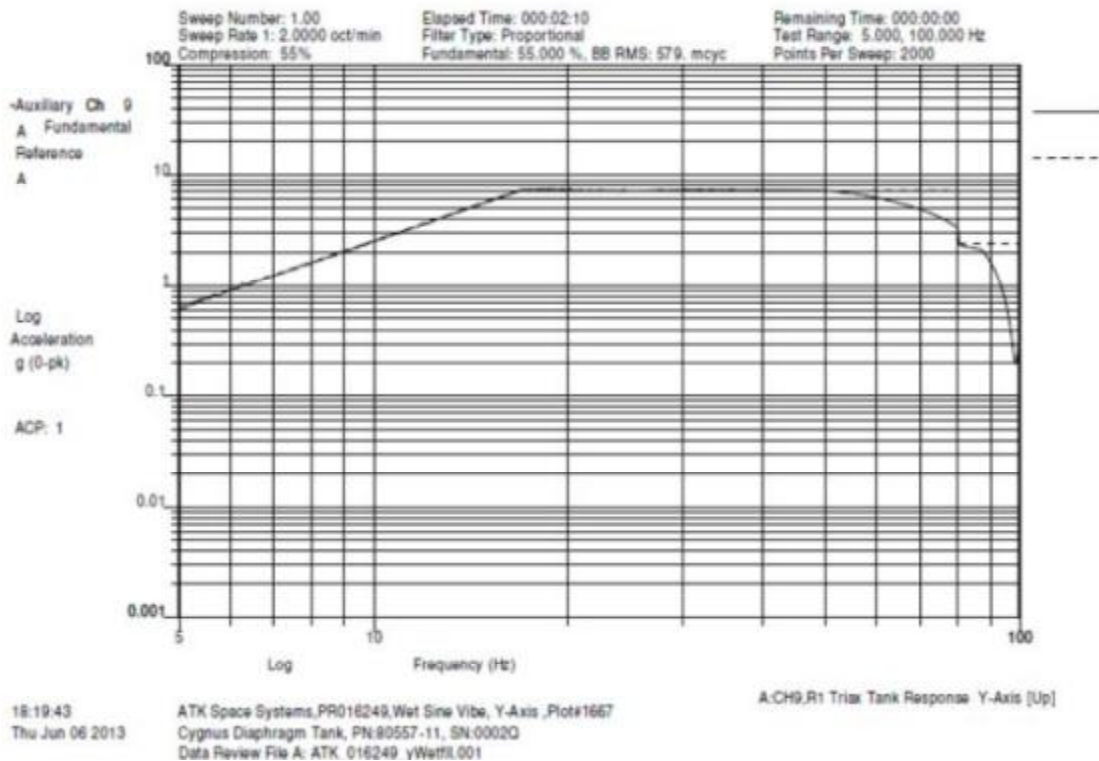
	<b>ATK Stress Analysis</b> (54-000360**) (Hz)	<b>Wet Sine Vibe Test</b> 1 <sup>ST</sup> Mode (Hz)	<b>Required Minimum</b> 1 <sup>st</sup> Mode (Hz)
X-Axis	91.5	109.5	> 65 Hz
Y-Axis	90.2	103.3	> 65 Hz
Z-Axis	58.2	55.5	> 50 Hz



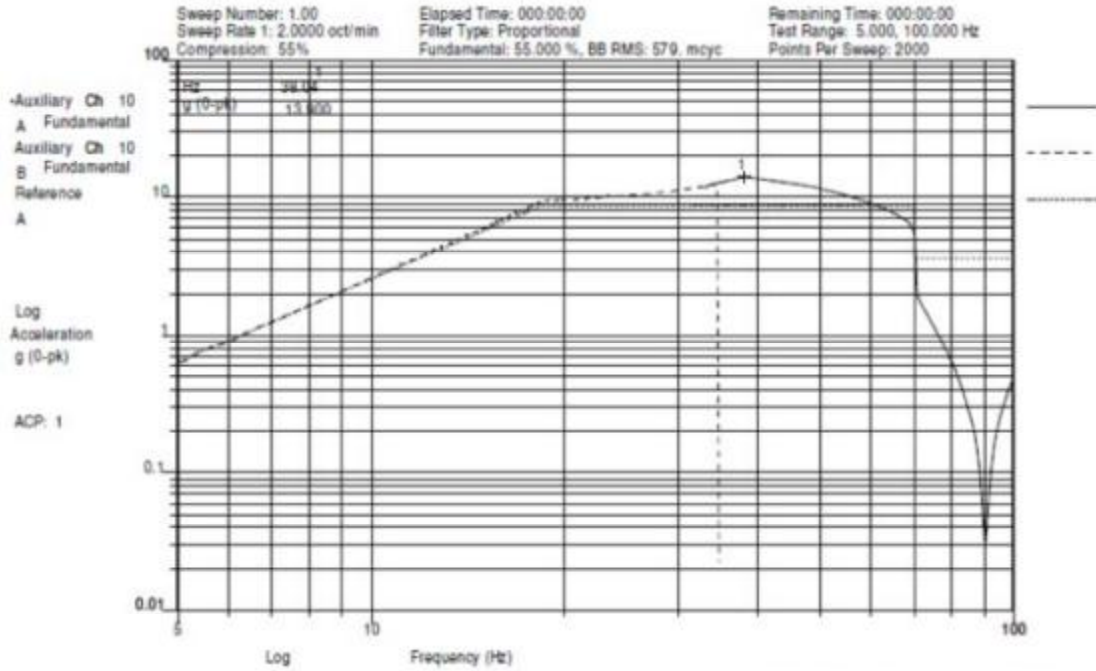
### X-axis C.G. response wet sine vibration



### Y-axis C.G. response wet sine vibration



# Z-axis C.G. response wet sine vibration



10:46:07  
Wed Jun 12 2013

ATK Space Systems,PR016249,Wet Sine Vibe, Z-Axis ,Plot#3528  
 Cygnus Diaphragm Tank, PN-80557-11, SN-0002Q  
 Data Review File A: ATK\_016249\_ZeDryfil.003  
 Data Review File B: ATK\_016249\_ZeDryfil.001

A:CH10,R1 Triax Tank Response Z-Axis [Up]  
 B:CH10,R1 Triax Tank Response Z-Axis [Up]

## Burst Pressure Test

Tank burst at 914 psig.

	Actual	Requirement
(1) Water Resistivity	8.2 <del>MΩ</del> ohm min.	500,000 ohm min.
(2) Water pH	7.1 pH	5.5 - 8.0
(3) Water Temperature	73 °F	Record
(4) Water Fill rate	2.0 gpm	4.3 gpm (max)
(5) Pressurization Rate	3 psi/sec	20 psi/sec
(6) Ambient Boom Room Temp	76 °F	Record
(7) Hold at Burst Pressure	716 psig	Record adj value from Table 6
(8) Burst Pressure	914 psig	700 psi normalized per Table 6
(9) Burst Pressure Hold Duration	18 sec	15 sec (minimum)



