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AN-Type Fittings in the International Space System (ISS) Node 2 Ammonia System Technical Assessment Report

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Technical Assessment Report

October 27, 2005

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1.0 Authorization and Notification

The request to conduct a technical assessment was submitted by an anonymous initiator to the NASA Engineering and Safety Center (NESC) on April 16, 2004.

David Hamilton, NESC's Chief Engineer at Johnson Space Center (JSC), performed the initial evaluation of the AN Fittings Plan on April 21, 2004.

This evaluation did not recommend an immediate NESC assessment. The NRB concurred and recommended that results of an NESC assessment performed on CALIPSO[1] AN fittings be transmitted to the ISS Program for consideration. The Program's AN Fittings Plan was re-reviewed in light of the CALIPSO recommendations and a second evaluation was completed by Tim Wilson, NESC Chief Engineer at the Kennedy Space Center (KSC). This evaluation noted the Program's approach was inconsistent with the NESC recommendations to CALIPSO and recommended the NESC perform an independent assessment.

The authorization to develop an Independent Technical Assessment (ITA) plan was approved by the NESC Review Board (NRB) on May 5, 2005.

[1] NESC CALIPSO Report # RP-04-01/03-001-E

2.0 Signature Page

Assessment Team Members

Signatures on file

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Steve Ernest
Safety & Mission Assurance Representative

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NDE Fluids/Thermal

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Joe Donato	Stratoflex

4.0 Executive Summary

Based on an anonymous request, an NESC Assessment Team was formed to investigate potential leakage problems from the ISS Program's Node 2 Anhydrous Ammonia System AN fittings. The Team's charter was to provide the ISS Program with a path to follow, which could include testing, to ensure the ISS Program felt confident that the AN fittings' leakage would not exceed specified limits in orbit.

KSC has had problems in the past with ground-based AN fittings leaking and an anonymous individual was concerned about similar fittings on the ISS. Node 2, constructed in Italy by Alenia, contains 30 AN fittings in an ammonia cooling system. Above specification leakage from these fittings could cause a personnel hazard on the ground and, in orbit, may result in a loss of functionality of the ammonia system.

As the Assessment Team began looking into Alenia's assembly and testing documentation, a number of discrepancies and irregularities were found. For instance, documentation showed that leakage tests of the Node 2 AN fittings were accomplished before the fittings were even assembled. The 1" AN fittings were qualified by similarity with a much smaller AN fitting that was used in a different system and environment (O_2). Other dissimilarities with this smaller fitting questioned this original qualification.

Given the issues raised by the documentation review, the integrity of the ammonia system was questioned. Since Node 2's ammonia system was already scheduled for a nitrogen (N_2) moisture purge, the Assessment Team recommended that a pressure decay test be run concurrently to determine the system's leakage rate. This test was approved and conducted with satisfactory results.

Using Alenia's documentation as basis, the Assessment Team conducted a number of interviews with individuals who had participated in or observed the assembly and testing process of Node 2's ammonia system. A chronological order of assembly and testing events was established. This event list was the basis for developing a 'Mimic' test, which took a flight hardware configuration (AN fitting, Stainless Steel (SS) Conical Seal, and attached flex hoses) through all the pressurizations, depressurizations, and vibrations that the actual hardware would encounter from initial assembly through on-orbit operations. Qualification launch vibrations were substituted for actual launch vibrations due to the aforementioned issues with qualification by similarity. All of these Mimic Tests had satisfactory results.

The leakage from Node 2's ammonia system is currently within specification and the results of the NESC testing have shown that AN fittings, properly assembled and exposed to the mimic test environment, do not exceed leakage rate specifications. Therefore, based these results and NESC conducted interviews, it is the judgment of the team that AN fittings in the Node 2 ammonia system are acceptable to support flight operations.

5.0 Assessment Plan

The assessment began with the intention of providing the ISS Program with recommendations on what to do with Node 2's ammonia system AN fittings. A plan for this approach was written and briefed to the NRB. The plan was approved and the Assessment Team began work. The Charter for this assessment was stated as follows:

> *"The goal and scope of the NESC directed AN Fittings Assessment on the ISS ITA is to review the available ISS AN Fitting data for Node 2 and provide the Program with a path to follow, that may include testing, such that the Program will feel confident that the fittings will not leak when flown".*

Subsequently, and at the request of the ISS Program, the Assessment Team prepared and conducted its own testing to gauge the veracity of the AN fittings. The approved original assessment plan is provided in Appendix D.

6.0 Description of the Problem, Proposed Solutions, and Risk Assessment

6.1 Problem

A concern was presented to the NESC regarding the AN fittings in the ISS's Node 2 anhydrous ammonia system. The issue raised was that AN fittings have a track record of leaking in KSC's ammonia ground system and that these Node 2 fittings may suffer from the same problem. Node 2, constructed by Alenia, contains approximately 30 AN fittings in the ammonia cooling system. Refer to Figure 6.1-1 for the schematic. A leaking ammonia fitting, or fittings, could cause one of the following consequences:

1. In orbit, a greater than specification leakage from AN fitting(s) could require 'more than planned for' replenishment of the ammonia and the proper functioning of the system would be in jeopardy of re-supply missions.
2. In orbit, a large leak could cause the disablement of critical ISS systems.
3. A leak during ground processing could be a personnel hazard.

An NESC Assessment Team was formed to review whether Node 2's ammonia system was safe to fly.

One of the standards used by the U.S. Military in airplanes is the Air Force-Navy Aeronautical Standard, or AN Parker[2]. Parker pioneered the flare fitting technology in the 1920s with the introduction of the inverted flare fitting which was later adopted by the U.S. Army Air Corps (the future U.S. Air Force). Prior to World War II, the Air Corps developed a fitting with a 37-degree flare, which became known as the "AN" fitting. These fitting types were used widely in the U.S. Military and in all forms of aviation between the 1930s and the 1960s. They still remain widely used today, but are gradually being replaced within the U.S. Military Aerospace Standards (AS). They provide a good seal when properly assembled. Use of too high a torque, not enough torque, unclean or scratched sealing surfaces, etc., can cause these fitting types to leak.

The Node 2 ammonia system (Figure 6.1-1) is known as the External Active Thermal Control System (EATCS) and is designed to accept rejected heat via heat exchangers from the water coolant loops. These water coolant loops receive rejected heat from within the ISS. The ammonia system is separated into two separate sections, Loop "A" and Loop "B". Alenia elected to use AN fittings rather than use welded joints and there are a total of 30 AN fittings, with 66

[2]Parker Hannifin Corporation – Tube Fittings Division
3885 Gateway, Blvd, Columbus Ohio 43228

sealing surfaces, in the two loops. The AN Fittings are used to connect a number of flex hoses that make up each of the ammonia loops. Each of these sealing surfaces uses a SS Conical Seal.

Anhydrous ammonia is a clear, colorless gas with a very distinct odor and is considered a high health hazard because it is corrosive to the skin, eyes, and lungs. Exposure to 300 ppm is immediately dangerous to life and health. Ammonia is also flammable at concentrations of approximately 15 to 28 percent by volume in air[3].

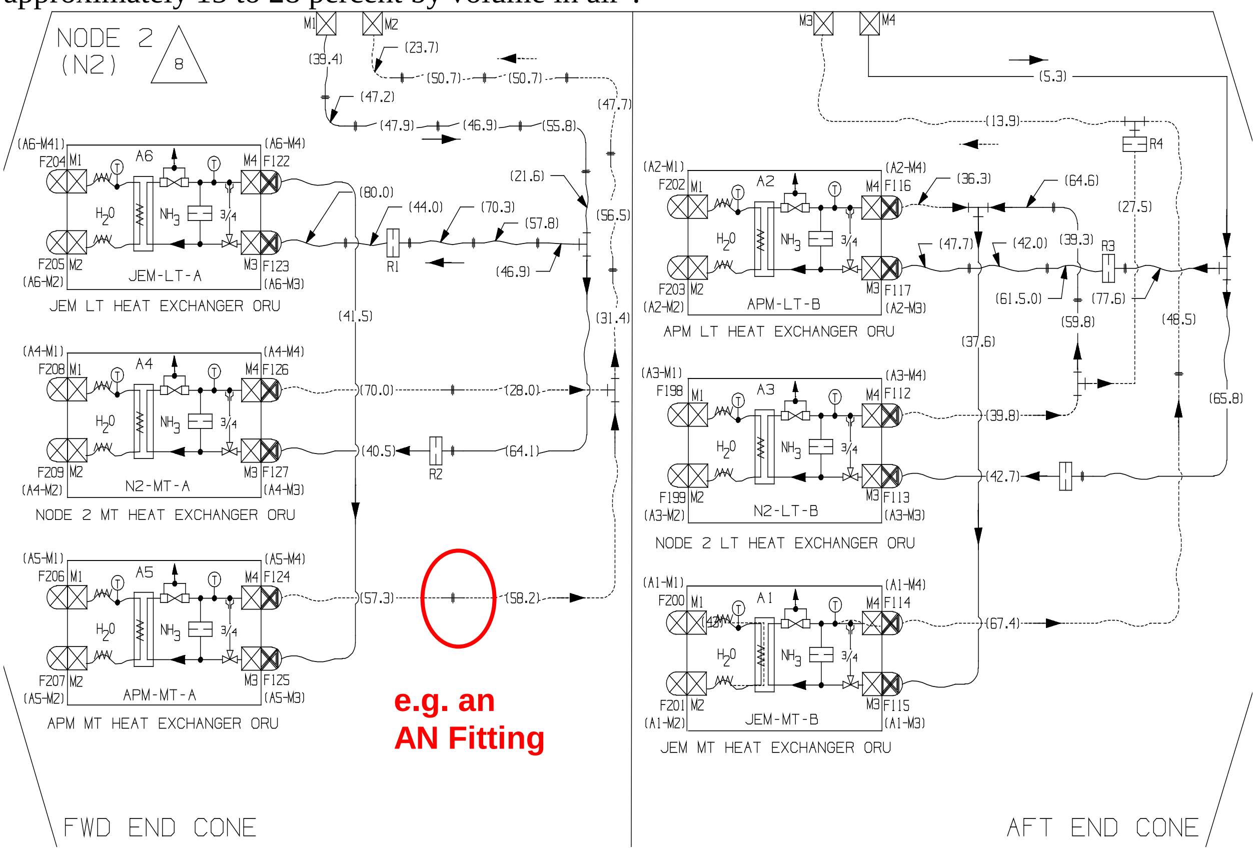


Figure 6.1-1. Node 2 Ammonia System Schematic

[3] http://www.osha.gov/SLTC/ammoniarefrigeration/

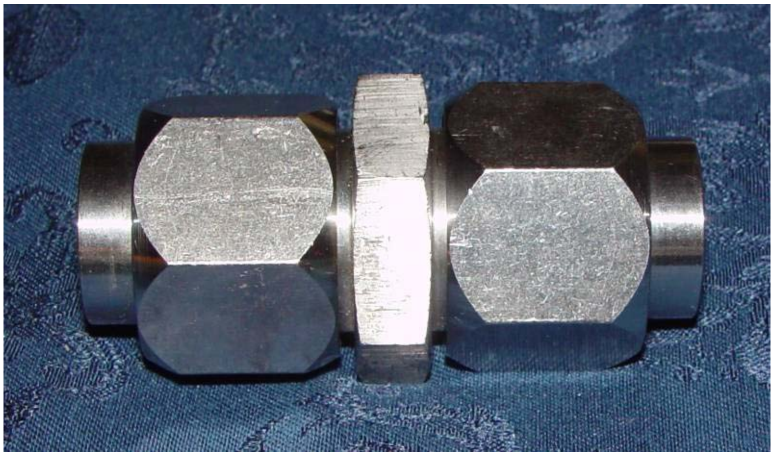


Figure 6.1-2. 1" AN Fitting Coupled with Two Nuts

Figure 6.1-3. 1" AN Fitting showing the SS Conical Seals

6.2 Problem Solutions

The ISS Program maintained that leak checks performed after assembly of the fittings were adequate to ensure flight integrity. No additional testing of the joints was planned. There were dissenting opinions within the ISS Program as to the integrity of the system and the adequacy of the leak checks and qualification testing. After some discussions with the ISS Program, the NESC offered to conduct the analysis necessary to resolve the issues with the AN Fittings.

6.3 Risk Assessment

The original risk assessment was presented to the NRB on May 20, 2004, and stated:

> *"The initial risk assessment: 1/3; Low probability of leak occurring, risk associated with individual segment leak is moderate (not safety of flight)".*

A subsequent risk assessment was completed by Tim Wilson, NESC KSC Chief Engineer, April 28, 2005. Refer to Figure 6.3-1 for the 5 x 5 risk matrix.

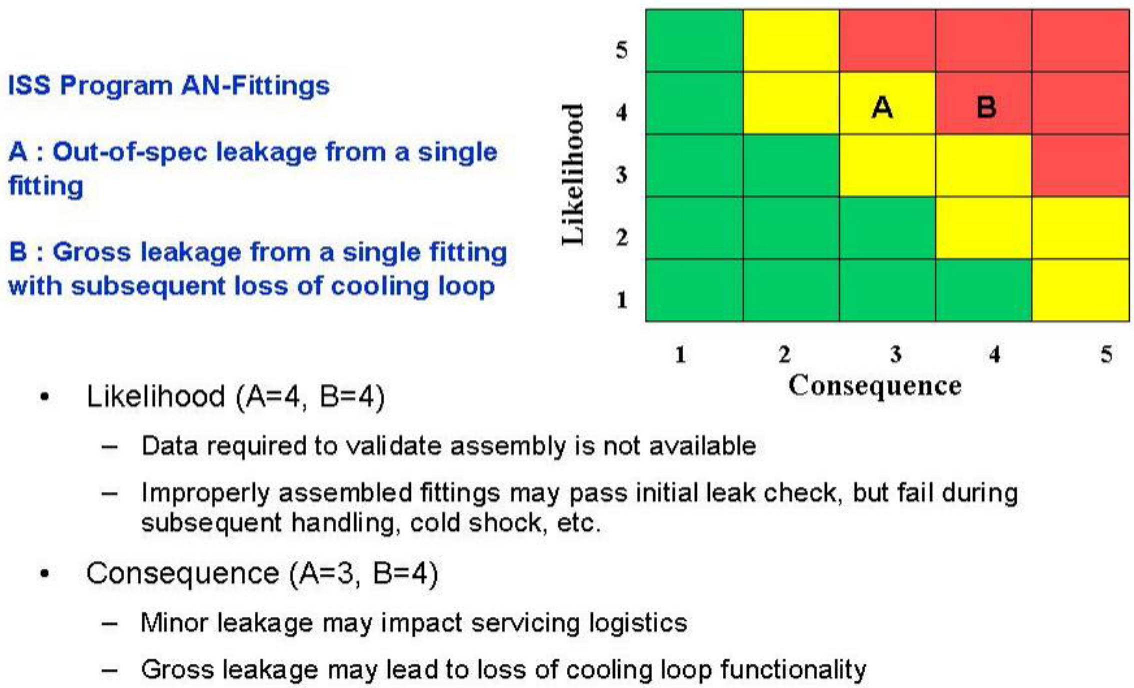


Figure 6.3-1. 5 x 5 Risk Assessment Conducted in April 2005

In this risk assessment, the lack of data led to the determination that likelihood of an unacceptable event may be relatively high. Refer to Appendix H for an overview of this assessment.

7.0 Investigation, Testing, and Data Analysis

7.1 The Investigation

The NESC Assessment Team held a Technical Interchange Meeting (TIM) at KSC on May 10, 2005, where they met with ISS Program personnel and reviewed the available documentation that accompanied Node 2 from Alenia. During this initial review, it was evident that problems existed with the assembly and test documentation. The most important issues noted were:

1. Flight qualification of the 1” AN fittings with SS seals (see Figures 6.1-2 and 6.1-3) was based on similarity to the successful qualification of an O_2 3/8-inch nickel seal AN fitting.
2. Records of a completed system level leak test could not be found in the documentation.
3. There were inconsistencies in the assembly documentation. For example, the leak checks that were conducted on individual fittings were almost always shown to have occurred before the fitting had even been assembled.

Additionally, a review of a previous NESC assessment (NESC CALIPSO report number RP-04-01/03-001-E) highlighted the potential leakage problem related to torque relaxation.

The Assessment Team decided on the following multi-pronged approach to review the suitability of the AN fittings for flight:

1. Assess Alenia’s 1” AN Fitting Flight Qualification.
2. Review the requirements for Ammonia System Level Testing.
3. Assess Alenia’s Ammonia Loops Assembly and Testing.
4. Review AN Fitting Torque Relaxation.

Each of these areas is discussed in more depth below.

1. 1” AN Fitting Flight Qualification

A review of Alenia’s flight qualification records for the 1” AN fittings was performed as well as the ISS Program’s standards for qualifying hardware.

Alenia's Qualification by Similarity (O_2-to-Ammonia)

The qualification and acceptance of the 1" flex lines, as presented by NASA[4], was per RQL-22-20-001 Oxygen Lines Junction Assembly Qualification Report, dated February 2, 2002. This qualification by similarity test was conducted using five assemblies of the 3/8" O_2 system hardline with unsupported spacing of 14.96". The seals used in the assembly were Voi-Shan nickel conical seals. The torque applied ranged between 38 Nm and 42 Nm. The three-axis vibration test was performed with the lines *unpressurized* at three times the maximum expected flight exposure for 180 seconds. The results showed one assembly increased leakage. However, non-conformance report (NCR) troubleshooting and disposition indicated the end cap was found to be leaking, not the joint under test. Leak rates of the remaining four assemblies all decreased after vibration and life testing.

As has been discussed, the 1" AN fittings were qualified by similarity. However, many parameters between the two AN fittings were not similar. Examples include:

- Non-pressurized versus pressurized.
- Size: 3/8" versus 1".
- Conical seal material: Nickel versus SS.
- Unsupported spacing: 14.96" for 3/8" O_2 fittings versus 23" maximum for Node 2 1" AN fittings.
- Torque utilized: 38 Nm - 42 Nm for 3/8" versus 185 Nm for 1".
- 3/8" hardline versus 1" flex hose.

Though not part of the qualification by similarity, Alenia requested that the Node 2 ammonia system flex hose provider, Idrosapiens, perform a characterization leak test using SS conical seals. This testing was not a full qualification of the 1" lines with the SS seals.

Idrosapiens performed qualification of the flex hose per the TR18-02 Node 2 ammonia Flexible Hoses Qualification Test Report. Three 1" flex lines were qualified by test for leakage, proof pressure, life (bending, pressure pulse), dynamic environment and burst. Section 3.3 of the Qualification Test Report documents a note stating that a short leakage characterization campaign was requested by the customer to characterize the flex hose leakage using SS seals instead of nickel. The torque value that was used for the leak test was 200 Nm. One line was torqued to greater than 200 Nm and had the smallest leak rate. Leak rates for the three initial tests at 200 Nm and pressurized to approximately 590 psia with He were 3 x 10^{-3} sccs, 7.2 x 10^{-4} sccs and 1.2 x 10^{-4} sccs. At greater than 200 Nm, the leak rate was 7.2 x 10^{-5} sccs at 590 psia

[4] Steve Clanton, MSFC, August 2004

with He. It is unknown if the lines were pressurized and subjected to random vibration prior to the leak characterization test.

White Sands Test Facility (WSTF) and NASA Glenn Research Center (GRC) personnel, with experience in the design and qualification of similar hardware, were contacted about the viability of Alenia's 'qualification by similarity' with the 3/8-inch fittings. Those individuals contacted stated that the qualification for this application was satisfactory but questioned the viability of qualification by similarity for vibration. The Assessment Team concurred that the vibration section of the qualification testing should be performed with simulated flight configurations using 1" AN fittings. This testing was later folded into the Mimic Test as described in Section 7.2.2.

2. System Level Testing

The total maximum ammonia system leakage rate for Node 2 specified by the ISS Program was 2.5 x 10^{-2} sccs of He at 500 psia per loop. A review of the Alenia documentation failed to produce any record of a system level leak test beyond a proof pressure test following the completion of the Node 2 ammonia system assembly. Alenia calculated the system level leak rate by summing the leak rates of all the individual components including all of the AN fittings. Alenia used a single seal leak rate of 3.6 x 10^{-4} sccs He to screen their joints in Loop A and 5.5 x 10^{-4} sccs He to screen their joints in Loop B, so these were the values used in the calculations. Differences in joint leakage rates between the loops are attributed to the number of AN fitting seals and components within the loops. (Note that this resulted in using 3.6 x 10^{-4} sccs of He as the joint leak rate specification for NESC testing, which was based on Alenia's most conservative joint leakage value).

The Assessment Team investigated what type of testing was best suited to prove the system's current integrity beyond individual joint leak checks. An overall system pressure decay check was decided upon for each of the ammonia loops. The performance of this type of test over an appropriate amount of time, using instrumentation that can detect small pressure changes, is an efficient way of providing the necessary confidence that system leakage (not individual joint leakage), is within specification. The system level leak rate specification that was provided by the ISS Program was used as the Pass/Fail criteria, after converting to a pressure of 385 psia (maximum relief valve setting) and with N_2, was 1.5 x 10^{-2} sccs N_2 per loop (refer to Section 7.2.1, Pressure Decay Test Results and Appendix F).

3. Assessing Alenia's Ammonia Loop Assembly and Testing

A thorough investigation was conducted to try to reconstruct what happened with the initial assembling and testing of the Node 2 ammonia system.

- Any and all available documentation was requested and a detailed review was conducted.

- Interviews were conducted with available personnel who helped with the assembly and testing and those who had observed the nodes assembled at Alenia. Personnel interviewed included:
  - Former Alenia employees who were involved with the assembly and leak checks on Node 2's ammonia system.
  - Defense Contract Management Agency (DCMA) personnel who observed the Node 2 assembly and testing.
  - ISS Program personnel who observed portions of the Node 2 assembly and testing.
- Questions relating to assembly and testing were presented to Alenia via the ISS Program.

The process of collecting and interpreting the pertinent data from the Node 2's manufacturer, in order to perform the required technical analysis, was challenging. When international partners are involved, technical interpretation challenges are magnified due to differences in language, manufacturing methods, and processing approaches. During the earlier reviews, the Assessment Team determined that help was needed to interpret Alenia's documentation (i.e., documentation tree organization; and understanding inconsistencies with dates recorded for system assembly and test, technical terms, and drawings). Interviews were conducted with the former Alenia employees to clarify the overall assembly and test process.

Initial data was provided by Dean Kunz (NASA, KSC) who went through numerous data files to locate, assemble and analyze pertinent assembly and test documentation. The documentation was then disseminated to the Assessment Team at the KSC TIM and an extensive review was performed. This review included:

- The 1" AN fitting assembly and torquing operation, post assembly pressurized proof tests and individual joint mass spectrometer leak checks.
- Non-conformances to understand problems that were encountered and documented.

To obtain official answers to the Team's questions relating to assembly dates and leak checks, including processes, two lists were submitted to the ISS Program Office, and subsequently forwarded to Alenia for review. Alenia's response to the first list helped the Team's understanding. A follow-on list of two key questions was also sent, the results of which are still pending. Additional technical help in locating drawings and documents was provided by Oleg Lvovsky of Applied Research and Engineering Sciences Corporation (ARES).

Alenia adopted the philosophy that technicians are highly trained and, therefore, assembly procedures do not require specific written work steps. For instance, the application of lubricant which prevents the galling of SS is not called out as a specific work step, but referenced in a separate document via the assembly drawing. In the Space Shuttle Program (SSP), for comparison, this lubricant installation would have its own installation step for the technician with a Quality Control individual's stamp as evidence of performance.

The Assessment Team investigated the level of torque used on the fittings. Alenia used SS seals from Voi-Shan which required a higher torque value (125 to 146 ft-lbf) than that specified from Stratoflex (95 to 114 ft-lbf), the AN fitting manufacturer. NESC discussions with Stratoflex indicate that the higher torque is acceptable as long as the AN fitting threads have not yielded. Alenia documentation indicates that 1" AN fittings were torqued to 136 ft-lbf, which is 19 percent higher than the Stratoflex specification limit. Thread analysis was performed (refer to Appendix I, AN Fittings Threaded Fastener Calculations) which concluded that the 136 ft-lbf torque level is below the yield point of the threads. The analysis also concluded that if the fittings were subjected to multiple loadings, the threads would not suffer fatigue damage. Post-test inspection of fittings used in the Team's testing revealed that the AN fitting threads were not damaged during repetitive loadings.

Finally, the Assessment Team could not, with certainty, determine what the surface finish was on the flex hose side of the joint. Alenia specification documentation called for a 100 µ-inches finish while the ISS Program's senior contacts at Alenia stated it was 16 µ-inches. The Assessment Team ended up using both conditions in its testing.(see Section 7.2).

Node 2 Assembly

The Assessment Team was able to determine that the ammonia system assembly was performed as follows:

- Bench assembly and torque of flex hose branches.
- Gross leak check on the bench of AN Fittings performed with He mass spectrometer.
- Install branches to the Node and torque.
- Proof pressurization check.
- Individual He mass spectrometer leak checks conducted by encapsulating each joint with a bag.
- Dew point check performed.
- System prepared for transport.

The Assessment Team came to the above sequence of events using the available documentation as a basis for conducting interviews of the participants. Further discussion of the above chronologically listed process is provided below.

Based on discussions with former Alenia employees, as well as DCMA representatives, it became evident that the Node 2 ammonia system was initially assembled in branches on the bench. Each branch consisted of several flex hoses which were connected together via the AN fittings. These fittings were then torqued to the specified flight value and hooked up to a helium (He) pressure source so that gross leak checks (confidence check using a He mass spectrometer probe) could be performed prior to branch installation onto the Node. Previous assembly issues at Alenia were concerned with obtaining within-specification joint leakage for 1” AN fittings. These issues originally surfaced when the ISS Program-approved nickel seals used in the system were replaced due to an incompatibility/corrosion concern. Subsequent leakage was attributed to the flares on the vendor-supplied flex hoses and to misalignment of the fittings with the seals during the critical assembly process.

When Alenia disassembled some fittings that had failed the gross leak checks on the bench, several galled fittings were noted. Some fittings were damaged beyond re-use and some of those could not be disassembled. These problems were reportedly due to several factors including the seal becoming misaligned or slipping off the fitting end (therefore, rotating into the threads during the assembly and torquing process) and the lack of proper lubrication. After some investigating, Alenia realized the criticality of properly assembling the joint with the seal aligned to avoid galling. This led to an increase in training for their engineers and technicians involved with the assembly process. Alenia improved the assembly techniques and continued to perform the gross leak check on the bench. This ensured confidence prior to installation and subsequent individual joint leak checks in a flight configuration on the Node.

Once flex hose branches were installed on the Node (aft and forward end cones and along the cylinder), the ends of the multiple branches were connected and torqued to complete the ammonia system assembly.

With the ammonia system completely assembled, a proof pressure test was conducted with N_2 to verify system integrity. The proof pressure check was performed at 740 psia with N_2 and held for a minimum of 5 minutes. Individual encapsulated joint mass spectrometer leak checks were then performed at a system pressure at approximately 500 psia He. A dew point check was performed after venting and re-pressurizing to approximately 500 psia with N_2. Finally, the system was vented and pressurized to 20 psia with N_2 in preparation for transportation to the USA.

Examples of Assembly Documentation Discrepancies

A number of discrepancies were noted in the Assessment Team’s detailed review of Alenia’s documentation. Examples include:

- Documents from Alenia indicated that all flex hoses were assembled and installed on the Node first, then torqued to the flight value.
- Documented leak check dates were prior to system assembly torquing dates.
- Torque specification (MSFC-STD-486D) in the assembly drawings actually applies to fasteners and not AN fittings.
- N_2 gas was called out in several places to perform He mass spectrometer leak checks (later confirmed by Alenia as typos).
- The documentation did not show a section of flex hoses and associated fittings as having been pressurized during leak checks.

AN Fitting Torque Relaxation

The NESC CALIPSO report (NESC report number RP-04-01/03-001-E) provided insight into AN fitting leakage characteristics. A review of this assessment noted that torqued fittings relaxed over time. The Team decided to investigate this issue and how it would relate to the AN fittings on Node 2. The report led AN fitting team members to contact several individuals who either performed or were involved with the CALIPSO report. It became apparent that torque relaxation was one of the major concerns potentially leading to an external leak, especially for larger diameter lines such as the 1” ammonia lines on Node 2. The CALIPSO report makes reference to a review of 0.25” Voi-Shan conical seals where, during pressure cycle testing, the largest change (decrease) in torque observed was 27 percent after the first pressure cycle, 13 percent on the second and none after the third. No torque loss was noticed after exposure to vibration. To combat the issue of torque relaxation, the CALIPSO program used multi-torquing on their fluid lines.

It is not definitively known whether Alenia used multi-torquing in the assembly of the 1” AN fittings on Node 2. This multi-torquing is not called out in the Alenia work procedure where the assembly of fittings takes place, but it is in an Alenia subdocument (SG-PR-AI-0281, “Piping Assembling Procedure for the Rigid Lines by Threaded Parts”). It specifies verification of the final torque one minute and at least one hour after the initial torque application. The fact that 1” AN fittings assembled at GRC needed to be re-torqued to consistently pass leak checks, leads to the belief that Alenia personnel had to do the same in order to pass their gross bench level and individual joint encapsulated leak checks.

7.2 Testing and Results

The Assessment Team decided on conducting or recommending the following tests:

1. **Pressure Decay Test.** Since the ISS Program was scheduled to conduct a N_2 moisture purge of the Node 2 ammonia system, the Team recommended that a pressure decay test be performed in conjunction with the purge to verify system integrity. This recommendation was approved (refer to CHIT in Appendix F) and accomplished with satisfactory results. Refer to Section 7.2.1 and Appendix J.
2. **Mimic Test.** A set of Mimic Tests was conducted that took an NESC assembled fitting through all the pressurizations, depressurizations, transportation vibrations, and launch qualification vibrations that Node 2's ammonia system had experienced and would experience from assembly to operation in orbit. The hardware used during these tests was flight hardware (AN Fittings, SS Conical Seals, and flex hoses). These tests used multi-torquing of the fittings and were conducted in two different series: Series A –surface finish of the female (flex hose) side of the fitting at 16 µ-inches, and Series B – surface finish of the female (flex hose) side of the fitting at 100 µ-inches. The surface finish for the male AN Fittings was 16 µ-inches for both series of tests. Refer to Section 7.2.2 and Appendix J.
3. **Surface Finish Test.** Because the Team received conflicting evidence concerning the surface finish of the mating surface on the flex hose side of the fitting (100 µ-inches versus 16 µ-inches), a leak test that used a surface finish of 100 µ-inches was planned. This test would attempt to obtain a within-specification leak rate using the AN fitting with a surface finish of 16 µ-inches and a flex hose mating surface finish of 100 µ-inches. Refer to Section 7.2.3 and Appendix J.
4. **Single Application of Torque Test.** Because Alenia's AN fitting assembly procedures did not address multi-torquing, an operation that the Team felt was critical to ensure system integrity, a test was conducted to see whether a single application of torque would be sufficient to affect a proper seal. See Section 7.2.4.

Chronological Information on the Team's Testing:

The Assessment Team initially received information (via the ISS Program from Alenia) that the surface finish of the mating surface on the flex hose side of the fitting was 16 µ-inches. That information was used in the development of the first Mimic Test (which later became the Mimic Test, Series A). After the completion of this initial Mimic Test, the Team came to understand that the surface finish of the mating surface on the flex hose side could also be 100 µ-inches. The Team, therefore, decided to do the above mentioned 'Surface Finish Test' to determine if this configuration could be made to attain a within-specification leak rate. When this test achieved a high degree of success, a second Mimic Test (Series B) using a surface finish of the mating surface on the flex hose side of 100 µ-inches was conducted.

7.2.1 Pressure Decay Test Results

The Node 2 pressure decay checks were performed at KSC from June 7-13, 2005 with satisfactory results. The Node 2 ammonia flight system relief valves were online during the test requiring the maximum allowable pressure for the decay test to be no more than 385 psia. Due to the volumes being pressurized and leak checked, and to obtain a high confidence value on the leak check with the instrumentation accuracy, the test ran for several days. Minimal temperature change was recorded during the test, which had a negligible effect on the decay rate.

Table 7.2-1. Results of the ISS Program conducted Pressure Decay Test on Node 2's Ammonia System

Node 2 Ammonia System	Specification	Test Results
Loop A	1.5×10^{-2} sccs N_2, 385 psia	1.1×10^{-2} sccs N_2, 385 psia
Loop B	1.5×10^{-2} sccs N_2, 385 psia	6.8×10^{-3} sccs N_2, 385 psia

Calculations and Resultant data are provided in Appendix E.

7.2.2 Mimic Test Development and Results

The ISS Program requested that the NESC provide confidence that the on-orbit deployment of the Node 2 ammonia system AN fittings would not leak. This philosophy guided the NESC Assessment Team toward the independent development of the "Mimic Test". The idea behind the Mimic Test was to subject an AN fitting, connected in a flight configuration to two flex hoses, to all the pressurizations and vibrations that the real system will experience from assembly through flight.

Mimic Test

During Mimic Test development, the Assessment Team considered performing multiple tests on fittings with different configurations of torque, pressure, and vibration to adequately cover all parameters which typically effect mechanical joint leakage. The Assessment Team concluded, after discussions with the ISS Program, that the temperature variation in the ammonia system is not a factor in AN fitting integrity. This test series was designed to build confidence in an on-orbit ammonia system that maintained leakage within specification.

The Mimic Test is a combined pressure cycle/leak/vibration test which captured the history of the 1" AN flight fittings by simulating the pressure cycles and vibration environments expected of the flight system. Table 7.2-2 shows the system pressure and vibration data (during transportation and launch) gathered as a function of time and assembled into the test plan outline.

Table 7.2-2. Mimic Test Flow

Item	Test Article Description	Node 2's AN Fittings Events
1.	The test article hardware is assembled with the fittings torqued to 185 Nm (136 ft-lbf).	Fittings torqued after assembly.
2.	The test article is pressurized to 500 psia He for a minimum of 5 minutes and a "Baggie-Type" He leak test is conducted on each individual seal @ 500 psia. To continue, both fitting seals must be less than the maximum allowable leak rate.	Branch fittings pressurized to 500 psia He prior to performing bench level gross leak check using the Probe technique. Provided Alenia confidence on fitting leakage post fitting assembly and torque, prior to installation of flex hose branches onto Node and official baggie leak check.
3.	The test article is vented and then pressurized to 750 psia He for 5 minutes.	System pressurized to proof pressure of approximately 750 psia N_2.
4.	The test article is vented and then pressurized to 500 psia He for 5 minutes.	System pressurized to approximately 500 psia He prior to individual baggie leak tests.
5.	The test article is vented and then pressurized to 500 psia He for a minimum of 5 minutes and then a "Probe-Type" He leak test will be conducted on each individual seal @ 500 psia.	System pressurized to 500 psia He in support of Dew Point Check.
6.	The test article is vented, pressurized to 20 psia He, and then exposed to Transportation Random Vibration levels.	System pressurized to 20 psia N_2 prior to being exposed to vibration levels during transport to the United Sates.
7.	The test article is pressurized to 380 psia He for a minimum of 5 minutes and a "Probe-Type" He leak test conducted on each individual seal @ 380 psia.	System pressurized to approximately 380 psia N_2 in support of KSC Pressure Decay Test.
8.	The test article is vented, pressurized to 150 psia He, and then exposed to Qualification Launch Random Vibration levels. Exceeds launch vibration levels.	System pressurized to 150 psia ammonia prior to being exposed to vibration levels during launch.
9.	The test article is pressurized to 380 psia He for a minimum of 5 minutes and a "Baggie-Type" He leak test is conducted on each individual seal @ 380 psia.	System pressurized to 380 psia ammonia once on orbit.
10.	The test article is pressurized to 500 psia He for a minimum of 5 minutes and a "Baggie-Type" He leak test is conducted on each individual seal @ 500 psia.	N/A Node 2. Leak test to compare to Step 2.
11.	The test article is vented and then the torque of the 1" AN fitting is measured using a torque wrench.	N/A Node 2. Torque check.

Transportation vibration levels were derived from the actual aircraft that delivered Node 2 to KSC. The duration of the transportation vibration test was based on flight distance. The actual launch vibrations were replaced with the qualification vibration levels, which were higher. This was done, as previously mentioned, to fold the 1" qualification requirements into this Mimic Test. Additional details, such as the multiple pressurizations encountered during assembly and test, were also addressed by the Mimic Test. Temperature was not considered a test parameter due to the relatively constant temperature observed by the system during the timeframe from assembly through orbital operations.

Leak Test Philosophy

A leak check specialist familiar with the encapsulated joint or "baggie" leak check technique, joined the Team at GRC to conduct the tests. Leeann Clayton, MSFC (Boeing), had worked with Alenia personnel in the area of leak checks during the Node 2 assembly. She was able to assist the Assessment Team in performing the mass spectrometer leak checks as they were performed in Italy.

The Team's "Baggie-Type" He leak tests were conducted per NASA specification SSP 41172 Rev. U, 4.2.11.2H Test Description and Alternatives, Method VIII – Accumulation. Baggie leak check guidance, new to Rev. U, was not in SSP 41172 when Alenia performed their tests. Leeann Clayton, therefore, was needed to teach Alenia personnel this methodology that would later be included in specification SSP 41172 as Method VIII. The maximum acceptable leak rate allowed was 3.6 x 10^{-4} sccs He at 500 psia per seal, as determined by values used by Alenia for single seals. This 5-minute period was the time Alenia used during their "Baggie-Type" leak checks.

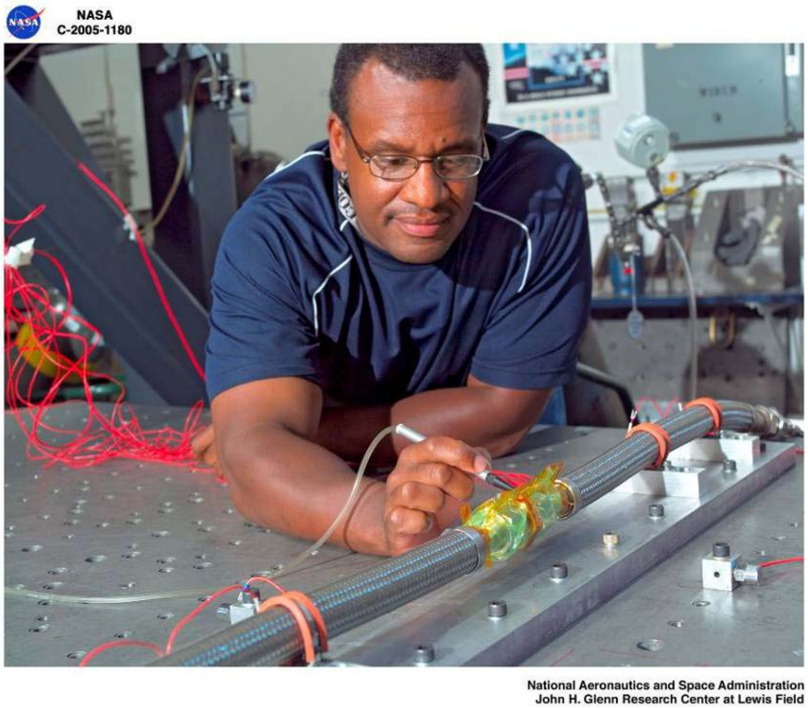


Figure 7.2-1. "Baggie Type" He Leak Test
(Brian Hurd, GRC Technician)

"Probe-Type" He leak tests were conducted per NASA specification SSP 41172 Rev U, 4.2.11.2E Test Description and Alternatives, Method V – Detector Probe. The maximum acceptable leak rate was also 3.6 x 10^{-4} sccs He at 500 psia per seal. The time required for the system to be at pressure was 5 minutes in accordance with Requirements Interpretation Agreement (RIA-NASA-00851, 11-14-02). This 5-minute period was the agreed upon minimum wait time Alenia used during their "Probe-Type" leak checks.

The 1" AN Fitting on ISS Mimic Test Plan (provided in Appendix B) was developed into the NESC 1" AN Fitting Mimic Test Procedure (provided in Appendix C) and performed at the NASA GRC Structural Dynamics Laboratory. These tests used multi-torquing of the fittings and were conducted in two different series: Series A – surface finish of the flex hose side of the fitting at 16 µ-inches, and Series B – surface finish of the flex hose side of the fitting at 100 µ-inches. The surface finish for the male AN Fittings was 16 µ-inches for both test series. The Mimic Test Summary is provided in Tables 7.2-3 and 7.2-4 while a graphical representation of crucial data is shown in Figure 7.2-2.

Table 7.2-3. Mimic Test Summary – Series A

Male and female surface finishes at 16 μ-inches
Acceptable leak rate 3.6 x 10^{-4} sccs He at Target Pressure

SERIES A			Test 1		Test 2		Test 3	
NODE 2 MIMIC EVENT	**Data Point**	**Target Pressure (psia)**	**Joint 1 LR (sccs)**	**Joint 2 LR (sccs)**	**Joint 1 LR (sccs)**	**Joint 2 LR (sccs)**	**Joint 1 LR (sccs)**	**Joint 2 LR (sccs)**
Initial leak check after assembly.	A	500	9.2 x 10^{-5}	6.9 x 10^{-6}	< 1 x 10^{-6}	<1 x 10^{-6}	1.6 x 10^{-4}	1.1 x 10^{-4}
Post dew point leak check.	B	500	2.1 x 10^{-4}	Pass (probe)	5.2 x 10^{-6}	<1 x 10^{-6}	1.8 x 10^{-4}	1.4 x 10^{-4}
Gross leak check after transportation from Alenia and completion of system decay test at KSC (probe technique, pass/fail).	C	380	Pass	Pass	Pass	Pass	Pass	Pass
Post launch vibration and on orbit system activation leak check.	D	380	<1 x 10^{-6}	<1 x 10^{-6}	<1 x 10^{-6}	<1 x 10^{-6}	1.6 x 10^{-4}	1.3 x 10^{-4}
Not Applicable to Node 2. Pressurization to 500 psia for NESC data point.	E	500	<1 x 10^{-6}	2.9 x 10^{-6}	<1 x 10^{-6}	<1 x 10^{-6}	2.9 x 10^{-4}	1.2 x 10^{-4}

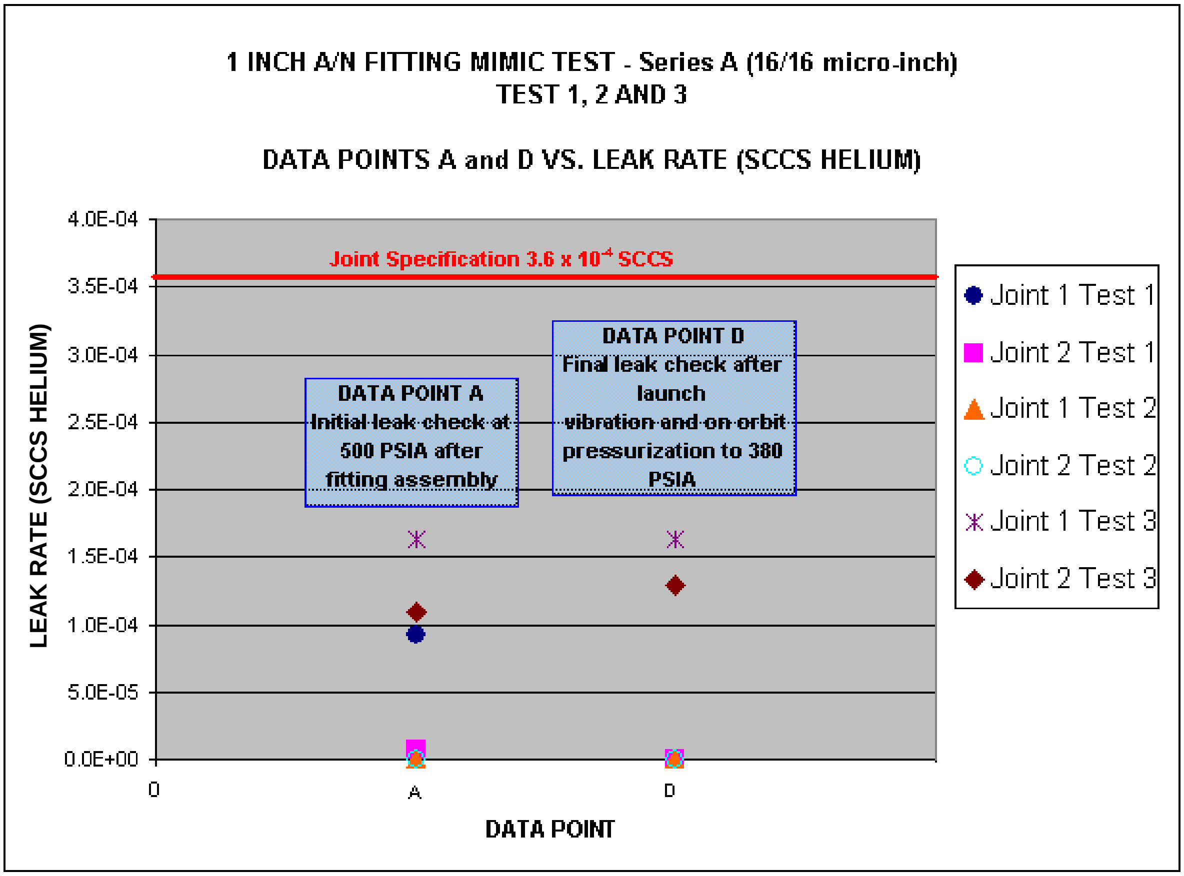


Figure 7.2-2. Mimic Test Results-Series A

Table 7.2-4. Mimic Test Summary – Series B

Male surface finishes at 16 µ-inches, female at 100 µ-inches
Acceptable leak rate 3.6 x 10^{-4} sccs He at Target Pressure

SERIES B			Test 4	
NODE 2 MIMIC EVENT	**Data Point**	**Target Pressure (psia)**	**Joint 1 LR* (sccs)**	**Joint 2 LR* (sccs)**
Initial leak check after assembly.	A	500	<$1x10^{-6}$	<$1x10^{-6}$
Post dew point leak check.	B	500	<$1x10^{-6}$	<$1x10^{-6}$
Gross leak check after transportation from Alenia and completion of system decay test at KSC (probe technique, pass/fail).	C	380	Pass	Pass
Post launch vibration and on orbit system activation leak check.	D	380	<$1x10^{-6}$	<$1x10^{-6}$
Not Applicable to Node 2. Pressurization to 500 psia for NESC data point.	E	500	<$1x10^{-6}$	<$1x10^{-6}$

*LR = Leak Rate

7.2.3 Surface Finish Tests

The purpose of this test was to observe whether a 16 to 100 µ-inch (AN Fitting to flex hose) sealing surface could be shown to pass the allowable leak rate specification. This test used a 16 µ-inch AN fitting and a 100 µ-inch cap to represent the flex hose (refer to Appendix G for the Surface Finish Test Procedure). A total of seven test articles were run to determine surface finish effects on AN fitting sealing capability. These assemblies were all multi-torqued to 136 ft-lbf (185 Nm) using the same techniques used during the Mimic Tests prior to pressurization and leak check. "Baggie" method leak checks were performed at a He pressure of 500 psia with a maximum leakage of 3.6 x 10^{-4} sccs to be considered passing. No vibration tests were performed. Post disassembly inspection of the two assemblies that failed, revealed dull or apparent seal rotation issues which may have caused them to fail. Refer to Table 7.2-5.

Table 7.2-5. Surface Finish Leak Tests

Results	Article 1	Article 2	Article 3	Article 4	Article 5	Article 6	Article7
Measured Leakage (sccs He at 500 psia)	3.6 x 10^{-2}	5.9 x 10^{-5}	9.7 x 10^{-5}	3.6 x 10^{-5}	1.3 x 10^{-4}	2 x 10^{-3}	1.9 x 10^{-5}
Pass/Fail	Fail	Pass	Pass	Pass	Pass	Fail	Pass

7.2.4 Single Application of Torque Tests

Because the Alenia assembly procedure and drawings do not address multi-torquing, tests were run to determine whether a single application of torque would provide a passing leak rate. A total of four AN fitting joints were checked to at a specified value of 136 ft-lbf (185 Nm). Joints were assembled using the same techniques used during the Mimic Tests except for the single torque application. "Baggie" method leak checks were performed at a He pressure of 500 psia with a maximum leakage of 3.6 x 10^{-4} sccs to be considered passing. Two post leak check torque checks were also performed to determine what torque relaxation had occurred. No vibration tests were performed. Refer to Table 7.2-6.

Table 7.2-6. Single Application of Torque Tests

Results	Test 1	Test 2	Test 3	Test 3
Fitting	Joint 2	Joint 2	Joint 1	Joint 2
Measured Leakage (sccs He at 500 psia)	Too High to Measure	1.4 x 10^{-3} Probe Method	1.5 x 10^{-4}	5.7 x 10^{-4}
Pass/Fail	Fail	Fail	Pass	Fail
Initial Torque	136 ft-lbf	136 ft-lbf	136 ft-lbf	136 ft-lbf
Post Test Torque Check	115 ft-lbf	125 ft-lbf	N/A	N/A

7.3 Data Analysis

Pressure Decay Test

The results of the pressure decay test in both Loops A and B were within the specification of allowable leakage. It should be noted that the ISS Program's pressure decay test encompassed components other than the AN Fittings that are the subject of this assessment, such as the many QDs and heat exchangers. The pressure decay test was an overall system integrity confidence test and its successful completion indicates that Node 2's ammonia system's integrity is satisfactory.

Mimic Test

Eight joints (6 from Series A, 2 from Series B) were fully tested during the four different runs of the Mimic Test (Tests 1 through 4). All of the fully tested joints passed the required leak rate of 3.6×10^{-4} sccs He at 500 psia. Most joints' leakage decreased significantly or stayed the same from initial post assembly leak check to on-orbit operations leak check. One joint's leak rate increased slightly during this period, but was well below specification.

The Mimic Tests have shown that a properly assembled 1" AN fitting that passes its initial leak check can be expected to survive the launch and ISS flight environment with no degradation of performance.

Surface Finish Test

Five of seven tested assemblies passed the leak check specification of 3.6×10^{-4} sccs He at 500 psia. The first assembly checked failed, which seemed to add credence to the decision to use 16 µ-inches finish for all the mimic testing. However, when 5 of 6 of the subsequent tests passed the initial leak check, it was discovered that surface finish on the flex hose side could be 100 µ-inches instead of 16 µ-inches finish. The Team, therefore, decided to run an additional Mimic Test using the 100 µ-inches surface finish. Refer to Figures 7.3-1 and 7.3-2.

While a smoother flex hose sealing surface finish (16 -inches) decreases the potential for leakage, based on these tests, a surface finish of 16 or 100 µ-inches can obtain an initial leakage rate within specifications. With this tight seal atained, the Mimic Tests have shown that either surface finish can provide a satisfactory seal.

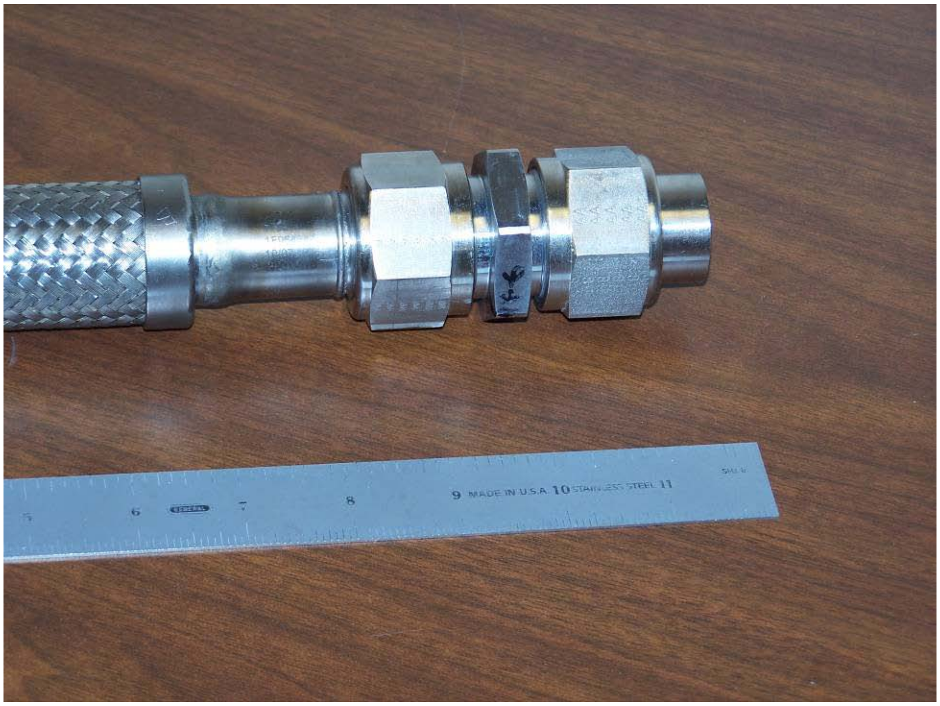


Figure 7.3-1. Surface Finish Test Assembly

Figure 7.3-2. Surface Finish Test Assembly - Exploded View

Single Application of Torque Test

Three of the four single-torqued AN fitting joints tested failed leak checks. Two of the three failed joints were checked for torque relaxation. The maximum relaxation that occurred was 21 ft-lbf (136 ft-lbf to 115 ft-lbf).

Subsequent multi-torquing of a failed single torqued joint resulted in a leak rate below specification.

Since multiple torque applications provided consistent results, this technique was used for the Mimic Tests. While Alenia's documentation does not definitively indicate whether this technique was used, it is unlikely satisfactory leak rates could have been obtained any other way.

Overall Data Analysis Summary

Analysis of the testing conducted showed the following:

- Proper assembly techniques are critical to obtaining a below specification joint leak rate.
- AN fittings subjected to a single initial torque application typicallly fail initial leak checks.
- Multiple applications of torque on AN fittings have a higher rate of success.
- Flex hose sealing surface finish of 16 µ-inches and 100 µ-inches can both yield successful results, yet a smoother (16 µ-inch) surface finish decreases the potential for leakage.
- In all but one case, the leak rates decreased or stayed the same after a fitting was exposed to the pressurization and vibration cycles expected of ISS Node 2's ammonia system.
- Once an AN fitting had an acceptable post assembly leak rate, it never leaked above specification despite numerous pressurizations and vibrations.
- Pressure decay test results indicate that the current status of the ISS Node 2 ammonia system is satisfactory.

8.0 Findings, Root Causes, Observations and Recommendations

8.1 Findings

Team findings from this assessment are listed below:

F-1. If properly assembled, NESC tests show that the leak rates of AN fittings will remain within specification when subjected to the same pressurization and vibration cycles that Node 2's ammonia system will have experienced through on-orbit activation (Mimic Test).

Four Mimic Tests were accomplished with satisfactory results. Once an AN fitting had an acceptable leak rate, it never leaked above specification despite numerous pressurization and vibration cycles. The leak rates decreased or remained essentially the same, which is consistent with the results provided in the NESC CALIPSO report.

F-2. While it is not possible to verify, through review of Alenia's documentation, the proper assembly of Node 2's Ammonia System AN fittings; other information including NESC Team conducted interviews, Alenia leak tests, and the NESC single torque test results all suggest that it is highly likely that the AN fittings were assembled properly.

Proper assembly is critical in ensuring that an AN fitting meets its leakage specifications. While discrepancies were found during the review of Alenia's assembly and test documentation, interviews with key individuals were able to determine the fitting assembly process and procedures for the subsequent leak tests. These interviews, Alenia's satisfactory individual AN fitting leak checks, and the Team's Single Torque tests, led the Team to conclude that it is highly likely that the AN fittings were assembled properly. Proper assembly includes steps such as maintaining cleanliness of the parts, ensuring adequate lubrication, and multi-torquing the fitting.

F-3. Based on NESC AN fitting tests and interviews, and Program system level tests, it is the judgment of the team that AN fittings in the Node 2 ammonia system are acceptable to support flight operations.

The pressure decay test results indicate that the existing Node 2 ammonia system integrity is currently acceptable. Based on the current ammonia system conditions, the results of the mimic testing indicate that AN fitting integrity within the system will remain acceptable through launch and on orbit operations.

8.2 Observations

O-1. Multiple applications of torque (multi-torquing) during the assembly process were required to consistently obtain leakage rates within specification.

During the Team's testing and after the first application of torque to a fitting, it was noted that the torque relaxed almost immediately. Tests were conducted on several fittings to observe if the fitting could pass a leak check with only a single torque application; one out of four passed. To obtain passing leak rates, multiple applications of torque were required during the assembly process.

While it is unknown whether Alenia used multi-torquing in the ammonia system assembly process, Alenia document SG-PR-A1-0281 indicates they were aware of the need to multi-torque.

O-2. Post-Mimic Test torque measurements conducted on joints (all of which were multi-torqued during initial assembly) indicated relaxations of 0.7 -15 percent.

Although torque relaxation occurred, none of the joints' leakage exceeded the joint specification of 3.6×10^{-4} sccs He at 500 psia throughout the Mimic Tests.

O-3. Flex hose sealing surface finish of both 16 µ-inches and 100 µ-inches were both successful in achieving acceptable leakage rates throughout the Mimic Tests.

The Team was unclear as to the exact surface finish of the flex hose side of the AN fitting connection. Alenia provided information that it was 16 µ-inches but also indicated, from other Alenia sources, that it was 100 -inches. While a smoother flex hose sealing surface finish (16 µ-inches) decreases the potential for leakage, testing found that sealing surface finishes of 16 µ-inches and 100 µ-inches are acceptable provided that an initial within specification leak rate can be obtained.

O-4. Alenia torqued the 1" AN fittings to a higher level (19 percent) than recommended by the fitting manufacturer to fully engage the Voi-Shan seal. The fitting manufacturer stipulates, however, that higher torques can be used provided yielding of the fitting's threads does not occur. Analysis and inspection of a fitting with a high number of torque cycles at GRC indicated that no damage or yielding occurred.

8.3 Recommendations

R-1. The ISS Program should conduct a pressure decay test of the Node 2 ammonia system. *The ISS Program accepted this recommendation, and the test was accomplished with results within specification.*

Refer to Section 7.2, Item 1, Pressure Decay Test.

R-2. To prevent similar issues with Node 3, which is currently being fabricated at Alenia, the following is recommended:

- As Alenia's final test on Node 3's ammonia loops, an overall system level leak test (such as the Pressure Decay Test) should be conducted.
- Alenia should properly and accurately address, document, and verify all steps (i.e., quality assurance) related to the manufacture and testing of the ammonia loops.

A system level leak check would screen the overall ammonia system (fittings, flex hoses, heat exchangers, etc.) for leakage, reducing any issues or concerns due to individual component mass spectrometer leak checks.

9.0 Lesson Learned

When AN fittings are used in fluid systems, assembly process control is critical to achieving a minimal or leak free joint.

Analysis of the NESC-conducted AN fitting testing showed that AN fitting joints will provide satisfactory service in flight fluid systems. It is critical that proper assembly techniques are followed in order to obtain a below specification joint leak rate. For example:

a. Initial inspection to verify condition of sealing surfaces.

b. Ensuring the proper cleanliness standards are maintained for all the parts being assembled.

c. Ensuring that the conical seal is properly positioned over the seating surface such that no misalignment occurs during the torquing process.

d. Ensuring that the proper lubrication of component threads is conducted.

Multi-torquing the fitting upon initial use in the system will provide the highest potential for achieving a within specification leak rate.

It is important to note that while AN fittings, properly assembled and tested, provide satisfactory service they may not be suitable for all applications and should be assessed on a case-by-case basis. Welded joints, or fittings incorporating internally-redundant seals, offer higher reliability by design and are better suited for space flight hardware applications. Selection of the specific joint type and assembly technique should be the subject of trade-off studies performed early in the design phase of a project.

Before work commences, training is advisable for techinicians who will be working with AN fittings. Both Alenia and the Team's technicians had leakage and galling problems in the beginning due to factors that may have included component misalignments, dirty surfaces, etc. Proper training and practice sessions are imperative.

When dealing with international partners of components, it is imperative that they properly and accurately address, document, and verify all steps related to the manufacture and testing of flight hardware. Quality assurance controls should be negotiated at the beginning of the agreement to ensure that the delivered flight hardware meets NASA standards. The NESC's Calipso report stated:

> "When NASA is involved in missions with outside partners, the level of NASA insight and influence on non-NASA hardware design, verification and acceptance testing should be documented, clearly communicated, and carried as a project risk to be tracked."

Resolving issues such as these at the beginning of a partnership will help to prevent concerns such as the subject of this assessment from becoming possible schedule driving problems.

10.0 Definition of Terms

Mimic Test	Test runs to independently verify the integrity of the 1" ISS AN fitting with SS seals. The Mimic Test is a combined Leak/Vibration/Pressure Cycle Test.
Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.
EATCS	Thermal control system designed to accept rejected heat via heat exchangers from the water coolant loops.
Finding	A conclusion based on facts established during the assessment/inspection by the investigating authority.
Galling	To fret and wear away by friction due to a loss of lubrication.
Lessons Learned	Knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in that it has real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or limits the potential for failures and mishaps, or reinforces a positive result.
Observation	A factor, event, or circumstance identified during the assessment/inspection that did not contribute to the problem, but if left uncorrected has the potential to cause a mishap, injury, or increase the severity should a mishap occur.
Problem	The subject of the technical assessment/inspection.
Requirement	An action developed by the assessment/inspection team to correct the cause or a deficiency identified during the investigation. The requirements will be used in the preparation of the corrective action plan.
Root Cause	Along a chain of events leading to a mishap or close call, the first causal action or failure to act that could have been controlled systemically either by policy/practice/procedure or individual adherence to policy/practice/procedure.

11.0 Minority Report (Dissenting Opinions)

There were no dissenting opinions during this assessment.

Volume II: Appendices

Appendix A. ITA/I Request Form (NESC-PR-003-FM-01)

NASA Engineering and Safety Center
Request Form

Submit this ITA/I Request, with associated artifacts attached, to: nrbexecsec@nasa.gov, or to NRB Executive Secretary, M/S 105, NASA Langley Research Center, Hampton, VA 23681

Section 1: NESC Review Board (NRB) Executive Secretary Record of Receipt

Received (mm/dd/yyyy h:mm am/pm) 4/16/2004 12:00 AM	Status: New	Reference #: 04-038-E
Initiator Name: Anonymous	E-mail: N/A	Center: N/A
Phone: (0)- - , Ext ____	Mail Stop: N/A	

Short Title: Concern on use of AN-type fittings in ISS Node 2 Ammonia System

Description: The ISS Node 2 has 6 ammonia –water heat exchangers installed on its exterior as part of the external active thermal control system. These exchangers allow waste heat from the Node 2 and its attached modules to be carried to the large heat rejection radiators located on the S1 and P1 trusses. The plumbing required to route all the fluids to these exchangers is quite extensive. The design chosen for the routing made use of more than 50 mechanical fluid fittings of the 'AN' type, with stainless steel 'crush washer' type seals. These same type fittings are used extensively in the ground ammonia servicing system at KSC and have been the root cause of a number of leaks, varying in size from small to large, particularly in the presence of cold shock type conditions.

Given the highly negative experience at KSC with this type fitting in ammonia service, there is some concern amongst a number of engineers to a) service a flight system with this design with ammonia in the SSPF high bay, exposing people (and nearly complete flight hardware) to the possibility of a leak; b) to fly a design with this many leak paths built in with very limited ability to isolate and repair a leak in flight. The consequence of a large in flight leak would be onerous.

The ISS Program has heard these concerns in the past, but given the schedule pressure extant to launch Node 2 by Feb 2004, the decision was made to leave the design as is. One concern about the design was addressed prior to shipment, namely that nickel crush washers were replaced with stainless steel. This may have led to reuse of fittings, which in KSC's experience has led to a higher likelihood of having a leak.

It is recommended that the NESC investigate the rationale for acceptability of such a design and the level of qualification testing performed on it.

Source (e.g. email, phone call, posted on web): Anonymous

Type of Request: Assessment

Proposed Need Date: 6/1/2004

Date forwarded to Systems Engineering Office (SEO): (mm/dd/yyyy h:mm am/pm):

Section 2: Systems Engineering Office Screening

Section 2.1 Potential ITA/I Identification

Received by SEO: (mm/dd/yyyy h:mm am/pm): 4/16/2004 12:00 AM

Potential ITA/I candidate? ☒Yes ☐ No

Assigned Initial Evaluator (IE): Dave Hamlton

Date assigned (mm/dd/yyyy): 4/21/2004

Due date for ITA/I Screening (mm/dd/yyyy): 5/6/2004

Section 2.2 Non-ITA/I Action

Requires additional NESC action (non-ITA/I)? ☐Yes ☐ No

NESC Request Form
NESC-PR-003-FM-01, v1.0 Page 1 of 3

If yes:
Description of action:
Actionee:
Is follow-up required? ☐ Yes ☐ No If yes: Due Date:
Follow-up status/date:
If no:
NESC Director Concurrence (signature):
Request closure date:
Section 3: Initial Evaluation
Received by IE: (mm/dd/yyyy h:mm am/pm):
Screening complete date:
Valid ITA/I candidate? ☐ Yes ☐ No
Initial Evaluation Report #: NESC-PN-
Target NRB Review Date:
Section 4: NRB Review and Disposition of NCE Response Report
ITA/I Approved: ☐ Yes ☐ No | Date Approved: | Priority: - Select -
ITA/I Lead: , Phone ( ) - , x
Section 5: ITA/I Lead Planning, Conduct, and Reporting
Plan Development Start Date:
ITA/I Plan # NESC-PL-
Plan Approval Date:
ITA/I Start Date | Planned: | Actual:
ITA/I Completed Date:
ITA/I Final Report #: NESC-PN-
ITA/I Briefing Package #: NESC-PN-
Follow-up Required? ☐ Yes ☐ No
Section 6: Follow-up
Date Findings Briefed to Customer:
Follow-up Accepted: ☐ Yes ☐ No
Follow-up Completed Date:
Follow-up Report #: NESC-RP-
Section 7: Disposition and Notification
Notification type: - Select - | Details:
Date of Notification:
Final Disposition: - Select -
Rationale for Disposition:
Close Out Review Date:

NESC Request Form
NESC-PR-003-FM-01, v1.0

Page 2 of 3

Form Approval and Document Revision History

Approved: ______________________________ __________
NESC Director Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Principal Engineers Office	29 Jan 04

Appendix B. 1" AN Fitting on ISS Mimic Test Plan

Glenn Research Center
Engineering & Technical Services Directorate
DEF/Thermal & Fluid Systems Branch

TEST PLAN
DE-TP-05-01A
Page 1 of 12

NESC Independent Technical Assessment (ITA)

1" AN Fitting on ISS

Mimic Test Plan

July 5, 2005 - Baseline
August 22, 2005 – Revision A

Bruce Frankenfield Date Fluids Engineer	Paul Solano Date Mechanical Engineer
Clinton Cragg Date NESC ITA Team Lead	Derrick Cheston Date NESC Glenn Chief Engineer
Andreas Dibbern Date NESC ITA Deputy	

Revision A - Added the following paragraghs: 4.1A Surface Finish Tests, 4.1B Mimic Tests-Series B, with 100 μ-inch flex hose connections, and 4.1C Single Application of Torque Tests. Also, in 4.1 Mimic Test Sequence (step 5), the helium leak test method was changed from "Probe-Type" to "Baggie-Type."

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

1.1 Test Objective

NASA Engineering and Safety Center (NESC) Independent Technical Assessment (ITA) team will perform a Mimic Test, at NASA Glenn Research Center, to independently verify the integrity of the 1" AN fitting with stainless steel seals. The Mimic Test is the following:

- The Mimic Test is a combined Leak/Vibration/Pressure Cycle Test. This test will capture the history of the 1" AN flight fitting and mimic the pressure cycles and vibration environments of the flight system from fabrication to on orbit operation. The 1" AN test fitting will be torqued to the flight value of 185 Nm. This test will verify that the flight system's pressure cycles and random vibration will not cause fitting leakage at the installed torque.

1.2 Scope

This test plan defines the assembly, inspection, leak and functional tests requirements to be conducted on the 1" AN fitting with stainless steel seals. Test Plan SDL-TP-05-30 defines the structural dynamic test requirements relating to the vibration tests.

2. APPLICABLE DOCUMENTS

The following documents are applicable to this procedure:

- N2-SP-AI-0025 — Node 2&3 ACS - 37º Flared Fittings Leakage Delta Qualification Test
- N2-RP-AI-0231 — Node Two - 37º Flared Fittings Random Vibration Test
- N2-TN-AI0021 — Node Two Vibro-Acoustic Response Analysis
- SSP 50290D — Prime Item Development Specification for Node 2
- GRC-W7735.0001 — Structural Dynamics Laboratory Request and Use Instructions, 12/20/2002
- SDL-TP-05-30 — Structural Dynamics Laboratory – 1" AN Fitting on ISS – Vibration Test Plan
- SSP41172U — Qualification and Acceptance Environmental Test Requirements

3. EQUIPMENT REQUIRED/REQUIREMENTS

3.1 Test Facility

The Mimic Test, a combined Leak/Vibration/Pressure Cycle Test, will be conducted at the NASA Glenn Structural Dynamics Lab, Bldg 56. The vibration test equipment includes the shaker table, its control system and its data recording system. The leak testing equipment includes a Veeco helium leak detector and the helium supply system, which will be relocated from the Zero Gravity Facility to the Structural dynamics Lab for this test. Also, an air or nitrogen purge system is required.

3.2 Test Article

- 1" AN union fitting (Parker PS5174J1616)
- stainless steel conical seals (Voi-Shan VSF1015S16)
- two flight simulated flex hoses (Titeflex 1F96454-529)
- nut and sleeves (AN818-16K and AS5176J16)
- thread lubricant (Braycote 803)

3.3 Vibration Test Fixture

The Test Article (1" AN fitting, stainless steel seals and two flex hoses) will be mounted to the vibration table surface using a suitable test fixture to simulate actual installation for random vibration testing. See Figure 1 - Test Article on Shaker Table. The Fixture will use two tubing loop clamps on 23" centers, symmetric about the 1" AN fitting, to secure the test assembly, plus two more tubing loop clamps near the free ends of both flex hoses. The assembly will be pressurized to 150 psia during the random vibration testing.

3.4 Requirements

- AN Fitting seal • maximum acceptable leak rate is 3.6 x 10^{-4} sccs GHe at test pressure indicated.
- Dwell time • system dwell time will be 5 minutes minimum at indicated test pressure prior to performing leak check.
- Random vibe level • level at 1.5 times the launch level.
- Transportation vibration level • level duration will be at one hour per 1000 miles transport.
- Cleanliness of fittings • fittings will be cleaned with Isopropyl Alcohol, dried in nitrogen purge.

4. TEST SPECIFICATION

4.1 Mimic Test Sequence

Mimic Test Sequence shall be repeated three times with new seals, per Mimic Test Procedure DE-PROC-05-01.

1. The test article hardware is assembled with the fittings torqued to 185 Nm (1635 in-lbs). *(flight fittings torque value)*

General note:
For steps 2-10, if for any reason the leakage exceeds requirement, perform step 11.

2. The test article is pressurized to 500 psia for a minimum of 5 minutes and a "Baggie-Type" helium leak test is conducted on each individual seal @ 500 psia. To continue,

both fitting seals must be less than the maximum allowable leak rate. *(bench leak test pressure level)*

3. The test article is vented and then pressurized to 750 psia, for 5 minutes. *(proof pressure level)*
4. The test article is vented and then pressurized to 500 psia for 5 minutes. *(assembly level leak test pressure)*
5. The test article is vented and then pressurized to 500 psia for a minimum of 5 minutes and then a "Baggie-Type" helium leak test will be conducted on each individual seal @ 500 psia. *(dew point check pressure cycle level)*
6. The test article is vented and then pressurized to 20 psia and then exposed to Transportation Vibration levels per 4.3. *(transportation pressure level)*
7. The test article is pressurized to 380 psia for a minimum of 5 minutes and a "Probe-Type" helium leak test will be conducted on each individual seal @ 380 psia. *(KSC Pressure Decay Test pressure level)*
8. The test article is vented and then pressurized to 150 psia and then exposed to Launch Random Vibration (qualification) levels per 4.4. *(launch pressure level)*
9. The test article is vented then pressurized to 380 psia for a minimum of 5 minutes and a "Baggie-Type" helium leak test is conducted on each individual seal @ 380 psia. *(on orbit pressure level)* NOTE: Venting is required to calibrate the leak check bag.
10. The test article is then pressurized to 500 psia for a minimum of 5 minutes and a "Baggie-Type" helium leak test is conducted on each individual seal @ 500 psia. *(leak test data point)*
11. The test article is vented and then the torque of the 1" AN fitting is measured using a dial indicator torque wrench.

4.1A Surface Finish Tests

Surface Finish Tests shall perform a "Baggie-Type" leak test, with six different fitting caps, which are identical in geometry to the flex hose end connection, except for a 100 μ-inch sealing surface. The Surface Finish Test shall only include 4.1 Mimic Test Sequence (steps 1, 2 and 11), per Surface Finish Test Procedure DE-PROC-05-02.

4.1B Mimic Tests-Series B

An additional Mimic Tests-Series B shall be performed one time, with flex hoses end connections with a 100 μ-inch sealing surface and new seals. The Mimic Test- Series B shall include 4.1 Mimic Test Sequence (all steps), per Mimic Test Procedure DE-PROC-05-01.

4.1C Single Application of Torque Tests

A Single Application of Torque Tests shall be performed on four joints, using the same assembling techniques in the Mimic Tests, except that the torque shall be applied only once and then followed by a "Baggie-Type" helium leak test. The Single Application of Torque Tests shall only include 4.1 Mimic Test Sequence (steps 1 and 2), per Mimic Test Procedure DE-PROC-05-01.

4.2 Leak Testing

"Baggie-Type" helium leak test will be conducted per NASA specification SSP 41172 Rev U, 4.2.11.2H Test Description and Alternatives, Method VIII – Accumulation. The maximum acceptable leak rate is 3.6 x 10^{-4} sccs per seal. The time required for the system to be at pressure is 5 minutes prior to taking the reading instead of the required 30 minutes referenced in the current version of SSP 41172. At the time Alenia performed their leak checks, Method VIII was not included in SSP 41172. This 5-minute period is the approximate minimum wait time Alenia used during their "Baggie-Type" leak checks.

"Probe-Type" helium leak test will be conducted per NASA specification SSP 41172 Rev U, 4.2.11.2E Test Description and Alternatives, Method V – Detector Probe. The maximum acceptable leak rate is 3.6 x 10^{-4} sccs per seal. The time required for the system to be at pressure is 5 minutes prior to taking the reading instead of the required 30 minutes reference in SSP 41172. This 5 minute period is the agreed upon minimum wait time Alenia used during their "Probe-Type" leak checks (ref. RIA-NASA-00851).

4.3 Transportation Vibration Testing

Transportation Vibration testing will be conducted to vibration test levels defined in SS 50290D, Prime Item Development Specification for Node 2. The Transportation Vibration test profiles are shown in Figure 3, 4 and 5 for each axis of vibration. The duration of the test shall be 330 minutes in each of three orthogonal axes of each test article. The testing sequence for the three different axes can be in any order that is convenient to the test program.

4.4 Random Vibration Testing

Launch Random Vibration testing will be conducted to vibration test levels defined in N2-RP-AI-0231, 37º Flared Fittings Random Vibration Test. The Random Launch Vibration test profile for the Qualification level is shown in Figure 2. The Launch Random Vibration profile was previously developed to test 3/8" AN Fittings and is the worst case on Node 2. The duration of the test shall be three minutes in each of three orthogonal axes of each test article.

4.5 Random Vibration Test Sequence

- X-Z Axes Fixture Survey (3 min.) (Lateral Directions)
  - X-Axis 1" AN Fitting #1 (3 min.)
  - Z-Axis 1" AN Fitting #1 (3 min.) (Fitting rotated 90º in fixture)
- Y-Axis Fixture Survey (3 min.) (Axial Direction)
  - Y Axis 1" AN Fitting #1 (3 min.)

5. DATA PRODUCTS

5.1 Test Report

A test report will be prepared that summarizes the tests performed. Results of all leak tests performed will be included in the report. Pass / Fail criteria will be established as follows:

1) Visual Checks after each axis.

2) All Helium Leak test results.

3) Final fitting torque measurement.

The inspections after each shake shall be documented and included with the above-mentioned baseline tests.

Any anomalies or deviations from this test procedure will be documented in the report including any test equipment limitations that may affect the ability to perform the testing over the entire frequency range required.

5.2 Photographic Data

The test set-up including the fixtured test specimens and the control measurement instrumentation shall be documented by photograph. Photographs included in the Test Report shall be labeled so as to identify the instrumentation and axis of test. Any damage incurred by the test specimen detected by post test visual inspection shall also be documented photographically.

5.3 Random Vibration Test Data

Control measurement random vibration data shall be analyzed as acceleration spectral density (g^2/Hz) vs. frequency (Hz) using a filter bandwidth of 2.5 Hz ((20-2000 Hz)/800 spectral lines = 2.5 Hz). Each plot shall also indicate the composite RMS acceleration for that measurement over the test frequency range. The average control plot shall also include the test duration and spectral density tolerance bands as specified in Paragraph 4.2 of this document. The magnetic data tapes from this testing shall be archived for a period of two years in the Structural Dynamics Test Lab facility.

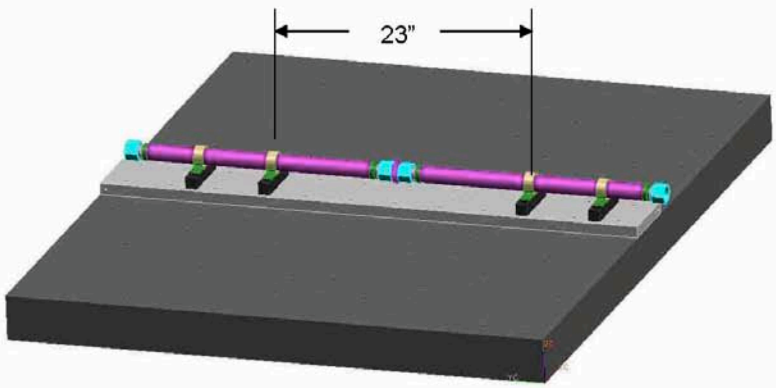
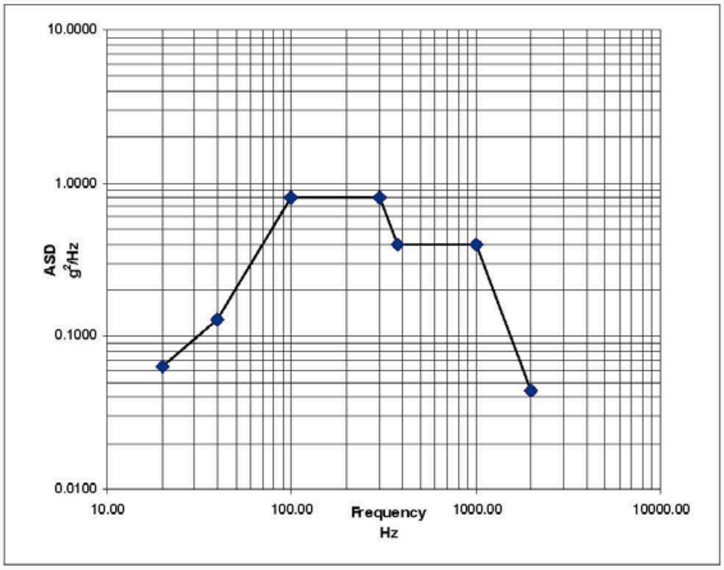


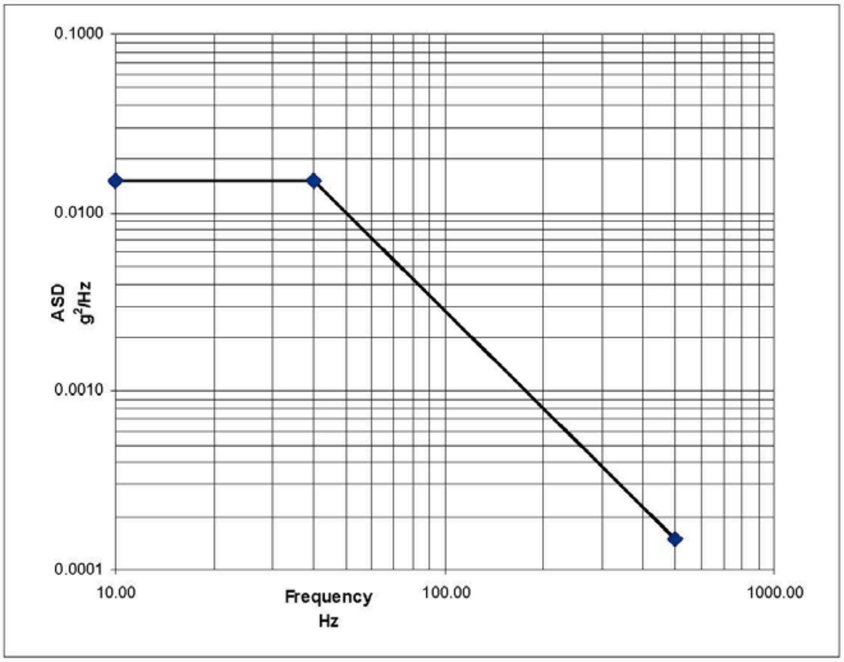
FIGURE 1: TEST ARTICLE ON SHAKER TABLE



Frequency (Hz)	Test Level
20.00	0.0640 g²/Hz
40.00	0.1280 g²/Hz
100.00	0.8000 g²/Hz
300.00	0.8000 g²/Hz
375.00	0.4000 g²/Hz
1000.00	0.4000 g²/Hz
2000.00	0.0440 g²/Hz
Duration:	**Overall**
180 seconds	24.95 g rms

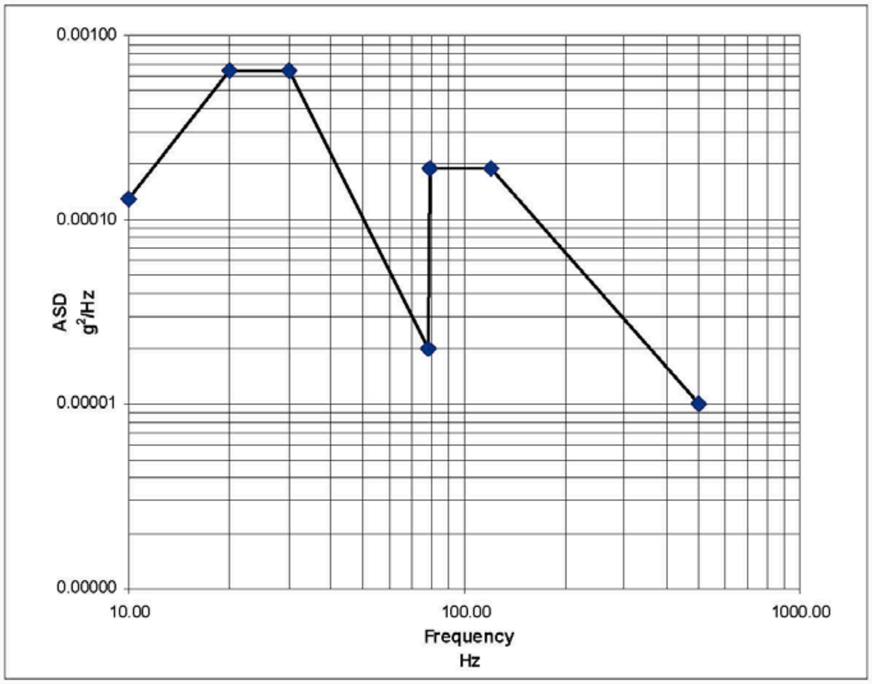
Qualification Level

FIGURE 2: 180 SECOND LAUNCH RANDOM VIBRATION TEST LEVEL



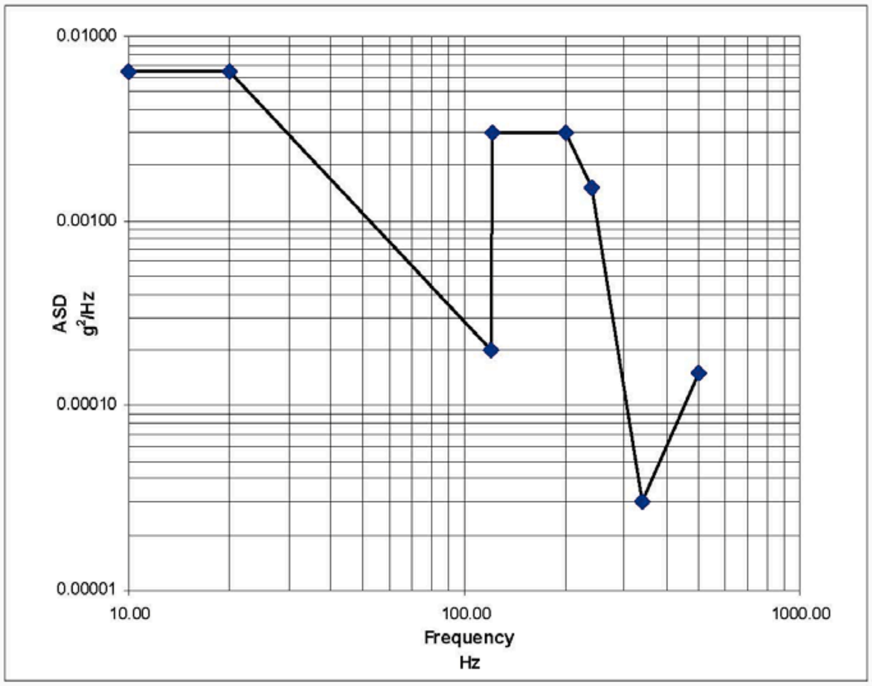
Frequency (Hz)	Test Level	
10-40	0.015	g²/Hz
40-500	-5.5	dB/octave
500	.00015	g²/Hz
Duration:	**Composite:**	
330 minutes	1.04 g_{rms}	

FIGURE 3: 330 MINUTE VERTICAL TRANSPORTATION RANDOM VIBRATION ENVIRONMENT



Frequency (Hz)	Test Level	
10	0.00013	g²/Hz
10-20	7.0	dB/octave
20-30	.00065	g²/Hz
30-78	-11.0	dB/octave
78	.00002	g²/Hz
79-120	.00019	g²/Hz
120-500	-6.2	dB/octave
500	.00001	g²/Hz
Duration: 330 minutes	**Composite:** 0.20 g rms	

FIGURE 4: 330 MINUTE LATERAL TRANSPORTATION RANDOM VIBRATION ENVIRONMENT



Frequency (Hz)	Test Level	
10-20	0.00650	g²/Hz
20-120	-5.8	dB/octave
120	.00020	g²/Hz
121-200	0.003	g²/Hz
200-240	-11.4	dB/octave
240	0.0015	g²/Hz
240-340	-33.8	dB/octave
340	0.00003	g²/Hz
340-500	12.6	dB/octave
500	0.00015	g²/Hz
Duration: 330 minutes	Composite: 0.74 g rms	

FIGURE 5: 330 MINUTE LONGITUDINAL TRANSPORTATION RANDOM VIBRATION ENVIRONMENT

Appendix C. NESC 1" AN Fitting Mimic Test Procedure

	Glenn Research Center Engineering & Technical Services Directorate	**NESC 1" AN FITTING MIMIC TEST PROCEDURE**	**TEST PROCEDURE** DE-PROC-05-01 ISSUE DATE: BASELINE 7/20/2005

This document specifies the detail procedural steps to perform the required Mimic Test Sequence as define in the document "Mimic Test Plan" DE-TP-05-01, Section 4.1. Each Test Article configuration, the test data for will be hand recorded on its own Mimic Test Procedure document and given a unique Test Run Number. The Testing Data Summary Report DE-SUM-05-01, will contain a running summary of the test data recorded for all Test Article configurations. A Test Results Spreadsheet DE-TRS-05-01, will contain a condensed table to compare the recorded data.

GENERAL NOTES

EMERGENCY PHONE NUMBER IS 911.
ONLY SYSTEM SAFETY HAZARD IS THE USE OF A COMPRESSED GAS (HELIUM).
A RELEASE OR VENTING OF HELIUM IS NOT PERSONNEL SAFETY HAZARD.

1. Applicable Documents

- DE-TP-05-01 — NESC 1" AN Fitting on ISS – Mimic Test Plan
- SSP 50290D — Prime Item Development Specification for Node 2
- SSP 41172 Rev U — Qualification & Acceptance Environmental Test Requirements
- GRC-W7735.00001 — Structural Dynamics Laboratory Request and Use Instructions, 12/20/2002

2. Test Article Identification

- The Test Article is composed of one AN Union fitting, two stainless steel conical seals, and two Flex Hoses.
- Tag or mark each 1" AN Union that is used for the Test Article as "F" for flight AN union (PS5174J1616) or "I" for Industrial AN union (16HTX SS), plus a two digit serial number. Example: "F-01" or "I-01".
- Tag or mark each 1" Flex Hose (Titeflex 1F96454-529) end connection, with a serial number.
  Example: Flex Hose #1 will have end connections #1 & #2, Flex Hose #2 will have end connections #3 & #4, etc.

3. Test Article Assembly Notes

- Verify all torque wrenches have been calibrated to the torque values required for assembly of the Test Article. A clean and uncluttered workspace shall be used for the forming and assembly of all Test Article hardware. Follow good workmanship practices to insure a high quality sealing surfaces.
- Prior to assembling the fittings, clean the conical seals and the sealing surfaces of the AN fittings and Flex Hoses, with isopropyl alcohol and wiped with a lint free cloth.
- During the assembly of the fittings, take extra care in the alignment and fit-up of the conical seals, with respect to the sealing surface.
- Lubricate the male threads of the fittings to avoid galling, but do not allow any lubricant on the metal sealing surfaces.

4. Leak Testing Notes

- Verify the Leak Tester has been calibrated for the range of possible leak rates of the Test Article.
- The calibrated helium leak source flow rate needs to be between 3.5×10^{-4} to 1.0×10^{-4} sccs.
- Prior to starting the Test Sequence, the leaks in the helium supply system shall minimize, by leak testing all fittings and components, using the detector probe method.
- Leak Testing in steps 2, 9 & 10 will be accomplished per SSP 41172 Rev U, 4.2.11.2, Method VIII-Accumulation method.
- Leak Testing in steps 5 & 7 will be accomplished per SSP 41172 Rev U, 4.2.11.2E, Method V-Detector Probe method.

5. Calibration Dates

- Torque Wrench model________________ cal date_______________
- Leak Tester model________________ cal date_______________
- Leak Source model________________ cal date_______________
- Pressure Transducer model________________ cal date_______________
- Shaker Table model________________ cal date_______________

Flex Hose End Fittings Installation

1.0 Verify the flaring machine is in good operating condition.
Record the flaring machine model.____________
2.0 Verify the flaring surfaces are clean and free of contamination or clean the hardware per the Test Article Assembly Notes.
3.0 Slide fitting nut and sleeve (AN8818-16K & AS5176J16) on the Flex Hose tube stub end.
4.0 Flare the stub end.
5.0 Repeat steps 2.0 thru 4.0 for the other Flex Hose tube stub end.
6.0 Inspect and clean both sealing surfaces of the Flex Hose with isopropyl alcohol and wipe with a lint free cloth.
7.0 Sign and date the completion the Flex Hose End Fittings Installation.___________________________

TEST SEQUENCE PROCEDURE

1.0 Test Article Assembly

1.1 The Test Article is composed of one AN Union fitting, two stainless steel Conical Seals, and two Flex Hoses. Other required fittings for the Test Article Assembly are: one Plug (16 PNTX SS), one Reducer (16-12 HTX SS), one Tube End Reducer (12-4 TRTX SS) and copper conical seals.
1.2 Clean the sealing surfaces of all Test Article Assembly hardware, including the conical seals, with isopropyl alcohol and wipe with a lint free cloth.
Record torque wrench model number_________________ calibration date____________________
1.3 Assembly of the fittings to the non-test ends of the two Flex Hoses.
1.3.1 Place the Plug (16 PNTX SS) into a vise and orient the Plug vertically.
1.3.2 Apply thread lubricant (Braycote 803) only to the male threads of the Plug fitting, keeping the sealing surface clean.
1.3.3 Place the 1” copper conical seal on the Plug and maintain a concentric alignment.
1.3.4 Lower the “non-test” end of the first Flex Hose on to the Plug and hand tighten the nut.
1.3.5 Using a torque wrench, tighten the nut to a torque value of 1635 in-lbs (136 ft-lbs).

1.3.6 Assemble the two reducers (16-12 HTX SS) & (12-4 TRTX SS) together using a ¾” copper conical seal and apply thread lubricate to the male threads. Torque the ¾” fitting to 1200 in-lbs (100 ft-lbs).
1.3.7 Place the Reducers into a vise and orient the Reducers vertically.
1.3.8 Apply thread lubricant (Braycote 803) only to the male threads of the Plug fitting, keeping the sealing surface clean.
1.3.9 Place the 1” copper conical seal on the Plug and maintain a concentric alignment.
1.3.10 Lower the “non-test” end of the second Flex Hose on to the Plug and hand tighten the nut.
1.3.11 Using a torque wrench, tighten the nut to a torque value of 1635 in-lbs (136 ft-lbs).

1.4 Final assembly of the Test Article

1.4.1 Place the Test Article AN Union fitting into a vise and orient the Union vertically.
1.4.2 Apply thread lubricant (Braycote 803) only to the male threads of the Union fitting, keeping the sealing surface clean.
1.4.3 Place the 1” stainless steel conical seal on the Union and maintain a concentric alignment.
1.4.4 Lower the first Flex Hose on to the Union and hand tighten the nut.
1.4.5 Using a torque wrench, tighten the nut to a torque value of **1635 in-lbs (136 ft-lbs) (185 Nm)**.
1.4.6 Record the tag number of the 1st Flex Hose and test end connection.______________
Record the torque value.___________(in-lbf)
1.4.7 Rotate the Union fitting in the vise, so that the Union fitting open end is vertical.
1.4.8 Apply thread lubricant (Braycote 803) only to the male threads of the Union fitting, keeping the sealing surface clean.
1.4.9 Place the 1” stainless steel conical seal on the Union and maintain a concentric alignment.
1.4.10 Lower the second Flex Hose on to the Union and hand tighten the nut.
1.4.11 Using a torque wrench, tighten the nut to a torque value of **1635 in-lbs (136 ft-lbs) (185 Nm)**.
1.4.12 Record the tag number of the 2nd Flex Hose and test end connection._____________
Record the torque value.____________(in-lbf)

1.5 Record the tag number of the AN union fitting._______________

1.6 Fasten the Test Article Assembly to the Vibration Adapter Plate, using the four tubing loop clamps. Torque each fastener to 100 in-lbs.

1.7 Connect the helium supply system to the ¼” fitting connection. Use a copper conical washer and torque the ¼” fitting to 165 in-lbs (14 ft-lbs).

1.8 Scribe a mark line on Test Article AN Union and Flex Hose nuts.

1.9 Sign and date the completion of Section 1.0.___________________________

2.0 Pressure Cycle to 500 psia and Leak Test (bench level test pressure)

NOTE - The maximum acceptable leak rate is 3.6 x 10^{-4} sccs per seal. The measured leak rate of both seals of the AN Union fitting must be less than the maximum acceptable leak rate, before starting Section 3.0. In Sections 5.0, 7.0, 9.0 and 10.0, if the measured leak rate is greater than the maximum acceptable leak rate, then the leak test procedure will be repeated. If the repeated leak test is still greater than the maximum acceptable leak rate, then stop the Test Sequence and perform Section 11.0 Fitting Torque Check.

2.1 Verify the helium supply and the Test Article was installed per the schematic, that the helium system has been leak tested, that all valves are closed and all fittings have been torqued to their correct values.
2.2 Verify the Test Article pressure is 0 psig.
2.3 Installed two Leak Test "enclosure" polyethylene bags, one bag around each Test Article fitting seal. The "enclosure" bag shall be tightly sealed with tape, at the union fitting hex nut and at the Flex Hose over braid cover end piece. .
2.4 Leak Test Calibration of each "enclosure" bag (Method VIII).
- 2.4.1 Enclosure Bag #1.
- 2.4.2 Measure the helium background reading of the room environment. (BG1)____________________(sccs)
- 2.4.3 Record the tag numbers of the test fitting and flex hose end.___________________
- 2.4.4 Insert the leak detector probe tip into the bag and take a bag background reading. (D1)_________________(sccs)
- 2.4.5 Remove the leak detector probe and then insert and seal the known helium leak source into the "enclosure" bag.
- 2.4.6 After exactly 5 minutes, insert the leak detector probe tip into the "enclosure" bag to quantitatively measure the helium response.
  Record the measured maximum helium response. (B1)____________________ (sccs)
  Record the known leak source flow rate. (A1)_______________ (sccs)
  Record the known leak source injection time length._________________(min)
- 2.4.7 Remove the helium leak source and leak detector probe from the Bag #1.
- 2.4.8 Enclosure Bag #2.
- 2.4.9 Record the tag numbers of the test fitting and flex hose end.___________________
- 2.4.10 Insert the leak detector probe tip into the bag and take a bag background reading. (D2)_________________(sccs)
- 2.4.11 Remove the leak detector probe and then insert and seal the known helium leak source into the "enclosure" bag.

2.4.12 After exactly 5 minutes, insert the leak tester probe tip into the "enclosure" bag to quantitatively measure the helium response.
Record the measured helium response. (B2)_____________________ (sccs)
Record the known leak source flow rate. (A2)________________ (sccs)
Record the known leak source injection time length.________________ (min)
2.4.13 Remove the helium leak source and leak detector probe from the Bag #2.

2.5 Prepare to begin helium pressurization by opening the helium K-bottle manual valve (HV-01). Verify helium supply pressure at the pressure regulator inlet.
2.6 Adjust pressure regulator (PR-05) to a downstream pressure of 25 psig.
2.7 Open the fill valve (HV-03), until the Test Article pressure is 25 psig. Close the fill valve (HV-03) and visually inspect the system for any gross leaks.
2.8 Verify all the fittings of the "non-test ends" of the Test Article are leak free, by using the detector probe method.
2.9 Adjust pressure regulator (PR-05) to a downstream pressure of 500 psig.
2.10 Open the fill valve (HV-03), until the Test Article pressure is 485 psig (500psia). Close the fill valve (HV-03) and visually inspect the system for any gross leaks.
2.11 Maintain the 485 psig pressure on the Test Article for a minimum of 5 minutes.
2.12 Leak Test Measurement of Bag #1 (Method VIII).
2.12.1 Measure the helium background reading of the room environment. (BG2)_____________________(sccs)
2.12.2 Record the tag numbers of the test fitting and flex hose end._____________________
2.12.3 Record the helium system pressure (PG-06).__________________ (psig)
2.12.4 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.
2.12.5 Insert the leak detector probe tip into the bag and take a bag background reading. (E1)__________________(sccs)
2.12.6 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.
2.12.7 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.
Record the helium exposure time.____________________ (min)
Record the maximum helium response. (C1)_____________________ (sccs)
Calculate Actual Leak Rate: A1(C1-E1)/(B1-D1) = ____________________ (sccs)
2.13 Leak Test Measurement of Bag #2 (Method VIII).
2.13.1 Record the tag numbers of the test fitting and flex hose end._____________________
2.13.2 Record the helium system pressure (PG-06).__________________ (psig)

2.13.3 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.
2.13.4 Insert the leak detector probe tip into the bag and take a bag background reading. (E2)__________________(sccs)
2.13.5 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.
2.13.6 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.
2.13.7 Record the helium exposure time.___________________ (min)
Record the maximum helium response. (C2)____________________ (sccs)
Calculate Actual Leak Rate: A2(C2-E2)/(B2-D2) = ___________________ (sccs)

2.14 Verify the fill valve (HV-03) is closed.
2.15 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).
2.16 Remove both "enclosure' Bags #1 & #2 from the Test Article.
2.17 Sign and date the completion of Section 2.0.___________________________

3.0 Pressure Cycle to 750 psia (proof pressure level)

3.1 **Warning: During this pressure cycle test, all personnel must remain a minimum 10 feet away from the Test Article.**
3.2 Adjust the outlet pressure of the pressure regulator (PR-05) to 750 psig.
3.3 Open the fill valve (HV-03), until the Test Article pressure is 735 psig (750 psia).
3.4 Close the fill valve (HV-03) and maintain this pressure for 5 minutes.
3.5 Verify the fill valve (HV-03) is closed.
3.6 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).
3.7 Adjust the outlet pressure of the pressure regulator (PR-05) to 500 psig.
3.8 Sign and date the completion of Section 3.0__________________________

4.0 Pressure Cycle to 500 psia (assembly level leak test pressure)

4.1 Verify the outlet pressure of the pressure regulator (PR-05) is 500 psig.
4.2 Open the fill valve (HV-03), until the Test Article pressure is 485 psig (500 psia).
4.3 Close the fill valve and maintain this pressure for 5 minutes.

4.4 Verify the fill valve (HV-03) is closed.
4.5 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).
4.6 Sign and date the completion of Section 4.0__________________________

5.0 Pressure Cycle to 500 psia and Leak Test (dew point check pressure level)

5.1 Verify the outlet pressure of the pressure regulator (PR-05) is 500 psig.
5.2 Open the fill valve (HV-03), until the Test Article pressure is 485 psig (500 psia).
5.3 Close the fill valve (HV-03) and maintain this pressure for a minimum of 5 minutes.
5.4 Leak Tester Calibration (Method V)
5.4.1 Measure the helium background reading of the room environment. (BG3)_____________________(sccs)
5.4.2 Record calibrated helium leak source flow rate._________________(sccs)
5.4.3 Pass the leak detector probe tip perpendicular across a calibrated helium leak at a scanning rate of 1/8" per second and at a distance of 1/8".
5.4.4 Record maximum leak detector output reading. _____________________(sccs)
Note: The resulting leak detector output shall be at least 40 percent above the helium background concentration.
5.5 Leak Testing Measurement (Method V)
5.5.1 Measure the helium background reading of the room environment. (BG4)_____________________(sccs)
5.5.2 The detector probe tip shall be passed perpendicular over the test surface (circumferential around both sealing surfaces) at a scanning rate of 1/8" per second and at a distance of 1/8". Any leak detector output greater than measured in 5.4.4, indicates a leak.
5.5.3 Record maximum leak detector output reading. _____________________(sccs)
5.5.4 If the maximum measured output reading in 5.5.3 > 5.4.4, then a failed leak rate is indicated. (IND)_______________
5.6 Verify the fill valve (HV-03) is closed.
5.7 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).
5.8 Adjust the outlet pressure of the pressure regulator (PR-05) to 20 psig.
5.9 Sign and date the completion of Section 5.0__________________________

6.0 Vibration @ Transportation Levels (transportation pressure level)

6.1 Verify the outlet pressure of the pressure regulator (PR-05) to 5 psig.
6.2 Open the fill valve (HV-03), until the Test Article pressure is 5 psig (20 psia).
6.3 Close the fill valve (HV-03) for the duration of the vibration tests.
6.4 Perform the random vibration test of the X axis for 330 minutes, per the Transportation Vibration levels in the document - Mimic Test Plan (DE-TP-05-01).
Record X-axis vibration start time and date.________________
Record X-axis vibration end time and date._________________
6.5 Rotate the Test Article and perform the random vibration test of the Y axis for 330 minutes, per the Transportation Vibration levels in the document - Mimic Test Plan (DE-TP-05-01).
Record Y-axis vibration start time and date.________________
Record Y-axis vibration end time and date._________________
Rotate the Test Article and perform the random vibration test of the Z axis for 330 minutes, per the Transportation Vibration levels in the document - Mimic Test Plan (DE-TP-05-01).
Record Z-axis vibration start time and date.________________
Record Z-axis vibration end time and date._________________
6.6 Record Pressure Test Article final pressure. (PG-06) ________________ (psig)
6.7 Close the fill valve (HV-03).
6.8 Sign and date the completion of Section 6.0____________________________

7.0 Pressure Cycle to 380 psia and Leak Test (KSC Pressure Decay Test)

7.1 Adjust the outlet pressure of the pressure regulator (PR-05) to 380 psig.
7.2 Open the fill valve (HV-03), until the Test Article pressure is 365 psig (380 psia).
7.3 Close the fill valve (HV-03) and maintain this pressure for a minimum of 5 minutes.
7.4 Leak Tester Calibration (Method V)
7.4.1 Measure the helium background reading of the room environment. (BG5)______________________(sccs)
7.4.2 Record calibrated helium leak source flow rate.___________________(sccs)

7.4.3 Pass the leak detector probe tip perpendicular across a calibrated helium leak at a scanning rate of 1/8" per second and at a distance of 1/8".

7.4.4 Record maximum leak detector output reading. ____________________(sccs)

Note: The resulting leak detector output shall be at least 40 percent above the helium background concentration.

7.5 Leak Testing Measurement (Method V)

7.5.1 Measure the helium background reading of the room environment. (BG6)____________________(sccs)

7.5.2 The detector probe tip shall be passed perpendicular over the test surface (circumferential around both sealing surfaces) at a scanning rate of 1/8" per second and at a distance of 1/8". Any leak detector output greater than measured in 5.4.4, indicates a leak.

7.5.3 Record maximum leak detector output reading. ____________________(sccs)

7.5.4 If the maximum measured output reading in 7.5.3 > 7.4.4, then a failed leak rate is indicated. (IND)______________

7.6 Verify the fill valve (HV-03) is closed.

7.7 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).

7.8 Adjust the outlet pressure of the pressure regulator (PR-05) to 150 psig.

7.9 Sign and date the completion of Section 7.0_________________________

8.0 Vibration @ Launch Qualification Levels (launch pressure level)

8.1 Verify the outlet pressure of the pressure regulator (PR-05) is 150 psig.

8.2 Open the fill valve (HV-03), until the Test Article pressure is 135 psig (150 psia).

8.3 Close the fill valve (HV-03).

8.4 Perform the random vibration test of the X axis for 3 minutes, per the Launch Vibration Qualification levels in the document - Mimic Test Plan (DE-TP-05-01).
Record the X-axis vibration start time, end time and date.________________________________

8.5 Rotate the Test Article and perform the random vibration test of the Y axis for 3 minutes, per the Launch Vibration levels in the document - Mimic Test Plan (DE-TP-05-01).
Record the Y-axis start time, end time and date.________________________________

8.6 Rotate the Test Article and perform the random vibration test of the Z axis for 3 minutes, per the Launch Vibration levels in the document - Mimic Test Plan (DE-TP-05-01).

Record the Z-axis start time, end time and date.___________________________________

8.7 Record the Test Article final pressure. (PG-06)____________(psig)

8.8 Verify the fill valve (HV-03) is closed.

8.9 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).

8.10 Sign and date the completion of Section 8.0___________________________

9.0 Pressure Cycle to 380 psia and Leak Test (on orbit pressure level)

9.1 NOTE - The maximum acceptable leak rate is 3.6×10^{-4} sccs per seal.

9.2 Verify the Test Article pressure is 0 psig.

9.3 Installed two Leak Test "enclosure" polyethylene bags, one bag around each Test Article fitting seal. The "enclosure" bag shall be tightly sealed with tape, at the union fitting hex nut and at the Flex Hose over braid cover end piece.

9.4 Leak Test Calibration of each "enclosure" bag (Method VIII).

9.4.1 Measure the helium background reading of the room environment. (BG7)______________________(scc)

9.4.2 Enclosure Bag #3. (same location as Bag #1)

9.4.3 Record the tag numbers of the test fitting and flex hose end.____________________

9.4.4 Insert the leak detector probe tip into the bag and take a bag background reading. (D3)__________________(sccs)

9.4.5 Remove the leak detector probe and then insert and seal the known helium leak source into the "enclosure" bag.

9.4.6 After exactly 5 minutes, re-insert the leak detector probe tip into the "enclosure" bag to quantitatively measure the helium response.

Record the measured maximum helium response. (B3)______________________ (sccs)

Record the known leak source flow rate. (A3)________________ (sccs)

Record the known leak source injection time length.__________________(min)

9.4.7 Remove the helium leak source from the Bag #3.

9.4.8 Enclosure Bag #4. (same location as Bag #2)

9.4.9 Record the tag numbers of the test fitting and flex hose end.____________________

9.4.10 Insert the leak detector probe tip into the bag and take a bag background reading. (D4)__________________(sccs)

9.4.11 Remove the leak detector probe and then insert and seal the known helium leak source into the "enclosure" bag.

9.4.12 After exactly 5 minutes, re-insert the leak tester probe tip into the "enclosure" bag to quantitatively measure the helium response.
Record the measured helium response. (B4)_____________________ (sccs)
Record the known leak source flow rate. (A4)_______________ (sccs)
Record the known leak source injection time length._______________ (min)

9.4.13 Remove the helium leak source and leak detector probe from the Bag #4.

9.5 Adjust the outlet pressure of the pressure regulator (PR-05) to 380 psig.

9.6 Open the fill valve (HV-03), until the Test Article pressure is 365 psig (380 psia).

9.7 Close the fill valve (HV-03) and maintain this pressure for a minimum of 5 minutes.

9.8 Leak Test Measurement of Bag #3 (Method VIII).

9.8.1 Measure the helium background reading of the room environment. (BG8)_____________________(sccs)

9.8.2 Record the tag numbers of the test fitting and flex hose end._____________________

9.8.3 Record the helium system pressure. (PG-06)_________________ (psig)

9.8.4 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.

9.8.5 Insert the leak detector probe tip into the bag and take a bag background reading. (E3)__________________(sccs)

9.8.6 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.

9.8.7 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.
Record the helium exposure time.___________________ (min)
Record the maximum helium response. (C3)____________________ (sccs)
Calculate Actual Leak Rate: A3(C3-E3)/(B3-D3) = ___________________ (sccs)

9.9 Leak Test Measurement of Bag #4 (Method VIII).

9.9.1 Record the tag numbers of the test fitting and flex hose end._____________________

9.9.2 Record the helium system pressure (PG-06)._________________ (psig)

9.9.3 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.

9.9.4 Insert the leak detector probe tip into the bag and take a bag background reading. (E4)__________________(sccs)

9.9.5 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.

9.9.6 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.

9.9.7 Record the helium exposure time.___________________ (min)
Record the maximum helium response. (C4)____________________ (sccs)
Calculate Actual Leak Rate: A4(C4-E4)/(B4-D4) = ___________________ (sccs)

9.10 Verify the fill valve (HV-03) is closed.
9.11 Sign and date the completion of Section 9.0.___________________________

10.0 Pressure Cycle to 500 psia and Leak Test (leak test data point)

10.1 Adjust the outlet pressure of the pressure regulator (PR-05) to 500 psig.
10.2 Open the fill valve (HV-03), until the Test Article pressure is 485 psig (500psia).
10.3 Close the fill valve (HV-03) and maintain this pressure for a minimum of 5 minutes.
10.4 Leak Test Measurement of Bag #3 (Method VIII).
10.4.1 Measure the helium background reading of the room environment. (BG9)_____________________(scc)
10.4.2 Record the tag numbers of the test fitting and flex hose end.____________________
10.4.3 Record the helium system pressure. (PG-06)________________(psig)
10.4.4 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.
10.4.5 Insert the leak detector probe tip into the bag and take a bag background reading. (E3*)_________________(sccs)
10.4.6 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.
10.4.7 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.
Record the helium exposure time.__________________ (min)
Record the maximum helium response. (C3*)___________________ (sccs)
Calculate Actual Leak Rate: A3(C3*-E3*)/(B3-D3) = __________________ (sccs)
10.5 Leak Test Measurement of Bag #4 (Method VIII).
10.5.1 Record the tag numbers of the test fitting and flex hose end.____________________
10.5.2 Record the helium system pressure. (PG-06)________________(psig)
10.5.3 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.
10.5.4 Insert the leak detector probe tip into the bag and take a bag background reading. (E4*)_________________(sccs)
10.5.5 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.
10.5.6 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.
10.5.7 Record the helium exposure time.__________________ (min)
Record the maximum helium response. (C4*)___________________ (sccs)
Calculate Actual Leak Rate: A4(C4*-E4*)/(B4-D4) = __________________ (sccs)

10.6 Verify the fill valve (HV-03) is closed.
10.7 Open the vent valve (HV-04),
10.8 Adjust the outlet pressure of the pressure regulator (PR-05) to 0 psig.
10.9 Close the helium K-bottle manual valve (HV-01).
10.10 Open the fill valve (HV-03),
10.11 When the Test Article pressure is 0 psig, close the helium system fill valve (HV-03) and vent valve (HV-04).
10.12 Verify that all valves are closed.
10.13 Leak Tester Calibration Verification (Method V)
10.13.1 Measure the helium background reading of the room environment. (BG10)______________________(sccs)
10.13.2 Record calibrated helium leak source flow rate.___________________(sccs)
10.13.3 Pass the leak detector probe tip perpendicular across a calibrated helium leak at a scanning rate of 1/8” per second and at a distance of 1/8”.
10.13.4 Record maximum leak detector output reading. ______________________(sccs)
10.14 Remove both “enclosure’ bags from the Test Article.
10.15 Sign and date the completion of Section 10.0.____________________________

11.0 Fitting Torque Check

11.1 Disconnect the ¼” helium supply connection.
11.2 Remove the Test Article from the Vibration Adaptor plate
11.3 Disassembly of the Test Article

Disassembly of the first Flex Hose

11.3.1 Place the Test Article into a vise, with the vise firmly holding the 1” AN Union hex.
11.3.2 Scribe a longitudinal mark on one of the flats of the Flex Hose hex nut and continue it on the Union body hex.
11.3.3 In the direction of tightening the Flex Hose nut, set the calibrated torque wrench to the lowest torque value in Table 1 and applied the torque to the Flex Hose nut and watch for nut movement. (Note - a second technician is required to continuously observe any nut movement).

11.3.4 If no nut movement occurs, reset the torque wrench to the next higher torque value in Table 1, and repeat step 11.3.3. Continue increasing the torque wrench settings, per Table 1, until the nut movement occurs or max torque of 136 ft-lbs is achieved.

11.3.5 Record the torque value at when nut movement occurred or record no nut movement at 1635 in-lbs (136 ft-lbs). ________________ (ft-lbf)

11.3.6 Record the tag number of the 1st Flex Hose and test end connection.______________

11.3.7 Loosen the nut on the Flex Hose and disconnect the Flex Hose from the Union, being careful not damaging the sealing surfaces or the conical seal.

Disassembly of the second Flex Hose

11.3.8 Place the Test Article into a vise, with the vise firmly holding the 1" AN Union hex

11.3.9 Scribe a longitudinal mark on one of the flats of the Flex Hose hex nut and continue it on the Union body hex.

11.3.10 In the direction of tightening the Flex Hose nut, set the calibrated torque wrench to the lowest torque value in Table 1 and applied the torque to the Flex Hose nut and watch for nut movement. (Note - a second technician is required to continuously observe any nut movement).

11.3.11 If no nut movement occurs, reset the torque wrench to the next higher torque value in Table 1, and repeat step 11.3.3. Continue increasing the torque wrench settings, per Table 1, until the nut movement occurs or max torque of 136 ft-lbs is achieved.

11.3.12 Record the torque value at when nut movement occurred or record no nut movement at 1635 in-lbs (136 ft-lbs). ________________ (ft-lbf)

11.3.13 Record the tag number of the 2nd Flex Hose and test end connection.______________

11.3.14 Loosen the nut on the Flex Hose and disconnect the Flex Hose from the Union, being careful not damaging the sealing surfaces or the conical seal.

11.4 Visually inspect all fitting connections for surface damage or contamination.

11.5 Bag and store the all Test Article hardware.

11.6 Record damage or remarks.____

____

____

11.7 Sign and date the completion of Section 11.0.__________________________________

END OF TEST SEQUENCE PROCEDURE

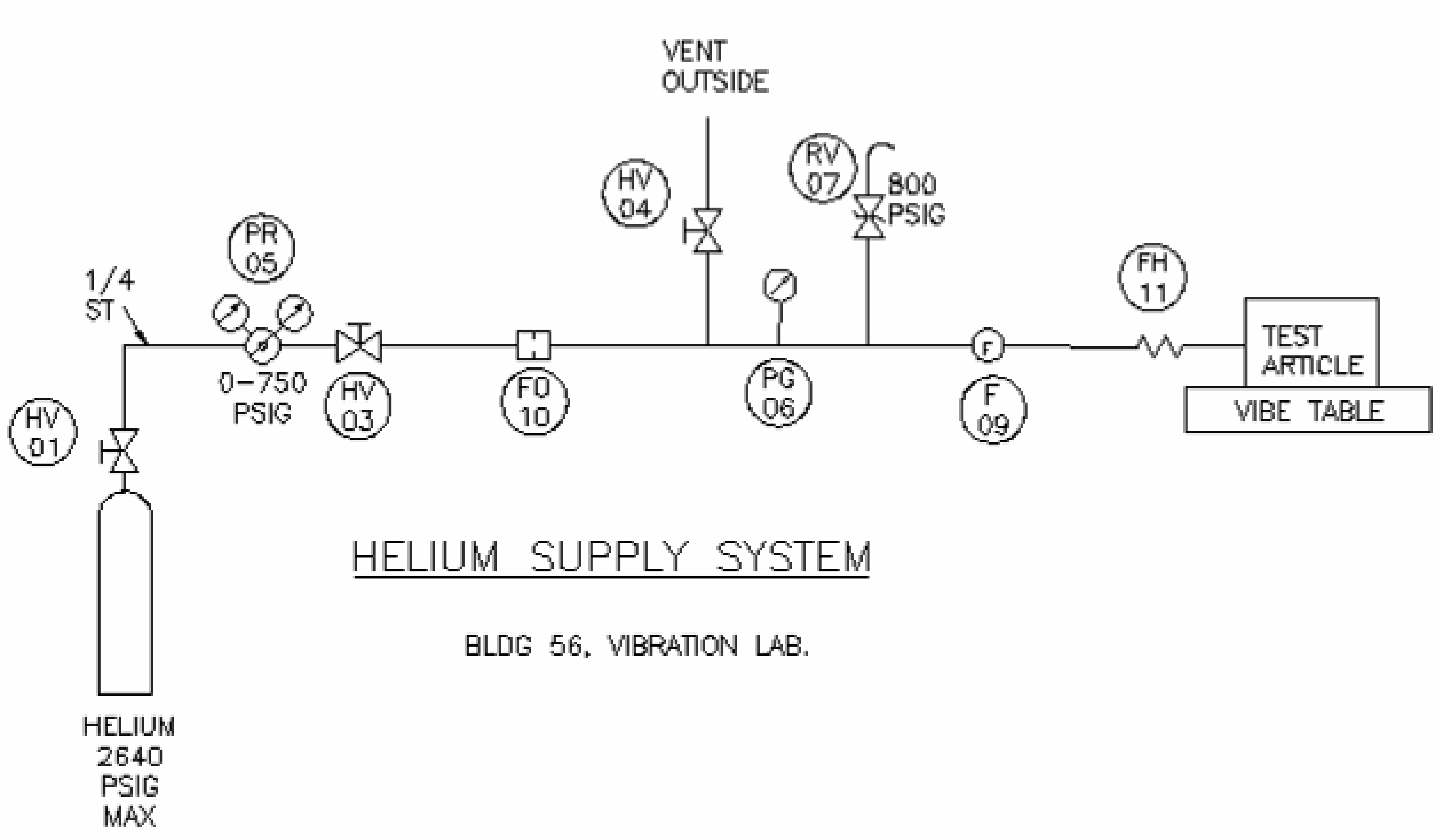
TABLE 1
Torque Checking Settings
For steps 11.3.4 & 11.3.10

Torque Wrench Setting (ft-lbs)	Percent of Full Torque (ft-lbs)
60	44.1
80	58.8
90	66.2
100	73.5
105	77.2
110	80.9
115	84.6
120	88.2
125	91.9
130	95.6
135	99.3
136	100

NESC AN Fitting Test at Vibe Lab

Helium Supply Parts List

	Item	mfgr	p/n	size	rated pressure	comments
Helium GSE					(psig)	
HV-01	Helium supply bottle, with shut off valve	Air Products			2640	290 scf
PR-05	Pressure Regulator	Scott	51-08AS-580	CGA 580	4000	0-800 psig outlet pressure
HV-03	Hand Valve	Scott	54-62S-4F	1/4"	3000	(Fill Valve)
FO-10	Flow Limiting Orifice	O'Keefe	B-63-SS	1/4"	4000	.063" orifice (Cv=.089)
HV-04	Hand Valve	Whitey	SS-1RS4	1/4"	5000	(Vent Valve)
PG-06	Pressure Transducer	Digibar	PE 100	1/4"	1000	0-1000 psig, cal +/-0.2% FS (Test Article pressure)
RV-07	Relief Valve	Nupro	SS-R4S4-C	1/4"	6000	800 psig set pressure (Cv=.9)
F-09	Filter	Nupro	SS-4F-7	1/4"	3000	
FH-11	Flex Hose	Swaglok	SS-FM4-72	1/4"	3100	6' long
Test Article						
	Flex Hose	Titeflex	1F96454-529	1"	500	Proof pressure 1000 psia, Burst pressure 2000 psia
	AN Union fitting	Parker	PS5174J1616	1"	7200	


VENT
OUTSIDE
HV
04
RV
07
800
PSIG
PR
05
1/4
ST
0-750
PSIG
HV
03
FO
10
PG
06
F
09
FH
11
TEST
ARTICLE
VIBE TABLE
HV
01
HELIUM SUPPLY SYSTEM
BLDG 56, VIBRATION LAB.
HELIUM
2640
PSIG
MAX

Appendix D. AN Fittings on the ISS Independent Technical Assessment Plan

(Approved by the NESC on June 5, 2005)

1.0 Identification

ITA/I #: 04-038-E	
Initiator Name: Anonymous	**Initiator Contact Info:** N/A
Short Title: AN Fittings on the International Space Station (ISS).	
Description: AN fittings have demonstrated leak history in use in KSC ground equipment. Concern is for leak risk on ISS Node 2.	
Date Received: April 16, 2004	**Date ITA/I Initiated:** May 5, 2005
Initial Evaluator Assigned: Tim R. Wilson	**Initial Evaluator Contact Info:** timmy.r.wilson@nasa.gov, 321-861-3868
Lead Assigned: Clinton H. Cragg	**Lead Contact Info:** clinton.h.cragg@nasa.gov, 757-864-2422

2.0 Charter

This Charter establishes the NESC-directed AN fittings on the ISS. An Independent Technical Assessment Team was established to review the available ISS AN Fitting data for Node 2 and to provide the Program with a path to follow, which may include testing, such that the Program will feel confident that the fittings will not leak when flown.

3.0 Scope

KSC has had problems in the past with AN fittings leaking and is concerned about similar fittings on the ISS. Node 2, constructed in Italy, contains approximately 67 AN fittings in an ammonia cooling system. Several issues concerning these fittings have come to the attention of the NESC. First, the system was originally installed with nickel crush washers that turned out to be incompatible with ammonia. The nickel washers were replaced with stainless steel washers. Second, leak checks appear to have been performed on some of the fittings on the bench and not in the installed position. Others that were easily accessible in the installed position were leak-checked in place. Although it may have been performed, there is no written record of a system-wide leak check. Third, the fittings were accepted (no delta qualification performed) based on the testing performed on a 3/8-inch fitting using different crush washers that were to be used in a different environment (i.e., not ammonia).

This assessment will review available documentation and consult with industry experts to provide the Program with recommendations on how to gage the reliability of these fittings.

4.0 Disengagement Criteria

This technical assessment will use the first baseline level on NESC engagement. This means that the assessment team will deliver the findings, recommendations, requirements, and observations and declare the work of the team completed. Responsibility for acceptable follow-up on the ITA team's requested actions would fall to the Programs' inline engineering and safety organizations. The inline organizations will generate responses, determine the adequacy, and assess the Program's residual risk given successful execution of the responses.

5.0 Team Listing

The ITA team was assembled with the direct help and support of the NESC's Discipline Experts (NDEs). One core team member is a contractor working for SRI International. All other members are NASA employees. With the approval of this plan, other outside entities may be invited to join the team as members and/or consultants.

An initial team meeting took place at KSC on May 10, 2005. This plan is the product of that meeting. The current members of the core team are provided in the table below.

NAME	CENTER	EXPERTISE	PHONE	E-MAIL
Team				
Clinton Cragg	LaRC	Team Lead	757/864-2422	clinton.h.cragg@nasa.gov
Andreas Dibbern	KSC	Deputy Team Lead	321/861-3939	andreas.dibbern-1@ksc.nasa.gov
Bruce Frankenfield	GRC	Mechanical Systems	216/433-6456	bruce.j.frankenfield@grc.nasa.gov
Jessica Mock	JSC	Human Factors	321/861-6652	jessica.l.mock@jsc.nasa.gov
Henry A. Rotter	JSC	NDE Fluids/Life Support/ Thermal	281/483-9249	henry.a.rotter@nasa.gov
Don Shockey	SRI	Materials		donald.shockey@sri.com
Paul Solano	GRC	Mechanical Systems	216/433-6518	paul.a.solano@grc.nasa.gov
Steve Ernest	KSC	SMA Rep	321/867-4788	Stephen.P.Ernest@nasa.gov
Elizabeth Blome	JSC	Liaison to ISS Program	281/244-7121	elizabeth.c.blome@nasa.gov
Consultants				
Dean Kunz	KSC	ISS Fluids	321/861-4162	dean.p.kunz@nasa.gov
Mark Terrone	KSC	NESC SEO	321/867-6149	mark.terrone-1@nasa.gov
Robert Beil	KSC	NESC SEO	321/861-3944	robert.j.beil-1@nasa.gov
Rayelle Thomas	KSC	Fluids Operations	321/867-6418	rayelle.e.thomas@nasa.gov
Tim Wilson	KSC	NESC Chief Engineer KSC	321/861-3868	timmy.r.wilson@nasa.gov
John McManamen	JSC	Mechanical Systems NDE	281/483-8958	john.p.mcmanamen@nasa.gov
Administrative Support				
Cynthia L. Bruno	LaRC	Analyst	757/864-6065	cynthia.l.bruno@nasa.gov
Jaime Belitz	LaRC	Scheduler	757/864-9340	j.l.belitz@larc.nasa.gov
Terri Derby	LaRC	Administrative Coordinator	757/864-9872	t.b.derby@larc.nasa.gov
Erin Moran	LaRC	Technical Writer	757/864-7513	e.moran@larc.nasa.gov

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6.0 Facilities/Tools/Other Logistics

One further face-to-face meeting may be held at a location TBD.

7.0 Activities/Work Breakdown Structure (WBS)

The ITA's proposed activities and WBS will occur within the following general framework:

7.1 Requirements and recommendations for a system level pressure decay test will be investigated and evaluated. While there are reports that the Italians conducted a system level test, there is no record of this test.

7.2 Review the optimal torque and the acceptable torque range for a leak-free seal of 1-inch diameter flex hose using stainless steel seals. Presumably there is a minimum torque required to crush the seal sufficiently to preclude leaking and presumably there is a torque above which the fitting surface is damaged and leaking can occur. Review actual torque applied to the fittings against this optimal and acceptable range.

7.3 Review the effects of material, tubing diameter, and multiple torque application on propensity to leak. Alenia qualified 1-inch diameter tubing and fittings with stainless steel seals by similarity to 3/8-inch diameter tubing and fittings with nickel seals. Alenia also conducted multiple torque fitting testing. This acceptance documentation and multiple torque testing data will be reviewed.

7.4 Review the perception that the fittings will not leak under the mechanical and thermal conditions expected during transport and service, or identify additional testing required to improve confidence. The vibration and thermal environments expected during launch and deployment, as well as those experienced during transport from Italy to the U.S., will be estimated.

7.5 Identify lessons-learned applicable to other ISS hardware, especially Node 3.

8.0 Deliverables

A final report with recommendations will be provided to the ISS Program.

9.0 Schedule

Key Milestones	
May 5, 2005	Assessment assigned by the NRB
May 19, 2005	Brief NRB on ITA Plan
June 2, 2005	Brief NRB on ITA Findings
Week of June 6, 2005	Briefing to the ISS Program

Refer to Appendix B for a more detailed schedule.

10.0 Key Stakeholders

The key stakeholders for this ITA are Mr. William Gerstenmaier, ISS Program Manager, Mr. William Panter, ISS Vehicle Office Chief, and Mike Conley, ISS System Warrant Holder.

11.0 Constraints

The constraints currently identified include a lack of adequate documentation of what kind of testing was conducted and the how testing was accomplished.

12.0 Resources Estimate

The total estimated funding required to support this ITA is $89,800. Details are provided in Appendix A.

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Appendix A. Resource Estimate

	FTE		$K
Labor (Fully Loaded)			
Civil Servants	**0.30**	**$**	**62.7**
Procurements	**0.13**	**$**	**11.9**
Contracts		$	11.9
Grants		$	-
Facilities		$	-
Other Govt Agency		$	-
Other Direct Costs		$	-
Consultants		$	-
CS Travel		**$**	**7.0**
Service Pools		**$**	**-**
Fabrication		$	-
Test		$	-
Wind Tunnel		$	-
Other		$	-
Total		**$**	**81.6**
Contingency Reserve		**$**	**8.2**
Total Estimated Funds Required		**$**	**89.8**

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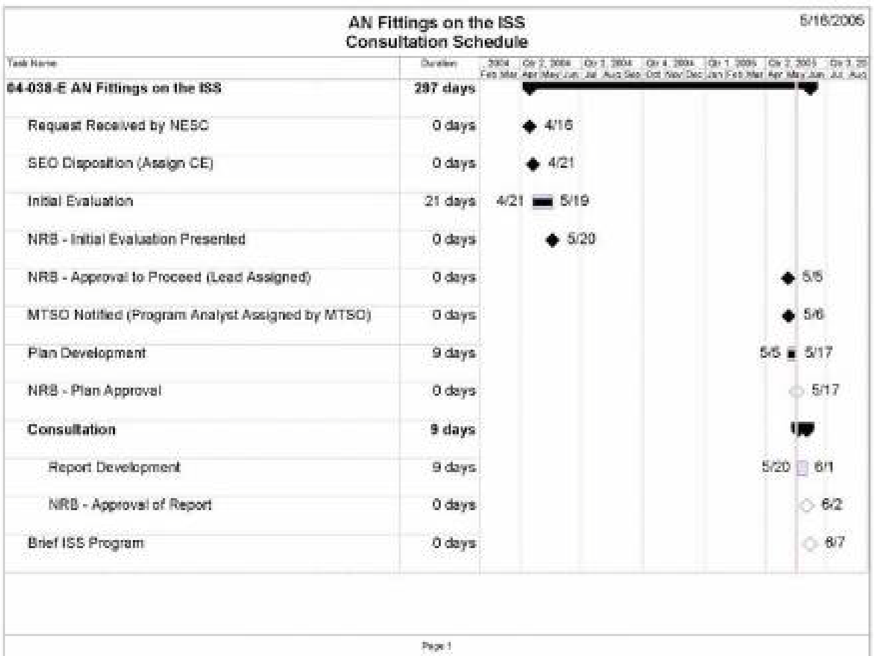
Appendix B. Schedule



Task Name	Duration
04-038-E AN Fittings on the ISS	**297 days**
Request Received by NESC	0 days
SEO Disposition (Assign CE)	0 days
Initial Evaluation	21 days
NRB - Initial Evaluation Presented	0 days
NRB - Approval to Proceed (Lead Assigned)	0 days
MTSO Notified (Program Analyst Assigned by MTSO)	0 days
Plan Development	9 days
NRB - Plan Approval	0 days
Consultation	**9 days**
Report Development	9 days
NRB - Approval of Report	0 days
Brief ISS Program	0 days

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Plan Approval and Document Revision History

Approved:	Original signature on file	6-5-05
	NESC Director	Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Principal Engineers Office	6-5-05

Appendix E. Pressure Decay Test Resultant Data

Node 2 EATCS Pressure Decay Leakage Testing

Problem

Calculate the leakage rate in sccs using the given formula

$LR = U * V_T * [(p_0+p_{std}) - (p_1+p_{std}) * (T_0/T_1) / (p_{std}*t)]$

Where LR is calculated leak rate (sccs), U is uncertainty = 1.05, V_T is total volume of the system (cc), p_0 is pressure at the start of the test (psig), p_{std} is standard atmospheric pressure (14.696 psia), p_1 is pressure at the end of the test (psig), T_0 is temperature at start of the test (R), T_1 is temperature at the end of the test (R), and t is the total time of the test (s).

Given

$U := 1.05$ $\quad p_{std} := 14.696\ psi$ $\quad V_{Loop\_A} := 35396\ cm^3$ $\quad V_{Loop\_B} := 24069\ cm^3$

Approximated

The Ground Support Equipment (GSE) consists of two 0.25 inch flex hoses 4 foot in length, a 0.25 inch cross (KC117K4) with two unions (KC171K4), two closed valves (79K80056-1), and a Flight interface adapter (70G851155-1023). For error in GSE volume, larger is more conservative therefore the fittings were estimated at 1 foot in length + the 4 feet of flex hose = 5 feet. The flight interface adapter was estimated as a 1 inch tube 15 inches in length. (A factor of 10 on the GSE approximation results in less than 0.1 psi change in Δp.)

$V_{GSE} := 5\ ft \cdot \pi \cdot (.125\ in)^2 + 15\ in \cdot \pi \cdot (.5\ in)^2$ $\qquad V_{GSE} = 241.319 \cdot cm^3$

Inputs

LOOP A

$t_A := 233880\ sec$	$t_A = 64.967 \cdot hr$	Duration of test
$p_{A0} := 366.7\ psi$		Pressure at start of test
$p_{A1} := 365.8\ psi$		Pressure at end of test
$T_{A0} := 71.6$	$T_{A0} := T_{A0} \cdot R + 459.67 \cdot R$	Temperature at start of test
$T_{A1} := 71.7$	$T_{A1} := T_{A1} \cdot R + 459.67\ R$	Temperature at end of test

LOOP B

$t_B := 223740\ sec$	$t_B = 62.15 \cdot hr$	Duration of test
$p_{B0} := 367.4\ psi$		Pressure at start of test
$p_{B1} := 366.3\ psi$		Pressure at end of test
$T_{B0} := 71.8$	$T_{B0} := T_{B0} \cdot R + 459.67 \cdot R$	Temperature at start of test
$T_{B1} := 71.5$	$T_{B1} := T_{B1} \cdot R + 459.67\ R$	Temperature at end of test

Calculations

$V_{TA} := V_{Loop\_A} + V_{GSE}$ $\qquad V_{TA} = 3.5637 \cdot 10^{4} \cdot cm^{3}$

$V_{TB} := V_{Loop\_B} + V_{GSE}$ $\qquad V_{TB} = 2.431 \cdot 10^{4} \cdot cm^{3}$

$\Delta p_{A} := p_{A1} - p_{A0}$ $\qquad \Delta p_{A} = -0.9 \cdot psi$

$\Delta T_{A} := T_{A1} - T_{A0}$ $\qquad \Delta T_{A} = 0.1 \cdot R$

$\Delta p_{B} := p_{B1} - p_{B0}$ $\qquad \Delta p_{B} = -1.1 \cdot psi$

$\Delta T_{B} := T_{B1} - T_{B0}$ $\qquad \Delta T_{B} = -0.3 \cdot R$

Limit = 1.5E-2 sccs Max

$$LR_{A} := V_{TA} \cdot U \cdot \frac{\left(p_{A0} + p_{std}\right) - \left(p_{A1} + p_{std}\right) \cdot \left(\frac{T_{A0}}{T_{A1}}\right)}{p_{std} \cdot t_{A}} \qquad LR_{A} = 1.058 \cdot 10^{-2} \cdot \frac{cm^{3}}{s}$$

$$LR_{B} := V_{TB} \cdot U \cdot \frac{\left(p_{B0} + p_{std}\right) - \left(p_{B1} + p_{std}\right) \cdot \left(\frac{T_{B0}}{T_{B1}}\right)}{p_{std} \cdot t_{B}} \qquad LR_{B} = 6.869 \cdot 10^{-3} \cdot \frac{cm^{3}}{s}$$

Appendix F. CHIT Form

INTERNATIONAL SPACE STATION (ISS) CHIT REQUEST FORM	
1. REQUESTING ORG: NASA – EC6	2. CONTROL NUMBER:
3. REQUESTER: Cindy Cross/EATCS Subsystem Mgr, 281-483-2832	4. PAGE: 1 OF 1
5. SUBJECT: Complete pressure decay test of Node EATCS lines, both loop A and loop B.	
6. POINT OF CONTACT: Mitch Sestile/321-867-5425	7. RESPONSIBLE NASA MANAGER/DATE:
8. NASA LAUNCH PACKAGE MANAGER/DATE:	
9. REASON FOR CHIT: Concern has been raised over the readiness for flight of the AN fittings used to connect the ammonia flex lines together on the external active thermal control system (EATCS). In preparation for filling these lines at KSC, it is deemed prudent to ensure that post installation handling, transportation and subsequent activities in the end cone areas have not reduced the integrity of the fluid system.	
10. REQUESTED ACTION AND ACTIONEE: It is requested that the KSC Node 2 Mission Processing Team perform a pressure decay test on both Loop A and Loop B ammonia lines. Success criteria for this test shall be a leakage rate of less than $1.5x10^{-2}$ sccs per loop using nitrogen gas at 385 +0/-5 psia. The leak test duration shall be no less than 64 hours for loop A and 55 hours for loop B. A stabilization period of no less than 2 hours shall be required once the system is at pressure and the start of the leak test. Temperature and pressure readings shall be taken than at the start of the test, the completion of the test and no less than every 12 hours in between. Potential heat loads on the element shall be minimized during this time in order to minimize temperature induced variations. Finally, pressure measurement accuracy of 0.2 psi or better is required.	
11. ACTION REQUIRED BY (CENTRAL TIME): Prior to flight ammonia load operations. Can be completed in series with moisture check requirements of RCN MA16638R2.	
12. IMPACT OF NON-APPROVAL: Failure to complete this test will increase the risk associated with the flight ammonia load. If not able to run co-incident with the moisture check requirements, additional setup and test time will be required to implement the action requested by this Chit	

13. COORDINATION: Glen Chin (NASA/KSC Mission Manager); Mitch Sestile (CAPPS/KSC Mission Manager); Steve Pavelitz (Node Project); Steve Huning (STS-120/10A Launch Package Integration Manager)	
14. IMPLEMENTATION SIGNATURE:	15. AUTHORIZATION DATE:
BOEING: NASA:	AUTH DATE: AUTH DATE:
16. EFFECTIVITY STATEMENT: SYSTEM: ELEMENT: PAYLOAD:	

Appendix G. **Surface Finish Test Procedure**

Glenn Research Center Engineering & Technical Services Directorate	NESC 1" AN FITTING SURFACE FINISH TEST PROCEDURE	TEST PROCEDURE DE-PROC-05-02 ISSUE DATE: 8/23/2005 BASELINE

This document specifies the detail procedural steps to perform the required Surface Finish Test as define in the document "Mimic Test Plan" DE-TP-05-01A, Section 4.1A. Each Test Article configuration, the test data for will be hand recorded on its own Surface Finish Test Procedure document and given a unique Test Run Number. The Testing Data Summary Report-Surface Finish Test (DE-SUM-05-02), will contain a running summary of the test data recorded for all Surface Finish Test configurations. A Test Results Spreadsheet DE-TRS-05-01, will contain a condensed table to compared the recorded data

GENERAL NOTES

EMERGENCY PHONE NUMBER IS 911.
ONLY SYSTEM SAFETY HAZARD IS THE USE OF A COMPRESSED GAS (HELIUM).
A RELEASE OR VENTING OF HELIUM IS NOT PERSONNEL SAFETY HAZARD.

1. **Applicable Documents**
   - DE-TP-05-01 — NESC 1" AN Fitting on ISS – Mimic Test Plan
   - SSP 50290D — Prime Item Development Specification for Node 2
   - SSP 41172 Rev U — Qualification & Acceptance Environmental Test Requirements
   - GRC-W7735.00001 — Structural Dynamics Laboratory Request and Use Instructions, 12/20/2002

2. **Test Article Identification**
   - The Test Article is composed of one AN Union fitting, one stainless steel conical seal, and one a 100 m-inch Cap.
   - Tag or mark each 1" AN Union that is used for the Test Article as "F" for flight AN union (PS5174J1616), plus a two digit serial number. Example: "F-01".
   - Tag or mark each 100 m-inch Cap that is used for the Test Article as "C" for Cap, plus a two digit serial number. Example: "C-01".

3. **Test Article Assembly Notes**
   - Verify all torque wrenches have been calibrated to the torque values required for assembly of the Test Article. A clean and uncluttered workspace shall be used for the forming and assembly of all Test Article hardware. Follow good workmanship practices to insure a high quality sealing surfaces.
   - Prior to assembling the fittings, clean the conical seals and the sealing surfaces of the AN fittings and Flex Hoses, with isopropyl alcohol and wiped with a lint free cloth.
   - During the assembly of the fittings, take extra care in the alignment and fit-up of the conical seals, with respect to the sealing surface.
   - Lubricate the male threads of the fittings to avoid galling, but do not allow any lubricant on the metal sealing surfaces.

4. Leak Testing Notes

- Verify the Leak Tester has been calibrated for the range of possible leak rates of the Test Article.
- The calibrated helium leak source flow rate needs to be between 3.5 x 10^{-4} to 1.0 x10^{-4} sccs.
- Prior to starting the Test Sequence, the leaks in the helium supply system shall minimize, by leak testing all fittings and components, using the detector probe method.
- Leak Testing in step 2 will be accomplished per SSP 41172 Rev U, 4.2.11.2, Method VIII-Accumulation method.

5. Calibration Dates

- Torque Wrench model_______________ cal date_______________
- Leak Tester model_______________ cal date_______________
- Leak Source model_______________ cal date_______________
- Pressure Transducer model_______________ cal date_______________

SURFACE FINISH TEST SEQUENCE PROCEDURE

1.0 Test Article Assembly

1.1 The Test Article is composed of one AN Union fitting, one stainless steel Conical Seal, and one 100 m-inch Cap. Other required fittings for the Test Article Assembly are: one flex hose, one Reducer (16-12 HTX SS), one Tube End Reducer (12-4 TRTX SS) and copper conical seals.

1.2 Clean the sealing surfaces of all Test Article Assembly hardware, including the conical seals, with isopropyl alcohol and wipe with a lint free cloth.

1.3 Assembly of the fittings to the non-test connections.

1.3.1 Assemble the two reducers (16-12 HTX SS) & (12-4 TRTX SS) together using a ¾" copper conical seal and apply thread lubricate to the male threads. Torque the ¾" fitting to 1200 in-lbs (100 ft-lbs).

1.3.2 Place the Reducers into a vise and orient the Reducers vertically.

1.3.3 Apply thread lubricant (Braycote 803) only to the male threads of the Reducer fitting, keeping the sealing surface clean.

1.3.4 Place the 1" copper conical seal on the Reducer and maintain a concentric alignment.

1.3.5 Lower the "non-test" end of the flex hose on to the Reducer and hand tighten the nut.

1.3.6 Using a torque wrench, tighten the nut to a torque value of 1635 in-lbs (136 ft-lbs).

1.3.7 Place the Test Article AN Union fitting into a vise and orient the Union vertically.

1.3.8 Apply thread lubricant (Braycote 803) only to the male threads of the Union fitting, keeping the sealing surface clean.

1.3.9 Place the 1" copper conical seal on the Union and maintain a concentric alignment.

1.3.10 Lower the open end of the Flex Hose on to the Union and hand tighten the nut.

2

1.3.11 Using a torque wrench, tighten the nut to a torque value of **1635 in-lbs (136 ft-lbs) (185 Nm)**.
1.3.12 Record the tag number of the AN Union fitting and Flex Hose end connection.______________

1.4 Final assembly of the Test Article
1.4.1 Rotate the Union fitting in the vise, so that the Union fitting open end is vertical.
1.4.2 Apply thread lubricant (Braycote 803) only to the male threads of the Union fitting, keeping the sealing surface clean.
1.4.3 Place the 1" stainless steel conical seal on the Union and maintain a concentric alignment.
1.4.4 Lower the 100 m-inch Cap on the AN Union and hand tighten the nut.
1.4.5 Using a torque wrench, tighten the nut to a torque value of **1635 in-lbs (136 ft-lbs) (185 Nm)**.
1.4.6 Record the tag number of the 100 m-inch Cap.____________
Record the torque value.____________(in-lbf)

1.5 Record the tag number of the AN union fitting.______________
1.6 Connect the helium supply system to the ¼" fitting connection. Use a copper conical washer and torque the ¼" fitting to 165 in-lbs (14 ft-lbs).
1.7 Sign and date the completion of Section 1.0.__________________________

2.0 Leak Test @ 500 psia.

2.1 Verify the helium supply and the Test Article was installed per the schematic, that the helium system has been leak tested, that all valves are closed and all fittings have been torqued to their correct values.
2.2 Verify the Test Article pressure is 0 psig.
2.3 Installed one Leak Test "enclosure" polyethylene bag around each AN Union/ 100 m-inch Cap. The "enclosure" bag shall be tightly sealed with tape, at the Union fitting hex nut and at the Cap.
2.4 Leak Test Calibration of each "enclosure" bag (Method VIII).
2.4.1 Enclosure Bag #1.
2.4.2 Measure the helium background reading of the room environment. (BG1)____________________(sccs)
2.4.3 Record the tag numbers of the AN Union and Cap.____________________
2.4.4 Insert the leak detector probe tip into the bag and take a bag background reading. (D1)_________________(sccs)
2.4.5 Remove the leak detector probe and then insert and seal the known helium leak source into the "enclosure" bag.
2.4.6 After exactly 5 minutes, insert the leak detector probe tip into the "enclosure" bag to quantitatively measure the helium response.
Record the measured maximum helium response. (B1)____________________ (sccs)
Record the known leak source flow rate. (A1)_______________ (sccs)
Record the known leak source injection time length._________________(min)
2.4.7 Remove the helium leak source and leak detector probe from the Bag #1.
2.5 Prepare to begin helium pressurization by opening the helium K-bottle manual valve (HV-01). Verify helium supply pressure at the pressure regulator inlet.

3

2.6 Adjust pressure regulator (PR-05) to a downstream pressure of 500 psig.
2.7 Open the fill valve (HV-03), until the Test Article pressure is 485 psig (500psia). Close the fill valve (HV-03) and visually inspect the system for any gross leaks.
2.8 Maintain the 485 psig pressure on the Test Article for a minimum of 5 minutes.
2.9 Leak Test Measurement of Bag #1 (Method VIII).
  2.9.1 Measure the helium background reading of the room environment. (BG2)____________________(sccs)
  2.9.2 Record the tag numbers of the AN Union and Cap.____________________
  2.9.3 Record the helium system pressure (PG-06).________________ (psig)
  2.9.4 Open the bag flap to the room environment, for 30 seconds, then seal bag flap.
  2.9.5 Insert the leak detector probe tip into the bag and take a bag background reading. (E1)_________________(sccs)
  2.9.6 Remove the leak detector probe, and then allow the helium system to leak into the enclosure for exactly 5 minutes.
  2.9.7 Re-insert the leak detector probe tip into the "enclosure" bag and quantitatively measure the helium response.
  Record the helium exposure time.__________________ (min)
  Record the maximum helium response. (C1)___________________ (sccs)
  Calculate Actual Leak Rate: A1(C1-E1)/(B1-D1) = __________________ (sccs)
2.10 Verify the fill valve (HV-03) is closed.
2.11 Open the vent valve (HV-04), when the Test Article pressure is 0 psig, then close vent valve (HV-04).
2.12 Remove both "enclosure' Bags #1 from the Test Article.
2.13 Sign and date the completion of Section 2.0.__________________________

3.0 Fitting Torque Check

3.1 Disconnect the ¼" helium supply connection.
3.2 Disassembly of the Test Article
Disassembly of the Cap
  3.2.1 Place the Test Article into a vise, with the vise firmly holding the 1" AN Union hex.
  3.2.2 Scribe a longitudinal mark on one of the flats of the Cap nut and continue it on the Union body hex.
  3.2.3 In the direction of tightening the Cap nut, set the calibrated torque wrench to the lowest torque value in Table 1 and applied the torque to the Cap nut and watch for nut movement. (Note - a second technician is required to continuously observe any nut movement).
  3.2.4 If no nut movement occurs, reset the torque wrench to the next higher torque value in Table 1, and repeat step 11.3.3. Continue increasing the torque wrench settings, per Table 1, until the nut movement occurs or max torque of 136 ft-lbs is achieved.
  3.2.5 Record the torque value at when nut movement occurred or record no nut movement at 1635 in-lbs (136 ft-lbs).
  ________________ (ft-lbf)
  3.2.6 Record the tag number of the Cap and AN Union.______________

4

3.2.7 Loosen the nut on the Flex Hose and disconnect the Flex Hose from the Union, being careful not damaging the sealing surfaces or the conical seal.

Disassembly of the Flex Hose

3.2.8 Place the Test Article into a vise, with the vise firmly holding the 1" AN Union hex

3.2.9 Loosen the nut on the Flex Hose and disconnect the Flex Hose from the Union, being careful not damaging the sealing surfaces or the conical seal.

3.3 Visually inspect all fitting connections for surface damage or contamination.

3.4 Bag and store the all Test Article hardware.

3.5 Record damage or remarks.____

3.6 Sign and date the completion of Section 3.0.__________________________

END OF TEST SEQUENCE PROCEDURE

5

TABLE 1
Torque Checking Settings
For steps 11.3.4 & 11.3.10

Torque Wrench Setting (ft-lbs)	Percent of Full Torque (ft-lbs)
90	66.2
100	73.5
105	77.2
110	80.9
115	84.6
120	88.2
125	91.9
130	95.6
135	99.3
136	100

6

Appendix H. Use of AN Fittings on ISS Risk Assessment

NASA Engineering and Safety Center

Use of AN Fittings on ISS

ITA/I Request 04-038-E
NESC Chief Engineer Review

Tim Wilson

Kennedy Space Center

05 May 05

Document Number RP-05-52

This briefing is for status only and does not represent complete engineering data analysis

Agenda	T. Wilson
	28 Apr 05

- Identification
- Background
- Initial Screening Checklist Results
- Safety Assessment
- Initial Risk Assessment
- Center/Program/Project Proposed Solution
- Initial Assessment of C/P/P Proposed Solution
- Recommended Course of Action
- Resources Expended

This briefing is for status only and does not represent complete engineering data analysis

Identification	T. Wilson
	28 Apr 05

- **ITA/I Number:** 04-038-E
- **ITA/I Title:** Use of AN Fittings on ISS
- **ITA/I Initiator:** Anonymous
- **ITA/I Initiation Date:** 04-16-04
- **Affected Center/Program/Project:** Kennedy Space Center
- **ITA/I Description:** AN fittings have demonstrated leak history in use in KSC ground equipment. Concern is for leak risk on ISS hardware

This briefing is for status only and does not represent complete engineering data analysis

Background

T. Wilson

28 Apr 05

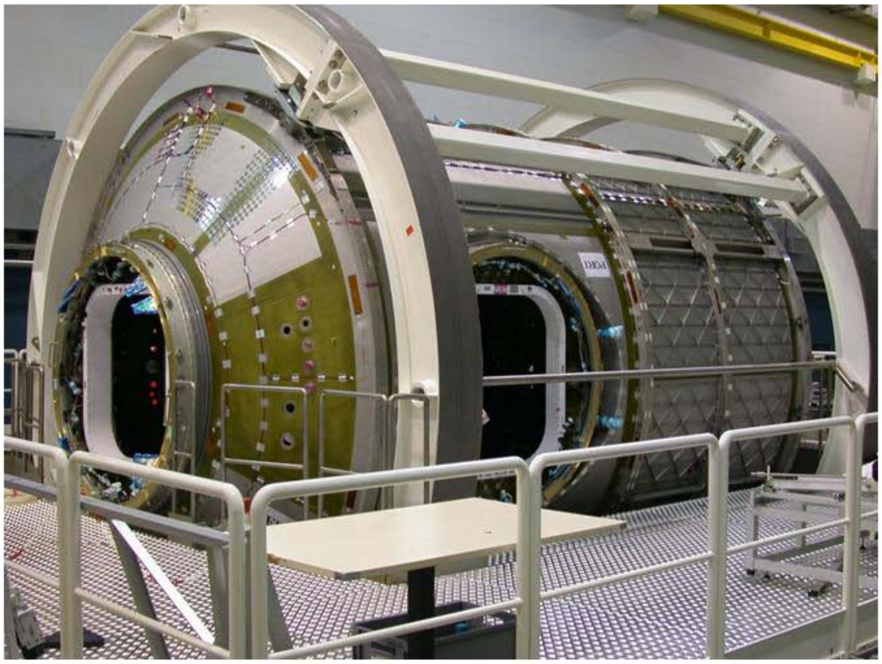
- ISS Node 2 has six ammonia-water heat exchangers
  - Three per end cone, installed on exterior of module
  - Part of Active Thermal Control System (ATCS)
- Exchangers transfer waste heat from the Node to the S1 and P1 truss radiators
- Flex hoses are used to connect the heat exchangers and are themselves interconnected with AN-type fittings
  - 58 1-inch fittings are installed on the Node
  - Fittings are sealed with stainless steel crush washers (conical seals)
- Concern is with the potential for leakage
  - AN fittings do not provide redundant seals against external leakage
  - Program has experienced a number of AN-fitting leaks in ground ammonia systems

This briefing is for status only and does not represent complete engineering data analysis

Background

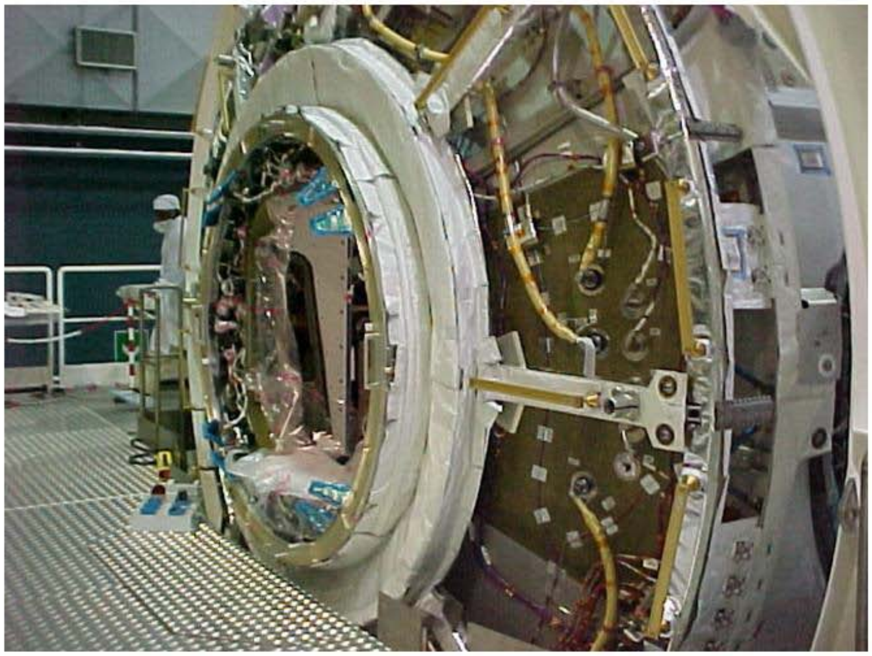
T. Wilson

28 Apr 05



This briefing is for status only and does not represent complete engineering data analysis

Background	T. Wilson
	28 Apr 05



This briefing is for status only and does not represent complete engineering data analysis

Background

T. Wilson

28 Apr 05

Background	T. Wilson
	28 Apr 05

This briefing is for status only and does not represent complete engineering data analysis

Background	T. Wilson
	28 Apr 05

- Issue first surfaced to NESC in April 04
- NRB decision at that time was not to conduct a formal assessment but to forward results of the CALIPSO assessment to the ISS Program and suggest they adopt those recommendations
  - Similar AN-fittings were used on CALIPSO, though of a different size and media (1/4-inch hydrazine vs. 1-inch ammonia)
  - CALIPSO concern was for potential for personnel exposure due to leakage during launch processing, not for in-flight leakage
- CALIPSO recommendations were forwarded to ISS Program
  - Verify fittings were assembled with rigorous processing controls
  - Verify post-assembly leak checks were performed
  - Verify certification testing brackets the expected service environment (vibration, thermal cycles, etc.)

This briefing is for status only and does not represent complete engineering data analysis

Background	T. Wilson
	28 Apr 05

- Follow-up meeting held with KSC ISS ground ops chief engineer and S&MA indicates concerns have not been addressed
  - Data of the kind required for CALIPSO is not available
  - Assembly concerns have surfaced
    - Fittings were dis-assembled and re-assembled at least once for replacement of nickel seals with stainless steel
    - Assembly personnel had difficulty reaching required torque levels
    - System was leak-checked where assembled, with some fittings on the bench and others on the ship. No documented, full-up leak check has been performed after flexhose handling and final installation.
  - Configuration certified may not be representative of flight
    - Cert was done on 3/8-inch AN-fittings with nickel seals
    - Node 2 fittings were certified by similarity to 3/8-inch fittings
- Additional work is required to fully address concerns

This briefing is for status only and does not represent complete engineering data analysis

NCE Checklist Items	T. Wilson
	28 Apr 05

- Checklist Item C
  - Lack of technical consensus: KSC ground ops and S&MA believe the risk of in-flight leakage is significant enough to warrant further work. Program believes leak checks already conducted are sufficient.
- Checklist Item G
  - Concern that insufficient testing or analysis has been done
- Checklist Item H
  - Involves a Crit1 or 1R system / component: Node 2 cooling loops are Crit 1R hardware.
- Checklist Item K
  - Involves exception to fly-as-you-test or test-as-you-fly: System certification may not have been performed with hardware in a flight or flight-like configuration.

This briefing is for status only and does not represent complete engineering data analysis

Safety Assessment	T. Wilson
	28 Apr 05

- Local S&MA position
  - KSC S&MA shares concern that issue has not been resolved
  - Additional testing is warranted to fully address the problem
- Key concern
  - Catastrophic leakage could result in loss of one or more cooling loops
    - Loss of a cooling loop results in loss of half the station's electrical power
    - Failure can be isolated at Node 2, but modules connected through Node 2 would still be affected
  - Minor leakage could cause a logistical problem for frequent re-supply and top-off

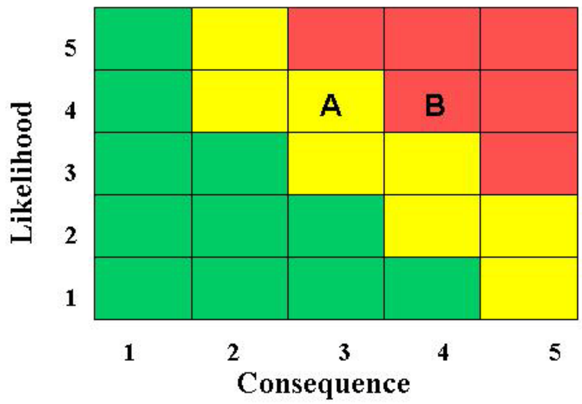
This briefing is for status only and does not represent complete engineering data analysis

Initial Risk Assessment	T. Wilson
	28 Apr 05

ISS Program AN-Fittings

A : Out-of-spec leakage from a single fitting

B : Gross leakage from a single fitting with subsequent loss of cooling loop



- Likelihood (A=4, B=4)
  - Data required to validate assembly is not available
  - Improperly assembled fittings may pass initial leak check, but fail during subsequent handling, cold shock, etc.
- Consequence (A=3, B=4)
  - Minor leakage may impact servicing logistics
  - Gross leakage may lead to loss of cooling loop functionality

This briefing is for status only and does not represent complete engineering data analysis

C/P/P Proposed Solution	T. Wilson
	28 Apr 05

- Fittings were subjected to bagged-joint leak checks post-assembly
- Fittings also passed an undocumented, in-place mass spec leak check after assembly
- Program maintains that successful completion of leak checks is adequate to mitigate risk and no further work is required
  - Fittings will leak if the stainless steel seal is not properly seated and crushed
  - High torque is required to crush the seal
  - Fittings would leak if they were not properly torqued
- System will be filled with ammonia before flight offering an opportunity for detection of gross leakage

This briefing is for status only and does not represent complete engineering data analysis

NCE Assessment of Proposed Solution

T. Wilson

28 Apr 05

- AN- fittings are assembly-sensitive
  - Potential for hidden flaws due to undetected defect in sealing surface or fitting
  - Proper lubrication required to prevent galling and false torque
  - Correct torque level required for joint integrity
    - Fittings may pass leak check without proper torque
    - Assertion they will always fail leak check if not properly assembled has not been demonstrated by test
- Leak check alone is not sufficient to demonstrate integrity of the joints
  - Improperly assembled fitting may pass leak check but fail when subjected to vibration or thermal cycles
  - System will not see significant thermal cycles (cold shock) until flight

This briefing is for status only and does not represent complete engineering data analysis

Recommended Course of Action

T. Wilson

28 Apr 05

- NCE Recommended Course of Action
  - NESC initiate a formal assessment of the ISS Node-2 AN fitting issue
  - Objectives
    - Demonstrate fittings will always leak unless seal is crushed
    - Demonstrate torque required to crush seal will provide joint integrity
    - Verify certification envelopes flight environment
    - Conduct testing if required to shore up certification
    - Explore options for in-place leak checks with system in flight configuration
- Rationale
  - Provides confidence fittings will not leak when Node is flown

This briefing is for status only and does not represent complete engineering data analysis

Resources Expended	T. Wilson 28 Apr 05

Resource Category		Expended
Labor	NASA	8 hours
	Other Government Agencies	
	Contractor	
Facility/Tool Costs		
Travel		
Other Direct Expenses		

This briefing is for status only and does not represent complete engineering data analysis

Appendix I. AN Fitting Threaded Fastener Calculations

Analysis of 1" AN Fitting Threads

Prepared by David Dawicke, NASA LaRC

A threaded fitting has a manufactured recommended torque range of 95-114 ft-lbf. During a test the fitting was assembled using a torque of 136 ft-lbf because the stainless steel seals that were used required a torque range of 125-145 ft-lbf. Post-test examination did not show any thread deformation during magnified visual examination. Other fittings were reportedly performed at an even higher torque range (173-210 ft-lbf) and visual thread deformations were observed. The purpose of this analysis is to determine if the threaded fitting will experience thread yielding at 136 ft-lbf and if repeated loading to 136 ft-lbf would result in a fatigue failure.

The analysis indicated that the 136 ft-lbf torque loading of the fitting will **not yield** the fitting. The high ductility of the CRES 304 steel would **not result in fatigue damage** for the expected 100's of loading cycles. However, the typical recommended tightening torque is 70-80% of the yield torque. The torque range, specified by Stratoflex, results in peak stresses that are 68-83% of the yield torque, roughly within the recommended range. The 136 ft-lbf torque loading would result in peak stresses that were 98% of the yield torque, outside of the typical recommended range. The following paragraphs describe the analysis used to support the above conclusions.

An analysis was conducted to determine the torque that causes thread yielding in a 1 inch diameter threaded fastener. Also, the fatigue life under repetitive torque loading was examined. Standard machine design stress formulas were used to estimate the thread yielding due to the torque loading. The fatigue life was calculated using a simple SN approach. The material behavior was obtained from the SAE Aerospace Material Specification (AMS) handbook.

The details of the threaded fastener are given in Table 1. The thread details were obtained from the design drawings from Stratoflex. The yield stress was obtained from the SAE Aerospace Material Specification for bars greater than 0.5 inch. The stress concentration factor for the threads and the empirical friction coefficient were obtained from handbook values.

Table 1. Thread Fastener Details

Material	CRES 304
Yield Stress (ksi)	30
Ultimate Stress (ksi)	75
Thread Designation	1.3125-12 UNJ-3A
Threads per inch	12
Diameter (inch)	1
Torque Range (ft-lb)	95 - 210
Stress Concentration Factor (K_t)	2.4
Empirical Friction Coef (C)	0.2

Standard threaded fastener equations were used to determine the peak stress at the first thread. The applied torque was converted to an axial force using the empirical friction coefficient.

$$F = T/(C\ d) \quad (1)$$

Where:
F = axial force
T = applied torque
C = empirical friction coefficient
d = fitting diameter

The effective cross sectional area of the fitting was determined from the fitting diameter and pitch of the threads.

$$A_s = \pi/4\ (d - 0.9743/n) \quad (2)$$

Where:
n = number of threads per inch

The peak stress at the first thread was determined from the axial force and the stress concentration factor.

$$\sigma = K_t\ F/A_s \quad (3)$$

where:
σ = peak stress

A summary of the calculations is provided in Table 2. Yielding at the threads is calculated to occur for applied torque greater than 138 ft-lbf.

Table 2. Summary of Stress Calculations

T	F	A_s	S_{avg}	σ
Given	F=T/(C d)	A_s=Pi/4(d - 0.9743/n)'	$S_{avg} = F/A_s$	$\sigma = K_t S_{avg}$
Torque (ft-lbf)	Axial Force (lbs)	Area subjected to stress (inch^2)	Average Stress (ksi)	Max local stress at 1st thread (ksi)
95	5700	0.663	8.6	20.6
114	6840	0.663	10.3	24.8
125	7500	0.663	11.3	27.1
136	8160	0.663	12.3	29.5
138	8280	0.663	12.5	**30.0**
145	8700	0.663	13.1	**31.5**
173	10380	0.663	15.7	**37.6**
210	12600	0.663	19.0	**45.6**

Appendix J. 1” AN Fittings Engineering Test Report

Glenn Research Center
Engineering & Technical Services Directorate
DEF/Thermal & Fluid Systems Branch

1" AN Fittings Testing

Engineering Test Report

October 20, 2005

Bruce Frankenfield

DE-REP-05-01

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APPENDIX

1. INTRODUCTION

1.1 Scope

This Engineering Test Report describes the testing details of the three NESC tests that were performed at the NASA Glenn Research Center. The NESC tests were accomplished, per the Mimic Test Plan DE-TP-05-01A, by either the Mimic Test Procedure DE-PROC-05-01 or the Surface Finish Test Procedure DE-PROC-05-02.

1.2 Background

The NASA Engineering and Safety Center (NESC) Independent Technical Assessment (ITA) team was formed to investigate a potential leakage concern regarding the AN-type fittings used on the International Space Station (ISS) – Node 2 Ammonia System. This leakage issue was raised because AN fittings have a track record of leaking in KSC's ammonia ground system and that the Node 2 fittings may have the same problem. During this NESC investigation, the NESC Assessment Team decided to recommend/conduct four different tests to better evaluate this potential leakage concern. The first test was performed at the Kennedy Space Center (KSC) on the Node 2 flight hardware, while the last three tests were performed at Glenn Research Center (GRC).

- The first recommended test was a **Pressure Decay Test** on the Node 2 ammonia system flight system to verify the flight system integrity. This test was approved and was accomplished by KSC personnel with satisfactory results. (Refer to Technical Assessment Report, Section 7.2.1 and Appendix E).
- The second recommended test was a **Mimic Test** which duplicated the Node 2 flight AN fitting's assembly process, all pressure cycles, the transportation vibrations and the launch qualification vibrations, from assembly to operation in orbit. All hardware used for the Mimic Tests were flight hardware (AN fittings, SS Conical Seals and Flex Hoses). These tests used multi-torqueing of the fittings and were conducted in two different series: Series A - surface finish of the flex hose connections at 16 μ-inch, and Series B – surface finish of the flex hose connections at 100 μ-inch. The surface finish for the male AN fitting was 16 μ-inch for both series of tests. All Mimic Tests were conducted by NESC assessment team personnel at GRC.
- The third recommended test was a **Surface Finish Test**, which performed leak tests on a connection with a flex hose end connection having a 100 μ-inch surface finish. This test was accomplished due to conflicting information of the flex hose sealing surface finish (100 μ-inch vs. 16 μ-inch). All Surface Finish Tests were conducted by the NESC Assessment Team personnel at GRC.
- This fourth recommended test was a **Single Application of Torque Test**, which performed leak tests on a connection which was assembled with a single application of torque. This test was accomplished since the Node 2 flight hardware assembly procedures did not address multi-torqueing, but the Assessment Team felt was critical to ensure system integrity. All Single Application of Torque Tests were conducted by NESC Assessment Team personnel at GRC.

2. APPLICABLE DOCUMENTS

The following applicable documents are part of the Appendices in the AN Type Fittings in the ISS Node 2 Ammonia System - Technical Assessment Report. The test requirements and the test sequence are described in the Mimic Test Plan, while the detail test procedure steps to perform the testing are described in the Test Procedures.

- DE-TP-05-01A Mimic Test Plan
- DE-PROC-05-01 Mimic Test Procedure
- DE-PROC-05-02 Surface Finish Test Procedure

3. TEST DESCRIPTION

3.1 Test Facility

The Mimic Tests were conducted in the Structural Dynamics Lab, Bldg 56, at NASA Glenn Research Center, Cleveland, Ohio. The Lab's vibration test equipment includes a horizontal shaker table, its control system and its data recording system. The helium leak testing equipment included a Veeco helium leak detector and the helium supply system, which was relocated from the Zero Gravity Facility to the Structural Dynamics Lab for this test. The Surface Finish Tests, which did not require vibration testing, were conducted at the Zero Gravity Facility.

3.2 Test Article

For the Mimic Tests, the Test Article used identical flight hardware to the maximum possible extent. The Mimic Tests used the following hardware:

- 1" AN union fitting (Parker PS5174J1616)
- Stainless steel conical seals (Voi-Shan VSF1015S16)
- Two flight simulated flex hoses (Titeflex 1F96454-529)
- Nut and sleeves (AN818-16K and AS5176J16)
- Thread lubricant (Braycote 803)

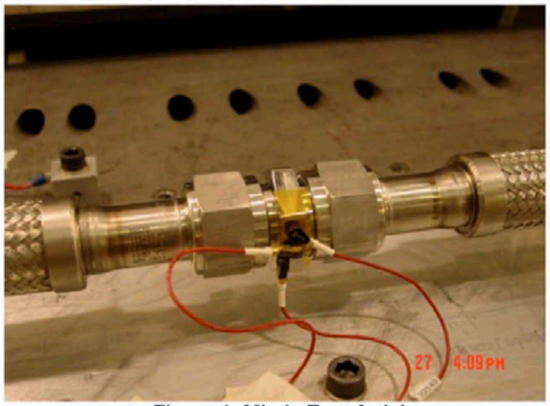

Figure 1. Mimic Test Article

All Test Article components used were identical to Node 2 flight hardware component, except for the flex hoses. The Node 2 ammonia system flight flex hoses were unavailable. Spare ISS flight flex hoses of the same size and style were used for the Mimic Tests. The one difference between the Node 2 flex hoses and the test flex hoses were the test hoses had tube stub ends, which were meant to be hard welded into the system. The test flex hoses were modified with new machined end connections, which were welded on the tube stub ends. The new end connections matched the Node 2 flex hose end connection specification, with a sealing surface finish machined to a 16 μ-inch finish.

3.3 Leak Testing

Two methods of leak testing were done during the Mimic Test. The quantitative leak test method was the “Baggie-Type” helium leak test, per NASA specification SSP 41172 Rev U, 4.2.11.2H Test Description and Alternatives, Method VIII – Accumulation. The maximum acceptable leak rate is 3.6 x 10^{-4} sccs He at 500 psia per seal. The time required for the system to be at pressure is 5 minutes prior to taking the reading instead of the required 30 minutes referenced in the current version of SSP 41172. At the time Alenia performed their leak checks, Method VIII was not included in SSP 41172. This 5 minute period is the approximate minimum wait time Alenia used during their “Baggie-Type” leak checks. The “Baggie-Type” leak test method produces an actual quantifiable leak rate value.

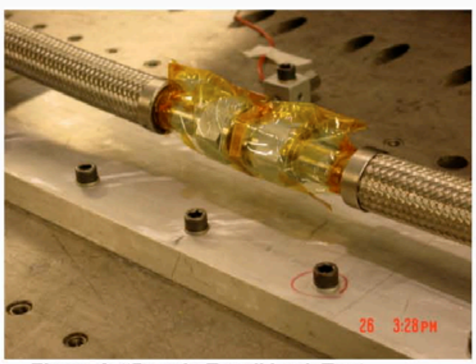

Figure 2. “Baggie-Type” Leak Test Bags

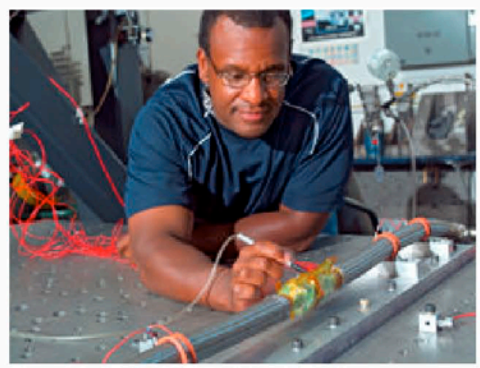

Figure 3. “Baggie-Type” Leak Testing

The pass/fail, non-quantitative leak test method was the “Probe-Type” helium leak, per NASA specification SSP 41172 Rev U, 4.2.11.2E Test Description and Alternatives, Method V – Detector Probe. The maximum acceptable leak rate is 3.6 x 10^{-4} sccs HE at 500 psia per seal. The time required for the system to be at pressure is 5 minutes prior to taking the reading instead of the required 30 minutes reference in SSP 41172. This 5 minute period is the agreed upon minimum wait time Alenia used during their “Probe-Type” leak checks (ref. RIA-NASA-00851). The “Probe-Type” leak test method only produces pass/fail leak rate.

3.4 Vibration Testing

The Test Article (1" AN fitting, stainless steel seals and two flex hoses) was mounted to the vibration table surface using an aluminum plate fixture, which simulated actual installation for random vibration testing. See Figure 5 - Test Article Mounted on the Shaker Table. The Test Article was held by two tubing loop clamps on 23" centers, symmetric about the 1" AN fitting, plus two more tubing loop clamps near the free ends of both flex hoses. The assembly was pressurized to 150 psia during the random launch qualification vibration testing. Each Test Article was tested to the vibration level conditions as defined in the Mimic Test Plan.

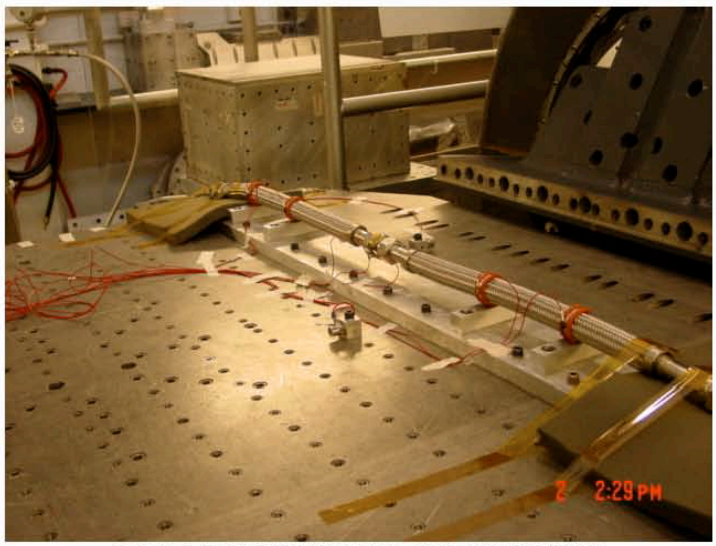

Figure 4. Test Article Mounted on the Shaker Table

3.5 Test Equipment

The test equipment used for the recorded measurements, during the Mimic Testing, was the following:

- The torque wrench was an adjustable, click-type, fixed ratchet, 50-250 ft-lb range. Snap-on, model # BRUTUS3R250D, with a 4% accuracy tolerance.
- The pressure transducer was a digital readout type. Digibar, model # PE 100, 0-1000 psig range, with a +/- 1 psig tolerance.
- The helium leak source was crimped capillary-type. Model # VSLC-4/5-3C-He-1/4T-400PSI-BFV, with a calibrated flow vs. pressure curve, with a +/- 0.2 x10^{-4} sccs flow tolerance.
- The helium leak tester was a mass spectrometry type. Veeco model - MS-31D. The "Baggie-type" leak testing accuracy is +/- 0.5 x10^{-6} sccs.
- The helium supply system was used for pressurization and leak testing the Test Article.

4. TESTING SUMMARY

All the NESC tests were accomplished, per the Mimic Test Plan DE-TP-05-01A, by either the Mimic Test Procedure DE-PROC-05-01 or the Surface Finish Test Procedure DE-PROC-05-02.

The assembly process for the Test Article strived to use the same techniques and assembly procedures for all Test Articles. Special attention was given to consistently duplicate the thread lubrication techniques, the sealing surface cleaning methods, and the method of multi-torqueing the fittings.

Figure 5. Torque Application During Assembly

4.1 Mimic Testing (Series A) Summary

Mimic Test #1 fully completed the required Mimic test sequence. The first Test Article used flex hoses with machined end fittings. After the assembly, both joints passed the initial leak test in step 2.0, with measured leak rates of 9.2 $x10^{-5}$ and 6.9 $x10^{-6}$ sccs. After the pressure cycles in steps 3.0 and 4.0, the "Probe-Type" leak test, in step 5.0, both joints had passing leak rates, but one joint was only marginally passing. That joint was retested using the more quantitative "Baggie-Type" leak test and it passed, with a measured leak rate of 2.1 $x10^{-4}$ sccs. For all future tests, step 5.0 was changed to the "Baggie-Type" leak test, instead of the "Probe-Type" leak test. The test article was subjected to vibration testing in steps 6.0 and 8.0, and pressure cycles in steps 7.0, 9.0 & 10.0 and the test article passed all required leak tests. In step 7.0, both joints passed the "Probe-Type" leak tests. In step 9.0, both joints passed with leak rates which were too low to measure (<1 $x10^{-6}$ sccs) and in step 10.0, the final leak rates were the <1.0 $x10^{-6}$ and 2.9 $x10^{-6}$ sccs. No physical damage was observed during the vibration testing. The torque relaxation measurement was not taken for this test. After the fitting disassembly, a visual inspection of the flex hose end connections found one surface scratch and the AN union had an indent blemish on its sealing surface. Possible causes of the scratches and blemish may have been particle contamination from the flex hose, which may not have been completely cleaned after welding. Future assembly steps will include a thorough cleaning of the flex hoses and also the mating sealing surfaces prior to assembly.

Mimic Test #2 fully completed the required Mimic test sequence. The Test Article used same AN union, but replaced, with new, the flex hoses and the conical seals. After the assembly, both joints passed the initial leak test in step 2.0, with leak rates of (<1 x10^{-6} sccs). After the pressure cycles in step 3.0 and 4.0, the both joints passed the "Baggie-Type" leak test in step 5.0, with a leak rate of 5.2 x10^{-6} and <1 x10^{-6} sccs. The test article was subjected to vibration testing in steps 6.0 and 8.0, and pressure cycles in step 7.0, 9.0 & 10.0 and the test article passed all required leak tests. In step 7.0, both joints passed the "Probe-Type" leak tests. In steps 9.0 and 10.0, both joints passed with leak rates that were too low to measure (<1 x10^{-6} sccs). No physical damage was observed during the vibration testing. The torque relaxation was measured for each connection at 130 ft-lbs and 135 ft-lbs. After the fitting disassembly, a visual inspection of both flex hose end connections found no damage, but the AN union had a surface fretting marks on both sealing surfaces.

Mimic Test #3 fully completed the required Mimic test sequence. The Test Article used same AN union, but replaced, with new, the flex hoses and the conical seals. After the assembly, both joints passed the initial leak test in step 2.0, with leak rates of 1.6 x10^{-4} and 1.1 x10^{-4} sccs. After the pressure cycles in steps 3.0 and 4.0, the both joints passed the "Baggie-Type" leak test in step 5.0, with a leak rate of 1.8 x10^{-4} and 1.4 x10^{-4} sccs. The test article was subjected to vibration testing in steps 6.0 and 8.0, and pressure cycles in step 7.0, 9.0 & 10.0 and the test article passed all required leak tests. In step 7.0, both joints passed the "Probe-Type" leak tests. In step 9.0, both joints passed with leak rates that were 1.6 x10^{-4} and 1.3 x10^{-4}. In step 10.0, both joints passed the final leak test with leak rates that were 2.9 x10^{-4} and 1.2 x10^{-4} sccs. No physical damage was observed during the vibration testing. The torque relaxation was measured for each connection at 135 ft-lbs and 115 ft-lbs. After the fitting disassembly, a visual inspection of both flex hose end connections found some surface pitting and the AN union had a surface fretting marks on both sealing surfaces. (See Appendix A – Tabulated Test Results Summary).

4.2 Surface Finish Testing Summary

The Surface Finish Tests used a machined end cap, which had the identical profile as the machined flex end connections, except the surface finish was 100 μ-inch. This test only performed a "baggie-type" leak test on the joint with the cap.

The first test used, as the Test Article, the same AN union from the Mimic Tests –Series A and the new 100 μ-inch cap and new conical seals. This joint failed the initial leak test at a leak rate of 3.6 x10^{-2} sccs.

Five more 100 μ-inch caps were fabricated for additional tests to duplicate the results in test run #15.

The next six tests used, as the Test Article, a new AN union fitting, new seals and new 100 μ-inch cap. Five out six joints passed the "baggie-type" leak test. The one joint which failed was likely caused by misalignment of the seal during assembly (next to last test). The leak rates were 5.9 x10^{-5}, 9.7 x10^{-5}, 3.6 x10^{-5}, 1.3 x10^{-4}, *2.0 x10^{-3}* and 1.9 x10^{-5} sccs. (See Appendix A – Tabulated Test Results Summary).

Since, the test data showed that flex hoses with a 100 µ-inch surface finish would likely pass the acceptance leak test, the assessment team felt is was necessary to perform the full mimic test using flex hoses with a 100 µ-inch surface (Mimic Test-Series B).

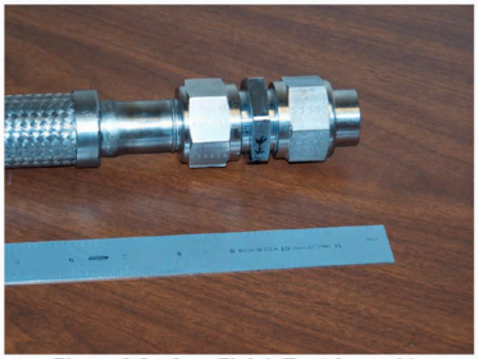

Figure 6 Surface Finish Test Assembly

4.3 Mimic Testing (Series-B) Summary

The Mimic Testing (Series-B) performed the identical tests as Mimic Testing (Series-A), except that the flex hose end connections had a 100 µ-inch surface finish, instead of a 16 µ-inch surface finish.

Mimic Test #4 fully completed the required Mimic test sequence. The Test Article used new AN union, conical seals and new flex hoses with end connections with a 100 µ-inch surface finish. After the assembly, both joints passed the initial leak test in step 2.0, with leak rates of <1.0 x10^{-6} sccs. After the pressure cycles in steps 3.0 and 4.0, the both joints passed the "Baggie-Type" leak test in step 5.0, with a leak rate of <1.0 x10^{-6} sccs. The test article was subjected to vibration testing in steps 6.0 and 8.0, and pressure cycles in steps 7.0, 9.0 & 10.0 and the test article passed all required leak tests. In step 7.0, both joints passed the "Probe-Type" leak tests. In steps 9.0 and 10.0, both joints passed with leak rates that were all <1.0 x10^{-6} sccs. No physical damage was observed during the vibration testing. The torque relaxation was measured for each connection at 120 ft-lbs and 125 ft-lbs. After the fitting disassembly, a visual inspection of both flex hose end connections found no defects and the AN union had a surface fretting marks on both sealing surfaces. (See Appendix A – Tabulated Test Results Summary).

4.4 Single Application of Torque Test Summary

These tests were conducted during Mimic tests. The test article used new flex hoses and new seals for this test. The test altered AN fitting assembly technique, by using only a single application of torque on the fitting. Three of four leak tested joints failed the initial leak test, with leak rates of >1.0 x10^{-2}, 1.4 x10^{-3}, 5.7 x10^{-4} and 1.5 x10^{-4} sccs. These results lead the assessment team to believe that multi-torqueing was necessary, and was performed on the flight hardware (see Appendix A – Tabulated Test Results Summary).

5. TEST OBSERVATIONS

5.1 Test Observations

- Proper assembly techniques are essential to obtaining a below specification joint leak rate.
- Torqueing the assembly, without a back-up wrenches, will cause the joint to rotate at the mating surface and possible damage to the sealing surface.
- Lubrication of the threads are essential for accurate and consistant torque values.
- Single torqued AN fittings have a high rate of failure.
- Multiple applications of torque on AN fittings have a higher rate of success.
- Flex hose sealing surface finish of 16 μ-inches and 100 μ-inches can both yield successful results.
- In all but one case, the leak rates decreased or stayed the same after a fitting has been exposed to the pressurizations and vibrations as seen by Node 2's ammonia system.
- Once an AN fitting had an acceptable post assembly leak rate, it never leaked above specification despite numerous pressurizations and vibrations.

DE-REP-05-01

Appendix A

Mimic Tests - Series A   Test Results Summary

Summary Table of test results of the three Test Articles,
per Mimic Test Plan DE-TP-05-01A and Mimic Test Procedure DE-PROC-05-01.

step	measurement	units	Test 1 Flex Hose conn. #1	Test 1 Flex Hose conn #2	Test 2 Flex Hose conn #1	Test 2 Flex Hose conn #2	Test 3 Flex Hose conn #1	Test 3 Flex Hose conn #2
	Date Test Completed		7/29/05	7/29/05	8/3/05	8/3/05	8/8/05	8/8/05
1.4.6 & 1.4.12	Flex Hose tag number		# 3	# 1	# 5	# 8	# 9	# 11
1.4.6 & 1.4.12	initial torque	ft-lbs	136	136	136	136	136	136
2.12.7 & 2.13.7	bag method leak rate	sccs	9.2×10^{-5}	6.9×10^{-6}	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$	1.6×10^{-4}	1.1×10^{-4}
5.5.4 Note 1	probe leak indication		pass	pass	n/a	n/a	n/a	n/a
5.5 Note 1	bag method leak rate	sccs	2.1×10^{-4}	n/a	5.2×10^{-6}	$<1.0 \times 10^{-6}$	1.8×10^{-4}	1.4×10^{-4}
7.5.4	probe leak indication		pass	pass	pass	pass	pass	pass
9.8.5 & 9.9.4	bag method leak rate	sccs	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$	1.6×10^{-4}	1.3×10^{-4}
10.4.5 & 10.5.4	bag method leak rate	sccs	$<1.0 \times 10^{-6}$	2.9×10^{-6}	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$	2.9×10^{-4}	1.2×10^{-4}
11.3.4 & 11.3.10	final torque	ft-lbs	n/a	n/a	130	135	135	115
			pass	pass	pass	pass	pass	pass

Maximum acceptable leak rate is 3.6×10^{-4} sccs per seal.
Note 1 - After test 1, the test procedure was modified at step 5.5.
The bag method leak test was performed (per steps 2.12 & 2.13), instead of probe method leak test.

DE-REP-05-01

Mimic Tests - Series B Test Results Summary (100 µ-inch flex hose conn.)

Summary Table of test results of the one Test Article,
per Mimic Test Plan DE-TP-05-01A and Mimic Test Procedure DE-PROC-05-01.

step	measurement	units	Test 4 Flex Hose connection #1	Test 4 Flex Hose connection #2
	Date Test Completed		9/20/05	9/20/05
1.4.6 & 1.4.12	Flex Hose tag number		# 27	# 31
1.4.6 & 1.4.12	initial torque	ft-lbs	136	136
2.12.7 & 2.13.7	bag method leak rate	sccs	0.3×10^{-6}	0.3×10^{-6}
5.5	bag method leak rate	sccs	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$
7.5.4	probe leak indication		pass	pass
9.8.5 & 9.9.4	bag method leak rate	sccs	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$
10.4.5 & 10.5.4	bag method leak rate	sccs	$<1.0 \times 10^{-6}$	$<1.0 \times 10^{-6}$
11.3.4 & 11.3.10	final torque	ft-lbs	120	125
			pass	pass

Maximum acceptable leak rate is 3.6×10^{-4} sccs per seal.

DE-REP-05-01

Surface Finish Tests - Test Results Summary (100 µ-inch flex hose conn.)

Summary Table of test results from the Surface Finish Tests,
per Mimic Test Plan DE-TP-05-01A and Surface Finish Test Procedure DE-PROC-05-02.

step	measurement	units	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
	Date Test Completed		8/8/05	8/23/05	8/23/05	8/23/05	8/23/05	8/23/05	8/23/05
1.4.6	Cap tag number		# 0	# 2	# 3	# 4	# 5	# 8	# 8
	Cap Surface Finish	micro -inch	100	100	100	100	100	100	100
1.4.6	Initial torque	ft-lbs	136	136	136	136	136	136	136
2.9.7	Bag method leak rate	sccs	$3.6x10^{-2}$	$5.9x10^{-5}$	$9.7x10^{-5}$	$3.6x10^{-5}$	$1.3x10^{-4}$	$2.0x10^{-3}$	$1.9x10^{-5}$
1.4.6	Final torque	ft-lbs	130	125	115	120	130	115	130
			Fail	Pass	Pass	Pass	Pass	Fail	Pass

Maximum acceptable leak rate is 3.6×10^{-4} sccs per seal.

All tests used a new flight AN Union, except Test 1, which used the original AN union fitting (F-1) in the Mimic Tests 1, 2 & 3, and Test 7, which used the opposite end of the AN Union that was used in Test 6.

DE-REP-05-01

Single Application of Torque Tests - Test Results Summary

Summary Table of test results from the Single Application of Torque Tests, per Mimic Test Plan DE-TP-05-01A and Mimic Test Procedure DE-PROC-05-01.

step	measurement	units	Test 1	Test 2	Test 3	Test 3
	Date Test Completed		8/3/05	8/3/05	8/3/05	8/3/05
	Joint #		2	2	2	1
1.4.6	Initial torque	ft-lbs	136	136	136	136
2.9.7	Bag method leak rate	sccs	$>1.0 \times 10^{-2}$	1.4×10^{-3}	5.7×10^{-4}	1.5×10^{-4}
1.4.6	Final torque	ft-lbs	115	125	n/a	n/a
			Fail	Fail	Fail	Pass

Maximum acceptable leak rate is 3.6×10^{-4} sccs per seal.

All tests used a new flight AN Union, except Test 1, which used the original AN union fitting (F-1) in the Mimic Tests 1, 2 & 3, and Test 7, which used the opposite end of the AN Union that was used in Test 6.

Appendix K. List of Acronyms

ARES	Applied Research and Engineering Sciences Corporation
AS	Aerospace Standards
DCMA	Defense Contract Management Association
EATCS	External Active Thermal Control System
GRC	Glenn Research Center
He	Helium
ISS	International Space Station
ITA	Independent Technical Assessment
JSC	Johnson Space Center
KSC	Kennedy Space Center
lbf	pounds force
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NCE	NESC Chief Engineer
NCR	Non-conformance Report
NDE	NESC Discipline Expert
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
O_2	Oxygen
psia	pounds per square inch absolute
PVS	Procedure Variance Form
QD	Quick Disconnects
sccs	standard cubic centimeters per second
SM&A	Safety Mission & Assurance
SS	Stainless Steel
SSP	Space Shuttle Program
TIM	Technical Interchange Meeting
WSTF	White Sands Test Facility

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Based on an anonymous request, an NESC Assessment Team was formed to investigate potential leakage problems from the ISS Program's Node 2 Anhydrous Ammonia System AN fittings. The Team's charter was to provide the ISS Program with a path to follow, which could include testing, to ensure the ISS Program felt confident that the AN fittings' leakage would not exceed specified limits in orbit. The findings from that assessment are contained in this document.

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Ammonia System; AN fittings; ISS; NESC; Node 2

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