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Test and Inspection Requirements for Frangible Joints Used in Human-Rated Spacecraft Applications

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Contents

Acronyms

AIAA	American Institute of Aeronautics and Astronautics
DOD	Department of Defense
DVT	Design Verification Test
FJ	frangible joint
FOD	foreign object debris
ID	identifier
JSC	Johnson Space Center
MDC	Mild Detonating Cord
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
MPE	maximum predicted environment
XTA	Expanding Tube Assembly

1.0 INTRODUCTION

The purpose of this document is to define a series of test and inspection requirements for a specific type of frangible joint (FJ) assembly used in human-rated spacecraft applications. It is intended to be an enhancement to the Commercial Crew Program Johnson Space Center (JSC) 62809D Human Rated Spacecraft Pyrotechnic Specification[1] and lists very specific tests and inspections with accompanying tables. This document does not eliminate any of the requirements stated in JSC 62809D.

Pyrotechnics devices such as FJ assemblies are inherently single-use mechanisms; consequently, the inability to test and demonstrate performance of the actual flight articles significantly affects the methods by which these devices are certified. Since the actual flight units themselves cannot be destructively evaluated, separate test units must be used in their place. The test articles must be equivalent to those used for flight for this to be effective. To gain confidence in the flight article performance, the pyrotechnic industry relies on the following methods:

- Single lot control
- Strict configuration and process controls
- Thorough nondestructive inspections
- Exposure to flight environments with margin
- Rigorous destructive testing of randomly selected samples
- Periodic age life sample testing of previously manufactured flight hardware

These methods are invaluable for revealing issues within distinct lots of pyrotechnic devices, although the effectiveness of these methods is limited by the degree to which they are applied and by how accurately flight conditions can be replicated in ground tests. Although performance failure of any destructive test sample is a cause to reject the entire lot, a successful sampling test, even under ideal conditions, still does not guarantee that no defects exist in the untested flight hardware and that it will perform as designed. Given these constraints, a robust test and inspection plan is critical to ensure that the system functions as designed with high reliability.

FJ assemblies have been used on unmanned space applications and military platforms for many years. Various industry and government standards define the test requirements for the acceptance and qualification of a broad category of hardware typically identified as frangible devices.[2,3,4] However, these standards do not cover all the requirements that are expected for a human-rated spacecraft and, in many instances, these standards lack specific details for FJ test articles and the associated test methods.

FJs are unsuitable for a typical randomly selected sample testing and inspection methods because of their large size, geometry, and complicated assembly processes. Deviations from the traditional approaches create unknowns associated with using FJs that go above and beyond those of other pyrotechnic devices.

FJs are typically used for fairing or stage separation. These parts can exceed 15 feet in length and are often curved to fit the vehicle circumference. The parts cannot be tested in the same conditions that will be present during flight since the full-scale parts do not usually fit on standard vibration tables or shock test plates. Instead, sub-length (reduced-length) assemblies must be specially manufactured for test purposes. The configuration of these subassemblies cannot be arbitrary. The configuration must replicate the dual-flight initiation interfaces identically and allow for applicable post-function inspections of the critical functional parameters of the hardware. Due to the deviation from test-like-you-fly approach, a robust, well-defined and unified single set of test and inspection requirements for these devices are extremely critical for human-rated spacecraft applications.

Many of the test and inspections in this document—particularly within the material certification, product acceptance, qualification, lot acceptance, and age life extension sections—are standard operating procedure for suppliers. This document provides detail on the individual items to avoid ambiguity. In particular, this document details the test and inspection requirements for offset notch (e.g., Sure-Sep, Two-Plate, or other shear notch concepts) style FJs with aluminum machined plates where the separation at the notch is a result of shock-induced shear. It is expected that a user would tailor the contents of this document for his or her particular vehicle application and provide a certifying organization with rationale for such tailoring. Tailoring to the requirements of this document requires approval of the certifying organization (e.g., NASA for a NASA human space flight program).

It is likely that suppliers on mature FJ designs have already conducted a number of the tests (e.g., detonation transfer margin tests) contained herein. Evidence of a successful test is acceptable in lieu of repeating a test if the specimens were representative of the FJ design under consideration. However, the user must provide a qualification by similarity justification in accordance with JSC 62809D, Section 4.4.10.

The FJ must perform in accordance with design specifications after subjection to all environments it would encounter in its lifecycle. This document does not cover all possible environments that may exist in unique applications; a user may determine that additional tests are necessary. The user must develop written inspection and test procedures with detailed acceptance criteria.

Note that the test tables within the body of the document were taken from the full table set and edited for ease of viewing, displaying only the information relevant to the particular section of the document. The full table set is included in the appendix. The requirements within these tables will be updated, as necessary, after the completion of the NASA Engineering and Safety Center FJ test and modeling project.

2.0 Design Verification Tests

2.1 Discussion

Design Verification Tests (DVTs) are conducted to verify an FJ design approach, prove out manufacturing processes, evaluate the effect of environmental exposure, and demonstrate proper function in the initial stages of an FJ design prior to qualification. Per Note A in Figure 1, the table includes tests recommended for typical FJ designs that may be modified, as appropriate. If a user is considering only minor modifications to an existing FJ design with mature manufacturing processes, similar full-scale geometry, and extensive flight history in similar environments, the focus on DVTs may not be as great as in applications with little history.

Recommended testing includes environmental exposure of six specimens, with subsequent function of two each at indicated temperatures. The Mild Detonating Cord (MDC) core load range for these tests should replicate those of normal flight hardware.

Design Verification Tests	
Test Specimen Configuration	Sublength (See Note B)
Quantity	6
Test Title (See Note A)	**Test Matrix**
Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation	X
Helium Leak	X
Thermal Cycle	X
Sine Vib (if applicable)	X
Random Vib	X
Shock	X
Helium Leak	X
Ambient Temperature Functional Test	2
High Temperature Functional Test	2
Low Temperature Functional Test	2

Note A	Indicated tests are recommended for typical FJ designs. Suppliers may add to or modify this test matrix as appropriate to reflect unique features or sensitivities of their application.
Note B	Test specimens shall be sublength FJ assemblies representative of flight hardware. Specimens shall include ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process as flight hardware. MDC shall be manufactured using the same production process as flight hardware.

Figure 1. Design Verification Tests table.

Prior to testing, full-length radiographs are taken of each FJ specimen using techniques that reveal several features. The MDC sheath and core are inspected to verify no cracks or other damages are present. The MDC to booster cup interface is inspected to verify the gap is within design limits. The charge holder is inspected to verify no gaps exist beyond design limits in the area of the end fittings. The radiographs establish the hardware acceptability prior to testing. The user may choose to repeat radiographic inspection after the DVT environmental exposure, especially in cases of extreme environments, to verify no damage occurred prior to functional tests.

Helium leak testing is conducted before and after environmental exposure to verify the FJ specimens have pretest sealing integrity of the internal energetics and integrity is maintained after exposure. Testing should be conducted on both ends of the assembly, with the exact methodology developed and documented by the user. The indicated leak rate acceptance criteria should be established per AIAA-S-113-2005, Method 103, based on actual leak rate requirement of $1x10^{-6}$ standard cubic centimeters per second (std cc/s) helium.

A thermal cycle test is conducted prior to dynamic environmental tests as defined in Military Standard (MIL-STD)-1576, Method 3407, or AIAA-S-113-2005, Method 204. Sine vibration (if applicable), random vibration, and shocks tests are performed using a test setup that simulates the flight boundary conditions. The test tolerances should meet the limits defined in AIAA-S-113-2005, Method 205, for the shock tests and Method 206 for the vibration tests.

Functional testing is conducted at ambient temperature, maximum predicted temperature during flight at time of function, and minimum predicted temperature during flight at time of function. Testing at high temperature will be conducted using simultaneous detonation inputs at both input ports, whereas ambient and low-temperature testing will be conducted using a single detonation input. Each specimen must achieve full separation with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If an explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection.

2.2 Configuration

Per Figure 1, Note B, test specimens will be sub-length FJ assemblies representative of, and built using the same manufacturing processes as, flight hardware.

2.3 Acceptance Criteria

Acceptance criteria includes full separation of each specimen with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection.

3.0 Margin/Development Tests

3.1 Detonation Transfer Margin Tests

3.1.1 Discussion

Within an FJ design, detonation must propagate across air gaps at the interfaces between the detonation inputs (typically explosive transfer line end tips or detonator end tips) and the booster cups installed onto each end of the internal MDC of the FJ. Detonation must also propagate across the discontinuity between each booster cup and the ends of the MDC.

Detonation Margin Tests identifiers (IDs) 1001 through 1005, shown in the Margin/Development Test table (Figure 2), demonstrate the ability of detonation to transfer across gaps in excess of design minimums and/or maximums. Tests IDs 1003 and 1004 may be combined together or with Test ID 1002 with suitable rationale provided by the user.

3.1.2 Configuration

Per Figure 2, Note A, test specimens are sub-length MDC assemblies with booster cups installed on each end. Prior to testing, acceptance of the specimens will be conducted per IDs 2001 through 2014 (see Appendix).

Specimens for ID 1005 include a gap between the MDC and the booster cup that is 4x the design maximum. For IDs 1001 through 1004, specimens are initiated at the near end at noted gaps/misalignments using explosive transfer line or detonators. The specimens for ID 1005 are initiated similarly but at the nominal design gap and alignment.

Margin / Development Tests							
ID	Test Specimen Configuration	MDC Assembly (See Note A)					
	Test Group	A	B	C	D	E	**Rationale**
	Quantity	5	5	5	5	5	
	Test Title	**Test Matrix**					
1001	Detonation transfer margin (at detonation input to Booster cup interface) - minimum gap margin at room temp	X					Demonstrate detonation transfer margin at explosive interfaces
1002	Detonation transfer margin (at detonation input to Booster Cup interface) - maximum gap margin at room temp		X				
1003	Detonation transfer margin (at detonation input to Booster Cup interface) - maximum axial misalignment margin at room temp			X			
1004	Detonation transfer margin (at detonation input to Booster Cup interface) - maximum angular misalignment margin at room temp				X		
1005	Booster cup to MDC max gap margin at room temp					X	

Note A	Groups A thru E specimens shall be sublength Mild Detonating Cord (MDC) assemblies with Booster Cups installed on each end. Specimens shall be manufactured under the same production process as flight hardware, except that Group E specimens will include an internal gap between the MDC and the Booster Cap.

Figure 2. Margin/Development Tests table, IDs 1001 through 1005, Specimen Groups A–E.

3.1.3 Acceptance Criteria

Successful detonation propagation into and through the MDC is determined by examination of witness sleeve, dent plate, or similar device at the far end of each MDC specimen.

3.1.4 References

AIAA S-113-2005 paragraphs 6.2.5.1 & 6.2.5.1.1 and MIL-HDBK-83578 paragraph 4.4.3.1 provide more detail on transfer margin across air gaps or discontinuities. Minimum and maximum gaps demonstrated for use on manned flight have traditionally been 1/2x and 4x the minimum and maximum design gap, respectively. Users should document and justify the gaps and angular/axial misalignments chosen for their testing via the tailoring process with associated rationale.

3.2 Functional Margin Tests

3.2.1 Discussion

The Functional Margin test series is conducted to demonstrate that the FJ is able to successfully separate when margin is applied to certain design features that are likely key to proper operation. The series primarily examines features that, at extreme limits, could potentially lead to improper function. One test series is conducted to demonstrate the ability of the FJ to separate without losing structural integrity, and includes a corollary option to characterize debris produced during this extreme event. The Margin/Development Tests table, including Functional Margin Tests, is shown in Figure 3.

Margin / Development Tests							
ID	Test Specimen Configuration	Sublength (See Note B)					
	Test Group	F	G	J	K	L	**Rationale**
	Quantity	6	6	6	6	5	
	Test Title						
1006	80% MDC core load margin (test 1/2 quantity at high temp & 1/2 quanitity at low temp)	X					Demonstrate ability to separate nominal rings using MDC with lower output, accounts for manufactuing & lot-to-lot variability
1007	120% MDC core load margin (test 1/2 quantity at high temp & 1/2 quantity at low temp)		X				Demonstrate ability to separate nominal rings using MDC with higher output without secondary fracture or rupture/outgassing
1008	Debris characterization (if design is sensitive to debris), perform concurrently with 120% MDF core load margin tests		X				Collect and analyze debris to evaluate versus vehicle sensitivity (if applicable to vehicle design)
1009	120% max notch thickness margin (test 1/2 quantity at high temp & 1/2 quantity at low temp)			X			Demonstrate ability to separate notch thickness higher than design limit using nominal MDC, accounts for dimensional & material variability
1010	Leg thickness margin tests (test 1/2 quantity at high temp & 1/2 quantity at low temp) (see Note C)				X		
1011	Ring assymetry tests (at room temp)					X	Demonstrate ability to separate with each side of ring geometry at opposing design tolerance extremes using nominal MDC, accounts for dimensional variability
Note B	Groups F thru L, N , & P test specimens shall be sublength FJ assemblies representative of flight hardware except for features specifically noted (e.g. core load, notch thickness). Specimens shall include ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process as flight hardware.						
Note C	Leg thickness margin levels shall be determined on a case by case basis, if the notch fracture has sensitivity to the variations in leg thickness.						

Figure 3. Margin/Development Tests table, IDs 1006-1011, Specimen Groups F-L.

3.2.2 Configuration

Per Figure 3, Note B*, all test specimens are sub-length FJ assemblies including ring segments, expanding tube assemblies, and end fittings. Prior to testing, acceptance of the specimens will be conducted per IDs 2001 through 2029 (see Appendix). It is expected that a user will evaluate his or her flight FJ configuration and justify the use of straight versus curved specimens. Except as specified, each test is conducted at high and low temperatures that bound maximum predicted environment (MPE) in the flight application to examine any effects on explosive output, material strength, etc. With the exception of ID 1007, each specimen is initiated at one end via explosive transfer line or detonator while the port in the far end fitting is plugged.

Test IDs 1006 and 1009 shown in Figure 3 examine the effect of low MDC core load and excessive ring notch thickness. ID 1006 is conducted on FJ specimens with nominal ring cross-section loaded with MDC at a core load $\leq$ 80% of the design tolerance minimum. ID 1009 is conducted with nominal MDC core load while notch thickness is $\geq$ 120% of the design tolerance maximum. Testing at low temperature verifies proper function with any reduction of MDC output, increase in charge holder stiffness, or shrinkage of charge holder material due to thermal effects. High temperature testing verifies proper operation in cases where ring material may become more ductile or charge holder material more pliable.

Test ID 1007 is conducted to demonstrate the ability to separate without loss of structural integrity. The FJ specimens have nominal ring cross-section and MDC at a core load $\geq$ 120% of the design tolerance maximum. These specimens are to be initiated simultaneously at both ends so that the detonation waves meet along the length of the specimen. Because ID 1007 is likely to produce the most debris, ID 1008 may be conducted concurrently at the user's discretion to collect and characterize debris if the user has identified a sensitivity in the overall vehicle design. Testing is conducted at a high temperature to maximize the output of the MDC, whereas low- and high-temperature testing is conducted to demonstrate proper function in the presence of any thermal effects on MDC output, ring and expanding tube material properties, and charge holder material properties.

Test IDs 1010 and 1011 examine variations in ring cross-sectional dimensions and are conducted using nominal core load MDC. Per Figure 3, Note C, ID 1010 focuses on leg thickness and is conducted on specimens manufactured at design extremes of thickness to verify the resulting change in leg stiffness does not impact separation. The user must determine whether a design is more sensitive to thin or thick legs and test accordingly; if unknown, the user may choose to tailor the testing to examine both extremes. ID 1011 examines the effect of extreme asymmetry of rings on FJ performance, with the dimensions on each side of each specimen manufactured at opposite design extremes. This testing is conducted to verify differences in structural "strength" between each side of the specimen will not result in incomplete fracture of one side of the specimen.

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* Note the text in Note B in Figure 3 is taken directly from the full table found in the Appendix. Only the references to Groups F through L apply to this section. Groups N and P are discussed in the Demonstration of Function with Structural Loading section.

3.2.3 *Acceptance Criteria*

Acceptance criteria includes full separation of each specimen with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If an explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection. Minor sooting may also be observed around the port plug and is not cause for rejection. It is expected that fine particulates may be liberated from the rings during function. If ID 1008 is conducted, collected debris must not exceed user's established limits (size and velocity) for his or her vehicle application.

3.3 Establish Quantitative Performance Measurement

3.3.1 *Discussion*

Figure 4 shows part of the Margin/Development Test table for test ID 1012, Specimen Group M. The intent of ID 1012 is to drive establishment of a methodology for quantitatively measuring Expanding Tube Assembly (XTA) performance along with determining minimum and maximum acceptance limits for that performance. Once these limits have been established, they will be applied during qualification testing as well as during testing of individual production lots of hardware.

Margin / Development Tests			
ID	Test Specimen Configuration		
	Test Group	M	Rationale
	Quantity	A/R	
	Test Title		
1012	Establish quantitative performance acceptance range for production lots of XTA	X	

Figure 4. Margin/Development Tests table, ID 1012, Specimen Group M.

3.3.2 *Configuration*

The user should determine the specimen configuration that enables reliable performance measurements to be taken, considering the unique sizing and features of the FJ application on his or her vehicle. To research potential methodologies and develop a database, a user may choose to take advantage of other testing conducted during the Margin/Development series, applying instrumentation and/or investigating various pretest and posttest measurements on existing specimens. Alternately, a user may focus on a particular specimen configuration (i.e., Specimen Group M) that requires a unique test series.

3.3.3 *Acceptance Criteria*

Acceptance criteria includes an established methodology to quantitatively measure XTA performance along with minimum and maximum limits for acceptance. A user should document measurement methodology along with the data and the statistical basis for establishing the limits. The methods developed by the users require approval of the certifying organization (e.g., NASA for a NASA human space flight program) for final implementation.

3.4 Demonstration of Function with Structural Loading

3.4.1 Discussion

Certain vehicle applications may subject an FJ to high structural loads prior to the time of function. In extreme cases, this loading environment may lead to localized yielding and work hardening of the FJ fracture notch. Significant loading conditions may also be present during flight at the time of FJ function, either during nominal flight or during potential abort scenarios. These conditions may not be applicable individually or in combination to a specific vehicle design, in which case the related tests need not be performed. In those cases where one or both of these loading conditions exist, Test IDs 1013 and 1014 shown in Figure 5 are intended to demonstrate successful FJ separation during or after exposure.

Margin / Development Tests				
ID	Test Specimen Configuration	Sublength (See Note B)		
	Test Group	N	P	Rationale
	Quantity	8	4	
	Test Title			
1013	The following test is applicable to designs subject to localized yielding/work hardening of the notch area and which are required to function under significant flight loading conditions: Cumulative Damage / Loading Test: a) Apply cyclic flight loads to (2) sublength specimens with min notch thickness and function while applying max predicted flight load at time of function. b) Apply cyclic flight loads to (2) sublength specimens with max notch thickness and function while applying max predicted flight load at time of function. c) Apply cyclic flight loads to (2) sublength specimens with min notch thickness and function without application of load. d) Apply cyclic flight loads to (2) sublength specimens with max notch thickness and function without application of load.	X		Demonstrate unit functionality with work hardening and with flight loading
1014	The following test is applicable to designs which are not subject to localized yielding/work hardening of the notch area but are required to function under significant flight loading conditions: Loading Test: a) Function (2) sublength specimens with min notch thickness while applying max predicted flight load at time of function. b) Function (2) sublength specimens with max notch thickness while applying max predicted flight load at time of function.		X	Demonstrate units functionality under flight loads
Note B	Groups F thru L, N , & P test specimens shall be sublength FJ assemblies representative of flight hardware except for features specifically noted (e.g. core load, notch thickness). Specimens shall include ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process as flight hardware.			

Figure 5. Margin/Development Tests table, IDs 1013-1014, Specimen Groups N and P.

Given that several scenarios could exist, the following tests are conducted as applicable:

- **Application includes work hardening as well as function under load (ID 1013a through 1013d)** – Cyclic loads derived from worst-case predicted environments are applied to eight sub-length specimens: four with notches at minimum design tolerance, and four with notches at maximum design tolerance. Subsequent to cyclic loading, certain specimens (as detailed in 1013a and 1013b) are functioned while the maximum predicted flight structural load at the time of function is applied. Other specimens (as detailed in 1013c and 1013d) are functioned without application of structural load.

- **Application includes work hardening, but not function under load (ID 1013c and 1013d)** – Cyclic loads derived from worst-case predicted environments are applied to four sub-length specimens; two with notches at minimum design tolerance, and two with notches at maximum design tolerance. Subsequent to cyclic loading, the specimens (as detailed in 1013c and 1013d) are functioned without application of structural load.

- **Application includes function under load, but no work hardening of notch (ID 1014a and 1014b)** – Four sub-length specimens are produced: two with notches at minimum design tolerance, and two with notches at maximum design tolerance. The specimens are (as detailed in 1014a and 1014b) are functioned while the maximum predicted flight structural load at the time of function is applied.

3.4.2 Configuration

Per Note B,[†] all test specimens are sub-length FJ assemblies including ring segments, expanding tube assemblies, and end fittings. Specimens will be manufactured as noted with notch thicknesses at minimum or maximum design tolerance extremes. It is expected that a user will evaluate his or her flight FJ configuration and justify the use of straight versus curved specimens. For ease of test, it is acceptable to apply cyclical loading to inert ring segment assemblies, then subsequently assemble XTA and end fittings into specimens prior to functional tests. Due to potential difficulty in precisely applying loads to specimens, users should consider instrumenting specimens with strain gages. These scenarios are primarily for compressive loading cases. User should determine the effects of the tensile loading on the FJ performance and test accordingly, if needed. Each specimen is initiated at one end via explosive transfer line or detonator while the port in the far end fitting is plugged.

3.4.3 Acceptance Criteria

Acceptance criteria includes full separation of each specimen with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection. Minor sooting may also be observed around the port plug and is not cause for rejection.

[†] The text in Note B in Figure 5 is taken directly from the full Margin/Development Test table (see Appendix). Only the references to Groups N and P apply to this section. Groups F through L are discussed in the Functional Margin Tests section.

4.0 Material Certification

4.1 Discussion

The three tables in Figure 6 include inspections and tests that are conducted "in process" as material is received and FJ subcomponents are manufactured. The tables address the MDC, the booster cups of the MDC, and other piece parts used in FJ construction. The items in the tables ensure that the constituent materials, as well as the finished subcomponents, meet design and performance requirements.

The inspections and tests in Figure 6 are to be conducted on all deliverable hardware as well as on all specimens used for testing. As such, these tables are referenced at the start of qualification and acceptance testing.

Material Certification		
ID	**Test Title**	**Quantity**
MDC Acceptance Inspection & Tests		
2001	Material Certifications	All
2002	Explosive Moisture Content (prior to loading)	Sample
2003	Visual	All
2004	Dimensional Inspection	Sample
2005	Core Load	Sample
2006	Velocity of Detonation	Sample
2007	X-Ray	All
2008	N-Ray	All

Material Certification		
ID	**Test Title**	**Quantity**
Booster Cup Acceptance Inspection & Tests		
2009	Material Certifications	All
2010	Explosive Moisture Content (prior to loading)	Sample
2011	Visual	All
2012	Dimensional Inspection	Sample
2013	Explosive Load Height	All
2014	X-Ray and N-Ray (See Note A)	All

Note A	N-Ray is required for all booster cups. User may choose to perform the booster N-Ray at the FJ assembly level Test ID 2028

Material Certification		
ID	**Test Title**	**Quantity**
Ring, Expanding Tube, Chargeholder, Manifold/End Fitting, etc Acceptance Inspection & Tests		
2015	Material Certifications & Heat Treat Records	All
2016	Ring & Expanding Tube Stock Material NDE	All
2017	First Article Inspection of Ring & Expanding Tube	Sample
2018	Dimensional Inspection (including 100% inspection of critical features)	All
2019	Ring Mechanical Properties after Heat Treat	Coupons from each end of each ring
2020	Ring & Expanding Tube NDE after machining / forming	All
2021	Expanding Tube Mechanical Properties after Heat Treat	Coupons from each end of each tube
2022	Chargeholder Material Properties	Durometer test along length of chargeholder

Figure 6. Material Certification table, IDs 2001 through 2008, 2009 through 2014, and 2015 through 2022.

Referring to Figure 6, ID 2001, ID 2009, and ID 2015 involve inspection of certifications and records for all indivi1dual components and raw materials to verify specification requirements and design specific requirements (e.g., single lot control) are met, are documented, and are traceable. Properties verified include physical and chemical properties of metals, heat treat records, explosive material analysis results, certifications and properties (as applicable) for elastomers, adhesives, and lubricants, and verification of shelf life for applicable materials.

ID 2002 and 2010 require verification of explosive moisture content prior to loading the MDC and booster cups. A sample of each explosive material is analyzed to verify conformance with user-established requirements.

ID 2003 through ID 2008 are inspections and tests conducted on the MDC after its manufacture. The MDC is 100% visually inspected for cracks, neckdowns, or other flaws. Samples of MDC are cut from the end of each tube for core load determination and dimensional inspection as well as velocity of detonation determination. Each MDC is radiographically inspected for voids, cracks, neckdowns, and foreign material, with specific acceptance criteria determined and documented by the user.

ID 2011 through ID 2014 are inspections conducted on MDC booster cups after loading. The booster cups are 100% visually inspected for cracks, dents, or other flaws. Explosive load height is 100% inspected to meet design requirements, and sample booster cups are inspected to ensure dimensions meet design requirements. Each radiograph of the booster cup is inspected for voids and foreign material, with specific acceptance criteria determined and documented by the user.

ID 2016 and ID 2020 are nondestructive inspections conducted on the ring and expanding tube material. ID 2016 is conducted on stock material prior to manufacturing whereas ID 2020 is conducted after machining and forming of material. The user will document the particular nondestructive methodologies and acceptance criteria used. Nondestructive inspections will also take into account the fracture criticality of the hardware.

ID 2017 and ID 2018 are dimensional inspections of all piece parts to verify design requirements are met. ID 2017 involves inspection of all dimensions on a first article of each part. ID 2018 is an inspection of all parts, with the user documenting the sampling level for each dimension as well as those critical dimensions for which 100% inspection is conducted.

ID 2019 and ID 2021 are tests to verify the mechanical properties of each ring and expanding tube meet specification requirements after heat treatment. IDs 2019 and 2021 involve cutting coupons from each end of each ring or tube and conducting mechanical property tests.

ID 2022 verifies the hardness of the charge holder material is within specification limits. The charge holder durometer will be inspected at user-established intervals along its length.
Depending on the design sensitivities, minimum and maximum material properties and dimensions should be established on all FJ critical components.

4.2 Configuration

The configuration of each item will vary, from inspection of certification paperwork to samples of finished subcomponents that are subject to testing. More detail on specific configurations is given in the Discussion subsection within this section.

4.3 Acceptance Criteria

This section includes numerous tests and inspections, and acceptance details are included in the Discussion subsection. Each item inspected or tested should meet design and specification requirements, and results should be documented and traceable for each part number and lot number. Failures of nondestructive tests and inspections result in rejection of the particular item. If a sampling method is used, any feature of a sample unit found to be discrepant will require 100% inspection of the entire lot for that feature.

5.0 Product Acceptance

5.1 Discussion

The series of “nondestructive” inspections and tests shown in Figure 7 are conducted, unless otherwise noted, on finished FJ assemblies, both full-length units as well as sub-length test units. The inspections demonstrate that individual units meet design requirements.

It is essential that the charge holder remain in place over the MDC inside the XTA tube so that the output of the MDC is effectively coupled to the tube. Thermal extremes or dynamic environments must not result in charge holder movement that results in gaps in MDC coverage within the tube. The user should verify via analysis and/or in-process inspections that his or her XTA design precludes charge holder gaps when exposed to worst-case natural and induced environments.

The inspections and tests in Figure 7 are to be conducted on all deliverable hardware as well as on all specimens used for testing. As such, this table is referenced at the start of qualification and acceptance testing.

ID 2023 involves 100% visual inspection of FJ units for no damage, cleanliness, no missing or improperly oriented parts, proper input port threads, no foreign object debris (FOD) in end fittings, and proper marking. Particular attention will be given to the fracture notch area along the length of the FJ and to the ends of the rails to ensure no damage is observed. As an in-process inspection, the installation of booster cups onto the ends of each MDC is also visually inspected to verify proper installation and no damage.

Product Acceptance		
ID	**Test Title**	**Quantity**
Product Acceptance Inspections & Tests (On assembled Frangible Joints)		
2023	Visual Inspection	All
2024	Dimensional Inspection	All
2025	Electrical Bond	All
2026	Booster Cup - MDC Pull Test (In process)	All
2027	Helium Leak Test	All
2028	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation	All
2029	Weight	Sample

Figure 7. Product Acceptance table, IDs 2023 through 2029.

ID 2024 involves inspection of each FJ unit to verify dimensions of the assembled unit (e.g., length and height, radius [as applicable], position of mounting holes, sizing of input ports) meet design requirements.

ID 2025 is a test conducted on each end of each FJ unit that verifies the unit does not exceed Class S or Class R bond characteristics as applicable. The resistance between the detonation input port interfacing surface and the structural mounting surface on each FJ end fitting will be measured. For FJ applications using explosive transfer line for detonation input, the resistance must be 1 Ohm or less. For FJ applications utilizing detonators incorporating electro-explosive devices, the resistance must be 2.5 milliohms or less.

ID 2026 is a nondestructive test conducted during the FJ manufacturing process that verifies the booster cup is properly installed onto each end of each assembly. Booster cups that lack sufficient installation strength may loosen during exposure to environments, potentially preventing detonation transfer into the MDC. The user will determine the exact methodology for pulling on each booster cup without damage to the cup or other FJ hardware as well as the force and time of application. The cup must withstand the application of pull force without movement or visible damage. Proper cup-to-MDC interface gap will be verified during ID 2029 radiograph inspection.

ID 2027 involves verifying that the energetic material within the FJ assembly is hermetically sealed. Helium leak tests should be conducted on both ends of the assembly, with the exact methodology developed and documented by the user.

ID 2028 consists of full-length radiographs of each FJ assembly using techniques that reveal several features. The MDC sheath and core are inspected to verify no cracks or neckdowns resulting from installation into the assembly. The MDC to booster cup interface is inspected to verify the gap is within design limits and no FOD is present at the interface. The charge holder is inspected to verify proper installation with no gaps beyond design limits in the area of the end fittings. The booster cup location is inspected to verify proper alignment with the detonator port. Both X-Ray and N-Ray methods should be considered, as necessary.

ID 2029 involves weighing a sample of completed FJ assemblies to verify they meet design requirements.

5.2 Configuration

These inspections and tests are generally conducted on finished FJ assemblies, both full-length deliverable units as well as sub-length test units. In certain cases, as noted in the Discussion subsection of this section, items are conducted during the manufacturing process.

5.3 Acceptance Criteria

This section includes a variety of tests and inspections, and acceptance details are included in the Discussion subsection. Each item inspected or tested should meet design and specification requirements, and results should be documented and traceable for each serial number and lot number. The indicated leak rate acceptance criteria should be established per AIAA-S-113-2005, Method 103, based on actual leak rate requirement of $1x10^{-6}$ std cc/s helium.

6.0 Qualification Tests

6.1 Sub-length Specimens

6.1.1 Discussion

Qualification testing is conducted to demonstrate that an FJ design, materials, and manufacturing process meets specification requirements required to certify the design. Qualification testing includes exposure to worst-case natural and induced environments expected over the operational lifecycle of the FJ. The user has the option to conduct this testing on a dedicated production lot of FJ specimens or on specimens manufactured with the first production lot of deliverable flight hardware, in which case qualification serves as the acceptance testing for that first production lot.

The qualification table shown in Figure 8 includes tests that expose specimens to environments that would be expected in a typical application, but may not capture unique environments as discussed in Note G. It is expected that a user will tailor the tests and sequences in this table, and will add unique testing as applicable to envelope the specific flight application of the hardware.

The qualification table includes three test groups, with the overall quantity of specimens in each group indicated. The sequential numbers within each test group indicate the applicable tests and the numerical sequence of each particular test. A number in parentheses indicates that a test is applicable to that sub-quantity of the overall test group, otherwise a test or inspection is applicable to all specimens in a group.

Referring to Figure 8, IDs 3001 and 3002 refer to the set of acceptance tests and inspections captured separately in this document as IDs 2001 – 2029. Materials and subcomponents used in the test specimens, as well as the specimens themselves, must successfully complete this series of tests and inspections.

ID 3004 is conducted to demonstrate that an undetected drop of an XTA will not prevent its proper function, once built into an FJ assembly. The three Group B specimens are each dropped once from a height of 6 feet onto a 0.5-inch minimum thickness steel plate. One of the three primary axes will be assigned to each specimen for drop orientation. If damage is visually detectable on a specimen per normal visual inspection criteria, that specimen will be removed from the sequence of subsequent tests. Alternately, testing may continue for engineering information only. If damage is not detectable, a specimen will continue the sequence of subsequent tests.

ID 3005 is conducted on the single XTA specimen in Group C. The specimen must not auto ignite after an hour of exposure to a temperature at least 50°F above the maximum predicted temperature during worst-case service life.

Qualification Tests				
ID	Test Specimen Configuration	Sublength (See Note A)	Sublength (See Note B)	Sublength XTA
	Test Group	A	B	C
	Quantity	15	3	1
	Test Title (See Note G)	**Sequence**		
3001	Material Certification	1	1	1
3002	Product Acceptance	2	2	2
3004	Six-Foot Drop (3 units, one drop per unit)		3	
3005	Auto-Ignition			3
3006	Salt Fog (if applicable to design)	3	4	
3007	High Temperature Storage (Age Life)	4 (10)		
3008	Thermal shock (if applicable to design)	5	5	
3009	Qual Level Thermal Cycle	6	6	
3010	Qual Level Sine Vib (if applicable)	7	7	
3011	Qual Level Random Vib	8	8	
3012	Qual Level Shock	9	9	
3013	Helium Leak Test	10	10	
3014	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	11	11	
3015	High Temperature Functional Test (See Note E)	12 (5)	12 (1)	
3016	Ambient Temperature Functional Test (See Note E)	12 (5)	12 (1)	
3017	Low Temperature Functional Test (See Note E)	12 (5)	12 (1)	
3018	Post-Functional Inspection of XTA and Ring Segments	13	13	
3019	Quantitive Performance Measurement	14	14	
Note A	Group A test specimens shall be sublength FJ assemblies, including ring segments and expanding tube assemblies (XTA) with flight-like end fittings, manufactured under the same production process and at the same time as the flight hardware. Ring segments may be cut from the ends of flight rings or they may be cut from sacrificial rings included in each heat treat batch. If multiple ring heat treat batches are included in a production lot of FJ's, ring segments from each batch shall be represented in the quantity of FJ test specimens.			
Note B	Group B test specimens shall be in accordance with Note A, except that Six-Foot Drop testing will be conducted only on the expanding tube assembles with flight-like end fittings. Following Six-Foot Drop testing, the expanding tube assemblies will be assembled into ring segments and testing will continue as indicated.			
Note E	Functional test setup of sublength specimens should address boundary conditions of flight articles. Test specimens shall be fixtured to replicate the interfacing structural attachment stiffness of the flight installation.			
Note G	The test matrix may not capture unique natural and induced environments (e.g. long duration space exposure, rain, cryogenic exposure, etc) that could be present in individual applications. Unique environments shall be evaluated and, subject to technical authority approval, added to the test matrix.			

Figure 8: Qualification Tests table, sub-length specimens, IDs 3001 through 3002, 3004 through 3019, Specimen Groups A through C.

ID 3006 and IDs 3008 through 3012 are environmental tests, as detailed below. After each test, the specimens will be visually examined and there must be no corrosion that would affect performance, no loosening or displacement of parts, and no visible damage. Specimens must successfully complete subsequent tests and inspections.

- ID 3006 salt fog, if applicable to a design, is conducted in accordance with MIL-STD-810, Method 509.
- ID 3008 thermal shock, if applicable to a design, is conducted in accordance with MIL-STD-810, Method 503.
- ID 3009 thermal cycle is conducted in accordance with MIL-STD-1576, Method 340,7 or AIAA-S-113-2005, Method 204. The temperature extremes are based on worst-case predicted environments for a particular FJ application.
- ID 3010 sine vibration testing is conducted if applicable to a particular design, in accordance with MIL-STD-810, Method 514.
- ID 3011 random vibration is conducted in accordance with AIAA-S-113-2005, Method 206.
- ID 3012 shock test is conducted in accordance with AIAA-S-113-2005, Method 205.

ID 3007 is an optional high-temperature exposure test to establish an initial 5-year age life for a production lot of FJs. It is included in the qualification table in the event a user performs qualification testing on specimens manufactured with the first production lot of deliverable FJs. Specific details on methodology, exposure times, and exposure temperatures can be found in AIAA S-113-2005 paragraph 5.5.1.3 (Method 209). If ID 3007 is not performed, the age life of the lot of FJs will be 1 year. The start date of the age life period will be the date of completion of testing that provides quantitative verification of acceptable performance. For usage of linear products such as MDC on manned flight, NASA has traditionally used the date of velocity of detonation testing to establish the start date for the age life period. However, ID 3019 is a quantitative measure of performance and, therefore, the date of completing IDs 3015–3017 is used as the age life start date.

ID 3013 helium leak testing is conducted after environmental exposure to verify the FJ specimens maintain sealing integrity of the internal energetics. Testing should be conducted on both ends of the assembly, with the exact methodology developed and documented by the user. The same acceptance criteria developed for ID 2027 should be utilized.

ID 3014 consists of full-length radiographs of each FJ specimen using techniques that reveal several features. The MDC sheath and core are inspected to verify no cracks or other damage resulting from environmental exposure. The MDC to booster cup interface is inspected to verify the gap remains within design limits. The charge holder is inspected to verify no gaps developed beyond design limits in the area of the end fittings. The booster cup location is inspected to verify proper alignment with the detonator port. Both X-Ray and N-Ray methods should be considered, as necessary.

IDs 3015 through 3017 consist of functional tests of FJ specimens. The tests are evenly divided between ambient temperature, testing at maximum predicted temperature during flight at time of function, and testing at minimum predicted temperature during flight at time of function. Testing at high temperature will be conducted using simultaneous detonation inputs at both input ports, whereas ambient and low temperature testing will be conducted using a single detonation input. Per Note E, test specimens will be fixtured to replicate the structural attachment stiffness of the flight installation. If one or more Group B specimens are eliminated from testing due to damage during 6-foot drop, the ambient specimen will be dropped from functional testing first, followed by the high-temperature specimen, then the low-temperature specimen. Posttest inspection and acceptance criteria are covered in ID 3018.

ID 3018 involves posttest inspection of each test specimen. Each specimen must achieve full separation with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection. Minor sooting may also be observed around the port plug and is not cause for rejection.

ID 3019 covers posttest inspection of the test specimens to measure predefined features (see ID 1012) and obtain quantitative performance measurements. These measurements will be compared to defined limits established via ID 1012 to verify acceptability.

6.1.2 Configuration

Per Notes A and B, Groups A and B test specimens will be sub-length FJ assemblies including all subcomponents present in full-scale assemblies, with specimen ring segments produced from flight rings. The Group C specimen will only consist of loaded XTA with assembled end fittings. All specimens will be manufactured using the same production process, and at the same time as full-scale flight assemblies.

6.1.3 Acceptance Criteria

This section includes a variety of tests and inspections, and acceptance details are included in the Discussion subsection. Results of testing, along with plotted data and worksheets, will be published in a test report.

6.2 Full-length Specimens

6.2.1 Discussion

Testing in the table shown in Figure 9 is part of FJ qualification and is unique in that it involves full-length specimens and, in the case of ID 3021, associated vehicle structures and subsystems. The user has the option to conduct this testing on a dedicated production lot of FJ specimens or on specimens manufactured with the first production lot of deliverable flight hardware.

Per note G, this table may not capture unique environments, and it is expected that a user will add tailor or add unique testing to this table as applicable.

The Qualification Table includes two test groups, with the overall quantity of specimens in each group indicated and discussed in further detail below. The sequential numbers within each test group indicate the applicable tests and the numerical sequence of each particular test. A remark in parentheses indicates that a test is applicable to that sub quantity of the overall test group.

IDs 3001 and 3002 refer to the set of acceptance tests and inspections captured separately in this document as IDs 2001 through 2029. The materials and subcomponents used in the test specimens, as well as the specimens themselves, must successfully complete this series of tests and inspections.

ID 3003 is a safety drop test conducted on the single full-length specimen in Group D. The specimen must not detonate or otherwise create a safety or disposal hazard as a result of the drop. Per Note C, this test will be conducted if mandated by the cognizant safety organization after the evaluation a particular FJ application.

Qualification Tests			
ID	Test Specimen Configuration	Full-Length Specimen (See Note C)	Full-Length Specimens (See Note D)
	Test Group	D	E
	Quantity	1	See below
	Test Title (See Note G)		
3001	Material Certification	1	1
3002	Product Acceptance	2	2
3003	Forty-Foot Drop	3	
3020	Thermal Expansion / Contraction		3 (One segment minimum)
3021	Full Scale Separation System Test(s) (See Note F)		4 (Flight Set)

Note C	Group D 40 Foot Drop safety test will be conducted if mandated by the cognizant safety organization. Test specimen shall be a full length FJ flight segment assembly including ring segments and expanding tube assembly with flight-like end fittings.
Note D	Group E test specimens shall be full-length FJ flight segment assemblies including ring segments and expanding tube assemblies with flight-like end fittings. A "Flight Set" will include the number of FJ segment assemblies necessary to span the circumference or linear distance of a separation plane (in large vehicle applications, this will typically include two or more FJ segment assemblies, where in smaller applications a single FJ segment assembly may span the entire separation plane).
Note F	A full scale separation test will be conducted to demonstrate that system separation performance requirements are met. Parameters to be evaluated include separation velocity, acceleration and angular motion; time to clear and clearances between separating hardware; flexible-body distortion and loads; amount of debris; and explosive shock levels. The data from the separation test is used to validate the analytical method and basic assumptions of the separation analysis. The validated method is then used to verify that requirements are met under worst-case flight conditions. When critical off-nominal conditions cannot be modeled with confidence, at least one additional separation test will be conducted to determine the effect on the separation process. Fixturing of full scale test specimens shall replicate the interfacing structural sections to simulate the separation subsystem boundary conditions existing in the flight article. Critical conditions of temperature, pressure, or loading due to acceleration shall be simulated or taken into account. The remaining boundary conditions for the separating bodies will simulate the conditions in flight at separation, unless the use of other boundary conditions permit an unambiguous demonstration that subsystem requirements can be met. When ambient atmospheric pressure may adversely affect the test results, such as for large fairings, the test will be conducted in a vacuum chamber duplicating the altitude condition encountered in flight at the time of separation.
Note G	The test matrix may not capture unique natural and induced environments (e.g. long duration space exposure, rain, cryogenic exposure, etc) that could be present in individual applications. Unique environments shall be evaluated and, subject to technical authority approval, added to the test matrix.

Figure 9. Qualification Tests table, full length FJ specimens, IDs 3001 through 3003, 3020, and 3021, Specimen Groups D and E.

ID 3020 is conducted to examine the dissimilar materials in the construction of an FJ and verify thermal expansion and contraction resulting from specimen exposure to MPE temperature extremes will not damage the segment assembly and will not affect its operation in subsequent testing. ID 3020 is performed on at least one of the flight segments that are subsequently functioned in the ID 3021 test. The specimen is fixtured to represent boundary conditions of the vehicle installation, including structural attachments of both the rings and the end fittings. The specimen is exposed to cycles of minimum and maximum predicted temperatures for an application, then examined to verify no buckling, permanent deformation, mechanical joint failure, or other visible damage is present.

ID 3021 full-scale separation testing utilizes an FJ flight set consisting of one or more full-length FJ flight segments as applicable per Note D and is conducted per Note F. The testing demonstrates that separation system performance requirements are met, including evaluation of separation dynamics, timing, and clearances, loads, debris, and shock levels. Fixturing and simulated environments will replicate in-flight boundary conditions. In cases where critical off-nominal boundary conditions cannot be modeled with confidence, additional full-scale testing may be conducted.

6.2.2 Configuration

Per Notes C and D, all test specimens will be full-length FJ flight segment assemblies, including ring segments, expanding tube assemblies, and end fittings. Larger vehicle applications will typically require two or more flight segment assemblies to span the circumference or linear distance of a separation plane and form a flight set. In smaller applications, a single segment may span the entire plane and constitute the flight set. The terminology “flight set” is therefore distinguished from “flight segment” in that multiple flight segments may be required to form a flight set depending on the application.

6.2.3 Acceptance Criteria

This section includes a variety of tests and inspections, and acceptance details are included in the Discussion subsection. Results of testing, along with plotted data and worksheets, will be published in a test report.

7.0 Lot Acceptance Tests

7.1 Discussion

Lot Acceptance Testing is conducted on each production lot of FJs to verify acceptable functionality and performance, verify adequate workmanship and material quality, and provide evidence of overall product acceptability for a given lot of hardware. Testing includes exposure to worst-case natural and induced environments over the lifecycle of an FJ. The user may tailor the tests and sequences in this table, and add unique testing as applicable.

Lot Acceptance Tests				
ID	Test Specimen Configuration	Sublength (See Note A)		
	Test Group	A	B	C
	Quantity	1/3 Specimens *	1/3 Specimens *	1/3 Specimens *
	Test Title	**Sequence**		
4001	Material Certification	1	1	1
4002	Product Acceptance	2	2	2
4003	High Temperature Storage (Age Life) (See Note B)	3	3	3
4004	Qual Level Thermal Cycle	4	4	4
4005	Qual Level Shock	5	5	5
4006	Qual Level Sine Vib (if applicable)	6	6	6
4007	Qual Level Random Vib	7	7	7
4008	Helium Leak Test	8	8	8
4009	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	9	9	9
4010	High Temp Functional Test (See Note C)	10		
4011	Ambient Temp Functional Test (See Note C)		10	
4012	Low Temp Functional Test (See Note C)			10
4013	Post-Functional Inspection of XTA and Ring Segments	11	11	11
4014	Quantitive Performance Measurement	12	12	12
* Total specimen quantity is the greater of 10 units or 10% of the lot. When quantity is not divisible by 3, odd units shall be assigned to Group C (low temp test), then Group A (high temp test).				
Note A	Test specimens shall be sublength FJ assemblies, including ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process and at the same time as the flight hardware. Ring segments may be cut from the ends of flight rings or they may be cut from sacrificial rings included in each heat treat batch. If multiple ring heat treat batches are included in a production lot of FJ's, ring segments from each batch shall be represented in the quantity of FJ test specimens.			
Note B	High Temperature Storage tests shall be conducted to establish an initial 5 year age life for a production lot. If High Temperature Storage tests are not conducted, an initial 1 year age life shall be established for a production lot.			
Note C	Functional test setup should address boundary conditions of flight articles. Test specimens shall be fixtured to replicate the interfacing structural attachment stiffness of the flight installation.			

Figure 10. Lot Acceptance Tests table, sub-length FJ specimens, IDs 4001 through 4014, Specimen Groups A through C.

In Figure 10, IDs 4001 and 4002 refer to the set of acceptance tests and inspections captured.

Figure 10 shows the Lot Acceptance Test Table. The Lot Acceptance Test includes three test groups, with the quantity of specimens equally divided between groups. As noted, the quantity tested will be 10 units or 10% of the lot, whichever is greater. The sequential numbers within each test group indicate the applicable tests and the numerical sequence of each particular test. IDs 4001 and 4002 refer to the set of acceptance tests and inspections captured separately in this document as IDs 2001 through 2029 (see Appendix). The materials and subcomponents used in the test specimens, as well as the specimens themselves, must successfully complete this series of tests and inspections.

ID 4003 is an optional high-temperature exposure test to establish an initial 5-year age life for a production lot of FJs. Specific details on methodology, exposure times, and exposure temperatures can be found in AIAA S-113-2005 paragraph 5.5.1.3 (Method 209). If ID 4003 is not performed, the age life of the lot of FJs will be 1 year. The start date of the age life period will be the date of completion of testing that provides quantitative verification of acceptable performance. For usage of linear products such as MDC on manned flight, NASA has traditionally used the date of velocity of detonation testing to establish the start date for the age life period. However, ID 4014 is a quantitative measure of performance and, therefore, the date of completing IDs 4010 through 4012 is used as the age life start date.

IDs 4004 through 4007 are environmental tests, as detailed below. The specimens will be visually examined after each test, and there must be no corrosion that would affect performance, no loosening or displacement of parts, and no visible damage. Specimens must successfully complete subsequent tests and inspections.

- ID 4004 thermal cycle is conducted in accordance with MIL-STD-1576, Method 3407, or AIAA-S-113-2005, Method 204. The temperature extremes are based on worst-case predicted environments for a particular FJ application.
- ID 4005 sine vibration testing is conducted if applicable to a particular design, in accordance with MIL-STD-810, Method 514.
- ID 4006 random vibration is conducted in accordance with AIAA-S-113-2005, Method 206.
- ID 4007 shock test is conducted in accordance with AIAA-S-113-2005, Method 205.

ID 4008 helium leak testing is conducted after environmental exposure to verify the FJ specimens maintain sealing integrity of the internal energetics. Testing should be conducted on both ends of the assembly, with the exact methodology developed and documented by the user. The same acceptance criteria developed for ID 2027 should be utilized.

ID 4009 consists of full-length radiographs of each FJ specimen using techniques that reveal several features. The MDC sheath and core are inspected to verify no cracks or other damage resulted from environmental exposure. The MDC to booster cup interface is inspected to verify the gap remains within design limits. The charge holder is inspected to verify no gaps developed beyond design limits in the area of the end fittings. The booster cup location is inspected to verify proper alignment with the detonator port. Both X-Ray and N-Ray methods should be considered, as necessary.

IDs 4010 through 4012 consist of functional tests of FJ specimens. The tests are evenly divided between ambient temperature, testing at maximum predicted temperature during flight at time of function, and testing at minimum predicted temperature during flight at time of function. Testing at high temperature will be conducted using simultaneous detonation inputs at both input ports, whereas ambient and low-temperature testing will be conducted using a single detonation input. Per Note C, test specimens will be fixtured to replicate the structural attachment stiffness of the flight installation. Posttest inspection and acceptance criteria are covered in ID 4013.

ID 4013 involves posttest inspection of each test specimen. Each specimen must achieve full separation with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection. Minor sooting may also be observed around the port plug and is not cause for rejection.

ID 4014 covers posttest inspection of the test specimens to measure predefined features (see ID 1012) and obtain quantitative performance measurements. These measurements will be compared to defined limits established via ID 1012 to verify acceptability.

7.2 Configuration

Per Figure 10, Note A, test specimens will be sub-length FJ assemblies including all subcomponents present in full-scale assemblies with specimen ring segments produced from flight rings. All specimens will be manufactured using the same production process, and at the same time as full-scale flight assemblies.

7.3 Acceptance Criteria

This section includes a variety of tests and inspections, and acceptance details are included in the Discussion subsection. Results of testing, along with plotted data and worksheets, will be published in a test report.

8.0 Age Life Extension Tests

8.1 Discussion

Age life extension tests are conducted to demonstrate that performance characteristics of an FJ production lot continue to meet acceptance criteria. Initial age life for an FJ production lot is established during lot acceptance testing, with the above test sequence used to extend the age life of that lot by the indicated time period. There is no limit to the number of times the age life of a production lot may be extended, as long as sufficient quantity of specimens from that lot are available to conduct testing. Age life specimens must be stored with the deliverable flight units from a lot so that they are exposed to the same environmental conditions. If the age life of an FJ production lot has expired, the age life testing in this section may be conducted to reestablish acceptability of the lot.

The user has the option of extending age life by 1- or 5-year periods by conducting the applicable set of testing indicated in the Age Life Extension Tests table in Figure 11. A 5-year extension utilizes additional test specimens and includes ID 5003 high-temperature storage tests. The sequential numbers within each test group indicate the applicable tests and the numerical sequence of each particular test. The start of the new age life period will be the date of completion of testing that provides quantitative verification of acceptable performance; i.e., the date of completing IDs 5010 through 5012 is used as the age life start date with ID 5014 providing the quantitative measure of performance.

ID 5001 involves 100% visual inspection of all FJ test specimens to verify no damage or corrosion, cleanliness, no missing or improperly oriented parts, and no FOD in end fittings. Particular attention will be given to the fracture notch area along the length of the FJ and to the ends of the rails to ensure no damage is observed. The MDC booster cups will be observed through both detonation ports to verify no signs of corrosion or damage.

ID 5002 and ID 5008 helium leak testing is conducted before and after environmental exposure to verify the FJ specimens have maintained sealing integrity of the internal energetics after extended storage as well as to verify sealing integrity has been maintained after environmental exposure tests are complete. Testing should be conducted on both ends of the assembly, with the exact methodology developed and documented by the user. The same acceptance criteria developed for ID 2027 should be utilized.

ID 5003 is an optional high-temperature exposure test to establish a 5-year age life extension for a production lot of FJs. Specific details on methodology, exposure times, and exposure temperatures can be found in AIAA S-113-2005 paragraph 5.5.1.3 (Method 209). If ID 5003 is not performed, the age life of the lot of FJs will be extended 1 year. The start date of the new age life period will be the date of completion of testing that provides quantitative verification of acceptable performance. For usage of linear products such as MDC on manned flight, NASA has traditionally used the date of velocity of detonation testing to establish the start date for the age life period. However, ID 5014 is a quantitative measure of performance and, therefore, the date of completing IDs 5010 through 5012 is used as the new age life start date.

ID	Test Specimen Configuration	Sublength (See Note A)			Sublength (See Note A)		
	Age Life Extension Time	One Year			Five Years		
	Test Group	A	B	C	A	B	C
	Quantity	2	1	2	4	2	4
	Test Title	**Test Matrix & Sequence**					
5001	Visual Inspection	1	1	1	1	1	1
5002	Helium Leak Test	2	2	2	2	2	2
5003	High Temperature Storage (Age Life)				3	3	3
5004	Qual Level Thermal Cycle	3	3	3	4	4	4
5005	Qual Level Shock	4	4	4	5	5	5
5006	Qual Level Sine Vib (if applicable)	5	5	5	6	6	6
5007	Qual Level Random Vib	6	6	6	7	7	7
5008	Helium Leak Test	7	7	7	8	8	8
5009	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	8	8	8	9	9	9
5010	High Temp Functional Test (See Note B)	9			10		
5011	Ambient Temp Functional Test (See Note B)		9			10	
5012	Low Temp Functional Test (See Note B)			9			10
5013	Post-Functional Inspection of XTA and Ring Segments	10	10	10	11	11	11
5014	Quantitive Performance Measurement	11	11	11	12	12	12

Note A	Test specimens shall be sublength FJ assemblies, including ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process and at the same time as the flight hardware. Ring segments may be cut from the ends of flight rings or they may be cut from sacrificial rings included in each heat treat batch. If multiple ring heat treat batches are included in a production lot of FJ's, ring segments from each batch shall be represented in the quantity of FJ test specimens.
Note B	Functional test setup should address boundary conditions of flight articles. Test specimens shall be fixtured to replicate the interfacing structural attachment stiffness of the flight installation.

Figure 11. Age Life Extension Tests table, 1- / 5-year age life tests on sub-length FJ specimens IDs 5001 through 5014, Specimen Groups A through C.

IDs 5004 through 5007 are environmental tests, as detailed below. After each test, the specimens are visually examined and there must be no corrosion that would affect performance, no loosening or displacement of parts, and no visible damage. Specimens must successfully complete subsequent tests and inspections.

- ID 5004 thermal cycle is conducted in accordance with MIL-STD-1576, Method 3407, or AIAA-S-113-2005, Method 204. The temperature extremes are based on worst-case predicted environments for a particular FJ application.
- ID 5005 sine vibration testing is conducted if applicable to a particular design, in accordance with MIL-STD-810, Method 514.
- ID 5006 random vibration is conducted in accordance with AIAA-S-113-2005, Method 206.
- ID 5007 shock test is conducted in accordance with AIAA-S-113-2005, Method 205.

ID 5009 consists of full-length radiographs of each FJ specimen using techniques that reveal several features. The MDC sheath and core are inspected to verify no cracks or other damage resulting from environmental exposure. The MDC to booster cup interface is inspected to verify the gap remains within design limits. The charge holder is inspected to verify no gaps developed beyond design limits in the area of the end fittings. The booster cup location is inspected to verify proper alignment with the detonator port. Both X-Ray and N-Ray methods should be considered, as necessary.

IDs 5010 through 5012 consist of functional tests of FJ specimens. The tests are divided between ambient temperature, testing at maximum predicted temperature during flight at time of function, and testing at minimum predicted temperature during flight at time of function. Testing at high temperature will be conducted using simultaneous detonation inputs at both input ports, whereas ambient and low temperature testing will be conducted using a single detonation input. Per Note B, test specimens will be fixtured to replicate the structural attachment stiffness of the flight installation. Posttest inspection and acceptance criteria are covered in ID 5013.

ID 5013 involves posttest inspection of each test specimen. Each specimen must achieve full separation with no secondary ring fracture, no expanding tube rupture, and no leakage of detonation by-products. If explosive transfer line is used for detonation input, minor sooting may occasionally be observed from the transfer line sheath and is not cause for rejection. Minor sooting may also be observed around the port plug and is not cause for rejection.

ID 5014 covers posttest inspection of the test specimens to measure predefined features (see ID 1012) and obtain quantitative performance measurements. These measurements will be compared to defined limits established via ID 1012 to verify acceptability. The measurements will also be compared to those taken on the same production lot of hardware during lot acceptance and examined for signs of performance degradation.

8.2 Configuration

Per Figure 11, Note A, test specimens will be sub-length FJ assemblies including all subcomponents present in full-scale assemblies with specimen ring segments produced from flight rings. All specimens will be manufactured using the same production process, and at the same time as full-scale flight assemblies.

8.3 Acceptance Criteria

This section includes a variety of tests and inspections, and acceptance details are included in the Discussion subsection. Results of testing, along with plotted data and worksheets, will be published in a test report.

9.0 Appendix – Full Test Tables

Test tables within the body of the document were taken from the full table set and edited for ease of viewing to only display information relevant to the particular section of the document. The full table set is included in this appendix.

Design Verification Tests	
Test Specimen Configuration	Sublength (See Note B)
Quantity	6
Test Title (See Note A)	**Test Matrix**
Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation	X
Helium Leak	X
Thermal Cycle	X
Sine Vib (if applicable)	X
Random Vib	X
Shock	X
Helium Leak	X
Ambient Temperature Functional Test	2
High Temperature Functional Test	2
Low Temperature Functional Test	2
Note A	Indicated tests are recommended for typical FJ designs. Suppliers may add to or modify this test matrix as appropriate to reflect unique features or sensitivities of their application.
Note B	Test specimens shall be sublength FJ assemblies representative of flight hardware. Specimens shall include ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process as flight hardware. MDC shall be manufactured using the same production process as flight hardware.

Margin / Development Tests															
ID	Test Specimen Configuration	MDC Assembly (See Note A)					Sublength (See Note B)						Sublength (See Note B)		
	Test Group	A	B	C	D	E	F	G	J	K	L	M	N	P	Rationale
	Quantity	5	5	5	5	5	6	6	6	6	5	A/R	8	4	
	Test Title	**Test Matrix**													
1001	Detonation transfer margin (at detonation input to Booster cup interface) - minimum gap margin at room temp	X													
1002	Detonation transfer margin (at detonation input to Booster Cup interface) - maximum gap margin at room temp		X												
1003	Detonation transfer margin (at detonation input to Booster Cup interface) - maximum axial misalignment margin at room temp			X											Demonstrate detonation transfer margin at explosive interfaces
1004	Detonation transfer margin (at detonation input to Booster Cup interface) - maximum angular misalignment margin at room temp				X										
1005	Booster cup to MDC max gap margin at room temp					X									
1006	80% MDC core load margin (test 1/2 quantity at high temp & 1/2 quanitity at low temp)						X								Demonstrate ability to separate nominal rings using MDC with lower output, accounts for manufactuing & lot-to-lot variability
1007	120% MDC core load margin (test 1/2 quantity at high temp & 1/2 quantity at low temp)							X							Demonstrate ability to separate nominal rings using MDC with higher output without secondary fracture or rupture/outgassing
1008	Debris characterization (if design is sensitive to debris), perform concurrently with 120% MDF core load margin tests							X							Collect and analyze debris to evaluate versus vehicle sensitivity (if applicable to vehicle design)
1009	120% max notch thickness margin (test 1/2 quantity at high temp & 1/2 quantity at low temp)								X						Demonstrate ability to separate notch thickness higher than design limit using nominal MDC, accounts for dimensional & material variability
1010	Leg thickness margin tests (test 1/2 quantity at high temp & 1/2 quantity at low temp) (see Note C)									X					
1011	Ring assymetry tests (at room temp)										X				Demonstrate ability to separate with each side of ring geometry at opposing design tolerance extremes using nominal MDC, accounts for dimensional variability
1012	Establish quantitative performance acceptance range for production lots of XTA											X			
1013	The following test is applicable to designs subject to localized yielding/work hardening of the notch area and which are required to function under significant flight loading conditions: Cumulative Damage / Loading Test: a) Apply cyclic flight loads to (2) sublength specimens with min notch thickness and function while applying max predicted flight load at time of function. b) Apply cyclic flight loads to (2) sublength specimens with max notch thickness and function while applying max predicted flight load at time of function. c) Apply cyclic flight loads to (2) sublength specimens with min notch thickness and function without application of load. d) Apply cyclic flight loads to (2) sublength specimens with max notch thickness and function without application of load.												X		Demonstrate unit functionality with work hardening and with flight loading
1014	The following test is applicable to designs which are not subject to localized yielding/work hardening of the notch area but are required to function under significant flight loading conditions: Loading Test: a) Function (2) sublength specimens with min notch thickness while applying max predicted flight load at time of function. b) Function (2) sublength specimens with max notch thickness while applying max predicted flight load at time of function.													X	Demonstrate units functionality under flight loads

Note A	Groups A thru E specimens shall be sublength Mild Detonating Cord (MDC) assemblies with Booster Cups installed on each end. Specimens shall be manufactured under the same production process as flight hardware, except that Group E specimens will include an internal gap between the MDC and the Booster Cap.
Note B	Groups F thru L, N , & P test specimens shall be sublength FJ assemblies representative of flight hardware except for features specifically noted (e.g. core load, notch thickness). Specimens shall include ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process as flight hardware.
Note C	Leg thickness margin levels shall be determined on a case by case basis, if the notch fracture has sensitivity to the variations in leg thickness.

Material Certification		
ID	**Test Title**	**Quantity**
MDC Acceptance Inspection & Tests		
2001	Material Certifications	All
2002	Explosive Moisture Content (prior to loading)	Sample
2003	Visual	All
2004	Dimensional Inspection	Sample
2005	Core Load	Sample
2006	Velocity of Detonation	Sample
2007	X-Ray	All
2008	N-Ray	All
Booster Cup Acceptance Inspection & Tests		
2009	Material Certifications	All
2010	Explosive Moisture Content (prior to loading)	Sample
2011	Visual	All
2012	Dimensional Inspection	Sample
2013	Explosive Load Height	All
2014	X-Ray and N-Ray (See Note A)	All
Ring, Expanding Tube, Chargeholder, Manifold/End Fitting, etc Acceptance Inspection & Tests		
2015	Material Certifications & Heat Treat Records	All
2016	Ring & Expanding Tube Stock Material NDE	All
2017	First Article Inspection of Ring & Expanding Tube	Sample
2018	Dimensional Inspection (including 100% inspection of critical features)	All
2019	Ring Mechanical Properties after Heat Treat	Coupons from each end of each ring
2020	Ring & Expanding Tube NDE after machining / forming	All
2021	Expanding Tube Mechanical Properties after Heat Treat	Coupons from each end of each tube
2022	Chargeholder Material Properties	Durometer test along length of chargeholder

Note A	N-Ray is required for all booster cups. User may choose to perform the booster N-Ray at the FJ assembly level Test ID 2028

Product Acceptance		
ID	**Test Title**	**Quantity**
Product Acceptance Inspections & Tests (On assembled Frangible Joints)		
2023	Visual Inspection	All
2024	Dimensional Inspection	All
2025	Electrical Bond	All
2026	Booster Cup - MDC Pull Test (In process)	All
2027	Helium Leak Test	All
2028	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	All
2029	Weight	Sample

Qualification Tests

ID	Test Specimen Configuration	Sublength (See Note A)	Sublength (See Note B)	Sublength XTA	Full-Length Specimen (See Note C)	Full-Length Specimens (See Note D)
	Test Group	A	B	C	D	E
	Quantity	15	3	1	1	See below
	Test Title (See Note G)	**Sequence**				
3001	Material Certification	1	1	1	1	1
3002	Product Acceptance	2	2	2	2	2
3003	Forty-Foot Drop				3	
3004	Six-Foot Drop (3 units, one drop per unit)		3			
3005	Auto-Ignition			3		
3006	Salt Fog (if applicable to design)	3	4			
3007	High Temperature Storage (Age Life)	4 (10)				
3008	Thermal shock (if applicable to design)	5	5			
3009	Qual Level Thermal Cycle	6	6			
3010	Qual Level Sine Vib (if applicable)	7	7			
3011	Qual Level Random Vib	8	8			
3012	Qual Level Shock	9	9			
3013	Helium Leak Test	10	10			
3014	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	11	11			
3015	High Temperature Functional Test (See Note E)	12 (5)	12 (1)			
3016	Ambient Temperature Functional Test (See Note E)	12 (5)	12 (1)			
3017	Low Temperature Functional Test (See Note E)	12 (5)	12 (1)			
3018	Post-Functional Inspection of XTA and Ring Segments	13	13			
3019	Quantitive Performance Measurement	14	14			
3020	Thermal Expansion / Contraction					3 (One segment minimum)
3021	Full Scale Separation System Test(s) (See Note F)					4 (Flight Set)
Note A	Group A test specimens shall be sublength FJ assemblies, including ring segments and expanding tube assemblies (XTA) with flight-like end fittings, manufactured under the same production process and at the same time as the flight hardware. Ring segments may be cut from the ends of flight rings or they may be cut from sacrificial rings included in each heat treat batch. If multiple ring heat treat batches are included in a production lot of FJ's, ring segments from each batch shall be represented in the quantity of FJ test specimens.					
Note B	Group B test specimens shall be in accordance with Note A, except that Six-Foot Drop testing will be conducted only on the expanding tube assembles with flight-like end fittings. Following Six-Foot Drop testing, the expanding tube assemblies will be assembled into ring segments and testing will continue as indicated.					
Note C	Group D 40 Foot Drop safety test will be conducted if mandated by the cognizant safety organization. Test specimen shall be a full length FJ flight segment assembly including ring segments and expanding tube assembly with flight-like end fittings.					
Note D	Group E test specimens shall be full-length FJ flight segment assemblies including ring segments and expanding tube assemblies with flight-like end fittings. A "Flight Set" will include the number of FJ segment assemblies necessary to span the circumference or linear distance of a separation plane (in large vehicle applications, this will typically include two or more FJ segment assemblies, where in smaller applications a single FJ segment assembly may span the entire separation plane).					
Note E	Functional test setup of sublength specimens should address boundary conditions of flight articles. Test specimens shall be fixtured to replicate the interfacing structural attachment stiffness of the flight installation.					
Note F	A full scale separation test will be conducted to demonstrate that system separation performance requirements are met. Parameters to be evaluated include separation velocity, acceleration and angular motion; time to clear and clearances between separating hardware; flexible-body distortion and loads; amount of debris; and explosive shock levels. The data from the separation test is used to validate the analytical method and basic assumptions of the separation analysis. The validated method is then used to verify that requirements are met under worst-case flight conditions. When critical off-nominal conditions cannot be modeled with confidence, at least one additional separation test will be conducted to determine the effect on the separation process. Fixturing of full scale test specimens shall replicate the interfacing structural sections to simulate the separation subsystem boundary conditions existing in the flight article. Critical conditions of temperature, pressure, or loading due to acceleration shall be simulated or taken into account. The remaining boundary conditions for the separating bodies will simulate the conditions in flight at separation, unless the use of other boundary conditions permit an unambiguous demonstration that subsystem requirements can be met. When ambient atmospheric pressure may adversely affect the test results, such as for large fairings, the test will be conducted in a vacuum chamber duplicating the altitude condition encountered in flight at the time of separation.					
Note G	The test matrix may not capture unique natural and induced environments (e.g. long duration space exposure, rain, cryogenic exposure, etc) that could be present in individual applications. Unique environments shall be evaluated and, subject to technical authority approval, added to the test matrix.					

Lot Acceptance Tests				
ID	Test Specimen Configuration	Sublength (See Note A)		
	Test Group	A	B	C
	Quantity	1/3 Specimens *	1/3 Specimens *	1/3 Specimens *
	Test Title	**Sequence**		
4001	Material Certification	1	1	1
4002	Product Acceptance	2	2	2
4003	High Temperature Storage (Age Life) (See Note B)	3	3	3
4004	Qual Level Thermal Cycle	4	4	4
4005	Qual Level Shock	5	5	5
4006	Qual Level Sine Vib (if applicable)	6	6	6
4007	Qual Level Random Vib	7	7	7
4008	Helium Leak Test	8	8	8
4009	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	9	9	9
4010	High Temp Functional Test (See Note C)	10		
4011	Ambient Temp Functional Test (See Note C)		10	
4012	Low Temp Functional Test (See Note C)			10
4013	Post-Functional Inspection of XTA and Ring Segments	11	11	11
4014	Quantitive Performance Measurement	12	12	12
* Total specimen quantity is the greater of 10 units or 10% of the lot. When quantity is not divisible by 3, odd units shall be assigned to Group C (low temp test), then Group A (high temp test).				
Note A	Test specimens shall be sublength FJ assemblies, including ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process and at the same time as the flight hardware. Ring segments may be cut from the ends of flight rings or they may be cut from sacrificial rings included in each heat treat batch. If multiple ring heat treat batches are included in a production lot of FJ's, ring segments from each batch shall be represented in the quantity of FJ test specimens.			
Note B	High Temperature Storage tests shall be conducted to establish an initial 5 year age life for a production lot. If High Temperature Storage tests are not conducted, an initial 1 year age life shall be established for a production lot.			
Note C	Functional test setup should address boundary conditions of flight articles. Test specimens shall be fixtured to replicate the interfacing structural attachment stiffness of the flight installation.			

Age Life Extension Tests								
ID	Test Specimen Configuration	Sublength (See Note A)				Sublength (See Note A)		
	Age Life Extension Time	One Year				Five Years		
	Test Group	A	B	C		A	B	C
	Quantity	2	1	2		4	2	4
	Test Title	**Test Matrix & Sequence**						
5001	Visual Inspection	1	1	1		1	1	1
5002	Helium Leak Test	2	2	2		2	2	2
5003	High Temperature Storage (Age Life)					3	3	3
5004	Qual Level Thermal Cycle	3	3	3		4	4	4
5005	Qual Level Shock	4	4	4		5	5	5
5006	Qual Level Sine Vib (if applicable)	5	5	5		6	6	6
5007	Qual Level Random Vib	6	6	6		7	7	7
5008	Helium Leak Test	7	7	7		8	8	8
5009	Full length radiograph to reveal: - MDC Sheath & Core - MDC to Booster Cap Interface - Chargeholder Installation - Booster to Detonator port interface	8	8	8		9	9	9
5010	High Temp Functional Test (See Note B)	9				10		
5011	Ambient Temp Functional Test (See Note B)		9				10	
5012	Low Temp Functional Test (See Note B)			9				10
5013	Post-Functional Inspection of XTA and Ring Segments	10	10	10		11	11	11
5014	Quantitive Performance Measurement	11	11	11		12	12	12

Note A	Test specimens shall be sublength FJ assemblies, including ring segments and expanding tube assemblies with flight-like end fittings, manufactured under the same production process and at the same time as the flight hardware. Ring segments may be cut from the ends of flight rings or they may be cut from sacrificial rings included in each heat treat batch. If multiple ring heat treat batches are included in a production lot of FJ's, ring segments from each batch shall be represented in the quantity of FJ test specimens.
Note B	Functional test setup should address boundary conditions of flight articles. Test specimens shall be fixtured to replicate the interfacing structural attachment stiffness of the flight installation.

10.0 References

[1] NASA Standard JSC 62809D: Human Rated Spacecraft Pyrotechnic Specification. NASA Johnson Space Center, 22 April 2010.

[2] Military Handbook MIL-HDBK-83578: Criteria for Explosive Systems and Devices used on Space Vehicles. Department of Defense, 1 January 1999.

[3] AIAA Standard S-113-2005: Criteria for Explosive Systems and Devices on Space and Launch Vehicles, AIAA, January 2005.

[4] Military Specification DOD-E-83578A: Explosive Ordnance for Space Vehicles, General Specification For. Department of Defense, 15 October 1987.

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this document is to define a series of test and inspection requirements for a specific type of frangible joint (FJ) assembly used in human-rated spacecraft applications. It is intended to be an enhancement to the Commercial Crew Program Johnson Space Center (JSC) 62809D Human Rated Spacecraft Pyrotechnic Specification and lists very specific tests and inspections with accompanying tables. This document does not eliminate any of the requirements stated in JSC 62809D. Many of the test and inspections in this document—particularly within the material certification, product acceptance, qualification, lot acceptance, and age life extension sections—are standard operating procedure for suppliers. This document provides detail on the individual items to avoid ambiguity. In particular, this document details the test and inspection requirements for offset notch style FJs with aluminum machined plates where the separation at the notch is a result of shock-induced shear. It is expected that a user would tailor the contents of this document for his or her particular vehicle application and provide a certifying organization with rationale for such tailoring. Tailoring to the requirements of this document requires approval of the certifying organization (e.g., NASA for a NASA human space flight program).

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