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NASA MANUFACTURING AND TEST REQUIREMENTS FOR NORMALLY CLOSED PYROVALVES FOR HAZARDOUS FLIGHT SYSTEMS APPLICATIONS

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FOREWORD

This Specification is published by the National Aeronautics and Space Administration (NASA) to describe essential technical requirements for purchased or in-house items, services, functions, or processes for NASA programs and projects and includes procedures necessary to determine that the requirements covered by the Specification have been met. These requirements are mandatory when specified as such by program documentation or contracts.

This Specification is approved for use by NASA Headquarters and NASA Centers, including Component Facilities and Technical Service Support Centers. The Specification also applies to the Jet Propulsion Laboratory and other contractors to the extent specified in section 1.2 in this document.

This Specification establishes requirements for pyrovalves and other parent metal barrier normally closed (NC) valves used in ELV payload hazardous spacecraft applications. Pyrovalves meeting these requirements will provide programs, NASA Payload Safety, and United States Air Force (USAF) Range Safety consistent and reliable hardware.

Requests for information, corrections, or additions to this Specification should be submitted via “Feedback “in the NASA Technical Standards System at https://standards.nasa.gov/.

Original Signed By:	***06-24-2015***
Ralph, R. Roe NASA Chief Engineer	Approval Date

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NASA MANUFACTURING AND TEST REQUIREMENTS FOR NORMALLY CLOSED PYROVALVES FOR HAZARDOUS FLIGHT SYSTEMS APPLICATIONS

1. SCOPE

1.1 Purpose

The purpose of this Specification is to establish and implement the manufacturing and test requirements and applications guidelines for normally closed (NC) parent metal shear-section valves. The Specification is a guide for design engineers to develop more detailed requirements for specific pyrovalve applications. Adherence to these requirements will reliably prevent NC parent metal valve leakage or other failure-induced release of hazardous fluids (liquids or gases) from National Aeronautics and Space Administration (NASA) payloads on Expendable Launch Vehicles (ELVs). This Specification does not address NC parent metal valve sizing, pressure drop, and other requirements.

This Specification may be called out in procurement specifications or other programmatic documentation to ensure valves meet structural requirements and are considered to be equivalent to other hazardous fluids pressure components, such as tubing, tanks, and fittings, and that any mode of external or internal leakage of the contained hazardous fluid is extremely improbable (3 X 10^{-}5) in accordance with NASA-STD-8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements, and AFSPCMAN 91-710, Air Force Space Command Range Safety User Requirements Manual, or equivalent document for the applicable range.

Appendix A of this Specification presents a checklist of documents to be prepared for NASA and/or Range Safety. The checklist is provided for manufacturers of NC pyrovalves used in personnel hazardous applications. It is a tool for documenting the detailed compliance to the intent of the safety specification. The checklist also provides an aid for payload safety, Range Safety engineers, and other subject matter experts in reviewing the documentation. Letter designations after the checklist item number refer to the following the requirement sources:

A. NESC-RP-10-00614, Pyrovalve Reliability Assessment for Expendable Launch Vehicle Payloads.

B. NSTS 1700.7B, Safety Policy and Requirements For Payloads Using the Space Transportation System.

C. NASA-STD 8719.24 and AFSPCMAN 91-710.

D. NASA-SPEC-5022, NASA Manufacturing and Test Requirements for Normally Closed Pyrovalves for Hazardous Flight Systems Applications.

For the purposes of this Specification, hazardous valve applications involve hazardous flight hardware pressure systems as defined by NASA-STD-8719.24 and AFSPCMAN 91-710, Volume 3, Chapter 12, Section 12.1.

1.2 Applicability

This Specification applies to NC pyrotechnically operated valves (pyrovalves), as well as to valves that use a different means of applying force, e.g., memory shape alloys to break out a section of a parent metal section allowing flow. The parent metal shear sections and interface tubes are defined by the term "parent metal" when they are machined from a single, certified bar of high-purity metal alloy with no welds.

This Specification is intended to be applied when these NC parent metal shear-section valves are used to prevent failure-induced release of hazardous fluids (liquid or gas) from spacecraft. It is primarily applicable to ELV payloads subject to NASA Payload Safety and United States Air Force (USAF) Range Safety Requirements, where a consistently high level of reliability and safety is required.

This Specification is approved for use by NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers, and may be cited in contract, program, and other Agency documents as a technical requirement. This Specification may also apply to the Jet Propulsion Laboratory or to other contractors, grant recipients, or parties to agreements only to the extent specified or referenced in their contracts, grants, or agreements.

Requirements are numbered and indicated by the word "shall." Explanatory or guidance text is indicated in italics beginning in section 4.

1.3 Tailoring

a. Tailoring of this Specification for application to a specific program or project shall be formally documented as part of program or project requirements and approved by the Technical Authority.

b. Any tailoring shall also be documented and communicated in writing to the appropriate range safety organization and the NASA Payload Safety Program Manager.

c. Each individual project shall clearly identify its Technical Authority early in the project development process.

1.4 Background

Pyrovalves (figure 1, Basic Pyrovalve Design and Features,) are typically lighter, more reliable, and in most cases less expensive than other types of valves. They also consume less electrical power. They are single-use devices that are used in propulsion systems to isolate propellants or pressurant gases. These fluids may be hazardous because of their toxicity, reactivity, temperature, or high pressure.

Note that in the simplified block diagram below not all detail features are shown so that those of major interest are more prominent. The diagram is provided to point out the various features that are discussed in this Specification. Features of some NC parent metal valve designs may differ.

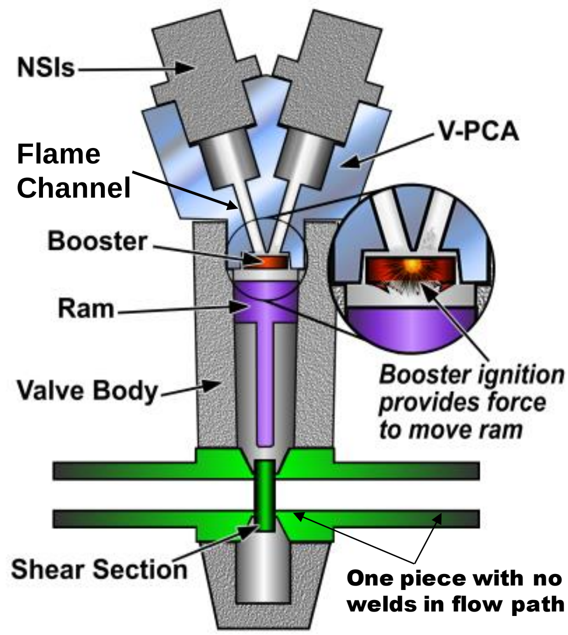

Figure 1—Basic Pyrovalve Design and Features

In 2013, the NESC concluded an extensive study of the reliability and safety of NC parent metal valves used in payloads carried aboard ELVs. The assessment successfully evaluated technical data to determine the risk of NC parent metal valve leakage or inadvertent activation in ELV payloads. The study resulted in numerous recommendations to ensure personnel and hardware/facility safety during ground processing of ELV payloads. One of those recommendations was to establish a NASA specification for NC parent metal valves. This Specification is a result of that recommendation, which is documented in NESC-RP-10-00614.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this Specification as cited in the text unless waived by the responsible Technical Authority.

2.1.1 The latest issuances of cited documents shall apply unless specific versions are designated.

2.1.2 Non-use of specific versions as designated shall be approved by the responsible Technical Authority.

The applicable documents are accessible via the NASA Standards and Technical Assistance Resource Tool at https://standards.nasa.gov/ or may be obtained directly from the Standards Developing Organizations or other document distributors.

2.2 Government Documents

Department of Defense (DoD)

AFSPCMAN 91-710	Air Force Space Command Range Safety User Requirements Manual, Volumes 1 through 7
MIL-STD-1522A	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, 28 May 1984

NASA

NASA-STD-5019	Fracture Control Requirements for Space Flight Hardware
NASA-STD-8719.12	Safety Standard for Explosives, Propellants, and Pyrotechnics
NASA-STD-8719.24	NASA Expendable Launch Vehicle Payload Safety Requirements
NESC-RP-10-00614	Pyrovalve Reliability Assessment for Expendable Launch Vehicle Payloads[1]
NSTS 1700.7B	Safety Policy and Requirements For Payloads Using the Space Transportation System

National Archives and Records Administration

49 CFR 173, Subpart A	Shippers—General Requirements for Shipments and Packagings, General
49 CFR 174	Carriage by Rail

[1] At the time of this writing, this document has not yet been released. It will be available to a restricted readership at http://www.nasa.gov/offices/nesc/reports/index_new.html. Contact White Sands Test Facility Publications for access.

49 CFR 175	Carriage by Aircraft
49 CFR 176	Carriage by Vessel
49 CFR 177	Carriage by Public Highway

2.3 Non-Government Documents

International Air Transport Association

ICAO DOC 9284	Dangerous Goods Regulations

International Civil Aviation Organization

Doc 9284	Technical Instructions for the Safe Transport of Dangerous Goods by Air

2.4 Order of Precedence

This Specification establishes requirements for NC pyrovalve and other NC parent metal shear-section valves used in ELV payload hazardous applications but does not supersede nor waive established Agency requirements found in other documentation.

2.4.1 Conflicts between this Specification and other requirements documents shall be resolved by the responsible Technical Authority.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms and Abbreviations

±	plus or minus
AFSPCMAN	Air Force Space Command Manual
AIAA	American Institute of Aeronautics and Astronautics
amp	ampere(s)
ASTM	ASTM International (formerly American Society for Testing and Materials)
CFR	Code of Federal Regulations
cm	centimeter(s)
dB	decibel
DoD	Department of Defense
DOT	Department of Transportation
EED	electroexplosive device
ELV	expendable launch vehicle
ft·lb	foot-pound
ICAO	International Civil Aviation Organization

in	inch(es)
ISO	International Organization for Standardization
ISS	International Space Station
J	Joule(s)
MAPTIS	Materials and Processes Technical Information System
MDP	maximum design pressure
MEOP	maximum expected operating pressure
MGWP	maximum ground working pressure
MIL	military
min	minute(s)
NASA	National Aeronautics and Space Administration
NAVORD	US Naval Ordnance Laboratory
NC	normally closed
NDE	non-destructive evaluation
NESC	NASA Engineering and Safety Center
NSI	NASA Standard Initiator
NSTS	National Space Transportation System
POD	probability of detection
RF	radio frequency
RP	report
S	standard
sec	second(s)
SI	Système International
SP	special report
SPEC	specification
STD	standard
USAF	United States Air Force
V-PCA	V-shaped Primer Chamber Assembly
W	Watt(s)

3.2 Definitions

Category A Electroexplosive Devices (EEDs)/Ordnance: EEDs or ordnance that, by the expenditure of their own energy or because they initiate a chain of events, may cause serious injury or death to personnel or damage to property.

Category B EEDs/Ordnance: EEDs or ordnance that, by the expenditure of their own energy or because they initiate a chain of events, will not cause serious injury or death to personnel or damage to property.

Expendable Launch Vehicle: In aerospace applications, a non-reusable launch vehicle used to carry a payload from Earth's surface to sub-orbital altitude, into orbit, or beyond.

Low Notch Sensitivity: The extent to which the sensitivity of a material to fracture is increased by the presence of a surface inhomogeneity, such as a notch, a sudden change in section, a crack, or a scratch. Low notch sensitivity is usually associated with ductile materials and high notch sensitivity with brittle materials.

Maximum Expected Operating Pressure (MEOP): The highest pressure that a pressure vessel, pressurized structure, or pressure component is expected to experience during its service life and still retain its functionality, in association with its applicable operating environments. This term is synonymous with maximum operating pressure or maximum design pressure (MDP) and, if required by the program, may include the effect of temperature, pressure transients and oscillations, vehicle quasi-steady and dynamic accelerations, and relief valve operating variability.

Payload: The object(s) within a payload fairing carried or delivered by a launch vehicle to a desired location and trajectory. A generic term that applies to all payloads , including but not limited to satellites, other spacecraft, experimental packages, reentry vehicles, dummy loads, cargo, and any motors attached to them in the payload fairing. (NASA-STD-8719.24, Annex 2). For this Specification, the term refers to cargo carried aboard a launch vehicle.

Requirements Testing: Conducted to determine if units meet the requirements of a specification or contract. May include non-destructive and destructive test(s).

Stringer: An elongated configuration of microconstituents of foreign (metallurgically distinct) material aligned in the direction of working. The term is commonly associated with elongated oxide or sulfide inclusions in steels.

4. REQUIREMENTS

4.1 Pyrovalve Analysis and Evaluation Process

4.1.1 NC parent metal valves shall be properly designed based on sound engineering and analysis to provide a level of protection against rupture or leakage at least equivalent to other parts of the pressure system, i.e., tubing, tanks, and fittings. For more details, see Appendix B in this Specification.

4.1.2 NC parent metal valves shall be designed and constructed to meet spacecraft pressure system requirements.

NC parent metal valves should undergo a complete development and qualifications program. This is typically performed according to a specific program or project technical specification. Analysis should be accomplished before manufacture to help preclude additional redesign and testing.

4.1.3 Several valve loadings shall be performed as a minimum: proof and burst test pressure loadings, media pressure loadings for pre-launch, launch loadings, pyrotechnic loadings, and pressure loadings after actuation.

The short-duration impulse loadings from pyrotechnic actuation are generally evaluated based on test results because of the challenges of accurately analyzing stresses from these loadings using mathematical or computer modeling.

4.1.4 Post-manufacturing analysis shall be required if design analysis, testing, and process control documentation that prove compliance to NASA-STD-5019 are not available.

4.1.5 In the case of requirement 4.1.4 above, testing and analysis shall demonstrate a minimum four times the pressurization cycles of the component.

4.1.6 If reliability analysis is used, it shall predict a risk of leakage less than $3x10^{-5}$ (extremely improbable) to comply with NASA-STD-8719.24 (Annex) and AFSPCMAN 91-710.

4.2 Systems-Level Considerations

The spacecraft system designer should be aware of system-level issues relative to inadvertent actuation of the NC parent metal valve.

Comprehensive testing and analysis of the ignition system may be required before the possibility of inadvertent ignition can be fully mitigated. However, this testing and analysis is beyond the scope of this Specification.

4.2.1 The NC parent metal valve initiator shall be a NASA Standard Initiator (NSI) or equivalent meeting the same No-Fire current and pin-to-case high-voltage protection requirements.
NASA-JSC P/N SEB26100001, Initiator, NASA Standard, (specification control drawing) contains these requirements.[2]

4.2.2 Grounding caps shall be installed on pyrovalve initiators at all times until the pyrovalve is installed in the spacecraft and the flight connectors are attached.

4.2.3 Ignition systems shall use twisted shielded control cables to protect from electromagnetic interference.

4.2.4 The actuation method of the NC parent metal valve shall meet all applicable safety requirements in NASA-STD-8719.24 (Annex) and AFSPCMAN 91-710 and prevent unintended actuation.

[2] Available only through NASA Johnson Space Center.

Although actuation of the valves used in aerospace applications is normally by pyrotechnics (initiators), the basic valve requirements can be applied to valves actuated by mechanical, electrical, hydraulic, and pneumatic or a combination of means. Whatever actuation method is chosen, the maximum no-fire energy should be known to a reliability of 0.995 at a 95-percent confidence level so that a factor of safety can be determined from all inadvertent sources of that energy (checklist item 2D).

4.2.5 For system applications, all qualified aerospace initiators shall meet strict No-Fire and All-Fire requirements.

The No-Fire requirement is a minimum of 1 amp and 1 W applied for 5 min at a reliability of 99.9 percent and confidence level of 95 percent. This is determined by either NAVORD 2101, Statistical Methods Appropriate for Evaluation of Fuzed Explosive-Train Safety and Reliability, (the Bruceton test) or ISO 14304, Annex B, All-Fire/No-Fire Test and Analysis Method, (the Neyer test) that requires 20 to 50 initiators for each test (checklist item 3BD).

Other sources of electrical energy, such as radio frequency (RF), can be compared to the No-Fire level of the initiator by tests to meet the factor of safety of a minimum of 20 dB, which is 100 to 1 in energy (W) (MIL-STD-1576, Military Standard: Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, paragraph 4.4.1.a) (checklist item 4BD). Mechanical, hydraulic, pneumatic, or a combination of means should have a similar safety margin.

4.2.6 The actuation method of the valve shall be qualified, with margin, in accordance with the application requirements when mounted on the valve.

System testing should include the range of environmental conditions appropriate to the application (checklist item 5D).

4.2.7 The valve design shall preclude inadvertent operation or leakage as a result of exposure to all potential environmental conditions while loaded with hazardous gases or liquids (checklist item 11A).

4.3 Pneumatic Pressure Tests

a. All valves shall meet pneumatic leak test and proof pressure test requirements in accordance with section 4.3.1 in this document.

b. Each valve lot shall be qualified by meeting burst pressure test requirements in accordance with section 4.3.1 in this document.

4.3.1 Proof Pressure and Leak Tests

a. All valves shall be proof tested to a minimum pneumatic proof pressure at 1.5xMEOP.

b. This capability shall be demonstrated on every unit during assembly, with pressure applied individually to each line and separately to the valve housing through the actuation ram chamber while the lines are vented.

Included as part of and after every proof pressure test is a helium leak test at a minimum of 1.0xMEOP with a resulting leak rate less than $1x10^{-6}$ standard cc/sec.

c. The test shall be performed on all parent metal shear-section and all parts of the valve exposed to pressure after valve actuation (checklist item 7AC).

d. All welds shall be leak tested either during assembly or acceptance testing (checklist item 32A).

Fracture mechanics and damage tolerance testing are to satisfy NASA-STD-5019.

e. Either non-destructive acceptance testing (checklist item 6C) shall be accomplished or the risk of defects be mitigated through process control.

f. If process control is used, approval shall be obtained from the NASA Fracture Control Board for spacecraft requiring this in programmatic requirements.

g. If fracture mechanics and crack growth analysis are used to verify compliance with NASA-STD-5019 (see section 4.1 of this Specification), growth of the maximum credible crack size shall be demonstrated to the fracture control authority to be non-credible, based on knowledge of quality control and manufacturing techniques used to make the NC parent metal valve.

h. However this capability is technically established, the NC parent metal valve shall be capable of surviving four times the design operational life.

i. If the valve design is to provide two separate and independent parent metal barriers to the flow before valve actuation, this capability shall be verified by proof testing at 1.5xMEOP, independently applied to each parent metal shear-section and then externally to the shear-section when welded in the housing, with no evidence of permanent deformation or leakage during LAT.

4.3.2 Burst Pressure Test

a. The minimum hold time for each burst pressure test shall be 5 min.

b. All NC parent metal valves shall meet a minimum design burst pressure of 2.5xMEOP for lines with diameters ≥3.8 cm (≥1.5 in) or 4.0xMEOP for lines with diameters <3.8 cm (<1.5 in).

(1) This capability shall be demonstrated on at least one NC parent metal valve from each lot.

(2) Testing shall be performed before and after actuation and on a sample of the units that have successfully functioned after destructive acceptance testing (checklist items 8AD and 33D).

NC parent metal used in hazardous systems without additional barriers to leakage may be required by USAF Range Safety and NASA Payload Safety to have a minimum design burst pressure requirement of 4.0 times maximum ground working pressure (MGWP). NC parent metal valves used in hazardous systems without additional barriers to leakage are considered Category A ordnance devices and have to follow NASA-STD 8719.24 and AFSPCMAN 91-710, Volume 3, Chapter 13, or equivalent document for applicable range. This requirement should be identified and documented early in the launch facility coordination process and be documented in the tailoring agreement. This requirement would not apply to Category B ordnance pyrovalve applications, which are, by definition, non-hazardous.

CAUTION: An expended (fired) pyrovalve may retain significant pressure in the primer chamber assembly for an indefinite period of time.

c. If the unit passes the burst pressure test, the pressure shall be increased until burst actually occurs or 4.00xMEOP is reached, at which point the test can be discontinued.

Additionally, if the valve does not fail after 4.00xMEOP, it meets the full safety factor applied to tubing <3.81 cm (<1.5in) in diameter (checklist item 33D).

4.4 General Requirements

4.4.1 Internal Structural Requirements

a. An NC valve used in ELV hazardous prelaunch applications shall provide a parent metal barrier in the shear-section.

Other shear-section barriers, such as a metal-to-metal seal, elastomeric seats, or O-rings, do not provide the same level of confidence and do not meet the intent of this Specification (checklist item 9A).

b. The internal shear-section shall be a continuous unit of non-welded parent metal.

This pertains to the area of the shear-section around the parent metal barrier that is opened upon actuation of the valve. The shear-section normally has flanges larger than the shear-

section outer diameter that are welded to the valve housing to prevent leakage after actuation. When installed in the system, the parent metal sections are directly welded to the system tubing (checklist item 9A).

c. The parent metal shear-section shall be the only part of the valve that is in contact with the hazardous fluids before the actuation of the valve *(checklist item 12D).*

4.4.2 Parent Metal Shear-Section and Valve Housing

Although many materials can be considered for the parent metal shear-section, the use of vacuum furnace remelt 304L stainless steel has a significant legacy for the shear-section application (checklist item 13D). (The L on 304L indicates extra-low-carbon stainless steel.) Other metals may require heat treatment after welding, as judged necessary by the responsible NASA materials specialist (checklist item 15D). The yield and tensile strength callouts may vary depending on the strength requirements. The standard yield and tensile strength may be used if they will meet the stress/force analysis requirements.

a. The use of a material other than 304L shall be carefully evaluated, with analysis showing that it meets NASA-STD-5019 requirements.

b. The following material characteristics (checklist item 13D) shall be addressed:

(1) Desirable characteristics shall include low notch sensitivity; good fatigue properties; low stress corrosion cracking; high elongation; and toughness at cryogenic, ambient, and high temperatures (checklist item 14D), if applicable.

(2) The material used for the parent metal shear-section shall have good weldability to the housing material and to the spacecraft tubing system.

(3) The parent metal shear-section and any other parts wetted by the fluids and/or combustion products shall be constructed of a metal or other material that is compatible with the fluids and/or combustion products.

The NASA Materials and Processes Technical Information System II (MAPTIS II), a single-point source for materials properties for NASA and NASA-associated contractors and organizations, contains physical, mechanical, and environmental properties for metallic and non-metallic materials.[3] *Other relevant resources for materials properties are NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft, AIAA SP-084-1999, Special Report: Fire, Explosion, Compatibility, and Safety Hazards of Hypergols – Hydrazine; AIAA SP-085-1999, Special Report: Fire, Explosion, Compatibility, and Safety Hazards of Hypergols – Monomethylhydrazine; and AIAA SP-086-2001, Special Report:*

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[3] http://maptis.nasa.gov/ Retrieved July 11, 2013.

Fire, Explosion, Compatibility, and Safety Hazards of Nitrogen Tetroxide. (checklist item 16D)

The parent metal shear-section may have stringers. Investigations have shown that the stringers that may occur in 304L are usually approximately 0.00127 cm (0.0005 in) in diameter and that the stringer material is not attacked by common fuels and oxidizers over a period of several years. Even if the stringers are oriented perpendicular to any thin break section, the chances of a leak from stringers are remote. However, a commonly used dye-penetrant etchant (a solution of nitric acid and hydrofluoric acid) has been shown to dissolve stringer material in 304L stainless steel. The solution attacks the material in the stringer and can cause leaks in thin sections. This solution should be avoided on any part of the valves (checklist item 17D). Note that, for 304L stainless steel, any significant stringer is screened out during the required proof and helium leak testing process.

The use of vacuum remelt raw material significantly reduces the likelihood of stringers occurring. Materials used in fracture-sensitive regions of the shear-section valve should be derived from alloy production processes that implement modern alloy remelting control practices, e.g. electroslag remelting, vacuum arc remelting, or vacuum induction melting, which serve to enhance alloy homogeneity, purity, and metallurgical soundness and reduce the potential for undesirable secondary inclusion phases that can have a detrimental effect on mechanical properties, fracture toughness, and pitting corrosion.

c. The valve housing shall meet the same proof pressure, burst pressure, and leak test requirements as the parent metal shear-section after the valve is actuated.

d. The housing and all other internal material that will be in contact with the hazardous fluids after actuation, e.g., rams, plugs, seals, shall also have the same requirements for materials compatibility with the hazardous fluids and the same welding compatibility requirements (checklist item 18D).

Before firing, a leak in the upstream-side parent metal seal could allow hazardous fluid at system pressure to enter the ram area. Similarly, after firing, leakage past the ram might occur. In either case, hazardous fluid could enter the ram area. Therefore, to ensure at least single-fault tolerance against external leakage, all internal valve materials that could then become wetted are to be fully compatible with the hazardous fluid.

Specific mission requirements may drive other requirements that are not covered by this Specification. For example, some applications require that the valve be in the system and pressurized for many years with corrosive propellants after it operates, causing stress corrosion or metal nitrate formation.

4.5 Dual Independent Shear-Section Parent Metal Barrier Valve

Figure 2, Dual Independent Parent Metal Shear-Section Valve, shows a two-piece, dual shear-section design. This design is generally considered to contain two inhibits to flow and is the preferred design approach.

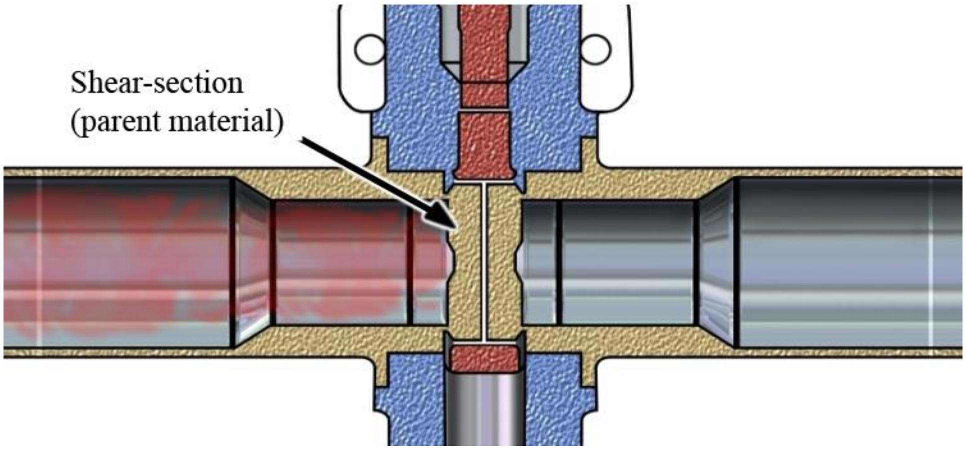

Figure 2—Dual Independent Parent Metal Shear-Section Valve

Figure 3, Dual One-Piece Parent Metal Shear-Section Valve, is a design generally considered to contain two independent barriers to flow (upstream and downstream "V" cut ligaments), but additional NDE and/or analysis may be required to show that the single piece either does not contain defects that may grow to leakage or that failure is not credible (extremely unlikely) during ground processing operations. Both designs, when qualified, can be acceptable for use in ELV payload hazardous flight applications (checklist item 20A).

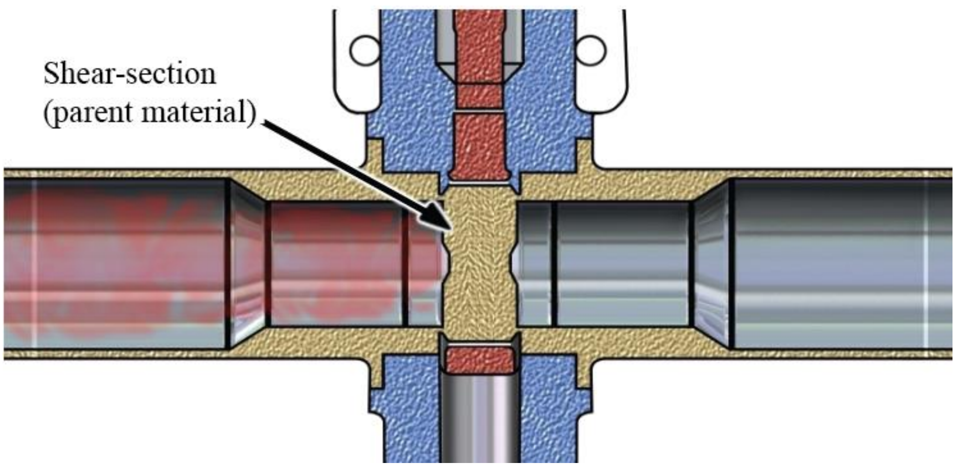

Figure 3—Dual One-Piece Parent Metal Shear-Section Valve

4.6 Manufacturing Requirements

4.6.1 Valves shall be manufactured, assembled, tested, and documented on a manufacturing lot basis (checklist item 20A).

Components require independent certification that the materials of construction conform to drawing specifications before fabrication.

a. The shear-sections shall be from the same melt and bar stock lot (checklist item 21D).

b. Samples of the first and, subsequently, every fourth bar shall be tested for composition, tensile strength, yield strength, and elongation (checklist item 23D).

c. Material certifications and traceability records shall be maintained and available.

4.6.2 The individual shear-section bars shall be identified, tracked, and kept in controlled storage as part of process control.

Parent metal shear-section valves used in single isolation configurations (without additional inhibits) need additional inspection and rigorous analysis to ensure the high unlikelihood that critical flaws exist.

4.6.3 For single isolation valves, a suitable and representative sample shall be removed from the middle or ends of each bar and submitted to an accredited laboratory for analysis.

a. The samples shall be polished, cleaned, and etched with a solution of nitric acid and hydrofluoric acid to remove 0.000762 to 0.00127 cm (0.0003 to 0.0005 in) from the surface.

b. The polished samples shall be examined by optical and scanning electron microscopy for voids to ensure that the manufacturer’s requirements are met.

c. The customer shall concur with the manufacturer’s requirements (checklist item 22D).

d. If any sample fails this test, the associated bar shall be rejected and removed from the lot.

4.6.4 The shear-section bar stock shall be machined at the same machine shop, using the same tooling and machine setup for each lot of shear-sections (checklist item 24D).

Shear-sections should be cleaned using the standard documented cleaning process for the material (checklist item 24D).

4.6.5 Tubes shall be passivated in accordance with an industry consensus standard as specified by a cognizant materials and process authority (checklist item 25D).

4.6.6 All shear-sections shall be dimensionally inspected.

a. Shear-section dimensions that are critical for containment of hazardous fluids shall be 100 percent inspected and recorded for each shear-section (checklist item 26D).

b. If applicable, the "V" notch angle, depth, and tip radius shall be measured by optical comparator or equivalent and verified to fully meet drawing requirements and indicate measured tip radius (checklist item 27D).

It is also recommended that the actual radius be documented to within measurement system accuracy (within ±0.000635 cm (±0.00025 in), traceable to a national standard). This will facilitate valve analysis, if required.

c. If the shear section has double "V" notches, the dimensions of both break areas shall be recorded and the inspector's identification affixed to the data.

4.6.7 There shall be an independent quality verification and data recording that the parent metal barrier conforms to the minimum thickness required by the design drawing (checklist item 28AD).

4.6.8 The risk of critical flaws in the "V" notch area shall be addressed.

a. In accordance with NASA-STD-5019, the initial critical flaw size shall be established by NDE, proof testing, or process control if the valve does not meet or exceed a demonstrated safety factor of 1.5.

This specification requires that the valve meet a demonstrated safety factor of 2.5 to 4.0, as applicable.

b. If the NDE method is used, it shall be demonstrated to be capable of detecting the minimum sized critical flaws.

Dye penetrants are generally used on flat surfaces (not in sharp groves), are not recommended, and should not be used unless a well-documented probability of detection (POD) study has been conducted to prove that the POD is greater than 90 percent with 95 percent confidence (termed 90/95 POD). Eddy current scanners with "V"-shaped sensor ends that ride in the groves are commonly used for other similar applications, such as detecting cracks in critical bolt threads, and could be considered for this application, as long as the technique has been fully validated. Questions regarding validation should be addressed to the NASA NDE Technical Fellow.

4.6.9 Etchant limitations: an etchant solution of nitric acid and hydrofluoric acid or other similar solutions that may dissolve stringers shall not be used internally or externally on the parent metal shear-section.

4.6.10 Valves shall be serialized and records of assembly production and inspection steps kept by serial number (checklist item 29D).

4.6.11 Shear-sections shall be welded to the housing subassembly.

a. Welding shall be done on a weld lot basis, using the same weld schedule and weld instructions for a specific weld and be done in a way that minimizes or eliminates "V" notch residual weld stress (checklist item 30D).

This means that the shear-section is to be outside the weld heat affected zone.

b. At a minimum, all housing welds shall be subjected to the full 1.5xMEOP proof test without leakage and pass visual inspection.

4.6.12 Although the pyrotechnic devices used to power the valve are specified by the program, they shall be made and tested from the same lot (checklist item 31D).

4.7 Hardware Records and Test Hardware

All manufacturing and inspection records and tested units shall be retained by the manufacturer for a minimum of 10 years, unless otherwise specified by contract (checklist item 36D).

5. VERIFICATION

After manufacturing is complete, the lot of valves shall be submitted to LAT.

5.1 Non-Destructive Acceptance Testing

The non-destructive 100-percent acceptance testing shall be performed in accordance with the product procurement specification (checklist item 34D), where required.

5.2 Destructive Acceptance Testing

Destructive acceptance testing shall be performed where specified by procurement documentation.

5.2.1 A sample for the destructive acceptance testing shall be randomly chosen by the customer.

5.2.2 The quantity of the destructive acceptance testing shall be the larger of 5 units or 10 percent of the production lot.

5.2.3 The sample shall be subjected to the specified pressures and temperatures and then fired to actuate the valve to the open position (checklist item 10A).

5.2.4 These units shall be X-rayed, tested for flow rate, leak tested to the requirements of the performance specification, and then submitted to a burst pressure test of 2.5xMEOP.

5.2.5 After passing the burst test, the units shall again be leak tested (checklist item 35D).

6. PACKAGING AND SHIPPING

6.1 Pyrovalves or other parent metal shear-section valves containing explosives or propellant charges shipped by rail, air, vessel, and/or public highway shall comply with the following: NASA-STD-8719.12, Safety Standard for Explosives, Propellants, and Pyrotechnics, and Department of Transportation (DOT) regulations: 49 Code of Federal Regulations (CFR) 173 Subpart A General, 49 CFR 174 Carriage By Rail, 49 CFR 175 Carriage By Aircraft, 49 CFR 176 Carriage By Vessel, and 49 CFR 177 Carriage By Public Highway.

6.2 Those transported by air shall comply with International Civil Aviation Organization (ICAO) DOC 9284, Technical Instructions for the Safe Transport of Dangerous Goods by Air, and International Air Transport Association, Dangerous Goods Regulations.

6.3 A Material Safety Data Sheet or Safety Data Sheet and, if applicable, a DOT explosive shipment approval shall accompany the shipment.

APPENDIX A

SAFETY DOCUMENT CHECKLIST

A.1 Purpose and/or Scope

The purpose of this appendix is to provide guidance by assisting manufacturers to properly document compliance to the intent of the NC parent metal valve Specification.

A.2 Checklist

The following checklist is provided for the manufacturer of an NC pyrovalve used in a hazardous application. The checklist assists in documenting the detailed compliance to the intent of the safety specification. It is understood that different NC pyrovalve designs may meet a safety requirement with a different approach or new backup material. The checklist also provides an aid for Range Safety in reviewing the documentation. Note that the manufacturer and the system designer may have to collaborate to complete the checklist.

A.2.1 Checklist Item Letter Definitions

The letter part of each checklist item refers to the source of the requirement as identified below:

A. NESC-RP-10-00614.
B. NSTS 1700.7B.
C. AFSPCMAN 91-710.
D. NASA-SPEC-5022.

A.2.2 Checklist

1AC List operating hazards, including cryogens, flammables, combustibles, or hypergols. List MEOP and stored energy levels exceeding 19,307 J (14,240 ft·lb) in accordance with AFSPCMAN 91-710, Vol. 3, Section 12, and MIL-STD-1522A.

2D List the maximum No-Fire energy threshold. (Reference section 4.2.4 in this Specification.)

3BD List the No-Fire level of the actuator at a reliability of 99.9 percent and confidence level of 95 percent, as determined by either a Bruceton test or a Neyer test. (See section 4.2.5 in this Specification.)

4BD Provide thresholds of other sources of energy such as RF and the safety margin. (Reference section 4.2.5 in this Specification.)

5D Provide qualification testing data for vibration, shock, and other environmental conditions. (Reference section 4.2.6 in this Specification.)

6C Provide detailed calculation of MEOP for the pyrovalve and the pressurization system when personnel could be endangered.

7AC Document proof pressure testing at 1.5xMEOP. For hypergol systems, document that this is followed by helium leak test at a minimum of 1.0xMEOP with a leak rate less than 1x10-6 standard cc/sec.

8AD Document burst pressure testing in qualification test before and after firing and after firing for LATs. (Reference section 4.3.2 in this Specification.)

9A Provide drawing of the non-welded parent metal shear-section to confirm it is a continuous unit of non-welded parent metal.

10A Document when the NC parent metal valve will be actuated to the open position.

11A Provide safety analysis of inadvertent operation or leakage of hazardous materials.

12D Provide verification that the only part of the valve in contact with the hazardous fluids before actuation is the parent metal shear-section. (Reference section 4.4.1 in this Specification.)

13D Provide a description of the material used for the parent metal shear-section. (Reference section 4.4.2 in this Specification.)

If the material used for the parent metal shear-section is 304L stainless steel, checklist items 14 through 17 do not apply.

14D Evaluate the physical properties of the material selected for the parent metal shear-section compared with the characteristics of 304L stainless steel as the baseline. (Reference section 4.2.5 in this Specification.)

15D Document the physical properties of the selected shear-section material to ensure weldability and to ensure that weld stresses will not create cracks in the “V” notch. (Reference section 4.4.2 in this Specification.)

16D Document the compatibility of the material used for the parent metal shear-section with the hazardous fluids to be used in the system. (Reference section 4.4.2 in this Specification.)

17D Document the compatibility of any cleaning, test, or service fluids with stringer materials to ensure they are not etched away. (Reference section 4.4.2 in this Specification.)

18D Document the compatibility of the hazardous fluids with the housing material. (Reference section 4.4.2 in this Specification.)

19D Document the NC parent metal valve design used: single parent metal, dual parent metal, or some other design. (Reference section 4.5 in this Specification.)

20A Document that the valves have been manufactured, assembled, tested, and documented on a manufacturing lot basis.

21D Document that the shear-sections are from the same melt and bar stock lot. (Reference section 4.6.1 in this Specification.)

22D Verify that the samples of the shear section bars have been examined for voids and other anomalies and document the results. (Reference section 4.6.3 in this Specification.)

23D Verify that samples of the shear-section bar have been tested for composition, tensile strength, yield strength, and elongation and that the results met the specification requirements for the shear-section material. (Reference section 4.6.1 in this Specification.)

24D Verify that shear-sections were machined at the same machine shop, using the same tooling and setup for the lot. Verify that the parts were properly cleaned. (Reference section 4.6.4 in this Specification.)

25D Verify the proper passivation of the shear-sections. (Reference section 4.6.5 in this Specification.)

26D Verify that critical shear-section dimensions are 100 percent inspected and recorded for each shear-section. (Reference section 4.6.6 in this Specification.)

27D Document the results of the shear-section "V" notch radius inspection and show how it meets the requirement(s). (Reference section 4.6.6 in this Specification.)

28AD Verify that an independent inspector (from a different company organization or company or as directed by contract) inspected and recorded the critical dimensions. (Reference section 4.6.7 in this Specification.)

29D Verify the serialization of the top assembly and the recording of the top assembly production and inspection steps by serial number. (Reference section 4.6.10 in this Specification.)

30D Verify the welding of the shear-sections to the housing using the same weld schedule and weld instructions. (Reference section 4.6.11 in this Specification.)

31D Document the lot numbers of all ordnance items used in the production and testing of NC parent metal valve lot. (Reference section 4.6.12 in this Specification.)

32A Proof pressure test all weld joints and parent metal shear-sections at 1.5xMEOP; then perform the helium leak test at a minimum of 1.0xMEOP with a resulting leak rate less than 1x10-6 standard cc/sec. All welds are to be tested either during assembly or acceptance testing.

33D Verify that, during qualification testing, one unit was tested for burst pressure at 2.5xMEOP for lines with diameters ≥3.8 cm (≥1.5 in) or 4.0xMEOP for lines with diameters <3.8 cm (<1.5 in) and then actuated and retested at the respective burst pressure test value. (Reference section 4.2.5 in this Specification.)

34D Record any required non-destructive testing results as part of the Lot Acceptance Test Report. (Reference section 5.1 in this Specification.)

35D Record any required destructive testing results as part of the Lot Acceptance Test Report. (Reference section 5.2.5 in this Specification.)

36D Retain all manufacturing, inspection, test hardware, and test results for a minimum of 10 years, unless otherwise specified by contract. (Reference section 4.7 in this Specification.)

APPENDIX B

PARENT METAL SHEAR-SECTION ANALYSIS PROCESS

B.1 Purpose and/or Scope

This appendix contains guidance in the form of additional details for design analysis and evaluation that may be required in certain situations. As valves subject to this Specification have to have a safety factor of at least 2.5, analysis is not generally required for shear valves unless there is measurable deformation.

B.2 NC Parent Metal Valve Analysis Process

When NC parent metal valve analysis is required, either before manufacturing or in the event that proper documentation has not been maintained, the analysis and evaluation process shall include the following:

B.2.1 Obtain valve documentation, including a full fabrication drawing set of the body and fittings and body weldment, to be used to support the analysis and evaluation process.

B.2.2 Identify the component loading(s) to be considered, including proof test pressure loadings, media pressure loadings for prelaunch, launch loadings, and pressure loadings after actuation as a minimum.

B.2.3 Identify all the materials used in the valve from the engineering drawings and the minimum material strength from the current literature, from the manufacturer's specifications, or from actual raw material analyses.

B.2.4 Review the valve design to identify areas that may control the design, including, as a minimum, the shear-section, tubing section, body housing, and welds.

The following section is added for reference purposes; note that a minimum safety factor of 2.5 applies.

B.2.5 Analyze the previously identified regions using mathematical, finite element analysis, and fracture mechanics, as required.

Depending on the stress levels, non-linear analysis may also be required. This analysis should result in identification of the regions that control the design, the net and peak stresses in these regions, and resulting factors of safety. The minimum design factors of safety are 1.5, based on yield strength, and 2.5, based on ultimate tensile strength, as needed to successfully complete the 1.5 proof and 2.5 design burst safety factors for other pressure components as required by AIAA

S-080-1998, Table 2. These analyses are based on worst-case assumptions for tolerances and material properties.

B.2.6 Demonstrate by fracture mechanics analysis a minimum safe life of four times the operational life of the component, based on NASA-STD-5019.

B.2.7 Summarize, document, transmit, and retain these results as required by the program or project.

APPENDIX C

REFERENCE DOCUMENTS

C.1 Purpose and/or Scope

The purpose of this appendix is to provide guidance in the form of reference documents.

C.2 Reference Documents

C2.2 Government Documents

DoD

MIL-STD-1576	Military Standard: Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems
NAVORD 2101	Statistical Methods Appropriate for Evaluation of Fuzed Explosive-Train Safety and Reliability

NASA

NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
NSTS/ISS 18798, Revision B	Interpretations of NSTS/ISS Payload Safety Requirements

C2.3 Non-Government Documents

American Institute of Aeronautics and Astronautics (AIAA)

AIAA S-080-1998	AIAA Standard for Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
AIAA SP-084-1999	Special Report: Fire, Explosion, Compatibility, and Safety Hazards of Hypergols – Hydrazine
AIAA SP-085-1999	Special Report: Fire, Explosion, Compatibility, and Safety Hazards of Hypergols – Monomethylhydrazine

AIAA SP-086-2001	Special Report: Fire, Explosion, Compatibility, and Safety Hazards of Nitrogen Tetroxide

ASTM International (ASTM)

ASTM E2374-08	Standard Practice for Ultrasonic Testing of Wrought Products

International Organization for Standardization (ISO)

ISO 14304 Annex B	All-Fire/No-Fire Test and Analysis Method