**METRIC/INCH-POUND**

**KSC-STD-Z-0005**
**Revision D**

# PNEUMATIC GROUND SYSTEMS DEVELOPMENT STANDARD

**NOT EXPORT CONTROLLED**

This document has been reviewed by the KSC Export Control Office and it has been determined that it does not meet the criteria for control under the International Traffic in Arms Regulations (ITAR) or Export Administration Regulations (EAR).

*Reference EDR Log #: 16680 NASA KSC Export Control Office, (321) 867-9209*

**December 10, 2024**

**Engineering Directorate**

National Aeronautics and
Space Administration

**John F. Kennedy Space Center**

KSC FORM 16-12 (REV. 6/95) PREVIOUS EDITIONS ARE OBSOLETE (CG 11/95)
KDP-KSC-T-5407 Rev Basic

## RECORD OF REVISIONS/CHANGES

| REV LTR | CHG NO. | DESCRIPTION | DATE |
|---|---|---|---|
| - | | Basic issue. | |
| A | | | September 21, 1977 |
| B | | | October 12, 1988 |
| | B-1 | Revised pages 7 and 8. | July 31, 2009 |
| C | | Updated document. | November 20, 2019 |
| D | | Revised definitions; added section 1.3; revised sections 2.0, 2.2, 3.1.1, 3.1.3, 3.1.4, 4.0, 4.1.2, 4.2.1, 4.2.3, 4.3, 4.4.1, 4.5, 4.5.1, 4.8.1, 4.8.2, 5.1, 5.3, 5.6, 5.7.1; revised Appendices A and B; added hyperlinks to applicable document citations. | December 10, 2024 |

## CONTENTS

## FIGURES

## ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Units of measure and some terms commonly understood within the subject disciplines have been abbreviated in the body of this document without callout but are included among the following.

| | |
|---|---|
| ° | degree |
| AFT | Applied Flow Technologies |
| API | American Petroleum Institute |
| ARP | Aerospace Recommended Practice |
| AS | Aerospace Standard |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| AWS | American Welding Society |
| CFR | Code of Federal Regulations |
| DOT | Department of Transportation |
| F | Fahrenheit |
| ft | foot |
| in | inch |
| KSC | John F. Kennedy Space Center |
| MAPTIS | Materials and Processes Technical Information System |
| MAWP | maximum allowable working pressure |
| MIL | military |
| MSFC | George C. Marshall Space Flight Center |
| NBBI | National Board of Boiler and Pressure Vessel Inspectors |
| NCS | national consensus standard |
| NIOSH | National Institute for Occupational Safety and Health |
| OSHA | Occupational Safety and Health Administration |
| psi | pound per square inch differential |
| psia | pound per square inch absolute |
| psig | pound per square inch gauge |
| PCTFE | polychlorotrifluoroethylene |
| PRD | pressure relief device |
| PTFE | polytetrafluoroethylene |
| SAE | Society of Automotive Engineers |
| SPEC | specification |
| STD | standard |
| UNS | unified numbering system |

| | |
|---|---|
| NIOSH | National Institute for Occupational Safety and Health |
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| SPEC | specification |
| STD | standard |
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## DEFINITIONS

For the purposes of this document, the following definitions apply.

**built-up backpressure:** the increase in pressure at the outlet of a pressure relief device that develops as a result of flow after the pressure relief device opens (reference: API 520 Part 1, paragraph 3.1).

**hazardous fluids:** gaseous oxygen, fuels, oxidizers, and other fluids that could cause corrosion, chemically or physically degrade materials in the system, cause an exothermic reaction.

**inlet losses:** the pressure drop between the pressure source (e.g., regulator, pressure vessel) and the pressure relief device inlet due to the maximum possible flow rate in a scenario in which the pressure relief device is required to operate (e.g., regulator fails open, vessel is pressurized above maximum allowable working pressure).

**set pressure (for pressure relief devices):** the value of increasing inlet static pressure at which a pressure relief device displays one of the operational characteristics as defined by opening pressure, popping pressure, start-to-leak pressure, burst pressure, breaking pressure, or buckling pressure. The applicable operating characteristic for a specific device design is specified by the device manufacturer (reference: ASME BPVC-XIII, Appendix I).

**set pressure tolerance (for pressure relief devices):** the range of pressures at which a pressure relief device can open (reference: ASME BPVC-XIII, Table 3.6.3.1-2).

**superimposed backpressure:** the static pressure that exists at the outlet of a pressure relief device at the time the device is required to operate. Superimposed backpressure is the result of pressure in the discharge system coming from other sources and may be constant or variable (reference: API 520 Part 1, paragraph 3.1.61).

This standard revision has been approved by the Engineering Directorate of the John F. Kennedy Space Center (KSC) and is mandatory for use at KSC.

# 1. SCOPE

## 1.1 Purpose

This standard establishes the minimum requirements for materials, processes, and engineering practices for the design of pneumatic ground systems for use at KSC. Where the requirements of this standard do not meet the minimum program or project requirements, the latter shall take precedence.

## 1.2 Applicability

a) This standard applies to all equipment, whether installed in facilities or portable, which handles gaseous media, including but not limited to breathing air, helium, hydrogen, methane, nitrogen, oxygen, and mixtures of these gases.

b) This standard does not apply to facility compressed air systems operating at or below 150 psig, vacuum systems, portable or mobile equipment covered by Department of Transportation (DOT) 49 CFR regulations, or life support equipment regulated by National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), or KSC-STD-Z-0008.

   *Design requirements for vacuum and compressed air systems operating at or below 150 psig can be found in KSC-DE-512-SM.*

c) These requirements apply to new equipment that has not been verified to meet requirements of a previous revision of this standard. Equipment designed or fabricated prior to the effective date of this standard may be verified as acceptable for use against the requirements of a previous revision of this standard. Any design changes to such equipment shall meet the requirements of this revision of this standard.

## 1.3 Use of Shall, May, Should, and Will

In this standard, the auxiliary verb “shall” denotes mandatory actions (i.e., requirements) that are verified. “May” denotes discretionary privilege or permission. “Should” denotes a good practice that is recommended but is not required. The terms “must” and “will” denote an expected outcome, a requirement levied by others, or a requirement that does not have mandated verification. When this standard is placed on a contract, the “will” statements in this standards manual are equivalent to “shall” statements for the purposes of the contract.

*Requirements denoted by “shall” require formal evidence for closure. “Will” is a formal requirement which is verified during design reviews and certification meetings but does not require formal documented evidence tied to that requirement.*

## 2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents should be specified in an attachment to the solicitation, Statement of Work, or contract.

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

Citations of applicable documents are hyperlinked to their appearance in 2.1 and 2.2. Citations of reference documents are not hyperlinked.

### 2.1 Government Documents

| | |
|---|---|
| 75M04185 | Identification Tag, Tubing and Hose Lines |
| 79K07491 | Installation of Purge Hardware |
| DOT 49 CFR | Code of Federal Regulations – Transportation |
| KDP-P-5042 | Engineering Directorate Acceptance Data Package Process Document |
| KNPR 8715.3-1 | KSC Safety Procedural Requirements Volume 1, Safety Procedural Requirements for Civil Servants/NASA Contractors |
| KSC-DE-512-SM | Ground Systems Development Standard |
| KSC-F-124 | Fittings, Flared Tube, Specification for |
| KSC-GP-425 | Fluid Fitting Engineering Standards |
| KSC-GP-435 | Engineering Drawing Practices<br>Volume I, Aerospace and Ground Support Equipment |
| KSC-SPEC-E-0002 | Modular Electrical Enclosures, Racks, Consoles, and Accessories, Specification for |
| KSC-SPEC-Z-0008 | Fabrication and Installation of Flared Tube Assemblies and Installation of Fittings and Fitting Assemblies, Specification for |
| KSC-STD-E-0015 | Marking of Ground Support Equipment |
| KSC-STD-Z-0017 | Engineering Analysis, Thermal/Fluid, Standard for |

| | |
|---|---|
| MIL-PRF-25567 | Leak Detection Compound, Oxygen Systems |
| MSFC-SPEC-384 | Leak Test Compound, LOX Compatible |
| NASA-STD-8719.17 | NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PVS) |

## 2.2 Non-Government Documents

| | |
|---|---|
| API 520 Part 1 | Sizing, Selection, and Installation of Pressure-Relieving Devices |
| ASME B16.5 | Pipe Flanges and Flanged Fittings |
| ASME B16.9 | Standards for Pipes and Fittings |
| ASME B31.3 | ASME Code for Pressure Piping, Process Piping |
| ASME B36.19 | Stainless Steel Pipe |
| ASME B40.100 | Pressure Gauges and Gauge Attachments |
| ASME BPVC-VIII | ASME Boiler & Pressure Vessel Code, Section VIII Division 1, Rules for Construction of Pressure Vessels |
| ASME BPVC-XIII | ASME Boiler & Pressure Vessel Code, Section XIII Rules for Overpressure Protection |
| ASTM A182 | Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service |
| ASTM A312 | Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes |
| ASTM A403 | Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings |
| ISO 14617 | Graphical Symbols for Diagrams |
| NBBI NB23 | National Board Inspection Code |
| SAE ARP901 | Bubble Point Test Method |
| SAE AS5202 | Port or Fitting End, Internal Straight Thread, Design Standard |

# 3. PIPING AND TUBING REQUIREMENTS

## 3.1 Tubing

### 3.1.1 Flared Tube Assemblies

Pneumatic distribution tubing runs shall be fabricated, installed, and tested in accordance with KSC-SPEC-Z-0008, except as otherwise specified herein.

### 3.1.2 Flared Fittings

a) Flared tubing runs shall be assembled by use of threaded fittings or a combination of threaded and butt-welded fittings. Fitting sizes shall be limited to 1/4 to 2 inch tube sizes.

b) Flared tube ends shall utilize a coupling nut (AS4326/KC142) and sleeve (AS4327/KC143) that matches the tube material (KSC-GP-425 material code K for UNS S30400, S31600, and S31603 tube, material code L for UNS N08367 and S31254 tube).

   *KSC-GP-425 material code L coupling nuts and sleeves are acceptable for use with all stainless steel tubing, but should be avoided due to increased cost.*

c) Threaded fittings shall be per KSC-GP-425 to the greatest extent possible, and shall be procured in accordance with KSC-F-124.

   *Fittings with equivalent KC and SAE AS part numbers in KSC-GP-425 are physically and functionally interchangeable. The SAE AS part number should be specified in design drawings and procurement documents when available.*

d) In cases where the system maximum allowable working pressure (MAWP) exceeds the MAWP specified in KSC-SPEC-Z-0008, threaded fittings shall be of the superpressure type. Installation design shall be in accordance with the manufacturer's instructions.

e) Other fitting types (e.g., pipe thread) shall not be used without approval of the KSC Engineering Technical Authority.

f) Fittings per KSC-GP-425 shall be substituted for plain-nose 37-degree fittings in designs under control of the KSC Engineering Technical Authority when leaks occur or modifications are necessary.

   *The fittings described in KSC-GP-425 are functionally interchangeable with plain nose 37-degree flared tube fittings, except that the maximum operating temperature is limited to 425°F.*

### 3.1.3 Maximum Allowable Working Pressure

The maximum allowable working pressure (MAWP) of all tubing and tube assemblies shall be in accordance with KSC-SPEC-Z-0008 and ASME B31.3.

*Fitting pressure ratings in KSC-SPEC-Z-0008 apply to stainless steel fittings (KSC-GP-425 material codes K and L, and KSC-GP-425 equivalent Aerospace Standard (AS) material codes J, K, R, and S) only. For other ductile materials, the MAWP may be determined by ASME B31.3 minimum wall thickness calculations, or by reducing the material's allowable stress per ASME B31.3 relative to that of type 316 stainless steel (20,000 psi).*

### 3.1.4 Threaded Ports

a) The standard port design for use with the fittings specified herein shall be per SAE AS5202.

*MS33649 ports are equivalent to SAE AS5202 ports. AND10049, AND10050, MC240, and MS16142 ports are generally compatible port designs but are not to be used for new design since occasional thread tolerance build-up on the KC fittings can prevent proper assembly of fitting to port.*

b) In cases where the system MAWP exceeds the MAWP specified in KSC-SPEC-Z-0008, ports shall be of the superpressure type and internally threaded. Installation design shall be in accordance with the manufacturer's instructions.

c) Other port types (e.g., pipe thread) shall not be used without approval of the KSC Engineering Technical Authority.

## 3.2 Piping

### 3.2.1 Maximum Allowable Working Pressure

The MAWP of all piping and pipe connections shall be determined based the criteria specified in ASME B31.3, paragraph 304.

### 3.2.2 Design and Installation

a) Buttwelded piping shall be used in systems where tubing is not practical (e.g., diameters larger than 2 inch are needed, or system MAWP exceeds tubing MAWP).

b) All piping installations shall be designed and installed in accordance with ASME B31.3, ASME B36.19, and the additional requirements specified herein.

### 3.2.3 Material

a) Pipe material shall be seamless, cold-drawn type 316 (UNS S31600) and/or 316L (UNS S31603) stainless steel per ASTM A312.

*Type 316L stainless steel pipe should be used in applications where corrosion resistance is desired and the system MAWP is less than the MAWP of type 316L pipe. In applications where corrosion resistance is desired and a higher MAWP is needed, type*

*316/316L dual-grade stainless steel pipe should be used. This applies to selection of fitting and mechanical joint materials as well.*

b) Other piping materials may be used with approval of the responsible materials and processes authority.

### 3.2.4 Fittings

a) Fittings, such as tees, crosses, elbows, and reducers, shall be of the buttweld type per KSC-GP-425 and ASME B16.9.

b) Fitting shall be type F316 and/or F316L stainless steel per ASTM A403.

### 3.2.5 Mechanical Joints

a) Mechanical joints in stainless steel piping shall consist of one of the following:

   i. Buttweld hubs per KC159, KC160, KC166, KC167, or KC168, clamp assemblies per KC155, and polytetrafluoroethylene (PTFE)-coated seal rings per KC162, and shall be assembled per KC163.
   ii. Flanged joints in accordance with ASME B16.5.

*Buttweld hubs are typically used in locations where space allowances cannot accommodate flanged joints.*

b) Mechanical joints shall be type F316 and/or F316L stainless steel per ASTM A182 (KSC-GP-425 material code C and/or D).

c) Space allowances shall be made for disengagement of all mechanical joints.

### 3.2.6 Welding and Radiography

All pipe welding and weld inspection shall be in accordance with KSC-DE-512-SM.

## 3.3 Marking and Identification

All piping and tubing runs shall be marked in accordance with KSC-DE-512-SM.

# 4. FLUID COMPONENT REQUIREMENTS

*Refer to K0000484851-GEN for a list of qualified components for use at KSC. While many of these components can be considered qualified for use at launch sites due to successful service in a previous spaceflight program, it is the designer's responsibility to determine the suitability of a particular component in its intended application.*

## 4.1 General

### 4.1.1 Maximum Allowable Working Pressure

The MAWP of all components shall be determined based on the criteria specified in ASME B31.3, paragraph 302 or 304, as applicable.

### 4.1.2 Materials

a) Unless otherwise specified herein or approved by the responsible materials and processes authority, all fluid component bodies and other pressure-containing parts shall be 300-series stainless steel per ASTM standards.

b) Components containing free-machining alloys such as UNS S30300 (type 303 stainless steel) and UNS S30323 (type 303Se stainless steel) used in corrosive environments shall be approved by the responsible materials and processes authority.

### 4.1.3 Pressure Connections

Unless otherwise specified herein, component pressure connections shall have internal threads per 3.1.4 for tubing applications, or be per 3.2.5 for piping applications.

### 4.1.4 Marking and Identification

a) Unless otherwise specified herein, all fluid components shall be permanently marked with the manufacturer's name, part number, and revision level, KSC part number and revision level (if applicable), and manufacturer's serial number (if applicable).

b) In addition, all flexible hoses, pressure regulators, valves, and filters shall be permanently marked with the component MAWP and flow direction.

## 4.2 Flexible Hoses

### 4.2.1 Application and Selection

a) Flexible hoses shall only be used when required for connection of portable equipment or to provide for movement between interconnecting fluid lines when no other feasible means are available.

b) Flexible hoses shall be selected, installed, and inspected in accordance with KSC-DE-512-SM, NASA-STD-8719.17, and KNPR 8715.3-1.

*Gases such as helium and hydrogen permeate slightly through PTFE-lined hoses. In applications where such permeation is undesirable, convoluted, unlined bellows or flexible metal hoses should be used. Such designs should include analysis in accordance with NSTS-08123 or MSFC-DWG-20M02540 to preclude premature failure due to flow-induced vibration. Acoustic coupling that can intensify the stresses caused by flow-induced vibration should be avoided by ensuring that normal fluid flow requirements do not exceed a velocity of Mach 0.2.*

### 4.2.2 Pressure Connections

Flexible hoses shall contain stainless steel coupling nuts in accordance with section 3.1.4 of this standard to connect to tubing or tube fittings, or stainless steel pipe fittings in accordance with section 3.2.5 of this standard to connect to piping or pipe fittings.

### 4.2.3 Marking and Identification

a) Flexible hoses shall be identified by an attached metal band per 75M04185-10, or by a dog tag attached with a nylon-coated steel cable, secured with a ferrule or wire-rope swaging sleeve.

b) Tags shall be die-stamped or electrochemically etched per KSC-STD-E-0015, with 1/8 inch lettering. Identification shall include the date (month and year) of fabrication, date (month and year) of hydrostatic test, hose MAWP, KSC part number if applicable, manufacturer name and part number, component unique identifier if applicable (e.g., A-number), and service medium (only for hoses used in oxygen, hydrocarbon, or hypergolic systems).

## 4.3 Pressure Gauges

*The requirements in this section do not apply to pressure gauges which are part of a commercial off-the-shelf (COTS) cylinder regulator assembly, or are associated with COTS pneumatic controllers, positioners, and other process control equipment.*

a) All pressure gauges shall conform to ASME B40.100.

b) Pressure gauges shall be selected so that the normal working pressure falls within the middle half of the gauge's full-scale range, unless the system operates over a very wide range of operating pressures. In all cases, the system MAWP shall not exceed the full-scale range of the gauge.

*This requirement does not apply to pressure transducers, which should have the smallest possible full-scale range to maximize accuracy. This may result in a gauge and transducer with different ranges at the same measurement point (e.g., a 750 psig circuit may utilize a 0-1500 psig gauge and a 0-1000 psig transducer).*

c) Pressure gauges shall be constructed of a one-piece solid front case, shatterproof window, pressure relief back, and bourdon tube pressure sensing element, as defined by ASME B40.100.

d) Pressure gauges used in oxygen systems as defined by section 5.1 shall include a bourdon tip bleed to facilitate cleaning.

*It is good design practice to include a bourdon tip bleed on all pressure gauges, regardless of the fluid medium.*

e) Liquid-filled case pressure gauges shall not be used.

## 4.4 Pressure Relief Devices

### 4.4.1 Application and Selection

a) Overpressure protection for pneumatic ground systems shall be provided by means of pressure relief devices (PRD) in accordance with ASME B31.3 for piping and tubing systems, ASME BPVC-VIII and ASME BPVC-XIII for stationary pressure vessels, or DOT 49 CFR for mobile pressure vessels.

b) PRD shall comply with KSC-DE-512-SM and NASA-STD-8719.17.

*Refer to NASA-STD-8719.17 for guidance on requirements for and selection of PRD for systems with an MAWP of less than 15 psig.*

c) When protecting a piping system downstream of a pressure regulator, the PRD flow capacity shall be greater than or equal to the flow capacity of the fully open upstream pressure regulator.

*Pressure regulators rarely fail fully open, and as a result PRDs typically have much higher flow capacities than needed for typical failure scenarios, such as improper manual adjustment or outlet pressure creep. API 520 Part 1 and API Standard 521 provide additional guidance for PRD selection and sizing.*

### 4.4.2 Installation

a) PRD for stationary pressure vessels shall be installed per ASME BPVC-VIII, paragraph UG-156.

b) PRD for piping or tubing systems shall be installed as close as practical downstream of each pressure-reducing device (e.g., regulator) or pressure source (e.g., compressor, gas recharger).

c) The opening through all pipe or tube, fittings, and components between a pressure vessel or piping system and its PRD shall have at least the area of the PRD inlet. Refer to Appendix A.I for guidance.

d) The layout of all pipe or tube, fittings, and components between a pressure source (e.g., vessel, regulator) and its PRD shall be sized such that the sum of pressures due to inlet losses, increase in PRD opening pressure due to PRD set pressure tolerance, and superimposed backpressure does not exceed 10% of the system or vessel MAWP or 3 psi, whichever is greater. Refer to Appendix A.II for guidance.

### 4.4.3 Discharge

a) The effects of the discharge from PRD shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment.

*Effects to be analyzed include, but are not limited to, thrust loads, noise, impingement of high-velocity gas or entrained particles, toxicity, oxygen enrichment, and flammability.*

b) When PRD discharge into piped disposal systems, the requirements in 5.5 shall apply.

c) The total backpressure at the PRD outlet, which is the sum of superimposed backpressure, and built-up backpressure, shall not exceed 10% of the PRD set pressure. Refer to Appendix A.III for guidance.

### 4.4.4 Setting and Testing

a) PRD set pressure shall not exceed the MAWP of the pressure vessel or the downstream piping or tubing system.

b) PRD shall be set by the manufacturer to the required set pressure.

c) Changes to the set pressure of PRD shall be performed only by the manufacturer or an ASME VR-certified vendor in accordance with NBBI NB23.

d) All PRD shall be retested in accordance with NBBI NB23 at time intervals in accordance with NASA-STD-8719.17.

### 4.4.5 Marking and Certification of Flow Capacity

a) Marking and certification of flow capacity of PRD shall be in accordance with ASME BPVC-XIII.

b) In addition, PRD shall be permanently marked with the manufacturer's name, part number, and revision level, KSC part number and revision level (if applicable), and manufacturer's serial number (if applicable).

## 4.5 Pressure Regulators

*Pressure regulators are intended to provide control of downstream pressure and systems should not rely on them to provide pressure isolation.*

### 4.5.1 Application and Selection

a) Pressure regulators shall be selected to maintain outlet pressures within the required system tolerance over the entire range of expected flow rates.

*Balanced valve pressure regulators should be used where widely varying inlet pressures would cause to set outlet pressure to exceed required tolerances.*

b) The effects of outlet pressure drop during flow (i.e., “droop”) on overall system performance shall be accounted for in the design documentation (e.g., analysis report or data manual) when selecting pressure regulators.

*When operating at or near their rated flow capacity, an undesired pressure drop usually occurs at the regulator outlet. This effect needs to be considered and accounted for in the system design. Manufacturer flow curves can be used to select appropriate regulators, but as best practice* ***regulators should normally operate between 20-80% of their rated flow capacity****. Typically, to ensure compliance with requirement 5.1(e), an upper limit of ~60% of the rated flow capacity is more appropriate (i.e., the regulator will still meet this 20-80% guideline after applying the requirement to maintain the required outlet pressure at a flow rate at least 25% above the required flow rate).*

c) Effects due to the ratio of upstream and downstream pressure on overall system performance shall be accounted for in the design documentation when selecting pressure regulators.

*For each stage of regulation,* ***the ratio of upstream to downstream pressure should not exceed 5:1 and the downstream pressure should be between 20-80% of the regulator’s rated outlet pressure.*** *This will maximize controllability of pressure and flow rate, minimize temperature changes due to Joule-Thomson expansion, and minimize the size of downstream PRD and discharge lines.*

d) For pressure regulation of gas cylinders, standard commercial-off-the-shelf cylinder regulators (with included pressure gauges) may be used, provided they meet all other governing requirements (e.g., DOT 49 CFR, KSC-DE-512-SM, NASA-STD-8719.17).

### 4.5.2 Dome-Loaded Pressure Regulators

*Dome-loaded pressure regulators are typically used for high flow applications. A typical dome-loaded pressure regulation circuit includes a manually-adjusted pressure regulator and/or a remotely-adjusted current-to-pressure regulator to set the outlet pressure of the dome-loaded regulator.*

a) Dome-loaded pressure regulators shall be of the externally-loaded type, except where circumstances require internal loading.

b) The dome shall have a MAWP of no less than the system MAWP at the regulator inlet.

c) The regulator diaphragm or piston shall be rated to withstand a differential pressure equal to the system MAWP without sustaining damage.

d) When the commodity providing the dome pressure differs from the process commodity, the designer shall evaluate the possibility of leakage and cross-contamination across the diaphragm that separates them.

### 4.5.3 Manually Adjusted Pressure Regulators

*Manually adjusted pressure regulators are typically used for low flow or dead-end applications where very accurate control of the outlet pressure is required.*

a) Manually adjusted pressure regulators shall reach a mechanical stop at both ends of the adjustment range (i.e., fully increased, fully decreased).

b) Application or removal of force to the manual adjustment shall not cause disassembly of the pressure-containing structure of the pressure regulator.

c) When used in conjunction with dome-loaded pressure regulators, manually adjusted pressure regulators shall incorporate an internal relief feature which decreases the outlet pressure as the regulator is manually adjusted (i.e., decreased).

d) Manually adjusted pressure regulators that do not incorporate an internal relief feature shall be accompanied with a vent valve immediately downstream of the pressure regulator outlet.

*Internal relief features are preferred on manually adjusted pressure regulators where possible (i.e., the fluid is non-hazardous, and the system location precludes an asphyxiation hazard). Some manually adjusted pressure regulators include vent ports, which can be used to satisfy requirement d) above.*

### 4.5.4 Current-to-Pressure Regulators

*Electronic current-to-pressure regulators are typically used in a dead-end application for precise, remote control of the outlet pressure of a dome-loaded pressure regulator.*

When used in conjunction with dome-loaded pressure regulators, current-to-pressure regulators shall incorporate an internal relief feature which decreases the outlet pressure as the regulator is electronically adjusted (i.e., decreased).

### 4.5.5 Materials

The material requirement in 4.1.2 does not apply to cylinder regulators described in 4.5.1(d) or current-to-pressure regulators described in 4.5.4.

## 4.6 Shutoff and Metering Valves

a) Valve stem travel shall reach a mechanical stop at both ends of the adjustment range (i.e., fully open, fully closed).

b) Application or removal of force to the stem-positioning device shall not cause disassembly of the pressure-containing structure of the valve.

c) Stem position indicators (if used) shall sense the position of the stem directly, not the position of the actuation device.

d) Shutoff valves shall be capable of isolating the fluid medium at the system MAWP from either side and shall be installed in accordance with the manufacturer's recommended flow direction for normal operation.

e) Manually actuated ball valves shall be equipped with positive local identification of flow-path position.

f) Split-body valves utilizing flat nonmetallic body gaskets shall be designed to restrain the gasket radially and shall include concentric serrations on the portions of the body halves mating with the gasket faces.

g) Balanced poppet manual valves that utilize external balancing ports or vents open to atmosphere shall not be used.

## 4.7 Filters

*Tee-type filters are preferred over in-line filters since the elements can be removed without disconnecting the filter from the fluid system. The location and performance (i.e., pore size) of filters are based on analysis of the system requirements and balances the need to protect critical components with minimizing system pressure losses.*

a) Filters shall be installed immediately upstream of all interfaces where control of particulate matter is critical and at other points as required to control particulate migration.

b) Filter elements shall maintain filtering quality and not be damaged when subjected to worst-case system conditions (i.e., maximum design flow rate with an element that is clogged to its maximum capacity).

c) All filters shall be designed with replaceable elements.

d) Filter elements shall be designed to withstand a differential pressure equal to or greater than the system MAWP without degradation of the filter element bubble point.

e) Determination of the largest pore or hole size of filters shall be in accordance with SAE ARP901, if applicable.

*SAE ARP901 is a recommended aerospace industry practice and is generally not an applicable test method for sintered metal filter elements. In such cases vendor documentation should outline test methods for determining effective pore size.*

f) Systems containing tee-type filters shall provide adequate clearance for filter element removal and replacement.

g) Systems containing in-line filters shall provide adequate clearance for removal and replacement of the entire filter assembly.

## 4.8 Pressure Vessels

### 4.8.1 Application

All pressure vessels shall meet the requirements of NASA-STD-8719.17 and KSC-DE-512-SM.

*Metallic pressure vessels in accordance with ASME BPVC-VIII are preferred for pneumatic ground systems. Damage to composite overwrap pressure vessels (COPV) can be difficult to detect and have the potential for catastrophic failure modes; therefore, COPV should not be used in ground-based applications.*

*Depending on the size of the vessel, ASME BPVC-VIII may require additional ports for inspection or other purposes. It is good design practice to ensure that pressure vessels include ports for inspection, venting, and/or draining as needed.*

### 4.8.2 User’s Design Requirements

All new pressure vessel specifications shall include preparation of a User’s Design Requirements Form per ASME BPVC-VIII Division 1, Nonmandatory Appendix KK.

### 4.8.3 Marking and Identification

Marking and identification of pressure vessels shall be in accordance with ASME BPVC-VIII and KNPR 8715.3-1.

*Where multiple pressure vessels are used to store the same fluid medium, only the most visible pressure vessel needs to be labeled.*

# 5. PNEUMATIC SYSTEM REQUIREMENTS

## 5.1 Pressure Regulation Circuits

*The design of pressure regulation circuits requires analysis of the system requirements, including those downstream of the design interface. Pressure regulation accuracy, minimum and maximum flow rate, and reliability are all considered in this analysis. Figure 1 and Figure 2 illustrate typical pressure-regulating circuit schematics.*

a) The number of regulation stages shall be determined in accordance with 4.5.1.

b) When redundant (parallel) regulation circuits are required, such circuits shall be designed for automatic switchover such that major components (e.g., filters, regulators, PRD) in either flow circuit can be repaired in place or removed without interrupting the flow in the parallel circuit.

c) Inlet and outlet isolation valves and intermediate vent valves shall be provided for shutdown and maintenance. The inlet and outlet isolation valves shall be bi-directional and capable of isolating the system MAWP in either direction without seat failure. Normal venting operations shall not cause filters to backflow.

d) When a manually-adjusted or current-to-pressure regulator is used to set the outlet pressure of a dome-loaded regulator, a test port and vent valve shall be provided downstream of the manually-adjusted or current-to-pressure regulator (refer to Figure 1 and Figure 2).

e) Pressure regulation circuits shall be designed with the capability to maintain the required outlet pressure at a flow rate at least 25% above the required flow rate.

f) The tolerance on outlet pressure (expressed as either a range or a discrete value with plus/minus allowances) of each pressure regulator shall be identified on all schematic drawings.

g) The nominal operating pressure (expressed as either a range or a discrete value with plus-minus allowances) and MAWP of each pressure regulation circuit shall be identified on all schematic drawings.

h) All pressure-regulating circuits shall be designed so that all components can be easily removed and replaced. Allowances shall be made for tool clearances and disengagement of mechanical joints.

*When designing a pressure regulation circuit, consider that when performing maintenance or repair on a pressure system, a pressure regulator or check valve cannot be used as the sole pressure isolation device.*

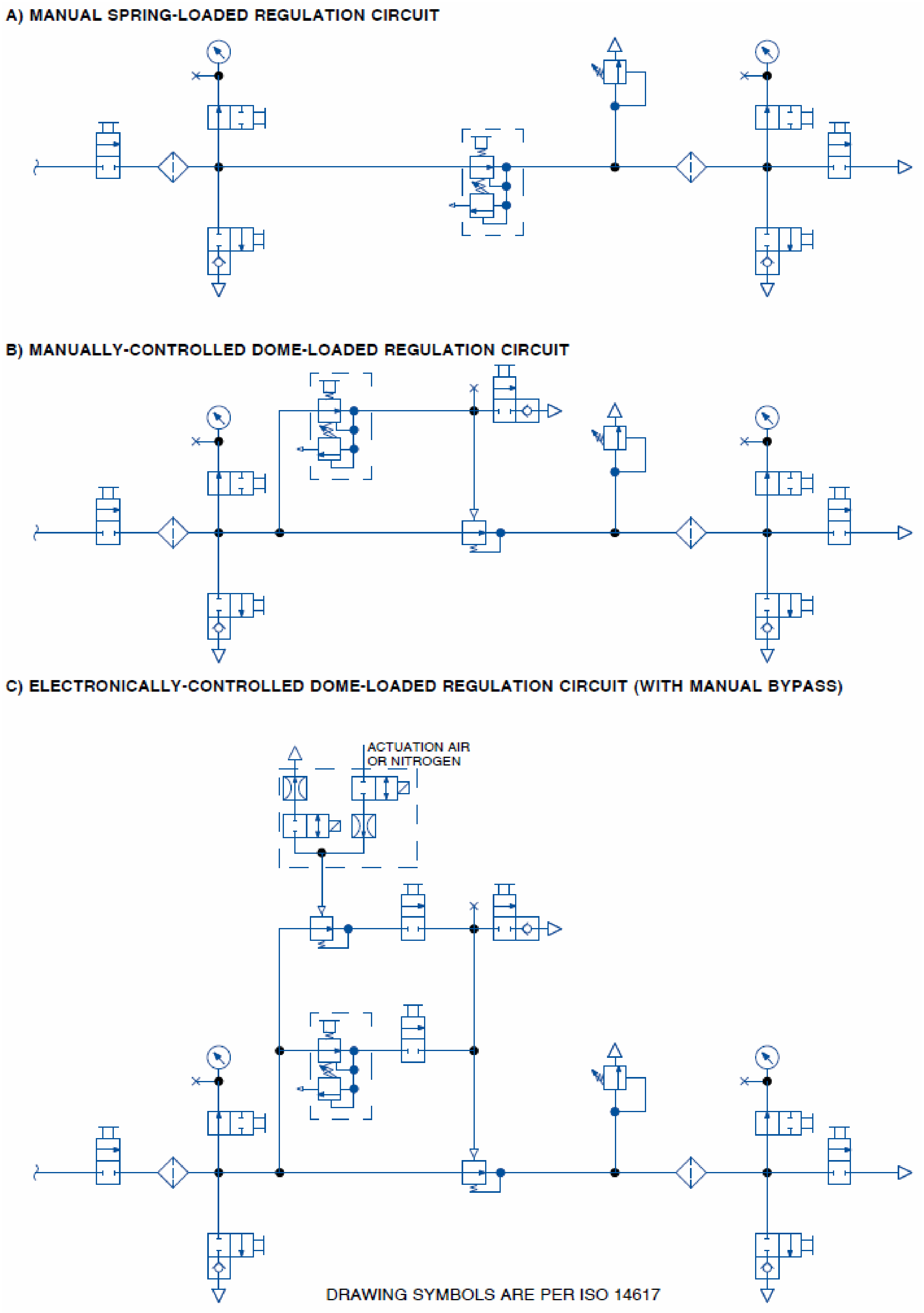
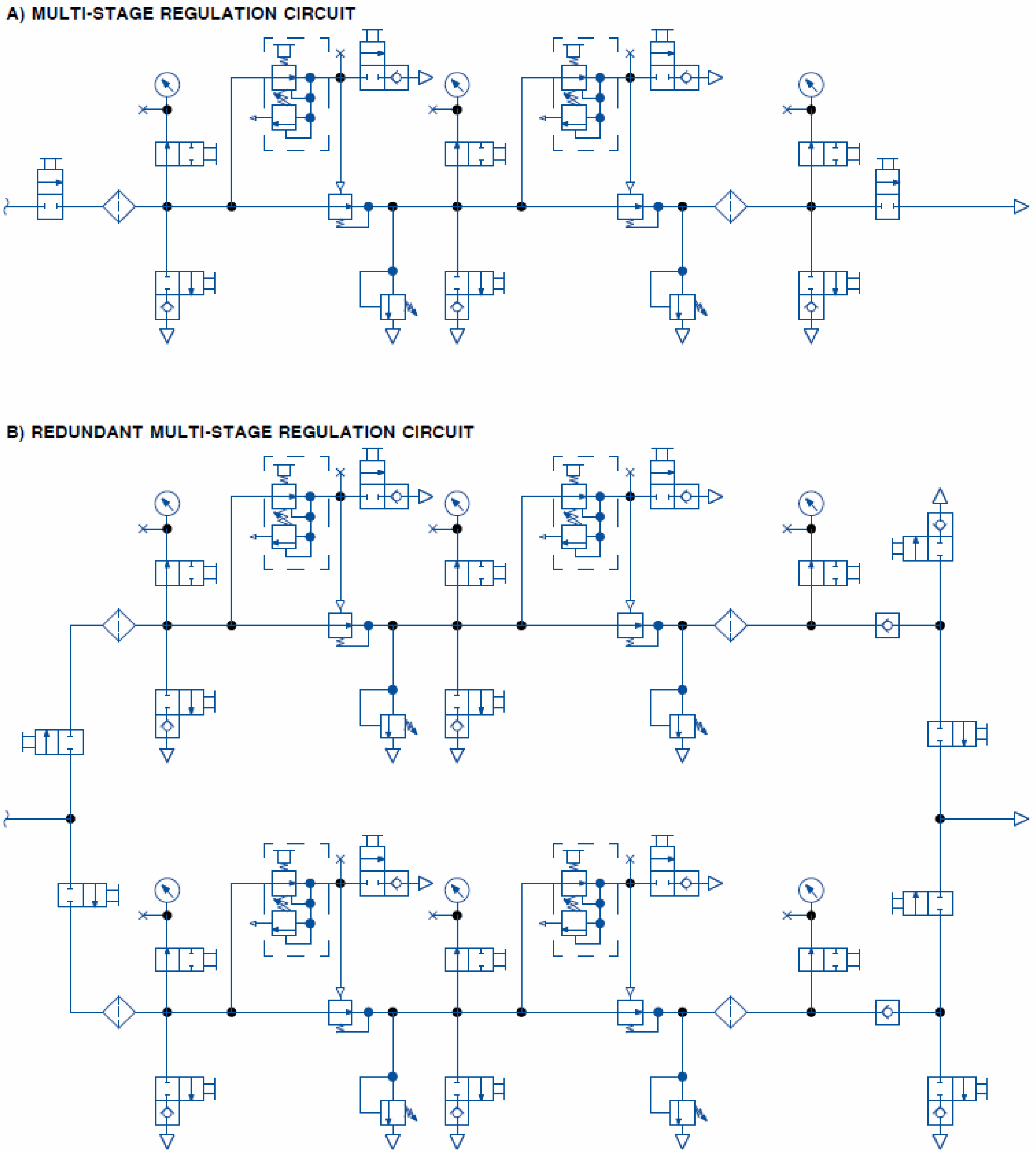


Figure 1. Typical Single-Stage Pressure Regulation Circuit


A) MULTI-STAGE REGULATION CIRCUIT

B) REDUNDANT MULTI-STAGE REGULATION CIRCUIT

**NOTE:** TWO-STAGE MANUALLY-CONTROLLED DOME-LOADED REGULATION CIRCUITS ARE SHOWN. AN EQUIVALENT LAYOUT MAY BE USED FOR SPRING-LOADED AND ELECTRONICALLY-CONTROLLED REGULATION CIRCUITS. ADDITIONAL STAGES MAY BE ADDED AS REQUIRED.

DRAWING SYMBOLS ARE PER ISO 14617

**Figure 2. Typical Multiple-Stage and Redundant Pressure Regulation Circuits**

## 5.2 Oxygen Systems

*For the purposes of this standard, oxygen systems are defined as any system containing pure oxygen pressurized above ambient pressure, breathing air or other mixed-gas systems where the partial pressure of oxygen at system MAWP is 30 psig or greater, and compressed air systems with a system MAWP of 150 psig or greater. Guidelines on the design of safe oxygen systems are contained in ASTM MNL 36, ASTM G63, ASTM G88, ASTM G94, and NASA/TM-2007-213740.*

*Special care needs to be taken in the design of oxygen systems to minimize heating effects due to rapid increases in pressure. Fast-opening valves which can produce high-velocity kinetic effects and rapid pressurization should be avoided. Shutoff valves that cannot be throttled prevent rapid pressurization of downstream components should include a bypass metering valve to allow for slow pressurization of the downstream system before the main shutoff valve is opened.*

Gaseous oxygen systems shall be designed in accordance with KSC-DE-512-SM.

## 5.3 Hypergol Systems

*The requirements listed below relate exclusively to mitigation of hypergolic propellant migration and do not constitute a complete design concept. Additional requirements for pressure regulation and sampling circuits are provided elsewhere in this standard. Figure 3(a) illustrates the minimum design requirements for pneumatic branches that interface with hypergolic propellant systems.*

a) Each pneumatic branch line that interfaces with a hypergolic propellant system shall have a hand-operated shutoff valve upstream of a spring-loaded poppet-type check valve to permit shutoff of the pneumatic supply and prevent backflow of hypergolic propellants into the pneumatic system.

b) Each pneumatic branch line that interfaces with a hypergolic propellant system shall be downstream of a pneumatic supply pressure regulator which serves only branches that interface with one type of hypergolic propellant (i.e., fuel or oxidizer).

c) A port shall be available upstream and downstream of each regulator to permit periodic sampling and analysis of the pneumatic medium for hypergol contamination. Except in systems in which the check valve is connected to a vent system and there is no means of isolation downstream of the check valve, a pressure gauge shall be provided at some point downstream of each check valve (either in the pneumatic system or the hypergol system) to indicate the pressure in the hypergolic propellant system.

*If there is no possibility of generating pressure downstream of the check valve, no pressure indication is needed.*

d) Except in systems described by (f) below, the pneumatic system downstream of and including each pressure regulator shall be constructed of materials that are compatible with the hypergolic propellant. The Materials and Processes Technical Information System (MAPTIS) will be consulted to obtain material codes and ratings.

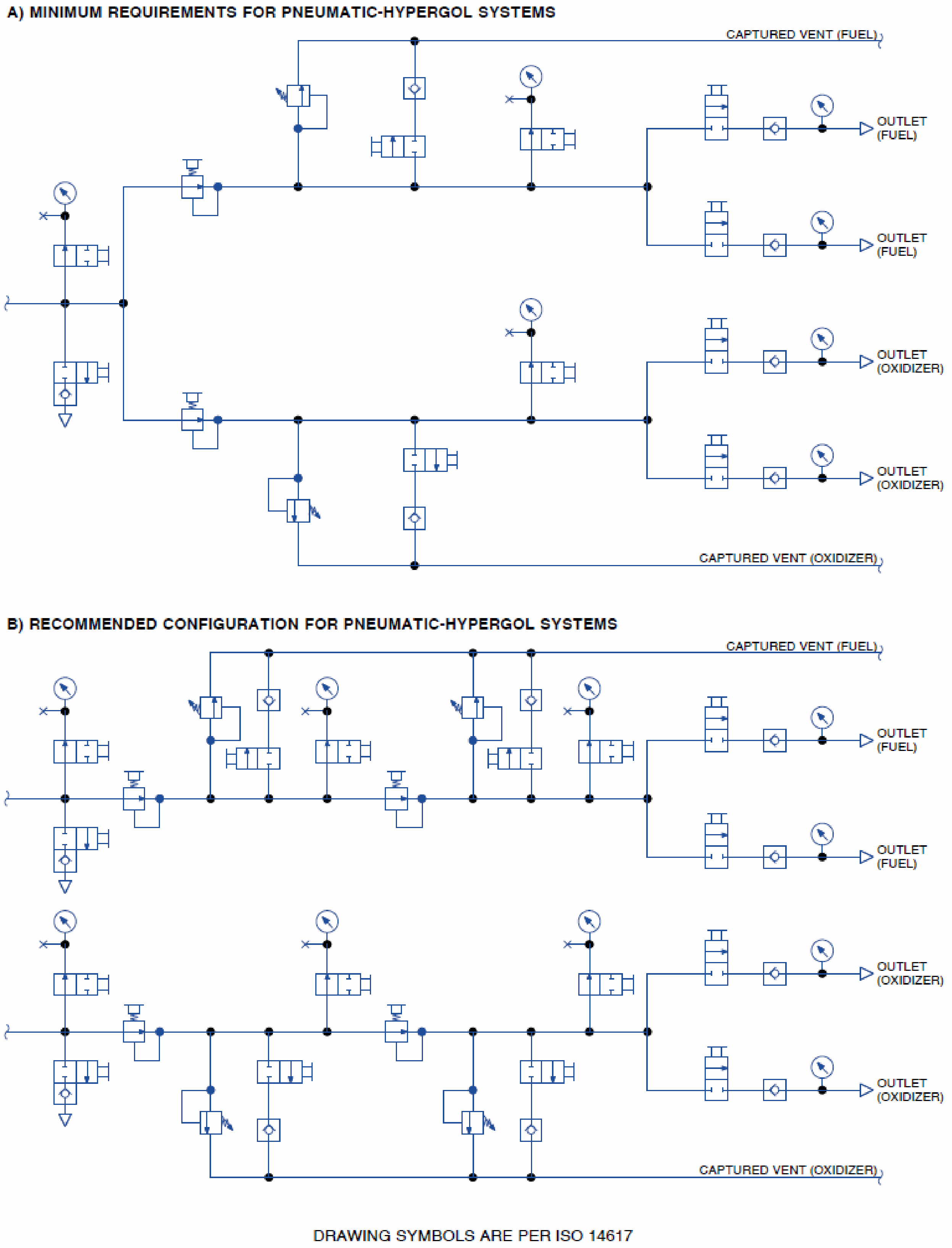
e) In cases where (1) an orifice is positioned downstream of the pneumatic pressure regulator, (2) pneumatic flow is autonomously established whenever the pneumatic system is opened to the hypergolic system, and (3) a pressure differential is continuously maintained across the orifice (e.g., aspirator systems), only the isolation valve immediately upstream of the orifice and all components downstream of (and including) the orifice must be compatible with the hypergolic propellant. The Materials and Processes Technical Information System (MAPTIS) will be consulted to obtain material codes and ratings.

f) Any sources of venting downstream of each pressure regulator (e.g., relief valve, vent valve, pressure regulator self-vent) shall be captured in a vent system dedicated to the hypergolic propellant with which the system interfaces.

g) The pneumatic system downstream of each pressure regulator shall be color-coded as a hypergolic propellant system in accordance with KSC-DE-512-SM.

*In addition to the requirements listed above, pneumatic systems that interface with hypergolic propellant systems should incorporate the following elements wherever practical (refer to Figure 3(b)):*

i. *Each hypergolic propellant system (e.g., hydrazine, monomethyl hydrazine, nitrogen tetroxide, etc.) should be served by an independent pneumatic system with a pressure vessel that serves only one propellant.*
ii. *The entire pneumatic system should be constructed of materials that are compatible with the hypergolic propellant.*
iii. *At least two stages of pneumatic pressure regulation should be provided upstream of the isolation valve.*


A) MINIMUM REQUIREMENTS FOR PNEUMATIC-HYPERGOL SYSTEMS

B) RECOMMENDED CONFIGURATION FOR PNEUMATIC-HYPERGOL SYSTEMS

DRAWING SYMBOLS ARE PER ISO 14617

Figure 3: Pneumatic-Hypergol System Configurations

## 5.4 Multiple Fluid Systems

a) Pneumatic systems that operate with multiple fluid supplies shall be designed to prevent accidental contamination or cross-connection of one inlet supply by another.

b) Each fluid supply shall terminate with an isolation valve followed by a check valve, with a vent valve installed in between the isolation valve and check valve (refer to Figure 4).

c) Operating procedures shall require closing of the isolation valve and opening of the vent valve in the active supply prior to activation (i.e., closing the vent valve and opening the isolation valve) of another supply.

d) Multiple fluid systems in which one or more hazardous fluid supplies is used shall be designed to physically prevent connecting of a hazardous fluid supply to the wrong inlet (e.g., different size inlet ports, use of right- and left-hand threaded ports).

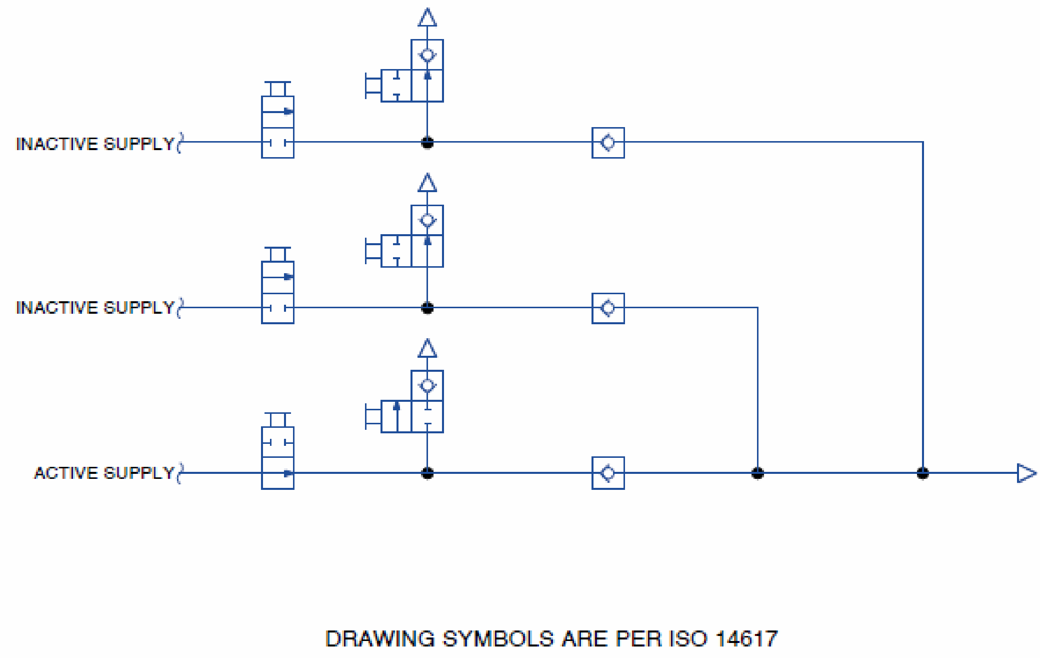


Figure 4: Multiple Fluid System Inlet Configuration

## 5.5 Vent Systems

a) If a pneumatic ground system requires disposal of hazardous fluids or protection of personnel from other hazards (e.g., excessive noise, high velocity impingement, asphyxiating conditions), a vent system shall be used.

b) Oxidizers and fuels (including vapors in an inert gas stream) shall not be discharged into the same vent system.

c) Vent systems for hazardous fluids other than oxygen shall be equipped with a means of inerting the vent system using a gas (e.g., nitrogen, helium) that is compatible with all interfacing system materials and fluids.

d) Vent system outlets shall be:
   i. conspicuously identified.
   ii. in locations that are normally inaccessible to personnel and prevent personnel hazards due to possible ignition (e.g., hydrogen and oxygen vents).
   iii. designed to prevent mixing of fuel and oxidizer at the discharge point.
   iv. designed to prevent accumulation of vented fluids in dangerous concentrations in areas frequented by personnel or vehicles.
   v. designed to preclude vented fluids from impinging on unprotected personnel.
   vi. designed to prevent personnel exposure to excessive venting noise via mufflers, silencers, or locating vent outlets in areas inaccessible to personnel.
   vii. protected against intrusion by rain and animals (e.g., birds, insects, spiders).
   viii. adequately supported to accommodate outlet thrust loads.

e) Vent systems shall be designed to minimize backpressure at the required venting flow rate. Refer to Appendix A.III for guidance on sizing and analyzing PRD vent lines.

f) Except for PRD vent lines, each line venting into a multiple-use vent system shall be protected against back-pressurization by means of a check valve if the upstream system MAWP is less than the potential vent system backpressure, or if the upstream system is not compatible with potential venting fluids.

## 5.6 Flexibility and Support

a) Tubing shall be supported in accordance with KSC-SPEC-Z-0008.

b) Piping shall be supported in accordance with ASME B31.3, paragraphs 319 and 321.

c) Large components and pressure vessels shall be supported to prevent exceedance of allowable stresses per ASME B31.3.

d) All supports shall be designed to protect against galvanic corrosion due to dissimilar tube/pipe and support materials.

*Tubing and piping that are not located in a corrosive or launch environment may be supported using strut channel (e.g., Unistrut) structures. Tubing and piping that are located in a corrosive or launch environment should be supported using common structural shapes that are better suited to corrosion resistance and launch-induced effects (e.g., vibration and blast loads). In all cases, environmental effects on support structures need to be considered in the system design.*

## 5.7 Layout, Marking, and Identification

### 5.7.1 System Layout

a) Pneumatic ground systems should be contained within a panel or enclosure, with manually functioning components (e.g., valve and regulator handles, pressure gauge dials) mounted to the panel or enclosure face.

b) Unless an alternate arrangement is approved in written correspondence by the KSC Engineering Technical Authority, and that correspondence is included in the design documentation prior to fabrication, panel or enclosure mounted pneumatic ground systems shall be arranged so that the nominal flow direction is from left to right when viewed from the front of the panel or enclosure.

   *In certain installations, it may be impractical or impossible to arrange the flow direction from left to right. In these cases, notes should be added to drawings and flow diagrams to alert users to a non-standard arrangement. Approval of such deviations is required during the design phase to ensure that the configuration and mitigations are properly reviewed and approved.*

c) Except for PRD outlets, all inlet and outlet connections to a panel or enclosure should run through a bulkhead fitting on the panel frame or enclosure assembly.

   *In cases where piping is used for interconnecting lines, or piping and/or pipe components are used within a panel or enclosure, it may be more practical to use pipe connections (e.g., flanges, buttweld hubs) in lieu of bulkhead connections.*

d) Inlet and outlet connections shall be spaced far enough from each other so that the identification markings on the front of the panel or enclosure can clearly identify each connection.

### 5.7.2 Flow Diagram

a) Each pneumatic panel or enclosure shall include a satin anodized aluminum flow diagram representing the panel or enclosure schematic.

b) Black lines shall be used to depict connections between panel-mounted components.

c) Components not visible from the front of the panel or enclosure shall be represented with the appropriate black schematic symbol per ISO 14617.

d) Pneumatic systems that are not panel or enclosure mounted shall include a black on satin anodized aluminum flow diagram visible to the system operator.

### 5.7.3 Components

a) Each mechanical and electromechanical component and interface connection shall be assigned a unique identifier that is depicted on the engineering drawing in accordance with KSC-GP-435, Vol. I.

b) Each mechanical and electromechanical component and interface connection shall be identified on the front of the panel or enclosure, or, for systems that are not panel or enclosure mounted, on the flow diagram described in 5.7.2(d).

c) Each mechanical and electromechanical component and interface connection shall be identified with an ink stamp or stencil as close to the component as possible on the back of the panel or enclosure or support structure.

*Where this practice is not feasible, a dog tag may be used to identify the component or interface connection.*

d) Mechanical and electromechanical components shall be identified with the component unique identifier and the component's function (e.g., inlet pressure gauge, vent valve, etc.).

e) Pressure regulators and PRD shall also be identified with their nominal set pressures, including the set pressure tolerance.

f) Interface connections shall be identified with the interface unique identifier, the interface function, the fluid medium, and the nominal operating pressure (e.g., 3000 psig GN2 Inlet, 750 psig GHe Outlet).

### 5.7.4 Titles and Descriptions

a) Each pneumatic system shall be provided with a functionally descriptive title that is assigned in the engineering drawing and prominently displayed either on the front of the panel or enclosure, or, for systems that are not panel or enclosure mounted, on the flow diagram described in 235.7.2(d).

b) The system title shall include, at a minimum, the name of the system and the engineering drawing number.

## 5.8 Flow and Thermal Analysis

Pneumatic ground systems shall be analyzed in accordance with KSC-STD-Z-0017.

## 5.9 Pressure System Certification

Pneumatic ground systems shall be verified as in compliance with NASA-STD-8719.17. Refer to Appendix B for guidance.

## 5.10 Environmental Protection

a) Pneumatic ground systems shall be designed to perform in the natural and induced environments to which they will be subjected during their lifecycles and in accordance with KSC-DE-512-SM.

b) Pneumatic ground systems that require hazardproofing or contain components that cannot withstand exposure to natural or induced environments shall be protected by an enclosure in accordance with KSC-SPEC-E-0002, equipped with a positive internal pressure purge utilizing purge hardware in accordance with 79K07491.

c) Components requiring an atmospheric reference pressure (e.g., certain types of pressure transducers) installed in an internally-purged enclosure shall be equipped with a means of furnishing the atmospheric reference pressure.

d) Enclosures designed to maintain static positive internal pressure shall not be used in pneumatic ground systems without approval of the KSC Engineering Technical Authority.

## 5.11 Material Compatibility

Pneumatic ground systems shall be designed and evaluated for material compatibility with the fluid medium in accordance with KSC-DE-512-SM.

## 5.12 Cleanliness

Surface cleaning of pneumatic ground systems shall be in accordance with KSC-DE-512-SM.

## 5.13 Hydrostatic Test

a) Tube assemblies shall be hydrostatically tested in accordance with KSC-SPEC-Z-0008 prior to final installation in the system.

b) Pipe assemblies shall be individually hydrostatically tested in accordance with ASME B31.3, paragraph 345, prior to final installation in the system.

c) Components shall be individually hydrostatically tested in accordance with ASME B31.3, paragraph 345, prior to final installation in the system.

## 5.14 Leak Test

a) Pneumatic ground systems shall be pneumatically leak tested in accordance with ASME B31.3, paragraph 345, and the Leak Testing of Pressure Vessels and Pressurized Systems (PVS) Above Design Pressure Memorandum of Interpretation (refer to Appendix C).

b) All pneumatic ground system mechanical connections, gasketed joints, seals, etc., shall be leak tested with the system fluid medium, except for hazardous gas systems, which shall be leak tested with a system compatible non-hazardous gas with a density as near as possible to the system fluid medium (e.g., gaseous helium for a gaseous hydrogen system).

c) Leak test solution shall conform to MIL-PRF-25567 Type I or MSFC-SPEC-384.

d) All test points shall be bubble tight for a minimum of one minute after leak test solution is applied. Bubble tight is defined to be no greater than 1 x $10^{-4}$ standard cubic centimeters per second of the leak test medium.

e) All surfaces shall be thoroughly rinsed clean of test solution using deionized water immediately upon completion of the leak test.

## 5.15 Quality Assurance

### 5.15.1 Acceptance Test

Acceptance testing of pneumatic ground systems shall include leak and functional testing, including at a minimum verification of regulator function, operation of manual and remote valves, checkout of electrical components and cables, and proper orientation of check valves.

### 5.15.2 Acceptance Data Packages

All pneumatic ground systems shall be provided with an Acceptance Data Package in accordance with KDP-P-5042, and shall also include, at a minimum, the following documentation as applicable:

i. As-built shop drawings and schematics
ii. Requests for information and deviation/waiver requests
iii. Material and component certifications
iv. Welding procedures, welder certifications, weld inspection reports, and weld maps
v. Protective coating inspection reports
vi. Cleaning procedure and record
vii. Hydrostatic test procedure and record
viii. Acceptance test procedure and record
ix. Material inspection receiving report (e.g., Form DD250)

### 5.16 Packaging, Handling, and Transportation

Packaging, handling, and transportation of pneumatic ground systems shall be in accordance with KSC-DE-512-SM.

## 6. NOTES

### 6.1 Intended Use

This standard defines the requirements for design of pneumatic ground systems and does not constitute a specification for the procurement, fabrication, or installation of the system or components.

### 6.2 Citation Data

Contract documents should cite this specification by number, title, and date. Drawings should cite this specification by number in a general note.

**NOTICE:** When Government drawings, specifications, or other data are used for any purpose other than in connection with definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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# APPENDIX A. PREESIRE RELIEF DEVICE SIZING AND INSTALLATION

## I. SIZING INLET LINES

Per ASME B31.3 and ASME BPVC-VIII requirements, the opening area from a pressure vessel or piping system to the PRD inlet must be at least as large as the PRD inlet. Since pneumatic systems frequently use regulators and PRDs that do not have matching port sizes, this requirement can be satisfied by installing an expander fitting directly on the outlet of the regulator (or other flow-controlling component). The area ratio of the tubing downstream of the regulator to the boss fitting on the regulator outlet port should not exceed 5:1. The diameter of the boss fitting can be found in KSC-GP-425 (dimension “A” for KC136/AS4320). Examples are listed below:

Meets guidance:
Regulator outlet: 1/2” AS5202
Expander on regulator: 1/2” boss to 3/4” tube
Tubing downstream of regulator: 3/4” OD x .065” wall
Area ratio: 0.302 in / 0.120 in = **2.52**
  Regulator outlet port area = ¼*π*(0.391 in)$^2$ = 0.120 in
  Tubing downstream of regulator: ¼*π*(0.750 in - 2*0.065 in)$^2$ = 0.302 in

Does not meet guidance:
Regulator outlet: 1/4” AS5202
Expander on regulator: 1/4” boss to 3/4” tube
Tubing downstream of regulator: 3/4” OD x .065” wall
Area ratio: 0.302 in / 0.0232 in = **13.0**
  Regulator outlet port area = ¼*π*(0.172 in)$^2$ = 0.0232 in
  Tubing downstream of regulator: ¼*π*(0.750 in - 2*0.065 in)$^2$ = 0.302 in

In a scenario where a PRD is required to operate (e.g., a regulator fails open), the sum of all pressure losses from the pressure source to the PRD inlet shall not exceed 10% of the system MAWP. The MAWP is determined by the design engineer, and is usually one of three things:

a) The set pressure of the PRD protecting that portion of the system.
b) The pressure rating of the lowest rated component in the portion of the system being protected by that PRD.
c) The maximum pressure specified in a requirements document, interface control document, or interface table.

The design pressure must be chosen and documented prior to hardware fabrication, because that determines the leak test pressure during fabrication.

## II. OVERPRESSURE ALLOWANCE

ASME BPVC-VIII requires the use of relief devices to prevent the pressure of a system or vessel from exceeding a certain value above the system or vessel MAWP. In most applications, a single relief device is used, and it must prevent the system or vessel from exceeding 110% of MAWP or MAWP plus 3 psi, whichever is greater. There are three potential sources of overpressure, all of which must be considered and added together to determine whether the system or vessel meets the overpressure allowance:

a) Inlet losses. This is the pressure drop between the pressure source and the PRD inlet while the PRD is open and flowing the maximum possible flow rate that the system can provide. In some cases (particularly piping systems), the maximum flow rate will be limited by the pressure source (such as a failed open regulator), and in other cases (particularly pressure vessels), the maximum flow rate will be the PRD's rated flow capacity. These losses mean that the pressure at the pressure source will be higher than the pressure at the PRD inlet. It is good engineering practice to limit these losses to no more than 3% of the PRD set pressure.

b) Increase in PRD opening pressure due to PRD set pressure tolerance. Most PRDs have a set point tolerance of ±3% of set pressure, or ±2 psi, whichever is greater. This means that the PRD may not open until the pressure at the PRD inlet is higher than the PRD's stamped set point. For example, a PRD set to 1000 psi may not open until the pressure at the PRD inlet is 1030 psi (3% higher), and a PRD set to 20 psi may not open until the pressure at the PRD inlet is 22 psi (2 psi higher). In these cases, the potential increase in PRD opening pressure (30 and 2 psi, respectively) must be accounted for in determining the allowable overpressure.

c) Superimposed backpressure. The set pressure of a PRD is a differential pressure (i.e., it is the difference between the pressures at the PRD inlet and outlet). Superimposed backpressure, which exists in the vent line prior to the PRD opening, therefore increases the PRD's opening pressure by the magnitude of superimposed backpressure on the vent line. For example, a PRD set to 1000 psi that vents directly to atmosphere will open when the PRD inlet pressure reaches 1000 (±30) psig, whereas if it is connected to a vent line with a constant superimposed backpressure of 100 psig, it will not open until the PRD inlet pressure reaches 1100 (±30) psig.

Built-up backpressure, which only exists after a PRD has opened, does not contribute to the overpressure allowance. In almost any system (except in ones with PRDs set to pressures lower than about 20 psi), the PRD orifice is a choke point at which the velocity of the fluid flowing through the PRD exceeds the local speed of sound. Variations in the pressure of a fluid downstream of a choke point (in the vent line) cannot directly affect the pressure of the fluid upstream of the choke point (at the PRD inlet). Therefore, built-up backpressure, which only exists downstream of a choke point, does not contribute to the system overpressure allowance.

The approach below details a standard method to determine if PRD inlet lines are compliant with ASME B31.3 and the requirements of this standard, using Applied Flow Technologies Arrow or similar software. If the inlet line size requirement referenced in Appendix A.I and the criteria in steps 6a, 6b, or 7a are met, then the system is considered compliant. Systems should be designed to meet the criterion in step 6a wherever possible.

1. Use a flow rate node to represent the pressure source outlet. Set the flow rate to the calculated maximum flow rate (the maximum flow rate of a failed open regulator or other flow-controlling component, or the PRD flow capacity for PRDs protecting a pressure vessel).
2. Use a pressure node to represent the PRD inlet. Set the **stagnation** pressure to the nominal PRD set pressure (in **psig**).
3. Connect the flow rate and pressure nodes with a pipe segment using the installed tube inner diameter, length, and surface roughness.
4. Bends and elbows can be modeled as embedded losses within the pipe segment, but place area change nodes (abrupt transition) where expansions are located on the hardware. Area change nodes can be excluded if they are directly on a pressure source outlet **other than a pressure vessel**; pressure vessel outlet ports should not be smaller than the size of the line connecting to the PRD that protects the pressure vessel.
5. Run the model with the pressure output in **psia**.
6. Compare the **stagnation** pressures at the flow rate node (pressure source outlet) and pressure node (PRD inlet).
    a. If the stagnation pressure at the pressure source outlet is **no more than 103%** of the stagnation pressure at the PRD inlet (PRD set pressure), then the PRD circuit is compliant and meets standard design practices.
    b. If the stagnation pressure at the pressure source outlet is **no more than 107%*** of the stagnation pressure at the PRD inlet (PRD set pressure), then the PRD circuit is compliant.
    c. If the stagnation pressure at the pressure source outlet is **more than 107%*** of the stagnation pressure at the PRD inlet (PRD set pressure), then the PRD inlet lines should be redesigned. If redesign is impractical, proceed to step 7.
7. Compare the **stagnation** pressure at the pressure source outlet to the MAWP (in **psia**) of the portion of the system that PRD is protecting. The MAWP is the pressure rating of the lowest rated component in that portion of the system, or maximum pressure allowed per system requirements.
    a. If the stagnation pressure at the pressure source outlet is **no more than** the MAWP, then the PRD circuit is compliant.
    b. If the stagnation pressure at the pressure source outlet is **more than** the MAWP, then the PRD inlet lines require redesign.

* *This value considers an assumed PRD set pressure tolerance of ±3%. If the selected PRD has a different set pressure tolerance, then replace this value with "110% of the PRD set pressure minus the PRD set pressure tolerance."*

## III. VENT LINE BACKPRESSURE

ASME BPVC-VIII provides no requirements and little guidance on the design of PRD vent lines. It recommends limiting the static pressure at the PRD outlet to no more than 10% of the PRD set pressure (paragraph M.7(c)). API 520 Part 1 similarly states that for conventional PRDs where the allowable overpressure is 10% of MAWP, the backpressure should not exceed 10% of the PRD set pressure (paragraph 5.3.3.1.3).

Backpressure (both superimposed* and built-up) acts against the PRD seat, applying force on the seat toward the closed position. If it is too high, backpressure can reduce the flow capacity of the PRD, and ultimately close it. API 520 Part 1 establishes a backpressure capacity correction factor, and states that if the backpressure does not exceed 10% of the PRD set pressure, then the correction factor is equal to 1.0 (i.e., there is no flow capacity reduction). Valve manufacturers (e.g., Anderson Greenwood Crosby) and laboratory testing support the assumption that PRD flow capacity is not affected when backpressure is less than 10% of the PRD set pressure.

In cases where backpressure must exceed 10% of the PRD set pressure, it is possible to apply a flow capacity reduction factor to the PRD. However, this requires an accurate flow curve from the valve manufacturer that shows the PRD flow capacity as a function of backpressure. There is also the added complication of configuration control; it is difficult to track the fact that the PRD is being used at a flow capacity less than the rated flow capacity stamped on the PRD. The preferred solution is to use a balanced bellows PRD. Balanced bellows PRDs protect the PRD spring from the effects of backpressure, allowing for much higher backpressure without reducing the PRD flow capacity.

* *In cases where superimposed backpressure is constant, it can be accounted for by reducing the PRD set pressure to no more than MAWP minus the superimposed backpressure. In this case, superimposed backpressure does not count toward the recommended backpressure limit. In cases where superimposed backpressure is not constant, such a PRD adjustment can negatively affect system performance (i.e., the PRD may open at a lower than desired pressure if there is little or no superimposed backpressure at the time), so it must count toward the recommended backpressure limit.*

The approach below details a standard method to determine if PRD vent lines are compliant with ASME B31.3 and the requirements of this standard, using Applied Flow Technologies Arrow or similar software. If the criteria in steps 6a, or 7a are met, then the system is considered compliant. Systems should be designed to meet the criterion in step 6a wherever possible.

1. Use a flow rate node to represent the PRD outlet. Set the flow rate to the calculated maximum flow rate (the maximum flow of a failed open regulator or other flow-controlling component, or the PRD flow capacity for PRDs protecting a pressure vessel).
2. Use a pressure node to represent the vent system outlet. Set the **stagnation** pressure to **0 psig**.
3. Connect the flow rate and pressure nodes with a pipe segment using the installed tube inner diameter, length, and surface roughness.
4. Bends and elbows can be modeled as embedded losses within the pipe segment, but place area change nodes (abrupt transition) where expansions are located on the hardware. This includes expanders installed directly on the PRD outlet; include a short pipe segment for the path from the expansion point to the PRD outlet).
5. Run the model with the pressure output in **psia**.
6. Compare the **stagnation** pressures at the flow rate node (PRD outlet) and the PRD set pressure (in **psia**).
    a. If the stagnation pressure at the PRD outlet is **no more than 10%** of the PRD set pressure, then the relief vent line is compliant and meets standard design practices.
    b. If the stagnation pressure at the regulator outlet is **more than 10%** of the PRD set pressure, then the PRD vent line should be redesigned. If redesign is impractical, and PRD manufacturer flow curves are available to determine a backpressure capacity correction factor, proceed to step 7*.
7. Calculate the PRD's reduced flow capacity (the backpressure capacity correction factor times the PRD flow capacity) and compare it to the calculated maximum flow rate from the pressure source (the maximum flow of a failed open regulator or other flow-controlling component).
    a. If the PRD's reduced flow capacity is **more than** the calculated maximum flow rate from the pressure source, then the PRD vent line is compliant.
    b. If the PRD's reduced flow capacity is **less than** the calculated maximum flow rate from the pressure source, then the system requires redesign (balanced bellows PRDs should be considered in these cases).

* *Step 7 does not apply to PRDs that protect pressure vessels. Vent lines for such PRDs must meet the criterion in step 6a.*

# APPENDIX B. PRESSURE SYSTEM CERTIFICATION

## I. CERTIFICATION OUTLINE AND REQUIRED PRODUCTS

A general outline and required products for a PVS Certification Report are detailed below:

- **Scope of certification:** fluid medium/media, MAWP, design temperature range.
- **System boundaries:** mechanical find numbers that define the boundaries of each pressure circuit (e.g., where the system begins, where MAWP changes, where the system ends).
- **Comprehensive integrity assessment:** verification of compliance with applicable national consensus standard (NCS) (e.g., ASME B31.3, ASME BPVC-VIII).
  - **Pressure relief device analysis:** verification that for each PRD, flow capacity exceeds maximum flow rate in failure scenario (e.g., regulator fails fully open), pressure drop from pressure source (e.g., regulator outlet) to PRD inlet does not exceed 7% of PRD set pressure (or 10% of PRD set pressure minus PRD set pressure tolerance), vent line backpressure does not exceed 10% of PRD setting (or PRD flow capacity reduction factor is known and acceptable for system).
  - **Flexibility analysis:** verification that piping, tubing, and components are adequately supported for the system's environmental loads and per applicable NCS (e.g., ASME B31.3, paragraphs 319 and 321).
  - **Material compatibility:** verification that all wetted materials are compatible with the fluid medium (e.g., oxygen compatibility assessment)
  - **Pressure vessel documentation:** NBBI registration number, ASME U-1 form, photograph of vessel nameplate
  - **Material certifications for pipe, tube, and fittings**
  - **Fluid component specifications:** materials, MAWP, hydrostatic/proof pressure, design code/burst pressure.
  - **Welding documentation:** Welding Procedure Specifications (WPS), Procedure Qualification Records (PQR), Welder Performance Qualifications (WPQ), weld maps, weld inspector certifications, weld inspection reports
  - **Hydrostatic and leak tests:** verification that tube assemblies have been hydrostatically tested per KSC-SPEC-Z-0008, and that other components and the system have been leak tested per applicable NCS (e.g., ASME B31.3, paragraph 345).
  - **Visual inspections:** verification that the system design documentation matches the as-built condition.
- **Initial service life and remaining life assessment** (see example)
- **Risk assessment code determination** (see example)
- **In-service inspection plan** (see example)

## II. EXAMPLE INITIAL SERVICE LIFE AND REMAINING LIFE ASSESSMENT

*This assessment does not consider stress concentrations due to bends or fittings, residual stresses in welded tubing, or damage mechanisms other than pressure cycles. Other damage mechanisms, if applicable to the system being evaluated, must be considered in the remaining life assessment.*

Tube assemblies in the [XXX] system are fabricated in accordance with KSC-SPEC-Z-0008, and may be analyzed for fatigue using KSC-5500-10739. The analysis calculates the number of full pressure cycles required to propagate an existing crack from a crack depth to wall thickness ratio (a/t) of 0.7 to 0.8, assuming a crack depth to width ratio (a/c) of 0.5.

Assuming 75 pressure cycles per year (one pressure cycle per day, five days per week, 15 weeks per year), the remaining life of the [XXX] system tubing is summarized below:

| **Tubing Size (OD x schedule)** | **Design Pressure (psig)** | **MAWP (psig)** | **Initial Service Life (cycles)** | **Cycles to Date (cycles)** | **Remaining Life of Tubing (cycles)** | **Remaining Life of Tubing (years)** |
|---|---|---|---|---|---|---|
| 1/4” x .035” | 880 | 6195 | No Limit* | 2 | No Limit | No Limit |
| 1/2” x .072” | 5868 | 6100 | 8538 | 2 | 8536 | 113 |
| 3/4” x .109” | 5868 | 6200 | 7124 | 2 | 7122 | 94 |
| 1” x .095” | 2500 | 3900 | 31362 | 2 | 31360 | 418 |
| 1-1/2” x .049” | 880 | 1200 | 43131 | 2 | 43129 | 575 |

* According to analysis, threshold stress intensity is never exceeded; crack growth will not occur.
Life of tubing cannot be determined using fatigue analysis.

Piping in the [XXX] system was analyzed using NASGRO fatigue crack growth software. Assuming 75 pressure cycles per year, the remaining life of the piping of the [XXX] system is summarized below:

| **Pipe Size (OD, schedule)** | **System Design Pressure (psig)** | **Initial Service Life (cycles)** | **Cycles to Date (cycles)** | **Remaining Life of Tubing (cycles)** | **Remaining Life of Tubing (years)** |
|---|---|---|---|---|---|
| 3” XXS | 5868 | 10103 | 2 | 10101 | 134 |
| 2” XXS | 5868 | 38171 | 2 | 38169 | 508 |
| 1-1/2” XXS | 5868 | 35382 | 2 | 35380 | 471 |

Remaining Life

The calculated remaining life of the [XXX] system (94 years) exceeds the maximum allowable remaining life per NASA-STD-8719.17 (40 years). The recertification period is half the remaining life (20 years).

## III. EXAMPLE RISK ASSESSMENT CODE DETERMINATION

The [XXX] system is comprised of small bore tubing and components operated at or below their rated pressure and temperature, and the pressure vessels at National Board-registered and being operated at or below their rated pressure and temperature. ASME B31.3 and ASME BPVC-VIII.1 requirements are satisfied. A Reliability and Safety Assessment (reference document number) was performed on the system, and did not identify any unmitigated hazards or single failure points.

The Risk Assessment Codes (RAC) were determined in accordance with NASA-STD-8719.17, Section 4.9.2, as follows:

Pressure Vessels

NASA-STD-8719.17, Table 2, Severity Determination: **I, Catastrophic**
NASA-STD-8719.17, Table 4, Item 1: **$10^{-6}$ failures/year**
Total hours pressurized: (15 weeks/year)(5 days/week)(8 hours/day) = **600 hours**
Personnel exposure hours per year: (15 weeks/year)(5 days/week)(8 hours/day) = **600 hours**
Personnel exposure fraction: 600 hours/600 hours = **1.0**
Probability of failure: ($10^{-6}$ failures/year)(1.0) = **$10^{-6}$**
NASA-STD-8719.17, Table 3, Probability Determination: **E, Improbable**
NASA-STD-8719.17, Table 1, RAC Determination: **4**

Tubing and Components

NASA-STD-8719.17, Table 2, Severity Determination: **I, Catastrophic**
NASA-STD-8719.17, Table 4, Item 10: **$10^{-3}$ failures/year**
Total hours pressurized: (15 weeks/year)(5 days/week)(8 hours/day) = **600 hours**
Personnel exposure hours per year: (15 weeks/year)(5 days/week)(8 hours/day) = **600 hours**
Personnel exposure fraction: 600 hours/600 hours = **1.0**
Probability of failure: ($10^{-3}$ failures/year)(1.0) = **$10^{-3}$**
NASA-STD-8719.17, Table 3, Probability Determination: **D, Remote**
NASA-STD-8719.17, Table 1, RAC Determination: **3**

## IV. EXAMPLE IN-SERVICE INSPECTION PLAN

The [XXX] system was evaluated for likelihood of damage by various mechanisms, as follows:

- Brittle fracture: Low
- Corrosion/erosion: Low
- Crack-like flaws: Low
- Fire damage: Not applicable
- Creep damage: Not applicable
- Mechanical damage: Moderate

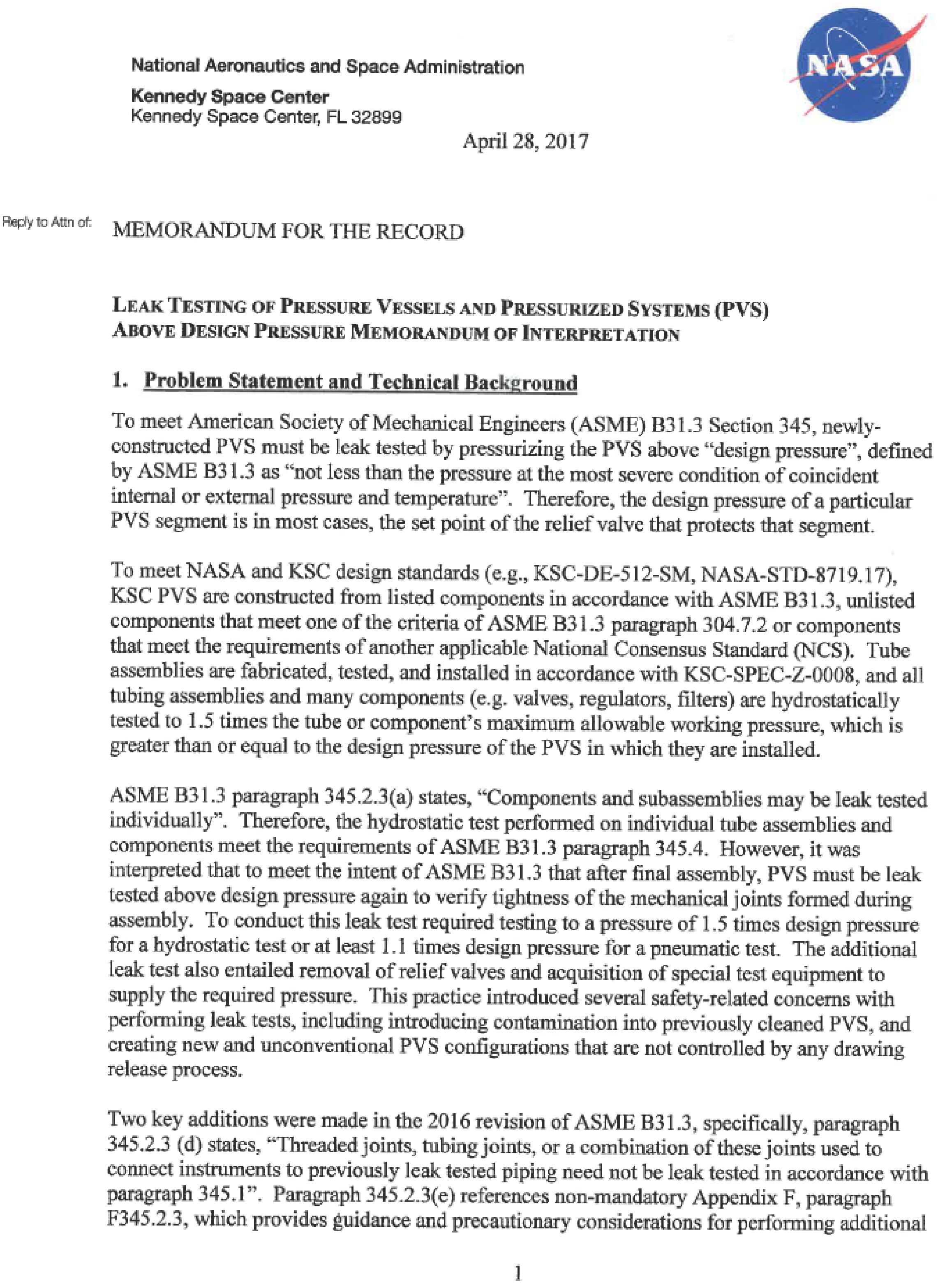
The following In-Service Inspection Plan assigns inspection intervals with consideration to the damage mechanisms identified above, and meets the intent of API 580. Initial inspections at certification include visual examination, configuration verification, and hydrostatic testing of all tube assemblies to 150% of their maximum allowable working pressure.

| **Category** | **Time Interval (Years)** | | | | | | **Notes** |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **5** | **10** | **20** | |
| Pressure Vessels | **VE** | | | | **VI** | **RE** | |
| Pressure Vessel Supports | **VE** | | | | | **RE** | |
| Piping and Supports | **VE** | | | | | **RE** | VE per API 570 |
| Flexible Hoses | **VE** | | | **HY** | | **RE** | VE per SAE ARP1658 |
| Relief Valves | **VE** | | **FT** | | **SI** | **RE** | FT per NASA-STD-8719.17 and NB23, VE per NASA-STD-8719.17, SI per NB-23 |
| Pressure Gauges | **VE** | | **CA** | | | **RE** | |
| Other Components | **VE** | | | | | **RE** | VE per API 570 |

Inspection Legend

| | |
|---|---|
| **CA** | Calibration |
| **FT** | Set Pressure Test |
| **HY** | Hydrostat at MAWP |
| **RE** | Recertification |
| **SI** | Service Interval |
| **VE** | External Visual Examination |
| **VI** | Internal Visual Examination |

# APPENDIX C. MEMORANDUM OF INTERPRETATION, LEAK TESTING OF PRESSURE VESSELS AND PRESSURIZED SYSTEMS (PVS) ABOVE DESIGN PRESSURE PRESSURE SYSTEM CERTIFICATION



National Aeronautics and Space Administration
**Kennedy Space Center**
Kennedy Space Center, FL 32899

April 28, 2017

Reply to Attn of: MEMORANDUM FOR THE RECORD

## LEAK TESTING OF PRESSURE VESSELS AND PRESSURIZED SYSTEMS (PVS) ABOVE DESIGN PRESSURE MEMORANDUM OF INTERPRETATION

### 1. Problem Statement and Technical Background

To meet American Society of Mechanical Engineers (ASME) B31.3 Section 345, newly-constructed PVS must be leak tested by pressurizing the PVS above "design pressure", defined by ASME B31.3 as "not less than the pressure at the most severe condition of coincident internal or external pressure and temperature". Therefore, the design pressure of a particular PVS segment is in most cases, the set point of the relief valve that protects that segment.

To meet NASA and KSC design standards (e.g., KSC-DE-512-SM, NASA-STD-8719.17), KSC PVS are constructed from listed components in accordance with ASME B31.3, unlisted components that meet one of the criteria of ASME B31.3 paragraph 304.7.2 or components that meet the requirements of another applicable National Consensus Standard (NCS). Tube assemblies are fabricated, tested, and installed in accordance with KSC-SPEC-Z-0008, and all tubing assemblies and many components (e.g. valves, regulators, filters) are hydrostatically tested to 1.5 times the tube or component's maximum allowable working pressure, which is greater than or equal to the design pressure of the PVS in which they are installed.

ASME B31.3 paragraph 345.2.3(a) states, "Components and subassemblies may be leak tested individually". Therefore, the hydrostatic test performed on individual tube assemblies and components meet the requirements of ASME B31.3 paragraph 345.4. However, it was interpreted that to meet the intent of ASME B31.3 that after final assembly, PVS must be leak tested above design pressure again to verify tightness of the mechanical joints formed during assembly. To conduct this leak test required testing to a pressure of 1.5 times design pressure for a hydrostatic test or at least 1.1 times design pressure for a pneumatic test. The additional leak test also entailed removal of relief valves and acquisition of special test equipment to supply the required pressure. This practice introduced several safety-related concerns with performing leak tests, including introducing contamination into previously cleaned PVS, and creating new and unconventional PVS configurations that are not controlled by any drawing release process.

Two key additions were made in the 2016 revision of ASME B31.3, specifically, paragraph 345.2.3 (d) states, "Threaded joints, tubing joints, or a combination of these joints used to connect instruments to previously leak tested piping need not be leak tested in accordance with paragraph 345.1". Paragraph 345.2.3(e) references non-mandatory Appendix F, paragraph F345.2.3, which provides guidance and precautionary considerations for performing additional leak testing after a subassembly has been taken apart and reassembled, implicitly stating that additional testing is recommended but not required. These additions provide the basis to supersede the previous interpretation from the 2014 revision of ASME B31.3, that after final assembly, the PVS must be leak tested above design pressure again to verify tightness of the mechanical joints formed during assembly.

The benefits of performing additional leak tests of fully-assembled PVS above design pressure do not justify the safety-related concerns introduced. KSC has a well-established process and requirements for designing and fabricating PVS. With Safety and Mission Assurance's guidance provided in this memorandum, the Program or Project Office may choose to exempt PVS from additional leak testing above design pressure. Section 2 provides the conditions under which an owner-operator may make this choice. Section 3 provides a list of inherent risks involving PVS that owner-operators must consider before deciding to exempt any PVS from additional leak testing above design pressure.

## 2. Exemptions to Leak Testing Assembled PVS Above Design Pressure

The following PVS may be exempted from leak testing above design pressure after full assembly at the discretion of the owner-operator:

- **Unmodified heritage PVS that has been previously certified and placed in service. In accordance with ASME B31.3, Section's 300 and 345,** these PVS do not require evidence of a leak test. Paragraph 300(c) (2) of ASME B31.3 states, "This code is not intended to apply to the operation, examination, inspection, testing, maintenance, or repair of piping that has been placed in service." Paragraph 345.1 states, "Prior to initial operation … each piping system shall be leak tested to ensure tightness." The leak test requirements in Section 345 do not apply retroactively to PVS that have previously been in service and are being used in their original configuration at a new location or for a new purpose. However, these PVS must be leak tested to maximum expected operating pressure prior to being recertified and placed back into service.
- **PVS in Normal Fluid Service per ASME B31.3.** In accordance with ASME B31.3, these PVS may be exempted if all of the following conditions are met:
  a) Components are listed in ASME B31.3 Table 326.1 or Appendix D, meet at least one criterion for unlisted components in ASME B31.3 Section 304.7.2, or meet the requirements of another applicable NCS.
  b) All pipe and tube assemblies have been individually hydrostatically tested to 1.5 times the assembly or component's maximum allowable working pressure.
  c) All joints created during assembly are mechanical (i.e. not joined by welding or brazing).
  d) The fully assembled PVS is leak tested to maximum expected operating pressure. All other PVS must be leak tested above design pressure in accordance with ASME B31.3 Section 345. Additionally, PVS in lethal service[1] must be subjected to a sensitive leak test in accordance with ASME B31.3 Section 345.8.

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[1] Lethal service at KSC includes reactive, energetic, and cryogenics fluids. Other methods for performing leak tests may be used after being evaluated and approved by the Pressure Systems Manager.

## 3. Risks Inherent to PVS Not Subjected to Additional Leak Testing Above Design Pressure

The following risks must be considered and accepted by the owner-operator prior to exempting any PVS from additional leak testing above design pressure:

- **PVS may leak if pressurized above design pressure.** This risk can be mitigated by the following:
  a) Set relief valves no higher than the maximum allowable working pressure of the weakest component in a particular PVS segment.
  b) Perform a risk and hazard assessment for the PVS.
  c) Do not use the PVS in lethal service.
- **PVS may have components that have not been properly hydrostatically tested.** This risk can be mitigated by the following:
  a) Put in place a robust configuration management system.
  b) Ensure appropriate documents (e.g., Acceptance Data Packages) provide traceability to hydrostatically-tested components.
- **PVS may have component with suspect materials or workmanship.** This risk can be mitigated by ensuring all PVS components meet the following:
  a) Components are approved by the organization's Design Authority and come from reputable suppliers (such as through the 79K80000 component specification series).
  b) Components are listed in ASME B31.3, meet one of the criteria for unlisted components in ASME B31.3 Section 304.7.2, or meet the requirements of another applicable NCS.
  c) Components are assembled and tested by qualified personnel with appropriate quality assurance oversight.

## 4. Alternative Test Methods to Meet Intent of ASME B31.3 for PVS Requiring an Additional Leak Test Above Design Pressure

If the Fabricator, Lead Designer, Program or Project choose to perform a leak test above operating pressure, then the following methods are acceptable to Safety and Mission Assurance:

- Use a pressure source that cannot exceed the allowable test pressure. This method ensures that the PVS being tested cannot be pressurized beyond the allowable test pressure. This can be accomplished by isolating the PVS to be tested from its normal pressure source, and connecting the inlet of the PVS to a compressed gas bottle or trailer that is supplied at a pressure no greater than 1.33 times design pressure. This allows the leak test to be performed without the cost and schedule delay of replacing all the system relief values for the test.
- Use two pressure-reducing regulators in series. This method, which is frequently utilized in certified laboratory PVS at KSC, ensures that at least two simultaneous component failures (two regulators failed fully open) are required to pressurize the PVS being tested above the allowable test pressure. This can be accomplished by connecting two portable pressure reducing units (PPRU) in series, connecting one PPRU to a regulator on the PVS being tested in series, or utilizing two regulators in

series on the PVS. This method also allows the leak test to be performed without replacing all the system relief valves for the test.

- Additional standard practices also prevent over-pressuring PVS. Regardless of the method used, an orifice will be installed where required to limit the flow rate from the pressure source to no greater than the flow capacity of the vent valves on the PVS being tested. Additionally, downstream portions of the PVS with lower design pressures will be isolated and configured with all vent valves open. These practices ensure that (1) if a closed valve or regulator begins to leak into a downstream segment of the PVS not being tested, that segment cannot be pressurized since it is configured with vent valves open; and (2) in the unlikely event that two regulators fail fully open simultaneously, vent valves on the segment of the PVS being tested can be opened to prevent pressurization beyond the allowable test pressure.

## 5. Documentation and Approval of Leak Test Configurations

Temporary test configurations to leak test PVS above design pressure may be documented and approved through one of the following processes:

- **PVS Exclusion Request (KSC Form 50-261).** This method can be used if the exclusion request is prepared in accordance with NASA-STD-8719.17, paragraph 4.2.4, Assessed Hazard Exclusion, and signed by the KSC Pressure Systems Manager. A configuration-controlled drawing may be required, at the discretion of the organization's Design Authority and the KSC Pressure Systems Manager. Typical requirements for such an exclusion request include:
    - a) Test schematic
    - b) Parts list
    - c) Component specifications (if not available in a KSC-managed system)
    - d) Analysis (such as relief valve sizing calculations, if not included in another configuration-controlled document)
    - e) Risk Assessment Code determination
    - f) Risk and Hazard Assessment (if not included in another configuration-controlled document)
- **Test configuration sheet in PVS design drawing.** This method can be used for newly-designed PVS that go through a formal design review process (e.g., KDP-P-2713 for standard design reviews). The test configuration must be included in the appropriate design review(s), approved by the organization's Design Authority, and released in the organization's configuration management system (e.g., TechDoc, KDDMS).
- **Separate test configuration drawing.** This method can be used for PVS that have already been reviewed and approved through a formal design review process. The test configuration drawing must go through a formal design review process (e.g., KDP-P-2723 for streamlined design reviews), approved by the organization's Design Authority, and released in the organization's configuration management system.

AGREED:

Eric A. Thaxton 4/28/17
Eric A. Thaxton, Ph.D., P.E. Date
Chief Mechanical Engineer, NE

Alan Dumont 4/28/17
Alan Dumont P.E. Date
Acting Pressure Systems Manager
Branch Chief, SA-E3