ORIGINAL

A3 Altitude Test Facility
at
NASA Stennis Space Center

Gaseous Nitrogen Ready Storage Vessels
11FGT-GM01

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Prepared by:

Jacobs Technology, Inc.
600 William Northern Boulevard
Tullahoma, TN 37388

Jacobs Project Number 90937

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Approved:

Originator: _____
Ty H. Proffitt

JTI Project Manager: _____
J. F. Thorington

NASA Construction Manager: _____

NASA Engineering and Science Directorate: _____

NATIONAL SPACE AERONAUTICS AND SPACE ADMINISTRATION
JOHN C. STENNIS SPACE CENTER
SSC, MISSISSIPPI 39529

1. PROJECT TABLE OF CONTENTS

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SECTION 01010

SUMMARY OF WORK

PART 1 GENERAL

1.1 SUMMARY

The work to be performed under this project consists of the design, fabrication, inspection, testing and delivery to Stennis Space Center (SSC), Stennis, Mississippi, at the A-3 Site, thirty-two (32) 1000 CFWV (cubic feet water volume) net gaseous nitrogen ready storage vessels. Each vessel shall be National Board Registered and ASME code stamped per ASME Code Section VIII, Div 1 or Div. 2. Each vessel shall be horizontally mounted, cylindrical type single wall construction with hemispherically shaped heads. Suitable saddle supports for 34 vessels shall be provided for stacked location on concrete pads. Concrete pads to be provided by others, all other support components (including anchor bolts and nuts) to be provided by vessel fabricator. Each vessel shall be suitable for the stationary, exposed above ground storage of gaseous nitrogen.

1.2 REFERENCES

The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by the basic designation. Refer to Section 01420, "Sources for Reference Publications", for information on obtaining publications.

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE AS5202	Bosses, Fluid Connector – Internal Straight Thread

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7	Minimum Design Loads for Buildings and Other Structures

SOUTHERN BUILDING CODE CONGRESS INTERNATIONAL (SBCCI)

SBCCI, Section 1606	Wind Loads

AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING

ASNT-TC-1A	Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
BOILER AND PRESSURE VESSEL CODE

ASME B16.9	Factory Made Wrought Steel Butt Welding Fittings
ASME B16.34	Valves – Flanged, Threaded and Welding Ends
ASME B31.3	Process Piping
Section II	Material Specifications
Section V	Non-Destructive Examination
Section VIII	Rules for Construction of Pressure Vessels – Division II
Section IX	Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators
ASME SA 105	Specification for Forgings, Carbon Steel, for Piping Applications
ASME SA 181	Specification for Carbon Steel Forgings, for General-Purpose Piping
ASME SA 182	Specification for Forged or Rolled-Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASME SA 193	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

ASME SA 194	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service or both
ASME SA 203	Specification for Pressure Vessel Plates, Alloy Steel, Nickel
ASME SA 204	Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum
ASME SA 225	Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel
ASME SA 234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
ASME SA 240	Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels
ASME SA 266	Specification for Carbon Steel Forgings for Pressure Vessel Components
ASME SA 285	Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate- Tensile Strength
ASME SA 299	Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
ASME SA 302	Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
ASME SA 350	Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components

ASME SA 387	Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
ASME SA 515	Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
ASME SA 516	Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower- Temperature Service
ASME SA 533	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybneum-Nickel
ASME SA 537	Specification for Pressure Vessel Plates, Heat Treated, Carbon-Manganese-Silicon Steel
ASME SA 737	Pressure Vessel Plates, High Strength, Low Alloy Steel

INTERNATIONAL CODE COUNCIL (ICC)

2006 IBC	International Building Code

STEEL STRUCTURES PAINTING COUNCIL (SSPC)

SSPC SP10	(1991) Surface Preparation Specification No. 10 Near-White Blast Cleaning

SSC STANDARDS AND SPECIFICATIONS (SSC)

SSC-DWG NO. 54000-GP11	Packaging and Preservation of cleaned components
SSTD 8070-0126	Tubing Systems for Facility Systems, Special Test Equipment and Aerospace Hardware

SSTD- 8070-0089 - FLUIDS	Surface Cleanliness Requirements for SSC Fluid Systems
SSC-STD-79-002	Sampling Requirements and Maximum Allowable Impurities for SSC Fluids and Fluid Systems
SSC SSTD-8070-0124-IDCODES	Identification of piping systems and above ground markers
NASA-STD-5008A	Protective coating of carbon steel, stainless steel, and aluminum on launch structures, facilities and ground support systems

1.3 SUBMITTALS

The following shall be submitted in accordance with Section 01330, "Submittals," in sufficient detail to show full compliance with the specification:

SD-01 Data

The Contractor shall furnish design calculations covering all parts of the storage vessels. Design calculations shall be submitted with the shop drawings. Six copies are due six weeks after award of the contract. Design calculations shall be stamped by a Professional Engineer and shall include:

ASME Code Calculations
Estimated vessel weight
Fatigue Analysis
Loading Transportation and Lift Plan

SD-02 Manufacturer's Catalog Data

Data composed of catalog cuts, brochures, circulars, specifications and product data, and printed information in sufficient detail and scope to verify compliance with requirements of the contract documents for all components including:

Hubs
Clamps
Seal rings
Bolting
Gaskets, Valves and Relief Devices

SD-04 Drawings

Shop Fabrication Drawings in .pdf format shall be submitted as check prints of each shop assembly, and detail drawings. Six printed copies are due six weeks after award of the contract.

"As Built" Record Drawings shall be submitted within six weeks of the vessel delivery. Six printed copies and one electronic copy (Autocad 2007 version) shall be delivered.

Shop drawings and Record Drawings shall include a Bill of Materials and show the location and details of:

Connections
Lifting points and special lifting or handling requirements
Nozzle attachments/reinforcement
Piping arrangements
External supports
Anchor bolt size and locations
Appurtenances
Foundation loading
Support frame
Approximate weight (dry and filled with potable water)
Design code
Design and maximum allowable operating conditions (i.e. pressure, temp)
Corrosion allowance
Joint Efficiency
Nondestructive examination type and requirements
Design service media
Cleaning level
Painting and bolt torque requirements and instructions
Complete Assembly
Center of Gravity

Along With the support, anchor, and foundation loading drawings, provide:

- *support pad interfaces*
- *assembly weights*
- *required clearances*
- *piping connection locations.*

Vessel concrete foundations on-site will be prepared by others

SD-07 Schedules

Six copies of Fabrication time schedules shall be submitted three weeks after award of contract.

SD-08 Statements

The Contractor shall submit six copies of the following items within three weeks after award of contract:

Requests to use existing ASME Code cases
Quality Control Manual
Hydrostatic and Mass Spectrometer Leak Check Procedures
Cleaning and Certification Procedures
Painting Specifications and Procedures
Certification of NDE Personnel per ASNT-TC-1A
Welder Qualifications to ASME Section IX
Welding Procedure Qualifications conforming to ASME Section IX
Welding Procedure Specifications conforming to ASME Section IX
NDT Procedures
Inspection Procedures
Welding Procedures & welder qualifications conforming to applicable requirements of ASME Boiler & Pressure Code Section VIII, Div 2, Part 3 and ASME Boiler & Pressure Code Section IX.

SD-09 Reports

Material reports shall be furnished for the materials used in the vessel. In addition to the specification for the base material, the report shall include the

specification for the weld material. Six copies are due six weeks after award of the contract. The following information shall be shown in the report:

Contract number
System
Pipe Specification (where applicable) or Use Material Specification (Base Material)
Material Specification of Weld or Bond
Charpy Test (where required by code)
Heat Treatment charts and records
Vessel Design and Calculations

SD-09 Reports (prior to fabrication)

Prior to commencement of fabrication, the Contractor shall submit six copies of the following items:

Certified Material Test Reports for plate, forging and welding materials, including weld filler materials
Certified Impact Test Reports (as applicable)
Certified Nil-ductility Test Reports (as applicable)
Heat Treatment Procedure

SD-09 Reports (prior to shipment)

Six copies of the following shall be submitted at the time that the vessel is ready for shipment:

Mill Test Reports
Facsimile of Nameplate Stamping
Manufacturer's Data Report
Hydrostatic Test Report including test set-up configuration and log of time versus pressure
All Reports for Non-Destructive Examination
All Radiographic Analysis Reports
One Complete Set of Radiographic Film
Weld Map
"As–Built" Construction Drawings in AutoCad 2007

SD-18 Records

At the time the vessels are ready for shipment, four copies of the following shall be submitted:

Heat Treatment Charts and Records
Spare Parts Recommendation List

1.4 GENERAL REQUIREMENTS

The storage vessel shall be designed, fabricated, tested, cleaned and delivered in accordance with the detailed requirements of this specification. The requirements specified herein are minimum requirements. The Contractor shall take whatever additional measures are necessary in his design, fabrication, inspection and testing to produce a storage vessel, which will satisfactorily pass the tests specified herein without damage. Where specific requirements are set forth, and where such specific requirements depart from requirements or alternatives contained in any documents referenced herein, the specific requirements contained herein shall govern and take precedence. The general arrangement of the vessel is shown in schematic form on Figure 1 of this specification.

1.5 QUALIFICATION OF VESSEL MANUFACTURER

The Contractor shall furnish with his bid, certification attesting to a minimum of 5 years experience by the manufacturer in design and manufacture of storage vessels of similar design. Name, phone number and address of references are required. The experience listing shall include a list of storage vessels fabricated, size, location of use, service, and date of manufacture.

1.6 DRAWINGS AND REPORTS

This section specifies the requirements for capacity and performance. Nothing shown on the drawings or contained in the design data shall relieve the Contractor from his responsibility to furnish a GN ready storage vessel meeting the requirements of this specification.

1.7 QUALITY ASSURANCE

The Contract Administrator and Government reserve the right to inspect all work at all times during and upon completion of fabrication and to witness any or all tests. The Contractor shall cooperate fully to enable the SSC Contracting Officer's Technical Representative (COTR) or Government designated representative to be present at the performance of any or all tests and any other activity as specifically requested. The Contractor shall furnish all equipment and materials for all tests except where specifically stated otherwise. The Contractor shall notify the SSC Contracting Officer's Technical Representative (COTR) fourteen (14) days prior to performance of any and all tests.

Mandatory hold points:

1. Government review and verification of welding procedures, qualification records and welder certifications before any welding is executed.
2. Government verification of vessel and piping x-ray interpretations and ultrasonic shearwave inspections and results; to be performed prior to hydrostatic proof pressure tests.
3. Hydrostatic proof pressure testing (including internal and external visual inspections prior to and following hydrostatic test), to be performed after government acceptance of all welding and x-rays.
4. Leak test.
5. Vessel cleaning.
6. Packaging of vessel for shipment.

1.8 WELDING PROCEDURE AND WELDING OPERATOR QUALIFICATIONS

1.8.1 General

Welding procedures and welders qualifications shall be performed in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. Should the supplier elect to provide automated welding for vessel construction, this must be stated in their proposal and additional requirements may be asked of supplier prior to award of contract.

1.8.2 Welding Procedure

Prior to vessel fabrication, welding procedures shall be submitted to the SSC Contracting Officer's Technical Representative (COTR) prior to any welding for approval. Material and weld metal used for parts subject to stress due to pressure shall be impact tested in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Part 3.

1.8.3 Qualifications of Welders

The determination of the qualification of welders, and the requirements for welding shall be in accordance with the applicable portions of the above referenced code and shall be submitted to the Contracting Officer's Technical Representative (COTR) for approval prior to any welding.

1.8.4 Weld Rods

Weld rods shall be suitable for the type of welding to be performed. Rods shall be stored to prevent contamination and deterioration by moisture. A drying oven or heater shall be used in accordance with recommendations and instructions of the rod manufacturer.

1.9 GUARANTEE

All equipment to be furnished under this specification shall be guaranteed against defective materials, design, and workmanship for a minimum period of one year from date of acceptance, either for beneficial use or final acceptance, whichever is earliest, but not before the equipment or system involved has passed all specified tests. Upon receipt of notice of failure of any part of the guaranteed equipment during the guaranty period, new replacement parts shall be furnished and installed promptly by the Contractor at no additional cost. The Contractor shall acknowledge his responsibility under these guaranty provisions by letter, stating the inclusive dates of the guaranty period for which the equipment and materials referred herein are guaranteed.

PART 2 PRODUCTS

2.1 MATERIALS

Metals shall be free from defects impairing strength, durability, and appearance, and of the best commercial quality for the purpose specified. All materials shall have structural properties to safely sustain and withstand strains and stresses to which the vessel is normally subjected. All materials shall be new and unused.

2.2 DESIGN AND FABRICATION

The vessel shall be designed, fabricated, and code stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2. A tube bank is not acceptable. See Figures 1 and 2 for general design of vessels and overall dimensions.

Materials of Construction:

All materials of construction shall conform to ASME Boiler and Pressure Vessel Code Section II. All material examination requirements and certifications required by ASME Boiler and Pressure Vessel Code Section VIII Div. 2, Part 3 shall be satisfied.

After completion of all forming and welding, the vessel shall be stress-relieved in accordance with Section VIII, Division 1 or Division 2, whichever applies, and Section IX of the ASME Boiler and Pressure Vessel Code.

2.2.1 Vessel Plate

All plate shall conform to the requirements of SA 203, SA 204, SA 225, SA 285, SA 299, SA 302, SA 515, SA 516, SA 387, SA 533, SA 537, SA 737, or an approved equal compatible with nitrogen service.

2.2.2 Vessel Forgings

All forgings shall conform to the requirements of SA 105, SA 181, SA 182, SA 266, SA 350, or an approved equal compatible with nitrogen service.

2.2.3 Design Capacity

The storage vessel shall be used to store gaseous nitrogen and shall be designed for a net water volume of 1000 ft^3 minimum.

2.2.4 Wind and Seismic Forces

The external support system shall be designed to withstand a 130-mph force wind (ref.: International Building Code) with no damage to the vessel. Reaction forces at the vessel supports shall be provided to the owner to verify the external support base design.

2.2.5 Vessel

2.2.5.1 Working Pressure

The maximum working pressure shall be 2,800 psig and shall be limited by the shell or head, not by minor parts.

2.2.5.2 Design Pressure

The design pressure shall be 3,080 psig

2.2.5.3 Welding

Welding shall be in accordance with the requirements of Section VIII, Division 1 or Division 2 of the ASME Boiler and Pressure Vessel Code. Welding procedures shall be submitted for approval before any welding is executed. The vessel shell sections shall be joined with full penetration butt-welds, and shall be 100 percent radiographically inspected. Backing rings and bars, if used, shall be removed prior to finishing the joint. The inner joint surface shall be ground smooth to facilitate cleaning.

All completed pressure retaining welds including those on all nozzle connections, penetrations, and lines joined to the vessel shall be 100% radiographically inspected. Nondestructive examinations shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section V.

Full penetration, pressure retaining welds that cannot be examined by radiography shall be ultrasonically examined and magnetic particle or liquid-penetrant examined at the root and cover pass.

2.2.5.4 Design Temperature

The design temperature shall be 130 °F to -20 °F for the gaseous nitrogen vessel. If the discharge nozzle is not equipped with a nozzle (thermal sleeve) insert as stated in Section 2.3.5.1, the nozzle material shall be rated to -100 °F in accordance with ASME Boiler and Pressure Vessel Code, Section II.

2.2.5.5 Corrosion Allowance

The corrosion allowance shall be zero.

2.2.5.6 Additional Criteria

Additional vessel design criteria shall take into account:

a. Reaction forces at lifting lugs.

b. Transportation loadings.

2.2.5.7 Maximum Demand Rate

The maximum gaseous nitrogen demand rate from each vessel is 30 pounds per second.

2.2.6 Design Life

The vessel shall be designed for a service life of 30 years.

2.2.7 Fatigue Analysis

A fatigue analysis, including vessel, manway, and bolts, shall be performed and certified by a registered professional engineer in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2, paragraph AD-160 for compliance with the following conditions:

30-year life

150 cycles per year	800 psig to 2800 psig
One proof test per year	0 psig to 4200 psig

2.2.8 External Supports

Vessel mounting shall be as required for the weight and shape of the vessel. The vessel shall have one fixed and one sliding saddle. The sliding saddle shall be supplied with a bearing plate. Longitudinal or circumferential weld seams shall be located so as to not interfere with openings, reinforcing pads, or saddle wear plates. When the covering of a weld seam is unavoidable, then the seam shall be ground flush and examined by magnetic particle or liquid penetrant prior to welding the reinforcing pad in place.

External frame supports, for horizontal positioning and vessel stacking, shall be constructed of SA 516 and conform to the foot print shown in Figures 1 and 2 of this specification. The centerline dimensions shown in Figures 1 and 2 for vessel spacing, elevations and supports are controlling dimensions.

2.2.9 Structural Bolting

Structural threaded bolting and studs shall conform to SA 193, Grade B7. Carbon steel nuts shall conform to SA 194, Grade 2H.

2.2.10 Lifting Lugs

Lifting lugs shall be provided at the top of the vessels. Lifting lugs shall be designed to lift the dry weight of the entire vessel including contractor-installed appurtenances.

2.3 PIPING AND NOZZLES

2.3.1 General

Not Used

2.3.2 Piping

Not used, vendor to form nozzle from plate.

2.3.3 Flanges and Fittings

2.3.3.1 Flanges

Grayloc ® or equal clamped type carbon steel hubs, seal rings, and clamps shall be used on vessel connections as shown in Fig.1 except where stated otherwise. The allowable stresses shall be based on the requirements of ASME Code, Section VIII, Division 1 or Division 2, whichever applies.

Test blind flanges are required and will remain with the vessel until final destination. Manufacturer shall provide spare parts lists for seals, gaskets, etc.

2.3.3.2 Carbon Steel Fittings

Carbon steel fittings shall conform to SA 234, WPB.

2.3.3.3 Tube Fittings

Stainless Steel tubing and tube fittings shall be flared type and straight thread boss type conforming to SSTD 8070-0126. Tube and tube fitting material shall be type 304, 304L, 304/304L, 316, 316L, or 316/316L stainless steel..

2.3.3.4 Mechanical Bolting

Mechanical threaded bolting, studs, and nuts shall conform to ASME SA193 Grade B7, for bolts and studs and ASME SA194, Grade 2H for nuts. All bolting exposed to ambient environment shall be coated with waterproof lubricant.

2.3.4 Flange and Nozzle Protection

Extreme care shall be exercised during all phases of fabrication, handling, shipping, and cleaning to insure maximum protection of all flanges, nozzles, and all other appurtenances. Warped flanges and sealing surfaces exhibiting the slightest evidence of imperfections based on the requirements of this section will not be accepted.

2.3.5 Vessel Penetrations

All nozzles shall be integrally reinforced. All vessel nozzles shall have Grayloc ® or equal clamped type hubs for sizes indicated except as stated or noted otherwise. Seal contact surfaces shall be 32 RMS or smoother. Seal rings shall have the same surface finish and be coated with virgin PTFE (Polytetrafluoroethylene) or silver.

2.3.5.1 Discharge Nozzle

A 4", sch 160, discharge nozzle shall be provided on the vessel as shown in Fig. 1. Discharge nozzle hub face needs to be perpendicular to nozzle axial centerline within +/- ¼-degree.

If the nozzle material is not rated for a minimum temperature of -100 °F or lower, a 300 series stainless steel nozzle (thermal sleeve) insert shall be provided to prevent the inner wall of the nozzle from going below -20 °F when nitrogen gas at -100 °F and 800 to 1000-psig static pressure is flowing at a rate of 30 pounds mass per second through the nozzle. The nozzle insert, if used, shall have an inside diameter of no less than 2.5-inches. Nozzle insert design shall be analyzed by FEA (FINITE ELEMENT ANALYSIS), with applied boundary conditions and forced convection heat transfer correlations, to show that nozzle and nearby/adjacent vessel wall temperatures do not go lower than the rated minimum temperature of materials.

If a nozzle insert is not used, the design of the discharge nozzle and the vessel head it is attached to shall be such that no material of the respective head is in contact with flowing gas that will lower material temperature below the minimum temperature rating of the head material (no surfaces of head form the circular flow passage upstream of the bore of the discharge nozzle).

Nozzle shall be designed to withstand the following combined forces during operation:

Force normal to Nozzle = 1500 lb
Force Axially applied at nozzle = 8000 lb
Moment about vertical axis normal to nozzle face = 18,000 ft-lb

2.3.5.2 Drain/Vent Nozzles

Two 3" size nozzles shall be provided on the vessel. These nozzles shall be provided with a blind flange hub drilled and tapped with a 1" SAE AS5202 connection to be used as a drain and vent respectively.

2.3.5.3 Inspection Manway

An 18" manway shall be provided on the vessel for inspection and cleaning. The minimum I.D. of manway and its seal ring to be no less than 18-inches. The manway nozzle shall be a Vector International FLANGELOK type flange or hub with a PTFE or silver coated 17-4PH stainless steel D-Type (ribless) seal ring. The manway hub or flange shall also be provided with a mating blind flange or hub with lifting lugs attached.

2.4 VALVES AND COMPONENTS

A pressure gage and valve cleaned to Level 1 of SSTD-8070-0089 -FLUIDS shall be installed on the vessel prior to shipment to monitor the 3-5 psig nitrogen blanket pressure referenced in Paragraph 3.1 Vendor shall provide a 1" SAE AS5202 threaded boss connection in each of the blind hubs that attach to the 3" high point vent and low point drains.

2.5 CLEANING

Before shipment, the Contractor shall clean the vessel for gaseous nitrogen service to a level conforming to Level 1 of SSTD- 8070-0089 FLUIDS. (See Appendix A1.) The Contractor shall submit to the Contracting Officer's Technical Representative (COTR) for approval a cleaning procedure and sampling methods which will ensure and verify the cleanliness. Cleaning solution selected by contractor shall not degrade coating on seal rings or gaskets.

2.6 PRESSURE TESTS

2.6.1 General

The vessel shall be hydrostatically proof pressure tested in accordance with the requirements of Section VIII, Division 1 or Division 2, of the ASME Boiler and Pressure Vessel Code, whichever division applies. The Contractor shall employ suitable leak detection procedures, which have been specifically approved by the SSC Contracting Officer's Technical Representative (COTR) and shall repair all leaks encountered. The Contractor shall furnish all the equipment and fluids required for completing the leak testing. Welding shall not be permitted on the vessels and/or piping after completion and acceptance of the tests.

The hydrostatic proof pressure test shall not be performed until all welds have been reviewed, accepted and documented as per the specifications with complete concurrence with the Manufacturer and the Contracting Officer's Technical Representative (COTR). Following hydro test, vessel shall be purged with dry nitrogen to remove residual test water.

2.6.2 Vessel Leak Test

After completion and government acceptance of hydrostatic proof pressure testing and precision cleaning and their results, the contractor shall perform a static leak test of the vessel pressurized to the maximum working pressure with a dry nitrogen-helium gas mixture containing no less than 10% helium by volume. The purity of each constitutient in the test gas mixture shall conform to SSC Standard 79-002. Leakage shall be determined using a "Leak-Tek" or approved equal solution applied at mechanical joints and weldments. Acceptance will be based on "no-leak" indication evidenced by the absence of all bubbles. The manufacturer shall repair any leaks, and repeat the test.

2.6.3 Test Media

The hydrostatic test media shall be water that is free of chlorides or other corrosive substances.

2.7 IMPACT TEST

Materials and weld metal used for parts subject to temperature below -20 °F shall be impact tested in accordance with ASME Boiler and Pressure Vessel Code Section VIII, Division 1 or Division 2, Part 3. Those materials, which are exempted from impact tests by ASME Boiler and Pressure Vessel Code, shall not be impact tested.

2.8 RADIOGRAPHIC EXAMINATION

2.8.1 General

Welding inspection shall be as per Section 01010, Paragraph 2.2.5.3

Should a conflict result on the film interpretation that cannot be settled between the Contracting Officer's Technical Representative (COTR) or his Designee and the Contractor, final interpretation shall be the responsibility of the NASA/SSC Level III NDT Specialist. The NASA/SSC Level III Specialist interpretation shall be final and binding to all parties involved.

At a minimum, the radiographic documentation shall show acceptance/rejection/identify the weld defect, the method of repair, and reflect repair traceability (R1, R2) as per ASME Section V requirements.

2.8.2 Radiographic Techniques

Radiographic techniques and interpretation thereof shall be in accordance with Article I-5 of Section VIII, Division 1 or Division 2 of the ASME Boiler and Pressure Vessel Code. One set of radiographic negatives shall be submitted with the report to the SSC Contracting

Officer's Technical Representative on completion of the vessels. Unacceptable welds shall be repaired and re-radiographed in accordance with the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code.

2.9 PAINTING

External surface preparation shall conform to NASA STD-5008A The color of the vessels will be a gloss white. Final selection will require the Contracting Officer's Technical Representative (COTR)'s approval.

2.10 MARKING AND IDENTIFICATION

2.10.1 Code Label

The vessel shall bear a standard Code nameplate with "U" Stamp certifying compliance with the ASME Code, Section VIII, Division 1 or with "U2" Stamp certifying compliance with the ASME Code, Section VIII, Division 1 or Division 2 and displaying Code required data.

2.10.2 Identification Label

In addition to the data required by the Code, the nameplates shall contain the following information:

(a) Intended Use: 1000 CFWV (Cubic Feet Water Volume) gaseous nitrogen storage vessel.

(b) The Government Specification and contract number.

(c) The contractor's name, address, equipment serial number and month and year built.

(d) Maximum allowable working pressure

(e) Information complying with the requirements of ASME Code Section VIII, Div. 1 or Div. 2, whichever applies.

PART 3 EXECUTION

3.1 TRANSPORTATION

After the cleaning, inspecting and sealing of the vessel has been completed, the vessel's cleanliness level shall be maintained for delivery to the A-3 site at SSC using a positive

3-5 psig blanket pressure of "clean" nitrogen in accordance with SSC STD 79-002. The vendor shall assure the proper securing and bracing required to safely transport the vessels to their final destination. The manufacturer shall deliver the vessel complete and ready for safe installation on site at the A-3 site at Stennis Space Center. Contractor to install a gauge & valve to monitor and maintain 3-5 psig blanket pressure. This gauge & valve and connected tubing and tube fittings are to be cleaned to Level 1 of SSTD-8070-0089-FLUIDS.

3.1.1 Loading, Transportation and Lift Plan

The vendor is responsible for the safe loading, securing and transportation of the vessel from his point of fabrication to Stennis Space Center, A-3 site. The safe transportation of the vessel shall comply with all Federal, state and local codes and regulations. Total weight of the loaded transporter shall be provided to the Contracting Officer's Technical Representative (COTR) prior to transportation and the Contractor is responsible for providing safe transportation of the vessel once it arrives at Stennis Space Center to its final designation within the center.

The vendor shall provide a lift plan that includes the net weight of the load, and gross weight of load "under the hook". A list of all required lifting slings, spreader bars and attachment devices required shall be provided for use to off-load the vessels. Each attachment/lift point on the vessel shall be properly identified to allow proper rigging for off-loading the vessel and assuring the proper configuration requirements are followed during the lifting and placing of the vessel from the transporter to the final horizontal position. The vendor shall include a drawing providing the center of gravity of the load and all other pertinent information that could affect the safe off-loading of the vessel. Lift plan to be reviewed and approved by SSC LDE Manager. Plan to be issued to SSC 30 business days prior to vessel delivery.

3.1.2 Unloading Phase

The vessel shall be delivered to the A-3 site at SSC. Vessel delivery will require a 24 hr advance notice as a minimum. Deliveries after 1:00 P.M. will not be off-loaded until the following day at no additional charge to SSC. Deliveries on Friday after 1:00 P.M. will not be off loaded until the following normal working day (Monday) at no additional charge to SSC. Unloading of the vessel will be performed by others based upon the Lifting Plan, information and documentation provided by the vendor as specified in 3.1.1. Any additional information concerning the load weight, center of gravity, configuration changes or any other information that may affect the safe off-loading and placement in the horizontal position must be provided prior to the off-loading of the vessel.

The Vessel manufacturer shall provide any special lifting structure (i.e. spreader bars) required as part of the vessel delivery.

3.2 Acceptance

The high pressure gas storage vessels shall be accepted by the Contracting Officer following:

(a) Successful completion of factory testing procedures
(b) Delivery to SSC, Mississippi of pressure vessels as specified herein
(c) Final Contracting Officer inspection of the vessels after delivery to SSC, Mississippi. This inspection shall verify construction and cleanliness to this document and the referenced documents
(d) Delivery of all deliverable documents

-- End of Section --

SECTION 01330

SUBMITTALS

PART 1 GENERAL

1.1 SUMMARY

Requirements of this Section apply to, and are a component part of, each section of the specifications.

1.2 SUBMITTALS

A standard transmittal form provided by the Government, SSC Form 581, shall be used to transmit each submittal. SSC form 581 will be provided by the COTR with instructions.

Submittal Description (SD): Drawings, diagrams, layouts, schematics, descriptive literature, illustrations, schedules, performance and test data, and similar materials to be furnished by the Contractor explaining in detail specific portions of the work required by the contract.

The following items, SD-01 through SD-19, are descriptions of data to be submitted for the project. The requirements to actually furnish the applicable items will be called out in each specification.

SD-01 Data

Submittals which provide calculations, descriptions, or other documentation regarding the work.

SD-02 Manufacturer's Catalog Data

Data composed of catalog cuts, brochures, circulars, specifications and product data, and printed information in sufficient detail and scope to verify compliance with requirements of the contract documents.

SD-03 Not Used

SD-04 Drawings

Submittals which graphically show relationship of various components of the work, schematic diagrams of systems, detail of fabrications, layout of particular elements, connections, and other relational aspects of the work.

SD-05 to SD-06 Not Used

SD-07 Schedules

Tabular list of data or tabular list including location, features, or other pertinent information regarding products, materials, equipment, or components to be used in the work.

SD-08 Statements

A document, required of the Contractor, or through the Contractor by way of a supplier, installer, manufacturer, or other Lower Tier Contractor, the purpose of which is to further the quality or orderly progression of a portion of the work by documenting procedures, acceptability of methods or personnel, qualifications, or other verification of quality.

SD-09 Reports

Reports of inspections and laboratory tests, including analysis and interpretation of test results. Each report shall be properly identified. Test methods used and compliance with recognized test standards shall be described.

SD-10 to SD-17 Not Used

SD-18 Records

Documentation to ensure compliance with an administrative requirement or to establish an administrative mechanism.

SD-19 Not Used

1.3 PREPARATION

1.3.1 Marking

Permanent marking shall be provided on each submittal to identify it by contract number; transmittal date; Contractor's, Subcontractor's, and supplier's name, address(es) and telephone number(s); submittal name; specification or drawing reference; and similar information to distinguish it from other submittals. Submittal identification shall include space to receive the review action by the Contracting Officer's Technical Representative (COTR).

1.3.2 Drawing Format

The drawings shall be created in AutoCAD and shall not be a conversion from other CAD systems. The electronic files shall have the "dwg" file-name extension and can be saved in AutoCAD v.2007 format. All submittals prior to "as-built" shall be in printed

format and/or Adobe Acrobat 7.0 or later. Final "as-built" drawings shall be submitted in both electronic format (on CD-ROM) and in printed format.

All geometry shall be created actual size in AutoCAD. Any required scaling shall be performed with appropriate viewports and not by direct scaling of the model geometry. Viewport scale (i.e. display scale) shall be indicated.

Printed drawing submittals shall be prepared on bond (20 lb. bond minimum) paper, not less than 8-1/2 by 11 inches nor larger than 30 by 42 inches in size, except for full size patterns or templates. Printed drawings shall be prepared to accurate size, with scale indicated, unless other form is required. Printed drawing reproducibles shall be suitable for reproduction and shall be of a quality to produce clear, distinct lines and letters. Printed drawings shall have dark lines on a white background.

Each drawing shall have the following information clearly marked thereon:

a. Job name, which shall be the general title of the contract drawings.

b. Date of the drawings and revisions with descriptions of all changes in the revision block.

c. Name of Contractor.

d. Name of Subcontractor.

e. Name of the item, material, or equipment detailed thereon.

f. Number of the submittal (e.g., first submittal, as-built, etc.) in a uniform location adjacent to the title block.

g. Government contract number shall appear in the margin, immediately below the title block.

Drawings shall be numbered in logical sequence. Contractor may use his own number system. Each drawing shall bear the number of the submittal in a uniform location adjacent to the title block. Government contract number shall appear in the margin, immediately below the title block, for each drawing.

A blank space, no smaller than 4 X 4 inches shall be reserved on the right hand side of each sheet for the Government disposition stamp.

1.3.3 Data Format

Required data submittals for each specific material, product, unit of work, or system shall be collected into a single submittal and marked for choices, options, and portions

applicable to the submittal. Marking of each copy of product data submitted shall be identical. Partial submittals will not be accepted for expedition of construction effort.

1.3.4 Samples

Samples shall be physically identical with the proposed material or product to be incorporated in the work, fully fabricated and finished in the specified manner, and full scale. Where variations in color, finish, pattern, or texture are inherent in the material or product represented by the sample, multiple units of the sample, showing the near-limits of the variations and the "average" of the whole range (not less than 3 units), shall be submitted. Each unit shall be marked to describe its relation to the range of the variation. Where samples are specified for selection of color, finish, pattern, or texture, the full set of available choices shall be submitted for the material or product specified. Sizes and quantities of samples shall represent their respective standard unit.

1.4 SUBMISSION REQUIREMENTS

1.4.1 Schedules

Within 21 days of notice to proceed, the Contractor shall provide, for approval by the Contracting Officer's Technical Representative (COTR), the following schedule of submittals:

a. A schedule of shop drawings and technical submittals required by the specifications and drawings. Schedule shall indicate the specification or drawing reference requiring the submittal: the material, item, or process for which the submittal is required; the "SD" number and identifying title of the submittal; the Contractor's anticipated submission date and the approval need date.

b. A separate schedule of other submittals required under the contract but not listed in the specifications or drawings. Schedule will indicate the contract requirement reference; the type or title of the submittal; the Contractor's anticipated submission date and the approved need date (if approval is required).

c. Submittals called for by the contract documents will be listed on one of the above schedules. If a submittal is called for but does not pertain to the contract work, the Contractor shall include it in the applicable schedule and annotate it "N/A" with a brief explanation. Approval of the schedules by the Contracting Officer's Technical Representative (COTR) does not relieve the Contractor of supplying submittals required by the contract documents but which have been omitted from the schedules or marked "N/A".

d. Copies of both schedules shall be re-submitted monthly annotated by the Contractor with actual submission and approval dates.

1.4.2 Drawings Submittals (For Review)

Six blackline prints of each drawing shall be submitted. One print, marked with review notations by the Contracting Officer's Technical Representative (COTR), will be returned to the Contractor.

1.4.3 Data Submittals

Five complete sets of indexed and bound product data shall be submitted. One set, marked with review notations by the Contracting Officer's Technical Representative (COTR), will be returned to the Contractor.

1.4.4 Samples

Two sets of identified samples shall be submitted. A copy of the transmittal form, marked with review notations including selections by the Contracting Officer's Technical Representative (COTR), will be returned to the Contractor.

Samples that are intended or permitted to be returned and actually incorporated in the work are so indicated in the individual technical sections. These samples will be returned to the Contractor, at his expense, to be clearly labeled, with installation location recorded. Samples shall be in undamaged condition at the time of installation.

Where mockups and similar large samples are required by individual technical sections, it is recognized that these are a special type of sample which cannot be readily "transmitted" as specified for submittal of samples. Otherwise, and except as indicated in the individual technical sections, the requirements for samples shall be complied with and a transmittal form shall be processed for each mockup, to provide a record of the activity.

1.5 GOVERNMENT'S REVIEW

1.5.1 Review Notations

The Contracting Officer's Technical Representative (COTR) will review submittals and provide pertinent notation within 14 calendar days after date of submission. Submittals will be returned to the Contractor with the following notations:

a. Submittals marked "Approved as Submitted." authorize the Contractor to proceed with the work covered.

b. Submittals marked "Approved, Except as Noted, Resubmission Not Required." authorize the Contractor to proceed with the work covered provided he takes no exception to the corrections. Notes shall be incorporated prior to submission of the final submittal.

c. Submittals marked "Approved, Except as Noted, Resubmission Required." require the Contractor to make the necessary corrections and revisions and to re-submit them for approval in the same routine as before, prior to proceeding with any of the work depicted by the submittal.

d. Submittals marked "Will Be Returned By Separate Correspondence" require the Contractor to follow the instructions given in the separate correspondence. If re-submission is required, the Contractor shall re-submit them for approval in the same routine as before prior to proceeding with any of the work depicted by the submittal.

e. Submittals marked "Disapproved" indicate noncompliance with the contract requirements and shall be re-submitted with appropriate changes. No item of work requiring a submittal shall be accomplished until the submittals are approved or approved as noted.

f. Submittals marked "Receipt Acknowledged" confirm receipt only.

g. Submittals marked "Other (Specify)" require the Contractor to follow the instructions given in the separate correspondence. If re-submission is required, the Contractor shall re-submit them for approval in the same routine as before, prior to proceeding with any of the work depicted by the submittal.

Contractor shall make corrections required by the Contracting Officer's Technical Representative (COTR). If the Contractor considers any correction or notation on the returned submittals to constitute a change to the contract drawings or specifications; notice as required under the clause entitled, "Changes in Contract Documentation" shall be given to the Contracting Officer's Technical Representative (COTR). Approval of the submittals by the Contracting Officer's Technical Representative (COTR) shall not be construed as a complete check, but will indicate only that the general method of construction and detailing is satisfactory. Contractor shall be responsible for the dimensions and design of connection details and construction of work. Failure to point out deviations may result in the Government requiring rejection and removal of such work at the Contractor's expense.

If changes are necessary to approved submittals, the Contractor shall make such revisions and submission of the submittals in accordance with the procedures above. No item of work requiring a submittal change shall be accomplished until the changed submittals are approved.

1.5.2 Sample Approval

Contractor shall furnish, for the approval of the Contracting Officer's Technical Representative (COTR), samples required by the specifications or by the Contracting

Officer's Technical Representative (COTR). The Contractor shall pay shipping charges. Materials or equipment requiring sample approval shall not be delivered to the site or used in the work until approved in writing by the Contracting Officer's Technical Representative (COTR).

Each sample shall have a label indicating:

a. Name of project

b. Name of Contractor

c. Material or equipment

d. Place of origin

e. Name of producer and brand

f. Specification section to which samples applies

g. Samples of furnished material shall have additional markings that will identify them under the finished schedules.

Contractor shall submit to the Contracting Officer's Technical Representative (COTR) two samples of materials where samples are requested. Contractor shall transmit with each sample a letter, original and two copies, containing the above information.

Approval of a sample shall be only for the characteristics or use named in such approval and shall not be construed to change or modify any contract requirements. Before submitting samples, the Contractor shall assure that the materials or equipment will be available in quantities required in the project. No change or substitution will be permitted after a sample has been approved.

Materials and equipment incorporated in the work shall match the approved samples. If requested, approved samples, including those which may be damaged in testing, will be returned to the Contractor, at his expense, upon completion of the contract. Samples not approved will also be returned to the Contractor at his expense, if so requested.

Failure of any materials to pass the specified tests will be sufficient cause for refusal to consider, under this contract, any further samples of the same brand or make of that material. Government reserves the right to disapprove any material or equipment, which has previously proved unsatisfactory in service.

Variations from contract requirements shall be specifically pointed out in transmittal letters. Failure to point out deviations may result in the Government requiring rejection and removal of such work at no additional cost to the Government.

The Contracting Officer's Technical Representative (COTR) may take samples of various materials or equipment delivered on-site or in-place for testing. Samples failing to meet contract requirements will automatically void previous approvals. Contractor shall replace such materials or equipment to meet contract requirements.

Approval of the Contractor's samples by the Contracting Officer's Technical Representative (COTR) shall not relieve the Contractor of his responsibilities under the contract.

1.6 PROGRESS SCHEDULE

1.6.1 Bar Chart

Contractor shall:

a. Submit the progress chart, for approval by the Contracting Officer's Technical Representative (COTR), within 21 days of Notice to Proceed, in 4 copies.

b. Prepare the progress chart in the form of a bar chart utilizing form "Construction Progress Chart" or comparable format acceptable to the Contracting Officer's Technical Representative (COTR).

c. Include no less than the following information on the progress chart:

(1) Break out by major headings for primary work activity.

(2) A line item break out under each major heading sufficient to track the progress of the work.

(3) A line item showing contract finalization task which includes punch list, clean-up and demolition, and final construction drawings.

(4) A materials bar and a separate labor bar for each line item. Both bars will show the scheduled percentage complete for any given date within the contract performance period. Labor bar will also show the number of men (man-load) expected to be working on any given date within the contract performance period.

(5) The estimated cost and percentage weight of total contract cost for each materials and labor bar on the chart.

(6) Separate line items for mobilization and drawing submittal and approval. (These items are to show no associated costs.)

d. Update the progress schedule 4 copies every 30 days throughout the contract performance period.

1.7 STATUS REPORT ON MATERIALS ORDERS

Within 21 days after notice to proceed, the Contractor shall submit, for approval by the Contracting Officer's Technical Representative (COTR), an initial status report on materials orders. This report will be updated and re-submitted every 28 days as the status on material orders changes.

Report shall list, in chronological order by need date, materials orders necessary for completion of the contract. The following information will be required for each material order listed:

a. Material name, supplier, and invoice number.

b. Bar chart line item or CPM activity number affected by the order.

c. Delivery date needed to allow directly and indirectly related work to be completed within the contract performance period.

d. Current delivery date agreed on by supplier.

e. When item d exceeds item c, the effect that delayed delivery date will have on contract completion date.

f. When item d exceeds item c, a summary of efforts made by the Contractor to expedite the delayed delivery date to bring it in line with the needed delivery date, including efforts made to place the order (or subcontract) with other suppliers.

PART 2 PRODUCTS (Not Applicable)

PART 3 EXECUTION (Not Applicable)

-- End of Section -

SECTION 01420

SOURCES FOR REFERENCE PUBLICATIONS

PART 1 GENERAL

1.1 REFERENCES

Reference publications are cited in other sections of the specifications along with identification of their sponsoring organizations. The addresses of the sponsoring organizations are listed below, and if the source of the publications is different from the address of the sponsoring organization, that information is also provided.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

Three Park Avenue
New York, NY 10016-5990
Ph: 212-591-7722
Fax: 212-591-7674
Internet: www.asme.org

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

400 Commonwealth Drive
Warrendale, PA 15096-0001
Ph: 412-776-4841
Fax: 412-776-5760
Internet: http://www.sae.org
e-mail: publications@sae.org

NASA & SSC STANDARDS AND SPECIFICATIONS (SSC)

Central Engineering Files
Building 2104
Stennis Space Center, MS 39529
Ph: 228-688-3043
Fax: 228-688-3503

-- End of Section --

APPENDIX A1

SSTD-8070-0089-FLUIDS

SURFACE CLEANLINESS REQUIREMENTS FOR SSC FLUID SYSTEMS

SSTD-8070-0089-FLUIDS
Revision B
July 2004

John C. Stennis Space Center Surface Cleanliness Requirements For SSC Fluid Systems

Original signed by

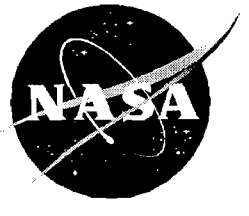
W. Kirk Miller
NASA SSC Center Operations
Project Management Division

Richard T. Rauch
NASA SSC Propulsion Test
Engineering Division

John Stealey
NASA SSC Safety & Mission Assurance

Issued by

Issued CEF 07/14/04
Central Engineering Files



National Aeronautics and
Space Administration

John C. Stennis Space Center
Stennis Space Center, MS 39529-6000

Document History Log

Revision Change	Date	Originator Phone	Description
Basic	07/03/02	M. Yentzen x87252	Initial release – supersedes SSC STD 79-001 Rev. K, with the following changes: New document number and format per SPG 1400.1; Change Center Ops signature title per NASA reorg.; 1.3.1 delete ref to SLP-05; 2.0 change refs per text mods, add SCD 54000-GM11; 5.1.1 Add Material and Process Control Team option; 5.2 change "can" to "may" throughout; 5.2.2 delete prohibition of HCFC-225g (AK-225g) on titanium alloys; 5.2.9 add new for *normal*-Propyl Bromide; 6.3 add note excluding level 2 and level 4; 10.0 change SLP-16 ref to new SSLP number; Appendix B: delete terms not used in the standard.
A	8/25/03	Doug Dike Ext 8-2803	2.0 deleted ASTM D1193 per text change in 5.4.1, 5.4.2 and 5.4.3; 5.4.1, 5.4.2 and 5.4.3 revised DI water requirements, including delete of reference to ASTM D1193, add of volume/area ratio limits and (in 5.4.2, particulate) qualifiers for complex configurations and surfactants; Table 1 new note ③ in "systems" block and footer listing for field dewpoint verification – subsequent notes renumbered; 6.5 revised for field dewpoint verification of assembled dump/vent systems open to the atmosphere. Note: mod to 6.5 and Table 1 incorporates changes per Variance NA63.
B	7/13/04	Dale Sewell Ext 8-2642	Added sentence to 5.2.9 that stipulates not to use *normal*-Propyl Bromide for NVR and/or particulate analysis of any type of Reflange Seal Rings. 6.5 was revised for weld prepared piping.

Table of Contents

TABLES

1.0 INTRODUCTION

1.1 PURPOSE

This standard (STD) establishes the surface cleanliness requirements for fluid systems, components, and inspection, measuring and test equipment (IM&TE) at Stennis Space Center (SSC).

1.2 APPLICABILITY

This STD applies to site-wide facility components and systems that require cleanliness certification.

1.3 RESPONSIBILITIES

1.3.1 SSC Activities

NASA and Contractor personnel responsible for engineering design, manufacture/fabrication, analysis, inspection or test operations shall implement this STD. NASA and the Contractor shall ensure compliance with requirements of this STD through surveillance, auditing and process verification. Design specifications and drawings shall identify cleanliness levels by the alphameric or numeric designations defined in this STD. Revision or cancellation of this STD shall be reviewed and approved in accordance with SSC standard SSTD-8070-0005-CONFIG.

1.3.2 Quality Control

NASA and/or Contractor QA shall verify that the surface cleanliness requirements for SSC fluid systems are satisfied.

2.0 REFERENCED DOCUMENTS

The referenced documents form an integral part of this standard and their latest issues shall apply unless otherwise specified.

A-A-59150	Federal Specification: Cleaning Compound, Solvent, Hydrofluoroether (HFE)
AMS 3649	SAE Industry Standard: Film, PCTFE Unplasticized
ASTM D4080	Standard Specification for Trichloroethylene, Technical and Vapor Degreasing Grade
ASTM D4376	Standard Specification for Vapor-Degreasing Grade Perchloroethylene (vapor degreasing use only)

ASTM D5501	Standard Test Method for Determination of Ethanol Content of Denatured Fuel Ethanol by Gas Chromotography
ASTM D6368	normal-Propyl Bromide (Ensolv®)
JSC SE-S-0073	Space Shuttle Specification Fluid Procurement and Use Control
MIL-C-81302	Cleaning Compound Trichlorotrifluoroethane (Freon)
MIL-T-81533	Trichloroethane 1,1,1, (Methyl Chloroform) Inhibited, Vapor Degreasing
NASA STD 6001	Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion
O-E-760	Federal Specification: Ethyl Alcohol (Ethanol); Denatured Alcohol; Proprietary/Industrial Solvents
SCWI-8500-0004-ENV	Hazardous Materials, Hazardous Waste and Solid Waste Procedures & Guidelines
SPG 1400.1	Document Preparation, Numbering and Management Guidelines
SPG 8715.1	SSC Safety and Health Procedures and Guidelines
SSC SCD 54000-GM10	Procurement of Solvent, Cleaning and Verification, Vertrel MCA 1,1,1,2,3,4,4,5,5,5 – Decafluoropentane (62 wt%) and Trans-1,2 – Dichloroethylene (38 wt%)
SSC SCD 54000-GM11	Procurement of Solvent, Cleaning, 1,3-Dichloro-1,1,2,2,3, - Pentafluoropropane, HCFC-225G
SSC SCD 54000-GP11	Packaging & Preservation of Cleaned Components
SSC STD 79-002	Sampling Requirements and Maximum Allowable Impurities for SSC Fluids and Fluid Systems
SSLP-1440-0001	SSC Records Management Program and Control of Quality Records
SSTD-8070-0005-CONFIG	Preparation, Review, Approval and Release of SSC Standards
TT-I-735	Federal Specification: Isopropyl Alcohol

3.0 GENERAL REQUIREMENTS

3.1 SAFETY

All procedures in this STD shall be performed in accordance with the applicable requirements of SPG 8715.1.

3.2 SYSTEM DESIGN

3.2.1 Breaks and Check Valves

When fluid systems are designed or modified, cleanliness breaks shall be established to enable connecting of systems that have different cleanliness levels.

a. Use dual check valves for the following cleanliness breaks: 1, 1X, 1XX or 1XXX (upstream) and 2, 2X, 2XX or 3 (downstream). Add filter if downstream particulate requirements are more stringent than upstream requirements.

b. Use single check valve for the following cleanliness breaks: 1, 1X, 1XX or 1XXX (upstream) and 2A (downstream).

c. Use filter for the following cleanliness breaks: any combination of 1, 1X, 1XX or 1XXX (upstream or downstream).

d. Use filter for the following cleanliness breaks: any combination of 2, 2X, 2XX or 3 (upstream or downstream).

3.2.2 Component Removal

Designs for systems and system components should enable the removal of all valves and components from the system. In cases where it is not practical to use removable components (e.g., V-J valves with buttweld end connections), component design shall enable removal of all internal piece parts of the component while it is connected to its respective system.

3.2.3 Component Disassembly

Complete disassembly is required prior to cleaning or verifying all components except for IM&TE and for components being field cleaned or verified by an approved procedure. Therefore, use of components that cannot be completely disassembled shall be avoided.

3.2.4 Bottles and Vessels

Designs of bottles and vessels shall incorporate adequate provisions for cleaning. These provisions shall include, but are not limited to, manway or "jet-mole" access (to inspect and flush/spray all significant surfaces wetted by service media) and low-point drains (to collect flush samples).

3.3 CLEANING

Cleaning is comprised of two categories: gross and precision. Gross cleaning may be accomplished by using one or more of the following processes or materials: mechanical cleaning, halogenated degreasers, alkaline or acid cleaners, detergents and tap or deionized (DI) water flushes. Precision cleaning is performed after gross cleaning and may be accomplished by employing methods such as solvent flushing.

Certification of a cleaned system, component and/or packaging material is required prior to packaging or securing the component or system.

3.4 ACIDITY AND ALKALINITY

Surfaces of components that have been cleaned and are rinsed with deionized water shall register a pH between 5.5 and 8.0 while the component is wet from the last rinse or after wetting the surface with deionized water.

3.5 DRYING AND TESTING GAS

Gas for drying and testing of items cleaned per this standard shall conform to SSC STD 79-002. When the cleanliness level particulate requirements are more stringent than those specified by SSC STD 79-002, the gas shall be pre-filtered through an appropriately sized filter prior to use or entry into a system or component to be dried or tested.

4.0 SPECIFIC REQUIREMENTS BY CLEAN LEVEL

The cleanliness level requirements imposed by this standard are specified in Table 1. Each cleanliness level in Table 1 requires visual inspection according to Section 6.2.

TABLE 1. CLEANLINESS LEVELS/REQUIREMENTS

CLEANLINESS LEVEL	PARTICULATE		NVR/HYDROCARBON mg/0.1m² (mg/ft²)①②		DEWPOINT/MOISTURE CONTENT	
	SIZE (MICRONS)	NUMBER (PARTICLES) no./0.1m² (no./ft²)①	TANKS/ VESSELS	LINES/ COMPONENTS	COMPONENTS	SYSTEMS ③
1	>2500	0	5	1	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	700<X<2500	1				
	175<X<700	5				
1X	>800	0	5	1	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	175<X<800	5				
1XX	>400	0	5	1	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	175<X<400	5				
1XXX	>100	0	5	1	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	50<X<100	1				
	25<X<50	11				
	15<X<25	75				
	<15	280				
2	N/A	N/A	N/A	N/A	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
2A	N/A	N/A	0④	0④	N/A	N/A
2X	>400	0	N/A	N/A	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	175<X<400	5				
2XX	>100	0⑤	N/A	N/A	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	50<X<100	5				
	25<X<50	68				
	0<X<25	⑥				
3⑦	N/A	N/A	N/A	N/A	N/A	N/A
4 (HYDRAULIC CLEAN)	>100	10	N/A	N/A	-54°C(-65°F) /24ppm	-40°C(-40°F) /128ppm
	50<X<100	60				
	25<X<50	530				
	10<X<25	2150				
	0<X<10	⑥				

①Test sample volumes for particulate and NVR analyses are specified in section 6.1.

②For the purposes of this standard, NVR may be determined by using any analytical method that accurately measures the hydrocarbon content of a particular solvent, e.g., gravimetric, TOC and FTIR.

③The requirement for field dewpoint verification of an existing assembled dump/vent line shall be determined by the end user. Field dewpoint verification is required on all newly installed dump/vent lines. Prior to or following installation, all newly installed components shall be properly processed and verified dry in accordance with the system cleanliness level requirement for both existing and newly installed dump/vent lines.

④Hydrocarbon residue as detected by fluorescence of the type and UV spectrum specified in the definition of "Black Light" from Appendix B shall be cause for rejection.

⑤One nonmetallic particle above the maximum is permitted.

⑥Particles in the specified range are not counted; however, a concentration of such particles sufficient to obscure membrane grid lines (silting) shall be cause for rejection.

⑦Commercial clean is equivalent to cleanliness level 3.

5.0 CLEANING FLUIDS, VERIFICATION FLUIDS AND RINSING AGENTS

5.1 GENERAL

Cleaning fluids, verification fluids and rinsing agents that can be used are specified in sections 5.2, 5.3 and 5.4.

The requirements of SCWI-8500-0004-ENV *Hazardous Materials, Hazardous Waste, and Solid Waste Procedures and Guidelines* shall be met when using verification fluids, cleaning fluids and rinsing agents at SSC.

Traceability of cleaning fluids, verification fluids and rinsing agents must be maintained throughout the cleaning and verification process. Traceability documentation shall include, at a minimum, fluid cleanliness certifications and product composition reports.

5.1.1 Compatibility of Cleaning Fluids, Verification Fluids and Rinsing Agents

Cleaning fluids, verification fluids and rinsing agents must be compatible with the item being cleaned, verified or rinsed and shall not cause immediate or latent degradation (e.g., leaching of plasticizers, swelling of softgoods or hardware corrosion).

The performing organization must verify that the cleaning fluids, verification fluids and rinsing agents selected for use are compatible with the item being processed. The SSC Material and Process Control Team may be used as a resource to ensure compatibility of cleaning fluids, verification fluids and rinsing agents prior to their use on new materials.

The performing organization must also ensure that cleaning, verification and rinsing processes employing multiple fluids do not degrade hardware (e.g., some mixtures of halogenated solvents and water are corrosive to some metals). Parts and components shall be dried or rinsed between operations as required to prevent the formation of corrosive mixtures.

5.1.2 Control Samples

Verification fluids and rinsing agents shall be sampled prior to use on hardware with cleanliness levels requiring an NVR or particulate analysis. Verification fluids and rinsing agents shall meet the cleanliness requirements of the item being verified or rinsed. The control sample for all fluids used to sample or rinse tanks and vessels shall have no more than 25 mg NVR per 500 ml of fluid. The control sample for all other hardware shall have no more than 1 mg NVR per 200 ml of fluid.

The control sample NVR may be subtracted from the test sample NVR to determine compliance with this standard; however, the control sample particulate results may not be subtracted from the test sample particle count.

When the control sample of a fluid does not meet the appropriate NVR requirement, the fluid cannot be used. The fluid must be distilled and resampled to verify that the NVR requirement is met. When the control sample of a fluid does not meet the appropriate particulate requirement, the fluid cannot be used. The fluid must be filtered with a clean, wire mesh filter and resampled to verify that the particulate requirement is met.

5.2 HALOGENATED SOLVENTS

When used for testing, halogenated solvents shall comply with the latest revision of the applicable procurement specifications referenced in subsections 5.2.1 through 5.2.8. In addition, the solvent shall meet the cleanliness requirements of the cleaned item or system. When the required NVR level of the solvent is less than the procurement specification, the solvent shall be distilled or cleaned to obtain the required NVR level.

Following use of any halogenated solvent (except for CFC-113, HFE-7100® and HCFC-225g) on items or systems with NVR requirements, verification is required to ensure that the solvent has been thoroughly removed from the item or system. Verification of solvent removal from significant surfaces shall be done in accordance with a NASA approved procedure. This verification must be supported with data that demonstrate removal of the solvent for the affected item or system. After removal of the solvent, the item or system must be purged with gas to dry it. Finally a gas sample shall be taken and analyzed to verify that the total gaseous hydrocarbon content is less than 5 ppm expressed as Methane.

5.2.1 Trichlorotrifluoroethane (CFC-113), MIL-C-81302, Type 1

CFC-113 may be used to perform NVR and/or particulate analysis, but it shall **not** be used on titanium alloys or for flushing hydraulic components or systems.

5.2.2 HCFC-225g (AK-225g), SSC DWG 54000-GM11

HCFC-225g may be used to perform NVR and/or particulate analysis, but it shall **not** be used for flushing hydraulic components or systems.

5.2.3 1,1,1 Trichloroethane (Methyl Chloroform), MIL-T-81533

1,1,1 Trichloroethane may be used to perform NVR and/or particulate analysis, but it shall **not** be used on titanium alloys or for flushing hydraulic components or systems.

5.2.4 Tetrachloroethylene (Perchloroethylene), ASTM D4376 (for vapor degreasing only) or ACS Spectrometric Grade (for cleaning and verification)

Tetrachloroethylene may be used to perform NVR and/or particulate analysis, but it shall not be used for titanium alloys, softgoods or hydraulic components/systems. When used for cleanliness verification, tetrachloroethylene shall not be used on items that contain enclosed or entrapped areas.

5.2.5 Trichloroethylene, MIL-T-27602 or ASTM D4080

Trichloroethylene may be used to perform NVR and/or particulate analysis, but it shall **not** be used on titanium alloys or for flushing hydraulic components or systems.

5.2.6 Methoxynonafluorobutane (Hydrofluoroether-7100)(HFE-7100®), A-A-59150 or JSC SE-S-0073

HFE-7100® may be used to perform particulate analysis or as a rinsing agent to remove Vertrel MCA® from items with an NVR requirement. HFE-7100® shall **not** be used as a test fluid for NVR analysis or for flushing hydraulic components or systems.

5.2.7 Decafluoropentane 62% & Trans-1,2-Dichloroethylene 38% (Vertrel MCA®), JSC SE-S-0073 or SSC DWG 54000-GM10

Vertrel MCA® may be used to perform NVR and/or particulate analysis, but it shall **not** be used for softgoods that have an NVR requirement, titanium alloys or hydraulic components or systems. Items or systems with NVR requirements shall be pre-dried in accordance with section 6.5; flushed with HFE-7100®; and verified to ensure solvent removal in accordance with section 5.2.

5.2.8 Decafluoropentane (HFC-4310 mee or Vertrel XF®), SSC DWG 54000-GM10

Vertrel XF® may be used to perform particulate analysis, but it shall **not** be used as a test fluid for NVR analysis or for flushing hydraulic components or systems.

5.2.9 *normal*-Propyl Bromide (Ensolv®), ASTM D6368

normal-Propyl Bromide may be used for NVR and/or particulate analysis for tanks and vessels. It shall **not** be used for NVR and/or particulate analysis for components. It may be used for NVR and/or particulate analysis for piping **only** if the solvent meets the NVR level of the systems being verified.

It shall not be used for NVR and/or particulate analysis of any type Reflange Seal Rings.

5.3 ALCOHOL SOLVENTS

All alcohol solvents used for testing shall comply with the latest procurement specifications listed in paragraphs 5.3.1 and 5.3.2. In addition, the alcohol control solvent shall meet the cleanliness requirements of the item being cleaned. Alcohol solvents shall **not** be used for cleaning, verifying or rinsing oxidizer systems (hardware and softgoods) or on any system that feeds into an oxidizer system.

5.3.1 Isopropyl Alcohol, TT-I-735, Grade A or ACS Reagent Grade

Isopropyl alcohol (isopropanol) may be used to perform particulate analysis; but it shall **not** be used as a test fluid for NVR analysis.

5.3.2 Ethyl Alcohol, 0-E-760

Ethyl alcohol (ethanol) may be used to perform particulate analysis, but it shall **not** be used as a test fluid for NVR analysis or for items that contain Teflon®.

5.4 DI BASED FLUIDS

NOTE

Dry film lubricated surfaces shall not undergo any DI water process for NVR and/or particulate verification.

5.4.1 DI Water Process for NVR Verification

When used for NVR verification, DI water shall conform to a resistivity of greater than 1 meg-ohm-cm or a conductivity of less than 1 micro-siemen-cm. DI water shall meet NVR and/or particulate requirements of the cleaned item. In addition, DI water shall require use of mechanical energy (e.g. high velocity impingement, sonication and heat); therefore, it should not be used on items of complex configuration. Verification and analysis methods must conform to a procedure that is approved by NASA PTD and supported with test data that demonstrate the efficacy of the process for the affected item or assembly.

To reliably detect an NVR level of 1 mg/0.1m^2, the DI water volume to hardware surface area ratio used for ultrasonic extraction and Total Organic Carbon (TOC) analyses shall not exceed 3 liters/0.1m^2.

5.4.2 DI Water Process for Particulate Analysis

When used for particulate verification, DI water shall conform to a resistivity of greater than 1 meg-ohm-cm or a conductivity of less than 1 micro-siemen-cm. The DI water shall meet the particulate requirements of the cleaned item. In addition, DI water shall require use of mechanical energy (e.g. high velocity impingement, sonication and heat); therefore, it should not be used on items of complex configuration. Use of a surfactant in the DI water final clean level test/verification flush solvent is acceptable but shall be limited to clean levels that do not require NVR analysis. Particulate analysis methods, including types and concentrations of surfactants used, solvent temperature controls, and application of mechanical energy, must conform to a procedure that is approved by NASA SSC PTD. Furthermore, the particulate analysis methods shall be supported with test data demonstrating the effectiveness of the process in removal of residual particle contaminants from all significant surfaces of the affected item or assembly.

5.4.3 DI Water/Rinsing Agent

When used for rinsing operations, the DI water shall conform to the resistivity of greater than 50,000 ohms-cm or a conductivity of less than 20 micro-siemen-cm.

6.0 CERTIFICATION TESTS

6.1 TEST SAMPLES

Test samples can be obtained by flushing or spraying significant surfaces with a solvent. For internal significant surface areas of 0.5 square meter or less (approximately 5 square feet), a 200-milliliter (minimum) sample shall represent approximately 0.1 square meter (approximately 1 square foot) of significant surface area. For internal significant surface areas greater than 0.5 square meter, a 100-milliliter (minimum) sample shall represent approximately 0.1 square meter of significant surface.

6.2 VISUAL INSPECTION

All significant surfaces that contact service fluids require visual inspection unless the surface is "inaccessible" as defined in Appendix B. The presence of gross contamination is not allowed. If visual evidence of contamination is found in a component or system, the foreign material shall be analyzed to determine its identity, source and compatibility with the service fluid.

NOTE

Scale-free discoloration due to welding, etching, heat treating, and passivation of lines, components or surfaces is permitted.

6.2.1 Flash Rust

Visible, scale-free surface oxidation (flash rust) is allowed on significant surfaces; however, it shall not exceed five percent of the internal significant surface area of systems or components. Furthermore, flash rust is not acceptable if it prevents the system or component from meeting cleanliness requirements.

6.2.2 Inspection Aids

Inspection aids such as lights, borescopes, mirrors and ultraviolet (UV) lamps (black lights) must meet the cleanliness requirements of the system or component that they inspect.

6.3 PARTICULATE ANALYSIS

NOTE

If silt is discovered during particulate analysis, investigate the system or component, determine the cause and correct the problem. Silting is unacceptable.

A test sample, as described in section 6.1, shall be analyzed for particle population and size. When a test sample meets Level 1 NVR requirements but fails particulate requirements, a gas purge of 3 meters per second or more can be used for particulate analysis in lieu of an additional fluid flush. This analysis must conform to a procedure that is approved by NASA PTD.

NOTE

This is not applicable to Level 2 or Level 4 verification processes.

6.4 NONVOLATILE RESIDUE (NVR) ANALYSIS

A test sample, as described in section 6.1, shall be used for NVR analysis. If the test sample NVR level is less than the control sample NVR level, the NVR analysis shall be considered invalid and the verification process shall be repeated.

If the spray or flush method of obtaining a test sample is not practical, a swab or wipe sampling technique may be used (with customer approval) for NVR analysis. This sampling method is performed by wiping a representative area of up to one square foot with a certified clean, solvent-soaked, lint-free swab or wipe. After wiping the area to be verified, each swab or wipe shall be flushed with approximately 200 ml of solvent and analyzed for NVR. Larger surfaces may require several random wipe tests to ensure that a representative portion of the surface area is sampled.

6.5 DRYNESS (DEWPOINT) ANALYSIS

Dewpoint Analysis certification is mandatory for all systems, components and IM&TE with a dewpoint requirement specified in Table 1, with the exception of:

- excepted components per stipulations in section 8.0;
- pipe, fittings, and pipe spools/sections with at least one weld-prepared end; and
- assembled dump/vent systems that are open to the atmosphere and are field verified for cleanliness level.

Whether or not this certification is required, proper processing and dryness verification in accordance with this standard is required for all IM&TE, components, fittings, pipe, tubing, and pipe sections/spools used in dump/vent systems and for all pipe sections/spools with at least one weld joint preparations.

a. Components and IM&TE assembled in a clean room do not require dewpoint testing if their disassembled parts are oven dried for 30 minutes at 66 degrees C (150 degrees F).

b. IM&TE with open configuration shall be purged with nitrogen for a minimum of 30 minutes. IM&TE with entrapped areas or closed configurations shall be vacuum dried at or below 20 in. of Hg for a minimum of 30 minutes. This will serve as certification that the item is dried.

c. If dryness certification cannot be obtained by the methods outlined in section 6.5(a) or (b), a dewpoint test shall be performed. Prior to performing a dewpoint test on the effluent gas from a system or component, heated gas at 135 degrees C shall be used to purge the system or component for a minimum of 30 minutes, or the gas shall be locked within the system or component for a minimum of 30 minutes. Prior to performing a dewpoint test on the effluent gas from a vessel, gas shall be heated to 135 degrees C to purge the vessel. The gas shall be locked within the vessel for a minimum of 8 hours prior to performing a sample. The gas is not required to maintain the 135 degrees C minimum requirement while locked up within the vessel.

NOTE

To certify dryness for cleanliness level 2 components (not 2A, 2X, 2XX), a system dewpoint analysis may be performed in lieu of performing individual dewpoint analyses on each component in the system.

7.0 FIELD PROCEDURES

CAUTION

Components containing softgoods incompatible with the test fluid in use shall be replaced with a temporary spool piece and/or a flange to prevent softgood degradation that could result from field cleaning/ verification operations.

7.1 FIELD CLEANING

Field cleaning is permissible for systems or components that are required to be cleaned to level 3 or level 2 (not 2A, 2X or 2XX). For all other systems or components, the provisions of section 7.2 must be satisfied before field cleaning is allowed.

7.2 CLEANING/VERIFICATION

a. Field cleaning/verification shall be performed only when all of the following apply, unless otherwise approved by the NASA Propulsion Test Directorate.

1. The item is part of a fixed installation and cannot be moved to a remote and controlled cleaning facility.

2. Cleaned replacements are not available.

3. System components having moving parts, close tolerance fluid passages, or zero flow velocity zones are replaced by pipe spool pieces or have all internal piece parts removed.

4. All pressure gages and other instrumentation are removed.

b. The flushing process for field cleaning/verification shall be performed by system flow-through at 1.2 meters per second or more, pressurized spraying, or by other methods approved by the NASA Propulsion Test Directorate.

c. Sampling methods shall comply with section 6.0.

7.3 FIELD CERTIFICATION

The certification of system or component cleanliness levels may be performed in the field; however, verification processes that precede certification, such as sample analysis, are best performed in a laboratory. Verification by flushing shall be performed in a clean room or other controlled environment unless it is performed in accordance with section 7.2.

7.4 CONTAMINATION CONTROL

Provide shelters, enclosures or a positive purge of sufficient quantity to prevent contamination of systems opened in the field. These preventive measures shall comply with NASA approved procedures.

7.4.1 Post-Verification Operations

Assembly, installation and removal of precision cleaned components shall be done with utmost care to prevent contamination. Certified clean gloves and tooling shall be used when handling cleaned significant surfaces.

7.4.2 Post-Verification Cleaning

Field hardware that meet cleanliness requirements do not need to be re-verified when contamination associated with field activities is completely accessible and can be removed by handwiping or purging.

NOTE

The certified clean, lint-free cloth used for handwiping shall be dry or moistened with a verification fluid that meets the requirements of this standard. Handwiping shall be performed in such a manner that the fluid does not flow into or become entrapped in the hardware.

7.4.3 Post-Verification Inspection

Surfaces of all cleaned components that will contact the service fluid shall be visually inspected for the presence of gross contaminants.

8.0 CERTIFICATION OF EXCEPTED COMPONENTS/SYSTEMS & SOFT GOODS

NOTE

When excepted components contain softgoods that must be removed prior to the certification process, the softgoods must be removed and precision cleaned as individual piece parts.

Components that cannot be certified using normal procedures or facilities (because of their size, construction, incompatibility with flushing solvent, or method of assembly) may be certified as excepted components. All excepted components, other than softgoods processed as excepted components due to solvent incompatibility, require approval by the NASA Propulsion Test Directorate Configuration Control Board.

Excepted components shall be certified by the tests described in section 6.0. When acceptable results are obtained, these components will be identified by notation "EXC." on the certification tag, which shall also indicate the required cleanliness level and certification test results. The "EXC." notation will identify that the component has been certified in accordance with this standard.

9.0 PROTECTION OF CLEANED SURFACES

All protective materials shall be compatible with the system or component surface in contact with the protective material. Protective materials shall also be designed to withstand the specified environment for the storage period and mode of delivery including impact protection of significant surfaces.

9.1 PACKAGING

a. Packaging requirements are specified in SSC drawing 54000-GP11. Before cleaning, prepare detailed instructions showing materials, methods and quality requirements for the packaging to ensure that cleanliness levels are maintained during periods of shipping and/or storage. These instructions shall be approved as specified by contract.

b. Cleaned and certified components shall be packaged within a controlled environment equal to or cleaner than the environment in which they were cleaned and certified. Outer protective wrap (e.g., dimple wrap) may be applied outside the controlled area. This procedure shall be approved by the Quality Assurance Representative and in accordance with the requirements of section 9.2.

9.2 PACKAGING FILMS

NOTE

Stainless steel threaded plugs, blind hubs and flanges can be used for the primary packaging inner barrier that isolates clean surfaces from ambient environments. Prior to use, these plugs, hubs and flanges (and their respective seals) shall be cleaned to the same cleanliness level as the cleaned item.

a. Packaging films used for packaging precision clean items must conform to the requirements of section 9.1. The cleanliness level of the inner wrap shall be at least equivalent to that of the exposed clean surfaces of the item packaged. The outer wrap shall be visibly clean.

b. Selection of a specific film shall be dictated by compatibility with the specified service medium.

c. Items that come in contact with liquid oxygen (LOX) and gaseous oxygen (GOX) fluids or systems shall be protected with an inner bag or layer of film such as fluorohalocarbon film (e.g., Aclar 22A and 33C) conforming to AMS 3649.

d. Removal of packaging film prior to installation of hardware into a system shall be performed such that all material is completely removed (i.e., no shreds, strips or pieces of material shall remain after packaging is removed).

10.0 RECORDS AND FORMS

Records and forms required by this standard shall be maintained as specified in SSLP-1440-0001. For Quality Records, refer to the SSC Master Records Index. Forms shall be the latest edition unless otherwise specified and may be obtained from the SSC Electronic Forms repository or the NASA SSC Forms Management Officer.

APPENDIX A
DEFINITIONS

Black Light - a high intensity, long-wave, low-energy, ultraviolet (UV) light (UV spectrum 3200-3800 angstroms).

Blanket Purge – the use of pressurized gas in an enclosed environment for protecting components, piping or vessels from contamination.

Certification – a written record demonstrating that requirements have been verified and achieved.

Cleaning - the removal of incompatible materials from the significant surfaces of components and systems within the scope of this standard.

Clean Room – a room in which precautions are employed to reduce contaminants in the air, producing a controlled environment for verification, assembly and packing of cleaned items.

Commercial Clean - without gross contamination.

Component - an item that is normally a combination of parts, subassemblies or assemblies and that is self-contained within a fluid system.

Contaminant - any material that could chemically react or mechanically interfere with a cleaned component, system or end item.

Control Sample - a specific volume of flushing solvent that is analyzed to determine a baseline contamination level before a test sample is attained.

Dewpoint - the temperature at which a gas becomes saturated with water vapor and condensation begins (usually atmospheric pressure).

Drying - reducing moisture/dewpoint levels by vacuum, purge, flush or oven-heated methods.

Excepted Component/System/Soft Good - an item or system that cannot be cleaned and certified using normal procedures or facilities because of their size, construction or method of assembly.

Field Certification - the process of certifying components in the field.

Field Cleaning - cleaning performed outside a shop or clean room environment.

Field Verification - process of obtaining samples in the field for subsequent laboratory analysis to certify cleanliness levels.

Fluid – a gas or liquid used in an SSC system or used to clean, test, dry or preserve test systems, subsystems, assemblies, components, IM&TE and support equipment.

Flushing Solvent - the solvent used to obtain the control sample and the test sample.

Gross Cleaning - the removal of gross contaminants.

Gross Contaminants - visible contaminants, such as moisture, corrosion, loose slag, oil, grease, scale, rust, soil, sludge and grit.

Hydrocarbon - any compound containing carbon and hydrogen bonds.

Inaccessible - unable to be viewed due to physical configuration.

Inspection – the verification method performed by visual observation under ambient or black light.

Inspection, Measuring and Test Equipment (IM&TE) - items used to perform measurements where distinct values are required for system performance or to demonstrate conformance to specified requirements.

Item - anything smaller than or contained within a system (e.g., assembly, component, IM&TE, piece part).

Method - a technique or process used to test, inspect or collect samples.

Micron – dimension of length equal to 0.001 millimeter (0.0000394 inch).

Moisture - the residual water (liquid/gas) in components or systems, measured in parts per million (ppm) or dewpoint.

Nonvolatile Residue (NVR) - the residue remaining after filtration and controlled evaporation of the final flushing solvent. NVR is specified in milligrams (mg) per square meter or square foot of significant surface. Since the predominant constituents of NVR are hydrocarbons, NVR and total hydrocarbon content are considered equivalent; therefore, analytical methods that determine total hydrocarbon (e.g., gravimetrics, FTIR and TOC) may be used to determine NVR.

Particle – a unit of matter with observable length, width, and thickness; usually measured in microns.

Particulate - multiple particles.

pH - a unit of measure on a scale of 0 to 14 that describes the acidity or alkalinity of a solution, (with 7 indicating neutrality, values below 7 indicating acidity level, and values above 7 indicating alkalinity level).

Precision Clean - a high level of cleanliness (i.e., cannot be verified with unaided eye) positively confirmed by a test for particle size/count and documented.

Sample - a selected portion or quantity of fluid collected to determine the cleanliness level of a system or component.

Significant Surfaces – those surfaces of components, piece parts, assemblies, subsystems, systems and ground support equipment that come in contact with test fluids or service fluids.

Silting - a background of particles below the size ranges counted and in such a quantity as to interfere with sample analysis.

Test - the process used to determine the cleanliness level of a system, component or packing material.

Test Sample - a specific volume of flushing solvent used for particulate and/or NVR analysis.

Ultraviolet (UV) Lamp – a lamp that produces "black light".

Verification - the process whereby one or more of the following methods is used for the purpose of certification: performing visual inspections, obtaining samples, analyzing/testing samples and reviewing inspection/test data.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

AMS	Aerospace Materials Specification
ASTM	American Society for Testing and Material
CFC-113	Trichlorotrifluoroethane (Freon)
DI	Deionized
FTIR	Fournier Transform Infrared
GOX	Gaseous Oxygen
IM&TE	Inspection Measuring and Test Equipment
JSC	Johnson Space Center
LOX	Liquid Oxygen
MIL	Military
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NVR	Nonvolatile Residue
PCTFE	Polychlorotrifluoroethylene
PTD	Propulsion Test Directorate
SAE	Society of Automotive Engineers
SCD	Specification Control Drawing
SPG	SSC Procedures and Guidelines
SSC	Stennis Space Center
SSLP	Stennis System Level Procedure
STD	Standard
SSTD	Stennis Standard
TOC	Total Organic Carbon
UV	Ultraviolet

APPENDIX A2

SSC-STD-79-002

SAMPLING REQUIREMENTS AND MAXIMUM ALLOWABLE IMPURITIES FOR SSC FLUIDS AND FLUID SYSTEMS

National Aeronautics and
Space Administration
John C. Stennis Space Center

SSC STD 79-002
Rev. H
26 April 2000

CONCURRENCE SHEET

SAMPLING REQUIREMENTS AND MAXIMUM ALLOWABLE IMPURITIES FOR SSC FLUIDS AND FLUID SYSTEMS

Richard J. Gilbrech	04/27/00	Samuel Dale McCarty	04/27/00
NASA PROPULSION TEST DIRECTORATE	DATE	NASA CENTER OPERATIONS DIRECTORATE	DATE
John L. Gasery, Jr.	04/27/00	Issued CEF	04/28/00
NASA S&MA	DATE	CENTRAL ENGINEERING FILES	DATE

CHANGE RECORD

REVISION	DATE	PAGE	DESCRIPTION
H	26 Apr 00	All	Complete rewrite including title change. Implements change for waiver NA49 (dated 4/10/92) re: LOX moisture analyses.

CONTENTS

TABLES

1.0 INTRODUCTION

1.1 PURPOSE

This SSC standard (STD) establishes the maximum allowable impurities and sampling criteria for the fluids (gases, liquids) used as propellants and pressurants to clean, test, dry, or preserve test systems, subsystems, assemblies, components, and support equipment at Stennis Space Center (SSC).

1.2 SCOPE

This STD applies to site-wide facility systems (including offsite procurements) associated with the following services.

- High Pressure (Missile Grade) Air (HPA)
- Helium (He)
- Hydrogen, Gas (GH_2) and Liquid (LH_2)
- Nitrogen, Gas (GN_2) and Liquid (LN_2)
- Oxygen, Gas (GOX) and Liquid (LOX)

1.3 RESPONSIBILITIES

1.3.1 SSC Activities

This standard shall be implemented by NASA and Contractor personnel responsible for engineering design, manufacture, fabrication, analysis, inspection, or test operations. NASA and the Contractor shall ensure compliance with the requirements of this standard through surveillance, auditing, and process verification. The SSC Propulsion Test Directorate (PTD) Test Engineering Division and the Center Operations and Support Directorate Facilities Engineering Division (FED) are responsible for the content of this SSC STD. Revision or cancellation of this STD shall be reviewed and approved as specified in SLP-05 and SSC STD 99-008.

1.3.2 Quality Control

NASA and/or Contractor QA are responsible for verifying the certification of systems. The scheduling and the frequency of sampling shall be as indicated in Section 5.0.

2.0 REFERENCED DOCUMENTS

The referenced documents form an integral part of this standard and the latest issues shall apply unless otherwise specified.

FED-STD 209	Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones
MIL-PRF-25508	Performance Specification, Propellant, Oxygen (Grade A)
MIL-PRF-27201	Performance Specification, Propellant, Hydrogen
MIL-PRF-27401	Performance Specification, Propellant Pressurizing Agent, Nitrogen (Grade B)
MIL-PRF-27407	Performance Specification, Propellant Pressurizing Agent, Helium (Grade A)
SLP-05	Document and Data Control
SLP-16	Control of Quality Records
SPG 8715.1	NASA/SSC Safety and Health Procedures and Guidelines
SSC STD 79-001	Surface Cleanliness Requirements for SSC Facility Fluid Systems
SSC STD 99-008	Guide for the Preparation, Approval and Release of SSC Standards

3.0 GENERAL REQUIREMENTS

3.1 SAFETY

All procedures in this standard shall be performed in accordance with applicable requirements in SPG 8715.1.

3.2 CONTROLLED ENVIRONMENTS

Areas where particulate samples are analyzed shall conform to requirements for controlled environment areas per FED-STD-209.

3.3 PROCEDURES

The performing unit shall work to approved procedures for performing all sampling and analyses. The NASA Monitor/Project Engineer and the NASA Quality Assurance Representative responsible for system integrity shall approve these procedures prior to work.

3.4 PERSONNEL INSTRUCTION

Personnel involved in obtaining and analyzing test samples shall be trained and/or certified and shall wear proper personal protective equipment (PPE). Precautions must be taken to prevent introduction of contaminants into test samples.

3.5 SAMPLING

Samples shall be taken at the gas user interface point downstream of filters, regulators, valves, and any other equipment normally installed in a line. If maintenance is performed without contamination control (79-001), or when contamination is suspected, then additional samples shall be taken at the next downstream user interface point. Unless otherwise specified, gas sample volume shall be a minimum of 0.850 standard cubic meter.

3.6 CERTIFICATION RECORDS

Logs or databases shall be used to document all sampling at each use point in order to monitor trends and/or failures. The data from these logs or databases will be maintained by the performing organization and may be used to determine if the sampling frequency as required by Section 5.1.2 needs to be modified.

3.7 REPORTS

All data gathered as a result of this standard shall be documented by the performing organization as designated by NASA QA, and shall include pertinent information recorded in logs or databases per section 3.6.

3.8 ANALYSIS EQUIPMENT

The equipment used to perform the analyses specified herein shall be approved for contamination testing by the performing organization as designated by NASA QA.

CAUTION

Prior to use, hand tools, materials, and equipment that may come into contact with significant surfaces or the service media shall be certified cleaned to the required system or component clean level in accordance with SSC STD 79-001.

4.0 MAXIMUM ALLOWABLE IMPURITIES

Requirements for maximum allowable impurities in the SSC Facility Transfer Systems at the receiving and user interface points are specified in Table 1. (Note that service fluid purity levels differ from system and component clean levels specified by SSC STD 79-001.)

NOTE

The impurities in all fluid samples shall be analyzed in the gaseous state.

TABLE 1. PROPELLANTS AND PRESSURANTS MAXIMUM ALLOWABLE IMPURITIES

PROPELLANT/PRESSURANT	REQUIREMENTS*	
PARAMETER	RECEIVING	USER INTERFACE POINTS
HELIUM, GAS (He)	Ref MIL-PRF-27407 (Grade A)	
Purity	99.995% He (min.)	99.994% He (min.)
Total Impurities	50	N/A
Specific Impurities	N/A	60
H_2	1	N/A
N_2 and Argon (receiving only)	14	36
O_2 and Argon (UIP only)	3	10
H_2O	9 (-61.1°C Dew Point)	9 (-61.1°C Dew Point)
Hydrocarbon**	5	5
Neon	23	N/A
CO	1	N/A
CO_2	1	N/A
Particulate (gas)	N/A	30µ-100µ: 25; >100µ: 0
Particulate (liquid)	N/A	N/A

TABLE 1. (Continued)

PROPELLANT/PRESSURANT	REQUIREMENTS*	
PARAMETER	RECEIVING	USER INTERFACE POINTS
HYDROGEN, GAS OR LIQUID (H_2) Ref MIL-PRF-27201		
Purity	99.995% H_2 (min.)	99.993% H_2 (min.)
Total Impurities	50	N/A
Specific Impurities	N/A	70
Selected Impurities:		
Parahydrogen	95.0% (liquid H_2 only)	N/A
N_2, H_2O, Hydrocarbon**	9 (-61.1°C Dew Point)	20 (9 for H_2O) (-61.1°C Dew Point)
O_2 and Argon	1	5
He	39	45
CO_2 plus CO	1	N/A
Particulate (gas)	N/A	N/A
Particulate (liquid)	N/A	N/A
NITROGEN, GAS OR LIQUID (N_2) Ref MIL-PRF-27401 (Grade B)		
Purity	99.99% N_2 (min.)	99.989% N_2 (min.)
Total Impurities	100	N/A
Specific Impurities	N/A	111
Selected Impurities: O_2	50	100
Hydrocarbon**	5	5
H_2O	6*** (-64.0°C Dew Point)	6.0***(-64.0°C Dew Point)
Particulate (gas)	N/A	30µ-100µ: 25; >100µ: 0
Particulate (liquid)	1 mg/liter	N/A
OXYGEN, GAS (GOX) OR LIQUID (LOX) Ref MIL-PRF-25508 (Grade A)		
Purity	99.6% O_2 (min.)	99.6% O_2 (min.)
Total Impurities	4000	N/A
H_2O	3 (-69.0°C Dew Point)	20 (-55.2°C Dew Point)
Hydrocarbon**	50	50
(C_2H_2) Acetylene	0.25 ppm by weight	N/A
Particulate (gas)	N/A	30µ-100µ: 25; >100µ: 0
Particulate (liquid)	1 mg/liter	N/A
HIGH PRESSURE AIR (HPA)		
Purity	N/A	18% O_2 (min.)
H_2O	N/A	24 (-53.9°C Dew Point)
Hydrocarbon**	N/A	15
Particulate (gas)	N/A	30µ-100µ: 25; >100µ: 0
Particulate (liquid)	N/A	N/A

*Unless otherwise specified, requirement levels are total ppm by volume.
**Total hydrocarbons expressed as Methane (CH_4).
***The maximum H_2O content is 6 ppm verified from the delivery manifest. This is less than the 11.5 ppm allowed in MIL-PRF-27401; however, historical data documents receipt of product within the lower limit.

5.0 FLUID SUPPLY SYSTEM CLEANLINESS REQUIREMENTS

NOTE

Taking gas and/or liquid samples certifies systems, but the impurities in all fluid samples are analyzed in a gaseous state.

5.1 CERTIFICATION OF FLUID SYSTEMS

Certification of a fluid system shall require testing of the sample fluid as described in sections 5.1.1, 5.1.2 and 5.1.3.

5.1.1 Initial Certification

For certification of a new system, except cylinder supplied gas as defined in 5.1.3, the following requirements must be satisfied.

a. Two consecutive samples at each user interface point in the system, taken 8 to 72 hours apart, shall comply with the user interface point requirements in Table 1.

b. Two additional samples taken consecutively at 5-to-10-day intervals from each user interface point shall comply with the hydrocarbon, moisture and particulate user interface point requirements in Table 1.

5.1.2 Periodic Certification

After initial certification of a fluid system, periodic certifications are required as follows.

NOTE

When contamination is suspected, tests shall be performed to verify the impurity levels of the fluid. If these tests indicate that contamination levels exceed the requirements of 5.1.2-a or -b, then necessary corrective action shall be taken to clean and purge the system. If three consecutive samples fail, the system shall be certified as specified in 5.1.1.

a. A supply fluid sample taken at the storage vessel, at 6-month intervals, shall comply with the user interface point requirements in Table 1.

b. A sample taken at each user interface point at 3-month intervals shall comply with the hydrocarbon, moisture and particulate user interface point requirements in Table 1.

5.1.3 Cylinder Supplied Gas Certification

A gas system may consist of a cylinder, or a bank of cylinders, equipped with one or more user interface points.

a. Initial certification shall require a sample obtained from the user interface point downstream from the cylinder gas system. This sample must meet the contamination level user interface point requirements specified in Table 1. The certification sample shall be taken with all bottle valves in the open position.

b. Periodic certification is not required; however, following cylinder replacement or maintenance the provisions of Section 5.2 shall apply.

5.1.4 Intermittent Certification of Usage Points

User interface points shall be initially certified in accordance with 5.1.1, and periodically certified in accordance with 5.1.2. If an initially certified user interface point has not subsequently been periodically certified, then (a) a sample shall comply with the user interface requirements in Table 1; and (b) a second sample, taken 8 to 72 hours later, shall comply with the hydrocarbon, particulate and moisture user interface point requirements in Table 1.

5.1.5 Testing, Drying and Preservation

Gases used in the testing, drying and preservation of components, assemblies and support/test equipment shall meet the hydrocarbon, moisture and particulate user interface point requirements specified in Table 1. When used for testing, drying and preservation, gas user interface points that are used daily shall be tested weekly; if used intermittently, they shall be verified at the time of use.

5.2 RECERTIFICATION OF SYSTEMS

5.2.1 Required

A fluid system requires recertification when any part has been disassembled, recleaned, or modified. Recertification requires the following.

a. If a positive pressure flow is not maintained, then a sample shall be obtained from the next downstream user interface point and tested to verify that all parameters comply with the user interface point requirements in Table 1. If this test fails, then necessary corrective action shall be taken to clean and purge the system. If three consecutive samples fail, the system shall be certified as specified in 5.1.1.

b. If a positive flow is maintained, the media shall be tested to verify that hydrocarbon, moisture and particulate meet the user interface point requirements in Table 1. If this test fails, then necessary corrective action shall be taken to clean and purge the system. If three consecutive samples fail, the system shall be certified as specified in 5.1.1.

5.2.2 Not Required

Recertification of a system is not required if all of the following are verified.

a. A positive purge is maintained on the system when the system is disassembled.

b. The system is disassembled for removal of a component or instrument for recertification or recalibration.

c. The instrument or component is installed in an open loop configuration.

6.0 RECORDS AND FORMS

Records and forms identified in this standard shall be maintained in accordance with SLP-16. For Quality Records refer to the SSC Master Records Index. All forms are assumed to be the latest edition unless otherwise specified and may be obtained from the SSC Electronic Forms repository or from the NASA SSC Forms Management Officer.

APPENDIX A

ACRONYMS AND ABBREVIATIONS

C_2H_2	Acetylene
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FED	Federal
H_2	Hydrogen
H_2O	Water
He	Helium
LH	Liquid Hydrogen
LN	Liquid Nitrogen
LOX	Liquid Oxygen
IPA	Isopropyl Alcohol
MIL	Military
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NVR	Nonvolatile Residue
O_2	Oxygen
PRF	Performance (spec)
PPE	Personal Protective Equipment
ppm	Parts per million (p/m)
QA	Quality Assurance
SLP	System Level Procedure
Spec	Specification
SPG	SSC Procedures and Guidelines
SSC	Stennis Space Center
STD	Standard
UIP	User Interface Point

APPENDIX B

DEFINITIONS

Certification - The attesting (in writing) that requirements are verified as having been met.

Dew Point - The temperature at which a gas becomes saturated with water vapor and condensation begins (usually atmospheric pressure.)

Fluid - Any gas or liquid used to clean, test, dry, or preserve test systems, subsystems, assemblies, components, and support equipment.

Hydrocarbon - Any compound containing carbon and hydrogen bonds.

Interface Point - A specific location where systems intersect.

Micron - Dimension of length equal to 0.001 millimeter (0.0000394 inch).

Moisture - The residual liquid/gas resulting from cleaned components or systems, measured in parts-per-million (PPM).

Nonvolatile Residue (NVR) - The residue remaining after filtration and controlled evaporation of the final flushing solvent. NVR is specified in milligrams (mg) per square meter or square foot of significant surface. The predominant constituents of NVR are hydrocarbons.

Particulate - Fibers or units of matter with observable length, width, and thickness, usually measured in microns.

Significant Surfaces - Those surfaces of components, piece-parts, assemblies, subsystems, systems, and ground support equipment that come in contact with test solvents.

Standard Cubic Meter - Volume of one cubic meter of gas at one atmosphere of pressure (i.e., 760 mm of mercury) at 70°F (21.1°C).

APPENDIX B (continued)

DEFINITIONS

Testing - The process of acquiring and analyzing samples to determine the impurities and purity levels.

User Interface Point - Any specific service port where commodities are extracted from the system. In some cases, the user interface point may be the specific port where commodities are injected into the system.

Verification - The process whereby one or more of the following methods is used for the purpose of certification: performing visual inspection, obtaining samples, analyzing/testing samples and reviewing inspection/test data.

APPENDIX A3

NASA STD-5008A

PROTECTIVE COATING OF CARBON STEEL, STAINLESS STEEL, AND ALUMINUM ON LAUNCH STRUCTURES, FACILITIES AND GROUND SUPPORT SYSTEMS

National Aeronautics and
Space Administration

METRIC/
INCH-POUND

NASA-STD-5008A
January 21, 2004

PROTECTIVE COATING OF CARBON STEEL, STAINLESS STEEL, AND ALUMINUM ON LAUNCH STRUCTURES, FACILITIES, AND GROUND SUPPORT EQUIPMENT

NASA TECHNICAL STANDARD

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DOCUMENT HISTORY LOG, NASA-STD-5008A

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		07/10/2001	Baseline Release
Revision	A	01/21/2004	Foreword: changed signature of W. Brian Keegan to Theron M. Bradley. Updated Table of Contents and KSC FORM 21-61ONS, Standardization Document Improvement Proposal. General editorial/punctuation changes/corrections throughout document: put brackets inside parentheses and deleted “etc.” following “e.g.” Used non, free and proof as combining forms. Put a hyphen between Sherwin Williams. Changed Ameron International, P.C.G. to P.C.F.G. and web site to www.ameron.com. Changed Materials Science Division (LO-G) to Spaceport Technology Development Office (YA-C2). Added paragraph 1.6, Environmental stewardship. Paragraph 2.2: Changed MIL-C-24667A to MIL-PRF-24667A. Deleted MIL-T-81772. Paragraph 2.3: Changed title of ASTM A653 to Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvanneeled) by the Hot-Dip Process and changed the ASTM address to 100 Barr Harbor Drive, West Conshohocken, PA 19482-2959. Changed the title of RP0188-88 to Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates. Changed the title of SSPC SP 5-94, Joint Surface Preparation Standard, to SSPC-SP 5-94/NACE No. 1, White Metal Blast Cleaning. Changed SSPC SP 10-94, Joint Surface Preparation Standard Near-White Blast Cleaning, to SSPC-SP 10-00/NACE No. 2, Near-White Blast Cleaning. Paragraph 3: Deleted AISC, American Institute of Steel Construction; cfm, cubic feet per minute; GFE, Government-furnished equipment; and KHB, Kennedy handbook. Changed LO-G to YA-C2-T. Added ASME, American Society of Mechanical Engineers; CFR, Code of Federal Regulations; HAP, hazardous air pollutant; PDCA, Painting and Decorating Contractors of America; and YA-F, Labs and Testbed Division. Changed mega Pascal to megapascal. Paragraph 4.1.2.4.e.2: Changed 235 to 239. Put parentheses around number listing. Paragraph 4.1.4: Changed Materials and Chemical Analysis Laboratory to Spaceport Technology Development Office. Paragraph 4.3.1: Added “and NASA policies” to the end of the last sentence. 4.4.1: Rewrote the first sentence. Added a sentence after the first sentence. 4.4.3.3 Added /environmental to safety/fire in the last sentence.

DOCUMENT HISTORY LOG, NASA-STD-5008A (cont)

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
			4.5.1: Added "An inorganic zinc coating used in a friction-type joint must be approved by the American Institute of Steel Construction (AISC)," after the fifth sentence. Paragraph 5.7.5, end of the third sentence: Added "while considering the accuracy of the measurement instrument." Appendix A, Section I: Changed zip code for Ameron International, P.C.F.G to 92821. Appendix A, Section II: Added Dimetcote D-9HS SB; SB to Cathacoat 304V; Cathacoat 304H SB; and ZincClad IIHS SB to Coating Designations and Type. Added InterZinc 22HS, SB, International Paint, 6001 Antoine Drive, Houston,TX 77091, (713) 682-1711, www.international-pc.com. Appendix B, Section II: Added (SB) to Primer (Type) D-21-9. Added D-9HS (SB) to Primer (Type) and PSX700(SB) to Topcoat (Type). Appendix B, Section III: Added D-9HS (SB) and ZincClad IIHS (SB) to Primer (Type). Added InterZinc 22HS (SB), 181 (SB) (IOT), International Paint, 6001 Antoine Drive, Houston, TX 77091, (713) 682-1711, www.international-pc.com. Changed Topcoat (Type) 7551 P1 (SB) (IOT) to 5555.

FOREWORD

This standard is approved for use by NASA Headquarters and all NASA Centers and is intended to provide a common framework for consistent practices across NASA programs.

This standard was developed to establish uniform engineering practices and methods and to ensure the inclusion of essential criteria in the coating of ground support equipment (GSE) and facilities used by or for NASA. This standard is applicable to GSE and facilities that support space vehicle or payload programs or projects and to critical facilities at all NASA locations worldwide. The John F. Kennedy Space Center Spaceport Engineering and Technology Directorate developed this standard.

This standard establishes practices for the protective coating of GSE and related facilities used by or for NASA programs and projects. This standard is for the design of nonflight hardware used to support the operations of receiving, transportation, handling, assembly, inspection, test, checkout, service, and launch of space vehicles and payloads at NASA launch, landing, or retrieval sites. These criteria and practices may be used for items used at the manufacturing, development, and test sites upstream of the launch, landing, or retrieval sites.

The information provided herein shall be used for the preparation of written, individual coating specifications for specific projects for the prevention of corrosion through the use of protective coatings on facilities, space vehicle launch structures, and ground support equipment in all environments. Due to the changing environmental considerations, new advances in corrosion control technology, and the wide array of possible applications, this document should not be used as a stand-alone specification that meets every contingency.

Requests for information, corrections, or additions to this standard should be directed to the Spaceport Engineering and Technology Directorate, Mail Code YA, Kennedy Space Center, Florida 32899, using the form attached to the back of this standard. Requests for general information concerning standards should be sent to the NASA Technical Standards Program Office, ED41, MSFC, AL 35812 (telephone 205-544-2448). This and other NASA standards may be viewed and downloaded, free of charge from our NASA Standards Home Page: http://standards.nasa.gov.

Original signed by:

Theron M. Bradley
Chief Engineer

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APPENDICES

PROTECTIVE COATING OF CARBON STEEL, STAINLESS STEEL, AND ALUMINUM ON LAUNCH STRUCTURES, FACILITIES, AND GROUND SUPPORT EQUIPMENT

1. SCOPE

1.1 Scope. This document establishes requirements for the application of protective coatings to prevent corrosion of exposed carbon steel, stainless steel, and aluminum.

1.2 Purpose. This document provides a design standard for experienced corrosion control engineers for the development of specifications including requirements for materials, equipment, safety, procedures, and quality assurance inspections. Due to the ever changing environmental considerations, new advances in corrosion technology and the wide array of possible applications, this document shall not be used as a stand-alone standard that meets every contingency. Refer to 7.1 for the intended use and surfaces to be coated according to this standard. Refer to Appendices A, B, and C for approved coating materials.

1.3 Applicability. This standard is applicable to facilities, launch structures, ground support equipment (GSE), test facilities, and structures that are intended for use at all NASA locations worldwide.

1.4 Zones of exposure. The following zones of exposure are established to define coating system requirements for surfaces located in specific environments:

a. Zone 1. Surfaces that receive rocket engine exhaust impingement.

b. Zone 2. Surfaces that receive elevated temperatures (above 65 degrees Celsius [above 150 degrees Fahrenheit]) and/or acid deposition from solid rocket booster exhaust with no exhaust impingement.

c. Zone 3a. Surfaces, other than those located in Zones 1 or 2, that receive acid deposition from solid rocket booster exhaust products.

Zone 3b. Surfaces that receive other types of chemical contamination (e.g., cooling towers, diesel exhaust stacks, acidic industrial environments, and water treatment facilities).

d. Zone 4a. Surfaces not located in the launch environment but located in a neutral pH corrosive marine industrial, or other chloride-containing environments.

Zone 4b. Surfaces located in neutral pH exterior environments in any geographical area.

Zone 4c. Surfaces located in indoor nonair-conditioned environments.

e. Zone 5. Continuous indoor air-conditioned environment such as offices or clean rooms. These areas shall have both temperature and humidity controlled more than 90 percent of the time.

f. Zone 6. Underground, intermittent, or continuous immersion in aqueous environments.

g. Zone 7. Surfaces under thermal insulation, such as chilled water, steam, and heated gas lines.

1.5 Method of specifying coating requirements. Specifications referencing this standard shall include the type of surface to be coated, the zone of exposure, surface preparation, defined paint system, coating thicknesses and, when applicable, the finish color required. These requirements should be assembled in a coating schedule for easy reference. The coating specification shall contain the following key elements: scope, applicable documents, submittals, environmental protection, waste management, safety/personnel protection, materials, tools and equipment, environmental conditions, work schedule, surface preparation (including a listing of abrasive-sensitive hardware to be prepared or protected), coating schedule, coating mixing and application, quality control inspection, reporting, and final acceptance. See Appendix D for a recommended outline and coating schedule of a coating specification.

1.6 Environmental stewardship. Environmental, health, and safety impacts of processes and materials should be taken into account when employing protective coating methods and techniques. Alternative, environmentally friendly materials, which do not contain hexavalent chromium, lead, cadmium, or hazardous air pollutants (HAPs), such as methyl ethyl ketone, toluene, and xylene, should be considered when determining the appropriate coating method/technique for each protective coating application. Coatings containing these hazardous materials are involved in a variety of air, water, and soil pollution concerns. Exposure to these materials also has health impacts that include eye and respiratory irritation, headache, dizziness, memory impairment, neurotoxicity and cancer.

2. APPLICABLE DOCUMENTS

2.1 General. The applicable documents cited in this standard are listed in this section for reference only. The specified technical requirements listed in the body of this document must be met whether or not the source document is listed in this section.

2.2 Government documents. The following Government documents form a part of this document to the extent specified herein. Unless otherwise specified, the issuances in effect on date of invitation for bids or requests for proposals shall apply.

CODE OF FEDERAL REGULATIONS (CFR)

29 CFR 1910	Occupational Safety and Health Administration (Occupational Safety and Health Standards)
29 CFR 1926	Occupational Safety and Health Administration (Safety and Health Regulations for Construction)

(Copies of the above documents are available from the Superintendent of Documents, U.S. Government Printing Office, North Capitol & H Streets, Washington, DC 20401.)

DEPARTMENT OF DEFENSE (DOD)

MIL-A-22262	Abrasive Blasting Media Ship Hull Blast Cleaning
MIL-P-85891	Plastic Media, for Removal of Organic Coatings

MIL-PRF-24667A	Coating System, Nonskid, for Roll or Spray Application (Metric)

FEDERAL

FED-STD-595	Colors Used in Government Procurement

MILITARY

T.O. 1-1-691	Aircraft Weapons Systems Cleaning and Corrosion Control

(Copies of the above documents are available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

KSC-STD-SF-0004	John F. Kennedy Space Center (KSC) – Safety Standard for Ground Piping Systems Color Coding and Identification
KSC-TM-584	John F. Kennedy Space Center (KSC) – Corrosion Control and Treatment Manual

(Unless otherwise indicated, copies of the above documents are available from any NASA Installation library or documentation repository.)

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issuances in effect on the date of invitation for bids or request for proposals shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A123	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A653	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvanneeled) by the Hot-Dip Process
ASTM A780	Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

ASTM C920	Standard Specification for Elastomeric Joint Sealants
ASTM D520	Standard Specification for Zinc Dust Pigment
ASTM D610	Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces
ASTM D714	Standard Test Method for Evaluating Degree of Blistering of Paints
ASTM D1654	Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
ASTM D4228	Standard Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces
ASTM D4752	Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub

(Copies of the above documents are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19482-2959.)

COMPRESSED GAS ASSOCIATION, INC.

G7.1	Commodity Specification for Air, Fourth Edition

(Copies of the above document are available from the Compressed Gas Association, Inc., Crystal Gateway 1, Suite 501, 1235 Jefferson Davis Highway, Arlington, VA 22202).

NATIONAL ASSOCIATION OF CORROSION ENGINEERS (NACE)

RP0188-88	Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
RP0288-88	Inspection of Linings on Steel and Concrete
TM 01-70	Visual Standard for Surfaces of New Steel Airblast Cleaned with Sand Abrasive
TM 01-75	Visual Standard for Surfaces of New Steel Centrifugally Blast Cleaned With Steel Grit and Shot

NACE Publication No. 6H189	A State-of-the-Art Report of Protective Coatings for Carbon Steel and Austenitic Stainless Steel Surfaces Under Thermal Insulation and Cementitious Fireproofing

(Copies of the above documents are available from the National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218-8340.)

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC-AB 1-91	Mineral and Slag Abrasives
SSPC-PA 2-96	Measurement of Dry Coating Thickness With Magnetic Gages
SSPC-SP 1-82	Solvent Cleaning
SSPC-SP 2-95	Hand Tool Cleaning
SSPC-SP 3-95	Power Tool Cleaning
SSPC-SP 5-94/NACE No. 1	White Metal Blast Cleaning
SSPC-SP 10-00/NACE No. 2	Near-White Blast Cleaning
SSPC-SP 11-95	Power Tool Cleaning to Bare Metal
SSPC-VIS 1-89	Visual Standard for Abrasive Blast Cleaning Steel
SSPC-VIS 3-95	Visual Standard for Power- and Hand-Tool Cleaned Steel

(Copies of the above documents are available from the Society for Protective Coatings, 4400 Fifth Avenue, Pittsburgh, PA 15213.)

2.4 Order of precedence. Where this document is adopted or imposed by contract on a program or project, the technical requirements of this document take precedence, in the case of conflict, over the technical requirements cited in other referenced documents. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. ABBREVIATIONS AND ACRONYMS USED IN THIS STANDARD

AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
CIP	Coating Inspector Program
DFT	dry film thickness
DOD	Department of Defense

EPA	Environmental Protection Agency
FED	Federal
GSE	ground support equipment
HAP	hazardous air pollutant
IOT	Inorganic topcoat
kPa	kilopascal
KSC	John F. Kennedy Space Center
ksi	kip per square inch
MPa	megapascal
NACE	National Association of Corrosion Engineers
NASA	National Aeronautics and Space Administration
NIOSH	National Institute of Occupational Safety and Health
no.	number
NSF	National Sanitation Foundation
OSHA	Occupational Safety and Health Act
PDCA	Painting and Decorating Contractors of America
PPE	personal protective equipment
psi	pound per square inch
RH	relative humidity
SB	solvent based
SRB	solid rocket booster
SSPC	Society for Protective Coatings
STD	standard
TCLP	Toxicity Characteristic Leaching Procedure
T.O.	technical order
VOC	Volatile Organic Content
WB	water based
YA-C2-T	Materials Sciences Laboratory
YA-F	Labs and Testbed Division

4. REQUIREMENTS

4.1 Materials.

4.1.1 Abrasive blasting aggregate. Blasting aggregates shall be approved materials in accordance with MIL-A-22262 or SSPC-AB1, Type I or II, Class A, or steel grit. Only materials approved in the QPL attached to MIL-A-22262 shall be used. The abrasive grade selected must produce the required surface profile and possess physical properties that are compatible with the requirements of this standard. The steel grit shall be neutral (6.0 to 8.0 pH), rust and oil free, dry, commercial-grade blasting grit with a hardness of 40 to 50 Rockwell C. The size shall be selected to produce the required anchor profile. For paint removal or cleaning of aluminum, stainless steel, and fiberglass, plastic media in accordance with MIL-P-85891 may be used as an alternate.

NOTE: Only aggregates that are free of crystalline silica shall be selected for use at NASA. Exemptions to this policy shall be coordinated with local Occupational Health Office.

NOTE: Blasting aggregate for abrasion-sensitive hardware (such as bellows, gimbal joints, and other thin-walled components) shall be materials that produce no

additional surface profile. Blasting operations shall not produce holes, cause distortion, remove metal, or cause thinning of the substrate.

4.1.2 Protective coatings, thinners, and cleaners. The following paragraphs establish minimum requirements for each generic type of protective coating specified in this document. See 4.4.3.1 for coating intercoat compatibility requirements. All coatings must possess physical properties and handling characteristics that are compatible with the application requirements of this standard, and all coatings must be self-curing. Thinners and cleaners for each coating, except those specified in 4.1.2.6, shall be procured from the manufacturer of the coating.

Procurement awards for coatings to be supplied according to this standard shall be made only for those products that have been tested, evaluated, and approved by the Spaceport Technology Development Office (YA-C2), KSC. The attention of suppliers is called to this requirement, and manufacturers are urged to arrange for testing of their product so that they may be eligible for award of contracts or orders for coatings to be supplied in accordance with this standard. To arrange for the product testing and testing criteria, manufacturers must contact YA-F, NASA, John F. Kennedy Space Center, FL 32899.

4.1.2.1 Inorganic zinc coatings. Inorganic zinc coatings that have been approved are listed in Appendix A. A coating must meet the following minimum requirements to be listed:

a. Self-curing, two package

b. Dry-temperature resistance to 400 degrees Celsius (750 degrees Fahrenheit) for 24 hours

c. Minimum shelf life of 12 months

d. Minimum of 83 percent zinc by weight in the applied dry film

e. Asbestos free, lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating)

f. Zinc dust pigment shall be Type II in accordance with ASTM D520

g. Attain a numerical rating of not less than 9 in accordance with ASTM D610 and ASTM D1654 and 9F in accordance with ASTM D714 when applied to composite test panels and exposed at the KSC beach corrosion test site. The coatings will be evaluated for initial acceptance following an exposure period of 18 months. The coatings must continue to provide acceptable protection and performance for a period of 5 years. Application characteristics must be judged acceptable prior to beach testing.

4.1.2.2 Primer and/or intermediate coatings. These coatings are listed in Appendix B.

4.1.2.2.1 Inhibitive polyamide epoxy coatings. Polyamide epoxy coatings shall conform to the following minimum requirements:

a. Polyamide-cured

b. Rust-inhibitive

c. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating)

d. Suitable as a primer for carbon steel, galvanized steel, and aluminum

e. Suitable as an intermediate coat between an inorganic zinc primer and an aliphatic polyurethane finish coat

f. Meet the compatibility requirements of 4.4.3.1

g. Minimum 40 percent volume solids

4.1.2.2.2 Noninhibitive polyamide epoxy coatings. Polyamide epoxy coatings shall conform to the following minimum requirements:

a. Polyamide-cured

b. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating)

c. Suitable as an intermediate coat between inorganic zinc primer and an aliphatic polyurethane finish coat

d. Meet the compatibility requirements of 4.4.3.1

e. Minimum 40 percent volume solids

f. Not to be used as a primer on steel

4.1.2.2.3 Water-reducible intermediate coatings. Water-reducible intermediate coatings shall conform to the following minimum requirements:

a. Self-curing, one or two package, water reducible

b. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating).

c. Suitable as an intermediate coat between inorganic zinc primers and water-reducible topcoats

d. Meet the compatibility requirements of 4.4.3.1

e. Minimum 30 percent volume solids

f. Not to be used as a primer on steel

4.1.2.3 Finish coatings.

4.1.2.3.1 Aliphatic polyurethane coatings. Aliphatic polyurethane coatings shall conform to the following minimum requirements:

a. Catalyst isocyanate cured

b. High-gloss finish (minimum 85 percent gloss at 60-degree angle)

c. Gloss and color retentive upon prolonged exterior exposure

d. Suitable as an exterior finish coat over an inorganic zinc primer with a polyamide epoxy intermediate coat

e. Meet the compatibility requirements of 4.4.3.1

f. Minimum 44 percent volume solids

g. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating).

4.1.2.3.2 Water-reducible topcoats. Water-reducible topcoats shall conform to the following minimum requirements:

a. Self-curing, one or two package, water reducible

b. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating).

c. Gloss and color retentive upon prolonged exterior exposure

d. Semi-gloss or high-gloss finish (semi-gloss 60 to 85 percent at 60-degree angle, high gloss minimum 85 percent at 60-degree angle)

e. Meet the compatibility requirements of 4.4.3.1

4.1.2.3.3 Inorganic topcoats. Inorganic topcoats shall conform to the following minimum requirements:

a. Dry-temperature resistance to 400 degrees Celsius (750 degrees Fahrenheit for 24 hours)

b. Suitable as a topcoat for inorganic zinc and galvanized steel in high-temperature environments

c. See Appendix B for approved coating systems

d. Lead-free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating

e. Attain a numerical rating of not less than 9 in accordance with ASTM D610 and ASTM D1654 and 9F in accordance with ASTM D714 when applied to composite test panels and exposed at the KSC beach corrosion test site. The coatings will be evaluated for initial acceptance following an exposure period of 18 months. The coatings must continue to provide acceptable protection and performance for a period of 5 years. Application characteristics must be judged acceptable prior to beach testing.

4.1.2.3.4 Polysiloxane topcoats. Polysiloxane topcoats shall conform to the following minimum requirements.

a. Suitable as a finish coat for exterior exposure

b. High-gloss finish (minimum 85 percent gloss at 65-degree angle)

c. Gloss and color retentive on prolonged outdoor exposure

d. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating)

e. Ameron PSX700 or equal

f. Attain a numerical rating of not less than 9 in accordance with ASTM D610 and ASTM D1654 and 9F in accordance with ASTM D714 when applied to composite test panels and exposed at the KSC beach corrosion test site. The coatings will be evaluated for initial acceptance following an exposure period of 18 months. The coatings must continue to provide acceptable protection and performance for a period of 5 years. Application characteristics must be judged acceptable prior to beach testing.

4.1.2.4 Epoxy mastic coatings. Epoxy mastic coatings shall conform to the following minimum requirements:

a. Specifically intended for use over mechanically-cleaned steel

b. Minimum 80 percent volume solids

c. Two-component, catalyst cured, aluminum pigmented

d. Lead free, cadmium free, and chromate free (less than 0.01 percent by weight of mixed coating).

e. Examples of epoxy mastic coating that currently meet these requirements include:

(1) Ameron Amerlock 400 AL
(2) Devoe Bar Rust 239
(3) Dupont 25P
(4) PPG DTR
(5) Sherwin-Williams B58
(6) Sigma 7476

4.1.2.5 Coal tar epoxy. Coal tar epoxy coating shall be a two-component, high-build tar epoxy. The coal tar epoxy shall have minimum volume solids of 65 percent and shall produce a one coat thickness of 585 to 710 micrometers (23 to 28 mils) wet coat or 405 to 510 micrometers (16 to 20 mils) per coat dry film thickness (DFT). Examples of coal tar epoxies that currently meet these requirements include the following:

a. Sherwin-Williams Hi-Mil Sher-Tar

b. Made Well 1103

c. Devoe Devtar 247

4.1.2.6 Potable water epoxy. All coatings for potable water immersion service shall be three-coat epoxy systems that are certified by the National Sanitation Foundation (NSF), Standard 61. Some NSF approved products include:

a. Ameron, Inc., Amercoat 395

b. Devoe Coatings Co., Bar Rust 233

c. Sherwin-Williams Co., Potable Water Epoxy

4.1.2.7 Nonskid coating. Approved nonskid coatings shall meet MIL-PRF-24667, Type 1, Composition G, as supplied by American Safety Technologies, Inc., 565 Eagle Rock Avenue, Roseland, NJ 07068, telephone (800) 631-7841, or approved equal (Primer MS-7C, Topcoat MS 400G, Color Topping MS-200).

4.1.3 Sealants/caulking. Sealants shall be self-curing, single-component, polysulfide rubber or polyurethane material only, conforming to ASTM C920, Type S, Grade NS, Class 25, use NT, A, and O. If not top coated, the caulking shall match the color of the joint surface being caulked. If caulking is to be used in a clean-room environment, an approved low off-gassing material shall be selected.

4.1.4 Chip-free clean-room paint. Paint systems for metal substrates in clean-rooms shall pass adhesion, off-gassing, flammability, and hypergolic compatibility testing at the NASA Spaceport Technology Development Office, Kennedy Space Center, Florida. Approved systems are listed in Appendix C.

4.2 Equipment.

4.2.1 Compressed air. The compressed air system shall be capable of delivering a continuous nozzle pressure to achieve the required surface cleanliness and profile, typically 620 kilopascals (kPa) [90 pounds per square inch (psi)] minimum to each blast nozzle in operation. The required air capacity will depend upon the configuration of the abrasive system used. The air system should comply with the instructions and recommendations of the manufacturer of the abrasive blasting system. The compressed air system shall be equipped with oil and moisture separators to ensure only clean, dry air is provided to the service outlet.

4.2.2 Abrasive blasting system. The abrasive blasting system shall comply with Occupational Safety and Health Act (OSHA), American National Standards Institute (ANSI), and National Institute of Occupational Safety and Health (NIOSH) configurations consisting of, but not limited to, a remote-controlled welded pressure pot conforming to American Society of Mechanical Engineers (ASME) Standards, the required length of blast hose, a venturi nozzle, a respiratory air-line filter, and a blast hood approved by the Mine Safety and Health Administration/NIOSH with the required length of air hose. The blasting system shall be designed to produce the specified cleanliness and profile when coupled with the available compressed air supply.

4.2.3 Coating application system. The coating application equipment shall be an airless spray system, conventional spray system, or other approved equipment in accordance with the coating manufacturer's recommendations and 4.4.3.6.

4.2.4 Breathing air. Compressed breathing air supplied to respiratory protection devices shall meet the requirements of the specification for Grade D breathing air as described in Compressed Gas Association, Inc., specification G7. Compressors for breathing air shall be constructed and located so as to avoid entry of contaminated air into the air supply system. Oil-lubricated compressors shall be equipped with a suitable in-line air filtration system that includes a carbon monoxide sensor and alarm and air-purifying sorbent beds and filters that remove water, dust particles, odors, oil, and other hydrocarbons. Oil-free breathing air compressors do not require carbon monoxide monitoring or air filtration systems. Occupational Health will be notified of all compressors brought on the job site for breathing air supply to coordinate breathing air system inspection. Breathing air couplings shall not be compatible with outlets for nonrespirable shop air or other gas systems to prevent inadvertent servicing of air-line respirators with nonrespirable gases or oxygen. The maximum air-line length for any approved supplied air respirator shall not exceed 100 meters (330 feet) measured from the pressure reducing valve. Air lines shall be protected from damage, including cutting, kinking, crushing, or burning. Notification will include written certification that the breathing air supplied by the compressors has been tested and the air meets the specification for grade D breathing air.

4.3 Safety requirements. Necessary precautions, in accordance with OSHA regulations and manufacturers' recommendations, shall be taken to ensure the safety of personnel performing the work required by this document and personnel who may be affected by such work. Some of the materials handled in accordance with this document are combustible, or toxic, or both. The Contractor shall be responsible for providing equipment as required for safe application and for instructing the users regarding the hazards and proper handling and disposal procedures to prevent damage to health. The Contractor shall provide safe access to all areas for the coating inspector. The Contractor shall submit a written safety plan that includes a Hazard Communication Program, a Respiratory Protection Program, and a Hearing Conservation Program that conforms to OSHA requirements. Where the Contractor is required to perform removal of surface coatings that contain lead, chromium, mercury, or cadmium, the safety plan shall also include specific provisions for OSHA compliance for work with these materials and include a hazardous coating removal program in compliance with 4.3.3.

4.3.1 Environmental requirements. The operations described in this standard have the potential to pollute the environment. All local, state, and Federal environmental regulations, as well as the installation environmental policies, shall be followed. Questions regarding these regulations and policies should be directed to the local environmental management organization. Material waste shall be handled and disposed in accordance with the local environmental regulations and NASA policies.

4.3.2 Personal protective equipment (PPE). When engineering controls are not available to protect workers, then PPE and/or administrative controls shall be used. Where required, PPE shall be provided, used, and maintained in a reliable and sanitary condition. Both the supervisors and the workers shall be properly instructed, trained, and certified in the selection, use, and maintenance of PPE.

4.3.3 Hazardous coating removal program. Each contractor shall have a hazardous coating removal program to document and control coating removal and application operations in strict compliance with OSHA 29CFR Part 1910.1025, 1926.62, and 1926.63. This program shall also include applicable requirements from Environmental Protection Agency (EPA) environmental protection issues and hazardous waste disposal.

4.4 General requirements.

4.4.1 Applicator qualifications. To ensure the highest quality of workmanship, only coating applicators who have worked in the printing trade sufficiently long enough to master the use of all applicable tools and materials shall be assigned to perform the work described herein. The applicator's proficiency and ability to attain the required quality of workmanship for the specified coating system can be verified by testing and qualification in accordance with ASTM D4228. In addition, the coating applicators shall provide written evidence of having successfully completed a comprehensive training program such as Painting and Decorating Contractors of America (PDCA)/NACE/SSPC Industrial Painters Training, or equal. The Contractor shall be responsible for providing all painting personnel an orientation on the proper mixing and application of the coatings specified, particularly inorganic zinc coatings. Topics in the orientation shall include specification requirements, material application characteristics, and inspection criteria. Only personnel receiving training may mix or apply coatings. The Contractor shall prepare representative sample areas which meet specification requirements.

4.4.2 Preparation of surfaces. All surfaces to be coated shall be clean, dry, and free from oil, grease, dirt, dust, corrosion, peeling paint, caulking, weld spatter, and any other surface contaminants. All surfaces that will become inaccessible after fabrication, erection, or installation shall be prepared and coated while accessible. Surface preparation and coating operations shall be sequenced so that freshly applied coatings will not be contaminated by dust or foreign matter. All equipment and adjacent surfaces not to be coated shall be protected from surface preparation operations. Working mechanisms shall be protected against intrusion of abrasive. All surfaces shall be degreased, as required, prior to subsequent surface preparation procedures or the application of protective coatings, or both. The following surface preparation techniques shall be used when specified in 4.5.

4.4.2.1 Cleaning and degreasing. Degreasing shall be by solvent cleaning, detergent washing, or steam cleaning in accordance with SSPC-SP 1. This procedure shall be followed when cleaning steel, galvanized steel, or stainless steel. NASA policy prohibits the use of chlorofluorocarbon solvents. Selection of solvents shall be in accordance with all applicable Federal, state, and NASA environmental policies. Water washing shall be done when high levels of chloride or other undesirable contaminants are found on the surfaces and shall be accomplished using standard industrial pressure cleaners with a pressure versus volume output balance that will ensure thorough and productive cleaning. High-pressure water cleaning shall not be used as a cleaning method if existing paint film on a surface exceeds any Toxicity Characteristic Leaching Procedure (TCLP) listed toxic characteristics. No chemical shall be added to the water used for the paint blasting/removal operation, and no discharge shall be directed to surface waters. A 40-micrometer filter mesh shall be utilized to screen wastewater discharge on operations performed over pervious surfaces. Points of discharge shall be identified prior to water blasting operations performed over impervious surfaces. All discharges shall then be channeled to pervious areas with a combination of sandbags and a 40-micrometer filter mesh. Any residues generated in water blasting operations shall be disposed of in accordance with the local environmental regulations. All records of water blasting operations shall be submitted to the local environmental management office. The cleaned surface shall be

free of loose coatings, chlorides, dirt, dust, mildew, grinding/welding/cutting debris, and visible contaminants. The surface shall be clean and dry prior to the abrasive blasting operations and application of coatings.

4.4.2.2 Abrasive blasting. The abrasive blasting aggregate shall be clean and dry and shall conform to 4.1.1. The abrasive blasting system shall conform to 4.2.2. Abrasive blasting shall be in accordance with the applicable paragraphs in 4.5. Abrasive residues shall be removed from the surface, leaving it clean and dry prior to the application of coatings. All abrasive blasting operations shall be contained for particulate emissions during work. The containment system shall be designed to comply with all applicable Federal, state, and local regulations as well as all NASA policies. Exemptions to this requirement shall be coordinated with the local environmental management office.

Care shall be taken in the identification and selection of aggregate for preparation of abrasive-sensitive hardware such as bellows, gimbal joints, and other thin-walled components.

4.4.2.3 Mechanical cleaning methods. Mechanical methods shall be in accordance with the applicable paragraph in 4.5.

4.4.3 Application of coatings. All prepared surfaces shall be coated within 6 hours after completion of surface preparation and before corrosion or recontamination occurs. Surfaces prepared under temperature and humidity control may be coated after 6 hours but only after surface preparation reinspection confirms the specified cleanliness. Any surface that shows corrosion or contamination, regardless of the length of time after preparation, shall be re-prepared. The application and handling characteristics of all coatings will vary. To obtain optimum performance, adequate written instructions from the manufacturer are essential and must be closely followed in conjunction with the requirements defined herein. The manufacturer's written recommendations for thinning, mixing, handling, and applying the product shall be strictly followed. All coatings shall be thoroughly worked into all joints, crevices, and open spaces. All newly coated surfaces shall be protected from damage. All equipment and adjacent surfaces not to be coated shall be protected from overspray and splattered coatings. All spray painting operations shall be contained for particulate emissions during work. The containment system shall be designed to comply with all Federal, state, and local regulations as well as all NASA policies. Exemptions to this requirement shall be coordinated with the local environmental management organization.

4.4.3.1 Coating systems. Coating systems for specified uses and substrates shall be as defined in 4.5 and shall conform to 4.1.2. All thinners and cleaners shall be products of the coating manufacturer except as defined in 4.1.2.7. To ensure intercoat compatibility, coating systems consisting of more than one coat shall be products of the same manufacturer, except for inorganic and polysiloxane topcoats as referenced in 4.1.2.3.3 and 4.1.2.3.4. Continuity of the coating manufacturer's system shall be maintained for the duration of an individual project.

4.4.3.2 Colors. Inorganic zinc coatings shall be pigmented so that there is a definite contrast between the coating and the dull gray appearance of the blasted steel surface during the coating application. Color coding for fluid system piping shall be in accordance with KSC-STD-SF-0004. Finish coat colors shall be in accordance with the following FED-STD-595 color numbers using pigments free of lead, chromium, and cadmium:

a. White, no. 17925

b. Blue, no. 15102 (safety)

c. Yellow, no. 13538 (standard)

d. Yellow, no. 13655 (safety)

e. Red, no. 11136

f. Red, no. 11105 (safety)

g. Black, no. 17038

h. Green, no. 14110 (safety)

i. Gray, no. 16187 (safety)

j. Brown, no. 10080 (safety)

k. Gray, no. 16473 (standard)

4.4.3.3 Storage of coating materials. Coating materials and thinners shall be stored in their original containers bearing the manufacturer's name, product identification, shelf life, and batch number. Coatings, thinners, and cleaners shall be stored in tightly closed containers in a covered, well-ventilated area where they will not be exposed to sparks, flame, direct sunlight, high heat, or rainfall. The manufacturer's written instructions for storage limitations shall be followed. Tarpaulins shall not be utilized as a sole means of covering coating materials for storage. If Material Safety Data Sheets are included with coating materials or thinners, they must be maintained in the area. The Contractor shall submit a written plan for approval for storage of coating materials for coordination with the local safety/fire/environmental organization.

4.4.3.4 Mixing and application instructions. Coating materials shall be thoroughly mixed prior to application with a mechanical mixing instrument that will not induce air into the coating, such as a Jiffy Mixer, manufactured by the Jiffy Mixer Company, Inc., San Francisco, CA, or approved equal. The mixer shall be powered by an air motor or an explosionproof electric motor. All mixing operations shall be performed over an impervious surface with provisions to prevent runoff to grade of any spilled material. The mixed coating material shall be strained through a 30- to 60-mesh screen prior to application. Thinning shall be for viscosity control only. The manufacturer's recommended thinner and amount shall be used except as defined in 4.1.2.7. The material shall be agitated as required during application to maintain uniform suspension of solids. Continuous rapid agitation shall be avoided. Spray equipment shall be adjusted to produce an even, wet coat with minimum overspray. The conventional pressure pot, when used, shall be kept at approximately the same level or above the spray gun for proper material delivery. Coatings shall be applied in even, parallel passes, overlapping 50 percent.

4.4.3.5 Weather conditions. No coating shall be applied when contamination from rainfall is imminent or when the temperature or humidity is outside limits recommended by the coating manufacturer. To prevent moisture condensation during application, surface temperature must be at least 3 degrees Celsius (5 degrees Fahrenheit) above the dewpoint. Wind speed shall not exceed 25 kilometers per hour (15 miles per hour) in the immediate coating area when using spray application methods.

NOTE: Relative humidity (RH) limitations using certain coatings shall be followed:

a. <40% RH solvent-based inorganic zinc coatings, PSX 700, and inorganic topcoats shall not be applied.

b. <40% or >80% RH water-based inorganic zinc coatings shall not be applied.

4.4.3.6 Methods of application. Coatings shall be applied with airless or conventional spray equipment, or both, according to 4.2.3. Application with brushes shall be permitted for minor touchup of spray applications and stripe coats of inorganic zinc. Organic midcoats and topcoats may be applied using brush, roller, or spray as applicable.

4.4.3.7 Coating finish. Each coat of material applied shall be free of runs, sags, blisters, bubbles, and mudcracking; variations in color, gloss, and texture; holidays (missed areas); excessive film buildup; foreign contaminants; dry overspray; etc. Special care shall be taken to ensure complete coverage and proper thickness on welds, corners, crevices, sharp edges, bolts, nuts, and rivets. Each coat of applied material shall be rendered clean, dry, and free from surface contaminants prior to the application of the next successive coating.

4.4.3.8 Touchup of welds and damaged coatings. Field welds and damaged coatings shall be touched up in accordance with 4.5.7. The coating shall be applied in accordance with 4.4.3.4 and 4.4.3.6. Touchup and repair shall be accomplished promptly after the damage or welding has occurred.

4.4.3.9 Coating, drying, and curing. The coating manufacturer's recommended drying and curing times for handling, recoating, and topcoating shall be followed. Coating manufacturer’s recommendations shall be followed to test coating for proper curing. Proper curing of solvent-based inorganic zinc-rich coatings must be verified by ASTM D4752 prior to further coating. Water-based inorganic zinc-rich coatings must be verified for curing, in accordance with the same procedure, but water must be substituted as the solvent.

NOTE: The cure of solvent-based inorganic zinc coatings can be accelerated by rinsing or spraying with fresh water after an initial overnight drying. Number and frequency of rinse cycles can vary with environmental conditions. Check with material manufacturer for recommended procedures.

4.4.4 Sealing/caulking. The perimeter of all faying surfaces, joints open less than 13 millimeters (1/2 inch), and skip-welded joints shall be completely sealed. The sealant shall be a self-curing, single-component, polysulfide rubber or polyurethane type, conforming to 4.1.3. The sealant shall be applied to the joint with a caulking gun following the application of the inorganic zinc primer on carbon steel. For topcoated zinc primers, apply caulking after epoxy intermediate coat, and for coatings on stainless steel, galvanized steel, and aluminum, apply caulking before application of the topcoat. The bead shall have a smooth and uniform finish and shall be cured (tacky to touch) prior to topcoat application.

4.5 Specific requirements.

4.5.1 Protection of carbon steel. Carbon steel surfaces shall be protected from atmospheric corrosion through the application of zinc coatings (inorganic zinc coating and/or hot-dip galvanizing and/or metallizing) as defined herein. New steel components, such as stair

treads, grating, handrails, pipes, and hardware (nuts, bolts, and fasteners), shall be hot-dip galvanized in accordance with 4.5.1.2.1, as applicable. All other carbon steel surfaces that are exposed to the atmosphere shall be coated with inorganic zinc conforming to 4.1.2 in accordance with 4.4.3, hot-dip galvanized (zinc coated) in accordance with 4.5.1.2.1, or metallized in accordance with 4.5.1.3. The zinc coatings may require topcoating with additional protective coatings as specified, but in neutral pH atmospheres, testing has proven untopcoated zinc to have superior performance. Carbon steel faying surfaces that are a part of all friction-type and electrical grounding joints shall be abrasive blasted and coated with 100 to 150 micrometers (4 to 6 mils) of inorganic zinc only, in accordance with 4.5.1.1.4, prior to installation. An inorganic zinc coating used in a friction-type joint must be approved by the American Institute of Steel Construction (AISC). The recommended coating application sequence for carbon steel shall be to abrasive blast and prime with inorganic zinc prior to installation or erection. Further topcoating, if required, shall be accomplished after all welding, grinding, or drilling has been completed, and areas damaged by these procedures have been properly repaired with inorganic zinc.

4.5.1.1 Protection with inorganic zinc.

4.5.1.1.1 Mechanical cleaning of carbon steel. After cleaning and degreasing in accordance with SSPC-SP 1, mechanical cleaning of carbon steel shall be used only as a preabrasive blasting preparation method. Carbon steel shall be mechanically cleaned using needle scalers and/or abrasive discs or wheels in accordance with SSPC-SP 2 or SSPC-SP 3. All weld slag, weld spatter, and foreign matter shall be removed from welds prior to abrasive blasting.

4.5.1.1.2 Abrasive blasting of carbon steel. Carbon steel shall be abrasive blasted to near-white metal (NACE no. 2 in accordance with NACE STD TM 01-70, NACE STD TM 01-75, or SSPC-SP 10) with aggregate conforming to the requirements in 4.1.1. The anchor profile of the blasted surface shall be 40 to 75 micrometers (1.5 to 3.0 mils). All rust shall be completely removed from pits and depressions.

4.5.1.1.3 Stripe coat application. Brush coating and/or stripe coating with a primer shall be applied to welds, cutouts, sharp edges, rivets, crevices, and bolts to ensure complete coverage and proper thickness prior to final primer applications.

4.5.1.1.4 Application of inorganic zinc coatings. Inorganic zinc coatings shall be applied to a DFT of 100 micrometers (4.0 mils) minimum to 150 micrometers (6.0 mils) maximum when they will be left untopcoated or when inorganic topcoat or ablative coating is applied. When the zinc coatings are to be topcoated with organic topcoats, the DFT shall be reduced to 65 micrometers (2.5 mils) minimum to 100 micrometers (4.0 mils) maximum. The proper DFT for the inorganic zinc coating shall be obtained in a single application, which may consist of multiple passes, while coating is still wet.

4.5.1.1.5 Topcoat systems for zinc coatings. The following topcoat systems shall be applied over the zinc coatings as required for each zone of exposure described in 1.1. Topcoats shall be applied at the DFT recommended by the manufacturer or as specified below. The film thickness of the topcoats shall be sufficient to ensure uniform coverage and color.

a. Zone 1. Zinc coatings shall be left untopcoated. As an alternate, surfaces may be topcoated with a heat-resistant coating material such as a silicone ablative.

b. Zone 2. An inorganic topcoat conforming to 4.1.2.3.3 shall be applied at a DFT of 75 to 125 micrometers (3 to 5 mils). As an alternate, surfaces may be topcoated with a heat-resistant coating material such as a silicone ablative.

c. Zones 3a and 3b. An intermediate/tie coat and a finish coat conforming to 4.1.2 shall be applied in accordance with 4.4.3. As an alternate, an inorganic topcoat conforming to 4.1.2.3.3 or a polysiloxane finish coat conforming to 4.1.2.3.4 shall be applied at a DFT of 75 to 125 micrometers (3 to 5 mils).

d. Zones 4a, 4b, and 4c. No topcoats are required, except for color coding, safety, identification, or special conditions. When required, topcoats shall be in accordance with 4.5.1.1.5.c.

e. Zone 5. Zinc coating is suggested but not required. As an alternate, use inhibitive epoxy primer and a polyurethane finish coat conforming to 4.1.2 at the manufacturer's recommended thickness.

f. Zone 6. The coating system shall be as specified in 4.5.4 and 4.5.5.

g. Zone 7. The coating system shall be as specified in NACE Publication No. 6H189.

4.5.1.2 Protection by galvanizing.

4.5.1.2.1 Galvanizing. Galvanizing (zinc coating) shall be accomplished after fabrication by the hot-dip process conforming to ASTM A123, ASTM A153, and ASTM A653. Galvanizing weight for steel sheet without further coating protection shall be ASTM A653, G165. All lower galvanizing weights for steel sheet must be further protected with coatings except for Zone 5 exposures.

NOTE: High-strength steels are susceptible to embrittlement by hydrogen during the galvanizing process. Steel components with an ultimate tensile strength above 900 megapascals (MPa) (130 kips per square inch [ksi]) or hardness above Rockwell C Hardness 28 shall not be galvanized.

4.5.1.2.2 Surface preparation of galvanizing.

CAUTION: Some galvanized configurations are susceptible to distortion when they are abrasive blasted. Special care shall be taken to ensure against any metal distortion by reducing blast nozzle pressure and increasing the working distance from nozzle to surface. In some cases, such as in the surface preparation of light-gage sheet, these precautions may not be sufficient to prevent distortion; and alternate procedures, such as abrading or mechanical cleaning, must be used to remove corrosion or roughen the surface. Galvanized surfaces shall be abrasive blasted with fine abrasives conforming to the requirements in 4.1.1 to remove corrosion and old coatings or roughen new surfaces. The blasted surface shall be free of all corrosion and foreign matter and have a uniform, slightly roughened appearance.

Galvanized surfaces to be further topcoated shall be prepared by degreasing in accordance with 4.4.2.1 prior to any additional surface preparation. After degreasing, abrasive blasting or

mechanical cleaning shall be performed as required by the zone of exposure. If galvanized steel is prepared for the application of coatings by abrasive blasting, it shall be lightly brush blasted with fine abrasive at a lower pressure of 275 to 420 kPa (40 to 60 psi) to provide a corrosionfree and uniform, slightly roughened surface. Care shall be taken not to completely remove the galvanized finish. The zinc coatings shall be maintained or rendered clean, dry, and free from contaminants prior to the application of topcoat systems. Field repair of damaged galvanizing shall be accomplished in accordance with ASTM A780 using inorganic zinc coatings.

Galvanized steel that is to be mechanically cleaned shall be cleaned in accordance with SSPC-SP 3 using abrasive discs/sheets, or other approved methods. All corrosion and foreign matter shall be completely removed and the entire surface slightly roughened.

4.5.1.2.3 Coating systems for galvanizing.

a. Zone 1. Galvanizing may be left untopcoated. As an alternate, surfaces may be topcoated with a heat-resistant coating material such as a silicone ablative.

b. Zone 2. After brush blasting, an inorganic topcoat conforming to 4.1.2.3.3 shall be applied at a DFT of 75 to 125 micrometers (3 to 5 mils). As an alternate, surfaces may be topcoated with a heat-resistant coating material such as a silicone ablative.

c. Zones 3a and 3b. After brush blasting, primer/tiecoat and finish coat conforming to 4.1.2 shall be applied in accordance with manufacturer's recommended thicknesses. As an alternate, inorganic topcoat conforming to 4.1.2.3.3 or a polysiloxane finish coat conforming to 4.1.2.3.4 shall be applied at a DFT of 75 to 125 micrometers (3 to 5 mils).

d. Zones 4a, 4b, and 4c. No topcoats are required for galvanizing weights meeting or exceeding ASTM A123, A153, and A653 G165. When steel sheet is galvanized less than ASTM A653 G165, further coating in accordance with Zone 3 is required. As an alternate to topcoats, steel sheet shall be degreased, brush blasted, and an inorganic zinc primer conforming to 4.1.2.1 applied to a DFT of 50 to 75 micrometers (2 to 3 mils).

e. Zone 5. No topcoats are required, except for color coding, safety, identification, or special conditions. When topcoats are required, the surface shall be degreased and an epoxy primer applied to a DFT of 40 to 75 micrometers (1.5 to 3.0 mils). Within 8 hours, a polyurethane finish coat conforming to 4.1.2 shall be applied to a DFT of 40 to 75 micrometers (1.5 to 3 mils). As an alternate, polysiloxane topcoat conforming to 4.1.2.3.4 shall be applied to a DFT of 75 to 125 micrometers (3 to 5 mils).

f. Zone 6. Coating system shall be as specified in 4.5.4 and 4.5.5.

g. Zone 7. The coating system shall be as specified in NACE Publication No. 6H189.

4.5.1.3 Protection with metallizing.

4.5.1.3.1 Mechanical cleaning of carbon steel. After cleaning and degreasing in accordance with SSPC-SP 1, mechanical cleaning of carbon steel shall be used only as a preabrasive blasting preparation method. Carbon steel shall be mechanically cleaned using needle scalers and/or abrasive discs or wheels in accordance with SSPC-SP 2 or SSPC-SP 3. All weld slag, weld spatter, and foreign matter shall be removed from welds prior to abrasive blasting.

4.5.1.3.2 Abrasive blasting of carbon steel. Carbon steel shall be abrasive blasted to near-white metal (NACE no. 2 in accordance with NACE STD TM-01-70, NACE STD TM 01-75, or SSPC-SP 10) with aggregate conforming to the requirements in 3.1.1. The anchor profile of the blasted surface shall be 40 to 75 micrometers (1.5 to 3 mils). All rust shall be completely removed from pits and depressions.

4.5.1.3.3 Stripe coat application. Stripe coating with metallizing shall be applied to welds, cutouts, sharp edges, rivets, crevices, and bolts to ensure complete coverage and proper thickness prior to final coating applications.

4.5.1.3.4 Application of metallized zinc coatings. Metal wire to be used with the arc spray metallizing equipment shall be pure zinc, 90-10 zinc-aluminum, or 85-15 zinc-aluminum alloys. Metallized zinc coatings shall be applied to a DFT of 100 micrometers (4 mils) minimum to 250 micrometers (10 mils) maximum when they will be left untopcoated or when inorganic topcoat or ablative coating is applied. When the metallized zinc coatings are to be topcoated with organic topcoats, the DFT shall be 100 micrometers (4 mils) minimum to 150 micrometers (6 mils) maximum.

4.5.1.3.5 Topcoat systems for metallized zinc coatings. The following topcoat systems shall be applied over the metallized zinc coatings as required for each zone of exposure described in 1.1. Topcoats shall be applied at the DFT recommended by the manufacturer or as specified below. The film thickness of the topcoats shall be sufficient to ensure uniform coverage and color.

a. Zone 1. Metallized zinc coatings shall be left untopcoated. As an alternate, surfaces may be topcoated with a heat-resistant coating material such as a silicone ablative.

b. Zone 2. An inorganic topcoat conforming to 4.1.2.3.3 shall be at a DFT of 75 to 125 micrometers (3 to 5 mils). As an alternate, surfaces may be topcoated with a heat-resistant coating material such as a silicone ablative.

c. Zone 3. An intermediate/tie coat and a finish coat conforming to 4.1.2 shall be applied in accordance with 4.4.3. As an alternate, an inorganic topcoat conforming to 4.1.2.3 shall be applied at a DFT of 75 to 125 micrometers (3 to 5 mils) or a polysiloxane finish coat conforming to 4.1.2.3.4 shall be applied at a DFT of 75 to 125 micrometers (3 to 5 mils).

d. Zones 4a, 4b, and 4c. No topcoats are required, except for color coding, safety, identification, or special conditions. When required, topcoats shall be in accordance with 4.5.1.3.5.c.

e. Zone 5. Metallized zinc coating is suggested but not required. As an alternate, use inhibitive epoxy primer and a polyurethane finish coat conforming to 3.1.2 at the manufacturer's recommended thickness.

f. Zone 6. The coating system shall be as specified in 4.5.4 and 4.5.5.

g. Zone 7. The coating system shall be as specified in NACE Publication No. 6H189.

4.5.2 Protection of aluminum.

NOTE: Aluminum requires special coatings if immersion conditions could occur. See 4.5.4 for coatings for immersion.

4.5.2.1 Surface preparation of aluminum.

CAUTION: Some aluminum configurations are susceptible to distortion and/or destruction when they are abrasive blasted. Special care shall be taken to ensure against any metal damage by choice of abrasive aggregate and by reducing blast nozzle pressure and increasing the working distance from nozzle to surface as necessary. In some cases, such as in the surface preparation of light-gage sheet, these precautions may not be sufficient to prevent distortion, and an alternate procedure, such as abrading or mechanical cleaning, must be used to remove corrosion or roughen the surface. Aluminum surfaces shall be abrasive blasted with fine abrasive conforming to the requirements in 4.1.1 to remove corrosion and old coatings or roughen new surfaces. The blasted surface shall be free of all corrosion and foreign matter and have a uniform, slightly roughened appearance.

Aluminum shall be prepared by degreasing and abrasive blasting or mechanical cleaning, as required by the condition and configuration of the surface. Abrasive blasting shall be used whenever possible using nonmetallic abrasives specified in 4.1.1. Mechanical cleaning shall be used only when abrasive blasting is impractical, would damage the structure or component, or is prohibited in the area of work. Aluminum shall be mechanically cleaned in accordance with SSPC-SP 3 using abrasive discs/sheets, or other approved methods. All corrosion and foreign matter shall be completely removed and the entire surface slightly roughened. Anodized or chemical conversion coated aluminum surfaces shall not be mechanically cleaned.

Abrasive blasting of bellows, gimbal joints, and other thin-walled, abrasion-sensitive components shall be blasted with walnut shells, plastic media, or approved equivalent in accordance with 4.1.1.

4.5.2.2 Protective coatings. The following protective coatings shall be applied to aluminum surfaces as required for each zone of exposure described in 1.1.

a. Zones 1, 2, and 3. The following coatings can be used to protect aluminum in the launch environment. To facilitate washdown of solid rocket booster (SRB) residue on critical hardware, inhibited polymide epoxy coating and aliphatic polyurethane topcoat may be used as well as other coatings such as polysiloxane and inorganic topcoats.

b. Zones 4 and 5. No protective coatings are required except for color coding, safety, identification, or special conditions for normal atmospheric service of 1000, 5000, and 6000 series alloys. However, aluminum that is located within 3.5 kilometers (2 miles) of the coastline, subject to chemical exposure, or other series alloys shall be fully coated according to 4.5.2.2.a.

c. Zone 6. The coating system shall be as specified in 4.5.4 and 4.5.5.

d. Zone 7. The coating system shall be as specified in NACE Publication No. 6H189.

4.5.3 Protection of stainless steel.

NOTE: Thin-walled 300-series stainless-steel tubing is subject to pitting corrosion failure in outdoor marine environments. For exterior installations, this tubing shall be degreased, prepared with a stainless-steel wire wheel or equal, and coated in accordance with 4.5.3.2.

4.5.3.1 Surface preparation of stainless steel. Stainless steel shall be prepared by degreasing in accordance with SSPC-SP 1 and mechanical cleaning or abrasive blasting. Abrasive blasting shall be used whenever possible. Using nonmetallic abrasives specified in 4.1.1, stainless steel shall be mechanically cleaned in accordance with SSPC-SP 3 using abrasive discs/sanding sheets, or other approved methods. All corrosion and foreign matter shall be completely removed and the entire surface slightly roughened.

CAUTION: Some stainless steel configurations are susceptible to distortion and/or destruction when they are abrasive blasted. Special care shall be taken to ensure against any metal damage by choice of abrasive aggregate and by reducing blast nozzle pressure and increasing the working distance from nozzle to surface as necessary. In some cases, such as in the surface preparation of light-gage sheet, these precautions may not be sufficient to prevent distortion, and an alternate procedure, such as abrading or mechanical cleaning, must be used to remove corrosion or roughen the surface. Stainless steel surfaces shall be abrasive blasted with fine abrasive conforming to the requirements in 4.1.1 to remove corrosion and old coatings or roughen new surfaces. The blasted surface shall be free of all corrosion and foreign matter and have a uniform, slightly roughened appearance.

4.5.3.2 Protective coating.

a. Zones 1, 2, and 3. The following coatings can be used to protect stainless steel in the launch environment. To facilitate washdown of SRB residue on critical hardware, inhibited polyamide epoxy coating and aliphatic polyurethane topcoat may be used as well as other coatings such as polysiloxane and inorganic topcoats.

b. Zones 4 and 5. No protective coatings are normally required for normal atmospheric service except for color coding, safety, identification, or special conditions. As an alternative for special conditions, stainless steel may be brush blasted and coated with inhibitive epoxy primer to a DFT of 50 to 75 micrometers (2 to 3 mils) followed by an appropriate finish coat that will provide a DFT of 50 to 75 micrometers (2 to 3 mils).

c. Zone 6. The coating system shall be as specified in 4.5.4 and 4.5.5.

d. Zone 7. The coating system shall be as specified in NACE Publication No. 6H189.

4.5.4 Underground, submerged, or continuously wetted surfaces. Surfaces that will be underground, submerged, or continuously wetted shall be prepared in accordance with SSPC-SP 5 with a profile of 75 to 100 micrometers (3 to 4 mils) and coated with coal tar epoxy conforming to 4.1.2.5.

NOTE: Coal tar epoxy coatings shall not be used for contact with potable water.

The coating shall be applied to a minimum DFT of 410 micrometers (16.0 mils) and checked for missed areas or pinholes with a properly calibrated holiday detector in accordance with NACE RP0188-88. Cathodic protection requirements shall be coordinated with the application of this coating.

4.5.5 Coating systems for potable water immersion service. All surface preparation for carbon steel shall be in accordance with SSPC-SP 5 with a surface profile of 75 to 100 micrometers (3 to 4 mils). All coatings for potable water service shall be selected from 4.1.2.6. All potable water coating systems shall be inspected in accordance with NACE standard recommended practices RP0288-88 and with RP0188-88.

4.5.6 Provision for nonskid surfaces. Where a nonskid walking surface is required, a nonskid coating conforming to 4.1.2.8 shall be applied as follows:

a. Carbon steel. Apply directly over the zinc coating (inorganic zinc or galvanizing). Follow surface preparation instructions defined for topcoating in 4.5.1.

b. Aluminum and stainless steel. Apply directly over these surfaces after surface preparation following instructions defined for topcoating in 4.5.2 and 4.5.3.

4.5.7 Coating systems for metallic surfaces under thermal insulation. Coating systems for carbon steel and stainless steel surfaces under thermal insulation and cementitious fireproofing shall be as specified in NACE Publication No. 6H189.

4.5.8 Repair of applied coatings. Newly applied coatings shall be repaired in accordance with Table I. Surfaces shall be prepared by water washing and by mechanical methods to SSPC-SP 11 to remove corrosion, weld slag, and to "feather back" coating edges. Touchup and repair shall be accomplished promptly after the damage has occurred. Touchup and repair of shop-applied coatings shall be accomplished using coatings from the same manufacturer as those applied in the shop.

4.5.9 Maintenance of existing coatings. Each support contractor responsible for maintaining facilities or ground support equipment shall develop a Coating Maintenance Plan. The plan shall include the following key elements: record keeping, routine inspection of facilities, coating repair criteria, coating systems, equipment requirements, procedures, training and certification, in-process inspection, and worker protection and environmental compliance. All operations shall be in strict accordance with 4.3.3.

5. QUALITY ASSURANCE PROVISIONS

5.1 Responsibility for inspection. The coating contractor/applicator shall provide continuous quality control inspection of his work to ensure complete conformance to the project specifications. A project-specific quality control coating inspection plan shall be submitted to the Contracting Officer for approval.

In addition, the Government and/or the Government's representative shall provide inspection of the surface preparation and coating application processes defined herein as required by the project specifications. The inspector shall perform all of the in-process inspections required by this standard and the project specifications. The assigned inspector shall be certified under

NACE Coating Inspector Program (CIP). The inspector shall witness, inspect, and test all protective coating work to verify complete compliance with the specified requirements. The assigned inspector shall document the work on the inspection forms described in 4.4. The daily inspection reports shall be prepared and signed daily and submitted to the Contracting Officer on a weekly basis as a minimum. When a nonconformance report is required, it shall be signed and submitted to the Contracting Officer within 1 working day from the time that it is written. After determining that all nonconformances have been corrected and/or the coating work is in compliance with this standard and the project specifications, a conformance verification report shall be completed for the specific item, area, or project. This report shall be signed and sealed by the assigned inspector. The application of the certified inspector's seal to the verification conformance report indicates that he has personally inspected the indicated work and has found it to be in compliance with the specified requirements. The seal shall not be affixed to the daily inspection report or to the nonconformance report. The contractor/applicator shall provide the inspector with safe access to the work.

TABLE I. Repair of Applied Coatings

Existing Coating	Repair Coating
Inorganic zinc	
Zones* 1 and 4	Inorganic zinc/epoxy mastic for small area touchup
Zone 2	Inorganic zinc/inorganic topcoat
Zones 3 and 5	Epoxy mastic/polyurethane/polysiloxane system for small area touchup
Galvanized steel	
Zones 1 and 4	Inorganic zinc/epoxy mastic for small area touchup
Zone 2	Inorganic zinc/inorganic topcoat
Zones 3 and 5	Epoxy mastic/polyurethane/polysiloxane system for small area touchup
Inorganic topcoat	
All zones	Inorganic zinc/inorganic topcoat
Epoxy/Polyurethane**	
Zones 3, 4 and 5	Epoxy/polyurethane system/polysiloxane
Water reducible	
Zones 3, 4, and 5	Water reducible intermediate/finish
Coal tar epoxy	
Zone 6	Coal tar epoxy

* Zones are defined in 1.1

**When this coating is replaced with inorganic zinc, complete removal of the existing coating is required.

The CIP is provided by NACE International, Education Department, P.O. Box 218340, Houston, Texas, 77218-8340, (281) 228-6200, FAX (281) 228-6300.

5.2 Requirements for inspection.

a. Zones 1, 2, and 3. Since these zones are located in the highly corrosive launch environment or other chemical exposures, NACE inspection shall be required for all surface preparation and coating applications. This includes all new work, new work touchup, major refurbishment of existing coatings, and modifications.

b. Zone 4. For systems requiring abrasive blasting and coating of metallic substrates, all surfaces shall require full NACE inspection with the following exception: For touchup of existing coatings, NACE inspection is not mandatory but recommended in cases of critical systems or equipment.

c. Zone 5. All clean-room structures fabricated of aluminum or carbon steel that will be abrasive blast cleaned and/or coated outside Zone 5 environments require NACE inspection. All other aluminum or carbon steel structures in Zone 5 environments are exempt from NACE inspection.

d. Zone 6. Since this zone is located in a highly corrosive underground environment or other submerged exposures, NACE inspection shall be required for all surface preparation and coating applications. This includes all new work, new work touchup, major refurbishment of existing coatings, and modifications.

e. Zone 7. Since this zone is located in a highly corrosive environment, NACE inspection shall be required for all surface preparation and coating applications. This includes all new work, new work touchup, major refurbishment of existing coatings, and modifications.

5.3 Inspection hold points. Mandatory inspection hold points shall include but not be limited to the following:

a. Verification of ambient weather conditions in accordance with 4.4.3.5

b. Prior to beginning of surface preparation work, to include the operation of equipment

c. After surface preparation work and before the beginning of the coating application work, to include the mixing of products

a. Before and after the application of each coat of material

e. After completion and prior to final acceptance

5.4 Inspection forms. All inspections shall be recorded and documented on forms acceptable to the customer. See Appendix E for examples of forms to be used.

5.5 Inspection prior to surface preparation and coating application. The following conditions shall be inspected prior to commencement of surface preparation and coating application operations.

5.5.1 Surface condition. The surface condition shall be visually inspected for compliance with 4.4.2. Special attention shall be given to weld spatter, sharp edges, flame or saw cuts, delaminations, burrs, slag, or other surface irregularities that effect performance of protective coatings prior to surface preparation.

5.5.2 Protection of adjacent surfaces. Adjacent surfaces shall be visually inspected for adequate protection in accordance with 4.4.2. This inspection shall be in conjunction with Government Quality Engineering.

5.5.3 Ambient weather conditions. The ambient weather conditions at the actual location of the work shall be determined before and during the surface preparation and coating application operations to ensure they are correct for the work being conducted. The air temperature, relative humidity, and dewpoint shall be determined through the use of a psychrometer in accordance with the manufacturer's instructions. The surface temperature shall be determined by using a surface temperature thermometer. Wind speed and direction shall be determined with a suitable instrument. No spray painting may proceed when the measured wind speed in the immediate coating area is above 25 kilometers per hour (15 miles per hour). All of these ambient weather conditions shall be recorded on the Coating System Daily Inspection Report as shown in Appendix E.

5.5.4 Compressed air cleanliness. The compressed air supply shall be inspected for the use of inline moisture and oil traps. Proper functioning of the traps shall be evaluated daily by allowing the air supply (down line from the traps) to blow against a clean, white cloth for several minutes. No moisture or oil should be deposited on the cloth.

5.5.5 Surface salt concentration. On structures within 3.5 kilometers (2 miles) of the ocean shore, the surface chloride concentration shall be determined using Saltesmo test strips (available from Gallard-Schlesinger Chemical Manufacturing Corporation [516] 333-5600) or other suitable methods and recorded in the inspection records weekly. Surfaces that measure 50 milligrams per square meter (0.00016 ounce per square foot) or above require water washing in accordance with 4.4.2.1.

5.6 Surface preparation inspection. The following inspections shall be made to ensure compliance with the surface preparation requirements in 4.4.2.

5.6.1 Abrasive blasting material. The abrasive blasting material shall be verified for compliance with 4.1.1.

5.6.2 Blast nozzle air pressure and size. The air pressure at the blast nozzle shall be determined through the use of a hypodermic needle air pressure gage. The needle of the gage shall be inserted as close to the nozzle as practically possible and in the direction of the air flow. Pressure readings should be taken with the blasting system in complete operation. The nozzle pressure shall be recorded. The nozzle shall be checked initially and then at a frequency determined by the NACE inspector with a blast nozzle orifice gage to ensure the compressor output correlates with the nozzle size.

5.6.3 Degree of surface cleanliness. The surface cleanliness shall be inspected after the completion of surface preparation procedures and prior to primer application to determine compliance with the applicable requirements of 4.5. The degree of cleanliness of abrasive blasted carbon steel shall be verified through the use of visual standards in accordance with 4.5.1.1.2. Galvanized steel, aluminum, and stainless steel shall be inspected for cleanliness in

accordance with 4.5.1.2, 4.5.2, and 4.5.3. The surface preparation cleanliness requirements defined in 4.5 shall be applicable to 100 percent of the subject area, including places that are difficult to reach. Use of SSPC-VIS 1-89 and SSPC-VIS 3-95 is recommended for judging surface cleanliness.

5.6.4 Surface profile or roughness. The anchor profile of an abrasive-blasted carbon steel surface shall be determined by using a surface profile gage, comparator, or replica tape. The profile shall be in accordance with 4.5.1.1.2. Galvanized steel, stainless steel, and aluminum surfaces shall be visually inspected as required for slight roughening in accordance with 4.5.1.2, 4.5.2, and 4.5.3.

5.6.5 Blasting of abrasive-sensitive components. Thin-walled, abrasive-sensitive components such as bellows assemblies or tubing will be protected during normal blasting operations in accordance with 5.5.2. Surface preparation of these sensitive components will use walnut shell or approved equivalent in accordance with 4.1.1 or mechanical methods in accordance with 4.4.2.3.

5.7 Coating application inspection. The following inspections shall be made to ensure compliance with the coating application requirements defined in 4.4.3.

5.7.1 Surface condition. The prepared surface shall be visually inspected and the time before coating shall be monitored for compliance with 4.4.3 before coatings are applied.

5.7.2 Coating materials. The coating materials shall be visually inspected for compliance with 4.4.3.1.

5.7.3 Storage of coating material. Coating material storage conditions shall be periodically inspected for compliance with 4.4.3.3.

5.7.4 Mixing and application of coatings. The mixing and application of all coatings shall be visually inspected to ensure compliance with 4.4.3.4, 4.4.3.6, and 4.4.3.9.

5.7.5 Coating finish and DFT. The finish and DFT of each applied coating shall be inspected for compliance with 4.4.3.7 and 4.5 prior to the application of successive coats. The DFT measurement on carbon steel shall be taken using a magnetic gage calibrated in accordance with SSPC-PA 2. DFT measurements taken in accordance with SSPC-PA 2 shall not have any readings below minimum specified while considering the accuracy of the measurement instrument. DFT measurements on aluminum and stainless steel shall be taken using an eddy current instrument that has been properly calibrated on surfaces similar to the coated surface.

5.8 Caulking inspection. All surfaces shall be visually inspected to determine compliance with the requirements for sealing and caulking in accordance with 4.4.4.

5.9 Galvanizing inspection. Galvanized carbon steel shall be inspected in accordance with the applicable ASTM standard in 4.5.1.2.1.

6. PREPARATION FOR DELIVERY

Not applicable.

7. NOTES

(This section contains information of a general or explanatory nature which may be helpful but is not mandatory.)

7.1 Intended use. This standard is intended to establish uniform practices, methods, and procedures. The information provided herein shall be used for the preparation of written, individual coating specifications for specific projects for the prevention of corrosion through the use of protective coatings on space vehicle launch structures, facilities, ground support equipment, and test facilities and structures in all environments. Due to the changing environmental considerations, new advances in corrosion control technology, and the wide array of possible applications, this document shall not be used as a stand-alone specification that meets every contingency. Attached Appendices are considered to be an integral part of this standard and should be used in the preparation of all coating specification and coating operations.

7.2 Additional related information. For information and guidance on dissimilar metals, corrosion-inhibiting lubricants, etc., refer to T.O. 1-1-691 and KSC-TM-584.

7.3 Key word listing.

facilities
ground support equipment
protective coating
structures

APPENDIX A

APPROVED PRODUCTS LIST FOR INORGANIC ZINC COATINGS

This list has been prepared for use by or for the Government in the procurement of products covered by this document, and such listing of a product is not intended to and does not connote endorsement of the product by NASA. All products listed herein have been tested and meet the requirements for the product as specified. This list is subject to change without notice; revisions or amendments of this list will be issued as necessary. The listing of a product does not release the supplier from compliance with the specification requirements. This list is arranged in two sections based on the coating material's Volatile Organic Content (VOC). Use of the information shown hereon for advertising or publicity purposes is strictly forbidden.

Thinners and cleaners for each of these coatings shall be procured from the manufacturer of the coating in accordance with 4.4.3.1 and 4.4.3.4.

The agency responsible for this list is the KSC Spaceport Technology Development Office (YA-C2).

Section I. Materials With Greater Than 420 Grams/Liter (3.5 Pounds/Gallon) VOC (SB is Solvent-Based and WB is Water-Based):

Coating Designation	Type	Manufacturer
Dimetcote 9	SB	Ameron International, P.C.F.G. 201 North Berry Street Brea, CA 92821 (800) 926-3766 www.ameron.com
MZ 13-F-12	SB	
Carbo-Zinc 11	SB	Carboline Company 350 Hanley Industrial Court St. Louis, MO 63114 (800) 677-0753 www.carboline.com
Cathacoat 304	SB	ICI Devoe Coatings 4000 Dupont Circle Louisville, KY 40207 (800) 654-2616 www.devoecoatings.com
Ganicin 347-Y-931	SB	DuPont Co. P. O. Box 80021 Wilmington, DE 19880 (302) 992-4928 (800) 572-1568

Coating Designation	Type	Manufacturer
PPG 1001	SB	PPG Industries, Inc. One PPG Place Pittsburgh, PA 15272 (800) 722-4509 www.ppg.com
Zinc-Clad B69-V-1	SB	Sherwin-Williams Company 101 Prospect Avenue N.W. Cleveland, OH 44115 (800) 336-1110 www.sherwin-williams.com
Sigma 7551	SB	Sigma Coatings, USA P.O. Box 816 Harvey, LA 70059 (504) 347-4321 (800)221-7978 www.sigmacoatings.com

Section II. Materials With Less Than 340 Grams/Liter (2.8 Pounds/Gallon) VOC (SB is Solvent-Based and WB is Water-Based):

Coating Designation	Type	Manufacturer
Dimetcote D-21-9 Dimetcote D-9HS	SB SB	Ameron P.C.F.G. 210 North Berry Street Brea, CA 92821 (800) 926-3766 www.ameron.com
Carbo-Zinc 11HS Carbo-Zinc D7 Carbo-Zinc 11 VOC	SB WB SB	Carboline Company 350 Hanley Industrial Court St. Louis, MO 63114 (800) 677-0753 www.carboline.com
Cathacoat 305 Cathacoat 304V Cathacoat 304H	WB SB SB	ICI Devoe Coatings Co. 4000 Dupont Circle Louisville, KY 40207 (800) 654-2616 www.devoecoatings.com
Ganicin 347WB	WB	DuPont Co. 1007 Market Street Wilmington, DE 19898 (302) 992-4928 (800) 572-1568

Coating Designation	Type	Manufacturer
Galvosil 1562	WB	Hempel Coatings, Inc. 6901 Cavalcade Houston, TX 77028 (713) 672-6641 www.hempel.com
InterZinc 22HS	SB	International Paint 6001 Antoine Drive Houston, TX 77091 (713) 682-1711 www.international-pc.com
Zinc Clad II Zinc Clad IIHS	SB SB	Sherwin-Williams Company 101 Prospect Avenue N.W. Cleveland, OH 44115 (800) 336-1110 www.sherwin-williams.com
Tornusil 7550 Sigma 7551 US	WB SB	Sigma Coatings, USA P.O. Box 826 Harvey, LA 70059 (504) 347-4321 (800) 221-7978 www.sigmacoatings.com

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APPENDIX B

APPROVED PRODUCTS LIST FOR TOPCOAT SYSTEMS

This list has been prepared for use by or for the Government in the procurement of products covered by this document, and such listing of a product is not intended to and does not connote endorsement of the product by NASA. All products listed herein have been tested and meet the requirements for the product as specified. This list is subject to change without notice; revisions or amendments of this list will be issued as necessary. The listing of a product does not release the supplier from compliance with the specification requirements. This list is arranged in two sections based on the coating material's Volatile Organic Content (VOC). Use of the information shown hereon for advertising or publicity purposes is strictly forbidden.

Thinners and cleaners for each of these coatings shall be procured from the manufacturer of the coating in accordance with 4.4.3.1 and 4.4.3.4.

The agency responsible for this list is the KSC Spaceport Technology Development Office (YA-C2).

Section I. Materials With Greater Than 420 Grams/Liter (3.5 Pounds/Gallon) VOC (SB is Solvent-Based and WB is Water-Based):

Primer (Type)	Midcoat (Type)	Topcoat (Type)	Manufacturer
Cathacoat 304 (SB)	201 (SB)*	359 (SB)	ICI Devoe Coatings Co. 4000 Dupont Circle Louisville, KY 40207 (800) 654-2616 www.devoecoatings.com
Cathacoat 304 (SB)	230 (SB)	369 (SB)	
Cathacoat 304 (SB)	201 (SB)*	369 (SB)	
PPG 1001 (SB)	97-139 (SB)	97-812 (SB)	PPG Industries, Inc. One PPG Place Pittsburgh, PA 15272 (800) 722-4509 www.ppg.com
PPG 1001 (SB)	97-148 (SB)	97-812 (SB)	
Sigma 7551 (SB)	5434 (SB)	5523 (SB)	Sigma Coatings, USA P.O. Box 826 Harvey, LA 70059 (504) 347-4321 (800) 221-7978 www.sigmacoatings.com

*Can be used as a direct to metal primer for stainless steel, aluminum, and Zone 5 environments.

Section II. Materials With Less Than 340 Grams/Liter (2.8 Pounds/Gallon) VOC (SB is Solvent-Based and WB is Water-Based):

Primer (Type)	Midcoat (Type)	Topcoat (Type)	Manufacturer
D-21-9 (SB) D-21-9 (SB) D-9 NS (SB)	400 (SB)*	450HS (SB) PSX700 (SB) PSX700 (SB)	Ameron P.C.F.G. 210 North Berry St. Brea, CA 92821 (800) 926-3766 www.ameron.intl.com
CZ-11HS (SB) CZ-11HS (SB) CZ-D7 (WB)	893 (SB) CM-15 (SB)* 3358 (WB)	134HS (SB) 3359 (WB) 3359 (WB)	Carboline Company 350 Hanley Industrial Ct. St. Louis, MO 63114 (800) 677-0753 www.carboline.com
Cathacoat 304 V (SB)	201 H (SB)	379 (SB)	ICI Devoe Coatings Co. 4000 Dupont Circle Louisville, KY 40207 (800) 654-2616 www.devoecoatings.com
Ganicin 347 (WB)	25P (SB)	333 (SB)	DuPont Co. 1007 Market Street Wilmington, DE 19898 (302) 992-4928 (800) 572-1568

*Can be used as a direct to metal primer for stainless steel, aluminum, and Zone 5 environments.

Section III. Inorganic Topcoat Systems (SB is Solvent-Based and WB is Water-Based):

Primer (Type)	Midcoat (Type)	Topcoat (Type)	Manufacturer
D-21-9 (SB) D-9 HS (SB)		741 (SB) (IOT)	Ameron P.C.F.G. 210 North Berry St. Brea, CA 92821 (800) 926-3766 www.ameron.intl.com
CZ-11 VOC (SB)		L3910-50 (SB) (IOT)	Carboline Company 350 Hanley Industrial Court St. Louis, MO 63114 (800) 677-0753 www.carboline.com

Primer (Type)	Midcoat (Type)	Topcoat (Type)	Manufacturer
Cathacoat 304V (SB)		701 (SB) (IOT)	ICI Devoe Coatings Co. 4000 Dupont Circle Louisville, KY 40207 (800) 654-2616 www.devoecoatings.com
InterZinc 22HS (SB)		181 (SB) (IOT)	International Paint 6001 Antoine Drive Houston, TX 77091 (713) 682-1711 www.international-pc.com
Zinc Clad II (SB) Zinc Clad II HS (SB)		LO3 (SB) (IOT)	Sherwin-Williams Company 101 Prospect Avenue N.W. Cleveland, OH 44115 (800) 336-1110 www.sherwin-williams.com
Sigma 7551 US (SB)		5555 (SB) (IOT)	Sigma Coatings, USA P.O. Box 826 Harvey, LA 70059 (504) 347-4321 (800) 221-7978 www.sigmacoatings.com

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APPENDIX C

APPROVED PRODUCTS LIST FOR CHIP-FREE CLEAN ROOM PAINT

Primer	Intermediate	Topcoat	Manufacturer
Intershield PRA 150/151	Intershield PGA 750/75	Intershield (white)PRA 550/560 Interthane (other color)	International Paint Courtaulds Coatings 3489 N.W. 167th St. Miami, FL 33056 (305) 620-9220 www.international-pc.com
Chemglaze 9720	Aeroglaze M1433	Aeroglaze A276	Lord Corporation Chemical Products Division P.O. Box 10038 Erie, PA 16514 (814) 868-3611
Chemglaze 9720	Aeroglaze M1433	Aeroglaze K3202	
Chemglaze 9720	Aeroglaze M1433	Chemglaze P250*	

*This system should not be used in areas where static discharge may be a problem.

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APPENDIX D

COATING SPECIFICATION KEY ELEMENTS

1. SCOPE
2. APPLICABLE DOCUMENTS
3. SUBMITTALS
4. ENVIRONMENTAL PROTECTION
5. WASTE MANAGEMENT
6. SAFETY/PERSONNEL PROTECTION
7. MATERIALS
8. TOOLS AND EQUIPMENT
9. ENVIRONMENTAL CONDITIONS
10. WORK SCHEDULE
11. SURFACE PREPARATION
12. COATING SCHEDULE (see next page)
13. COATING MIXING AND APPLICATION
14. QUALITY CONTROL INSPECTION
15. REPORTING
16. FINAL ACCEPTANCE

APPENDIX D

COATING SCHEDULE

SURFACE DESCRIPTION (STEEL, CONCRETE, SURFACE A, B, ETC.)	APPROXIMATE SURFACE AREA SQUARE FEET	SURFACE PREPARATION TYPE	PROFILE RANGE	FIRST COAT			SECOND COAT			THIRD COAT		
				TYPE	WFT/ DFT	COLOR	TYPE	WFT/ DFT	COLOR	TYPE	WFT/ DFT	COLOR

APPENDIX E

COATING SYSTEM DAILY INSPECTION REPORT

COATING SYSTEM DAILY INSPECTION REPORT

DATE	REPORT NO.	PROJECT REF. NO.	PAGE OF
PROJECT DESCRIPTION	LOCATION	CONTRACTOR	
INSPECTING ORGANIZATION	INSPECTOR	APPLICABLE SPECIFICATION NO.	

I. DESCRIPTION OF ITEMS AND/OR AREAS

II .DESCRIPTION OF WORK PERFORMED/REMARKS

SAMPLE

III. PRE-WORK SURFACE CONDITION

- ☐ SUBSTRATE _____
- ☐ GENERAL DESCRIPTION _____
- ☐ PRIMED FOR SUBSEQUENT COATS: REFERENCE REPORT DATED _____
- ☐ PREVIOUSLY PAINTED. DEGREE OF CORROSION _____
- ☐ NEW METAL. DEGREE OF CORROSION _____

OBSERVED DEFECTS

		CORRECTED
OIL & GREASE	☐	☐
SHARP EDGES	☐	☐
WELD SPATTER	☐	☐
MOISTURE	☐	☐
LAMINATIONS	☐	☐
SOLUBLE SALTS	☐	☐
_____	☐	☐
_____	☐	☐

IV. ENVIRONMENTAL CONDITIONS

TIME	:	:	:	:
AIR TEMP °F				
WET BULB TEMP °F				
RELATIVE HUMIDITY	%	%	%	%
DEW POINT °F				
SURFACE TEMP MIN/MAX °F	/	/	/	/
WIND DIRECTION				
WIND SPEED (MPH)				

REMARKS

V. SURFACE PREPARATION

- ☐ SOLVENT CLEAN _____
- ☐ HAND TOOL _____
- ☐ POWER TOOL _____
- ☐ HP WATER WASH _____
- ☐ _____
- ☐ _____

☐ **ABRASIVE BLAST**

- ABRASIVE TYPE _____
- BLAST NOZZLE PRESSURE _____
- SURFACE PROFILE (AVG) _____
- DEGREE OF SURFACE CLEANLINESS _____
- COMPRESSED AIR CLEANLINESS _____

START TIME ____:____ STOP TIME ____:____
APPROXIMATE SQ. FT. PREPARED _____
REMARKS _____
PROFILE EFFECT ON TYPE ☐ 1 ☐ 2 GAUGE _____mils

VI. PRODUCT/MIXING

COATING PRODUCT TYPE	MANUFACTURER	CATALOG NO./NAME	COLOR

COATING BATCH NUMBERS
(A) _____
(B) _____
(C) _____

THINNING
THINNER _____
BATCH NO. _____
QTY ADDED _____
% BY VOLUME _____

CAULKING
TYPE _____
MFG _____
PRODUCT NO. _____
BATCH NO. _____

☐ **FIRST COAT**
☐ **SECOND COAT**
☐ **THIRD COAT**
☐ _____

TIME MIXED _____ : _____
KIT SIZE _____
GALS MIXED _____
CONTAINER CONDITION _____
PROPERLY STORED? _____
MIXING INSTRUMENT _____
MATERIAL TEMP °F _____

REMARKS _____

VII. COATING APPLICATION

METHOD OF APPLICATION _____
EQUIPMENT DESCRIPTION _____
ATOMIZING AIR CLEANLINESS _____
BRUSHED STRIPE COAT APPLIED TO HARD TO COAT AREAS? _____

START TIME ____:____ STOP TIME ____:____
APPROXIMATE SQ. FT. COATED _____
GALS COATING APPLIED _____
REMARKS _____
WET FILM THICKNESS (AVG) _____ MILS

VIII. POST CURE INSPECTION

☐ DFT WORKSHEET ATTACHED

	GAUGE READING	ACTUAL	DATE VERIFIED
SURFACE EFFECT ON GAUGE		N/A	
TOTAL DFT FROM PREVIOUS COATS (AVG)			
DFT THIS COAT (AVG)			

GENERAL APPEARANCE/REMARKS _____

IX.NON-CONFORMANCE ITEMS

DESCRIPTION OF DEFECT	DEFECTIVE ITEMS/AREAS	SPECIFICATION REF. SECTION	N.C.R. NO.	DATE CORRECTED

_____
INSPECTOR'S SIGNATURE DATE

KSC FORM 28-589 (REV. 8/95)

APPENDIX E (CONT'D)

COATING SYSTEM DAILY INSPECTION REPORT

COATING SYSTEM DAILY INSPECTION REPORT (CONTINUATION SHEET)

DATE	REPORT NO.	PROJECT REF. NO.	PAGE OF

TIME	REMARKS

INSPECTOR'S SIGNATURE DATE

KSC FORM 28-589A (3/91)

APPENDIX F

DRY FILM THICKNESS MEASUREMENT WORKSHEET

DRY FILM THICKNESS MEASUREMENT WORKSHEET

DATE	REPORT NO.	PROJECT REF. NO.	APPLICABLE SPECIFICATION	PAGE OF

ITEM/AREA DESCRIPTION	SPOT	SPOT READINGS 1	2	3	TOTAL	AVG (÷3)	% MIN
	A						
	B						
	C						
APPROX SQ. FT.	D						
	E						
							TOTAL
SPECIFIED DFT ____ - ____ MILS							AVG (÷5)
RANGE ACHIEVED ____ - ____ MILS							
REFERENCE REPORT DATED ____ FOR APPLICATION RECORD							

ITEM/AREA DESCRIPTION	SPOT	SPOT READINGS 1	2	3	TOTAL	AVG (÷3)	% MIN
	A						
	B						
	C						
APPROX SQ. FT.	D						
	E						
							TOTAL
SPECIFIED DFT ____ - ____ MILS							AVG (÷5)
RANGE ACHIEVED ____ - ____ MILS							
REFERENCE REPORT DATED ____ FOR APPLICATION RECORD							

ITEM/AREA DESCRIPTION	SPOT	SPOT READINGS 1	2	3	TOTAL	AVG (÷3)	% MIN
	A						
	B						
	C						
APPROX SQ. FT.	D						
	E						
							TOTAL
SPECIFIED DFT ____ - ____ MILS							AVG (÷5)
RANGE ACHIEVED ____ - ____ MILS							
REFERENCE REPORT DATED ____ FOR APPLICATION RECORD							

ITEM/AREA DESCRIPTION	SPOT	SPOT READINGS 1	2	3	TOTAL	AVG (÷3)	% MIN
	A						
	B						
	C						
APPROX SQ. FT.	D						
	E						
							TOTAL
SPECIFIED DFT ____ - ____ MILS							AVG (÷5)
RANGE ACHIEVED ____ - ____ MILS							
REFERENCE REPORT DATED ____ FOR APPLICATION RECORD							

REMARKS

TOTAL SQUARE FOOTAGE COATED (APPROX)	INSPECTOR'S SIGNATURE	DATE

KSC FORM 28-588 (3/91)

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER **NASA-STD-5008A**	2. DOCUMENT DATE **January 21, 2004**

3. DOCUMENT TITLE

Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)*	7. DATE SUBMITTED

8. PREPARING ACTIVITY

a. NAME **Director of Spaceport Engineering & Technology**	d. TELEPHONE *(Include Area Code)* **(321) 867-7770**

c. ADDRESS *(Include Zip Code)*

National Aeronautics and Space Administration, Mail Code: YA
Kennedy Space Center, FL 32899

APPENDIX A4

SSC-DWG NO. 54000-GP11

PACKAGING AND PRESERVATION OF CLEANED COMPONENTS

SYM	ZONE	DESCRIPTION	DATE	APPROVED
		REVISIONS		

	SIGNATURE	DATE
DRAWN	PENNY B. LADNIER	6/17/96
CHECKED	C. ADCOX	6/18/96
ENGINEER	D.P. DONNER	6/26/96
ISSUED	ISSUED/CEF	7/16/96
SUBMITTED	DOUG DIKE	6/27/96
NASA SAFETY		
APPROVED	S.D. McCARTY	7/1/96
USED ON	54000-D001	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

JOHN C. STENNIS SPACE CENTER
SSC, MS 39529-6000

PACKAGING & PRESERVATION OF CLEANED COMPONENTS

SIZE	DWG. NO.	REV.
B	54000-GP11	0

AUTHORITY FSR-10TCP10000 | SHEET 1 OF 5

CADD CONTROLLED DRAWING
CADD P/N:
SCD\54000\GP11R0\SHT1

1.0 SCOPE

THIS SPECIFICATION COVERS THE REQUIREMENTS FOR PACKAGING AND PRESERVATION OF COMPONENTS, PIECE PARTS AND SOFTGOODS THAT HAVE BEEN CLEANED TO A SPECIFIED CLEAN LEVEL.

2.0 DEFINITIONS

2.1 ACLAR – TRANSPARENT, COLORLESS, CONTAMINATE–FREE POLYCHLOROTRIFLUOROETHYLENE (ACLAR 22A) FILM WITH A NOMINAL .0015 TO .0030 INCH THICKNESS.

2.2 COMPONENT – AN ARTICLE WHICH IS NORMALLY A COMBINATION OF PARTS, SUB–ASSEMBLIES, OR ASSEMBLIES AND IS A SELF–CONTAINED ELEMENT WITHIN A COMPLETE OPERATING UNIT.

2.3 FEP TEFLON – TRANSPARENT, VIRGIN FLUORINATED ETHYLENE PROPYLENE FILM WITH NO COLORING OR ADDITIVES OF ANY DESCRIPTION, AND A NOMINAL 2 MIL (.002") THICKNESS.

2.4 ITEM – THE WORD ITEM(S) IS USED HEREIN, FOR BREVITY, TO INDICATE COMPONENTS, PARTS, EQUIPMENT OR ANY COMBINATION OF THESE TERMS.

2.5 MARKING – THE APPLICATION OR USE OF MARKS, SYMBOLS, AND ADDRESSES FOR PURPOSES OF GUIDING OR DIRECTING THE SAFE HANDLING AND SHIPPING OF PACKAGED ITEMS.

2.6 NYLON, ANTI–STATIC – TRANSPARENT POLYAMIDE (NYLON 6 OR EQUAL) FILM WITH A NOMINAL 2 MIL (.002") THICKNESS, CONTAINING AN ORGANIC, ANTI–STATIC AGENT THROUGHOUT THE FILM.

2.7 PACKAGING – APPLICATION OR USE OF ADEQUATE PROTECTIVE MEASURES TO PREVENT DAMAGE FROM PHYSICAL HAZARDS OR CONDITIONS INCLUDING, AS APPLICABLE, WRAPPING FOR PROTECTION FROM PHYSICAL DANGER, CUSHIONING, INTERIOR CONTAINERS, AND COMPLETE IDENTIFICATION MARKING, UP TO BUT NOT INCLUDING THE EXTERIOR SHIPPING CONTAINER EXCEPT WHEN A UNIT CONTAINER IS ALSO THE SHIPPING CONTAINER.

2.7.1 PRIMARY (OR INTIMATE) PACKAGING – MATERIAL USED TO COVER AND PROTECT PRECISION CLEANED ITEMS.

2.7.2 SECONDARY (OR ENVIRONMENTAL) PACKAGING – MATERIAL USED TO PROVIDE PROTECTION TO THE PRIMARY PACKAGING AND AS AN ADDITIONAL BARRIER TO PROTECT THE PRECISION CLEANED ITEM.

2.8 PACKING – THE FINAL PLACEMENT OF ITEMS OR PACKAGES IN EXTERIOR SHIPPING CONTAINERS OR OTHER MEDIA INCLUDING THE NECESSARY BLOCKING, BRACING OR CUSHIONING, WEATHERPROOFING, AND EXTERIOR STRAPPING.

2.9 PART – THE LEAST SUBDIVISION OF A COMPONENT: A PIECE THAT FUNCTIONS IN INTERACTION WITH OTHER ELEMENTS OF A COMPONENT, BUT IS ITSELF NOT ORDINARILY SUBJECT TO DISASSEMBLY.

2.10 POLYETHYLENE, ANTI–STATIC – PINK, PLASTIC FILM WITH A NOMINAL 6 MIL (.006") THICKNESS, CONTAINING AN ORGANIC, ANTI–STATIC AGENT THROUGHOUT THE FILM.

2.11 PRECISION CLEAN – FOR THE PURPOSES OF THIS PROCEDURE, A HIGH DEGREE OF CLEANLINESS WHICH HAS BEEN VERIFIED TO MEET THE REQUIREMENTS OF A SPECIFIED CLEAN LEVEL (e.g., SSC STANDARD 79–001 LEVEL 1XX, KSC–123 LEVEL VC–UV).

2.12 PRESERVATION – APPLICATION OR USE OF ADEQUATE PROTECTIVE MEASURES TO PREVENT DETERIORATION FROM ENVIRONMENTAL HAZARDS OR CONDITIONS INCLUDING, AS APPLICABLE, THE USE OF APPROPRIATE CLEANING AND DRYING METHODS, PRESERVATIVES, AND WRAPPING FOR PROTECTION FROM CHEMICAL DANGER.

2.13 SHIPPING AND HANDLING – THE ACT OF TRANSPORTING AND HANDLING PACKAGED AND PACKED ITEMS FROM ONE PLACE TO ANOTHER.

2.14 SIGNIFICANT SURFACES – ANY SURFACE OF AN ITEM THAT CONTACTS THE SERVICE MEDIA AND/OR IS SUBJECT TO CLEAN LEVEL VERIFICATION. SIGNIFICANT SURFACES ARE SUBJECT TO THE PACKAGING AND PRESERVATION REQUIREMENTS OF THIS SPECIFICATION.

2.15 TAPE – A WATERPROOF, PRESSURE–SENSITIVE, ADHESIVE STRIP WITH BACKING MATERIAL MADE OF PLASTIC FILM WHICH MAY BE EITHER COLORED OR TRANSPARENT AND IS USED FOR PACKAGING AND SEALING. (TAPE WITH WOVEN FABRIC CLOTH BACKING MATERIAL MAY BE USED TO SECURE LEVEL 3 COMPONENT PACKAGING, AND SECONDARY PACKAGING ONLY.)

3.0 PACKAGING AND PRESERVATION

NOTE

SELECTION OF THE PRIMARY PACKAGING FILM IS BASED ON THE INTENDED SERVICE MEDIA OF THE ITEM. REFERENCE TABLE 1 FOR MATERIAL GUIDE WHEN SELECTING/VERIFYING PACKAGING MATERIAL.

TABLE 1
REQUIRED PACKAGING FOR SPECIFIC MEDIA/CLEANLINESS LEVEL

MEDIA/CLEANLINESS LEVEL	PACKAGING REQUIREMENT
ALL PRECISION CLEANED ITEMS FOR LO/GO SERVICE MEDIA.	• PRIMARY SEAL (OR BAG) OF ACLAR/FEP TEFLON FILM • SECONDARY SEAL (OR BAG) OF POLYETHYLENE FILM
ALL PRECISION CLEANED ITEMS FOR WHICH NO SERVICE MEDIA IS SPECIFIED.	
ALL PRECISION CLEANED ITEMS FOR SERVICE MEDIA OTHER THAN LO/GO [EXCEPT LEVEL 3 COMPONENTS (VISUALLY CLEAN)].	• PRIMARY SEAL (OR BAG) OF NYLON FILM • SECONDARY SEAL (OR BAG) OF POLYETHYLENE FILM
LEVEL 3 (VISUALLY CLEAN) ITEMS.	• PRIMARY SEAL (OR BAG) OF POLYETHYLENE FILM • SECONDARY SEAL NOT REQUIRED

3.1 GENERAL NOTES

3.1.1 THE OXYGEN COMPATIBLE PRIMARY SEALING MATERIAL SPECIFIED IN THIS PROCEDURE IS ACLAR OR FEP TEFLON FILM, AND IS TO BE USED ON ALL LO/GO ITEMS. ACLAR OR FEP TEFLON MAY ALSO BE USED AS THE PRIMARY SEALING MATERIAL FOR ALL OTHER APPLICATIONS, HOWEVER DUE TO COST CONSIDERATIONS AND THE TENDENCY FOR THE FILM TO SLOUGH, THEY SHOULD ONLY BE USED WHEN ABSOLUTELY NECESSARY.

3.1.2 ACLAR OR FEP TEFLON FILM SHALL BE USED AS THE PRIMARY SEALING MATERIAL ON PRECISION CLEANED ITEMS FOR WHICH NO SERVICE MEDIA IS SPECIFIED.

3.1.3 ANTI–STATIC NYLON SHALL BE THE PREFERRED PRIMARY PACKAGING MATERIAL ON ALL OTHER (NON–LO/GO) PRECISION CLEANED ITEMS, WITH THE EXCEPTION OF LEVEL 3 (VISUALLY CLEAN) ITEMS.

3.1.4 METAL CAPS, PLUGS, HUBS, ETC, (STAINLESS STEEL FOR STAINLESS COMPONENTS AND CARBON STEEL FOR CARBON COMPONENTS), MAY BE USED IN LIEU OF ACLAR/FEP TEFLON OR NYLON FILMS TO PROTECT SIGNIFICANT SURFACES OF PRECISION CLEANED ITEMS. WHEN USING METAL CLOSURES AS PRIMARY PACKAGING, NO SECONDARY PACKAGING MATERIAL IS REQUIRED.

3.1.5 ALL PRIMARY PACKAGING MATERIALS WILL BE CERTIFIED AS CLEAN AS, OR CLEANER THAN, THE ITEM IT IS TO PROTECT.

3.1.6 THE SECONDARY (OR ENVIRONMENTAL) PACKAGING SPECIFIED IN THIS PROCEDURE IS ANTI–STATIC POLYETHYLENE. THIS SECONDARY MATERIAL PROVIDES PHYSICAL PROTECTION ONLY. ALTHOUGH IT DOES NOT REQUIRE THE CLEANLINESS CERTIFICATION OF THE PRIMARY PACKAGING MATERIAL, THE POLYETHYLENE MATERIAL SHALL BE VISUALLY CLEAN.

3.1.7 DUE TO THE HIGH WATER VAPOR TRANSMISSION RATE (W.V.T.R.) OF NYLON FILMS, NYLON IS TO BE USED AS A PRIMARY COVER ONLY, AND THIS IS PERMITTED ONLY WHEN IT IS USED IN CONJUNCTION WITH A SECONDARY COVER OF POLYETHYLENE PACKAGING MATERIAL.

3.1.8 ADEQUATE OVER–PACKAGING OF ITEMS SHALL BE PROVIDED AS REQUIRED, IN ADDITION TO THE PACKAGING HEREINAFTER SPECIFIED, TO PROTECT THE ITEMS DURING HANDLING, SHIPPING AND STORAGE.

3.1.9 PACKAGING OF SOFT GOODS SHALL NOT CONSTRAIN THE PART OR IN ANY WAY IMPEDE THE PART'S ORIGINAL CONFIGURATION. THE PACKAGING SHALL BE SUFFICIENTLY OVERSIZED TO ALLOW FOR FREE MOVEMENT WITHIN THE PRIMARY SEALING MATERIAL.

3.1.10 AN ITEM FOR WHICH NYLON IS USED AS THE PRIMARY COVER SHALL HAVE ITS CLEANING CERTIFICATION CARD STAMPED "NOT PACKAGED FOR OXYGEN SERVICE".

3.2 FILTER ELEMENTS

3.2.1 DUE TO THE FRAGILE CONSTRUCTION AND HIGH COST OF STAINLESS STEEL FILTER ELEMENTS, SPECIAL CARE MUST BE APPLIED IN PACKAGING AND TRANSPORT. THE FOLLOWING NOTICES MUST BE APPLIED BETWEEN THE PRIMARY AND SECONDARY PACKAGING: "THIS END UP", "FRAGILE", "HANDLE WITH CARE".

3.2.2 FILTER ELEMENTS RECEIVED IN WOODEN CONTAINERS SHALL BE DOUBLE BAGGED PER STEP 3.2.1 AND RETURNED IN THE SAME WOODEN CONTAINERS. SMALL FILTER ELEMENTS SHALL BE DOUBLE BAGGED PER STEP 3.2.1 AND PLACED IN PASTEBOARD BOXES OR OTHER SUITABLE RIGID CONTAINERS, WITH ADEQUATE PADDING TO PREVENT FILTER DAMAGE. THE EXTERIOR OF THE CONTAINER SHALL BE LABELED "THIS END UP", "FRAGILE", "HANDLE WITH CARE".

3.2.3 THE CLEANING CERTIFICATION CARD SHALL BE SEALED IN A POLYETHYLENE BAG, AND ATTACHED TO THE OUTSIDE CONTAINER.

3.3 LO/GO COMPONENTS, PIECE PARTS, AND SOFTGOODS

3.3.1 COMPONENTS

3.3.1.1 COMPONENTS SHALL HAVE ALL PORTS AND OTHER SIGNIFICANT SURFACES PROTECTED BY COVERING WITH ONE LAYER OF CLEAN ACLAR OR FEP TEFLON FILM. SECURE AND REINFORCE THE ACLAR OR FEP TEFLON FILM WITH TAPE.

3.3.1.2A FOR SMALL COMPONENTS WHOSE SIZE WILL PERMIT PLACING THE ENTIRE COMPONENT IN A POLYETHYLENE BAG, COVER THE ACLAR, OR FEP TEFLON FILM BY PLACING THE ENTIRE COMPONENT IN A POLYETHYLENE BAG. THE CLEANING CERTIFICATION CARD SHALL BE PLACED IN THE POLYETHYLENE BAG WITH THE COMPONENT PRIOR TO SEALING.

3.3.1.2B FOR COMPONENTS WHOSE SIZE WILL NOT PERMIT PLACING THE ENTIRE COMPONENT IN A POLYETHYLENE BAG, COVER THE ACLAR, OR FEP TEFLON FILM WITH ONE LAYER OF POLYETHYLENE AND SECURE WITH TAPE. THE CLEANING CERTIFICATION CARD SHALL BE SEALED IN A POLYETHYLENE ENVELOPE AND ATTACHED TO THE COMPONENT.

3.3.1.3 OPENINGS (1–1/2" AND LARGER) SHALL HAVE AN ADDED COVER OF METAL OR HARDBOARD OVER THE SECONDARY PACKAGING TO PREVENT DAMAGE. SECURE HARD COVER WITH TAPE.

3.3.2 SMALL PARTS AND SOFTGOODS

NOTE

SMALL PARTS AND SOFTGOODS FOR WHICH NO SERVICE MEDIA IS SPECIFIED SHALL BE PACKAGED PER STEP 3.3.2.1.

3.3.2.1 SMALL PARTS AND SOFTGOODS SHALL BE SEALED IN ONE ACLAR OR FEP TEFLON BAG AND PLACED INTO ONE POLYETHYLENE BAG. THE CLEANING CERTIFICATION CARD SHALL BE PLACED BETWEEN THE PRIMARY AND SECONDARY BAG PRIOR TO SEALING. PURGING OR EVACUATION OF OVER-PACKAGING SHALL NOT BE REQUIRED.

3.3.3 VESSEL OR TANK PORTS

3.3.3.1 VESSEL OR TANK PORTS SHALL BE SEALED BY APPLYING ONE LAYER OF CLEAN ACLAR OR FEP TEFLON FILM OVER THE PORTS AND SECURING WITH TAPE. THE ACLAR OR FEP TEFLON SHALL BE TAPED ON THE OUTSIDE AREA OF THE PORT, ABOVE (OR BEHIND) THE THREADED AREA. COVER THE ACLAR OR FEP TEFLON WITH POLYETHYLENE, AND SECURE WITH TAPE.

3.3.3.2 SEAL THE CLEANING CERTIFICATION CARD INSIDE A POLYETHYLENE ENVELOPE AND ATTACH IT TO THE VESSEL OR TANK.

3.4 ALL PRECISION CLEANED COMPONENTS, PIECE PART AND SOFTGOODS, EXCEPT LEVEL 3 AND LO/GO ITEMS

3.4.1 COMPONENTS

3.4.1.1 COMPONENTS SHALL HAVE ALL PORTS AND OTHER SIGNIFICANT SURFACES PROTECTED BY COVERING WITH ONE LAYER OF CLEAN NYLON FILM. SECURE AND REINFORCE THE NYLON FILM WITH TAPE.

3.4.1.2A FOR SMALL COMPONENTS WHOSE SIZE WILL PERMIT PLACING THE ENTIRE COMPONENT IN A POLYETHYLENE BAG, COVER THE NYLON FILM BY PLACING THE ENTIRE COMPONENT IN A POLYETHYLENE BAG. THE CLEANING CERTIFICATION CARD SHALL BE STAMPED "NOT PACKAGED FOR OXYGEN SERVICE" AND PLACED IN THE POLYETHYLENE BAG WITH THE COMPONENT PRIOR TO SEALING.

3.4.1.2B FOR COMPONENTS WHOSE SIZE WILL NOT PERMIT PLACING THE ENTIRE COMPONENT IN A POLYETHYLENE BAG, COVER THE NYLON FILM WITH ONE LAYER OF POLYETHYLENE AND SECURE WITH TAPE. THE CLEANING CERTIFICATION CARD SHALL BE STAMPED "NOT PACKAGED FOR OXYGEN SERVICE", SEALED IN A POLYETHYLENE ENVELOPE AND ATTACHED TO THE COMPONENT.

3.4.1.3 OPENINGS (1-1/2" OR LARGER) SHALL HAVE AN ADDED COVER OF METAL OR HARDBOARD OVER THE SECONDARY PACKAGING TO PREVENT DAMAGE. SECURE HARD COVER WITH TAPE.

3.4.2 SMALL PARTS AND SOFTGOODS

NOTE

SMALL PARTS AND SOFTGOODS FOR WHICH NO SERVICE MEDIA IS SPECIFIED SHALL BE PACKAGED PER STEP 3.3.2.1

3.4.2.1 SMALL PARTS AND SOFTGOODS SHALL BE SEALED IN ONE NYLON BAG AND PLACED INTO ONE POLYETHYLENE BAG. THE CLEANING CERTIFICATION CARD SHALL BE STAMPED "NOT PACKAGED FOR OXYGEN SERVICE" AND PLACED BETWEEN THE PRIMARY AND SECONDARY BAG PRIOR TO SEALING. PURGING OR EVACUATION OF OVER-PACKAGING SHALL NOT BE REQUIRED.

3.4.3 VESSEL OR TANK PORTS

3.4.3.1 VESSEL OR TANK PORTS SHALL BE SEALED BY APPLYING ONE LAYER OF CLEAN NYLON FILM OVER THE PORTS AND SECURING WITH TAPE. THE NYLON SHALL BE TAPED ON THE OUTSIDE AREA OF THE PORT, ABOVE (OR BEHIND) THE THREADED AREA. COVER THE NYLON WITH POLYETHYLENE, AND SECURE WITH TAPE.

3.4.3.2 STAMP THE CLEANING CERTIFICATION CARD "NOT PACKAGED FOR OXYGEN SERVICE", SEAL IT INSIDE A POLYETHYLENE ENVELOPE AND ATTACH IT TO THE VESSEL OR TANK.

3.5 LEVEL 3 (VISUALLY CLEAN) COMPONENTS, PIECE PARTS AND SOFTGOODS

3.5.1 FOR ITEMS WHOSE SIZE WILL NOT PERMIT PLACING THE ENTIRE ITEM IN A POLYETHYLENE BAG, COVER ALL PORTS AND OTHER SIGNIFICANT SURFACES WITH ONE LAYER OF POLYETHYLENE FILM AND SECURE WITH TAPE. THE CLEANING CERTIFICATION CARD SHALL BE SEALED IN A POLYETHYLENE ENVELOPE AND ATTACHED TO THE ITEM.

3.5.2 FOR ITEMS WHOSE SIZE WILL PERMIT PLACING THE ENTIRE ITEM IN A POLYETHYLENE BAG, PLACE THE ENTIRE LEVEL 3 ITEM IN A POLYETHYLENE BAG. THE CLEANING CERTIFICATION CARD SHALL BE SEALED INSIDE THE POLYETHYLENE BAG WITH THE COMPONENT.

3.6 SPARE CARBON STEEL COMPONENTS

3.6.1 CLEANED SMALL CARBON STEEL COMPONENTS (LESS THAN 1-1/2") THAT ARE TO BE WAREHOUSED FOR INDEFINITE PERIODS OF TIME SHALL HAVE, IN ADDITION TO THE PROPER PACKAGING, A SUITABLE BAGGED DESICCANT AND A HUMIDITY CARD INDICATOR (STOCK NO. 6685-00-752-8240G OR EQUIVALENT) PLACED INSIDE THE OUTER POLYETHYLENE FILM COVER OR BAG PRIOR TO SEALING.

3.6.2 CLEANED CARBON STEEL COMPONENTS (1-1/2" OR LARGER) REQUIRE AN INERT GAS BLANKET FOR INDEFINITE WAREHOUSE STORAGE. USE THE FOLLOWING METHOD FOR PACKAGING.

3.6.2.1 INSTALL A CERTIFIED CLEAN HUB AND SEAL RING, OR FLANGE WITH GASKET (AS REQUIRED) WITH A SCHRAEDER VALVE ON ONE PORT OF THE COMPONENT.

3.6.2.2 INSTALL A CERTIFIED CLEAN HUB AND SEAL RING, OR FLANGE AND GASKET (AS REQUIRED) TAPPED FOR A 0–60 (MAXIMUM) PSIG PRESSURE GAUGE ON THE OPPOSITE PORT OF THE COMPONENT.

3.6.2.3 PURGE THROUGH THE SCHRAEDER VALVE WITH GN APPROXIMATELY THREE MINUTES TO EVACUATE ALL AIR. REDUCE GN PURGE TO THE MINIMUM PRESSURE REQUIRED TO MAINTAIN POSITIVE PRESSURE ON THE COMPONENT.

3.6.2.4 WHILE STILL MAINTAINING POSITIVE PURGE PRESSURE, INSTALL THE PRESSURE GAUGE. INCREASE GN PRESSURE IN COMPONENT TO 20 ±5 PSIG. RECORD STABILIZED PRESSURE READING IN "REMARKS" SECTION OF THE CLEANING CERTIFICATION CARD.

3.6.2.5 VERIFY NO PRESSURE LOSS AFTER A MINIMUM 12 HOUR WAITING PERIOD TO INSURE PRESERVATION OF THE COMPONENT.

3.6.2.6 THE CLEANING CERTIFICATION CARD SHALL BE SEALED IN A POLYETHYLENE ENVELOPE AND ATTACHED TO THE COMPONENT.

APPENDIX A5

SSTD 8070-0126

TUBING SYSTEMS FOR AEROSPACE SYSTEMS, SPECIAL TEST EQUIPMENT AND AEROSPACE HARDWARE

SSTD-8070-0126
Revision Basic
January 2007

National Aeronautics and
Space Administration

John C. Stennis Space Center
Stennis Space Center, MS 39529-6000

JOHN C. STENNIS SPACE CENTER

TUBING SYSTEMS FOR FACILITY SYSTEMS, SPECIAL TEST EQUIPMENT, AND AEROSPACE HARDWARE

Original signed by

Randall Canady
NASA SSC Center Operations
Project Management Division

Bartt Hebert
NASA SSC Engineering & Science
Directorate

Issued by

Issued CEF 02/09/07
Central Engineering Files

Document History Log

Revision	Date	Originators/ Phone	Description
Basic	01/12/07	Bill St. Cyr 8-1134 Larry DeQuay 8-1956	Initial Release; supersedes SSC STD 47-220. New document number and format per SPR 1400.1, *John C. Stennis Space Center Document Preparation, Numbering, and Management Guidelines and Standards*. Added/specified sections per SPR 1400.1.

Table of Contents

1.0 PURPOSE

This standard provides the design requirements and operating limits for tubing and tube fittings at Stennis Space Center (SSC) for facility and special test equipment (STE). This standard may be used for aerospace hardware tubing systems where deemed appropriate. These provisions are intended to assure system reliability, safety, and cost effective interchangeability between tube system hardware and components.

2.0 APPLICABILITY

This standard covers all facility and STE tubing systems erected/assembled with the following:

a. tubing with 37° flared ends;
b. tubing with flareless ends connected to Swagelok® type flareless tube fitting end connections;
c. tubing with coned-and- (left hand) threaded ends;
d. tube fittings with 37° flared, Swagelok® type flareless, NPT, and coned-and- (left hand) threaded end connections;
e. fittings with SAE (formerly AN/MS) straight internal (female) thread patterned boss connections; and,
f. fittings with SAE (formerly AN/MS) straight thread external (male) thread patterned end connections that connect to boss connections stated in e. above.

Tube fittings that have end connections other than those listed above are not governed by and are not permitted under this standard.

Pressure and temperature ratings are specified for tubes with outside diameters between 0.250" (6.35 mm) and 2.00" (50.8 mm) with wall thicknesses of 0.028" (0.71 mm) and over. Other diameters and wall thicknesses may be used provided they meet the minimum requirements of ANSI/ASME B31.3.

Piping supplied per Nominal Pipe Size (NPS) (e.g., 8" Schedule 5S, 2" Schedule 40, etc.) is not governed by this standard. However, pipe that is threaded and connected to NPT fitting connections may reduce the pressure rating of the connection below those stated in this standard; details are provided in Section 4.2.

Freon®, Heating, Ventilating and Air Conditioning (HVAC), and low pressure (less that 150-psig) water tubing systems are not governed by this standard. Facility compressed air systems operating at 150 psig or less and vacuum systems are not governed by this standard. Refer to International Association of Plumbing and Mechanical Officials (IAPMO), Uniform Plumbing Code (UPC), American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) standards, and applicable piping system specifications referenced in SSTD 8070-

0043-PIPE for design, fabrication, erection, construction, testing, and cleaning requirements for these systems.

Existing designs are not required to comply with this standard except that any modifications or changes to the existing designs shall meet the minimum requirements of this standard.

3.0 REFERENCED DOCUMENTS

ANSI/AIAA G-095-2004, *Guide to Safety of Hydrogen and Hydrogen Systems*

ANSI/ASME B1.20.1, *Pipe Threads, General Purpose, (Inch)*

ANSI/ASME B31.3, *Process Piping*

ANSI/ASME *Boiler & Pressure Vessel Code*, Sections V and VIII

ASME B46.1, *Surface Texture (Surface Roughness, Waviness, and Lay)*

ASTM A213/A213M, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*

ASTM A632, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small Diameter) for General Service*

49 CFR 195, *Code of Federal Regulations, Title 49, Part 195, Transportation of Hazardous Liquids by Pipeline*

MIL-T-8504, *Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded*

MIL-T-8808, *Tubing, Steel, Corrosion-Resistant (18-8 Stabilized) Aircraft Hydraulic Quality*

MS28777, *Washer, Flat, Aircraft Hydraulic Backup* (Inactive for New Design)

MSS SP-6, *Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings*

NASA/MSFC-STD-506, *Standard Materials and Processes Control*

NASA-STD-6001, *Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion*

SAE AIR310, *Fittings, Catalog of Flared, Flareless, Pipe Threaded, Port, Hose, and Other Type Tube Standard Connectors*

SAE AMS 5556, *Steel, Corrosion and Heat Resistant, Seamless or Welded Hydraulic Tubing, 18Cr – 11Ni – 0.07 Cb (SAE 30347), Solution Heat Treated* (UNS S34700)

SAE AMS 5566, *Steel, Corrosion Resistant, Seamless or Welded Hydraulic Tubing, 19Cr – 10Ni (SAE 30304), High Pressure, Cold Drawn* (UNS S30400)

SAE AMS 5567, *Steel, Corrosion Resistant, Seamless or Welded Hydraulic Tubing, 19Cr – 10Ni (SAE 30304) Solution Heat Treated* (UNS S30400)

SAE AMS-T-6845, *Tubing, Steel, Corrosion-Resistant (S30400), Aerospace Vehicle Hydraulic System 1/8 Hard Condition*

SAE AS 758, *Fittings – Installation in Straight Threaded Boss*

SAE AS 930, *Fitting End, Straight Thread, Boss Connection, Design Standard*

SAE AS 1098, *Fitting End, Flared Tube, for Seal Ring, Standard Dimensions for, Design Standard* (Formerly KC105)

SAE AS 1099, *Fitting End, Bulkhead Flared Tube, for Seal Ring, Standard Dimensions for, Design Standard* (Formerly KC104)

SAE AS 1941, *Fitting End, Straight Thread, High Pressure, Boss Connection, Design Standard*

SAE AS 4320, *Fitting End, Straight Thread, Standard Dimensions for, Design Standard*

SAE AS 4330, *Tubing, Flared, Standard Dimensions for, Design Standard- FSC 4730* (Formerly MS33584)

SAE AS 4395, *Fitting End, Flared Tube Connection, Design Standard* (Formerly MS24385 and MS33656)

SAE AS 4396, *Fitting End, Bulkhead, Flared Tube Connection, Design Standard* (Formerly MS24386 and MS33657)

SAE AS 4841, *Fittings, 37° Flared, Fluid Connection* (Formerly MIL-F-5509 in part)

SAE AS 4842, *Fittings and Bosses, Pipe Threaded, Fluid Connection* (Formerly MIL-F-5509 in part)

SAE AS 4842/1, *Fittings, 37° Flared to Pipe Threaded, Fluid Connection*

SAE AS 4842/2, *Fittings, Flareless to Pipe Threaded, Fluid Connection*

SAE AS 4875, *Fittings, Straight Threaded Boss or Flanged, Fluid Connection* (Formerly MIL-F-5509 in part)

SAE AS 4875/1, *Fittings, Straight Thread Boss or Flanged to 37° Flared, Fluid Connection*

SAE AS 5179, *Nut, Fitting, Port* (Formerly AN6289)

SAE AS 5201, *Fitting End, External Taper Pipe Thread, Design Standard* (Formerly AND100775 and MS33677)

SAE AS 5202, *Port or Fitting End, Internal Straight Thread, Design Standard* (Formerly MS33649C and SAE AS33649)

SAE AS 8791, *(R) Hydraulic and Pneumatic Retainers (Back-Up Rings), Polytetrafluoroethylene (PTFE) Resin* (Replaces MS28774)

SAE AS 28778, *Packing, Preformed, Straight Thread Tube Fitting Boss - FSC 5331* (Replaced MS28778)

SAE AS 33583, *Tubing End Double Flare, Standard Dimensions for - FSC 4730* (Formerly MS33583)

SAE AS 71051, *Pipe Threads, Taper, Aeronautical National Form, Symbol ANPT – Design and Inspection Standard*

SSC Standard 34-004, *Classes of Welding Inspection*

SSC Standard 79-010, *SSC Requirements for Materials Used In LOX/GOX Service*

SSC Drawing No. 54000-GM30, *Specification for Materials Used In LOX and GOX Service Exempt from Batch Test Requirements*

SSC SOI-8080-0016, *Material and Process Control for Propulsion Test Facilities and Systems*

SSTD-8070-0007-CONFIG, *Variance and Alternate Standard Request*

SSTD-8070-0043-PIPE, *Facility Piping Systems at Stennis Space Center*

USAF TO 00-25-223, *Integrated Pressure Systems and Components (Portable and Installed)*

4.0 REQUIREMENTS

All tubing shall be seamless; tubing with seam welds is not permitted.

All metallic and non-metallic materials, including lubricating oils and greases used to assemble tube systems, shall be compatible with the service media and must conform to material traceability and service media compatibility requirements delineated in other SSC and NASA requirements documents. For example, SSC Standard 79-010, SSC Specification Control Drawing (SCD) 54000-GM30, and NASA-STD-6001 govern non-metal material compatibility requirements for oxygen and other oxidizer fluid (i.e. fluorine) systems. Guidance regarding hydrogen embrittlement resistant materials is provided in NASA/MSFC Std. 506 and ANSI/AIAA G-095.

Installation of fluid tube systems shall conform to tube routing and external system support spacing requirements of USAF TO 00-25-223. Tables 1A and 1B provide recommended maximum span distance between external supports for tubing systems. Contact between dissimilar metals shall be prevented or provisions to prevent galvanic corrosion shall be used in all tubing system installations. A neat and orderly routing of tube systems, where multiple criss-crossing of tube runs is avoided, is required. All connections and components shall be accessible for inspection, disassembly and removal.

TABLE 1A
Spacing of External Supports for Tubing Systems with Tubing and Fittings Specified by Sections 4.1 and 4.2

Nominal Tube OD (inches)	Maximum Span (feet)		
	Stainless & Carbon Steel	Aluminum & Titanium Alloys	Bronze & Copper Alloys
1/8 to ½, excl.	4	4	3
½ to 1, excl.	6	5	4
1 to 2	9	7	5

TABLE 1B
Spacing of External Supports for Tubing Systems with (Coned-and-Threaded) Tubing and Fittings Specified by Sections 4.3 and 4.4

Nominal Tube OD (inches)	Service Fluid Type	Maximum Allowable Working Pressure (psig)	Maximum Spacing of Supports or Anchors (feet)
¼ to 1	Gaseous & Cryogenic	6,000 to 10,000	4
¼ to 1	Gaseous & Cryogenic	Above 10,000	3
¼ to 1, incl.	Hydraulic *	6,000 to 30,000	4
* Note: Liquid Service Fluid with Minimum Service Temperatures above -50°F			

Tube system routing shall incorporate expansion loops and offsets such that the yield stress is not exceeded under the combined stresses from internal fluid pressure, thermal expansion or contraction, dead weight loads, external interfaces, and wind loads.

In selected cases, a detailed stress analysis in accordance with ANSI/ASME B31.3 will be required to assure that yield stresses are not exceeded for system pressure retaining materials.

4.1 Tubing for Fluid Pressure Less Than 10,000 psig

All tubing for fluid pressure less than 10,000 psig shall meet the requirements of one of the material specifications and grades listed in Table 2. Planned use of any other material or specification requires either a Variance for facility fluid systems or a Materials Usage Agreement (MUA) for STE, prepared and approved in accordance with SSTD-8070-0007-CONFIG or SSC SOI-8080-0016, respectively.

Design of tube pressure systems for fluid pressures less than 10,000 psig shall meet, as a minimum, the requirements of ANSI/ASME B31.3. Hydrostatic and pneumatic pressure test requirements are given in sections 4.7 and 4.8. In some situations, or to meet specific customer requirements, requirements that are more stringent with higher factors of safety may be required.

Table 3A lists the maximum allowable working pressure for various tube sizes based on the minimum wall thicknesses permitted for ASTM A269 tubing and the requirements of ANSI/ASME B31.3. Refer to ANSI/ASME B31.3 for calculation of the maximum allowed pressure or minimum wall thickness required for other diameters and wall thicknesses. These pressure ratings also apply to tube bends provided the minimum wall thickness is maintained after bending.

CAUTION

Although the tubing may be rated to pressures as described in Table 3A, system pressure ratings may be limited to lower pressures based on tube fittings or other system components. The lowest pressure rating of any system component is the maximum allowed operating pressure for the tubing system.

Table 3B lists boss connection pressure ratings.

Table 3C lists increased pressure ratings for NPT end connections meeting additional requirements.

Table 3D lists required thread engagement length for NPT end connections.

All tubing dimensional tolerances for OD (Outside Diameter) and wall thickness, prior to swaging or flaring, shall conform to those shown in Table 4.
Flared tube ends: Tube ends to be used with flared fittings shall be flared to conform to the geometric requirements of SAE AS4330 or SAE AS33583.

TABLE 2
Material Specifications for Austenitic Stainless Steel Tubes

Specification	Diameter Range, in [mm]	Thickness Range, in [mm]	Grade or Type	SMYS (ksi/MPa)	SMTS (ksi/MPa)	B31.3 Allowable Stress*
ASTM A269 (Seamless only)	0.25 I.D. and over [6.35 I.D.]	0.020 and over [0.508]	TP 304, TP 316, TP 321, TP 347	30/207	75/517	20.0 ksi 138 MPa
			TP304L, P316L	25/172	70/483	16.7 ksi 115 MPa
ASME SA213 ASTM A213	0.125 ID to 5.00 O.D. [3.175 to 127]	0.015 to 0.50 [0.381 to 12.7]	TP 304, TP 316, TP 321, TP 347	30/207	75/517	20.0 ksi 138 MPa
			TP304L, P316L	25/172	70/483	16.7 ksi 115 MPa
ASTM A632 (Seamless only)	0.050 to < 0.5 O.D. [1.27 to <12.7]	0.005 to <0.065 [0.127 to <1.651]	TP 304, TP 316, TP 321, TP 347	30/207	75/517	20.0 ksi 138 MPa
			TP304L, P316L	25/172	70/483	16.7 ksi 115 MPa
AMS 5556** (Type 1 only)	All diameters and wall thickness		347	30/207	75/517 Max. spec	20.0 kPi 138 MPa
AMS 5557** (Type 1 only)	All diameters and wall thickness		321	30/207	75/517 Max. spec	20.0 ksi 138 MPa
AMS 5566** (Type 1 only)	All diameters and wall thickness		304	75/517	105/724 Max. spec	40.0 ksi 276 MPa
AMS 5567** (Type 1 only)	All diameters and wall thickness		304	30/207	100/689 Max. spec	20.0 ksi 138 MPa
AMS-T-6845 (Type 1 only)	0.25 O.D. and over [6.35 O.D.]	All	304	75-110/ 517-759	105-140/ 724-965	35.0-46.7 ksi 241-322 MPa
MIL-T-8504 # (Type 1 only)	All diameters and wall thickness		304	30/207	75/517 Max. spec	20.0 ksi 138 MPa
MIL-T-8808 # (Type 1 only)	All diameters and wall thickness		321, 347	30/207	75/517 Max. spec	20.0 ksi 138 MPa

Notes: * to 150°F per ANSI/ASME B31.3, based on lesser of 1/3 SMTS and 2/3 SMYS. (Only ASTM A269 is B31.3 listed.)
** Hydraulic Tubing
# Specification is now inactive for new design, except for replacement purposes, but tubing that was previously manufactured under this specification can be used for existing and new systems when available

TABLE 3A

Maximum Allowable Working Pressures, Stainless Steel Tubing and Tube Fittings with Flared and NPT End Connections; Tubing is in accordance with ANSI/ASME B31.3 (AISI Types 304, 316, 321 and 347).

Nominal Tube Wall Thickness	NOMINAL TUBE OUTSIDE DIAMETER (OD)								
	0.250	**0.375**	**0.500**	**0.750**	**1.000**	**1.250**	**1.500**	**1.750**	**2.000**
0.025	3571	2342	1848	1221	911	727	603	517	452
0.028	4035	2637	2079	1372	1022	816	677	579	507
0.032	4665	3037	2390	1574	1172	934	775	663	580
0.035	**5147**	3341	**2626**	1727	1285	1024	849	726	635
0.042	6306	4063	3185	2086	1550	1234	1022	874	764
0.049	**7515**	**4806**	3755	**2451**	**1817**	1445	1196	1023	893
0.058	*9361*	5790	4507	2927	2165	1720	1422	1215	1061
0.062	*10000*	6240	4848	3142	2322	1843	1523	1301	1136
0.065		6581	**5107**	**3304**	**2440**	1935	1599	1366	1192
0.072		7395	5720	3686	2717	2153	1778	1517	1324
0.083		*8951*	6711	4298	3158	2498	2060	1757	1532
0.094		*10000*	*7736*	4923	3606	2848	2346	2000	1742
0.095			***7827***	**4981**	**3648**	2880	2372	2022	1761
0.102			*8209*	5388	3938	3105	2556	2177	1896
0.109			*8834*	5800	4231	3332	2741	2334	2032
0.120			***9823***	**6461**	**4698**	3694	3035	2581	2246
0.125			*10000*	6767	4913	3859	3169	2695	2344
0.152				*8179*	6103	4773	3907	3315	2879
0.188					*7770*	6039	4923	4166	3610
0.190					*7862*	6112	4981	4214	3652
0.250						*8333*	6767	5696	4918
End Connection Type									
37° Flared Tube	9600	9600	7400	7150	5300	5200	4600	4600	4600
NPT (Non-H_2 Service) *	6200	4900	5600	5000	4000	3600	3600	3200	3200
NPT (H_2 Service)	3000	3000	3000	3000	3000	3000	3000	3000	3000

Notes: All dimensions are in inches, all pressures in psig, temperatures not exceeding 150°F. For "L" grades of stainless steel, the MAWP shall be multiplied by a factor of 0.833 based on equation (3c) of B31.3 and tube minimum wall thickness.

Tubing with pressure ratings shown in **BOLD** are usually stocked in the warehouse.

Entries shown in *italics* represent tubing with $t \geq D/6$. See ANSI/ASME B31.3, para.304.1.2 (b).

See section 4.2 for other restrictions on maximum working pressures on 37° flared tube fittings.

* If threaded pipe is connected to FNPT end connections, the listed pressure ratings above are valid only if pipe is Schedule 80S or heavier and if pipe material has allowable stress of 20,000 psi or higher per ASME B31.3. To attain higher pressure ratings for Non-H_2 service with 20,000 psi allowed material stress, refer to Table 3C.

TABLE 3B

Boss Connection Pressure Ratings

Nom. Size (in.)	Maximum Allowable Working Pressure (psig)					
	SAE AS930 to SAE AS5202 w/ Harrison K-Seal ® or Equiv. #	SAE AS930 to SAE AS5202 w/ SAE AS28778 O-Ring *	SAE AS1941 or AS4320 to SAE AS5202 w/ Harrison K-Seal ® or Equiv. #	SAE AS1941 or AS4320 to SAE AS5202 w/ SAE AS28778 O-Ring *	SAE AS1098 or AS4395 to SAE AS5202 w/ Harrison K-Seal ® or Equiv. #	SAE AS1098 or AS4395 to SAE AS5202 w/ SAE AS28778 O-Ring *
0.25	5200	7150	4850	6800	6050	8000
0.375	4200	5950	4750	6500	5300	7000
0.50	4050	5500	5950	7350	5450	6900
0.75	2650	3700	4950	5950	6250	7300
1.00	2250	3200	5050	6050	4400	5350
1.25	1950	2750	4400	5200	5150	5950
1.50	1750	2450	4400	5050	5900	6650
1.75	1500	2150	3750	4450	5650	6250
2.00	1350	1950	3400	4050	6200	6600

Notes:

* See section 4.2 for SAE AS28778 O-Ring requirements and allowances, recommendations, and requirements that govern substitution of other type seals for these O-Rings

See section 4.2 for K-Seal ® requirements

TABLE 3C

Increased Pressure Ratings (above those listed in Table 3A) for NPT End Connections with Associated Requirements; Non H_2 Service Only

Nominal Size (inches)	Pressure Rating (psig)	Minimum OD or Distance Between Flats on FNPT Part (inches) *	Minimum Schedule of Connected Pipe, if Used	Maximum Allowed Bore of MNPT Part (inches) **
1/4	7700	0.794	80S	0.332
3/8	6500	0.931	80S	0.455
1/2	6000	1.127	80S	0.583
1/2	8050	1.264	160	0.511
1/2	10550	1.484	XXS	0.326
3/4	7650	1.546	160	0.667
3/4	9050	1.714	XXS	0.511
1	4700	1.648	80S	1.002
1	6800	1.850	160	0.878
1	8800	2.162	XXS	0.689
1-1/4	4000	2.010	80S	1.326
1-1/4	5350	2.163	160	1.223
1-1/4	8150	2.529	XXS	0.992
1-1/2	3650	2.265	80S	1.550
1-1/2	5300	2.472	160	1.408
1-1/2	7550	2.791	XXS	1.200
2	5250	3.086	160	1.775
2	6600	3.323	XXS	1.612

Notes: * Increase Dimension by Distance Between Axial Centerline of Part, at Its FNPT End Connection as defined by OD or Midpoints between Parallel External Flats, and Axial Centerline of FNPT Thread Pattern; if this distance is greater than 0.001-inches (Concentricity of thread and part OD outside 0.001-inch allowed tolerance)

** Decrease Dimension by Distance Between Axial Centerline of Bore (or ID), at the MNPT End Connection, and Axial Centerline of the MNPT Thread Pattern; if this distance is greater than 0.001-inches (Concentricity of thread and bore / ID outside 0.001-inch allowed tolerance)

- Material used for fittings and pipe must have allowable stress of 20,000 psi or higher per ASME B31.3 for above pressure ratings.

TABLE 3D
Required Thread Engagement Length for NPT End Connections

Nominal Size (inches)	Minimum Allowed Thread Engagement Length (inches)
1/16	0.160
1/8	0.162
1/4	0.235
3/8	0.241
1/2	0.320
3/4	0.339
1	0.422
1-1/4	0.446
1-1/2	0.463
2	0.496
Note: Above values reflect minimum allowed thread engagement for all cases. However, longer thread engagements shall be attained as needed to provide snug, wrench-tight, or interference fit in order to prevent loosening of connection under cyclic loads and vibration conditions.	

TABLE 4
Permissible Variation in Diameter and Wall Thickness

Tube Size Outside Diameter, in	Permissible Variation in Outside Diameter, in. (mm)	Permissible Variation in Wall Thickness *
Up to 0.50	± 0.005 (0.13)	± 15%
0.50 to 1.00, excl	± 0.005 (0.13)	± 10%
1.00 to 1.50, excl	± 0.006 (0.15)	± 10%
1.50 to 2.00	± 0.010 (0.25)	± 10%
* **Note:** When tubes have an inside diameter of 60% or less of the outside diameter, the permissible variation in diameter is ± 12.5 %.		

4.2 Fittings for Fluid Pressures Less Than 10,000 psig

Forged, wrought or cold worked metallic fitting materials shall be used. Castings are not permitted.

Flared Tube Fittings. 37° flared tube fittings made of type 304, 316, 321, or 347 austenitic stainless steel may be used in pressure systems for pressures up to those shown in Table 3A for various tubing sizes provided the manufacturer's pressure or temperature rating for any component is not exceeded. Maximum allowable working pressure for tube fittings connected

to female (internal) thread boss connections are limited to those specified in Table 3B. Appendix B provides diagrams of flared tube and boss connections listed in Tables 3A and 3B.

For tube fittings made of materials other than type 304, 316, 321, or 347 austenitic stainless steel, the maximum allowable working pressure shall be determined as follows:

$$P = P_{T2} \times (S_A/20{,}000)$$

where: P = Maximum Allowable Working Pressure (in psig)
P_{T2} = Maximum Allowable Working Pressure from Table 3A or 3B above (in psig)
S_A = Allowed Stress of New Material per ASME B31.3 (in psi)

Prior to assembly of tube to flared tube fittings, the tube end shall be flared to conform to the geometric requirements of SAE AS4330 or SAE AS33583.

For flared tube fittings (such as adaptor fittings) with multiple types or sizes of end connections, the pressure rating of the fitting shall be no greater than that of the end connection having the lowest pressure rating.

SAE AIR310 is an aid for locating and identifying various fitting designs and configurations. Tubing and tube fittings listed in SAE AIR310 that have flareless, beam seal, socket weld, swivel, and hose type end connections are not permitted. Tube and fittings made of titanium shall not be used in oxidizer systems nor in systems rated for oxidizer service; i.e., oxidizer media can contact internal surfaces. Aluminum fittings are limited to 400-psia in systems rated for oxygen services.

Other tube fittings not listed in SAE AIR310 with straight thread end connections conforming to SAE AS930, AS1098, AS1099, AS1941, AS4320, AS4395, AS4396, and AS5202 and with NPT end connections conforming to ASME B1.20.1, SAE AS5201, and SAE AS71051 are permitted provided that minimum wall thicknesses (of pressure boundaries) are equal to or greater than those specified for similar fittings listed in SAE AIR310.

Seals Used for Boss Connections. OmniSeal®, OmniSeal RACO®, Raco® or equivalent spring energized seals should be substituted for SAE AS28778 O-Rings in cryogenic, hydrogen, helium, and high pressure gas services to provide leaktight sealing; i.e. assure conformance to leak test requirements in section 4.8. With the exception of K-Seals ®, seals that are used as substitutes for SAE AS28778, O-Rings shall fit within same seal containment cavity and shall be totally encapsulated as shown in Figures B-3 and B-5.

For positionable boss connections, as shown in Figure B-5, install in accordance with SAE AS758, except that hydraulic fluid lubricant shall not be used for systems rated for oxygen, oxidizer, or cryogenic services nor for any other systems that interface with oxygen, oxidizer, or

cryogenic systems; e.g. where the possibility of lubricant migration into an oxidizer or cryogenic system exists. If used, lubricants for oxidizer and cryogenic fluid systems shall conform to requirements stated in section 4.0.

K-Seals®, illustrated in Figure B-4, shall be Stanley-Harrison series 12120 or equivalent with spacer thickness not to exceed 0.063-inch.

O-Rings used in cryogenic and oxidizer services shall be Virgin PTFE, except that Viton® is also permitted for non-cryogenic oxygen service. O-Rings used for oxygen services shall be PTFE or Viton® conforming to SSC Drawing 54000-GM30. O-Rings used for other services shall be PTFE, Viton®, or Buna-N.

Spring energized seals, including OmniSeal®, OmniSeal RACO®, Raco®, K-Seal® type seals or equivalents, shall be PTFE, metallic with PTFE coating, or uncoated metallic.

CAUTION

Uncoated metallic seals are highly prone to leakage if 16 RMS or smoother microfinish is not maintained on all seal contact surfaces. Uncoated metallic seals should be used only where necessary, such as cases where service temperatures or service fluid compatibility issues preclude the use of PTFE or PTFE coated seals. User is cautioned to use great care during assembly and disassembly of boss connections with uncoated metallic seals to assure that finishes on sealing surfaces are not scratched or damaged.

Metallic materials used for spring energized seals are restricted to type 304, 304L, 316, 316L, A286, 17-4, and 17-7 stainless steels, Inconel 718, Inconel X-750, and Elgiloy® alloys unless an alternate material is approved under a variance request or MUA. Type 17-4PH and 17-7PH stainless steels are not permitted for hydrogen service.

NPT Connections on Tube Fittings. NPT connections on tube fittings may be used at pressure ratings specified on Table 3A or Table 3C. If higher pressure ratings of Table 3C are used, then dimensions, schedule of connected pipe, if applicable, and material properties must conform to those listed/stated on that table. In all cases, the length of thread engagement shall be equal to or greater than values shown on Table 3D.

Virgin PTFE tape shall be used for sealing NPT thread connections. For oxygen service, the virgin PTFE tape shall conform to the latest revision of NASA/SSC Drawing 54000-GM30. The PTFE tape shall be wrapped around the external (male) thread in the direction used for loosening the thread connection, stretching over threads so that it conforms to the shape of the thread. There shall be no overlapping PTFE tape on the engaging thread. Overlap the starting turn (wrap or layer) by approximately ½-inch and break the tape. For one-inch and larger NPT thread connections use two identical wrappings side be side. Assembly of thread connection can then be made.

CAUTION

The use of NPT connectors in hydrogen and helium services can be highly prone to leakage, especially at operating pressures exceeding 3000-psig, cryogenic service temperatures, or moderate to high frequency cyclic loading and stress conditions.

The use of additional turns (wraps or layers) of PTFE tape on the male thread may be used to acquire leak-tight NPT connections provided that minimum thread engagement length specified in Table 3D above is attained. When additional turns of PTFE tape are used, the final turn shall overlap the start of the initial turn by approximately ½-inch. Break off remaining tape prior to assembling the connection.

When disassembling NPT connections, remove all old tape from the internal and external threads and use new PTFE tape as described above prior to reuse.

SWAGELOK® Flareless Type Tube Fittings. The use of Swagelok® type tube fittings is normally restricted to systems in which the maximum operating pressure does not exceed 3000 psig for fittings up to 1-inch tube size and 1500 psig for fittings over 1 inch through 2 inches tube sizes and the temperature does not exceed 150°F. The listing of approved Swagelok® flareless type tube fittings allowed for use at SSC is provided in Appendix C.

When operating conditions of the system do not allow for use of 37° flared tube fittings or coned and threaded type tube fittings, Swagelok® type tube fittings may be used at pressures higher than those listed above. Such use shall be covered by an approved variance request or MUA.

All Swagelok® type flareless type tube fittings shall be manufactured from AISI 316 stainless steel unless operating pressures, temperatures, and hazards associated with service media preclude the use of this material. Use of materials other than AISI 316 stainless steel shall be covered by an approved variance request or MUA.

The system design pressure shall not exceed the manufacturer's pressure rating for the fitting. Swagelok® type tube fittings are generally rated to the maximum working pressure of the tubing. However, some fittings with type AN, O-Seal, SAE/MS or pipe ends may have lower ratings.

To minimize the possibility of leaks in any gas system due to tube surface defects such as scratches, Swagelok® recommends the minimum wall thickness shown in Table 5 be used. Assembly of Swagelok® type fittings shall be in accordance with manufacturer's recommended procedures.

Table 5
Minimum Recommended Tube Wall Thicknesses
For Swagelok® Fittings in Gas Service (from manufacturer's catalog)

Tube OD, in	Nominal Minimum Wall Thickness, in	Tube OD, in	Nominal Minimum Wall Thickness, in
0.25	0.028	0.875	0.083
0.375	0.035	1.00	0.083
0.50	0.049	1.25	0.109
0.625	0.065	1.50	0.134
0.75	0.065	2.00	0.180

4.3 Tubing for Fluid Pressure of 10,000 psig and Higher

Coned and (Left Hand) Threaded Tubing (also known as Superpressure® Tubing) may be used for medium and high pressure service when the required operating pressure exceeds the capability of flared or swaged tubing and tube fitting systems. Typical pressure ratings for seamless cold worked (cold drawn) AISI type 304/316 stainless steel coned and threaded tubing at a maximum service temperature of 100°F are shown in Table 6. Maximum operating pressure for higher temperatures shall be in accordance with manufacturer's published recommendations. Hydrostatic and pneumatic pressure test requirements shall conform to sections 4.7 and 4.8. Consult manufacturer's catalogs for other diameters and pressures.

CAUTION

Although the tubing may be rated to pressures as described in Table 5, system pressure ratings may be limited to lower pressures based on tube fittings or other system components. The lowest pressure rating of any system component is the maximum allowed operating pressure for the tubing system.

TABLE 6
Maximum Allowable Working Pressures
Coned and LH Threaded Medium and High Pressure Tubing
Maximum Service temperature 100° F

Nominal Tube Size, in	Tube ID, in	Pressure Rating, psig (to Temp. 100°F)	Flow Area, in^2	Producers (see Appendix E)
0.5625	0.359	10,000	0.101	AE
0.75	0.516	10,000	0.209	AE, HiP
1.00	0.688	10,000	0.371	AE, HiP
0.25	0.109	20,000	0.009	AE, BuT, HiP
0.375	0.203	20,000	0.032	AE, BuT, HiP
0.5625	0.312	20,000	0.076	AE, BuT, HiP, NSI
0.75	0.438	20,000	0.151	AE, BuT, HiP
1.00	0.562	20,000	0.248	AE, BuT, HiP
1.00	0.438	30,000	0.151	AE, HiP
0.5625	0.250	40,000	0.048	AE
0.25	0.083	60,000	0.005	AE, BuT, HiP, NSI
0.375	0.125	60,000	0.012	AE, BuT, HiP, NSI
0.5625	0.187	60,000	0.028	AE, BuT, HiP, NSI

Note: Above pressure ratings correspond to tube and fittings made of cold worked AISI Type 304/316 stainless steel with SMYS of 60,000 psi and SMTS of 110,000 psi (1/8 hard condition). If tube and fittings are made of another material, new pressure ratings are determined as follows:

$$P_{new} = P_{T4} \times (S_A/40{,}000)$$

where: P_{new} = New Pressure Rating (in psig)
P_{T4} = Pressure Rating from Table 5 above (in psig)
S_A = Allowed Stress of New Material per ASME B31.3 (in psi)

For cold worked stainless steel parts that are welded, see Section 4.5 for pressure rating reductions.

4.4 Coned and (Left Hand) Threaded Tube Fittings

Coned and threaded tube fittings are those that utilize end connection geometries illustrated in Appendix D.

Medium pressure coned and threaded tubing fittings (10,000 psig to 20,000 psig) are not interchangeable with high pressure coned and threaded tube fittings (30,000 psig and over).

Coned and threaded tube fittings that also have other types of end connections allowed by this standard (such as MS/AN to Autoclave and other adaptor fittings) may be used, but the pressure

rating of the fitting shall be down-rated to that of the fitting connection having the lowest pressure rating.

Tube ends shall be prepared as shown in Appendix D prior to connecting the respective tube fitting connection. It is critical that all burrs, shavings, slivers, and contaminant particles be removed from the conical taper end and tip of each tube end prior to connecting a tube to a fitting.

To achieve improved leak-tight integrity of the coned and threaded type tubing connection it may be necessary to hone or wipe the conical surfaces to an 8 RMS or smoother microfinish and to assure that the rim of the conical tip on the tube or male connection is coplaner in a plane that is perpendicular to the tube or fitting bore axial centerline within ± ¼ degree.

4.5 Welded Tube Connections

Full penetration welded tube connections are permitted. Socket or other type weld connections that have surfaces not accessible to visual inspection and removal of contaminants by cleaning agents are not permitted.

Welding shall meet the requirements of ANSI/ASME B31.3.

To obtain the maximum pressure rating for the system, 100% of the welds shall be non-destructively examined and pass a Class 1 weld inspection in accordance with SSC Standard 34-004.

If 100% NDE is not performed, the system pressure rating shall be reduced in accordance with the requirements of ANSI/ASME B31.3.

When coned-and-threaded tubing and tube fittings made of cold worked or hardened (1/8 hard condition) stainless steel are welded, the pressure rating of each welded tube or fitting shall be reduced to 50% of the corresponding value listed in Table 6.

4.6 Pipe Runs

Butt-welded pipe and pipe fittings are approved alternates to the use of pressure tubing. Refer to SSTD-8070-0043-PIPE for pipe, pipe fitting, and pipe system requirements.

4.7 Proof Pressure Test Requirements

With the exception of selected vent system segments/sections, all tube system sections, components, and connections shall be hydrostatically tested at 1.5 times the system design pressure prior to placing the system into operational service.

Vent system segments and sections exempted from proof pressure tests are limited to those where the total axial centerline length is no greater than 10 feet and where the system section/segment exits directly to ambient atmosphere. Furthermore, there shall be only one mechanical, non-welded, joint in each of the respective sections/segments, which is to be located at the upstream end of this section/segment.

On a case by case basis and with approval of the NASA Safety representative, pneumatic pressure tests at 1.25 times maximum system operating pressure or at 1.25 times system design pressure are permitted in lieu of hydrostatic pressure testing. Appropriate measures to reduce or eliminate rapid explosion or gas decompression hazards to personnel and hardware to acceptable risk and hazard abatement levels shall be incorporated when pneumatic proof pressure tests are performed. All proof pressure tests shall be in full compliance with all applicable requirements of 49 CFR 195. All proof pressure test procedures shall conform to all applicable (pressurized) leak test requirements of ASME B31.3.

Hydrostatic proof pressure tests may be performed on separate tubing system sections, fittings, tubing runs, and components prior to precision cleaning and final assembly of the same. Systems and system sections may be disassembled after hydrostatic proof pressure tests to enable or facilitate precision cleaning of system hardware. However, with the exception of (microscopically thin) oxide layers produced on material surfaces during passivation processes, the configuration, material properties, and material boundary wall thicknesses of tested parts, fittings, and tubing may not be altered after completion of the hydrostatic proof pressure tests. Additionally, proof pressure tests shall be performed after completion and acceptance of all tubing system weld joints/connections.

4.8 System Leak Test Requirements

With the exception of selected vent system segments/sections, pneumatic leak tests are required for all fluid tube systems, after final assembly of the system.

Vent system segments and sections exempted from leak tests are limited to those where the total axial centerline length is no greater than 10 feet and where the system section/segment exits directly to ambient atmosphere. Furthermore, there shall be no cross-sectional flow area changes in each of the respective sections/segments and there shall be only one mechanical, non-welded, joint which is to be located at the upstream end of each of these sections/segments.

Leak tests that are not performed by NASA test operations personnel shall be performed with test gas at maximum system operating pressure or at system design pressure. For hydrogen and helium tubing systems, leak test gas shall be helium or a nitrogen-and-helium gas mixture with a minimum of 10% volume (mole) fraction of helium. Nitrogen, air, helium, or a mixture of these gases may be used for leak testing of systems that are not rated or used in hydrogen or helium service.

When leak tests are not performed with test gas at maximum system operating pressure nor at system design pressure, they shall be performed at pressures between 40 and 150 psig. In these cases, systems with flammable, highly reactive, and hazardous service fluids, such as hydrogen and oxygen, shall be equipped with fully operable and remote leak detection equipment prior to and during system pressurization.

Leakage through all system mechanical and welded joints shall be measured by "soap solution," "Leak-Tec®," or equivalent bubble test or mass spectrometer with sensitivity set to 10^{-4}sccm or lower. Zero visible or "bubble tight" external system leakage is required for bubble tests. A maximum of 10^{-4} sccm external system leakage is allowed for mass spectrometer tests unless a higher leakage rate is deemed acceptable by the NASA Mechanical Test Operations Engineer, Engineer responsible for the tested tubing system(s), or governing CCB.

All system leakage test procedures shall conform to all applicable ASME B31.3 requirements. All system leakage tests shall conform to applicable requirements of 49 CFR 195.

Appendix A - Acronyms, Abbreviations, and Definitions

AIAA	American Institute of Aeronautics and Astronautics
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
AMS	Aerospace Material Specification (from SAE)
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CCB	Configuration Control Board
DR	Deviation Request
FNPT	Female (Internal Thread) NPT
H_2	Hydrogen
IAPMO	International Association of Plumbing and Mechanical Officials
HVAC	Heating, Ventilating and Air Conditioning
LH	Left Hand(ed)
MAWP	Maximum Allowable Working Pressure
MNPT	Male (External Thread) NPT
MPa	Mega-Pascal
MSFC	Marshall Space Flight Center
MUA	Materials Usage Agreement (from SOI-8080-0016)
NASA	National Aeronautics and Space Administration
NPS	Nominal Pipe Size
NPSM	National Pipe Straight Mechanical (ANSI/ASME B1.20.1)
NPT	(American) National (Standard Taper) Pipe Thread (ANSI ASME B1.20.1)
OD	Outside Diameter
psi	Pounds Force per Square Inch
psig	Pounds Force per Square Inch (Gauge)
PTFE	Polytetrafluoroethylene
RMS	Root Mean Square (Roughness, in micro-inches, ASME B46.1)
SAE	Society of Automotive Engineers
sccm	standard cubic centimeter per minute
SCD	Specification Control Drawing
SOI	Standard Operating Instructions
SMYS	Specified Minimum Yield Strength
SMTS	Specified Minimum Tensile Strength
SSC	Stennis Space Center
SSTD	Stennis Space Center Standard
STE	Special Test Equipment (provided by SSC)
USAF	United States Air Forces
UPC	Uniform Plumbing Code
XXHY	Double Extra Heavy (Pipe Schedule)
XXS	Double Extra Strong (Pipe Schedule)

Tube For the purposes of this standard, tube is defined as a pressure-tight cylinder used to convey a fluid or to transmit a fluid pressure, with its dimensions specified by its outside diameter (OD) and wall thickness in decimal (preferred) or fraction of an inch. Tube sizes covered by this standard range from 0.05" to 2" OD, with wall thickness ranging from 0.005" to 0.250".

Pipe For reference purposes, a pipe is defined as a pressure-tight cylinder used to convey a fluid or to transmit a fluid pressure, with its dimensions specified by its nominal pipe size (NPS) and schedule. For example, stainless steel pipe sizes range from 1/8" NPS to 72" diameter and above. Pipe schedules, which refer to wall thickness, range from 5 (or 5S for stainless steel pipe) to XXS (or XXHY) and above.

Appendix B - Flared Tube and Straight Thread Boss Connections

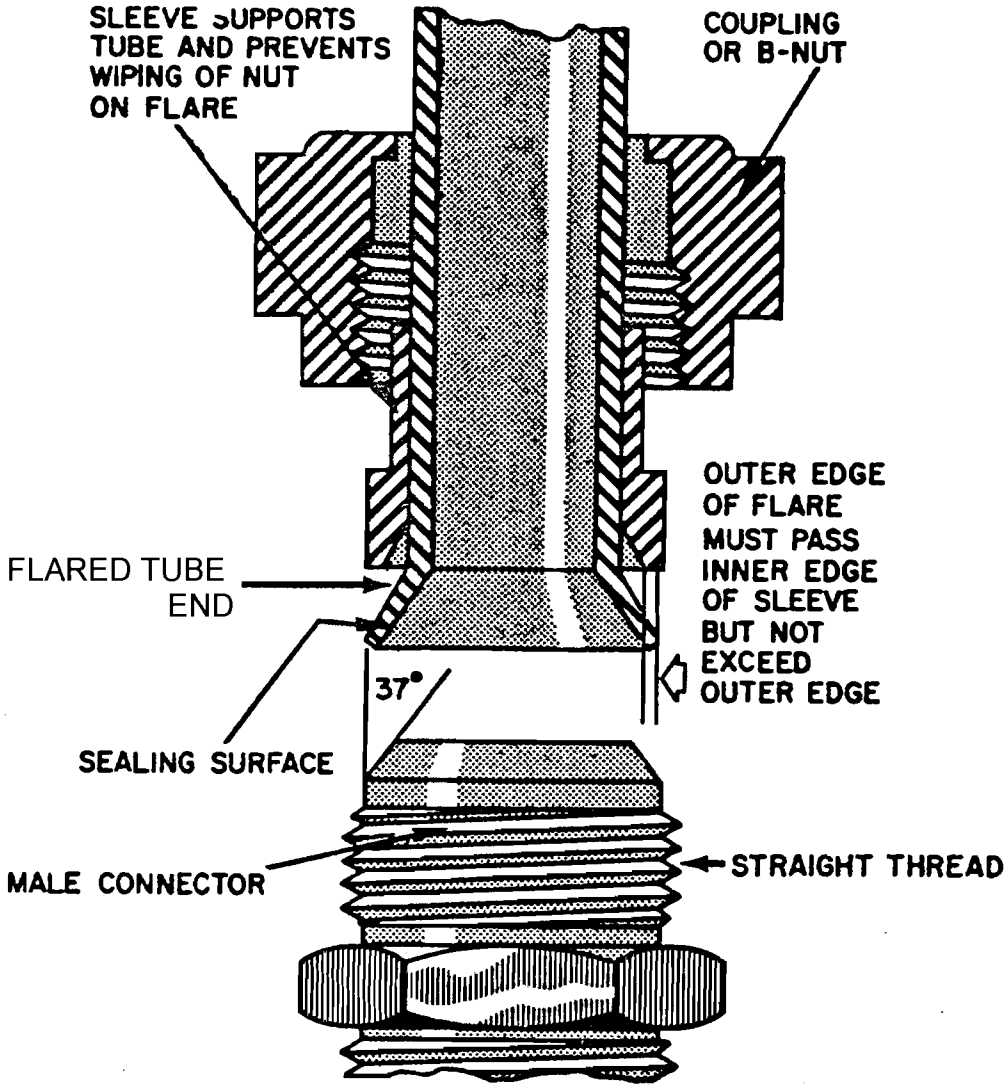


Figure B-1; Three-Piece 37° Flared Tube Fitting Connection, Disassembled

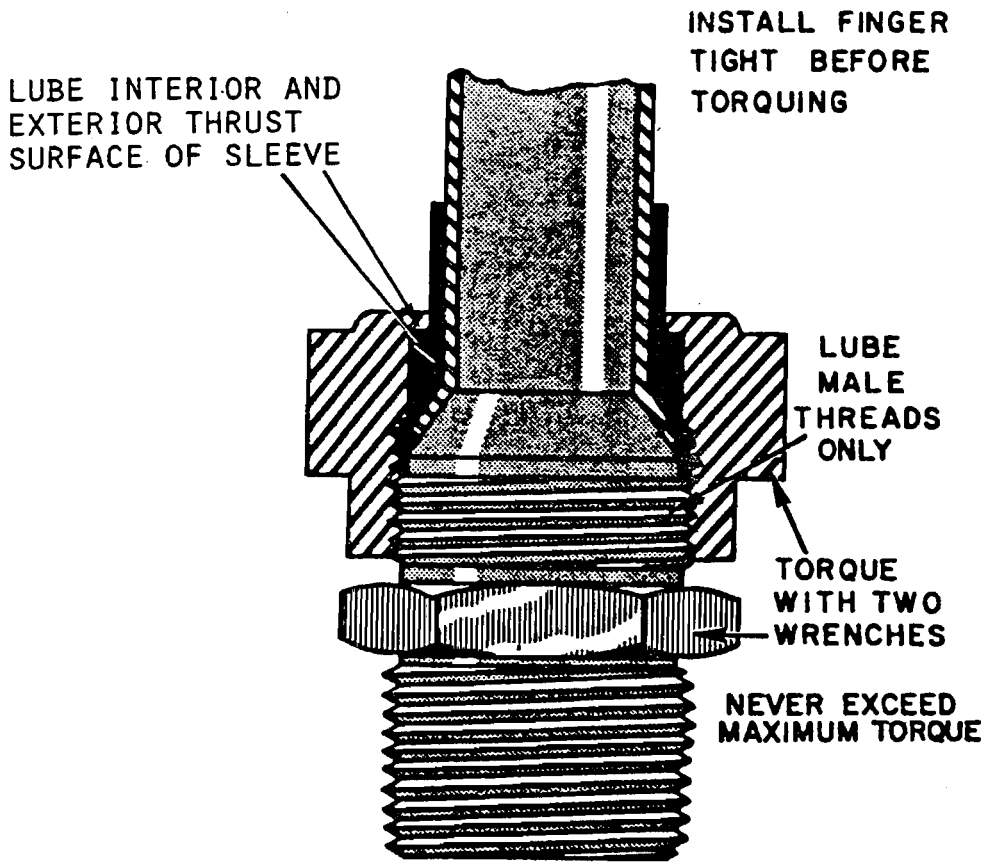
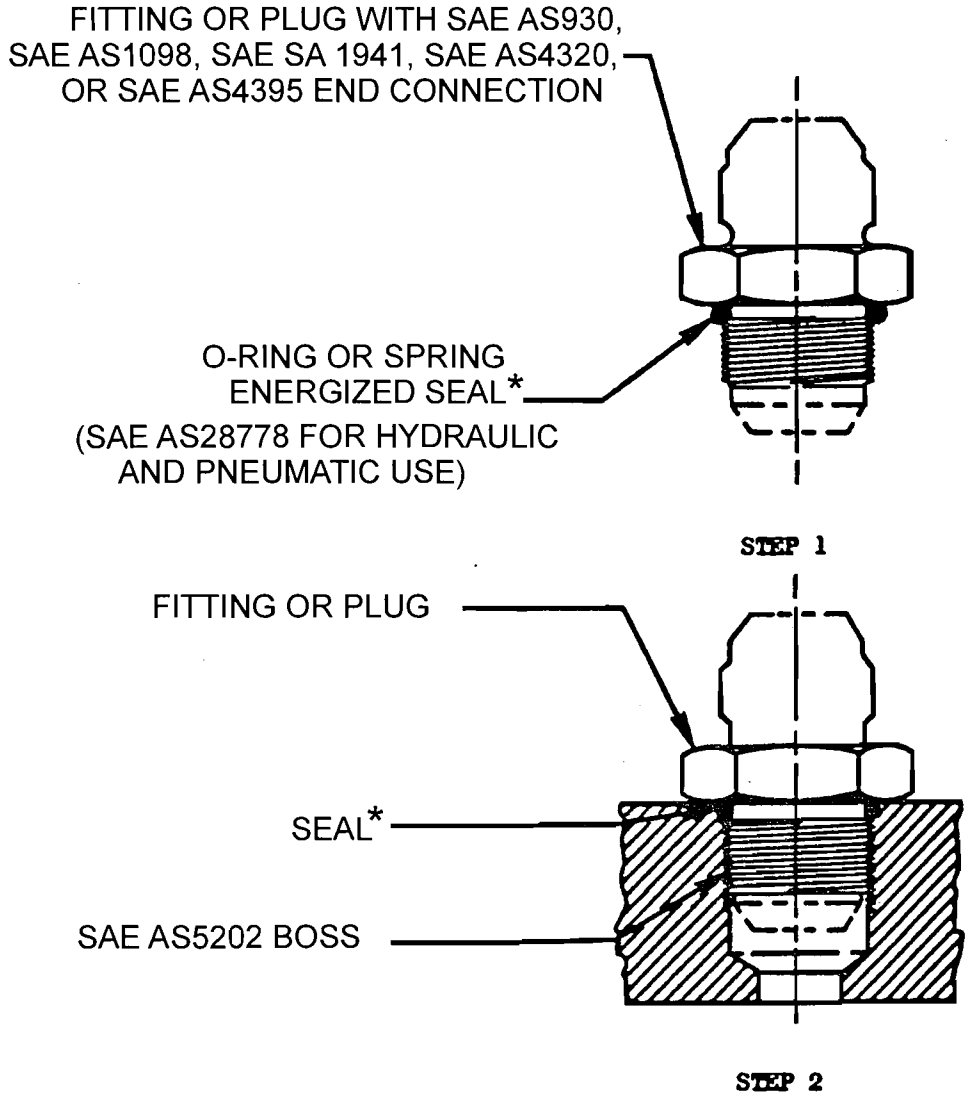


Figure B-2; Three-Piece 37° Flared Tube Fitting Connection, Assembled



* Reference Section 4.2, "Seals Used for Boss Connections" subsection, for detailed seal requirements

Figure B-3; SAE AS930, AS1098, AS1941, AS4320, or AS4395 to SAE AS5202 Boss Connection with O-Ring or Spring Energized Seal

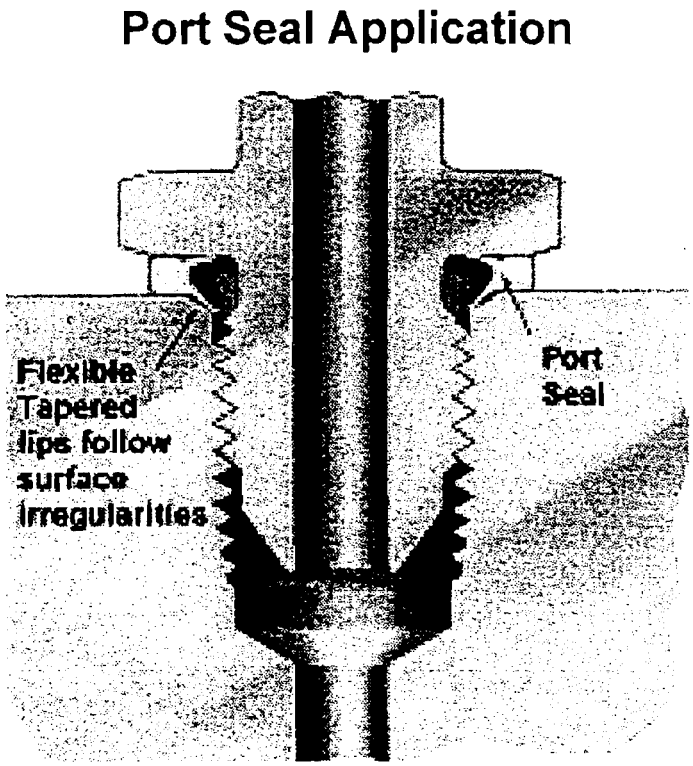
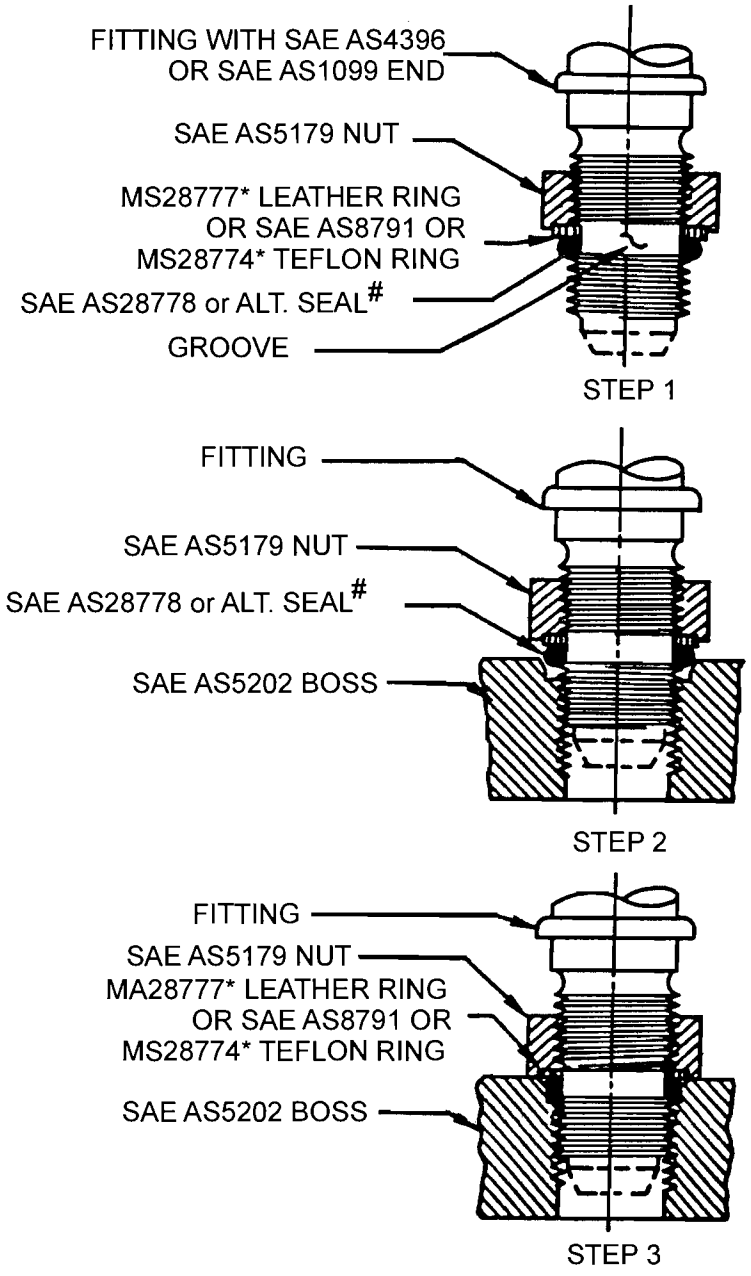


Figure B-4; SAE AS930, AS1098, AS1941, AS4320, or AS4395 to SAE AS5202 Boss Connection with K-Seal ® or Equivalent Type Seal



* MS28774 and MS28777 rings are used for existing designs and replacement purposes only, not to be used for new designs and systems

\# Refer to "Seals Used for Boss Connections" subsection in Section 4.2 for detailed requirements for Alternate and SAE AS28778 Seals

Figure B-5; Positionable Fitting End into SAE AS5202 Boss

Appendix C - Approved Double Ferrule Flareless Type (Swagelok®) Tube Fittings

Swagelok® to Male NPT Adapter		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/16	1/16	-100-1-1
1/16	1/8	-100-1-2
1/16	1/4	-100-1-4
1/8	1/16	-200-1-1
1/8	1/8	-200-1-2
1/8	¼	-200-1-4
1/8	3/8	-200-1-6
1/8	1/2	-200-1-8
3/16	1/8	-300-1-2
3/16	¼	-300-1-4
¼	1/16	-400-1-1
¼	1/8	-400-1-2
¼	¼	-400-1-4
¼	3/8	-400-1-6
¼	½	-400-1-8
¼	3/4	-400-1-12
5/16	1/8	-500-1-2
5/16	¼	-500-1-4
5/16	3/8	-500-1-6
3/8	1/8	-600-1-2
3/8	¼	-600-1-4
3/8	3/8	-600-1-6
3/8	½	-600-1-8
3/8	¾	-600-1-12
½	1/8	-810-1-2
½	¼	-810-1-4
½	3/8	-810-1-6
½	½	-810-1-8
½	¾	-810-1-12
½	1	-810-1-16
5/8	3/8	-1010-1-6
5/8	½	-1010-1-8
5/8	¾	-1010-1-12
¾	½	-1210-1-8
¾	¾	-1210-1-12
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male NPT Adapter (Continued)		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
¾	1	-1210-1-16
7/8	3/4	-1410-1-12
7/8	1	-1410-1-16
1	1/2	-1610-1-8
1	3/4	-1610-1-12
1	1	-1610-1-16
1 ¼	1	-2000-1-16
1 ¼	1 ¼	-2000-1-20
1 ½	1 ½	-2400-1-24
2	2	-3200-1-32
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Male NPT Adapter		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
2	1/8	-2MO-1-2
3	1/8	-3MO-1-2
3	1/4	-3MO-1-4
4	1/8	-4MO-1-2
4	1/4	-4MO-1-4
6	1/8	-6MO-1-2
6	1/4	-6MO-1-4
6	3/8	-6MO-1-6
6	1/2	-6MO-1-8
8	1/8	-8MO-1-2
8	1/4	-8MO-1-4
8	3/8	-8MO-1-6
8	1/2	-8MO-1-8
10	1/8	-10MO-1-2
10	1/4	-10MO-1-4
10	3/8	-10MO-1-6
10	1/2	-10MO-1-8
10	3/4	-10MO-1-12
12	1/8	-12MO-1-2
12	1/4	-12MO-1-4
12	3/8	-12MO-1-6
12	1/2	-12MO-1-8
12	3/4	-12MO-1-12
14	1/4	-14MO-1-4
14	3/8	-14MO-1-6
14	1/2	-14MO-1-8
15	1/2	-15MO-1-8
16	3/8	-16MO-1-6
16	1/2	-16MO-1-8
16	3/4	-16MO-1-12
18	1/2	-18MO-1-8
18	3/4	-18MO-1-12
20	1/2	-20MO-1-8
20	3/4	-20MO-1-12
22	3/4	-22MO-1-12
22	1	-22MO-1-16
25	1/2	-25MO-1-8
25	3/4	-25MO-1-12
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Male NPT Adapter (Continued)		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
25	1	-25MO-1-16
28	1	-28MO-1-16
28	1 1/4	-28MO-1-20
32	1 1/4	-32MO-1-20
38	1 1/2	-38MO-1-24
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male NPT Bulkhead Adapter		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-11-2
1/4	1/8	-400-11-2
1/4	1/4	-400-11-4
3/8	1/4	-600-11-4
3/8	3/8	-600-11-6
3/8	1/2	-600-11-8
1/2	3/8	-810-11-6
1/2	1/2	-810-11-8
3/4	3/4	-1210-11-12
1	1	-1610-11-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Male NPT Bulkhead Adapter		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/4	-6MO-11-4
12	1/2	-12MO-11-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Straight Thread Adapter		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/8	5/16-24	-200-1-2ST
1/8	7/16-20	-200-1-4ST
1/8	9/16-18	-200-1-6ST
1/4	7/16-20	-400-1-4ST
1/4	9/16-18	-400-1-6ST
1/4	3/4-16	-400-1-8ST
1/4	7/8-14	-400-1-10ST
5/16	1/2-20	-500-1-5ST
3/8	7/16-20	-600-1-4ST
3/8	9/16-18	-600-1-6ST
3/8	3/4-16	-600-1-8ST
3/8	7/8-14	-600-1-10ST
1/2	9/16-18	-810-1-6ST
1/2	3/4-16	-810-1-8ST
1/2	7/8-14	-810-1-10ST
1/2	1 1/16-12	-810-1-12ST
5/8	3/4-16	-1010-1-8ST
5/8	7/8-14	-1010-1-10ST
3/4	3/4-16	-1210-1-8ST
3/4	1 1/16-12	-1210-1-12ST
7/8	1 3/16-12	-1410-1-14ST
1	1 1/16-12	-1610-1-12ST
1	1 5/16-12	-1610-1-16ST
1 1/4	1 5/8-12	-2000-1-20ST
1 1/2	1 7/8-12	-2400-1-24ST
2	2 1/2-12	-3200-1-32ST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Straight Thread, Long Adapter		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/4	7/16-20	-400-1L-4ST
5/16	½-20	-500-1L-5ST
3/8	9/16-18	-600-1L-6ST
1/2	3/4-16	-810-1L-8ST
5/8	7/8-14	-1010-1L-10ST
3/4	1 1/16-12	-1210-1L-12ST
7/8	1 3/16-12	-1410-1L-14ST
1	1 5/16-12	-1610-1L-16ST
1 1/4	1 5/8-12	-2000-1L-20ST
1 1/2	1 7/8-12	-2400-1L-24ST
2	2 1/2-12	-3200-1L-32ST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male NPT Elbow, 90°		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/16	1/16	-100-2-1
1/16	1/8	-100-2-2
1/8	1/16	-200-2-1
1/8	1/8	-200-2-2
1/8	1/4	-200-2-4
3/16	1/8	-300-2-2
3/16	1/4	-300-2-4
1/4	1/16	-400-2-1
1/4	1/8	-400-2-2
1/4	1/4	-400-2-4
1/4	3/8	-400-2-6
1/4	1/2	-400-2-8
5/16	1/8	-500-2-2
5/16	1/4	-500-2-4
5/16	3/8	-500-2-6
3/8	1/8	-600-2-2
3/8	1/4	-600-2-4
3/8	3/8	-600-2-6
3/8	1/2	-600-2-8
3/8	3/4	-600-2-12
1/2	1/4	-810-2-4
1/2	3/8	-810-2-6
1/2	1/2	-810-2-8
1/2	3/4	-810-2-12
5/8	3/8	-1010-2-6
5/8	1/2	-1010-2-8
5/8	3/4	-1010-2-12
3/4	1/2	-1210-2-8
3/4	3/4	-1210-2-12
7/8	3/4	-1410-2-12
1	3/4	-1610-2-12
1	1	-1610-2-16
1 1/4	1 1/4	-2000-2-20
1 1/2	1 1/2	-2400-2-24
2	2	-3200-2-32
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Male NPT Elbow, 90°		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
3	1/8	-3MO-2-2
3	1/4	-3MO-2-4
4	1/8	-4MO-2-2
4	1/4	-4MO-2-4
6	1/8	-6MO-2-2
6	1/4	-6MO-2-4
6	3/8	-6MO-2-6
6	1/2	-6MO-2-8
8	1/8	-8MO-2-2
8	1/4	-8MO-2-4
8	3/8	-8MO-2-6
8	1/2	-8MO-2-8
10	1/8	-10MO-2-2
10	1/4	-10MO-2-4
10	3/8	-10MO-2-6
10	1/2	-10MO-2-8
12	1/4	-12MO-2-4
12	3/8	-12MO-2-6
12	1/2	-12MO-2-8
12	3/4	-12MO-2-12
15	1/2	-15MO-2-8
16	3/8	-16MO-2-6
16	1/2	-16MO-2-8
16	3/4	-16MO-2-12
18	1/2	-18MO-2-8
18	3/4	-18MO-2-12
20	1/2	-20MO-2-8
20	3/4	-20MO-2-12
22	3/4	-22MO-2-12
22	1	-22MO-2-16
25	3/4	-25MO-2-12
25	1	-25MO-2-16
32	1 1/4	-32MO-2-20
38	1 1/2	-38MO-2-24
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male NPT Elbow, 45°		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/4	1/8	-400-5-2
1/4	1/4	-400-5-4
3/8	1/8	-600-5-2
3/8	1/4	-600-5-4
3/8	3/8	-600-5-6
1/2	3/8	-810-5-6
1/2	1/2	-810-5-8
3/4	3/4	-1210-5-12
1	1	-1610-5-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Straight Thread Positionable Elbow, 45°		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/4	7/16-20	-400-5-4ST
3/8	9/16-18	-600-5-6ST
1/2	3/4-16	-810-5-8ST
3/4	1 1/16-12	-1210-5-12ST
1	1 5/16-12	-1610-5-16ST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Straight Thread Positionable Elbow, 90°		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/4	7/16-20	-400-2-4ST
1/4	9/16-18	-400-2-6ST
5/16	1/2-20	-500-2-5ST
3/8	9/16-18	-600-2-6ST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Straight Thread Positionable Elbow, 90° (Continued)		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
3/8	3/4-16	-600-2-8ST
1/2	3/4-16	-810-2-8ST
5/8	7/8-14	-1010-2-10ST
3/4	1 1/16-12	-1210-2-12ST
7/8	1 3/16-12	-1410-2-14ST
1	1 5/16-12	-1610-2-16ST
1 1/4	1 5/8-12	-2000-2-20ST
1 1/2	1 7/18-12	-2400-2-24ST
2	2 1/2-12	-3200-2-32ST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male NPT on Branch Tee		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-3TTM
1/8	1/4	-200-3-4TTM
3/16	1/8	-300-3TTM
1/4	1/8	-400-3TTM
1/4	1/4	-400-3-4TTM
5/16	1/8	-500-3TTM
3/8	1/4	-600-3TTM
3/8	3/8	-600-3-6TTM
1/2	3/8	-810-3TTM
1/2	1/2	-810-3-8TTM
5/8	1/2	-1010-3TTM
3/4	3/4	-1210-3TTM
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Male NPT on Branch Tee		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6MO-3TTM
8	1/8	-8MO-3TTM
10	1/4	-10MO-3TTM
12	3/8	-12MO-3TTM
16	1/2	-16MO-3TTM
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Male NPT on Run Tee		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6MO-3TMT
6	1/4	-6MO-3-4TMT
8	1/4	-8MO-3-4TMT
12	1/4	-12MO-3-4TMT
12	1/2	-12MO-3-8TMT
16	1/2	-16MO-3TMT
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male NPT on Run Tee		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-3TMT
1/8	1/4	-200-3-4TMT
3/16	1/8	-300-3TMT
1/4	1/8	-400-3TMT
1/4	1/4	-400-3-4TMT
5/16	1/8	-500-3TMT
3/8	1/4	-600-3TMT
3/8	3/8	-600-3-6TMT
1/2	3/8	-810-3TMT
1/2	1/2	-810-3-8TMT
5/8	1/2	-1010-3TMT
3/4	3/4	-1210-3TMT
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to SAE/MS Straight Thread on Run Tee, Positionable		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/4	7/16-20	-400-3TST
3/8	9/16-18	-600-3TST
1/2	3/4-16	-810-3TST
3/4	1 1/16-12	-1210-3TST
1	1 5/16-12	-1610-3TST
1 1/4	1 5/8-12	-2000-3TST
1 1/2	1 7/8-12	-2400-3TST
2	2 1/2-12	-3200-3TST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Straight Thread on Branch Tee, Positionable		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/4	7/16-20	-400-3TTS
3/8	9/16-18	-600-3TTS
1/2	3/4-16	-810-3TTS
3/4	1 1/16-12	-1210-3TTS
1	1 5/16-12	-1610-3TTS
1 1/4	1 5/8-12	-2000-3TTS
1 1/2	1 7/8-12	-2400-3TTS
2	2 1/2-12	-3200-3TTS
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Female NPT Adapter		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/16	1/16	-100-7-1
1/16	1/8	-100-7-2
1/8	1/8	-200-7-2
1/8	1/4	-200-7-4
3/16	1/8	-300-7-2
1/4	1/8	-400-7-2
1/4	1/4	-400-7-4
1/4	3/8	-400-7-6
1/4	1/2	-400-7-8
5/16	1/8	-500-7-2
5/16	1/4	-500-7-4
3/8	1/8	-600-7-2
3/8	1/4	-600-7-4
3/8	3/8	-600-7-6
3/8	1/2	-600-7-8
3/8	3/4	-600-7-12
1/2	1/4	-810-7-4
1/2	3/8	-810-7-6
1/2	1/2	-810-7-8
1/2	3/4	-810-7-12
5/8	3/8	-1010-7-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Female NPT Adapter (Continued)		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
5/8	1/2	-1010-7-8
5/8	3/4	-1010-7-12
3/4	1/2	-1210-7-8
3/4	3/4	-1210-7-12
7/8	3/4	-1410-7-12
1	3/4	-1610-7-12
1	1	-1610-7-16
1 1/4	1 1/4	-2000-7-20
1 1/2	1 1/2	-2400-7-24
2	2	-3200-7-32
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Female NPT Bulkhead Adapter		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-71-2
1/4	1/8	-400-71-2
1/4	1/4	-400-71-4
3/8	1/4	-600-71-4
1/2	3/8	-810-71-6
1/2	1/2	-810-71-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Female NPT Bulkhead Adapter		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/4	-6MO-71-4
12	1/2	-12MO-71-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Female NPT Elbow, 90°		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-8-2
1/8	1/4	-200-8-4
3/16	1/8	-300-8-2
1/4	1/8	-400-8-2
1/4	1/4	-400-8-4
1/4	3/8	-400-8-6
1/4	1/2	-400-8-8
5/16	1/8	-500-8-2
5/16	1/4	-500-8-4
3/8	1/8	-600-8-2
3/8	1/4	-600-8-4
3/8	3/8	-600-8-6
3/8	1/2	-600-8-8
1/2	1/4	-810-8-4
1/2	3/8	-810-8-6
1/2	1/2	-810-8-8
5/8	3/8	-1010-8-6
5/8	1/2	-1010-8-8
3/4	1/2	-1210-8-8
3/4	3/4	-1210-8-12
7/8	3/4	-1410-8-12
1	3/4	-1610-8-12
1	1	-1610-8-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Female NPT Elbow, 90°		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6MO-8-2
6	1/4	-6MO-8-4
6	1/2	-6MO-8-8
8	1/4	-8MO-8-4
10	1/8	-10MO-8-2
10	1/4	-10MO-8-4
12	1/4	-12MO-8-4
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Female NPT Elbow, 90° (Continued)		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
12	1/2	-12MO-8-8
16	1/2	-16MO-8-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Female NPT on Run Tee		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-3TFT
1/4	1/8	-400-3TFT
1/4	1/4	-400-3-4TFT
3/8	1/4	-600-3TFT
1/2	3/8	-810-3TFT
1/2	1/2	-810-3-8TFT
3/4	3/4	-1210-3TFT
1	3/4	-1610-3-12TFT
1	1	-1610-3TFT
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Female NPT on Run Tee		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6MO-3TFT
6	1/4	-6MO-3-4TFT
8	1/8	-8MO-3TFT
8	1/4	-8MO-3-4TFT
10	1/4	-10MO-3TFT
12	3/8	-12MO-3TFT
12	1/4	-12MO-3-4TFT
16	1/2	-16MO-3TFT
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Female NPT on Branch Tee		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-3TTF
1/4	1/8	-400-3TTF
1/4	1/4	-400-3-4TTF
3/8	1/4	-600-3TTF
3/8	3/8	-600-3-6TTF
3/8	1/2	-600-3-8TTF
1/2	1/4	-810-3-4TTF
1/2	3/8	-810-3TTF
1/2	1/2	-810-3-8TTF
5/8	1/2	-1010-3TTF
3/4	3/4	-1210-3TTF
1	3/4	-1610-3-12TTF
1	1	-1610-3TTF
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Union	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-100-6
1/8	-200-6
3/16	-300-6
1/4	-400-6
5/16	-500-6
3/8	-600-6
1/2	-810-6
5/8	-1010-6
3/4	-1210-6
7/8	-1410-6
1	-1610-6
1 1/4	-2000-6
1 1/2	-2400-6
2	-3200-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® to Female NPT on Branch Tee		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6MO-3TTF
6	1/4	-6MO-3-4TTF
8	1/8	-8MO-3TTF
8	1/4	-8MO-3-4TTF
10	1/4	-10MO-3TTF
12	3/8	-12MO-3TTF
12	1/4	-12MO-3-4TTF
16	1/2	-16MO-3TTF
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Swagelok® Union		
Metric Tube OD (mm)	Fractional Tube OD (in.)	Swagelok® Basic Part Number *
2	1/8	-2MO-6-2
2	1/4	-2MO-6-4
3	1/8	-3MO-6-2
4	1/8	-4MO-6-2
4	1/4	-4MO-6-4
6	1/8	-6MO-6-2
6	1/4	-6MO-6-4
6	5/16	-6MO-6-5
8	1/4	-8MO-6-4
8	3/8	-8MO-6-6
10	1/8	-10MO-6-2
10	1/4	-10MO-6-4
10	5/16	-10MO-6-5
10	3/8	-10MO-6-6
12	5/16	-12MO-6-5
12	3/8	-12MO-6-6
12	1/2	-12MO-6-8
15	1/2	-15MO-6-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Swagelok® Union (Continued)		
Metric Tube OD (mm)	Fractional Tube OD (in.)	Swagelok® Basic Part Number *
16	5/8	-16MO-6-10
18	3/4	-18MO-6-12
20	1/2	-20MO-6-8
20	1	-20MO-6-16
25	1	-25MO-6-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® Union	
Tube OD (mm)	Swagelok® Basic Part Number *
2	-2MO-6
3	-3MO-6
4	-4MO-6
6	-6MO-6
8	-8MO-6
10	-10MO-6
12	-12MO-6
14	-14MO-6
15	-15MO-6
16	-16MO-6
18	-18MO-6
20	-20MO-6
22	-22MO-6
25	-25MO-6
28	-28MO-6
32	-32MO-6
38	-38MO-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Reducing Union		
Tube OD (in.)	Reduced Tube OD (in.)	Swagelok® Basic Part Number *
1/8	1/16	-200-6-1
3/16	1/16	-300-6-1
3/16	1/8	-300-6-2
1/4	1/16	-400-6-1
1/4	1/8	-400-6-2
1/4	3/16	-400-6-3
5/16	1/8	-500-6-2
5/16	1/4	-500-6-4
3/8	1/16	-600-6-1
3/8	1/8	-600-6-2
3/8	1/4	-600-6-4
3/8	5/16	-600-6-5
1/2	1/8	-810-6-2
1/2	1/4	-810-6-4
1/2	3/8	-810-6-6
5/8	3/8	-1010-6-6
5/8	1/2	-1010-6-8
3/4	1/4	-1210-6-4
3/4	3/8	-1210-6-6
3/4	1/2	-1210-6-8
3/4	5/8	-1210-6-10
1	1/2	-1610-6-8
1	3/4	-1610-6-12
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® Reducing Union		
Tube OD (mm)	Reduced Tube OD (mm)	Swagelok® Basic Part Number *
3	2	-3MO-6-2M
6	2	-6MO-6-2M
6	3	-6MO-6-3M
6	4	-6MO-6-4M
8	6	-8MO-6-6M
10	6	-110MO-6-6M
10	8	-10MO-6-8M
12	6	-12MO-6-6M
12	8	-12MO-6-8M
12	10	-12MO-6-10M
16	10	-16MO-6-10M
16	12	-16MO-6-12M
18	12	-18MO-6-12M
25	18	-25MO-6-18M
25	20	-25MO-6-20M
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® Bulkhead Union	
Tube OD (mm)	Swagelok® Basic Part Number *
3	-3MO-61
4	-4MO-61
6	-6MO-61
8	-8MO-61
10	-10MO-61
12	-12MO-61
14	-14MO-61
15	-15MO-61
16	-16MO-61
18	-18MO-61
20	-20MO-61
32	-32MO-61
38	-38MO-61
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Bulkhead Union	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-100-61
1/8	-200-61
3/16	-300-61
1/4	-400-61
5/16	-500-61
3/8	-600-61
1/2	-810-61
5/8	-1010-61
3/4	-1210-61
1	-1610-61
1 1/4	-2000-61
1 1/2	-2400-61
2	-3200-61
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok ® Bulkhead Reducing Union		
Tube OD (in.)	Reduced Tube OD (in.)	Swagelok® Basic Part Number *
1/4	1/8	-400-61-2
3/8	1/4	-600-61-4
1/2	1/4	-810-61-4
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Union Elbow, 90°	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-100-9
1/8	-200-9
3/16	-300-9
1/4	-400-9
5/16	-500-9
3/8	-600-9
1/2	-810-9
5/8	-1010-9
3/4	-1210-9
7/8	-1410-9
1	-1610-9
1 1/4	-2000-9
1 1/2	-2400-9
2	-3200-9
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Union Tee	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-100-3
1/8	-200-3
3/16	-300-3
1/4	-400-3
5/16	-500-3
3/8	-600-3
1/2	-810-3
5/8	-1010-3
3/4	-1210-3
7/8	-1410-3
1	-1610-3
1 1/4	-2000-3
1 1/2	-2400-3
2	-3200-3
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Union Elbow, 90°	
Tube OD (mm)	Swagelok® Basic Part Number *
3	-3MO-9
4	-4MO-9
6	-6MO-9
8	-8MO-9
10	-10MO-9
12	-12MO-9
14	-14MO-9
15	-15MO-9
16	-16MO-9
18	-18MO-9
20	-20MO-9
22	-22MO-9
25	-25MO-9
28	-28MO-9
32	-32MO-9
38	-38MO-9
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Union Tee	
Tube OD (mm)	Swagelok® Basic Part Number *
2	-2MO-3
3	-3MO-3
4	-4MO-3
6	-6MO-3
8	-8MO-3
10	-10MO-3
12	-12MO-3
14	-14MO-3
15	-15MO-3
16	-16MO-3
18	-18MO-3
20	-20MO-3
22	-22MO-3
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Union Tee (Continued)	
Tube OD (mm)	Swagelok® Basic Part Number *
25	-25MO-3
28	-28MO-3
32	-32MO-3
38	-38MO-3
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Reducing on Branch Union Tee		
Tube OD (in.)	Reduced Tube OD (in.)	Swagelok® Basic Part Number *
3/8	1/4	-600-3-6-4
1/2	1/4	-810-3-8-4
1/2	3/8	-810-3-8-6
5/8	3/8	-1010-3-10-6
3/4	3/8	-1210-3-12-6
3/4	1/2	-1210-3-12-8
1	3/8	-1610-3-16-6
1	1/2	-1610-3-16-8
1	3/4	-1610-3-16-12
1 1/4	1	-2000-3-20-16
1 1/2	1	-2400-3-24-16
2	1	-3200-3-32-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Reducing on Run Union Tees		
Tube OD (in.)	Reduced Tube OD (in.)	Swagelok® Basic Part Number *
3/8	1/4	-600-3-4-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Reducing on Run and Branch Union Tee		
Tube OD (in.)	Reduced Run & Branch Tube OD (in.)	Swagelok® Basic Part Number *
1/2	3/8	-810-3-6-6
5/8	3/8	-1010-3-6-6
3/4	3/8	-1210-3-6-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Reducing on Run and Branch Union Tee			
Tube OD (in.)	Reduced Run Tube OD (in.)	Reduced Branch Tube OD (in.)	Swagelok® Basic Part Number *
5/8	1/2	3/8	-1010-3-8-6
3/4	1/2	3/8	-1210-3-8-6
1	3/4	3/8	-1610-3-12-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel			

Swagelok® Union Cross	
Tube OD (in.)	Swagelok® Basic Part Number *
1/8	-200-4
1/4	-400-4
5/16	-500-4
3/8	-600-4
1/2	-810-4
3/4	-1210-4
1	-1610-4
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Union Cross	
Tube OD (mm)	Swagelok® Basic Part Number *
3	-3MO-4
6	-6MO-4
8	-8MO-4
10	-10MO-4
12	-12MO-4
16	-16MO-4
18	-18MO-4
20	-20MO-4
25	-25MO-4
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® to Male SAE/MS Flared End Union		
Tube OD (in.)	Flared Tube Nom. Size (in.)	Swagelok® Basic Part Number *
1/16	1/8	-100-6-2AN
1/8	1/8	-200-6-2AN
1/8	1/4	-200-6-4AN
1/4	1/4	-400-6-4AN
5/16	5/16	-500-6-5AN
3/8	1/4	-600-6-4AN
3/8	3/8	-600-6-6AN
1/2	1/2	-810-6-8AN
3/4	3/4	-1210-6-12AN
1	1	-1610-6-16AN
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Male SAE/MS Flared End Bulkhead Union		
Tube OD (in.)	Flared Tube Nom. Size (in.)	Swagelok® Basic Part Number *
1/4	1/4	-400-61-4AN
3/8	3/8	-600-61-6AN
1/2	1/2	-810-61-8AN
3/4	3/4	-1210-61-12AN
1	1	-1610-61-16AN
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Swagelok® Tube End Reducer		
Tube OD (in.)	Swaged Tube End OD (in.)	Swagelok® Basic Part Number *
1/16	1/8	-100-R-2
1/16	1/4	-100-R-4
1/8	1/16	-200-R-1
1/8	1/8	-200-R-2
1/8	3/16	-200-R-3
1/8	1/4	-200-R-4
1/8	3/8	-200-R-6
1/8	1/2	-200-R-8
3/16	1/8	-300-R-2
3/16	1/4	-300-R-4
1/4	1/8	-400-R-2
1/4	3/16	-400-R-3
1/4	1/4	-400-R-4
1/4	5/16	-400-R-5
1/4	3/8	-400-R-6
1/4	1/2	-400-R-8
1/4	5/8	-400-R-10
1/4	3/4	-400-R-12
5/16	3/8	-500-R-6
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes with pre-swaged nuts and ferrules on the tube end		

Swagelok® to Swagelok® Tube End Reducer (Continued)		
Tube OD (in.)	Swaged Tube End OD (in.)	Swagelok® Basic Part Number *
5/16	1/2	-500-R-8
3/8	1/4	-600-R-4
3/8	3/8	-600-R-6
3/8	1/2	-600-R-8
3/8	5/8	-600-R-10
3/8	3/4	-600-R-12
1/2	1/4	-810-R-4
1/2	3/8	-810-R-6
1/2	1/2	-810-R-8
1/2	5/8	-810-R-10
1/2	3/4	-810-R-12
1/2	1	-810-R-16
5/8	3/4	-1010-R-12
5/8	7/8	-1010-R-14
5/8	1	-1010-R-16
3/4	1/2	-1210-R-8
3/4	1	-1210-R-16
1	1 1/4	-1610-R-20 #
1	1 1/2	-1610-R-24 #
1	2	-1610-R-32 #
1 1/4	1 1/2	-2000-R-24 #
1 1/4	2	-2000-R-32 #
1 1/2	2	-2400-R-32 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes with pre-swaged nuts and ferrules on the tube end		

Swagelok® to Swagelok® Tube End Long Reducer		
Tube OD (in.)	Swaged Tube End OD (in.)	Swagelok® Basic Part Number *
3/8	1/2	-600-RF-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Metric Swagelok® Tube End Reducer		
Tube OD (mm)	Swaged Tube End OD (mm)	Swagelok® Basic Part Number *
2	3	-2MO-R-3M
3	4	-3MO-R-4M
3	6	-3MO-R-6M
3	10	-3MO-R-10M
4	6	-4MO-R-6M
6	3	-6MO-R-3M
6	8	-6MO-R-8M
6	10	-6MO-R-10M
6	12	-6MO-R-12M
6	18	-6MO-R-18M
8	6	-8MO-R-6M
8	10	-8MO-R-10M
8	12	-8MO-R-12M
10	6	-10MO-R-6M
10	8	-10MO-R-8M
10	12	-10MO-R-12M
10	15	-10MO-R-15M
10	18	-10MO-R-18M
12	6	-12MO-R-6M
12	8	-12MO-R-8M
12	10	-12MO-R-10M
12	16	-12MO-R-16M
12	18	-12MO-R-18M
12	20	-12MO-R-20M
12	22	-12MO-R-22M
12	25	-12MO-R-25M
16	12	-16MO-R-12M
18	12	-18MO-R-12M
18	16	-18MO-R-16M
18	20	-18MO-R-20M
18	22	-18MO-R-22M
18	25	-18MO-R-25M
20	16	-20MO-R-16M
20	18	-20MO-R-18M
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® to Metric Swagelok® Tube End Reducer (Continued)		
Tube OD (mm)	Swaged Tube End OD (mm)	Swagelok® Basic Part Number *
20	22	-20MO-R-22M
20	25	-20MO-R-25M
22	18	-22MO-R-18M
22	20	-22MO-R-20M
22	25	-22MO-R-25M
25	18	-25MO-R-18M
25	20	-25MO-R-20M
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® to Swagelok® Tube End Bulkhead Reducer	
Tube OD (in.)	Swagelok® Basic Part Number *
1/8	-200-R1-2
1/4	-400-R1-4
3/8	-600-R1-6
1/2	-810-R1-8
5/8	-1010-R1-10
1	-1610-R1-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® to Swagelok® Tube End Reducer		
Tube OD (mm)	Swaged Tube End OD (in.)	Swagelok® Basic Part Number *
2	1/8	-2MO-R-2
3	1/8	-3MO-R-2
3	1/4	-3MO-R-4
4	1/4	-4MO-R-4
6	1/8	-6MO-R-2
6	1/4	-6MO-R-4
6	5/16	-6MO-R-5
6	3/8	-6MO-R-6
6	1/2	-6MO-R-8
8	3/8	-8MO-R-6
8	1/2	-8MO-R-8
10	3/8	-10MO-R-6
10	1/2	-10MO-R-8
12	1/2	-12MO-R-8
12	3/4	-12MO-R-12
18	3/4	-18MO-R-12
18	1	-18MO-R-16
25	1	-25MO-R-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Tube End to Swagelok® Integral Ferrule Tube End Connector	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-101-PC
1/8	-201-PC
1/4	-401-PC
5/16	-501-PC
3/8	-601-PC
1/2	-811-PC
3/4	-1211-PC
1	-1611-PC
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Tube End to Metric Swagelok® Integral Ferrule Tube End Connector	
Tube OD (mm)	Swagelok® Basic Part Number *
3	-3M1-PC
6	-6M1-PC
8	-8M1-PC
10	-10M1-PC
12	-12M1-PC
15	-15M1-PC
16	-16M1-PC
18	-18M1-PC
20	-20M1-PC
25	-25M1-PC
28	-28MO-PC #
32	-32MO-PC #
38	-38MO-PC #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part includes nuts & ferrules	

Swagelok® Integral Ferrule Tube End to Reducing Swagelok® Tube End Connector		
Tube OD (in.)	Reduced Tube OD (in.)	Swagelok® Basic Part Number *
1/8	1/16	-201-PC-1
1/4	1/16	-401-PC-1
1/4	1/8	-401-PC-2
3/8	1/8	-601-PC-2
3/8	1/4	-601-PC-4
1/2	1/4	-811-PC-4
1/2	3/8	-811-PC-6
3/4	1/2	-1211-PC-8
1	1/2	-1611-PC-8
1	3/4	-1611-PC-12
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Metric Swagelok® Integral Ferrule Tube End to Reducing Metric Swagelok® Tube End Connector		
Tube OD (mm)	Reduced Tube OD (mm)	Swagelok® Basic Part Number *
6	3	-6M1-PC-3M
8	6	-8M1-PC-6M
10	6	-10M1-PC-6M
10	8	-10M1-PC-8M
12	6	-12M1-PC-6M
12	8	-12M1-PC-8M
12	10	-12M1-PC-10M
16	12	-16M1-PC-12M
28	25	-28M1-PC-25M
32	25	-32M1-PC-25M
38	25	-38M1-PC-25M
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Cap	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-100-C
1/8	-200-C
3/16	-300-C
1/4	-400-C
5/16	-500-C
3/8	-600-C
1/2	-810-C
5/8	-1010-C
3/4	-1210-C
7/8	-1410-C
1	-1610-C
1 1/4	-2000-C
1 1/2	-2400-C
2	-3200-C
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Cap	
Tube OD (mm)	Swagelok® Basic Part Number *
2	-2MO-C
3	-3MO-C
4	-4MO-C
6	-6MO-C
8	-8MO-C
10	-10MO-C
12	-12MO-C
14	-14MO-C
15	-15MO-C
16	-16MO-C
18	-18MO-C
20	-20MO-C
22	-22MO-C
25	-25MO-C
28	-28MO-C
32	-32MO-C
38	-38MO-C
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Plug	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-100-P
1/8	-200-P
3/16	-300-P
1/4	-400-P
5/16	-500-P
3/8	-600-P
1/2	-810-P
5/8	-1010-P
3/4	-1210-P
7/8	-1410-P
1	-1610-P
1 1/4	-2000-P
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Plug (Continued)	
Tube OD (in.)	Swagelok® Basic Part Number *
1 1/2	-2400-P
2	-3200-P
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Plug	
Tube OD (mm)	Swagelok® Basic Part Number *
2	-2MO-P
3	-3MO-P
4	-4MO-P
6	-6MO-P
8	-8MO-P
10	-10MO-P
12	-12MO-P
15	-15MO-P
16	-16MO-P
18	-18MO-P
20	-20MO-P
22	-22MO-P
25	-25MO-P
28	-28MO-P
32	-32MO-P
38	-38MO-P
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Low Dead Volume Union	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-1F0-6GC
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Low Dead Volume Union Tee	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-1F0-3GC
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Female Column End Fitting Union		
Tube OD (in.)	Sample End Tube OD (in.)	Swagelok® Basic Part Number *
1/4	1/16	-400-6-1FGC
3/8	1/16	-600-6-1FGC
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Low and Zero Volume Reducing Union		
Tube OD (in.)	Sample End Tube OD (in.)	Swagelok® Basic Part Number *
1/8	1/16	SS-200-6-1ZV
1/4	1/16	SS-400-6-1ZV
3/8	1/16	SS-600-6-1ZV
1/2	1/16	SS-810-6-1ZV
1/8	1/16	SS-200-6-1LV
1/4	1/16	SS-400-6-1LV
3/8	1/16	SS-600-6-1LV
* Standard part is made of type 304 or 316 Stainless Steel		

Swagelok® Tube Fitting with Integral ANSI (Raised Face) Flange		
Tube OD	Swagelok® Basic Part Number	ANSI Flange Class *
1/2"	SS-8F0-F8-150	150
	SS-8F0-F8-300	300
10mm	SS-10MF0-F8-150	150
	SS-10MF0-F8-300	300
12mm	SS-12MF0-F8-150	150
	SS-12MF0-F8-300	300
* Special Order to have Concentric 90° V-Groove Serrations in Flange Face per MSS SP-6 if connected pipe system flanges are required to have this design feature		

Swagelok® Vent Protector (Mud Dauber Fitting)	
Thread Size (in.)	Swagelok® Basic Part Number *
1/4	MS-MD-4M
3/8	MS-MD-6M
1/2	MS-MD-8M
3/4	MS-MD-12M
* Standard part is made of type 304 or 316 Stainless Steel	

Swagelok® Tube End to Male NPT Adapter		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-2-TA-1-2
1/8	1/4	-2-TA-1-4
3/16	1/8	-3-TA-1-2
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes assembled with nuts and ferrules		

Swagelok® Tube End to Male NPT Adapter (Continued)		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
3/16	1/4	-3-TA-1-4
1/4	1/8	-4-TA-1-2
1/4	1/4	-4-TA-1-4
1/4	3/8	-4-TA-1-6
1/4	1/2	-4-TA-1-8
5/16	1/8	-5-TA-1-2
5/16	1/4	-5-TA-1-4
3/8	1/8	-6-TA-1-2
3/8	1/4	-6-TA-1-4
3/8	3/8	-6-TA-1-6
3/8	1/2	-6-TA-1-8
1/2	1/4	-8-TA-1-4
1/2	3/8	-8-TA-1-6
1/2	1/2	-8-TA-1-8
5/8	1/2	-10-TA-1-8
3/4	1/2	-12-TA-1-8
3/4	3/4	-12-TA-1-12
1	3/4	-16-TA-1-12
1	1	-16-TA-1-16
1 1/4	1 1/4	-20-TA-1-20 #
1 1/2	1 1/2	-24-TA-1-24 #
2	2	-32-TA-1-32 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes assembled with nuts and ferrules		

Metric Swagelok® Tube End to Male NPT Adapter		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6-MTA-1-2
6	1/4	-6-MTA-1-4
8	1/4	-8-MTA-1-4
10	1/4	-10-MTA-1-4
10	3/8	-10-MTA-1-6
10	1/2	-10-MTA-1-8
12	1/4	-12-MTA-1-4
12	1/2	-12-MTA-1-8
28	1	-28-MTA-1-16 #
28	1 1/4	-28-MTA-1-20 #
32	1 1/4	-32-MTA-1-20 #
38	1 1/2	-38-MTA-1-24 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes assembled with nuts and ferrules		

Swagelok® to Male SAE/MS Straight Thread Adapter		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1/8	5/16-24	-2-TA-1-2ST
1/4	7/16-20	-4-TA-1-4ST
3/8	7/16-20	-6-TA-1-4ST
3/8	9/16-18	-6-TA-1-6ST
3/8	3/4-16	-6-TA-1-8ST
1/2	9/16-18	-8-TA-1-6ST
1/2	3/4-16	-8-TA-1-8ST
5/8	7/8-14	-10-TA-1-10ST
3/4	1 1/16-12	-12-TA-1-12ST
1	1 5/16-12	-16-TA-1-16ST
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes assembled with nuts and ferrules		

Swagelok® to Male SAE/MS Straight Thread Adapter (Continued)		
Tube OD (in.)	SAE/MS Thread Size (in.)	Swagelok® Basic Part Number *
1 1/4	1 5/8-12	-20-TA-1-20ST #
1 1/2	1 7/8-12	-24-TA-1-24ST #
2	2 1/2-12	-32-TA-1-32ST #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes assembled with nuts and ferrules		

Swagelok® Tube End to Female NPT Adapter (Continued)		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1	3/4	-16-TA-7-12
1	1	-16-TA-7-16
1 1/4	1 1/4	-20-TA-7-20 #
1 1/2	1 1/2	-24-TA-7-24 #
2	2	-32-TA-7-32 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes with assembled nuts & ferrules		

Swagelok® Tube End to Female NPT Adapter		
Tube OD (in.)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-2-TA-7-2
1/8	1/4	-2-TA-7-4
3/16	1/4	-3-TA-7-4
1/4	1/8	-4-TA-7-2
1/4	1/4	-4-TA-7-4
1/4	3/8	-4-TA-7-6
1/4	1/2	-4-TA-7-8
5/16	1/4	-5-TA-7-4
3/8	1/8	-6-TA-7-2
3/8	1/4	-6-TA-7-4
3/8	3/8	-6-TA-7-6
3/8	1/2	-6-TA-7-8
1/2	1/4	-8-TA-7-4
1/2	3/8	-8-TA-7-6
1/2	1/2	-8-TA-7-8
5/8	1/2	-10-TA-7-8
3/4	1/2	-12-TA-7-8
3/4	3/4	-12-TA-7-12
3/4	1	-12-TA-7-16
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Ordered part comes with assembled nuts & ferrules		

Metric Swagelok® Tube End to Female NPT Adapter		
Tube OD (mm)	NPT Nom. Pipe Size (in.)	Swagelok® Basic Part Number *
6	1/8	-6-MTA-7-2
6	1/4	-6-MTA-7-4
8	1/4	-8-MTA-7-4
10	1/4	-10-MTA-7-4
10	3/8	-10-MTA-7-6
10	1/2	-10-MTA-7-8
12	1/4	-12-MTA-7-4
12	1/2	-12-MTA-7-8
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Tube End to Male SAE/MS Flared End Adapter		
Tube OD (in.)	Flared Tube Size (in.)	Swagelok® Basic Part Number *
¼	1/4	-4-TA-1-4AN
3/8	1/4	-6-TA-1-4AN
3/8	3/8	-6-TA-1-6AN
½	1/2	-8-TA-1-8AN
¾	3/4	-12-TA-1-12AN
1	1	-16-TA-1-16AN
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Tube End to Integral Sleeve Flared Tube End; Equipped with Ferrules & Tube Coupling Nuts		
Tube OD (in.)	Flared Tube Size (in.)	Swagelok® Basic Part Number *
1/8	1/8	-200-A-2ANF
1/8	1/4	-200-A-4ANF
1/4	1/4	-400-A-4ANF
3/8	3/8	-600-A-6ANF
1/2	1/2	-810-A-8ANF
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel		

Swagelok® Nut **	
Tube OD (in.)	Swagelok® Basic Part Number
1/16	-102-1
1/8	-202-1
3/16	-302-1
1/4	-402-1
5/16	-502-1
3/8	-602-1
1/2	-812-1
5/8	-1012-1
3/4	-1212-1
7/8	-1412-1
1	-1612-1
1 1/4	-2002-1
1 1/2	-2402-1
2	-3202-1
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel ** Knurled Nuts up to one (1) inch are available in the same sizes as shown for SWAGELOK Nuts. To order, add suffix **K** to part number.	

Metric Swagelok® Nut **	
Tube OD (in.)	Swagelok® Basic Part Number *
2	-2M2-1
3	-3M2-1
4	-4M2-1
6	-6M2-1
8	-8M2-1
10	-10M2-1
12	-12M2-1
14	-14M2-1
15	-15M2-1
16	-16M2-1
18	-18M2-1
20	-20M2-1
22	-22M2-1
25	-25M2-1
28	-28M2-1
32	-32M2-1
38	-38M2-1
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel ** Knurled Nuts up to one (1) inch are available in the same sizes as shown for SWAGELOK Nuts. To order, add suffix **K** to part number.	

Swagelok® Male Nut	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-1F2-1GC
1/8	-2F2-1GC
1/4	-4F2-1
1/2	-8F2-1
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Metric Swagelok® Male Nut	
Tube OD (mm)	Swagelok® Basic Part Number *
10	-10MF2-1
12	-12MF2-1
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel	

Swagelok® Back Ferrule	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-104-1
1/8	-204-1
3/16	-304-1
1/4	-404-1
5/16	-504-1
3/8	-604-1
1/2	-814-1
5/8	-1014-1
3/4	-1214-1
7/8	-1414-1
1	-1614-1
1 1/4	-2004-1 #
1 1/2	-2404-1 #
2	-3204-1 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Use silver coated ferrules for stainless steel tube & fittings	

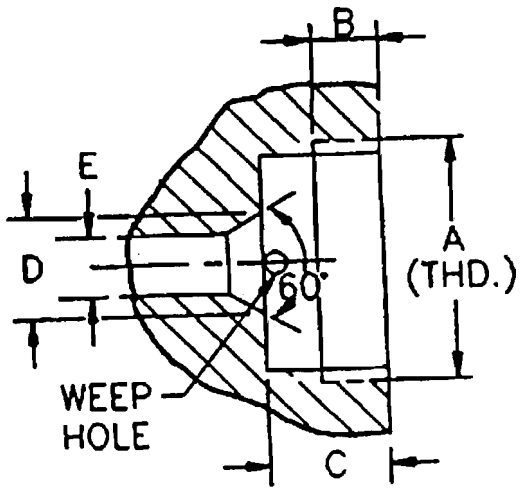
Metric Swagelok® Back Ferrule	
Tube OD (mm)	Swagelok® Basic Part Number *
2	-2M4-1
3	-3M4-1
4	-4M4-1
6	-6M4-1
8	-8M4-1
10	-10M4-1
12	-12M4-1
14	-14M4-1
15	-15M4-1
16	-16M4-1
18	-18M4-1
20	-20M4-1
22	-22M4-1
25	-25M4-1
28	-28M4-1 #
32	-32M4-1 #
38	-38M4-1 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Use silver coated ferrules for stainless steel tube & fittings	

Swagelok® Front Ferrule	
Tube OD (in.)	Swagelok® Basic Part Number *
1/16	-103-1
1/8	-203-1
3/16	-303-1
1/4	-403-1
5/16	-503-1
3/8	-603-1
1/2	-813-1
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Use silver coated ferrules for stainless steel tube & fittings	

Swagelok® Front Ferrule (Continued)	
Tube OD (in.)	Swagelok® Basic Part Number *
5/8	-1013-1
3/4	-1213-1
7/8	-1413-1
1	-1613-1
1 1/4	-2003-1 #
1 1/2	-2403-1 #
2	-3203-1 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Use silver coated ferrules for stainless steel tube & fittings	

Metric Swagelok® Front Ferrule	
Tube OD (mm)	Swagelok® Basic Part Number *
2	-2M3-1
3	-3M3-1
4	-4M3-1
6	-6M3-1
8	-8M3-1
10	-10M3-1
12	-12M3-1
14	-14M3-1
15	-15M3-1
16	-16M3-1
18	-18M3-1
20	-20M3-1
22	-22M3-1
25	-25M3-1
28	-28M3-1 #
32	-32M3-1 #
38	-38M3-1 #
* Add "SS" prefix to Basic Part No. for type 316 Stainless Steel # Use silver coated ferrules for stainless steel tube & fittings	

Appendix D - Coned and Left Hand Threaded Tube & Tube Fittings



10,000 psi and 20,000 psi rated tube fittings

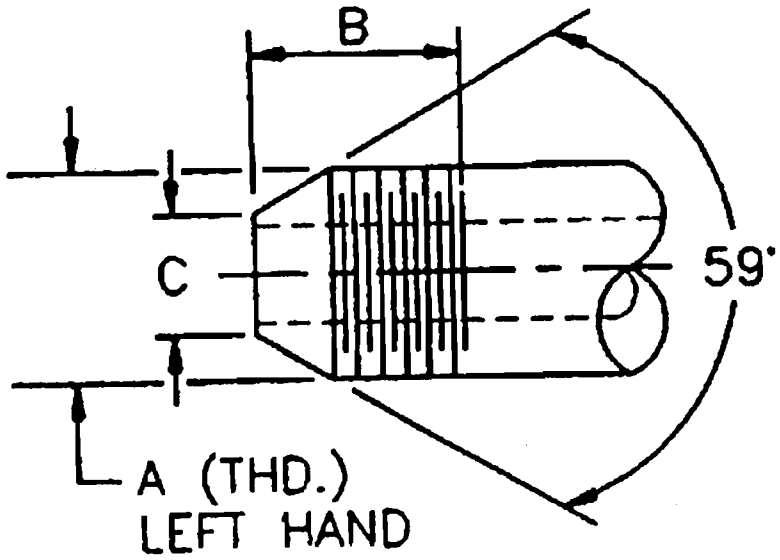
Tube OD	A Thread	B	C	D (Dia)	E (Dia) 20,000 psi	E (Dia) 10,000 psi
0.25	7/16 – 20	.28	.50	.19	.109	
0.375	9/16 – 18	.38	.62	.31	.203	
0.5625	13/16 – 16	.44	.75	.50	.312	.359
0.75	¾ - 14 NPSM	.50	.94	.62	.438	.516
1.00	1-3/8 - 12	.81	1.31	.88	.562	.688

40,000 psi and 60,000 psi rated tube fittings

Tube OD	A Thread	B	C	D (Dia.)	E (Dia) 60,000 psi	E (Dia) 40,000 psi
0.25	9/16 – 18	.38	.44	.17	.094	
0.375	3/4 – 16	.53	.62	.26	.125	
0.5625	1-1/8 – 12	.62	.75	.38	.188	.250

Figure D-1 Female End Connection Dimensions

Note: Dimensions are all in inches, shown for reference only, and should not be considered as actual machining dimensions.



10,000 psi and 20,000 psi rated tubes

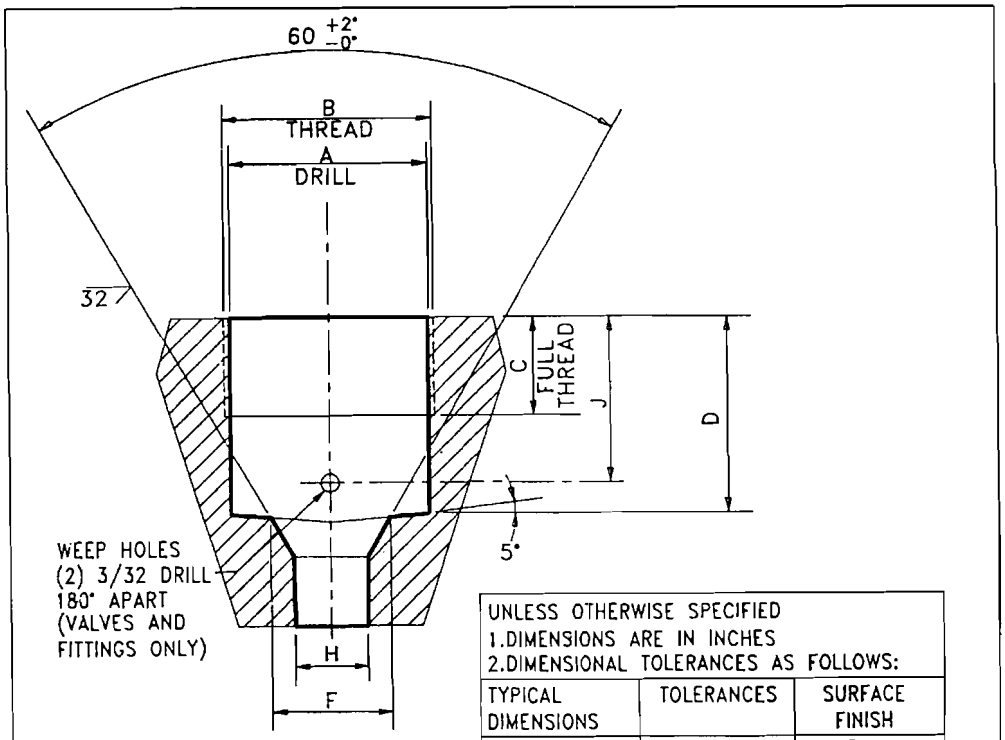
Tube OD	A Thread	B	C (Dia) 20,000 psi	C (Dia) 10,000 psi
0.25	1/4 – 28 L.H.	.34	.141	
0.375	3/8 – 24 L.H.	.44	.250	
0.5625	9/16 – 18 L.H.	.50	.406	.438
0.75	¾ - 16 L.H.	.62	.562	.578
1.00	1 – 14 L.H.	.78	.719	.812

40,000 psi and 60,000 psi rated tubes

Tube OD	A Thread	B	C (Dia) 60,000 psi	C (Dia) 40,000 psi
0.25	1/4 – 28 L.H.	.56	.125	
0.375	3/8 – 24 L.H.	.75	.219	
0.5625	9/16 – 18 L.H.	.94	.281	.312

Figure D-2 Tubing End Dimensions (inches)

Note: Dimensions are shown for reference only and should not be considered as actual machining dimensions.



UNLESS OTHERWISE SPECIFIED
1.DIMENSIONS ARE IN INCHES
2.DIMENSIONAL TOLERANCES AS FOLLOWS:

TYPICAL DIMENSIONS	TOLERANCES	SURFACE FINISH
0.0	±.060	32
0.00	±.030	32
0.000	±.015	32

ANGLES: ± 2°

BREAK CORNERS 0.015 MAX. R. OR CHAM.

FILLETS: 0.015 TO 0.030 R.

CHAMFER THREADS 45° TO ROOT DIA. ON 1/4 THREAD SIZE AND LARGER.

TUBE O.D. (INCHES)	CONNECTION TYPE	DIMENSIONS (INCHES)						
		A	B	C	D	F	H	J
1/4	SF250CX20	25/64	7/16-20 UNIFIED CLASS 2B	0.28	0.500	0.188	0.109	0.406
3/8	SF375CX20	33/64	9/16-18 UNIFIED CLASS 2B	0.38	0.625	0.312	0.203	0.500
9/16	SF562CX20	3/4	13/16-16 UNIFIED CLASS 2B	0.44	0.750	0.500	0.359	0.656
3/4	SF750CX20	0.953 +.010 -.000	3/4-14 NPSM	0.50	0.938	0.625	0.516	0.781
1	SF1000CX20	1.285 +.010 -.000	1 3/8-12 UNIFIED CLASS 2B	0.81	1.312	0.875	0.688	1.125

Figure D-3 20,000 psi Rated Coned & Threaded Tube Fitting Female End Connection Details

Appendix E - Coned and Left Hand Threaded Tube and Tube Fitting Manufacturers

Coned and Threaded Tube and Tube Fittings are produced by the manufacturers shown below. Use of tube and fittings produced by other manufactures requires an approved Variance or MUA.

AE:

Autoclave Engineers
2930 W. 22nd St., Box 5051
Erie, PA 16512-5051
(818) 838-5700
(800) 458-0409
Fax: (814) 833-0145

BuT:

BuTech Pressure Systems
4928 Pittsburgh Avenue
Erie, PA 16509
(814) 833-4904
Fax (814) 833-2612
e-mail: hq@butech-valve.com
http://www.butech-valve.com

HiP:

High Pressure Equipment Company
P.O. Box 8248
1222 Linden Avenue
Erie, PA 16505
(814) 838-2028
(800) 289-7447
Fax: (814) 838-6075
e-mail: sales@highpressure.com
http://www.highpressure.com

NSI:

Newport Scientific Inc. (formerly Aminco)
8246-E Sandy Court
Jessup, Maryland 20794
(301) 498-6700
Fax: (301) 490-2313

APPENDIX A6

SSTD 8070-0124-IDCODES

IDENTIFICATION OF PIPING SYSTEMS AND ABOVE GROUND MARKERS

SSTD-8070-0124-IDCODES
Revision Basic
June 2003

John C. Stennis Space Center
Identification of Piping Systems and Above-Ground Markers

Original signed by

Robert J. Heitzman
NASA SSC Center Operations
Operations and Maintenance Division

Randy Galloway
NASA SSC Propulsion Test
Operations Division

Nick Cenci
NASA SSC Office of Safety
and Mission Assurance

Issued by

Issued CEF 06/19/2003
Central Engineering Files

National Aeronautics and
Space Administration

John C. Stennis Space Center
Stennis Space Center, MS 39529-6000

Document History Log

Revision	Date	Originator	Description
Basic	6/9/03	Glen Liebig ext. 8-2219	Initial release – supersedes SSC STD 80-005 Rev A, and STD 80-001, Rev B, with the following major changes: New document number and format per SPG 1400.1; New document title; Reclassification of Paint Standard as Identification Code (broader scope includes paint color codes for piping and associated markers); change to requirements for commercial tape and complex configurations; 1.0 revised to include SSC Piping Systems, including Special Test Equipment (per Section 2.0); 2.0 added new; subsequent sections renumbered; 3.0 modified to delete obsolete documents; 4.0, 7.0 and 8.0 added new; 5.1 (was 3.1) rewritten and reorganized; 6.0 (was 3.0, 3.2, 3.3 and 4.0) rewritten and reorganized.

Table of Contents

TABLES AND FIGURES

1.0 PURPOSE

This Standard establishes the methods and color codes for identification of underground and aboveground piping systems and their associated aboveground markers at Stennis Space Center (SSC) in accordance with ANSI A13.1, ANSI Z535.1 and FED-STD-595.

2.0 APPLICABILITY

This standard applies to all SSC facilities piping systems, including Special Test Equipment. This standard is not applicable to electrical units; ventilation units; storage vessels; supports, brackets or other accessories; or pipelines installed in missiles, spacecraft or aircraft.

3.0 REFERENCES

Referenced documents are assumed to be the latest version unless otherwise specified.

ANSI A13.1	Scheme for the Identification of Piping Systems
ANSI Z535.1	Safety Color Code
FED-STD-595	Colors Used in Government Procurement
SPG 1400.1	Document Numbering, Preparation and Management Guidelines
SSLP-1440-001	SSC Records Management Program and Control of Quality Records
SSTD-8070-0005-CONFIG	Preparation, Review, Approval and Release of SSC Standards

4.0 RESPONSIBILITIES

This standard shall be maintained and controlled in accordance with the responsibilities and requirements of SSTD-8070-0005-CONFIG.

5.0 PIPING SYSTEMS IDENTIFICATION

5.1 DEFINITIONS

a. Piping Systems. Piping systems are defined as conduits for the transport of gases, liquids, semi-liquids, or fine particulate dust. For the purpose of this standard, piping systems shall include tubing and pipes of any kind as well as fittings, valves and pipe coverings.

b. Primary Color Warning. A primary color warning is the color assigned to the class into which a material is classified in accordance with its primary hazard from a safety standpoint. These colors appear as a circular band on piping systems and as lettering and line symbols on markers.
c. Secondary Color Warning. A secondary color warning is the color assigned as a warning of a secondary hazard possessed by a material having a type of hazard distinctly different from that indicated by its primary color warning. These colors appear as flow direction arrows on piping systems and as the field on markers.
d. Legend. A legend is any lettered identification required on a piping system. Legends identify the contents (by complete names or by generally recognized abbreviations, symbols, letters, numbers, or combinations thereof) and the pressure rating.

5.2 COLOR CODES

Exact identification of material in any SSC piping system is mandatory and shall be made by means of color codes and legends as specified herein. Attention shall be given to visibility with reference to pipe markings.

Color-coding of piping systems provides accurate and immediate visual and written identification of the contents and hazards within the piping system, which provides greater safety and lessens the chances of confusion during work in areas with numerous piping systems.

Hazard classes for all piping system contents are identified by 8 colors, the appearance of any of which on a piping system shall provide a danger warning for the hazard in the system (refer to Table 5-1). Where the application of a warning color will blend in with the background or onto the unpainted surface of a pipe or tubing, that area of the system will be painted white or black as required to provide adequate contrast and visibility.

Piping systems that do not require warning colors may be painted to match their surroundings, if not in conflict with other color designations in this standard, or such systems may be painted aluminum, black, or remain unpainted. This exception does not apply to any material, harmless or otherwise, specifically identified and listed in this standard.

TABLE 5-1. HAZARD CONTENTS COLOR CODES

Color	Color Code *	Acceptable Abbreviations	Used to Identify
Yellow	13655	FLAM	Flammable materials known ordinarily as flammables or combustibles.
Brown	10080	TOXIC	Toxic and poisonous materials. All materials extremely hazardous to life or health under normal conditions such as toxics or poisons.
Blue	15102	AAHM	Anesthetics and harmful materials. All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property but not normally productive of dangerous quantities of fumes or vapors.
Green	14187	OXYM	Oxidizing materials that readily furnish oxygen for combustion and fire producers which react explosively or with the evolution of heat in contact with many other materials.
Gray	16187	PHDAN	Physically dangerous materials. All materials, not dangerous in themselves, which are asphyxiating in confined areas or which are generally handled in a dangerous physical state of pressure or temperature.
Red	11105	FPM	Fire protection materials. All materials provided in piping systems or in compressed gas cylinders exclusively for use in fire protection.
Black	17038	Not Applicable	General use in systems not identified by other colors, or used for lettering or background for tape.
White	17875	Not Applicable	General use in systems not identified by other colors, or used for lettering or background for tape.
*Color code number conforms to requirements of FED-STD-595.			

Piping identification is broken down into 3 types of color code markings on the outside of the pipe to identify the pipe contents hazard, flow direction and legend (contents name and pressure). This identification may be accomplished by using commercially available ANSI A13.1 approved tape or direct painting. All paint shall be lead free. Where paint will not adhere to piping (e.g., systems constructed of stainless steel, galvanized carbon steel, special alloys), use commercially available tape or wrap-around banding. In systems comprised of tubing, the use of commercially available tape is encouraged. The inspection and replacement of tape on systems should be addressed in a regular maintenance cycle, as the tape will deteriorate over time faster than paint. On non-vacuum jacketed pipe where the internal fluid can reach below -50ºF, the material for markings shall be rated for -423ºF temperatures or shall be thermally insulated from the outer pipe wall. Color code applications for common SSC systems are identified in Section 5.3.

5.2.1 Contents Hazard (Primary Color)

The first set of markings (primary color warning) identifies the content of the pipe by using a specific color per Table 5-1 to identify the primary hazard. The entire piping system may be painted or color bands may be used at specific intervals along the piping system. The use of color bands is encouraged as the appearance of the bands will attract the attention of personnel and will serve as an indication of a hazardous system to personnel who are colorblind. If color bands are used, the spacing shall be frequent enough to provide identification throughout the system. Sizes of color bands are specified in Figure 5-1.

NOTE

Under no circumstances shall the distance between color bands exceed forty feet inside a building or test stand, and no more than 200 feet on cross-country lines.

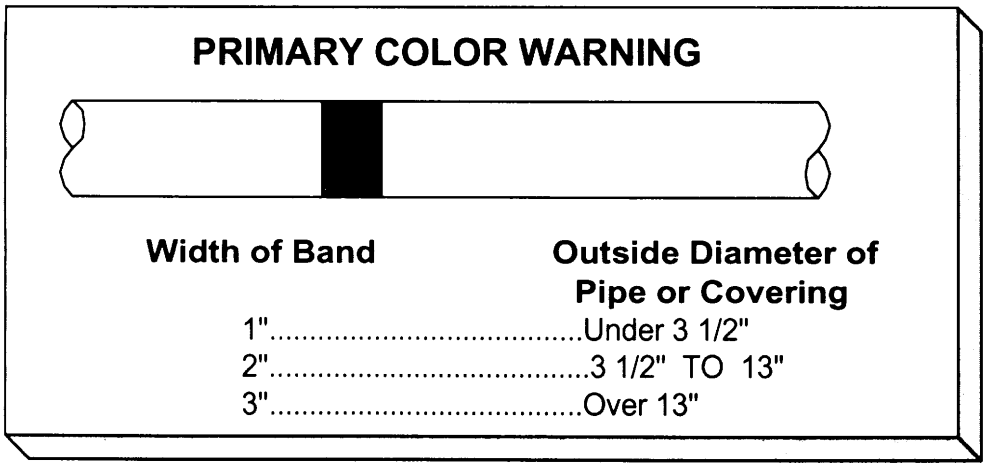


Figure 5-1. Contents Hazard Markings

5.2.2 Flow Direction Arrow (Secondary Color)

The second set of markings (secondary color warning) is shown as the flow direction arrow, which is color coded per Table 5-1 to identify a second hazard associated with the piping content. If a second hazard does not exist, the flow arrow is black or white. The flow arrow is taped or painted on the outside of the pipe and shall be formatted and proportionally sized to the piping system per Figure 5-2. Commercially available ANSI A13.1 approved tape with directional arrows, diamonds, or arrowheads may be used on piping and tubing systems. If the content can flow in either direction, a double-headed arrow shall be used.

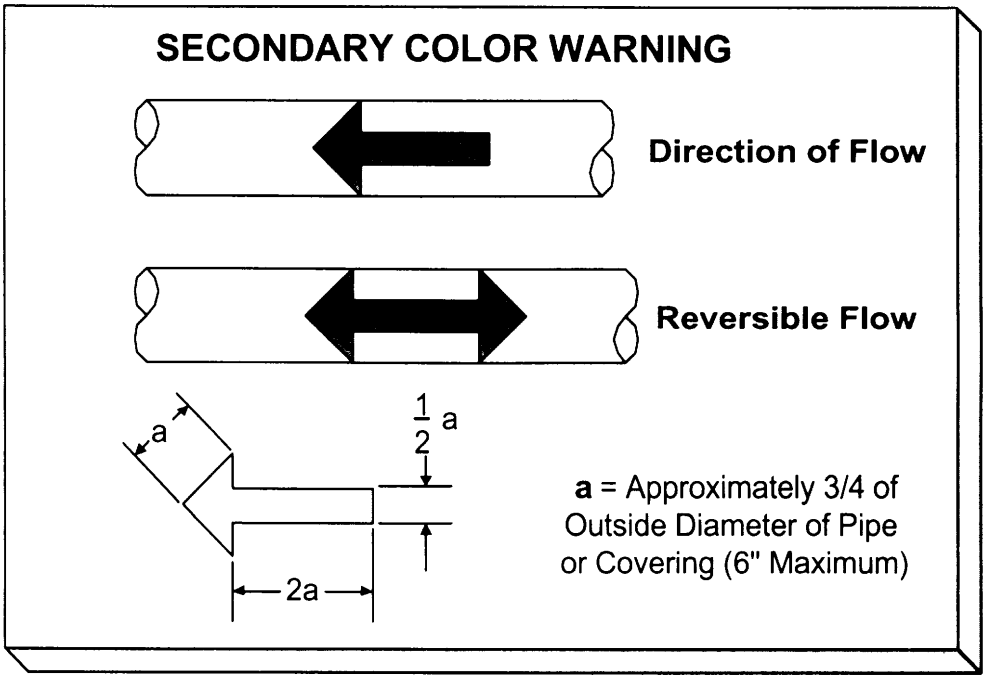


Figure 5-2. Flow Direction Arrow Markings

5.2.3 Legend

The third set of markings is the legend, which consists of the contents, by name or recognized abbreviations, and the contents pressure rating. The legend may be taped or stenciled onto the sides of the pipe. Legends shall be prominently displayed in black or white lettering adjacent to color warnings to reduce errors by operating personnel. Where the view is unobstructed, it is recommended the legend be located on the two lower quarters of the pipe or covering. Lettering in this position is unlikely to be obscured by dust collection or mechanical damage; however, legends should be clearly visible from operating positions, especially those adjacent to control valves. Where pipelines are located above or below the normal line of vision, lettering shall be placed below or above the pipe horizontal centerline. Legends shall be applied close to valves or flanges; adjacent to changes in direction, branches, and where pipes pass through walls or floors; and at intervals on straight pipe runs sufficient for identification.
Note: For configurations of extreme complexity or limited accessibility, alternate techniques may be used per ANSI A13.1.

Legend lettering and background shall be sized per Table 5-2 and colored per Table 5-3. The pressure rating (which is not required if less than 60 psig) is located immediately below the contents name per Figure 5-3(a) or, for smaller sized piping, directly beside the contents name per Figure 5-3(b).

NOTE

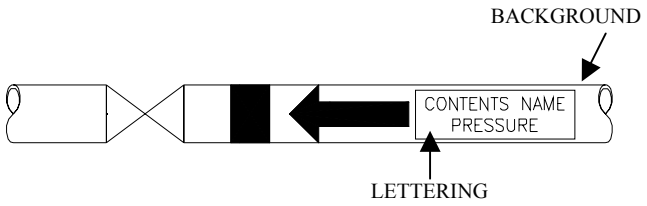
If tape is used for labeling, the pressure background color may be white for all hazard classifications; but, the contents background color must comply with Table 5-3.

TABLE 5-2. LEGEND LETTERING AND BACKGROUND SIZES

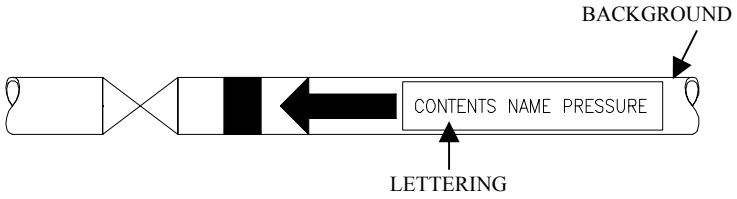
Outside Diameter of Pipe or Covering *		Background Length		Letter Size	
Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
¾ to 1 ¼	19 to 32	8	200	½	13
1 ½ to 2	38 to 51	8	200	¾	19
2 ½ to 6	64 to 150	12	300	1 ¼	32
8 to 10	200 to 250	24	600	2 ½	64
Over 10	Over 250	32	800	3 ½	89
*For pipe sizes smaller than ¾ inch, commercially available ANSI A13.1 approved tape may be used. Arrow sizes shall be in proportion to the pipe size per Figure 5-2; background color shall be as specified in Table 5-3, and background length shall be as specified above for ¾" pipe or as practicable in proportion to the length of the pipe.					

TABLE 5-3. LEGEND AND HAZARD CLASSIFICATION COLOR CODES

Classification	Background Color	Letter Color
Materials Inherently Hazardous		
Flammable or Explosive	Yellow	Black
Chemically Active or Toxic	Yellow	Black
Extreme Temperatures or Pressures	Yellow	Black
Materials of Inherently Low Hazard		
Liquid or Liquid Mixture	Green	White
Gas or Gas Mixture	Blue	White
Fire Protection Materials		
Water, Foam, CO2, Halon, etc.	Red	White



(a) Pressure Below Contents Name



(b) Pressure Directly Beside Contents Name

Figure 5-3. Legend (Contents and Pressure) Markings

5.3 SSC SYSTEMS APPLICATIONS

Common materials in SSC piping systems and their associated color markings are listed in Table 5-4.

TABLE 5-4. SSC PIPING SYSTEM COLOR CODES

System (contents/service), abbreviations	Contents Hazard (Primary) Color	Flow Direction Arrow (Secondary) Color	Legend Background Color	Legend Lettering Color
Air (>60 PSI), HA	Gray	Green	Blue	White
Helium (Gas) compressed, HE	Gray	Black	Blue	White
Hydrogen (Gas), GH	Yellow	Black	Yellow	Black
Hydrogen (Liquid), LH	Yellow	Gray	Yellow	Black
Hydrogen Peroxide, H202	Green	Blue	Yellow	Black
Hydrocarbon Fuels	Yellow	Black	Yellow	Black
Hydraulic Oil, HD	Yellow	Gray	Yellow	Black
Methane, LM/GM	Yellow	Black	Yellow	Black
Natural Gas, NG	Yellow	Brown	Yellow	Black
Nitrogen (Gas), GN	Gray	Black	Blue	White
Nitrogen (Liquid), LN	Gray	Black	Yellow	Black
Oxygen (Gas), GO	Green	Black	Yellow	Black
Oxygen (Liquid), LO	Green	Gray	Yellow	Black
Triethyl aluminum/ Triethyl boron, TEA/TEB	Yellow	Brown	Yellow	Black
Water (>50 PSI or >150F) (Industrial, IW)	Gray	Black	Yellow	Black
Water (Potable), PW	White	Black	White	Black
Water (Fire Protection)	Red	White	Red	White

6.0 MARKER REQUIREMENTS

All underground piping systems at SSC require above ground markers. This section defines how markers are constructed, where they shall be placed, and how they shall be labeled and colored.

6.1 TYPES AND COLOR CODES

Markers are of two different types: flat and upright. Flat markers (Figure 6-1) are the preferred markers due to the ease of maintenance around them. Upright markers are the original style markers used at SSC; however, they shall be replaced with flat markers when new pipe lines are installed or when maintenance is performed on existing underground piping. (The upright marker is illustrated in Figure 6-2 for reference only.)

The marker shall identify the exact content of the underground line, including the primary and secondary color warnings per Section 5.2. The marker shall also identify any directional and elevation changes in the pipe line. Refer to Figure 6-1.

6.2 DESIGN AND INSTALLATION

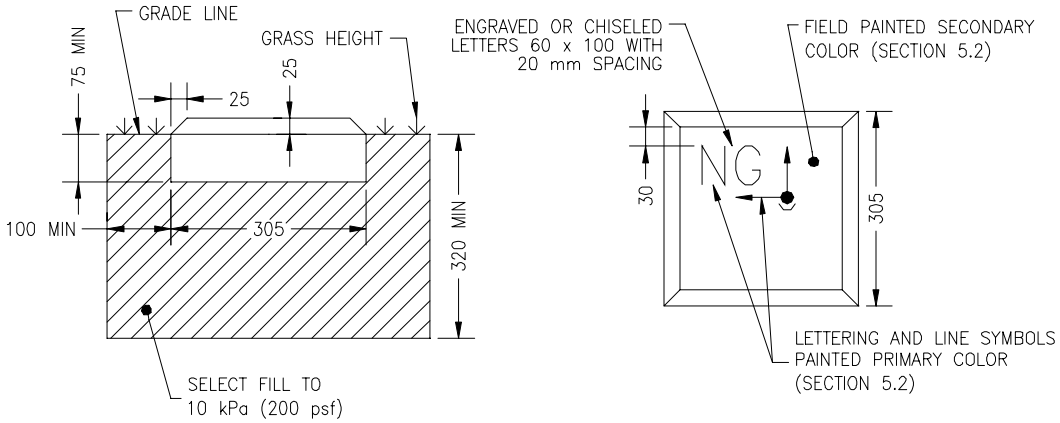
All new markers for underground pipe shall be constructed of concrete and conform to the standard marker design sketch in Figure 6-1. Lettering and line symbols for pipe contents and directional changes are also illustrated in Figure 6-1.

6.3 PAINTING

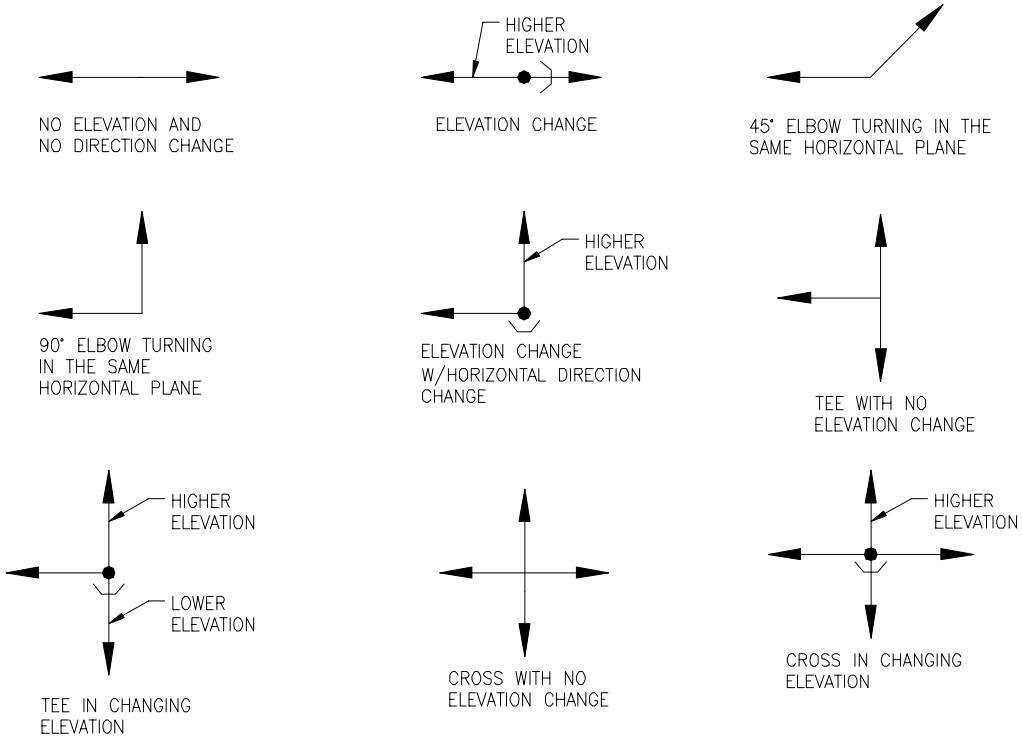
All markers shall be painted with lead free paint. The flat marker surface area shall be painted with the secondary color according to Section 5.2. The letters (abbreviations) and line symbols for pipe (contents flow direction and changes in pipe elevation) shall be engraved or chiseled into the concrete and shall be painted the primary color according to Section 5.2 and as illustrated in Figure 6-1.

6.4 LOCATION

Permanent flat markers for underground piping shall be located directly above the pipeline to indicate any and all changes in direction or elevation of the pipe line. Markers shall be maintained at each major bend, changes in line direction, line splits, take-offs and on each side of all railroad and road crossings. When a line changes direction or elevation, a marker shall be placed directly above the change. Additional marker locations shall be selected to give adequate warning to prevent accidental damage to the system. On long straight runs of pipe, markers shall be placed strategically close enough such that they can be located when performing maintenance or modification work. The distance between markers for straight runs of pipe shall be a maximum of 100 m (330 ft), measured from marker to marker.



(a) Configuration



(b) Line Symbol Examples

Figure 6-1. Flat Marker

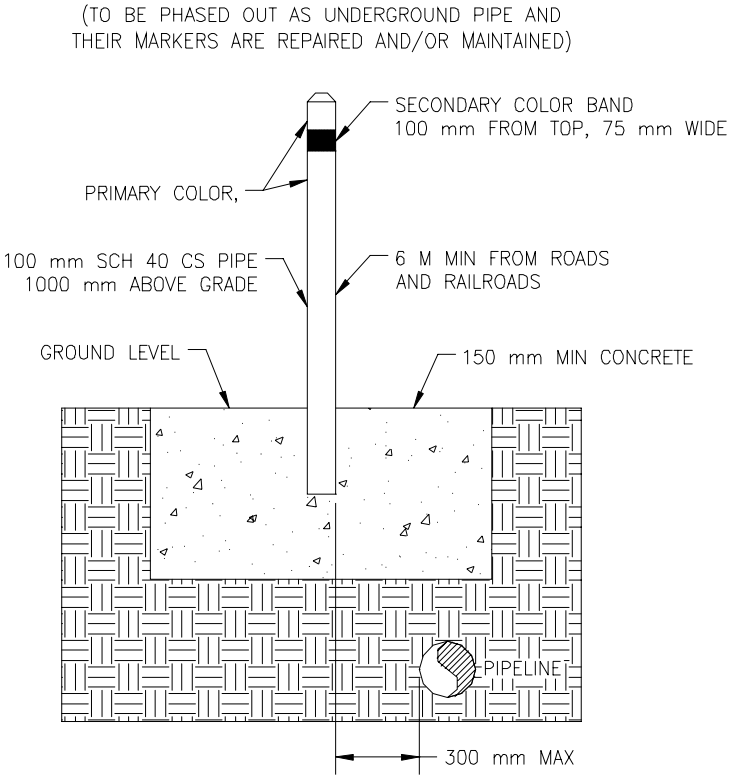


Figure 6-2. Upright Marker

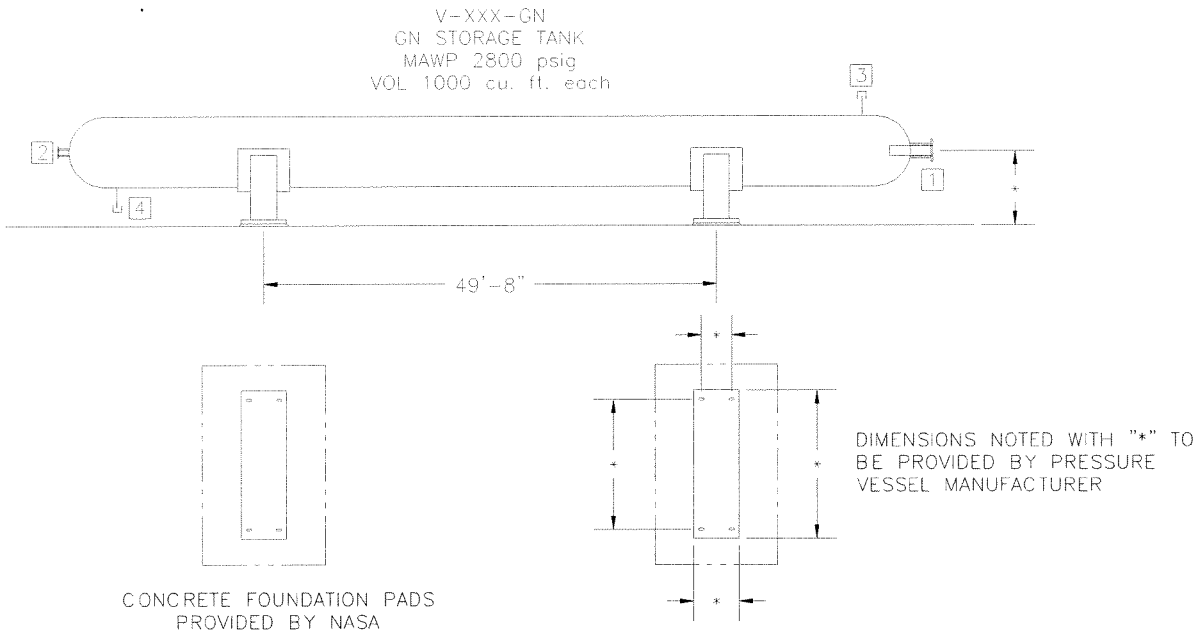
(FOR REFERENCE ONLY)

7.0 RECORDS

Records required by the performance of this standard shall be maintained in accordance with SSLP-1440-0001.

8.0 ACRONYMS

ANSI	American National Standards Institute
CS	Carbon Steel
FED	Federal
SPG	Stennis Procedures and Guidelines
SSC	Stennis Space Center
SSLP	Stennis System Level Procedure
STD	Standard
SSTD	Stennis Standard



I.D.	FUNCTION	SIZE	END CONNECTION	REMARKS
1	DISCHARGE NOZZLE	4"	GRAYLOC ®	STAINLESS INSERT MAY BE REQUIRED, REF SEC 2.3.5.1
2	ACCESS MANWAY	18"	VECTOR FLANGELOK® OR EQUIVALENT WITH RIBLESS D-TYPE SEAL RING	
3	HIGH POINT VENT	3"	GRAYLOC® (W/1" SAE AS5202 CONNECTION DRILLED AND TAPPED INTO HUB	
4	LOW POINT DRAIN	3"	GRAYLOC® (W/1" SAE AS5202 CONNECTION DRILLED AND TAPPED INTO HUB)	

Figure 1; Gaseous Nitrogen Vessel Nozzle Orientation and Overall Dimensions

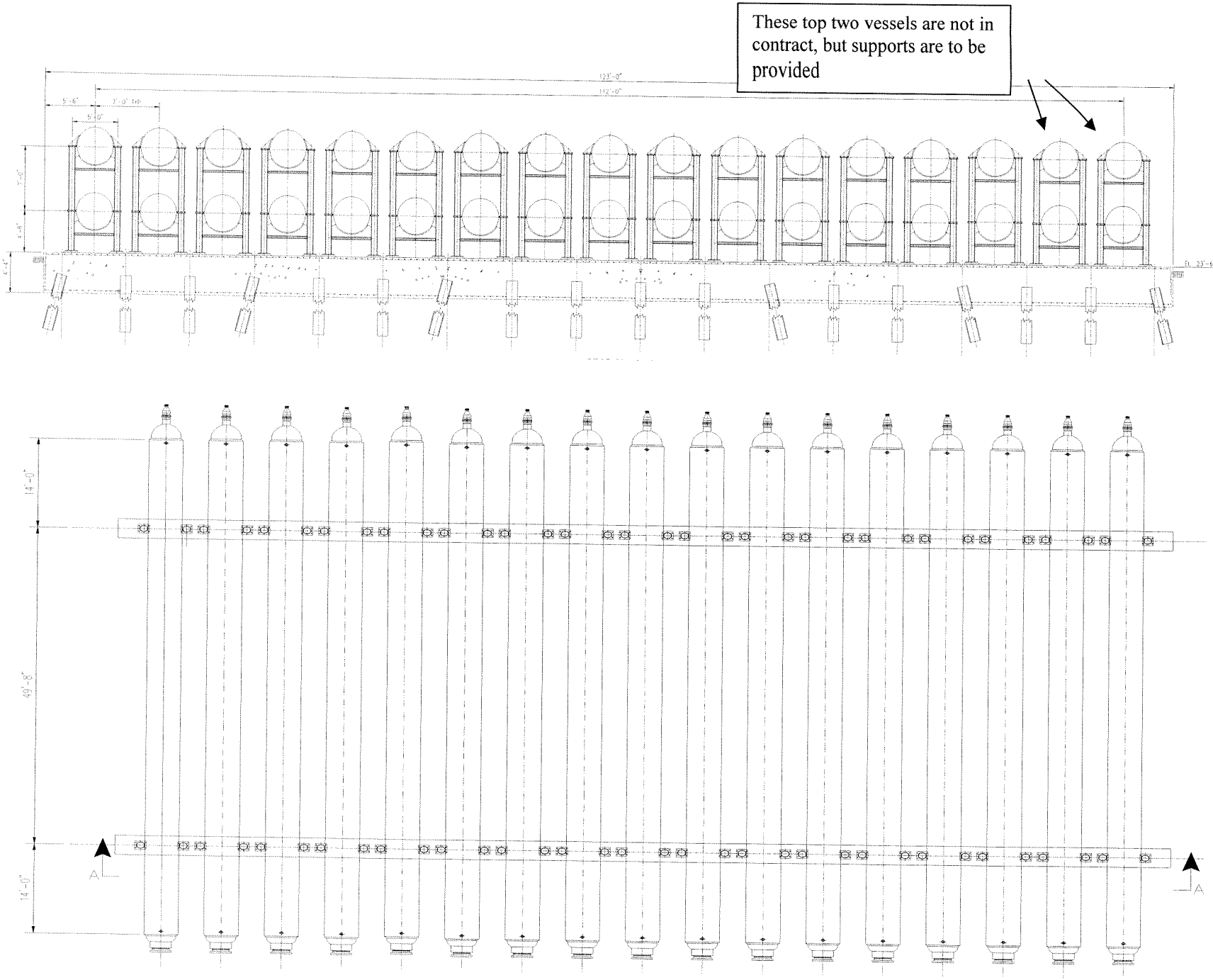


Figure 2; Gaseous Nitrogen Vessel Support Details

End of Specification