National Aeronautics and
Space Administration

MSFC-STD-3535
BASELINE
EFFECTIVE DATE: April 8, 2009

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

EM01

MULTIPROGRAM/PROJECT COMMON-USE DOCUMENT

Standard for Propellants and Pressurants used for Test and Test Support Activities at SSC and MSFC

Approved for Public Release; Distribution is Unlimited

CHECK THE MASTER LIST—
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		4/8/09	Initial Release. Supersedes MSFC-PROC-404 and SSC Standard 79-002.

FOREWORD

This standard was developed by the NASA George C. Marshall Space Flight Center (MSFC) and the NASA John C. Stennis Space Center (SSC) to provide uniform engineering and technical requirements across both Centers for contamination control of propellants and pressurants. This standard has been endorsed and approved for use at the MSFC and the SSC.

This standard establishes core requirements, practices, and methods to assure the quality of propellants and pressurants are maintained. The movement toward joint standardization is driven by past contamination experiences and different technical requirements and practices at both Centers. Non-standard Center practices complicate test interfaces and increase operational risks and costs.

Approving Authorities:

Melvin R. Carruth — 8/28/2008

Carruth, Melvin R. (MSFC-EM01)
Manager, Materials and Processes Laboratory — Approval Date

Richard K. Burt — 8/28/08

Burt, Richard K. (MSFC-ET01)
Manager, Test Laboratory — Approval Date

Thomas R Galloway — 8/28/08

Galloway, Thomas R. (SSC-EA00)
Director, Engineering & Science Directorate — Approval Date

TABLE OF CONTENTS

SECTION **PAGE**

1. PURPOSE

The purpose of this standard is to specify the minimum requirements for the certification and maintenance of propellant and pressurant (P/P) systems used for the purpose of rocket engine testing, test operations, ground support operations, center laboratory operations, and center facility operations.

2. APPLICABILITY

This standard is applicable to ground-based rocket propulsion test, test support, center sample analysis laboratory, and center operation facilities for P/P requiring system certification. P/P quality provided to the user interface points shall meet or exceed program, test article, center or laboratory requirements. Programs or customers may impose additional requirements. In such cases, process changes and supplemental procedures may be required.

Propellants and pressurants covered in this standard are high purity air (HPA), gaseous nitrogen (GN_2), liquid nitrogen (LN_2), gaseous hydrogen (GH), liquid hydrogen (LH), gaseous oxygen (GOX), liquid oxygen (LOX), gaseous helium, and liquid helium, and breathing air.

3. APPLICABLE DOCUMENTS

3.1 General

The documents listed in this section contain provisions that constitute requirements of this standard. The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority. The applicable documents are accessible via the National Aeronautics and Space Administration (NASA) Technical Standards System at http://standards.nasa.gov, directly from the Standards Developing Organizations, or from other document distributors.

3.2 Government Documents

MIL-PRF-25508, Performance Specification Propellant, Oxygen

MIL-PRF-27201, Performance Specification Propellant, Hydrogen

MIL-PRF-27404, Performance Specification Propellant Pressurizing Agent, Helium

MIL-PRF-27401, Performance Specification Propellant Pressurizing Agent, Nitrogen

MIL-PRF-32207, Performance Specification Propellant, Methane

MPR 8715.1, Marshall Safety, Health, and Environmental (SHE) Program

MSFC-SPEC-164B, Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems

MWI 8715.1, Electrical Safety Program

NPR 1400.1, NASA Directives Procedural Requirements

NPR 1441.1, NASA Records Retention Schedules

SPR 1440.1, Records Management Program Requirements

SPR 8715.1, NASA/SSC Safety and Health Procedural Requirements

3.3 Non-Government Documents

ASME B 31.1, Power Piping

ASME B 31.3, Process Piping

CGA G-7.1, Commodity Specification for Air

3.4 Order of Precedence

When this standard is applied as a requirement or imposed by contract on a program or project, the technical requirements of this standard take precedence, in the case of conflict, over the technical requirements cited in applicable documents or referenced guidance documents.

4. ACRONYMS AND DEFINITIONS

4.1 Acronyms and Abbreviations

ASME	American Society of Mechanical Engineers
C	Celsius
CO	Carbon Monoxide
CO_2	Carbon Dioxide
C_2H_2	Acetylene
CGA	Compressed Gas Association
CH_4	Methane
F	Fahrenheit
GH	Gaseous Hydrogen
GOX	Gaseous Oxygen
GN_2	Gaseous Nitrogen
He	Helium
H_2	Hydrogen
H_2O	Water
HPA	High Purity Air
LEL	Lower Explosion Limit
LH	Liquid Hydrogen
LN_2	Liquid Nitrogen
LOX	Liquid Oxygen
m	Meter
mg	milligram
MIL	Military
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirement

N_2	Nitrogen
O_2	Oxygen
OJT	On-the-Job Training
POC	Point of Contact
P/P	Propellant / Pressurant
PPE	Personal Protective Equipment
ppm	Parts per million
psig	Pounds per Square Inch Gauge
scf	Standard Cubic Foot
scfm	Standard Cubic Foot per Minute
SHE	Safety, Health, and Environmental Program
SSC	John C. Stennis Space Center
UIP	User Interface Point

4.2 Definitions

Analytical Sample: Sample taken during a maintenance activity or after decertification of a system that is for engineering-based analysis only. The information will be used to assist in preparing a system for certification.

Certification: A process in which a written record is generated that demonstrates that the requirements of this standard have been met and verified.

Certification Sample: Any sample taken by certified personnel on a system that is currently certified or taken on a system under maintenance or a de-certified system for the purpose of certification.

Certified System: A certified system is comprised of clean components and subsystems initially verified through a multiple sample process as meeting the requirements of this standard. Only certified P/P's shall be used in this system which requires periodic sampling to maintain certification.

Condensable Hydrocarbons: Oily mist or droplets containing carbon and hydrogen components and other elements in a gas stream. These are expressed as the mass of oil (e.g., milligrams) per a specified volume of gas. (See Appendix C.)

Contaminant: Any material that could reduce the intended purity of a pressurant/propellant thereby allowing chemical reaction or mechanical interference with a cleaned component, system, or end item.

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

Fiber: A flexible structure having a length-to-width ratio of 10-to-1 or greater.

Hydrocarbon: Any compound containing carbon and hydrogen.

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

Moisture: The residual liquid/gas/water measured in parts-per-million (ppm) by volume.

Non-Certified System: A utility or facility system not intended to be certified.

Particulate: Matter with observable length, width, and thickness usually measured in micrometers. This definition includes fibers.

Propellants/Pressurants (P/P): All cryogenic and non-cryogenic fluid products such as liquid or gaseous oxygen, hydrogen, helium, nitrogen, and rocket propellants that are used to support combustion for propulsion, pressurize propulsion systems, purge systems, simulate high-vacuum space conditions, or create inert atmospheres.

Receiving Tank: Tanks used for receiving commodity at gas generation or storage facility.

Run Tank: Tank that feeds directly to test article.

Sample: A selected portion of material, usually from a larger amount, taken or provided for inspection, certification or verification.

Sample Point: The designated point in a system or component from which a representative sample may be taken.

Storage Tank: (e.g., Barges) Tanks used to transfer commodity to run tanks, trailers, or test articles.

System Maintenance: A process whereby a closed propellant/pressurant system is opened for the purpose of preventive or corrective maintenance or system modification. This does not normally include connecting and disconnecting of test articles and equipment.

Total Hydrocarbon: For the purpose of this document, the total hydrocarbon content will be gaseous hydrocarbons expressed as methane and defined by any compound containing carbon and hydrogen.

User Interface Point: The point between the propellant/pressurant system operator (supplier) and the end user (customer) which is determined by contract, agreement or specification requirements.

Verification: Testing performed to determine whether previously certified gas system continues to satisfy specification requirements.

5. RESPONSIBILITIES

Responsibilities for the requirements and applications of this standard are as specified in the text herein. All users of this standard shall comply with its requirements and verify the latest version prior to use.

The NASA SSC Engineering and Science Directorate and MSFC Materials and Processes Laboratory are responsible for approval of the content of this standard and have final authority for its interpretation. Concurrence from both Centers, in signature form, is required for any revision/clarification to this document.

NASA and contractor personnel have various responsibilities for planning, approval, supervising, monitoring, notifying, and documenting, as specified throughout this standard.

6. GENERAL

Certification sampling requirements are identified in this standard. Once the process of certification or recertification of a system has begun, no analytical or other samples shall be allowed.

Samples shall be taken at predetermined gas or liquid sample points downstream of filters, regulators, valves, and any other equipment normally installed in a line.

6.1 Common Sampling Team

The common sampling team will consist of a dedicated group of personnel with common processes, equipment, and training/certifications to perform the assigned functions. Team members may consist of personnel from a single contractor or any combination of government and personnel from different contractors.

In order to achieve consistent and reliable results, all personnel on the team shall be trained or certified to the same requirements.

A NASA or contractor point of contact (POC) will be identified as the common sampling team lead. Some responsibilities of the team lead include:

a. Assuring failed sample results are communicated to the appropriate parties.

b. Prioritizing the sampling schedule when there are conflicts.

c. Serving as the focal point for technical issues related to sampling.

d. Verifying common sampling team personnel maintain updated training.

e. Performing quarterly reviews of the sampling database.

See Appendix A for minimum training requirements.

6.2 Common Sampling Equipment

The common sampling team shall control the use of all approved portable sampling panels and related equipment, while maintaining records pertaining to preventive and corrective maintenance.

Note: Fixed pressure-reducing or sampling panels are the responsibility of the system operator.

The sample analysis laboratory shall control the use of all sampling containers and related equipment and maintain records pertaining to preventive and corrective maintenance.

6.3 Sampling Schedule

The common sampling team shall create and maintain a sampling schedule for taking periodic gas and liquid samples. This sampling schedule should be created with inputs from fluid system operators, customers, and the sample analysis laboratory. The schedule should identify each designated sampling port, along with the fluid to be sampled and sampling frequency.

P/P system sampling frequency shall meet the requirements of Section 7.2.

6.4 Sample Database

The common sampling team shall create and maintain a sampling database to document gas and liquid samples. All samples taken, analytical, periodic (see table 1) and system certification, shall be maintained in the database, but shall be distinctively identified to prevent confusion. At a minimum, a quarterly data review shall be performed on the periodic data to verify overall system integrity.

6.5 Sample Points

Sample points are points in a P/P system located and configured to provide representative system conditions for sampling operations. These discreet points are typically valves and are identified by each site and documented on applicable system drawings.

6.6 Procedures

The common sampling team shall work to approved procedures for all sampling and analysis. Acceptable procedures shall include technical steps required to safely perform and maintain accuracy and process control. Sampling practices/techniques noted in Appendix B shall be incorporated into approved procedures.

The owners/operators of the system to be sampled shall be responsible for preparing the system prior to any sampling activity.

6.7 Safety

Personnel involved in sampling processes specified herein shall be required to adhere to safety requirements as specified by their Center.

6.8 Environmental

The mitigation of possible impacts to the environment takes precedence over function, cost, or expediency. Environmental impacts and concerns should be reported to the appropriate Center's Environmental Officer.

6.9 Training and Personnel Certification

Personnel involved in sampling processes shall be instructed to exercise precautionary measures necessary to reduce introduction of contaminants. Minimum classroom training requirements are noted in Appendix A. On-the-job training (OJT) required to meet certification requirements will be documented at each given center.

6.10 Quality Assurance

Sampling processes shall be validated to demonstrate the ability of the process to achieve required results. The processes shall be approved by the cognizant sampling personnel management and other NASA/contractor organizations as required. Process procedures shall describe methods and techniques, which control critical parameters. Approved changes to the procedures shall be documented. Monitoring and measuring equipment shall be controlled per the Center's requirements to ensure accuracy.

7. GENERAL PROPELLANT/PRESSURANT SAMPLING REQUIREMENTS

7.1 Propellant/Pressurant System Sampling Frequency Rationale

Sampling frequency was determined based on such considerations as use of the system, commodity, adverse trends, customer requirements and risk.

A quarterly sampling frequency does not provide enough data points to establish identifiable trends within gas piping systems. Data gathered from sampling operations at SSC since August 2007 has provided adequate data points for trending capability. MSFC weekly sampling data supports the proposed frequency requirements.

Based on the benefits of a common sampling team, the samples supplied to the analysis lab will be consistent. Samples will be analyzed for all parameters as specified at the User Interface Points (UIP's). The database for sample results will be used to identify trends that could impact the integrity of site-wide systems.

7.2 Propellant/Pressurant System Sampling Frequency

When used for testing, drying and preservation, gaseous systems that are used daily shall be tested with a frequency adequate to ensure the maintenance of system integrity as defined in table 1 below. If intermittent sampling is elected due to extended system non-use, the system shall be sampled and verified prior to use.

Table 1. Periodic Sampling Requirements

Propellant / Pressurant	Gaseous Generation Facilities	Delivery Piping Systems/ User Interface Points	Trailers
High Purity Air	Every 2 Weeks	Monthly	Each Every 6 Months*
Gaseous Nitrogen	Every 2 Weeks	Monthly	Each Every 6 Months*
Liquid Nitrogen	See Additional Requirement 4	Not Applicable	Each Every 3 Months
Gaseous Hydrogen	Every 2 Weeks	Monthly	Each Every 6 Months*
Liquid Hydrogen	See Additional Requirement 4	Upon Request	Upon Request
Gaseous Oxygen	Upon Request	Upon Request	Each Every 6 Months
Liquid Oxygen	See Additional Requirement 4	Not Applicable	Each Every 3 Months
Gaseous Helium	Every 2 Weeks	Monthly	Each Every 6 Months*
Liquid Helium	See Additional Requirement 4	Not Applicable	Not Applicable

Additional Requirements:

1. All samples are for in-service systems or components only. Specific sampling requirements for out-of-service or stand-by systems or components should be in accordance with program-specific plans for those items (* SSC gas trailers will be sampled per load.).
2. Liquid Hydrogen and Liquid Oxygen barges will be sampled prior to delivery.
3. Sampling downstream of the user interface point shall occur as requested by user.
4. Cryogenic tanks will be sampled at the discretion of the operator or per agreement between the operator and the customer.

7.3 Gaseous Sampling Requirements

Gaseous P/P's typically include oxygen, nitrogen, hydrogen, helium, and the high purity air system (missile grade air). These P/P's are sampled at designated sample points to verify the sample analysis requirements of Table 2 in Section 11.

Note: Designated sample points may include truck tube banks, sampling points near maintenance or system break points, and pressure vessels.

7.4 Particulate Sampling in Gaseous Propellants/Pressurants

Particulate sampling equipment shall be verified/certified clean prior to use. High-pressure or low-pressure filter holders may be used depending on the systems sampled. The filter holder will contain a filter disc (0.45 micron).

7.5 Cryogenic Liquid Sampling Requirements

Liquid P/P systems are sampled at designated sample points in Section 7.3 to verify the sample analysis requirements of Table 2 in Section 11.

Only cosmodyne sampler, model CS-4.4 or equivalent, verified/certified clean for specific P/P, LOX, LH or LN, will be used for liquid sampling.

Insulated flex hoses, cleaned to the specific level for the P/P, will be used to connect the cosmodyne sampler to the sample point.

7.6 Sampling for Condensable Hydrocarbons in Propellant/Pressurant Systems

Gaseous P/P sampling shall be performed on the nitrogen, helium, and high purity air systems to verify that these systems are free of condensable hydrocarbons.

Sampling for condensable hydrocarbons is only performed on fluids that are pressurized to system operating pressures by compressors that contain hydrocarbon lubricants (i.e., oils). These sample points must be near the point where the gas is introduced into the distribution system.

See Appendix C for condensable hydrocarbon sample analysis procedures.

8. PROPELLANT/PRESSURANT SAMPLING EQUIPMENT

8.1 General

Portable sample panels shall receive proper preventative maintenance on a scheduled basis and corrective maintenance when required. The design of portable sample panels shall incorporate applicable standards for fail-safe use and personnel safety, along with considerations for ease of operations.

Prior to use, hand tools, materials, and equipment that may come into contact with significant surfaces or the service media shall be verified/certified and identified as cleaned, maintained clean or field cleaned to the required system or component level where it is being used.

8.2 Detailed Sampling Equipment

8.2.1 Cryogenic Liquid Sampling Equipment

All equipment identified as verified/certified "clean" shall be cleaned, maintained clean or field cleaned as appropriate to the system level where it is being used. Only Cosmodyne sampler, model CS-4.4 or equivalent, is to be used for collecting liquid samples. An insulated clean flex hose (Cosmodyne part number 2601191-1 or equivalent) shall be used.

8.2.2 Gas Sampling Equipment

A gas sampling cylinder (hoke, watermelon, or equivalent) rated for the appropriate maximum pressure shall be used for gas samples.

8.2.3 Particulate Sampling Equipment

Particulate sampling shall be performed with an appropriately pressure-rated filter holder containing a verified/certified filter disc (0.45 micron).

8.2.4 Moisture Sampling Equipment

A moisture meter approved by the gas analysis laboratory is required for moisture content determinations in the field.

8.2.5 Condensable Hydrocarbons Sampling Equipment

A condensable hydrocarbon sampler is a filter holder that contains a sintered porous disc that has a 10-micron nominal pore size.

8.3 Propellant/Pressurant Sampling Panels

To assist in the collection of high-pressure gas samples, a pre-fabricated "sample panel" may be used in lieu of individual components. These pressure-reducing sample panels may be permanently installed at the sample location or be portable in nature. See Section 8.3.1 for advantages and disadvantages.

The panels shall be designed per the ASME B31.3 and in a manner to prevent over pressurization, damage to hardware, and injury to personnel. The hand-operated pressure regulator should have a flow rate as low as possible to reduce the size of the relief valve, or burst disk protecting the sample bottle. The range of the calibrated gage shall be such that the normal operating pressure of the panel reads approximately mid-range of the gage.

If the panels are used to obtain particulate data, the hand-operated regulators must be those without built-in filters. The panel must also have either a calibrated flow-meter or a calibrated orifice, or it must be controlled by an approved written procedure detailing flow rate requirements.

Panels shall include labeled inlets and outlets, pressure limits, P/P's for which it is suitable and appropriate valve identifiers and cautions.

8.3.1 Advantages and Disadvantages of Types of Sample Panels

The permanent installed pressure-reducing panels have the advantage of eliminating possible cross-contamination of the sample taken from previous locations and the individual components can possibly be smaller in size and cheaper. The disadvantage of the permanent panels is that one is required for each sample point, and therefore may be cost prohibitive if several sample points are required.

The portable sample panels have the advantage in that "one panel serves all," or a few panels will serve all locations or different gases. The disadvantages are the possible cross-contamination of samples and if panels are designed for different pressures, a safety issue arises when using a panel not suited for the pressure being sampled.

8.3.2 Sample Container Preparation

All new sample containers shall be verified/certified clean prior to initial use.

The following processes are acceptable for preparing cylinders to measure the maximum allowable contaminants in P/P systems for routine samples:

a. Vacuum – using a pump system, the vessel shall be pulled to a vacuum of 50 microns or less to assure there is no residual gas left in the vessel; or
b. Purge/Vent – purge each vessel by flowing sample gas from the sample point through the sample vessel for a minimum of three minutes to ensure that all residual gas has been removed.

9. SAMPLE ANALYSIS REQUIREMENTS

9.1 General Propellant/Pressurant Sample Analysis

Samples taken may be gas and/or liquid, but the impurities in all P/P samples shall be analyzed in a gaseous state. All analyses shall be performed to approved procedures.

Particulate samples shall be evaluated in either a verified/certified clean room or at verified/certified clean work stations (flow benches).

9.2 Propellant/Pressurant Sample Analytical Methods

Unless otherwise stated, samples shall be analyzed using examples in Appendix C**.** Calibration gas standards are required to calibrate analytical instruments used for sample analysis.

9.3 Hydrocarbon Content

Hydrocarbon Content performed on both gaseous and cryogenic liquid samples shall be expressed as methane. A hydrocarbon analyzer capable of detecting one part per million of methane shall be used to determine hydrocarbon content. The equipment shall be operated in accordance with the manufacturer's instructions.

9.4 Condensable Hydrocarbon

Condensable hydrocarbon content shall be determined in accordance with Appendix C.

9.5 Moisture Content

Moisture content shall be determined using a moisture analyzer capable of detecting one part per million of water. The equipment shall be operated in accordance with the manufacturer's instructions.

The following approved test equipment or equivalent items are required for moisture content determinations:

a. Electrolytic hygrometer
b. Aluminum Oxide Hygrometer

9.6 Sample Analysis Laboratory Identification of Failed Samples

When a sample does not meet requirements as specified by the requester, the sample analysis laboratory shall immediately notify the requester and the sampling team POC that the sample has failed. Should the requestor not be available, the requestor's management shall be notified immediately. See Section 12 for notification process of end user.

10. CERTIFICATION REQUIREMENTS

10.1 Initial Certification

During the initial certification process, if any sample fails to meet the requirements of Table 2 (Section 11) the initial certification process shall be restarted. The initial certification process shall be repeated until the system is certified. (Note: The nonconformance process will not take affect until the system has been certified.)

Two consecutive samples at each gas sample point in the system, taken 8 to 72 hours apart, shall comply with the user interface point requirements identified in Table 2 (Section 11).

Two additional samples taken consecutively at 5-to-10 day intervals from each gas sample point shall comply with the user interface point requirements identified in table 2 (Section 11).

Example: S1= 0 hrs, S2= 8 hrs, S3= 5 days, S4= 10 days

10.1.1 Certification Requirements for User Interface Points (Usage Points)

UIP's shall be certified in accordance with the initial certification requirements and periodically verified in accordance with requirements in table 1.

10.2 Systems under Maintenance

To maintain certification while under maintenance, approved contamination control procedures must be followed. Sampling may or may not be required to verify continued certification.

Examples when sampling is not required:

a. The removal and replacement of a relief valve, pressure indicator, vent valves, or other instrumentation at the end of a line.

b. The change-out of an in-line component with an end-to-end purge.

If contamination control procedures are not followed, sampling is required.

Engineering can request sampling at any time**.**

10.3 Recertification Requirements for Propellant/Pressurant Systems

When recertification is required, two consecutive samples at each affected sample point in the system shall be taken 8 to 72 hours apart and both shall comply with the UIP requirements identified in Table 2 (Section 11). If one sample fails to meet the requirements, the process shall be repeated until the system is recertified. (Note: The nonconformance process will not take affect until the system has been certified.)

Example: Sample 1 = 0 hrs, Sample 2 = 8 to 72 hrs

10.4 Certification Requirements for Cylinder Supplied Gas

A gas system may consist of a cylinder, or a bank of cylinders, equipped with one or more user interface points. Note: For the purposes of this standard, k bottles are not considered gas cylinders.

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 2. 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, a recertification sample shall meet the requirements of table 2.

11. PROCUREMENT AND DELIVERY REQUIREMENTS / MAXIMUM ALLOWABLE IMPURITIES

Gases used in the testing, drying and perseveration of components, assemblies and support/test equipment shall meet all of the user interface point requirements specified in Table 2.

Table 2. Propellant/Pressurant Requirements

PROPELLANT/PRESSURANT	REQUIREMENTS	
PARAMETER	**PROCUREMENT**	**USER INTERFACE POINTS**
HELIUM, GAS (He) Ref MIL-PRF-27407 (Grade A)		
Purity	99.995% He (min.)	99.994% He (min.)
Total Impurities (max ppm)	50	N/A
Specific Impurities (max ppm)	N/A	60
H_2 (max ppm)	1	N/A
N_2 and Argon (receiving only)	14	N/A
O_2 and Argon (max ppm)	3	10
N_2 (max ppm)	N/A	40
H_2O (max ppm)	9 (-61.1°C Dew Point)	9 (-61.1°C Dew Point)
Volatile Hydrocarbon (max ppm)**	5	5
Neon (max ppm)	23	N/A
CO (max ppm)	1	N/A
CO_2 (max ppm)	1	N/A
Particulate (gas)	N/A	30µ-100µ: 25; >100µ: 0
Particulate (liquid)	N/A	N/A
Condensable Hydrocarbons	N/A	0.25 mgs (max)

PROPELLANT/PRESSURANT	REQUIREMENTS	
PARAMETER	**PROCUREMENT**	**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 (max ppm)	50	N/A
Specific Impurities (max ppm)	N/A	70
Parahydrogen	95.0% (liquid H_2 only)	
Selected Impurities: N_2, Hydrocarbon**	9 (-61.1°C Dew Point)	N/A
H_2O	N/A	9 (-61.1°C Dew Point)
O_2 and Argon (max ppm)	1	5
N_2 (max ppm)	N/A	15
Volatile Hydrocarbons (max ppm)	N/A	5
He (max ppm)	39	45
CO_2 plus CO (max ppm)	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 (max ppm)	100	N/A
Specific Impurities (max ppm)	N/A	111
O_2	50	100
Volatile Hydrocarbons** (max ppm)	5	5
H_2O (max ppm)	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
Condensable Hydrocarbons	N/A	0.25 mgs (max.)
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 (max ppm)	4000	N/A
H_2O (max ppm)	3 (-69.0°C Dew Point)	20 (-55.2°C Dew Point)
Volatile Hydrocarbons** (max ppm)	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

PROPELLANT/PRESSURANT	REQUIREMENTS	
PARAMETER	**PROCUREMENT**	**USER INTERFACE POINTS**
HIGH PURITY AIR (HPA)		
O_2	N/A	18-23 ½ %
H_2O (max ppm)	N/A	24 (-53.9°C Dew Point)
Volatile Hydrocarbons** (max ppm)	N/A	15
Particulate (gas)	N/A	30µ-100µ: 25; >100µ: 0
Particulate (liquid)	N/A	N/A
Condensable Hydrocarbons	N/A	0.25 mgs (max.)
ALCOHOL (IPA)		
Purity	87.4 – 87.9	N/A
H_2O (% by weight)	Balance	N/A
NVR (% by weight)	0.002	N/A
BREATHING AIR Ref CGA G-7.1 (Grade D)		
Oxygen, balance is predominantly nitrogen	N/A	19.5-23.5 %
Carbon dioxide (max ppm)	N/A	1000
Carbon monoxide (max ppm)	N/A	10
Odor	N/A	†
Condensable Hydrocarbons	N/A	5 mg/m^3

* Unless otherwise specified, requirement levels are total ppm by volume.
** Total volatile (gaseous) 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.
† - Specific measurement of odor in gaseous air is impractical. Air may have a slight odor but the presence of a pronounced odor should render the air unsatisfactory.

Notes:

1) High purity air should not be used as breathing air in a confined area for long periods of time. This air is typically very dry and could cause respiratory problems. If you use high purity air through a self-contained breathing apparatus, you are required to follow guidelines and requirements for grade (L) in document CGA G-7.1.
2) Procurements are certified by the vendor and the certification results are sent to the procuring organization. These results shall satisfy the procurement requirements unless analytical verification tests are requested by engineering.
3) Purity is determined by subtracting specific or total impurities from 100% or by direct analysis. (For N_2 and He, purity is normally calculated by subtracting the specific impurities from 100%.)

12. QUALITY ASSURANCE REQUIREMENTS

The NASA and/or contractor quality assurance (QA) organization shall determine the appropriate level of monitoring, surveillance, or inspection based on such considerations as customer requirements, contract requirements, and positive or negative trends. NASA QA or their designee may perform scheduled or unscheduled audits of specified buy points verifying the process. At the discretion of each Center's Chief Engineer, Safety and Mission Assurance (S&MA) Manager, and, for certified samples, NASA QA or their designated representatives may be required to be present during sampling operations for specified buy points (verify, witness, or inspect) in the approved procedures. They may also be required to verify sample analysis results at a specified buy point in approved procedures.

12.1 Nonconformance Reporting

NASA and Contractor QA shall be notified of failed sample results per the applicable Center procedure. The Center's nonconformance documentation, investigation, and disposition process shall be implemented.

The safety and critically of the test hardware for a given system should be considered when deciding what type of nonconformance reporting process should be used. At a minimum, a "flash" report shall be sent to concerned/involved parties documenting the nonconformance. The reporting process will begin after a maximum of two failed samples have been declared by the lab.

The two samples taken for analysis can be taken at the same time using two different sampling containers at each sample point, a primary and a backup where one sample container is for analysis, and the second for analysis only if the first one fails.

Note: The purpose of the backup sample is to verify sampling technique associated with a failed primary sample.

A second approach would be to take two independent samples at different times or days.

Unless specific gas analysis requirements are submitted to the lab, the analysis lab will verify a sample has passed or failed based on the requirements within this standard.

12.2 Waivers and Deviations

Any substitutions, deviations, or modifications to this procedure shall be made only with the approval of the cognizant authority for waivers and deviations.

13. RECORDS AND REPORTS

13.1 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 sampling team and may be used to determine the adequacy of the sampling frequency. All records generated for equipment maintenance shall be maintained per NPR 1441.1, NASA Records Retention Schedules.

13.2 Reports

Data gathered as a result of this standard shall be documented by the performing organization as designated by NASA Quality Assurance, and shall include pertinent information recorded in logs or databases. All test results shall be made available upon request.

Forms shall be the latest edition unless otherwise specified.

For Quality Records, refer to the Master Records Index.

APPENDIX A – MINIMUM TRAINING REQUIREMENTS

Note: On-the-job-training (OJT) will be Center-specific.

A1. Sampling Certification

Common sampling team lead will be responsible for verifying the certification of team members.

Each person is responsible for taking site-specific classes that are required by the Safety, Health and Environmental (SHE) Group and any classes required by employer.

A.2 Minimum Requirements for Sampling Certification

Annual Physical

LO/TO --- (Lock Out/Tag Out) Training

O_2/LEL --- (Oxygen/Lower Explosion Limits) Meter Training

Hearing Conservation

High Pressure Safety Training

Cryogenic Safety Training

A.3 Minimum Requirements for OJT for Certification in Fluid Sampling

OJT requirements for certifications are developed into specific OJT training packages with the necessary lesson plans, instructional material, qualification tests, and OJT training required to perform a specific critical task or hazardous operation. Details of these OJT requirements for specific certifications will be maintained by the individual's Supervisor/Team Lead. These packages must be approved by the respective site Certification Boards.

Demonstrate knowledge of tests and monitoring equipment.

Review and become knowledgeable of procedures and work documents.

Buddy System Training.

System Cleanliness Training.

Area Access Control Training (as required).

Gas Sampling Training.

Cryogenic Sampling Training.

Pass a written exam covering the contents of sampling fluid systems.

The common sampling team's certification will be recognized for sampling at either Center as long as there is at least one representative from the specific site accompanying the team.

APPENDIX B - COMMON SAMPLE PRACTICES/TECHNIQUES

B.1 System Interfaces with Different Cleanliness Levels

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

- Use a filter for any cleanliness level breaks that have different particulate levels and the same nonvolatile residue (NVR) level or no NVR level.

- Use dual check valves for any cleanliness level breaks that have different NVR requirements. Add a filter if downstream particulate requirements are more stringent than upstream requirements. An upstream system must have the same or higher NVR cleanliness level requirements than the downstream system.

B.2 Gas Samples

- Perform sampling using detailed step-by-step procedures that includes all tooling, equipment and personal protective equipment (PPE) requirements as well as Cautions, Warnings, etc.
- Purge-out/flow through sample port prior to connecting sample panel.
- Prior to sampling, purge the sample point valve and regulator/flex hose at the rate of 10.0 (plus or minus 1) scfm or at an audible purge for a minimum of 2 minutes.
- Avoid the use of ball flow meters for gas sample portable; instead, use calibrated orifices and flow for specified time in order to enhance safety and process consistency.
- Ensure all equipment is relief protected (gages, etc.)
- Access to sampling area should be restricted to involved personnel.
- No welding, heat or spark producing operations are allowed in an area where H_2 sampling is to take place.
- Maintain slight positive purge during panel (or Millipore) hook-up and disconnect of inert gas samples.
- Purge system for inertion and air/moisture removal for GH samples.
- Monitor by "sniff check" sampling panel, hoses, container and other equipment during GH sample taking operations.
- Avoid sampling during rain or high moisture/fog conditions.

- Particle level determination for gas systems shall be made using a minimum 30 scf sample. Gas flow rate through the sampler, while accumulating the sample, shall be 10 (plus or minus 1 scfm) or maximum flow rate for systems not capable of 10 scfm. The sample size for gases from a system of cylinders shall be 10 scf minimum. A positive flow of at least 0.5 scfm shall be maintained during the installation and removal of the sampler.

Note: Although particles should be imbedded in the filter disc surface, handle the filter holder so as not to jar particles from the filter. Hold the filter holder with the inlet port up.

B.3 Cryogenic Liquid Samples

Once cosmodyne is connected to UIP of the vessel and the system is ready for sampling, the cosmodyne must be chilled properly. Open the sample valve, flow through the cosmodyne inlet and outlet port and chill the cosmodyne until a steady stream of liquid is coming out the cosmodyne outlet port. This could be 5 to 10 minutes. On liquid hydrogen samples, the vent hose should show signs of liquid air. To guarantee liquid has made it to the sampler, this could take up to 60 minutes depending on the location of the sample point. Once cosmodyne is adequately chilled, open the sample-collecting valve on the cosmodyne for 1 to 2 minutes and close. Verify between 200 psig to 400 psig pressure on the cosmodyne gauge for adequate sample.

APPENDIX C - CONDENSABLE HYDROCARBON SAMPLE ANALYSIS

C.1 SCOPE

This specification establishes the procedure for the determination of entrained, condensable hydrocarbons in high-pressure (100-6000 psi) gas supply systems. The procedures required by this specification shall not be used for the sampling of combustible gases.

C.2 Detail Requirements

Gas Sample Volume – During sample collection, the minimum total volume sampled shall be 30 scf. The minimum total volume of gas sampled from systems of cylinders shall be 10 scf. Volume requirements are met when sampling collection procedure is followed.

C.3 Procedure

C.3.1 Sample Collection

a. Before connecting sampler, apply purge to the sample line.

b. Remove the sampler from the sealed bag. A positive flow shall be maintained during installation and removal of the sampler. Remove the protective AN plug from the inlet and attach the sampler directly to the standard AN fitting at the console or sampling port.

Note: Do not add pressure line extensions between sampling port and the system being sampled.

c. Open the system valve to achieve a pressure drop reading above 500 psi and sample for 1 minute. If a pressure drop of 500 psi can not be obtained, refer to Table C-1 for the required sampling time. No sampling shall be conducted below a pressure drop of 200 psi.

C.3.2 Condensable Hydrocarbons

A sample can be obtained at the source by passing the sampling gas through a precision cleaned gas sampling device as shown in Figure C–1. Volume surface area requirements are met when sampling collection per Table C-1 is followed**.**

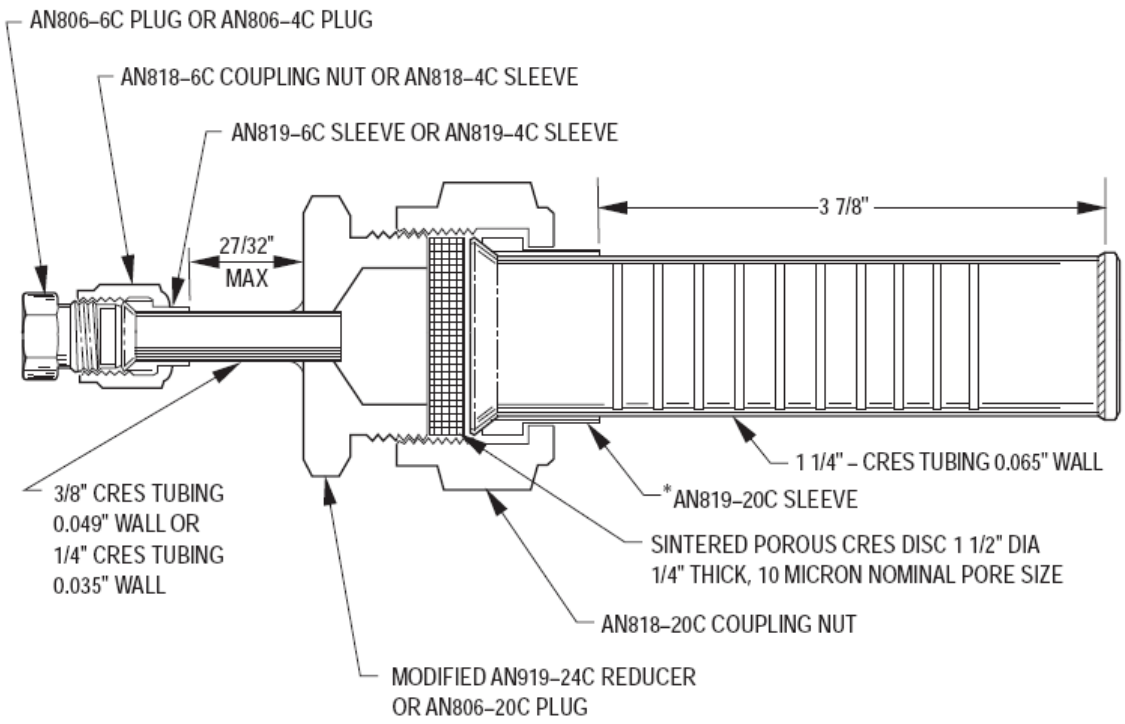

Figure C–1. Gas Sampler for Condensable Hydrocarbons

Table C-1 Sampling Time

Nitrogen [1]	
Pressure Drop (psi) [3]	Sampling time (min / 0.1m^2)
200–499	2.5 min
> 500	1.2 min
Helium [2]	
Pressure Drop (psi) [3]	Sampling time (min / 0.1m^2)
200–299	2.5 min
> 300	1.2 min

Note:

[1] N_2 is used as the sampling gas for oxidizer and nitrogen systems

[2] Helium is used as the sampling gas for helium and fuel systems and can be used for sampling oxidizers

[3] Pressure drop is defined as the pressure reading on the gauge at the sampling location when the sampler is connected and the valve is open.

a. Remove the sampler from the sample port and reinstall the AN plug in the inlet of the sampler and insert sampler into Teflon or Aclar bag that complies with MSFC-SPEC-164B. Pass the sampling gas through the sampling device under the conditions listed in Table C-1.

b. Submit to the analysis lab, disassemble the sampler and place the sintered stainless steel disc in Gooch crucible or a 47mm diameter filter holder/filtering apparatus.

c. Flush 200ml of a halogenated solvent through the sintered disc. Repeat twice using the same solvent.

d. Determine the condensable hydrocarbons using the infrared procedure described in Section C.5.

C.4 Infrared Spectrometric Transmission Method for Condensable Hydrocarbons Analysis

C.4.1 General

This method involves evaporating an aliquot of solvent (AK225g, etc.), picking up the residue in tetrachloroethylene and analyzing the solution with an infrared spectrometer.

C.4.2 Equipment

a. Fourier Transform Infrared (FTIR) Spectrometer

b. Quartz cell, 20mm path length (10 mm optional)

c. Pharmaceutical grade mineral oil

d. Tetrachloroethylene, spectrometric grade

e. Temperature controlled oven (optional)

C.4.3 Calibration

a. Before using this method, the FTIR spectrometer shall be initially calibrated.

b. Follow manufacturer’s instructions for internal optical alignment if required, and optimal energy throughput. Instrument parameters (number of scans, wave number resolution, gain ranging radius, etc.) should be adjusted as needed to optimize results.

c. Using tetrachloroethylene in a 20 mm quartz cell, perform a background (single beam) scan daily or before use between 3200 cm^{-1} and 2600 cm^{-1}. The background spectrum will be used to develop absorbance spectra for the calibration standards in (d.)

d. Calibrate the FTIR spectrometer by preparing mineral oil standards in tetrachlorethylene. A minimum of five calibration points shall be obtained. The final calibration concentrations shall range from 0.01 mg/ml to an upper limit of 0.3 mg/ml. Progressing from the lowest calibration standard to the highest standard, scan the various hydrocarbon blends in the 3200 cm^{-1} and 2600 cm^{-1} range using a 20 mm quartz cell. The quartz cell should be flushed twice with tetrachloroethylene and a minimum of two times using a standard of the next highest concentration level when changing standards. Intermediate standards should bracket the analytical range of interest.

e. Use the spectra from (d.) above to compute the least squares regression calibration coefficients. The correlation coefficient for the linear regression or quadratic model should be 0.990 or better. Either peak intensity or area can be modeled. The calibration curve cannot have a y intercept of zero, and it should not be forced to go through zero.

C.5 Infrared Analysis Procedure

a. Perform a background scan daily with tetrachloroethylene or before use between 3200 cm^{-1} and 2600 cm^{-1}. The single beam background spectra will be used to develop absorbance spectra for analyzing samples.

b. Following the initial calibration and the background scan (a), analyze check standards daily or before sample analysis. The check standards shall represent 0.01 mg/ml and 0.2 mg/ml. The check standards (mineral oil in tetrachloroethylene) should read within ±10%.

c. Filter the solvent sample (e.g., AK225g,) through a 10 micron pore size or less filter paper or membrane, compatible with the fluids being tested. Collect the filtered solvent into a cleaned container.

d. Evaporate the sample or a representative aliquot of the solvent sample to near dryness (3 to 5 ml) using a steam bath or rotary evaporator or a thermostatically controlled hot plate. Remove the beaker before dryness and place in an oven at a maximum temperature 110 °C and allow it to dry or with forced air (draft from the fume hood) flowing over the sample or with a nitrogen purge.

e. Allow the beaker or flask to cool and add 7 mls of tetrachloroethylene to the residue.

f. Briefly swirl the solvent over the residue and transfer the solution to a 20 mm quartz cell. Use care during transfer to avoid loss of the sample due to spilling or overfilling of the cell.

g. Record a sample infrared absorption spectrum between 3200 to 2600 cm^{-1} using the same cell path length that was used to develop the calibration curve.

h. Determine the amount of mgs. of hydrocarbon in the sample by using the least squares regression calibration curve (0). If the sample concentration is greater than the highest calibration standard, a dilution of the sample with tetrachloroethylene shall be made and the appropriate dilution factor applied.

$$NVR = (M_S)\ (Vs)$$

Where:

M_S = FTIR measured sample concentration (e.g., mg/ml)

Vs = Tetrachloroethylene volume used to reconstitute the sample residue (e.g., 7 ml)

NVR = mgs of hydrocarbon

i. Perform a hydrocarbon blank on the filtered control solvent (steps c. through h.) and subtract the results from the value obtained for the sample (h).

APPENDIX D - GENERAL GUIDELINES FOR PRESSURE-PURGE INERTING

The intention of this appendix is to give general guidance when pressure-purging gaseous systems. Engineering evaluation and procedural documentation is required before any inerting process can be performed.

Considerations when generating procedures:

1. The geometry of the piping system or vessel needs to be evaluated. This includes the location of the inlet and outlet ports, etc.

2. The physical properties of the commodity and purge gas need to be evaluated; this includes the densities of the individual gases. Will the purge gas "sweep" the commodity out of the system, or will the two gasses be required to mix before the system can be inerted. If mixing is desired, the velocity of the purge gas should be considered. Turbulent flow will lend to better mixing.

Below is a formula that can be used to calculate the approximate number of purge cycles required to inert a system.

Calculate the number of cycles necessary to obtain the desired maximum concentration of hydrogen using the formula below. Note that NASA/SSC is continuing analysis of the pressure-purge inerting process and the following analysis is believed to be safety conservative for pressure-purge cycle determination.

1) **Vent the system to a minimum pressure level** (preferably 2-3 pounds per square inch gauge (psig)) if the system is at a higher pressure. Selection of the minimum pressure limit is to minimize purge gas requirements and ensure positive system pressure is maintained throughout the pressure-purge inerting process. For large high pressure gas distribution systems, venting to 50 psi or lower has been found effective.

2) **Pressurize the system to a chosen maximum pressure with purge gas.** Nominally, use three times the minimum purge pressure. Low maximum pressure minimizes the purge gas requirements for pressure-purge inerting. A maximum pressure (P_{max}) of 3x the minimum pressure (P_{min}) level provides an effective balance between inert gas usage and the operations associated with the required number of pressure cycles.

3) **Repeat steps 1 and 2 for the calculated number of cycles and verify desired gas concentration by gas sampling.**

Expression to Calculate the Number of Cycles:

$$\left(\frac{P_{min}}{P_{max}}\right)^n = \phi$$

where: n = # of pressure cycles assuming isothermal Pressure-Purge process
P_{min} = Minimum pressure of cycle, psia
P_{max} = Maximum pressure of cycle, psia (using inert gas)
ϕ = Desired final concentration of gas purged from system (%/100)

The above equation is a satisfactory cycle estimate if isothermal conditions are maintained during the pressure-purge inerting process. However, it underestimates the required number of pressure-purge cycles under isentropic conditions (e.g., if rapid pressure-purge cycling is employed such that the system gas temperature is not allowed to stabilize between the P_{min}-P_{max}-P_{min} pressure levels). For isentropic conditions, it is recommended additional cycles be added to the isothermal pressure-purge cycle relation above.

For an isentropic pressure-purge process:

$$\#\ \text{cycles} = n + 2 \quad \text{for } 0.01 < \phi < 0.1 \quad (1\% - 10\% \text{ concentrations})$$
$$= n + 3 \quad \text{for } \phi < 0.01 \quad (1\% \text{ concentration})$$

EXAMPLE: (CALCULATION USING FORMULAS)

An empty, ambient temperature LH_2 tank needs to be inerted to 0.8% H_2 concentration to enable tank entry. The tank initial pressure is 3 psi (100% GH_2).

Assume:
1. The tank will be vented to 3 psig [17.7 pounds per square inch absolute (psia)] for the pressure-purge cycling process.
2. A maximum tank purge pressure of 38.4 psig (53.1 psia).
3. The pressure-purge process is isothermal.

(**Note:** The average ambient pressure at SSC is 14.7 psia.)

Calculation:

$$\left(\frac{Pmin}{Pmax}\right)^n = \phi$$

$$\left(\frac{17.7}{53.1}\right)^n = (.00800)$$

n = 4.4 or 5 cycles required

if the pressure-purge cycling were performed rapidly, such that the tank pressurant temperature varied between P_{min} and P_{max} and the process assumed to be isentropic, the number of cycles needed would be 8 (= n+3 since $0.008 = \phi < 0.01$).

Members of the Propellant and Pressurant team, that participated in the creation of this document.

Marshall Space Flight Center Members

Perkins, James H. (MSFC-EM10) Co-Team Lead
Chemistry Team Lead

Booker, Carroll T. (MSFC-QD11)
MSFC Quality

Burton, John W. (MSFC- Teledyne Brown Engineering)
Engineering Chief, PP&C

Hill, Tony D. (MSFC- INFO PRO)
Chemist, MSFC Environmental Gas Laboratory

Nugent, John A. (MSFC- Teledyne Brown Engineering)
Safety and Quality Assurance Chief, PP&C

Shepherd, Christena C. (MSFC-QD11)
Team Lead, Vehicle Systems Test Assurance

Gladdney, Murray R. (MSFC-ET02, Total Solutions Inc.)
System Analyst/Technical Writer

John C. Stennis Space Center Members

Failla, David P. (SSC-EA10) Co-Team Lead
A-1 Test Stand Operations Manager

Addlesperger, Terry D. (SSC-EA10)
Lead, Operations Management

Sones, Anthony (SSC-PWR)
Test, Facility and Controls Manager

Knight, Jody G. (SSC- ERC/JT)
Technical Specialist II, Test Support Services

Olive, Curtis D. (SSC- Jacobs Technology)
Senior Mechanical Design Engineer

Ross, Harold R. (SSC-AGT)
Lead, Gas & Materials Science Lab

Wells, Brenda N. (SSC- Jacobs Technology)
SSC Standards Administrator/Technical Writer

White, Timothy L. (SSC-QA00)
AST, Quality Assurance, SSME Test Operations

McCarty, Samuel D. (SSC-RA20)
AST, Experimental Facilities Development