

ISO 15859 PROPELLANT AND FLUID SPECIFICATIONS: A REVIEW AND COMPARISON WITH MILITARY AND NASA SPECIFICATIONS*

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ABSTRACT

This work presents an overview of the International Organization for Standardization (ISO) 15859 International Standard for *Space Systems – Fluid Characteristics, Sampling and Test Methods* Parts 1 through 13 issued in June 2004. These standards establish requirements for fluid characteristics, sampling, and test methods for 13 fluids of concern to the propellant community and propellant characterization laboratories: oxygen, hydrogen, nitrogen, helium, nitrogen tetroxide, monomethylhydrazine, hydrazine, kerosene, argon, water, ammonia, carbon dioxide, and breathing air. A comparison of the fluid characteristics, sampling, and test methods required by the ISO standards to the current military and NASA specifications, which are in use at NASA facilities and elsewhere, is presented. Many ISO standards' composition limits and other content agree with those found in the applicable parts of NASA SE-S-0073, NASA SSP 30573, military performance standards and details, and Compressed Gas Association (CGA) commodity specifications. The status of a current project managed at NASA Johnson Space Center White Sands Test Facility (WSTF) to rewrite these documents is discussed.

INTRODUCTION

Fluid operations at a spaceport or launch facility may involve a number of operators and supplier/customer interfaces, from the fluid production plant to the delivery to the launch vehicle or spacecraft. The purpose of the International Organization for Standardization (ISO) 15859 *Space Systems – Fluid Characteristics, Sampling and Test Methods* Parts 1 through 13 that was issued June 2004 is to establish uniform requirements for the components, sampling, and test methods of fluids used in the servicing of launch vehicles, spacecraft, and ground support equipment.¹⁻¹³ The fluid composition limits specified are intended to define the purity and impurity limits of the fluid for loading into the launch vehicle or spacecraft. The fluid sampling and test methods are acceptable methods for verification of the fluid composition limits.

ISO 15859 Parts 1 through 13 are applicable to any sampling operation required to ensure that when the fluid enters the launch vehicle or spacecraft the fluid composition complies with the limits provided in the respective Part or with any technical specification agreed to for a particular use. All Parts specify fluid composition limits and establish the sampling and test requirements for fluid composition verification. All Parts are applicable to flight hardware and ground facilities, systems, and equipment. All Parts are applicable only to influents.

ISO 15859 Parts 1 through 13 are use specifications only. It is important to differentiate between use specifications and procurement specifications. Use specifications are specific composition limits for the fluid delivered at the interface. Procurement specifications are specific composition limits for the fluid purchased by the supplier. Space Shuttle and International Space Station are the specifications of greatest interest to NASA and in addition to providing the use specifications, NASA SE-S-0073 *Space*

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*Shuttle Specification Fluid Procurement and Use Control*¹⁴ references the procurement specifications and NASA SSP 30573 *Space Station Program Fluid Procurement and Use Control Specification*¹⁵ provides the procurement specifications for the applicable fluids. Because no use specifications of military origin were identified at the time this manuscript was prepared, any comparison of ISO 15859 Parts 1 through 13 to military procurement specifications are for information only. Use specifications may be more or less stringent than procurement specifications, depending on the fluid and the program of interest. Use specifications are typically defined by the program, or they may be internal to a manufacturer or to a private industry. Manufacturer and private industry specifications are often proprietary and none could be obtained for discussion in this paper. In the case of breathing air, the Occupational Safety and Health Administration (OSHA) has specific legal requirements, which are discussed in this paper.

ISO 15859 Part numbers and titles are as follows:

- Part 1: Oxygen
- Part 2: Hydrogen
- Part 3: Nitrogen
- Part 4: Helium
- Part 5: Nitrogen Tetroxide Propellants
- Part 6: Monomethylhydrazine Propellant
- Part 7: Hydrazine Propellant
- Part 8: Kerosine[†] Propellant
- Part 9: Argon
- Part 10: Water
- Part 11: Ammonia
- Part 12: Carbon Dioxide
- Part 13: Breathing Air

The documents were prepared by ISO Technical Committee (ISO/TC) 20, *Aircraft and Space Vehicles*, Subcommittee (SC) 14, *Space Systems and Operations*. The secretariat of ISO/TC 20 and of SC 14 at the time these standards were voted on by the participating countries was the American National Standards Institute (ANSI). The participating countries and their corresponding member bodies who voted on these standards were:

- Brazil (ABNT) Associação Brasileira de Normas Técnicas
- Canada (SCC) Standards Council of Canada
- China (SAC) Standardization Administration of China
- France (AFNOR) Association Française de Normalisation
- Germany (DIN) Deutsches Institut für Normung
- Italy (UNI) Ente Nazionale Italiano di Unificazione
- Japan (JISC) Japanese Industrial Standards Committee
- Russian Federation (GOST R) Federal Agency on Technical Regulation and Metrology
- Ukraine (DSTU) State Committee of Ukraine on Technical Regulation and Consumer Policy
- United Kingdom (BSI) British Standards Institution
- USA (ANSI) American National Standards Institute

Approval by ≥ 66.66 percent of the member bodies casting a vote was required for publication as an International Standard. Participating bodies having abstained were not counted in the vote. The secretariat country and its member body counted as a participant voting member. Voting results are shown in Table 1.

[†] European spelling. The U.S. spelling (kerosene) is used when appropriate in this document.

Table 1. Summary of ISO 15859 Standard

	Brazil (ABNT)	Canada (SCC)	China (SAC)	France (AFNOR)	Germany (DIN)	Italy (UNI)	Japan (JISC)	Russian Federation (GOST R)	Ukraine (DSTU)	United Kingdom (BSI)	USA (ANSI)
Oxygen	Approve	Approve	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Hydrogen	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Nitrogen	Approve	Approve	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Helium	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Nitrogen Tetroxide Propellants	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Mono- methyl- hydrazine Propellant	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Hydrazine Propellant	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Kerosine Propellant	Approve	Approve	Approve	Abstain	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Argon	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Water	Approve	Approve	Approve	Disapprove*	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve
Ammonia	Approve	Approve	Approve	Abstain	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Carbon Dioxide	Approve	Approve	Approve	Abstain	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Breathing Air	Approve	Approve	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve	Approve	Approve

*Comment

OBJECTIVE

The objective of this paper is to provide a review of ISO 15859 Parts 1 through 13 and to compare them with military, NASA, or other specifications as applicable. This review has been prepared to provide increased awareness of the ISO 15859 aerospace fluid standards for the Joint Army Navy NASA Air Force (JANNAF) propellant community.

ORGANIZATION OF ISO 15859 Parts 1-13

ISO 15859 Parts 1 through 13 follow a standard format containing the following clauses:

FORWARD

This clause is identical for all Parts except that the specific standard number is referred to in the corresponding document.

INTRODUCTION

This clause is identical for all Parts. The introduction establishes the purpose of the standard, which is to establish uniform requirements for the components, sampling, and test methods of the fluids.

SCOPE

This clause specifies the fluid types and grades.

NORMATIVE REFERENCES

This clause provides references that are stated to be indispensable for the application of the document.

- Oxygen: ISO 9000 *Quality Management Systems - Fundamentals and Vocabulary*¹⁶
- Hydrogen: ISO 9000, ISO 14687 *Hydrogen Fuel – Product Specification*¹⁷
- Nitrogen: ISO 9000
- Helium: ISO 9000
- Nitrogen tetroxide propellants: ISO 9000
- Monomethylhydrazine propellant: ISO 9000
- Hydrazine propellant: ISO 9000
- Kerosine propellant: ISO 3012 *Petroleum Products – Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels – Potentiometric Method*,¹⁸ ISO 3014 *Petroleum Products – Determination of the Smoke Point of Kerosine*,¹⁹ ISO 9000
- Argon: ISO 9000
- Water: Nineteen ISO Water Quality standards,²⁰⁻³⁸ ISO 9000
- Ammonia: ISO 7103 *Liquefied Anhydrous Ammonia for Industrial Use – Sampling – Taking a Laboratory Sample*,³⁹ ISO 7104 *Liquefied Anhydrous Ammonia for Industrial Use – Determination of Water Content – Gas Chromatographic Method*,⁴⁰ ISO 7105 *Liquefied Anhydrous Ammonia for Industrial Use – Determination of Water Content – Karl Fischer Method*,⁴¹ ISO 7106 *Liquefied Anhydrous Ammonia for Industrial Use – Determination of Oil Content – Gravimetric and Infra-red Spectrometric Methods*,⁴² ISO 9000
- Carbon Dioxide: ISO 9000
- Breathing Air: ISO 9000

TERMS AND DEFINITIONS

This clause specifies terms and definitions pertinent to the Part.

CHEMICAL COMPOSITION

This clause specifies fluid composition limits. All Parts provide that the chemical composition of the fluid delivered to the flight vehicle interface shall be in accordance with the composition limits of that part when tested in accordance with the applicable test methods, unless otherwise provided in an applicable technical specification.

PROCUREMENT

This clause specifies procurement information.

- Oxygen – Procurement should be in accordance with an applicable national or international standard.
- Hydrogen – Procurement should be in accordance with ISO 14687 *Hydrogen Fuel – Product Specification*^{17,43} or an applicable national standard.
- Nitrogen, Helium, Nitrogen tetroxide propellants, Monomethylhydrazine propellant, Hydrazine propellant, Kerosene propellant, Argon, Water, Ammonia, Carbon Dioxide, and Breathing Air – Procurement should be in accordance with an applicable national standard.

FLUID SAMPLING

This clause contains provisions for fluid sampling that are very similar for all Parts 1 through 13.

TEST METHODS

This clause specifies the analytical test methods required to determine the composition limits of the fluid. While test methods specific to the respective test method are listed in this clause, flexibility is allowed by the statement in clause 7.1 of each Part that “Other test methods not listed in this part of ISO 15859 are acceptable if agreed upon by the supplier and the customer.”

ANNEX(ES)

Provided as applicable.

REVIEW AND COMPARISON

A brief, high-level review and comparison of ISO 15859 Parts 1 through 13 with corresponding NASA and military specifications is provided. The comparison includes only chemical composition, procurement, fluid sampling, and test methods for the purpose of providing an awareness of major agreements and differences with the documents used in the comparison. Units were converted to appropriate common values for comparative purposes. As applicable, limits for moisture content (as water concentration or dewpoint) were compared after conversion to common units.

Particulate requirements in the applicable ISO 15859 Parts cannot be directly correlated to SE-S-0073 or SSP 30573, because the NASA and Space Station requirements are driven by the particular subsystems to which they may be applied. SE-S-0073 and SSP 30573 typically use particulate size distribution criteria rather than particulate by weight, and have particulate size distribution criteria specific to the applicable fluid and subsystem. ISO 15859 Parts provide no particulate size distribution criteria and therefore this aspect cannot be compared to SE-S-0073 and SSP 30573. This is a very important distinction between ISO 15859 Parts and NASA and Space Station requirements. Because of the complexity of the NASA and Space Station requirements, little further detail is addressed regarding lack of particulate size distribution in the ISO 15859 Parts in this manuscript.

Additionally, because the notes in the corresponding SE-S-0073 and SSP 30573 specifications are extensive, not all notes are addressed in the comparison below.

PART 1: OXYGEN

ISO 15859-1 applies to oxygen: Type I, Grade A: standard, purging/pressurization, Grade CB: crew breathing, Grade F: fuel-cell) and Type II (Grade A: oxidizer, Grade B: oxidizer, Grade F: fuel-cell). ISO 15859-1 Type I Grade A composition limits are identical to Compressed Gas Association (CGA) G-4.3-2000 *Commodity Specification for Oxygen*⁴⁴: Type I Grade E. ISO 15859-1 Type I Grade A does not correspond with any SE-S-0073 requirements; SSP 30573 Type A requirements; Military (MIL)-PRF-25508F *Performance Specification Propellant, Oxygen*⁴⁵ requirements; or MIL-PRF-27210G *Performance Specification Oxygen, Aviator's Breathing, Liquid and Gas*⁴⁶ requirements. ISO 15859-1 Type I Grade CB composition limits are identical to SE-S-0073 Table 6.3-24 Breathing Oxygen and has some limits that agree with MIL-PRF-27210G Type I oxygen. ISO 15859-1 Type I and Type II Grade F composition limits are identical to each other and the same as SE-S-0073 Table 6.3-4 Gaseous and Liquid Oxygen for purity, alkyne hydrocarbon, total hydrocarbon, moisture, nitrous oxide, halogenated hydrocarbon, and carbon dioxide and carbon monoxide, but have additional composition limits for methane, ethane, propane, a more stringent chlorinated hydrocarbon requirement (0.01 µL/L vs. 0.1ppm), and a requirement for "Other [nitrogen, argon, krypton, etc]" that, however, could be met by the aggregate impurities summation. SE-S-0073 Table 6.3-4 contains a requirement for no odor; ISO 15859-1 Type I and Type II Grade F have no odor requirements. ISO 15859-1 Type I and Type II Grade F composition limits are met by a blend of the procurement and interface requirements of SSP 30573 Table 4.1-2.14A requirements with the exception of a more stringent chlorinated hydrocarbon requirement (0.01 µL/L vs. 0.1ppm/v (max)) for the SSP 30573 interface requirement and the "Other [nitrogen, argon, krypton, etc]" requirement that is not present in SSP 30573 Table 4.1-2.14A procurement or interface requirements. ISO 15859-1 Type II Grade A composition limits are the same as SE-S-0073 Table 6.3-2 Liquid Oxygen, except for the additional requirement of 0.1 µL/L (max) for carbon monoxide and 3 µL/L (max) for carbon dioxide when required to meet hardware needs. ISO 15859-1 Type II Grade B composition limits do not correspond with SE-S-0073 or SSP 30573 requirements, but are the same as Grade B oxygen requirements in MIL-PRF-25508F with the exceptions that an "Impurities" requirement is not called out in ISO 15859-1; this, however, could be met by the purity requirement (99.5 percent min), and for limits of 0.1 µL/L (max) for carbon monoxide and 3 µL/L (max) for carbon dioxide when required to meet hardware needs. Additionally, ISO 15859-1 Type II Grade B composition limits are identical to CGA G-4.3 Type II Grade C, except ISO 15859 has limits of 0.1 µL/L (max) for carbon monoxide and 3 µL/L (max) for carbon dioxide when required to meet hardware needs.

ISO 15859-1 sampling parameters are in reasonable agreement with corresponding parameters in GCA-4.3, which is referenced by both MIL-PRF-27210G and MIL-PRF-25508F.

Some test methods described in ISO 15859-1 are found in CGA G-4.3. MIL-STD-1564A *Military Standard Procedure for Calibration and Analysis of Trace Contaminants in Aviators Breathing Oxygen by Infrared Spectroscopy*⁴⁷ describes a procedure for determining trace gaseous contaminants in oxygen, nitrogen, and air by infrared spectroscopy.

PART 2: HYDROGEN

ISO 15859-2 applies to hydrogen: Type I (Grade A: fuel, Grade F: fuel) and Type II (Grade A: fuel, Grade F: fuel). ISO 15859-2 Type I Grade A and Type II Grade A composition limits are identical to each other and to SE-S-0073 Table 6.3-6 Gaseous and Liquid Hydrogen, without notes. ISO 15859-2 Type I Grade A hydrogen composition limits are vastly different from the referenced ISO 14687 composition limits for Type I Grade A hydrogen for purity (99.994 percent vs. 98.0 percent), nitrogen, water and volatile hydrocarbons combined (9.0 µL/L vs. 1.9 percent¹⁷), oxygen plus argon (5.0 µL/L vs. 1.9 percent⁴³), and possibly helium (45 µL/L vs. no requirement) and total gaseous impurities (60 µL/L vs. no requirement). ISO 15859-2 Type I Grade F composition limits are in close agreement with ISO 14687 Type I Grade C composition limits, with the exception of helium (40 µL/L vs. 39 µmol/mol). ISO 15859-2 Type I Grade F and Type II Grade F are identical to each other except Type I Grade F has no

specification for para-hydrogen (balance ortho-hydrogen) volume fraction (percent min) while Type II requires 95.0 percent min. ISO 15859-2 Type II Grade F composition limits are in close agreement with ISO 14687 Type II requirements, with the exception of helium (40 µL/L vs. 39 µmol/mol). ISO 15859-2 Type I Grade F and Type II Grade F composition limits are similar to SSP 30573 Table 4.1-2.11 Hydrogen (Interface) with identical requirements for purity (99.995 percent), oxygen plus argon (1 µL/L), and carbon dioxide plus carbon monoxide (1 µL/L), and similar requirements for nitrogen, water and volatile hydrocarbons combined (10 ppm vs. 9 ppm), and helium (40 ppm vs. 39 ppm). ISO 15859-2 Type I Grade F and Type II Grade F have a requirement for total gaseous impurities (60 µL/L max), which is not in SSP 30573 Table 4.1-2.11, but this specification could be met by an aggregate impurity summation. Additionally, SSP 30573 Table 4.1-2.11 has no interface requirement for para-hydrogen (liquid only). ISO 15859-2 Type I Grade F and Type II Grade F composition limits are similar to MIL-PRF-27201C *Performance Specification Propellant, Hydrogen*⁴⁸ with the exception of nitrogen, water and volatile hydrocarbons combined (9.0 µL/L vs. 10 ppm) and helium (40 µL/L vs. 39 ppm). ISO 15859-2 Type I Grade F and Type II Grade A composition limits do not correspond to CGA G-5.3 *Commodity Specification for Hydrogen*⁴⁹ Type I Grade F and Type II Grade A, respectively.

ISO 15859-2 specifies the types and grades of hydrogen should be procured in accordance with ISO 14687 or an applicable national standard. As described above, Type I Grade A hydrogen procured to ISO 14687 Type I Grade A would fail some of the requirements of ISO 15859-2, such as purity (99.994 percent vs. 98.0 percent). Type II Grade A procured to ISO 14687 Type II could allow the fluid to meet the composition limits of ISO 15859-2. Type I and Type II Grade F are not specified in ISO 14687.

Sampling of liquid (Type II hydrogen) is not addressed in ISO 15859-2. ISO 15859-2 sampling parameters for gaseous (Type I hydrogen) are otherwise in reasonable agreement with corresponding parameters in CGA G-5.3 and ISO 14687. ISO 15859-2 sampling parameters do not directly correlate with MIL-PRF-27210C or the referenced American Society for Testing and Materials (ASTM) sampling methods (ASTM F-307 *Standard Practice for Sampling Pressurized Gas for Gas Analysis*⁵⁰ (for Type I) or ASTM F-310 *Standard Practice for Sampling Cryogenic Aerospace Fluids*⁵¹ (for Type II)).

The test methods described in ISO 15859-2 closely match those in CGA G-5.3 and ISO 14687. MIL-PRF-27210C specifies a method for the determination of para-hydrogen and refers to CGA G-5.3 for the determination of gaseous purity and gaseous impurities. ISO 15859-2 uses verbiage almost identical to MIL-PRF-27210C for the determination of para-hydrogen.

PART 3: NITROGEN

ISO 15859-3 applies to nitrogen: Type I (Grade A: purging/pressurizing, Grade B: crew breathing, Grade C, Grade F, Grade J) and Type II (Grade A: purging/pressurizing, Grade B: crew breathing, Grade C, Grade F). ISO 15859-2 does not specify the method for purity determination (direct or indirect) for Type I and Type II Grade A, Grade C, Grade F, and Type I Grade J as in SE-S-0073 Table 6.3-3 Gaseous Nitrogen and SSP 30573 Table 4.1-2.13 Nitrogen. ISO 15859-3 Type I and Type II Grade A composition limits are identical to SE-S-0073 Table 6.3-3 Gaseous Nitrogen, with the exception that an aggregate 5000 µL/L (max.) Total Impurities is specified in ISO 15859-3. ISO 15859-3 Type I and Type II Grade A composition limits are identical to SSP 30573 Table 4.1-2.13 Nitrogen Grade A (interface) requirements. ISO 15859-3 Grade Type I and Type II Grade A composition limits are identical to MIL-PRF-27401D *Performance Specification Propellant Pressurizing Agent, Nitrogen*⁵² Grade A.

ISO 15859-3 Type I and Type II Grade B composition limits are identical to SE-S-0073 Table 6.3-5 Gaseous and Liquid Nitrogen requirements for manned and flight use, except there is additionally a maximum allowed limit for argon of 20 µL/L (if required by use) and an aggregate 100 µL/L (max) total impurity limit. ISO 15859-3 also imposes a more stringent (5.0 ppm) requirement on Type I and Type II Grade B than Table 6.3-5 (50 ppm) for the maximum allowable limit of total hydrocarbons (as methane) for Environmental Control and Life Support System (ECLSS) ground test only; consequently, Type I and Type II Grade B would fail SE-S-0073 Table 6.3-5 ECLSS use specifications. ISO 15859-3 Type I and Type II Grade B composition limits are identical to MIL-PRF-27401D Grade B except for additional requirements for aromatic hydrocarbons as benzene, halogenated hydrocarbons, chlorinated hydrocarbons, nitrous oxide, and odor that are not present in MIL-PRF-27401D. ISO 15859-3 Type I and

Type II Grade B composition limits do not correspond with CGA G-10.1 *Commodity Specification for Nitrogen*⁵³ Grade B requirements and no other ISO 15859-3 Grades correspond to CGA G-10.1 Grades.

ISO 15859-3 Type I and Type II Grade C composition limits do not correspond to any SE-S-0073 requirements. ISO 15859-3 Type I and Type II Grade C composition limits are identical to SSP 30573 Table 4.1-2.13 Nitrogen Grade C (not for manned test and flight use), except for particulate. ISO 15859-3 Type I and Type II Grade C composition limits are identical to MIL-PRF-27401 Grade C.

ISO 15859-3 Type I and Type II Grade F composition limits, which have intermediate limits on purity (99.9 percent), water (15 µL/L), oxygen (5000 µL/L), particulate (1 mg/L), and total impurities (1000 µL/L), do not correspond to any SE-S-0073 or SSP 30573 requirements; however, Type I and Type II Grade F nitrogen would meet the more stringent Type I and Type II Grade C requirements. See the text above for a comparison of Type I and Type II Grade C nitrogen with SE-S-000073 and SSP 30573 requirements.

ISO 15859-3 Type I Grade J, which has the most stringent limits on purity (99.999 percent), water (10 µL/L), oxygen (5 µL/L), and total impurities (10 µL/L) does not correspond to any SE-S-0073 or SSP 30573 requirements.

ISO 15859-3 sampling parameters are in reasonable agreement with corresponding parameters in CGA G-10.1. ISO 15859-3 sampling parameters do not directly correlate with MIL-PRF-27401D or its referenced ASTM sampling methods (for Type I⁵⁰ or for Type II⁵¹).

The test methods described in ISO 15859-3 are in part similar to those in MIL-PRF-27401D, which references CGA G-10.1 for several methods. Some of the test methods found in ISO 15859-3 are also found in CGA G-10.1. The purity determination is allowed by one of four methods, including subtraction of aggregate impurities. Two of these methods involve the use of a mass spectrometer; one to measure the aggregate of all impurities and the other to measure nitrogen at mass 28. Use of a mass spectrometer to measure oxygen, hydrogen, argon, odor, and particulate matter (in addition to the other impurities) in nitrogen does not appear to be analytically feasible; applicability to odor and particulate may be a typographical error. Use of a mass spectrometer to determine nitrogen purity at mass 28 may not be practicable for other reasons. Although interference by carbon monoxide is recognized in Clause 7 and it is specified that carbon monoxide must be determined by another method, there is no mention of interference by ethane and ethylene (or other possible contaminants), which give mass 28 fragments as well. Perhaps of greater concern is the relative abundance of ¹⁵N, a naturally occurring nitrogen isotope, because Clause 7 does not address isotopic abundances. The isotopic abundance of ¹⁴N is 99.632 percent and of ¹⁵N is 0.368 percent⁵⁴. Because ¹⁵N₂ has a mass of 30 and ¹⁵N¹⁴N has a mass of 29, these naturally occurring nitrogen isotopes would appear as impurities by mass 28 definition. The presence of ¹⁵N-containing naturally occurring nitrogen isotope "impurities" would cause Type I and Type II Grades B (99.99 percent by the indirect method) and Type I Grade J (99.999 percent) to fail either both purity or total impurities. The presence of ¹⁵N-containing naturally occurring isotopes would severely impact either purity or total impurities of Type I and Type II Grade A (99.5 percent) by contribution to the purity limit (99.5 percent) or total allowable impurities (0.5 percent). Therefore, the applicability of a mass spectral method using mass 28 as a nitrogen purity indicator does not appear to be analytically feasible. If isotopic abundance is not taken into account, a mass spectral method might only be applicable to isotopically depleted nitrogen (less ¹⁵N¹⁴N and ¹⁵N₂), a commodity unlikely to exist in use quantities. Fragmentation issues would further limit the feasibility of using a mass 28 as a nitrogen purity indicator. CGA G-10.1 allows the use of a mass spectrometer for the determination of aggregate impurities only, and does not discuss mass 28 as a nitrogen purity indicator. The particulate matter content test in ISO 15859-3 is described in significantly less detail than in MIL-PRF-27401D.

PART 4: HELIUM

ISO 15859-4 applies to helium: Type I (Grade A: purging and pressurizing, Grade F: purging and pressurizing, Grade J: purging and pressurizing) and Type II (Grade A: purging and pressurizing, Grade F: purging and pressurizing). ISO 15859-4 Type I and Type II Grade A composition limits are identical to SE-S-0073 Table 6.3-1 Propellant Pressurizing Agent, Helium without its exceptions allowed by the notes. There are no SE-S-0073 requirements relevant to ISO 15859-4 for Type I Grades F and J, and Type II Grade F. ISO 15859-4 Types and Grades do not correlate with CGA G-9.1 *Commodity Specification for Helium*,⁵⁵ which specifies limiting characteristics for gaseous helium (Type I) only. It is also notable that ISO 15859-4 Type I J helium is different from CGA G-9.1 Grade J.

ISO 15859-4 Type I and Type II Grade F have the same purity requirements as SSP 30573 Table 4.1-2.9 Helium interface requirements, but the allowable limits (with the exception of purity and neon) are different, and there is an additional requirement for total allowable impurities that is not found in SSP 30573. ISO 15859-4 Type II Grade F composition limits are in partial agreement with MIL-PRF-27407B *Performance Specification Propellant Pressurizing Agent, Helium*⁵⁶ Type I Grade A limits.

ISO 15859-4 Type I Grade J, which has the most stringent limits on purity (99.999 percent), water (1.9 µL/L), oxygen (5 µL/L), hydrocarbons (as methane) (0.1 µL/L), oxygen (1 µL/L), nitrogen (3 µL/L), carbon monoxide plus carbon dioxide (1 µL/L), and total allowable impurities (10 µL/L) does not correspond to any SE-S-0073 or SSP 30573 requirements.

ISO 15859-4 sampling parameters. ISO 15859-4 sampling parameters are in reasonable agreement with corresponding parameters in CGA G-9.1. ISO 15859-4 parameters do not directly correlate with MIL-PRF-27407B parameters, though the latter references CGA G-9.1.

Some of the test methods described in ISO 15859-4 are also found in CGA G-9.1, which is referenced by MIL-PRF-27407B.

PART 5: NITROGEN TETROXIDE PROPELLANTS

ISO 15859-5 specifies composition limits and physical properties of nitrogen tetroxide (N₂O₄)-based propellants. It applies to NTO, MON-1, MON-3, MON-10, and MON-25 as well as grades standard (no iron requirement) and low-iron (0.5 µg per g or 1.0 µg per g iron maximum). ISO 15859-5 classification of dinitrogen tetroxide Types and Grades are identical to the classifications of Types and Grades in MIL-PRF-26539E *Performance Specification Propellants, Dinitrogen Tetroxide*.⁵⁷ ISO 15859-5 composition limits for NTO are identical to the requirements of MIL-PRF-26539E; however ISO 15859-5 requires the determination of chlorides in NTO and MIL-PRF-26539E has a note allowing this determination not be performed on NTO propellant manufactured by the ammonia oxidation process. ISO 15859-5 composition limits for MON-1 are identical to the requirements for MON-1 in MIL-PRF-26539E. ISO 15859-5 composition limits for MON-3 are identical to the requirements for MON-3 in SE-S-0073 Table 6.3-10 Propellant, Nitrogen Tetroxide (MON-3) and SSP 30573 Table 4.1-2.23 Propellant, Nitrogen Tetroxide (MON-3) (Interface). ISO 15859-5 composition limits for MON-3 are less stringent than MIL-PRF-26539E for NO (1.5 percent vs. 2.5 percent min.) and for water equivalents (0.2 percent vs. 0.17 percent), except for requirement for N₂O₄ (97.0 percent min.) that is not found in MIL-PRF-26539E. ISO 15859-5 composition limits for MON-10 have subtle differences from MIL-PRF-26539E, having a requirement for N₂O₄ assay (88.8 percent), no specified limit for N₂O₄ + NO (percent min.), a less stringent Water equivalent (0.20 percent max. vs. 0.17 percent max), a less stringent Iron content (1.0 µg/g max vs. 0.5µg/g max), and no specified Particulate matter (mg/L max.) ISO 15859-5 composition limits for MON-25 are identical to the requirements for MON-25 in MIL-PRF-26539E. ISO 15859-5 also requires NTO to be a homogeneous liquid when examined visually by transmitted light that NTO shall be red-brown and MON shall be green. SE-S-0073 Table 6.3-10 does not have a color requirement for MON-3. The ISO 15859-5 color requirements are identical to those in MIL-PRF-26539E.

ISO 15859-5 sampling parameters do not correspond and do not contain the level of detail corresponding to the sampling parameters in MIL-PRF-26593D.

The test methods described in ISO 15859-5, which have significantly little detail, are found in full detail in MIL-PRF-26593E. The ISO 15859-5 method for nitrogen tetroxide purity uses the wrong indicator, bromothymol blue, taken from MIL-PRF- 26593E that was in error.⁵⁸ Bromothymol blue will result in an analytical error. The proposed revision MIL-PRF-26593F *Performance Specification Propellants, Dinitrogen Tetroxide*⁵⁹ corrects that indicator to methyl red, which had been used in revisions of MIL-PRF-26593D and earlier. ISO 15869-5 neither specifies the quality of reagents used nor provides for referee methods in the event of disputes as in MIL-PRF-26593E.

PART 6: MONOMETHYLHYDRAZINE PROPELLANT

ISO 15859-6 applies to monomethylhydrazine propellant: Grade A (98.0 percent pure) and Grade F (98.5 percent pure). ISO 15859-6 Grade A composition limits are identical to SE-S-0073 Table 6.3-9 Propellant, Monomethylhydrazine, and SSP 30573 Table 4.1-2.22 Propellant, Monomethylhydrazine except for two distinctions: The ISO 15859-6 components "Water" and "Particulate matter" appear to correspond to "Water plus soluble impurities" and "Nonvolatile residue" in SE-S-0073 Table 6.3-9 and SSP 30573 Table 4.1-2.22, respectively, but chemically and analytically they do not. Additionally, Tables 6.3-9 and 4.1-2.22 specify a density determination at 77 °F (25 °C) for engineering information only that is not found in ISO 15859-1 Grade A. Grade A monomethylhydrazine composition limits are less stringent than MIL-PRF-27404C *Performance Specification Propellant, Monomethylhydrazine for purity*⁶⁰ (98.0 percent vs. 98.3 percent min.), and water (2.0 percent vs. 1.5 percent max.), but the particulate limit (10 mg/L max.) is the same. The composition limits for Grade F monomethylhydrazine are more stringent than SE-S-0073 Table 6.3-9 with higher purity (98.5 percent min. vs. 98.0 percent min), water (0.5 percent max. vs. 2.0 percent max), particulate, sodium (2 mg/L vs. no requirement), ammonia (0.2 percent max. vs. no requirement), and monomethylamine (methylamine) (0.3 percent max. vs. no requirement). SSP 30573 does not include monomethylhydrazine so there is no comparison. Grade F monomethylhydrazine does not correlate to MIL-PRF-27404C due to purity (98.5 percent min. vs. 98.3 percent min.) and similar considerations for sodium, ammonia, and methylamine. Grade F may be of French origin for an Ariane 5 rocket, but this could not be fully verified at the time of publication. ISO 15859-6 also requires monomethylhydrazine propellant to be a clear homogeneous liquid when examined visually by transmitted light. This is not required by SE-S-0073, but is required by MIL-PRF-27404C.

ISO 15859-6 sampling parameters do not correspond to the sampling parameters in MIL-PRF-27404C.

The test methods described in ISO 15859-6, which have significantly little detail, are found in full detail in MIL-PRF-27404C. ISO 15869-6 does not specify the quality of reagents used as in MIL-PRF-2740C. ISO 15859-6 Annex A (Gas Chromatography (GC) Applications) provides that GC with a thermal conductivity detector and various columns (typical GC conditions and column parameters are not specified) should be used as the reference or preferred method for some impurities. In contrast, no referee method is provided in MIL-PRF-27404C but the GC conditions are far more explicit than in ISO 15859-6.

PART 7: HYDRAZINE PROPELLANT

ISO 15859-7 applies to anhydrous hydrazine propellant: Standard [normal production and quality control (suitable for most uses)], monopropellant [normal product with strict control of specified impurities (to be specified only for monopropellant catalytic engines where extended life of the catalyst is desired)] and high purity (special production with strict control of specified impurities). ISO 15859-7 Standard Grade composition limits are similar to SE-S-0073 Table 6.3-11 Propellant, Hydrazine Test Fluid for Sundstrand, fuel pump test only, for purity (98.0 percent min.) and water (1.5 percent max), except that Standard Grade has no requirements for chloride and carbon dioxide as does Test Fluid. The composition limits for Standard grade are identical to MIL-PRF-26536E *Performance Specification Propellant, Hydrazine*,⁶¹ Standard Grade. ISO 15849-7 composition limits for Monopropellant Grade are

identical to SE-S-0073 Table 6.3-11 Orbiter Grade except for Particulate. ISO 15849-7 composition limits for Monopropellant Grade are also identical to SE-S-0073 Table 6.3-11 SRB Grade and SSP 30573 Monopropellant Grade (interface) except for purity (98.3 percent min. vs. 98.5 percent min.), water (1.2 percent max. vs. 1.0 percent max), and particulate. ISO 15859-7 Monopropellant Grade composition limits are identical to MIL-PRF-26536E Monopropellant Grade except for purity (98.3 percent min. vs. 98.5 percent min.) and water (1.2 percent max vs. 1.0 percent max). ISO 15859-7 High Purity grade composition limits have some different limits from SE-S-0073 grades and SSP 30573 Monopropellant Grade, with purity (99 percent min.), aniline (0.003 percent max.), iron (0.0004 percent max.) NVR (0.001 percent max.) and other volatile carbonaceous materials (OVCM) (0.005 percent max.) being more stringent. ISO 15859-7 High Purity Grade composition limits are identical to the requirements of MIL-PRF-26536E High Purity Grade.

ISO 15859-7 also requires hydrazine propellant to be a clear homogeneous liquid when examined visually by transmitted light. This is not required by SE-S-0073, but is required by MIL-PRF-26536E.

ISO 15859-7 sampling parameters do not correspond to the sampling parameters in MIL-PRF-26536E.

The test methods described in ISO 15859-7, which have significantly little detail, are found in full detail in MIL-PRF-26536E. ISO 15869-7 does not specify the quality of reagents used, as in MIL-PRF-26536E. ISO 15859-7 Annex A (Gas Chromatography (GC) Applications) provides that GC with various detectors, columns and traps (typical GC conditions, column parameters, and trap temperatures are not specified) should be used as the reference or the preferred method some impurities, though the full intent of the annex is unclear, perhaps due to translation. Referee methods are provided in MIL-PRF-26536E, but are far more explicit than in ISO 15859-7.

PART 8: KEROSENE PROPELLANT

ISO 15859-8 applies to kerosene. In addition to composition limits, chemical and physical property limits are specified. There are no use specifications for kerosene propellant in SE-S-0073 or SSP 30573. ISO 15859-8 chemical composition, and chemical and physical properties of kerosene are nearly identical to the requirements of MIL-P-25576C *Military Specification Propellant, Kerosene*,⁶² which was superseded by MIL-DTL-25576D *Detail Specification Propellant, Rocket Grade Kerosene*,⁶³ with differences such as the exception of the maximum allowable olefin concentration (2.0 percent max. vs. 1.0 percent max) and no limitation on copper strip corrosion. The antioxidant, metal deactivators, and dye requirements of ISO 15859-8 are in close agreement with both MIL-P-25576C and MIL-DTL-25576D. In general, ISO 15859-8 shows only partial agreement with MIL-DTL-25576D, with the notable exception that MIL-DTL-25576D contains composition limits for RP-1 and RP-2 while ISO 15859-8 refers only to kerosene.

ISO 15859-8 sampling parameters do not correlate with MIL-P-25576C; its referenced sampling method ASTM D-270 *Methods of Sampling Petroleum and Petroleum Products*,⁶⁴ which was withdrawn in 1982 and replaced by ASTM D-4057 *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*,⁶⁵ and ASTM D-4177 *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*.⁶⁶ ISO 15859-8 sampling parameters do not correlate with MIL-DTL-25576D or its referenced sampling methods (ASTM D-4057 and ASTM D-4177).

Two of the test methods described in ISO 15859-8 are referenced to ISO 3012 (*Petroleum Products - Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels - Potentiometric Method*) and ISO 3014 (*Petroleum Products - Determination of the Smoke Point of Kerosine*). The remainder of the methods described in ISO 15859-8, which have significantly little detail, are found in full detail in several ASTM test methods or in Federal Test Method Standard Number 791C – *Lubricants, Liquid Fuels, and Related Products; Method of Testing*⁶⁷ (referenced in MIL-P-25576C). MIL-DTL-275576D refers exclusively to several ASTM methods. ISO 15869-8 does not specify the quality of reagents used.

PART 9: ARGON

ISO 15859-9 applies to argon used for purging and pressurization: Type I and Type II. ISO 15859-9 composition limits for argon are the same for Type I and II (the composition table does not distinguish them), and no Grades are specified. ISO 15859-9 composition limits for argon are identical to MIL-A-18455C *Military Specification Argon, Technical*,⁶⁸ except that MIL-A-18455C additionally states that the argon shall not contain oil or odorous or toxic impurities, verbiage that is not present in ISO 15859-9. ISO 15859-9 composition limits are the same as SE-S-0073 Table 6.3-12 Argon, and SSP 30573 Table 4.1-2.5 Argon (interface) for purity, oxygen, hydrogen, and nitrogen, but is less stringent for dewpoint (-53.8 °C vs. -85 °F (-65 °C) (for both SE-S-0073 Table 6.3-12 and SSP 30573 Table 4.1-2.5)). Note that a dewpoint value of -53.8°C converts to -65 °F, which may be purely coincidental or may be a discrepancy between some of these specifications. ISO 15859-9 composition limits do not match any grades or types in CGA G-11.1 *Commodity Specification for Argon*⁶⁹ except for the purity only of Type I and Type II Grade F.

ISO 15859-9 sampling parameters are in reasonable agreement with corresponding parameters in CGA G-11.1. ISO 15859-3 sampling parameters do not correlate with MIL-A-18455C, which references CGA G-11.1.

Some of the test methods described in ISO 15859-9 are also found in CGA G-11.1. The use of mass spectrometry (without prior gas chromatographic separation) for purity determination is allowed, though no mass number(s) are provided and there is no information provided regarding argon isotopic abundance (⁴⁰Ar (99.6003 percent), ³⁸Ar (0.0632 percent), and ³⁶Ar (0.3365 percent))⁵⁴. If ⁴⁰Ar was used as the purity indicator (though it is not specified as mass 28 is for nitrogen in ISO 15859-3), the presence of either of other two natural isotopes (³⁸Ar and ³⁶Ar) would cause the fluid to fail the purity specification (99.985 percent). Additionally, there is almost no commonality between the test methods in ISO 15859-9 and MIL-A-18455C.

PART 10: WATER

ISO 15859-10 applies to water and is applicable only to potable water and high-purity demineralized or deionized water, used for cooling and servicing: Type HP (high purity) and Type P [potable (drinking)]. It is not applicable to other types of water that may be provided to a space system. ISO 15859-10 composition limits for Type HP water are in good agreement with SSP 30573 Table 4.1-2.17 Water (High Purity Deionized) Grade B (as delivered to the interface), except the former has a pH requirement of 8.0 and the latter allows a pH range from 6.00 to 8.00 and has no requirement for Total Solids or Surface Tension. ISO 15859-10 Type HP composition limits are identical to SE-S-0073 Table 6.3-8 Water Grade B for conductivity and chlorides, but differ in pH requirement (8.0 (no range allowed) vs. 6.0-8.0) and surface tension requirement (72.73 ± 1.0 dyn/cm vs. 72.73 dyn/cm (no range allowed)). ISO 15859-10 composition limits for Type HP water are in reasonable agreement with corresponding values in SE-S-0073 Table 6.3-30 Airlock LCG Cooling Water and Table 6.3-32 Heat Transport Water. ISO 15859-10 composition limits for Type P water are in fair agreement with SE-S-0073 Table 6.3-16 Potable Water, except there are composition limits specified for potassium and selenium, chromium is hexavalent, some of the ionic composition limits are lower, and there is a pH requirement of 5.0 to 8.0. SSP 30573 does not have a requirement for potable water. ISO 15859-10 composition limits for potable water have only some requirements similar to SSP 50260 Internal Space Station Medical Operations Requirements Documents (ISS MORD)⁷⁰ Table 5.2-1 Water Quality Requirements for the ISS Russian Segment for Russian Ground-Supplied Potable, SVOZ; Regenerated Potable, SRV-K; and Shuttle-Supplied Potable, CWC grades of potable water. ISO 15859-10 composition limits for potable water also have only some requirements similar to SSP 41000AY System Specification for the International Space Station⁷¹ Table LXX Water Quality Requirements.

ISO 15869-10 states that sampling shall conform to the requirements of ISO 5667-1 *Water Quality – Sampling – Part 1: Guidance on the Design of Sampling Programmes*, ISO 5667-2 *Water Quality – Sampling – Part 2: Guidance on Sampling Techniques*, ISO 5667-3 *Water Quality – Sampling – Part 3: Guidance on the Preservation and Handling of Water Samples*, and ISO 5667-5 *Water Quality –*

Sampling – Part 5: Guidance on Sampling of Drinking Water and Water Used for Food and Beverage Processing. These documents provide considerable information but are guidance documents and not standards. No attempt was made to compare these documents with ASTM, Standard Methods for the Examination of Water and Wastewater,⁷² and Environmental Protection Agency sampling requirements.⁷³

Some of the test methods briefly described in ISO 15859-10 are found in full detail in several of the referenced ISO documents. Other of the test methods provide significantly little detail but can be found in full detail in corresponding ASTM documents, some of which are referenced in NASA JSC-SPEC-C-20C *Water, High Purity Specification For*,⁷⁴ Standard Methods for the Examination of Water and Wastewater, various Environmental Protection Agency methods, and analytical chemistry textbooks.

PART 11: AMMONIA

ISO 15859-11 applies to ammonia. ISO 15859-11 composition limits for ammonia are identical to SE-S-0073 Table 6.3-18 Ammonia. ISO 15859-11 components and composition limits are different than SSP 30573 Table 4.1-2.4 Ammonia (Option 1 Interface and Option 2 Interface). The ISO 15859-11 composition limits for ammonia are different from O-A-445C *Federal Specification Ammonia, Technical*.⁷⁵ ISO 15859-11 is more stringent for purity (99.99 percent vs. 99.98 percent) and water (50 ppm vs. 250 ppm), and less stringent for oil (6 ppm vs. 5 ppm). While ISO 15859-11 has composition limits for chlorides and O-A-445C does not, O-A-445 C has additional requirements for contaminant (pyridine, naphthalene, and hydrogen sulfide) testing when the ammonia is produced with hydrogen from a source other than natural gas.

ISO 15869-11 states that sampling may be performed in accordance with ISO 7103 (*Liquefied Anhydrous Ammonia for Industrial Use – Sampling – Taking a Laboratory Sample*) or with ISO 15859-11 subclauses 6.2 to 6.10. ISO 7103 refers only to the sampling of anhydrous (liquid) ammonia and is not applicable to gaseous ammonia sampling. ISO 15859-11 sampling requirements do not correspond to O-A-445C.

The test methods described in ISO 15859-11 have little commonality with O-A-445C. Only Karl Fisher titration used for the determination of moisture as described in ISO 15859-11 is also found in O-A-445C. While ISO 15859-11 references ISO 7106 (*Liquefied Anhydrous Ammonia for Industrial Use – Determination of Oil Content – Gravimetric and Infrared Spectrometric Methods*), it states that oil shall be determined by an infrared spectrometric method (not gravimetric method) in accordance with ISO 7106. O-A-445 C employs a gravimetric method (using carbon tetrachloride extraction and evaporation) for the determination of oil that is similar to that in ISO 7106. The test methods for water do not include the method described in CGA G-2.2 *Guideline Method for Determining Minimum of 0.2 Percent Water in Anhydrous Ammonia*,⁷⁶ perhaps because the CGA G-2.2 method is designed for the determination of relatively gross amounts of water and consequently lacks the required sensitivity.

PART 12: CARBON DIOXIDE

ISO 15859-12 applies to gaseous or liquid carbon dioxide intended for purging and pressurization. ISO 15859-12 composition limits are for purity and water only. ISO 15859-12 composition limits for carbon dioxide are identical to SE-S-0073 Table 6.3-17 Carbon Dioxide. SSP 30573 Table 4.1-2.7 Carbon Dioxide Grade A (Interface) requirements are equally stringent for purity, but less stringent for water (moisture). SSP 30573 carbon dioxide Grade A contains additional requirements for carbon monoxide, hydrogen sulfide, nitric oxide, nitrogen dioxide, ammonia, and sulfur dioxide. ISO 15859-12 requirements for water are identical to BB-C-101C *Federal Specification Carbon Dioxide (CO₂): Technical and USP*⁷⁷ Grade B. The ISO 15859-12 purity requirements are less stringent (99 percent vs. 99.5 percent) and there are no requirements for acidity and odor. ISO 15859-12 composition limits do not correspond with any of the five types (E, G, H, I, and J) found in CGA 6.2 *Commodity Specification for Carbon Dioxide*,⁷⁸ which are typically more stringent and have requirements for many limiting characteristics other than water and purity required by ISO 15859-12.

ISO 15859-12 requirements for sampling size correspond with CGA G-6.2.

The test methods described in ISO 15859-12 for purity and water content agree closely with CGA G-6.2. However, as discussed above, CGA G-6.2 has many more requirements than ISO 15859-12 for other types.

PART 13: BREATHING AIR

ISO 15859-13 applies to breathing air intended for purging and pressurization of space systems in addition to flight hardware and ground support facilities, systems, and equipment. ISO 15859-13 composition limits for breathing air are identical to SE-S-0073 Table 6.3-29 Breathing Air Mixture (1) (for ground test only) for both compressor source (launch site(s) only) and cryogenic source air. ISO 15859-13 composition limits for compressed source air are different from SSP 30573 Table 4.1-2.2 Air (Breathing) Options 1, 2, and 3 (Interface). ISO 15859-13 composition limits for liquid source air are identical to SSP 30573 Table 4.1-2.2 requirements for Option 1, Interface, cryogenic source air, with the exception of an odor requirement (none) and hydrocarbon components and limits. Some of the ISO 15859-12 composition limits correlate with BB-A-1034B *Federal Specification Compressed Air, Breathing*.⁷⁹

ISO 15859-13 compressed source and liquid source composition limits meet CGA G-7.1 *Commodity Specification for Air*⁸⁰ Grade D requirements for carbon dioxide, carbon monoxide, odor, but have a higher oxygen limit (23.8 percent vs. 23.5 percent) and no requirement for condensed oil. Additionally, ISO 15859-13 has specific limits for nitrogen, rare gases, water, total hydrocarbons, acetylene (for liquid source only), halogenated hydrocarbons, chlorinated hydrocarbons, nitrous oxide, and aromatic hydrocarbons that are not found in CGA G-7.1 Grade D. ISO 15859-13 composition limits for compressed source and liquid source air comply with the OSHA 29 CFR 1910.134 *Respiratory Protection*⁸¹ requirements for carbon monoxide content, carbon dioxide content, and lack of noticeable odor in breathing air, but the upper oxygen limits (23.8 percent) exceed the upper OSHA limit (23.5 percent), and there is a lack of requirement for condensed oil content that is similarly not found for compressed air in SE-S-0073 Table 6.3-29. The OSHA requirement for condensed oil (5 mg/m³) is identical to that found for oil (mist and vapor and particulate matter in SSP 30573 Table 4.1-2.2 Air (Breathing) "As Delivered to Interface (Option 3)", but not required in Options 1 or 2, which are cryogenically sourced. The OSHA standard requires compressed breathing air meet the requirements for Grade D breathing air described in CGA G-7.1 to include oxygen content (v/v) of 19.5-23.5 percent, condensed oil content of 5 milligrams per cubic meter of air or less, carbon monoxide content of 10 ppm or less, carbon dioxide content of 1,000 ppm or less, and lack of noticeable odor. Although OSHA does not require liquid air to meet Grade D breathing air requirements, CGA G-7.1 does not require condensed oil to be determined if the air is synthesized from oxygen and nitrogen produced by air liquefaction, as would be applicable to cryogenic source air.

Many but not all the test methods described in ISO 15859-13 are found in CGA G-7.1. ISO 15859-13 describes additional methods. MIL-STD-1564A (*Military Standard Procedure for Calibration and Analysis of Trace Contaminants in Aviators Breathing Oxygen by Infrared Spectroscopy*) describes a procedure for determining trace gaseous contaminants in oxygen, nitrogen, and air by infrared spectroscopy.

DISCUSSION

The summary below discusses various aspects of the clauses ISO 15859 Parts 1 through 13.

SCOPE

The ISO 15859 types and grades do not always correlate with other types and grades of fluids of both U.S. and ISO origin. For example, ISO 15859 Type I Grade F hydrogen limits are vastly different from ISO 14647 Type I Grade F hydrogen. As referenced in ISO 15859 Part 2, Type I grade F hydrogen procured to the ISO 14647 would fail ISO 15859 Type I Grade F specifications.

NORMATIVE REFERENCES

The ISO 15859 Parts 1 through 13 standards never reference source or possible source documents unless they are of ISO origin and do not even reference their predecessor documents, ISO 14951 Parts 1 through 13, respectively. All parts do not reference the corresponding U.S. military specifications or applicable parts of SE-S-0073 documents from which major portions were clearly derived. SE-S-0073, SSP 30573, ASTM, and CGA commodity specifications are also not referenced. All documents reference ISO 9000, which is of dubious (if any) utility other than to establish a quality management system.

TERMS AND DEFINITIONS

These vary by document.

CHEMICAL COMPOSITION

There are no requirements for particulate distribution such as are specified in SE-S-0073 and SSP 30573. Composition limits are sometimes but not always consistent with SE-S-0073, SSP 30573, military specifications, and CGA commodity specifications, with the caveat "unless otherwise provided in an applicable technical specification." Some fluid types and grades do not correspond with corresponding CGA Commodity Specification Types and Grades, such as Type I and Type II Grade B nitrogen, and Type I Grade J helium. This could introduce confusion to the user if the corresponding specification sources (ISO or CGA, as appropriate) for types and grades of fluids were not clearly specified.

PROCUREMENT

Procurements are to be made in accordance with national or international standards, but these are not specified except in the case of hydrogen. As described above, Type I grade F hydrogen procured to the referenced ISO 14647 standard would fail ISO 15859 Type I Grade F specifications.

FLUID SAMPLING

These requirements are very similar for each of Parts 1 through 13 and verbatim for the gaseous sampling provisions for oxygen, hydrogen, nitrogen, helium, argon, ammonia, carbon dioxide, and breathing air with the exception of the cautionary notes. While the intention of this paper is not to reproduce the ISO standards but to increase awareness, it is noteworthy that this clause specifies that a fluid sampling plan containing specified subjects should be (non-mandatory) established by all the involved operators, from the production to the space vehicle interface, and approved by the final user. Additionally, it states that sampling activities and test methods shall (mandatory) comply with all safety regulations and rules applicable to that task. While the requirement for the plan is non-mandatory, it states the plan shall (mandatory) specify sampling points, sampling procedures, sampling frequency, sample size, number of samples, test methods, and responsibilities of any involved operator. This curious mix of mandatory and non-mandatory requirements coupled with many other caveats leave the user with many options not typically found in a conventional, binding standard, such as:

- Responsibility for Sampling
 - Unless otherwise provided in an applicable technical specification
 - Unless otherwise directed by the customer
- Sampling Points
 - Unless otherwise specified
- Sampling Frequency
 - In accordance with a time agreed upon by the supplier and the customer
- Sample Size
 - Quantity shall be sufficient
- Number of Samples
 - Any number of samples agreed by the supplier and the customer

- Storage Container
 - Unless otherwise provided by the applicable sampling plan
- Gaseous or Liquid Samples
 - Specific options for obtaining samples
- Rejection
 - Disposal of the rejected fluid shall be specified by the customer

Parts of the fluid sampling criteria are occasionally similar to CGA commodity specifications.

TEST METHODS

With the exception of water, which has extensive ISO reference documents, test method detail ranges from little to partial and would require use of (non-referenced) MIL standards, commodity specifications, and ASTM methods. Mandatory use of the test methods has the caveat that “Other test methods not listed in these Parts of ISO 15859 are acceptable if agreed upon by the supplier and the customer”. Additionally, referee methods are not always specified and they lack the detail typically found in the corresponding military specifications. Some technical errors or possible technical errors have been identified, including the indicator for MON oxidizer assay, and possibly the use of mass spectrometry for purity determinations (nitrogen and argon).

In the conventional sense of standards, such as NASA, military, or ASTM, the ISO 15859 Standards are guides because all of their requirements are non-binding and non-mandatory.

WSTF EFFORTS

WSTF has a program that is currently being evaluated internally to rewrite ISO 15859 Parts 1 through 13. For a formal rewrite of ISO standards to occur, formal acceptance to begin this process is required by ISO. Once prepared, the documents would be sent for NASA agency review then review by the interested technical community. Comments and responses are then formally addressed. Once the documents meet the approval of ANSI, they are sent out for review and comments at the international level. Finally, the voting process is begun and the standards are accepted or rejected by ISO. At this time, preliminary discussions with the international partners at the ISO/TC 20 SC 14 subcommittee have been initiated.

RELATED SPECIFICATIONS

ISO 14951 *Space Systems – Fluid Characteristics* Parts 1 through 13 (1999)⁸²⁻⁹⁴ preceded the ISO 15859 standards and provide only fluid characteristics. The fluid characteristics of ISO 14951 Parts 1 through 13 correspond to the fluid characteristics sections of ISO 15859 Parts 1 through 13, respectively.

British Standards Institution (BSI) ISO 15859 *Space Systems – Fluid Characteristics, Sampling and Test Methods* Parts 1 through 13,⁹⁵⁻¹⁰⁷ which are the British Standard Aerospace Series, reproduce verbatim ISO 15859 (*Fluid Characteristics, Sampling and Test Methods*) Parts 1 through 13, respectively. They were implemented as United Kingdom (UK) national standards on August 16, 2004.

CONCLUSIONS

ISO 15859 Parts 1 through 13 are standards for aerospace fluids including propellants and pressurizing gases. Their requirements are consistent with a blend of some but not all NASA shuttle and international space station use specifications, military procurement specifications, and GCA commodity specifications. The “requirements” in the ISO standards are typically qualified (“unless otherwise provided, directed, specified, agreed...”), which functionally makes them guides rather than standards. Because the requirements are qualified to the extreme, they are non-mandatory and non-binding. Therefore, there may be little reason to change them except for errata or technical errors. The

documents would not be anticipated to replace SE-S-0073 because they typically duplicate them except for particulate requirements, which are lacking. If an extensive re-write of these standards were to be undertaken, a reasonable recommendation would be to replace them with their corresponding military or federal specifications, as applicable, by incorporation by reference. This would achieve consistency with the well-researched and widely used aerospace fluid standards currently in use by the U.S.

REFERENCES

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4. ISO 15859-4:2004. *Space Systems – Fluid Characteristics, Sampling Test Methods – Part 4: Helium*. International Organization for Standardization. Geneva, Switzerland, 2004.
5. ISO 15859-5:2004. *Space Systems – Fluid Characteristics, Sampling Test Methods – Part 5: Nitrogen Tetroxide Propellants*. International Organization for Standardization. Geneva, Switzerland, 2004.
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***ISO 15859 Propellant and Fluid
Specifications: A Review and Comparison
with Military and NASA Specifications***

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Objective

- Introduce International Standard (ISO) 15859 Space Systems – Fluid Characteristics, Sampling and Test Methods Parts 1 through 13, issued in June 2004
- Provide awareness of the basic content of these standards
- Provide and discuss comparisons with:
 - NASA SE-S-0073 Space Shuttle Specification Fluid Procurement and Use Control
 - SSP 30573 Space Station Program Fluid Procurement and Use Control Specification. International Space Station Alpha.
 - Applicable Military Specifications and Details, and Federal Standards
 - CGA commodity specifications
- Present and discuss some issues
- Describe WSTF's current efforts



General – Standards and Specifications

- Structure of standards and specifications (examples)
- International – ISO, others
- National – ANSI, ASTM, AIAA, ASTM, ASME, AWS, NFPA, OSHA, others
- DoD – MIL PRF, MIL DTL, others
- Associations – CGA
- Program
 - NASA SE-S-0073 and SSP 30573 are of vital importance to Shuttle Transport Systems and International Space Station programs, respectively. These documents are large and provide exacting detail on fluid requirements.



General – Standards and Specifications

- Typically these ISO standards stand alone
- Many related MIL standards stand alone; others refer to CGA commodity specifications for test methods
- NASA SE-S-0073 is a program requirement and contains references to procurement specifications use specifications
- SSP 30573 is a program requirement and contains procurement and use specifications and various test methods



ISO 15859 Parts 1-13

- Part 1: Oxygen
- Part 2: Hydrogen
- Part 3: Nitrogen
- Part 4: Helium
- Part 5: Nitrogen Tetroxide Propellants
- Part 6: Monomethylhydrazine Propellant
- Part 7: Hydrazine Propellant
- Part 8: Kerosine Propellant
- Part 9: Argon
- Part 10: Water
- Part 11: Ammonia
- Part 12: Carbon Dioxide
- Part 13: Breathing Air

The documents were prepared by ISO Technical Committee ISO/TC 20, *Aircraft and Space Vehicles*, Subcommittee (SC) 14, *Space Systems and Operations*. The secretariat was the American National Standards Institute (ANSI).



Background

- International Standard ISO 15859 Space Systems – Fluid Characteristics, Sampling and Test Methods Parts 1-13 establish requirements for the components, sampling, and test methods of fluids used in the servicing of launch vehicles, spacecraft and ground support equipment
- ISO 15859 Parts 1-13 are applicable to any sampling operation required to ensure that, when the fluid enters the launch vehicle or spacecraft, the fluid composition complies with the limits provided in the respective Part or with any technical specification agreed for a particular use.
- Each Part is a “use” standard (sample taken at the interface)
- No Part defines or references a program



Background

Summary of ISO 15859 Standard

	Brazil (ABNT)	Canada (SCC)	China (SAC)	France (AFNOR)	Germany (DIN)	Italy (UNI)	Japan (JISC)	Russian Federation (GOST R)	Ukraine (DSTU)	United Kingdom (BSI)	USA (ANSI)
Oxygen	Approve	Approve	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Hydrogen	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Nitrogen	Approve	Approve	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Helium	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Nitrogen Tetroxide Propellants	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Mono-methyl-hydrazine Propellant	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Hydrazine Propellant	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Kerosine Propellant	Approve	Approve	Approve	Abstain	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Argon	Approve	Approve	Approve	Disapprove*	Approve	Abstain	Approve	Approve	Approve	Approve	Approve
Water	Approve	Approve	Approve	Disapprove*	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve
Ammonia	Approve	Approve	Approve	Abstain	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Carbon Dioxide	Approve	Approve	Approve	Abstain	Approve	Approve	Approve	Approve	Approve	Approve	Approve
Breathing Air	Approve	Approve	Approve	Disapprove*	Approve	Approve	Approve	Approve	Approve	Approve	Approve

*Comment



Part 1 - Oxygen

- Type I (Grade A: standard, purging/pressurization, Grade CB: crew breathing, Grade F: fuel-cell) and Type II (Grade A: oxidizer, Grade B: oxidizer, Grade F: fuel-cell)
- Type I Grade CB composition limits are identical to SE-S-0073 Table 6.3-24 Breathing Oxygen, and have some limits that agree with MIL-PRF-27210G Type I
- Type II Grade B composition limits do not correspond with SE-S-0073 or SSP 30573 requirements, but with minor exceptions are similar to MIL-PRF-25508F Grade B
- Type II Grade B composition limits are identical to CGA G-4.3 Type II Grade C, except for limits of 0.1 $\mu\text{L/L}$ (max) for CO and 3 $\mu\text{L/L}$ (max) for CO₂ when required to meet hardware needs



Part 2 - Hydrogen

- Type I (Grade A: fuel, Grade F: fuel) and Type II (Grade A: fuel, Grade F: fuel).
- Type I Grade A and Type II Grade A composition limits are identical to each other and to SE-S-0073 Table 6.3-6 Gaseous and Liquid Hydrogen, without notes.
- Type I Grade F and Type II Grade F composition limits are similar to SSP 30573 Table 4.1-2.11 Hydrogen (Interface) with identical requirements for purity (99.995%), oxygen plus argon (1 $\mu\text{L/L}$), and carbon dioxide plus carbon monoxide (1 $\mu\text{L/L}$), and similar requirements for nitrogen, water and volatile hydrocarbons combined (10 ppm vs 9 ppm), and helium (40 ppm vs. 39 ppm). Type I Grade F and Type II Grade F have a requirement for Total gaseous impurities (60 $\mu\text{L/L}$ max), which is not in SSP 30573 Table 4.1-2.11, but this specification could be met by an aggregate impurity summation. Additionally, SSP 30573 Table 4.1-2.11 has no interface requirement for para-hydrogen (liquid only).



Part 2 – Hydrogen (continued)

- Type I Grade F and Type II Grade F composition limits are similar to MIL-PRF-27201C Performance Specification Propellant, Hydrogen, with the exception of nitrogen, water and volatile hydrocarbons combined (9.0 $\mu\text{L/L}$ vs. 10 ppm) and helium (40 $\mu\text{L/L}$ vs. 39 ppm).
- Type I Grade F and Type II Grade A composition limits do not correspond to CGA G-5.3 Commodity Specification for Hydrogen Type I Grade F and Type II Grade A, respectively.



Part 3 - Nitrogen

- Type I (Grade A: purging/pressurizing, Grade B: crew breathing, Grade C, Grade F, Grade J) and Type II (Grade A: purging/pressurizing, Grade B: crew breathing, Grade C, Grade F). Slush hydrogen is not included.
- Type I and Type II Grade A composition limits are identical to SE-S-0073 Table 6.3-3 Gaseous Nitrogen, with the exception that an aggregate 5000 $\mu\text{L/L}$ (max) total impurity limit is specified.
- Type I and Type II Grade C composition limits are identical to SSP 30573 Table 4.1-2.13 Nitrogen Grade C (Interface, not for manned test and flight use) except for Particulate.
- Type I and Type II Grade A composition limits are identical to MIL-PRF-27401D "Performance Specification Propellant Pressurizing Agent, Nitrogen" Grade A.
- Type I and Type II Grade B composition limits do not correspond with CGA G-10.1 Commodity Specification for Nitrogen Grade B



Part 4 - Helium

- Type I (Grade A: purging and pressurizing, Grade F: purging and pressurizing, Grade J: purging and pressurizing) and Type II (Grade A: purging and pressurizing, Grade F: purging and pressurizing).
- Type I and Type II Grade A composition limits are identical to SE-S-0073 Table 6.3-1 Propellant Pressurizing Agent, Helium without exceptions allowed by the notes.
- ISO 15859-4 Type I and Type II Grade F have the same purity requirements as SSP 30573 Table 4.1-2.9 Helium (Interface) and similar components, but the allowable limits (with the exception of purity and neon) are different, and there is an additional requirement for Total Allowable Impurities that is not found in SSP 30573.



Part 4 – Helium (continued)

- Type I and Type II Grade F have the same purity requirements as SSP 3073 Table 4.1-2.9 Helium. Water (moisture), hydrocarbons (as methane), oxygen, nitrogen + argon, hydrogen, carbon dioxide and carbon monoxide have subtle (ppm) differences in allowable composition limits and whether they are reported as aggregates or individually. The limit for neon is identical.
- Type II Grade F composition limits are in partial agreement with MIL-PRF-27407B “Performance Specification Propellant Pressurizing Agent, Helium” Type I Grade A limits.
- Type I J helium composition limits are different from CGA G-9.1 Commodity Specification for Helium Grade J.



Part 5 – Nitrogen Tetroxide Propellants

- NTO, MON-1, MON-3, MON-10, and MON-25 as well as grades standard (no iron requirement) and low-iron (0.5 $\mu\text{g/g}$ or 1.0 $\mu\text{g/g}$ iron maximum)
- Types and Grades are identical to the Types and Grades in MIL-PRF-26539E Performance Specification Propellants, Dinitrogen Tetroxide.
- NTO composition limits are identical to the requirements of MIL-PRF-26539E.
- MON-1 composition limits are identical to the MIL-PRF-26539E Performance Specification Propellants, Dinitrogen Tetroxide.



Part 5 – Nitrogen Tetroxide Propellants (continued)

- MON-3 composition limits are identical to the requirements of for MON-3 in SE-S-0073 Table 6.3-10 and SSP 30573 Table 4.1-2.23 Propellant, Nitrogen Tetroxide (MON-3) (Interface) , which are less stringent than MIL-PRF-26539E for NO (1.5% vs. 2.5% min.) and for Water equivalents (0.2% vs. 0.17%), and there is a requirement for N_2O_4 assay (97.0% min.).
- MON-10 composition limits have subtle differences from MIL-PRF-26539E, having a requirement for N_2O_4 assay (88.8%), no specified limit for $N_2O_4 + NO$ (%min.), a less stringent Water equivalent (0.20 %max. vs. 0.17 % max), a less stringent Iron content (1.0 $\mu\text{g/g}$ max vs. 0.5 $\mu\text{g/g}$ max), and no specified Particulate matter (mg/L max.)
- MON-25 composition limits are identical to the requirements for MON-25 in MIL-PRF-26539E



Part 6 - Monomethylhydrazine Propellant

- Grade A (98.0 % pure) and Grade F (98.5 % pure)
- Grade A composition limits are identical to SE-S-0073 Table 6.3-9 and SSP 30573 (Interface), except the ISO components “Water” and “Particulate matter” appear to correspond to “Water plus soluble impurities” and “Nonvolatile residue” in SE-S-0073 Table 6.3-9 and SSP 30573 Table 4.1-2.22, respectively, but chemically and analytically they do not.
- Grade A MMH composition limits are less stringent than MIL-PRF-27404C Performance Specification Propellant, Monomethylhydrazine for purity (98.0% vs 98.3% min.), and water (2.0% vs. 1.5% max.), but the particulate limit (10 mg/L max.) is the same
- Grade F MMH composition limits do not correlate with a Grade in MIL-27404C due to purity (98.5% min. vs. 98.3% min.) and similar considerations for sodium, ammonia, and methylamine. Grade F may be of French origin for an Ariane 5 rocket.



Part 7 - Hydrazine Propellant

- Anhydrous hydrazine propellant: Standard [normal production and quality control (suitable for most uses)], monopropellant [normal product with strict control of specified impurities (to be specified only for monopropellant catalytic engines where extended life of the catalyst is desired)] and high purity (special production with strict control of specified impurities).
- Standard grade composition limits are identical to MIL-PRF-26536E “Performance Specification Propellant, Hydrazine”, Standard Grade.
- Monopropellant Grade composition limits are identical to SE-S-0073 Table 6.3-11 Orbiter Grade except for Particulate. Monopropellant Grade composition limits are also identical to SE-S-0073 Table 6.3-11 SRB Grade and SSP 30573 Monopropellant Grade (interface) except for purity (98.3% min. vs. 98.5% min.), water (1.2% max. vs. 1.0% max), and particulate.



Part 7 - Hydrazine Propellant (continued)

- Monopropellant Grade composition limits are identical to MIL-PRF-26536E Monopropellant Grade except for purity (98.3% min. vs. 98.5% min.) and water (1.2% max vs. 1.0% max).
- High Purity Grade composition limits are identical to MIL-PRF-26536E High Purity Grade.



Part 8 - Kerosine Propellant

- Kerosene
- No use specifications for kerosene propellant in SE-S-0073, SSP 30573, or any other NASA requirements that could be identified.
- Chemical composition, and chemical and physical properties of kerosene are nearly identical to the requirements of MIL-P-25576C Military Specification Propellant, Kerosene
- Only partial agreement with MIL-DTL-25576D, with the notable exception that MIL-DTL-25576D applies specifically to RP-1 and RP-2



Part 9 - Argon

- Argon used for purging and pressurization: Type I and Type II (no Grades specified)
- Composition limits are the same for Type I and Type II
- Composition limits are the same as SE-S-0073 Table 6.3-12 Argon, and SSP 30573 Table 4.1-2.5 Argon (interface) for purity, oxygen, hydrogen, and nitrogen, but is less stringent for dewpoint (-53.8 °C vs. -85 °F (-65 °C) (for both SE-S-0073 and SSP 30573).
- Composition limits do not match any Grades or Types in CGA G-11.1 Commodity Specification for Argon except for the purity only of Type I and Type II Grade F
- Composition limits are identical to MIL-A-18455C Military Specification Argon, Technical, except that MIL-A-18455C additionally states that the argon shall not contain oil or odorous or toxic impurities



Part 10 - Water

- Applies to water and is applicable only to potable water and high-purity demineralized or deionized water, used for cooling and servicing: Type HP (high purity) and Type P [potable (drinking)]. It is not applicable to other types of water that may be provided to a space system.
- Type HP composition limits are in good agreement with SSP 30573 Table 4.1- 2.17 Water (High Purity Deionized) Grade B (as delivered to the interface), except the former has a pH requirement of 8.0 and the latter allows a pH range from 6.00 to 8.00 and has no requirement for Total Solids or Surface Tension.
- Type HP composition limits are identical to SE-S-0073 Table 6.3-8 Water Grade B for conductivity and chlorides, but differ in pH requirement (8.0 (no range allowed) vs. 6.0-8.0) and surface tension requirement (72.73 ± 1.0 dyn/cm vs. 72.73 dyn/cm (min.) (no range allowed)).
- Type HP composition limits are in reasonable agreement with corresponding values in SE-S-0073 Table 6.3-30 Airlock LCG Cooling Water and Table 6.3-32 Heat Transport Water.



Part 10 – Water (continued)

- Type P composition limits are in fair agreement with SE-S-0073 Table 6.3-16 Potable Water, except there are composition limits specified for potassium and selenium, chromium is hexavalent, some of the ionic composition limits are lower, and there is a pH requirement of 5.0 to 8.0.
- Composition limits for potable water have only some requirements similar to SSP 50260 Table 5.2-1 Water Quality Requirements for the ISS Russian Segment for Russian Ground-Supplied Potable, SVOZ; Regenerated Potable, SRV-K; and Shuttle-Supplied Potable, CWC grades of potable water.
- Composition limits for potable water also have only some requirements similar to SSP 41000AY Table LXX Water Quality Requirements. SSP 30573 does not have a requirement for potable water.



Part 11 - Ammonia

- Applies to ammonia (no Types specified)
- Composition limits are identical to SE-S-0073 Table 6.3-18 Ammonia.
- Components and composition limits are different than SSP 30573 Table 4.1-2.4 Ammonia Option 1 (interface) and Option 2 (interface).
- Composition limits for ammonia are different O-A-445C Federal Specification Ammonia, Technical. Part 11 is more stringent for purity (99.99% vs. 99.98%) and water (50 ppm vs. 250 ppm), and less stringent for oil (6 ppm vs. 5 ppm). While Part 11 has composition limits for chlorides and O-A-445C does not, O-A-445 C has additional requirements for contaminant (pyridine, naphthalene, and hydrogen sulfide) testing when the ammonia is produced with hydrogen from a source other than natural gas.



Part 12 – Carbon Dioxide

- Applies to gaseous or liquid carbon dioxide intended for purging and pressurization. No Types are specified. Composition limits are for purity and water only.
- Composition limits are identical to SE-S-0073 Table 6.3-17 “Carbon Dioxide”.
- Composition limits are equally stringent with SSP 30573 Table 4.1-2.7 Carbon Dioxide Grade A (Interface) requirements for purity, but are more stringent for water (moisture). SSP 30573 Carbon dioxide Grade A contains additional requirements for carbon monoxide, hydrogen sulfide, nitric oxide, nitrogen dioxide, ammonia, and sulfur dioxide.
- Requirements for water are identical to BB-C-101C “Federal Specification Carbon Dioxide (CO₂): Technical and USP” Grade B but purity requirements are less stringent (99% vs. 99.5%) and there are no requirements for acidity and odor.
- Composition limits do not correspond with any of the 5 Types (E, G, H, I, and J) found in CGA-6.2 Commodity Specification for Carbon Dioxide, which are typically more stringent and have requirements for many limiting characteristics other than water and purity.



Part 13 – Breathing Air

- Applies to breathing air intended for purging and pressurization of space systems in addition to both flight hardware and ground support facilities, systems, and equipment.
- Breathing air composition limits are identical to SE-S-0073 Table 6.3-29 Breathing Air Mixture (1) (for ground test only) for both compressor source (launch site(s) only) and cryogenic source air.
- Composition limits for Compressed Source air are different from SSP 30573 Table 4.1-2.2 Air (Breathing) Options 1, 2, and 3 (interface). Composition limits for Liquid Source air are identical to SSP 30573 Table 4.1-2.2 requirements for Option 1 (interface, cryogenic source air, with the exception of an odor requirement (none) and hydrocarbon components and limits.



Part 13 – Breathing Air (continued)

- Some of the composition limits correlate with BB-A-1034B Federal Specification Compressed Air, Breathing.
- Compressed source and liquid source composition limits meet CGA G-7.1 “Commodity Specification for Air” Grade D requirements for carbon dioxide, carbon monoxide, odor, but have a higher oxygen limit (23.8% vs 23.5%) and no requirement for condensed oil. Additionally, Part 13 has specific limits for nitrogen, rare gases, water, total hydrocarbons, acetylene (for liquid source only), halogenated hydrocarbons, chlorinated hydrocarbons, nitrous oxide, and aromatic hydrocarbons that are not found in CGA G-7.1 Grade D.



Specific Issues

- All (except Kerosene)
 - There are no requirements for particle size distribution, which are very important in SE-S-0073 and SSP 30573
- Nitrogen
 - Allowed use of mass spectrometry and mass 28 for purity determination. Isotopic abundance of ^{15}N yielding $^{14}\text{N}^{15}\text{N}$ (mass 29) and $^{15}\text{N}_2$ (mass 30) would contribute to or cause failure of purity by direct or indirect methods.
- NTO Propellant
 - There is no note allowing the chlorides determination not be performed on fluid manufactured by the ammonia oxidation process
 - Wrong indicator (bromothymol blue) is specified for the NTO purity determination. MIL-PRF-26539F (proposed) corrects this (back) to methyl red (as was in Rev. D and earlier)
- Argon
 - Allowed use of mass spectrometry for purity determination. Though no mass number is specified (as is for nitrogen) the presence of ^{38}Ar (0.0632%), and ^{36}Ar (0.3365%) would cause ^{40}Ar (99.6003%) to fail purity.



Specific Issues

- Ammonia
 - This Part states that sampling may be performed in accordance with ISO 7103 or with ISO 15859-11 sub-clauses 6.2 to 6.10. ISO 7103 refers only to the sampling of anhydrous (liquid) ammonia and is not applicable to gaseous ammonia sampling



General Issues

- ISO 15859 Parts 1-13 are “use” specifications (samples taken at the interface).
- They are by comparison, a combination of use, procurement, and commodity specifications
- The majority of composition limits appear to be verbatim or derived from Space Shuttle (SE-S-0073, International Space Station (SSP 30573), U.S. military specifications, and/or Compressed Gas Association (CGA) commodity specifications. One specification for an MMH grade may be of French origin for an Ariane 5.



General Issues (continued)

- “Requirements” are always qualified: “Unless otherwise provided, directed, specified, agreed...”
 - This makes the documents “Guides” rather than “Standards”
- The documents do not reference their source (or possible source) documents unless they are of ISO origin, depriving the user of the useful additional information.
- Aerospace users require full details to implement the provision of standards, otherwise they are of limited or no utility.



General Issues (continued)

- The detail in test methods derived from U.S. military specifications range from little to partial, and is typically inadequate.
- Typically lacking are referee methods (or referee methods in sufficient detail) that a standard should contain in the event of a dispute.
- Several technical errors or possible technical errors have been identified.

Slide 31

L2

2nd bullet: changed nitrate to nitrite

should 2nd-5th bullets be under the first bullet?

LMIT-ODIN, 3/14/2005



WSTF Involvement

- WSTF reviewed these standards when they were in Final Draft status, but they were issued before comments could be addressed.
- At that time, WSTF proposed these standards be re-written and the proposal was accepted by the NASA Technical Standards Program Office.
- This presentation summarized a small part of the effort to understand the relationship between the ISO standards, NASA specifications, and MIL documents to develop an approach to the re-write effort.
- Some of these issues are being discussed with the ISO subcommittee.
- An approach incorporating the MIL documents (by reference) is being suggested.



Conclusion

- 13 ISO aerospace fluid standard documents were reviewed and discussed
- Each was compared with applicable NASA Space Shuttle, International Space Station, military standards, federal standards, and CGA commodity specifications, as applicable
- A comparison of composition limits, test methods, and other features was presented
- Several issues were identified
- WSTF is currently pursuing options to resolve the issues