International Thermal Interoperability Standards (ITIS)

Draft C – February 2018

REVISION AND HISTORY

REV.	DESCRIPTION	PUB. DATE
Draft	Draft Release	04-18-17
Draft A	Major update for September and Checkpoint Review	09-29-17
Draft B	Update based on NASA internal feedback	10-27-17
Draft C	Update based on Industry feedback	02-09-18

PREFACE

INTERNATIONAL THERMAL INTEROPERABILITY STANDARDS

This document establishes standards for commonality across elements, vehicles, systems and/or components relative to thermal control, as required for future human exploration missions. The standards specifically address fluids to be employed in active external and internal coolant loops, and coldplates that interface directly to those coolant loops.

Configuration control of this document is the responsibility of the International Space Station (ISS) Multilateral Coordination Board (MCB), which is comprised of the international partner members of the ISS. The National Aeronautics and Space Administration (NASA) will maintain the International Thermal Interoperability Standards under Human Exploration and Operations Mission Directorate (HEOMD). Any revisions to this document will be approved by the ISS MCB.

INTERNATIONAL THERMAL INTEROPERABILITY STANDARDS

CONCURRENCE

FEBRUARY 2018

Associate Administrator Human Exploration and Operations
NASA

Date

Executive Director, Human Space Programs
State Space Corporation “Roscosmos”

Date

Director of Human Spaceflight and Operations
European Space Agency

Date

Director General, Space Exploration
Canadian Space Agency

Date

Executive Director
Japan Aerospace Exploration Agency

Date

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1.0 INTRODUCTION

This International Thermal Interoperability Standards is the result of a collaboration by the International Space Station (ISS) membership to establish, interoperable interfaces, terminology, techniques, and environments to facilitate collaborative endeavors of space exploration in cis-Lunar and deep space environments.

Standards that are established and internationally recognized have been selected where possible to enable commercial solutions and a variety of providers. Increasing commonality while decreasing unique configurations has the potential to reduce the traditional barriers in space exploration: overall mass and volume required to execute a mission. Standardizing interfaces reduces the scope of the development effort and allows more focus on performance instead of form and fit.

The information within this document represents a set of parameters enveloping a broad range of conditions, which if accommodated in the system architecture support greater efficiencies, promote cost savings, and increase the probability of mission success. These standards are not intended to specify system details needed for implementation nor do they dictate design features behind the interface, specific requirements will be defined in unique documents.

1.1 PURPOSE AND SCOPE

The purpose of this thermal interoperability standard is to document agree-to selections of fluids to be employed in active external and internal coolant loops, and agreed-to requirements for coldplates that interface directly to those coolant loops. This standard supports reliability and commonality for cooling systems that work across elements. It provides standardization for the chemical, physical and particulate limitations for the selected fluids to be utilized in flight systems/hardware and for associated ground systems; further, this document establishes the procurement requirements for the selected fluids to ensure technical performance in future thermal systems. This document also provides basic, common design parameters to allow developers to independently develop and/or provide compatible coldplates.

1.2 RESPONSIBILITY AND CHANGE AUTHORITY

Any proposed changes to this standard by the participating partners of this agreement shall be brought forward to the International Thermal Interoperability Standards team for review.

Configuration control of this document is the responsibility of the International Space Station (ISS) Multilateral Coordination Board (MCB), which is comprised of the international partner members of the ISS. The National Aeronautics and Space Administration (NASA) will maintain the Thermal Standards under Human Exploration and Operations Mission Directorate (HEOMD). Any revisions to this document will be approved by the ISS MCB.

1.3 PRECEDENCE

This paragraph describes the hierarchy of document authority and identifies the document(s) that take precedence in the event of a conflict between content.

Applicable documents include requirements that must be met. If a value in an applicable document conflicts with a value herein, then the value in this standards document takes precedence and shall be used.

Reference documents are either published research representing a specific point in time, or a document meant to guide work that does not have the full authority of an Applicable document. If a value in this document conflicts with a value in a referenced document, then it should be assumed that the value here takes precedent.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. Applicable documents are levied by programs with authority to control system design or operations. The documents listed in this paragraph are applicable to the extent specified herein. Inclusion of applicable documents herein does not in any way supersede the order of precedence identified in Section 1.3 of this document.

SN-C-0005C, Rev. D	Contamination Control Requirements for the Space Shuttle Program
ASTM D1193 - 06(2011)	Standard Specification for Reagent Water
A-A-59150 (Rev. A)	CLEANING COMPOUND, SOLVENT, HYDROFLUOROETHER (HFE)
SSP 30245, REV. E	SPACE STATION ELECTRICAL BONDING REQUIREMENTS
MIL-PRF-27401F	PROPELLANT PRESSURIZING AGENT, NITROGEN
CGA G-10.1	COMMODITY SPECIFICATION FOR NITROGEN
MIL-STD-1246, REV. C	MILITARY STANDARD PRODUCT CLEANLINESS LEVELS AND CONTAMINATION CONTROL PROGRAM
SSP 30573, REV. F	SPACE STATION PROGRAM FLUID PROCUREMENT AND USE CONTROL SPECIFICATION
IEST-STD-CC1246E	PRODUCT CLEANLINESS LEVELS – APPLICATIONS, REQUIREMENTS, AND DETERMINATION
NASA-STD-6016A	STANDARD MATERIALS AND PROCESSES REQUIREMENTS FOR SPACECRAFT
IECLSSIS	INTERNATIONAL ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ECLSS) INTEROPERABILITY STANDARDS
SLS-SPEC-159, REV. D	CROSS PROGRAM DESIGN SPECIFICATION FOR NATURAL ENVIRONMENTS (DSNE)
IERIS	INTERNATIONAL EXTERNAL ROBOTIC INTEROPERABILITY STANDARDS (IERIS)

SSP-41172, REV. AD	QUALIFICATION AND ACCEPTANCE ENVIRONMENTAL TEST REQUIREMENTS
SSP 57000, Rev. R	PRESSURIZED PAYLOADS INTERFACE REQUIREMENTS DOCUMENT

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document. These reference documents may or may not be specifically cited within the text of this document.

ESD 3000	Space Launch System Mission Planners Guide
SSP 30219, REV. J	Space Station Reference Coordinate Systems, International Place Station Program

3.0 INTERNATIONAL THERMAL INTEROPERABILITY FLUIDS STANDARDS

3.1 GENERAL

The goal of establishing standards and agreeing on other assumptions is to maximize the success of future human spaceflight missions conducted as international partnerships. The ability of components, systems, or vehicles delivered from multiple sources to work together as an effective system is important to the success of actual missions. Good collaboration can make technology development and system maturation more efficient, by sharing the lessons learned and failures that drive requirements. Using standard assumptions can also make development more efficient by making tests conducted by one partner relevant and valid to multiple partners.

This section of the document is focused on fluid cleanliness requirements and fluid specifications, which are agreed to across the international partnerships for implementation in thermal systems of future mission flight vehicles and ground support hardware. Note that the candidate fluids considered and those then specified within this standards document are those with historical precedence/flight experience and/or coolants that are currently or planned to be extensively tested with data, testing results, analyses, etc. to be provided to/shared with all agencies; this is necessary due to issues with materials compatibility, proprietary considerations, specific additives, etc. Additionally, any biocides or other additives must be included in the database and testing programs, and consideration must be given to simulating/testing accurately with the in-space cabin environment as this can affect the chemistry of the coolant(s) over time.

This document is specific to fluids introduced into the flight thermal system hardware or circulated through interfacing ground support equipment (GSE) during ground operations prior to launch. In addition, these fluids might also be employed as determined by the hardware provider(s) during transport, short-term storage, functional check-outs, cleaning, servicing, and/or assembly. This standard does not control the selection of fluids during the design and development of flight hardware and does not control fluids introduced into hardware before delivery to the launch site(s). It is the responsibility of the thermal systems hardware provider(s) to preclude the introduction of fluids that are incompatible with and potentially damaging to flight hardware before delivery to the launch site(s).

This standard does not control the composition of gases that are introduced into flight hardware, solely for the purpose of instrumentation calibration prior to launch. Further, it does not control the composition of flight gases that are manifested solely for the purpose of in-flight instrumentation calibration, if this is feasible or required. However, contamination controls in this standard do apply to calibration gases introduced to the thermal system during ground operations and during flight if applicable.

The content herein also requires commonality in the procurement requirements and management of the thermal fluids specified for both flight and ground operations. Details are given for the selected fluids relative to chemical and physical properties, and particulate limitations.

3.1.1 SYSTEM ARCHITECTURE CONCEPT

The thermal control system is designed to maintain the overall vehicle(s)/module(s) within thermal limits as required for the crew and equipment during all phases of the mission; this includes rejecting the waste heat from the vehicle(s)/module(s), maintaining hardware within its specified temperature limits, and controlling the crew cabin environment to maintain the walls above the dew point. Coolant loops are used to transfer heat energy from vehicle/module components/subsystems to radiators for overall rejection and/or to transport the excess heat to equipment or a spacecraft region needing additional heat energy for operation. The thermal control system must be a robust design that can operate over a range of heat loads in external environments ranging from the cold of deep space to the warm environment that results from full sun on one side of the vehicle plus planetary infrared radiation.

This standards document has been prepared to support future exploration missions, without consideration to a specific mission or space vehicle(s) architecture. However, to provide a framework and common understanding, this standard is applicable to permanent spacecraft elements of the DSG and the overall thermal system can be assumed to be servicing one or more physically connecting vehicles and/or modules with human occupants and powered equipment located internally and externally. It is assumed that the vehicles/modules each have individual active thermal control systems but all elements share the same internal fluids for commonality, as well as the external coolants. Internal loops might also be cross-strapped/connected-together. This document only addresses the coolants for the active flowing loops; passive thermal components/hardware that contain internal coolant fluids such as heat pipes are not controlled by this document. Note that visiting space vehicles that are not permanently attached, or are not resident, docked or operated open loop with DSG for an extended period might employ alternate fluids that must be compliant with standards and specifications required for safety and operations that are out-of-scope or not detailed in this standards document.

In addition to exclusions stated in Section 1.1, this standards document does not currently address vehicle(s)/module(s) dormancy periods, very high-power vehicle systems (i.e., nuclear), all elements of the thermal system (e.g., does not address all hardware components such as pumps and heat exchangers, or avionics), design for redundancy, failure tolerance or corrective action(s) for off-nominal cases, layout or specific architecture of the thermal system components, operational details such as heat load distribution with the modules, spacesuit thermal control, or performance degradation over time. This standard does specify the coolants to be employed in active external and internal coolant loops, and provides the chemical, physical and particulate limitations for the selected fluids to be utilized in flight systems/hardware and for associated ground systems at the launch site(s). Further, this document establishes the procurement requirements for the selected fluids and other important information (e.g., responsibilities, regulations).

3.1.2 ENGINEERING UNITS OF MEASURE

The International System of Units for measurement will be utilized for future missions; this is also commonly known as the Systeme Internationale (SI) system of measurement. All angular dimensions will be in degrees. Prefixes may be added to the units specified herein to ease understanding by the reader.

3.2 PROCUREMENT

Coolant fluids introduced into flight hardware after cleanliness acceptance shall meet or exceed the requirements as specified in Table 3.5-2.

3.3 FLUID USE

No fluid shall be introduced into the coolant loop(s) flight hardware after pre-flight cleaning, testing and inspection(s) are completed except those specified in Tables 3.5-1.1 and 3.5-1.2. Note that fluids used for assembly, cleaning/flushing, storage, transport and/or testing are not included in this document, but are likely to be the same as those specified in SSP 30573 Rev. F**,** Space Station Program Fluid Procurement and Use Control Specification for the thermal control system. Nitrogen is included in Tables 3.5-1.1 and 3.5-1.2 as it is the likely fluid of choice for pressurization (e.g., accumulator(s)) based on historical precedence/experience and/or current use in spaceflight hardware/systems. Further detailed requirements for fabrication, servicing, maintenance, etc. of the thermal coolant loops are not included in this document, but are likely to be the same/similar to those specified in SSP 30573 Rev. F.

3.3.1 NASA, IP, AND CONTRACTOR RESPONSIBILITIES

3.3.1.1 SYSTEMS REQUIREMENT

Where the requirements of this document do not reflect a required specification or the system/subsystem requirements specified are inadequate, it shall be the hardware provider’s responsibility to notify the National Aeronautics and Space Administration (NASA) or the International Partner (IP) procuring agency so that specifications meeting the system’s requirements can be generated and included in this standard.

3.3.1.2 THERMAL SYSTEM GFE

It shall be the prime contractor’s, NASA’s or the IP’s responsibility to ensure that their selected contractors/subcontractors and/or government activities comply with the requirements of this standard for thermal system GFE and/or flight hardware.

3.3.1.3 PROVISIONED FLUIDS

NASA or the IP will be responsible for procurement control of fluids used for their provisioned ground, flight and/or contractor-required government-furnished fluids. NASA or the IP will provide appropriate documented assurance and/or certification that fluids procured through their agency(ies) and/or contractors meet the requirements specified in this document.

3.3.2 WASTE FLUIDS

Waste or used coolant fluids shall meet and sustain the regulations of all government and local environmental agencies per the requirements specified for the country(ies) of usage. Note that this should include pre-negotiation and arrangement of pickup and transport of waste or used fluids to authorized treatment, storage and/or disposal vendor(s).

3.4 HARDWARE CLEANLINESS FOR REFLIGHT

Thermal system tanks or coolant lines that are designed to be launched, returned, refilled, and re-launched shall not require the system to be re-cleaned to the original precision cleanliness requirements prior to being refilled if the hardware has been maintained clean, which includes the following requirements:

1) Protective caps shall be installed or open connectors shall be bagged when the system is not in use.
2) Positive pressure shall be maintained in the returned assemblies when not within a clean room capable of maintaining hardware precision cleanliness
3) Once returned, exposed fluid interfaces on the tanks or flow system shall be inspected and cleaned (if necessary) to Visible Clean Plus Ultraviolet –Highly Sensitive (VC+ UV – HS) level per SN-C-0005C prior to being refilled.

If contamination is observed at any point in the process, the hardware cleanliness is considered suspect and shall be reviewed and assessed by the appropriate disciplines; this may result in requiring the system(s) and/or affected components to be drained and cleaned/serviced prior to refill and re-launch.

3.5 VERIFICATION

3.5.1 SAMPLING

Coolant fluids supplied to flight hardware shall have been sampled and verified as meeting the chemical and physical requirements of Table 3.5-2 in accordance with the procedures of the applicable procurement specification, unless other analysis procedures are specifically delineated herein.

3.5.1.1 SAMPLING FOR TEST/SUPPORT EQUIPMENT

Gases used in testing of flight hardware do not impact the composition of flight fluids, therefore a reduced set of compositional requirements limited to condensable contaminates is permitted. All test/support equipment supplying gases for any reason (such as cleaning, flushing, testing, or assembly aid) to flight hardware systems shall meet the following minimum sampling requirements. Test/support equipment gases shall be tested at the interface with flight hardware (as defined by section 3.5.1.2) and meet the requirements defined in table 3.5-1 for moisture, total hydrocarbons measured as methane and particulates for the specific fluid if the requirement for the characteristics are defined. Fluid procurement, interface filter and hardware cleanliness requirements delineated in this document shall still be met.

The following scenarios will require re-sampling of fluids at the interface with flight hardware (as defined by section 3.5.1.2) after the following system changes:

1. Changing out of any component in the support equipment (valves, regulators, etc.).
2. Changing of source gas cylinders to a different lot code.

The following scenarios will not require re-sampling of fluids at the interface with flight hardware after system changes so long as all work is conducted in accordance to Table 3.5-1 Note 1:

1. Breaking of connections without hardware changes.
2. Changing of source gas cylinders with the same lot code.
3. Testing of different flight hardware when the support equipment setup has not been changed.

Deviation from the requirement outlined in Table 3.5-1 Note 1 shall require the minimum re-sampling requirements above.

Test equipment supplying gases for internal thermal system hardware which will ultimately be filled with Table 3.5-1.2 Internal Heat Transport Fluid are exempt from the above sampling at flight hardware interface requirements, but still must meet all fluid procurement, interface filter, and hardware cleanliness requirements.

3.5.1.2 SAMPLING LOCATION, FREQUENCY, AND TECHNIQUE

The sampling location, frequency, and technique shall provide representative samples of liquid or gas being tested to assure that, with the sampling approach utilized, the fluid meets the requirements at the interface. The sub-tables of Table 3.5-1 specify requirements at the interface.

TABLE 3.5-1 COOLANT FLUIDS SERVICING REQUIREMENTS.

The tables included herein contain the fluid and particulate/cleanliness requirements.

External Heat Transport Fluid	3.5-1.1
Internal Heat Transport Fluid	3.5-1.2

Note 1. Most precision cleanliness specifications use a standard terminology to define hardware particulate cleanliness levels, e.g., Level 100, where the level number is related to the maximum particle size permitted. However, the exact definition of particulate cleanliness levels varies from specification to specification. The most commonly used commercial specification, IEST-STD-CC1246, Product Cleanliness Levels – Applications, Requirements, and Determination, allows one particle to be larger than the cleanliness level number and requires counting of particulate in four size-range "bins" smaller than the cleanliness level number. Historical NASA Center (and some contractor) specifications will be emulated for this document, and are both more conservative and less conservative in that these specifications prohibit any particles larger than the cleanliness level number but do not require counting of particulate in the two smallest bin sizes required by IEST-STD-CC1246, respectively.

TABLE 3.5-1.1 EXTERNAL HEAT TRANSPORT FLUID

Fluid	Chemical Composition	Supply System	Particulate Control	
			Supply interface/ final filter absolute rating	System/supply system surface cleanliness level per IEST-STD-CC1246 (see Table 3.5-1, Note 1) (Notes 1, 3-4)
Operational Fluids:				
Ethoxy-nonafluorobutane (Note 2)	Table 3.5-2.1	GSE, FSE	10 micron	Level 200A (Note 5)
Nitrogen/N_2	Table 3.5-2.3	GSE, ECLSS	10 micron	Level 200A

Note 1. MIL-STD-1246, Revision C, Military Standard Product Cleanliness Levels and Contamination Control Program may be used as an alternate.

Note 2: This fluid is available from 3M™ as Novec™ HFE-7200. <TBR 3-1>

Note 3. Personnel training. A certification-training course shall be established and required for anyone working around precision-cleaned hardware. The focus of the course shall be on awareness and shall require a minimum one-hour of instruction time. As a minimum, the course content shall include definition of precision cleanliness, problems that have occurred on the International Space Station (ISS) and other spacecraft as appropriate with precision- cleaned hardware, the best practices for maintaining cleanliness, and specific controls identified at the site where work will be performed.

Note 4. Maintaining system cleanliness. Hardware (including GSE) that has not been precision-cleaned shall not be brought into the vicinity of precision-cleaned flight hardware (for fit checks etc.) without protection to the flight hardware (i.e., wrapped in approved packaging material). Clean room bags shall always be used to transport cleaned hardware (including GSE), even short distances when outside of the clean room environment. Precision-cleaned hardware shall be exposed only in a particulate controlled environment, including the use of flow benches providing a Class 100,000 CWA or better, when conducting hardware inspections. Clean room gloves shall be used during all handling of precision-cleaned flight hardware and GSE. Any inspection tools that are to be exposed to precision-cleaned fluid systems hardware (borescopes, etc.) shall be visibly cleaned and maintained clean. Solvents such as isopropyl alcohol (IPA) shall be filtered to 10 microns or better prior to use. All precision cleaned open tubes and lines must be protected, i.e. wrapped or bagged with approved materials, as soon as possible after fabrication, until final installation. All precision-cleaned fluid systems configured for flight shall have integrity seals installed. Precision cleaned hardware that has been welded shall remain capped (non-particle generating caps or wrapped and taped) at the ends during x-ray operations to avoid potential contamination of hardware.

Note 5. An “A” following level number indicates a nonvolatile residue (NVR) limit of 1 mg/0.1 m2 or 1 mg/0.1 liter.

Note 6. Coolant loops shall be leak tested at the Maximum Design Pressure (MDP) per SSP-41172, Rev. AD, Qualification and Acceptance Environmental Test Requirements.

TABLE 3.5-1.2 INTERNAL HEAT TRANSPORT FLUID

Fluid	Chemical Composition	Supply System	Particulate Control	
			Supply interface/ final filter absolute rating	System/supply system surface cleanliness level per IEST-STD-CC1246 (see Table 3.5-1, Note 1) (Notes 1-3)
<u>Operational Fluids:</u>				
35/65 inhibited propylene glycol-water mixture **<TBR 3-2>**	Table 3.5-2.2	GSE, FSE	10 micron	Level 200A (Note 4)
Nitrogen/N2	Table 3.5-2.3	GSE, ECLSS	10 micron	Level 200A

Note 1. MIL-STD-1246, Revision C, Military Standard Product Cleanliness Levels and Contamination Control Program may be used as an alternate.

Note 2. Personnel training. A certification-training course shall be established and required for anyone working around precision-cleaned hardware. The focus of the course shall be on awareness and shall require a minimum one-hour of instruction time. As a minimum, the course content shall include definition of precision cleanliness, problems that have occurred on the International Space Station (ISS) and other spacecraft as appropriate with precision- cleaned hardware, the best practices for maintaining cleanliness, and specific controls identified at the site where work will be performed.

Note 3. Maintaining system cleanliness. Hardware (including GSE) that has not been precision-cleaned shall not be brought into the vicinity of precision-cleaned flight hardware (for fit checks etc.) without protection to the flight hardware (i.e., wrapped in approved packaging material). Clean room bags shall always be used to transport cleaned hardware (including GSE), even short distances when outside of the clean room environment. Precision-cleaned hardware shall be exposed only in a particulate controlled environment, including the use of flow benches providing a Class 100,000 CWA or better, when conducting hardware inspections. Clean room gloves shall be used during all handling of precision-cleaned flight hardware and GSE. Any inspection tools that are to be exposed to precision-cleaned fluid systems hardware (borescopes, etc.) shall be visibly cleaned and maintained clean. Solvents such as isopropyl alcohol (IPA) shall be filtered to 10 microns or better prior to use. All precision cleaned open tubes and lines must be protected, i.e. wrapped or bagged with approved materials, as soon as possible after fabrication, until final installation. All precision-cleaned fluid systems configured for flight shall have integrity seals installed. Precision cleaned hardware that has been welded shall remain capped (non-particle generating caps or wrapped and taped) at the ends during x-ray operations to avoid potential contamination of hardware.

Note 4. An “A” following level number indicates a nonvolatile residue (NVR) limit of 1 mg/0.1 m2 or 1 mg/0.1 liter.

Note 5. Coolant loops shall be leak tested at the Maximum Design Pressure (MDP) per SSP-41172, Rev. AD, Qualification and Acceptance Environmental Test Requirements.

TABLE 3.5-2 CHEMICAL AND PHYSICAL CHARACTERISTICS OF COOLANT FLUIDS.

The tables included herein contain physical and chemical characteristics of fluids that will be used in coolant loop(s) of future space vehicle(s)/module(s). The characteristics of the allowable fluids as procured and delivered are as follows:

(**Note:** it is acceptable to procure to an alternate fluid specification if it meets or exceeds the “procurement” technical requirements as specified below and is documented in a verification assessment to this specification requirement.)

HFE-7200 (ethoxy-nonafluorobutane) **<TBR 3-1>**	3.5-2.1
Internal Heat Transport Fluid (35/65 inhibited propylene glycol-water (PGW) mixture) **<TBR 3-2>**	3.5-2.2
Nitrogen	3.5-2.3

TABLE 3.5-2.1 HFE-7200 (ETHOXY-NONAFLUOROBUTANE).

Procurement within the United States shall be in compliance with the Commercial Item Description A-A-59150 (Rev. A), with the exception of the boiling point for HFE-7200 is nominally 76 deg. C instead of the 60 deg. C +/- 2 specified in the CID. Procurement outside of the U.S. shall be in compliance as specified or in accordance with verified, equivalent requirements provided and governed within the country(ies) of concern; deviations will require review and approval at the ISS MCB.

CHARACTERISTICS	REQUIREMENTS	
	Procurement	As Delivered to Interface
Appearance	Clear Colorless Liquid	Clear Colorless Liquid
Purity	99.5% (min)	99.5% (min)
Non-volatile Residue	1 ppm (max)	1 ppm (max)
Acidity (as HCl)*	1 ppm (max)	1 ppm (max)
Moisture	15 ppm (max)	15 ppm (max)
Free Fluoride*	1 ppm (max)	1 ppm (max)

*These requirements are identical to those for HFE-7100 as specified in SSP 30573 Rev. F, Space Station Program Fluid Procurement and Use Control Specification

Note 1: Use limits apply to both new and reclaimed HFE-7200. Each time new or reclaimed HFE-7200 is introduced into the thermal system/subsystem, sampling and certification are required prior to use.

Note 2: Prior to launch/flight, representative samples of the solvent used in flight equipment/systems shall be taken at least weekly when in continuous use, or for each individual application when not used on a continuous basis, to assure these use limits are met.

Note 3: Whenever the solvent has been used in the thermal system/subsystem including associated GSE, it will not be used/re-used for any other system/subsystem (GSE or flight). In addition, the thermal system shall not use solvent that has been used previously in other system/subsystems including GSE, or for other purposes such as cleaning.

Note 4: The maximum exposure limit for HFE-7200 established by the manufacturer is 200 ppm over an 8-hour period. Appropriate personnel safety precautions must be taken to ensure this limit is not exceeded.

Note 5: HFE-7200 is compatibility with most metals and hard polymers, but is not compatible with some types of soft and elastomeric materials. For implementation in future space vehicles/modules, the agency/partner responsible for providing specific thermal GSE and/or flight hardware must verify that the system/subsystem materials exposed to HFE-7200 are compatible. Data on compatibility of materials with HFE-7200 should be shared by each agency/partner when it is obtained via vendors, testing, etc.

TABLE 3.5-2.2 INTERNAL HEAT TRANSPORT FLUID

(35/65 inhibited propylene glycol and water mixture)

This coolant shall be produced using a commercially available, inhibited propylene glycol concentrate < TBD 3-1>, to provide an inhibited PGW mixture. Procurement of a specific formulation of inhibited propylene glycol concentrate and associated vendor(s) shall be agreed to by all partner space agencies and approved via the ISS MCB; the selected concentrate shall be identified and procurement requirements (e.g., chemical properties, quality control) designated in a future update to this standards document or a future specification document.

<table>
<tr><th>Characteristics</th><th>Requirement</th><th>Test Method</th></tr>
<tr><td colspan="3">Sufficient water shall be added to the inhibited propylene glycol concentrate to reduce the propylene glycol concentration to 35 +/- 1 percent by weight. Water used to dilute the concentrate shall be in accordance with ASTM D1193 Type I, II, or III, any grade. The acceptance requirements for the inhibited PGW shall be given in a future update to this standards document or a future specification document < TBD 3-1>.</td></tr>
</table>

NOTE 1: If coolant is added to a flight system, it shall meet the as delivered-to-interface/system requirements for mixed coolant or be specially adjusted as required to bring out-of-specification as circulated coolant back into specification.

TABLE 3.5-2.3 NITROGEN

(Procurement shall be to specification MIL-PRF-27401, Propellant, Pressurizing Agent, Nitrogen; Grade A, B, or C with direct method required for determining the nitrogen content (Note 1).

CHARACTERISTICS	REQUIREMENTS			
	Procurement: Grade A	As Delivered to Interface (Grade A)	Procurement: Grade B	As Delivered to Interface (Grade B)
Purity	99.5% by volume (min) by indirect method	99.5% by volume (min) by indirect method	99.99% by volume (min) by indirect method	99.99% by volume (min) by indirect method 95.0% by volume (min) by direct method
Total Impurities	5000 ppm (max)	5000 ppm (max)	100 ppm (max)	100 ppm (max)
Total Hydrocarbons (as methane) (Note 2)	58.3 ppm (max)	58.3 ppm (max)	5.0 ppm (max)	5.0 ppm (max)
Halogenated Solvents	N/A	5 ppm (max)	N/A	5 ppm (max)
Oxygen	5000 ppm (max)	5000 ppm (max)	50 ppm (max)	50 ppm (max)
Argon	N/A	N/A	20 ppm (max)	N/A
Moisture	-64°F (max) Dew point @ 1 atm 26.3 ppm (max)	26.3 ppm (max)	-75°F (max) Dew point @ 1 atm 11.5 ppm (max)	11.5 ppm (max)
Particulate (Type II - Liquid Only)	1.0 mg/l (max)	N/A (Note 3)	1.0 mg/l (max)	N/A (Note 3)

NOTE 1: Procurement may also be to CGA G-10.1, Commodity Specification for Nitrogen, Quality Verification Level (QVL) L, M, Q, R, or S. These grades all have a higher minimum nitrogen content than any of the MIL-PRF-27401 grades, but QVL S is the only grade that meets the MIL-PRF-27401 requirement for maximum hydrogen content (<0.5 ppm). Analysis of argon concentration is not required.

NOTE 2: Percent nitrogen includes trace quantities of Neon, Helium, and small amounts of Argon.

NOTE 3: Other impurities discernible from instrument noise shall be identified and quantified.

4.0 HUMAN EXPLORATION MISSIONS COLDPLATE STANDARD

4.1 GENERAL

This section of the document is focused on the physical and fluid interfaces of coldplates to be employed in future flight vehicles. The content herein drives commonality in the design, sizing, fabrication, performance, etc. This document does not address the complete thermal system to be incorporated in future space vehicles, and does not reference other components that may be employed in that system such as heat exchangers, pumps, etc.

4.1.1 ITEM DEFINITION

For the purposes of this standard, it is assumed that each coldplate represents an assembly forming either a contact-type or radiative-type heat exchanger. Note that it is likely all internal coldplates will be contact-type, and all external coldplates will be radiative-type, similar to coldplates employed on the International Space Station. Each coldplate will provide for thermal control of electronics and/or other interfacing equipment. It is likely that each coldplate will have single flow-through passages with heat acquisition and transport on one or both sides. Standard operation will enable heat transfer to the fluid in the interfacing coolant loop. While the coldplates will operate with a range of coolant flow rates, it is expected that the internal coolant loop will maintain the localized temperature above the cabin dew point. It is likely that multiple sizes of coldplates will be employed for the vehicle(s)/module(s) to accommodate internal and external equipment. Further, it is assumed that at least one size/designed coldplate will be employed for common equipment rack-equivalents (e.g., rack, pallet) located within the vehicle(s)/module(s).

4.1.2 INTERFACE DESCRIPTION

Coldplates have both physical and fluid interfaces. The physical interfaces for coldplates include the structural mounting surfaces/attachment points and associated hardware.

It is likely that both the internal and external coldplates will be mounted/attached to secondary support structure using bolts, and non-transferable to alternate locations within or external to the vehicle(s)/module(s). The fluid interfaces include the connection point(s) and any associated hardware to connect the flow passages to the external coolant loop(s), to allow unimpeded flow of coolant through the coldplate.

The internal equipment to be cooled will be mounted to the coldplate flat surface(s) with bolts. The fluid interfaces include the connection point(s) and any associated hardware to connect the flow passages to the coolant loop(s), to allow unimpeded flow of coolant through the coldplate.

The external coldplates will have fins on the cooling surface(s) which will mesh with fins that are on the equipment to be cooled; once the equipment is installed, there is radiative heat transfer between the equipment fins and the colder coldplate fins. The external coldplates will accommodate robotic and/or EVA attachment or replacement of the interfacing equipment, which may include provision for alignment guides, robotic and/or suit-compatible grasps or handles, visual alignment labels, attachment/locking hardware, mechanisms for soft-dock and/or hard-stop, etc.

4.1.3 INTERFACE RESPONSIBILITIES

Section 4 of this document is written with the intent of providing standards for coldplate assemblies which will be directly connected to the coolant loop(s) of future module/vehicle(s). Interfacing secondary support structure(s), fasteners for surface mounting of equipment, connecting tubing, insulation, sensors, cabling/electrical lines, and any other items not mentioned in Section 4.1.2, or within this document, will be provided by the module/vehicle integrator; the provider(s) will ensure those interfacing items are compatible with coldplates meeting the standards outlined herein.

It is assumed that future vehicles will utilize modules and rack-equivalents (e.g., rack, pallet) like those used on the International Space Station, and integration of coldplates to the rack-equivalent(s) will be completed by the module/vehicle integrator or provider. In addition, future vehicles may utilize Orbital Replacement Units (ORUs) for replacement or trade out of equipment externally, and again the module/vehicle integrator or provider will ensure that the ORU hardware and its interface are compatible with external coldplates meeting the standards outlined herein.

4.1.4 COORDINATE SYSTEM

It is assumed that future vehicles will utilize module(s) and rack-equivalents like on the International Space Station. Therefore, a coordinate system such as that defined in SSP 30129, Space Station Reference Coordinate System for body-fixed systems will be agreed to and utilized.

4.1.5 ENGINEERING UNITS OF MEASURE

This will be as described in Section 3.1.2.

4.2 ENVELOPE

A number of coldplate sizes will be provisioned to accommodate a range of equipment interface requirements. While most coldplates are intended for cooling equipment internal to the pressurized vehicle(s)/module(s), some coldplates will be implemented for external applications.

Table 4.2-1 shows standardized internal coldplate sizes. In addition, while there would be various part numbers depending on the agency(ies), contractor(s), etc., designators are shown to be added to the end of the part number(s) for consistency in designating size and location.

TABLE 4.2-1 STANDARD INTERNAL COLDPLATE SIZES

COLDPLATE Designator	Heat Transfer Area (contact area) in width of the plate (inlet/outlet ports) vs. length (cm x cm)	REFERENCE: Heat Transfer Area (contact area) converted to English Units (in x in) +/- 0.1	Maximum Weight (dry) (kg)
-IC1	8.8 x 15.8	3.5 x 6.2	0.6
-IC2	15.8 x 22.8	6.2 x 9	1.05
-IC3	15.8 x 36.8	6.2 x 14.5	1.43
-IC4	15.8 x 43.8	6.2 x 17.2	1.64
-IC5	22.8 x 8.8	9 x 3.5	0.76
-IC6	22.8 x 15.8	9 x 6.2	1.05
-IC7	22.8 x 29.8	9 x 11.7	1.6
-IC8	22.8 x 36.8	9 x 14.5	1.89
-IC9	22.8 x 50.8	9 x 20	2.47
-IC10	29.8 x 22.8	11.7 x 9	1.67
-IC11	71 x 45.2	28 x 17.8	11

Note 1: The dimensions only address the heat transfer surface(s) where equipment would be mounted; the thickness of the coldplate(s) is not included.

Note 2: The dimensions shown do not include the tube stubs or any other protrusion(s) beyond the heat transfer surface and edges of the coldplate.

Note 3: The designators indicate “I” for “internal”, “C” for “coldplate” and a numerical designator to distinguish the coldplates based on overall dimensions/size.

Note 4: The dimensions for the heat transfer area are shown in English units as reference only, as the engineering units of measure are given in Section 3.1.2.

Note 5: The –IC11 coldplate is assumed for common equipment rack-equivalents.

There is no equivalent table for external coldplates as it is assumed these will be customized to accommodate the equipment to be interfaced, similar to the external Orbital Replacement Units (ORUs) on the ISS. Note that Table 4.2-1 is not intended to preclude the use of customized internal coldplates in special cases or if needed.

4.3 STRUCTURAL REQUIREMENTS

4.3.1 STRUCTURAL LOAD DISTRIBUTION

4.3.1.1 STRUCTURAL LOADS

The structural loads that will be imparted to the coldplates will be dependent on the launch vehicle(s). It is likely that the maximum loads transmitted would occur during launch combined with ascent vibration, and additionally that these would likely be the worst-case loads imparted over the course of the mission(s). The coldplates will be designed for the maximum axial and lateral loads specified for the launch/mission vehicle(s) such as those specified for the Space Launch System (SLS) per the Space Launch System Mission Planners Guide, ESD 30000, Section 5.2.1 Spacecraft/Payload Design or alternatively to the loads specified/documented for the as-built SLS or an alternative launch vehicle, whichever is greater. It is assumed that the coldplates are completely supported by secondary structure, and the loads will be evenly distributed among the coldplate attach points.

4.3.1.2 MOUNTING BOLT FORCES

The maximum mounting bolt torque for all internal coldplates is 9 Nm. The maximum mounting bolt torque for all external coldplates is **<TBD 4-1>** Nm.

4.3.1.3 EQUIPMENT MOUNTING LOADS

Equipment mounting refers to items to be attached/interfaced to the internal coldplate surface(s) to provide conductive cooling. The maximum mounting bolt torque for attached equipment to internal coldplates shall be less than the torque strength values for an unpressurized suit or bare hand, for the 5th percentile female as defined in SSP 57000, Rev. R, Pressurized Payloads Interface Requirements Document.

4.3.2 WEIGHT

Coldplates will not exceed the maximum dry weights as specified in Table 4.2-1.

4.4 MECHANICAL

4.4.1 INTERNAL COLDPLATE TO SECONDARY SUPPORT STRUCTURE INSTALLATION

Coldplates will provide mounting holes along the edges. The spacing of the mounting holes will be matched to the mounting surface, but be no closer than 4.0 cm apart. The holes will accommodate 0.19-32 (#10-32) bolts. The coldplates will be mounted to the secondary support structure using a sufficient number of mounting holes such that the structural load distributions stated in Section 4.3.1 are not exceeded.

4.4.2 EXTERNAL COLDPLATE TO SECONDARY SUPPORT STRUCTURE INSTALLATION

Coldplates will provide mounting holes along the edges. The spacing of the mounting holes will be matched to the mounting surface, but be no closer than **<TBD 4-3>** apart. The holes will accommodate **<TBD 4-2>** bolts. The coldplates will be mounted to the secondary support structure using a sufficient number of mounting holes such that the structural load distributions stated in Section 4.3.1 are not exceeded.

4.4.3 INTERNAL COLDPLATE SURFACE FINISH

All internal coldplate, active heat transfer area/surface(s) will be stainless steel material.

4.4.3.1 INTERNAL COLDPLATE LOCAL FLATNESS

The local flatness on each internal coldplate equipment mounting side(s) will be 0.01 cm/cm with an overall flatness of 0.03 cm. The flatness is measure in the fully restrained and supported condition.

4.4.3.2 INTERNAL COLDPLATE ROUGHNESS

Coldplate mounting/conductive surfaces will have a surface finish with a maximum roughness of 6.3 micro-m RMS (Root Mean Square).

4.4.3.3 INTERNAL COLDPLATE ENHANCED BONDING SURFACE(S)

The internal coldplates will provide a stainless-steel bonding surface at the interface between the coldplate and the mounted equipment/item(s). However, an interface material may be used for significantly enhanced thermal conductivity at interface and must be compliant with the NASA-STD-6016A, Standard Materials and Processes Requirements for Spacecraft. The selected material must be easy to release and replace, and robust to preclude degradation with equipment placement and replacement.

4.4.4 LOCATION AND ORIENTATION

The internal coldplates will be mounted throughout the pressurized areas of future vehicle/module(s). It is also possible for coldplates to be mounted externally, to provide cooling for external equipment/systems. The preferred orientation is to locate the coldplates such that the crew and/or cameras can inspect the fluid connectors by simply removing the applicable close-out panel or other access point.

4.5 HOLES

4.5.1 INTERNAL COLDPLATES

The internal coldplate interface surface(s) will contain through holes (0.64 cm) for mounting equipment to the coldplate. The through holes will be located and spaced in a 70 mm x 70 mm grid pattern.

4.5.1.1 SUPPORT STRUCTURE

The coldplate support structure will provide mounting holes to accommodate capture bolts **<TBD 4-2>** in compliance with the coldplate mounting hole pattern described in 4.5.1.

4.5.1.2 FASTENERS

The coldplates shall be mounted/installed onto the secondary support structure with captured bolts **<TBD 4-2>.**

4.5.2 EXTERNAL COLDPLATES <TBD 4-4>

The external coldplate interface surface(s) will include radiative fins to mesh with fins on the equipment to be cooled. The coldplates must be compatible with the requirements specified in the International External Robotic Interoperability Standards (IERIS) **<TBD 4-4>.**

4.5.2.1 SUPPORT STRUCTURE

The coldplate support structure will provide mounting holes to accommodate capture bolts to allow attachment to external secondary support structure in compliance with

IERIS, including non-interference with the radiative fins and other protrusions/hardware on the interfacing equipment to be cooled.

4.5.2.2 FASTENERS

The coldplates shall be mounted/installed onto the secondary support structure with captured bolts **<TBD 4-2>.**

4.5.3 INTERNAL COLDPLATE BONDING REQUIREMENTS

The coldplates will provide a Class R bonding path in accordance with SSP-30245 from the installed equipment to the secondary support structure through the conductive contact surface. Non-conductive materials will not be applied to this surface.

4.6 INTERNAL COLDPLATE THERMAL PERFORMANCE

When activated for the mission, coldplates internal to the vehicles/modules shall operate while being exposed to the cabin atmospheric conditions described in the International Environmental Control and Life Support System (ECLSS) Interoperability Standards (IECLSSIS).

4.6.1 HEAT REMOVAL CAPACITY

The heat flux requirement is given as the average the coldplate shall remove. The coldplates specified in Table 4.2-1 must have a capability to provide/cool an average of 1 W/cm^2.

4.6.2 HEAT DISSIPATION TO CABIN AIR

For coldplates mounted internally in vehicle/module(s), the coldplates will dissipate no appreciable heat (in no case exceeding 10% of the coldplate’s load) to the internal vehicle/module air system.

4.7 EXTERNAL COLDPLATE THERMAL PERFORMANCE

When activated for the mission, coldplates external to the vehicles/modules shall operate while being exposed to the environmental conditions provided in the Cross Program Design Specification for Natural Environments (DSNE), SLS-SPEC-159, Revision D.

4.7.1 HEAT REMOVAL CAPACITY

The heat flux requirement is given as the average and maximum the coldplate shall remove. The maximum value also denotes the maximum flux that an ORU can impart to the radiative interface. The external radiative coldplates shall accept an average heat flux of **<TBD 4-5>** W/cm^2, with a local maximum/peak value not to exceed **<TBD 4-5>** W/cm^2.

4.8 FLUID INTERFACES

4.8.1 OPERATING FLUID CHARACTERISTICS

The operating fluid media for coldplates located externally on the vehicle/module(s) will be as shown in Table 3.5-1.1.

The operating fluid media for coldplates located internally in the vehicle/module(s) will be as shown in Table 3.5-1.2.

4.8.2 EXTERNAL LEAKAGE

The external leakage of the coldplates shall be verified at the Maximum Design Pressure (MDP) per SSP-41172, Rev. AD, Qualification and Acceptance Environmental Test Requirements.

4.8.3 FLUID CONNECTORS

The coldplates located internal and external to the vehicle/module(s) will be fabricated with tube stubs for connection to the internal/external coolant loop(s). It is assumed that all coldplates will be positioned and the fluid connections will be permanently attached in place.

4.9 INTERNAL COLDPLATE ELECTRICAL INTERFACES

4.9.1 BONDING RESISTANCE

The coldplates will provide a Class R/H bonding path in accordance with SSP 30245 at the physical interface between the installed or interfacing equipment to be cooled and the coldplate surface. The impedance will not exceed 2.5 mohm for DC; 100 mohms at 1 MHz; and 0.1 ohm for Class H (shock).

5.0 OPERATIONAL ENVIRONMENTS

When the thermal control system is activated and operated in the planned mission location(s)/environment(s), the coolant and coldplates internal to the vehicles/modules shall operate while being exposed to the cabin atmospheric conditions described in the International Environmental Control and Life Support System (ECLSS) Interoperability Standards (IECLSSIS).

When the thermal control system is activated and operated in the planned mission location(s)/environment(s), the coolant and coldplates located externally on the vehicles/modules shall operate while being exposed to the environmental conditions provided in the Cross Program Design Specification for Natural Environments (DSNE), SLS-SPEC-159, Revision D.

6.0 FUTURE TOPICS FOR POSSIBLE STANDARDIZATION

<TBD 6-1>

APPENDIX A ACRONYMS AND ABBREVIATIONS

CDD	Concept Description Document
DSNE	Design Specification for Natural Environments
ECLSS	Environmental Control and Life Support System
GSE	Ground Support Equipment
HFE	Hydrofluoroether
IERIS	International External Robotic Interoperability Standards
IP	International Partner
ISS	International Space Station
MAX	Maximum
MDP	Maximum Design Pressure
MCB	Multilateral Coordination Board
MIN	Minimum
NASA	National Aeronautics and Space Administration
ORU	Orbital Replacement Unit
QVL	Quality Verification Level
REV	Revision
RMS	Root Mean Square
SLS	Space Launch System
TBD	To Be Determined
TBR	To Be Resolved

APPENDIX B GLOSSARY

<TBD App-B>

APPENDIX C OPEN WORK

Table C-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBD item is numbered based on the section where the first occurrence of the item is located as the first digit and a consecutive number as the second digit (i.e., <TBD 4-1> is the first undetermined item assigned in Section 4 of the document). As each TBD is solved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

TABLE C-1 TO BE DETERMINED ITEMS

TBD	Section	Description
< TBD 3-1>	3.5	Determination and agreement on the commercially available, inhibited propylene glycol concentrate to be used for the internal coolant mixture. In addition, need agreement on the mixture ratio and open sharing of data from testing in the Orion/MPCV program.
<TBD 4-1>	4.3	Need to define the maximum mounting bolt torque for all external coldplates.
<TBD 4-2>	4.4	Need to define the bolts to be used for mounting the external coldplates.
<TBD 4-3>	4.4	Need to define the spacing for mounting of external coldplates.
<TBD 4-4>	4.5	Additional content is needed for the external coldplates, and updates must be coordinated with the Robotics Standards team once their document is further developed.
<TBD 4-5>	4.7	Need to define and agree to the heat flux capacity for external coldplates.
<TBD 6-1>	6.0	Need to identify future topics for possible standardization.
<TBD App-B>	App.B	Need to fill in the Glossary

Table C-2 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBR issue is numbered based on the section where the first occurrence of the issue is located as the first digit and a consecutive number as the second digit (i.e., <TBR 4-1> is the first unresolved issue assigned in Section 4 of the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

TABLE C-2 TO BE RESOLVED ISSUES

TBR	Section	Description
<TBR 3-1>	3.5	Need agreement with all IPs that the external coolant fluid will be Novec™ HFE-7200 produced by 3M™.
<TBR 3-2>	3.5	Need agreement with all IPs that the internal coolant fluid will be a 35/65 inhibited propylene glycol-water mixture.

APPENDIX D SYMBOLS DEFINITION

N/A