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-	06/08/17	INITIAL RELEASE	N/A
A	09/24/19	~~Clariying~~Clarifying criteria for the definition of dwell times for cold start, powered freeze/thaw, & freeze out. Additional definitions & figure ~~clean up~~clean-up will be included.	5-8, 10, 12-27, 29-43

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1 ~~SCOPE~~SCOPE

This specification establishes the requirements for the construction of a two-phase heat transport system (TPHTS) that is to be used in either space flight applications, qualification testing, or engineering model applications. This specification covers the required construction, screening and processing criteria for each type of assembly. The requirements in this document shall be performed by the manufacturer supplying the TPHTS or a SEAKR approved facility.

This specification is intended to be applied in conjunction with the **Program Specific Document** in order to establish acceptable engineering and product assurance requirements of the TPHTS in terrestrial and space flight applications.

2 ~~APPLICABLE DOCUMENTS~~APPLICABLE DOCUMENTS

The following standards and documents for a part of this drawing are applied to the extent specified herein. In the event that there are discrepancies between the referenced documents and this document, the order of precedence shall be as follows:

a) SEAKR Purchase Order (PO)
b) SEAKR **Program Specific Document**
c) This SCD
d) Other specifications or standards (e.g. military standard, etc.) referenced herein

The latest released revision of this document at the time of the PO is effective.

2.1 Reference Specifications

ECSS-E-ST-31-02C	Space Engineering: Two-Phase Heat Transport Equipment
10232	Specification for Painting, Coating, and Markings, SEAKR
10075	Prohibited Materials Plan, SEAKR
10097	SCD, Extensive Screening of Two-phase Heat Transport Systems, SEAKR
10237	Part Certifications and Conformances
~~SEWI-7013~~	~~Perform Receiving Inspection~~
AFSPCMAN-91-710v3	Range Safety User Requirements Manual
AIAA-S-080-1998	Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
ASTM E595	Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
AS9102	Aerospace First Article Inspection Requirement

3 DEFINITIONS ~~AND~~ AND ACRONYMS

3.1 DEFINITIONS

The following terms are specific to the present standard:

Arterial Feature

Design feature to minimize viscous losses by using separate fluid flow passages (arteries) in combination with fine capillary structures

Batch

A batch is defined as a group of TPHTS assemblies that are sent through the furnace at once for the sintering process. Each batch requires wick structure bonding verification.

Burst Factor (K_{BURST})

Multiplying factor applied to the maximum design pressure (MDP) to obtain the design burst pressure

K_{BURST} = 2.5, unless otherwise specified by the **Program Specific Document**

Burst Pressure

Pressure at which collapse, rupture, or unstable fracture of the TPHTS system occurs

Constant Conductance Heat Pipe (CCHP)

Heat pipe with a fixed thermal conductance between evaporator and condenser at a given temperature

Design Burst Pressure (P_{BURST})

Internal pressure that the THPTS assemblies is required to maintain without collapse, rupture, or unstable fracture of the TPHTS system

$P_{BURST} = K_{BURST} * MDP$

Detrimental Deformation

Structural deformation, deflection, or displacement that prevents the TPHTS from performing its intended function, or reduces the probability of a successful mission. Flight units shall exhibit no deformation. Qualification units that exhibit deformation shall be submitted to SEAKR for evaluation.

Differential Pressure

Internal pressure minus the external pressure

Dry Out

Depletion of working fluid in the evaporator section at high heat inputs when the capillary pressure gain falls below the pressure drop in the circulating fluid

External Pressure

Absolute pressure outside the TPHTS

Exposure Temperature Range

Temperature range to which the TPHTS will be exposed to throughout the entire mission

Factor of Safety (FOS_P)

Factor by which the MEOP is multiplied by in order to account for uncertainties in the manufacturing process and material properties

$FOS_P = 1.0$

Flaw

Local discontinuity in the material, including but not limited to, gouges, chips, cracks, and dents

Freeze Tolerant

Characteristic of a TPHTS of which the amount of general degradation or the size and distribution of local defects during operation do not lead to the mechanical or thermal failure of the TPHTS

Heat Pipe

TPHTS consisting of a single pipe with liquid and vapor passages arranged in a manner that allows the two fluid phases to move in counter flow, also see TPHTS definition

Heat Transport Capability

Maximum amount of heat that can be transported by a TPHTS from the evaporator to the condenser

Internal Pressure

Absolute pressure inside the two-phase heat transport system

Lot

A lot is defined as a group of charged and sealed TPHTS assemblies that are of the same configuration, produced on the same production line and on the same ~~job order.~~ purchase order.

Job Order

Written instructions to perform work according to specified requirements, within the specified timeframe and cost estimates. Generally, this is synonymous with a purchase order (PO).

Maximum Design Pressure (MDP)

The internal pressure of the TPHTS at the maximum temperature of the exposure temperature range

$MDP = MEOP*FOS_P$

Maximum Expected Operating Pressure (MEOP)

The highest pressure that the two-phase heat transport system is expected to experience during its mission life in association with its applicable environment

Mechanical Failure

Rupture, collapse, degradation, excessive wear, or any other phenomenon resulting in an inability to sustain design limit loads, pressures, and environments

Proof Factor (K_{PROOF})

Multiplying factor applied to the maximum design pressure (MDP) to obtain the design proof pressure

K_{PROOF} = 1.25, unless otherwise specified by the **Program Specific Document**

Program Specific Document

A project specific drawing/specification which provides design, construction, and physical dimensions as well as the thermal and mechanical testing requirements

Proof Pressure

Product of MDP and proof factor

$P_{PROOF} = K_{PROOF} * MDP$

Residual Stress

Stress that remains in the TPHTS after processing, fabrication, assembly, testing, or operation

Start-up

Operational phase beginning with an initial application of heat to the evaporator until nominal operation of the device is established

Thermal Performance Temperature Range

Temperature range that the TPHTS is qualified thermally

Thermal Failure

Degradation or any other phenomenon resulting in the inability to transfer the required power levels

Two-phase Heat Transport Systems (TPHTS)

Hermetically closed system filled with a working fluid that transports thermal energy by a continuous evaporation/condensation process using latent heat of the working fluid

Vapor Chamber (VC)

One or two piece TPHTS consisting flat plates of rectangular or complex geometry with liquid and vapor passages arranged in a manner that allows the two fluid phases to move in counter flow, also see TPHTS definition

3.2 ABBREVIATIONS

The following acronyms are used throughout this standard:

Abbreviation	Meaning
C	Celsius
CCHP	constant conductance heat pipe
EIDP	end item data package
EM	engineering model
FOS_P	factor of safety for pressure vessel
HP	heat pipe
K_{BURST}	factor for burst pressure testing
K_{PROOF}	factor for proof pressure testing
MDP	maximum design pressure
MEOP	maximum expected operating temperature
NDI	non-destructive inspection/examination
PHL	parasitic heat loss
PN	part number
PO	purchase order
PSD	**Program Specific Document**
Q_{EVAP}	required power to be applied at the TP_{EVAP} as defined in the Program Specific Document with the addition of PHL
Q_{MAX}	maximum power level required by Program Specific Document
Q_{MIN}	minimum power level required by Program Specific Document
Q_V	verification power level that may be required by Program Specific Document, typically 1.25*Q_{MAX}
SCD	source control drawing
SEWI	SEAKR Engineering work instruction
T_{BOUND}	required temperature to be maintained at the TP_{COND} as defined in Program Specific Document
TP_{COND}	test point on the condenser as defined in the Program Specific Document
TP_{ENG}	evaluation test point defined in the Program Specific Document
TP_{EVAP}	test point on the evaporator as defined in the Program Specific Document
TPHTS	two-phase heat transport system
VC	vapor chamber
W	Watt

4 TWO-PHASE HEAT TRANSPORT SYSTEMS CATEGORIZATION

4.1 CONSTANT CONDUCTANCE HEAT PIPES (CCHP)

Constant conductance heat pipes consist of a single vessel with a capillary structure extending over the entire length. These designs are systems that rely on principles of thermal conductivity and phase transition. The working fluid at the evaporator turns into a vapor by absorbing heat from the evaporator. The vapor then travels along the heat pipe to the condenser and condenses back into a liquid – releasing the latent heat. The working fluid then returns to the evaporator through capillary action in the wick structure. Since heat pipes transfer the heat input into the system along the axis of the pipe these systems are well suited for cooling discrete heat sources. For heat pipes, the liquid and vapor passages are fabricated in a manner that allows the two fluid phases to move in counter flow.

4.2 VAPOR CHAMBERS (VC)

Vapor chambers consist of a single or two-part vessel with a capillary structure extending from the condenser to the evaporator locations. Like heat pipes, vapor chamber systems rely on principles of thermal conductivity and phase transition. Generally, vapor chambers are a planar version of a heat pipe that can spread heat in two dimensions. Since vapor chamber systems have the ability to transfer heat in two directions they are well suited for high power and high heat flux applications where the evaporator area is small.

5 PART NUMBERS AND UNIT MARKING

Identification of all TPHTS assemblies shall consist of a base part number, a dash configuration, a test subgroup configuration and a serial number. All units shall be marked with a full part number which includes the base part number, the dash configuration, and the test subgroup configuration. Additionally, all units shall be serialized as defined in Section 5.2.~~. Section 5.2.~~ The information that is required on the part shall be as follows:

XXXXXXX	**-AAA**	**-UUZZ**	**WWYYNNNN**
Base PN (5 - 7 digits)	Dash Configuration	Test Subgroup	Serial Number

Marking shall not interfere with the TPHTS operation or part attachment locations, such as the bottom of the heat sink. Part marking shall be in accordance with the method provided below. The preferred method of part marking shall be specified in the **Program Specific Document**. Vendor shall engrave, etch or ink stamp the part number and serial number where shown in the **Program Specific Document**. Marking depth is not to exceed 0.010 inches.

Alternative methods of part marking may be used with the prior approval of SEAKR Engineering.

5.1 ~~PART NUMBERING~~PART NUMBERING

The part number for a TPHTS assembly shall consist of a base part number, a dash configuration, a test subgroup configuration. These three identifiers are outlined above. Prototype, EM, flight and qualification units are generally similar to one another in design and construction; they are only differentiated by the test subgroup configurations. For the test subgroup configuration, the UU designator defines the required unit acceptance testing for the program. The first letter of the UU subgroup will be identified with a P, E or F in the first digit which represents a prototype, EM or flight test flow respectively (e.g., P0, E0, E1, F0, F1, etc.). TPHTS assembly test subgroup configurations are defined in Table 1 ~~Table 1~~ and Table 2. ~~Table 2~~.

For flight lots, the test subgroup configuration with the ZZ designator defines the required lot based qualification testing that is required for the program (e.g., F0Q0, F1Q1, etc.). The quantities and selection of required units for qualification are defined in Section 8.3.1~~8.3.1~~. The units selected for qualification shall be marked per Section 5 as well as Section 10 of this document.

Examples:

Flight units for a lot of the 19002-009 configuration may have a part number as follows:

19002-009-F1Q1

This part number shows that the 19002-009 assembly has been subjected to the subgroup F1 flight acceptance test flow in Table 2~~Table 2~~ and that the lot has been qualified to the subgroup Q1 requirements ~~in Table 3~~in Table~~Table 3~~.

The qualification units for a lot the above lot of 19002-009 configuration would have a part number as follows:

19002-009-F1Q1-QUAL

This part number shows that the 19002-009 assembly has been subjected to the subgroup F1 flight acceptance test flow in Table 2~~Table 2~~ as well as the subgroup Q1 requirements in Table 3~~Table 3~~. See Section 10 for more details on qualification unit marking.

Historical TPHTS assembly dash configurations may have a zero in the first digit (-0BB) are for flight designs while configurations with a one in the first digit (-1BB) are for EM designs. The last two digits in the dash configuration (“BB”) are numbers that represent the specific design formation (e.g., 09, 10, 19, 29, etc.).

Example:

In these instances, a historical EM design of the 19005 base number may be denoted as:

19005-109

Currently, a 19005-009-E0 would be an equivalent part number to the 19005-109.

5.2 PART SERIALIZATION

Each HP assembly shall be serialized after heat pipe to heat sink(s) attachment. For assemblies with multiple heat pipes, the serialization shall apply to the assembly. Both the part number and serial number marking may be done at the heat sink detail level, but the action of assembling the heat sink to the heat pipe forever establishes that assembly as a unique, serialized, inseparable HP assembly. In other words, if the serial number is marked at the detail level, the serial number shall reflect the date code of the assembly.

Each VC assembly shall be serialized after final assembly. Both the part number and serial number marking may be done at the detail level, but the action of assembling the VC forever establishes that assembly as a unique, serialized, assembly.

As previously stated, part markings shall have both a part number and a serial number. The serial number shall be week, year, and a four digit number at the point of heat pipe to heat sink(s) ~~attachment in~~attachment in the following format:

WW	YY	NNNN
2-Digit Week Code (01 to 52)	2-Digit Year Code	Item Number (e.g., 0001)

The four digit serial number extension shall be unique to each individual part number, such that each configuration for a given part (-009, -010, etc.) may have an identical series of serial numbers. For example, there may both be a P/N 19002-009-UUZZ S/N 22160001 and a P/N 19002-010-UUZZ S/N 22160001.

5.3 PIPE SERIALIZATION

Each individual heat pipe shall be serialized with traceability maintained to the next higher level assembly, and shall be documented in the EIDP.

~~CAGE CODE~~

~~Each TPHTS assembly shall be marked with the vendor's cage code along with the part number and serial number of the assembly.~~

6 ~~DESIGN, CONSTRUCTION, AND PHYSICAL DIMENSIONS~~DESIGN, CONTRUCTION, AND PHYSICAL DIMENSIONS

The design, construction, and physical dimensions of the TPHTS assembly shall be per this SCD and per the **Program Specific Document**.

EM, Flight, and the flight assemblies selected for qualification testing shall be processed to standard manufacturer's quality requirements. Dimensional and other requirements in the **Program Specific Document** shall be met. SEAKR Engineering's incoming inspection criteria for flight assemblies are specified in Section 9.1. These requirements are provided in this SCD to allow the TPHTS manufacturer to review the rejection criteria to which their product will be subjected upon delivery and inspection.

6.1 GENERAL CONSTRUCTION

6.1.1 Constant Conductance Heat Pipes (CCHP)

All CCHP systems shall be designed and manufactured in a manner in which no arterial features in the wick will be present. Additionally, the CCHP systems shall be insensitive to gravity to ensure the unit can operate in adverse gravity conditions. A HP assembly shall be made up of at least one of the following: (1) an evaporative heat sink, (2) a heat pipe, and/or (3) a condenser block.

6.1.2 Vapor Chambers (VC)

All VC systems shall be designed and manufactured in a manner in which no arterial features in the wick will be present without prior SEAKR approval. Additionally, the VC systems shall be insensitive to gravity to ensure the unit can operate in adverse gravity conditions

6.2 MATERIALS

For TPHTS assemblies, the condenser and/or heat sink shall be made from the material in the **Program Specific Document**. The HP envelope and wick material as well as structure shall be as specified in the **Program Specific Document**. The working fluid specified in the **Program Specific Document** shall be verified by the manufacturer to be compatible with the wick and envelope material. For CCHP's, the final shape shall be annealed as stated in the **Program Specific Document**. Unless otherwise specified in the **Program Specific Document**, any solder used on the TPHTS assembly shall have at least 3% lead. ~~be Sn63/Pb37 and/or Sn96.5/Ag3.5.~~ B~~Unless otherwise specified in the **Program Specific Document**, b~~brazing material shall be ~~Cu80/P5/Ag15.~~ approved by SEAKR prior to start of production.

Alternative materials for the construction of the heat sink, condenser block, envelope, wicking structure, or brazing ~~material~~ shall only be used with prior approval from SEAKR Engineering or as specified in the **Program Specific Document**.

Inks used on the TPHTS assembly to stamp the part number or otherwise mark information on the part will comply with SEAKR specification 10232. All materials in the final assembly must meet the outgassing requirements of ASTM E595 upon delivery.

All materials used in these products shall adhere to the Prohibited Materials Requirements per SEAKR specification 10075, and shall not contain (1) pure unalloyed tin, (2) tin alloy containing more than 97% tin, or (3) un-plated cadmium, zinc, or brass.

6.3 DIMENSIONS

All dimensions for machined parts and assemblies are found in the **Program Specific Document**.

The crimped end of an HP assembly shall be located as shown in the **Program Specific Document**. The final crimped end dimensions are also shown in the **Program Specific Document**. None of the crimped end material may protrude beyond the outer diameter of the un-crimped HP. The crimped end shall be crimped and sealed per manufacturer's best practices.

6.4 CHANGE OF PRODUCTS OR PROCESSES

The manufacturer shall not make changes to the product or ~~in~~ the processes, procedures, or design used in the fabrication, inspection, or test of the product as stipulated in AS9102 (Aerospace First Article Inspection Requirement) without prior written notification of approval from SEAKR Engineering. This change control applies to all changes or improvements made after initial qualification or initial procurement of the product by SEAKR Engineering.

7 QUALITY ASSURANCE PROVISIONS

7.1 MANUFACTURING PROCESSES

All TPHTS assemblies shall be manufactured and tested in a consistent manner using similarly trained technicians and a consistent set of equipment and processes. The series of equipment and tooling used to fabricate the heat pipes shall be documented. The same fabrication processes used to manufacture the qualification test units shall be used for all subsequent builds. The substitution or use of alternate methods after qualification testing has begun is prohibited.

If a lot of a given part number and dash configuration is produced with a fabrication process that differs from the previously tested qualification units out of necessity (due to process obsolescence, availability, or program requirements), then previous qualification history for that part number and dash configuration does not apply. The lot produced with new methods must be treated as a “first lot”. Selection of the number of qualification units for a first lot is defined in Section 8.3.1. Additionally, SEAKR shall be notified of any changes to the manufacturing process for subsequent lots in accordance with Section 6.4..

7.2 LOT

A lot is defined as a group of charged and sealed TPHTS assemblies that are of the same configuration, produced on the same production line and on the same job order.

7.2 MANAGING UNIT FAILURES DURING LOT TESTING

If any TPHTS assembly demonstrates thermal or mechanical failure during the acceptance test program the failure is to be considered a yield occurrence. In the event a TPHTS assembly demonstrates thermal or mechanical failure during the qualification test program the failure is to be considered a lot failure.

7.3 FIRST LOT QUALIFICATION

“First Lot” is defined as the first run of 30 or more of the same TPHTS assembly configuration, produced on the same production line in accordance sSection 6.4. Therefore the first build of 30 or more of a TPHTS assembly configuration on a line represent the first lot of that TPHTS assembly configuration for purpose of Qualification. If a lot of of 30 or more of a TPHTS assemblies y configuration are built on a different production line (per Ssection 6.4), this represents yet another “first lot”. The number of Flight units selected for Qualification for each configuration and production lot shall be per Section 8.3.18.3.1.

7.4 QUALIFICATION LOT MATERIALS

The same sealing material composition, solder alloy, or brazing alloy metal used to manufacture the qualification test units shall be used for all subsequent builds. The substitution or use of alternate sealing material compositions, solder alloys, or brazing alloys~~s~~ after qualification testing has begun is prohibited.

If a lot of a given part number and dash configuration is produced with a sealing material composition, solder alloy, or brazing alloy ~~material~~ that differs from the previously tested qualification units out of necessity (due to materials obsolescence, availability, or program requirements), then previous qualification history for that part number and dash configuration does not apply. The lot produced with new materials must be treated as a "first lot". Selection of the number of qualification units for a first lot is defined in Section 8.3.1~~8.3.1~~.

~~7.5 BATCH~~

~~A batch is defined as a group of TPHTS assemblies that are sent through the furnace at once for the sintering process.~~

~~7.6~~7.5 WICK STRUCTURE BONDING VERIFICATION

For HP assemblies, a representative sample of the sintered wick structure of each batch shall be provided to SEAKR for approval within 2 business days from the time the vendor receives the report ~~that is sent through the furnace shall be tested~~ in order to verify that the wick structure is properly attached to the pipe.

~~7.7 JOB ORDER~~

~~Written instructions to perform work according to specified requirements, within the specified timeframe and cost estimates.~~

7.8 Nonconformance Reporting

SEAKR does not grant the supplier MRB authority. All nonconformances requiring a Repair or Use As Is disposition shall be reported to SEAKR within 48 hours of discovery. All processing including test failures or tests that do not meet engineering test parameters on the hardware shall cease until written instruction is given by SEAKR engineering and/or quality. ~~Depending on the severity of the nonconformance SEAKR will make every effort to provide written direction within 48 hours or less.~~

7.9 Standard Reworks

SEAKR defines a standard rework as the documented technique for a specific type of nonconformance, which has been demonstrated to be an adequate method for returning the part to full conformance. All processes that are noted to have the opportunity for standard reworks shall be approved by SEAKR prior to implementation into the manufacturing traveler.

~~Examples of processes that may be deemed a standard rework would include operations such~~

~~as reflowing of solder or removal of evaporators and condensers from failed assemblies for reuse.~~

The limits to standard reworks shall be agreed upon prior to incorporation and will be reflected in the planning for that operation. ~~All hardware that is subject to standard rework shall be segregated from the normal production flow and tracked separately.~~ The standard rework status must be reflected in the EIDP. Any hardware that exceeds the agreed upon standard rework limits is to be scrapped and records are to be made available upon SEAKR request.

8 ~~TESTING FLOW~~TESTING FLOW

Prototype, EM, Flight, and Qualification TPHTS assemblies will undergo acceptance testing per Sections 8.1, 8.2, 8.3 and 8.4, respectively. The **Program Specific Document** may contain tailored EM, Flight and Qualification test flows that differ from the baseline testing provided in this specification. These tailored test flows supersede the test flows in this specification. Additional details regarding quantities, pass/fail criteria, and test procedures are provided in subsequent sections or in the **Program Specific Document**.

8.1 EM ASSEMBLIES ACCEPTANCE TEST FLOW

All EM TPHTS assemblies (dash configurations -AAA-EU) shall undergo the testing flow provided in Table 1~~Table 1~~ below, unless superseded by a Custom Acceptance Test flow, as outlined in **Program Specific Document.** EM assemblies do not need to go through additional qualification testing as described in Section 8.3~~8.3~~. For EM acceptance test flows, additional custom test requirements beyond –E2 may be defined in the **Program Specific Document.** In this case, the U in the –EU configuration will be identified with an N+1 number (~~ie~~i.e., E3, E4, E5, etc…).

Table 1: EM Assembly Acceptance Test Flow and Parameters

ID	Examination	Conditions	Quantity	Ref.
Subgroup E0, (-E0) – SEAKR Test Flow 0				
1	Inspection	Dimensional and visual Inspection, Weight	100%	9.1
2	Freeze-Thaw Cycling	**Number of Cycles:** 10 Cycles **Orientation**: Crimp Down T_{BOUND}: -40°C to +90°C Q_{EVAP}: N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	100%	9.5
3	Electrical Resistance	Electrical resistance is < 2.5 mΩ	100%	9.6
4	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) T_{BOUND}: 45°C Q_{EVAP}: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD**	100%	9.2
5	Inspection	Dimensional and visual Inspection, Weight	100%	9.1
Subgroup E1, (-E1) – SEAKR Test Flow 1				
1	Inspection	Dimensional and visual Inspection, Weight	100%	9.1
2	Freeze-Thaw Cycling	**Number of Cycles:** 10 Cycles **Orientation**: Crimp Down T_{BOUND}: -40°C to +90°C Q_{EVAP}: N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	100%	9.5
3	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4
4	Electrical Resistance	Electrical resistance is < 2.5 mΩ	100%	9.6
5	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) T_{BOUND}: 45°C Q_{EVAP}: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD**	100%	9.2
6	Inspection	Dimensional and visual Inspection, Weight	100%	9.1
Subgroup E2, (-E2) – (Program Specific Subgroup Testing)				
SEE PROGRAM SPECIFIC DOCUMENT (PSD)				

8.2 Flight Assemblies Acceptance Test Flow

All of the flight assemblies (dash configurations -AAA-FUQZ) shall undergo the testing flow provided below in Table 2~~Table 2~~, unless superseded by the **Program Specific Document**. For flight acceptance test flows, additional custom test requirements beyond –F2 may be defined in the **Program Specific Document.** In this case, the U in the –FU configuration will be identified with an N+1 number (~~ie~~i.e., F3, F4, F5, etc…).

Table 2: Flight Acceptance Test Flow for Flight Assemblies

ID	Examination	Conditions	Quantity	Ref.
Subgroup F0, (-F0) – SEAKR Test Flow 0				
1	Inspection	Dimensional and visual Inspection Weight	100%	9.1
2	Freeze-Thaw Cycling	**Number of Cycles:** 130 Cycles **Orientation**: Crimp Down T_{BOUND}: -40°C to +90°C Q_{EVAP}: N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	100%	9.5
3	Cold Start Cycling	**Number of Cycles:** 20 Cycles **Orientation**: Vertical (Evaporator Up) T_{BOUND}: -40°C to +40°C Q_{EVAP}: Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	100%	9.7
4	Electrical Resistance	Electrical resistance is < 2.5 mΩ	100%	9.6
5	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) T_{BOUND}: 45°C Q_{EVAP}: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD**	100%	9.2
6	Inspection	Dimensional and visual Inspection Weight	100%	9.1

ID	Examination	Conditions	Quantity	Ref.
Subgroup F1, (-F1) – SEAKR Test Flow 1				
1	Inspection	Dimensional and visual Inspection Weight	100%	9.1
2	Freeze-Thaw Cycling	**Number of Cycles:** 130 Cycles **Orientation**: Crimp Down **T_{BOUND}**: -40°C to +90°C **Q_{EVAP}:** N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	100%	9.5
3	Cold Start Cycling	**Number of Cycles:** 20 Cycles **Orientation**: Vertical (Evaporator Up) **T_{BOUND}**: -40°C to +40°C **Q_{EVAP}:** Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	100%	9.7
4	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4
~~3~~5	Electrical Resistance	Electrical resistance is < 2.5 mΩ	100%	9.6
~~5~~6	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) **T_{BOUND}**: 45°C **Q_{EVAP}:** Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD**	100%	9.2
~~6~~7	Inspection	Dimensional and visual Inspection Weight	100%	9.1
Subgroup F2, (-F2) – (Program Specific Subgroup Testing)				
SEE PROGRAM SPECIFIC DOCUMENT (PSD)				

8.3 QUALIFICATION ASSEMBLIES

8.3.1 Selection of Qualification Assemblies

The specific number of flight assemblies selected for additional qualification testing is dependent on the history of the qualification testing that has been performed for the specific TPHTS assembly (i.e. if the specific flight assembly configuration has been qualification tested in the past).

For the first lot created of a flight assembly of a specific part number and dash configuration, several units shall be subjected to additional qualification testing. When PO requires Q0, Q1, Q2 qualification, Aa minimum of three (3) units is required for to pass qualification. When PO requires Q3, Q4 qualification, Subgroup 1 and a a minimum of two (2) units is required to pass qualification. for Subgroups 3 and 4, respectively. Quantities subjected to Subgroup 2 (if applicable) testing are defined in the **Program Specific Document**. Note that qualification test flow is subject to program requirements, and notNote that all qualification units will shall be subjected to only one qualification subgroup.undergo testing in all four subgroups.

If the first lot of a specific part number and dash configuration have already been subjected to, and successfully passed, qualification testing, the number of qualification units may be reduced per the PO. At a minimum, subsequent orders shall qualify one (1) unit per required subgroup. ; then up to four (4) units from each subsequent lot for that part number and configuration are required to go through qualification testing. A minimum of one (1) unit is required for each of the four subgroups. Note that qualification test flow is subject to program requirements, and not all qualification units will undergo testing in all four subgroups.

8.3.2 Qualification Assemblies Test Flow

All of the flight assemblies selected for qualification (dash configurations -AAA-FUQZ) shall be tested per Section 8.28.2 unless superseded by the **Program Specific Document**. After the successful flight acceptance testing of the entire lot of manufactured flight assemblies, a specific number of flight units from the flight lot shall be selected at random (per Section 8.3.18.3.1) from each dash configuration to undergo qualification testing. Therefore, part numbers followed by –QUAL (19002-009-F1Q1-QUAL) are selected from the same flight assemblies (19002-009-F1Q1) that have already passed acceptance testing.

Qualification test flow is subject to program requirements. Table 3Table 3 below outlines the most extensive test flow that may be required of a qualification unit. However, the actual qualification test flow for a given part number and configuration, and the subgroup testing to be conducted, will be provided in the **Program Specific Document**. Required qualification tests shall be marked by SEAKR Engineering, and all tests shall be performed in the order in which they are listed. For qualification test flows, additional custom test requirements beyond –FUQ4 may be defined in the **Program Specific Document.** In this case, the U in the –FUQU configuration will be identified with an N+1 number (ieii.e., Q6, Q7, Q8, etc…).

Qualification of TPHTS assemblies is divided into four possible subgroups. If more than one subgroup is listed in the **Program Specific Document**, then tests shall be conducted in parallel, and with each subgroup requiring an individual set of sample units for analysis. Meaning, sample units undergoing Subgroup 1 tests shall not be subjected to tests of Subgroups 2, 3, or 4, and vice versa.

Table 3: Test Flow for Flight Assemblies Selected for Qualification

ID	Examination	Condition	Quantity	Ref.
Subgroup Q0, (-UUQ0) – SEAKR Test Flow 0 ~~(3 Units for First Lot, 1 Unit for Repeat Lots)~~				
1	Flight Acceptance Testing	All units selected for qualification required to first undergo Flight Acceptance Testing	100%	8.2
2	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) **T_{BOUND}**: 85°C **Q_{EVAP}:** Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.2
4	Freeze-Thaw Cycling	**Number of Cycles:** 100 Cycles **Orientation**: Crimp Down **T_{BOUND}**: -40°C to +90°C **Q_{EVAP}:** N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	3 or 1	9.5
5	Electrical Resistance	Electrical resistance is < 2.5 mΩ	3 or 1	9.6
6	Reduced Thermal Performance	**Orientation**: Vertical (Evaporator up) **T_{BOUND}**: 85°C **Q_{EVAP}:** Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.3
7	Cold Start Testing	**Number of Cycles:** 60 Cycles **Orientation**: Vertical (Evaporator Up) **T_{BOUND}**: -40°C to +40°C **Q_{EVAP}:** Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	3 or 1	9.7

ID	Examination	Condition	Quantity	Ref.
8	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) **T_{BOUND}**: 85°C **Q_{EVAP}:** Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.2
9	Inspection	Dimensional and visual Inspection Weight	100%	9.1
10	Qual Unit Marking	Mark all qualification units	100%	10.0
Subgroup Q1, (-UUQ1) – SEAKR Test Flow 1 ~~(3 Units for First Lot, 1 Unit for Repeat Lots)~~				
1	Flight Acceptance Testing	All units selected for qualification required to first undergo Flight Acceptance Testing	100%	8.2
2	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) **T_{BOUND}**: 85°C **Q_{EVAP}:** Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.2
4	Freeze-Thaw Cycling	**Number of Cycles:** 100 Cycles **Orientation**: Crimp Down **T_{BOUND}**: -40°C to +90°C **Q_{EVAP}:** N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	3 or 1	9.5
5	Electrical Resistance	Electrical resistance is < 2.5 mΩ	3 or 1	9.6
6	Reduced Thermal Performance	**Orientation**: Vertical (Evaporator up) **T_{BOUND}**: 85°C **Q_{EVAP}:** Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.3
7	Cold Start Testing	**Number of Cycles:** 60 Cycles **Orientation**: Vertical (Evaporator Up) **T_{BOUND}**: -40°C to +40°C **Q_{EVAP}:** Q_{MAX} from **PSD** **Duration:** N/A	3 or 1	9.7

ID	Examination	Condition	Quantity	Ref.
		Ambient Temperature: Atmospheric **Ambient Pressure**: Atmospheric		
8	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4
9	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) $\mathbf{T_{BOUND}}$: 85°C $\mathbf{Q_{EVAP}}$: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.2
10	Inspection	Dimensional and visual Inspection Weight	100%	9.1
11	Qual Unit Marking	Mark all qualification units	100%	10.0
Subgroup Q2, (-UUQ2) – (Program Specific Subgroup Testing)				
SEE PROGRAM SPECIFIC DOCUMENT (PSD)				
Subgroup Q3, (-UUQ3) – ~~(2 Units for First Lot, 1 Unit for Repeat Lots)~~				
1	Flight Acceptance Testing	All units selected for qualification required to first undergo Flight Acceptance Testing	100%	8.2
2	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) $\mathbf{T_{BOUND}}$: 85°C $\mathbf{Q_{EVAP}}$: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.2
3	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4
4	Freeze-Thaw Cycling	**Number of Cycles:** 70 Cycles **Orientation**: Crimp Down $\mathbf{T_{BOUND}}$: -40°C to +90°C $\mathbf{Q_{EVAP}}$: N/A **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	3 or 1	9.5
5	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4
6	Electrical Resistance	Electrical resistance is < 2.5 mΩ	3 or 1	9.6
7	Reduced Thermal Performance	**Orientation**: Vertical (Evaporator up) $\mathbf{T_{BOUND}}$: 85°C $\mathbf{Q_{EVAP}}$: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A	3 or 1	9.3

ID	Examination	Condition	Quantity	Ref.
		Ambient Temperature: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**		
8	Cold Start Testing	**Number of Cycles:** 60 Cycles **Orientation**: Vertical (Evaporator Up) T_{BOUND}: -40°C to +40°C Q_{EVAP}: Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric	3 or 1	9.7
9	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4
10	Gas Plug Test	To be carried out during Aging Test	3 or 1	9.8
11	Aging Test	**Orientation**: Vertical (Evaporator up) T_{BOUND}: N/A Q_{EVAP}: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** 300 hours **Ambient Temperature**: +85°C **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD**	3 or 1	9.9
12	Thermal Performance	**Orientation**: Horizontal and Vertical (Evaporator up) T_{BOUND}: 85°C Q_{EVAP}: Q_{MIN} and Q_{MAX} from **PSD** **Duration:** N/A **Ambient Temperature**: N/A **Ambient Pressure**: 1 x 10^{-5} torr **Pass/Fail Criteria:** See **PSD**	3 or 1	9.2
13	Inspection	Dimensional and visual Inspection Weight	100%	9.1
14	Qual Unit Marking	Mark all qualification units	100%	10.0
Subgroup Q4, (-UUQ4)~~ – (2 Units for First Lot, 1 Unit for Repeat Lots)~~				
1	Flight Acceptance Testing	All units selected for qualification required to first undergo Flight Unit Test Flow	100%	8.2
2	Pressure Cycle Test	**Number of Cycles:** 2000 **Orientation**: Any **Pressure Range**: 1 bar to MDP (psia) **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD** for MDP value	2 or 1	9.11

ID	Examination	Condition	Quantity	Ref.
3	Hermetic Screening	See SEAKR document 10097~~, Section 4.1.~~	100%	9.4

4	Burst Pressure Test	**Orientation**: Any **K_{BURST} Factor:** 2.5 **Burst Pressure:** K_{BURST} * MDP (psia) **Duration:** 15 minutes **Ambient Temperature**: Atmospheric **Ambient Pressure**: Atmospheric **Pass/Fail Criteria:** See **PSD** for MDP. After 15 minutes, increase pressure until burst occurs	2 or 1	9.12
5	Visual Inspection	Dimensional and visual inspection Weigh	100%	9.1
6	Qual Marking	Mark all qualification units	100%	10.0

8.4 PROTOTYPE ASSEMBLIES ACCEPTANCE TEST FLOW

All prototype TPHTS assemblies (dash configurations -AAA-PU) shall undergo the testing flow provided in Table 4Table 4 below, unless superseded by a Custom Acceptance Test flow, as outlined in **Program Specific Document.** Prototype assemblies do not need to go through additional qualification testing as described in Section 8.38.3. For Prototype acceptance test flows, additional custom test requirements beyond –P2 may be defined in the **Program Specific Document.** In this case, the U in the –PU configuration will be identified with an N+1 number (iei.e., P3, P4, P5, etc…).

Table 4: Prototype Assembly Acceptance Test Flow and Parameters

ID	Examination	Conditions	Quantity	Ref.
Subgroup P0, (-P0) – SEAKR Test Flow 0				
1	Functionality Testing	N/AQualitative EvaluationN/A	100%	9.19
2	Inspection	Dimensional and visual Inspection, Weight	100%	9.1

9 TESTING REQUIREMENTSTESTING REQUIREMENTS

Testing conditions and pass/fail criteria are detailed in subsequent sections. The standard individual test flows for EM, Flight, and Qualification assemblies are summarized graphically in Figure Figure 9-19-1. Note that the **Program Specific Document** may contain modified test flows for EM, Flight and Qualification assemblies based on unique program requirements that supersede the tests flows provided herein. Similarly, test flows provided in the **Program Specific Document** may contain some combination of customer defined test flows (e.g., Subgroup 2), and/or the Subgroups listed here (e.g., Subgroup 0, 1).

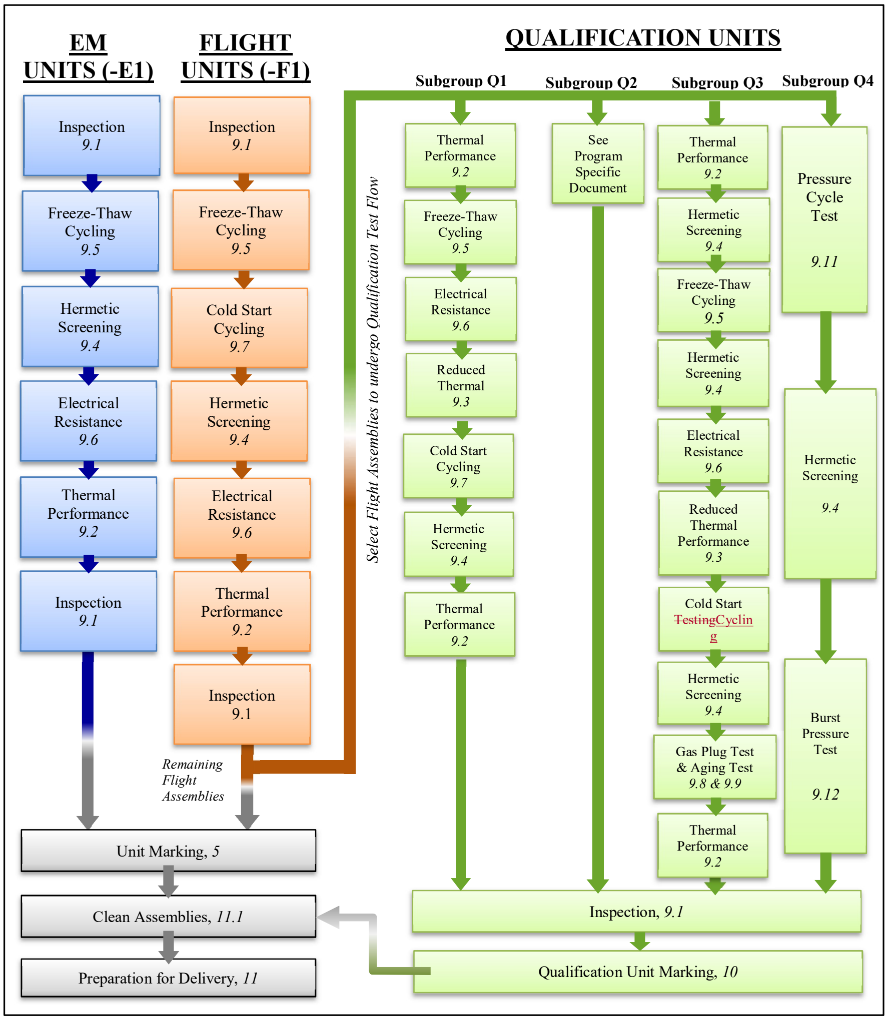

Figure 9-1: Reference Assembly Test Flow Diagram

9.1 INSPECTION

9.1.1 Assembly Weights

All units shall be weighed and the results documented by part number and serial number. Weight shall be measured with a precision of ±1 gram, or better, and provided as part of the end item data package with the equivalent British Imperial System unit provided as a reference. There are no pass/fail criteria for weight.

9.1.2 Visual Inspection

All units shall be visibly inspected ~~in accordance with SEWI-7013, and~~ per the requirements summarized below. This inspection will be SEAKR's criteria that the heat pipes will be subjected to upon delivery. Any assemblies that do not meet the visual inspection requirements are subject to return to the manufacturer.

Dimensions: For HP assemblies a go/no-go check of pipe diameter will be conducted. Heat sink and HP overall dimensions and parallelism will be checked against manufacturer's dimensional inspection report.

Visual: TPHTS assemblies will be visually inspected for flaws due to handling and/or machining, including chips, cracks, and dents. For HP assemblies the pipe will also be inspected for any anomalous imperfections, such as obvious bulges, bends, or cracks.

Cold Solder Joints: HP assemblies will be inspected for evidence of cold solder joints. A positive fillet shall be present around the entire solder joint. Inspection will check for large voids in solder, or pockets where all of the void boundaries/walls can't be seen under 10x magnification (i.e. holes or tunnels through entire solder joints)

Braze Material: HP assemblies utilizing a braze process will be inspected for evidence of pitting and cracking. Inspection will check for excessive surface pitting or pockets where all of the void boundaries/walls can't be seen under 10x magnification (i.e. holes or tunnels)

9.1.3 Special NDI

Any units exhibiting mechanical or thermal failures shall be inspected in accordance with special NDI methods. The following methods of special NDI are acceptable:

~~a) Magnetic particle~~
~~b~~a) Radiographic
~~c~~b) Ultrasonic
~~d~~c) Eddy current
~~e~~d) Thermal, in accordance with an approved company process specification.

If necessary, other methods in accordance with an approved company process specification or other industry document may be used to supplement the above methods with SEAKR approval.

9.2 THERMAL PERFORMANCE TESTING

All EM, Flight, and Qualification TPHTS assemblies subjected to performance testing are to be characterized by measurement of the thermal resistance exhibited by the device. This thermal resistance is to be measured from a test point ~~on the surface interfacing with the power source~~ ~~(~~designated TP_{EVAP} in the **Program Specific Document**~~)~~ to a test point on the surface of the condenser end of the assembly (designated TP_{COND} in the **Program Specific Document**). For tests conducted in atmosphere, the TPHTS assembly shall be insulated against excess losses via convection and radiation. Both TP_{EVAP} and TP_{COND} shall be recorded for each serialized unit.

The precision of the measurement and calculation of thermal resistance shall be assumed to yield usable values no greater than two decimal places. For example, a measurement and calculation yielding a resistance of 0.304 shall be rounded down to 0.30 and a thermal resistance determined to be 0.305 shall be rounded up to 0.31.

9.2.1 Test Conditions

For EM and Flight unit assemblies, thermal performance testing will be carried out at atmospheric pressure. For Qualification unit assemblies, thermal resistance testing will be carried out such that pressure is less than or equal to 1×10^{-5} torr. The condenser temperature will be maintained at the boundary condition temperature (T_{BOUND}) specified in the **Program Specific Document**, with a tolerance ~~of ±1.5°C.~~of +/-2.5°C. The required power levels (Q_{MIN}, Q_{MAX}, or Q_V) specified in the **Program Specific Document** shall be applied at the TP_{EVAP} location with a tolerance of ±5%.

Measurements will be taken with the TPHTS assembly in both the horizontal orientation and the vertical orientation (evaporative end up), as the vertical orientation is the worst conductive case scenario. Vertical orientation is defined as the end of evaporative side of the TPHTS assembly, "TP_{EVAP}" ~~end~~ in the **Program Specific Document**, being placed such that the maximum vertical distance is achieved from the opposite end "TP_{COND}" of the TPHTS assembly.

For tests conducted in atmospheric conditions, as is the case with EM and Flight assemblies, parasitic heat loss (PHL) shall be determined experimentally and used as the basis for actual heater power application. Therefore, for each given power level listed in the **Program Specific Document**, the sum of the nominal power level and the PHL shall be applied to the heater. PHL need only be calculated on the first unit of each dash configuration. This value may be reused on subsequent test units, provided the test setup remains the same. The same fixtures for qualification and acceptance test shall be used and any deviation from this shall require SEAKR's approval.

Thermal performance data for all assemblies shall be provided in two sets:

(1) PHL excluded in thermal resistance calculation:

$$\theta\ \text{PHL Ex.} = \frac{\Delta T}{Applied\ Power - PHL} = \frac{\Delta T}{Nominal\ Power}$$

(2) PHL included in thermal resistance calculation:

$$\theta\ \text{PHL In..} = \frac{\Delta T}{Applied\ Power}$$

In these calculations, ΔT is the temperature difference between TP_{EVAP} and TP_{COND}. Calculations associated with the pass/fail criteria shall be conducted using the nominal stated power levels (Q_{MIN} and Q_{MAX}) in the **Program Specific Document**. Photographs of as-run setups in both the horizontal and vertical orientation for all assemblies shall be provided in the end item data package of Section 11.2~~11.2~~.

9.2.2 Pass/Fail Criteria

All EM, Flight, and Qualification assemblies shall exhibit a thermal resistance less than or equal to the maximum limits provided in the **Program Specific Document**. These requirements shall be met for both the HORIZONTAL condition and the worst case VERTICAL condition. The vendor shall test all power levels listed in the **Program Specific Document** and evaluate the thermal resistance at each level; however, not all levels may be used to assess pass/fail criteria for the assemblies. If pass/fail criteria is not assigned to a power level, that specific power level shall be evaluated and the associated thermal resistance shall be provided. In this scenario, a power level without pass/fail criteria is being evaluated as a point of reference only. The power levels used to assess pass/fail criteria and those used for reference only shall be identified in the **Program Specific Document**.

9.3 REDUCED THERMAL PERFORMANCE TESTING

Reduced thermal performance testing shall be carried out in accordance with Section 9.2~~9.2~~ with the following exception TPHTS assemblies will be evaluated in the VERTICAL condition only, as the vertical orientation is the worst conductive case scenario. All power levels shall be evaluated. All EM, Flight, and Qualification assemblies shall exhibit a thermal resistance less than or equal to the maximum limits provided in the **Program Specific Document**.

9.4 HERMETIC SCREENING

For the required EM, Flight, and Qualification assemblies, ~~the~~ Hermetic Screening shall be performed as specified in ~~Section 4.1 of~~ SEAKR Document 10097. An affirmation statement of successful screening shall be provided with the delivered units.

9.5 FREEZE-THAW TESTING

For EM and Flight assemblies, freeze-thaw testing will be conducted at ambient pressure and at temperatures ranging from -40° to +90°C. EM and Flight assemblies will undergo cycles as defined in Section 88 or the **Program Specific Document** with a tolerance of- ±+10/-0°C on the upper temperature bound, and a tolerance of +0/-10°C on the lower temperature bound1.5°C.

All Qualification assemblies shall successfully pass flight freeze-thaw cycles at ambient pressure as part of Flight assembly acceptance testing. Each qualification assembly will then be tested for additional freeze-thaw cycles less than or equal to 1 x 10^{-5} torr at atmospheric or lower pressure and at temperatures ranging from -40°C to +90°C, per Section 88 or the **Program Specific Document** with a tolerance of +10/-0°C on the upper temperature bound, and a tolerance of +0/-10°C on the lower temperature bound±1.5°C. All assemblies shall not exhibit detrimental deformation after freeze-thaw testing.

Data requirements shall be logged and preserved includingpreserved includinge temperature versus time cycle evidence data logged for the chamber cycles, power applied to the evaporator heaters, and the orientation that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after freeze thaw testing.

9.6 ELECTRICAL RESISTANCE TESTING

The electrical resistance between the "TP_{EVAP}" and "TP_{COND}" locations defined in the **Program Specific Document** of the TPHTS assembly shall be less than 2.5 milliohms. This test may be completed at any point after thermal cycling.

9.7 Cold Start Testing

All assemblies shall be subjected to cold start testing for the number of cycles per Section 8~~8~~ unless otherwise specified in the **Program Specific Document**. There is no allowance for excess or insufficient cycles. ~~All assemblies of each configuration shall be mounted inside a thermal cycle chamber (no vacuum).~~ The assemblies shall be vertical unless specified otherwise in the **Program Specific Document**. A heater is attached to the evaporator end of each assembly capable of dissipating required power levels in the **Program Specific Document**.

For all assemblies, cold start testing will be conducted at ambient pressure and at temperatures ranging from -40°C to +40°C with a tolerance of +10/-0°C on the upper temperature bound, and a tolerance of +0/-10°C on the lower temperature bound~~±1.5°C~~. The required power levels (Q_{MIN}, Q_{MAX}, or Q_V) specified in the **Program Specific Document** shall be applied at the TP_{EVAP} location with a tolerance of ±5%. Dwell time at the extremes shall be ~~a minimum of 1 hour~~ determined by the supplier and is calculated based on the change in heat transfer. This constraint is to be defined by an average change in heat transfer rate which needs to be +/- 0.010 W/min for a duration of 15 minutes prior to the ramp up/down. For most CCHP's the calculations are to be defined as:

Assumptions:

$$A_{hp} = Cross\_Sectional\_Area\_Of\_Pipe$$

$$k_{copper} := 380 \frac{W}{m \cdot K}$$

$$dX = Axial\_Length\_Of\_Pipe\_Between\_TCs$$

Conductive Heat Transfer Rate Definition:

$$Heat\_Transfer\_Rate_1 = -k_{copper} \cdot A_{hp} \cdot \frac{dTemp1}{dX}$$

$$Heat\_Transfer\_Rate_2 = k_{copper} \cdot A_{hp} \cdot \frac{dTemp2}{dX}$$

where dTemp is the change in temperature from time step n to time step n+1

Change in Conductive Heat Transfer Rate:

$$Change\_In\_Transfer\_Rate = \frac{Heat\_Transfer\_Rate_2 - Heat\_Transfer\_Rate_1}{dTime(s)}$$

Average Change in Conductive Heat Transfer Rate:

Average change is defined as the average of Change_In_Transfer_Rate for a 15 minute period prior to ramp up/down

For embedded CCHP systems and VC's, the above assumptions can be modified as necessary to achieve the appropriate calculation.

The TPHTS assembly shall be insulated against excess losses via convection and radiation. Parasitic heat loss (PHL) shall be determined experimentally and used as the basis for actual heater power application. Therefore, for each given power level listed in the **Program Specific Document**, the sum of the nominal power level and the PHL shall be applied to the heater. PHL need only be calculated on the first unit of each dash configuration. This value may be reused on subsequent test units, provided the test setup remains the same.

A cycle is defined as the following sequence which is depicted in Figure 9-2**Figure 9-2**:

Example:

The chamber is first lowered to -40°C. After dwelling at -40°C for 1 hour, the heater is turned on and adjusted to 15W and the chamber ramped to +40°C. The heater power is maintained at 15W through the ramp to +40°C. There is then a 1 hour dwell at +40°C with the heater powered to 15W. The heater is then powered off and the chamber is ramped back down to -40°C.

The maximum ramp rate shall be 5°C/minute or less. If the ramp rate is deviated from this SEAKR shall be notified. The above procedure is repeated until all required cycles have been completed.

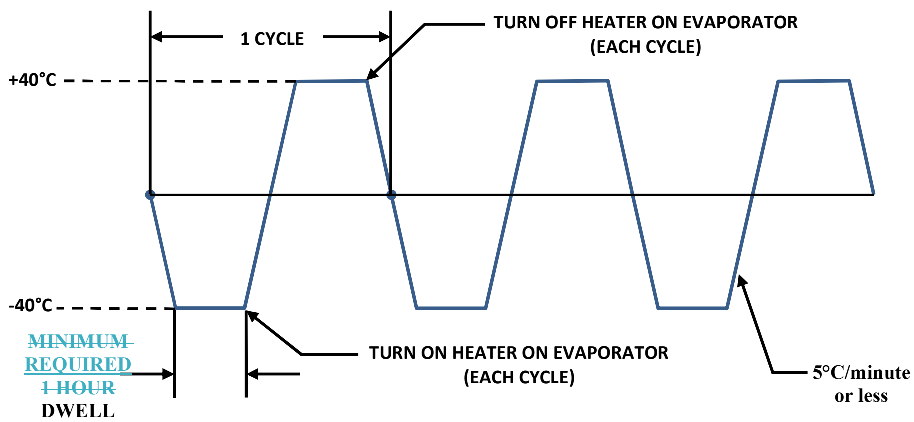

Figure 9-2: Cold Start Test Cycle Diagram

Data requirements shall be logged and preserved including temperature versus time cycle evidence for the chamber cycles, power applied to the evaporator heaters, and the orientation that the heat pipe assemblies were testedData requirements shall include data logged for the chamber cycles, power applied to the evaporator heaters and the orientation that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after cold start testing.

9.8 Gas Plug Test

The gas plug test shall be performed during aging and life tests in the vertical orientation such that reflux mode is induced on the unit. The condenser shall be instrumented with temperature sensors in short, axial distances. The axial temperature profile shall be checked before beginning the aging or life test, at approximately 25%, 50%, and 75% completion, and upon 100% completion ~~of the aging or life test~~.

The non-condensable gas content shall be determined based on the measured temperature profile. It shall be demonstrated that non-condensable gas generation over the lifetime enables the unit to meet the performance requirements in the **Program Specific Document**.

9.9 Aging Test

The Aging Test shall be performed at the maximum specified operation temperature provided in the **Program Specific Document** with the assembly in the vertical orientation. The Aging Test duration shall be a minimum of 300 hours ~~in~~ at atmospheric pressure.

9.10 Life Test

Life test shall be performed at the maximum specified operation temperature provided in the **Program Specific Document** with the assembly in the vertical orientation. The Life Test duration shall be a minimum of 8,000 hours ~~in~~ at atmospheric pressure.

9.11 Pressure Cycle Test

The ~~burst~~ pressure cycle test shall only be carried out at the final configuration, with all parts of the product including joints, braze, welds, and end fittings fully assembled. The pressure cycle test shall consist of a minimum of 2,000 cycles unless otherwise specified by the **Program Specific Document.** Cycles shall be conducted such that the internal pipe pressure ~~shall be~~is between 1 bar and the maximum design pressure (MDP) in the **Program Specific Document** at ambient temperature. Test pressures shall have a tolerance of +5 psi/-0 psi. The required MDP is specified as an absolute pressure. Atmospheric pressure shall be accounted for in the subsequent test pressure.

9.12 Burst Pressure Test

The burst pressure test shall only be carried out at the final configuration, with all parts of the product including joints, braze, welds, and end fittings fully assembled. For lots requiring multiple qualification units, only one (1) unit from the selected qualification units shall be subjected to this test. The test shall be performed by applying K_{BURST}*MDP for a minimum duration of 15 minutes unless otherwise specified by the **Program Specific Document**. No rupture or leak shall occur during the burst pressure test. Test pressures shall have a tolerance of +5 psi/-0 psi.

After the designated hold-time, the pressure shall be further increased until rupture occurs and the pressure at rupture shall be recorded. Unless otherwise specified by the **Program Specific Document**, ~~I~~it is permissible to remove pipes from blocks for burst test. The upper limit shall not exceed 370°C. The required MDP is specified as an absolute pressure. Atmospheric pressure shall be accounted for in the subsequent test pressure.

Example Calculation:

Variables:
K_{BURST} = 2.5, MDP = 10.2psi
Ambient Pressure = 14.7psi (assumed value for example only, value may vary depending on ambient conditions at the time of test

Therefore, the required design burst pressure to be maintained for 15 minutes is:

Design burst pressure = (2.5*10.2psi) +14.7psi = 40.2psi

The required temperature for the test to maintain the design burst pressure shall then be determined from the saturation curve of water. Using the above calculated pressure, this would correlate to a temperature of approximately ~~≈~~131°C.

9.13 Transport Capability Test

9.13.1 Test Conditions

Transport capability testing shall be set up in the fixture and tested in the environments as directed in Section ~~9.2~~9.2. For tests conducted in atmosphere, the TPHTS assembly shall be insulated against excess losses via radiation. Tested orientations shall be as defined in the **Program Specific Document.** The power applied to the TP_{EVAP} location shall be Q_V with the condenser temperature (TP_{COND}) maintained at the T_{BOUND} defined in the **Program Specific Document.** The temperature tolerance ~~is ±1.5°C~~is +/-2.5°C with the power applied at the TP_{EVAP} location at a tolerance of ±5%.

9.13.2 Pass/Fail Criteria

All EM, Flight, and Qualification assemblies shall exhibit a thermal resistance less than or equal to the maximum limits provided in the **Program Specific Document**. These requirements shall be met for both the HORIZONTAL condition and the worst case VERTICAL condition. The vendor shall test all power levels listed in the **Program Specific Document** and evaluate the thermal resistance at each level; however, not all levels may be used to assess pass/fail criteria for the assemblies. If pass/fail criteria is not assigned to a power level, that specific power level shall be evaluated and the associated thermal resistance shall be provided. In this scenario, a power level without pass/fail criteria is being evaluated as a point of reference only. The power levels used to assess pass/fail criteria and those used for reference only shall be identified in the **Program Specific Document**.

9.14 PROOF PRESSURE TEST

The proof pressure test shall only be carried out at the final configuration, with all parts of the product including joints, braze, welds, and end fittings fully assembled. It shall be performed by applying K_{PROOF}*MDP for a minimum duration of 15 minutes, or per the conditions and durations provided in the **Program Specific Document**. No rupture or leak shall occur during the proof pressure test.

Example Calculation:

Variables:
K_{PROOF} =1.25, MDP = 10.2psi
Ambient Pressure = 14.7psi (assumed value for example only, value may vary depending on ambient conditions at the time of test

Therefore, the required design burstproof pressureproof pressure to be maintained for 15 minutes is:

Design burstProof pressureProof pressure = (1.25*10.2psi) +14.7psi = 26.2psi

The required temperature for the test to maintain the design burstproof pressure shall then be determined from the saturation curve of water. Using the above calculated pressure, this would correlate to a temperature of approximately≈117°C.

9.15 FREEZE OUT TESTING

The freeze-out test shall be performed for the required cycles at the temperatures provided in the **Program Specific Document**. All assemblies of each configuration shall be mounted inside a thermal cycle chamber (no vacuum). The assemblies shall be vertical unless specified otherwise in the **Program Specific Document**. A heater is attached to the evaporator end of each assembly capable of dissipating required power levels in the **Program Specific Document**.

For all assemblies, freeze out testing will be conducted at ambient pressure and at temperatures ranging from -40°C to +40°C with a tolerance of +10/-0°C on the upper temperature bound, and a tolerance of +0/-10°C on the lower temperature bound.±5°C. The required power levels (Q_{MIN}, Q_{MAX}, or Q_V) specified in the **Program Specific Document** shall be applied at the TP_{EVAP} location with a tolerance of ±5%. Dwell time at the extremes shall be a minimum of 1 hour determined by the supplier and is calculated based on the change in heat transfer. This constraint is to be defined by an average change in heat transfer rate which needs to be +/- 0.010 W/min for a durationduration of 15 minutes prior to the ramp up/down. For most CCHP's the calculations are to be defined as:

Assumptions:

$$A_{hp} = \text{Cross\_Sectional\_Area\_Of\_Pipe}$$

$$k_{copper} := 380 \frac{W}{m \cdot K}$$

$$dX = \text{Axial\_Length\_Of\_Pipe\_Between\_TCs}$$

Conductive Heat Transfer Rate Definition:

$$\text{Heat\_Transfer\_Rate}_1 = -k_{copper} \cdot A_{hp} \cdot \frac{dTemp1}{dX}$$

$$\text{Heat\_Transfer\_Rate}_2 = k_{copper} \cdot A_{hp} \cdot \frac{dTemp2}{dX}$$

where dTemp is the change in temperature from time step n to time step n+1

Change in Conductive Heat Transfer Rate:

$$\text{Change\_In\_Transfer\_Rate} = \frac{\text{Heat\_Transfer\_Rate}_2 - \text{Heat\_Transfer\_Rate}_1}{dTime(s)}$$

Average Change in Conductive Heat Transfer Rate:

Average change is defined as the average of Change_In_Transfer_Rate for a 15 minute period prior to ramp up/down

For embedded CCHP systems and VC's, the above assumptions can be modified as necessary to achieve the appropriate calculation.

The TPHTS assembly shall be insulated against excess losses via radiation. Parasitic heat loss (PHL) shall be determined experimentally and used as the basis for actual heater power application. Therefore, for each given power level listed in the **Program Specific Document**, the sum of the nominal power level and the PHL shall be applied to the heater. PHL need only be calculated on the first unit of each dash configuration. This value may be reused on subsequent test units, provided the test setup remains the same.

A cycle is defined as the following sequence which is depicted ~~in **Figure 9-3**~~~~Figure 9-3~~in Figure:

Example:

The chamber is first raised to +40°C. After dwelling at +40°C for 1 hour, the heater is turned on and adjusted to 15W and the chamber ramped to -40°C. The heater power is maintained at 15W through the ramp to -40°C. There is then a 1 hour dwell at -40°C with the heater powered to 15W. The heater is then powered off and the chamber is then ramped back up to +40°C.

The maximum ramp rate shall be 5°C/minute or less. If the ramp rate is deviated from this SEAKR shall be notified. The above procedure is repeated until all required cycles have been completed.

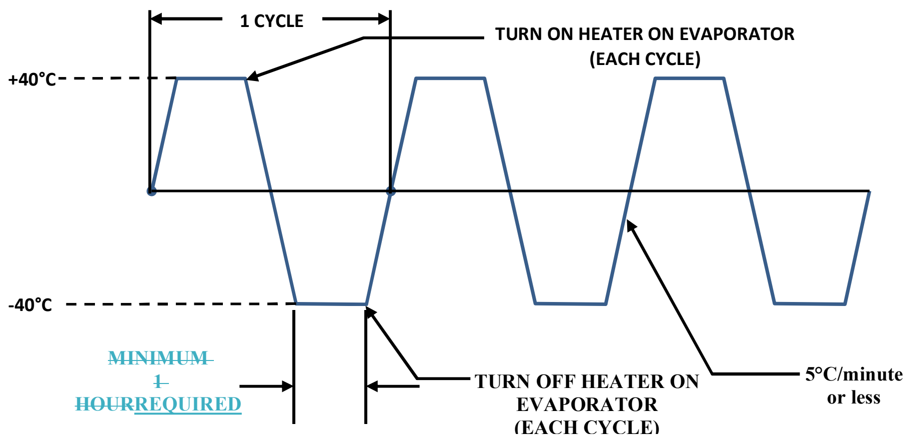

Figure 9-3: Freeze Out Test Cycle Diagram

Data requirements shall be logged and preserved including temperature versus time cycle evidence for the chamber cycles, power applied to the evaporator heaters, and the orientation that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after freeze thaw testing.

~~Data requirements shall include data logged for the chamber cycles, power applied to the evaporator heaters and the orientation (horizontal or vertical) that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after freeze-out testing.~~

9.16 Maximum Design Transport Limit

The transport limit testing shall be set up in the environments as directed in Section 9.29.2 in order to determine the maximum heat transport capability of the TPHTS assembly at a given temperature. For tests conducted in atmosphere, the TPHTS assembly shall be insulated against excess losses via radiation and/or convection. Tested orientations shall be as defined in the **Program Specific Document.** The power applied to the TP_{EVAP} location shall begin with Q_{MAX} with the condenser temperature (TP_{COND}) maintained at the T_{BOUND} defined in the **Program Specific Document.** The applied power shall then be incrementally increased by 5W until the limit of the assembly has been reached and the system begins to exhibit dry out conditions. The temperature tolerance is of +/-2.5ºC ±1.5°C with the power applied at the TP_{EVAP} location at a tolerance of ±5%.

9.17 POWERED FREEZE-THAW TESTING

The powered freeze-thaw test shall be performed for the required cycles at the temperatures provided in the **Program Specific Document**. All assemblies of each configuration shall be mounted inside a thermal cycle chamber (no vacuum). The assemblies shall be vertical unless specified otherwise in the **Program Specific Document**. A heater is attached to the evaporator end of each assembly capable of dissipating required power levels in the **Program Specific Document**.

For all assemblies, powered freeze-thaw testing will be conducted at ambient pressure and at temperatures ranging from -40°C to +40°C with a tolerance of +10/-0°C on the upper temperature bound, and a tolerance of +0/-10°C on the lower temperature ~~bound±1.5°C unless~~bound unless otherwise specified in the **Program Specific Document**. The required power levels (Q_{MIN}, Q_{MAX}, or Q_V) specified in the **Program Specific Document** shall be applied at the TP_{EVAP} location with a tolerance of ±5%. Dwell time at the extremes shall be ~~a minimum of 1 hour~~ determined by the supplier and is calculated based on the change in heat transfer. This constraint is to be defined by an average change in heat transfer rate which needs to be +/- 0.010 W/min for ~~a duration~~duration of 15 minutes prior to the ramp up/down. For most CCHP's the calculations are to be defined as:

Assumptions:

$$A_{hp} = Cross\_Sectional\_Area\_Of\_Pipe$$

$$k_{copper} := 380 \frac{W}{m \cdot K}$$

$$dX = Axial\_Length\_Of\_Pipe\_Between\_TCs$$

Conductive Heat Transfer Rate Definition:

$$Heat\_Transfer\_Rate_1 = -k_{copper} \cdot A_{hp} \cdot \frac{dTemp1}{dX}$$

$$Heat\_Transfer\_Rate_2 = k_{copper} \cdot A_{hp} \cdot \frac{dTemp2}{dX}$$

where dTemp is the change in temperature from time step n to time step n+1

Change in Conductive Heat Transfer Rate:

$$Change\_In\_Transfer\_Rate = \frac{Heat\_Transfer\_Rate_2 - Heat\_Transfer\_Rate_1}{dTime(s)}$$

Average Change in Conductive Heat Transfer Rate:

Average change is defined as the average of Change_In_Transfer_Rate for a 15 minute period prior to ramp up/down

For embedded CCHP systems and VC's, the above assumptions can be modified as necessary to achieve the appropriate calculation.

The TPHTS assembly shall be insulated against excess losses via radiation. Parasitic heat loss (PHL) shall be determined experimentally and used as the basis for actual heater power application. Therefore, for each given power level listed in the **Program Specific Document**, the sum of the nominal power level and the PHL shall be applied to the heater. PHL need only be calculated on the first unit of each dash configuration. This value may be reused on subsequent test units, provided the test setup remains the same.

A cycle is defined as the following sequence which is depicted in Figure 9-4Figure 9-4:

Example:

The chamber is first raised to +40°C. After dwelling at +40°C for 1 hour, the heater is turned on and adjusted to 15W and the chamber ramped to -40°C. The heater power is maintained at 15W through the ramp to -40°C. There is then a 1 hour dwell at -40°C with the heater powered to 15W. The chamber is then ramped back up to +40°C. The subsequent cycles are performed with the heater powered until completion of the test.

The maximum ramp rate shall be 5°C/minute or less. If the ramp rate is deviated from this SEAKR shall be notified. The above procedure is repeated until all required cycles have been completed.

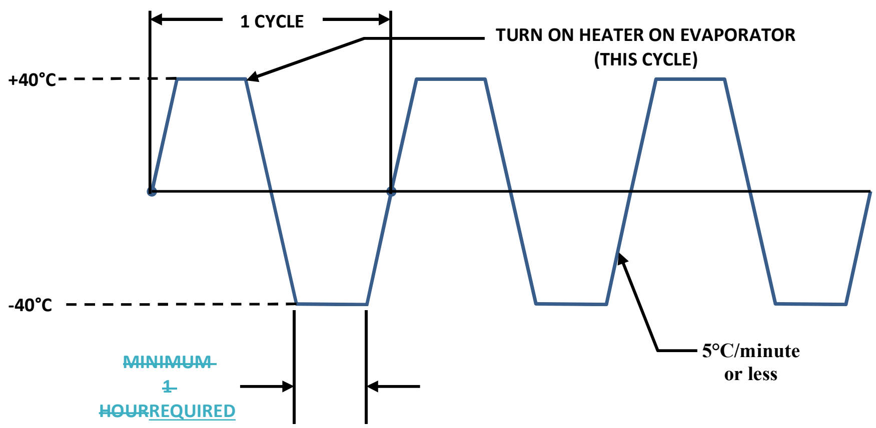

Figure 9-4: Powered Freeze-Thaw Test Cycle Diagram

Data requirements shall be logged and preserved including temperate versus time cycle evidence for the chamber cycles, power applied to the evaporator heaters, and the orientation that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after freeze thaw testing.

~~Data requirements shall include data logged for the chamber cycles, power applied to the evaporator heaters and the orientation (horizontal or vertical) that the heat pipe assemblies~~

~~were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after powered freeze-thaw testing.~~

9.18 ACCELERATED LIFE TEST

The accelerated life test shall be performed at 150°C with the assembly in the vertical orientation. The Life Test duration shall be a minimum of 672 hours in atmospheric pressure. Data requirements shall be logged and preserved including temperature versus time evidence, power applied (if applicable) to the evaporator heaters, and the orientation that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after accelerated life.

~~Data requirements shall include data logged for the temperature delta of the unit and the orientation that the heat pipe assemblies were tested. All assemblies shall not exhibit mechanical failure, thermal failure, or detrimental deformation after accelerated life testing.~~

9.19 GENERAL FUNCTIONALITY TESTING

The THPTS assembly functionality may be verified using manufacturer's best practices either via warm up testing or thermal performance testing in accordance with Section 9.2. If demonstrated through warm up testing, a qualitative measurement against a non-functioning heat pipe shall be included.

10 QUALIFICATION UNIT MARKINGS

Documentation of all acceptance testing data shall be clearly marked to indicate the serialized flight units selected for qualification testing. After completion of all testing, the qualification assemblies shall be marked with red/orange dot in addition to a "-Q" or "-QUAL" immediately following the part and serial number engravings on the part. In addition, the bag containing the part shall be clearly marked with the words "QUALIFICATION UNIT - NOT FOR FLIGHT".

In the event a burst pressure test is conducted as part of a qualification test, the unit shall be marked as specified in this section (-Q or –Qual). All units that have been taken to failure shall have a hole drilled in the evaporator block to identify the units as non-functional hardware. If the unit evaporator and/or condenser blocks become separated from the heat pipe during the test, the unit shall be delivered as is with all pieces included in the package.

11 ~~PREPARATION FOR DELIVERY~~PREPARATION FOR DELIVERY

The packaged assemblies shall be packed in shipping containers that provide adequate protection against damage during shipment. Manufacturer shall bag and tag individual assemblies with part number, serial number, and any other SCD required information in preparation for delivery.

11.1 CLEANING FOR DELIVERY

The completed assemblies shall be visually clean. Additionally, the assemblies shall be cleaned with acetone, or another suitable cleaner, to remove any tape residue or other contaminants (i.e. silicone from thermal transfer material) that may be present or deposited on the assemblies during testing or handling. After cleaning, the completed assemblies shall be baked out at 65°C

± 5°C for a minimum of 1 hour to remove solvents.

11.2 END ITEM DATA PACKAGE

Each TPHTS assembly shall have an end item data package (EIDP) in word or PDF format included with delivery. As detailed below the EIDP meets the intent of AS9102 First Article Inspection Requirement and SEAKR does not require the use of Forms 1, 2 and 3. An example template for the data package is included in Appendix A and must include as a minimum:

1. Certificate of Compliance for wick adhesion cross section test, and arterial features for all EM, Flight, and Qualification assemblies
2. Certificate of Conformance and Certificate of Analysis for for all materials that areis a subcomponent of the final delivered assembling including tubing, wick material, braze, solder andsolder and working fluid used for TPHTS on all EM, Flight, and Qualification assemblies in accordance with 10237
3. All Nonconformance Rework or Repair Documentation including Repair, Rework, Use As Is (if applicable)
4. Documentation of weight for each unit (in grams and pounds)
5. Photographs of as-run setups of horizontal and vertical testing for the first run of each required test per lot.all required tests
6. Temperature versus time cycle plots evidence Certificate of Analysis and evidence for all required EM, Flight, and Qualification unit testing including table of cycle count summaries per test. completion
7. An affirmation statement of successful hermetic screening per Section 9.49.4. This is to be a general statement for the units that pass, no specific data is to be provided as part of the final EIDP
8. Thermal Performance (°C/W) for all power levels (W) specified by the **Program Specific Document** and between the specified locations
   a. For EM, Flight, and Qualification assemblies, two sets of calculations encompassing thermal performance both with and without PHL shall be supplied, per Section 9.2.19.2.1
   a.b. For qualification units, max transport limits per Section 9.16 shall be supplied (when applicable).
9. Material Certifications per the **Program Specific Document** and SEAKR Document 10237Deleted
10. Dimensional Inspection Reports for detail and top-level assemblies
11. Affirmation statement of visual and dimensional inspections conducted per Section 9.19.1
12. Transport capability curves adverse gravity and horizontal in power vs. temperature
13. Photographs of the wick structure bonding verification shall be provided

APPENDIX A: EIDP TEMPLATE

SECTION 1 – CERTIFICATES OF COMPLIANCE
SECTION 2 – MATERIAL CERTIFICATES OF ANALYSIS
SECTION 3 – REPAIR DOCUMENTATION
SECTION 4 – THERMAL PERFORMANCE RESULTS
SECTION 5 – REDUCED THERMAL PERFORMANCE TEST RESULTS
SECTION 6 – TRANSPORT CAPABILITY TEST RESULTS
SECTION 7 – MAXIMUM DESIGN TRANSPORT LIMIT TEST RESULTS
SECTION 8 – HERMETIC SCREENING COMPLIANCE STATEMENT
SECTION 9 – FREEZE-THAW TEST RESULTS
SECTION 10 – POWERED FREEZE-THAW TEST RESULTS
SECTION 11 – COLD START TEST RESULTS
SECTION 12 – FREEZE-OUT TEST RESULTS
SECTION 13 – GAS PLUG TEST RESULTS
SECTION 14 – AGING TEST RESULTS
SECTION 15 – LIFE TEST RESULTS
SECTION 16 – PRESSURE CYCLE TEST RESULTS
SECTION 17 – PROOF PRESSURE TEST RESULTS
SECTION 18 – BURST PRESSURE TEST RESULTS
SECTION 19 – ELECTRICAL RESISTANCE TEST RESULTS
SECTION 20 – INSPECTION RESULTS
SECTION 21 – WICK STRUCTURE BONDING VERIFICATION RESULTS
SECTION 22 – PHOTOGRAPHS OF TEST SETUPS AND TOOLING