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SHEET REVISION STATUS

All sheets are at the same revision

ORIGINATOR Susana Douglas Original signature on file		**DATE**	**FSC: 4540**
APPROVED Lou Fetter Original signature on file			General Specification for Thermofoil Heater, All-Polyimide, Space Applications
ENGINEERING APPROVAL Bruce Meinhold Original signature on file			
CODE 562 SUPERVISORY APPROVAL Kusum Sahu Original signature on file			
ADDITIONAL APPROVAL			**S-311-P-841**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

CAGE CODE: 25306

1.0 SCOPE

1.1 Purpose. This specification establishes the requirements for thermofoil heaters of an all-polyimide (adhesive-less) construction for high reliability space applications. It defines the process, test verification, and inspections required by product used in space flight applications.

2.0 APPLICABLE DOCUMENTS

2.1 Government Specifications, Standards, and Handbooks. The following documents in effect on this date of invitation for bids or requests for proposal form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoD ISS) and supplement thereto, in effect on the date of the contract or purchase order.

Military Standards

MIL-STD-129	Standard Practice, Military Marking for Shipment and Storage
MIL-STD-202	Test Method Standard, Electronic and Electrical Component Parts
MIL–STD–1285	Standard Practice, Marking of Electrical and Electronic Parts
MIL–STD–1580	Test Method Standard, Destructive Physical Analysis for Electronic, Electromagnetic, and Electromechanical Parts

Military Specifications

MIL-DTL-81381	Detail Specification, Wire, Electric, Polyimide-Insulated, Copper or Copper Alloy

National Aeronautics and Space Administration Goddard Space Flight Center (NASA GSFC)

EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating
S-311-M-70	Specification for the Performance of Destructive Physical Analyses (DPA)

2.2 Non–Government Publications. The following documents form a part of this document to the extent specified herein.

American National Standards Institute (ANSI)

ANSI/ISO/IEC 17025	General Requirements for the Competence of Testing and Calibration Laboratories
ANSI/NCSL Z540.3	Requirements for the Calibration of Measuring and Test Equipment

American Society for Testing and Materials (ASTM)

ASTM D5213	Standard Specification for Polymeric Resin Film for Electrical Insulation and Dielectric Applications
ASTM E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

European Space Components Coordination (ESCC)

ESCC 3901/019	Detail Specification, Polyimide Insulated Wires and Cables, Low Frequency, 600V, -200 to 200°C

International Organization for Standardization (ISO)

ISO 9001	Quality Management Systems – Requirements

Society of Automotive Engineers (SAE) International

AS9100	Quality Management Systems – Aerospace Requirements
AS22759	Aerospace Standard, Wire, Electrical, Fluoropolymer Insulated, Copper or Copper Alloy

2.3 Order of precedence. In the event of any conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence. However, nothing in this text shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

3.1 Individual Item Requirements. Heaters supplied to this specification shall be in accordance with the requirements specified herein and the manufacturer's detailed drawing. Any conflict between the requirements of this specification and the heater detailed drawing shall constitute a product non-conformance to this specification, for which performance and reliability cannot be guaranteed.

3.2 Part or Identifying Number (PIN). The PIN shall be as specified in the manufacturer's detailed drawing.

3.3 Temperature rating. Heaters shall meet the temperature requirements below. Note, the maximum operating temperature limit of 220°C corresponds to a zero power level. Appropriate derating should be applied at higher temperatures to account for self-heating.

Storage (non-operating) temperature range: -65 to 220 °C
Operating temperature range: -65°C to 220 °C

3.4 Design and construction. Heaters shall be of the design and physical construction specified herein.

3.4.1 Materials. The heater construction materials shall be in conformance with the requirements specified herein. However, when a definite material is not specified, a material shall be used that will enable the heaters to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guarantee of acceptance of the finished product. All materials used in the design shall withstand the heater operating temperature range specified in paragraph 3.3, with the exception of the backside mounting adhesive.

3.4.1.1 Thermal vacuum outgassing. All construction materials must meet outgassing requirements of 1.0% total mass loss (TML) maximum and 0.1% collected volatile condensable materials (CVCM) maximum, when tested in accordance with 4.5.4.1.

3.4.1.2 Heater element. The heating element shall be composed of a Ni-600 Inconel (nickel-chromium-iron) alloy. Single or dual resistive elements may be used in the design, but must be of a single layer in cross-section. The element(s) shall be an etched foil uniform in cross-section, with a minimum trace width of 0.010 in. (0.0254 cm) by design. Spacing between foil traces shall not be less than 0.010 in. (0.0254 cm) by design. The spacing between the outer foil trace and the heater edge, defined as the border trim, shall not be less than 0.010 in. (0.0254 cm) by design.

3.4.1.3 Base material and protective cover layer. A polyimide (Kapton) layer shall be used as the heater base material, also known as the substrate or mounting surface. A second polyimide layer over the heating element shall provide a protective enclosure.

3.4.1.4 Lead wire. The lead wire color, gauge size, length, and part/specification number shall be in accordance with the heater detailed drawing. Lead wire shall consist of a silver-coated copper alloy conductor and adhere to the applicable

wire specifications and standards listed in section 2.0 of this specification. The wire size shall be a minimum of 26 gauge for high strength copper alloy conductors and 24 gauge for all other copper conductors. Lead wire insulation may consist of polyimide (Kapton), polytetrafluoroethylene (PTFE/Teflon), or ethylene-tetrafluoroethylene (ETFE) materials.

3.4.1.5 Lead termination. The termination of the lead wire shall be of a welded construction, containing a minimum of two weld points between the lead wire and landing bond pad. Lead wire terminations shall be enclosed in a hardened Hysol epoxy potting, in order to secure lead wires to the heater such that lead pull stresses are not transmitted to the weld joint.

3.4.1.6 Backside mounting adhesive (optional). Heaters require the installation of adhesive on the heater backside in order to mount the product in the desired application. The user has the option to install this adhesive post-delivery of the product, or to request product from the manufacturer with installed backside adhesive. In the latter circumstance, a high temperature acrylic adhesive (3M 966 or equivalent) shall be used that meets the outgassing requirements of paragraph 3.4.1.1, and the application thermal requirements in the final installed configuration (as defined by the user). The manufacturer shall only apply the backside adhesive to product after completion of all quality inspections specified in section 4.0 herein. Failure to do so will cause degradation to the adhesive and potential damage to the heaters during voltage conditioning.

3.4.2 Configuration and physical dimensions. The heater outline, terminal lead configuration, and physical dimensions (length, width, and thickness) of the product shall be as specified in the detailed drawing. The dimensional tolerance for length and width shall not exceed ±2% of the dimensional values. The heater thickness, measured over foil traces, shall not exceed 0.010 in. (0.0254 cm) by design, and shall not vary by more than ±0.001 in. (0.0254 mm) of the thickness specified in the detailed drawing.

3.5 Workmanship. Heaters shall be processed in such a manner as to be uniform in quality, and shall be free of any defects affecting life, serviceability, or performance. At a minimum, product shall adhere to the criteria below when inspected per paragraph 4.4.1.

3.5.1 Heater element foil: The foil element shall be free of the defects described below.

3.5.1.1 Localized reduction. Any defect that results in a localized reduction of more than 30% of the heater element width shall constitute a failure. These defects include, but are not limited to, over-etching of the foil trace, voids, mouse-bites, and scratches that fully penetrate through the metal foil to the base polyimide material. Surface scratches are not cause for rejection.

3.5.1.2 Fractures and cracks. The presence of any fracture or crack in the foil element shall be cause for rejection.

3.5.1.3 Element to element and border trim spacing. Any foil defect, such as metal trace protrusions or remaining un-etched foil in the element to element or border trim spacing, shall not reduce the spacing to less than 0.005 in. (0.0127 cm). Bridging between adjacent foil traces shall be cause for rejection.

3.5.1.4 Cross-section. The presence of foil inclusions, raised spots, or other foil defects that result in a non-uniform cross-section, shall be cause for rejection. Over-etching of the foil resulting in a trapezoidal cross-section of the foil trace shall only be cause for rejection if the trace width is reduced by more than 30%.

3.5.2 Base material and protective cover layer: Polyimide (Kapton) base and cover layers shall be free of delamination, blisters, or bubbles that reduce the element to element and trim border spacing requirements to less than 0.005 in. (0.0127 cm). Any delamination between the heating element and the substrate (mounting surface) shall be cause for rejection. Minor scratches, abrasions, and pinholes on the Kapton surface are acceptable provided they do not expose the heater element. Kapton surface indentations and wrinkles are acceptable, provided there is no evidence of delamination. Slight edge separation of the polyimide on the border trim line is acceptable. Nicks, tears, or cuts on the heater edge which have a sharp point and can lead to crack propagation further into the conducting region, shall be cause for rejection. Polyimide protrusions or burrs on the heater edge shall be cause for rejection if detected by the unaided eye.

3.5.3 Lead wire: The lead wire insulation shall be free of cracks, splits, and any nicks or cuts that expose the wire conductor. Minor scratches, abrasions, and deformations of the insulation are acceptable. Evidence of discoloration, corrosion, or flaking of the conductor or conductor plating shall be cause for rejection.

3.5.4 Lead termination. No voids or gaps between the lead wire and landing bond pad shall be present at the weld locations. Surface indentations of the polyimide around or surrounding the lead wire attach region are acceptable, provided there is no evidence of delamination. Punctures in the polyimide substrate at the weld locations are cause for rejection. Excess epoxy from the lead attach potting material shall not extend to the heater backside.

3.5.5 Foreign material: Any loose foreign object debris (FOD) shall be removed from the assembly. FOD entrapped in the polyimide shall be cause for rejection if delamination occurs in the surrounding area or if bridging adjacent foil element traces. Additionally, conductive FOD shall be cause for rejection if it reduces the element to element or border trim spacing to less than 0.005 in. (0.0127 cm). Conductive debris can be characterized by a shiny or bright appearance using bright-field microscopy. Any embedded FOD that causes a projection on the mounting surface is considered rejectable.

3.6 Power rating. Heaters shall have a maximum power rating of 4.5 W/in^2 (0.7 W/cm^2) when suspended in still air at 25°C. Note, this power rating is for test purposes only and is not indicative of the maximum power rating in application (with heater mounted to a heat sink). Actual rated power (or voltage) shall be specified in the detailed drawing. For rated power levels greater than 4.5 W/in^2, the manufacturer shall indicate the mounting adhesive type used when determining the rating.

3.7 DC resistance (DCR). When heater elements are tested as specified in paragraph 4.4.2, the measured resistance shall be within the tolerance of the value specified by the detailed drawing.

3.8 Dielectric withstanding voltage (DWV). When heaters are tested as specified in paragraph 4.4.3, the leakage current between the element and the outer surface shall not exceed 1 mA.

3.9 Insulation resistance (IR). When heaters are tested as specified in paragraph 4.4.4, the insulation resistance shall not be less than 1000 megohms.

3.10 Thermal shock. When heaters are tested as specified in paragraph 4.4.5, there shall be no evidence of physical damage. The change in DCR shall not exceed ±1%.

3.11 Voltage conditioning. When heaters are tested as specified in paragraph 4.4.6, there shall be no evidence of physical damage, including blistering, delamination, or bubbles. The change in DCR shall not exceed ±1%, the insulation resistance shall not decrease, and the DWV leakage current shall not exceed 1 mA.

3.12 Low-temperature operation. When heater elements are tested as specified in paragraph 4.5.2.1, there shall be no evidence of physical damage. The change in DCR shall not exceed ±1%.

3.13 Lead pull strength. When heaters are tested as specified in paragraph 4.5.2.2, there shall be no loosening or fracturing of the lead attachment and no delaminations in the heater element. The change in DCR shall not exceed ±1%.

3.14 Life. When heaters are tested as specified in paragraph 4.5.3.1, there shall be no evidence of physical damage, including blistering, delamination, or bubbles. The change in DCR shall not exceed ±1%, the insulation resistance shall not decrease, and the DWV leakage current shall not exceed 1 mA.

3.15 Marking. Heaters shall be marked with the part number, cage code, date code, characteristics, and ratings. Date code and cage code shall be in accordance with MIL-STD-1285. Markings shall be made with an opaque permanent low outgassing ink and shall remain legible at the end of all performance and quality inspection tests.

3.16 Percent Defective Allowable (PDA). When calculated per paragraph 4.4.8, the cumulative PDA shall be ≤ 10%.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. The manufacturer is responsible for the performance of all inspection requirements, as specified herein. GSFC reserves the right to perform any of the inspections specified herein, where such inspections are deemed necessary to verify conformance to the prescribed requirements.

4.2 Design and source approval. Prior to qualification, the manufacturer's facility shall be subjected to survey at the option of GSFC. Compliance with ANSI/NCSL Z540.3, ANSI/ISO/IEC 17025, or equivalent is required. In addition, the history and detailed engineering of the specific heater design shall be reviewed, as well as the documented manufacturing and quality control procedures. Only those sources approved in the design and source approval phase shall be eligible for qualification or award of contract under this specification. Source approval and design approval do not constitute part lot acceptance or an equivalent thereof.

4.2.1 Qualification. Heaters supplied in full conformance to this specification shall be product which has been granted qualification approval by NASA GSFC.

4.2.1.1 QPLD status. Manufacturers supplying heaters to this specification and pre-approved as a source of supply by NASA GSFC, shall be listed as a qualified manufacturer for this product in the latest revision of the GSFC Qualified Parts List Directory (QPLD).

4.2.2 QPLD summary report. Manufacturers supplying heaters to this specification shall provide an annual product summary to the GSFC QPLD Administrator specified in paragraph 6.2. The summary shall include the total number of lots manufactured to this specification, with pass/fail statistics (inspection lot level).

4.2.3 Retention of qualification. On an annual basis, the manufacturer shall verify the retention of qualification with the GSFC QPLD Administrator. Retention is based on meeting the following requirements:

a. The manufacturer has not modified the design of the item.
b. The specification requirements for the item have not been amended so far as to affect the character of the item.
c. Lot rejection for group A inspection has not occurred.
d. The requirements for group B inspection have been met every 24 months with zero occurrence of failures.
e. The manufacturer has supplied an annual QPLD summary report and group B inspection data every 24 months.

4.2.4 Requalification. Requalification shall be imposed following any change in design, manufacture, materials, or quality control procedures as reviewed and approved during qualification. Requalification shall be required if it is demonstrated that any stipulation initially presented in the manufacturer's certification no longer applies.

Inspection discrepancies that are not suitably explained by failure analysis or by other means, and for which corrective actions have not been implemented, shall also be considered a basis for disqualification by GSFC.

4.3 Classification of inspections. The inspections specified herein are classified as follows:

a. Group A Inspection
b. Group B Inspection

4.3.1 Inspection of product for delivery. Inspection of product for delivery to this specification shall consist of Group A inspection.

4.3.2 Inspection lot. An inspection lot shall consist of all heater products of the same design and construction of a single nominal resistance value and voltage rating, processed as a single lot through all manufacturing steps on the same equipment, and identified by a common date code (see paragraph 3.15).

4.4 Group A inspection. Group A inspection shall be performed on 100% of the product for each inspection lot of heaters supplied to this specification. Group A inspection shall consist of the following tests listed in Table I, performed in the order shown.

Table I – Group A Inspection.

Test / Inspection	Requirement Paragraph	Method Paragraph
Visual and Mechanical Inspection	3.4, 3.5, and 3.15	4.4.1
DCR	3.7	4.4.2
DWV	3.8	4.4.3
IR	3.9	4.4.4
Thermal Shock	3.10	4.4.5
Voltage Conditioning	3.11	4.4.6
PDA	3.16	4.4.8

4.4.1 Visual and mechanical inspection. Visual and mechanical inspection shall be performed using a minimum magnification of 10X, to verify that the physical dimensions, workmanship, and markings are in accordance with the requirements of paragraphs 3.4, 3.5, and 3.15. A Coordinate Measuring Machine (CMM) may be used to verify physical dimensions.

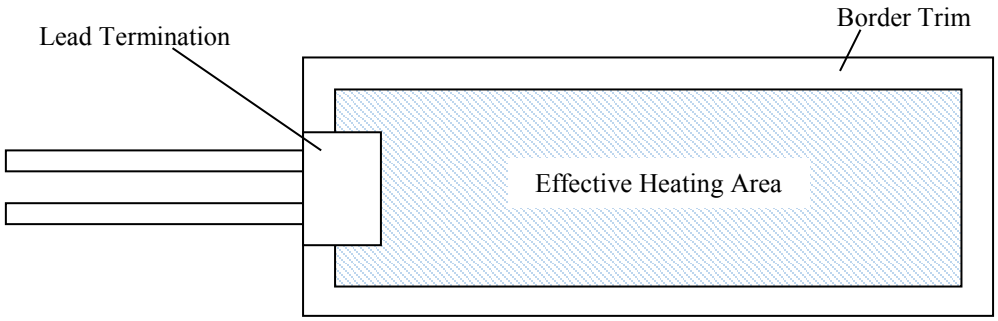
4.4.2 DC resistance (DCR). The DCR shall be measured between the heater leads at 25°C per MIL-STD-202, Method 303 and shall meet the requirements of paragraph 3.7.

4.4.3 Dielectric withstanding voltage (DWV). Heaters shall be tested per MIL-STD-202, Method 301, at 500 VRMS for one minute. The potential shall be applied between the element and conductive plates that are in intimate contact with the complete outer surface of the heater. The measured leakage current shall meet the requirements of paragraph 3.8.

4.4.4 Insulation resistance (IR). The insulation resistance shall be measured between the element and the entire outside surface at 25°C per MIL-STD-202, Method 302, Test Condition B, and shall meet the requirements of paragraph 3.9.

4.4.5 Thermal shock. The unmounted heaters shall be tested per MIL-STD-202, Method 107, Test Condition C, except using a maximum temperature limit of 220°C. Heaters shall meet the requirements of paragraph 3.10.

4.4.6 Voltage conditioning. Heaters shall be conditioned by suspension in still air at 25°C ± 5°C by their terminal leads. The applied voltage shall be the voltage required to reach either the maximum operating temperature of 220°C, as verified by infrared imaging, or the maximum rated power density of 4.5 W/in^2, whichever is higher (see Figure 1 for explanation of voltage calculation based on rated power density). The voltage shall be applied continuously for a minimum of 168 hours, after which the heaters shall meet the requirements of paragraph 3.11. For dual element heaters, both elements shall be powered simultaneously.



The rated voltage (V_{rated}) may be calculated based on rated power density using the formula below:

$$V_{rated} = \sqrt{(P_{rated} \times A \times R_{nom})}$$

where

V_{rated} = Rated voltage (V)
P_{rated} = Maximum rated power density (W/in.^{2})
A = Effective heating area, defined as the total heater area excluding the border trim and the lead wire termination pads (in.^{2})
R_{nom} = Nominal resistance (Ω)

Figure 1 – Sample schematic of a heater shown for the purposes of demonstrating rated voltage calculation based on maximum rated power density.

4.4.7 Failures. Heaters that do not pass Group A inspection shall be removed from the inspection lot and shall not be furnished to this specification.

4.4.8 Lot rejection. PDA shall be calculated by combining all failures identified during Group A thermal shock and voltage conditioning test, and dividing by the total number of heaters submitted to thermal shock test. Failures at visual inspection and initial electrical do not count towards PDA calculation. PDA shall meet the requirements of paragraph 3.16, or the entire inspection lot shall be considered non-conforming product and rejected.

4.5 Group B Inspection. Heaters used for Group B inspection shall have successfully passed all Group A inspections. Group B inspection shall be performed by the manufacturer on sample units produced with equipment, processes, and procedures normally used in production. Data from an established reliability program subjecting the same or similar parts to equivalent or more stringent testing may be submitted for part or all of the Group B inspection requirements. Group B inspection tests and sample size are specified in Table II and below, and shall be performed in the order shown.

Table II – Group B Inspection.

Test / Inspection	Requirement Paragraph	Method Paragraph	Sample Size
Subgroup 1			10
Low-Temperature Operation	3.12	4.5.2.1	
Lead Pull Strength	3.13	4.5.2.2	
Subgroup 2			10
Life	3.14	4.5.3.1	
Destructive Physical Analysis (DPA)	3.4, 3.5	4.5.3.2	1
Subgroup 3 Thermal Vacuum Outgassing*	3.4.1.1	4.5.4.1	2

* In lieu of test, the manufacturer may submit prior outgas test data for identical or similar product that uses the same construction materials, provided the specified requirement and test method are met.

4.5.1 Sample size. The number of heaters to be subjected to Group B inspection shall be 22, as shown in Table II.

4.5.2 Subgroup 1. Sample size shall be ten (10) with zero (0) rejects allowed.

4.5.2.1 Low-temperature operation. The unmounted heaters shall be placed in a chamber at -65°C, and after one-hour stabilization at this temperature, full-rated continuous power (as defined in paragraph 3.6) shall be applied for 45 minutes. Fifteen (15) minutes after removal of power, the heaters shall be brought to 25°C ± 5°C in a period not exceeding 8 hours and DC resistance measured after approximately 24 hours at 25°C. The heaters shall meet the requirements of paragraph 3.12.

4.5.2.2 Lead pull strength. The leads shall be tested per MIL-STD-202, Method 211, Test Condition A at 3 lbs. (1.36 kg) and shall meet the requirements of paragraph 3.13.

4.5.3 Subgroup 2. Sample size shall be ten (10) with zero (0) rejects allowed.

4.5.3.1 Life. Heaters shall have rated power applied for 1000 hours continuously while suspended in still air at 25°C. Heaters shall meet the requirements of paragraph 3.14. The applied voltage shall be the voltage required to reach either the maximum heater operating temperature of 220°C or the maximum rated power density of 4.5 W/in^2, whichever is higher.

4.5.3.2 Destructive Physical Analysis (DPA). Destructive physical analysis shall be performed on one (1) life test sample per GSFC S-311-M-70, and shall additionally meet the requirements of paragraphs 3.4 and 3.5 herein. A minimum of two (x- and y-) axes shall be examined.

4.5.4 Subgroup 3. Sample size shall be two (2) with zero (0) rejects allowed.

4.5.4.1 Thermal vacuum outgassing. Heaters shall meet the requirements of paragraph 3.4.1.1 when tested in accordance with ASTM-E595.

4.5.5 Failures. A failure during group B inspection shall be cause for refusal to grant qualification.

5.0 PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Heaters shall be individually packaged and shall be afforded preservation and packaging in accordance with the supplier's normal commercial practice.

5.2 Packaging. Heaters packaged as specified shall be packed in containers of the type, size, and kind commonly used for the purpose, and in a manner that will ensure acceptance by a common carrier and a safe delivery at the destination. Shipping containers shall comply with the uniform freight classification rules or regulations of other carriers as applicable to the mode of transportation.

5.3 Marking. In addition to any special marking required by the contract or order, unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with MIL-STD-129.

6.0 NOTES

6.1 Ordering data. Acquisition documents should specify the following:

a. Number, title, and date of this specification
b. Part number and/or detailed drawing number
c. Quantity

6.2 Data Address. When supplemental data, reports, or information requests are to be transmitted to GSFC, the following address shall be used, unless otherwise specified.

Custodian: QPLD Administrator
Parts, Packaging, and Assembly Technologies Office, Code 562
Goddard Space Flight Center
8800 Greenbelt Road
Mailstop 562.0
Greenbelt, Maryland 20771

6.3 Notice. When GSFC drawings, specification, or other data are used for any purpose other than in connection with a definitely related GSFC procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; the fact that GSFC might have formulated, furnished, or in any way supplied the said drawings, specification, or other data is not to be regarded by implication or otherwise in any manner licensing the holder or any person or corporation, or conveying any right or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

6.3 Approved source(s) of supply. Identification of the suggested source(s) of supply hereon is not to be construed as a guarantee of present or continued availability as a source of supply for the item.

6.4 Use and application information. The following precautions should be noted when selecting a heater design for space flight use.

6.4.1 Lead wire application information. Polyimide or Teflon insulated lead wire are the vendor preferred use in the specified heater construction, due to the high temperature properties associated with these insulation types. However, the user should always take the necessary precautions when selecting an appropriate lead wire type in their particular application.

6.4.1.1 Polyimide insulation. Polyimide wire may be preferred for its light weight and excellent mechanical, electrical, and radiation resistance properties. However, the insulation of this wire has known reliability problems in certain applications. Extended exposure to moisture or alkaline cleaning chemicals has been shown to degrade the insulation's mechanical strength, resulting in flaking of the outer insulation tape, and cracking from vibration or movement when installed around tight radius bends. Therefore, the user should ensure the wire insulation will NOT be used in such a way that allows for the potential of repeated mechanical wear such as chafing, or any movement that can cause abrasions or cuts in the insulation.

6.4.1.2 Teflon insulation. When using Teflon insulated wire, the user should use caution to prevent compression or pinching of the insulation, due to its cold flow (creep) characteristics. The user is advised NOT to route Teflon insulated wires over sharp edges and tight turns, or apply tight stitches and tie wraps to the wire.

6.4.2 Radiation performance. The user is cautioned to evaluate the radiation resistance of the heater construction materials specified herein for the intended space environment in their particular application. While Kapton is known to be highly resistant to radiation effects, Teflon insulation of lead wire can be degraded by solar radiation above 5×10^5 rads. Polymers, in general, should be closely evaluated for radiation resistance.

6.4.3 Mounting application information. When applying a mounting adhesive to the heater backside, avoidance of air entrapment and bubbles is essential to achieve desired performance. The same is true when physically mounting the heater to the heat sink. Adhesive and mounting application practices recommended by the manufacturer should be used. It is important to select an adhesive that will maintain the bond throughout the design life in the application. In addition, it is recommended to apply a fillet of adhesive between exposed heater edges and the surface onto which the heater is being mounted, especially if being mounted on a curved surface. Additional mounting practices may be required when mounting to curved surfaces with small diameters. At any time, the heater should never be flexed at a radius of curvature smaller than 0.03 in. The lead termination region should never be flexed and should remain mounted on a flat surface.