REVISIONS			
SYMBOL	DESCRIPTION	DATE	APPROVAL
A	Document completely revised and rewritten and retitled. Previous revision level (original issue) usable on prior contracts citing S-311-320. Previous revision level (original issue) not usable in any contracts after issue of this Revision (A).	1/27/94	

SHEET REVISION STATUS

SH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
REV	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
SH	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
REV	A	A	A	A	A	A														

ORIGINATOR Q.GhulamAli/Unisys	DATE 12/29/93	FSC: 5950
APPROVED W.B.THOMAS, III/GSFC/312	1/6/94	GENERAL SPECIFICATION FOR SIMPLE CUSTOM ELECTROMAGNETIC ASSEMBLIES
APPROVED PARTS ENGINEERING SECTION	1/27/94	
APPROVED HEAD, PARTS BRANCH	1/27/94	S-311-320 REV A

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

CAGE CODE: 25306

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1. SCOPE

1.1 **Scope.** This specification covers the general requirements and quality assurance provisions for processing, inspecting, and testing of simple custom electromagnetic assemblies. This specification is approved by the Goddard Space Flight Center for use in applications requiring Grade 2 or Class C parts. The requirements of this specification shall apply (i.e., be flowed down) to any vendor or sub-tier vendor manufacturing devices for GSFC Grade 2 or Class C applications.

1.2 **Classification.**

1.2.1 **Classes.** Two classes of requirements are defined in this specification:

Grade 2 (Class B, MIL-STD-981) and
Class C (GSFC only).

1.2.2 **Types.** The devices covered by this specification are classified into five types of construction:

1.2.2.1 **Type 1.** Toroidal inductors or transformers of ferrite or molypermalloy powder core construction. This construction employs an insulated toroid (taped or epoxy coated) wound with a specified number of turns of magnet wire. The winding may be vacuum impregnated with epoxy, polyimide or other material to protect it from the environment.

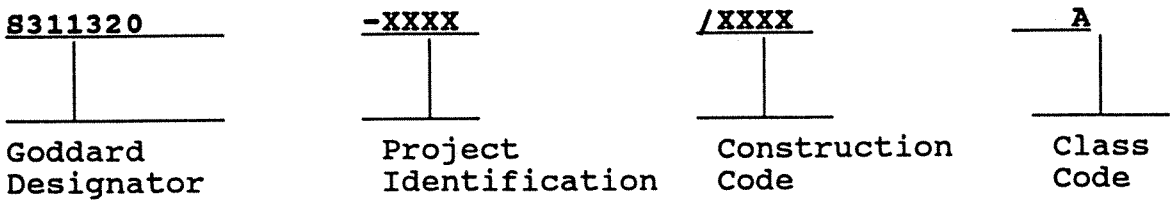
1.2.2.2 **Type 2.** Transformers of ferrite pot-core construction. The pot-core consists of two ferrite core pieces and a prewound bobbin wound with a specified number of turns of magnet wire. The wound bobbin is placed inside the center of the pot core. The assembly is held together using a screw, spring washer and a nut.

1.2.2.3 **Type 3.** Transformers having the C-core construction. This type of construction may utilize a single core, single coil; single core, double coil; or double core, single coil type construction. This type of construction may also utilize tape wound nickel-iron C-cores.

1.2.2.4 **Type 4.** Transformers having the E-core construction (lattice wound). The core consists of two E-core pieces matched against each other. The center leg can be gapped or ungapped. Magnet wire is wound over an insulation placed around the center leg of one E-core piece. The other E-core piece is then matched against the first one. The assembly is held together by suitable means. This type of construction is suited to both low and high voltage transformer designs.

1.2.2.5 **Type 5.** All of the above types that are either impregnated or encapsulated with an epoxy or potting compound.

1.3 **Part Number.** Magnetic devices manufactured in accordance with the requirements of this specification shall be identified by a Goddard part number as follows:



1.3.1 **Goddard designator.** Designates product manufactured to this specification.

1.3.2 **Project Identification.** A unique designator of four alphanumeric characters which identifies the GSFC project for which these devices are manufactured.

1.3.3 **Construction Code.** A four-digit number which identifies the device type.

1.3.4. **Class Code.** A single letter which identifies the application requirements: B for Class B (Grade 2) and C for Class C.

1.4 **Detail Specification.** Specific requirements, including, but not limited to, materials of construction, number of wire turns, special construction methods or requirements, and any specific test or inspection requirements beyond those required by this specification, shall be specified in a detail drawing for each detail part number.

2. APPLICABLE DOCUMENTS

2.1 **Documents.** The following documents 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 (DoDISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

FEDERAL

J-W-1177	-	Wire, Magnet, Electrical
QQ-S-571	-	Solder, Tin Alloy; Tin-Lead Alloy and Lead Alloy

TT-I-735	-	Isopropyl Alcohol

MILITARY

MIL-T-27	-	Transformers and Inductors (Audio, Power and High-Power Pulse), General Specification For
MIL-F-14256	-	Flux, Soldering, Liquid, Paste Flux, Solder Paste and Solder-Paste Flux, (For Electronics/Electrical Use), General Specification For
MIL-W-22759	-	Wire, Electric Fluorocarbon Insulated, Copper or Copper Alloy

STANDARDS

MILITARY

MIL-STD-202	-	Test Methods for Electronic and Electrical Component Parts
MIL-STD-1285	-	Marking of Electrical and Electronic Parts
MIL-STD-45662	-	Calibration System Requirements
MIL-STD-981	-	Design, Manufacturing and Quality Standards for Custom Electro-magnetic Devices for Space Applications

(Copies of federal and military specifications and standards are available from the Standardization Documents Order Desk, Building 4, Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

OTHER PUBLICATIONS

American Society For Testing and Materials (ASTM)

ASTM-E-595	-	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Material from Outgassing in a Vacuum Environment.
ASTM-D-2240	-	Standard Test Method for Rubber Property-Durometer Hardness

(Application for copies should be addressed to the American Society for Testing and Materials, 12916 Race Street, Philadelphia, PA 19103-1187.)

National Aeronautics and Space Administration (NASA)

NHB 5300.4 (3A) - Requirements for Soldered Electrical Connections

NASA RP-1124 - Outgassing Data for Selecting Space Craft Materials

(Non-Government Standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries, other information services or through the applicable GSFC Project Office.)

2.2 **Order of precedence.** In the event of a conflict between the text of this document and any references cited herein, the order of precedence in descending order shall be:

a. The detail drawing or specification.

b. This document.

c. A cited reference.

However, nothing in this document or a detail specification shall supersede applicable laws and regulations unless a specific exemption has been made.

3. REQUIREMENTS

3.1 **Detail requirements.** The individual item requirements shall be as specified herein and in the applicable detail drawing or specification (see 1.4).

3.2 **Physical dimensions.** The dimensions shall be as specified in the applicable detail drawing for the individual device type.

3.3 **Weight.** Inductors and transformers shall not exceed any weight specified in the applicable detail drawing or specification.

3.4 **Workmanship.** Inductors and transformers shall be processed in such a manner to be uniform in quality when inspected in accordance with 4.6.1. Devices shall be free of defects that will affect life, serviceability, or performance.

3.5 **Electrical characteristics.** When subjected to tests specified in 4.6.5 the devices shall meet the requirements specified in the applicable detail drawing for each part number. The test methods and conditions shall be as specified in 4.6.5.

3.6 **Materials**

3.6.1 **Materials.** The requirements for materials shall be as specified in this document. However, when a definite material is not specified, a material shall be used which will enable the device to meet the performance requirements. Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of finished product.

3.6.1.1 **Outgassing.** Materials used in inductors and transformers for a space flight application shall not exceed a maximum total mass loss (TML) of 1.0 percent and a maximum collected volatile condensable material (CVCM) of 0.1 percent when tested in accordance with ASTM-E-595. Certificate(s) of compliance for using acceptable materials listed in NASA Reference Publication 1124 may be substituted in lieu of testing.

3.6.1.2 **Magnet wire.** Magnet wire shall conform to and be the types and sizes specified in Federal Specification J-W-1177 and shall be of the appropriate temperature class for the maximum temperature within the winding. Magnet wire used for inductor or transformer windings shall conform to the size limitations of Table I. Temperature rise limits specified in a detail drawing shall be observed in selecting wire sizes. Procuring activity approval shall be required when other types and sizes of magnet wire are used.

TABLE I. Wire Limitations for Magnet Wire

Device Type	Minimum Wire Size (AWG)	
	Grade 1 (Class B)	Class C
Inductor	40	44
Transformer	44	44

3.6.1.2.1 **Classes and Types of magnet wire.** Magnet wire used in the design and construction of parts shall be of the following Class and Type:

a. J-W-1177/9 solderable polyurethane resin with a superimposed coating of polyamide resin, Type SUN2, Class 130.

b. J-W-1177/12 polyester-imide or polyester-amide-imide, Type H2, Class 180.

c. J-W-1177/14 polyester, polyester-imide or a polyester-amide-imide resin with a superimposed

coating of polyamide-imide resin, Type K2, Class 200.

d. J-W-1177/15 polyimide resin, Type M2, Class 220

NOTE: Single layer polyester (Isonel*) insulated wire with a polyurethane resin (Gripeze*) overcoat is considered suitable for use in high voltage transformers. The wire is solderable without stripping.

* Isonel is a trademark of the Schenectady Chemicals and Gripeze is a registered trademark of the Phelps Dodge Company.

3.6.1.2.2 **Magnet wire acceptability.** Magnet wire used in the design and construction of devices manufactured in accordance with this specification shall meet the following criteria:

Criteria A (Initial procurement).

a. Magnet wire procured for use in devices manufactured to the requirements of this specification shall not be older than two years from the date of its manufacture.

b. The magnet wire supplier shall submit Certificate of Compliance that the wire meets the Groups A, B, and C inspections of Federal Specification J-W-1177.

c. Magnet wire shall be stored continuously in a clean controlled environment at a temperature of +25 degrees Celsius (±5°C), at no less than one standard atmospheric pressure, and at a relative humidity of between 30 and 70 percent. Storage shall preclude the wire from being damaged by abrasion or contact with other objects.

Criteria B (Extended use).

a. Magnet wire can be used for an additional 3 years provided that the device manufacturer's written procedures show compliance to all requirements stated in criteria A. Additionally, prior to each use for a given project or application, a twelve inch wire sample shall be taken from the applicable wire spool. The wire sample shall be wound on a bobbin or spool of similar size and shape and annealed at +125 degrees Celsius for 1 hour. One end of the wire, two inches in length, shall be bent backwards to approximately the same radius as the winding. The end shall be immersed

in clean isopropyl alcohol for 20-30 seconds and dried. The wire shall be examined under a microscope of 3x to 10X magnification. Wire that shows crazing (microscopic cracks on the surface) or peeling (strippable outer insulation) shall be annealed for an additional 1 hour and reexamined. If crazing or peeling persists after this second annealing, the entire spool shall be rejected for use in assembling devices to this specification.

b. Wire older than five years from the date of its original manufacture shall be evaluated to verify its performance for up to an additional two years in accordance with (c), below. Upon passing this evaluation, the wire shall be usable for a period of one year.

c. A two feet length of magnet wire from each applicable wire spool shall be subjected to the following tests by the device manufacturer or by an outside laboratory approved by the procuring activity. The tests shall be performed in accordance with the requirements of Federal Specification J-W-1177. The wire sample shall pass the following evaluation tests:

   i. visual and dimensional requirements,

   ii. adhesion and flexibility test, including the mandrel test,

   iii. elongation,

   iv. springback, and

   v. dielectric breakdown at rated temperature.

3.6.1.3 **Insulated wire (when applicable).** When insulated wire is used as wire terminals, the wires shall be of the types and sizes specified in MIL-W-22759. Wire size shall conform to the limits of Table II. Procuring activity approval shall be required when other types and sizes of insulated wire are used as terminals.

3.6.1.4 **Termination limitations (when applicable).** Internal wire leads, when used, shall be attached to the coils, shields, terminals or case by soldering, welding, brazing, crimping or other method (e.g., lead-sweating of nylon-coated wires) in such a manner as to provide adequate electrical connection and mechanical strength. Where soft solder is used to provide the electrical connection, wire leads shall be anchored mechanically. Wire sizes shall conform to the limits specified in Table II.

TABLE II. Termination Limitations

Type of Termination	Minimum Terminal/Self Lead Wire Size (AWG)	
	Class B	Class C
External terminal or self lead	28	28

3.6.1.5 **Bobbin.** Unless otherwise specified, bobbins for use in "C", "E" or pot core type transformers shall be of acetal resin (Delrin*) or glass epoxy grade G-11 material.

* Delrin is a registered trademark of the Du Pont Company.

3.6.1.6 **Solder and Soldering flux.** Solder, when used, shall be in accordance with Federal Specification QQ-S-571, except that pure tin shall not be used. Soldering flux shall be in accordance with MIL-F-14256, type R or RMA for Class B or C.

3.6.1.7 **Plating/finish.** All metallic surfaces including mounting screws, nuts, washers and terminals shall be protected against corrosion. Cadmium or zinc plating shall not be used on any surface exposed to the space environment. Tin plating, when specified, shall be in accordance with MIL-T-10727 or electro-tin fused, except that the minimum lead content shall be 3 percent. Pure tin plating is prohibited as a final plating or as an undercoat.

3.7 **Radiographic inspection.** When specified, the devices shall be subjected to radiographic inspection in accordance with the requirements of Appendix A of this document.

3.8 **Marking.** Devices shall be marked on the part as specified in the procurement document or detail specification. Identification shall include, as a minimum, the part number, terminal(s) identification, lot date code, procurement document number, and CAGE code (if applicable). Marking shall conform with Method I of MIL-STD-1285. If marking cannot be placed directly on the device, the device shall be tagged.

3.9 **Manufacturing practices.** The manufacturer shall prepare written procedures specifying processes used for receiving inspections of component materials and for constructing and testing transformers and inductors. These manufacturer procedures shall, as a minimum, conform to the requirements of this specification. Any changes in procedures shall be submitted in writting to the procuring activity for approval

prior to implementing the change. Failure to provide prior, written notification may constitute sufficient reason for GSFC withdrawing approval for manufacturing and supplying devices under this specification.

3.9.1 **Clean handling.** Operators shall wear clean gloves free of oil and talc or wear finger cots during assembly operations. Magnet wire spools shall be handled ONLY by the rims of the spools. Materials and piece parts being stored or transferred to or between work stations shall be kept in static free containers or bags which keep the materials and parts free of dust.

3.9.2 **Solvents.** Magnet wire crazing may result from uncontrolled exposure to solvents, such as water or alcohol. Using alcohol or alcohol-based solvents for cleaning magnet wire or assemblies shall be controlled and documented in the manufacturing process procedures.

3.9.3 **Work areas.** Work and inspection areas shall be kept clear of all foreign materials prior to and during assembly or inspection of devices being manufactured under this specification. The work areas used for assembling or inspecting shall not be used to store any parts or materials used on any other devices.

3.9.4 **Carriers.** Wound cores, coils or bobbins shall not be carried or stored on pegboards with nails or be placed on any surface that may cause damage to their wire or insulation. Any carriers used shall be covered with a material that will prevent contamination of the devices by dust or other particulate materials during transport and storage.

3.9.5 **Travelers.** A lot traveler specifying each manufacturing and inspection operation in the proper sequence, shall be provided with each lot of devices. During manufacture and inspection, each operator or inspector shall record the date and initial or stamp the lot traveler for each operation (or inspection) prior to moving the devices to the next operation or work station.

3.9.6 **In-process inspection.** All critical in-process operations used in manufacturing these devices shall be inspected by a qualified inspector or operator. All inspection points shall be specified in the manufacturing process document. The device examination shall include, but not be limited to, inspection for conformance to the construction and workmanship criteria specified below.

3.9.6.1 **Lead wires.** Lead wires, if used, shall have stress relief of at least three times the insulated wire diameter whenever practical. Stress relief loops shall not interfere with other conductive paths. For any

bend, the radius of the bend shall not be less than three times the insulated wire diameter. In addition, the magnet wire shall also have adequate stress relief and shall be anchored to the coil. A device that has a sharp bend in any lead wire (solid or stranded) and shows neckdown shall be rejected.

3.9.6.2 **Crossover of turns.** There shall be no uninsulated crossover of any one turn in any one layer of insulated, interleaved layer-wound coils, nor any crossover to an adjacent winding segment of toroidal or cylindrical coils wound in segments. All situations where the voltage stress exceeds the ability of the magnet wire insulation to withstand it shall be avoided.

3.9.6.3 **Splices.** Magnet wires shall not be spliced within the same winding nor shall lead wires be spliced to windings of the same size. Solder connections of magnet wires between windings, series connections of designed multi-wound series windings, or winding connections to lead wires shall not be regarded as a splice, within the definition of this section.

3.9.6 4 **Cores.** Prior to processing, all cores and bobbins shall be inspected visually by the operator for the following:

a. "C" cores and "E" cores shall not show distortion, misalignment of pole faces, nicks or burrs, excessive spacing in the gap, or any other defect that may affect device performance.

b. Ferrite Pot-Cores shall be free of cracks and chips. Chip-outs (resulting from ferrite manufacturing) smaller than 0.02 inch in their largest dimension that do not reduce the magnetic path cross section by more than 5 percent shall be acceptable.

c. All molypermalloy powder cores (MPP) shall be coated by phenolic resin or epoxy impregnation to provide a minimum breakdown strength of 500 V rms.

d. Bobbins shall be free of sharp edges or irregular surfaces to minimize damage to the winding.

3.9.6.4.1 **Protective coating.** When possible ferrite and powder toroidal cores shall be epoxy or parylene coated or be tape wrapped prior to winding. Wire shall be protected from abrasion in areas of contact with core.

3.9.6.4.2 **Rejection criteria.** Cores that fail to meet one or more of the requirements specified in 3.9.6.4 and 3.9.6.4.1 shall be removed from the lot. Rejected parts shall not be used in any magnetic assemblies for space flight applications.

3.9.7 **Cleaning operations.** All cores, bobbins and metal parts shall be cleaned using suitable solvents such as acetone, methyl alcohol, and deionized water. After cleaning the devices shall be oven-dried at 100 degrees Celsius for 2 hours. Parts shall be stored in clean boxes or bags.

3.9.8 **Coil windings.**

3.9.8.1 **Tension.** A suitable device shall be used to provide a uniform tension during machine winding of any coil having a wire size number of 18 AWG or finer. Tension control on wire larger than 18 AWG is preferred but not mandatory. For winding machines which cannot accommodate any tension device, other criteria shall be established. For coils wound on square forms, special provision must be made to prevent excessive tension on the corners. This device and the winding machine used shall be inspected for proper operation prior to beginning the winding of each lot. Any portion of a tensioning device which contacts the magnet wire (pulleys, sliders, etc) shall be free of nicks, burrs, rough spots, or any other defect that could damage the coil wire.

3.9.8.2 **Wire breaks.** There shall be no wire breaks for **any** winding within the coil. The winding operation is considered complete only when the coil has been wound with an unbroken winding. Should the magnet wire break during winding it may be unwound and rewound with new wire. In no case may a broken coil wire be repaired. If magnet wire opens after the device is assembled, the device shall be rejected. Devices designed as multi-series connected windings are not identified as wire breaks within the definition of this paragraph.

3.9.8.3 **Crossed wires.** Coil windings shall be even and smooth. For **interleaved insulated layer-wound** coils, no uninsulated turns shall cross over other turns. For **toroidal, cylindrical** or **random wound bobbin** coils wound in segments, there shall be no uninsulated cross-over of any one turn to an adjacent winding segment.

3.9.8.4 **Kinks, nicks, and damaged insulation.** No kinks, nicks, or insulation damage shall be introduced during coil winding.

3.9.8.5 **Tapes.** Use of pressure-sensitive adhesive tapes shall be kept to a minimum. The adhesive system shall meet the outgassing requirements of 3.6.1.1.

3.9.8.6 **Bobbin Winding.** Bobbin (molded spool) winding shall be performed in accordance with the manufacturer's winding drawing or specification and shall include as a minimum the following:

a. For bobbins designed for use in a high density layer winding, the first turn shall be kept flush to the flange. All others shall be even from flange to flange.

b. Tension shall be maintained to reduce stretching of magnet wire to minimize changes in its electrical characteristics.

c. If for any reason work stops during the winding process, the wire shall be taped to maintain tension until work resumes.

d. A gap or void in layers shall be avoided to eliminate wedging of wire into the gap. If there is a gap next to a spool flange or if a turn next to a flange is too tight, wire may try to wedge down between the flange of previously wound layers causing the flange to bow out. This could cause extreme pressure on the winding or winding layers and lead to a short circuit (catastrophic failure) between turns or layers.

e. In a pot core transformer, the outermost layer in a wound bobbin shall be constrained to within 0.003 inches of the bobbin edge to allow adequate electrical clearances.

NOTE. Take care to protect winding or winding layers near the spool flange (edge) by wrapping with insulated tape whenever permissible.

3.9.8.7 **Toroidal winders (when applicable).** Shuttle rings and sliders shall be inspected for nicks, burrs and rough spots. Toroidal inductors or transformers shall be inspected visually for physical damage after removal from the shuttle.

3.9.8.8 **De-reeling.** De-reeling (de-spooling) of devices shall be such that it will not cause variations in tension beyond the control of the tension device. All portions of the device which contact the magnet wire (pulleys, sliders, spool flange, etc) shall be free of nicks, burrs, and rough spots.

3.9.9 **Soldering.** Soldering and preparation for soldering shall conform to NHB 5300.4 (3A). Any standard used in lieu of or in addition to NHB 5300.4(3A) shall require approval of the procuring activity.

3.9.10 **Impregnation and encapsulation.** These requirements (3.9.10) are applicable only to Type 5 transformer assemblies or to other assemblies using these processes.

3.9.10.1 **Pre-pot visual examination.** Prior to device potting, a visual examination shall be made using a microscope of 3X to 10X power magnification to ensure the device conforms to the requirements specified in 3.9.10.8

3.9.10.2 **Drying.** Before impregnating and potting, all devices shall be dried at sufficient temperatures and for a sufficient length of time to remove all moisture and cure all tapes. Vacuum drying of devices is preferred. Devices shall be impregnated within 20 minutes after being removed from the drying oven or vacuum chamber. If this is impractical, the devices shall be stored in controlled dry atmosphere. If the devices are exposed to a relative humidity greater than 30 percent for 30 minutes or more, they shall be redried at a sufficient temperature and for a sufficient length of time to remove all moisture.

3.9.10.3 **Impregnation.** Each device shall be impregnated in an appropriate chamber to assure thorough, void-free impregnation, when applicable.

3.9.10.4 **Curing.** The cure schedule shall be sufficient to cure the impregnation and potting compound completely throughout the device. Impregnating, potting and bonding materials shall be cured in vacuum in accordance with their manufacturer's recommendations or product bulletin.

3.9.10.5 **Preparation of cups or molds.** Cups or molds shall be prepared for potting or impregnating as follows:

a. Plastic or metal cups shall be cleaned with solvents that will not degrade the part, such as commercial grades of isopropyl alcohol, acetone, Stoddard solvent, or equivalent. Plastic cups shall be sandblasted or otherwise etched on their inside surface to assure good resin adhesion to the cups.

NOTE: Cleaned inner surfaces shall not be touched with bare hands or fingers. Cups or molds shall be stored in a clean environment after they are cleaned.

b. Wipe molds with the same solvents used in (a) above to remove visible dust, dirt, and other undesirable matter.

c. The final rinse on cups and molds should be done with the same solvent(s) used in their initial cleaning (a, above).

3.9.10.6 **Impregnating and potting compounds.** All impregnating and potting compounds must be **degassed** prior to impregnating and potting. Pot life of these compounds shall be in accordance with the manufacturer's recommendations or data sheets and shall not be exceeded. All potting materials shall be dated for expiration of their shelf life and shall not be used after this date.

3.9.10.7 **Equipment.** Vacuum chambers and other impregnation or potting equipment shall be capable of maintaining the required pressure and temperature for the time period specified in the detail drawing. The chamber interior, chamber lid seal, resin containers and device holding fixtures shall be free of dirt and other foreign materials that may inhibit proper operation of the equipment.

3.9.10.8 **Voids.** Devices shall be potted or encapsulated in a manner to prevent voids, bubbles, and cracks.

3.9.10.8.1 **Internal voids.** There shall be no internal voids greater than 0.015 inch in the largest dimension located within 0.005 inch of any conductor, solder joint, or terminal. The total volume of all voids and the volume of any one void shall not exceed 10 and 5 percent, respectively, of the total volume of encapsulant within the device. Any voids shall not jeopardize the mechanical or functional integrity of the device.

3.9.10.8.2 **Surface voids and depressions.** Surface voids and depressions shall not reduce the thickness of the covering over internal parts to less than 0.060 inch.

3.9.10.8.3 **Extraneous material.** Care shall be taken to ensure that extraneous material is not introduced during the potting process.

3.9.11 **Product conformance.** Devices manufactured in conformance with a detail drawing and this specification shall meet all the specified requirements for that product. Lack of a specified quality conformance inspection or qualification test for determining conformance to a specific requirement shall not relieve any device from meeting that requirement.

4.0 QUALITY ASSURANCE REQUIREMENTS

4.1 **Inspection conditions.** Unless otherwise specified, all inspections, measurements and tests shall be conducted at a temperature of +25°C (±5°C), a pressure of no less than one standard atmosphere and a relative humidity of between 30 and 70 percent.

4.2 **Chamber environmental control.** Chambers used in testing of devices shall have as a minimum:

a. Controls capable of maintaining the temperature of any single reference point within the working area to ±2°C (±3.5°F).

b. A temperature uniformity within the chamber so that the temperature at any given point shall not deviate more than 3°C (5.4°F) from the reference point.

4.3 **Inspections required.** The inspections and tests for simple custom electromagnetic devices covered by this specification are classified as:

a. Qualification Inspection.

b. Quality Conformance Inspection.

4.4 **Qualification inspection.** Devices designed and manufactured in accordance with these specification requirements and an applicable detail drawing shall be capable of meeting all of the qualification tests specified in para. 4.6 of MIL-T-27. Qualification tests are performed at the discretion of the procuring activity to determine if the devices supplied in accordance with this specification meet the requirements stated herein. Unless otherwise specified in the procurement document or Non-Standard Parts Approval Request (NSPAR), performing qualification tests by a manufacturer is not required by this specification. Other transformers constructed using the same design, materials, processes and manufacturing methods shall be considered qualified under the provisions of this specification (qualification by similarity). Additional qualification tests shall not be required unless specifically requested by the procuring activity.

4.4.1 **Type 5 transformer qualification.** Type 5 transformer assemblies only (i.e., encapsulated assemblies) and excepting high voltage transformers shall be subjected to five (5) life cycles a week for a minimum of twelve (12) weeks i.e., a total of 2016 hours. Four (4) of these cycles shall consist of a twenty (20) hour period during which the transformers are operated at a temperature of 85 degrees Celsius with electrical conditions as specified in the detail drawing or specification and a four (4) hour period of operation at room ambient temperature without excitation. The fifth cycle of the week shall be a sixty-eight (68) hour period at a temperature of 85 degrees Celsius and a four (4) hour period of excitation at room ambient temperature. An electrical test circuit shall be devised so that an open circuit or short circuit during

this life cycle test shall be detected and the time of failure recorded.

Upon completion of the life test, transformers shall be tested for insulation resistance and dielectric withstanding voltage (at reduced voltage). Samples also shall be examined for physical and electrical damage. The procuring activity shall be notified within 48 hours of any failures. Catastrophic failures (electrical failures, physical damage) shall be subjected to failure analysis to determine the cause of failure.

4.4.2 **High voltage transformer assembly qualification.** Transformers that are designed for high voltage use in the ultra-high vacuum of space shall be subjected to a corona discharge test. The device to be tested shall be mounted on a suitable test fixture or board prior to placing it in the chamber. The oscilloscope shall have the sensitivity to indicate low discharge levels and shall have a reasonably uniform response up to 200 kilohertz. The test voltage shall be applied under pressure and shall be equivalent to pressures ranging from sea level to the altitude or vacuum specified in the detail drawing or specification. The applied voltage shall be increased slowly to generate an output voltage equivalent to 1.5 times the nominal output voltage. The device shall be observed for distortion in waveform and flow of excessive current through the windings.

4.5 **Quality conformance inspection.** Quality Conformance Inspection (QCI) shall be performed on all devices, i.e. 100 percent inspection. Tests applicable to a particular device type shall be as specified in Table IV. Test requirements shall be as specified in para. 4.6. of this document.

Any device that fails to meet the individual device requirements specified in the detail drawing shall be removed from the lot and shall not be used as flight hardware. Unless otherwise specified, the manufacturer shall be responsible for performing all inspection requirements specified herein. The procuring activity reserves the right to perform any of the inspections set forth in this specification and the detail drawing where such tests are considered necessary to assure device conformance to their requirements.

4.5.1 **Inspection lot.** Devices shall be produced in lots or sublots. An inspection lot shall consist of all inductors and transformers of the same part number, part type, and class. Each device within a given lot shall be wound with the wire traceable to the same wire draw lot, wound on the same machine or hand wound by the same operator, and have all other operations performed without change in processes.

4.5.1.1 **Grade 2 (Class B).** Devices within each lot shall be serialized. The lot information shall include lot identification, quantity, date of operation, and operator identification.

4.5.1.2 **Class C.** The lot control requirements are the same as for Grade 2 (Class B) devices. Requirement for serialization of Class C devices is not mandatory.

4.5.2 **Lot acceptance.** If during the 100 percent quality conformance inspection the number of failures exceeds the number allowed in Table III, the entire lot shall be rejected. Remaining devices from a rejected lot shall not be used to form a new lot without prior written approval of the procuring activity. Defects in markings or from handling which do not affect the form, fit or function shall not be cause for lot rejection.

Table III Sampling Plan

Lot Size	Failures allowed
0 - 10	0
11 - 20	1
21 - 50	5 % of the lot

4.5.3 **Rejected lots.** If an inspection lot is rejected, a detailed report shall be submitted to the procuring activity describing the cause of failure and any corrective actions required. The report shall include, as a minimum, the following information:

(a) Cause of failure and failure mechanism,

(b) Failure analysis report, if separate from (a),

(c) Corrective action and implementation plan, and

(d) A proposal for rescreening the devices.

Devices shall not be rescreened without prior written approval and instructions from the procuring activity.

4.6 **Methods of inspection**

4.6.1 **Visual and dimensional examination (external).** Devices shall be examined to verify that the materials, physical dimensions, construction, weight, and workmanship are in accordance with the applicable detail drawings.

4.6.2 **Thermal Shock.** Thermal shock test shall be performed in accordance with Method 107 of MIL-STD-202. The following details and exceptions shall apply:

a. Test condition. Condition A, except the number of cycles shall be 10 minimum.

If the Condition A lower test temperature is suspected of causing a reliability risk (inducing potential latent failures), test temperatures may be altered so that the lowest test temperature is 10 degrees Celsius less than either the spacecraft (or instrument) mission operating temperature or thermal vacuum test temperature, whichever is lower. In this case, the upper test temperature shall be increased by the amount the lower test temperature was raised to maintain an equivalent thermal shock temperature differential. The responsible GSFC Project Office shall establish the thermal shock test temperatures to be used for its program at the beginning of the procurement or build. These established test temperatures shall be communicated to the responsible Flight Assurance Manager and Parts Engineer in the Office of Flight Assurance.

b. Continuity monitor (when specified). Devices shall be continually monitored for continuity during the entire final cycle to verify no intermittent conditions. Equipment shall be capable of detecting intermittent opens exceeding 100 microseconds.

c. Measurement before and after cycling. DC winding resistance and winding inductance (see 4.6.5.2 and 4.6.5.3) shall be measured.

d. Visual inspection. After cycling devices shall be examined for evidence of physical damage such as cracks, bursting or bulging of the case or corrosion of termination which may affect the mechanical or electrical operation of the device.

4.6.3 **Dielectric Withstanding Voltage (DWV).**

4.6.3.1 **At atmospheric pressure.** Each device manufactured to conform with the requirements of this specification shall be subjected to the DWV test in accordance with Method 301 of MIL-STD-202. The following details and exceptions apply:

a. Magnitude and type of test voltage - As specified in the detail drawing or specification (in Vrms).

b. Duration of applied voltage - As specified in the detail drawing or specification (in seconds minimum).

c. Points of applied test voltage - between windings and between windings and case. (When applicable, shielding shall be measured as a winding.)

d. Examination during and after test - devices shall be examined for evidence of arcing, flashover, breakdown of insulation, and other damage.

4.6.3.2 **At barometric pressure.** High voltage transformer assemblies only shall be tested as specified in 4.6.3.1 and in accordance with Method 105 of MIL-STD-202. The following details and exceptions apply:

a. Test condition, as specified in the detail drawing or specification.

b. Magnitude of test voltage shall be as specified in Table XII of MIL-T-27.

4.6.4 **Burn-in** (when specified). Each device shall be subjected to the burn-in for 96 hours minimum. The following criteria shall apply:

a. Temperature	Device maximum rated temperature
b. Voltage or current	Device maximum rated voltage or current
c. Frequency	Minimum, as specified in the detail drawing or specification
d. Load	Maximum rated load ± 10 percent

Dielectric withstanding voltage, insulation resistance, and electrical characteristics shall be measured after burn-in; and the device shall be stabilized at room ambient temperature before measurement. Devices that fail to meet the requirements specified in the detail specification shall be removed from the lot.

4.6.5 **Electrical characteristics.** Devices shall be subjected to the electrical tests specified herein. Test data shall be taken for each unit; individual readings of observed values shall be recorded by device serial number for Grade 2 devices; for Class C devices only the observed values in the lot need to be recorded.

4.6.5.1 **Insulation resistance.** Devices shall be tested in accordance with Method 302 of MIL-STD-202 with the following details and exceptions:

a. For devices specified with a rated voltage of 28 Vdc or less, insulation resistance shall be measured at 100 Vdc. For devices having a rated voltage of 100

volts or more, the insulation resistance shall be measured at 2.5 times the rated voltage or 500 Vdc whichever is less.

b. Inductors shall be measured for resistance between one lead and ground plane or to the core, if it is conductive. Transformers shall be measured between each winding and ground and between all leads of a winding and of each of the remaining sets of windings.

c. The test duration shall be 2 minutes ± 30 seconds.

d. The insulation resistance shall be 1000 Mohms minimum.

4.6.5.2 **DC winding resistance.** The dc resistance of each winding shall be measured by using the inspection conditions specified in 4.1 and 4.2, as applicable. For resistances less than 1 ohm, measurements shall be made with a Kelvin bridge or equivalent. The change in resistance shall be calculated. After thermal shock exposure the resistance shall not change by more than 3 percent, i.e. $\Delta R = (R_1-R_2)/R_2 \times 100\%$, $R_1>R_2$

4.6.5.3 **Winding inductance.** The inductance of each winding shall be measured. When voltage, frequency, and test current are specified in the device detail drawing, measurements shall be made at the voltage, frequency and current specified. The inductance of each winding shall be recorded. The change in inductance shall be calculated. After thermal shock exposure the inductance shall not change by more than 3 percent, i.e. $\Delta L = (L_1-L_2)/L_2 \times 100\%$, $L_1>L_2$

4.6.5.4 **Turns ratio.** The turns ratio or voltage ratio shall be measured with a voltmeter or by other suitable means. The applied voltage (in Vrms or in mVrms) and test frequency shall be as specified in the detail drawing or specification.

4.6.5.5 **Polarity.** With the device windings connected in series and with a voltage applied to one of the windings, a comparision shall be made between the sum of the voltages across the individual windings and the voltage across the series windings. Any other suitable method of determining polarity is permissible.

5.0 **PACKING**

5.1 **Preparation for delivery.** Devices shall be prepared for delivery in accordance with MIL-T-27, Level C.

6.0 NOTES

6.1 **Notice.** When GSFC drawings, specifications or other data are sent for any purpose other than a GSFC procurement, 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 said drawings, specifications or other data is not to be regarded by implication or otherwise as licensing the holder or any person or corporation in any manner, or conveying any right or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:

Parts Branch/Code 311.2
Goddard Space Flight Center
Greenbelt, MD 20771

TABLE IV. Quality Conformance Inspection (100%)

TEST (1)	TYPE 1		TYPE 2	TYPE 3	TYPE 4	TYPE 5
	Inductor	Transformer	Non-encapsulated			Encapsulated
External visual and dimensional examination	X	X	X	X	X	X
Initial electrical characteristics (2)	(3)	X	X	X	X	X
Thermal shock	(4)	(4)	X	X	X	X
Burn-in (when specified)	(5)	X	X	X	X	X
Dielectric Withstanding Voltage (6)			X	X	X	X
Insulation resistance		X	X	X	X	X
Final electrical characteristics (2)	(3)	X	X	X	X	X

(1) Tests shall be performed in accordance with the requirements specified elsewhere within this document.
(2) Electrical parameter tests shall be as specified in 4.6.5.
(3) DC resistance and inductance only.
(4) Thermal shock shall be limited to 5 cycles only.
(5) Subject inductors to a 24 hour non-operating burn-in only.
(6) With the approval of the procuring activity the corona test specified in 4.4.2 may be substituted for the barometric pressure test.

Appendix A

RADIOGRAPHIC INSPECTION

1. **SCOPE**

1.1 **Scope.** This appendix contains details for performing radiographic inspections for devices manufactured in accordance with this specification. This appendix is a mandatory part of this specification (see para. 3.7).

2. **APPLICABLE DOCUMENTS**

2.1 **Documents.** Not applicable to this appendix.

3. **Radiographic inspection.** Devices shall be tested in accordance with Method 209 of MIL-STD-202. The following details and exceptions shall apply:

a. Radiographic quality. The radiograph shall render a clear sharp image of the penetrameter.

b. Image quality indicator. A radiograph of the penetrameter shall be included on each radiograph film. The penetrameter may be made from a sample of the same type as that being radiographed, with an AWG number 48 tungsten wire mounted across the body. The photograph shall be of sufficient clarity to permit detection of a particle 0.020 inch in diameter.

3.1 **Views.** Radiographs shall be taken of each device in each of three axes: X, Y, and Z. When inadequate coverage is provided, additional views shall be taken as deemed necessary to satisfy the criteria defined herein.

3.2 **Examination.** The radiographic examination shall include, but not be limited to, inspection for extraneous materials, alignment clearance and processing damage.

3.2.1 **Extraneous material.** There shall be no visible extraneous materials that can damage insulation or cause an electrical short circuit between conductors or connections. Loose or excessive bonding materials such as weld or solder splash, solder balls and short lengths of unattached wire shall be considered extraneous material.

3.2.2 **Alignment and clearances.** Acceptable devices shall exhibit adequate internal electrical and mechanical clearances. Unacceptable alignment and clearances include the following:

a. Insufficient clearance between wires and metallic case, between winding and case, other conductive supports, or external surfaces.

b. Lead wire under tension that can be subjected to further stress by thermal expansion or contraction.

c. Inadequate clearance of wire and installation holes, where the wires can be damaged during installation.

d. Inadequate clearance between adjacent terminals caused by wire pigtails or wire alignment.

e. Inadequate clearance between wires.

3.2.3 **Processing damage.** Unacceptable processing damage includes the following:

a. Raveled or frayed wire ends that can separate or pierce insulation, other wires or parts.

b. Partially broken wire strands. Multiple strand wire in which one or more strands have separated.

c. Missing or incomplete soldering or welding of connections.

d. Excess wire lengths that are unsupported and can move freely under mechanical or thermal stresses.

e. Unauthorized splices or repairs of broken wires or terminals.

f. Voids in encapsulant in contact with the lead between the coil and external surface that completely surround the wire or, although not surrounding the wire, extend greater than 20 percent of the distance from the coil to the external surface.