

INCH-POUND

MIL-DTL-28791B  
 10 July 2006  
 SUPERSEDING  
 MIL-DTL-28791A  
 17 April 2002

## DETAIL SPECIFICATION

ISOLATORS AND CIRCULATORS, RADIO FREQUENCY,  
GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

## 1. SCOPE

1.1 Scope. This specification covers the general requirements for isolators and circulators, coaxial, waveguide, and stripline radio frequency for use in armed service radar and radio application.

1.2 Part or identifying number (PIN). Pins to be used for devices acquired to this specification are created as follows. The PIN consists of the letter "M" followed by the basic number of the specification sheet, and an assigned dash number ([see 3.1](#)).

M28791/1 - 001

Military designator and  
specification sheet number -----

Dash number designated  
on specification sheet -----

## 2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4 or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4 or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract ([see 6.2](#)).

## COMMERCIAL ITEM DESCRIPTIONS

A-A-59588 - Rubber, Silicone.

## FEDERAL SPECIFICATIONS

TT-P-645 - Primer, Paint, Zinc-Molybdate, Alkyd Type.

Comments, suggestions, or questions on this document should be addressed to: Commander, Defense Supply Center Columbus, ATTN: DSCC-VAT, P.O. Box 3990, Columbus, OH 43218-3990, or e-mailed to [TubesAmps@dla.mil](mailto:TubesAmps@dla.mil). Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at <http://assist.daps.dla.mil>.

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### DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-3922	-	Flanges, Waveguide, General Purpose, General Specification for.
MIL-F-14072	-	Finishes for Ground Based Electronic Equipment.
MIL-DTL-15090	-	Enamel, Equipment, Light Gray (Navy Formula No. 111).
MIL-PRF-39012	-	Connectors, Coaxial, Radio Frequency, General Specification for.
MIL-I-28791/1	-	Isolator, Radio Frequency, Coaxial.

### FEDERAL STANDARDS

FED-STD-H28	-	Screw-Thread Standards for Federal Services.
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### DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-129	-	Military Marking for Shipment and Storage.
MIL-STD-202	-	Electronic and Electrical Component Parts.
MIL-STD-1285	-	Marking of Electrical and Electronic Parts.
MIL-STD-2073-1	-	DoD Standard Practice for Military Packaging.

### DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-454	-	General Guidelines for Electronic Equipment.
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(Copies of the above documents are available online at <http://assist.daps.dla.mil> or <http://assist.daps.dla.mil/quicksearch> or from the Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, issues of these documents are those cited in the solicitation or contract ([see 6.2](#)).

#### ASTM INTERNATIONAL (ASTM)

ASTM-B210	-	Aluminum and Aluminum-Alloy Drawn Seamless Tubes (DoD adopted).
ASTM-B372	-	Copper and Copper-Alloy, Seamless, Rectangular Waveguide Tube (DoD adopted).

(Copies of the above documents are available online at <http://www.astm.org> or can be requested from ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959.)

#### INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 10012-1	-	Equipment, Quality Assurance Requirements for Measuring - Part 1: Metrological Confirmation System for Measuring Equipment (DoD adopted).
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(Copies of this document are available from the International Organization for Standardization, American National Standards Institute, 11 West 42<sup>nd</sup> Street, 13<sup>th</sup> Floor, New York, NY 10036 or at <http://www.iso.ch>.)

#### NCSL INTERNATIONAL

NCSL-Z540.1	-	Calibration Laboratories and Measuring and Test Equipment (DoD adopted).
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(Copies can be obtained online at <http://www.ncsli.org> and are available at NCSL International, 2995 Wilderness Place Suite 107, Boulder, CO 80301-5404.)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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## 3. REQUIREMENTS

3.1 Specification sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheets. In the event of any conflict between requirements of this specification and the specification sheet, the latter shall govern.

3.2 First article inspection. Products furnished under this specification shall be products which have passed the first article inspection in [4.4](#).

3.3 Materials. The materials shall be as specified herein; however, when a definite material is not specified, a material shall be used which will enable the isolators and the circulators to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of the finished product.

3.3.1 Copper alloy. Copper alloy used in the fabrication of waveguide-type isolators and circulators shall conform to commercial bronze, 90 percent, of ASTM-B372. Copper alloy used in the fabrication of coaxial-type isolators shall conform to the material requirements of ASTM-B372, 99.90 percent purity.

3.3.2 Aluminum alloy. Aluminum alloy shall conform to the requirements for 6061 or 6063 of ASTM-B210. The finished waveguide shall have an "F" temper and after heat treatment and aging, shall meet the mechanical properties of the T6 temper of ASTM-B210.

3.3.3 Rubber. Rubber shall conform to the requirements in A-A-59588.

3.3.4 Pure tin. The use of pure tin, as an underplate or final finish, is prohibited both internally and externally. Tin content of radio-frequency isolator and circulator components and solder shall not exceed 97 percent, by mass. Tin shall be alloyed with a minimum of 3 percent lead, by mass ([see 6.6](#)).

3.4 Design and construction. Isolators and circulators shall be designed and constructed to conform to the requirements specified ([see 3.1](#)), in a manner entirely suitable for their intended use. They shall be of the lightest practicable weight consistent with the strength required for sturdiness, safety, and reliability. Isolators and circulators shall be fully shielded to external magnetic fields.

3.4.1 Waveguide isolators and circulators. The mating face of the isolators or of the circulators shall be so designed and manufactured as to provide the mating characteristics of the flange specified ([see 3.1](#)) in accordance with MIL-DTL-3922.

3.4.2 Coaxial isolators and circulators. Connectors shall be as specified ([see 3.1](#)). The material and gauging for receptacle connectors shall conform to the requirements of MIL-PRF-39012.

3.4.3 Dimensions. The dimensions shall be as specified ([see 3.1](#)).

3.4.4 External finish. External finish shall be applied to the isolators and to the circulators regardless of plating or chemical treatment, except that the mating surfaces shall not be coated. The primer coat shall be zinc chromate conforming to TT-P-645. Two finish coats of enamel, conforming to type III, class 2, of MIL-DTL-15090, shall be applied. External coatings shall be applied as continuous films.

3.4.5 Dissimilar metals. Dissimilar metals between which an electromotive couple may exist shall not be placed in contact with each other. Refer to MIL-F-14072 for the definition of dissimilar metals.

3.4.6 Screw threads. Screw threads shall be in accordance with FED-STD-H28. If used, helical inserts shall be selected (for information refer to MIL-HDBK-454, Guideline 12).

3.4.7 Engineering parameters. The parameters of nominal impedance, voltage rating, frequency range, temperature range, and power rating shall be as specified ([see 3.1](#)).

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3.5 Dielectric withstanding voltage (applicable to coaxial circulators only). When circulators are tested as specified in 4.7.2, there shall be no evidence of breakdown.

3.6 Isolation. When isolators and circulators are tested as specified in 4.7.3, the isolation shall be as specified (see 3.1).

3.7 Insertion loss. When isolators and circulators are tested as specified in 4.7.4, the insertion loss shall not exceed the value specified (see 3.1).

3.8 Voltage standing wave ratio (VSWR). When isolators and circulators are tested as specified in 4.7.5, the VSWR shall not exceed the value specified (see 3.1).

3.9 Shock (specified pulse). When isolators and circulators are tested as specified in 4.7.6, there shall be no change in electrical or mechanical performance.

3.10 Temperature cycling. When isolators and circulators are tested as specified in 4.7.7, there shall be no evidence of damage or electrical degradation due to the test.

3.11 Moisture resistance. When isolators and circulators are tested as specified in 4.7.8, there shall be no change in electrical or mechanical performance or destructive corrosion. Destructive corrosion shall be construed as any type of corrosion which in any way interferes with electrical or mechanical performance.

3.12 Vibration, high frequency. When isolators and circulators are tested as specified in 4.7.9, there shall be no change in electrical or mechanical performance.

3.13 Marking. Isolators and circulators shall be marked with the military part number, manufacturer's code and numbers identifying each port (see 3.1). Marking shall be applied directly on the isolators or on an attached name plate. Marking shall be in accordance with MIL-STD-1285.

3.14 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.15 Workmanship. Isolators and circulators shall be processed in such a manner as to be uniform in quality and shall be free from defects that affect life, serviceability, or appearance.

#### 4. VALIDATION

4.1 Test equipment and inspection facilities. Test and measuring equipment and inspection facilities of sufficient accuracy, quality and quantity to permit performance of the required inspection shall be established and maintained by the supplier. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with NCSL-Z540.1 or ISO 10012-1.

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

- (a) Materials inspection (see 4.3).
- (b) First article inspection (see 4.4).
- (c) Conformance inspection (see 4.6).

4.3 Materials inspection. Materials inspection shall consist of certification supported by verifying data that the materials listed in table I used in fabricating the isolator or the circulator are in accordance with the applicable referenced specifications or requirements prior to such fabrication.

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TABLE I. Materials inspection.

Material	Requirement paragraph	Applicable specification
Copper alloy	3.3.1	ASTM-B372
Aluminum alloy	3.3.2	ASTM-B210
Rubber	3.3.3	A-A-59588

4.4 First article inspection.

4.4.1 Samples. First article inspection shall be performed by the supplier, after award of the contract and prior to production, at a location acceptable to the Government. First article inspection shall be performed on sample units that have been produced with equipment and procedures normally used in production. First article approval is valid only on the contract or purchase order under which it is granted unless extended by the Government to other contracts or purchase orders.

4.4.2 Sample size. Two isolators and/or two circulators shall be subjected to the first article inspection.

4.4.3 Inspection routine. The first article samples shall be subjected to the inspection specified in tables I and II.

TABLE II. First article inspection.

Examination or test	Requirement paragraph	Test method paragraph
Visual and mechanical examination.....	3.1 thru 3.4, 3.13 and 3.14	4.7.1
Dielectric withstanding voltage 1/.....	3.5	4.7.2
Isolation .....	3.6	4.7.3
Insertion loss.....	3.7	4.7.4
VSWR .....	3.8	4.7.5
Shock (specified pulse).....	3.9	4.7.6
Temperature cycling .....	3.10	4.7.7
Moisture resistance.....	3.11	4.7.8
Vibration, high frequency .....	3.12	4.7.9

1/ Coaxial type circulators only.

4.4.4 Failures. One or more failures shall be cause for refusal to grant first article approval.

4.5 Inspection conditions. Unless otherwise specified herein, all inspections shall be performed in accordance with the test conditions specified in the "GENERAL REQUIREMENTS" of MIL-STD-202.

4.6 Conformance inspection.

4.6.1 Inspection of product for delivery. Inspection of product for delivery shall consist of groups A and B inspections.

4.6.1.1 Inspection lot. An inspection lot shall consist of all isolators or all circulators of one type produced under essentially the same conditions, and offered for inspection at one time.

4.6.1.2 Group A inspection. Group A inspection shall consist of the examinations and test specified in table III in the order shown.

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TABLE III. Group A inspection.

Examination or test	Requirement paragraph	Test method paragraph
Visual and mechanical examination	3.1 thru 3.4, 3.13 and 3.14	4.7.1
Dielectric withstanding voltage <u>1/</u>	3.5	4.7.2

1/ Applicable to coaxial only.

4.6.1.2.1 Group A sampling plan. Statistical sampling and inspection shall be performed on an inspection lot basis with a random sample of isolators or of circulators selected in accordance with [table IV](#). The acceptance levels shall be based upon the zero defective sampling plan. No failures shall be permitted.

4.6.1.2.2 Rejected lots. If an inspection lot is rejected, the supplier may rework it to correct the defects, or screen out the defective units, and resubmit for re-inspection (see 4.6.1.2.1). Such lots shall be separate from new lots, and shall be clearly identified as reinspected lots.

TABLE IV. Group A sampling plan.

Lot size	Sample size
1-13	100 percent
14-150	13
151-280	20
281-500	29
501-1200	34
1201-3200	42
3201-10,000	50
10,001-35,000	60
35,001-150,000	74
150,001-500,000	90
500,001 and over	102

4.6.1.3 Group B inspection. Group B inspection shall consist of the examinations and tests specified in [table V](#), in the order shown, and shall be made on five (5) sample units which have been subjected to and have passed the group A inspection.

TABLE V. Group B inspection.

Test	Requirement paragraph	Test paragraph
Isolation	3.6	4.7.3
Insertion loss	3.7	4.7.4
VSWR	3.8	4.7.5

4.6.1.3.1 Rejected lots. If an inspection lot is rejected, the supplier may rework it to correct the defects, or screen out the defective units, and resubmit for re-inspection (see 4.6.1.3). Such lots shall be separate from new lots, and shall be clearly identified as reinspected lots.

4.6.1.3.2 Disposition of sample units. Sample units that have passed all the group B inspection may be delivered on the contract or purchase order if the lot is accepted and the sample units are still within specified electrical tolerances.

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4.6.2 Inspection of marking. The sampling and inspection of interior package marking shall be in accordance with the group A and B conformance inspection requirements of MIL-STD-2073-1. The sampling and inspection of marking for shipment and storage shall be in accordance with the quality assurance provisions of the applicable container specification and the marking requirements of MIL-STD-129.

4.7 Methods of examination and test.

4.7.1 Visual and mechanical examination. Isolators and circulators shall be examined to verify that the materials, design, construction, physical dimensions, marking and workmanship are in accordance with applicable requirements ([see 3.1](#)).

4.7.2 Dielectric withstanding voltage (applicable to coaxial circulators only) ([see 3.1](#) and [3.5](#)). Circulators shall be tested in accordance with method 301 of MIL-STD-202. The following details apply:

- a. Special conditions:
  - 1) The maximum relative humidity shall be 50 percent.
  - 2) The voltage shall be metered on the high side of the transformer.
- b. Magnitude of test voltage ([see 3.1](#)): The voltage shall be instantaneously applied.
- c. Nature of potential: Alternating current.
- d. Points of application of the test voltage: Between the center contact and the shell of the coaxial connector.

4.7.3 Isolation ([see 3.6](#)). [Isolators:] With the output port 2 of the test isolator connected to the input circuitry, and the input port 1 connected to the output circuitry ([see figure 1](#)), the frequency range shall be swept and the isolation measured. [Circulators:] With the input port 1 of the test circulator connected to the input circuitry, the output port 2 terminated with a matched load and the port 3 connected to the output circuitry ([see figure 2](#)), the frequency range shall be swept and the insertion loss measured. This procedure shall be repeated for all circulator ports.

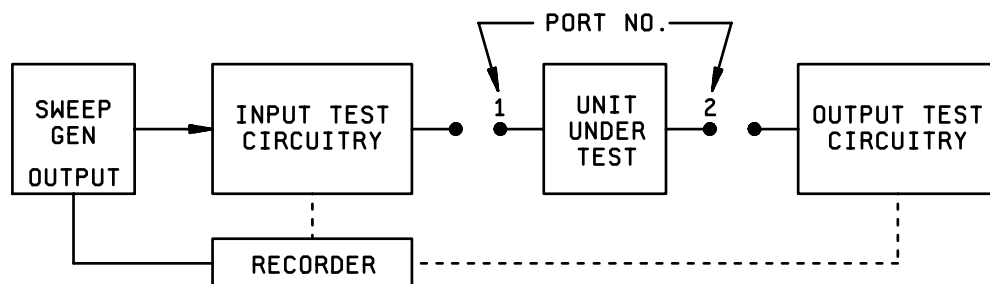
4.7.4 Insertion loss ([see 3.7](#)). [Isolators:] With the input port 1 of the test isolator connected to the input circuitry and the output port 2 connected to the output circuitry ([see figure 1](#)), the frequency range shall be swept and the insertion loss measured. [Circulators:] With the input port 1 of the circulator connected to the input circuitry, the output port 2 connected to the output circuitry ([see figure 2](#)) and the port 3 terminated with a matched load, the frequency range shall be swept and the insertion loss measured. This procedure shall be repeated for all circulator ports.

4.7.5 Voltage standing wave ratio (VSWR) ([see 3.8](#)). [Isolators:] With the input port 1 of the test isolator connected to the input circuitry and the output port 2 connected to the output circuitry ([see figure 1](#)), the frequency range shall be swept and the input VSWR measured. Ports 1 and 2 shall be interchanged and the output VSWR measured. [Circulators:] With the input port 1 of the circulator connected to the input circuitry, the output port 2 and the port 3 terminated with a matched load, the frequency range shall be swept and the input VSWR measured. This procedure shall be repeated for all circulator ports ([see figure 2](#)).

4.7.6 Shock (specified pulse) ([see 3.9](#)). Isolators and circulators shall be subjected to method 213 of MIL-STD-202. The following details shall apply:

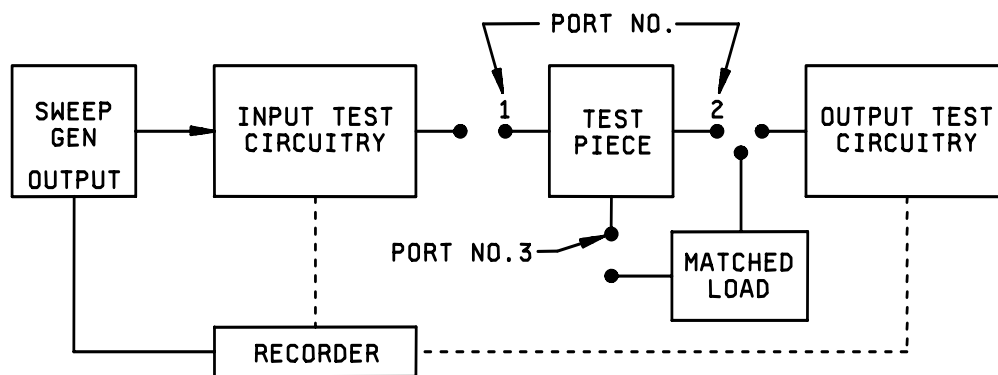
- a. Mounting: Isolators and circulators shall be clamped to the test fixture.
- b. Test condition: I.
- c. Measurements after test: Insertion loss and VSWR shall be measured as specified in [4.7.4](#) and [4.7.5](#).

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NOTE: The input and output circuitry shall be such that the errors in the measurement quantities are small. The values given in the specification sheet include worst case test circuitry errors.

FIGURE 1. Test set-up for isolation, insertion loss and VSWR (isolators).



NOTE: The input and output circuitry shall be such that the errors in the measurement quantities are small.

FIGURE 2. Test set-up for isolation, insertion loss, and VSWR (circulators).



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4.7.7 Temperature cycling ([see 3.10](#)). Isolators and circulators shall be tested in accordance with method 102, MIL-STD-202. The following details and exceptions shall apply:

- a. Test condition: D, except that the low temperature shall be -65°C and the high temperature shall be +105°C.
- b. Measurements after test: Insertion loss and VSWR shall be measured as specified in [4.7.4](#) and [4.7.5](#).

4.7.8 Moisture resistance ([see 3.11](#)). Isolators and circulators shall be tested in accordance with method 106 of MIL-STD-202. The following details shall apply:

- a. Loading voltage: Not applicable.
- b. Measurements after test: Insertion loss and VSWR shall be measured as specified in [4.7.4](#) and [4.7.5](#).

4.7.9 Vibration, high frequency ([see 3.12](#)). Isolators and circulators shall be tested in accordance with method 204 of MIL-STD-202. The following details shall apply:

- a. Mounting: Isolators or circulators shall be attached to the vibration table by clamps. A clamp shall be placed around the center of each isolator or circulator and no part of the isolator or circulator shall touch any object other than the clamp.
- b. Test condition: B.
- c. Measurements after test: Insertion loss and VSWR shall be measured as specified in [4.7.4](#) and [4.7.5](#).

## 5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order ([see 6.2](#)). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system command. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

## 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. Isolators and circulators are intended for use in military equipment in the frequency range specified.

6.2 Ordering data. Acquisition documents should specify the following:

- a. Title, number, and date of the specification and the specification sheet.
- b. If required, the specific issue of individual documents referenced ([see 2.1](#)).
- c. Packaging requirements ([see 5.1](#)).
- d. Special marking, if required ([see 3.13](#)).
- e. Complete PIN.

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6.3 Definitions. For the purpose of the specification, the following definitions apply.

6.3.1 Isolator. A ferrite device that allows RF energy to pass in one direction with little attenuation while radio frequency energy flowing in the opposite direction is attenuated. A circulator with one port terminated in a matched impedance will function as an isolator.

6.3.2 Circulator. A ferrite device having three or more ports with the characteristic that energy entering port 1 couples to port 2, energy entering port 2 couples to port 3 and energy entering the highest numbered port couples to port 1.

6.4 Subject term (keyword) listing.

Aluminum	Insertion loss
Coaxial	Radar
Copper	Stripline
Dielectric withstanding voltage	VSWR
Ferrite	Waveguide

6.5 Environmentally preferable material. Environmentally preferable materials should be used to the maximum extent possible to meet the requirements of this specification. Table VI lists the Environmental Protection Agency (EPA) top seventeen hazardous materials targeted for major usage reduction. Use of those materials should be minimized or eliminated unless needed to meet the requirements specified herein ([see section 3](#)).

TABLE VI. EPA top seventeen hazardous materials.

Benzene	Dichloromethane	Tetrachloroethylene
Cadmium and Compounds	Lead and Compounds	Toluene
Carbon Tetrachloride	Mercury and Compounds	1, 1, 1 - Trichloroethane
Chloroform	Methyl Ethyl Ketone	Trichloroethylene
Chromium and Compounds	Methyl Isobutyl Ketone	Xylenes
Cyanide and Compounds	Nickel and Compounds	

6.6 Tin whisker growth. The use of alloys with tin content greater than 97 percent, by mass, may exhibit tin whisker growth problems after manufacture. Tin whiskers may occur anytime from a day to years after manufacture and can develop under typical operating conditions, on products that use such materials. Conformal coatings applied over top of a whisker-prone surface will not prevent the formation of tin whiskers. Alloys of 3 percent lead, by mass, have shown to inhibit the growth of tin whiskers ([see 3.3.4](#)). For additional information on this matter, refer to ASTM-B545 (Standard Specification for Electrodeposited Coatings of Tin).

6.7 Changes from the previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

Custodians:

Army - CR  
Navy - EC  
Air Force - 11  
DLA - CC

Preparing activity:  
DLA - CC

(Project 5985-2006-015)

Review activities:

Navy - MC, OS  
Air Force - 99

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at <http://assist.daps.dla.mil>.