

PERFORMANCE SPECIFICATION

CAPACITOR, FIXED, CERAMIC DIELECTRIC, SWITCH MODE POWER SUPPLY (GENERAL PURPOSE AND TEMPERATURE STABLE), STANDARD RELIABILITY AND HIGH RELIABILITY, 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 general purpose (BQ, BR, and BX characteristics) and temperature stable (BP characteristic) ceramic capacitors for use in switch mode power supplies. Two product levels are offered: B level (standard reliability) and T level (high reliability). An acceleration factor of 8:1 has been used to relate life test data obtained at 200 percent of rated voltage at maximum rated temperature to rated voltage at rated temperature.

1.2 Classification. Capacitors covered by this specification should be classified by the style, as specified (see 3.1).

1.2.1 Part or Identifying Number (PIN). Capacitors specified herein (see 3.1); are identified by a PIN which consists of the product level designator, basic number of the performance specification, and a series of coded characters. The coded characters provide information concerning the characteristic, specification sheet number, capacitance, capacitance tolerance, voltage, and, where applicable, lead configuration. The PIN is in the following form:

1/	<u>M49470</u>		<u>R</u>		<u>01</u>		<u>474</u>		<u>K</u>		<u>C</u>		<u>N</u>
	Performance specification indicating MIL-PRF-49470		Characteristic (1.2.1.1)		Performance specification sheet number (indicating MIL-PRF-49470/1)		Capacitance (1.2.1.2)		Capacitance tolerance (1.2.1.3)		Rated voltage (1.2.1.4)		Configuration (see 1.2.1.5)

1.2.1.1 Characteristic. The characteristic refers to the voltage-temperature limits of the capacitor. The first letter (B) (not shown) identifies the rated temperature range of -55°C to +125°C. The second letter indicates the voltage-temperature limits as shown in table I.

1/ A "T" prefix is used in place of the "M" for T level product.

Comments, suggestions, or questions on this document should be addressed to: CERDEC PRD: RDER-PRO, Building 6010 K-130, Aberdeen Proving Ground, Aberdeen, MD 21005 or emailed to usarmy.APG.cerdec.mbx.standardization-crx@mail.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at <https://assist.dla.mil>.



TABLE I. Characteristic.

Symbol	Capacitance change with reference to +25°C	
	Step A through step D of table XII	Step E through step G of table XII
P	0 ppm/°C ±30 ppm/°C	0 ppm/°C ±30 ppm/°C
Q	±15 percent	+15, -50 percent
R	±15 percent	+15, -40 percent
X	±15 percent	+15, -25 percent

1.2.1.2 Capacitance. The nominal capacitance value, expressed in picofarads (pF) is identified by a three digit number; the first two digits represent significant figures and the last digit specifies the number of zeros to follow.

1.2.1.3 Capacitance tolerance. The capacitance tolerance is identified by a single letter in accordance with table II.

TABLE II. Capacitance tolerance.

Symbol	Capacitance tolerance
J	±5 percent
K	±10 percent
M	±20 percent

1.2.1.4 Rated voltage. The rated voltage for continuous operation at +125°C is identified by a single letter as shown in table III.

TABLE III. Rated voltage.

Symbol	Rated voltage
Z	25
A	50
B	100
C	200
E	500

1.2.1.5 Configuration. The configuration is identified by single letter; as shown in [table IV](#) (see 3.1).

TABLE IV. Configuration.

Symbol (last digit of PIN)	Lead style	Height profile (Dimension A)	Formed lead length, L (inches)
N	N (straight)	Standard	N/A
L	L (formed)	Standard	.070 ± .010
M	L (formed)	Standard	.045 ± .010
J	J (formed)	Standard	.070 ± .010
K	J (formed)	Standard	.045 ± .010
A	N (straight)	Low	N/A
B	L (formed)	Low	.070 ± .010
D	L (formed)	Low	.045 ± .010
C	J (formed)	Low	.070 ± .010
F	J (formed)	Low	.045 ± .010

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 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 of documents cited in sections 3 and 4 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.

DEPARTMENT OF DEFENSE SPECIFICATIONS

- MIL-I-46058 - Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)
- MIL-PRF-49470/1 - Capacitor, Fixed, Ceramic Dielectric, Switch Mode Power Supply (General Purpose and Temperature Stable), Standard Reliability and High Reliability, Unencapsulated, Horizontally Stacked, Style PS01
- MIL-PRF-49470/2 - Capacitor, Fixed, Ceramic Dielectric, Switch Mode Power Supply (General Purpose and Temperature Stable), Standard Reliability and High Reliability, Encapsulated, Horizontally Stacked, Style PS02

DEPARTMENT OF DEFENSE STANDARDS

- MIL-STD-202 - Test Methods Standard Electronic and Electrical Component Parts
- MIL-STD-202-103 - Method 103, Humidity (Steady State)
- MIL-STD-202-104 - Method 104, Immersion
- MIL-STD-202-105 - Method 105, Barometric Pressure (Reduced)
- MIL-STD-202-106 - Method 106, Moisture Resistance
- MIL-STD-202-107 - Method 107, Thermal Shock
- MIL-STD-202-108 - Method 108, Life (at Elevated Ambient Temperature)
- MIL-STD-202-204 - Method 204, Vibration, High Frequency
- MIL-STD-202-208 - Method 208, Solderability
- MIL-STD-202-210 - Method 210, Resistance to Soldering Heat

MIL-PRF-49470D

MIL-STD-202-211	-	Method 211, Terminal Strength
MIL-STD-202-213	-	Method 213, Shock (Specified Pulse)
MIL-STD-202-215	-	Method 215, Resistance to Solvents
MIL-STD-202-301	-	Method 301, Dielectric Withstanding Voltage
MIL-STD-202-302	-	Method 302, Insulation Resistance
MIL-STD-202-305	-	Method 305, Capacitance
MIL-STD-790	-	Standard Practice for Established Reliability and High Reliability Qualified Products List (QPL) Systems for Electrical, Electronic, and Fiber Optic Parts Specifications
MIL-STD-1276	-	Leads for Electronic Component Parts

(Copies of these documents are available online at <http://quicksearch.dla.mil/>.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents are those cited in the solicitation or contract.

ELECTRONIC COMPONENTS INDUSTRY ASSOCIATION (ECIA)

ECIA EIA-469	-	Standard Test Method for Destructive Physical Analysis (DPA) of Ceramic Monolithic Capacitors
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(Copies of this document is available online at <http://www.ecianow.org>.)

SOLID STATE TECHNOLOGY ASSOCIATION (JEDEC)

JEDEC JESD557	-	Statistical Process Control Systems
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(Copies of this document is available online at <http://www.jedec.org>.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, 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.

3. REQUIREMENTS

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

3.2 Qualification. Capacitors furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list (QPL) before contract award (see 4.4 and 6.3). In addition, the manufacturer shall obtain certification from the qualifying activity that the QPL requirements of 3.3 and 4.2.1 have been met and are being maintained.

3.3 QPL system. The manufacturer shall establish and maintain a QPL system for parts covered by this specification. Requirements for this system are specified in [MIL-STD-790](#). In addition, the manufacturer shall establish a Statistical Process Control (SPC) system that meets the requirements of 3.3.1.

3.3.1 SPC system. As part of the overall [MIL-STD-790](#) QPL system, the manufacturer shall establish a SPC system that meets the requirements of [JEDEC JESD557](#). Typical manufacturing processes for application of a SPC include raw material mixing and blending, dielectric sheet manufacturing, stacking and electrode printing, laminating and dicing, chip firing, termination, conformal coating, and encapsulation.

3.4 Materials. Materials shall be as specified herein. However, when a definite material is not specified, a material shall be used which will enable the capacitors to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guarantee of the acceptance of the finished product.

3.5 Interface and physical dimension requirements. Capacitors shall meet the interface and physical dimensions specified (see 3.1).

3.5.1 Dielectric parameters. Capacitors supplied to this specification shall have a minimum dielectric thickness (T) of 0.8 mil for 25 volt and 50 volt rated capacitors or 1 mil for capacitors with ratings above 50 volts. Dielectric thickness is the actual measured thickness of the fired ceramic dielectric layer. Voids, or the cumulative effect of voids, shall not reduce the total dielectric thickness by more than 50 percent (see figure 1).

3.5.2 Electrode parameters. Nickel electrodes shall not be used in capacitors supplied to this specification.

3.5.3 Lead attachment. When solder is utilized to attach the lead frame to the chip capacitor, the solder shall have a liquidus temperature of +260°C or greater.

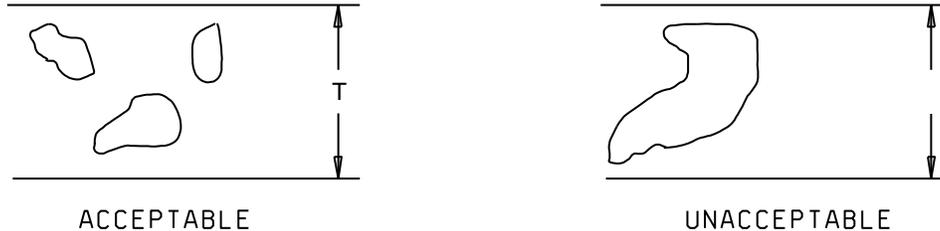


FIGURE 1. Dielectric parameters.

3.5.4 Terminal lead finish. The terminal lead finish shall be in accordance with code 32 or code 52 of MIL-STD-1276 (NOTE: The 200 microinch maximum dimension for code 52 is not applicable).

3.5.4.1 Solder dip (retinning). The manufacturer may solder dip/retin the leads of capacitors supplied to this specification provided the solder dip process (see appendix A) has been approved by the qualifying activity.

3.5.4.2 Pure tin. The use of pure tin, as an underplate or final finish, is prohibited both internally and externally. Tin content of capacitor components and solder shall not exceed 97 percent, by mass. Tin shall be alloyed with a minimum of 3 percent lead, by mass (see 6.5).

3.6 Ultrasonic inspection (T level product only). Prior to assembly, all chip capacitors shall be subjected to ultrasonic examination. When examined in accordance with 4.8.1, capacitors that exhibit unacceptable responses as specified in ECIA EIA 469 shall be rejected, except in the case of false responses (see B.1.2.4). If false responses are suspected, the manufacturer may individually examine the capacitor and accept it if the false response is confirmed.

3.7 Chip level DPA (T level product only). When examined as specified in 4.8.2, chip capacitors shall meet the defect criteria of ECIA EIA 469. The ECIA EIA 469 delamination criteria shall be replaced with the following:

- a. Any single delamination of an interface of material layers exceeding 20 percent of the overall interface (pertaining to the overall chip element length or width), and exceeding .005 inch (0.13 mm).
- b. Any single delamination of an interface of material layers, in the active area, which exceeds .005 inch (0.13 mm), and displaces adjacent dielectric layers by more than 50 percent of the average nominal dielectric thickness.

- c. Any knitline delamination which exceeds 20 percent of the length of the knitline interface (end margin length) or which exceeds .010 inch (0.25 mm), whichever is smaller.
- d. Any delamination in any material interface of a side margin.

NOTE: Delaminations or longitudinally migrating voids within a dielectric material layer may be treated as delaminations at material interfaces; or, they may be treated as dielectric voids, in which case the zone of interest must include all of the migratory segments (see figures [ECIA EIA 469 D.1](#) and [D.2](#)).

3.8 In-process visual examination. When capacitors are inspected as specified in [4.8.3](#), no device shall be acceptable that exhibits the following:

3.8.1 Ceramic body defects.

- a. Cracks or pre-chipouts.
- b. Exposed electrodes.
- c. Delaminations.
- d. Electrodes visible in chipouts.
- e. Chipouts longer than 30 percent of each axis or longer than .100 inch (2.54 mm), whichever is less.
- f. Lifted terminations.

3.8.2 Lead attachment defects.

- a. Exposed electrodes.
- b. Solder balls or conductive epoxy particles.
- c. Exposed base metal on the lead frame that exceeds 5 percent of the total solderable area.
- d. Less than or equal to 80 percent solder attachment.
- e. Fractured solder.
- f. Bent, twisted or fractured leads.
- g. Residual flux.

3.9 Thermal shock and voltage conditioning. When tested as specified in [4.8.5](#), capacitors shall withstand the extremes of high and low temperature without visible damage and meet the following requirements:

- a. Insulation resistance (at +125°C): As specified in 3.10.
- b. Dielectric withstanding voltage (at +25°C): As specified in 3.11.
- c. Insulation resistance (at +25°C): As specified in 3.10.
- d. Dissipation factor (at +25°C): As specified in 3.12.
- e. Capacitance (at +25°C): Shall be within the tolerance specified (see [3.1](#)).

3.10 Insulation resistance. When measured as specified in 4.8.11, the insulation resistance shall not be less than the following:

- a. At +25°C, rated voltage: 100,000 megohms or 1,000 megohm- μ F, whichever is less.
- b. At +125°C, rated voltage: 10,000 megohms or 100 megohm- μ F, whichever is less.

3.11 Dielectric withstanding voltage. When tested as specified in 4.8.8, there shall be no evidence of breakdown or visible evidence of arcing or sparking.

3.12 Dissipation factor. When determined as specified in 4.8.7, the dissipation factor shall be 0.15 percent maximum for the BP characteristic and 2.5 percent maximum for all other characteristics.

3.13 Capacitance. When measured as specified in 4.8.6, the capacitance shall be within the specified tolerance (see 3.1).

3.14 Barometric pressure. Capacitors shall withstand the dc potential specified in 4.8.9 without flashover or damage.

3.15 Solderability. When capacitors are tested as specified in 4.8.12, the dipped surface of the leads shall be at least 95 percent covered with a new, smooth, solder coating. The remaining 5 percent may contain only small pinholes or rough spots; these shall not be concentrated in one area. All pins are common per side. For inspection purposes, all pins per side are considered as one lead. Bare base metal where the solder dip failed to cover the original coating is an indication of poor solderability and shall be cause for failure. In case of dispute, the percent of coverage with pinholes or rough spots shall be determined by actual measurement of these areas, as compared to the total area.

3.16 Voltage-temperature limits. The capacitance change over the range of temperatures specified in 4.8.13 shall not exceed the limits specified (see table I). The capacitance value obtained in step C of table XII shall be considered as the reference point.

3.17 Vibration, high frequency. When capacitors are tested as specified in 4.8.14, there shall be no intermittent contacts of 0.5 millisecond (ms) or greater duration, open-circuiting or short-circuiting, or evidence of mechanical damage.

3.18 Immersion. When tested as specified in 4.8.15, capacitors shall meet the following requirements:

- a. Visual examination: No mechanical damage. Marking shall remain legible.
- b. Dielectric withstanding voltage: As specified in 3.11.
- c. Insulation resistance: Not less than 50 percent of the initial requirement.
- d. Capacitance: Change not to exceed ± 3 percent of initial measured value for the BP characteristic or ± 10 percent for all other characteristics.
- e. Dissipation factor (at +25°C): Shall not exceed initial limits.

3.19 Shock, specified pulse. When tested as specified in 4.8.16, there shall be no momentary or intermittent contact of 0.5 ms or greater duration, open-circuiting or short-circuiting, or other evidence of breakdown, arcing, and mechanical damage.

3.20 Resistance to soldering heat. When tested as specified in 4.8.17, capacitors shall meet the following requirements:

- a. Insulation resistance at +25°C: Not less than the initial +25°C requirement.
- b. Capacitance: Shall change not more than ± 3 percent for the BP characteristic or -5 percent to +15 percent for all other characteristics.
- c. Dissipation factor: Shall not exceed the initial limits.

3.21 Moisture resistance. When tested as specified in 4.8.18, capacitors shall meet the following requirements:

- a. Visual examination: No mechanical damage. Marking shall remain legible.
- b. Dielectric withstanding voltage: As specified in 3.11.
- c. Insulation resistance: Not less than 30 percent of the initial +25°C requirement for the BP characteristic; not less than 10 percent of the initial +25°C requirement for all other characteristics.
- d. Capacitance: Change not to exceed ± 3 percent from initial measured value for the BP characteristic or ± 10 percent from the initial measured value for all other characteristics.
- e. Dissipation factor: As specified in 3.12.

3.22 DPA (T level only). When inspected as specified in 4.8.19, there shall be no evidence of capacitor cracking.

3.23 Resistance to solvents. When capacitors are tested as specified in 4.8.20, there shall be no evidence of mechanical damage and the marking shall remain legible.

3.24 Terminal strength. When capacitors are tested as specified in 4.8.10, there shall be no loosening or rupturing of the terminals.

3.25 Humidity, steady-state, low voltage (T level only). When tested as specified in 4.8.21, capacitors shall meet the following requirements:

- a. Visual examination: There shall be no mechanical damage, and marking shall remain legible.
- b. IR (at +25°C): Shall meet the initial 25°C requirement specified in 3.10.
- c. Capacitance change (BQ, BR and BX): Shall not change more than ± 10 percent from the initial measured value.
- d. Capacitance change (BP): Shall not change more than ± 0.3 percent of the nominal value or 0.3 pF, whichever is greater, from the initial measured value.

3.26 Life (at +125°C). When tested as specified in 4.8.22, capacitors shall meet the following requirements:

- a. Insulation resistance (at +125°C): As specified in 3.10.
- b. Visual examination: No mechanical damage. Marking shall remain legible.
- c. Insulation resistance (at +25°C): As specified in 3.10.
- d. Capacitance: Shall not change more than ± 3 percent for the BP characteristic or ± 20 percent for all other characteristics.
- e. Dissipation factor: As specified in 3.12.

3.27 Low temperature storage. When tested as specified in 4.8.23, capacitors shall withstand the low temperature as specified without evidence of mechanical damage.

3.28 Marking. Capacitors shall be marked as specified herein. Paper labels shall not be used. Other markings that in any way interfere with, obscure, or confuse those specified herein, are prohibited. Each capacitor shall be legibly marked with smear-resistant ink that will withstand the environmental conditions specified herein. At the option of the manufacturer, capacitors may be laser marked. The marking shall remain legible after all tests. Additional marking is allowed provided it does not interfere with the required marking.

3.28.1 Marking legibility (laser marking only). When tested as specified in 4.8.4.1, the marking shall remain legible.

3.28.2 Full marking. Capacitors shall be marked with at least the "JAN" or "J" marking, date code, manufacturer's name or trademark or Commercial and Government Entity (CAGE) code, and capacitance and capacitance tolerance codes, in accordance with the following examples. The date code shall consist of the year and week. For example: The third week of 1996 would be 9603 for a 4-digit date code or 603 for a 3-digit date code. At the option of the manufacturer, the date code may be placed on a separate line.

Case codes 1, 2, and 6 shall be marked with a complete PIN, "JAN" brand, 4-digit date code, the manufacturer's name or trademark or CAGE code, the capacitance value, and the rated voltage. These shall be marked on the top of the stack.

Case codes 4 and 5 shall be marked with the following sequence of information:

"J" brand (1 digit), product level designator ("B" or "T")
 Manufacturer's identification (1 to 5 digits)
 Capacitance code (3 digits) and capacitance tolerance (1 digit)
 Date code (3 or 4 digits)

Case code 4 or 5 example

JT
12345
106K
9603

Case code 3 shall either be fully marked or partially marked like case code 4 or 5 parts, at the option of the manufacturer.

3.28.3 Substitution of capacitance tolerance and rated voltage. Parts qualified and marked to tighter capacitance tolerance or higher rated voltage are substitutable, with acquiring agency approval, for parts marked to looser capacitance tolerance or lower rated voltage provided all other values, such as case size, characteristic, and leads are the same. Unless specified in the contract or order (see 6.2), the substitutable parts shall not be remarked. In the event that the capacitance tolerances or rated voltages are remarked, the lot date code on the parts shall not be changed, and the workmanship criteria shall be met.

3.28.4 Product level substitution. Capacitors qualified and marked as T level capacitors are substitutable, with acquiring agency approval, for M level capacitors provided all other characteristics specified in the PIN (see 1.2) are the same. Unless specified in the contract or order (see 6.2), the substitutable parts shall not be remarked. In the event that the product level is remarked, the lot date code on the parts shall not be changed, and the workmanship criteria shall be met.

3.28.5 JAN and J marking. The United States Government has adopted and is exercising legitimate control over the certification marks "JAN" and "J", respectively, to indicate that items so marked or identified are manufactured to, and meet all the requirements of specifications. Accordingly, items acquired to, and meeting all of the criteria specified herein and in applicable specifications shall bear the certification mark "JAN" except that items too small to bear the certification mark "JAN" shall bear the letter "J". The "JAN" and "J" shall be placed immediately before the part number except that if such location would place a hardship on the manufacturer in connection with such marking, the "JAN" or "J" may be located on the first line above or below the part number. Items furnished under contracts or orders which either permit or require deviation from the conditions or requirements specified herein on in applicable specifications shall not bear "JAN" or "J". In the event an item fails to meet the requirements of this specification and the applicable specification sheets, the manufacturer shall remove completely the military part number and the "JAN" or the "J" from the sample tested and also from all items represented by the sample. The "JAN" or "J" certification mark shall not be used on products acquired to contractor drawings or specifications. The United States Government has obtained Certificate of Registration Number 504,860 for the certification mark "JAN" and Registration Number 2,577,735 for the certification mark "J".

3.29 Recycled, recovered, environmentally preferable, or biobased materials. Recycled, recovered, environmentally preferable, or biobased 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.

3.30 Workmanship. Capacitors shall be processed in such a manner as to be uniform in quality when using 2X minimum to 4X maximum magnification. External leads shall not exhibit cuts, nicks, or scrapes exceeding 10 percent of the length of the leads. The surface of the lead may exhibit bare base metal on the edges and cut ends of the pins but not on the flat portion of the leads. These capacitor leads are not expected to be solderable above the seating plane for unencapsulated or solderable within .050 inch (1.27 mm) of the seating plane for encapsulated parts (see 3.1).

4. VERIFICATION

4.1 Classification of inspections.

- a. Qualification inspection (see 4.4).
- b. Verification of qualification (see 4.5).
- c. In-process inspection and conformance inspection (see 4.6).
- d. Group B inspection (see 4.7).

4.2 Reliability and quality.

4.2.1 QPL system. The manufacturer shall establish and maintain a QPL system in accordance with 3.3. Evidence of such compliance is a prerequisite for qualification and retention of qualification.

4.2.2 SPC. A SPC program shall be established and maintained in accordance with JEDEC JESD557. Evidence of such compliance shall be verified by the qualifying activity as a prerequisite for qualification and retention of qualification.

4.3 Inspection conditions and methods.

4.3.1 Conditions. Unless otherwise specified herein, all inspections shall be made in accordance with the "GENERAL REQUIREMENTS" of MIL-STD-202 except relative humidity shall not exceed 75 percent. Accuracy of all test voltage measurements shall be within ± 2.0 percent of the specified voltage.

4.3.2 Methods.

4.3.2.1 Reference measurements. When requirements are based on comparative measurements made before and after conditioning, the reference measurement shall be considered the last measurement made at +25°C ±3°C prior to conditioning. Unless reference measurements have been made within 30 days prior to the beginning of conditioning, they shall be repeated.

4.3.3 Power supply. The power supply used for life testing shall have a regulation of ±2 percent or less of the specified test voltage.

4.4 Qualification inspection. Qualification inspection shall be performed at a laboratory acceptable to the Government (see 6.3), on sample units produced with equipment and procedures normally used in production.

4.4.1 Sample size. The number of capacitors to be submitted for qualification inspection shall be as specified in table V and in appendix A. Each capacitor style shall be qualified separately.

4.4.2 Test routine. Sample units shall be subjected to the qualification inspection specified in table V, in the order shown. All sample units shall be subjected to the inspection of group I and group II. The sample shall then be divided as specified in table V for group III through group VIII, and subjected to the tests for their particular group.

4.4.3 Failures. Failures in excess of those allowed in table V shall be cause for refusal to grant qualification approval.

4.5 Verification of qualification. Every 12 months, the manufacturer shall provide verification of qualification to the qualifying activity. Continuation of qualification shall be based on meeting the following requirements:

- a. MIL-STD-790 program.
- b. The capacitor design, construction, basic materials or critical processes have not been modified without prior approval from the qualifying activity.
- c. Lot rejection for group A inspection does not exceed 10 percent or one lot, whichever is greater.
- d. Group B inspection.

In the event that no production occurred during the reporting period, a report shall be submitted certifying that the company still has the capabilities and facilities necessary to produce the item. If during 2 consecutive reporting periods there has been no production, the manufacturer may be required, at the discretion of the qualifying activity, to submit the products to testing in accordance with the qualification inspection requirements.

TABLE V. Qualification inspection.

Inspection	Requirement paragraph	Test method paragraph	Number of sample units to be inspected	Number of defectives permitted <u>1/</u>
<u>Group I</u> Thermal shock and voltage conditioning	3.9	4.8.5	All units	Not Applicable
<u>Group II</u> <u>2/</u> Visual and mechanical examination: Material Physical dimensions Interface requirements (other than physical dimensions) Marking Workmanship	3.4 3.1 3.5 and 3.5.1 3.28 3.30	4.8.4	<u>3/</u> 67 (T level) <u>3/</u> 55 (B level)	1
<u>Group III</u> Low temperature storage Barometric pressure Terminal strength	3.27 3.14 3.24	4.8.23 4.8.9 4.8.10	6	1
<u>Group IV</u> Voltage-temperature limits Vibration, high frequency Immersion	3.16 3.17 3.18	4.8.13.1 4.8.14 4.8.15	12	1
<u>Group V</u> Shock, specified pulse Resistance to soldering heat Moisture resistance	3.19 3.20 3.21	4.8.16 4.8.17 4.8.18	12	1
<u>Group VI</u> DPA (T level only)	3.22	4.8.19	6	0
<u>Group VII</u> Humidity, steady state, low voltage (T level only)	3.25	4.8.21	6	0
<u>Group VIII</u> Life	3.26	4.8.22	24	1

1/ A sample unit having one or more defects will be charged as a single defective.

2/ Nondestructive examinations and tests.

3/ One additional sample unit is included in each sample of 67/55 sample units to permit substitution for the permitted defective in group II.

4.6 In-process inspection and conformance inspection.

4.6.1 In-process inspection. Each production lot shall be inspected as individual chips prior to assembly and as stacked assemblies, after attachment of the termination lead frame, in accordance with table VI.

TABLE VI. In-process inspection.

Inspection	Requirement paragraph	Test method paragraph	Sample size	
			Chips	Stacked assembly
Ultrasonic inspection (T level only)	3.6	4.8.1	100%	N/A
Chip level DPA (T level only)	3.7	4.8.2	see table VII	N/A
In-process visual examination	3.8	4.8.3	100%	100%

TABLE VII. Chip level destructive physical analysis sample size.

Lot size	Minimum sample size Case codes 1, 2, 6 <u>1/</u>	Minimum sample size Case codes 3, 4, 5 <u>2/</u>	Accept	Reject
1 – 500	7	14	0	1
501 – 10000	16	32	1	2
10001 – 35000	25	50	2	3
35001 – 500000	40	80	3	4

1/ Case codes 1, 2, and 6 parts require 2 cuts: one cut at approximately 25 percent from top of part and one cut at approximately 25 percent from bottom of part.

2/ Case codes 3, 4, and 5 parts require one cut at location determined by manufacturer.

4.6.2 Conformance inspection. Inspection of B level product for delivery shall consist of group A inspection. Inspection of T level product for delivery shall consist of in-process inspection, group A, and subgroups 4 and 5b of group B.

4.6.2.1 Inspection and production lot.

4.6.2.1.1 Inspection lot. An inspection lot shall consist of all capacitors of the same voltage-temperature characteristic, produced under essentially the same conditions with the same basic materials, and offered for inspection in the same week. The capacitance values and voltages produced shall be represented in the lot in approximately the ratio of production. Styles PS01 and PS02 may be combined:

4.6.2.1.2 Production lot. A production lot shall consist of all capacitors of the same style, voltage rating, nominal capacitance value, voltage-temperature characteristic, and termination finish. Manufacture of all parts in the lot shall have been started, processed, assembled, and tested as a group. Lot identity shall be maintained throughout the manufacturing cycle. In addition, for T level capacitors, a production lot shall consist of a single chip lot. A single chip lot is one that is processed from a single lot of dielectric powder in a continuous basis.

4.6.3 Group A inspection. Group A inspection shall consist of the inspections specified in [table VIII](#).

TABLE VIII. Group A inspection.

Inspection	Requirement paragraph	Test method paragraph	Sampling procedure	
<u>Subgroup 1</u> Thermal shock and voltage conditioning <u>1/</u>	3.9	4.8.5	100% inspection	
<u>Subgroup 2</u> Visual and mechanical examination: Material Physical dimensions Interface requirements (other than physical dimensions) Marking <u>2/</u> Workmanship	3.4 3.1 3.5 and 3.5.1 3.28 3.30	4.8.4	13 samples 0 failures	
<u>Subgroup 3</u> Solderability <u>3/</u>	3.15	4.8.12	<u>B Level</u> 5 samples 0 failures	<u>T level</u> 3 samples 0 failures
<u>Subgroup 4</u> DPA (T level only)	3.22	4.8.19	3 samples 0 failures	

1/ Post checks are required (see 3.9).

2/ Marking defects are based on visual examination only. Any subsequent electrical defects shall not be used as a basis for determining marking defects.

3/ The manufacturer may request the deletion of the subgroup 3 solderability test, provided an inline or process control system for assessing and assuring the solderability of leads can be validated and approved by the qualifying activity. Deletion of the test does not relieve the manufacturer from meeting this test requirement.

4.6.3.1 Subgroup 1 tests. Subgroup 1 tests shall be performed on a production lot basis on 100 percent of the product supplied under this specification. Capacitors failing the tests of subgroup 1 shall be removed from the lot. For B level capacitors, if, during the 100 percent inspection, screening requires that more than 10 percent of the capacitors or 1 capacitor, whichever is greater, be discarded, the entire lot shall be rejected. For T level capacitors, if screening requires more than the percent defectives allowable (PDA) allowed in [table IX](#), the entire lot shall be rejected.

4.6.3.2 Manufacturer's production inspection. If the manufacturer performs tests similar to those specified in subgroup 1, [table VIII](#) as the final step of their production process, group A, subgroup 1 inspection may be waived and the data resulting from the manufacturer's production tests may be used instead. Authority to waive the subgroup 1 inspections shall be granted by the qualifying activity only. The following criteria must be complied with:

- a. Tests conducted by the manufacturer during production shall be clearly identical to, or more stringent than, that specified for subgroup 1.
- b. Manufacturer subjects 100 percent of the product supplied under this specification to their production tests.
- c. The parameters measured and the failure criteria shall be the same as, or more stringent than, those specified herein.
- d. The lot rejection criteria is the same as, or more stringent than, that specified herein.
- e. The manufacturer shall make available all information concerning the test procedures and instrumentation used in their production tests.
- f. Once approved, the manufacturer shall not change the test procedures or criteria without prior notification of, and concurrence by, the qualifying activity.

4.6.3.3 Rejected lots. Production lots exceeding the PDA of group A, subgroup 1 inspection shall be rejected and shall not be resubmitted.

TABLE IX. T level PDA for subgroup 1, group A inspection.

Case code	PDA last 48 hours during voltage conditioning	PDA overall
1	1% or 1 unit, whichever is greater	8% or 1 unit, whichever is greater
2	1% or 1 unit, whichever is greater	8% or 1 unit, whichever is greater
3	1% or 1 unit, whichever is greater	8% or 1 unit, whichever is greater
4	.5% or 1 unit, whichever is greater	5% or 1 unit, whichever is greater
5	.5% or 1 unit, whichever is greater	5% or 1 unit, whichever is greater
6	1% or 1 unit, whichever is greater	8% or 1 unit, whichever is greater

4.6.3.4 Subgroup 2.

4.6.3.4.1 Sampling plan. Subgroup 2 tests shall be performed on an inspection lot basis for B level capacitors and on a production lot basis for T level capacitors. In the event of one or more failures, the lot shall be rejected.

4.6.3.4.2 Rejected lots. The rejected lots shall be segregated from new lots and those that have passed inspection. Rejected lots shall be 100 percent reworked or scrapped. The rejected lot may be rescreened and the defects removed. The lot may then be resubmitted to the sample plan. If one or more defects of the same type are found in this second sample, the lot is rejected and shall not be supplied to this specification. If another defect of a different type is found in the second sample, a rescreen for that defect is also permitted.

4.6.3.5 Subgroup 3.

4.6.3.5.1 Sampling plan. Solderability tests shall be performed on an inspection lot basis for B level capacitors and on a production lot basis for T level capacitors. The samples shall be selected randomly and subjected to the solderability test. The manufacturer may use electrical rejects from the subgroup 1 and subgroup 2 tests for all or part of the samples to be used for solderability testing. If there are one or more defects, the lot shall be rejected.

4.6.3.5.2 Rejected lots. In the event of one or more defects, the manufacturer may use one of the following options to rework the lot:

- a. Each production lot that was used to form the failed inspection lot shall be individually submitted to the solderability test as required in 4.6.3.5.1. Production lots that pass the solderability test are available for shipment. Production lots failing the solderability test can be reworked only if submitted to the solder dip procedure in 4.6.3.5.2b.
- b. The manufacturer shall submit the failed production lot to a 100 percent solder dip; using an approved solder dip process in accordance with [appendix A](#). Two hundred sample units from this lot shall then be subjected to all group A, subgroup 1, post-electrical tests, with no defects allowed.
 - (1) If the sample units pass the group A, subgroup 1, post-electrical tests, five additional units shall then be subjected to the solderability test, with no defects allowed. If there are one or more defects, the lot shall be considered rejected and shall not be furnished against the requirements of this specification.
 - (2) If the sample units fail group A, subgroup 1 post-electrical tests, these tests shall be performed on 100 percent of the lot. The lot must meet the PDA requirements as specified in [4.6.3.1](#). If the PDA requirements are not met, the lot shall be considered rejected and shall not be furnished against the requirements of this specification. If the PDA requirements are met, five sample units shall be subjected to the solderability testing criteria of [4.6.3.5.2b\(1\)](#).

4.6.3.5.3 Disposition of samples. The solderability test is considered a destructive test and samples submitted to the solderability test shall not be supplied on the contract or order.

4.6.3.6 Subgroup 4 (T level only).

4.6.3.6.1 Sampling plan. Three samples shall be selected randomly from every production lot and subjected to the DPA test. If there are one or more defects, the lot shall be rejected.

4.7 Group B inspection. Group B inspection shall consist of the tests specified in [table X](#) in the order shown, and shall be performed on sample units selected from lots which have passed group A inspection. The tests of subgroups 1, 2, 3, and 5a shall be done on a periodic basis. The tests of subgroup 4 and subgroup 5b shall be done on each T level production lot. T level parts shall not be shipped until the conclusion of the 1,000 hour life test. For B level product, except where the results of this inspection show noncompliance with the applicable requirements (see [4.7.3](#)), delivery of products which have passed group A inspection shall not be delayed pending the results of this inspection.

4.7.1 Sampling plan.

4.7.1.1 Subgroup 1 through subgroup 3. The number of sample units required by [table X](#) shall be taken from production for the period 12 months after initial qualification and if successfully passed, 24 months thereafter and subjected to the applicable tests for their particular subgroups. Capacitor styles manufactured during that period shall be represented, as far as practical, in at least the approximate ratio of production.

4.7.1.2 Subgroup 4 (T level only). For subgroup 4, the number of sample units required by [table X](#) shall be taken from each T level production lot.

4.7.1.3 Subgroup 5a (B level only). For subgroup 5a, the number of sample units required by [table X](#) shall be taken from production every 3 months. Two groups shall be formed:

Group 1: Case sizes 3, 4, and 5 (listed in order from largest to smallest).

Group 2: Case size 6, 2, and 1 (listed in order from largest to smallest).

Group 1 and group 2 shall each be divided into two voltage temperature limit (VTL) groups: (BQ, BR and BX) and BP as shown in [table XI](#). Case sizes manufactured during the period shall be represented, as far as practical, in the approximate ratio of production for each VTL group.

The following units shall be included in each VTL group:

- a. The highest capacitance value, in the highest voltage rating, in the largest case size produced.
- b. The highest capacitance value, in the lowest voltage rating, in the largest case size produced.

No more than one failure is allowed in two consecutive quarters.

4.7.1.4 Subgroup 5b (T level only). For subgroup 5b, the number of sample units required by [table X](#) shall be taken from each T level production lot.

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TABLE X. Group B inspection. 1/

Inspection	Requirement paragraph	Test method paragraph	Number of sample units to be inspected	Number of defectives permitted 2/	
<u>Subgroup 1</u> 3/ Voltage-temperature limits Resistance to solvents 4/ 5/ Immersion Terminal strength 4/	3.16 3.23 3.18 3.24	4.8.13.2 4.8.20 4.8.15 4.8.10	12	1	6/ 1
<u>Subgroup 2</u> Resistance to soldering heat Moisture resistance	3.20 3.21	4.8.17 4.8.18	12	1	
<u>Subgroup 3</u> Marking legibility (laser marking only)	3.28.1	4.8.4.1	6	1	
<u>Subgroup 4</u> (T level only) Humidity, steady-state, low voltage	3.25	4.8.21	6	0	
<u>Subgroup 5a</u> (B level only) Life	3.26	4.8.22	12	7/ 1	
<u>Subgroup 5b</u> (T level only) Thermal shock and electrical tests Life	3.9 3.26	4.8.5.1 and 4.8.5.3 4.8.22	12	1	

1/ Unless otherwise specified herein, when necessary, mounting of group B samples shall be at the discretion of the manufacturer.

2/ A sample unit having one or more defects shall be charged as a single defective.

3/ Order of tests is at discretion of manufacturer.

4/ Sample size shall be 3 pieces with zero defectives permitted.

5/ When more than one marking type is used, an additional three samples shall be added for each additional marking type (see 3.28).

6/ Total of one defect allowed for combination of subgroup 1, subgroup 2, and subgroup 3 inspections.

7/ No more than 1 failure allowed in two consecutive quarters except if manufacturer is maintaining T level.

TABLE XI. Group B, subgroup 5a test groups.

Styles PS01 and PS02			
Case sizes 3, 4, and 5		Case sizes 6, 2, and 1	
BQ, BR, BX	BP	BQ, BR, BX	BP
12	12	12	12

4.7.2 Disposition of sample units. Sample units that have been subjected to group B inspection shall not be delivered on the contract.

4.7.3 Noncompliance (B level only). If a sample unit fails to pass group B inspection, the manufacturer shall notify the qualifying activity and cognizant inspection activity of such failure and take corrective action on the materials or processes, or both, as warranted, and on all units of product which can be corrected and which were manufactured under essentially the same conditions, with essentially the same materials and processes, and which are considered subject to the same failure. Acceptance and shipment of the product shall be discontinued until corrective action, acceptable to the Government, has been taken. After the corrective action has been taken, group B inspection shall be repeated on additional sample units (all inspections), or the inspection that the original sample failed, at the option of the qualifying activity. Group A inspection may be reinstated, however, final acceptance shall be withheld until the group B inspection has shown that corrective action was successful. In the event of failure after reinspection, information concerning the failure and corrective action taken shall be furnished to the cognizant inspection activity and the qualifying activity.

4.8 Methods of examination and test.

4.8.1 Ultrasonic inspection (T level product only) (see 3.6). Capacitors shall be examined in accordance with [appendix B](#). The following details and exceptions shall apply:

- a. Output device: Either a hard or soft copy shall be acceptable provided defects are noted on the copy. Soft copies shall be in a non-proprietary software format.
- b. Views: Views shall be bulk scan.
- c. Scan resolution: Scan resolution shall be .010 inch or less. At the option of the manufacturer, capacitors may be imaged double-sided.
- d. Retention: Retention period shall be 10 years.

4.8.2 Chip level DPA (T level product only) (see 3.7). Prior to assembly, chip capacitors selected in accordance with [table VI](#) shall be examined for the criteria specified in [3.7](#).

4.8.3 In-process visual examination (see 3.8).

4.8.3.1 Prior to assembly, all chip capacitors shall be visually examined using 7X to 10X magnification, for the criteria specified in [3.8.1](#).

4.8.3.2 After assembly, all capacitor stacks shall be visually examined using 7X to 10X magnification, for the lead attachment criteria specified in [3.8.2](#).

4.8.4 Visual and mechanical examination. All capacitors shall be examined using 7X to 10X magnification to verify that the materials, design, construction, physical dimensions, and marking are in accordance with the applicable requirements (see [3.1](#), [3.4](#) through [3.5.1](#) inclusive, and [3.28](#)). All capacitors shall also be examined using 2X to 4X magnification to verify that workmanship is in accordance with the applicable requirements (see [3.30](#)).

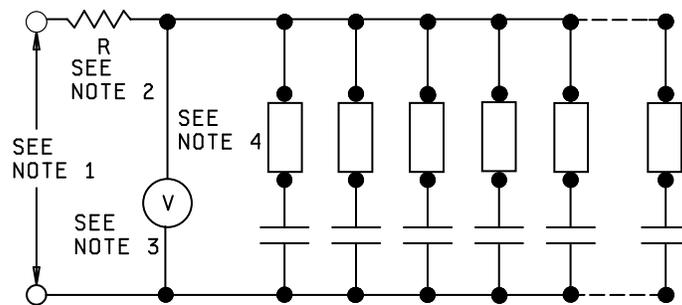
4.8.4.1 Marking legibility (laser marking only, see 3.28.1). Capacitors shall be coated with .005 inch (0.13 mm) minimum of silicone resin insulating compound, type SR of [MIL-I-46058](#). After curing, coated capacitors shall be examined for legibility under normal production room lighting by an inspector with normal or corrected 20/20 vision.

4.8.5 Thermal shock and voltage conditioning (see 3.9). Capacitors shall be subjected to the tests of [4.8.5.1](#) and [4.8.5.2](#).

4.8.5.1 Thermal shock. Capacitors shall be tested in accordance with [MIL-STD-202-107](#). The following details shall apply:

- a. Test condition A, except that in step 3, units shall be tested at +125°C.
- b. Number of cycles:
 - (1) Qualification:
 - (a) T level: 100 cycles.
 - (b) B level: 5 cycles.
 - (2) Group A:
 - (a) T level: 20 cycles.
 - (b) B level: 5 cycles.
 - (3) Group B:
 - (a) T Level: 100 cycles.
 - (b) B level: N/A.

4.8.5.2 Voltage conditioning. Capacitors shall be subjected to the voltage conditioning test in [4.8.5.2.1](#) for B level or [4.8.5.2.2](#) for T level, or the optional voltage conditioning test in [4.8.5.2.3](#). It shall be verifiable that all parts offered for electrical tests have been exposed to the required voltage conditioning for the required time duration. See figure 2 for a suggested test circuit. An alternate test circuit can be used, provided the notes of figure 2 are followed.



NOTES:

1. The power supply shall be capable of supplying the required test voltage.
2. The current limiting device shall be a resistor and/or a fuse. The current shall be limited to no more than 10A.
3. There shall be a voltage monitor that will trigger an alarm and shut off the test if the applied voltage drops by more than 5 percent. Time without voltage does not apply toward the minimum voltage conditioning hours (see [4.8.5.2.1](#) and [4.8.5.2.2](#)).
4. At the option of the manufacturer, a fuse or a resistor may be used in series with each capacitor. The value of the resistors and fuses shall be such that they do not restrict the power supply's ability to provide the required test voltage to the capacitor under test (± 5 percent).

FIGURE 2. Suggested test circuit.

4.8.5.2.1 Voltage conditioning (B level). Voltage conditioning shall consist of applying a minimum of twice the rated voltage (120 percent of rated voltage for 500 volt rated parts) to the capacitors at the maximum rated temperature +4°C, -0°C for 96 hours, minimum. Voltage shall be applied and shall reach maximum value within two minutes maximum. After testing, perform measurements of 4.8.5.3.

4.8.5.2.2 Voltage conditioning (T level). Voltage conditioning shall consist of applying a minimum of twice the rated voltage (120 percent of rated voltage for 500 volt rated parts) to the capacitors at the maximum rated temperature +4°C, -0°C for a minimum of 168 hours and a maximum of 264 hours. Voltage conditioning may be terminated at any time during the 168 to 264 hour time interval, provided that the number of failures detected during the last 48 hours of test meets the PDA requirements specified in table IX. Failures shall be determined by +125°C IR failures. +125°C IR measurements should be made at 120 hours, 168 hours, 216 hours, and 264 hours as necessary. Measurements may be made more often or at different times as long as the last 48 hour PDA can be substantiated. Voltage shall be applied and shall reach maximum value within two minutes maximum. After testing, perform measurements of 4.8.5.3.

If the voltage conditioning test is performed with individual fuses in series with each part, any part tested in a position where a fuse fails shall be tested for +125°C insulation resistance. If the part meets the initial requirements for +125°C insulation resistance, the parts shall be rejected but shall not count against the PDA in table IX. The manufacturer also has the option to not test parts with fuse failures and count these toward the PDA.

4.8.5.2.3 Optional voltage conditioning (capacitors with voltage ratings of 200 volts or less only). The manufacturer, with approval from the qualifying activity, may perform an optional voltage conditioning test instead of the standard voltage conditioning tests of 4.8.5.2.1 or 4.8.5.2.2. All conditions of 4.8.5.2.1 (B level) or 4.8.5.2.2 (T level) apply, with the exception of the voltage applied, the test time, and the time required for meeting the PDA (T level only). The accelerated condition selected for the optional voltage conditioning shall be used for the duration of the test. At no time shall a combination of standard and optional voltage conditioning be allowed on the same samples. The minimum time duration, $T_{test(min.)}$, and the time required for meeting the PDA (T level), $T_{test(PDA)}$, shall be calculated as follows:

$$T_{test(min.)} = \frac{A}{(E_{test}/E_{rated})^3} \quad T_{test(PDA)} = \frac{384}{(E_{test}/E_{rated})^3}$$

Where: $2 \times E_{rated} \leq E_{test} \leq 4 \times E_{rated}$

E_{test}	=	Applied voltage
E_{rated}	=	Rated voltage of the capacitor
$T_{test(min.)}$	=	Minimum test time in hours
$T_{test(PDA)}$	=	Time required for meeting the PDA (T level only)
A	=	1344 for T level or 800 for B level based on an acceleration factor of 8:1.

4.8.5.3 Measurements after testing. After completion of the test, the insulation resistance shall be measured at +125°C in accordance with 4.8.11.2. The units shall then be allowed to stabilize at room temperature (+25°C). After stabilization at room temperature, the dielectric withstanding voltage, insulation resistance, capacitance and dissipation factor shall be measured as specified in 4.8.8.1, 4.8.11.1, 4.8.6, and 4.8.7, respectively.

4.8.6 Capacitance (see 3.13). Capacitors shall be tested in accordance with MIL-STD-202-305. The following details and exceptions shall apply:

- Test frequency: 1 kilohertz ±100 Hz.
- Voltage: A root-mean-square potential of 1.0 volt ±0.2 volt (open circuit voltage).

NOTE: Following a dielectric withstanding voltage or insulation resistance test, capacitance measurement may be delayed for a period up to 24 hours.

4.8.7 Dissipation factor (see 3.12). The dissipation factor shall be measured with a capacitance bridge or other suitable method at the frequency and voltage specified in 4.8.6a and 4.8.6b. Unless otherwise specified, the inherent accuracy of the measurement shall be ± 2 percent of the reading plus 0.1 percent dissipation factor (absolute). Suitable measurement techniques shall be used to minimize errors due to the connections between the measuring apparatus and the capacitor. The dissipation factor shall be measured under the same conditions as capacitance.

4.8.8 Dielectric withstanding voltage (see 3.11).

4.8.8.1 Dielectric. Capacitors shall be tested in accordance with MIL-STD-202-301. The following details shall apply:

- a. Magnitude and nature of test voltage: A minimum of 150 percent of the dc rated voltage for 500 volt rated parts, and a minimum of 250 percent of the dc rated voltage for all other voltage ratings.
- b. Duration of application of test voltage: 5 seconds ± 1 second. The test voltage shall be raised from zero volts to the specified value within 1 second, maximum.
- c. Points of application of test voltage: Between the capacitor-element terminals.
- d. Limiting value of surge current: Shall be limited to between 30 mA and 50 mA.
- e. Examination after test: Capacitors shall be examined for evidence of damage and breakdown.

4.8.8.2 Body insulation (encapsulated styles only, see 3.1). Capacitors shall be tested as specified in 4.8.8.1 with the following exception: Points of application of test voltage-capacitors shall be wrapped with a conductive tape or foil so that the conductive tape or foil shall not be less than .0625 inch (1.59 mm) and more than .125 inch (3.18 mm) away from the lead wires. A dc potential of 1,300 volts shall be applied between the two leads on either side connected together and the tape or foil for a period of 5 seconds ± 1 second. The test circuit shall be so arranged that the surge current does not exceed 50 mA.

4.8.9 Barometric pressure (see 3.14). Capacitors shall be tested in accordance with MIL-STD-202-105. The following details and exceptions shall apply:

- a. Method of mounting: Securely fastened by their normal mounting means.
- b. Test condition: D (100,000 feet) (30.48 km) (.315 inch (8.00 mm) of mercury).
- c. Test during subjection to reduced pressure: A dc potential equal to 80 percent of the dc rated voltage for 500 volt rated parts, and 100 percent of the rated voltage for all other voltage ratings, shall be applied for a period of 5 seconds ± 1 second.
- d. Points of application: The test voltage shall be applied between the capacitor-element terminals.
- e. Surge current: Shall not exceed 50 mA.
- f. Examination during and after test: Capacitors shall be visually monitored for evidence of flashover or damage.

4.8.10 Terminal strength (see 3.24). Capacitors shall be tested in accordance with MIL-STD-202-211. The following details and exceptions shall apply:

- a. Test condition A.
- b. Preparation of specimen: "J" and "L" style leads shall be straightened.

- c. Method of holding: Capacitors shall be held firmly by the body without contacting the lead frame. The load shall be applied gradually and evenly across the length of one terminal by soldering a tie bar across the leads on one side of the capacitor or via special fixturing (see [figure 3](#)). "N" style leads may be tested with the original tie bar in place.
- d. Applied force: Case codes 1, 2, 3, 4, and 6: 5 pounds.
Case code 5: 4 pounds.
- e. Direction of applied force: The point of application of the force and the force applied shall be in the direction of the axes of the terminations, as shown in [figure 3](#).
- f. Examination after test: Capacitors shall be visually examined for evidence of loosening or rupturing of the terminals.

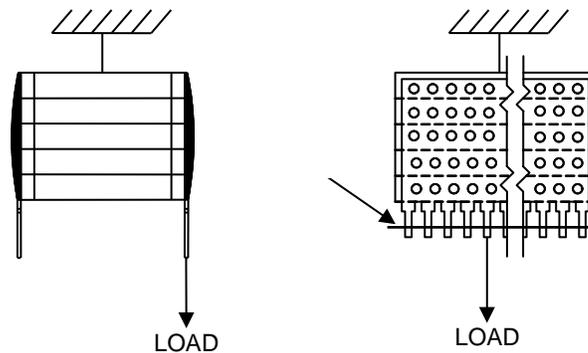


FIGURE 3. Terminal strength - direction of applied force.

4.8.11 Insulation resistance (see [3.10](#)). Capacitors shall be tested in accordance with [MIL-STD-202-302](#). The vendors may determine criteria tighter than the specification limit to which the capacitors may be screened. Only capacitors that fail the specification limit shall be counted against the PDA. The following details shall apply.

4.8.11.1 Insulation resistance at +25°C.

- a. Test potential: Rated voltage, minimum.
- b. Test temperature: +25°C
- c. Special conditions: If a failure occurs at a relative humidity above 50 percent, the insulation resistance may be measured again at any relative humidity less than 50 percent.
- d. Points of measurement: Between the mutually insulated points.

4.8.11.2 Insulation resistance at +125°C.

- a. Test potential: Rated voltage minimum.
- b. Test temperature: +125 ±3°C
- c. Special conditions: Capacitors shall have stabilized at +125°C with test voltage applied prior to performing the test.
- d. Points of measurement: Between the mutually insulated points.

4.8.12 Solderability (see 3.15). Capacitors shall be tested in accordance with MIL-STD-202-208. The following details shall apply:

- a. The capacitors shall be preheated. The preheat shall not exceed 4°C per second. The maximum preheat temperature shall be within 50°C of the solder bath temperature.
- b. Number of terminations to be tested: All leads (see 3.1) (All pins are common per side. For inspection purposes, all pins per side are considered as one lead).
- c. The leads shall be immersed up to the seating plane for unencapsulated parts, or to within .050 inch (1.27 mm) of the seating plane for encapsulated parts (see 3.1).

4.8.13 Voltage-temperature limits (see 3.16).

4.8.13.1 For qualification inspection. The temperature of each capacitor shall be varied as specified in table XII. Capacitance measurements shall be made at the frequency and voltage specified in 4.8.6a and 4.8.6b. The dc rated voltage need only be applied to the capacitor in each of step E through step G of table XII until voltage stability is reached and the capacitance measurement is made. Capacitance measurements shall be made at each step specified in table XII and at a sufficient number of intermediate points between step B and step G to establish a true characteristic curve. Capacitance measurements at each temperature shall be taken only after the test temperature has stabilized.

4.8.13.2 For quality conformance inspection. Capacitance measurements shall be made as specified in 4.8.13.1, except that the measurements shall be made only for step C, step D, step E, and step G of table XII.

TABLE XII. Voltage-temperature limit cycle.

Step	Voltage, dc	Temperature, °C
A	None	+25 ± 2
B	None	-55 ± 2
C ^{1/}	None	+25 ± 2
D	None	+125 ± 2
E	Rated	+125 ± 2
F	Rated	+25 ± 2
G	Rated	-55 ± 2

^{1/} Reference point.

4.8.14 Vibration, high frequency (see 3.17). Capacitors shall be tested in accordance with MIL-STD-202-204. The following details and exception shall apply:

- a. Mounting: Capacitors shall be rigidly mounted; by the body. Electrical connections to the leads shall be made in such a manner that the leads are not damaged during the vibration test (i.e., external wiring to the capacitor shall be sufficiently supported). The test fixture shall be so constructed as to preclude any resonance within the test range. An examination of the mounting fixture shall be made on a vibrator. If any resonant frequencies are observed, adequate steps must be taken to damp the structure.
- b. Electrical load conditions: During the test, a dc potential equal to rated voltage or 200 volts, whichever is less (see 3.1), shall be applied between the terminals of the capacitor element under test.
- c. Test condition D: 20 G's.
- d. Duration and direction of motion: Three hours in each of three mutually perpendicular planes.

- e. Measurements during vibration: During the last cycle in each direction, an electrical measurement shall be made to determine intermittent contacts of 0.5 ms or greater duration, or open-circuiting or short-circuiting.
- f. Examination after vibration: Capacitors shall be visually examined for evidence of mechanical damage.

4.8.15 Immersion (see 3.18). Capacitors shall be tested in accordance with MIL-STD-202-104. The following details shall apply:

- a. Test condition: B.
- b. Examinations and measurements after final cycle: Capacitors shall be visually examined for evidence of mechanical damage and obliteration of marking; dielectric withstanding voltage, insulation resistance at +25°C, capacitance, and dissipation factor shall then be measured as specified in 4.8.8.1, 4.8.11.1, 4.8.6, and 4.8.7, respectively.

4.8.16 Shock, specified pulse (see 3.19). Capacitors shall be tested in accordance with MIL-STD-202-213. The following details shall apply:

- a. Mounting: Capacitors shall be rigidly mounted by the body.
- b. Test condition I: 100 G's.
- c. Measurements during shock: During the last shock in each direction, an electrical measurement shall be made to determine intermittent contacts of 0.5 ms or greater duration, or open-circuiting or short-circuiting.
- d. Examination after shock: Capacitors shall be visually examined for evidence of breakdown, arcing, and mechanical damage.

4.8.17 Resistance to soldering heat (see 3.20). Capacitors shall be tested in accordance with MIL-STD-202-210. The following details and exceptions shall apply:

- a. The capacitors shall be preheated. The preheat shall not exceed 4°C per second. The maximum preheat temperature shall be within 50°C of the solder bath temperature.
- b. Surface oxides and dross shall be skimmed off the solder pot immediately before lead immersion to ensure full and complete heat flow through the leads.
- c. Depth of immersion in the molten solder: To a minimum of .050 inch -0 inch, +.020 inch (1.27 mm -0 mm, +0.51 mm) from the capacitor body.
- d. Test condition:
 - (1) N lead style: test condition B.
 - (2) J and L lead styles: test condition I.
- e. Measurements after test: Dielectric withstanding voltage, insulation resistance at +25°C, capacitance, and dissipation factor shall be measured as specified in 4.8.8.1, 4.8.11.1, 4.8.6, and 4.8.7, respectively.
- f. Internal examination after test: Not required.

4.8.18 Moisture resistance (see 3.21). Capacitors shall be tested in accordance with MIL-STD-202-106. The following detail and exceptions shall apply:

- a. Initial measurements: Not applicable.
- b. Number of cycles: Twenty continuous cycles.

- c. Step 7b: Not applicable.
- d. Loading: During the first ten cycles only, a dc potential of 100 volts or rated voltage, whichever is less, shall be applied across the capacitor terminals. There shall be a voltage monitor that will indicate when the applied voltage drops or increases by more than 5 percent, and shut off the test. The resistance of the voltage monitor shall be a minimum of 10X the equivalent resistance of the series resistor and the device under test.
- e. Examinations and final measurement: On completion of step 6 of the final cycle, capacitors shall be conditioned at +25°C ±5°C and a maximum relative humidity of 55 percent for a period of 18 hours minimum, 24 hours maximum, and shall be visually examined for evidence of mechanical damage and obliteration of marking; dielectric withstanding voltage, insulation resistance at +25°C, capacitance, and dissipation factor shall then be measured as specified in [4.8.8.1](#), [4.8.11.1](#), [4.8.6](#), and [4.8.7](#), respectively.

4.8.19 DPA (T level only) (see [3.22](#)). Capacitors shall be examined as specified in [ECIA EIA-469](#) for the criteria specified in [3.22](#).

4.8.20 Resistance to solvents (see [3.23](#)). Capacitors shall be tested in accordance with [MIL-STD-202-215](#). The following details shall apply:

- a. The marked portion of the capacitor body shall be brushed.
- b. Capacitors shall be visually examined for evidence of mechanical damage and obliteration of marking.

4.8.21 Humidity, steady state, low voltage (see [3.25](#)). Capacitors shall be tested in accordance with [MIL-STD-202-103](#), condition A. The following details and exceptions shall apply:

Note: At no time during test shall voltage greater than 1.55 volts be applied to any capacitor under test.

- a. Initial measurements: Capacitance shall be measured in accordance with [4.8.6](#).
- b. Tests: Capacitors shall be subjected to an environment of +85°C with 85 percent relative humidity for 240 hours minimum. Cycling shall not be performed. A dc potential of 1.3 ± 0.25 volts shall be applied continuously through a 100 kilohm resistor.
- c. Final measurements: On completion of test, remove the capacitors from the chamber and allow 3 hours, 30 minutes, ±30 minutes for drying and stabilization at 25°C before performing insulation resistance (through a 100 kilohm resistor at 1.3 ± 0.25 volts) and capacitance in accordance with [4.8.11.1](#) and [4.8.6](#), respectively. The capacitors shall then be examined for evidence of mechanical damage and obliteration of marking.

4.8.22 Life (at +125°C) (see [3.26](#)). Capacitors shall be tested in accordance with [MIL-STD-202-108](#). The following details and exceptions shall apply:

- a. Distance of temperature measurements from specimens, in inches: Not applicable.
- b. Operating conditions: Capacitors shall be subjected to +125°C at a minimum of 120 percent of the rated dc voltage for 500 volt rated parts, and a minimum of 200 percent of dc rated voltage for all other voltage ratings. Voltage shall be applied and shall reach maximum value within two minutes, maximum. Test circuitry shall be the same as that required for voltage conditioning (see [4.8.5.2](#)).
- c. Length of test:
 - (1) T level qualification: 4,000 hours, minimum.
 - (2) B level qualification: 1,000 hours, minimum.
 - (3) B level and T level group B: 1,000 hours, minimum.

d. Measurements during and after exposure:

- (1) T level product: Insulation resistance shall be measured during exposure to the high test temperature at 250 hours, 1000 hours, and 4000 hours as specified in 4.8.11.2. Measurements may be taken at additional times. At the option of the manufacturer, the capacitors may be transferred to another chamber maintained at the same temperature for the purpose of measuring insulation resistance. The insulation resistance measurement shall be made only after the units have stabilized at the test temperature. The capacitors shall then be returned to the inspection conditions specified in 4.3 and shall be visually examined for evidence of mechanical damage and obliteration of marking; insulation resistance, capacitance, and dissipation factor, shall be measured as specified in 4.8.11.1, 4.8.6, and 4.8.7, respectively.
- (2) B level product: At the conclusion of this test and while the capacitors are at the high test temperature, the insulation resistance shall be measured as specified in 4.8.11.2. At the option of the manufacturer, the capacitors may be transferred to another chamber maintained at the same temperature for the purpose of measuring insulation resistance. The insulation resistance measurement shall be made only after the units have stabilized at the test temperature. The capacitors shall then be returned to the inspection conditions specified in 4.3 and shall be visually examined for evidence of mechanical damage and obliteration of marking; insulation resistance, capacitance, and dissipation factor, shall be measured as specified in 4.8.11.1, 4.8.6, and 4.8.7, respectively.

4.8.23 Low temperature storage (see 3.27). Capacitors shall be subjected to exposure at -65°C +0°C, -3°C for a period of 8 hours, minimum.

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 commands. 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 not mandatory.)

6.1 Intended use. These capacitors are primarily designed for use where a small physical size with comparatively large electrical capacitance and high insulation resistance is required. General purpose (BQ, BR, and BX characteristics) ceramic capacitors are not intended for frequency-determining or precision circuits but are suitable for use as by-pass, filter, and noncritical coupling elements in high-frequency circuits. All of these applications are of the type where dissipation factor is not critical and moderate changes due to temperature, voltage, and frequency variations do not affect the proper functioning of the circuit. BP characteristic ceramic capacitors are for use in critical frequency determining applications, timing circuits, and other applications where absolute stability is required. Two product levels are offered: B level (standard reliability) and T level for higher reliability applications.

6.1.1 Caution. Capacitors covered by this specification of case size 5 may be prone to arcing if used above 300 volts.

6.1.2 Precautionary note. Capacitors covered by this specification are very susceptible to thermal shock damage due to their large ceramic mass. Temperature profiles used should provide adequate temperature rise and cool-down time to prevent damage from thermal shock. The capacitors should be preheated. The preheat and cool down should not exceed 4°C per second. The maximum preheat temperature should be within 50°C of the solder bath temperature. Consult manufacturers for further recommendation.

6.1.3 Precautionary note. Capacitors covered by this specification have high mass and are susceptible to thermal and mechanical damage. Special board assembly processing and mounting precautions may be necessary especially in high vibration environments. Consult manufacturers for recommendations.

6.2 Acquisition requirements. Acquisition requirements should specify the following:

- a. Title, number, and date of this specification, the applicable specification sheet, and the complete PIN (see 1.2.1).
- b. Capacitor marking requirements (see 3.28.3 and 3.28.4).
- c. Packaging requirements (see 5.1).

6.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in the Qualified Products List whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is CERDEC PRD: RDER-PRO, Building 6010 K-130, Aberdeen Proving Ground, Aberdeen, MD 21005; however, information pertaining to qualification of products may be obtained from DLA Land and Maritime, ATTN: VQP, PO Box 3990, Columbus, OH 43218-3990, or by email to vqp.chief@dla.mil. An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at <https://assist.dla.mil>.

6.3.1 Copies of SD-6. Copies of SD-6, "Provisions Governing Qualification" are available online at <https://assist.dla.mil>.

6.4 Case insulation. It is not intended that the case insulation be subjected to sustained voltage in excess of 150 percent of the dc rated voltage of the capacitor. Supplementary insulation should be provided where the case may come in contact with higher voltage.

6.5 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. For additional information on this matter, refer to [ASTM-B545](#) (Standard Specification for Electrodeposited Coatings of Tin).

6.6 Subject term (key word) listing.

Dielectric withstanding voltage
Dissipation factor
Insulation resistance
Statistical process control (SPC)

6.7 Changes from previous issue. The margins of this specification are marked with vertical lines to indicate where changes from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last previous issue.

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APPENDIX A

PROCEDURE FOR QUALIFICATION INSPECTION

A.1 SCOPE

A.1.1 Scope. This appendix details the procedure for submission of samples for qualification inspection of capacitors covered by this specification. The procedures for extending qualification of the required sample to other capacitors covered by this specification; is also outlined herein. This appendix is a mandatory part of this specification. The information contained herein is intended for compliance.

A.2 SUBMISSION

A.2.1 Sample.

A.2.1.1 Single-style submission. A sample of the size required in [table V](#), of the highest capacitance value in each voltage rating, in each voltage-temperature limit, in each style for which qualification is sought shall be submitted.

A.2.1.2 Extension of qualification by similarity. Qualification may be extended for each case type, unencapsulated or encapsulated. The number of samples submitted for qualification shall be evenly divided for all groups in [table A-I](#).

TABLE A-I. Qualification samples.

Qualification inspection group (see table V)	Number of samples of each case type
Group III	3 each of the unencapsulated and encapsulated.
Group IV	6 each of the unencapsulated and encapsulated.
Group V	6 each of the unencapsulated and encapsulated.
Group VI	3 each of the unencapsulated and encapsulated.
Group VII	3 each of the unencapsulated and encapsulated.
Group VIII	12 each of the unencapsulated and encapsulated.

A.3 EXTENT OF QUALIFICATION

A.3.1 Single-style submission.

- a. Capacitance: Range qualification will be restricted to values equal to and less than the capacitance value submitted.
- b. Capacitance tolerance: Capacitance tolerance qualification will be restricted to tolerances equal to and wider than the tolerance submitted.
- c. DC rated voltage qualification will be restricted to that submitted. Operating temperature range and voltage-temperature limit qualification will be restricted to that submitted.

A.3.2 Product level.

A.3.2.1 B level qualification from T level. Qualification of the T level product qualifies to the B level product of same design.

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A.3.2.2 T level qualification from B level. To add T level qualification once qualified to B level, the following needs to be accomplished, in the following order:

- a. [Table V](#), group I (Thermal shock - 100 cycles). Voltage conditioning after thermal shock is not required but may be performed at the manufacturer's option. Electrical measurements of [4.8.5.3](#) shall be performed regardless of whether voltage conditioning is performed or not.
- b. [Table V](#), group VI (DPA) with the requirements of [3.7](#) and [3.22](#).
- c. [Table V](#), group VII (Humidity, steady state, low voltage).
- d. [Table V](#), group VIII (Life - 4,000 hours minimum).

The lot used for qualification shall not be sold as T level parts.

A.4 SOLDER DIP (RETINNING) LEADS

A.4.1 Solder dip (retinning) leads. The manufacturer may solder dip/retin the leads of capacitors supplied to this specification provided the solder dip process (A.4.2) or an equivalent process has been approved by the qualifying activity.

A.4.2 Qualifying activity approval. Approval of the solder dip process will be based on one of the following options:

- a. When the original lead finish qualified was hot solder dip lead finish 52 in accordance with [MIL-STD-1276](#) (NOTE: The 200 microinch maximum thickness is not applicable). The manufacturer shall use the same solder dip process for retinning as was used in the original manufacture of the capacitor.
- b. When the lead originally qualified was not solder dip lead finish 52 of [MIL-STD-1276](#) as prescribed in A.4.2a, approval for the process to be used for solder dip shall be based on the following procedure:
 - (1) Twenty samples of any capacitance value for each style and lead finish shall be subjected to the manufacturer's solder dip process. The capacitors shall then be subjected to all [group A](#), subgroup 1 post-electrical tests with no defects allowed.
 - (2) Ten of the samples shall then be subjected to the solderability test, with no defects allowed.
 - (3) The remaining 10 samples shall be subjected to the resistance to soldering heat test, followed by the moisture resistance test with no defects allowed.

A.4.3 Solder dip/retinning options. The manufacturer may solder dip/retin as follows:

- a. As a corrective action if the lot fails the group A solderability test.
- b. After the group A inspection has been completed, and following the solder dip/retinning process, the dielectric withstanding voltage, insulation resistance (at +25°C), dissipation factor, and capacitance measurements shall be performed on 100 percent of the lot. The percent defective allowable (PDA) shall be the same as that allowed for subgroup 1 of the group A inspection.

APPENDIX B

ULTRASONIC INSPECTION OF CERAMIC CAPACITORS

B.1 SCOPE

B.1.1 Scope. This appendix specifies the procedures and practices necessary for ultrasonic inspection of ceramic capacitors. Ultrasonic imaging is a nondestructive method for detecting internal physical defects in ceramic capacitors which are not otherwise visible. Ultrasonic imaging techniques are intended to reveal such flaws as delaminations, voids, and cracks. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

B.1.2 Definitions.

B.1.2.1 Bulk scanning. Bulk scanning is the process of using a single c-scan to image the entire thickness of the capacitor. Typically, the transducer is focused 50 percent into the capacitor.

B.1.2.2 C-scan. C-scan is a scan in an x-y plane with the z axis location fixed.

B.1.2.3 Double sided scanning. Double sided scanning is the process of using 2 c-scans to image a capacitor, where both scans have the capacitors oriented with the electrodes perpendicular to the sound wave. After the first scan, the capacitors are flipped over 180° and scanned a second time. Typically, the transducer is focused 25 percent into the capacitor.

B.1.2.4 False responses. When performing ultrasonic imaging, a response typically indicates the presence of air trapped in the capacitor body. The air is due to voids, delaminations, or cracks. When the response does not indicate the presence of air, it is a false response. False responses are typically seen when imaging non flat surfaces such as the edges of a capacitor or terminated surfaces.

B.1.2.5 Field of view: Field of view is the x-y area scanned. Optimal field of view is determined by multiplying the spot size by pixel density.

B.1.2.6 Reflection mode. Reflection mode uses one transducer to both send and receive ultrasound (often called pulse/echo).

B.1.2.7 Resolution. Resolution is the ability of a particular ultrasound system to discriminate closely spaced features. For a system using a focused transducer, the resolution is dependent on the material of the capacitor under test, the characteristics of the transducer, the characteristics of the pulser and receiver, the coupling fluid used, and software capability.

B.2 APPARATUS

B.2.1 Ultrasonic inspection equipment. The ultrasonic equipment shall be capable of performing c-scans in the reflection mode. The frequency will be such that the acoustic wave can penetrate the ceramic capacitor and image the back surface. If this is not possible, double sided scanning should be considered, but the depth that the sound wave will penetrate should be well understood. The resolution of the scan shall be adequate to detect defects as specified (see 4.8.1), relative to the size of the capacitor.

B.2.2 Output device. When specified (see 4.8.1), a hard or soft copy, grey (or color) scale image, shall be recorded for each capacitor scanned. The image or hard copy shall have sufficient resolution to meet the specified requirements (see 4.8.1). Maximum contrast shall be used to highlight rejects.

B.2.3 Holding tank. The holding tank shall be level and designed to hold the coupling fluid and locating fixtures without corroding or contaminating the capacitors under test.

B.2.4 Ultrasonic detector. Focused transducers capable of reflection mode imaging shall be used for inspection.

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B.3 PROCEDURE

B.3.1 Mounting and handling. If offline inspection is used, capacitors shall be set-up in fixtures in order to identify and locate accept/reject pieces. Capacitors shall be fixtured so that the electrodes are perpendicular to the sound wave pulse from the transducer. If this is not possible, a second scan should be performed with the capacitors rotated 90° from the original scan. If any adhesive is used to fixture the capacitors, it shall be easily removed and not contaminate the capacitors. The coupling fluid is typically water or any other suitable fluid that will not contaminate the capacitors under test. Capacitors shall only be immersed in water for the time necessary to complete the imaging. Capacitors shall be cleaned and dried after imaging. Care shall be taken to ensure that no moisture remains trapped in the capacitors after drying.

B.3.2 Views. Unless otherwise specified (see 4.8.1), bulk scanning shall be used. Each capacitor shall be imaged at least once or as specified (see 4.8.1).

B.3.3 Recording and marking. Images used for accept/reject determination shall be of sufficient resolution to meet the specified requirements (see 4.8.1). Reject or unclassified capacitors shall be clearly noted on the records. Information stored with the records should clearly indicate the original identification of the image.

B.3.4 Identification. All capacitors must be identified prior to imaging. A detailed tally shall be kept of the number of capacitors inspected, number of capacitors accepted, and number of capacitors failed.

B.3.5 Set-up verification. Verification of the test set-up shall be carried out on periodic basis. Unless otherwise specified (see 4.8.1), the supplier shall determine the verification method to be used. The verification method used shall demonstrate that the set-up will find known defects and shall be approved by the qualifying activity.

B.3.6 Tests. The frequency of the transducer used shall be sufficient to resolve defects equal to or larger than the specified requirements (see 4.8.1), while still penetrating at least 50% (double-sided imaging) or 100% (single sided imaging) of the capacitor. Gate settings, receiver attenuation, and other equipment settings shall be selected to achieve the resolution specified (see 4.8.1).

B.3.7 Operating personnel. Personnel engaged in ultrasonic inspection shall have training in ultrasonic imaging procedures and techniques. They shall be certified by their employer to be capable of setting up and operating the equipment to meet the specified requirements (see 4.8.1) and ensuring that the accept/reject determinations are valid.

B.3.8 Interpretation of ultrasonic images. Ultrasonic images shall be inspected to determine that each capacitor meets the specified criteria (see 4.8.1). Hard copy or electronic images shall be of adequate resolution and lighting to make valid accept/reject determinations.

B.3.9 Examination and acceptance criteria. Capacitors shall be rejected when they have ultrasonic responses that indicate the presence of voids, cracks, or delaminations that exceed the allowances specified (see 3.6).

B.4 REPORT

B.4.1 Inspection record. The manufacturer or test facility shall maintain adequate verification of the results of the ultrasonic inspection. A complete record of the details of the inspection shall be kept by the manufacturer or test facility. If the capacitors are scanned at a location other than that of the manufacturer, the items listed below shall be included in the summary report provided to the manufacturer. The record or manufacturer's procedures shall include the following information:

- a. Equipment used, including the transducer frequency, focal length, diameter, and serial number, if applicable.
- b. Scan resolution.
- c. Field of view / pixel density.

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- d. Fixturing method and adhesive used, if applicable.
- e. Whether capacitors are terminated or unterminated.
- f. Typical thickness of the capacitors imaged.
- g. Number of capacitors scanned and the accept/reject quantities.
- h. Date.
- i. Name of operator.
- j. Capacitor type or part number.
- k. Capacitor manufacturer.
- l. Ultrasonic laboratory, if other than capacitor manufacturer.
- m. Typical scanned images for accept capacitors.

B.4.2 Retention. All ultrasonic images and reports shall be maintained for the period specified (see 4.8.1).

B.5 CALCULATIONS

B.5.1 Fundamental resolution of transducer (λ):

$$\lambda = c/f$$

Where: λ = wavelength
 c = material sound velocity
 f = frequency

NOTE: For detection, the flaw must be a minimum of half the wavelength.

B.5.2 F number ($F\#$):

$$F\# = \text{Focal length} / \text{Diameter}$$

B.5.3 Spot size (ΔX):

$$\Delta X = 1.22 \times F\#(\lambda/2)$$

B.5.4 Resolution of focused transducer in reflection mode (R):

$$R = .707\Delta X$$

B.5.5 Depth of field (ΔZ):

$$\Delta Z = 7.1(F\#)^2(\lambda/2)$$

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B.5.6 Example.

For a 50 MHz transducer with a focal length of .5 inch, a diameter of .250 inch, and using 5.53×10^3 m/s as the velocity of sound in barium titanate:

$$\lambda = 5.53 \times 10^3 / 50 \times 10^6 = .00011 \text{ m} = .0044 \text{ inch}$$

$$\lambda/2 = 55 \text{ } \mu\text{m} = .0022 \text{ inch}$$

$$F\# = .5 / .25 = 2$$

$$\Delta X = 1.22 \times 2(.0022) = .0054 \text{ inch}$$

$$R = .707(.0054) = .0038 \text{ inch}$$

$$\Delta Z = 7.1(2)^2(.0022) = .0625 \text{ inch}$$

TABLE B-1. Typical transducer resolution and depth of focus for barium titanate based ceramic capacitors.

Transducer frequency (MHz)	Fundamental resolution		Focal length (inches)	Diameter (inches)	F#	Spot size (inches)	Theoretical resolution (inches)	Optimal FOV (@512, in)	Optimal FOV (@1024, in)	Depth of focus (inches)
	(μm)	(inches)								
10	275	.0100	2.000	.500	4	.0488	.03450	24.9856	49.9712	2.2720
10	275	.0100	.750	.375	2	.0183	.01294	9.3696	18.7392	.5680
15	180	.0070	.750	.500	1.5	.0128	.00906	6.5587	13.1174	.2237
20	137	.0050	1.250	.250	5	.0153	.01078	7.8080	15.6160	1.7750
20	137	.0050	.500	.250	2	.0061	.00431	3.1232	6.2464	.2840
30	92	.0036	1.250	.250	5	.0110	.00776	5.6218	11.2435	1.2780
30	92	.0036	.750	.250	3	.0066	.00466	3.3731	6.7461	.4601
30	92	.0036	.500	.250	2	.0044	.00311	2.2487	4.4974	.2045
50	55	.0022	1.000	.250	4	.0107	.00759	3.7478	7.4957	.2499
50	55	.0022	.500	.250	2	.0054	.00381	1.8739	3.7478	.0625
75	38	.0015	.500	.250	2	.0018	.00129	.9370	1.8739	.0852
100	25	.0010	.500	.250	2	.0012	.00086	.6246	1.2493	.0568
100	25	.0010	.200	.250	0.8	.0005	.00035	.2499	.4997	.0091

Custodians:
Army - CR
Navy - EC
Air Force - 85
DLA - CC
Other - NA

Preparing activity:
Army - CR

Agent:
DLA - CC

(Project 5910-2018-001)

Review activities:
Army - AR, AT, AV, MI
Navy - MC
Air Force - 19, 99
Other - MDA

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