

MILITARY SPECIFICATION

CAPACITORS, FIXED, ELECTROLYTIC (SOLID ELECTROLYTE), TANTALUM,
ESTABLISHED RELIABILITY,
GENERAL SPECIFICATION FOR

FAILURE RATE LEVELS "M", "P" AND "R" ARE
INACTIVE FOR NEW DESIGN AFTER 2 FEBRUARY 1984.

FAILURE RATE LEVEL "S" IS INACTIVE
FOR NEW DESIGN AFTER 15 AUGUST 1984.

This specification is approved for use by all Depart-
ments and Agencies of the Department of Defense.

1: SCOPE

1.1 Scope. This specification covers the general requirements for established reliability, insulated, tantalum, electrolytic (solid electrolyte), fixed capacitors, hermetically sealed $1/$ in metal cases (see 6.1). Rated voltages range from 6 to 100 volts dc with surge voltages of 8 to 130 volts dc, respectively (see 4.7.19). These capacitors have reliability ratings established on the basis of life tests performed at specified voltage at +85°C for failure rate (FR) levels ranging from:

- a. 1.0 percent per 1,000 hours to 0.001 percent per 1,000 hours in accordance with MIL-STD-690. These FR levels are established at a 50-percent confidence level and are maintained at a 10-percent producer's risk (Exponential distribution).
- b. 0.1 percent per 1,000 hours to 0.0001 percent per 1,000 hours (1 FIT) $2/$ at a 90-percent confidence level (Weibull distribution).

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

$1/$ For the purpose of this specification, a hermetically-sealed capacitor is one in which the capacitance element is contained within a sealed enclosure of ceramic, glass or metal, or combinations thereof, where sealing is accomplished by material fusion, welding, brazing, or soldering.

$2/$ FIT = failure unit = one failure per 10^9 device hours.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Space and Naval Warfare Systems Command, ATTN: SPAWAR 3111, Department of the Navy, Washington, DC 20363, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1425) appearing at the end of this document or by letter.

2. APPLICABLE DOCUMENTS

2.1 Government specification and standards. Unless otherwise specified, the following specification and standards, or the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation, form a part of this specification to the extent specified herein.

SPECIFICATION

MILITARY

MIL-C-39028 - Capacitors, Packaging of.

(See supplement 1 for list of associated specification sheets.)

STANDARDS

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
 MIL-STD-202 - Test Methods for Electronic and Electrical Component Parts.
 MIL-STD-690 - Failure Rate Sampling Plans and Procedures.
 MIL-STD-790 - Reliability Assurance Program for Electronic Parts Specifications.
 MIL-STD-310 - Environmental Test Methods.
 MIL-STD-1276 - Leads, Weldable, for Electronic Component Parts.
 MIL-STD-1285 - Marking of Electrical and Electronic Parts.

(Copies of the specification and standards required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

2.2 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein (except for associated detail specifications, specification sheets or MS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede 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 sheets. In the event of any conflict between requirements of this specification and the specification sheets, the latter shall govern (see 6.2).

3.2 Qualification. Capacitors furnished under this specification shall be products which are qualified for listing on the applicable qualified products list at the time set for opening of bids (see 4.4 and 6.3). In addition, the manufacturer shall obtain certification from the qualifying activity that the reliability assurance requirements of 4.1.1 have been met and are being maintained. Unless acquired from the manufacturer or his authorized distributor listed or approved for listing on the qualified products list, parts furnished under this specification shall not be considered as having met the requirements of this specification.

3.3 Reliability. Reliability of capacitors furnished under this specification shall be established and maintained in accordance with the procedures and requirements specified in MIL-STD-790 and MIL-STD-690 with details specified in 4.1.1, 4.4.4, and 4.6.1.3. The reliability rating is identified by the following FR level symbols:

Symbol	Exponential FR level (%/1,000 hrs)	Symbol	Weibull FR level (%/1,000 hrs)
M	1.0	B	0.1
P	0.1	C	0.01
R	0.01	D	0.001
S	0.001	E	0.0001 (1 FIT)

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 guaranty of the acceptance of the finished product.

3.4.1 Sleeving. The sleeving shall be of a nonfungus nutrient material (cardboard shall not be used). In addition, the material used shall not soften, creep, or shrink to a point where any part of the cylindrical case is left uncovered at any test temperature specified herein.

3.5 Design and construction. Capacitors shall be of the design, construction, and physical dimensions specified (see 3.1). Nonpolarized capacitors shall be constructed from two CSR13 polarized units which have passed group A inspection.

3.5.1 Case. Each capacitor shall be enclosed in a hermetically-sealed metal case which will protect the capacitor element from moisture and mechanical damage under all test conditions specified herein. Nonpolarized capacitors, consisting of two hermetically-sealed capacitors joined together, need not be hermetically sealed within the joining sleeve.

3.5.2 Terminal leads. Terminal leads shall conform to MIL-STD-1276; the lead type, length, and diameter shall be as specified (see 3.1). Terminal leads shall be permanently secured internally and externally.

3.6 Thermal shock. When tested as specified in 4.7.2, capacitors shall withstand the extremes of high and low temperatures without visible damage.

3.7 Voltage aging (exponential only). When tested as specified in 4.7.3, capacitors shall meet the following requirements:

DC leakage - - - - - Shall not exceed the requirement specified in 3.10.
 Capacitance- - - - - Shall be within the tolerance specified (see 3.1).
 Dissipation factor - - - - - Shall not exceed the requirement specified in 3.12.
 Equivalent series resistance
 (CSR21 only) - - - - - Shall not exceed the requirement specified (see 3.1).

3.8 Seal (polarized capacitors only, see 3.1). When capacitors are tested as specified in 4.7.4, there shall be no evidence of leakage.

3.9 Radiographic inspection (polarized capacitors only, see 3.1) (not applicable to exponential distribution FR level "M"). When capacitors are tested as specified in 4.7.5, radiographic inspection shall disclose no evidence of improperly made connections, misalignment of slugs and seals or eyelets, substandard soldering or structural weakness, or solder particles or slivers (see 6.4).

3.10 DC leakage. When measured as specified in 4.7.6, the dc leakage shall not exceed the applicable value specified (see 3.1).

3.11 Capacitance. When measured as specified in 4.7.7, the capacitance shall be within tolerance of the nominal value specified (see 3.1).

3.12 Dissipation factor. When measured as specified in 4.7.8, the dissipation factor shall not exceed the value specified (see 3.1).

3.13 Equivalent series resistance (ESR) (style CSR21 only). When measured as specified in 4.7.9, the ESR shall not exceed the value specified (see 3.1).

3.14 Shock (specified pulse) (see 3.1). When capacitors are tested as specified in 4.7.10, there shall be no intermittent contacts of 0.5 millisecond (ms) or greater duration, or arcing or other indication of breakdown, nor shall there be any open- or short-circuiting or evidence of mechanical damage.

3.15 Vibration, high frequency (polarized capacitors only, see 3.1). When capacitors are tested as specified in 4.7.11, there shall be no intermittent contacts of 0.5 ms or greater duration, or arcing or other indication of breakdown, nor shall there be any open- or short-circuiting or evidence of mechanical damage.

3.16 Salt spray (corrosion). When capacitors are tested as specified in 4.7.12, there shall be no harmful corrosion, and at least 90 percent of any exposed metal surface of the capacitor shall be protected by the finish. There shall be no unwrapping of, or mechanical damage to, the sleeving. Marking shall remain legible.

NOTE: Harmful corrosion shall be construed as being any type of corrosion which in any way interferes with the mechanical or electrical performance of the capacitor.

3.17 Thermal shock and immersion (polarized capacitors only, see 3.1). When tested as specified in 4.7.13, capacitors shall meet the following requirements:

DC leakage - - - - - Shall not exceed the requirement specified in 3.10.
 Capacitance- - - - - Shall change not more than ± 3 percent from the value obtained when measured as specified in 4.7.7.
 Dissipation factor - - Shall not exceed the requirement specified in 3.12.
 Visual examination - - There shall be no evidence of harmful corrosion (as defined in 3.16), mechanical damage, or obliteration of marking.

3.18 Solderability (polarized capacitors only, see 3.1). When capacitors are tested as specified in 4.7.14, the dipped portion of the leads shall conform to the solid-wire termination criteria of method 208 of MIL-STD-202.

3.19 Terminal strength (polarized capacitors only, see 3.1). When capacitors are tested as specified in 4.7.15, there shall be no loosening of the terminals nor permanent damage to the terminals, terminal weld, or terminal solder, as applicable.

3.20 Moisture resistance (polarized capacitors only, see 3.1). When tested as specified in 4.7.16, capacitors shall meet the following requirements:

DC leakage - - - - - Shall not exceed the requirement specified in 3.10.
 Capacitance- - - - - Shall change not more than ± 2 percent from the value obtained when measured as specified in 4.7.7.
 Dissipation factor - - Shall not exceed the requirement specified in 3.12.
 Visual examination - - There shall be no evidence of harmful corrosion (as defined in 3.16), mechanical damage, or obliteration of marking.

3.21 Sleeving (polarized capacitors only, see 3.1). When capacitors are tested as specified in 4.7.17, the sleeving shall withstand the specified potential without breakdown; and the insulation resistance shall be 1,000 megohms, minimum.

3.22 Stability at low and high temperatures (polarized capacitors only, see 3.1). When tested as specified in 4.7.18, capacitors shall meet the following requirements:

Step 1 (+25°C):

DC leakage- - - - - Shall not exceed the requirement specified in 3.10.
 Capacitance - - - - - Shall be within tolerance of the nominal value specified (see 3.1).
 Dissipation factor- - - - - Shall not exceed the requirement specified in 3.12.

Step 2 (-55°C):

Capacitance - - - - - Shall change not more than the applicable value specified (see 3.1) from the step 1 measured value.
 Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

Step 3 (+25°C):

DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).
 Capacitance - - - - - Shall change not more than ± 2 percent from the step 1 measured value.
 Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

Step 4 (+85°C):

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).
- Capacitance - - - - - Shall change not more than the applicable value specified (see 3.1) from the step 1 measured value.
- Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

Step 5 (+125°C):

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).
- Capacitance - - - - - Shall change not more than ±12 percent from the step 1 measured value.
- Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

Step 6 (+25°C):

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).
- Capacitance - - - - - Shall change not more than ±2 percent from the step 1 measured value.
- Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

3.23 Surge voltage (polarized capacitors only, exponential only, see 3.1). When tested as specified in 4.7.19, capacitors shall meet the following requirements:

- DC leakage- - - - - Shall not exceed the requirement specified in 3.10.
- Capacitance - - - - - Shall change not more than ±2 percent from the value obtained when measured as specified in 4.7.7.
- Dissipation factor- - - - - Shall not exceed the requirement specified in 3.12.

3.24 Life (polarized capacitors only, exponential only, see 3.1). When capacitors are tested as specified in 4.7.20, there shall be no mechanical damage, intermittent shorts, or permanent shorts or opens.

3.24.1 Qualification inspection. When tested as specified in 4.7.20.1, capacitors shall meet the following requirements:

At +25°C:

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).
- Capacitance - - - - - Shall change not more than the applicable value specified (see 3.1) from the value obtained when measured as specified in 4.7.7.
- Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

At +85°C:

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).

At +125°C:

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).

3.24.2 Quality conformance inspection.

3.24.2.1 Group A inspection. When tested as specified in 4.7.3 or 4.7.25, exponential or Weibull as applicable, capacitors shall meet the requirements specified in 3.7 or 3.29. Weibull failure rate level requirements of 4.7.5 and 3.29 shall be accepted in lieu of group B inspection data.

3.24.2.2 Group B inspection, exponential only. When tested as specified in 4.7.20.2.1, capacitors shall meet the requirements specified in 3.24.1.

3.24.2.3 Group C life or extended life (see 4.6.1.3.2). When tested as specified in 4.7.20.2.2, capacitors shall meet the following requirements:

At +25°C:

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).
- Capacitance - - - - - Shall change not more than ±10 percent from the value obtained when measured as specified in 4.7.7.
- Dissipation factor- - - - - Shall not exceed the applicable value specified (see 3.1).

At +85°C:

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).

At +125°C:

- DC leakage- - - - - Shall not exceed the applicable value specified (see 3.1).

3.25 Fungus (polarized capacitors only, see 3.1). The manufacturer shall certify that all external materials are fungus resistant or shall perform the test specified in 4.7.21. When tested as specified in 4.7.21, examination shall disclose no evidence of fungus growth on the external surface.

3.26 Resistance to solvents. When capacitors are tested as specified in 4.7.22, there shall be no evidence of mechanical damage and the marking shall remain legible.

3.27 Resistance to soldering heat (polarized capacitors only, see 3.1). When tested as specified in 4.7.23, capacitors shall meet the following requirements:

- DC leakage- - - - - Shall not exceed the requirement specified in 3.10.
- Capacitance - - - - - Shall change not more than ±2 percent from the value obtained when measured as specified in 4.7.7.
- Dissipation factor- - - - - Shall not exceed the requirement specified in 3.12.
- Visual examination- - - - - There shall be no evidence of external damage.

3.28 Ripple current (style CSR21 only). When capacitors are tested as specified in 4.7.24, there shall be no mechanical damage, intermittent shorts, or permanent shorts or opens, and the capacitors shall meet the following requirements:

At +25°C:

- DC leakage- - - - - Shall not exceed the applicable value specified in 3.10.
- Capacitance - - - - - Shall change not more than ±2.0 percent from the value obtained when measured as specified in 4.7.7.
- Dissipation factor- - - - - Shall not exceed the applicable value specified in 3.12.
- ESR - - - - - Shall not exceed the applicable value specified in 3.13.

3.29 Weibull FR level grading (in lieu of 3.7). When tested as specified in 4.7.25, capacitors shall exhibit decreasing failure rate with respect to time as evidenced by a value of beta (β) which is less than 0.9; and the instantaneous failure rate in the last interval shall be no more than the failure rate specified. After grading, capacitors shall meet the following requirements:

DC leakage- - - - -	Shall not exceed the requirement specified in 3.10.
Capacitance - - - - -	Shall be within the tolerance specified (see 3.1).
Dissipation factor- - - - -	Shall not exceed the requirement specified in 3.12.
ESR (CSR21 only)- - - - -	Shall not exceed the requirement specified (see 3.1).

Capacitors tested as specified in 4.7.25 shall be exempt from group A percent defective allowable (PDA) provisions (see 4.6.1.2); exempt from 3.24.2.2 group B inspection (see 4.6.1.3); and exempt from 3.24.2.3 extended life (see 4.6.1.3.2).

3.30 Marking.

3.30.1 Capacitor marking. Capacitors shall be marked in accordance with method I of MIL-STD-1285 and shall include the specified information, in the sequence shown, for the applicable case size (see 3.1) as shown in the following examples:

EXAMPLE (case sizes A, A1, and B1):

M39003	-	Military specification number.
02 - TM	-	Specification sheet number and trademark.
2054J	-	Nonsignificant dash number and "J" for JAN.
<u>3/</u> +424 A	-	Polarity, date code (first digit indicates year and the next two digits indicate the week), and lot symbol(s).

EXAMPLE (case size B):

M39003	-	Military specification number.
01 -	-	Specification sheet number.
6007J	-	Nonsignificant dash number and "J" for JAN.
12345	-	Source code.
<u>4/</u> +424 A	-	Polarity, date code (first digit indicates year and the next two digits indicate the week), and lot symbol(s).

EXAMPLE (case sizes C and D):

M39003	-	Military specification number.
01 - 6300J	-	Specification sheet number, nonsignificant dash number and "J" for JAN.
<u>5/</u> +12 μ F	-	Positive terminal identifier and capacitance value.
10% 75 V	-	Capacitance tolerance and voltage rating.
12345	-	Source code.
8424 AB	-	Date code, lot code.

- 3/ Polarity symbol shall be near the positive terminal and may be placed on either end of the fourth line of type depending on the marking orientation with respect to the polarity.
- 4/ Polarity symbol shall be near the positive terminal and may be placed on either end of the fifth line of type depending on the marking orientation with respect to the polarity.
- 5/ Polarity symbol shall be near the positive terminal and may be placed on either end of the third line of type depending on the marking orientation with respect to the polarity.

EXAMPLE (case sizes W, X, Y, and Z):

M39003	-	Military specification number.
04 - 3168J	-	Specification sheet number, nonsignificant dash number and "J" for JAN.
.0023 μ F	-	Capacitance value.
10% 100VNP	-	Capacitance tolerance and voltage rating, nonpolarized.
8424 AB 12345	-	Date code, lot code, source code.

Additional marking may appear at the option of the manufacturer provided that it does not interfere with the required marking.

3.30.2 Package marking. For Government shipments, all packages shall be marked with the capacitance value, capacitance tolerance, dc rated voltage, contract number of the part (not the package), National Stock Number (NSN), source code, and the date of packaging.

3.30.3 "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 electrical equipment, namely, resistors, capacitors, electron tubes and the like, acquired by, or manufactured for use by, or for the Government in accordance with standard Government specifications. Accordingly, capacitors acquired to, and meeting all of, the criteria specified herein and in applicable specification sheets (see 3.1) shall bear the certification mark "JAN", except that capacitors too small to bear the certification mark "JAN" shall bear the letter "J". Capacitors furnished under contracts or orders which either permit or require deviation from the conditions or requirements specified herein and in applicable specification sheets (see 3.1) shall not bear "JAN" or "J". In the event a capacitor sample fails to meet the requirements of this specification and the applicable specification sheet (see 3.1), the manufacturer shall remove the "JAN" or "J" from the sample tested and also from all capacitors represented by the sample. The United States Government has obtained Certificate of Registration No. 504,860 for the certification mark "JAN".

3.30.4 Supplying to higher FR levels. A manufacturer may supply to all higher FR levels than that to which he is qualified. Parts qualified and marked to lower FR levels are substitutable for higher FR level parts, and shall not be remarked unless specified in the contract or purchase order.

3.31 Workmanship. Capacitors shall be processed in such a manner as to be uniform in quality and shall be free from cold soldering, harmful corrosion (see 3.16), pits, cracks, dents, rough edges, and other defects that will affect life, serviceability, or appearance. Solder on the surface of the case shall be smooth and unbroken and shall have no pin holes or girdle.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Reliability assurance program. A reliability assurance program shall be established and maintained in accordance with MIL-STD-790, with the following exceptions:

- a. In lieu of the procedure for production lot identification, the manufacturer shall, as a minimum, be able to identify the time period which the final production operation was performed on each item of product prior to final test. The date or lot code marked on each part shall be identified to an inspection lot.
- b. Traceability of materials shall not apply.

Evidence of such compliance shall be verified by the qualifying activity of this specification as a prerequisite for qualification and continued qualification.

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

- a. Qualification inspection (see 4.4).
- b. Verification of qualification (see 4.5).
- c. Quality conformance inspection (see 4.6).

4.3 Inspection conditions and methods.

4.3.1 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.

4.3.2 Methods.

4.3.2.1 AC measurements. AC measurements shall be made at the frequency specified. The magnitude of the ac voltage shall be equal to or less than 1.0 volt root mean square (rms). For all ac measurements of polarized capacitors, the maximum dc bias voltage shall be equal to or less than 2.2 volts.

4.3.2.2 Reference measurements. When requirements are based on comparative measurements made before and after conditioning, the reference measurements shall be considered the last measurements made at $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ 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 rated voltage. The power source employed for dc leakage current measurements shall be stabilized to at least ± 100 parts per million. During measurements there must be no voltage fluctuations of sufficient amplitude to produce a variation in the current measurement as read with any dc leakage current tester used to test capacitors.

4.4 Qualification inspection (polarized capacitors only, see 3.1 and 30.3). 6/ 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 subjected to qualification inspection shall be as specified in the appendices to this specification. Each capacitor style shall be qualified separately.

4.4.2 Inspection routine. The sample shall be subjected to the inspections specified in table I, in the order shown. All sample units shall be subjected to the inspection of group I. Two sample units shall be subjected to the visual and mechanical examination (internal) and 177 sample units (189 sample units for CSR21) shall be subjected to the remaining inspections of group II. The 177 units successfully completing group II inspection shall then be divided as specified in table I for groups III to VIII inclusive, (189 units for CSR21, successfully completing group II inspections shall then be divided as specified in table I for groups III to IX inclusive), and subjected to the inspections for their particular group; for combined voltage group submissions, each type shall be equally represented in each group.

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

4.4.4 FR qualification.

6/ Qualification approval will be based on the successful completion of the tests specified in table I, and will not be withheld pending completion of the extended life test of 4.4.4.1a.

4.4.4.1 Exponential. Exponential FR qualification shall be in accordance with the general and detailed requirements of MIL-STD-690 and the following details:

- a. Procedure I - Qualification at the initial FR level. FR level "M" of FRSP-50 shall apply. Sample units shall be subjected to the qualification inspection specified in group VII, table I (see 4.4.2). The entire life test sample shall be continued on test to 10,000 hours as specified in 4.7.20.2.2 upon completion of the 2,000-hour qualification test.
- b. Procedure II - Extension of qualification to lower FR levels. To extend qualification to FR level "P", data shall be limited to each voltage group within a style; for FR levels "R" and "S", data from two or more voltage groups within a style of similar construction may be combined.
- c. Procedure III - Maintenance of FR level qualification. Maintenance period B of FRSP-10 shall apply. Regardless of the number of production lots produced during this period, the specified number of unit hours shall be accumulated to maintain qualification (see 4.6.1).

4.4.4.2 Weibull. Weibull FR qualification will be granted only to manufacturers who have achieved FR level "P" in accordance with 4.4.4.1. To extend qualification to include Weibull FR levels, the manufacturer shall demonstrate the capability of Weibull FR level grading, see 4.7.25, to the qualifying activity.

4.5 Verification of qualification (polarized capacitors only, see 3.1). Every 6 months, the manufacturer shall compile a summary of the results of quality conformance inspections and, where applicable, extended FR test data, in the form of a verification of qualification report, and forward it to the qualifying activity as the basis of continued qualification approval. In addition to the periodic submission of FR test data, the manufacturer shall immediately notify the qualifying activity whenever the FR data indicates that the manufacturer has failed to maintain his qualified FR level. Continuation shall be based on evidence that, over the 6-month period, the following has been met:

- a. Verification by the qualifying activity that the manufacturer meets the requirements of MIL-STD-790.
- b. The manufacturer has not modified the design of the item. Change in design includes but is not limited to any change of materials or processes.
- c. The specification requirements for the item have not been amended so as to affect the character of the item.
- d. Lot rejection for group A does not exceed 5 percent or one lot, whichever is greater; not applicable to table IIIB.
- e. Requirements for group C are met.
- f. The records of all FR tests combined per style substantiate that the "M" or "P" FR level has been maintained or that the manufacturer continues to meet the "R" or "S" FR level for which qualified, although the total component hours of testing may not, as yet, meet the requirements of 4.4.4.1c.
- g. The records of all Weibull life FR tests are summarized for each style, stress level, and acceleration factor (see table IIIC).

If group C requirements were not met and the manufacturer has taken corrective action satisfactory to the Government, the forwarding of the verification of qualification report may be delayed until within 30 days after completion of retesting of the periodic quality conformance tests. In this case, the qualifying activity shall be notified of this condition within the time that the original verification of qualification report was due. All reports shall be certified by a responsible company official. The qualifying activity shall be contacted for the report format.

TABLE I. Qualification inspection.

Inspection	Requirement paragraph	Test method paragraph	Number of sample units to be inspected	Number of failures allowed ^{1/}
<u>Group I</u> ^{2/}				
Thermal shock - - - - -	3.6	4.7.2	} All units	} Not applicable
Voltage aging - - - - -	3.7	4.7.3		
Seal - - - - -	3.8	4.7.4		
Radiographic inspection (not applicable to FR level "M") - - - - -	3.9	4.7.5		
<u>Group II</u>				
Visual and mechanical inspection (internal) - -	3.1, 3.4, and 3.5	4.7.1	2	0
Visual and mechanical inspection (external) ^{2/ 3/} - - - - -	3.1, 3.4, 3.5, 3.30, and 3.31	4.7.1	} <u>4/</u>	} 1
DC leakage ^{2/} - - - - -	3.10	4.7.6		
Capacitance ^{2/} - - - - -	3.11	4.7.7		
Dissipation Factor ^{2/} - - -	3.12	4.7.8		
ESR ^{2/} (style CSR21 only) -	3.13	4.7.9		
<u>Group III</u>				
Shock (specified pulse) - -	3.14	4.7.10	} 12	} 1
Vibration, high frequency -	3.15	4.7.11		
Salt spray (corrosion) - -	3.16	4.7.12		
Thermal shock and immersion - - - - -	3.17	4.7.13		
<u>Group IV</u>				
Solderability - - - - -	3.18	4.7.14	} 12	
Terminal strength - - - - -	3.19	4.7.15		
Moisture resistance - - - - -	3.20	4.7.16		
Sleeving - - - - -	3.21	4.7.17		
<u>Group V</u>				
Stability at low and high temperatures - - - - -	3.22	4.7.18	} 12	
Surge voltage - - - - -	3.23	4.7.19		
<u>Group VI</u> ^{5/}				
Life (at +125 C) - - - - -	3.24.1	4.7.20.1	24	
<u>Group VII</u> ^{5/}				
Life (at +85 C) - - - - -	3.24.1	4.7.20.1	102	1
<u>Group VIII</u>				
Fungus - - - - -	3.25	4.7.21	} 8	} 0
Resistance to solvents - -	3.26	4.7.22		
Resistance to soldering heat - - - - -	3.27	4.7.23		
<u>Group IX</u>				
Ripple current (CSR21 only)	3.28	4.7.24	12	1

- 1/ A sample unit having one or more defects shall be considered as a single failure.
2/ Nondestructive tests.
3/ Marking defects are based on visual examination only and shall be charged only for illegible, incomplete, or incorrect marking.
4/ The sample size for CSR21 shall be 189 units, and the sample size for all other styles shall be 177. One additional sample unit is included in each sample size to permit substitution for the failure allowed in groups II through VI.
5/ For qualification of design changes only, qualified manufacturers may submit Weibull data in lieu of groups VI and VII test data.

TABLE II. Voltage groups.

Style	Voltage group	Case size	Voltage range
			Volts
CSR09,	1	A and B; A1 and B1; W and X	6 through 35
CSR13,	2	C and D; Y and Z	5 through 35
or	3	A and B; A1 and B1; W and X	36 through 100
CSR91	4	C and D; Y and Z	36 through 100
CSR23	5	A and B	5 through 20
or	6	C and D	6 through 20
CSR33	7	A and B	21 through 50
	8	C and D	21 through 50
CSR21	9	C and D	6 through 20
	10	C and D	21 through 50

4.6 Quality conformance inspection.

4.6.1 Inspection of product for delivery. Inspection of product for delivery shall consist of groups A and C inspections for nonpolarized units and groups A, B (if applicable, see 3.1), and C inspections for polarized units. However, shipment need not be held pending the results of group C tests.

4.6.1.1 Inspection lot.

4.6.1.1.1 Exponential distribution. An inspection lot shall consist of capacitors of the same style from the same production line or lines, of the same basic design, produced under essentially the same conditions, and offered for inspection during a single work week. Styles CSR09 and CSR13 may be combined for maintenance of FR levels "R" and "S". Each style must be maintained to at least the "P" level. Total hours for both styles combined must justify "R" or "S". Combinations of case sizes and voltages within a style that may be combined to form a lot are shown in table II.

4.6.1.1.2 Weibull distribution. An inspection lot shall consist of capacitors of the same style, voltage rating, design, and nominal capacitance rating produced in the same case size. 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. All anodes shall be fabricated from a single identifiable powder lot.

4.6.1.2 Group A inspection. Group A inspection shall consist of the inspections specified in table IIIA or IIIB, and shall be made on the same set of sample units, in the order shown.

4.6.1.2.1 Sampling plan.

4.6.1.2.1.1 Polarized units. For subgroups 1 and 4 (as applicable, see 3.1), sampling shall be as specified in table IIIA or table IIIB. Statistical sampling and inspection for subgroups 2 and 3 shall be in accordance with MIL-STD-105. The acceptable quality levels (AQL) and limiting quality (LQ) where $P_a = 10\%$ shall be as specified in table IIIA or table IIIB. At the option of the manufacturer, numerically lower AQL's may be used as long as the specified LQ is not exceeded numerically. Major and minor defects shall be as defined in MIL-STD-105 and as specified in tables IIIA and IIIB. For exponential distribution:

- a. The samples selected to form the lot shall be representative of the case sizes and voltage groups produced during the sampling period.
- b. If, during the 100-percent inspections of subgroup 1, when applicable, screening requires that over 5 percent of the capacitors be discarded, the lot shall be rejected and shall not be resubmitted. Defective units obtained from lots with less than five percent defective allowed (PDA) may be reworked, resubmitted only once and thermal shock only need not be done again.
- c. A one-percent PDA shall apply to all resubmitted lots.

4.6.1.2.1.2 Nonpolarized units. Nonpolarized units shall be subjected to the thermal shock and voltage aging test as specified in table IIIA. If, during the 100-percent inspection, screening requires that over 5-percent of the capacitors be discarded, the lot shall be rejected.

TABLE IIIA. Group A inspection (exponential distribution).

Inspection	Requirement paragraph	Test method paragraph	Quality levels (percent defective)	
			FR level	
			M	P, R, and S
<u>Subgroup 1</u>				
Thermal shock- - - - -	3.6	4.7.2	100% inspection	} 100% inspection
Voltage aging <u>1/</u> - - - -	3.7	4.7.3	100% inspection	
Seal <u>2/</u> - - - - -	3.8	4.7.4	100% inspection	
Radiographic inspection <u>2/</u> <u>3/</u> - - - - -	3.9	4.7.5	Not required	
All FR levels				
			Major	Minor
<u>Subgroup 2</u> <u>2/</u>				
Visual and mechanical inspection (external)- -	3.1, 3.4, 3.5, 3.30, and 3.31	4.7.1	1.0 (AQL) 7.6 (LQ)	4.0 (AQL) 18.0 (LQ)
All FR levels				
<u>Subgroup 3</u> <u>2/</u>				
Stability at low and high temperatures - - - - -	3.22	4.7.18	0.65 (AQL) 4.8 (LQ)	
<u>Subgroup 4</u> <u>2/</u>				
Surge voltage- - - - -	3.23	4.7.19	12 <u>4/</u>	

- 1/ Applicable to CSR21 and CSR33 only.
- 2/ Not applicable to nonpolarized units, see 4.6.1.2.1.2 and 3.1.
- 3/ Exempt from 5% PDA; rejects shall not be delivered on the contract or order.
- 4/ Twelve units from subgroup 3 samples to be submitted to this test, one failure allowed.

TABLE IIIB. Group A inspection (Weibull distribution).

Inspection	Requirement paragraph	Test method paragraph	Quality levels (percent defective)		
			All FR levels		
			Major	Minor	
<u>Subgroup 1</u>					
Thermal shock <u>1</u> / - - - - -	3.6	4.7.2	100% inspection		
Life (accelerated failure rate) <u>1</u> <u>2</u> / - - - - -	3.29	4.7.25	100% inspection		
Seal <u>1</u> / - - - - -	3.8	4.7.4	100% inspection		
Radiographic inspection <u>1</u> / <u>2</u> / <u>3</u> / - - - - -	3.9	4.7.5	100% inspection		
<u>Subgroup 2</u> <u>1</u> /					
Visual and mechanical inspection (external) - -	3.1, 3.4, 3.5, 3.30, and 3.31	4.7.1	1.0 (AQL) 7.6 (LQ)	4.0 (AQL) 18.0 (LQ)	
			All FR levels		
<u>Subgroup 3</u> <u>1</u> /			Sample	Accept	Reject
Stability at low and high temperatures - - - - -	3.22	4.7.18	13 pcs.	1 failure	2 or more failures

- 1/ Not applicable to nonpolarized units, see 4.6.1.2.1.2 and 3.1.
- 2/ Exempt from 5% PDA; rejects shall not be delivered on the contract or order.
- 3/ Not applicable to Weibull graded units marked with exponential M-level FR dash numbers.

4.6.1.2.2 Manufacturer's production inspection. If the manufacturer performs tests similar to those specified in subgroup 1, table IIIA or table IIIB, as the final step of his 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 inspection shall be granted by the qualifying activity only. The following criteria shall 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. Test conditions shall be equal to or more stringent than those specified for subgroup 1.
- b. Manufacturer subjects 100 percent of the product supplied under this specification to his production tests.
- c. The parameters measured and the failure criteria shall be the same or more stringent than those specified herein.
- d. The lot rejection criteria are the same or more stringent than that specified herein.
- e. The manufacturer shall make available all information concerning the test procedures and instrumentation used in his production tests. This data shall be provided as part of the evaluation required for MIL-STD-790. The manufacturer shall also make available to the Government all records of all detail test data resulting from production tests.
- f. Once approved, the manufacturer shall not change the test procedures or criteria without prior notification and concurrence by the qualifying activity.

4.6.1.2.3 Disposition of sample units. Sample units which have been subjected to subgroup 4 of group A inspection shall not be delivered on the contract or purchase order.

4.6.1.2.4 Rejected lots. Inspection lots rejected as a result of failure to pass subgroup 2 inspection may be resubmitted for Government acceptance only if the manufacturer performs 100-percent inspection on capacitors of the lot for those characteristics which were defective and resulted in rejection of the lot, removes all defective units and resubmits the lot for quality conformance inspection. Inspection lots rejected as a result of failure to pass subgroup 3 or 4 shall not be resubmitted. Resubmitted lots shall be kept separate from new lots, and shall be clearly identified as resubmitted lots.

4.6.1.3 Group B inspection (polarized units only) (exponential only). Group B inspection shall consist of the test specified in table IV, and shall be made on sample units which have been subjected to and have passed the group A (subgroups 1, 2, and 3) inspections.

TABLE IV. Group B inspection.

Inspection	Requirement paragraph	Test method paragraph
Life (at +85°C) - - - - -	3.24.2.2	4.7.20.2.1

4.6.1.3.1 Sampling plan. A sample shall be selected at random from each inspection lot that has passed group A (subgroups 1, 2, and 3) inspections. The sample chosen shall be representative of each voltage group with the highest capacitance value in each case size represented in the lot (see 4.6.1.1.1). Sampling for quality conformance life test shall be as specified herein. The detailed quality conformance procedures of MIL-STD-690, with the following details and exceptions, shall apply:

- a. Lot sampling: 110 samples.

- b. Duration of lot conformance FR test: 240 hours.
- c. Failure criteria: As specified in 3.24; one failure per lot.
- d. Permissible combination of voltage ratings and case sizes: As specified in 4.6.1.1.1.
- e. Disposition of samples and inspection lot: Sample units which have been subjected to group B inspection may be delivered on the contract or purchase order provided they are 100-percent inspected to verify that they meet all of the requirements listed in table IIIA, subgroup 2, and that the dissipation factor, capacitance, and dc leakage are within the initial limits specified (see 3.1). The inspection lot may be shipped upon completion of lot conformance FR test.

Even though the lot has been rejected, those units in the lot which were predesignated for extended life testing shall remain or be placed on test for the full length of time.

4.6.1.3.2 Extended life. In addition, a minimum of 10 units shall be selected at random from each inspection lot and subjected to the extended life test specified in 4.7.20.2.2. The manufacturer may increase this sample size if desired in order to develop the necessary number of unit hours of data for maintenance or extension of qualification. The sample size may vary over the minimum from lot to lot at the manufacturer's option. The units selected for the extended life test may be from those subjected to group B inspection or from other units in the lot. In any case, the units to be subjected to the extended life test shall be predesignated before any life tests are initiated. The extended life test may be initiated periodically with units accumulated from each lot, or may be initiated on a lot-by-lot basis. The units selected for extended life test from each lot shall be representative of the capacitance values, case sizes, and voltages included in the lot to the maximum extent possible. In any case, over the production period covered by the maintenance of qualification requirements, the data shall be representative of the case sizes, voltages, and range of values produced.

4.6.1.3.3 Failure in group B inspection. If an inspection lot is rejected as a result of failure to pass group B inspection, the lot shall not be resubmitted. Even though the lot has been rejected, those units which were predesignated for extended life testing shall remain or be placed on test for the full length of time.

4.6.2 Periodic inspection. Periodic inspection shall consist of group C inspection. Except where the results of these inspections show noncompliance with the applicable requirements (see 4.5.2.1.3), delivery of products which have passed groups A and B shall not be delayed pending the results of these periodic inspections.

4.6.2.1 Group C inspection. Group C inspection shall consist of the tests specified in table V, in the order shown. Group C inspection shall be made on sample units selected from inspection lots which have passed the group A inspection for nonpolarized units and Weibull distribution inspection lots; and groups A and B inspections for polarized units (exponential distribution inspection lots).

4.6.2.1.1 Sampling plan.

4.6.2.1.1.1 Polarized units. There shall be 56 sample units of each style (68 sample units for CSR21) taken from production every 2 months and subdivided as specified for subgroups 1, 2, 3, 4, and 6 listed in table V and subjected to the tests specified in those subgroups, in the order shown. The maximum and minimum case sizes manufactured during that month shall be represented in the sample in at least the approximate ratio of production. Allowable failures shall be as specified in table V.

4.6.2.1.1.2 Nonpolarized units. There shall be 12 sample units of style CSR91 taken from production every 2 months that style CSR91 is produced, subdivided as specified in subgroup 5 of table V and subjected to the tests specified in that subgroup, in the order shown. The maximum and minimum case sizes manufactured during that month shall be represented in the sample in at least the approximate ratio of production. No failures are allowed.

TABLE V. Group C inspection.

Inspection	Requirement paragraph	Test method paragraph	Number of samples	Allowable failures		
<u>Subgroup 1</u>						
Shock (specified pulse) - - - -	3.14	4.7.10	} 12	} 1		
Vibration, high frequency - - -	3.15	4.7.11				
Salt spray (corrosion) - - - -	3.16	4.7.12				
Thermal shock and immersion - -	3.17	4.7.13				
<u>Subgroup 2</u>						
Solderability - - - - - - - - -	3.18	4.7.14	} 12		} 1	
Terminal strength - - - - - - -	3.19	4.7.15				
Moisture resistance - - - - - - -	3.20	4.7.16				
Sleeving - - - - - - - - - - -	3.21	4.7.17				
<u>Subgroup 3</u>						
Life (at +125°C) - - - - - - -	3.24.2.3	4.7.20.2.2	24	} 0		
<u>Subgroup 4</u>						
Resistance to solvents - - - - -	3.25	4.7.22	} 8			} 0
Resistance to soldering heat - -	3.27	4.7.23				
<u>Subgroup 5</u> ^{1/}						
Salt spray (corrosion) - - - - -	3.16	4.7.12	} 6		} 0	
Resistance to solvents - - - - -	3.26	4.7.22				
<u>Subgroup 6</u>						
Ripple current (CSR21 only) - -	3.28	4.7.24	12	1		

^{1/} Nonpolarized capacitors only, see 3.1.

4.6.2.1.2 Disposition of sample units. Sample units which have been subjected to group C inspection shall not be delivered on the contract or purchase order.

4.6.2.1.3 Noncompliance. If a sample fails to pass group C inspection, the manufacturer shall notify the qualifying activity and the 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 are manufactured under 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 qualifying activity has been taken. After the corrective action has been taken, group C inspection shall be repeated on additional sample units (all inspections, or the inspection which the original sample failed, at the option of the qualifying activity). Groups A and B inspections may be reinstated; however, final acceptance and shipment shall be withheld until the group C inspection has shown that the corrective action was successful. In the event of failure after reinspection, information concerning the failure shall be furnished to the cognizant inspection activity and the qualifying activity.

4.6.3 Inspection of packaging. The sampling and inspection of the preservation, packing, and container marking shall be in accordance with the requirements of MIL-C-39028.

4.7 Methods of inspection.

4.7.1 Visual and mechanical inspection. Capacitors shall be examined from a distance of 6 inches in normal room lighting and without the aid of magnification to verify that the materials, design, construction, physical dimensions, marking and workmanship are in accordance with the applicable requirements (see 3.1, 3.4, 3.5, 3.30 and 3.31). If closer examination is required, the capacitors shall be examined at no greater than 4X maximum magnification.

4.7.2 Thermal shock (see 3.6). Capacitors shall be tested in accordance with method 107 of MIL-STD-202. The following details shall apply:

- a. Special mounting: Not applicable.
- b. Test condition letter: B.
- c. Measurements before and after cycling: Not applicable.

4.7.3 Voltage aging (exponential only) (see 3.7). Capacitors shall be placed in a suitable test chamber maintained at $\pm 55 \text{ C} \pm 5 \text{ C}$ and shall be subjected to the applications of rated dc voltage, minimum, for a minimum of 40 hours, except nonpolarized capacitors (see 3.1) shall be tested for 20 hours, minimum, in each direction. The aging circuit shall have a total resistance, exclusive of the capacitor, but including fuse wiring and internal impedance of the power supply, of not more than 3 ohms under any operating condition. Capacitors shall be removed from the chamber, stabilized at room ambient conditions (see 4.3), and the dc leakage, capacitance, dissipation factor, and ESR (CSR21 only) shall then be measured as specified in 4.7.6, 4.7.7, 4.7.8, and 4.7.9, respectively.

4.7.4 Seal (polarized capacitors only, see 3.1) (see 3.8). Capacitors shall be tested in accordance with method 112 of MIL-STD-202. The following detail and exception shall apply:

- a. Test condition letter: A, D, or equivalent.
- b. Examination after test: Not applicable.

This test may be accomplished prior to the addition of the sleeve.

4.7.5 Radiographic inspection (polarized capacitors only, see 3.1) (not applicable for FR level "M") (see 3.9). Capacitors shall be tested in accordance with method 209 of MIL-STD-202. The following details shall apply:

- a. Radiographic quality: Sufficient definition to determine that specimens are free from defects specified in 3.9 and shall render a clear sharp image of the penetrameter.
- b. Image-quality indicator: An image of the penetrameter shall be included on each radiograph. The penetrameter may be made from a sample capacitor, of the same style as the capacitor being radiographed, with an AWG number 48 copper, gold, or tungsten wire mounted across the capacitor body, or it may be fabricated in accordance with, or be equivalent to, the example in figure 1.
- c. Positions of specimen: One plane at 90-degree rotation perpendicular to the longitudinal axis. If failures exceed the allowable limit, Xray shall be performed in two planes for all subsequent lots. The manufacturer may return to one-plane testing when three sequential lots meet specification limits.
- d. Evaluation of images:
 - (1) Special kind of viewing equipment: Magnifying glass.
 - (2) Magnification: 10X.
 - (3) Defects to be sought in specimen: As specified in 3.9.

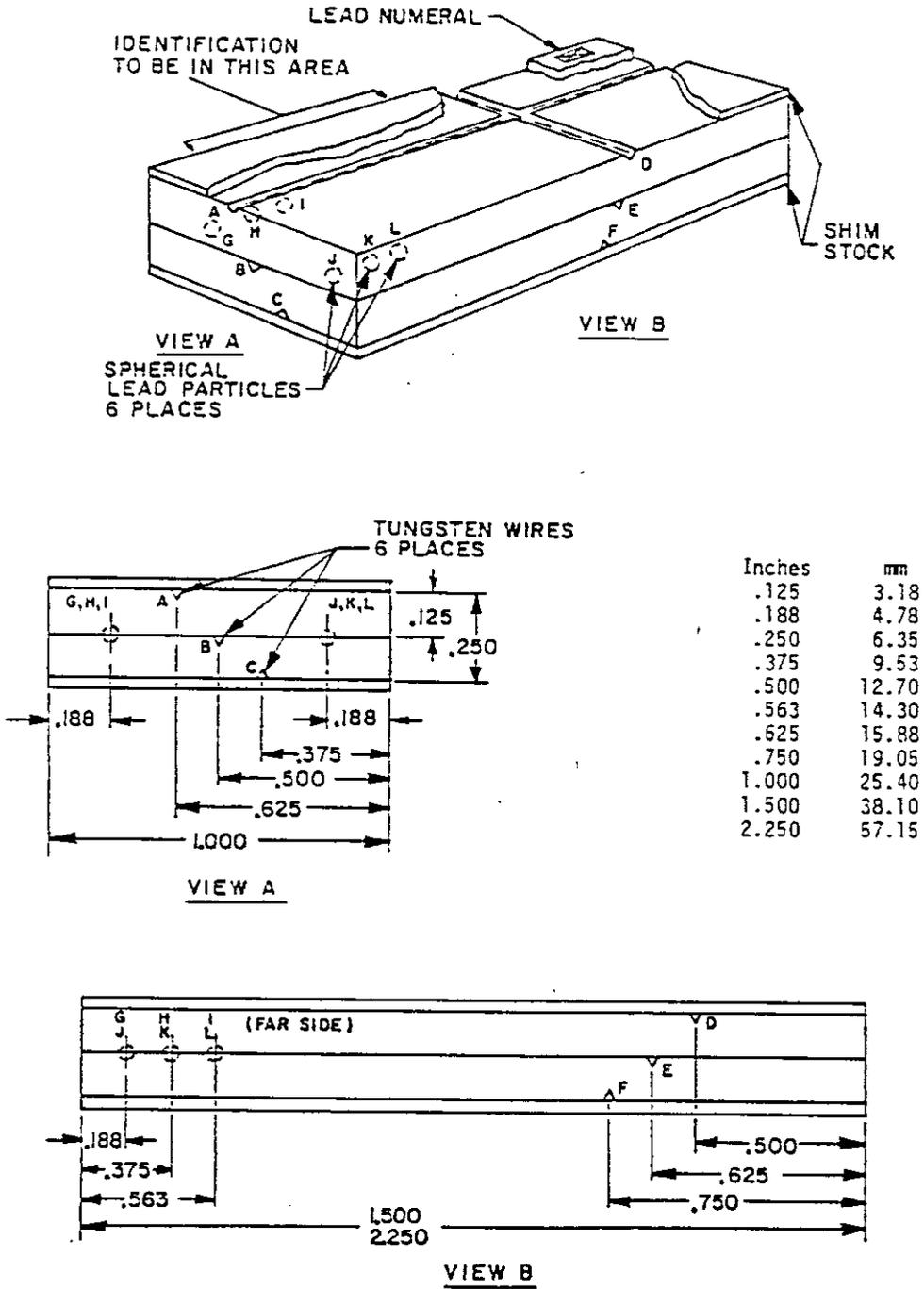


FIGURE 1. Image quality indicator (optional).

TABLE OF IMAGE QUALITY INDICATORS

Tungsten wire diameters						Lead particle diameters						Steel shim stock
A	B	C	D	E	F	G	H	I	J	K	L	
.002 (0.05)	.001 (0.03)	.0005 (0.013)	.0005 (0.013)	.001 (0.03)	.002 (0.05)	.015 (0.38)	.010 (0.25)	.008 (0.20)	.006 (0.15)	.004 (0.10)	.002 (0.05)	None
"	"	"	"	"	"	"	"	"	"	"	"	.002 (0.05)
"	"	"	"	"	"	"	"	"	"	"	"	.005 (0.13)
"	"	"	"	"	"	"	"	"	"	"	"	.007 (0.18)
.003 (0.08)	.002 (0.05)	.001 (0.03)	.001 (0.03)	.002 (0.05)	.003 (0.08)	"	"	"	"	"	"	.010 (0.25)
.003 (0.08)	.002 (0.05)	.001 (0.03)	.001 (0.03)	.002 (0.05)	.003 (0.08)	"	"	"	"	"	"	.015 (0.38)
.005 (0.13)	.003 (0.08)	.002 (0.05)	.002 (0.05)	.003 (0.08)	.005 (0.13)	"	"	"	"	"	"	.025 (0.64)
.005 (0.13)	.003 (0.08)	.002 (0.05)	.002 (0.05)	.003 (0.08)	.005 (0.13)	"	"	"	"	"	"	.035 (0.89)

NOTES:

1. Dimensions are in inches.
2. Metric equivalents are given for general information only.
3. Wires to tungsten, shim stock to be carbon steel, particles to be lead. Center section to be .125 (3.18 mm) layers of clear acrylic plastic, bonded with clear plastic cement of low X-ray density. Fasteners may be used within .250 (6.35 mm) or less from each corner, but shall not interfere with end use of the penetrometer. Bottom surface shall be flush.
4. All dimensions shown are ±.005 (0.13 mm), except wires and shim stock, which shall be within standard mill tolerances, and lead particles which shall be ±.0002 (0.005 mm). Groove details are not critical except that wire must be embedded flush or below surface of plastic and centered at location shown. Particle-hole sizes are not critical, but should not exceed .031 (0.79 mm) in diameter and depth, and must be centered as shown within ±.005 (0.13 mm).
5. Additional layers of shim stock may be used as necessary.
6. Identification marking shall be permanent and legible. Location and size of character is not critical but shall not interfere with or obscure the radiographic image details.

FIGURE 1. Image quality indicator (optional) - Continued.

4.7.6 DC leakage (see 3.10). DC leakage shall be measured using the dc rated voltage ± 2 percent at the applicable test temperature (see 3.1), after a maximum electrification period of 5 minutes. A 1,000-ohm resistor shall be placed in series with the capacitor to limit the charging current. A steady source of power, such as a regulated power supply, shall be used. Measurement accuracy shall be within ± 2 percent or 0.02 microampere (μA), whichever is greater (see 4.3.3). For nonpolarized capacitors, measurements shall be made in both directions.

4.7.7 Capacitance (see 3.11). Capacitors shall be tested in accordance with method 305 of MIL-STD-202. The following details shall apply:

- a. Test frequency: 1,000 ± 100 hertz (Hz) for CSR21 only and 120 ± 5 Hz for all other styles.
- b. Limit of accuracy: Measurement accuracy shall be within ± 2.0 percent of the reading for ± 10 and ± 20 percent capacitance tolerance items and ± 0.5 percent of the reading for ± 5 percent capacitance tolerance items.
- c. Magnitude of polarizing voltage: Unless otherwise specified (see 3.1), maximum dc bias shall be 2.2 volts for all ac measurements. The magnitude of the ac voltage shall be limited to 1.0 volt rms.

4.7.8 Dissipation factor (see 3.12). The dissipation factor shall be measured at the frequency specified in 4.7.7a, by means of a polarized capacitance bridge. The inherent accuracy of the measurement shall be $\pm (2$ percent actual value $+ 0.001)$.

4.7.9 Equivalent series resistance (ESR) (style CSR21 only) (see 3.13). The ESR at the applicable temperature shall be measured directly or determined from measurements obtained from a bridge. The following details shall apply:

- a. Test temperature and tolerance: $+25^{\circ}\text{C} \pm 5^{\circ}\text{C}$.
- b. Test frequency: 100 kHz ± 5 kHz.
- c. Limit of accuracy: Measurement accuracy shall be within ± 5.0 percent of the reading.
- d. Magnitude of polarizing voltage: Unless otherwise specified (see 3.1), the maximum dc bias shall be 2.2 volts for all ac measurements. The magnitude of the ac voltage shall be limited to 0.5 volt rms maximum.

4.7.10 Shock (specified pulse) (polarized capacitors only, see 3.1) (see 3.14). Capacitors shall be tested in accordance with method 213 of MIL-STD-202. The following details and exceptions shall apply:

- a. Special mounting means: Capacitors shall be rigidly mounted on a mounting fixture by the body. (Potting compounds may be used to secure the capacitor body as long as the compound does not support the leads.) Leads shall be secured to rigidly supported terminals, so spaced that the length of each lead from the capacitor is approximately .375 inch when measured from the edge of the supporting terminal. Leads shall be within 30 degrees of being parallel. When securing leads, care shall be taken to avoid pinching the leads.
- b. Test condition letter: I (100 g peak).
- c. Measurements and electrical loading during shock: During the test, observations shall be made to determine intermittent contact or arcing or open- or short-circuiting. Detecting equipment shall be sufficiently sensitive to detect any interruption with a duration of 0.5 millisecond (ms). The dc rated voltage shall be applied to the capacitors during the test.
- d. Examinations after test: Capacitors shall be visually examined for evidence of arcing, breakdown, and mechanical damage.

4.7.11 Vibration, high frequency (polarized capacitors only, see 3.1) (see 3.15). Capacitors shall be tested in accordance with method 204 of MIL-STD-202. The following details and exceptions shall apply:

- a. Mounting of specimens: Capacitors shall be securely mounted as specified in 4.7.10a.
- b. Electrical load conditions: During the test, the specified dc rated voltage (see 3.1) shall be applied to the capacitors.
- c. Test condition letter: D (20 g).
- d. Duration and direction of motion: Four hours in each of two mutually perpendicular directions (total of eight hours), one parallel and the other perpendicular to the cylindrical axis.
- e. Measurements during vibration: During the last cycle, an electrical measurement shall be made to determine intermittent operation or open- or short-circuiting. Observations shall also be made to determine intermittent contact or arcing or open- or short-circuiting. Detecting equipment shall be sufficiently sensitive to detect any interruption with a duration of 0.5 ms, or greater.
- f. Measurements after vibration: Not applicable.
- g. Examination after test: Capacitors shall be visually examined for evidence of mechanical damage.

4.7.12 Salt spray (corrosion) (see 3.16). Capacitors shall be tested in accordance with method 101 of MIL-STD-202. The following details and exceptions shall apply:

- a. Applicable salt solution: 5 percent.
- b. Test condition letter: B (48 hours).
- c. Measurements after exposure: Not applicable.
- d. Examinations after test: Capacitors shall be visually examined for evidence of corrosion or other defects that will affect life or serviceability.

4.7.13 Thermal shock and immersion (polarized capacitors only, see 3.1) (see 3.17).

4.7.13.1 Thermal shock. Capacitors shall be tested in accordance with method 107 of MIL-STD-202. The following details and exceptions shall apply:

- a. Conditioning prior to first cycle: 15 minutes at the inspection conditions specified in 4.3.
- b. Test condition letter: B.
- c. Measurements before and after cycling: Not applicable.

4.7.13.2 Immersion. Following temperature cycling, capacitors shall be tested in accordance with method 104 of MIL-STD-202. The following details and exceptions shall apply:

- a. Test condition letter: B.
- b. Measurements after final cycle: Within 30 minutes after removal from the final immersion bath, the dc leakage, capacitance, and dissipation factor shall be measured as specified in 4.7.6, 4.7.7, and 4.7.8, respectively.
- c. Examination after test: Capacitors shall be visually examined for evidence of corrosion, mechanical damage, and obliteration of marking.

4.7.14 Solderability (polarized capacitors only, see 3.1) (see 3.19). Capacitors shall be tested in accordance with method 208 of MIL-STD-202. The following details shall apply:

- a. Number of terminations of each part to be tested: Two, as follows.
 - (1) Negative leads: 0.125 ±.025 inch from end of case.
 - (2) Positive leads: 0.125 ±.025 inch from the point of "clean lead" emerging from the seal eyelet.

4.7.15 Terminal strength (polarized capacitors only, see 3.1) (see 3.19).

4.7.15.1 Pull. Capacitors shall be tested in accordance with method 211 of MIL-STD-202. The following details shall apply:

- a. Test condition letter: A.
- b. Method of holding: The body of the capacitor shall be secured.
- c. Applied force: Three pounds.

4.7.15.2 Twist. Capacitors shall be tested in accordance with method 211 of MIL-STD-202. The following detail and exception shall apply:

- a. Test condition letter: D.
- b. Number of rotations: Three.

Capacitors shall be visually examined for loosening of terminals and permanent damage to the terminals, terminal welds, or terminal solder, as applicable.

4.7.16 Moisture resistance (polarized capacitors only, see 3.1) (see 3.20). Capacitors shall be tested in accordance with method 106 of MIL-STD-202. The following details and exceptions shall apply:

- a. Special mounting: Not applicable.
- b. Initial measurements: DC leakage, capacitance, and dissipation factor shall be measured as specified in 4.7.6, 4.7.7, and 4.7.8, respectively.
- c. Polarization and loading voltages: Not applicable.
- d. Exception: Step 7b not required.
- e. Final measurements: After the final cycle and within 2 to 6 hours after removal of the capacitors from the humidity chamber, the dc leakage, capacitance, and dissipation factor shall be measured as specified in 4.7.6, 4.7.7, and 4.7.8, respectively, at the inspection conditions specified in 4.3.
- f. Examinations after test: Capacitors shall be visually examined for evidence of corrosion, mechanical damage, and obliteration of marking.

4.7.17 Sleeving (polarized capacitors only, see 3.1) (see 3.21).

4.7.17.1 Dielectric strength. The capacitors shall be placed in a V-block. The sleeving shall then be subjected to a dc potential of 2,000 volts with a maximum leakage of 20 µA between the capacitor case and the intimately associated metal V-block. The voltage shall be applied uniformly at the rate of 500 volts per second. Electrification time shall be 1 minute ±5 seconds.

4.7.17.2 Insulation resistance. The capacitors shall be placed in a V-block as specified in 4.7.17.1 and the insulation resistance between the case and V-block shall be measured with a polarizing voltage of 500 ±50 volts dc for 1 minute +0, -15 seconds. The measurement shall be repeated five times, rotating the unit in the block each time.

4.7.18 Stability at low and high temperatures (polarized capacitors only, see 3.1) (see 3.22). Capacitors shall be measured for dc leakage, capacitance, and dissipation factor as specified in 4.7.5, 4.7.7, and 4.7.8, respectively, at each of the temperatures specified in table VI, except that dc leakage measurements at -55°C (step 2) are not required. After the measurements of capacitance and dissipation factor have been made at the -55°C temperature (step 2), rated voltage shall be applied through a 33-ohm load for a minimum of 5 minutes. The capacitors shall be brought to thermal stability at each test temperature. Thermal stability will have been reached when no further change in capacitance is observed between two successive measurements taken at 15-minute intervals.

TABLE VI. Temperature for stability test.

Step	Test temperature
1	$+25^{\circ}\text{C}$ ($\pm 2^{\circ}\text{C}$)
2	-55°C ($+0, -3^{\circ}\text{C}$)
3	$+25^{\circ}\text{C}$ ($\pm 2^{\circ}\text{C}$)
4	$+85^{\circ}\text{C}$ ($+4, -0^{\circ}\text{C}$)
5	$+125^{\circ}\text{C}$ ($+4, -0^{\circ}\text{C}$)
5	$+25^{\circ}\text{C}$ ($\pm 2^{\circ}\text{C}$)

4.7.19 Surge voltage (polarized capacitors only, see 3.1) (see 3.23). Capacitors shall be subjected to 1,000 cycles of the applicable surge voltage as follows:

<u>DC rated voltage at $+85^{\circ}\text{C}$ (volts)</u>	<u>DC surge voltage at $+85^{\circ}\text{C}$ (volts)</u>
6	8
10	13
15	20
20	26
35	46
50	65
75	98
100	130

The ambient temperature during cycling shall be $+85^{\circ}\text{C}$. Each cycle shall consist of a 30-second surge voltage application followed by a 30-second discharge period. Voltage application shall be made through a resistor of 33 ohms. The tolerance of the resistor shall be ± 5 percent. Each surge voltage cycle shall be performed in such a manner that the capacitor is shorted terminal-to-terminal through a copper bar, or an equivalent low resistance at the end of the 30-second application. An alternate method of shorting the capacitors is discharge through the same resistance that is utilized for charging. After the final cycle, the capacitors shall be stabilized at the inspection conditions specified in 4.3, and the dc leakage, capacitance, and dissipation factor shall be measured as specified in 4.7.6, 4.7.7, and 4.7.8, respectively.

4.7.20 Life (polarized capacitors only, see 3.1) (see 3.24).

4.7.20.1 For qualification inspection. Capacitors shall be tested in accordance with method 108 of MIL-STD-202. The following details and exception shall apply:

- a. Distance of temperature measurements from specimens, in inches: Not applicable.
- b. Method of mounting: Capacitors shall be mounted by their leads.

- c. Test temperature and tolerance: Capacitors being subjected to the test of group VI of table I shall be tested at $+125^{\circ}\text{C} \pm 4$, -0°C . Capacitors being subjected to the test of group VII of table I shall be tested at $+85^{\circ}\text{C} \pm 4$, -0°C .
- d. Operating conditions: Rated dc voltage (see 3.1) or derated voltage at $+125^{\circ}\text{C}$, as applicable (see table VII), shall be applied gradually (not to exceed 5 minutes either by a slow build-up of the voltage or through a resistor which shall be shorted out within 5 minutes). Voltage shall be applied continuously, except for measurement periods. The impedance of the voltage source, as seen from the terminals of each capacitor, shall not exceed 3 ohms (1 ohm for style CSR33). Storage batteries or an electronic power supply capable of supplying at least 1 ampere when a capacitor is shorted shall be used.
- e. Test condition letter: F (2,000 hours).
- f. Measurements during exposure: DC leakage at the applicable high test temperature shall be made at the following intervals: 0; 240 ± 48 , -0 hours; 1,000 ± 48 , -0 hours; and 2,000 ± 72 , -0 hours.
- g. Measurements after exposure: Capacitors shall be returned to the inspection conditions specified in 4.3, and shall be visually examined for evidence of mechanical damage; dc leakage, capacitance, and dissipation factor shall then be measured as specified in 4.7.6, 4.7.7, and 4.7.9, respectively (see 3.24.1). In addition, capacitors shall be subjected to the dielectric strength test as specified in 4.7.17.1 following measurements specified in table VII.

TABLE VII. Voltage.

Rated voltage (at $+85^{\circ}\text{C}$)	Derated voltage (at $+125^{\circ}\text{C}$)
Volts, dc	Volts, dc
6	4
10	7
15	10
20	13
35	23
50	33
75	50
100	67

4.7.20.2 For quality conformance inspection.

4.7.20.2.1 Performance check. Capacitors shall be tested as specified in 4.7.20.1, with the following exceptions:

- The duration of the test shall be 240 hours.
- The $+85^{\circ}\text{C}$ rated voltage shall be used for this test.
- The test temperature and tolerance shall be $+85^{\circ}\text{C} \pm 4$, -0°C .
- The dielectric strength test need not be performed.

4.7.20.2.2 Extended life test. Capacitors shall be tested as specified in 4.7.20.1, except that the duration of the test shall be 10,000 hours. DC leakage (at the applicable high test temperature) shall be made at the following intervals: 0; 240 ± 48 , -0 hours; 1,000 ± 48 , -0 hours; 2,000 ± 72 , -0 hours; and every 2,000 hours thereafter until 10,000 ± 96 , -0 hours have elapsed. The final measurements shall be in accordance with 4.7.20.1g.

4.7.21 Fungus (polarized capacitors only, see 3.1) (see 3.25). Capacitors shall be tested in accordance with method 508 of MIL-STD-810.

4.7.22 Resistance to solvents (see 3.26). Capacitors shall be tested in accordance with method 215 of MIL-STD-202. The following details shall apply:

- a. The marked portion of the capacitor body shall be brushed, with sleeve in place.
- b. The number of sample units to be examined shall be as specified in table I or table V, as applicable.
- c. Capacitors shall be visually examined for evidence of mechanical damage and obliteration of marking.

4.7.23 Resistance to soldering heat (polarized capacitors only, see 3.1) (see 3.27). Capacitors shall be tested in accordance with method 210 of MIL-STD-202. The following details shall apply:

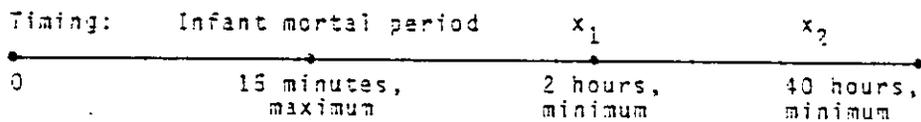
- a. Depth of immersion in molten solder:
 - (1) Negative leads: 0.125 ±.025 inch from end of case.
 - (2) Positive leads: 0.125 ±.025 inch from the point of "clean lead" emerging from the seal eyelet.
- b. Test condition letter: 8, except immersion duration shall be 20 ±2 seconds.
- c. Cooling time prior to measurement after test: 30 minutes minimum.
- d. Measurements after test: DC leakage, capacitance, and dissipation factor shall be measured as specified in 4.7.6, 4.7.7, and 4.7.8, respectively.
- e. Visual examination: No evidence of external damage (internal examination not required).

4.7.24 Ripple current (style CSR21 only) (see 3.28). Capacitors shall be tested in accordance with the following details:

- a. Method of mounting: Capacitors shall be mounted by their leads.
- b. Test temperature and tolerance: +25°C ±5°C in a still air enclosure.
- c. Operating conditions: A sinusoidal alternating voltage at a frequency of 40 ±2 kHz shall be superimposed on 50 percent rated voltage so that the peak voltages do not exceed the value of the rated direct voltage of the capacitor. The maximum rated ripple current shall be applied continuously, except for measurement periods. The direct voltage shall be supplied by a regulated power supply free from surges, having a low internal resistance, and shall be applied to each capacitor section through a separate resistor. DC power supply regulation shall remain within ±2 percent or less. AC power source regulation shall be within ±5 percent on current at 40 ±2 kHz with less than 10 percent distortion.
- d. Duration of test: 240 hours.
- e. Measurements after exposure: Capacitors shall be returned to the inspection conditions specified in 4.3, and shall be visually examined for evidence of mechanical damage; dc leakage, capacitance, dissipation factor, and ESR shall then be measured as specified in 4.7.6, 4.7.7, 4.7.8, and 4.7.9, respectively.

4.7.25 Weibull FR level grading (see 3.29). Capacitors shall be tested in accordance with method 109 of MIL-STD-202. The following details and exceptions shall apply:

- a. Distance of temperature from specimens, in inches: Not applicable.
- b. Method of mounting: Capacitors shall be mounted by their leads.
- c. Test temperature and tolerance: $+85^{\circ}\text{C} +4^{\circ}$, -0°C .
- d. Operating conditions: Accelerated dc voltage as applicable (see table VIII), shall be applied gradually (not to exceed 5 minutes by a slow build-up of the voltage). Maximum acceleration, 20,000:1. Voltage shall be applied continuously, except for failure count periods. The impedance of the voltage source, as seen from the terminals of each capacitor, shall not exceed one ohm. An electronic power supply capable of supplying at least 3 amperes when a capacitor is shorted shall be used.
- e. Duration of test: 40 hours minimum.



- f. Failure definition: A failure is defined as a blown fuse or equivalent.
- g. Failure count during test: The lot size (see 4.6.1.1.2) to be graded is established after removal of gross defectives (infant mortality) (15 minutes, maximum). The first failure count shall be performed at least 2 hours after the test was started. The number of blown fuses and the time under test shall be recorded to within ± 0.1 hour. Calculate the fraction failed, p_1 , at time, x_1 , see equation 4 (6.8.2). Optionally, MIL-STD-690, table II FRSP-90 may be used to compute the failure rate base on the accelerated part hours generated when $C = 0$, (see 6.8.1).
- h. Failure count after test: A failure count shall be performed after 40 hours minimum after the test was started. The number of blown fuses and the time under test shall be recorded to within ± 0.1 hour. Calculate the cumulative fraction failed, p_2 , at time, x_2 , see equation 4 (6.8.2).
- i. Lot failure rate: Determine $Z(t)$ from equation 3 (6.8.1). If the desired failure rate has been achieved, the lot may be removed from test.
- j. Continuation grading: If the desired failure rate has not been reached, the lot may be continued on test. The time to reach the failure rate goal may be determined from equation 5 (6.9.2). If the time calculated to reach the goal failure rate is excessive, the lot may be discarded in favor of a new lot.
- k. Measurements after exposure: Capacitors shall be removed from the test, be stabilized at room ambient conditions (see 4.3) and the dc leakage, capacitance, dissipation factor, and ESR (CSR21 only) shall be measured as specified in 4.7.6, 4.7.7, 4.7.8, and 4.7.9, respectively.

5. PACKAGING

5.1 Packaging requirements. The requirements for packaging shall be in accordance with MIL-C-39028 (see 6.1.3).

6. NOTES

6.1 Intended use. Capacitors covered by this specification are intended mainly for use in filter, bypass, coupling, blocking, and other low-voltage applications (such as transistor circuits) where stability, size, weight, and shelf life are important factors (see 6.1.1). The dc leakage and dissipation factor of the suggested unit should be taken into consideration when designing transistor, timing, phase-shifting, and vacuum-tube-grid circuits.

6.1.1 Parallel operation. Operation of capacitors in parallel increases the risk of dc surge current failures in low-impedance circuits. The user is cautioned that the energy stored in a parallel capacitor circuit may discharge through other capacitors in the circuit.

6.1.2 Life degradation. The life of these capacitors is primarily dependent on voltage and temperature. These capacitors should not be used above the derated voltage at maximum rated temperature, +125°C. The FR level at +125°C is not established in this specification; however, proof tests at +125°C are required (see 4.7.20).

6.1.3 Application of packaging.

6.1.3.1 Shipments to Government activities. The packaging requirements of this specification are primarily intended for the preparation of capacitors for shipment to Government activities.

6.2 Ordering data. The contract or purchase order should specify the following:

- a. Title, number, and date of this specification.
- b. Title, number, and date of the applicable specification sheet, and the complete part number (see 3.1).
- c. If gold-plated leads are desired (see MIL-C-39003/2).
- d. Lead length, if different from that specified. Lead length may be specified to a minimum of 1 inch long for use in tape and reel automatic insertion equipment.

6.3 Qualification. 7/ With respect to products requiring qualification, awards will be made only for products which are at the time set for opening of bids, qualified for inclusion in the applicable qualified products list, whether or not such products have actually been so listed by that date. The attention of the contractors is called to this requirement, 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 the Space and Naval Warfare Systems Command, Washington, DC; however, information pertaining to qualification of products may be obtained from the Defense Electronics Supply Center (DESC-E), 1507 Wilmington Pike, Dayton, Ohio 45444.

6.4 Visual aids for radiographic inspection. Figures 2, 3, and 4 are artists representations of radiographs for guidance in negative evaluation (see 3.9).

7/ SD-6, "Provisions Governing Qualification", is issued for the information of applicants requesting qualification of products. Copies of this publication may be obtained from the Commanding Officer, Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

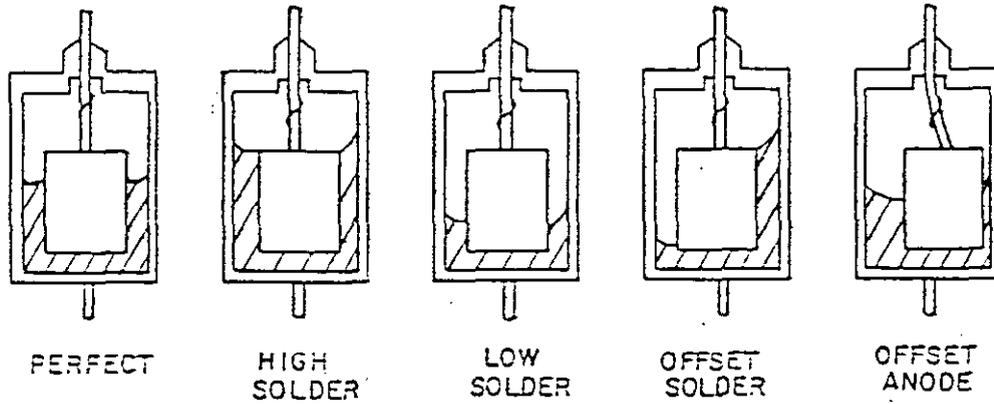


FIGURE 2. Acceptable parts.

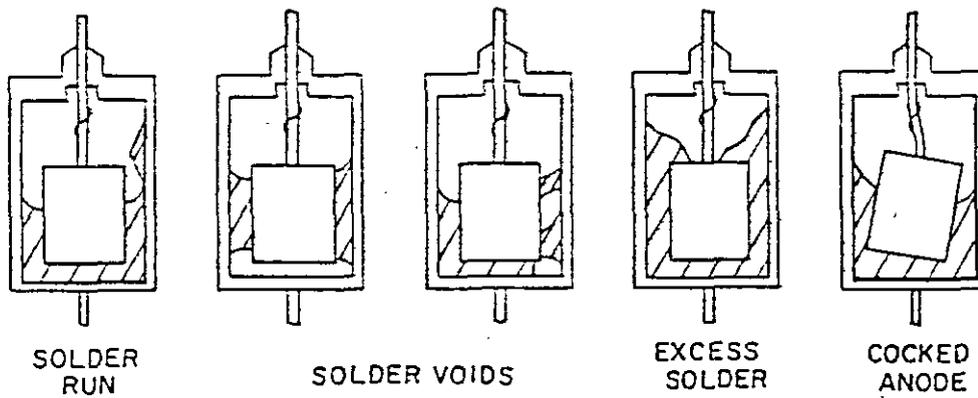


FIGURE 3. Minor defects - acceptable.

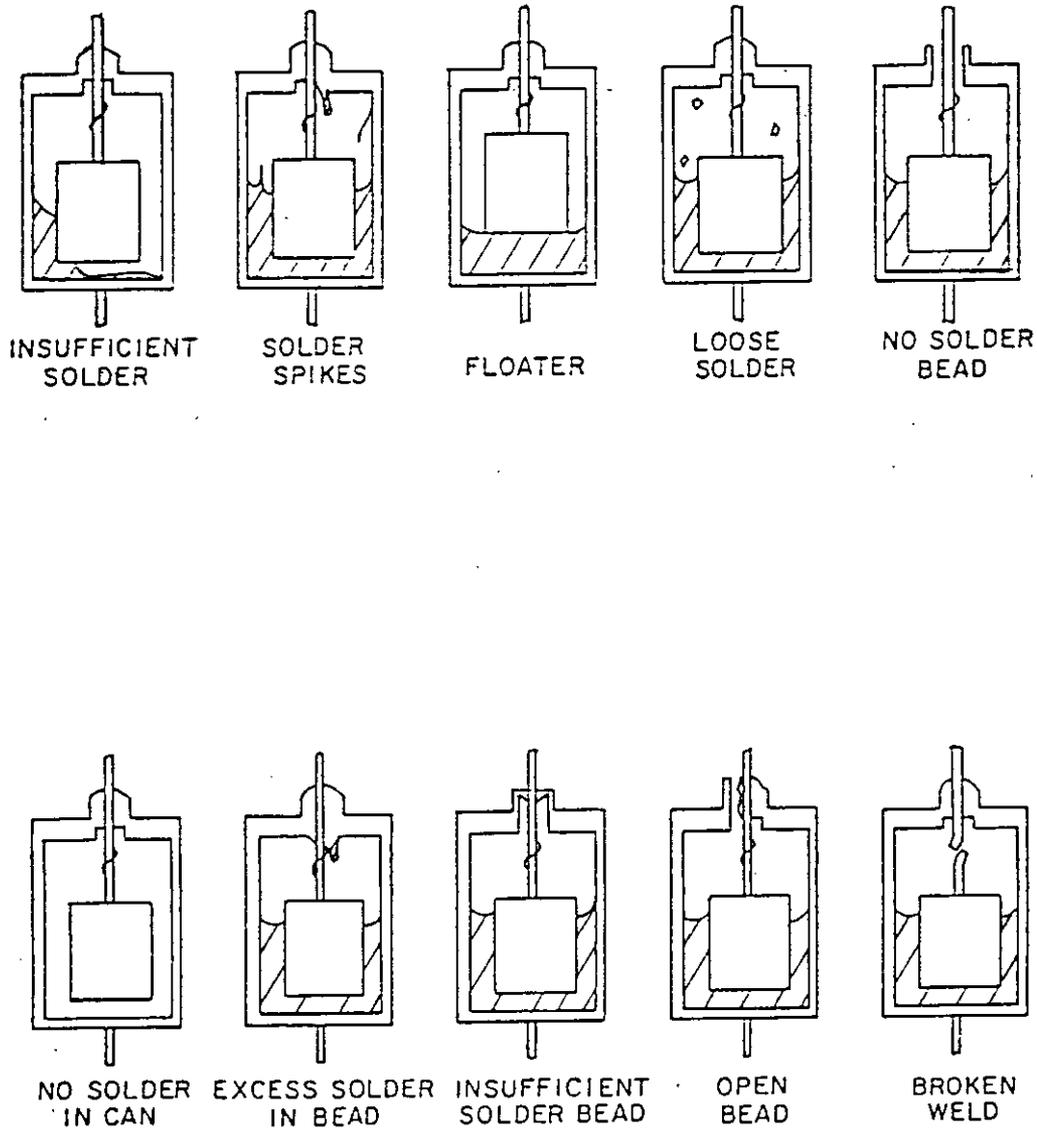


FIGURE 4. Major defects - rejectable.

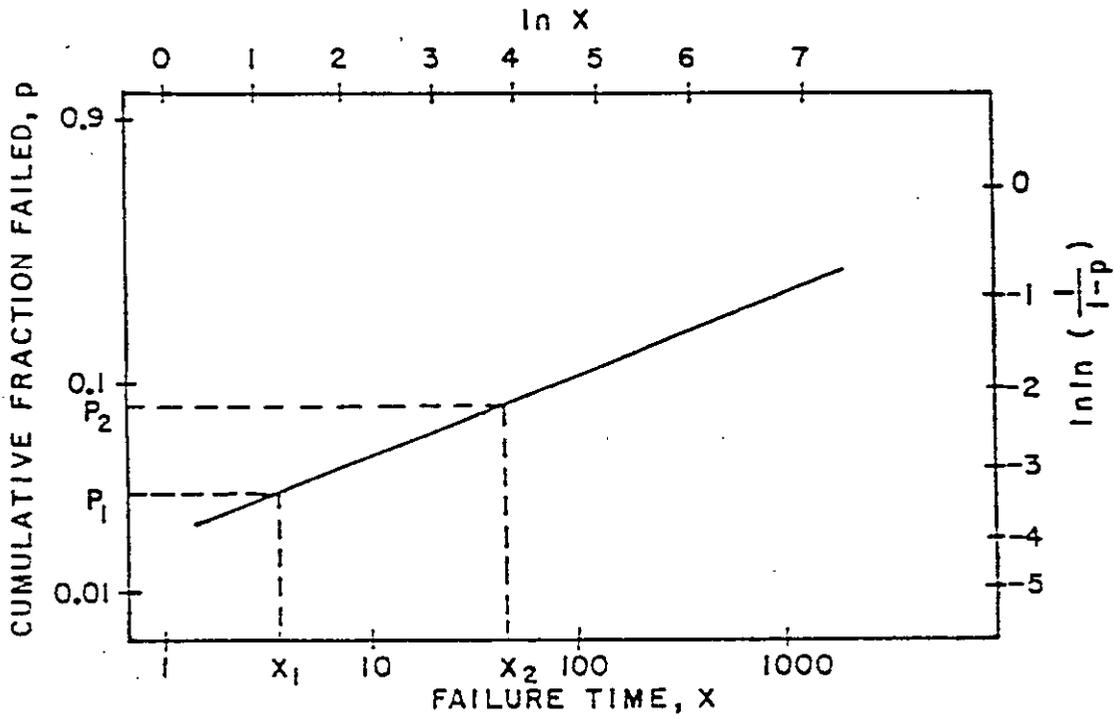


FIGURE 5. Typical weibull plot.

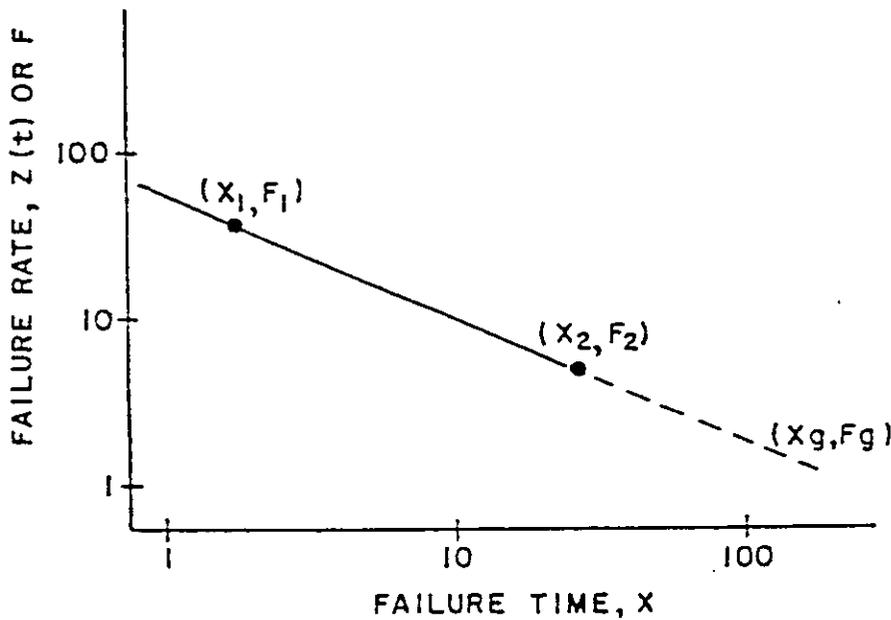


FIGURE 6. Failure rate versus time.

6.5 Standard capacitor types. Equipment designers should refer to MIL-STD-198, "Capacitors, Selection and Use of", for standard capacitor types and selected values chosen from this specification. MIL-STD-198 provides a selection of standard capacitors for new equipment design.

6.6 Supersession data. Capacitors of this specification unilaterally supersede the capacitor types and styles of equivalent capacitance, capacitance tolerance, voltage rating, case size, and failure rate level covered under MIL-C-39003F (see 3.1). For failure rate levels B, C, D, and E, the superseding specification changes the method for calculating failure rate. The reliability of the capacitors made against the specification has not changed. The superseding specification requires lot-by-lot assessment of failure rate in place of a statistical process average. Qualified manufacturers may mark exponential failure rate dash numbers on parts that have been Weibull graded to levels B, C, D, or E. Items having a Weibull failure rate level (FRL) may be substituted for items of an exponential FRL. For example, symbol "B" may replace symbols "M", "P", "R" and "S". Weibull FR determination is based on lot-by-lot 100% quality conformance accelerated failure rate life testing. For example:

2500 capacitors have a voltage rating (V_r) of 50 V dc.
 X40 hours Weibull life test at 65 V dc. Voltage applied (V_a).
 X279.1496 acceleration factor for $V_a/V_r = 1.3000$.
 27,914,960 accelerated part hours.

Weibull FRL's are determined from actual lot performance data. Exponential FRL determination starts with several production lots which may be included in the same inspection lot. For example, 4 production lots of 2,500 capacitors having a voltage rating of 50 V dc are offered for inspection in the same inspection lot.

10,000 capacitors with a voltage rating (V_r) of 50 V dc.
 X40 hours voltage conditioning at 50 V dc minimum.
 400,000 part hours, however, exponential lot voltage conditioning performance data are not used to determine FRL's.

110 samples are drawn from the inspection lot of 10,000 capacitors
 X240 hours group B life test at 50 V dc voltage applied.
 26,400 part hours, however, data accumulated and used to determine FRL's.

10 samples selected upon completing each group B inspection.
 X9760 hours continuation life testing to 10,000 hours.
 97,500 rated condition part hours for FRL maintenance.

Exponential FRL's are based on the aggregate averages of a few samples drawn from many lots maintained in accordance with MIL-STD-690.

Parts qualified to failure rate level	Substitutable for failure rate level
D	M, P, R, S, B and C
C	M, P, R, S and B
B	M, P, R and S
S	M, P, and R
R	M and P
P	M

6.7 Soldering heat. Caution should be exercised when subjecting these units to soldering heat. Preheat and soldering exposure times and temperatures should be held to a minimum.

6.8 Weibull FR level determination. Time ordered distribution of failures for solid tantalum capacitors is described by the Weibull equation:

Equation 1

$$F(x) = 1 - \exp \left[-\frac{x^\beta}{\alpha} \right]$$

Where: $F(x)$ = cumulative fraction failed (p) at time x
 x = actual test time
 β = Weibull "shape parameter" (beta)
 α = Weibull "scale parameter"

This relationship may be plotted on graph paper which is constructed with $\ln x$ as abscissae and $\ln \ln 1/(1-p)$ as ordinates. Auxiliary scales allow plotting x and p directly. A straight line is obtained. The slope of this line is β , and the y -intercept is $-\ln \alpha$. Figure 5 illustrates a typical Weibull plot.

At any time x , values for β and p can be obtained and the lot failure rate $Z(x)$ may be calculated from Equation 3. A second plot of failure rate versus time may be drafted as indicated on figure 6. The slope of this line is $\beta-1$. Acceptable capacitor lots always exhibit decreasing failure rate with respect to time as evidenced by a value of β which is less than unity.

6.8.1 Acceleration factors. In order to provide the equivalent of several thousand hours of testing within a practical time frame, voltage acceleration is employed. It has been determined that the application of voltage in excess of rated voltage produces a higher failure rate than that observed when the devices are operated at the nominal voltage rating. On the Weibull plot, a straight line, parallel to the line representing rated voltage is obtained. The increased number of failures indicated by the line representing the higher voltage results from increased dielectric stress. The slopes (β) of both lines are essentially the same, but the time (x) required to produce any specified p is reduced as voltage is increased. As a result, acceleration factors may be specified which define the relationship between operation at rated voltage and operation at higher-than-rated voltages. For example, a lot of capacitors having a voltage rating of 50 V dc might be tested at 65 V dc.

In this case, the ratio of applied voltage to rated voltage is 1.30, resulting in an acceleration factor (A) of 279. In practical terms, operation of these capacitors for 1 hour at 65 V dc is equivalent to operation at 50 V dc for 279 hours. This relationship may be mathematically represented as:

Equation 2

$$Z(t) = Z(Ax) = \frac{\beta}{\alpha} x^{\beta-1} \cdot \frac{1}{A}$$

In conjunction with Equation 1, this function may be restated as:

Equation 3

$$Z(t) = F = \frac{-\beta \ln(1-p)}{x} \cdot \frac{10^5}{A}$$

The 10^5 factor allows for expression of $Z(t)$ in terms of percent per 1,000 hours when x denotes hours. Table VIII illustrates a range of acceleration factors normally used for Weibull FR determination.

6.8.2 Grading calculations. On the basis of failure counts at x_1 and x_2 as specified in 4.7.25, the slope between these points is calculated as follows:

Equation 4

$$\beta = \frac{\ln \ln \left(\frac{1}{1-p_2} \right) - \ln \ln \left(\frac{1}{1-p_1} \right)}{\ln x_2 - \ln x_1}$$

The failure rate at time x_2 is then determined from Equation 3:

$$F_2 = \frac{-b \ln(1-p_2) 10^5}{x_2^A}$$

If b is greater than 0.9, the lot shall be rejected from the MIL-C-39003 program.

If additional grading time is required to reach the desired failure rate, the required time x_g may be determined as follows:

Equation 5

$$\ln x_g = \frac{\ln F_g - \ln F_2}{b - 1} + \ln x_2$$

Equation 6

$$A = 7.03412025 \cdot 10^{-9} \cdot e^{18.77249321 \cdot \frac{V_a}{V_r}}$$

A = Acceleration factor

e = Natural logarithm

V_a = Accelerated voltage

V_r = Rated voltage

TABLE VIII. Nominal acceleration factors.

Grading stress V_a/V_r 1/	Accelerated factor
1.0000	1.0000
1.1000	6.5355
1.2000	42.7128
1.3000	279.1496
1.4000	1,824.3823
1.5000	11,923.2626
1.5276	20,000.0000

1/: V_a = accelerated voltage.
 V_r = rated voltage.

EXAMPLES: A. 880 capacitors tested at a grading stress level of 1.2300 (75.0139 acceleration factor) for 40 hours resulted in zero failures.

880 (75.0139 X 40) = 2,640,489 hours

$C = 0$

FR = B level (MIL-STD-690, FRSP-90)

B. 1,350 capacitors tested at a grading stress level of 1.3300 (490.2535 acceleration factor) for 40 hours resulted in zero failures.

1,350 (490.2535 X 40) = 26,473,689 hours

$C = 0$

FR = C level (MIL-STD-690, FRSP-90)

- C. 400 capacitors tested at a grading stress level of 1.4000 (1824.3823 acceleration factor) for 40 hours resulted in 1 failure at x_1 ; no additional failures at x_2 .

$$400 (1824.3823 \times 40) = 29,190,117 \text{ hours}$$

$$C = 1 \\ \text{FR} = \text{B level (MIL-STD-690, FRSP-90)}$$

- D. 100 capacitors tested at a grading stress level of 1.4000 (1824.3823 acceleration factor) for 41 hours resulted in 3 failures at x_1 ; no additional failures at x_2 .

$$100 (1824.3823 \times 41) = 7,479,967.430$$

$$C = 3 \\ \text{FR} = \text{B level}$$

OR assume one additional failure at x_2

$$x_1 = 2 \text{ hours} \\ x_2 = 41 \text{ hours} \\ p_1 = .03 \\ p_2 = .04 \\ A = 1824.3823$$

$$s = \frac{\ln \ln \frac{1}{1-p_2} - \ln \ln \frac{1}{1-p_1}}{\ln x_2 - \ln x_1}$$

$$= \frac{\ln \ln \frac{1}{1-.04} - \ln \ln \frac{1}{1-.03}}{\ln 41 - \ln 2}$$

$$= \frac{\ln \ln 1.041666 - \ln \ln 1.030928}{3.713572 - .693147}$$

$$= \frac{-3.1935499 - (-3.4913617)}{3.02042425}$$

$$= \frac{0.2928118}{3.020425} = .096944$$

$$\text{FRL} = \frac{-s \ln (1-p_2) 10^5}{x_2 A} = \frac{-.096944 \ln (.96) 10^5}{41(1824.3823)}$$

$$= \frac{-.096944 (-.040822) 10^5}{74799.67} = 0.00000053 \times 10^5$$

$$= \frac{.0053\%}{1,000} \text{ hours}$$

To compute hours needed to verify 0.001% per 1,000 hours FRL:

$$\ln x_g = \frac{\ln F_g - \ln F_2}{\beta - 1} + \ln x_2$$

x_2 = hours at point 2

x_g = hours to test (goal)

F_2 = observed FRL at x_2

F_g = Failure rate level (goal)

$$\begin{aligned} \ln x_g &= \frac{\ln F_g - \ln F_2}{\beta - 1} + \ln x_2 \\ &= \frac{\ln (.001) - \ln .0053}{-.903056} + \ln 41 \\ &= \frac{-6.9077553 - (-5.2400485)}{-.909045} + 3.713572 \\ &= \frac{-1.6677068}{-.903056} + 3.713572 \\ &= 1.8467369 + 3.713572 \\ &= 5.5603089 \end{aligned}$$

x_g = 259.90 hours

6.9 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

6.10 Subject term (key word) listing.

Electrolytic
Established reliability
Hermetically sealed
Nonpolarized
Polarized
Solid electrolytic
Tantalum

APPENDIX A

PROCEDURES FOR QUALIFICATION INSPECTION
(EXPONENTIAL DISTRIBUTION)

10. SCOPE

10.1 This appendix details the procedures for submission of samples, with related data, 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.

20. SUBMISSION

20.1 Sample. For qualification to "M" level in accordance with table I.

20.1.1 Single type submission. A sample consisting of 177 sample units (189 sample units for CSR21) of each case size, dc rated voltage, and capacitance tolerance for which qualification is sought shall be submitted.

20.1.2 Combined voltage group submission. A maximum of two voltage groups shall be represented (see table II). Except for styles CSR09 and CSR21, a sample consisting of 89 sample units of the highest capacitance value in the size B case of the lowest voltage and 89 sample units of the highest capacitance value in the size B case of the highest voltage; and a sample of 89 units of the highest capacitance value in the lowest voltage and 89 sample units of the highest capacitance value in the highest voltage in each qualification group (see table IX) for which qualification is sought shall be submitted. For style CSR09 (see 3.1), the sample shall consist of 89 units of the highest capacitance value in the lowest voltage and 89 sample units of the highest capacitance value in the highest voltage in each qualification group. For style CSR21, the combined-voltage group submission shall be the same as for CSR09 except that the number of sample units to be submitted shall be 95 in each qualification group.

TABLE IX. Examples of combined voltage group submissions. 1/

Style	Dash no.	Rated voltage	Capacitance	Number of sample units to be submitted
		<u>Volts, dc</u>	<u>μF</u>	
CSR13 (see MIL-C-39003/1)	2246	6	56	89
	2289	20	15	89
	2251	6	330	89
	2301	20	100	89
	2304	35	6.8	89
	2368	50	4.7	89
	2312	35	47	89
	2380	50	22	89
	2411	75	3.9	89
	2473	100	2.7	89
	2421	75	15	89
	5167	100	6.8	89
CSR09 (see MIL-C-39003/2)	0002	6	18	89
	0024	20	6.8	89
	0029	35	2.7	89
	0033	50	1.8	89
	0051	75	1.2	177

See footnote at end of table.

APPENDIX A

TABLE IX. Examples of combined voltage group submissions - Continued. 1/

Style	Dash no.	Rated voltage	Capacitance	Number of sample units to be submitted
		Volts, dc	μ F	
CSR23 (see MIL-C-39003/3)	0104	6	100	89
	0153	20	27	89
	0114	6	1000	89
	0163	20	180	89
	0166	35	10	89
	0180	50	6.8	89
	0174	35	68	89
	0187	50	39	89
CSR33 (see MIL-C-39003/6)	0004	6	100	101
	0014	6	1000	101
	0053	20	27	101
	0063	20	180	101
	0066	35	10	101
	0074	35	68	101
	0080	50	6.8	101
	0087	50	39	101
CSR21 (see MIL-C-39003/9)	0008	6	330	95
	0050	20	100	95
	0063	35	47	95
	0083	50	22	95

1/ This table is set up as a guide. For other combinations, refer to the text of this appendix.

20.2 Test data. When tests are to be performed at a Government laboratory, prior to submission, all sample units shall be subjected to all of the group I tests in table I. Each submission shall be accompanied by the test data obtained from these tests. The performance of the destructive tests by the manufacturer on a duplicate set of sample units is encouraged, although not required. All test data shall be submitted in duplicate.

20.3 Certification of material. When submitting samples for qualification, the manufacturer shall submit certification, in duplicate, that the materials used in his capacitors are in accordance with the applicable specification requirements.

20.4 Description of items. The manufacturer shall submit a detailed description of the capacitors being submitted for inspection, including information on the type of welds or solder buttons; the type of electrodes; the type of seals (inner or outer, as applicable); the case and lead materials; the case insulating material (when applicable); and the case finish.

30. EXTENT OF QUALIFICATION

30.1 Single type submission. Capacitance range qualification will be restricted to values equal to or less than the capacitance value submitted. Voltage range approval will be restricted to the voltages equal to or less than that submitted in the same voltage group (see table II). Case size approval will be restricted to that submitted, except that approval of case size B or B1 may be a basis for approval of case size A or A1 respectively, approval of case size D may be a basis for approval of case size C. Qualification of 20-percent capacitance tolerance will be restricted to the 20-percent tolerance; qualification of 10-percent tolerance will be the basis for granting qualification for the 20-, 10-, and 5-percent capacitance tolerance.

APPENDIX A

30.2 Combined voltage group submission. Qualification of the types submitted will be a basis for qualification of all intermediate voltages in the qualification group (see table X). Capacitance range, case size, and capacitance tolerance qualification shall be as specified in 30.1. Examples of combined voltage-group submissions are listed in table IX.

30.3 Nonpolarized coverage for polarized submission. Qualification of polarized style CSR13 will be the basis for approval of nonpolarized style CSR91. Qualification will be restricted to the approval granted under 30.1 and 30.2 and will be granted only to manufacturers qualified to style CSR13 capacitors.

TABLE X. Example of qualification group. 1/

Style	Qualification group	Case size	DC rated voltage
CSR13 (see MIL-C-39003/1)	I	A and B	6, 10, 15, and 20
	II	C and D	5, 10, 15, and 20
	III	A and B	35 and 50
	IV	C and D	35 and 50
	V	A and B	75 and 100
	VI	C and D	75 100
CSR09 (see MIL-C-39003/2)	I	A1 and B1	6, 10, 15, and 20
	III	A1 and B1	35 and 50
	V	A1 and B1	75
CSR23 (see MIL-C-39003/3)	I	A and B	6, 10, 15, and 20
	II	C and D	6, 10, 15, and 20
	III	A and B	35 and 50
	IV	C and D	35 and 50
CSR21 (see MIL-C-39003/9)	II	C and D	6, 10, 15, and 20
	IV	C and D	35 and 50
CSR33 (see MIL-C-39003/6)	I	A and B	6, 10, 15, and 20
	II	C and D	6, 10, 15, and 20
	III	A and B	35 and 50
	IV	C and D	35 and 50

1/ This table is set up as a guide. For other combinations, refer to the text of the appendix.

40. QUALIFICATION APPROVAL FOR LOWER FR LEVELS

40.1 Extension of qualification to lower FR levels shall be in accordance with 4.4.4 of this specification.

APPENDIX B

PROCEDURES FOR QUALIFICATION INSPECTION
(WEIBULL DISTRIBUTION)

10. SCOPE

10.1 Weibull FR level qualification. Weibull failure rate qualification will be extended only to manufacturers who have achieved the "P" level failure rate in accordance with 4.4.4. To extend qualification to include Weibull failure rate level, the manufacturer shall certify and demonstrate the capability of Weibull FR level grading (see 4.7.25) to the qualifying activity. Full range qualification shall be in accordance with table XI.

TABLE XI. Matrix for Weibull qualification testing voltage (dc) and capacitance (μF). 1/ 2/ 3/

Style	6 V	10 V	15 V	20 V	35 V	50 V	75 V	100 V	Case size	
CSR13 4/	6.8	4.7	3.3	2.2	N/A	1.0	.68 μF ^{2/}	.56 μF ^{2/}	A	
	56	39	22	15	6.8	3.9 ^{2/}	2.7 ^{2/}	3.9	2.7 ^{3/}	B
	180	120	68	47 ^{2/}	22	18.0	10	6.8 ^{2/}	C	
	330	220	150	100	47 ^{2/}	22	15 ^{2/}	N/A	D	
CSR09	2.7	2.2	1.5	1.0	.47 ^{2/}	.27	.18 ^{2/}	N/A	A1	
	18	15	8.2	6.8	2.7	1.8 ^{2/}	1.2 ^{2/}	N/A	B1	
CSR33 5/	12	8.2	5.6	3.9	1.8	1.5 ^{2/}	N/A	N/A	A	
	100	82	39 ^{2/}	27	10	6.8 ^{2/}	N/A	N/A	B	
	470	270	180	68 ^{2/}	120	47	27 ^{3/}	N/A	N/A	C
	1,000	560	330	180	68	39 ^{2/}	N/A	N/A	D	
CSR21	180	120	68	47 ^{2/}	22	18 ^{2/}	N/A	N/A	C	
	330	220	150	100 ^{2/}	47	22 ^{2/}	N/A	N/A	D	

1/ All capacitance tolerances shall be ± 10 percent.

2/ The voltage and capacitance levels shown for this case size must be tested to obtain full range qualification at the B, C or D failure rate levels.

3/ An exception is made for the C or D failure rate levels of the CSR13 B case 100 V or CSR33 C case 50 V; a 2.2- μF CSR13 and a 22- μF CSR33 shall be tested.

4/ Qualification to style CSR13 will qualify style CSR01.

5/ Qualification to style CSR33 will qualify style CSR23.

Custodians:

Army - ER
Navy - EC
Air Force - 85

Review activities:

Navy - SH
Air Force - 17, 99
DLA - ES

User activities:

Navy - AS, MC, OS
Air Force - 11, 19

Preparing activity:

Navy - EC

Agent:

DLA - ES

(Project 5910-1525)

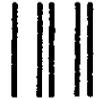
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