NOT MEASUREMENT SENSITIVE

MIL-HDBK-198
14 July 1999

DEPARTMENT OF DEFENSE HANDBOOK

CAPACITORS,

SELECTION AND USE OF

This handbook is for guidance only. Do not cite this document as a requirement.

AMSC N/A FSC 5910

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FORWARD

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

2. This handbook provides selected standard capacitors for use in the design of Department of Defense equipment. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

a. The application information and performance characteristics contained in this handbook are offered for guidance and are not to be considered as mandatory. Additional application information will be added when coordinated with the Department of Defense.

b. Additional capacitor types will be added to this handbook as they are developed and coordinated with the Department of Defense.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Defense Supply Center, Columbus, ATTN: DSCC-VAT, 3990 East Broad Street, Columbus, Ohio 43213-1199 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

CONTENTS

CONTENTS

CONTENTS

SECTION 1: SCOPE

1.1 Scope. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply. This handbook consists of the following:

a. Selected standard capacitor types, for use in the design and manufacturing of Department of Defense equipment under the jurisdiction of the Department of Defense.

b. Guides for the choice and application of capacitors for use in Department of Defense equipment.

Requirements for capacitors listed in this handbook are covered in the applicable specification (see 2.1). When it has been determined that circuit requirements cannot be met by using capacitor styles or characteristics listed in the applicable specifications, the design engineer should, with the approval of the cognizant activity, select from the applicable capacitor specification styles or characteristics not listed herein.

1.2 Purpose of handbook.

a. To provide the equipment designer with a selection of standard capacitors for use in most Department of Defense applications.

b. To control and minimize the variety of capacitors used in Department of Defense equipment in order to facilitate logistic support of equipment in the field.

c. To outline criteria pertaining to the use, choice, and application of capacitors in Department of Defense equipment.

SECTION 2: APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issue of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

HANDBOOKS

DEPARTMENT OF DEFENSE

MIL-HDBK-1131 - Storage Shelf Life and Reforming Procedures for Aluminum Electrolytic Fixed Capacitors.

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-PRF-20 - Capacitors, Fixed, Ceramic Dielectric (Temperature Compensating), Established and Non-Established Reliability, General Specification For.

MIL-PRF-81 - Capacitors, Variable, Ceramic Dielectric, General Specification For.

MIL-PRF-123 - Capacitors, Fixed, Ceramic Dielectric (Temperature Stable and General Purpose), High Reliability, General Specification For.

MIL-PRF-14409 - Capacitors, Variable (Piston Type, Tubular Trimmer), General Specification For.

MIL-PRF-19978 - Capacitors, Fixed, Plastic (or Paper-Plastic) Dielectric, (Hermetically Sealed in Metal, Ceramic, or Glass Cases), Established and Non-Established Reliability, General Specification For.

MIL-PRF-23269 - Capacitors, Fixed, Glass Dielectric, Established Reliability, General Specification For.

MIL-PRF-39001 - Capacitors, Fixed, Mica Dielectric, Established Reliability, General Specification For.

MIL-PRF-39003 - Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability, General Specification For.

MIL-PRF-39006 - Capacitors, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability, General Specification For.

MIL-PRF-39014 - Capacitors, Fixed, Ceramic Dielectric (General Purpose), Established Reliability and Non-Established Reliability, General Specification For.

MIL-PRF-39018 - Capacitors, Fixed, Electrolytic (Aluminum Oxide), Established Reliability and Non-Established Reliability, General Specification For.

MIL-PRF-39022 - Capacitors, Fixed, Metallized, Paper-Plastic Film, or Plastic Film Dielectric, Direct and Alternating Current, (Hermetically Sealed in Metal or Ceramic Cases), Established Reliability, General Specification For.

MIL-PRF-49137 - Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Molded, Conformal Coated and Metal Cased With Plastic End-Fill, Non-Hermetically Sealed, Established Reliability, General Specification For.

MIL-PRF-49470 - Capacitors, Fixed, Ceramic Dielectric, Switch Mode Power Supply, (General Purpose and Temperature Stable), General Specification For.

MIL-PRF-55365 - Capacitors, Fixed, Electrolytic (Tantalum), Chip, Non-Established Reliability, Established Reliability, General Specification For.

MIL-PRF-55514 - Capacitors, Fixed, Plastic (or Metallized Plastic) Dielectric, DC or DC-AC, in Nonmetal Cases, Established Reliability, General Specification For.

MIL-PRF-55681 - Capacitors, Chip, Multiple Layer, Fixed, Unencapsulated, Ceramic Dielectric, Established Reliability and Non-Established Reliability, General Specification For.

MIL-PRF-83421 - Capacitors, Fixed, Metallized, Plastic Film Dielectric, (DC, AC, or DC and AC), Hermetically Sealed in Metal or Ceramic Cases, Established Reliability, General Specification For.

MIL-PRF-87164 - Capacitors, Fixed, Mica Dielectric, High Reliability, General Specification For.

MIL-PRF-87217 - Capacitors, Fixed, Supermetallized Plastic Film Dielectric, Direct Current For Low Energy, High Impedance Applications, Hermetically Sealed in Metal Cases, High Reliability, General Specification For.

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Defense Automated Printing Service, Building 4D (DPM-DODSSP), 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

SECTION 3: DEFINITIONS

3.1 Rating and design application terms. A list of common terms used in rating and design application of capacitors is as follows:

a. Ambient temperature. Average or mean temperature of the medium (air, gas, liquid, etc.,) surrounding an object.

b. Anode. Positive electrode of a capacitor.

c. Capacitance. Property of a capacitor which determines its ability to store electrical energy when a given voltage is applied, measured in farads, microfarads, or picofarads.

d. Capacitance tolerance. The part manufacturer's guaranteed maximum deviation (expressed in percent) from the specified nominal value at standard (or stated) environmental conditions.

e. Capacitive reactance. Opposition offered to the flow of an alternating or pulsating current by capacitance, measured in ohms.

f. Capacitor. Electronic component part consisting essentially of two conducting surfaces separated by an insulating (dielectric) material. A capacitor stores electrical energy, blocks the flow of direct current, and permits the flow of alternating or pulsating current to a degree dependent on the capacitance and the frequency.

(1) Capacitor, liquid-filled. A capacitor in which a liquid impregnant occupies substantially all of the case volume not required by the capacitor element and its connections. (Space may be allowed for the expansion of the liquid under temperature variations.)

(2) Capacitor, liquid-impregnated. A capacitor in which a liquid impregnant is dominantly contained within the foil-winding and paper-winding, but does not occupy substantially all of the case volume.

(3) Capacitor, temperature-compensating. A capacitor whose capacitance varies with temperature in a known and predictable manner.

g. Cathode. Negative electrode of a capacitor.

h. DC leakage (DCL). Stray direct current of relatively small value which flows through or across the surface of solid or liquid insulation when a voltage is impressed across the insulation.

i. Dielectric. The insulating material (e.g., air, paper, mica, oil, etc.,) between the plates of a capacitor.

j. Dielectric absorption. Property of an imperfect dielectric whereby all electric charges within the body of the material caused by an electric field are not returned to the field.

k. Dielectric constant. Property of a dielectric material that determines how much electrostatic energy can be stored per unit volume when unit voltage is applied. (It is the ratio of the capacitance of a capacitor filled with a given dielectric to that of the same capacitor having a vacuum dielectric.)

l. Dielectric strength. Maximum voltage that a dielectric material can withstand without rupturing. (The value obtained for the dielectric strength will depend on the thickness of the material and on the method and conditions of test.)

m. Dissipation factor (DF). The ratio of resistance to reactance, measured in percent.

n. Electrolyte. Current-conducting solution (liquid or solid) between two electrodes or plates of a capacitor at least one of which is covered by a dielectric film.

o. Equivalent series resistance (ESR). The square root of the difference between the impedance squared and the reactance squared.

p. Flashpoint of impregnant. The temperature to which the impregnant (liquid or solid) must be heated in order to give off sufficient vapor to form a flammable mixture.

q. Impedance (Z). Total opposition offered to the flow of an alternating or pulsating current, measured in ohms. (Impedance is the vector sum of the resistance and the capacitive reactance, i.e., the complex ratio of voltage to current.)

r. Impregnant. A substance, usually liquid, used to saturate paper dielectric and to replace the air between its fibers. (Impregnation increases the dielectric strength and the dielectric constant of the assembled capacitor.)

s. Inactive for new design. May be used on systems designed before, but shall not be used on systems designed after the date of inactivation. Applicable to Department of Defense specifications, specification sheets, and parts covered therein.

t. Insulation resistance (IR). Direct current resistance between two conductors that are separated by an insulating material.

NOTE: Capacitors are commonly subjected to two insulation resistance tests. One test determines the insulation resistance from terminal to terminal while the other test determines the insulation resistance from one or more terminals to the exterior case or insulating sleeve.

u. Partially inactive for new design. Containing both active and inactive Department of Defense specification sheets (for Department of Defense specifications), or both active and inactive parts (for Department of Defense specification sheets).

v. Power factor (PF). The ratio of resistance to impedance, measured in percent.

w. Quality factor (Q). The ratio of capacitive reactance to resistance.

x. Radio interference. Undesired conducted or radiated electrical disturbances, including transients, which may interfere with the operation of electrical or electronic communications equipment or other electronic equipment.

y. Ripple voltage (or current). The ac component of a uni-directional voltage or current (the ac component is small in comparison with the dc component).

z. Stability. The ability of a part to resist changes of characteristic values and coefficients.

aa. Surge voltage (or current). Transient variation in the voltage or current at a point in the circuit; a voltage or current of large magnitude and short duration caused by a discontinuity in the circuit.

bb. Temperature coefficient (TC). Change in capacitance of a capacitor per degree change in temperature. It may be positive, negative, or zero and is usually expressed in parts per million per degree Celsius (ppm/°C).

SECTION 4: GENERAL REQUIREMENTS

4.1 Choice of capacitor types. The variety of capacitor types used in any particular equipment should be the minimum necessary to obtain satisfactory performance. Where more than one type of capacitor may be used in a given application (i.e., molded mica or glass types), consideration should be given to cost and availability (use of strategic materials, multiple sources, etc.). The capacitors identified in this handbook meet all the criteria for standard types (see 1.1, 4.4, and table I).

4.1.1 Reliability. Where quantitative reliability requirements specified as part of the equipment requirements are such that the use of parts with established reliability (ER) is dictated, such parts should be selected from the ER specification.

4.1.2 Qualified sources. After a preliminary selection of the desired capacitor has been made, reference should be made to the applicable qualified products list for listing of qualified sources.

4.2 Item identification. A type designation for any capacitor referenced herein may be constructed as indicated in the example given in the applicable section. The Part Identification Number (PIN) designations are depicted in the applicable specification.

4.3 Conflict of requirements. This handbook provides selected standard capacitors for use in the design of Department of Defense equipment. This handbook is for guidance only. This handbook cannot be cited as a requirement.

4.4 Criteria for inclusion in this handbook. The criteria for the inclusion of capacitor types in this handbook are as follows:

a. The capacitor should be the best type available for general use in military equipment.

b. Coordinated Department of Defense specifications should be available (see 2.1).

c. Capacitors should be in production, or should have been in production.

SECTION 5: DETAILED REQUIREMENTS

5.1 Detailed requirements. The detailed requirements for standard capacitor types are contained in the applicable specification listed in this handbook.

SECTION 6: NOTES

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

6.1 Intended use. General application notes are as indicated in the appendix.

6.2 Subject term (key word) listing.

Anode
Capacitive reactance
Cathode
Dielectric absorption
Power factor
Quality factor
Radio interference

APPENDIX

GENERAL APPLICATION INFORMATION

SECTION 1: SCOPE

1.1 Scope. The application information in this handbook is designed to help in the selection of specified capacitors (application information pertaining to specific capacitor types is contained in the applicable sections). As with other types of components, the most important thing a user must decide is which of the numerous types of capacitors will be best for use in the military equipment being designed. Proper selection in its broadest sense is the first step in building reliable equipment. To properly select the capacitors to be used, the user must know as much as possible about the types from which to choose. The advantages and disadvantages should be known, as well as their behavior under various environmental conditions, their construction, and their effect on circuits and the effect of circuits on them, and a knowledge of what makes capacitors fail. The information contained herein is intended for guidance only.

1.1.1 Capacitor usage. Capacitors are used as energy-storage components to accumulate energy through long periods of time and to discharge the energy over longer or shorter periods. Parallel RC circuits will maintain bias in a circuit for long periods and, as in filter circuits, will smooth out pulsating direct current. By-pass capacitors are used to prevent the flow of direct current without impeding the flow of alternating current and attenuate low frequency currents while permitting higher frequency currents to pass. In combination with resistors, capacitors are used to reduce radio interference caused by arcing contacts, and to increase the operational life of the contacts.

1.1.2 Capacitor types. All capacitors, of the types widely used in electronic equipment, can be grouped into one of six basic types. They are glass and mica, electrolytic, paper and plastic, ceramic, air, and vacuum. These basic types differ from each other in size, cost, capacitance, and general characteristics. Some are better than others for a particular purpose; no one type has all of the best characteristics. The choice among them, therefore, depends on the requirements, both initial and long-term, the environment in which they must exist, and numerous other factors which the designer must understand. The designer must realize that the summaries of the requirements of a particular application must be taken into consideration and compared with the advantages and drawbacks of each of the several types, before a final choice is made. Table I shows the Department of Defense capacitor specification types covered in this handbook while table II provides a detailed selection guide for the capacitors.

1.2 Environmental effects on characteristics and life. The characteristics and life of all capacitors are dependent on the environments to which capacitors are exposed. Effects of various environmental conditions on capacitors are as follows:

1.2.1 Temperature:

a. The temperature at which the dielectric operates is a function of the ambient temperature in which the capacitor is located; the heat which is radiated or conducted to the capacitor; the internal heating of the capacitor due to I^2R losses in the conductors and dielectric; the physical construction and thermal conductivity of the materials inside the capacitors; the transfer of heat internally by conduction and convection to the container; and the heat lost from the container by convection, conduction, and radiation.

b. The insulation resistance decreases as the temperature increases. The power factor is a complex function of temperature. With polarized dielectrics, temperature-frequency combinations exist where there are large increases in power factor. This may not present any difficulties at low temperatures, since internal heating will raise the dielectric temperature and lower the power factor. An increase in power factor at high temperatures may cause thermal instability and must be considered.

c. The capacitance of polarized dielectrics is a complex function of temperature, voltage, and frequency; nonpolarized dielectrics exhibit less change than polarized materials. It is to be noted that as the ambient temperature is decreased, many dielectrics will exhibit a very large decrease in capacitance with a relatively small change in temperature. The increased power factor at this temperature may raise the dielectric temperature sufficiently to recover the lost capacitance; however, it must be considered that when the capacitor is initially energized while at low temperatures, the capacitance will be a small percentage of its nominal value, and if the internal heating is effective, the thermal time constant of the capacitor must be considered. A change in the distance between the conductors and the effective area of the conductor due to dimensional changes will cause a change in capacitance.

d. The dielectric strength of the dielectric decreases as the temperature increases.

e. The life of a capacitor, in general, decreases with an increase in temperature. Life as a function of operating temperature is a complex function and should be determined from life-test data. In the absence of this data, the familiar 10°C rule for a chemical reaction may be used as a rough approximation. This rule states that the life decreases by a factor of two for each 10°C rise in temperature. This rule, however, should never be used outside of the temperature range specified by the manufacturer, since chemical reactions of an entirely different nature may take place at extreme temperatures. This rule should not be applied to liquid and gaseous dielectric without further investigation.

f. The operating temperature and changes in temperature also affect the mechanical structure in which the dielectric is housed. The terminal seals utilizing elastic materials or gaskets may leak due to the set temperature characteristics. The expansion and contraction of materials with different thermal coefficients may cause leaks at joints. Electrolysis effects in glass terminals increase as the temperature increases. The increase in internal pressure of liquids and gases may cause leaks. A decrease in internal pressure due to the lowering of the temperature may cause internal arc-over.

g. If the capacitor is operated in the vicinity of a component operating at high temperature, the flashpoint of the impregnant should be considered.

1.2.2 Pressure:

a. The dielectric strength of gases is a function of pressure, temperature, frequency, and humidity. Hermetically-sealed units must have terminals designed to operate satisfactorily at the required pressure.

b. The heat loss by convection of a capacitor is a function of pressure and must be considered.

c. Reduced pressure may produce leaks in hermetically-sealed units. An increase in pressure on the container of rolled capacitors in rectangular containers may increase the capacitance by decreasing the distance between the conductors.

1.2.3 Shock and vibration. The capacitors and mounting brackets, when applicable, must be of a design which will withstand the shock and vibration requirements of the particular application.

1.2.4 Moisture. Moisture in the dielectric will decrease the dielectric strength, life, and insulation resistance, and increase the power factor of the capacitor. In general, capacitors which operate in high humidities should be hermetically sealed. The effect of moisture on pressure contacts which are not gas-tight may result in a high resistance or open contact.

1.2.5 Aging. Capacitor aging is a term used to describe the negative, logarithmic capacitance change that takes place in ceramic capacitors with time. As one might expect, the more stable dielectrics have the lowest aging rates.

Temperature compensating dielectrics, such as MIL-PRF-20 and MIL-PRF-55681 components with a characteristic of 0 ±30 ppm/°C, over the operating temperature range of -55°C to +125°C, do not appear to age at all; however, all ceramic capacitors with high dielectric constants display an aging characteristic.

General purpose dielectrics, particularly those with a capacitance change of ±15 percent (or greater) over the -55°C to +125°C operating temperature range, comprise this high dielectric constant family and represent the group we are concerned with.

High K ceramic dielectrics with a barium-titanate formula exhibit a phenomenon known as Curie Point crystal-phase transformation. Simply stated, most of the tiny crystals that make up the ceramic micro-structure are of cubic symmetry at a temperature of 120°C and above. Below 120°C, these same crystals take on a tetragonal shape. The specific relationship between this crystal-phase transformation and aging is not clearly understood, but it is known that they are directly related. As the crystals change from cubic to tetragonal shape, stresses are set up in the dielectric and are subsequently relieved gradually. This electrical "aging" phenomenon seems to follow the same logarithmic patterns observed in mechanical models of stress relief. Each time the capacitor is heated to approximately 120°C (Curie Point), all of the negative capacitance change that may have taken place is recovered. Upon cooling, the aging cycle begins again. This recovery process is commonly referred to as "de-aging". The entire process of aging and de-aging is predictable and can be repeated infinitely.

Another important parameter that affects capacitor aging is the application of polarizing voltage. The application of a dc voltage approximately equal to the capacitor's rating will cause an abrupt negative capacitance change; however, when the voltage is removed, the capacitor does not return to its original polarized value. If this exercise were performed on a capacitor with a known aging characteristic and the results were plotted, the resultant curves would resemble those on figure 1.

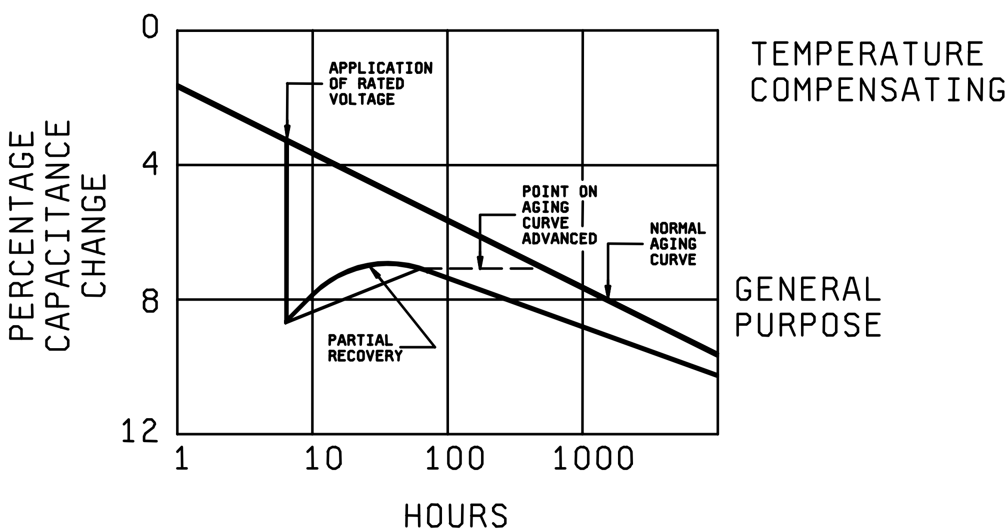

FIGURE 1. Capacitor aging curves.

The dc voltages and subsequent dielectric polarization of the capacitor micro-structure serve to relieve some of the stresses in the dielectric. This moves the point on the aging curve forward approximately 1.5 decades.

Most general purpose state-of-the-art dielectrics found in industry have aging rates varying from 1.5 percent to 4 percent.

In summary, the following points should be kept in mind when dealing with the phenomenon of ceramic capacitor aging:

a. The process is completely repeatable and predictable.

b. Capacitance change is negative and logarithmic with respect to time.

c. Application of dc bias can move a point on the curve forward in time.

This wide capacitance change, as a result of "shelf" aging and temperature cycling, illustrates why tight-tolerance high K ceramics are not common in the electronics industry.

1.2.6 Capacitor tests. The average component is a complex device. For this reason it is impossible for the manufacturer to guarantee an exact minimum life of an individual capacitor; for example, under any given circuit or environmental condition of usage, all he can do is to provide statistical guides as to the probable minimum life or reliability of the unit when considered as a member of a large family of units.

1.2.7 Capacitor misuse. A capacitor may fail when subjected to environmental or operational conditions for which the capacitor was not designed or manufactured. The designer must have a clear picture of the safety factors built into the units, of the safety factors he adds of his own accord, and of the numerous effects of circuit and environmental conditions on the parameters. It is not enough to know only the capacitance and the voltage rating. It is important to know to what extent the capacitance varies with environment; how much the internal resistance of the capacitor varies with temperature, current, voltage, or frequency; of the effects of all of these factors on insulation resistance, breakdown voltage, and other basic capacitor characteristics which are not essential to the circuit but which do invariably accompany the necessary capacitance.

1.3 Principal applications. Some of the principal applications of the various types of capacitors are shown in table II.

1.4 Capacitor selection. The designer, in selecting a capacitor type for a particular function to be performed, must weigh numerous factors before coming to a final decision. Selection normally starts with the most important characteristic for the application, then selecting and compromising other characteristics.

1.4.1 Selection factors. The most important of these factors are noted below with some of the reasons why these factors are important.

1.4.1.1 Temperature effects:

a. Capacitance:

(1) By variations in dielectric constant.

(2) By changing conductor area or spacing.

b. Leakage current, through change in specific resistance.

c. Breakdown voltage at high temperatures and effect of frequency on heating.

d. Current rating, when affected by heating.

e. Oil, gas, or electrolyte leakage through seals.

1.4.1.2 Humidity effects:

a. Leakage current.

b. Breakdown voltage.

c. Effect on power factor or Q.

1.4.1.3 Barometric pressure effects:

a. Breakdown voltage.

b. Oil, gas, or electrolyte leakage through seals.

1.4.1.4 Applied voltage effects:

a. Leakage current.

b. Heating and its accompanying effects.

c. Breakdown of dielectric; effect of frequency.

d. Corona.

e. Insulation to case or chassis.

1.4.1.5 Vibration effects:

a. Capacitance change through mechanical vibration.

b. Mechanical distortion of elements, terminals, or case.

1.4.1.6 Current effects:

a. Effect on internal temperature rise and life of capacitor.

b. Ability of conductors to carry currents from a thermal viewpoint.

1.4.1.7 Life. Affected by all environmental and circuit conditions.

1.4.1.8 Stability. Also affected by all environmental and circuit conditions.

1.4.1.9 Retrace. After a capacitance change.

1.4.1.10 Size, volume, cost, and mounting method.

1.4.2 Capacitor selection chart. Tables I and II list the capacitor styles available in each specification represented in this standard. The data given is approximate and is meant as an aid in selecting capacitors only.

1.5 Application data. The following should be considered in the selection and use of a capacitor type:

a. The capacitance tolerance that the circuit designer uses in order to design a circuit which will operate satisfactorily for the desired time requires (1) acceptable tolerances according to specification; (2) capacitance-temperature characteristics; (3) capacitance-voltage characteristics; (4) retrace characteristics; (5) capacitance-frequency characteristics; (6) dielectric absorption; (7) capacitance as a function of pressure, vibration, and shock; and (8) capacitor aging in the circuit and shelf storage.

b. Capacitance between the capacitor terminals and case may be a consideration, as will stray capacitance and leakage currents. The terminal connected to the outside conductor is often identified by the manufacturer so that the circuit can minimize these effects.

c. The capacitance-temperature characteristic can be compensated for by using more than one type of capacitor to obtain the required capacitance. The characteristics of other circuit components may also be used for compensation.

d. The peak voltage which is applied to the capacitor should not exceed the rating in the applicable specification. The safety factor between the peak applied voltage, the test voltage, and the breakdown voltage is of a statistical nature. The same peak voltage, in general, may decrease with (1) aging, (2) an increase in temperature, (3) an increase of area of dielectric, (4) higher frequencies of applied voltage, (5) a decrease in pressure, or (6) the entrance of moisture into the capacitor. In many applications, it is necessary to derate the capacitor from the specified voltage to provide the desired performance for the required time. It is to be emphasized that short-duration transient voltages cannot be neglected in capacitor applications.

e. The use of the self-healing properties of certain types of capacitors may not be desirable in circuits where intermittent failures and noise would be troublesome. Some types are not self-healing at low voltages.

f. Operation of capacitors above the corona-starting voltage will reduce the life and will produce noise. Liquid-impregnated dielectrics have a higher corona-starting voltage than dry solid dielectrics.

g. When a capacitor is operated at high voltages above ground, and when it is insulated from ground with supplementary insulation, one terminal should be connected to the case, since the division of voltage depends on capacitance between capacitor rolls and case and the capacitance between case and chassis.

h. The peak charge and discharge currents must be considered on the basis of the time constant of the circuit.

i. Internal heating and ambient temperature must be considered.

j. To determine the surface temperature rise of a capacitor, multiply the volt-amperes supplied to the unit by the power factor. This gives the watts lost in the capacitor. Dividing the watts lost by the surface area in square inches and referring to figure 2 will give the approximate surface temperature rise.

k. Environmental conditions such as humidity, pressure, corrosive atmospheres, fungus growth, shock, and vibration must be considered.

l. The insulation resistance must be considered, especially at high temperatures.

m. In series operation on dc, balancing resistors should be considered.

n. The effective inductance of a large capacitor can be reduced by shunting it with a small capacitor.

o. The inductance of various types of capacitors varies over wide limits.

p. Since capacitors have inductance, the operation of capacitors in parallel in circuits with fast rise times or transients may result in transient oscillations.

q. Poor electrical contacts may open at low voltages and be noisy.

r. The stored energy in capacitors can be dangerous to personnel and equipment and suitable precautions should be taken.

s. Extended-foil paper capacitors are generally considered superior to inserted-tab types, having less inductance and less series-contact resistance. These are important factors in low voltage applications and in low signal-to-noise-ratio circuits.

t. Oil-filled or acid-filled units should not be subjected to severe mechanical stresses. Leakage of the fluid can destroy the capacitor together with adjacent components.

u. Liquid-filled units should not be used inverted because internal corona may result.

v. Nonhermetically-sealed capacitors may be pervious to moisture by the process of "breathing."

w. Capacitors for ac and pulse operation require special ratings and tests; these are not covered in most military specifications.

TABLE I. Capacitor categories.

CERAMIC	MIL-PRF-20	Temperature Compensating (ER and Non-ER)
	MIL-PRF-81	Variable (Non-ER)
	MIL-PRF-123	Temperature Stable and General Purpose (High Reliability)
	MIL-PRF-39014	General Purpose (ER and Non-ER)
	MIL-PRF-49470	Switch Mode Power Supply (High Reliability)
	MIL-PRF-55681	Chip (ER)
ELECTROLYTIC	MIL-PRF-39003	Solid Electrolyte Tantalum (ER)
	MIL-PRF-39006	Nonsolid Electrolyte Tantalum (ER)
	MIL-PRF-39018	Aluminum Oxide (ER)
	MIL-PRF-49137	Solid Electrolyte Tantalum (Non-ER)
	MIL-PRF-55365	Tantalum Chip (ER and Non-ER)
GLASS	MIL-PRF-14409	Variable Piston Type Tubular Trimmer (Non-ER)
	MIL-PRF-23269	(ER)
MICA	MIL-PRF-39001	(ER)
	MIL-PRF-87164	(High Reliability)
PAPER / PLASTIC	MIL-PRF-19978	(ER)
	MIL-PRF-39022	DC/AC (ER)
	MIL-PRF-55514	DC or DC-AC (ER)
	MIL-PRF-83421	DC/AC, Hermetically Sealed (ER)
	MIL-PRF-87217	DC for Low Energy, High Impedance Applications (High Reliability)

APPENDIX

SECTION 2: APPLICABLE DOCUMENTS.

This section is not applicable to this appendix.

SECTION 3: GENERAL CHARACTERISTICS OF CAPACITORS

3.1 General characteristics of ceramic capacitors.

3.1.1 MIL-PRF-20, CCR and CC, Capacitors, Fixed, Ceramic Dielectric (Temperature Compensating), Established Reliability and Non-Established Reliability.

3.1.1.1 Use. These ceramic, temperature compensating, fixed capacitors are primarily designed for use where compensation is needed to counteract reactive changes, caused by temperature variations, in other circuit components. Ceramic capacitors are substantially smaller than paper or mica units of the same capacitance and voltage rating. They can be used where mica or paper capacitors have too wide a capacitance tolerance. The lead placement makes ceramic capacitors suitable for printed-circuit use.

By using these units, frequency drift in radio frequency, oscillator, and intermediate frequency (IF) circuits due to temperature effects can be compensated individually in each circuit. In IF stages where the frequency variation is uniform, satisfactory operation can be obtained by designing the temperature-compensating capacitor into the oscillator circuit. RF circuit reactive changes caused by temperature variations cannot be compensated for in the oscillator circuit; in these cases, and where more critical tuning accuracy is required, it is necessary that compensating capacitors be inserted directly into each circuit.

In RF circuits tuned by a variable capacitor, a shunt compensating capacitor of low value and high compensating characteristics may be used. In slug-tuned circuits, the total capacitance required can be provided by using a compensating capacitor having the desired temperature coefficient. In oscillator circuits, more linear tuning can be obtained by using proper temperature coefficients in both the series and the shunt capacitances of the tank circuit.

High insulation resistance makes these capacitors well suited to coupling applications between plate and grid circuits of electron tubes. Extremely low leakage and small physical size make them suitable for transistor circuit design. They are also useful in filter and by-pass circuits.

If possible, the temperature-time curve of the selected capacitor should be the exact opposite of the temperature-time curve of the coil (or other component) being stabilized. Combinations of different capacitance values and temperature coefficients can give more precise compensation than can be obtained from a single capacitor. Full consideration should be given to the physical placement of compensating, and compensated for, components. Locations near hot transistors will cause much greater reactive variations than spots adjacent to a cool, external chassis.

Ceramic dielectrics are frequency sensitive, both the capacitance and the capacitance change with temperature will be different at different measuring frequencies. For extremely accurate compensation, the units should be measured at the proposed operating frequency.

Capacitors meeting the ER requirements specified herein have a FRL ranging from 1.0 percent per 1,000 hours to 0.00l percent per 1,000 hours. These FRLs are established at a 90-percent confidence level based on the life test parameters specified and are maintained at a 10-percent producer's risk. An acceleration factor of 8:1 has been used to relate the life test data at 200 percent of rated voltage at the applicable high test temperature to the rated voltage at the applicable high test temperature.

3.1.1.2 Construction. Physically, the most common types of temperature-compensating, ceramic-dielectric capacitors are small monolithic tubular and rectangular types covered by insulating resin, plastic, or ceramic. Because the constituent materials have molecular polar moments, the dielectric constants of some mixes reach hundreds (even thousands) of times the value of paper, mica, and plastic films. This results in ceramic-dielectric capacitors having the largest capacitance-to-size ratios of all high-resistance dielectrics.

3.1.1.3 Dielectric strength. It is recommended that supplementary insulation be used where the capacitor body will normally contact parts with a potential difference of more than 750 volts.

3.1.2 MIL-PRF-81, CV, Capacitors, Variable, Ceramic Dielectric.

3.1.2.1 Use. These capacitors are small-sized trimmer capacitors designed for use where fine tuning adjustments are periodically required during the life of the equipment. Normally they are used for trimming and coupling in such circuits as intermediate frequency, radio-frequency, oscillator, phase shifter, and discriminator stages. Because of their low mass, these units are relatively stable against shock and vibration which tend to cause changes in capacitance. Where a higher order of stability is required, air trimmers should be used. Capacitance and adjustment are relatively linear.

3.1.2.2 Construction. Each unit consists of a single stator and a single rotor for each section, made of ceramic material impregnated with transformer or silicone oil. Pure silver is fired and burnished on the top of the base of the stator in a half-moon pattern. The rotor, usually of titanium dioxide, has pure silver contact points. The contact surfaces of both the stator and the rotor are ground and lapped flat, thus eliminating air space variations with temperature.

The principle of operation is similar to that of an air-dielectric tuning capacitor where the overlap of the stator and rotor determines the capacitance; in these units, the ceramic dielectric replaces the air dielectric. Rotors may be rotated continuously; full capacitance change occurs during each rotation. The approximate maximum capacitance point is indicated on the capacitor.

3.1.2.3 Mounting. These capacitors may be mounted close to a metal panel with little increase in capacitance. To avoid cracking or chipping of the ceramic mounting base, a resilient mounting (or mounting surface spacer) should be used.

3.1.2.4 Capacitance change with temperature. When measurements are made after the capacitors have reached thermal stability at each temperature setting (at a frequency between 0.1 and 1.2 megahertz (MHz), and with the capacitor set at 80 to 90 percent of maximum capacity, the changes of nominal capacitance from the value measured at +25°C may vary from -4.5 to +14.0 percent at -55°C or -10.0 to +2.0 percent at +85°C. Since the temperature sensitivity is nonlinear over the capacitance range and varies greatly between units, these capacitors should not be designed into circuits as temperature compensating units. The capacitance drift remains within 0.5 pF.

3.1.3 MIL-PRF-123, CKS, Capacitors, Fixed, Ceramic Dielectric, (Temperature Stable and General Purpose), High Reliability.

3.1.3.1 Use. These high reliability, general purpose (BX and BR) and temperature stable (BP and BG) ceramic leaded and nonleaded capacitors are intended for space, missile and other high reliability applications. Capacitors covered by this specification may be used in critical frequency determining applications, timing circuits, and other applications where absolute stability is required (BP and BG) and in applications where appreciable variations in capacitance with respect to temperature, voltage, frequency and life can be tolerated (BX and BR). Life tests in this specification are performed at 2 times rated voltage at maximum rated temperature, and an assumed acceleration factor of 8:1 is used to relate life test data obtained at 2 times rated voltage to performance at rated voltage.

3.1.4 MIL-PRF-39014, CKR, Capacitors, Fixed, Ceramic Dielectric (General Purpose), Established Reliability and Nonestablished Reliability.

3.1.4.1 Use. These capacitors are primarily designed for use where a small physical size with comparatively large electrical capacitance and high insulation resistance is required. Ceramic capacitors are substantially smaller than paper or mica units of the same capacitance and voltage rating. General-purpose ceramic capacitors are not intended for precision use but are suitable for use as by-pass, filter, and noncritical coupling elements in high-frequency circuits where appreciable changes in capacitance, caused by temperature variations, can be tolerated. These units are not recommended for use directly in frequency-determining circuits. Typical recommended applications include resistive-capacitance coupling for audio and radio frequency, RF and intermediate frequency cathode bypass, automatic volume control filtering, tone compensation, volume-control RF bypass, antenna coupling, and audio-plate RF bypass. All of these applications are of the type where dissipation factor is not critical, and moderate changes due to temperature, voltage, and frequency variations do not affect the proper functioning of the circuit. For example: An emitter bypass for 100 megahertz (MHz), having a nominal capacitance of 680 picofarads (pF), will give a capacitance reactance of 2.34 ohms. Since this reactance is very small compared with the emitter resistor, there would be no measurable effect on the 2.34-ohm value if the capacitance should change by several percent due to a temperature variation, nor would a dissipation of 4 percent be noticeable.

Disk and thin-plated subminiature types are extremely compact and have an inherent low-series inductance due to their construction. The placement of the leads facilitates making close-coupled low-inductance connections and these capacitors are suitable for printed-circuit applications. High insulation resistance allows these capacitors to be used in vacuum-tube grid circuits; their extremely low leakage and small physical size make them suitable for use in transistor circuitry.

During circuit design, consideration should be given to the changes in dielectric constant caused by temperature, electric field intensity, applied frequency, and shelf aging.

ER capacitors covered by this specification have FRLs (M, P, R, and S) ranging from 1.0 to 0.001 percent per 1,000 hours. These FRLs are established at a 90-percent confidence level and maintained at a 10-percent producer's risk and based on life tests performed at maximum rated voltage at maximum rated temperature. An acceleration factor of 8:1 has been used to relate life test data obtained at 200 percent of rated voltage at maximum rated temperature, to rated voltage at rated temperature.

3.1.4.2 Humid operating conditions. Ceramic dielectric materials are effectively impermeable, and have practically no moisture absorption even after considerable exposure to humid conditions. Thus, these units are intended to operate, through their full temperature range, at relative humidities up to 95 percent. Nevertheless, the termination materials under moisture conditions are subject to ionic migration that can cause capacitor failure (see 2.8).

3.1.4.3 Construction. A ceramic capacitor consists of a ceramic dielectric on which a thin metallic film, usually silver, has been fired at very high temperatures. Terminal leads are attached to the electrodes by a pressure contact or by soldering. Ceramic capacitors are encapsulated to protect the dielectric from the environment and to electrically insulate the capacitor. The disk types are covered by an insulating resin, plastic, or ceramic; the thin-plated subminiature types may be dipped, molded, or placed into preformed cases. Because the dielectric constants of some mixes reach hundreds (even thousands), of times the value of paper, mica, and plastic films. This results in ceramics having the largest capacitance-to-size ratios of all high-resistance dielectrics.

3.1.4.4 Soldering. Care should be used in soldering the leads. Excessive heat may damage the encapsulation and weaken the electrode to terminal lead contact. Sudden changes in temperature, such as those experienced in soldering, can crack the encapsulation or the ceramic dielectric. Leads should not be bent close to the case nor should any strain be imposed on the capacitor body to avoid fracturing the encapsulation or ceramic dielectric.

3.1.4.5 Dissipation factor. For the recommended applications, the dissipation factor is negligibly low. The power factor decreases as temperature is increased; this provides an advantage where operation above room temperature is required.

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

3.1.4.7 Capacitance as a function of operating conditions. The dielectric constant of these capacitors exhibits a considerable dependence on field strength. Large variations in capacitance may be experienced with changes in ac or dc voltages. The dielectric constant may decrease with time and may be as low as 75 percent of the original value after 1,000 hours. The dielectric constant is dependent on frequency and decreases as the frequency is increased; it also decreases with temperature.

3.1.4.8 Silver migration. When silver electrodes in the ceramic capacitor are exposed to high humidities and high dc potentials, silver ion migration may take place and short circuit capacitors after relatively short periods of time. Excessive moisture during periods of storage should be avoided since the encapsulation material may absorb moisture and silver ion migration may occur when the capacitors are later put into service.

3.1.5 MIL-PRF-49470, PS, Capacitor, Fixed, Ceramic Dielectric, Switch Mode Power Supply (General Purpose and Temperature Stable). These ceramic capacitors are primarily designed for use in switch mode power supplies. General purpose (BQ, BR, and BX characteristics) ceramic capacitors are not intended for frequency-determining or precision circuits but are suitable for use as by-pass, filter, and noncritical coupling elements in high-frequency circuits. All of these applications are of the type where dissipation factor is not critical and moderate changes due to temperature, voltage, and frequency variations do not affect the proper functioning of the circuit. BP characteristic ceramic capacitors are for use in critical frequency determining applications, timing circuits, and other applications where absolute stability is required. An acceleration factor of 8:1 has been used to relate life test data obtained at 200 percent of rated voltage at maximum rated temperature to rated voltage at rated temperature.

3.1.6 MIL-PRF-55681, CDR, Capacitor, Chip, Multiple Layer, Fixed, Ceramic Dielectric, Established Reliability and Non-Established Reliability.

3.1.6.1 Use. These ceramic chip capacitors are intended to be used in thin and thick film hybrid circuits where micro-circuitry is indicated for filter by-pass coupling applications, and where variation in capacitance with respect to temperature, voltage, frequency, and life can be tolerated. This specification also covers another ER capacitor, using ceramic dielectric, primarily intended for use in resonant circuits with high Q factor and stability of capacitance with respect to temperature, frequency, and life.

ER capacitors covered by this specification have FRLs ranging from 1.0 percent to 0.001 percent per 1,000 hours. These FRLs are established at a 90-percent confidence level and maintained at a 10-percent producer's risk and are based on life tests performed at maximum rated voltage at maximum rated temperature. An acceleration factor of 8:1 has been used to relate life test data obtained at 200 percent of rated voltage at maximum rated temperature, to rated voltage at rated temperature.

3.1.6.2 Ambient operating conditions. Designers are cautioned to give consideration to the change in dielectric constant with temperature, shelf aging, and electric-field intensity, and should recognize that the insulation resistance may vary with humidity and organic contamination of the ceramic chip surfaces.

3.1.6.3 Metallized terminations. It should be noted that when pure silver is used for the terminations, silver migration between the terminations may occur under conditions of simultaneous application of high humidity and dc voltage. This produces a troublesome electrical leakage path across the capacitor chip. Addition of about 20 percent of palladium to the silver to form an alloy will retard the tendency toward silver migration. Complete overcoating of the silver termination by the lead-tin bonding solder also will retard the tendency toward silver migration. Addition of about 3 percent of silver to the lead-tin bonding solder will tend to reduce the leaching of the silver from a silver termination during the solder bonding operation.

3.1.6.4 Effect of mounting reliability. Voltage temperature limits, resistance to thermal shock, and reliability may be affected as a result of mounting on substrates with dissimilar coefficients of expansion from capacitor material. Care should be taken in the selection of substrate material.

3.2 General characteristics of electrolytic capacitors.

3.2.1 MIL-PRF-39003, CSR, Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Established Reliability.

3.2.1.1 Use. These tantalum capacitors 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. 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. 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. 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 FRL at +125°C is not established in this specification; however, proof tests at +125°C are required.

Rated voltages range from 6 to 100 volts dc with surge voltages of 8 to 130 volts dc, respectively. These capacitors are designed for full rated voltage operation between -55°C and +85°C, derated linearly between +85°C and +125°C to the value shown in table I of the specification. These capacitors have reliability ratings established on the basis of life tests performed at specified voltage at +85°C for FRLs ranging from 1.0 percent per 1,000 hours to 0.001 percent per 1,000 hours in accordance with MIL-STD-690. These FRLs are established at a 60-percent confidence level and are maintained at a 10-percent producer's risk for Exponential distribution and 0.1 percent per 1,000 hours to 0.001 percent per 1,000 hours at a 90-percent confidence level for Weibull distribution.

These capacitors are available as polarized and nonpolarized types. Polarized types should have their cases at the same potential as the negative lead; they should be used only in dc circuits with polarity observed. Nonpolarized types should be used where reversal of potential occurs.

3.2.1.2 Construction. A porous tantalum pellet or wire serves as the anode of a solid tantalum capacitor. The surfaces of the anode are electrochemically converted to an oxide of tantalum which serves as the dielectric. These surfaces are coated with an oxide semiconductor which is the working electrolyte in solid form. This oxide semiconductor establishes contact with all of the complex surfaces of the anodized pellet and is capable of healing imperfections of the tantalum oxide dielectric film.

NOTE: In high impedance circuits, momentary breakdowns (if present) will self-heal; however, in low impedance circuits, their self-healing characteristics under momentary breakdown of the dielectric film will be nonexistent. The large currents in low impedance circuits will cause permanent damage to the capacitor.

3.2.1.3 Voltage derating. When properly derated, these units may be operated over a temperature range of -55°C to +125°C. The derated voltage at +125°C is approximately 66 percent of the full rated voltage.

3.2.1.4 Reverse voltage. These capacitors are capable of withstanding peak voltages in the reverse direction equal to 15 percent of their dc rating at +25°C; 10 percent at +55°C; 5 percent at +85°C; and 1 percent at +125°C.

3.2.1.5 Permissible ripple voltage. These capacitors may be operated with an impressed ripple (ac) voltage provided the capacitors do not exceed their heat-dissipation limits. Total heat-dissipation limits depend on the ambient operating temperature and the operating frequency. For example. A 10 μF capacitor of any voltage may be operated at 1.9 V rms, 120 Hz, 25°C; or at 0.75 V rms, 120 Hz, 125°C. When this same capacitor is subjected to a ripple frequency of 1,000 Hz, the permissible ripple voltage must be reduced by the ratio of permissible ac at 120 Hz as follows: 1.9 times 0.47/ 1.9 equals 0.47 V rms at 25°C, 1,000 Hz; or 0.75 times 0.47/1.9 equals 0.19 V rms at 125°C, 1,000 Hz. The sum of the applied dc bias voltage and the peak of the ac ripple voltage should not exceed the dc rated voltage for the applicable ambient temperature. Permissible ac voltage determined may be applied when the dc voltage is zero or near zero, provided the negative peak of the ac voltage does not exceed the allowable reverse voltage limits of 1 percent of the rated voltage at +125°C. For CSR21 capacitors, ripple voltage is more often limited by restraints on reversal of voltage. Ripple current limitations are more significant because the degradation mode is thermal and must not be allowed to exceed the maximum levels specified for each rating, frequency, and ambient temperature.

3.2.1.6 Series and parallel networks. It is recommended that when these capacitors are connected in series, the maximum voltage across the network should not be greater than the lowest voltage rating of any capacitor in the network, or that voltage divider resistors be used to prevent over voltage on one or more units of the series capacitor group.

To obtain a higher capacitance than can be obtained from a single capacitor, a number of units may be connected in parallel. However, the sum of the peak ripple and the applied dc voltage should not exceed the dc working voltage of the unit with the lowest voltage rating. The connecting leads of the parallel network should be large enough to carry the combined currents without reducing the effective capacitance due to series lead resistance.

3.2.1.7 Comparison with aluminum electrolytics. Tantalum solid electrolytic capacitors differ from aluminum electrolytics in several important aspects; namely, substantially indefinite shelf life, superior low temperature characteristics, complete freedom from electrolyte leakage, and higher operating temperatures. However, because tantalum electrolytic capacitors generally are more costly than aluminum electrolytic capacitors, consideration should be given to the use of aluminum electrolytic capacitors if their performance characteristics and physical sizes are suitable and if the application will permit.

3.2.1.8 Mounting. Supplementary mounting means should be used where the application of these capacitors involves vibration frequencies above 55 Hz.

3.2.1.9 Increased reliability. Failure rate is a function of temperature, applied voltage, and circuit impedance. Increased reliability may be obtained by derating the temperature and applied voltage and increasing circuit impedances.

DC leakage current increases when either voltage or temperature is increased; the rate of increase is greater at the higher values of voltage and temperature. A point can be reached where the dc leakage current will avalanche and attain proportions that will permanently damage the capacitor. Consequently, capacitors should never be operated above their rated temperature and rated voltage for that temperature.

By increasing the circuit impedance, the leakage current is reduced. In life testing the solid tantalum capacitor, the capacitance and dissipation factor are very stable over long periods of time and hence are not a suitable measure of deterioration. Leakage current variation is a better indicator of capacitor condition. In the life test in MIL-PRF-39003, a maximum impedance of 3 ohms is allowed. It is recommended that a minimum circuit impedance of 3 ohms per applied volt (1.5 ohms per volt for CSR21) be utilized to attain improved reliability.

3.2.2 MIL-PRF-39006, CLR, Capacitors, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability.

3.2.2.1 Use. These capacitors are limited to applications at 125 Vdc or below. Their primary use is in low voltage power supply filtering circuits but also may be used in coupling and bypassing, circuit isolation, tuning, timing, power factor correction and phase shifting applications. Their low leakage current (lowest of all the tantalum types) is not appreciable below +85°C; and at ordinary operating temperatures is comparable to good quality paper capacitors, yet they are much smaller in size. These capacitors have the highest capacitance per size, or volumetric efficiency, of all capacitor dielectrics.

3.2.2.2 Construction: These capacitors consist of a sintered-pellet, acting as the anode, which is electrochemically treated to form a layer of tantalum oxide dielectric. The electrode is a liquid, normally a sulfuric acid solution, which establishes contact with all of the complex surfaces of the anodized pellet. The case, of which the inner surface may be covered with anodized tantalum powder, or some other material, becomes the cathode. To prevent the loss of the liquid electrolyte, the case is normally grooved with a seal ring against a Teflon™ top gasket. The top of the case is then closed using a hermetic glass-to-metal, or a non-hermetic elastomer, seal.

3.2.2.3 Voltage derating. When properly derated, these units may be operated over a temperature range of -55°C to +125°C. The derated voltage at +125°C is approximately 66 percent of the full rated voltage.

3.2.2.4 Reverse voltage. Styles CLR79, CLR81, CLR90 and CLR91 capacitors are for dc application only; however, they will withstand up to 3 volts of reverse bias. Style CLR82 is a non-polarized design for higher reverse dc voltage or ac voltage applications.

3.2.2.5 Series and parallel applications. Whenever tantalum capacitors with unequal values of dc leakage or capacitance are connected in series for higher voltage operation, it may be desirable to place a resistor in parallel across each unit. Unless a shunt resistor is used, the dc rated voltage can be exceeded on the capacitor in the series network with the highest impedance at the active circuit frequencies.

To obtain a higher capacitance than can be obtained from a single capacitor, a number of units may be connected in parallel. However, the sum of the peak ripple and the applied dc voltage should not exceed the dc rated voltage. The connecting leads of the parallel network should be large enough to carry the combined currents without reducing the effective capacitance due to series lead resistance.

3.2.2.6 Reliability. Capacitors covered by this specification have reliability established for FRL ranging from 1.0 percent to 0.001 percent per 1,000 hours in accordance with MIL-STD-690. These FRLs are established at a 60-percent confidence level and are maintained at a 10-percent produce’s risk. Ongoing testing to maintain these FRLs is conducted at full rated voltage and +85°C. Increased reliability may be obtained by derating the temperature and applied voltage, and increasing circuit impedance.

3.2.2.7 Mounting. Supplementary mounting means should be used where the application of these capacitors involves vibration frequencies above 55 Hz.

3.2.3 MIL-PRF-39018, CUR and CU, Capacitors, Fixed, Electrolytic (Aluminum Oxide), Established Reliability and Non-Established Reliability.

3.2.3.1 Use. These aluminum oxide electrolytic capacitors are intended for use in filter and bypass applications where large capacitance values are required in small cases and where excess of capacitance over the nominal value can be tolerated. Aluminum electrolytic capacitors provide the smallest volume, mass, and cost per microfarad of any type of capacitor with the exception of the tantalum electrolytic capacitor. For polarized capacitors, the applied ac peak voltage should never exceed the applied dc voltage; the sum of the applied ac peak and dc voltages should never exceed the dc rated voltage.

These capacitors are not recommended for airborne equipment applications since they should not be subjected to low barometric pressure and low temperatures at high altitudes. These aluminum electrolytic capacitors can be derated only for a short period since derating for any length of time may result in the necessity for re-forming. Even though they have vents designed to open at dangerous pressures, explosions can occur because of gas pressure or a spark ignition of free oxygen and hydrogen liberated at the electrodes. Provisions should be made to protect surrounding parts.

These capacitors are generally used where low frequency, pulsating, dc signal components are to be filtered out, and as cathode by-pass capacitors in self-biasing circuits. These capacitors are designed for applications where accuracy of capacitance is relatively unimportant.

As a rule, for selection of emitter by-pass capacitors, a ratio of bias resistance to by-pass reactance of about 10 to 1 is allowed. Ratios up to 20 to 1 may be used in high-fidelity-amplifier work or where space and economical considerations permit. Electrolytic capacitors provide the equipment designer with an unusually lightweight unit of high capacitance in a compact container.

ER capacitors covered by this specification have reliability established on the basis of life tests performed at rated voltage at 85°C for FRLs ranging from 1.0 percent to 0.001 percent per 1,000 hours in accordance with MIL-STD-690. These FRLs are established at a 60-percent confidence level and are maintained at a 10-percent producer's risk.

3.2.3.2 Construction. The capacitor consists of aluminum foil rolled onto a porous spacer. The foil is approximately .003 to .005 inch (0.08 to 0.13 mm) thick. The spacer is impregnated with an electrolyte and separates the anode and cathode. The electrolyte is usually an aqueous solution of ammonium borate, boric acid, and glycol. The metal cases are provided with an insulating sleeve which has an insulation resistance of at least 100 megohms.

It should be noted that the insulation resistance refers to the sleeve and not to the resistance between the terminals and the case. For proper performance, the case of all styles should be considered to be at the same potential as the negative terminal.

3.2.3.3 Voltage rating. The thickness of the oxide film which is formed both initially on the foil and during the forming operations on the completed capacitor determines the maximum peak or surge voltage which may be applied. For maximum reliability and long life, the dc working voltage should not be more than approximately 80 percent of full rating so that surges can be kept within the full-rated working voltage. The time of surge-voltage application should not be more than 30 seconds every 10 minutes

3.2.3.4 Derating. Style CU15 capacitors may be voltage derated in order to operate at temperatures up to +125°C. The percent of derating varies from approximately 20 to 33 percent depending on the particular voltage rating involved.

3.2.3.5 Seal. Even though these capacitors have vents designed to open at dangerous pressures, explosions can occur because of gas pressure or a spark ignition of free oxygen and hydrogen liberated at the electrodes. Provisions should be made to protect surrounding parts.

3.2.3.6 Polarization. Nonpolarized capacitors should be used in applications where reversal of potential occurs. Polarized capacitors should be used only in dc circuits with polarity properly observed. If ac components are present, the sum of the peak ac voltage plus the applied dc voltage must not exceed the dc rating. The peak ac value should also be less than the applied dc voltage so that polarity may be maintained, even on negative peaks, to avoid overheating and damage.

3.2.4 MIL-PRF-49137, CX, Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, Molded, Conformal Coated and Metal Cased with Plastic End-Fill, Nonhermetically Sealed.

3.2.4.1 Use. These tantalum electrolytic 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. These capacitors are intended to be used only where supplemental moisture protection is provided or for noncritical applications where hermetic moisture protection is not required.

3.2.5 MIL-PRF-55365, CWR, Capacitors, Fixed Tantalum, Nonestablished Reliability, Established Reliability.

3.2.5.1 Use. These tantalum chip capacitors are primarily intended for use in thick and thin film hybrid circuits or surface mount applications for filter, bypass, coupling, and other applications where the alternating current (ac) component is small compared to the direct current (dc) rated voltage and where supplemental moisture protection is available. The ER capacitors have reliability ratings established in exponential distribution and Weibull distribution.

The reliability ratings are determined on the basis of life tests performed at specified voltage at +85°C. The exponential failure rates are 1.0 percent per 1,000 hours to 0.001 percent per 1,000 hours. These exponential failure rates are established at a 60-percent confidence level and are maintained at a 10-percent producer's risk. The Weibull failure rates are 0.1 percent per 1,000 hours to 0.0001 percent per 1,000 hours (1 FIT) at a 90-percent confidence level. FIT is one failure per 10^9 device hours.

3.2.5.2 Construction. A porous tantalum slab serves as the anode. The surfaces of the anode are electrochemically converted to an oxide of tantalum which serves as the dielectric. These surfaces are coated with an oxide semiconductor which is the working electrolyte in solid form.

3.2.5.3 Voltage derating. The derated voltage at +125°C is approximately 66 percent of the full rated voltage.

3.2.6.4 Mounting. These capacitors are designed for mounting by reflow solder or conductive epoxy on circuit substrates.

3.3 General characteristics of glass capacitors.

3.3.1 MIL-PRF-14409, PC, Capacitors, Variable (Piston Type, Tubular Trimmer).

3.3.1.1 Use. These capacitors are small-sized, tubular-trimmer, variable capacitors designed for use where fine tuning adjustments are periodically required during the life of the equipment. Normally they are used for trimming and coupling in such circuits as intermediate frequency, radio-frequency, oscillator, phase shifter, and discriminator stages. Because of their low mass, these units are relatively stable against shock and vibration which tend to cause changes in capacitance. Capacitance change versus rotation is linear within ±10 percent. Backlash is virtually nonexistent except on styles PC39 and PC43 which have a maximum backlash of 2 percent.

3.3.1.2 Construction. Styles PC18, PC46, PC19, PC47, PC25, PC26, PC30, and PC32 capacitors are constructed of a series of concentric circular metal bands which interleaf and are variable by adjustment of the related depth of the interface. All other style capacitors are constructed of glass, quartz, sapphire, or alumina dielectric cylinders and metal tuning pistons. A portion of the cylinder is plated with metal to form the stator and the metal piston, controlled by a tuning screw, acts as the rotor for these variable capacitors. The overlap of the stator and rotor determines the capacitance. The self-contained piston within the dielectric cylinder functions as a low inductance coaxial assembly.

3.3.2 MIL-PRF-23269, CYR, Capacitors, Fixed, Glass Dielectric, Established Reliability.

3.3.2.1 Use. These capacitors are intended for use in any equipment where known orders of reliability are required, and are primarily designed as a substitute for mica-dielectric capacitors as a step toward conservation of critical mica. They are effective substitutes for mica-dielectric capacitors and can be employed for many applications where mica-dielectric capacitors are used, provided consideration is given to the differences in temperature coefficient and dielectric loss. They are capable of withstanding environmental conditions of shock, vibration, acceleration, extreme moisture, vacuum, extended life of 30,000 hours and more, and high operating temperatures such as experienced in missile-borne and space electronic equipment.

The FRL are established at a 90 percent confidence level and maintained at a 10 percent producer's risk and are based on life tests performed with rated voltage applied at 125°C. An acceleration factor of 5:1 has been used to relate life test data obtained at 150 percent of rated voltage at 125°C to rated voltage at 125°C.

3.3.2.2 Construction. Glass-dielectric capacitors are composed of alternate layers of glass ribbon and the electrode material. After assembly, the units are sealed together by high temperature and pressure to form a rugged monolithic block. Since the terminal leads are fused to the glass case, the seal cannot be broken without destroying the capacitor. Although these capacitors are of monolithic structure, they are not necessarily hermetically sealed since the coefficient of thermal expansion of the terminals does not match that of the case. These construction features provide the following advantages: fixed temperature coefficient, high insulation resistance, low dielectric absorption, miniaturization, and the ability to operate in environments involving high humidity and high temperatures. The physical size of the glass-dielectric capacitor is smaller than, or approximately very closely, the size of the "postage-stamp" type mica-dielectric capacitor.

3.3.2.3 Shock. Glass capacitors are resistant to high G loads but they are susceptible to damage from mild mechanical shocks.

3.4 General characteristics of mica capacitors.

3.4.1 MIL-PRF-39001, CMR, Capacitors, Fixed, Mica Dielectric, Established Reliability and Nonestablished Reliability.

3.4.1.1 Use. These mica capacitors are intended for use in equipment where a known order of reliability is required. The ER capacitors have a FRL ranging from 1.0 percent per 1,000 hours to 0.001 percent per 1,000 hours. The FRL is established at a 90 percent confidence level. An acceleration factor of 25:1 has been used to relate the life test at 150 percent of rated voltage at rated temperature to rated voltage at rated temperature.

3.4.1.2 Construction. Muscovite mica is the most commonly used material. It has a dielectric constant between 6.5 and 8.5 and can be split into thin sheets; it is nonporous and does not readily absorb moisture. Protection from moisture is provided to obtain high-capacitance stability and low losses. The two techniques used to form the capacitors covered in this section are by stacking the mica sheets through the silvered-mica process or by the use of tin-lead foil to separate the mica sheets. The molded units referenced in this section are fixed terminal capacitors. Terminals are attached to the mica stacks by the use of pressure clips which have been solder-coated for maximum mechanical strength. The molded case is made of a polyester material which also exhibits high insulation resistance and high resistance to moisture absorption and transmission. The molded case also imparts rigidity to the capacitor in the event the capacitor is subjected to vibration or shock.

3.4.2 MIL-PRF-87164, CMS, Capacitors, Fixed, Mica Dielectric, High Reliability.

3.4.2.1 Use. These high reliability mica capacitors are intended for use in space, launch vehicles, or other high reliability applications. Capacitors covered by this specification may be used in critical applications where the utmost in stability and dependability is required and where variations in capacitance with respect to temperature, voltage, frequency, and life cannot be tolerated. An acceleration factor of 25:1 has been used to relate life test data obtained at 150 percent of rated voltage at rated temperature to rated voltage at rated temperature.

3.5 General characteristics of paper and plastic capacitors.

3.5.1 MIL-PRF-19978, CQR and CQ, Capacitors, Fixed, Plastic (or Paper-Plastic) Dielectric (Hermetically Sealed in Metal, Ceramic or Glass Cases), Established and Non-Established Reliability.

3.5.1.1 Use. These capacitors are designed for use in circuit applications requiring high insulation resistance, low dielectric absorption, or low loss factor over wide temperature ranges, and where the ac component of the impressed voltage is small with respect to the dc voltage rating. These capacitors may be used where an ac component is present provided that: (1) the sum of the dc voltage and the peak ac voltage does not exceed the dc voltage rating or (2) the peak ac voltage does not exceed 20 percent of the dc voltage rating at 60 Hz, 15 percent at 120 Hz; or 1 percent at 10,000 Hz. Where heavy transient or pulse currents are encountered, the requirements of MIL-PRF-19978 are not sufficient to guarantee satisfactory performance, and due allowance must therefore be made in the selection of a capacitor.

Polystyrene dielectric capacitors (characteristic P). Capacitors of polystyrene dielectric, because of their low dielectric absorption and radiofrequency losses, are intended primarily for use in calculators, computers, integrators, time-base oscillators, laboratory standards, and other pulse applications. The outstanding characteristics of these capacitors are low temperature coefficient and stability.

Polyethylene terephthalate dielectric capacitors (characteristic M). Capacitors of polyethylene terephthalate dielectric are intended for use in high temperature applications similar to those served by hermetically sealed paper capacitors, but where higher insulation resistance at the upper temperature limits is required.

Paper and polyethylene terephthalate dielectric capacitors (characteristics E, F, G, and K). Capacitors of paper and polyethylene terephthalate dielectric are intended for applications where small case sizes and high temperature operation are required.

Polytetrafluoroethylene dielectric capacitors (characteristic T). Capacitors of polytetrafluoroethylene dielectric are intended for high temperature applications where high insulation resistance, small capacitance change, and low dielectric absorption are required. These capacitors exhibit excellent insulation resistance values at high temperatures.

Polycarbonate dielectric capacitors (characteristic Q). Capacitors of polycarbonate dielectric are especially suitable for use in tuned circuits and precision timing due to their capacitance stability and minimum capacitance change with temperature.

ER capacitors have FRLs ranging from 1.0 percent to 0.001 percent per 1,000 hours. These FRLs are established at a 90-percent confidence level and maintained at a 10-percent producer's risk and are based on life tests performed at maximum rated voltage and maximum rated temperature. An acceleration factor of 5:1 has been used to relate the life test data obtained at 140 percent of rated dc voltage at the applicable high test temperature to the rated voltage at the applicable high test temperature. This specification also covers removable mounting retainers for use with applicable capacitors.

3.5.1.2 Construction. The present drive towards miniaturization, closer electrical tolerances, and higher operating temperatures is being met by the use of thin plastic-film dielectrics in the construction of capacitors. The greatest advantage of plastic-film dielectrics over natural dielectrics (such as paper and mica) is that the plastic film is a synthetic that can be made to meet specific requirements (such as thickness of dielectric and high heat-resistance). Many plastic-film capacitors are not impregnated but are wound and encased "dry". Plastic dielectric capacitors have insulation resistance values far in excess of those for paper capacitors and, since they are nonabsorbent, their moisture characteristics are superior to those of mica.

There are several types of plastic films available for use as a capacitor dielectric. They may be used individually or in a combination with other films and with paper in order to obtain the compromised advantages of the specific electrical characteristics of each individual film. The more common films include polyethylene terephthalate and polycarbonate. When properly applied, plastic dielectric films lead to the solution of many special capacitor problems. Capacitors using polyethylene terephthalate film as the dielectric are perhaps the most common of the plastic film types on the market today. Some manufactures use only one sheet of plastic film for those with low voltage ratings whereas at least two sheets of paper are used in conventional paper types. The principal advantage of polyethylene terephthalate dielectric capacitors is the high order of insulation resistance values available over the dielectric temperature range of -55°C to +125°C; however, for military applications, the high temperature limit is +85°C. Polyethylene terephthalate dielectric capacitors have an insulation resistance that is normally about 100,000 megohms per microfarad at room temperature and about 25,000 megohms per microfarad at +85°C. These insulation resistance values decrease considerably when polyethylene terephthalate dielectric capacitors are impregnated. However, a higher volt per mil rating is possible by impregnation and the possibility of corona and catastrophic failures due to pinholes in the dielectric are minimized.

3.5.1.3 Barometric pressure (flashover) for metal-cased tubular capacitors. The dc voltage that may be applied to metal-cased tubular capacitors at altitudes other than 80,000 feet may be obtained from a figure in MIL-PRF-19978, except that the dc voltage ratings must not be exceeded.

3.5.2 MIL-PRF-39022, CHR, Capacitors, Fixed, Metallized, Paper-Plastic Film, or Plastic Film Dielectric, Direct and Alternating Current, (Hermetically Sealed in Metal or Ceramic Cases), Established Reliability.

3.5.2.1 Use. These capacitors are primarily intended for use in power supply filter circuits, by-pass applications, and other applications where the alternating current (ac) component of voltage is small with respect to the applied dc voltage and where occasional periods of low-insulation resistance and momentary breakdowns can be tolerated. However, CHR01 styles may be used for applications requiring a tight capacitance tolerance, excellent capacitance stability, very high insulation resistance, and low loss factors where the ac component of voltage is large with respect to the applied dc voltage and where momentary breakdowns cannot be tolerated.

NOTE: these capacitors (not applicable to ac style CHR49) may be used where an ac component is present provided that (1) the sum of the dc voltage and the peak ac voltage does not exceed the dc voltage rating, and (2) the ac voltage does not exceed 20 percent of the dc voltage rating or the value calculated from the following formula, whichever is smaller:

$$V_p\ AC = \sqrt{\frac{(T_{dc} - T)\,A\,e}{\pi\, f\, C\, D}}$$

Where: V_p AC = Peak value of ac component.

T_{dc} = Applicable high test temperature in degrees Celsius.

T = Maximum ambient operating temperature expected within equipment containing capacitor.
A = Exposed capacitor case surface area in square centimeters (cm), exclusive of portion occupied by terminal mountings.
e = Convection coefficient in watts per cm^2 / °C. (The value of "e" is approximately equal to 0.0006.)
f = Frequency in Hertz of ac component.
C = Nominal capacitance in farads.
D = 2 (maximum DF at applicable high test temperature).

The FRLs are established at a 90 percent confidence level and maintained at a 10 percent producer's risk and are based on life tests performed at maximum rated voltage and maximum rated temperature. Unless otherwise specified an acceleration factor of 5:1 has been used to relate life test data obtained at 140 percent of rated voltage at maximum rated temperature, to rated voltage at rated temperature.

3.5.2.2 Construction. The construction of metallized plastic capacitors differs from conventional plastic capacitors in that instead of having separate layers of metal foil (capacitor plates) and plastic dielectric, the metal comprising the capacitor plates is imposed directly on one side of the plastic dielectric by means of a metallizing process. This technique results in an overall size reduction for metallized plastic capacitors when compared to conventional plastic-foil capacitor types of equal ratings. This space saving is the outstanding feature of the metallized plastic capacitor. A 200-volt metallized plastic capacitor has 0.75 the volume of the conventional plastic construction; at 600 volts, this ratio increases to 0.8; above 600 volts, the metallized plastic capacitor provides no size advantage.

Another advantage resulting from the metallizing technique is that the capacitors are self-healing. The metallic film imposed on the plastic is very thin and if breakdown occurs, a tiny area of the thin film surrounding the breakdown point burns away, leaving the capacitor operable, but with a slightly reduced capacitance. In the conventional plastic-foil type (where the foil is thicker), sustained conduction can occur on a breakdown causing a large area of the plastic surrounding the breakdown to be carbonized resulting in a permanent short-circuit.

The breakdown of the metallized plastic capacitor can be either of two types; i.e., (1) a complete breakdown lasting for only a moment (momentary breakdown) or (2) a sharp reduction in insulation resistance lasting for an extended period of time, but eventually returning to normal (period of low insulation). The general characteristics of the metallized plastic type, aside from the breakdowns, are similar to the conventional plastic type except for a significantly lower insulation resistance, approximately in the order of 10 to 1.

3.5.2.3 Prevention of corona. All metal parts, fittings, conductors, and attachments which operate at higher potential than other adjacent parts of the housing, should be carefully finished in order to insure that all sharp corners and edges are removed to minimize the possibility of corona discharge. Parts, from which the removal of sharp corners and edges would be impractical, such as conductors, should be spaced in such a manner as to prevent harmful corona discharges.

3.5.2.4 Mounting. Capacitors with dimension L or D of 1.375 or .672 inches (34.93 or 17.07 mm), respectively, and greater, should not be supported by their leads. These capacitors should be provided with a supplementary means for mounting, such as a tangential bracket.

3.5.3 MIL-PRF-55514, CFR, Capacitors, Fixed, Plastic (or Metallized Plastic) Dielectric, DC or DC-AC, in Nonmetal Cases, Non-Established and Established Reliability.

3.5.3.1 Use. These capacitors are designed for use in circuit applications requiring high insulation resistance, low dielectric absorption, or low loss factor over wide temperature ranges, and where the ac component of the impressed voltage is small with respect to the dc voltage rating.

NOTE: These capacitors may be used where an ac component is present provided that (1) the sum of the dc voltage and the peak ac voltage does not exceed the dc voltage rating or (2) the peak ac voltage does not exceed 20 percent of the dc voltage rating at 60 Hz; 15 percent at 120 Hz; or 1 percent at 10,000 Hz. Where heavy transient or pulse currents are encountered, the requirements of MIL-PRF-55514 are not sufficient to guarantee satisfactory performance, and due allowance must therefore be made in the selection of a capacitor.

Capacitors acquired under provisions of this specification will experience failure at a rate depending almost exclusively upon the manner in which the capacitors are used. For military applications, in view of their limited long term moisture resistant characteristics, these capacitors should be used in potted or encapsulated circuit packaging systems. In any case, the acquiring activity should review the specific application. Where the capacitors are not incorporated in an encapsulated or potted circuit package, hermetically sealed foil capacitors of MIL-PRF-19978 or hermetically sealed metallized capacitors of MIL-PRF-39022 or MIL-PRF-83421 are recommended. In addition, the life of the capacitors specified herein is primarily dependent upon the operating temperature and applied voltage. They should not be used above rated voltage or temperature.

Polyethylene terephthalate. These capacitors are intended for high-temperature applications similar to those served by hermetically-sealed paper capacitors, but where high insulation resistance at the upper temperature limits is required.

Polycarbonate. These capacitors are intended for applications where minimum capacitance changes with temperature is required; they are especially suitable for use in tuned and precision timing circuits.

ER capacitors covered by this specification have FRLs ranging from 1.0 percent to 0.001 percent per 1,000 hours. These FRLs are established at a 90-percent confidence level and maintained at a 10-percent producer's risk and based on life tests performed at +85°C. An acceleration factor of 5:1 has been used to relate life test data obtained at 125 percent, or 140 percent of rated voltage at +85°C, to rated voltage at +85°C. The product levels are based on catastrophic failures and failures occurring outside the degradation limits.

3.5.3.2 Construction.

Plastic film. The present drive towards miniaturization, closer electrical tolerances, and higher operating temperatures is being met by the use of thin plastic-film dielectrics in the construction of capacitors. The greatest advantage of plastic-film dielectrics over natural dielectrics (such as paper and mica) is that the plastic film is a synthetic that can be made to meet specific requirements (such as thickness of dielectric and high heat resistance). Many plastic-film capacitors are not impregnated but are wound and encased "dry". Plastic dielectric capacitors have insulation resistance values far in excess of those for paper capacitors and since they are nonabsorbent, their moisture characteristics are superior to those of mica.

There are several types of plastic films available for use as a capacitor dielectric. They may be used individually or in a combination with other films in order to obtain the compromised advantages of the specific electrical characteristics of each individual film. The more common films include polyethylene terephthalate and polycarbonate. When properly applied, plastic dielectric films lead to the solution of many special capacitor problems.

Metallized plastic. The construction of metallized plastic capacitors differs from conventional plastic capacitors in that instead of having separate layers of metal foil (capacitor plates) and plastic dielectric, the metal comprising the capacitor plates is imposed directly on one side of the plastic dielectric by means of a metallizing process. This technique results in an overall size reduction for metallized plastic capacitors when compared to conventional plastic-foil capacitor types of equal ratings. This space saving is the outstanding feature of the metallized plastic capacitor.

Another advantage resulting from the metallizing technique is that the capacitors are self-healing. The metallic film imposed on the plastic is very thin and if breakdown occurs, a tiny area of the thin film surrounding the breakdown point burns away, leaving the capacitor operable, but with a slightly reduced capacitance. In the conventional plastic-foil type (where the foil is thicker), sustained conduction can occur on a breakdown causing a large area of the plastic surrounding the breakdown to be carbonized resulting in a permanent short-circuit.

The breakdown of the metallized plastic capacitor can be either of two types; i.e., (1) a complete breakdown lasting for only a moment (momentary breakdown) or (2) a sharp reduction in insulation resistance lasting for an extended period of time, but eventually returning to normal (period of low insulation). The general characteristics of the metallized plastic type, aside from the breakdowns, are similar to the conventional plastic type except for a significantly lower insulation resistance, approximately in the order of 10 to 1.

3.5.3.3 Mounting. Capacitors covered by this specification should be mounted by a bracket or clamp, or they should be potted when vibration or shock are likely to be encountered in service. When a bracket or clamp is used, care should be taken to assure that the capacitor body is not deformed.

3.5.4 MIL-PRF-83421, CRH, Capacitors, Fixed, Metallized, Plastic Film Dielectric, (DC, AC, or DC and AC), Hermetically Sealed in Metal or Ceramic Cases, Established Reliability.

3.5.4.1 Use. These metallized plastic film capacitors are primarily intended for use in power supply filter circuits, by-pass applications, and other applications where the ac component of voltage is known or a significant factor. Styles covered by this specification may be used for applications requiring a tight capacitance tolerance, excellent capacitance stability, very high-insulation resistance, and low-loss factors where the ac component of voltage is large with respect to the applied dc voltage.

Capacitors covered by this specification have FRLs established at a 90 percent confidence level and maintained at a 10 percent producer's risk and, unless otherwise specified, are based on life tests performed at maximum rated voltage at maximum rated temperature. Unless otherwise specified, an acceleration factor of 5:1 has been used to relate life-test data obtained at 140 percent of rated voltage at maximum rated temperature, to rated voltage at rated temperature.

3.5.4.2 Construction. Metallized plastic film capacitors differ from plastic foil types which have separate layers of metal foil (capacitor plates) and plastic dielectric. The metal comprising the metallized capacitor plates is a thin conductive coating on one side of the plastic dielectric by means of a metallizing process. This technique results in an overall size reduction for metallized plastic capacitors when compared to plastic foil capacitors of equal voltage rating and capacitance value. Typically, a 1 μF, 50 volts dc metallized polycarbonate capacitor will occupy approximately one third the volume of a similar polycarbonate foil capacitor.

Another advantage resulting from the metallizing technique is that the capacitors are self-healing. Generally, the voltage breakdown occurs through a small hole or thin spot in the dielectric with the fault current melting away the conductive metal coating adjacent to the fault area. After clearing, the capacitors will continue to operate normally with the possibility of reduced insulation resistance, increased dielectric absorption and no significant change to capacitance value or dissipation factor. Clearing will occur only if there is sufficient energy available from the circuit and/or stored in the capacitor. Minimum stored energy in the range of 100 to 500 microjoules is recommended to insure clearing. Applications for these capacitors should be limited to circuits that will provide sufficient energy to insure clearing and are insensitive to momentary breakdowns (clearing actions). In the conventional plastic-foil types (where the foil is thicker), sustained conduction can occur on a breakdown causing a large area of the plastic surrounding the breakdowns to be carbonized resulting in a permanent short-circuit.

The breakdown of the metallized plastic capacitor can be either of two types; i.e., (1) a complete breakdown lasting for only a moment (momentary breakdown) or (2) a sharp reduction in insulation resistance lasting for an extended period of time, but eventually returning to normal (period of low insulation). The general characteristics of the metallized plastic type, aside from the breakdowns, are similar to the conventional plastic type except for a significantly lower insulation resistance, approximately in the order of 10 to 1.

3.5.4.3 Prevention of corona. All metal parts, fittings, conductors, and attachments which operate at higher potential than other adjacent parts of the housing, should be carefully finished in order to insure that all sharp corners and edges are removed to minimize the possibility of corona discharge. Parts, from which the removal of sharp corners and edges would be impractical, such as conductors, should be spaced in such a manner as to prevent harmful corona discharges.

3.5.4.4 Mounting. Capacitors with dimension L or D of 1.375 or .670 inches ((34.93 or 17.20 mm), respectively, and greater, should not be supported by their leads. These capacitors should be provided with a supplementary means for mounting, such as a tangential bracket.

3.5.5 MIL-PRF-87217, CHS, Capacitors, Fixed, Supermetallized Plastic Film Dielectric, Direct Current for Low Energy, High Impedance Applications, Hermetically Sealed in Metal Cases, High Reliability.

3.5.5.1 Use. These supermetallized plastic film capacitors are intended for use in low-energy and high impedance applications such as integrators, RC timing circuits, precision filters and other applications where the ac component of voltage is not significant. Capacitors covered by this specification are unique due to the fact that they are available in tight tolerances and exhibit excellent capacitance stability over long life, as well as high insulation resistance and low loss factor.

Capacitors covered by this specification have FRLs established at a 90-percent confidence level and maintained at a 10-percent producer's risk and, unless otherwise specified, is based on MIL-PRF-83421 life tests performed at maximum rated voltage at maximum rated temperature.

TABLE II. Capacitor selection guidance table.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-20 (Fixed, ceramic, temperature compensating, established and nonestablished reliability)	27	CCR75	Tubular, axial lead (0.160 X 0.090)	.1 pF to 75 pF (200V) 82 pF to 240 pF (100V) 270 pF to 680 pF (50V)
	28	CC76/CCR76	Tubular, axial lead (0.250 X 0.090)	82 pF to 130 pF (200V) 270 pF to 680 pF (100V) 750 pF to 1,000 pF (50V)
	29	CCR77	Tubular, axial lead (0.390 X 0.140)	150 pF to 680 pF (200V) 750 pF to 2,200 pF (100V) 2,400 pF to 5,600 pF (50V)
	30	CC78/CCR78	Tubular, axial lead (0.500 X 0.250)	820 pF to 3,300 pF (200V) 3,900 pF to 12,000 pF (100V) 15,000 pF to 27,000 pF (50V)
	31	CC79/ CCR79	Tubular, axial lead (0.690 X 0.350)	3,900 pF to 10,000 pF (200V) 15,000 pF to 39,000 pF (100V) 47,000 pF to 82,000 pF (50V)
	35	CCR05/CCR09	Molded, radial lead (0.190 X 0.190)	1 pF to 330 pF (200V) 360 pF to 1,800 pF (100V) 2,000 pF to 3,300 pF (50V)
	36	CCR06	Rectangular, radial lead (0.290 X 0.290)	360 pF to 1,800 pF (200V) 2,000 pF to 4,700 pF (100V) 5,100 pF to 18,000 pF (50V)
	37	CC07/CCR07	Rectangular, radial lead (0.480 X 0.480)	2,200 pF to 4,700 pF (200V) 5,600 pF to 12,000 pF (100V) 15,000 pF to 100,000 pF (50V)
	38	CC08/CCR08	Rectangular, radial lead (0.480 X 0.480)	3,900 pF to 4,700 pF (200V) 15,000 pF to 18,000 pF (100V) 56,000 pF to 68,000 pF (50V)
MIL-PRF-81 (Variable, ceramic)	1	CV11	Variable	1.5-7.0 pF to 7.0-45.0 pF (500V)
	4	CV31/CV32	Variable	2.0-8.0 pF to 8.0-25.0 pF (350V) 3.0-15.0 pF to 15.0-60.0 pF (200V)
	5	CV34	Variable	1.5-8.0 pF to 4.0-15.0 pF (350V) 4.0-20.0 pF to 15.0-60.0 pF (200V)
	6	CV35/CV36	Variable	1.0-3.0 pF to 5.0-25.0 pF (100V) 7.0-40.0 pF (25V)
	8	CV42	Variable	2.0-7.0 pF to 5.2-30.0 pF (100V)
	9	CV98	Variable	0.5-2.5 pF to 5.0-20.0 pF (250V)
	10	CV99	Variable	1.0-4.5 pF to 8.0-50.0 pF (250V)
	12	CV50/CV51	Variable	2.0-6.0 pF to 6.5-30.0 pF (100V)
MIL-PRF-123 (Ceramic, temperature stable and general purpose, high reliability)	1	CKS05	Molded, radial lead	4.7 pF to 4,700 pF (100V) 270 pF to 10,000 pF (50V)
	2	CKS06	Molded, radial lead	270 pF to 100,000 pF (100V) 2,700 pF to 1,000,000 pF (50V)
	3	CKS07	Molded, radial lead	2,700 pF to 470,000 pF (100V) 11,000 pF to 1,000,000 pF (50V)
	4	CKS11	Molded, axial lead	4.7 pF to 1,000 pF (100V) 110 pF to 4,700 pF (50V)
	5	CKS12	Molded, axial lead	110 pF to 4,700 pF (100V) 240 pF to 10,000 pF (50V)
	6	CKS14	Molded, axial lead	240 pF to 10,000 pF (100V) 1,100 pF to 47,000 pF (50V)
	7	CKS15	Molded, axial lead	1,100 pF to 100,000 pF (100V) 2,400 pF to 180,000 pF (50V)
	8	CKS16	Molded, axial lead	2,400 pF to 470,000 pF (100V) 11,000 pF to 1,000,000 pF (50V)
	10	CKS51	Chip (0805)	1 pF to 4,700 pF (50V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-123 (Ceramic, temperature stable and general purpose, high reliability)	11	CKS52	Chip (1210)	300 pF to 47,000 pF (50V)
	12	CKS53	Chip (1808)	300 pF to 100,000 pF (50V)
	13	CKS54	Chip (2225)	1,100 pF to 470,000 pF (50V)
	16	CKS22	Molded, 2 pin DIP	1 pF to 820 pF (200V) 1,000 pF to 10,000 pF (100V) 12,000 pF to 100,000 pF (50V)
	17	CKS23	Molded, 2 pin DIP	560 pF to 10,000 pF (200V) 2,700 pF to 220,000 pF (100V) 4,700 pF to 10,000 pF (50V)
	18	CKS24	Molded, 2 pin DIP	120,000 pF to 470,000 pF (100V)
MIL-PRF-14409 (Variable, piston type, tubular trimmer)	4	PC38	Piston type, tubular trimmer	0.6-1.8 pF (750V) 0.6-5.5 pF to 0.8-16 pF (1,250V)
	4	PC48	Piston type, tubular trimmer	0.8-5.5 pF (750V) 0.8-11.0 pF to 1.0-38.0 pF (1,250V)
	5	PC39	Piston type, tubular trimmer	1.0-16.0 pF to 1.0-120.0 pF (1000V)
	6	PC40	Piston type, tubular trimmer	0.6-1.8 pF to 0.8-16.0 pF (750V)
	6	PC50	Piston type, tubular trimmer	0.8-11.0 pF to 1.0-38.0 pF (750V)
	7	PC41	Piston type, tubular trimmer	0.6-1.8 pF to 0.8-16.0 pF (750V)
		PC51	Piston type, tubular trimmer	0.8-5.5 pF to 0.8-38.0 pF (750V)
	8	PC42	Piston type, tubular trimmer	0.6-1.8 pF (750V) 0.6-5.5 pF to 0.8-16 pF (1,250V)
	8	PC52	Piston type, tubular trimmer	0.8-11.0 pF to 1.0-38.0 pF (1,250V) 0.8-5.5 pF (750V)
	9	PC43	Piston type, tubular trimmer	1.0-16.0 pF to 1.0-60.0 pF (1,000V)
	12	PC25/PC31	Piston type, tubular trimmer	0.6-6.0 pF to 1.0-20.0 pF (250V)
	13	PC26	Piston type, tubular trimmer	0.6-6.0 pF to 1.0-30.0 pF (250V)
	14	PC27	Piston type, tubular trimmer	0.35-3.5 pF (250V)
	14	PC28	Piston type, tubular trimmer	0.35-3.5 pF to 0.5-5.0 pF (250V)
	14	PC29	Piston type, tubular trimmer	0.35-3.5 pF to 0.8-10.0 pF (250V)
	15	PC30	Piston type, tubular trimmer	0.6-3.5 pF to 0.6-5.0 pF (250V)
	15	PC32	Piston type, tubular trimmer	1.5-14.0 pF (250V)
	15	PC34	Piston type, tubular trimmer	0.8-10.0 pF (250V)
	16	PC21/PC22/PC23/ PC24	Piston type, tubular trimmer	0.3-1.2 pF to 0.8-8.0 pF (500V)
	17	PC17	Piston type, tubular trimmer	1.0-5.5 pF to 1.5-40.0 pF (250V)
	18	PC18/PC46	Piston type, tubular trimmer	1.0-10.0 pF (250V) 1.0-14.0 pF (125V)
	19	PC19/PC47	Piston type, tubular trimmer	1.0-10.0 pF (250V) 1.0-14.0 pF (125V)
MIL-PRF-19978 (Plastic or paper-plastic, hermetically sealed, established and nonestablished reliability)	2	CQ20	Tubular, axial lead, hermetically sealed in ceramic or glass, non-established reliability	0.00047 µF to 0.015 µF (15,000V) 0.00047 µF to 0.022 µF (12,500V) 0.00047 µF to 0.039 µF (10,000V) 0.00047 µF to 0.068 µF (7,500V) 0.00047 µF to 0.15 µF (5,000V) 0.001 µF to 0.33 µF (3,000V) 0.0010 µF to 0.68 µF (2,000V) 0.00010 µF to 1.0 µF (1,000V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-19978 (Plastic or paper-plastic, hermetically sealed, established and nonestablished reliability)	3	CQ72	Rectangular, large can, hermetically sealed, non-established reliability	0.1 µF to 2.0 µF (12,500V, 10,000V) 0.1 µF to 2.0 µF (7,500V, 6,000V) 0.1 µF to 4.0 µF (5,000V, 4,000V) 0.1 µF to 6.0 µF (3,000V) 0.1 µF to 12.0 µF (2,500V) 0.25 µF to 15.0 µF (2,000V) 0.1 µF to 15.0 µF (1,500V, 1,000V) 0.25 µF to 15.0 µF (600V, 400V)
	5	CQ07	Tubular, axial lead, hermetically sealed, non-established reliability	0.001 µF to 0.22 µF (600V) 0.0012 µF to 0.47 µF (400V) 0.001 µF to 0.68 µF (200V) 0.0022 µF to 1.0 µF (100V) 0.0047 µF to 1.0 µF (50V)
	8	CQR07	Tubular, insulated, axial lead, hermetically sealed, established reliability	0.001 µF to 0.22 µF (600V) 0.0012 µF to 0.47 µF (400V) 0.001 µF to 0.68 µF (200V) 0.0022 µF to 1.0 µF (100V) 0.0039 µF to 1.0 µF (50V)
	9	CQR09	Tubular, insulated, axial lead, hermetically sealed, established reliability	0.001 µF to 0.47 µF (1,000V) 0.001 µF to 0.47 µF (600V) 0.0027 µF to 0.47 µF (400V) 0.0039 µF to 1.0 µF (200V)
	10	CQR12	Tubular, uninsulated, axial lead, tangential retainer, hermetically sealed, established reliability	0.001 µF to 0.47 µF (1,000V) 0.001 µF to 0.47 µF (600V) 0.0027 µF to 0.47 µF (400V) 0.0039 µF to 1.0 µF (200V)
	11	CQR13	Tubular, uninsulated, axial lead, threaded-stud retainer, hermetically sealed, established reliability	0.18 µF to 0.47 µF (1,000V) 0.001 µF to 0.47 µF (600V) 0.0027 µF to 0.47 µF (400V) 0.0039 µF to 1.0 µF (200V)
	13	CQR29	Tubular, insulated, axial lead, hermetically sealed, established reliability	0.001 µF to 0.22 µF (1,000V) 0.001 µF to 0.68 µF (600V) 0.001 µF to 1.0 µF (400V) 0.001 µF to 1.0 µF (200V) 1.2 µF to 6.8 µF (100V) 0.001 µF to 1.2 µF (50V) 1.5 µF to 10.0 µF (30V)
	14	CQR32	Tubular, uninsulated, axial lead, tangential retainer, hermetically sealed, established reliability	0.001 µF to 0.22 µF (1,000V) 0.001 µF to 0.68 µF (600V) 0.001 µF to 1.0 µF (400V) 0.001 µF to 1.0 µF (200V) 1.2 µF to 6.8 µF (100V) 0.001 µF to 1.2 µF (50V) 1.5 µF to 10.0 µF (30V)
	15	CQR33	Tubular, uninsulated, axial lead, threaded-stud retainer, hermetically sealed, established reliability	0.082 µF to 0.22 µF (1,000V) 0.001 µF to 0.68 µF (600V) 0.001 µF to 1.0 µF (400V) 0.001 µF to 1.0 µF (200V) 1.2 µF to 6.8 µF (100V) 0.001 µF to 1.2 µF (50V) 1.5 µF to 10.0 µF (30V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-23269 (Glass, established reliability)	1	CYR10	Axial lead (0.344 X 0.172)	0.5 pF to 300 pF (100V)
	2	CYR15	Axial lead (0.469 X 0.266)	220 pF to 1,200 pF (100V)
	3	CYR20	Axial lead (0.734 X 0.422)	560 pF to 3,300 pF (100V)
	4	CYR30	Axial lead (0.766 X 0.750)	3,600 pF to 6,200 pF (100V)
	10	CYR51	Radial lead (.300 X .200)	1 pF to 560 pF (300V)
	10	CYR52	Radial lead (.300 X .300)	620 pF to 1,000 pF (300V)
	10	CYR53	Radial lead (.500 X .300)	1,100 pF to 2,400 pF (300V)
MIL-PRF-39001 (Mica, established reliability)	5	CMR03	Dipped, radial lead	1.0 pF to 120 pF (300V) 15 pF to 200 pF (100V) 22 pF to 400 pF (50V)
	5	CMR04	Dipped, radial lead	1.0 pF to 390 pF (500V)
	5	CMR05	Dipped, radial lead	1.0 pF to 390 pF (500V)
	5	CMR06	Dipped, radial lead	430 pF to 4,700 pF (500V)
	5	CMR07	Dipped, radial lead	5,100 pF to 20,000 pF (500V)
	5	CMR08	Dipped, radial lead	22,000 pF to 91,000 pF (500V)
MIL-PRF-39003 (Electrolytic, solid electrolyte, tantalum, established reliability)	1	CSR13	Tubular, axial lead, hermetically sealed, polarized	0.0047 μF to 4.7 μF (50V)
	2	CSR09	Tubular, axial lead, hermetically sealed, polarized	0.047 μF to 1.2 μF (75V) 0.22 μF to 1.8 μF (50V) 0.33 μF to 2.7 μF (35V) 0.56 μF to 6.8 μF (20V) 1.8 μF to 15 μF (10V)
	3	CSR23	Tubular, axial lead, hermetically sealed, polarized	1.2 μF to 39 μF (50V) 1.8 μF to 68 μF (35V) 2.7 μF to 180 μF (20V) 4.7 μF to 330 μF (15V) 6.8 μF to 560 μF (10V) 10 μF to 1,000 μF (6V)
	4	CSR91	Tubular, axial lead, hermetically sealed, nonpolarized	0.0023 μF to 1.3 μF (100V) 0.34 μF to 7.5 μF (75V) 0.0023 μF to 11.0 μF (50V) 2.8 μF to 23.0 μF (35V) 0.6 μF to 50.0 μF (20V) 1.3 μF to 75.0 μF (15V) 1.9 μF to 110.0 μF (10V) 2.8 μF to 160.0 μF (6V)
	6	CSR33	Tubular, axial lead, hermetically sealed, polarized	1.2 μF to 39.0 μF (50V) 1.8 μF to 68.0 μF (35V) 2.7 μF to 180.0 μF (20V) 4.7 μF to 330.0 μF (15V) 6.8 μF to 560.0 μF (10V) 10.0 μF to 1000.0 μF (6V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-39003 (Electrolytic, solid electrolyte, tantalum, established reliability)	9	CSR21	Tubular, axial lead, hermetically sealed, polarized, high frequency	5.6 µF to 22 µF (50V) 22 µF to 47 µF (35V) 27 µF to 100 µF (20V) 56 µF to 150 µF (15V) 82 µF to 220 µF (10V) 150 µF to 330 µF (6V)
	10	CSS13	Tubular, axial lead, hermetically sealed, polarized, high reliability	0.15 µF to 15 µF (75V) 0.12 µF to 22 µF (50V) 5.6 µF to 47 µF (35V) 1.2 µF to 100 µF (20V) 2.7 µF to 150 µF (15V) 3.9 µF to 220 µF (10V)
	10	CSS33	Tubular, axial lead, hermetically sealed, polarized, high reliability	1.2 µF to 39 µF (50V) 1.8 µF to 65 µF (35V) 2.7 µF to 180 µF (20V) 6.8 µF to 560 µF (10V)
MIL-PRF-39006 (Electrolytic, nonsolid electrolyte, tantalum, established reliability)	22	CLR79	Tubular, axial lead, hermetically sealed, polarized	1.7 µF to 56 µF (125V) 2.5 µF to 86 µF (100V) 3.5 µF to 110 µF (75V) 5 µF to 160 µF (50V) 8 µF to 300 µF (30V) 15 µF to 540 µF (15V) 20 µF to 750 µF (10V) 25 µF to 850 µF (8V) 30 µF to 1,200 µF (6V)
	25	CLR81	Tubular, axial lead, hermetically sealed, polarized, extended capacitance range	6.8 µF to 82 µF (125V) 10 µF to 120 µF (100V) 22 µF to 220 µF (75V) 27 µF to 270 µF (60V) 33 µF to 330 µF (50V) 56 µF to 560 µF (30V) 68 µF to 680 µF (25V) 100 µF to 1,000 µF (15V) 150 µF to 1,500 µF (10V) 180 µF to 1,800 µF (8V) 220 µF to 2,200 µF (6V)
	28	CLS79	Tubular, axial lead, hermetically sealed, polarized, high reliability	1.7 µF to 56 µF (125V) 2.5 µF to 86 µF (100V) 3.5 µF to 110 µF (75V) 4 µF to 140 µF (60V) 5 µF to 160 µF (50V) 10 µF to 350 µF (30V) 15 µF to 540 µF (15V) 20 µF to 750 µF (10V) 25 µF to 850 µF (8V) 30 µF to 1,200 µF (6V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-39006 (Electrolytic, nonsolid electrolyte, tantalum, established reliability)	29	CLS81	Tubular, axial lead, hermetically sealed, polarized, extended capacitance range, high reliability	6.8 μF to 82 μF (125V) 10 μF to 120 μF (100V) 22 μF to 220 μF (75V) 27 μF to 270 μF (60V) 33 μF to 330 μF (50V) 56 μF to 560 μF (30V) 68 μF to 680 μF (25V) 100 μF to 1,000 μF (15V) 150 μF to 1,500 μF (10V) 180 μF to 1,800 μF (8V) 220 μF to 2,200 μF (6V)
	30	CLR90	Tubular, axial lead, hermetically sealed, polarized, low ESR	1.7 μF to 56 μF (125V) 2.5 μF to 86 μF (100V) 3.5 μF to 110 μF (75V) 5 μF to 160 μF (50V) 8 μF to 300 μF (30V) 15 μF to 540 μF (15V) 20 μF to 750 μF (10V) 25 μF to 850 μF (8V) 30 μF to 1,200 μF (6V)
	31	CLR91	Tubular, axial lead, hermetically sealed, polarized, extended capacitance range, low ESR	6.8 μF to 82 μF (125V) 10 μF to 120 μF (100V) 22 μF to 220 μF (75V) 27 μF to 270 μF (60V) 33 μF to 330 μF (50V) 56 μF to 560 μF (30V) 68 μF to 680 μF (25V) 100 μF to 1,000 μF (15V) 150 μF to 1,500 μF (10V) 180 μF to 1,800 μF (8V) 220 μF to 2,200 μF (6V)
	32	CLR82	Tubular, axial lead, hermetically sealed, nonpolarized	25 μF (100V) 35 μF (75V) 50 μF (50V) 90 μF (30V) 110 μF (25V) 180 μF (15V) 250 μF (10V) 410 μF (6V)
MIL-PRF-39014 (Ceramic, general purpose, established and nonestablished reliability)	1	CKR05	Molded, radial lead (.190 X .190)	10 pF to 1,000 pF (200V) 1,200 pF to 10,000 pF (100V) 12,000 pF to 100,000 pF (50V)
	2	CKR06	Molded, radial lead (.290 X .290)	1,200 pF to 10,000 pF (200V) 12,000 pF to 100,000 pF (100V) 120,000 pF to 1,000,000 pF (50V)
	5	CKR11	Tubular, axial lead (.160 X .090)	10 pF to 4,700 pF (100V) 5,600 pF to 10,000 pF (50V)
	5	CKR12	Tubular, axial lead (.250 X .090)	5,600 pF to 10,000 pF (100V) 12,000 pF to 47,000 pF (50V)
	5	CKR14	Tubular, axial lead (.390 X .140)	12,000 pF to 100,000 pF (100V) 56,000 pF to 270,000 pF (50V)
	5	CKR15	Tubular, axial lead (.500 X .250)	56,000 pF to 330,000 pF (100V) 470,000 pF to 1,000,000 pF (50V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-39014 (Ceramic, general purpose, established and nonestablished reliability)	20	CKR08	Molded, radial lead (.290 X .290)	1,200,000 pF to 2,000,000 pF (50V)
	21	CKR31	Tubular, axial lead (.250 X .100)	270 pF to 51,000 pF (50V)
	21	CKR32	Tubular, axial lead (.250 X .140)	12,000 pF to 100,000 pF (50V)
	22	CKR22	Molded, 2 pin DIP (.260 X .175)	1.0 pF to 820 pF (200V) 560 pF to 10,000 pF (100V) 2,700 pF to 100,000 pF (50V)
	22	CKR23	Molded, 2 pin DIP (.260 X .195)	560 pF to 10,000 pF (200V) 2,700 pF to 100,000 pF (100V) 4,700 pF to 220,000 pF (50V)
	22	CKR24	Molded, 2 pin DIP (.260 X .320)	120,000 pF to 150,000 pF (100V) 180,000 pF to 1,000,000 pF (50V)
	23	CKR04	Molded, radial lead (.190 X .190)	10 pF to 1,000 pF (200V) 1,200 pF to 10,000 pF (100V) 12,000 pF to 100,000 pF (50V)
MIL-PRF-39018 (Electrolytic, aluminum oxide, established and nonestablished reliability	1	CU13/CUR13	Tubular, axial lead, polarized	1.0 µF to 12 µF (350V) 1.5 µF to 18 µF (300V) 2.2 µF to 27 µF (250V) 3.3 µF to 39 µF (200V) 4.7 µF to 56 µF (150V) 8.2 µF to 68 µF (100V) 12 µF to 120 µF (75V) 22 µF to 180 µF (50V) 33 µF to 390 µF (30V) 68 µF to 680 µF (15V) 100 µF to 820 µF (10V) 220 µF to 1000 µF (7V)
	2	CU15	Tubular, axial lead, nonpolarized	.68 µF to 10 µF (250V) 1.0 µF to 15 µF (200V) 1.8 µF to 22 µF (150V) 2.2 µF to 33 µF (100V) 3.9 µF to 56 µF (75V) 6.8 µF to 82 µF (50V) 15 µF to 180 µF (30V) 33 µF to 390 µF (15V) 39 µF to 470 µF (10V) 47 µF to 680 µF (7V)
	3	CU17/CUR17	Tubular, axial lead, polarized	5.6 µF to 120 µF (350V) 8.2 µF to 150 µF (300V) 10 µF to 180 µF (250V) 15 µF to 270 µF (200V) 18 µF to 330 µF (150V) 22 µF to 470 µF (100V) 47 µF to 820 µF (75V) 100 µF to 1,800 µF (50V) 150 µF to 2,700 µF (30V) 390 µF to 6,800 µF (15V) 470 µF to 8,200 µF (10V) 680 µF to 12,000 µF (7V)

TABLE II. Capacitor selection guidance table - Continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-39018 (Electrolytic, aluminum oxide, established and nonestablished reliability	4	CU71/CUR71	Tubular, large can, screw-insert terminals, polarized	68 µF to 2,200 µF (350V) 100 µF to 3,400 µF (300V) 100 µF to 3,300 µF (250V) 150 µF to 4,100 µF (200V) 220 µF to 4,700 µF (150V) 250 µF to 6,800 µF (100V) 530 µF to 14,000 µF (75V) 1,000 µF to 39,000 µF (50V) 1,800 µF to 48,000 µF (40V) 2,200 µF to 58,000 µF (30V) 2,200 µF to 68,000 µF (25V) 2,800 µF to 82,000 µF (20V) 3,300 µF to 110,000 µF (15V) 4,700 µF to 150,000 µF (10V) 6,800 µF to 220,000 µF (5V)
	6	CUR91	Tubular, large can, screw-insert terminals, polarized	210 µF to 4,700 µF (150V) 410 µF to 9,500 µF (100V) 1,400 µF to 39,000 µF (50V) 1,800 µF to 48,000 µF (40V) 2,200 µF to 58,000 µF (30V) 2,500 µF to 67,000 µF (25V) 2,800 µF to 82,000 µF (20V) 4,000 µF to 110,000 µF (15V) 5,000 µF to 140,000 µF (10V) 8,000 µF to 220,000 µF (5V)
	7	CUR19	Tubular, four terminal, axial lead, polarized	50 µF to 320 µF (200V) 70 µF to 470 µF (150V) 130 µF to 470 µF (100V) 200 µF to 1,300 µF (75V) 300 µF to 2,000 µF (50V) 550 µF to 3,600 µF (40V) 700 µF to 4,500 µF (30V) 900 µF to 5,700 µF (25V) 1,200 µF to 8,600 µF (20V) 1,400 µF to 10,000 µF (16V) 1,700 µF to 12,000 µF (10V) 2,000 µF to 14,000 µF (7.5V) 2,400 µF to 16,000 µF (5V)
	12	CUR72/CU72	Tubular, large can, screw-insert terminals, polarized, extended capacitance range	270 µF to 5,600 µF (400V) 330 µF to 6,800 µF (350V) 330 µF to 6,800 µF (315V) 680 µF to 15,000 µF (250V) 1,000 µF to 22,000 µF (200V) 1,200 µF to 27,000 µF (150V) 2,200 µF to 47,000 µF (100V) 2,700 µF to 56,000 µF (75V) 10,000 µF to 180,000 µF (50V) 15,000 µF to 330,000 µF (35V) 22,000 µF to 470,000 µF (25V) 33,000 µF to 680,000 µF (15V) 47,000 µF to 1,000,000 µF (10V) 56,000 µF to 1,200,000 µF (5V)

TABLE II. Capacitor selection guidance table - continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-39018 (Electrolytic, aluminum oxide, established and nonestablished reliability	13	CUR22	Tubular, single end mounting, polarized	56 µF to 560 µF (250V) 68 µF to 680 µF (200V) 82 µF to 820 µF (150V) 120 µF to 1,200 µF (100V) 150 µF to 1,500 µF (75V) 220 µF to 2200 µF (63V) 390 µF to 3900 µF (50V) 680 µF to 6,800 µF (30V) 1,500 µF to 15,000 µF (16V) 2,200 µF to 22,000 µF (10V) 3,300 µF to 33,000 µF (7V)
MIL-PRF-39022 (Metallized, paper-plastic or plastic film, direct and alternating current, hermetically sealed, established reliability	1	CHR09	Tubular, axial lead, DC	.01 µF to 2.2 µF (600V) .047 µF to 3.3 µF (400V) .1 µF to 12 µF (200V) .018 µF to 12 µF (50V)
	2	CHR19	Tubular, axial lead, DC	.047 µF to 3.3 µF (400V) .1 µF to 8.2 µF (200V)
	7	CHR49	Tubular, axial lead, AC	.01 µF to .1 µF (400V) to 10 µF (80V)
	8	CHR12	Tubular, axial lead, DC	.01 µF to 2.2 µF (600V) .047 µF to 3.3 µF (400V) .1 µF to 12 µF (200V) .15 µF to 12 µF (50V)
	10	CHR10	Tubular, axial lead, DC	.01 µF to 1 µF (600V) .01 µF to 2.7 µF (400V) .01 µF to 10 µF (200V) .01 µF to 22 µF (100V) .047 µF to 22 µF (50V)
	11	CHR20	Rectangular, radial lead, DC	.033 µF to 1 µF (30V)
	11	CHR21	Rectangular, radial lead, DC	.01 µF to .68 µF (50V)
	11	CHR22	Rectangular, radial lead, DC	.0056 µF to .22 µF (100V)
	11	CHR23	Rectangular, radial lead, DC	.0033 µF to .1 µF (150V)
	11	CHR24	Rectangular, radial lead, DC	.0022 µF to .068 µF (200V)
	11	CHR25	Rectangular, radial lead, DC	.001 µF to .039 µF (300V)
MIL-PRF-49137 (Electrolytic, solid electrolyte, tantalum, nonhermetically sealed, nonestablished reliability)	1	CX01	Molded, tubular, axial lead, polarized, nonhermetically sealed	.1 µF to 5.6 µF (50V) .47 µF to 10 µF (35V) 1.5 µF to 12 µF (25V) 10 µF to 18 µF (20V) 15 µF to 33 µF (15V) 2.7 µF to 56 µF (10V) 3.9 µF to 68 µF (6V)
	2	CX02/CX12	Dipped, tubular, axial lead, polarized, nonhermetically sealed	.1 µF to 22 µF (50V) 6.8 µF to 47 µF (35V) 1.5 µF to 68 µF (25V) 2.2 µF to 100 µF (20V) 3.3 µF to 150 µF (15V) 4.7 µF to 220 µF (10V) 6.8 µF to 330 µF (6V)

TABLE II. Capacitor selection guidance table - continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-49137 (Electrolytic, solid electrolyte, tantalum, nonhermetically sealed, nonestablished reliability)	5	CX05	Molded, tubular, axial lead, polarized, nonhermetically sealed	.1 μF to 4.7 μF (50V) .33 μF to 10 μF (35V) 1 μF to 10 μF (25V) 1.5 μF to 15 μF (20V) 2.2 μF to 33 μF (15V) 3.3 μF to 47 μF (10V) 4.7 μF to 47 μF (6V)
	6	CX06/CX16	Molded, rectangular, radial lead, polarized, nonhermetically sealed	.1 μF to 22 μF (35V) .68 μF to 33 μF (25V) .1 μF to 47 μF (20V) .1 μF to 68 μF (15V) .15 μF to 100 μF (10V) .22 μF to 150 μF (6V) .33 μF to 68 μF (4V) 1.5 μF to 220 μF (3V) .47 μF to 10 μF (2V)
MIL-PRF-49470 (Ceramic, switch mode power supply, general purpose and temperature stable)	1	PS01	Horizontally stacked, unencapsulated	.01 μF to 39 μF (500V) .022 μF to 120 μF (200V) .047 μF to 180 μF (100V) .056 μF to 270 μF (50V)
	2	PS02	Horizontally stacked, encapsulated	.01 μF to 39 μF (500V) .022 μF to 120 μF (200V) .047 μF to 180 μF (100V) .056 μF to 270 μF (50V)
	3	PS03	Horizontally stacked, conformal coated	.01 μF to 39 μF (500V) .022 μF to 120 μF (200V) .047 μF to 180 μF (100V) .056 μF to 270 μF (50V)
	4	PS04	Vertical stacked, unencapsulated	.01 μF to 39 μF (500V) .022 μF to 120 μF (200V) .047 μF to 180 μF (100V) .056 μF to 270 μF (50V)
	5	PS05	Vertical stacked, encapsulated	.01 μF to 39 μF (500V) .022 μF to 120 μF (200V) .047 μF to 180 μF (100V) .056 μF to 270 μF (50V)
	6	PS06	Vertical stacked, conformal coated	.01 μF to 39 μF (500V) .022 μF to 120 μF (200V) .047 μF to 180 μF (100V) .056 μF to 270 μF (50V)
MIL-PRF-55365 (Electrolytic, tantalum, chip, established reliability)	4	CWR06	Conformally coated tantalum chips	0.1 μF to 4.7 μF (50V) 0.22 μF to 6.8 μF (35V) 0.33 μF to 15 μF (25V) 0.47 μF to 22 μF (20V) 0.68 μF to 33 μF (15V) 1.0 μF to 47 μF (10V) 1.5 μF to 68 μF (6V) 2.2 μF to 100 μF (4V)

TABLE II. Capacitor selection guidance table - continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-55365 (Electrolytic, tantalum, chip, established reliability)	4	CWR09	Molded tantalum chips	0.1 µF to 4.7 µF (50V) 0.22 µF to 6.8 µF (35V) 0.33 µF to 15 µF (25V) 0.47 µF to 22 µF (20V) 0.68 µF to 33 µF (15V) 1.0 µF to 47 µF (10V) 1.5 µF to 68 µF (6V) 2.2 µF to 100 µF (4V)
	8	CWR11	Molded tantalum chips (metric)	0.1 µF to 4.7 µF (50V) 0.1 µF to 6.8 µF (35V) 0.33 µF to 15 µF (25V) 0.47 µF to 22 µF (20V) 0.68 µF to 33 µF (15V) 1.0 µF to 47 µF (10V) 1.5 µF to 68 µF (6V) 2.2 µF to 100 µF (4V)
MIL-PRF-55514 (Plastic or metallized plastic, DC or DC-AC, established reliability)	1	CFR02	Tubular, axial lead, DC, non-hermetically sealed	.001 µF to .1 µF (600V) .0018 µF to 1 µF (400V) .001 µF to 1 µF (200V) .001 µF to 1 µF (100V)
	4	CFR05/CFR06	Tubular, axial lead, DC, non-hermetically sealed	.01 µF to 5 µF (400V) .01 µF to 10 µF (200V) .001 µF to 20 µF (100V) .001 µF to 50 µF (50V)
	7	CFR09	Tubular, axial lead, DC or AC, non-hermetically sealed	.01 µF to 3.9 µF (200V) .015 µF to 5 µF (150V) .027 µF to 10 µF (100V) .033 µF to 15 µF (75V) .056 µF to 18 µF (50V)
	8	CFR12/CFR16	Molded, radial lead, DC, non-hermetically sealed	.001 µF to .0033 µF (250V) .0039 µF to .0056 µF (200V) .0068 µF to .0082 µF (150V) .01 µF to .018 µF (100V) .022 µF to .027 µF (75V) .033 µF to 1 µF (50V)
	9	CFR13/CFR14	Tubular, axial lead, DC, non-hermetically sealed	1 µF to 10 µF (400V) 1 µF to 20 µF (200V) 1 µF to 30 µF (100V)
	10	CFR15	Tubular, axial lead, DC, non-hermetically sealed	.0056 µF to .56 µF (800V) .0012 µF to 1 µF (600V) .0068 µF to 1 µF (400V) .012 µF to 1 µF (200V)
	11	CFR26/CFR27	Oval, lug termination	5 µF to 50 µF (100V) 5 µF to 50 µF (75V) 10 µF to 50 µF (50V)
	12	CFR29	Oval, radial leads	3 µF to 50 µF (100V) 3 µF to 50 µF (75V) 10 µF to 50 µF (50V)

TABLE II. Capacitor selection guidance table - continued.

Specification	Spec. sheet	Styles	Description (dimension - inches)	Available capacitance range (Voltage)
MIL-PRF-55681 (Ceramic, chip, multiple layer, unencapsulated, established and nonestablished reliability)	1	CDR01	Chip (0805)	10 pF to 3,300 pF (100V) 3,900 pF to 4,700 pF (50V)
	1	CDR02	Chip (1805)	220 pF to 10,000 pF (100V) 12,000 pF to 22,000 pF (50V)
	1	CDR03	Chip (1808)	330 pF to 33,000 pF (100V) 3,900 pF to 68,000 pF (50V)
	1	CDR04	Chip (1812)	1,200 pF to 56,000 pF (100V) 82,000 pF to 180,000 pF (50V)
	2	CDR05	Chip (1825)	3,900 pF to 150,000 pF (100V) 220,000 pF to 330,000 pF (50V)
	3	CDR06	Chip (2225)	6,800 pF to 10,000 pF (100V)
	4	CDR11/CDR12	Chip, high frequency (0505)	0.1 pF to 1,000 pF (50V)
	4	CDR13/CDR14	Chip, high frequency (1111)	0.1 pF to 100 pF (500V) 110 pF to 200 pF (300V) 220 pF to 470 pF (200V) 510 pF to 620 pF (100V) 680 pF to 5,100 pF (50V)
	5	CDR21/CDR22/ CDR23/CDR24/ CDR25	Chip, high frequency (1411)	0.1 pF to 100 pF (500V) 110 pF to 200 pF (300V) 220 pF to 470 pF (200V) 510 pF to 620 pF (100V) 680 pF to 5,100 pF (50V)
	7	CDR31	Metric chip (2.0 mm X 1.25 mm)	1 pF to 4,700 pF (100V) 510 pF to 18,000 pF (50V)
	8	CDR32	Metric chip (3.2 mm X 1.6 mm)	1 pF to 15,000 pF (100V) 1,110 pF to 39,000 pF (50V)
	9	CDR33	Metric chip (3.2 mm X 2.5 mm)	1,000 pF to 27,000 pF (100V) 2,400 pF to 100,000 pF (50V)
	10	CDR34	Metric chip (4.5 mm X 3.2 mm)	2,200 pF to 56,000 pF (100V) 5,100 pF to 180,000 pF (50V)
	11	CDR35	Metric chip (4.5 mm X 6.4 mm)	4,700 pF to 150,000 pF (100V) 11,000 pF to 470,000 pF (50V)
MIL-PRF-83421 (Metallized, plastic film, DC, AC, or DC and AC, hermetically sealed, established reliability)	1	CRH01	Axial lead, hermetically sealed	0.001 μF to 22 μF (30V)
	1	CRH02	Axial lead, hermetically sealed	0.001 μF to 10 μF (50V)
	1	CRH03	Axial lead, hermetically sealed	0.001 μF to 10 μF (100V)
	1	CRH04	Axial lead, hermetically sealed	0.001 μF to 3.9 μF (200V)
	1	CRH05	Axial lead, hermetically sealed	0.001 μF to 2.0 μF (400V)
	2	CRH11	Axial lead, hermetically sealed	0.47 μF to 25 μF (100V)
	2	CRH12	Axial lead, hermetically sealed	0.18 μF to 5 μF (200V)
	2	CRH13	Axial lead, hermetically sealed	0.001 μF to 2.0 μF (400V)
MIL-PRF-87164 (Mica, high reliability)	1	CMS04	Dipped, radial lead	1 pF to 200 pF (500V)
	2	CMS05	Dipped, radial lead	1 pF to 240 pF (500V)
	3	CMS06	Dipped, radial lead	270 pF to 2,700 pF (500V)
	4	CMS07	Dipped, radial lead	3,000 pF to 22,000 pF (500V)
	5	CMS03	Dipped, radial lead	1 pF to 120 pF (300V)
MIL-PRF-87217 (Supermetallized plastic film, direct current for low energy, high impedance applications, hermetically sealed, high reliability)	1	CHS01	Axial lead, hermetically sealed	0.001 μF to 10 μF (30V)
	1	CHS02	Axial lead, hermetically sealed	0.001 μF to 10 μF (50V)
	1	CHS03	Axial lead, hermetically sealed	0.001 μF to 10 μF (100V)

TABLE III. Principal capacitor applications.

Specification	Application												
MIL-PRF-	ER	Type	Blocking	Buffering	By-passing	Coupling	Filtering	Tuning	Temperature compensating	Trimming	Motor starting	Timing	Noise suppression
20	X	Ceramic			X	X	X	X	X				
81		Ceramic Trimmer		X		X		X					
123		Ceramic			X	X	X						
14409		Piston Trimmer						X		X			
19978	X	Plastic	X	X	X	X	X						
23269	X	Glass	X		X	X		X					
39001	X	Mica	X	X	X	X	X	X				X	
39003	X	Solid Tantalum	X		X	X	X						X
39006	X	Wet Tantalum	X		X	X	X				X		
39014	X	Ceramic			X	X	X						
39018	X	Aluminum	X		X	X	X						
39022	X	Metallized Plastic	X		X		X						
49137	X	Solid Tantalum	X		X	X	X						
49470		Ceramic, SMPS	X	X	X	X	X	X		X			X
55365	X	Solid Tantalum Chip			X	X	X						
55514	X	Plastic	X		X								
55681	X	Ceramic Chip			X	X	X						
83421	X	Metallized Plastic	X	X	X	X	X	X			X	X	
87164	X	Mica	X	X	X	X	X	X				X	
87217	X	Metallized Plastic	X	X	X	X	X	X			X	X	

TABLE IV. Detailed specification number by style number.

Performance specification	Style		Performance specification	Style
MIL-PRF-20/27	CCR75		MIL-PRF-14409/15	PC30
MIL-PRF-20/28	CC76, CCR76		MIL-PRF-14409/15	PC32
MIL-PRF-20/29	CCR77		MIL-PRF-14409/15	PC34
MIL-PRF-20/30	CC78, CCR78		MIL-PRF-14409/16	PC21
MIL-PRF-20/31	CC79 , CCR79		MIL-PRF-14409/16	PC22
MIL-PRF-20/35	CCR05		MIL-PRF-14409/16	PC23
MIL-PRF-20/35	CCR09		MIL-PRF-14409/16	PC24
MIL-PRF-20/36	CCR06		MIL-PRF-14409/17	PC17
MIL-PRF-20/37	CC07, CCR07		MIL-PRF-14409/18	PC18
MIL-PRF-20/38	CC08, CCR08		MIL-PRF-14409/18	PC46
			MIL-PRF-14409/19	PC19
MIL-PRF-81/1	CV11		MIL-PRF-14409/19	PC47
MIL-PRF-81/4	CV31			
MIL-PRF-81/4	CV32		MIL-PRF-19978/2	CQ20
MIL-PRF-81/5	CV34		MIL-PRF-19978/3	CQ72
MIL-PRF-81/6	CV35		MIL-PRF-19978/5	CQ07
MIL-PRF-81/6	CV36		MIL-PRF-19978/8	CQR07
MIL-PRF-81/8	CV42		MIL-PRF-19978/9	CQR09
MIL-PRF-81/9	CV98		MIL-PRF-19978/10	CQR12
MIL-PRF-81/10	CV99		MIL-PRF-19978/11	CQR13
MIL-PRF-81/12	CV50		MIL-PRF-19978/13	CQR29
MIL-PRF-81/12	CV51		MIL-PRF-19978/14	CQR32
			MIL-PRF-19978/15	CQR33
MIL-PRF-123/1	CKS05			
MIL-PRF-123/2	CKS06		MIL-PRF-23269/1	CYR10
MIL-PRF-123/3	CKS07		MIL-PRF-23269/2	CYR15
MIL-PRF-123/4	CKS11		MIL-PRF-23269/3	CYR20
MIL-PRF-123/5	CKS12		MIL-PRF-23269/4	CYR30
MIL-PRF-123/6	CKS14		MIL-PRF-23269/10	CYR51
MIL-PRF-123/7	CKS15		MIL-PRF-23269/10	CYR52
MIL-PRF-123/8	CKS16		MIL-PRF-23269/10	CYR53
MIL-PRF-123/10	CKS51			
MIL-PRF-123/11	CKS52		MIL-PRF-39001/5	CMR03
MIL-PRF-123/12	CKS53		MIL-PRF-39001/5	CMR04
MIL-PRF-123/13	CKS54		MIL-PRF-39001/5	CMR05
MIL-PRF-123/16	CKS22		MIL-PRF-39001/5	CMR06
MIL-PRF-123/17	CKS23		MIL-PRF-39001/5	CMR07
MIL-PRF-123/18	CKS24		MIL-PRF-39001/5	CMR08
MIL-PRF-14409/4	PC38		MIL-PRF-39003/1	CSR13
MIL-PRF-14409/4	PC48		MIL-PRF-39003/2	CSR09
MIL-PRF-14409/5	PC39		MIL-PRF-39003/3	CSR23
MIL-PRF-14409/6	PC40		MIL-PRF-39003/4	CSR91
MIL-PRF-14409/6	PC50		MIL-PRF-39003/6	CSR33
MIL-PRF-14409/7	PC41		MIL-PRF-39003/9	CSR21
MIL-PRF-14409/7	PC51		MIL-PRF-39003/10	CSS13
MIL-PRF-14409/8	PC42		MIL-PRF-39003/10	CSS33
MIL-PRF-14409/8	PC52			
MIL-PRF-14409/9	PC43		MIL-PRF-39006/22	CLR79
MIL-PRF-14409/12	PC25		MIL-PRF-39006/25	CLR81
MIL-PRF-14409/12	PC31		MIL-PRF-39006/28	CLS79
MIL-PRF-14409/13	PC26		MIL-PRF-39006/29	CLS81
MIL-PRF-14409/14	PC27		MIL-PRF-39006/30	CLR90
MIL-PRF-14409/14	PC28		MIL-PRF-39006/31	CLR91
MIL-PRF-14409/14	PC29		MIL-PRF-39006/32	CLR82

APPENDIX

TABLE IV. Detailed specification number by style number.

Performance specification	Style		Performance specification	Style
MIL-PRF-39014/1	CKR05		MIL-PRF-55514/4	CFR05
MIL-PRF-39014/2	CKR06		MIL-PRF-55514/7	CFR09
MIL-PRF-39014/5	CKR11		MIL-PRF-55514/8	CFR12
MIL-PRF-39014/5	CKR12		MIL-PRF-55514/8	CFR16
MIL-PRF-39014/5	CKR13		MIL-PRF-55514/9	CFR13
MIL-PRF-39014/5	CKR14		MIL-PRF-55514/9	CFR14
MIL-PRF-39014/5	CKR15		MIL-PRF-55514/10	CFR15
MIL-PRF-39014/5	CKR16		MIL-PRF-55514/11	CFR26
MIL-PRF-39014/20	CKR08		MIL-PRF-55514/11	CFR27
MIL-PRF-39014/21	CKR31		MIL-PRF-55514/12	CFR29
MIL-PRF-39014/21	CKR32			
MIL-PRF-39014/22	CKR22		MIL-PRF-55681/1	CDR01
MIL-PRF-39014/22	CKR23		MIL-PRF-55681/1	CDR02
MIL-PRF-39014/22	CKR24		MIL-PRF-55681/1	CDR03
MIL-PRF-39014/23	CKR04		MIL-PRF-55681/1	CDR04
			MIL-PRF-55681/2	CDR05
MIL-PRF-39018/1	CU13, CUR13		MIL-PRF-55681/3	CDR06
MIL-PRF-39018/2	CU15		MIL-PRF-55681/4	CDR11
MIL-PRF-39018/3	CU17, CUR17		MIL-PRF-55681/4	CDR12
MIL-PRF-39018/4	CU71		MIL-PRF-55681/4	CDR13
MIL-PRF-39018/6	CUR91		MIL-PRF-55681/4	CDR14
MIL-PRF-39018/7	CUR19		MIL-PRF-55681/5	CDR21
MIL-PRF-39018/12	CU72		MIL-PRF-55681/5	CDR22
MIL-PRF-39018/13	CUR22		MIL-PRF-55681/5	CDR23
			MIL-PRF-55681/5	CDR24
MIL-PRF-39022/1	CHR09		MIL-PRF-55681/5	CDR25
MIL-PRF-39022/2	CHR19		MIL-PRF-55681/6	CDR26
MIL-PRF-39022/7	CHR49		MIL-PRF-55681/6	CDR27
MIL-PRF-39022/8	CHR12		MIL-PRF-55681/6	CDR28
MIL-PRF-39022/10	CHR10		MIL-PRF-55681/6	CDR29
MIL-PRF-39022/11	CHR21		MIL-PRF-55681/6	CDR30
MIL-PRF-39022/11	CHR22		MIL-PRF-55681/7	CDR31
MIL-PRF-39022/11	CHR23		MIL-PRF-55681/8	CDR32
MIL-PRF-39022/11	CHR24		MIL-PRF-55681/9	CDR33
MIL-PRF-39022/11	CHR25		MIL-PRF-55681/10	CDR34
			MIL-PRF-55681/11	CDR35
MIL-PRF-49137/1	CX01			
MIL-PRF-49137/2	CX02		MIL-PRF-83421/1	CRH01
MIL-PRF-49137/2	CX12		MIL-PRF-83421/1	CRH02
MIL-PRF-49137/5	CX05		MIL-PRF-83421/1	CRH03
MIL-PRF-49137/6	CX06		MIL-PRF-83421/1	CRH04
			MIL-PRF-83421/1	CRH05
MIL-PRF-49470/1	PS01		MIL-PRF-83421/2	CRH11
MIL-PRF-49470/2	PS02		MIL-PRF-83421/2	CRH12
MIL-PRF-49470/3	PS03		MIL-PRF-83421/2	CRH13
MIL-PRF-49470/4	PS04			
MIL-PRF-49470/5	PS05		MIL-PRF-87164/1	CMS04
MIL-PRF-49470/6	PS06		MIL-PRF-87164/2	CMS05
			MIL-PRF-87164/3	CMS06
MIL-PRF-55365/4	CWR06		MIL-PRF-87164/4	CMS07
MIL-PRF-55365/4	CWR09		MIL-PRF-87164/5	CMS03
MIL-PRF-55365/8	CWR11			
			MIL-PRF-87217/1	CHS01
MIL-PRF-55514/1	CFR02		MIL-PRF-87217/1	CHS02
MIL-PRF-55514/4	CFR05		MIL-PRF-87217/1	CHS03

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

Review activities:
Army - AR
Navy - AS, CG, MC, OS, SH
Air force - 19, 99

Preparing activity:
DLA - CC

(Project 5910-2018)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.

2. The submitter of this form must complete block1s 4, 5, 6, and 7, and send to preparing activity.

3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:	**1. DOCUMENT NUMBER** MIL-HDBK-198	**2. DOCUMENT DATE** (YYMMDD) 990714

3. DOCUMENT TITLE
Department of Defense Handbook, Capacitor, Selection and Use of.

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Incl Area Code) (1) Commercial (2) DSN (If applicable)	7. DATE SUBMITTED (YYYYMMDD)

8. PREPARING ACTIVITY

a. NAME Defense Supply Center, Columbus ATTN: VAT	b. TELEPHONE (Include Area Code) (1) Commercial (2) DSN
c. ADDRESS (Include Zip Code) 3990 East Broad Street Columbus, OH 43213-1199	**IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:** Defense Standardization Program Office (DLSC-LM) 8725 John J. Kingman Road, Suite 2533 Fort Belvoir, Virginia 22060-6221 Telephone (703) 767-6888 DSN 427-6888