INCH-POUND
MIL-PRF-3098K
w/AMENDMENT 1
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SUPERSEDING
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PERFORMANCE SPECIFICATION

CRYSTAL UNITS, QUARTZ
GENERAL SPECIFICATION FOR

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

1. SCOPE

1.1 Scope. This specification covers the general requirements for quartz crystal units.

1.2 Part or Identifying Number (PIN). The PIN for crystal units meeting all the requirements of this specification are coded as shown and as specified (see 3.1):

CR	15	Blank or B or S for space level	/U	1M000000
Component (see 1.2.1)	Number (see 1.2.2)	Product level (see 1.2.3)	Basic indicator (see 1.2.4)	Specified frequency (see 1.2.5)

1.2.1 Component. Crystal units are identified by the two letter symbol “CR”.

1.2.2 Number. The number identifies a type of crystal unit which has certain electrical and physical characteristics covered as described in the specification sheet (see 3.1). The number comprises one or more digits.

1.2.3. Product level. The CR crystal number followed immediately by the /U or an optional B before the /U will indicate a crystal for general purpose military applications. The letter S immediately following the CR crystal number will indicate a crystal for high reliability space applications.

EXAMPLES: CR15/U1M000000 or CR15B/U1M000000 - general purpose military applications crystal
CR15S/U1M000000 - high reliability space applications

1.2.4 Basic indicator. The basic application for which a crystal unit has been designed is indicated by the symbol “/U” denoting “general utility”.

Comments, suggestions, or questions on this document should be addressed to: US Army Communications-Electronics RDEC, ATTN: RDER-PRQ-QE, Fort Monmouth, NJ 07703-5201 or emailed to Mike.G.Williams@us.army.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil.

1.2.5 Specified frequency. The specified frequency expressed in hertz (Hz) is identified by eight characters, consisting of seven digits and a letter. The letter is used simultaneously as a decimal point and as a multiplier. For frequency values:

a. Greater than or equal to 1,000 Hz but less than 1 megahertz, the letter "K" is used to represent a decimal point.

b. Greater than or equal to 1 megahertz, the letter "M" is used to represent a decimal point.

All digits preceding and following the letter (K or M) of the group represent significant figures. The following are examples of using the eight characters in constructing the specified frequency:

Designation	Frequency
1K000000 to 9K999999	1 to 9.999999 kilohertz, inclusive
10K00000 to 99K99999	10 to 99.99999 kilohertz, inclusive
100K0000 to 999K9999	100 to 999.9999 kilohertz, inclusive
1M000000 to 9M999999	1 to 9.999999 megahertz, inclusive
10M00000 to 99M99999	10 to 99.99999 megahertz, inclusive
100M0000 to 999M9999	100 to 999.9999 megahertz, inclusive

2. APPLICABLE DOCUMENTS

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

2.2 Government documents.

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

DEPARTMENT OF DEFENSE SPECIFICATIONS

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

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-202	-	Test Methods for Electronic and Electrical Component Parts.
MIL-STD-790	-	Established Reliability and High Reliability Qualified Products List (qpl) Systems for Electrical, Electronic, and Fiber Optic Parts Specifications.
MIL-STD-810	-	Environmental Engineering Considerations and Laboratory Tests.
MIL-STD-883	-	Microcircuits.
MIL-STD-1285	-	Marking of Electrical and Electronic Parts.

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or https://assist.daps.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094).

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

MSFC-STD-355 - Radiographic Inspection of Electronic Parts.

(Copies of this document are available online at http://www.nasa.gov/centers/marshall/home/index.html or from the George C. Marshall Space Flight Center, Mail Code EL 31, MSFC, AL 35812-9999, Phone: 205-544-2014).

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

ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES (IPC)

IPC-2221 - Printed Board Design Generic Standard on.
J-STD-004 - Requirements for Soldering Fluxes.

(Copies of this document are available from http://www.ipc.org/ or Association Connecting Electronics Industries, 3000 Lakeside Drive, 309 S, Bannockburn, IL 60015, PH 847-615-7100, FAX 847-615-7105).

NATIONAL CONFERENCE OF STANDARDS LABORATORIES (NCSL)

NCSL-Z540.3 - Requirements for Calibration of Measuring and Test Equipment.

(Copies of this document are available from http://www.ncsli.org/ or from the National Conference of Standards Laboratories (NCSL) International, 1800 30th Street, Suite 305, Boulder, CO 80301-1026.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM-E595 - Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment.

(Copies of this document are available at www.astm.org or from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959.)

BRITISH STANDARDS INSTITUTION (BSI)

IEC 60122-1 - Quartz Crystal Units of Assessed Quality - Part 1: Generic Specification - Third Edition.

IEC 60444-1 - Measurement of Quartz Crystal Unit Parameters by Zero Phase Technique in a Pi-Network - Part 1: Basic Method for the Measurement of Resonance Frequency and Resonance Resistance of Quartz Crystal Units by Zero Phase Technique in a Pi-Network - Edition 2.0.

(Copies of these documents are available from http://www.iec.ch/, IEC - International Electrotechnical Commission, 3 Rue de Varembe, PO Box 131, Geneva, Switzerland CH-1211, Phone: 41-22-919-02-11, Fax: 41-22-919-03-00.

ELECTRONIC INDUSTRIES ASSOCIATION (EIA)

EIA-477	-	Cultured Quartz
EIA-512	-	Standard Methods for Measurement of the Equivalent Electrical Parameters of Quartz Crystal Units, 1 kHz to 1GHz.
EIA-557	-	Statistical Process Control Systems

(Copies of these documents are available online at http://www.ecaus.org/eia/site/index.html or from the Electronic Industries Alliance, 2500 Wilson Boulevard, Arlington, VA 22201).

INTERNATIONAL STANDARDS INSTITUTE (ISO)

ISO 10012	-	Measurement management systems - Requirements for measurement processes and measuring equipment.

(Copies of this document are available from http://www.iso.org/ or from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.)

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

3. REQUIREMENTS

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

3.2 Qualification. Crystal units furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list before contract award.

3.3 Product level requirement. Two product levels, S, and B are provided for this specification. Product levels S and B crystal units shall be those which have been subjected to and passed all applicable requirements, tests, and inspections specified herein.

3.4 Qualified Products List (QPL) system. The manufacturer shall establish and maintain a QPL system for parts covered by this specification (see the appendix for additional information). Additional requirements for this system when product level S qualification is sought are specified in MIL-STD-790. For product level S, the manufacturer shall also establish a Statistical Process Control (SPC) that meets the requirements of EIA-557.

3.5 Materials. Materials shall be used which will enable the crystal units to meet the performance requirements of this specification. Note, that the use of pure tin, as an underplate or final finish, is prohibited both internally and externally. Tin content of crystal unit components and solder shall not exceed 97 percent, by mass. Tin shall be alloyed with a minimum of 3 percent lead, by mass (see 6.7). Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of the finished product.

3.5.1 Outgassing (Product level S only when specified see 3.1). Materials utilized shall have a maximum total mass loss of 1.0 percent and a maximum Collected Volatile Condensable Material (CVCM) content of 0.1 percent when tested in accordance with ASTM-E595. No cadmium or zinc plating shall be used in the fabrication of the crystal unit.

3.5.2 Holder base and cover. Material shall be used which will enable the crystal holder to conform to the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of the finished product.

3.5.3 Quartz. If the type of quartz is specified (see 3.1), it shall conform to the following requirements (see 3.5):

3.5.3.1 Cultured quartz. If cultured quartz is specified, it shall have been cut from a bar which met the requirements of EIA-477. The Q-grade shall be as specified (see 3.1) but not worse than grade 1.8 for thickness-shear type resonators. For product level S, the grower, autoclave ID, date code, and bar ID shall be provided.

3.5.3.2 Swept cultured quartz. If swept cultured quartz is specified, the sweeper, sweep lot number, electrode description (material and application technique, e.g., pressure, sputtered, or evaporated), sweeping atmosphere, sweeping temperature, electric field and current profiles shall be provided as specified (see 3.1).

3.5.3.3 Natural quartz. If natural quartz is specified (see 3.1), documentation must be provided to substantiate the supplier.

3.5.4 Soldering and soldering flux. When soldering and soldering flux are used in the fabrication of crystal units, they shall be of such a quality as to enable the unit to meet all the requirements of this specification (see 3.5). Flux residue shall be removed completely from all surfaces.

3.6 Interface, construction, and physical dimension requirements. Crystal units shall meet the interface, construction, and physical dimensions specified (see 3.1).

3.6.1 Glass parts. Glass seals shall be free from cracks. Minute flaking around the feather edge of a meniscus shall not be considered a crack.

3.6.2 Supporting structure. Interference, friction, crimping, or similar joining of parts unreinforced by solder, welding, adhesive, etc. shall not be used to support or provide electrical contact for the quartz resonator.

3.6.3 Bonding. Electrical connection shall be made to the quartz resonator electrodes by an electrically conductive cement, solder, thermocompression bond, ultrasonic bond, parallel-gap weld, electroplated metal bond or by another method providing intimate metal-to-metal continuity. Interference, friction, crimped or similar joining of parts unreinforced by solder, welding, etc. shall not be used.

3.6.4 Sealing conditions. Crystal units shall be hermetically sealed in vacuum or with a backfill gas as specified (see 3.1). The type of gas, purity, temperature and pressure used at sealing shall be provided for informational purposes.

3.6.5 Pin alignment The pins in the base of the crystal unit shall freely and completely enter the pin-alignment test gage. If a physical gage is not used, the dimensions and spacing of the pins shall conform to the limiting dimensions of pin-alignment test gage as viewed on a shadow-graph (see 4.10.2.1.2). The pin undercut may be omitted.

3.6.6 Final frequency adjustment. The final frequency adjustment shall not be accomplished by means of abrasion of the electrode, exposure of the crystal resonator to a halogen vapor, or by mechanical application of any loading material.

3.6.7 Tin plated finishes. Use of tin plating is prohibited as a final finish and as an undercoat (see 6.7). Use of tin-lead (Sn-Pb) finishes are acceptable provided that the minimum lead content is 3 percent, by mass (see 3.5).

3.6.8 Solderable terminals. Solderable terminals shall be as specified (see 3.1) and shall meet the solderability requirements specified herein (see 3.7).

3.7 Solderability. When crystal units are tested as specified in 4.10.3, the solderable terminals shall meet the criteria specified in the test method.

3.7.1 Ceramic package. The terminal pads of the package shall be suitable for the specified lead attachment method (see 3.1) when tested as specified in 4.10.3.1.

3.8 Resistance to solvents (when specified see 3.1). The marking shall not become illegible or discolored when tested as specified in 4.10.4.

3.9 Resistance to soldering heat (when specified see 3.1). When crystals are tested as specified in 4.10.5, there shall be no damage which would adversely affect normal operation of the crystal. The changes in frequency and resistance shall not exceed the specified limits.

3.10 Frequency and resistance (Product level S only).

3.10.1 Resistance versus temperature (R vs T). When tested as specified in 4.10.6.1, the resistance shall not exceed the specified maximum at any temperature between and including the specified limits (see 3.1).

3.10.2 Frequency versus temperature (static). The requirements for frequency versus temperature depend upon the intended application. The specified parameters shall be within the limits specified when tested as specified in 4.10.6.1 at the drive level, load capacitance, and rate of change of temperature specified (see 3.1).

3.10.3 Coupled modes (frequency - resistance anomalies). The frequency versus temperature characteristic shall be free of the effects of coupled modes over the specified temperature range, as demonstrated by the absence of deviations in the frequency versus temperature characteristic greater than the specified amount from the specified polynomial (see 4.10.6.2.1) when tested as specified in 4.10.6.2. The resistance and, if specified, the slope of the resistance versus temperature characteristic shall not exceed the values specified over the temperature range specified (see 3.1) when tested as specified in 4.10.6.2.

3.11 Capacitance.

3.11.1 Capacitance, shunt, C_0 (when specified, see 3.1). When tested as specified in 4.10.7.1, the shunt capacitance, C_0, shall be as specified (see 3.1).

3.11.2 Capacitance, motional, C_1 (Product level S only). The motional capacitance, C_1, shall be as specified (see 3.1), when tested as specified in 4.10.7.2.

3.12 Quality factor ("Q") (Product level S only). The quality factor shall exceed the value specified (see 3.1), when tested as specified in 4.10.8.

3.13 Unwanted modes (fundamental mode or overtone units). When tested as specified in 4.10.9, all unwanted modes shall have resistance that exceeds two times the main mode resistance.

3.14 Insulation resistance. The insulation resistance shall not be less than 500 megohms when tested as specified in 4.10.10.

3.15 Drive sensitivity (of frequency and resistance) (Product level S only). The difference between the maximum and minimum frequency and resistance shall not be larger than the specified amounts (see 3.1), when tested as specified in 4.10.11.

3.16 Internal gas analysis (Product level S only). The internal water vapor content shall not exceed 5,000 ppm at +100ºC, when tested in accordance with 4.10.12. Polymer impregnations or secondary seal (backfill, coating, or other uses of organic or polymeric materials to effect, improve the seal) of the crystal package shall not be permitted.

3.17 Shock (specified pulse). When crystal units are tested as specified in 4.10.13, changes in frequency and resistance shall not exceed specified values (see 3.1). Measurements of frequency and resistance shall be made immediately before and immediately after the test (see 4.10.1.2), except that for group A inspection, these measurements of frequency and resistance are not required.

3.18 Reduced drive level (overtone units, and when specified, fundamental units)(Product level B only). When tested as specified in 4.10.17, the resistance shall not exceed the maximum specified (see 3.1).

3.19 Vibration, acceleration and acoustical noise.

3.19.1 Vibration (frequency and resistance offset). When tested as specified in 4.10.14.1, changes in frequency and resistance of the crystal unit shall not exceed specified values (see 3.1). Measurements of frequency and resistance shall be made immediately before and immediately after the test (see 4.10.1.2).

3.19.2 Acceleration sensitivity (vibration) (Product level S only). If specified, the vibration induced acceleration sensitivity shall not exceed the value specified for the maximum acceleration specified over the frequency range specified when tested in specified in 4.10.14.2. No mechanical resonances shall be present at any frequency between the limits specified (see 3.1).

3.19.3 Frequency and resistance offset (steady state acceleration) (Product level S only). If specified, change in frequency and resistance shall not exceed the values specified (see 3.1), when tested as specified in 4.10.14.3.

3.19.4 Acceleration sensitivity (steady state) (Product level S only). If specified, the frequency change per unit of acceleration shall not exceed the value specified at any acceleration level below the maximum specified (see 3.1), when tested as specified in 4.10.14.4.

3.19.5 Acoustical noise(Product level S only). If specified, the ratio of the power in a 1 Hz bandwidth of a single sideband to the power in the carrier shall not exceed the values specified for the acoustic frequencies specified (see 3.1), when tested as specified in 4.10.14.5.

3.20 Thermal frequency repeatability (Product level S only). If specified, the maximum frequency difference among any of the frequencies at each turnover temperature shall be less than the value specified (see 3.1), when tested as specified in 4.10.15. If there are two turnover temperatures, the maximum difference among the values of f(UTP) - f(LTP) shall be less than the value specified (see 3.1).

3.20.1 Thermal frequency hysteresis(Product level S only). If specified, the thermal frequency hysteresis, as measured as specified in 4.10.15.2, shall not exceed the specified value (see 3.1).

3.21 Particle impact noise detection (PIND) (Product level S only). If specified, crystal units shall be subjected to the test specified in 4.10.16.

3.22 Frequency and resistance (Product level B only). The frequency and resistance of the crystal unit shall be within the limits specified when tested under the following conditions as applicable (see 3.1 and 4.10.18).

3.22.1 Frequency stability (controlled). Throughout the operating temperature range, the frequency of crystal units designed for operation under controlled temperature conditions shall not deviate from the measured frequency at the reference temperature by more than the value specified (see 3.1), and shall also be within the specified frequency tolerance limits, when crystal units are tested as specified in 4.10.18.2.

3.22.2 Operable temperature range (controlled). Crystal units designed for operation under controlled temperature conditions shall be required to oscillate over the operable temperature range of the unit, but not necessarily within the specified frequency and resistance limits, when tested in accordance with 4.10.18.3.

3.22.3 Low temperature storage. When crystal units are tested as specified in 4.10.18.4, the resistance shall not exceed the maximum specified when the unit is operated at the rated drive level (see 3.1), except when performed in conjunction with reduced drive level (see 4.10.17).

3.23 Thermal shock. There shall be no evidence of cracking, chipping or breaking in any part of the crystal unit when examined as specified in 4.10.19.1 for product level B or 4.10.19.2 for product level S. If specified, changes in frequency and resistance shall not exceed the specified values (see 3.1) when tested as specified in 4.10.19.2. When tested as specified in 4.10.19.2, changes in frequency and resistance of the crystal unit shall not exceed specified values (see 3.1). Measurements of frequency and resistance shall be made immediately before test and a minimum of 30 minutes after test to allow units to return to thermal equilibrium (see 4.10.1.2).

3.24 Seal. When tested as specified in 4.10.25, the leakage rate of crystal units shall not exceed 10^{-8} atmospheric cubic centimeters per second (atm cc/sec).

3.25 Thermal time constant (Product level S only) . If specified, the thermal time constant shall be defined as the time required for the frequency to reach its “static” value (see 3.10.2) at 63°C ±1°C after a step change in ambient temperature from 0°C to 100°C. When measured as specified in 4.10.20, the thermal time constant shall not exceed the value specified (see 3.1).

3.25.1 Frequency overshoot (Product level S only). If specified, the frequency overshoot, as defined in 4.10.20.1, shall not exceed the value specified, (see 3.1).

3.26 Barometric pressure (reduced) (product level S). If specified, crystal units shall be subjected to the test specified in 4.10.25.

3.27 Salt atmosphere (corrosion). When tested as specified in 4.10.21, there shall be no evidence of excessive corrosion. Corrosion that causes impairment of the electrical or mechanical performance of the unit shall be considered excessive.

3.28 Moisture resistance. When tested as specified in 4.10.22, the frequency and resistance of the crystal units shall be within the limits specified in 3.22, and the insulation resistance shall be not less than 500 megohms.

3.29 Aging. When tested as specified in 4.10.27.1 for product level B or 4.10.27.3 for product level S, the difference between the highest and lowest frequencies measured shall not exceed the value specified (see 3.1). Also, for product level S, if specified, the aging rate per day at day 30 (40 for qualification testing and conformance testing) and the maximum frequency change for a one-day period shall be less than the value specified. The resistance shall not change by more than the specified amount (see 3.1).

3.29.1 Accelerated aging. When tested as specified in 4.10.27.2 for product level B or 4.10.27.4 for product level S, the difference in frequency between the measurements made immediately prior to and immediately after conditioning shall not exceed 5 parts per million (ppm), 2 ppm for product level S, or the value specified (see 3.1) and shall not exceed the maximum resistance specified (see 3.1).

3.30 Terminal strength.

3.30.1 Terminal pull. When tested as specified in 4.10.23.1, there shall be no evidence of damage to the terminal or glass seal, or movement of the terminal relative to the glass at the point of seal.

3.30.2 Terminal bend (applicable to crystal units with undercut pins). When tested as specified in 4.10.23.2, terminals shall not break and glass seals shall not crack or chip.

3.30.3 Wire-lead bend (applicable to crystal units with wire-lead terminals). When tested as specified in 4.10.23.3, there shall be no severing of the terminal, or cracking or chipping of the glass.

3.30.4 Wire-lead twist (applicable to crystal units with wire-lead terminals) (Product level S only). When tested as specified in 4.10.23.4, there shall be no serving of the terminals, or cracking or chipping of the glass.

3.31 Bond strength (when specified, see 3.1). When tested as specified in 4.10.24, the junction between each supporting wire or other supports and the surface of the resonator shall have a minimum bond strength as specified (see 3.1).

3.32 Radiation hardness (product level S only).

3.32.1 Total dose. If specified, the radiation-induced changes in frequency and resistance shall not exceed the value specified (see 3.1), when tested as specified in 4.10.28.1.

3.32.2 Dose rate. If specified, the maximum radiation-pulse induced changes in frequency and resistance shall not exceed the values specified (see 3.1), when tested as specified in 4.10.28.2. The radiation pulse-induced changes in frequency and resistance after the specified time interval shall not exceed the values specified (see 3.1).

3.32.3 Neutrons. If specified, the neutron-induced changes in frequency and resistance shall not exceed the values specified (see 3.1), when tested as specified in 4.10.28.3.

3.32.4 Accumulated time error. If specified, the time integral of the radiation-induced frequency change for the specified time interval (see 3.1), shall not exceed the value specified when tested as specified in 4.10.28.4.

3.33 Marking. As a minimum, the PIN and contractor's identification shall be marked on the crystal unit in accordance with method I of MIL-STD-1285. The marking shall be located on the largest visible surface of the crystal unit. The PIN may be marked on more than one line provided the PIN is continuous except where it "breaks" from one line to another. The break shall not occur within the "specified frequency" marking. The PIN specified in 1.2 shall not be marked on any crystal unit which the contractual requirements shall be considered a deviation. Crystal units shall also be marked with the year and week of the final test in accordance with MIL-STD-1285. The contractor's designated symbol or Commercial and Government Entity (CAGE) code shall also marked on the unit.

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

3.35 Workmanship. Crystal units shall be processed in such a manner as to be of uniform quality and free from any defects that would adversely affect life, serviceability, or appearance. The interior of the crystal shall contain no flux, quartz or grinding particles, residue, or other foreign or unapproved materials. There shall be no evidence of fractures in the resonator, cracks, or flaked edges. Electrode material shall be clean and untarnished. There shall be no evidence of final frequency adjustment by means of abrasion of the electrode, exposure of the crystal element to a halogen vapor, or mechanically applied loading materials

4. VERIFICATION

4.1 Classification of inspection. The inspection requirements specified herein are classified as follows:

a. Materials inspection (See 4.4)

b. Screening (see 4.6)

c. Qualification inspection (see 4.7).

d. Conformance inspection (see 4.8).

e. Periodic inspection (see 4.9).

4.2 QPL system. The manufacturer shall establish and maintain a QPL system as described in 3.4. Evidence of such compliance shall be verified by the qualifying activity of this specification as prerequisite for qualification and retention of qualification.

4.3 Test equipment and inspection facilities. Test and measuring equipment and inspection facilities of sufficient accuracy, quality, and quantity to permit performance of the required inspection shall be established and maintained by the contractor. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with NCSL-Z540.3, ISO 10012, or an equivalent system approved by the qualifying activity.

4.3.1 Test sets.

4.3.1.1 Frequency correlation. The frequency of a given crystal unit shall be within 5 ppm for product level B and 0.1 ppm for product level S of the frequency (see 3.1) measured in the reference standard test set (see 4.3.1.3).

4.3.1.2 Resistance correlation. The resistance of a given crystal unit shall be within 10 % for product level B and 5% for product level S of its resistance as measured in the reference standard test set (see 4.3.1.3).

4.3.1.3 Reference standard test sets. The reference standard test set shall be furnished by the contractor. The reference standard test set shall conform to IEC-60444-1 or be correlatable to EIA-512. The contractor is responsible for certifying to the qualifying activity that the reference standard test set conforms to the appropriate standard (see 4.3.1.3.1). The reference standard test standard set shall be used to check the characteristics and accuracy of the contractor's equivalent test set.

4.3.1.3.1 Certification of reference standard test sets. Certification of compliance with IEC 60444-1 and EIA-512 shall consist of the following:

a. Functional diagram of the contractor's system showing interconnection, equipment manufacturer, and model designations.

b. Flow charts and descriptions of all software modules used in the control of equipment and estimation of parameter values.

c. Flow charts and descriptions of instrument calibration and error correction routines.

d. Traceability for test fixtures and reference impedance devices required for the calibration, verification, and use of the standard test set.

4.4 Materials inspection. Materials inspection shall consist of certification from the source that the materials used in fabricating the crystal units are in accordance with the applicable requirements prior to such fabrication. In the absence of certification from the source, a certificate of analysis or certified inspection data shall be required as proof of conformance to applicable requirements.

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

4.6 Screening. Crystal units to be delivered in accordance with this specification shall be subjected to and pass All screening tests of table I for the product level specified, in the order shown, prior to performance of any verification inspection. Unless otherwise specified (see 3.1), the percentage defective allowed (PDA) shall be 10 percent for product level B and 5 percent for product level S.

4.6.1 Sample. A sample shall consist of all crystal units (100 percent screening).

4.6.2 Failures. Crystal units which fail any test criteria in the screening sequence shall be removed from the lot at the time of observation or immediately at the conclusion of the test in which the failure was observed. Once rejected and verified as a failure, rework may be performed.

4.6.3 Lots resubmitted for screening. Lots may be resubmitted for screening one time only and may be resubmitted only when the observed percentage of defectives does not exceed twice the specified percent defective allowed. For acceptance, reworked crystal units shall be subjected to and pass the complete screening sequence for the applicable device product level.

TABLE I. Screening (100 percent).

Test inspection	Product level S Method-condition	Product level B Method-condition
Pre-seal visual examination	4.10.2.2	4.10.2.2
PIND	4.10.16	N/A
Thermal frequency repeatability	4.10.15, 10 cycles	N/A
Frequency	4.10.6; Frequency and resistance shall be measured at the specified reference temperature.	4.10.18
Unwanted modes	4.10.9	N/A
Capacitance	4.10.7	N/A
Shunt	4.10.7.1	N/A
Motional	4.10.7.2	N/A
Quality factor	4.10.8	N/A
Aging	4.10.27.3, 30 days at 85ºC, Δf/f ≤ 2 ppm	N/A
Drive sensitivity (frequency, resistance)	4.10.11, Δf/f ≤ 2 ppm; R ≤ ± 10% or ± 3 Ω whichever is greater	N/A
		N/A
Vibration	4.10.14, Δf/f ≤ 1 ppm	N/A
Thermal shock	4.10.19.2, Δf/f ≤ 1 ppm	N/A
Insulation resistance	4.10.10	N/A
Coupled modes	4.10.6.2: Resistance shall not exceed the maximum value specified and the frequency shall not deviate from a fourth order equation curve best fit by more than: a) 1 ppm when accompanied by a reversal of slope, b) 1.5 ppm when not accompanied by a reversal of slope.	N/A
Frequency and equivalent resistance at Reference temperature	4.10.6; Frequency and resistance shall be measured at the specified reference temperature.	N/A
Frequency and resistance verses temperature (static)	4.10.6.1	N/A
Seal	4.10.26	4.10.26
Radiographic inspection (when specified)	Per MSFC-STD-355	N/A
Visual (External) and mechanical inspection	4.10.2.1	4.10.2.1

4.7 Qualification inspection. Qualification inspection shall be performed at a laboratory acceptable to the Government on sample units produced with equipment and procedures normally used in production.

4.7.1 Sample size. Thirty samples (Product level B) or forty five samples (Product level S) shall be subjected to qualification inspection as specified in the appendix to this specification.

4.7.2 Inspection routine. Samples shall be subjected to the qualification inspection specified in table II or table II-A in the order shown, for the applicable device product level.

4.7.3 Failures. For product level B one or more failures may be the basis for refusing to grant qualification approval. For product level S two failures in any one test shall be cause for refusal to grant qualification. Failure of one sample unit in one or more inspections shall be considered a single failure.

4.7.4 Extension of qualification. Qualification by similarity for qualification of similar crystal units is specified in the appendix. The contractor also has the option of recommending additional qualification by similarity proposals for approval by the qualifying activity.

4.7.5 Retention of qualification. To retain qualification, the contractor shall provide verification to the qualifying activity of the following items every 12 months:

a. MIL-STD-790 program (for product level S only).

b. Design of the crystal has not been modified.

c. Screening tests and conformance tests have been performed as specified herein.

d. The contractor retains the capability to manufacture and test crystals to this specification.

e. Periodic group B inspections have been performed as applicable.

NOTE: If product level S oscillators are produced, product level S oscillators shall be used in retaining qualification for product level S and product level B. Product level B oscillators will be used in retaining qualification for product level B only.

In the event that no production has occurred in this period, the contractor shall still verify to the qualifying activity that the capacity to manufacture and test QPL crystal units still exists and that the contractor wants to remain on the QPL.

4.8 Conformance inspection.

4.8.1 Inspection of product for delivery. Inspection of product for delivery shall consist of group A inspection.

4.8.1.1 Testing after storage. When a crystal unit is stored for 30 days or longer after group A inspection and before shipment, it (product level B) shall be subjected to the frequency test for controlled and noncontrolled crystal units (see 4.10.18). Those crystal units failing this test shall not be delivered on the contract. Failure in excess of 10 percent of the lot shall be cause for rejection of the lot. Product level S crystals shall be subjected to the frequency and resistance test (see 4.10.6).

4.8.1.2 Inspection lot. An inspection lot shall consist of all crystal units of similar types and one frequency or assorted frequencies within the range covered by that type produced under essentially the same conditions, and offered for inspection at one time (see appendix for preferred groupings).

4.8.1.3 Group A inspection. Group A inspection shall consist of the inspections specified in table III or table III-A for the applicable product level.

4.8.1.3.1 Product level S crystal units only. Group A inspection shall be performed on 100 percent of the lot.

4.8.1.3.1.1 Product level S lot rejection criteria. If 10 percent or more of the units in a lot fail accelerated aging (see 3.28, drive sensitivity (see 3.15, or internal gas analysis (see 3.16), that lot shall be rejected. Resubmission is prohibited.

4.8.1.3.2 Product level B crystal units only. The tests in subgroup 1 shall be performed in the order shown and on the same set of sample units. The test in subgroup 2 may be performed on a separate set of sample units.

4.8.1.3.2.1 Sampling plan. A sample of parts shall be randomly selected from each inspection lot in accordance with table III. If one or more defects are found, the lot shall be rescreened for that defect and the defects removed. After screening and removal of defects, a new sample of parts shall be randomly selected again in accordance with table III. If one or more defects are found in the second sample for the same defect or rejection cause, the lot shall be rejected and shall not be supplied to this specification. When the lots, as defined in 4.8.1.2, consists of less than 90 units, two or more such lots may be combined into grand lots. The grand lots may contain inspection lots from different groups. The sample selected from those grand lots shall be, to the greatest extent possible, representative of the crystal types in each component lot. There shall be a minimum of one type from each group and the choice of sample shall be proportional.

4.8.1.3.2.2 Manufacturer's production inspection. If the manufacturer performs tests similar to those specified in group A, subgroup 1, as the final step of his manufacturing process, the subgroup 1 test may be eliminated when approved by the qualifying activity. The following criteria must be complied with:

a. The production tests are identical to, or more stringent than, the subgroup 1 tests.

b. One hundred percent of the product supplied to these tests.

c. Failure criteria are identical to, or more stringent than, the subgroup 1 tests.

d. Lot rejection criteria are documented.

e. Once approved, future changes require approval from the qualifying activity.

4.8.1.3.2.3 Disposition of sample units. Sample units which have passed all group A inspections may be delivered on the contract if the lot is accepted and sample units are still within specified electrical tolerances (see 3.1).

TABLE II. Qualification inspection for product level B crystals.

Inspection	Requirement paragraph	Method paragraph
Visual and mechanical inspection	3.5, 3.6, 3.35	4.10.2
Solderability	3.7	4.10.3
Resistance to solvents (4 sample units)	3.8	4.10.4
Resistance to soldering heat (when applicable)	3.9	4.10.5
Shock (specified pulse)	3.17	4.10.13
Vibration	3.19.1	4.10.14.1
Low temperature storage	3.22.3	4.10.18.4
Reduced drive level 1/	3.18	4.10.17
Frequency and resistance	3.22	4.10.18
Frequency stability (controlled)	3.22.1	4.10.18.2
Operable temperature range (controlled)	3.22.2	4.10.18.3
Capacitance shunt (when specified)	3.11.1	4.10.7.1
Unwanted modes	3.13	4.10.9
Insulation resistance	3.14	4.10.10
Thermal shock	3.23	4.10.19.1
Seal	3.24	4.10.26
Salt atmosphere(corrosion)	3.27	4.10.21
Moisture resistance	3.28	4.10.22
Aging	3.29	4.10.27.1
Terminal strength 2/	3.30	4.10.23
Visual and mechanical inspection (internal) 3/	3.5, 3.6, 3.35	4.10.2.2
Bond strength (when specified)	3.31	4.10.24

1/ Applicable to overtone units and, when specified, fundamental units.
2/ Two sample units only from those to be used for visual and mechanical inspection (internal).
3/ Six sample units, two each from the lower end, middle, and upper frequency.

TABLE II-A. Qualification inspection for product level S crystals.

Subgroup I (all sample unit)		
Solderability or lead attachment	3.7	4.10.3
Ceramic package (when applicable)	3.7.1	4.10.3.1
Resistance to solvents (4 sample units)	3.8	4.10.4
Resistance to soldering heat (when applicable)	3.9	4.10.5
Visual (external) and mechanical inspection	3.5, 3.6, 3.34	4.10.2
Frequency and resistance	3.10	4.10.6
Resistance vs temperature (R vs T)	3.10.1	4.10.6.1
Frequency vs Temperature (static temperature run)	3.10.2	4.10.6.1
Coupled modes (frequency-resistance anomalies)	3.10.3	4.10.6.2
Capacitance	3.11	4.10.7
Capacitance, shunt (when specified)	3.11.1	4.10.7.1
Capacitance, motional (when specified)	3.11.2	4.10.7.2
Quality factor (“Q”) (when specified)	3.12	4.10.8
Unwanted modes	3.13	4.10.9
Insulation resistance	3.14	4.10.10
Accelerated aging	3.29.1	4.10.27.4
Drive sensitivity (of frequency and resistance)	3.15	4.10.11
Internal gas analysis	3.16	4.10.12
Subgroup II (1/3 of sample units)		
Shock	3.17	4.10.13
Vibration, acceleration, and acoustical noise	3.19	4.10.14
Vibration (Frequency and resistance offset) (when specified)	3.19.1	4.10.14.1
Acceleration sensitivity (vibration) (when specified)	3.19.2	4.10.14.2
Frequency and resistance offset (steady state acceleration) (when specified)	3.19.3	4.10.14.3
Acceleration sensitivity (steady state) (when specified)	3.19.4	4.10.14.4
Acoustical noise (when specified)	3.19.5	4.10.14.5
Thermal frequency repeatability (when specified)	3.20	4.10.15
Thermal frequency hysteresis	3.20.1	4.10.15.2
Subgroup III (1/3 of sample units)		
Particle impact noise detection (PIND) (when specified)	3.21	4.10.16
Moisture resistance	3.28	4.10.22
Salt atmosphere	3.27	4.10.21
Terminal strength (two sample units)	3.30	4.10.23
Terminal pull (when applicable)	3.30.1	4.10.23.1
Terminal bend (when applicable)	3.30.2	4.10.23.2
Wire-lead bend (when applicable)	3.30.3	4.10.23.3
Wire-lead twist (when applicable)	3.30.4	4.10.23.4
Visual (internal) 1/	3.5, 3.6, 3.35	4.10.2.2
Bond strength (when specified) 1/	3.31	4.10.24

See footnote at end of table.

TABLE II-A. Qualification inspection for product level S crystals – Continued.

Subgroup IV (1/3 of sample units)		
Thermal shock	3.23	4.10.19.2
Thermal time constant (when specified)	3.25	4.10.20
Frequency overshoot	3.25.1	4.10.20.1
Subgroup V (all sample units from subgroups II and IV)		
Barometric pressure	3.26	4.10.25
Seal	3.24	4.10.26
Aging	3.29	4.10.27.3
Radiation hardness	3.32	410.28
Total dose (when specified)	3.32.1	4.10.28.1
Dose rate (when specified0	3.32.2	4.10.28.2
Neutrons (when specified)	3.32.3	4.10.28.3
Accumulated time error (when specified)	3.32.4	4.10.28.4
Subgroup VI (Two unsealed units)		
Visual (internal)	3.5, 3.6, 3.35	4.10.2.2
Bond strength	3.31	4.10.24

1/ Six sample units other than those from terminal strength.

TABLE III. Group A inspection for product level B crystals.

Inspection	Requirement paragraph	Method paragraph
Subgroup I		
Visual and mechanical inspection (external) 1/	3.5, 3.6, 3.35	4.10.2.2
Low temperature storage	3.22.3	4.10.18.4
Reduced drive level 2/	3.18	4.10.17
Frequency and resistance	3.22	4.10.18
Frequency stability (controlled)	3.22.1	4.10.18.2
Operable temperature range (controlled)	3.22.2	4.10.18.3
Capacitance shunt (when specified)	3.11.1	4.10.7.1
Unwanted modes	3.13	4.10.9
Seal	3.24	4.10.26
Subgroup ll		
Accelerated aging	3.29.1	4.10.27.2

1/ Two sample units only for external dimensions.
2/ Applicable to overtone units and, when specified, fundamental units.

TABLE III-A. Group A inspection for product level S crystals.

Inspection	Requirement paragraph	Method paragraph
Subgroup I		
Visual (external) and mechanical	3.5, 3.6, 3.35	4.10.2.2
Shock	3.17	4.10.13
Frequency and resistance	3.10	4.10.6
Resistance vs temperature (R vs T)	3.10.1	4.10.6.1
Frequency vs Temperature (static temperature run)	3.10.2	4.10.6.1
Coupled modes (frequency-resistance anomalies)	3.10.3	4.10.6.2
Internal gas analysis	3.16	4.10.12
Unwanted modes	3.13	4.10.9
Capacitance	3.11	4.10.7
Capacitance, shunt (when specified)	3.11.1	4.10.7.1
Capacitance, motional (when specified)	3.11.2	4.10.7.2
Quality factor (“Q”) (when specified)	3.12	4.10.8
Seal	3.24	4.10.26
Subgroup II		
Accelerated aging	3.29.1	4.10.27.4
Drive sensitivity (of frequency and resistance)	3.15	4.10.11

1/ Two sample units only for external dimensions.
2/ Applicable to overtone units and, when specified, fundamental units.

TABLE IV. Group A sampling plan.

Lot size	Sample Size
1 to 13	100 percent
14 to 150	13
151 to 280	20
281 to 500	29
501 to 1,200	34
1,201 to 3,200	42
3,201 to 10,000	50
10,001 to 35,000	60
35,001 to 150,000	74
150,000 to 500,000	90
500,001 and over	102

4.9 Periodic inspection. Periodic inspection shall consist of Group B inspection.

4.9.1 Product level S only. Group B inspections shall consist of the inspections specified in table VI-A in the order shown. Inspection sampling shall be in accordance with table V. Group B inspection shall be made on sample units which have passed group A inspection. Delivery of product shall be delayed pending acceptance of group B inspection for the production lot. The sample shall be representative of the lot with respect to frequency distribution, containing as far as practicable, proportions equivalent to those of the lot.

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

4.9.1.1.1 Noncompliance. If an inspection lot fails to pass group B inspection, the inspection lot shall not be delivered on the contract or purchase order. The manufacturer shall notify the qualifying activity and cognizant inspection activity of the failure and take corrective action on the materials or processes, or both as warranted. A failure analysis shall be performed on the failing product and forwarded to the qualifying activity. A copy of the results shall be maintained by the manufacturer. If three successive lots of any type of crystal unit or three successive lots of a single type of crystal fail quality conformance testing (groups A and B), the qualifying activity shall be notified within 96 hours and the qualifying activity, at its discretion, may remove the failing product from the qualified products list.

4.9.2 Product level B only. Group B inspections shall consist of the inspections specified in table VI. Group B inspections shall be performed on sample units that have passed group A inspections. Every 12 months the tests of subgroup 1 shall be performed on at least 13 units in the order shown. Subgroup 2 tests shall be performed on at least 13 units every 6 months. At the manufacture's option and risk, the same 13 samples may be used for both subgroup 1 and subgroup 2. The aging test shall be performed after moisture resistance and prior to terminal strength testing. No defects are allowed. The contractor shall test representative samples for each type or group (see table VI) for which original qualification was granted. When extension of qualification was used to qualify a broad grouping of types, then periodic inspection may be performed on only one of the groups to remain qualified under retention of qualification. The contractor may also propose alternative style/groupings for approval by the qualifying activity for the group B inspections. The frequency of group B inspections may be reduced as shown in table VI with the approval of the qualifying activity.

4.9.2.1 Disposition of sample units. Sample units subjected to the group B inspections shall not be delivered on contracts. However, if a separate set of sample units have been subjected to subgroup II testing only, then they may be delivered on contracts.

4.9.2.1.1 Noncompliance. If a sample fails to pass group B inspection, the contractor shall notify the qualifying activity of such failure and take corrective action on the materials and processes, or both, as warranted, and on all units of product which can be corrected and which were manufactured under essentially the same conditions, with essentially the same materials, processes, etc., and which are considered subject to the same failure. Acceptance and shipment of the product shall be discontinued until corrective action acceptable to the qualifying activity has been taken.

TABLE V. Group B product level S sampling plan.

LOT SIZE	Sample Size	
	Subgroup I	Subgroup II
1 - 500	21	29
501 -12000	27	34
12001 - 32000	35	42
32000 and over	38	50

TABLE VI. Group B inspection . for product level B crystals

Inspection	Requirement paragraph	Method paragraph
Subgroup I 1/		
Solderability	3.7	4.10.3
Resistance to solvents (4 sample units)	3.8	4.10.4
Shock (specified pulse)	3.17	4.10.13
Vibration	3.19.1	4.10.15.1
Thermal shock	3.23	4.10.19.1
Seal	3.24	4.10.26
Salt atmosphere (corrosion)	3.27	4.10.21
Moisture resistance	3.28	4.10.22
Terminal strength 2/	3.30	4.10.23
Visual and mechanical examination (internal) 2/	3.5, 3.6, 3.35	4.10.2.2
Bond strength (when specified) 2/	3.31	4.10.24
Subgroup II 3/		
Insulation resistance	3.14	4.10.10
Aging	3.29	4.10.27.1

1/ If the contractor can demonstrate that any of these tests have been performed for three consecutive periods with zero failures, the frequency of this test, with the approval of the qualifying activity, can performed every 36 months. If the design, material, construction, or processing of the crystal units change, or if there are any quality problems or failures, the qualifying activity may require resumption of the original test frequency.

2/ Only two units are required. These two sample units shall be subjected to terminal strength, visual and mechanical (internal), and bond strength (when specified see 3.1).

3/ If the contractor can demonstrate that any of these tests have been performed for six consecutive periods with zero failures, the frequency of this test, with the approval of the qualifying activity, can be performed every 36 months. If the design, material, construction, or processing of the crystal units change, or if there are any quality problems or failures, the qualifying activity may require resumption of the original test frequency.

TABLE VI-A. Group B inspection . for product level S crystals.

Subgroup I		
Solderability or lead attachment 1/	3.7	4.10.3
Ceramic package (when applicable)	3.7.1	4.10.3.1
Resistance to solvents (4 sample units)	3.8	4.10.4
Vibration, acceleration, and acoustical noise	3.19	4.10.14
Vibration (Frequency and resistance offset) (when specified)	3.19.1	4.10.14.1
Acceleration sensitivity (vibration) (when specified)	3.19.2	4.10.14.2
Frequency and resistance offset (steady state acceleration) (when specified)	3.19.3	4.10.14.3
Acceleration sensitivity (steady state) (when specified)	3.19.4	4.10.14.4
Acoustical noise (when specified)	3.19.5	4.10.14.5
Thermal shock	3.23	4.10.19.2
Thermal time constant (when specified)	3.25	4.10.20
Frequency overshoot	3.25.1	4.10.20.1
Thermal frequency repeatability (when specified)	3.20	4.10.15
Thermal frequency hysteresis	3.20.1	4.10.15.2
Resistance to soldering heat	3.9	4.10.5
Moisture resistance	3.28	4.10.22
Salt atmosphere (corrosion)	3.27	4.10.21
Particle impact noise detection (PIND) (when specified)	3.21	4.10.16
Terminal strength (two sample units)	3.30	4.10.23
Terminal pull (when applicable)	3.30.1	4.10.23.1
Terminal bend (when applicable)	3.30.2	4.10.23.2
Wire-lead bend (when applicable)	3.30.3	4.10.23.3
Wire-lead twist (when applicable)	3.30.4	4.10.23.4
Visual (internal) 1/	3.5, 3.6, 3.35	4.10.2.2
Subgroup II		
Insulation resistance	3.14	4.10.10
Aging	3.29	4.10.27.3
Radiation hardness	3.32	4.10.28
Total dose (when specified)	3.32.1	4.10.28.1
Dose rate (when specified0	3.32.2	4.10.28.2
Neutrons (when specified)	3.32.3	4.10.28.3
Accumulated time error (when specified)	3.32.4	4.10.28.4

1/ Six sample units other than those from terminal strength.

4.10 Methods of inspection.

4.10.1 General test criteria. The following general test criteria apply, unless otherwise specified, when testing crystal units.

4.10.1.1 Frequency and resistance measurements. For crystal units with long wire-lead terminals, the test point shall be .125 inch ±.0625 inch (3.17 mm ±1.587 mm) from the holder base. The remainder of the lead shall be shielded. For crystal units with metal holders, measurement of frequency or resistance, or both, shall be made with the holder grounded.

4.10.1.1.1 At room or other reference temperature. With the crystal unit operating in the applicable test set (see 3.1 and 4.3.1.3.1) and in thermal equilibrium at the specified reference temperature, the frequency and resistance shall be measured.

a. For crystal units designed for operation under noncontrolled temperature conditions, measurements shall be made with the units in thermal equilibrium at room temperature.

b. For crystal units designed for operation under controlled temperature conditions, measurements shall be made with the units in thermal equilibrium at the reference temperature specified (see 3.1).

4.10.1.2 Measurements before and after a test. When frequency and resistance are measured before and after a test for determining change during the test, both measurements shall be made with the crystal unit in thermal equilibrium at the same temperature ±1°C, and the drive level set at the same practical minimum. Measured changes in frequency and resistance during the test shall not exceed the respective maximum changes specified for the particular test. However, at the minimum drive level, it is not necessary that the unit operate within the overall tolerances for frequency and resistance since a change in drive level does affect the operating characteristics of the crystal, especially its frequency. All crystal units (including those designed for operation at antiresonance) shall be measured at series resonance, R_r.

4.10.1.3 Measurements after test. When frequency and resistance are to be measured after a test to determine compliance with specified tolerances, the measurement shall be made at the specified drive level. For crystal units designed for operation under noncontrolled temperature conditions, measurements shall be made with the units in thermal equilibrium at room temperature. For crystal units designed for operation under controlled temperature conditions, measurements shall be made with the units in thermal equilibrium at the reference temperature. A minimum of 30 minutes for noncontrolled units, and a minimum of 5 minutes for controlled units shall be allowed in order for the units to return to thermal equilibrium before making frequency and resistance measurements.

4.10.1.4 Drive level adjustment. When rated drive level (see 3.1) is specified for a test, it shall be adjusted immediately before each test. No further adjustment shall be made between measurements during a temperature-run test (except in case of line voltage fluctuation or a test lasting longer than an hour).

4.10.2 Visual and mechanical inspection.

4.10.2.1 External. Crystal units shall be examined to verify that the external interface, construction, physical dimensions, marking, and workmanship are in accordance with the applicable requirements (see 3.1, 3.5, 3.6, 3.32, 3.34 and table VII).

4.10.2.1.1 Glass seals. Ten power magnification minimum shall be used to examine the glass parts (see 3.6.1).

4.10.2.1.2 Pin alignment. An applicable pin alignment test gage or shadowgraph shall be used to determine pin alignment (see 3.6.5). When bosses appear on the crystal unit, the gage must be relieved to admit them.

TABLE VII. Defect classification for visual and mechanical inspection (external).

Requirement	Requirement paragraph
Interface, construction and physical dimensions:	
Dimensional tolerances, including pin-diameter and pin spacing tolerances	3.1, 3.5, 3.6
Glass seals, cracks (see 4.10.2.1.1)	3.6.4
Pin alignment (see 4.10.2.1.2)	3.6.5
Marking:	
Incorrect or incomplete information marked	3.33
Incorrect method, size, location, or center of marking	3.33
Workmanship:	
Missing, wrong, or defective parts	3.35
Soldering fluxes and their residues not removed after soldering	3.35
Loose solder or other foreign particles in crystal unit (checked by shaking the unit)	3.35
Burrs and sharp edges not removed from metal parts	3.35
Incorrect mounting of holder cover to base	3.35
Metal corroded	3.35
Metal soiled or dented	3.35

4.10.2.2 Internal. Crystal units, except glass-enclosed, shall be disassembled or if pre-seal is specified, crystal units shall be inspected prior to sealing, and the interior shall be examined to verify that the internal design, construction, and workmanship are in accordance with applicable requirements (see 3.1, 3.5, 3.6, and 3.34). The crystal resonator shall be inspected with a 10X magnification while illuminated. For glass-enclosed crystal units, internal inspection may be performed visually without disassembly. Measurement of wall thickness is not applicable for glass-enclosed crystal units. When internal inspection is required (see table I), two crystal units from each ten sample units of the frequency range for which qualification is sought shall be subjected to the internal inspection specified (see table VIII).

TABLE VIII. Defects for visual and mechanical examination (internal).

Requirement	Requirement paragraph
Interface, construction and physical dimension requirements:	
Unit does not meet requirements	3.1, 3.5, 3.6
Frequency adjustment by abrasion halogen vapor coating, or mechanically applied loading materials	3.6.6
Bond strength does not meet requirement	3.30
Workmanship:	
Cracks or holes in the weld contact area where crystal support members are welded to the holder base terminal pins	3.35
Loose or broken terminal pins or crystal mounting supports	3.35
Cracks or separations in electrically conductive bonding cement between quartz crystal and support member	3.35
Fractures of any size and location in the crystal quartz resonator; or cracked or flaked edges; or fractures, cracks, or peeling of the electrodes.	3.35
Rosin, flux, or loose weld spatter, bonding cement, or other particulate matter	3.35
Less than 0.005 inch clearance between quartz resonator and the package walls	3.35

TABLE VIII. Defects for visual and mechanical examination (internal) - Continued/.

Requirement	Requirement paragraph
Quartz crystal resonator not parallel, or crystal and package wall not perpendicular to crystal holder base within 10°	3.35
Joining of packages by interference, friction, crimping or similar methods unreinforced by welding	3.35
Any surface, including cover, exhibiting contamination, corrosion, adhereing particulate, film, flux residue, fingerprint, or other materials not intended by design	3.35
Adhering weld splatter exceeding 0.03 inch dimension through any plane. Weld splatter shall be considered adherent when it cannot be removed with a 20 psig gas blow of dry, oil-free nitrogen	3.35
Base terminal and crystal mounting support exhibits nicks, misalignment, cuts, cracks, or distortion. Scratches in the plating of the package terminals and deformation of the terminals/supports in the weld area shall be acceptable	3.35
Quartz crystal not centered within +0.030 inch in its mounting with respect to the quartz holder base	3.35
Missing, wrong, or defective parts	3.35

4.10.3 Solderability (see 3.7). Each wire lead terminal shall be subjected to method 208 of MIL-STD-202.

4.10.3.1 Ceramic package (see 3.7.1).

4.10.3.2 Parallel-gap welding or thermocompression bonding. Gold or gold-plated wires or ribbons shall be attached using the specified method (see 3.1). Each wire or ribbon shall be subjected to test condition C, method 2011, or MIL-STD-883.

4.10.3.3 Solderability (lead integrity). If soldering is specified, (see 3.1), a copper wire, 0.25 mm in diameter (AWG #30) shall be soldered to each terminal. Each wire shall be subjected to test condition A and test condition B (flexible leads), method 2004 of MIL-STD-883.

4.10.4 Resistance to solvents (see 3.8). The crystal units shall be tested in accordance with method 215 of MIL-STD-202.

4.10.5 Resistance to soldering heat (see 3.9). Crystal units shall be tested in accordance with method 210 of MIL-STD-202. The following details and exceptions shall apply:

a. Measurement before test: The frequency and resistance shall be measured as specified in 4.10.1.2 and 4.10.18 for product level B and 4.10.1.2 and 4.10.6.1 for product level S.

b. Special preparation of the specimen: Leads shall be dipped in RMA flux in accordance with J-STD-004, and then dipped into solder, both for 5+1/2 seconds. The bath shall be maintained at 260°C +5°C. The parts shall be immersed to within .075+.025 inch of the body.

c. Test condition C (260°C +5°C, 10+2 seconds: Board top side shall reach 200°C minimum). A board with a maximum area of 9 square inches shall be used, and the leads shall not be cut. Crystal units shall be mounted on the circuit board in accordance with IPC-2221 mounting practices.

d. Measurements after test: After completion of the cleaning (isopropyl alcohol only) process and following a minimum 3 hour cooling period, the frequency and resistance shall be measured as specified in 4.10.1.3 and 4.10.18 for product level B and 4.10.1.3 and 4.10.6.1 for product level S.

e. Examination after test: Crystal units shall be examined for evidence of mechanical damage.

4.10.6 Frequency and resistance (see 3.10)(Product level S only).

4.10.6.1 Frequency and resistance versus temperature (static temperature run)(see 3.10.2). The crystal unit shall be measured with the specified series load capacitor (see 3.1) or with an equivalent phase offset described in 4.10.7.2.1 at the specified drive current. The load capacitor shall have a temperature coefficient commensurate with the required accuracy. The temperature shall be varied at the rate specified (or slower) over the range specified. Frequency and resistance data shall be recorded at least as often as specified (see 3.1). In the region of the turnover temperature or inflection temperature, the rate of change of temperature and the data recording interval shall be adjusted as specified. The data shall be analyzed statistically or graphically to determine the required frequencies, temperatures and slopes (see 3.1). Unless otherwise specified, the maximum rate of change of temperature shall not exceed 10°C/minute.

4.10.6.2 Coupled modes (see 3.10.3). The frequency versus temperature data shall be analyzed by determining the best fit to the specified order polynomial (see 4.10.7.2.1). All frequency residuals (see 4.10.7.2.1) shall be less than the value specified. If specified, the resistance versus temperature data shall be analyzed by determining the maximum slope (averaged over a 5°C temperature interval) and the maximum resistance in the temperature range specified (see 3.1).

4.10.6.2.1 Polynomial and residuals.

$$f \text{ versus } T: f(T) : f(T) = f(0°C)\,(1+AT+BT^2+CT^3+DT^4)$$

Frequency residual = f(measured at T) – f(calculated from polynomial at T)

4.10.7 Capacitance .

4.10.7.1 Capacitance, shunt (when specified, see 3.1) (see 3.11.1). Crystal shunt capacitance, C_0, shall be tested in accordance with method 305 of MIL-STD-202. The capacitance shall be measured from terminal to terminal, with the crystal holder ungrounded, at a frequency which is lower than the fundamental frequency of the unit, and at which the unit shows no oscillation response.

4.10.7.2 Capacitance, motional (see 3.11.2) (Product level S only).. The motional capacitance, C_1, is defined in accordance with IEC 60122-1. The load resonant frequency (f_L) is measured using two load capacitances connected successively in series with the crystal unit. The results obtained with two load capacitors C_{L1} and C_{L2} can be combined so that:

$$C_1 = \frac{2\Delta C_L \Delta f_1 \Delta f_2}{f_r \Delta f}$$

where

ΔC_L = $C_{L2} - C_{L1}$
Δf = $f_{L1} - f_{L2}$
Δf_1 = $f_{L1} - f_r$
Δf_2 = $f_{L2} - f_r$
f_r = Resonance frequency

it is necessary to maintain the current through the crystal unit constant to within 10 percent and the frequencies must be corrected for temperature variations during the test, if necessary. The two C_L's shall be chosen such that Δf, Δf_1 and Δf_2 are large enough with respect to the frequency resolution of the measurement system to deliver the required accuracy.

4.10.7.2.1 Phase offset method. An alternate method for determining the value of C_1 is the phase offset method. This method is useful in a transmission or reflection type vector impedance system. The exact implementation is hardware depended. In principle, the frequency is offset an amount, Δf, from resonance and the phase shift is measured. The admittance is calculated and the shunt capacitance of the fixture and the crystal unit is subtracted. The same measurement is performed at $-\Delta f$ from resonance. Using the motional resistance, R_1, the motional reactance at $+\Delta f$ is determined. The motional inductance is calculated from:

$$L_1 = [1/(8\pi f)] [X_1 (\Delta f) - X_1(-\Delta f)]$$

C_1 is calculated from

$$C_1 = \frac{1}{(2\pi f_r)^2 L_1}$$

4.10.8 Quality factor (see 3.12) (Product level S only)... The quality factor, Q, as defined by

$$Q = \frac{1}{2\pi f_r R_1 C_1}$$

Shall be determined using the largest value of R_1 measured in the temperature range specified (see 3.1). R_1 shall be calculated from R_L using the following equation.

$$R_1 = \frac{R_L}{(1 + C_0/C_L)^2}$$

4.10.9 Unwanted modes (fundamental mode or overtone units) (see 3.13). The resistance of any unwanted mode in the frequency range of ±20 percent around the main mode shall exceed two times the main mode resistance when measured at the test drive level.

4.10.10 Insulation resistance (see 3.14). Crystal units shall be measured in accordance with method 302 of MIL-STD-202, using a test potential of 50 to 55 volts. This measurement shall be made from terminal to terminal and from each terminal to the holder case, if the holder is metal.

4.10.11 Drive sensitivity (of frequency and resistance (see 3.15))(Product level S only)... The crystal units shall be conditioned at a temperature of at least 125°C for a duration of at least 1 hour. After conditioning, the units shall be stored at room temperature for 3-6 hours. Measurement of the resonant frequency and resistance shall be made at no fewer than 4 drive levels between 5 microamperes or less and the rated drive level. The levels shall be chosen at nominally equal intervals on a logarithmic scale. The sequence of measurements shall be from lowest drive current to highest drive current. The crystal unit shall not have been operated from the beginning of the conditioning period to the start of the frequency and resistance measurement at the lowest drive level. A drive level 10 dBm above the minimum is allowed to find the response.

4.10.12 Internal gas analysis (see 3.16) (product level S only). Internal water vapor content shall be tested in accordance with MIL-STD-883, method 1018.

4.10.13 Shock (specified pulse) (see 3.17). Crystal units shall be tested in accordance with method 213 of MIL-STD-202. The following details shall apply:

a. For product level B; Test condition C (100G) and for product level S; test condition F (1500G) for T0-5 style packages and test condition E (1000G) for T0-8 style packages.

b. Measurements of frequency and resistance before and after the test shall be made in accordance with 4.10.1.2.

4.10.14 Vibration , acceleraton, and acoustical nose (see 3.19).

4.10.14.1 Vibration (Frequency and resistance offset) (see 3.19.1). Crystal units shall be tested in accordance with MIL-STD-202 using the method specified (see 3.1). The following details and exceptions shall apply:

a. Test method as specified (see 3.1):

Product level B:

(1) Method 201: 2 hours, or

(2) Method 204: Test condition A, 3 hours.

Product level S:

Method 214: Test condition IF for screening and qualification testing and test condition 1K ($\Delta f/f \leq 1$ ppm) for conformance testing.

b. Direction of motion: Specimens shall be rigidly mounted on the horizontal platform of a vibration machine so that the applied vibration shall be as follows:

(1) One-third of the units (to the nearest integral number) shall have the direction of vibration parallel to the pin length.

(2) The second third of units shall have the direction of vibration perpendicular to the largest surface.

(3) The remaining third of the sample units shall have the direction of vibration perpendicular to the pin length and parallel to the largest surface.

c. Time of traverse of frequency range: 1 minute to 2 minutes (Method 201).

d. Measurements of frequency and resistance before and after the test shall be made in accordance with 4.10.1.2.

4.10.14.2 Acceleration sensitivity (vibration) (see 3.19.4) (Product level S only). The crystal unit, operating in an appropriate oscillator or other measurement system, shall be rigidly mounted to the platform of a vibration machine. A sinusoidal vibration shall be applied to the vibration machine at a level not to exceed 20g or the value specified (see 3.1). The frequency of vibration, fv, shall be varied over the frequency range specified (see 3.1) in a logarithmic progression of not fewer than 7 frequencies per decade. At each vibration frequency the relative sideband intensity, i.e., the ratio of the power at the unmodulated signal frequency, shall be determined. The acceleration sensitivity at each vibration frequency, shall be determined from the following:

$$y_i = \frac{2 f_v 10^{(I_i(f_v)/20)}}{a_i v_0}$$

where

y_i = Acceleration sensitivity along axis i (i = 1, 2, or 3)
f_v = Vibration frequency
a_i = Acceleration frequency
v_o = Carrier frequency
$I_i(f_v)$ = Relative sideband intensity (power ration) in dB when the vibration at frequency fv is along the i axis.

The acceleration sensitivity for each ax is the maximum value measured for any vibration frequency in the range specified (see 3.1).

The above procedure is repeated for two other axes such that the three axes are mutually perpendicular. The acceleration sensitivity of the crystal unit shall be determined from the following:

$$|\Gamma| = \sqrt{\gamma_1^2 + \gamma_2^2 + \gamma_3^2}$$

4.10.14.2.1 Mechanical resonance (product level S only). A mechanical resonance is present if there is a peak in the acceleration sensitivity versus vibration frequency curve.

4.10.14.3 Frequency and resistance offset (steady state acceleration) (see 3.19.3) (Product level S only). A steady state acceleration shall be applied at the specified level for the specified duration (see 3.1). Each inspection lot shall be divided such that one-third of the units are being accelerated in one of three mutually perpendicular directions. The frequency and resistance shall be measured before and after exposure in accordance with 4.10.1.2.

4.10.14.4 Acceleration sensitivity (steady state) (see 3.19.4). (Product level S only). The frequency shall be monitored in a suitable oscillator or other test set. The acceleration shall be produced using a centrifuge or similar machine. Measurements shall be made for at least 5 equally spaced acceleration levels between 20 percent of the maximum and the maximum specified. The frequency change per unit g of acceleration shall be determined graphically for all acceleration levels up to the maximum specified (see 3.1).

4.10.14.5 Acoustical noise (see 3.19.5) (Product level S only).. Crystal units shall be tested in accordance with procedure I, method 515, MIL-STD-810. The single sideband ration of the power in a 1 Hz bandwidth to the power in the carrier shall be determined for the frequency range of 10 Hz to 10,000 Hz.

4.10.15 Thermal frequency repeatability (see 3.20) (Product level S only). The crystal unit shall be subjected to the temperature cycle specified in 4.10.15.1. The frequency at each turnover temperature shall be determined using the method of least squares from the data obtained at the five temperatures immediately above and the five temperatures immediately below the turnover temperatures. The difference between the lower turnover frequency and the upper turnover frequency is defined as df.

4.10.15.1 Temperature cycle (Product level S only).

a. Temperature cycle: As specified (see 3.1).

b. Repeat temperature cycle the specified number of times (see 3.1).

4.10.15.2 Thermal frequency hysteresis (see 3.20.1) (Product level S only).

a. Segment 1: The temperature of the crystal unit shall be stepped in increments, not to exceed 5°C, starting from the specified lower temperature limit, T_L, up to the upper temperature limit, T_H. At each step, after thermal equilibrium has been reached, temperature and frequency measurements shall be taken.

b. Segment 2: Step the temperature from T_H to T_L. Take temperature and frequency measurements as in segment 1.

c. Segment 3: Same as segment 1.

d. Segment 4: Same as segment 2.

e. Using a least square fit, determine the coefficients to a fourth order polynomial for segment 1.

f. Calculate four sets of residuals using the data from each segment and the polynomials determined in e above.

g. The thermal frequency hysteresis is 1/2 of the maximum difference among the values obtained by correcting the residuals obtained in f by straight line segments.

4.10.16 Particle impact noise detection (PIND) (see 3.21) (Product level S only). Crystal units shall be tested as specified in method 2020 of MIL-STD-883, test condition A, for one cycle.

4.10.17 Reduced drive level (overtone units, and when specified, fundamental units, see 3.1 or 3.18) (Product level B only). Crystal units shall be tested as specified in 4.10.17.1. This test may be performed as part of the low temperature storage test (see 4.10.18.4).

4.10.17.1 Drive level and resistance. Crystal units shall be tested at a level that is 25 percent of the test drive level or ≤100 microwatts, whichever is less. The crystal units shall not exceed the maximum specified resistance when tested at the reduced drive level.

4.10.18 Frequency and resistance (see 3.22) (Product level B only). Crystal units shall be inserted into the applicable test set and measurements shall be taken under the following conditions as applicable:

4.10.18.1 Operating range (noncontrolled) (see 3.22). Measurements of frequency and resistance of crystal units, designed for operation under noncontrolled temperature conditions, shall be performed at the specific resonance and rated drive level (see 3.1 and 4.10.1.4). The temperature of the crystal unit shall be varied so as to traverse the entire operating range from low temperature to high temperature. For the operating temperature range of -55°C to 105°C, the temperature range shall be traversed for a minimum of 7 minutes unless otherwise specified (see 3.1). For other operating temperature ranges, the time shall be proportional. Measurements of frequency and resistance shall be recorded continuously or at intervals to ascertain that tolerances are not exceeded at any instant. The temperature of the end points shall be accurate to within ±1°C of specified temperatures. The end point frequencies shall be within ±5 percent of the specified overall frequency tolerance when compared to the equilibrium frequency at these end-point temperatures. The temperature run shall be performed automatically from the low temperature to the high temperature. No manual adjustments shall be made to the test setup once the temperature run has begun. The unit shall not be disassembled, and indirect means shall be used for determining the temperature of the resonator. (NOTE: This type of temperature run may cause some distortion of the frequency temperature characteristics).

4.10.18.2 Operating range (controlled) and frequency stability (see 3.22.1). The units shall not be disassembled, and indirect means shall be used for determining the temperature of the resonator. Measurements of frequency and resistance of a crystal unit, designed for operation under controlled temperature conditions, shall be performed at specified resonance (see 3.1) and rated drive levels specified in 4.10.18.2.1 or 4.10.18.2.2.

4.10.18.2.1 Method A - continuous. Measurement shall be taken continuously over the operating temperature range. The rate of temperature change shall not exceed 2°C per minute.

4.10.18.2.2 Method B - incremental. Measurements shall be taken over the operating temperature range at intervals no greater than 2.5°C. These measurements shall include the two extremes as well as the reference temperature, assuring that the resonator has reached thermal equilibrium before each measurement is made.

4.10.18.3 Operable range (controlled) (see 3.22.2). Crystal units designed for operating under controlled temperature conditions shall be subjected to a temperature run over the operable range (see 3.1). The rate of change of temperature shall not exceed 2.5°C per second. The units shall be monitored for continuous oscillation, however, measurements of frequency and resistance are not required.

4.10.18.4 Low temperature storage (see 3.22.3). Crystal units shall be subjected for 2 hours to a temperature equal to or lower than the low end of the operable temperature range specified (see 3.1) and shall be measured with the crystal unit at a temperature no higher than the low end of the operable temperature range. Unless otherwise specified (see 3.1), fundamental mode crystals shall be measured for resistance as specified 4.3.1.3.1 at nominal drive level. Crystals units for which a low drive level test is required (overtone units and fundamental units, when specified (see 3.1)) shall be measured at reduced drive level (see 4.10.17).

4.10.19 Thermal shock.

4.10.19.1 Product level B thermal shock (see 3.23). Crystal units shall be tested in accordance with method 107 of MIL-STD-202. The following details shall apply:

a. Test condition: B (with one-half hour for step 1 and step 3).

b. Wire mounted low frequency crystal units (under 800 kHz) shall have a high ambient temperature of 100°C, +3°C, -0°C for each temperature cycle. Measurements are not required in group A inspection.

c. Measurements of frequency and resistance before and after the test shall be made in accordance with 4.10.1.2.

4.10.19.2 Product level S thermal shock (see 3.23). Crystal units shall be tested in accordance with method 107 of MIL-STD-202. The test condition shall be B-1 for screening and shall be B-2 for qualification and conformance testing.

4.10.20 Thermal time constant (see 3.25) (Product level S only). The crystal unit, in thermal equilibrium at 0°C ±1°C and operating in a suitable test system shall be rapidly (less than 0.5 seconds) immersed in a suitable liquid bath held at 100°C ±1°C and held for at least three minutes. The frequency of the crystal unit shall be recorded every 0.1 second starting at least 10 seconds before insertion into the 100°C bath and ending after the three minute soak. The time required for the frequency to change to its static value (see 3.10.2) at 63°C ±1°C shall be recorded as the thermal time constant. If the frequency crosses the 63°C value more than once, the longest time shall determine the time constant.

4.10.20.1 Frequency overshoot (see 3.25.1). The frequency overshoot shall be defined as:

$$\text{Frequency overshoot} = (f_d - f_s)/f(100°C)$$

Using figures 1 and 2 as a guide and where

$f_d = f_t$ (dynamic) – f(100°C) (dynamic)

$f_s = f_t$ (static) – (f100°C) (static)

and

f_t = turnover frequency

f (100°C) = frequency at 100°C

The static values are obtained from the data taken in support of 4.10.6.1. The dynamic values are obtained from the data taken in support of 4.10.20.

4.10.21 Salt atmosphere (corrosion) (see 3.27). Crystal units shall be tested in accordance with method 101 of MIL-STD-202. The following details shall apply:

a. Test condition: B.

b. Measurements of frequency and resistance after the test shall be measured as specified in 4.10.1.3.

4.10.22 Moisture resistance (see 3.28). Crystal units shall be tested in accordance with method 106 of MIL-STD-202. The following details and exceptions shall apply:

a. Mounting: Normal mounting means, except during measurements.

b. Initial measurements: Not applicable.

c. Subcycle: Step 7b, the vibration subcycle, shall be omitted.

d. Polarization and loading voltage: Not applicable.

e. Final measurement: After drying period, frequency and resistance shall be measured as specified in 4.10.1.3. Insulation resistance shall be measured in accordance with method 302 of MIL-STD-202, using a test potential of 50 volts to 55 volts. This measurement shall be made from pin to pin and from each pin to the holder case..

4.10.23 Terminal strength.

4.10.23.1 Terminal strength (see 3.30.1). Crystal units shall be tested in accordance with method 211 of MIL-STD-202. The following details shall apply:

a. Test condition: A.

b. Applied force: 4 pounds for pin terminals, and 2 pounds for wire-lead terminals, applied to each terminal.

4.10.23.2 Terminal bend (applicable to crystal units with undercut pins) (see 3.30.2). Each terminal shall be subjected to method 211 of MIL-STD-202, test condition B. The following details and exceptions shall apply:

a. Applicable bending tool to be in accordance with figure 3 or equivalent. (Any convenient means may be used for holding the body or base of the crystal unit.) The tool shall engage that segment of the pin-terminals beyond the undercut portion.

b. Number of bending operations: Two (see 3.30.2).

c. The bending cycle shall start with a 15 degree bend ±2 degree bend in one direction, followed by a bend of 30 degrees ±2 degrees in the opposite direction, and completed by a bend of 15 degrees ±2 degrees back to the starting position.

4.10.23.3 Wire-lead bend (applicable to crystal units with wire-lead terminals) (see 3.30.3). Crystal units shall be tested in accordance with method 211 of MIL-STD-202. The following details shall apply:

a. Test condition: C.

b. Applied load: 1 pound.

4.10.23.4 Wire-lead twist (applicable to crystal units with wire-lead terminals) (see 3.30.4) (Product level S only). Crystal units shall be tested in accordance with method 211 of MIL-STD-202, test condition D.

4.10.24 Bond strength (when specified, see 3.1) (see 3.31). The strength of the bond between each wire, ribbon, or other support structure and the quartz resonator shall be tested in shear for "AT" resonators and in tension for resonators below 800 kHz, by gradually applying a force along the support member unit the specified bond strength is reached (see 3.1). The full force shall be applied for not more than 1 minute. Breakage of the quartz resonator, during this test, shall not be construed as bond-strength failure.

4.10.25 Barometric pressure (reduced) (when specified, see 3.26) (Product level S only). Crystal units shall be tested in accordance with method 105 of MIL-STD-202. The following details shall apply:

a. Mounting: Normal means.

b. Test condition letter: Test condition B.

c. Test during subjection to reduced pressure: None.

d. Tests after subjection to reduced pressure: Visual examination, the unit shall be visually examined for evidence of any seal puncture.

4.10.26 Seal (see 3.24). The crystal units shall be subjected to the procedures specified in 4.10.26.1 and 4.10.26.2. Fine leak check shall precede gross leak check.

4.10.26.1 Fine leak check(Product levels B and S). Crystal units shall be tested in accordance with method 112 of MIL-STD-202. The following details apply:

a. Test condition: C

b. Procedure – III: Without tracer gas.
IV: With tracer gas.

c. Leakage rate sensitivity: 1×10^{-8} atm cm^3/s.

4.10.26.2 Gross leak check (Product level S only). Crystal units shall be tested in accordance with method 112 of MIL-STD-202, test condition D, or E.

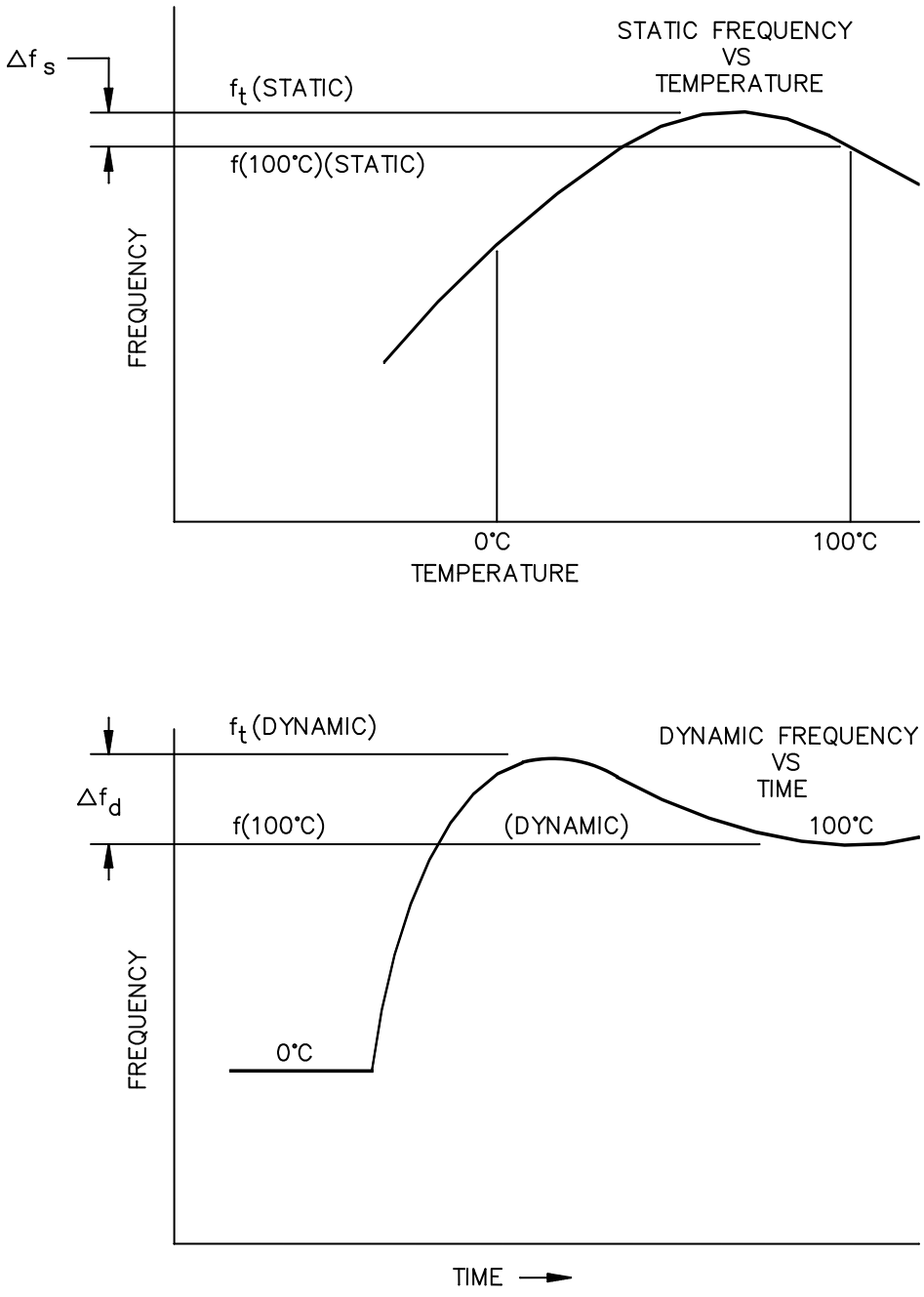


FIGURE 1. Frequency overshoot (upper turnover temperature between 0°C and 100°C.

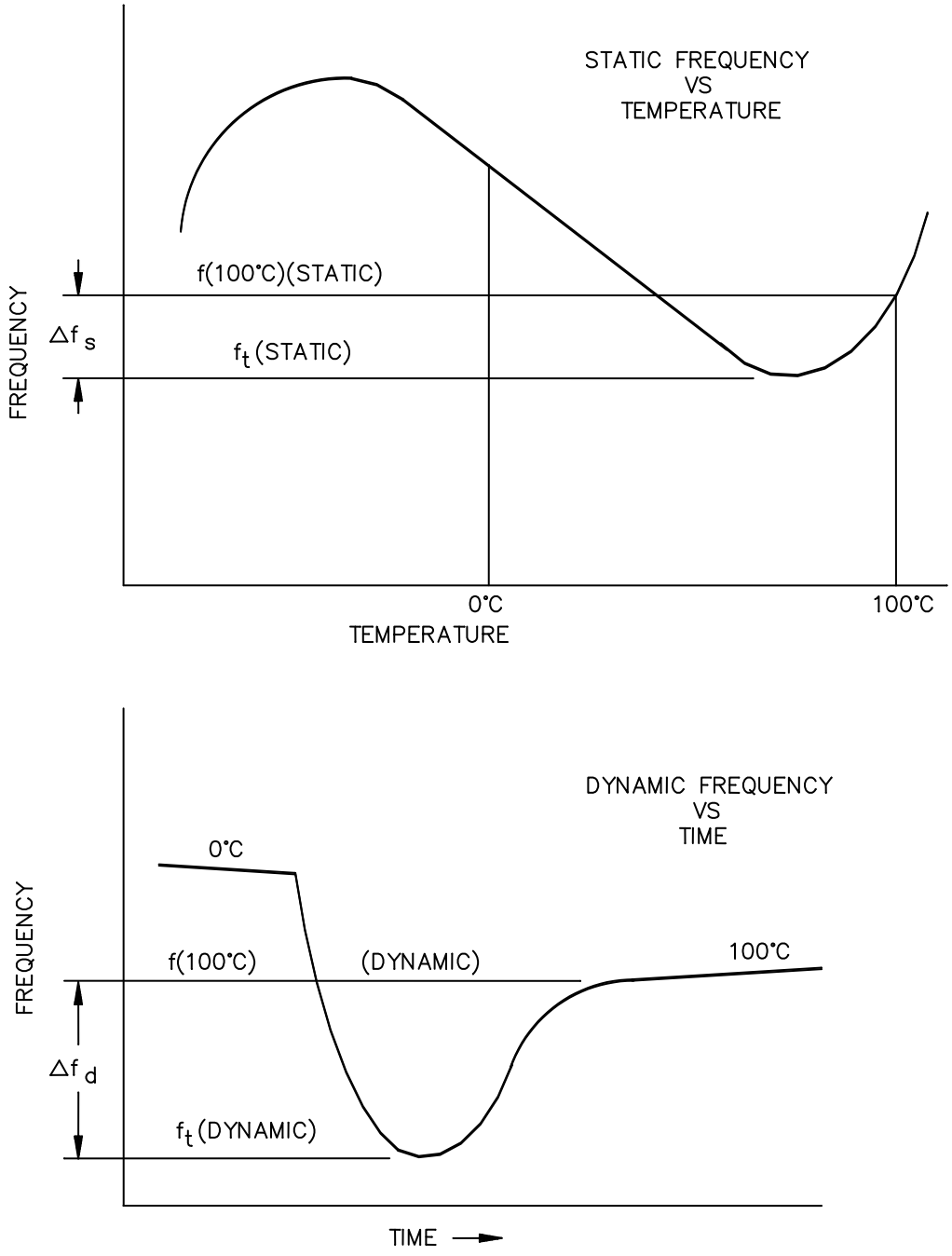
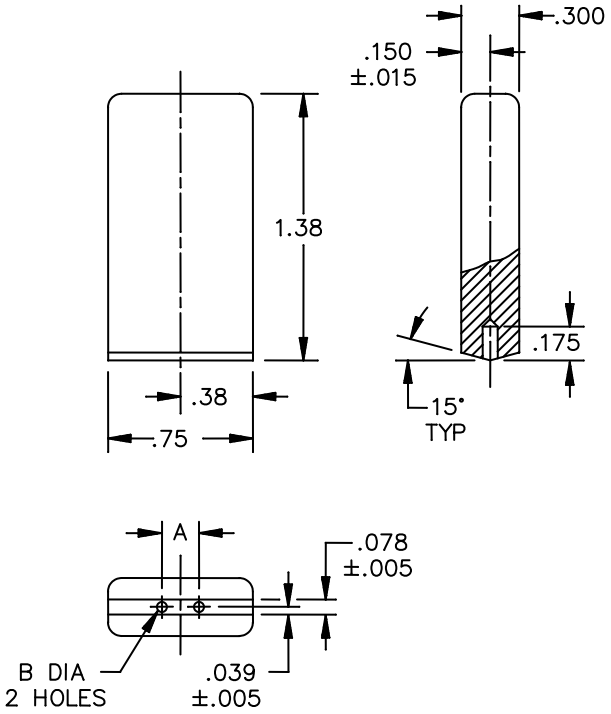


FIGURE 2. Frequency overshoot (lower turnover temperature between 0°C and 100°C; Upper turnover temperature above 100°C.

Nominal pin diameter	A	B
.040	.1920	.0520
.050	.4860	.0630



Inches	mm	Inches	mm
.005	0.13	.150	3.81
.015	0.38	.175	4.44
.039	0.99	.1920	4.877
.040	1.02	.300	7.62
.050	1.27	.38	9.7
.0520	1.321	.4860	12.344
.0630	1.600	.75	19.0
.078	1.98	1.38	35.1

NOTES:
1. Dimensions are in inches.
2. Metric equivalents are given for general information only.
3. Unless otherwise specified, tolerances are ±.02 (0.5 mm), ±.003 (0.08 mm) and ±.0005 (0.013 mm).

FIGURE 3. Tool for terminal bend test.

4.10.27 Aging.

4.10.27.1 Product level B aging (see 3.29). Crystal units shall be maintained at the aging temperature for a continuous period of 30 days as follows:

Crystal type	Aging	Temperature
Noncontrolled	±5 ppm	85°C ±2°C
Controlled	±5 ppm	85°C ±2°C or referenced temperature
Controlled	Less than ±5 ppm	Reference temperature

The frequency shall be measured twice a week at intervals of not less than 2 days nor more than 4 days. The initial measurement of frequency shall be taken at the end of the first 24 hours, and the final measurement at the end of the 30-day test. The difference between the initial aging measurement temperature and subsequent measurement temperatures shall not exceed 0.5°C. All crystal units (including those designed for operation at antiresonance) shall be measured at series resonance, R_r, whenever crystal impedance meters are used (see 4.3.1). When other test oscillators are employed, the crystal unit may be operated above the series-resonant frequency.

The frequency resetability of the test set system shall be 5×10^{-7} for those crystal units which are rated at 5 ppm/month. The frequency resetability for other crystal units shall be as specified (see 3.1). The drive level shall be as specified in 4.10.1.4. The same test set shall be used throughout the test. The crystal unit should remain in the test chamber throughout the test. If a condition brings the temperature of the units below the aging temperature for a time interval of more than 1 hour, no measurement shall be made until 24 hours after temperature restoration, and the 30-day test period shall be lengthened by the length of time the temperature failed.

4.10.27.2 Product level B accelerated aging (see 3.29.1). Crystal units shall be measured for frequency and resistance at room ambient temperature and then conditioned in an oven at 105°C ±3°C for 168 hours minimum. The crystal units shall then be removed from the oven and allowed to stabilize at the same room ambient temperature (±2°C). The crystal units shall then be measured again for frequency and resistance (see 4.10.18). As an alternative, with the approval of the qualifying activity, the contractor may condition the crystal units in an oven at a temperature of 125°C ±3°C for 72 hours minimum.

4.10.27.3 Product level S aging (see 3.29). Crystal units shall be maintained at the specified aging temperature (see 3.1) for a continuous period of 30 days (40 days for qualification testing and conformance testing). Resistance measurements shall be made prior to inserting the crystal units into the oven and after removal from the oven upon completion of the test. After insertion in the oven, the crystal units shall be stabilized for two days at the aging temperature prior to beginning the data acquisition cycle. The time origin for data analysis shall be the beginning of the stabilization period. The frequency of each unit shall be measured immediately after the stabilization period. The frequency of each unit shall be measured a minimum of 4 times per week for 28 days at intervals of at least 20 hours. The data obtained shall be fit using the method of least squares to the function:

$$f(t) = A(\ln(Bt+1))+f_o$$

where f(t) is the frequency of the crystal unit t days after the start of the aging cycle, and A, B, and f_o are constants to be determined from the lease square fit. The calculated frequency f_o is for the beginning of the aging cycle.

If the aging trend is not monotonic, the measurement period shall be extended to 40 days (50 days for qualification testing and conformance testing) after the extremum in the aging trend. For the total aging period of n days, the data for the last 28 days shall be fit to the above function.

The aging rate per day at day n and the total frequency change from day n-30 (n-40 for qualification testing and conformance testing) to day n shall be determined from the equation using the above determined constants. The maximum frequency shift between any two successive data points shall be determined from the original data.

The square root least square fit variance of the data from the function shall not exceed 10 percent of the total aging change allowed during the test period.

4.10.27.4 Product level S accelerated aging (see 3.29.1). Crystal units shall be measured for frequency and resistance (see 4.10.1.2 and then conditioned in an oven at 125°C for 160 hours ± 1 hour. The crystal units shall then be removed from the oven and measured for frequency and resistance in accordance with 4.10.1.2.

4.10.28 Radiation hardness (see 3.32) (product level S only).

4.10.28.1 Total dose (see 3.32.1). Total dose radiation testing shall be performed in accordance with method 1019 of MIL-STD-883. The crystal units shall be subjected to the specified total dose (see 3.1). For total dose levels below 1 mrad, the frequency shall be measured during the irradiation. The temperature of the crystal units shall be maintained at a turnover temperature. For total dose levels and 1 mrad, the frequency shall be measured within four days following irradiation in accordance with 4.10.1.2. the resistance shall be measured in accordance with 4.10.1.2 within four days following irradiation.

4.10.28.2 Dose rate (see 3.32.2). The crystal units shall be subjected to the specified radiation pulse. The frequency shall be measured during the irradiation and for the specified time subsequent to irradiation. The temperature of the crystal units shall be maintained at a turnover temperature during the test.

4.10.28.3 Neutrons (see 3.32.3). The crystal units shall be subjected to the specified neutron fluence. The frequency shall be measured during irradiation. The temperature of the crystal unit shall be maintained at a turnover temperature during the test. The resistance shall be measured in accordance with 4.10.1.2. The frequency change due to any incidental non-neutron irradiation shall be properly accounted for.

4.10.28.4 Accumulated time error (see 3.32.4). The crystal unit shall be subjected to the specified total dose at the specified does rate. The time integral of the radiation-induced frequency offset, for the specified time interval (see 3.1), shall be determined.

5. PACKAGING

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

6. NOTES

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

6.1 Intended use. These crystal units are intended for use in military equipment systems and space systems for frequency control.

6.2 Acquisition requirements. Acquisition documents must specify the following:

a. Title, number, date of the specification, the applicable specification sheet, and the complete PIN (see 1.2 and 3.1).

b. The specific issue of individual documents referenced, if required. If not otherwise specified, the versions of the individual documents referenced will be those in effect on the date of release of the solicitation (see 2.2 and 2.3).

c. Packaging requirements (see 5.1).

6.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in the Qualified Products List (QPL) whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or purchase orders for the products covered by this specification. The activity responsible for the Qualified Products List is Communications-Electronics RDEC ATTN: RDER-PRQ-QE Fort Monmouth, NJ 07703-5201; however, Information pertaining to qualification of products may be obtained from the Defense Supply Center Columbus (DLA Land and Maritime-VQH), P.O. Box 3990, Columbus, OH 43218-3990 or by email at vqh.jre@dla.mil.

6.4 Definitions. The following definitions apply:

6.4.1 Crystal unit. A crystal unit is an assembly that consists of a quartz resonator (quartz blank plus electrodes) suitably mounted within a crystal holder.

6.4.2 Crystal holder. A crystal holder is the sealed enclosure in which a quartz resonator is mounted; it includes a cover or covers, a base or frame with suitably insulated pins or terminals and some means for closure. Designation of a holder does not designate the mounting structure for the resonator.

6.4.3 Frequency range. The frequency range of a crystal unit type is the range from minimum to maximum in which any frequency within this range may be specified.

6.4.4 Nominal frequency (fnominal). The nominal frequency is the frequency at which the crystal unit is designed to operate under the conditions specified by the specification sheet.

6.4.4.1 Resonance frequency (fr). The lower of the two frequencies of the crystal unit alone, under specified conditions, at which the electrical impedance of the crystal unit is resistive.

6.4.4.2 Antiresonance frequency (fa). The higher of the two frequencies of a crystal unit alone, under specified conditions, at which the electrical impedance of the crystal unit is resistive. This frequency is not normally used in frequency control applications.

6.4.4.3 Load resonance frequency (fL). The lower of the two frequencies of a crystal unit in combination with a series load capacitor, under specified conditions, at which the electrical impedance of the crystal unit and capacitor is resistive. The value of fL is related to fr by the following expression:

$$fL = fr + (fr/2)\ (C1/(Co+CL))$$

where

C1 is the motional capacitance
CL is the load capacitor
Co is the crystal unit shunt capacitance

6.4.5 Resistance.

6.4.5.1 Resonance resistance (Rr). The resistance of the crystal unit alone at the resonant frequency, fr.

6.4.5.2 Load resonance resistance (RL). The resistance of the crystal unit in combination with a series load capacitor at the load resonance frequency, fL. The value of RL is related to the value of Rr by the following expression:

$$RL = Rr(1+Co/CL)2$$

6.4.6 Frequency tolerances.

6.4.6.1 Overall tolerance. The maximum allowed deviation of the frequency (fr or fL as specified) from nominal frequency due to all specified causes. All environmental and electrical conditions must be specified as well as the time duration for which the tolerance is defined.

6.4.6.2 Aging tolerance. The permissible deviation due to time under specified conditions. The frequency change per unit of time (aging rate) under constant environmental conditions is, in general, not a constant. Therefore, extrapolation of aging must be performed with care, taking environmental changes into account.

6.4.7 Drive level. A measure of the electrical excitation of the crystal unit expressed in terms of the current through the device at a resonant frequency.

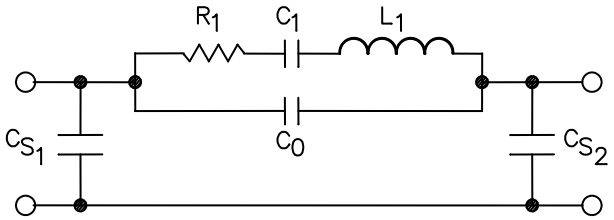
NOTE: Older specifications state the level of drive is the power dissipated by a calibration resistor.

6.4.8 Unwanted mode. A resonance of a crystal unit other than that associated with the nominal frequency. It should be noted that all crystal cuts have unavoidable modes of response. These modes must be considered when specifying the limit level of unwanted modes.

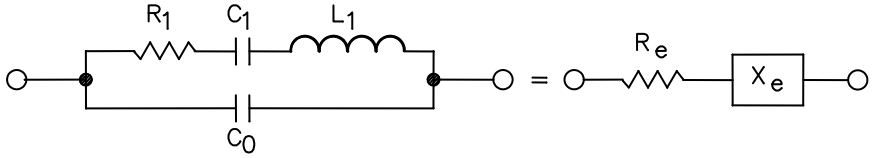
6.4.9 Coupled modes (frequency – resistance anomalies). Deviations from a normal frequency versus temperature characteristic. These deviations may be due to unwanted modes of vibration coupling to the desired mode, or they may be due to some processing or fabrication defect. The effect of coupled modes can generally be reduced by a reduction of crystal drive.

6.4.10 Equivalent circuits.

6.4.10.1 Three terminal equivalent circuit.

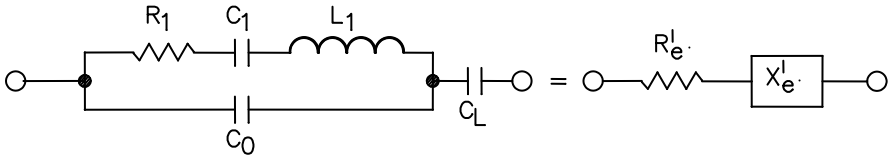


6.4.10.2 Two terminal equivalent circuit.



When f = fr, Re = Rr, Xe = 0

6.4.10.3 Two terminal equivalent circuit with series load capacitor.



When f = fL, Rle = RL, Xle = 0

6.4.10.4 Shunt capacitance. Co is the capacitance between the two terminals of the resonator (see IEC 60122-1).

6.4.10.5 Motional capacitance. The motional capacitance is C1 (see IEC 60122-1).

6.4.10.6 Stray capacitance. CS1 and CS2 are the stray capacitances of each terminal to the package.

6.4.11 Thickness shear resonator. A crystal unit using a thickness shear mode of motion of the quartz resonator.

6.5 Subject term (keyword) listing.

Aging
Coupled modes
Drive level
Drive sensitivity
Frequency range
Frequency tolerance
Motional capacitance
Resonance frequency
Resonance resistance
Shunt capacitance
Thickness shear resonator
Unwanted modes

6.6 International standardization agreement. Certain provisions of this specification are the subject of international standardization agreement, NATO NEPR 39. When amendment, revision, or cancellation of this specification is proposed, which will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.

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

6.8 Filling and sealing. Previous experience on these types of products has shown that filling and sealing the crystal unit as described herein has allowed the crystal to meet the performance requirements of this specification. Crystal units can be evacuated, filled with a mixture of 90 percent dry nitrogen and 10 percent dry helium, and sealed. This evacuation, filling, and seal process should be completed in an appropriate chamber. This chamber should be evacuated to an absolute pressure of not greater than 1 torr prior to filling and sealing. The dew point of the gas should be -55°C or lower.

6.9 Environmentally preferable material. Environmentally preferable materials should be used to the maximum extent possible to meet the requirements of this specification. As of the dating of this document, the U.S. Environmentally Protection Agency (EPA) is focusing efforts on reducing 31 priority chemicals. The list of chemicals and additional information is available on their website at http://www.epa.gov/osw/hazard/wastemin/priority.htm. Included in the list of 31 priority chemicals are cadmium, lead, and mercury. Use of the materials on the list should be minimized or eliminated unless needed to meet the requirements specified herein (see section 3).

6.10 Amendment notations. The margins of this specification are marked with vertical lines to indicate modifications generated by this amendment. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations.

APPENDIX A

PROCEDURE FOR QUALIFICATION INSPECTION

A.1 SCOPE

A.1.1 Scope. This specification covers the procedures for submitting samples of crystal units for qualification inspection by this specification. This appendix is a mandatory part of this specification. The information contained herein is intended for compliance only.

A.2 APPLICABLE DOCUMENTS. This section is not applicable to this appendix.

A.3 SUBMISSION

A.3.1 Sample. Sampling for qualification shall be as follows:

a. Sample for product level B crystals. Unless otherwise specified, 30 sample units of each crystal type, except for grouping permitted in table IX (or other groupings approved by the qualifying activity) shall be submitted. If it is desired to qualify for a limited frequency band within the crystal unit range, 30 sample units shall be required in the band. Ten of the 30 unit group shall be at the lower end, 10 near the middle, and 10 at the upper end of the frequency range over which qualification is sought. A single frequency crystal unit may be qualified upon submission of 10 samples at the desired frequency. No failures are permitted.

b. Sample for product level S crystals. Unless otherwise specified, 45 sample units of each crystal type, except for grouping permitted in table IX (or other groupings approved by the qualifying activity) shall be submitted. If it is desired to qualify for a limited frequency band within the crystal unit range, 45 sample units shall be required in the band. Ten of the 45 unit group shall be at the lower end, 15 near the middle, and 15 at the upper end of the frequency range over which qualification is sought. A single frequency crystal unit may be qualified upon submission of 15 samples at the desired frequency. No failures are permitted.

A.3.2 Certification of material. When submitting samples for qualification, the contractor shall submit certification that the materials used in the components are in accordance with the applicable specification requirements.

A.4 EXTENT OF QUALIFICATION

A.4.1 Extent of qualification. Extent of qualification shall be as follows:

a. Qualification obtained for one group type crystal shall be the basis for extending qualification to other crystal unit groups as identified in table IX. The contractor has the option of proposing alternative groupings for approval by the qualifying activity.

b. Extension of qualification will usually be restricted to the frequency range of the group originally qualified. The contractor may request approval for a greater frequency range band than that qualified provided additional data is submitted demonstrating the contractor's capability to manufacture these units. Data from tests similar to the group A electrical tests, seal test, and visual and mechanical test may be the basis for approval by the qualifying activity.

c. Extension of qualification shall be restricted to the same manufacturing facility, using the same or similar manufacturing processing and materials.

TABLE IX. Grouping for qualification. 1/

Group number 2/ 3/	Crystal unit types 2/ 4/
2	CR37/U†
2A	CR42/U
3	CR45/U†
5	CR63/U†, CR46/U, CR25/U
5A	CR104/U, CR47/U, CR26/U
7	CR69/U†, CR78/U, CR64/U, CR79/U, CR97/U
7A	CR60/U, CR106/U, CR139/U
8	CR85/U†, CR130/U, CR125/U, CR119/U, CR18/U, CR58/U, CR19/U, CR157/U, CR89/U, CR6/U, CR5/U, CR8/U,
8A	CR62/U, CR36/U, CR27/U, CR35/U, CR28/U, CR131/U
9	CR1/U†, CR91/U, CR96/U, CR95/U
10	CR114/U†, CR124/U
11	CR112/U†, CR134/U, CR136/U, CR129/U, CR137/U
11A	CR135/U, CR109/U
12	CR148/U†, CR52/U
12A	CR65/U
13	CR152/U†, CR76/U, CR77/U, CR67/U, CR117/U, CR55/U, CR72/U, CR81/U
13A	CR84/U, CR61/U
14	CR111/U†, CR128/U
14A	CR113/U
15	CR54/U†
15A	CR75/U
16	CR80/U†, CR83/U, CR141/U, CR56/U, CR82/U
16A	CR59/U
17	CR116/U†, CR105/U, CR110/U, CR149/U, CR98/U, CR151/U, CR107/U
17A	CR123/U, CR122/U
18A	CR74/U, CR108/U
19	CR159/U, CR165/U
These crystal units must be individually qualified (unless an alternative plan is approved by the qualifying activity)	CR33/U, CR71/U, CR73/U, CR101/U, CR102/U, CR103/U, CR127/U, CR142/U, CR150/U

1/ See 40.1.
2/ The pair of groups (e.g., 2 and 2A) may be qualified by a single set of samples for each pair, provided: (1) The samples are for the type indicated by the symbol "†", and (2) The samples are tested for and successfully pass the temperature-run test over the operating range for the controlled types. As an alternative procedure, when one group of noncontrolled crystal unit have been qualified, a separate set of samples may be submitted for the leading item of the bracketed controlled group in the event only the temperature-run test need be performed.
3/ Some group numbers have been omitted due to the cancellation of some crystal unit types.
4/ Qualification of one crystal unit type constitutes qualification of all others of the same group that follow it in the group listing.

Custodians:
Army - CR
Navy - EC
Air Force - 99
DLA - CC

Review activities:
Army - AR, MI, SM
Navy - AS, CG, MC, OS, SH
Air Force - 19, 84
NASA - NA

Preparing activity:
Army - CR

Agent:
DLA - CC

(Project 5955-2011-019)

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