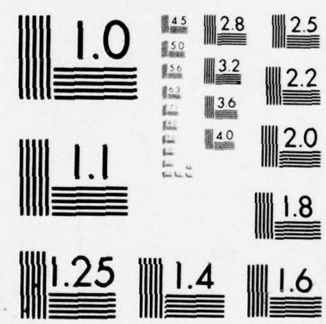
AD-A053 582 GENERAL ELECTRIC CO ST PETERSBURG FL NEUTRON DEVICES DEPT F/G 9/1
QUARTZ CRYSTAL FABRICATION FACILITY.(U)
NOV 77 J M FRANK, R J NEY
UNCLASSIFIED GEPP-309 NL

1 OF 1
AD
A053582

END
DATE
FILMED
6-78
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
ECOM-HH610964CPW3/01-A

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
(6) Quartz Crystal Fabrication Facility.

5. TYPE OF REPORT & PERIOD COVERED
First Semiannual
October 1, 1976-March 31, 1977

6. PERFORMING ORG. REPORT NUMBER
(14) GEPP-309

7. AUTHOR(s)
(10) J. M. Frank
R. J. Ney

8. CONTRACT OR GRANT NUMBER(s)
Project Order No.
HH610964CPW3/01

9. PERFORMING ORGANIZATION NAME AND ADDRESS
General Electric Company
Neutron Devices Department
P. O. Box 11508
St. Petersburg, Florida 33733

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
DA 2769754

11. CONTROLLING OFFICE NAME AND ADDRESS
United States Army Electronics Command
Fort Monmouth, New Jersey 07703
DRSEL-PP-I-PI-1

12. REPORT DATE
(11) Nov[redacted]77

13. NUMBER OF PAGES
(12) 44p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(9) Semiannual rept. no. 1, 1 Oct 76-31 Mar 77,

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

DDC
RECEIVED
MAY 4 1978
B

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
Approved for public release; distribution unlimited.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Quartz crystal units, quartz crystal unit processing, oil-free vacuum system, cryogenic vacuum system, plating of quartz crystal units, sealing of quartz crystal units, gold evaporant source, nozzle beam gold evaporant source, cleaning of quartz crystal units, vacuum manipulator, frequency control device processing.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The specification objectives for a high production, in line, ultrahigh vacuum, precision crystal unit final processing system now being constructed are reviewed. Design features of the system including methods for ultraviolet cleaning, bakeout, plating and sealing of crystal units having ceramic flat pack enclosures in an oil-free, cryogenic vacuum system are outlined. Entrance and exit air lock chambers and transports provide means to maintain the critical process chambers at high vacuum continuously. Experimentation to develop and prove several process modules → over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED 391 470

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (continued)

being incorporated into the final system is described and initial results reported. Emphasis is placed on simplicity of design, operational reliability, modular interchangeability, cleanliness, and future automation aspects.

CONTENTS

ILLUSTRATIONS

TABLES

PURPOSE

The purpose of this program is the realization of a specialized vacuum system for use in the production of high precision crystal units for military use. This program is funded by the U. S. Army Electronics Command (ERADCOM), Fort Monmouth, New Jersey, and is being performed by the Neutron Devices Department of the General Electric Company, located at St. Petersburg, Florida, a contractor of the U. S. Department of Energy.

This contract, HH610964CPW3/01, is a two-year effort and is scheduled for completion in the fall of 1978. The vacuum system will provide for the final processing of crystal units in ceramic flat pack enclosures without exposure to atmospheric contamination. Cleaning, bakeout, plating and sealing processes are included. The feasibility of the ceramic flat pack enclosure and associated processing has been demonstrated by the Frequency Control Devices Team at ERADCOM through work in their laboratory and in conjunction with contractors.

A vacuum system production goal of 200 units per 8-hour shift has been established by ERADCOM. It is anticipated that future contracts will provide facilities for preassembly and final testing of the flat pack units and a pilot production facility will then exist.

INTRODUCTION

The causes of aging and thermal hysteresis in quartz resonators are reasonably well understood.[1] It has been shown that quartz resonator unit enclosure materials as well as final crystal processing techniques influence aging. The development of low permeation ceramic enclosures and sealing techniques is being carried out, under separate contracts, to provide perhaps an optimum enclosure concept for precision, low aging, high shock resonators.[2,3] Significant improvements in final processing techniques are being developed. These techniques include the use of ultraviolet cleaning of piece parts in an ozone atmosphere to remove surface contaminants,[4] simultaneous deposition of electrode metal, such as gold, on each side of a resonator to reduce aging due to stress relaxation, and bakeout and sealing of resonator assemblies in an oil-free, ultrahigh vacuum environment.

This report describes the initial work being carried out to define, design, construct, prove, and demonstrate a vacuum system for final processing of ceramic flat pack enclosed quartz resonators. The system is planned for use in the production of crystal units for more critical military applications.

CERAMIC FLAT PACK CRYSTAL UNIT

Design and processing details of ceramic flat pack enclosed precision crystal units were most recently reviewed at the 30th Symposium on Frequency Control (1976).[3] A typical flat pack enclosure, as shown in Figure 1, includes a square ceramic frame and identical top and bottom ceramic covers. The ceramic is 95 percent alumina and the enclosures can be vacuum fired to 800°C without damage. Each frame has two gold plated, tungsten metallized electrical feedthroughs to accommodate external connection and mounting of the crystal support structure. Resonator support is accomplished using thin nickel clips that are thermo-compression bonded to a metallized ledge of the ceramic frame.

The "window frame" style of the mounted resonator allows for simultaneous electroding from both sides, a feature of the final processing vacuum system. Figure 1 illustrates the mounting technique and appearance of the crystal-frame assembly as it will enter the final processing system. The seal surfaces of both the frame and the cover are plated gold over a metallized layer composed of molybdenum, manganese and titanium hydride. The final seal incorporates a gold gasket between the seal surfaces. Since the entire crystal assembly can easily withstand bakeout in vacuum up to 325°C, and as all surfaces have been further cleaned by exposure to ultraviolet light in a partial pressure of oxygen, the seal surfaces are exceedingly free of contaminants and the seal can be affected by modest use of force and temperature.

The advantages of the ceramic flat pack enclosure are that only materials of low gas permeation and solubility are used, and that the final processing temperature is limited by the quartz rather than the packaging material. Precision crystal units incorporating these features are being developed for use in the REMBASS program.

VACUUM SYSTEM DESIGN OBJECTIVES

The system is intended to meet the requirements of SCS-512, Electronics Command Technical Requirements for Shock Resistant Crystal Units, dated 23 October 1975, Paragraph 3.20.8 which states, "The last four processing operations: cleaning, bake-out, plating, and sealing shall be performed without exposure of the vacuum system and crystal unit components to contaminating atmosphere between operations...oil free pumps shall be used...all backfilling shall be with pure dry gases or gas mixtures...appropriate steps shall be taken to prevent dirt, loose

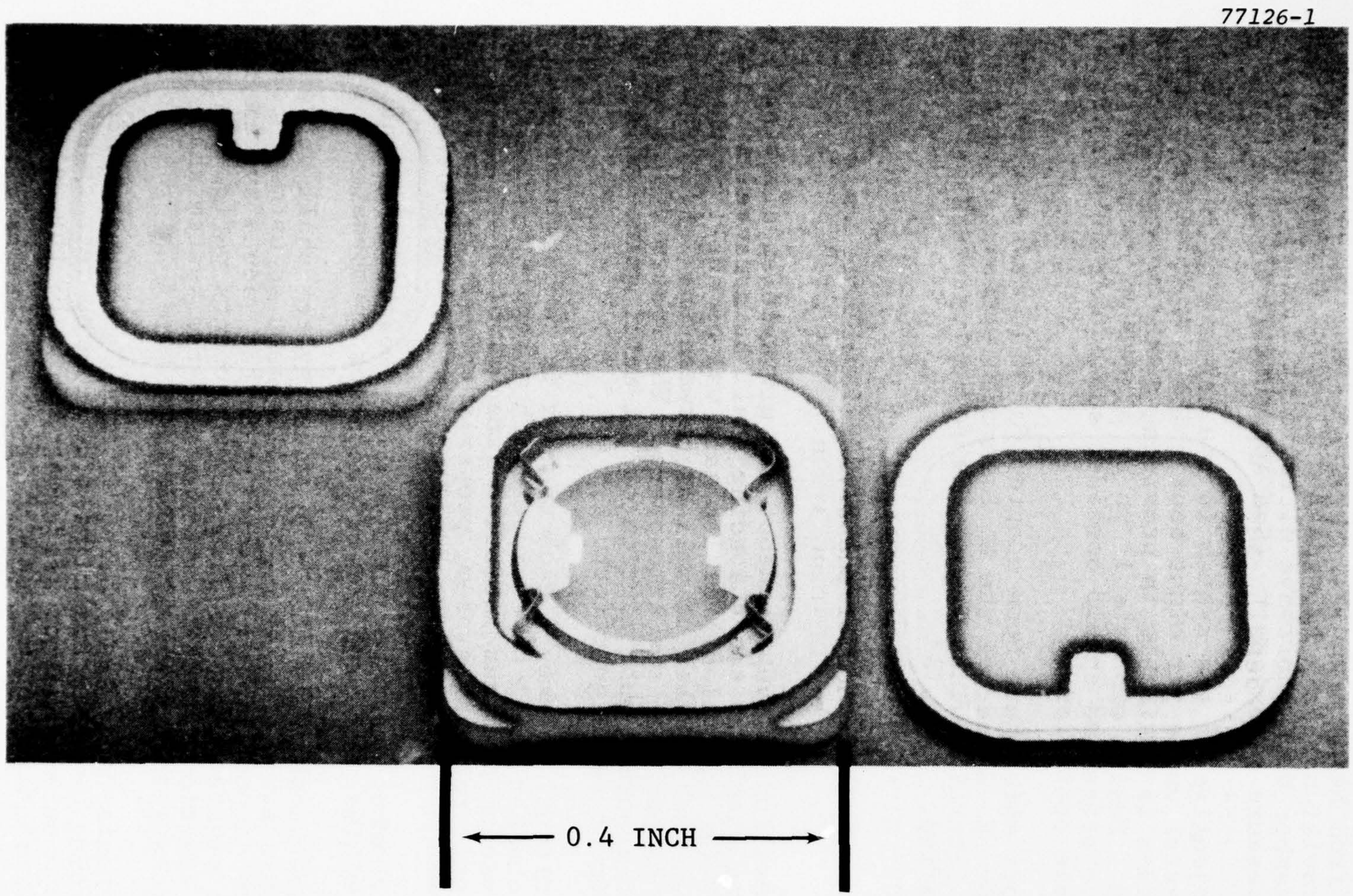


Figure 1. Typical Ceramic Flat Pack Crystal Unit

particles from being present...chambers shall be bakeable to 250°C...provisions shall be made for flooding the entire inside of each chamber with shortwave ultraviolet radiation in a partial pressure of oxygen." (See Appendix.)

A prime objective of the system is the capability to process up to 200 crystal units per eight-hour shift. A production rate of this order is desirable in providing industry acceptance of the method. Design emphasis is to be placed on reliability and ease of operation and should consider subsequent automation of all feasible operations.

The concepts which have been adopted for this system were outlined by Dr. E. Hafner of the U. S. Army Electronics Command, Frequency Control Devices Team. The following design principles were specified.

VACUUM SYSTEM DESIGN PRINCIPLES

1. Chambers for loading, bakeout and ultraviolet cleaning, plating, sealing, and unloading shall be arranged in line. Viton* (or equivalent) sealed gate valves shall be used between each chamber as well as between the load and unload chambers and the atmosphere. The system design is to permit eventual substitution of all-metal valves with a minimum of redesign effort.

2. The internal volume of each chamber is to be minimized. Each chamber shall be equipped with a separate cryogenic high vacuum pump and isolation gate valve(s). A common cryogenic roughing system, properly valved, is permitted. Ultimate system pressure shall be 1×10^{-8} Torr or less.

3. Each chamber shall be individually removable from the system with minimal perturbation of the other chambers.

4. All subassemblies within the vacuum system shall be designed as replaceable modular units. Alignment adjustment tolerances among the modules or within the vacuum system shall be no tighter than 0.040 inch. Components performing similar functions in different parts of the system shall be interchangeable wherever possible.

5. Components and subassemblies expected to require frequent servicing or replacement shall be mounted retractably through gate valves or be transportable by the main transport mechanism of the vacuum system.

---

*Trademark, E. I. du Pont de Nemours & Co.

6. Trays used for piece part transport through the system shall be designed for minimum surface area and thermal capacity.

7. Frequency plating shall be done in two steps, with final plating following base plating with minimum delay.

DESIGN IMPLEMENTATION

As of the end of this report period, all vacuum system and process hardware design approaches have been worked out. Experimental work, where warranted, and design detailing of many items are being carried out.

VACUUM SYSTEM ENVELOPE

The vacuum system envelope has been defined as circular chambers of 304 L stainless steel pipe. The individual sections are located in line and along a common transport centerline. Minimal diameters and standard lengths have been maintained as a design goal.

Figure 2 is an isometric plan of the system. Table 1 lists the fabrication facility dimensions. Total system length is about 24 feet. Each chamber is terminated with a standard 6-inch Conflat* flange which mates directly to 6-inch gate valves, which are being specified. The system volume is about 6 cubic feet, exclusive of appendages.

RESONATOR TRAY CARRIER

Resonator piece parts which are ready for processing in the vacuum system consist of the "window frame" crystal-frame assembly and two covers, each having a gold gasket bonded to the seal surface. Assemblies are loaded into a stainless steel tray, on edge, in a cover-frame-cover sequence. A tray test model is shown in Figure 3. The tray is being designed to accept up to 20 sets of parts that are maintained in a vertical attitude and spaced by lateral ribbon springs in the tray side rails.

Partly or fully loaded trays are introduced into the entrance chamber and engaged with the tray transport (Figure 4). The overall system will use six transports of identical construction.

---

*Trademark, Varian Associates

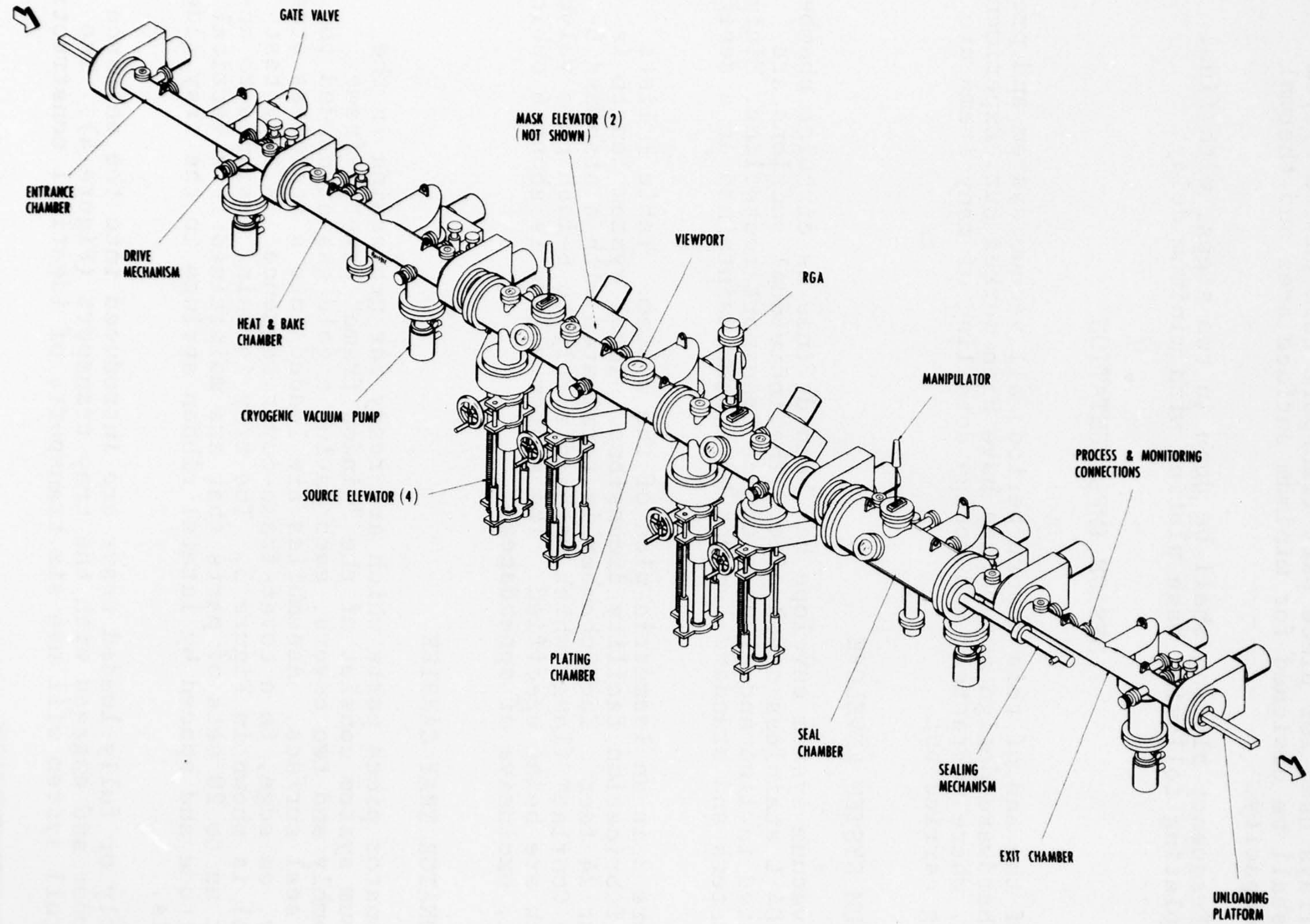


Figure 2. Quartz Crystal Fabrication Facility

Table 1. Fabrication Facility Dimensions

Chamber (Ref. Figure 2)	O.D. (Inches)	Length (Inches)
Entrance	4	40
Heat & Bake	6	40
Plating	8	84
Seal	10	40
Exit	4	40

7793-3

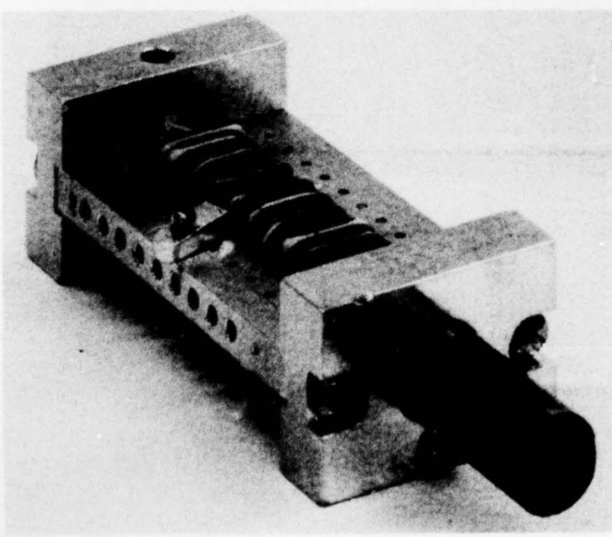


Figure 3. Enclosure Parts in Tray

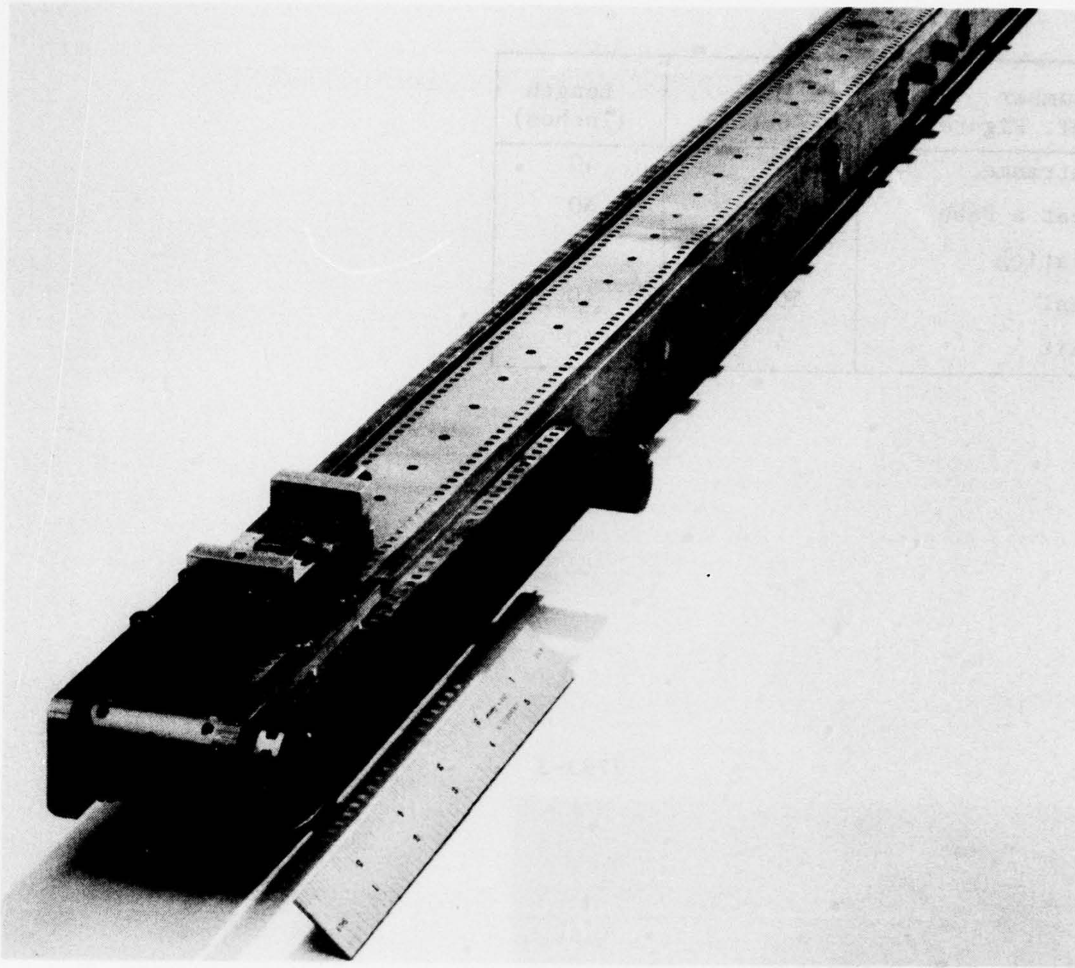


Figure 4. Tray Transport

Tray design is based on part configuration as well as requirements for cleaning, plating and sealing. As each tray moves along the six transports of the system, the crystal units are cleaned (bakeout and ultraviolet exposure), plated from two sides, and diffusion bond sealed.

Separation of flat pack parts on the tray is to accommodate equable ultraviolet light exposure and to provide high conductance outgassing pathways. The isolated vertical attitude of the flat pack frame is advantageous at the plating step to allow frame extraction from and return to the tray in separate fixturing during plating. As will be later described, a vacuum manipulator is used to extract the frames from, and return them to, the tray.

Tray mass and surface area are minimized to reduce gas load and to permit rapid heat-up and cool-down of piece parts. The lateral spring separators in the tray side rails permit use of the trays directly in the sealing fixture. As will be described later, a movable ram enters the slot provided at each tray end and causes each cover and frame in turn to be moved toward a reaction ram. All parts are brought in contact with one another just prior to application of sealing force.

TRAY TRANSPORT

A standard transport design has been adopted (Figure 4). Six transports of identical construction are used to move the part trays along a given chamber and across the gate valves between chambers. Each transport consists of a 0.002-inch thick stainless steel endless belt which has the format of 35-mm film. Belt drive and support is via stainless steel, 35-mm sprocket wheels that are affixed to solid side rails using molybdenum-disulfide coated ball bearings. A separate narrow belt drives an end sprocket using a magnetically-coupled feedthrough from outside the vacuum wall. These belts are also coated on both sides with molybdenum disulfide as a vacuum lubricant. Holes positioned along the center line of the belt engage pins extending below each part tray.

All system transports are located on a common center line. Vacuum chamber center lines are each offset from the transport center line as constrained by other limitations.

VACUUM MANIPULATOR

Precision part manipulation within a vacuum system has always been a difficult problem. The design concepts for this system have been chosen to minimize the amount and precision of part movement.

There are three process steps, however, which will require through-wall manipulation. At each of the two plating steps the vacuum manipulator, Figure 5, must grasp a frame, remove it from a tray, and position the frame in a plating mask. When plating is complete, the manipulator returns the frame to a tray and grasps the next frame. At the sealing step a vacuum manipulator is required to lift the tray from the transport and position the tray in the sealing fixture. After sealing, the tray is returned to the transport for exit through the exit chamber.

7793-2

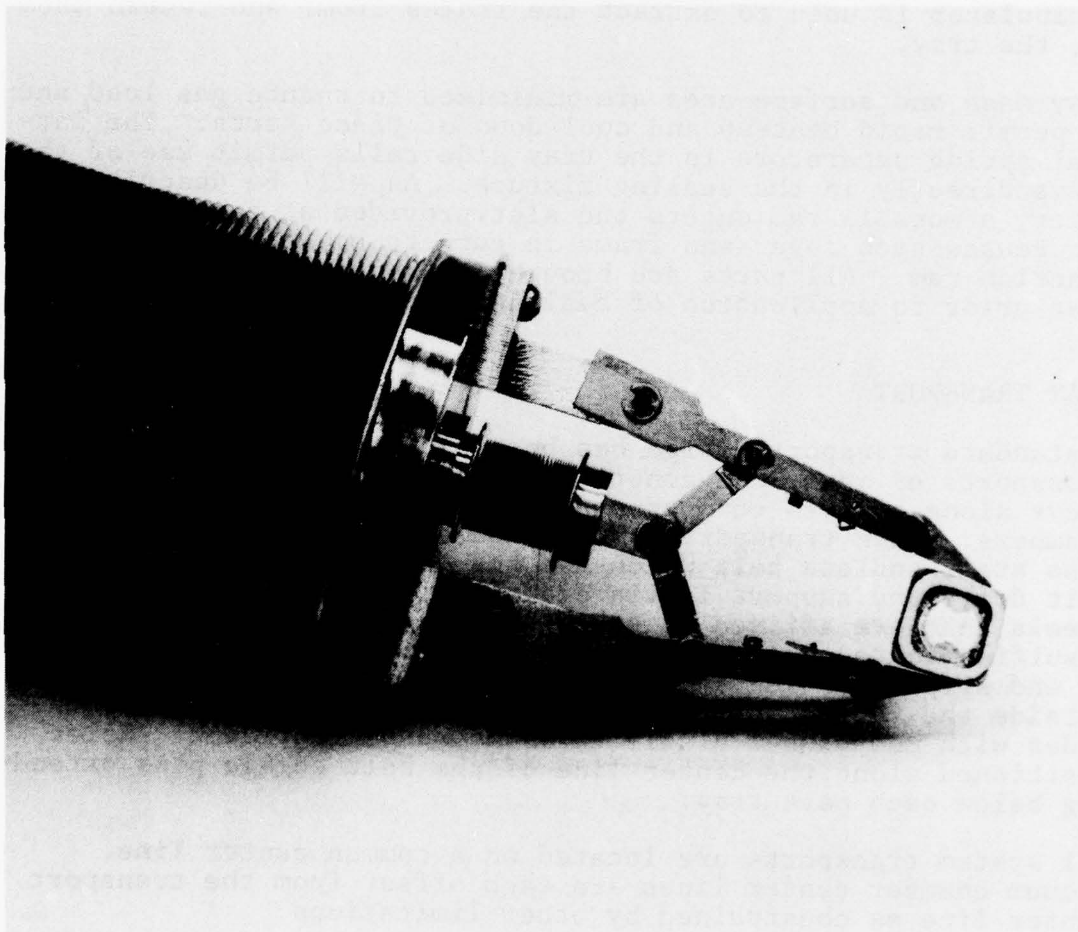


Figure 5. Vacuum Manipulator With Frame Assembly

Vacuum manipulator design features three welded metal bellows to provide three separate movements. The large bellows, in conjunction with a ball and socket, provides up to 30° off-axis movement. The intermediate size bellows provides up to 4-inch axial travel, while the small bellows provides the grasping motion to the forceps. A model manipulator module is shown in Figure 6.

The manipulator is designed to mate with a standard 4-inch Conflat flange. The chamber between the ball/socket and the bellows is maintained under rough vacuum to bias the home position of the manipulator. This rough vacuum can be modulated in the eventual automation of the manipulator function.

Bellows design has been conservative and infinite life can be anticipated.

At the plating step the manipulator is equipped with forceps to grasp the crystal unit frame. At the sealing step the forceps are changed as required to grasp a "T" bar that engages the part tray. Other point-of-operation modules can be used with the basic manipulator to provide other functions.

EVAPORATION SOURCE

Of the design features being planned for the vacuum system, the use of a nozzle beam gold evaporant source in the plating chamber presents perhaps the most difficult engineering task.

Simultaneous double-sided plating to frequency using gold evaporant would seem to require source patterns oriented horizontally. A simple filament source has, of course, a horizontal component but the source would require continual recharging, which is incompatible with high production rate processes.

It was shown by Andres[5] that a directional, high flux evaporant source, based on the theory of nozzle beams, could be configured to emit vapor in a horizontal direction, operate in high vacuum, and minimize evaporant wastage. Andres has predicted that a highly collimated flux equivalent to a plating rate of 10 Å/s requires a source chamber temperature of about 1900°C. This plating rate is useful for production crystal fabrication; however, the high temperature places severe restrictions on material selection.

Four such sources will be required for the final processing vacuum system. Each of these sources will be located on an elevator head such that each source can be raised

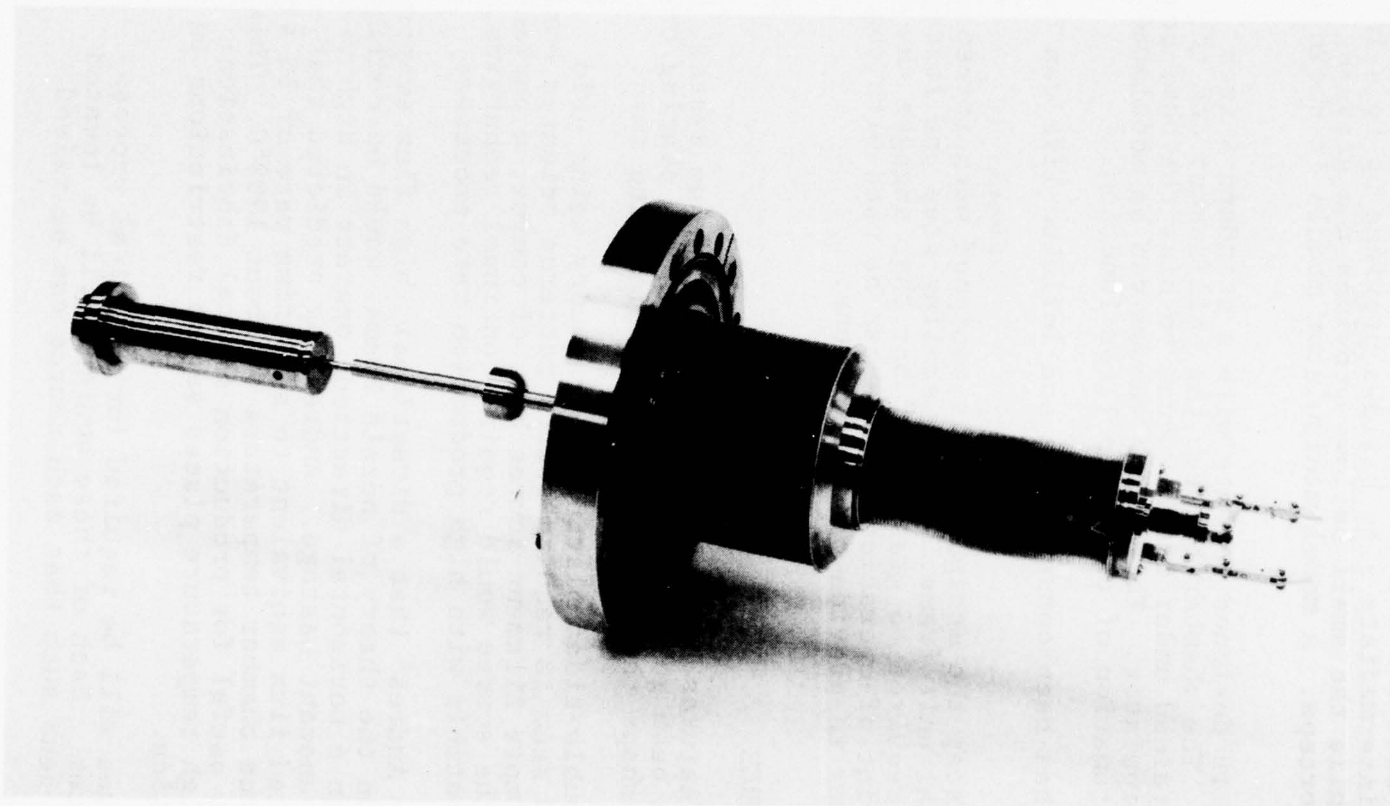


Figure 6. Prototype Vacuum Manipulator Module

into operating position or withdrawn through a gate valve for infrequent recharging or maintenance. Such an arrangement permits the main chambers to remain at high vacuum at all times.

Source-to-substrate distance of about 7 inches is required because of elevator/gate valve geometry. This distance is not a severe handicap with collimated beams and will reduce crystal heat-up from radiant energy during deposition.

Associated with the material selection problem is the thermal management problem. Small size, efficient thermal shielding and conductive heat rejection are obvious requirements.

ELECTRODE MASK HEAD

Similar to the retractable source, retractable elevators containing electrode masks are required in the plating chamber. Each mask holder will be a plug-in module into a mask head. Masks can be moved into and out of the vacuum system using special carrier trays and placed in position for use by the vacuum manipulator. The mask head will contain various load capacitors and other electronics necessary for plating to frequency. Probes for electrical connection with crystal enclosure leads are included.

SEALING FIXTURE

A special fixture that will accept a tray and provide heat-up to 320°C and load force up to 1000 pounds is required in the sealing chamber.

The entire sealing fixture, including heaters and hydraulic rams, is being designed as a demountable module. The module interfaces with the system using a standard 4-inch o.d. Conflat flange. All electrical and mechanical connections are accommodated through suitable flange feedthroughs.

SYSTEM INSTRUMENTATION

All pumping of the vacuum system is cryogenic. Cryosorb roughing pumps and cryogenic high vacuum pumps are specified. Vacuum instrumentation will include thermocouple gages, ionization gages, and a quadrupole residual gas analyzer.

The system is being designed for manual operation. Readout devices are being specified, when available, to include digital output so that the system operation can be automated, possibly to include computer or microprocessor control, at a future time.

EXPERIMENTAL RESULTS

As noted previously, all conceptual design aspects of the system, based primarily on ECOM visualization, have been worked out. Design detailing and hardware procurement/fabrication have been started as indicated below.

Part tray models have been built and tested. A tray with a capacity of up to four crystal assemblies has been fabricated and successfully tested.

Two transports have been fabricated and have demonstrated ability to transfer a tray across the gate valve gap. Life testing has indicated a two-year life for the belt. Since the belt failed at the weld, a revised joining procedure is expected to extend the life substantially.

A prototype manipulator was fabricated and feasibility was demonstrated. Design drawings have been modified to increase the radial travel limit and to incorporate use of a standard 4-inch o.d. flange for mounting. A second model is now being fabricated.

Two vendors' models of cryogenic high vacuum pumps have been evaluated under simulated use conditions. Although there are slight differences in construction between the two, both should operate satisfactorily.

Since successful implementation of the overall vacuum system is predicated upon a working nozzle beam source, major engineering and development effort has been placed on the source work. Several experimental models have been evaluated with some success.

CONCLUSIONS

1. Conceptual design has been worked out on schedule.
2. Tray, transport, and vacuum manipulator feasibility has been demonstrated.
3. Cryogenic high vacuum pumps have been shown to be desirable on this vacuum system.
4. Engineering feasibility of a nozzle beam source has been demonstrated.

PROGRAM FOR NEXT PERIOD

Work in the first six months of this contract has progressed on schedule and the following activity is planned for the coming semiannual period.

1. Complete development of the nozzle beam source and specify the production design.
2. Fabricate models of mask and mask head, elevators, and sealing mechanism.
3. Complete detailed drawings of all system components.
4. Place purchase orders for all major system and long lead components.
5. Fabricate/procure trays, transports, manipulators as required for the final system.
6. Specify and place purchase orders for all system instrumentation hardware.

ACKNOWLEDGMENTS

The authors wish to express their appreciation for the tireless efforts of Dr. E. Hafner of the U. S. Army Electronics Command, Frequency Control Devices Team, in providing the overall system visualization and sustained counsel during the current work.

APPENDIX

ELECTRONICS COMMAND

TECHNICAL REQUIREMENTS

SCS-512

SHOCK RESISTANT CRYSTAL UNITS

1. SCOPE

1.1 Scope.- This specification covers the requirements and processing technique for shock resistant 20 MHz fundamental mode quartz crystal units.

2. APPLICABLE DOCUMENTS

2.1 Documents.- The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-C-3098	**Crystal Units, Quartz.**
MIL-H-10056	**Holders, Crystal Standards.**

OTHER

ECOM TR#4134	**ECOM Technical Report: Packaging Precision Quartz Crystal Resonators.**

STANDARDS

FEDERAL

FED-STD-209	**Clean Room and Work Station Requirements, Controlled Environment.**

MILITARY

MIL-STD-202	**Test Methods for Electronic and Electrical Component Parts.**
MIL-STD-883	**Test Methods and Procedures for Microelectronics.**

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer. Both title and number or symbol should be stipulated when requesting copies.)

3. REQUIREMENTS

3.1 General description.- This specification covers the requirements for producing precision, shock resistant, microcircuit compatible, fundamental mode crystal units, in accordance with MIL-C-3098 and this document, over an operating temperature range of -40°C to 75°C.

3.2 Performance characteristics.- Performance characteristics of the crystal units apply over the full ambient operating temperature range of -40°C to 75°C (unless otherwise specified) and consist of Tables II and III, and as follows:

3.2.1 Frequencies.- The frequencies, at a load capacitance of 20 pF, shall be:

(a) 17,000,000 Hz ± 170 Hz.

(b) 19,200,000 Hz ± 192 Hz.

(c) 20,000,000 Hz ± 200 Hz.

(d) 22,000,000 Hz ± 220 Hz.

3.2.2 Crystal resistance.- The resonance resistance of the crystal units shall not exceed 6 ohms.

3.2.3 Power level.- 150 microwatts ± 10%.

3.2.4 Capacitance.- The unit's motional capacitance (C_1) shall be 12.5 femto-farads ± 1.2 femto-farads. (See 4.7.7).

3.2.5 Reliability - Crystal Units.- The failure rate of crystal units shall not exceed 1%/1000 hours at a 60% confidence level when subjected to the test specified in 4.9.

3.3 Design, construction, and physical dimensions.- The crystal resonators shall be hermetically sealed in microcircuit compatible ceramic crystal enclosures HC-(XM-48)/U which are microcircuit equivalent to HC-18. The enclosure consists of a frame with a top and bottom lid as shown in Figure 2. Clips, such as the ones shown in Figure 3, are attached to the corners of the frame. A more complete package description can be found in ECOM Technical Report entitled "Packaging Precision Quartz Crystal Resonators."

3.4 Solderability.- Solder terminals shall be solderable. (See 4.7.1).

3.5 Shock.- The frequency change shall not exceed 5×10^{-7} after being subjected to shock forces of 1000g. (See 4.7.2).

3.6 Vibration.- After being subjected to a vibration of 20g peak at a frequency of 10 to 2000 Hz, the maximum change in the resonant frequency shall not exceed 5×10^{-7} and the maximum change in resonant resistance shall not exceed 10%. (See 4.7.3).

3.7 Reduced drive level.- When tested as specified in 4.7.8, the resistance shall not exceed 6 ohms.

3.8 Frequency and equivalent resistance.- The frequency and equivalent resistance of the crystal unit shall be within the limits specified in 3.2.1 and 3.2.2 respectively. (See 4.7.9).

3.9 Low-temperature storage.- When subjected to a temperature of -55°C for 2 hours, the resistance shall be as specified in 3.2.2. (See 4.7.10).

3.10 Temperature run.- The frequency temperature characteristics shall be free of coupled modes, the frequency difference between the upper and lower turning points at resonance shall be 18 ppm ± 3 ppm and the resonance resistance shall not exceed 6 ohms. The maximum rate of change of resonance resistance with temperature shall not exceed 0.2 ohms/10°C at any temperature in the range of -40°C to 75°C. (See 4.7.11).

3.11 Thermal frequency repeatability.- The absolute values of the frequency changes $f_{U1} - f_{U2}$ $f_{U1} - f_{U3}$, $f_{U2} - f_{U3}$, and $f_{L1} - f_{L2}$, shall not exceed 5×10^{-8} when the crystal units are exposed to the prescribed temperature cycle. (See 4.7.6).

3.12 Unwanted modes.- There shall be no unwanted modes of oscillation (resonant frequencies other than the desired operating frequency) within ± 20% of the desired operating frequency. In addition, there shall be no abrupt frequency shifts and no intermittent oscillations. (Some crystal units may not start oscillating immediately at the plus 20 percent setting, or may cease oscillating during detuning, without resumption of oscillation on further detuning. These conditions are permitted.) (See 4.7.12).

3.13 Thermal shock.- When subjected to rapid changes in temperature between 0°C and 100°C, no part of the crystal unit shall crack, chip or break. (See 4.7.4).

3.14 Seal.- The leakage rate of the crystal units shall not exceed 10^{-10} atm cc/sec. (See 4.7.5).

3.15 Salt spray (corrosion).- When subjected to a salt spray atmosphere 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. (See 4.7.13).

3.16 Moisture resistance.- After subjection of temperatures up to 65°C and a relative humidity of up to 100% for 10 days, the frequency and resistance of the crystal units shall be within the limits specified in 3.2.1 and 3.2.2, and the insulation resistance shall be not less than 500 megohms. (See 4.7.14).

3.17 Aging.- After 4 weeks stabilization at the upper turnover temperature and an additional 30 days at that temperature, at no time during the 30 days shall the crystal frequency deviate more than 1 x 10^{-8}/week. (See 4.7.15).

3.18 Accelerated aging.- After being conditioned in an oven at 105° ± 3°C for 168 hours and then allowed to stabilize at room ambient temperature, the difference in frequency between the measurements made immediately prior to and immediately after conditioning shall not exceed 0.5 ppm. After conditioning, the resonance resistance shall not exceed 6 ohms. (See 4.7.16).

3.19 Marking.- Marking shall be in accordance with MIL-C-3098.

3.20 Crystal processing requirements.-

3.20.1 Crystal processing flow chart.- Figure 1 is a flow chart of the minimum required manufacturing processes.

3.20.2 Resonator blank inspection.- When the resonator blanks are subjected to intense light at 10 X magnification there shall be no visible imperfections such as chips, cracks or scratches. (See 4.8.1).

3.20.3 Cleaning stations.- Crystal unit components exposed to the atmosphere shall be cleaned immediately prior to insertion into a vacuum chamber. The cleaning procedure shall result in surfaces which are free, on an atomic level, of both organic and inorganic contaminants.

3.20.3.1 Hydrophobic (organic) contamination.- The resonators shall be considered clean from hydrophobic (organic) contamination if uniform interference fringes are observed when they are subjected to condensation of water. (See 4.8.2.1).

3.20.3.2 Inorganic contamination.- The crystal unit components shall be considered clean from inorganic contaminants if the resistivity of the final rinse water remains above 10^{+7} ohm-cm. (See 4.8.2.2).

3.20.4 Enclosure vacuum bakeout.- Enclosure vacuum bakeout shall be performed at 800°C ± 10°C and 10^{-7} torr pressure, minimum. (See 4.8.3).

3.20.5 Resonator vacuum bakeout.- The resonators shall be baked in an oil free high vacuum system at a less than 10^{-8} torr pressure. The bakeout temperature shall be variable up to 400°C. The resonators shall be free of hydrophobic contamination (see 3.20.3.1). (See 4.8.4).

3.20.6 Spot plating.- Spot plating shall be performed in an oil free high vacuum system at less than 10^{-7} torr pressure. The rate of deposition shall be variable, and the film thickness shall be monitored. Materials that have a strong adhesion to quartz, such as chromium-gold, shall be used. After the spot is subjected to a scratch by a metal instrument, there shall be no evidence of peeling at 100 X magnification. (See 4.8.5).

3.20.7 Resonator mounting and bonding.- The resonators shall be mounted and bonded to the enclosure in a clean area, containing as a minimum, a laminar flow clean bench producing a cleanliness equivalent to Class 100 as defined in FED-STD-209 "Clean Room and Work Station Requirements, Controlled Environment." The bond shall be a nickel electrobond with a strength of at least 10 ounces. At the completion of the mounting and bonding process, the resonators shall cause no distortion in the reflection of a straight line from the resonator surface. The resonators shall then be inspected and cleaned as specified in 3.20.2 and 3.20.3. (See 4.8.6).

3.20.8 Final assembly.- The last four processing operations; cleaning, bakeout, plating, and sealing, shall be performed without exposure of the vacuum systems and crystal unit components to contaminating atmosphere between operations. The high vacuum chambers shall have a base pressure of 10^{-8} torr minimum. Only oil free pumps shall be used. All back-filling shall be with pure dry gases or controlled gas mixtures. Appropriate steps shall be taken to prevent dirt, loose particles and other forms of contaminants from being present in any of the chambers. The vacuum chambers shall be bakeable to 250°C. Provisions shall be made for flooding the entire inside of each processing chamber with short wave ultraviolet (UV) radiation in the presence of a partial pressure of oxygen. (See 4.8.7).

3.20.8.1 Cleaning.- The mounted crystal resonators and package parts shall be cleaned immediately prior to the high vacuum operations for bake, plate and seal by short wave UV irradiation while in a partial pressure of oxygen. The length of time the crystal components are subjected to the UV irradiation, the wavelength of the UV irradiation, and the partial pressure of oxygen, shall be sufficient to produce the necessary concentration of ozone for cleaning. The resonators shall be considered clean from hydrophobic (organic) contamination if uniform interference fringes are observed when they are subjected to condensation of water. (See 4.8.7.1).

3.20.8.2 Bakeout.- The mounted crystal units and package covers shall be vacuum baked prior to plating. The bakeout temperature shall be variable up to 450°C with a tolerance of ± 5°C. The vacuum during bakeout shall be 10^{-6} torr minimum. (See 4.8.7.2).

3.20.8.3 Plating.- The electrodes shall be deposited by thermal evaporation. In order to minimize stresses that could cause aging, the two sides of the resonator shall be plated simultaneously at equal rates, such that the final thicknesses of the electrodes shall be within 10% of one another. In order to minimize the aging due to mass transfer inside the completed resonator, the electrode material shall be of high purity, and it shall be deposited onto the crystal units rapidly so as to minimize the sorption of contaminants by the electrodes during deposition. The changing and outgassing of the evaporation sources and the replenishing and outgassing of the electrode material shall be performed in a "loading and outgassing" chamber. The pressure during plating shall not rise above 1 x 10^{-6} torr. The rate of evaporation shall be adjustable. The alignment of the electrodes shall be within 0.010 inch of the center of the crystal blanks and within 0.002 inch with respect to each other. Provisions shall be made for heating the mounted quartz blank during plating. Also, during plating, the crystal unit frequencies shall be monitored by means of a hermetically sealed oscillator located near the crystal unit's terminals. The temperature to which the blanks are heated during plating shall be variable up to 300°C with a tolerance of ± 5°C. (See 4.8.7.3).

3.20.8.4 Sealing.- The sealing apparatus shall be capable of applying a force that is variable up to 1 ton, it shall be capable of heating the package up to 400°C with a tolerance of ± 5°C, and it shall be capable of providing combinations of these pressures and temperatures simultaneously. Gauges shall be provided with resolution appropriate for thermocompression bonding and for cold weld sealing. The sealed crystal units shall be transferred to the "unload" chamber for unloading so that the sealing chamber can remain under high vacuum continuously. Provision shall be made for sealing the crystal units in an inert atmosphere. (See 4.8.7.4).

4. QUALITY ASSURANCE PROVISIONS

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

4.2 Classification of inspection.- Inspection shall be classified as follows:

(a) Processing control inspection. (See 4.4).

(b) First article inspection (does not include preparation for delivery). (See 4.5).

(c) Quality conformance inspection. (See 4.6).

4.3 Test plan.- The contractor prepared Government-approved test plan, as cited in the contract, shall contain:

(a) Time schedule and sequence of examinations and tests.

(b) A description of the method of test and procedures.

(c) Programs of any automatic tests including flow charts and block diagrams.

(d) Identification and brief description of each inspection instrument with date of most recent calibration.

4.4 Processing control inspection.- Processing control shall consist of Table I in the order shown and all the tests included in the Government-approved test plan.

4.5 First article.- Unless otherwise specified in the contract, the first article inspection shall be performed by the contractor.

4.5.1 First article units.- The contractor shall furnish the number of crystal units at each frequency as specified in the contract. (See 3.2.1).

4.5.2 First article inspection.- The first article inspection shall consist of Tables I and II and all the tests included in the Government-approved test plan (See 4.3), to show compliance with the requirements of Section 3. No failures shall be permitted in Table II. The tests in Tables I and II are to be performed in the order shown.

4.6 Quality conformance inspection.- Quality conformance inspection shall consist of tests specified in Tables I, III, IV and paragraph 4.6.3 in the order shown.

4.6.1 Group A inspection.- Group A inspection shall consist of Table III. The inspection shall be made either on the same sample or separate samples for subgroups 1 and 2.

4.6.1.1 Sampling plan.- Statistical sampling and inspection shall be in accordance with MIL-STD-105 for general inspection level II. The acceptable quality level (AQL) shall be as specified in Table II. Major and minor defects shall be defined in Table V of MIL-C-3098 and MIL-STD-105.

4.6.2 Group B inspection.- Group B inspection shall consist of Table IV.

4.6.2.1 Sampling plan.- Statistical sampling and inspection shall be in accordance with MIL-STD-105 for special inspection level S-4. Major and minor defects are as defined in Table VI of MIL-C-3098 and MIL-STD-105.

4.6.3 Reliability.- Reliability test shall be as specified in 4.9.

4.7 Methods of examination and test.- Methods of examination and test shall be as specified in the appropriate tables and as follows:

4.7.1 Solderability.- Each terminal area shall be subjected to method 2002 of MIL-STD-883. (See 3.4).

4.7.2 Shock.- The crystal units shall be tested in accordance with MIL-STD-202, method 213B, Test Condition E, (except that the duration time shall be 6m sec) and one blow in each of three mutually perpendicular planes. The frequency shall then be measured in accordance with 4.7.9. (See 3.5).

4.7.3 Vibration.- The crystal units shall be tested for vibration per MIL-STD-202, method 204C, Test Condition D. The frequency and resonance resistance shall then be measured in accordance with 4.7.9. (See 3.6).

4.7.4 Thermal shock.- The crystal units shall be tested for thermal shock per paragraph 4.8.12.2 of MIL-C-3098. After completion of the test the units shall be examined for cracks, chips, or breaks. (See 3.13).

4.7.5 Seal.- The sealed crystal units shall be tested for hermeticity according to MIL-STD-202, method 112, Test Condition C, Procedure III. Backfill pressure and gross leak test conditions used shall be as specified in the Government-approved test plan.

4.7.6 Thermal frequency repeatability.- The crystal units shall be subjected to the following temperature cycle:

(a) Heat from room temperature to the upper turning point temperature and, after thermal equilibrium is reached, measure the frequency (f_{U1}) in accordance with 4.7.9.

(b) Heat to 85°C and maintain at this temperature for one hour.

(c) Lower the temperature to the upper turning point temperature and, after thermal equilibrium is reached, measure the frequency (f_{U2}) in accordance with 4.7.9.

(d) Lower the temperature to the lower turning point temperature and, after thermal equilibrium is reached, measure the frequency (f_{L1}) in accordance with 4.7.9.

(e) Cool the unit to -55°C and maintain at this temperature for one hour.

(f) Raise the temperature to the lower turning point temperature and, after thermal equilibrium is reached, measure the frequency (f_{L2}) in accordance with 4.7.9.

(g) Heat to the upper turning point temperature and, after thermal equilibrium is reached, measure the frequency (f_{U3}) in accordance with 4.7.9.

4.7.7 Capacitance.- The unit's motional capacitance shall be measured by using an applicable crystal impedance meter specified in MIL-C-3098. (See 3.2.4).

4.7.8 Reduced drive level.- Reduced drive level shall be measured in accordance with paragraph 4.8.6 of MIL-C-3098. (See 3.7).

4.7.9 Frequency and resonance resistance.- Frequency and resonance resistance shall be measured in accordance with paragraph 4.8.8 of MIL-C-3098.

4.7.10 Low-temperature storage.- Crystal units shall be subjected to a temperature of -55°C for 2 hours and shall then be measured for resistance with the crystal at a temperature of -55°C. The resistance shall be measured at reduced drive level. (See 4.7.8 and 3.9).

4.7.11 Temperature run.- Temperature run shall be performed in accordance with paragraphs 4.8.10 and 4.8.10.1 of MIL-C-3098. (See 3.10).

4.7.12 Unwanted modes.- Unwanted modes shall be measured in accordance with paragraph 4.8.11.1 of MIL-C-3098. (See 3.12).

4.7.13 Salt spray.- Salt spray shall be performed in accordance with paragraph 4.8.14 of MIL-C-3098. The units shall then be inspected for excessive corrosion. (See 3.15).

Table I.- Process control requirements

Requirement	Reqt Para	Test Para	No. units tested per each batch 1/	Frequency of test	Failure Evaluation
Resonator blank inspection	3.20.2	4.8.1	All	each resonator	2/
Cleaning stations	3.20.3	4.8.2	1	each batch	3/
Enclosure vacuum bakeout	3.20.4	4.8.3	1	" "	3/
Resonator vacuum bakeout	3.20.5	4.8.4	1	" "	3/
Spot plating	3.20.6	4.8.5	1	" "	4/
Resonator mounting and bonding	3.20.7	4.8.6	As specified in 4.8.6	" "	As specified in 4.8.6
Cleaning stations	3.20.3	4.8.2	1	" "	3/
Resonator blank inspection	3.20.2	4.8.1	All	each resonator	2/
Final assembly:	3.20.8	4.8.7	As specified in 4.8.7	each batch	As specified in 4.8.7
Cleaning	3.20.8.1	4.8.7.1			
Bakeout	3.20.8.2	4.8.7.2			
Plating	3.20.8.3	4.8.7.3			
Sealing	3.20.8.4	4.8.7.4			

1/ A batch shall be defined as a group of crystal unit components which are subjected to a specific process at one time.

2/ Failed units shall be rejected.

3/ A failure shall require batch be rejected or recycled.

4/ A failure shall require batch be rejected.

Table II.- <u>First article</u>

Examination or test	Reqt Para	Method Para	No. Units to be tested[1]
Visual and mechanical examination (external)	3.2, 3.3	4.7.17	15
Solderability	3.4	4.7.1	15
Shock	3.5	4.7.2	15
Vibration	3.6	4.7.3	15
Reduced drive level	3.7	4.7.8	15
Capacitance	3.2.4	4.7.7	15
Frequency and equivalent resistance	3.8	4.7.9	15
Low-temperature storage	3.9	4.7.10	15
Temperature run	3.10	4.7.11	15
Thermal frequency repeatability	3.11	4.7.6	15
Unwanted modes	3.12	4.7.12	15
Thermal shock	3.13	4.7.4	15
Seal	3.14	4.7.5	15
Salt spray (corrosion)	3.15	4.7.13	3
Moisture resistance	3.16	4.7.14	3
Aging	3.17	4.7.15	15
Visual and mechanical examination (internal)	3.2, 3.20.6, 3.20.7, 3.20.8.3	4.7.17	2
Reliability [2]	3.2.5	4.9	46

[1] This is the number of units at <u>each</u> frequency to be tested (see 3.2.1), except for Reliability test.

[2] The lot of 46 units selected must be representative of the four frequencies.

Table III.- Group A inspection

Examination or test	Reqt Para	Method Para	AQL (percent defective) Major	Minor
Subgroup 1				
Visual and mechanical examination (external) 1/	3.2,3.3	4.7.17	-	-
Shock	3.5	4.7.2	1.0	-
Reduced drive level	3.7	4.7.8		
Frequency and resonance resistance	3.8	4.7.9		
Low-temperature storage	3.9	4.7.10		
Temperature run	3.10	4.7.11		
Thermal frequency repeatability	3.11	4.7.6		
Unwanted modes	3.12	4.7.12		
Seal	3.14	4.7.5		
Subgroup 2				
Accelerated aging	3.18	4.7.16	1.0	-

1/ Two sample units only for external dimensions. No failures permitted.

Table IV.- Group B inspection

Examination or test	Reqt Para	Method Para.	AQL (percent defective) Major	Minor
Solderability	3.4	4.7.1		
Capacitance	3.2.4	4.7.7		
Shock	3.5	4.7.2		
Vibration	3.6	4.7.3		
Thermal shock	3.13	4.7.4		
Seal	3.14	4.7.5	1.0	-
Salt spray (corrosion)	3.15	4.7.13		
Moisture resistance	3.16	4.7.14		
Visual and mechanical examination (internal)	3.2,3.20.6, 3.20.7, 3.20.8.3	4.7.17		

4.7.14 Moisture resistance.- Moisture resistance shall be performed in accordance with paragraph 4.8.15 of MIL-C-3098. Frequency and resonance resistance shall then be measured in accordance with 4.7.9. (See 3.16).

4.7.15 Aging.- Aging shall be performed in accordance with paragraph 4.8.16 of MIL-C-3098. (See 3.17).

4.7.16 Accelerated aging.- Accelerated aging shall be performed in accordance with paragraph 4.8.16.1 of MIL-C-3098. (See 3.18).

4.7.17 Visual and mechanical examination.- Visual and mechanical examination shall be performed in accordance with paragraph 4.8.2 of MIL-C-3098.

4.8 Processing control inspections.- The following inspections are performed as specified during the fabrication of the crystal units.

4.8.1 Resonator blank inspection.- Each resonator blank shall be inspected for chips, cracks and scratches under intense light at 10 X magnification. Only those crystal blanks which are free of visible imperfections at 10 X magnification shall be processed. This inspection shall also be performed prior to final assembly. (See 3.20.2 and 3.20.7).

4.8.2 Cleaning stations.-

4.8.2.1 Hydrophobic (organic) contamination.- The resonators shall be checked for hydrophobic contamination by selecting one wafer from each batch and holding it over hot distilled and deionized water so as to produce condensation. The resulting interference fringes are then observed over the whole surface facing the water for uniformness. (See 3.20.3.1).

4.8.2.2 Inorganic contamination.- The resonators shall be checked for inorganic contaminants prior to insertion into the final processing system by monitoring the resistivity of the final rinse water. (See 3.20.3.2).

4.8.3 Enclosure vacuum bakeout.- Suitable measuring devices shall be used to record a temperature of 800°C ± 10°C and a pressure of less than 10-7 torr in the vacuum bakeout oven. (See 3.20.4).

4.8.4 Resonator vacuum bakeout.- One resonator from each batch shall be held over hot distilled and deionized water so as to produce condensation. The interference fringes on the whole surface facing the water shall be observed for uniformness. (See 3.20.5).

4.8.5 Spot plating.- The spots shall be scratched with a sharply pointed metal instrument (such as a straight pin) and then observed at 100 X magnification. Units subjected to this test shall not be delivered on the contract. (See 3.20.6).

4.8.6 Resonator mounting and bonding.- After mounting and bonding, each unit shall be inspected for distortion by observing the reflection of a straight line from the resonator surface. The strength of the electrobond shall be determined by performing a pull test on one unit from end batch processed. Units subjected to the pull test shall not be delivered on the contract. (See 3.20.7).

4.8.7 Final assembly.- At the completion of the final four processes, (cleaning, bakeout, plating and sealing), each batch shall contain a unit that has not been sealed. This unit shall then be examined for cleanliness (see 4.8.7.1) and plating (see 4.8.7.3). (See 3.20.8). If unit fails cleanliness and/or plating requirements, the entire batch shall be rejected.

4.8.7.1 Cleaning.- The resonators shall be inspected for hydrophobic contamination using the method described in 4.8.3.1. (See 3.20.8.1).

4.8.7.2 Bakeout.- Suitable measuring devices shall be used to ascertain the actual temperature (and accuracy to which it is maintained), and pressure of the vacuum bakeout oven.

4.8.7.3 Plating.- A visual and mechanical examination in accordance with paragraph 4.8.2 of MIL-C-3098 will be made to insure the alignment of the electrodes conforms to 3.20.8.3. Suitable measuring devices shall be used to monitor the plating chamber pressure and the resonator temperature. (See 3.20.8.3).

4.8.7.4 Sealing.- A seal test will be performed on one unit from each batch using the method described in 4.7.5. Suitable measuring devices shall be used to record sealing force and temperature during the sealing process. (See 3.20.8.4).

4.9 Reliability.-

4.9.1 Prerequisite.- The crystal units to be used for this evaluation shall be selected from lots which have successfully completed Groups A and B inspections. (See 3.2.5).

4.9.2 Reliability test oven.- The units selected for the reliability evaluation shall be stored in an oven maintained at the upper turnover temperature and stable to at least ± 0.01°C. The oven shall be constructed with suitable electrical connectors so each crystal unit can be oscillated and measured to the required accuracy.

4.9.3 Reliability test cycle.- The reliability test cycle shall consist of submitting 50 units of each frequency (200 units total) to the following sequence of tests which shall be repeated at weekly intervals. All frequency measurements shall be made in a measurement system capable of measurements reproducible to 2 parts in 10^9:

(a) Resonance resistance measurements shall be made in the test set prior to inserting the crystals in the oven and after removal from the oven on completion of the test.

(b) After insertion in the oven the crystal units shall be stabilized for 4 weeks at the upper turnover point prior to beginning the reliability test cycle.

(c) Measure and record the resonant frequency of each crystal unit 4 weeks after the oven stabilizes at the upper turnover point.

(d) The crystal units shall be maintained at the upper turnover point for an additional 6 weeks. Measure and record the resonant frequency of each crystal unit during this period.

4.9.4 Reliability evaluation.- The test data obtained from the twice weekly measurements during the test cycle shall be evaluated at the end of the 6 week period. Units showing a frequency change of more than 1×10^{-8} per week during the test period shall be classified as failures.

4.9.5 Failure-rate criteria.- When subjected to the reliability test cycle specified above, the failure rate shall not exceed 1%/1000 hours at a 60% confidence level (i.e. equivalent to 1 failure for 200 units over a 1000 hour period of testing).

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be as specified in the contract.

6. NOTES

6.1 Processing facility accommodations.- The processing equipment should accommodate, as a minimum, the four different sizes of microcircuit compatible crystal enclosures as follows:

(a) The microcircuit compatible equivalent of the HC-6.

(b) The microcircuit compatible equivalent of the HC-18.

(c) The microcircuit compatible equivalent of the HC-32.

(d) The microcircuit compatible equivalent of the HC-44.

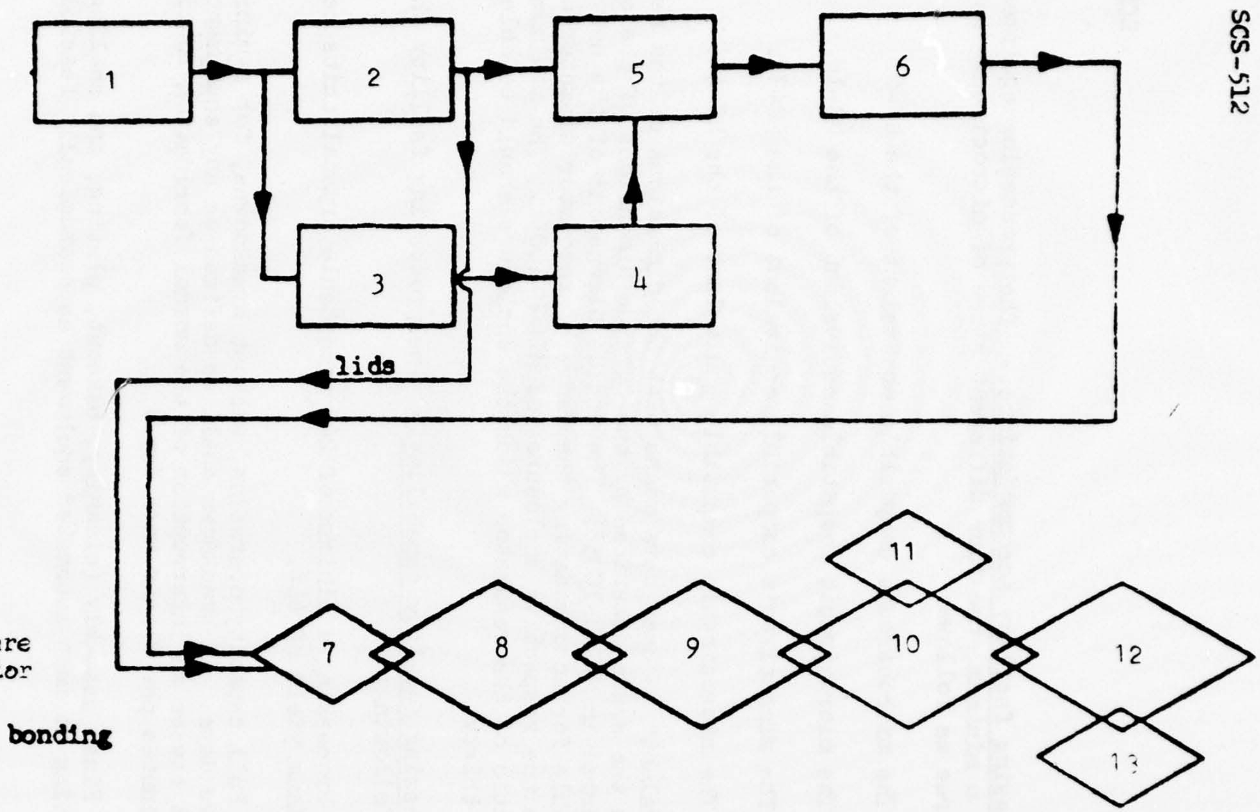
The term "equivalent" as used here means that the dimensions of the new enclosure will fit within the space described by the outside dimensions of the corresponding enclosures referred in MIL-H-10056. The inside dimensions of the new enclosures should be suitable for accommodating the range of resonator diameter normally accommodated in the respective enclosures of MIL-H-10056. The minimum diameter to thickness ratio of the resonator which the enclosure should be able to accommodate is thirty.

6.2 Processing facility capability.- The processing facility should be capable of the following:

(a) Processing a minimum of 200 acceptable crystal units per 8 hour day with a minimum yield of 66%.

(b) Full capacity operation, without breakdowns, for a minimum of five consecutive days. (A breakdown shall be defined as any equipment related occurrence that causes an interruption of the normal fabrication routine for more than 10 minutes per 8 hour work day.)

(c) Final assembly (cleaning, bakeout, plating, and sealing) should be performed using as much automated equipment as economically feasible.



1 Cleaning station
2 Vacuum furnace - enclosure
3 Vacuum furnace - resonator
4 Spot plating station
5 Clean area: mounting & bonding
6 Cleaning station
7 Loading chamber
8 Cleaning chamber
9 Bakeout chamber
10 Plating chamber
11 Loading & outgassing chamber (filaments)
12 Sealing chamber
13 Unloading chamber

Figure 1. Crystal Processing Flow Chart

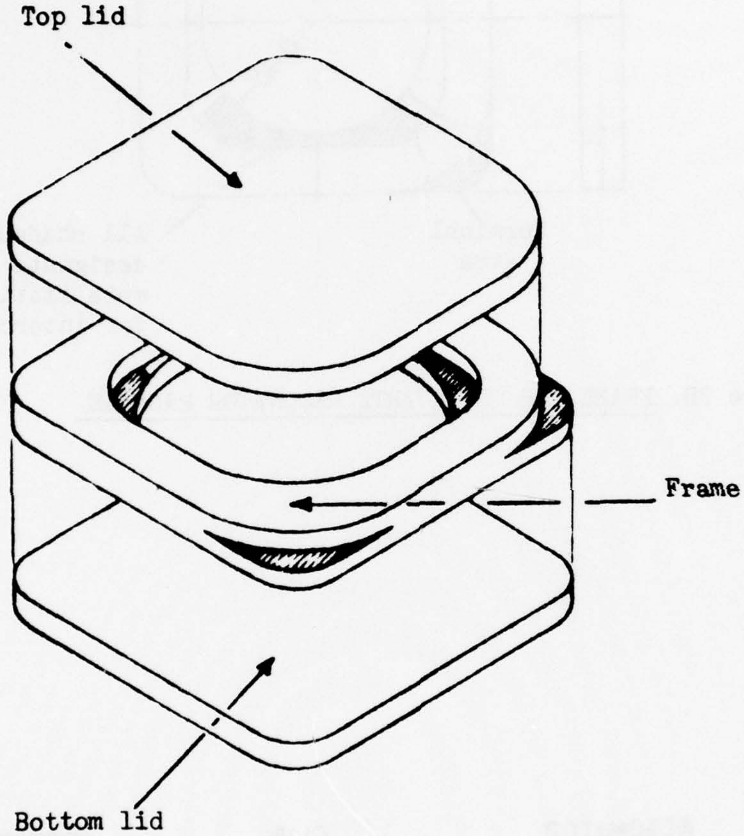


Figure 2A. EXPLODED VIEW OF THE QUARTZ RESONATOR PACKAGE.

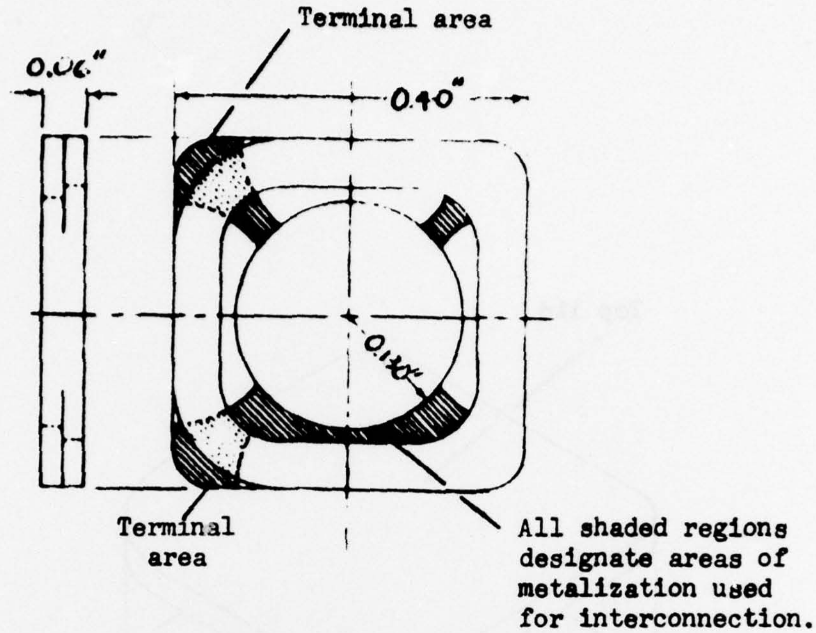


Figure 2B. FRAME FOR THE QUARTZ RESONATOR PACKAGE

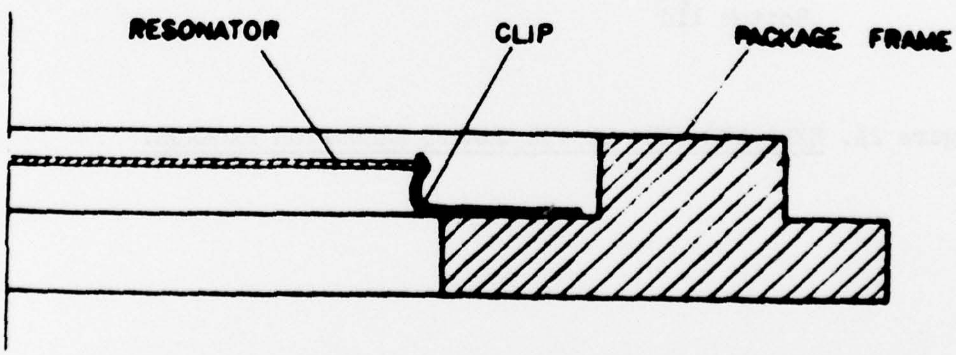


Figure 3. CROSS SECTION OF PACKAGE FRAME SHOWING RESONATOR AND MOUNTING CLIP CONGIGURATION

ELECTRONICS COMMAND
TECHNICAL REQUIREMENTS

SCS-512
AMENDMENT-1
20 March 1976
SUPERSEDING
ERRATA SHEET

SHOCK RESISTANT CRYSTAL UNITS

This amendment forms a part of Electronics Command Technical Requirements SCS-512, 23 October 1975

Page 2

3.2.3, delete "150 microwatts ± 10%" and substitute "15 microwatts ± 10%".

Page 3

3.5, delete and substitute:

"3.5 Shock.- For the 1000g crystal unit, the frequency change shall not exceed $5X10^{-7}$ after being subjected to shock forces of 1000g. For the 15000g crystal unit, the frequency change shall not exceed $2X10^{-6}$ after being subjected to shock forces of 15000g. (See 4.7.2)."

3.10, delete "18 ppm ± 3 ppm" and substitute "18 ppm ± 5 ppm".

3.11, add comma after "$f_{U1}- f_{U2}$".

Page 4

3.17, delete paragraph in its entirety.

Page 8

4.7.2, delete and substitute:

"4.7.2 Shock (see 3.5).- The crystal units shall be tested in accordance with MIL-STD-202, method 213B, Test Condition F, with the following exceptions:

(a) For the 1000g crystal units - the shock peak value shall be 1000g and the duration 6 msec.

(b) For the 15000g crystal units - the shock peak value shall be 15000g and the duration 6 msec."

Page 11

Table II, delete column heading "Examination or test" and substitute "Examination or test 2/".

Table II, delete "Aging" test.

Table II, delete "Reliability 2/" and substitute "Reliability".

Table II, Under "No. of Units to be tested" column for Reliability:

delete, "46" and substitute "25"

Table II, In "footnote 1": delete, "except for Reliability test."

Table II, delete "footnote 2" in its entirety and substitute:

"2/The tests shall be performed on the same set of sample units except for reliability. The reliability test may be performed on a separate set of sample units."

Page 14

4.7.15, delete paragraph in its entirety.

Page 17

6., delete Section 6, "NOTES" in its entirety.

Page 19

Figure 2A, delete "bottom lid" and substitute "bottom lid (metallized on bottom)".

REFERENCES

1. E. Hafner and J. R. Vig, "Packaging Precision Quartz Crystal Resonators," Technical Report, ECOM-4134, U. S. Army Electronics Command, Fort Monmouth, New Jersey, July 1973. Copies available from NTIS, Accession Number AD763215.

2. P. D. Wilcox, et al, "A New Ceramic Flat Pack for Quartz Resonators," Technical Report, ECOM-4396, U. S. Army Electronics Command, Fort Monmouth, New Jersey, April 1976. (For a similar treatment of the subject, see: Proceedings, 29th Annual Symposium on Frequency Control, U. S. Army Electronics Command, Fort Monmouth, New Jersey, pp 202-210, 1975.) Copies available from EIA - see Reference 5.)

3. R. D. M. Peters, "Ceramic Flat Pack Enclosures for Precision Quartz Crystal Units," Technical Information Series Report, GEPP-246, General Electric Company, Neutron Devices Department, St. Petersburg, Florida, September 1976. (For a similar treatment of the subject, see: Proceedings, 30th Annual Symposium on Frequency Control, ECOM, pp 224-231, 1976.)

4. J. W. LeBus, J. R. Vig, "UV/Ozone Cleaning of Surfaces," IEEE Transactions; Parts, Hybrids and Packaging, Vol. PHP-12, #4, pp 365-370, December 1976.

5. R. P. Andres, "Design of a Nozzle Beam Type Metal Vapor Source," Technical Report, ECOM-4437, U. S. Army Electronics Command, Fort Monmouth, New Jersey, October 1976. (For a similar treatment of the subject, see: Proceedings, 30th Annual Symposium on Frequency Control, U. S. Army Electronics Command, Fort Monmouth, New Jersey, pp 232-236, 1976. Copies available from Electronic Industries Association, 2001 Eye Street, N.W., Washington, D.C., 20006.)

DISTRIBUTION

101 Defense Documentation Center
ATTN: DDC-TCA
Cameron Station (Bldg 5)
012 Alexandria, VA 22314

103 Code R123, Tech Library
DCA Defense Comm Engrg Ctr
1860 Wiehle Ave
001 Reston, VA 22090

104 Defense Communications Agency
Technical Library Center
Code 205 (P. A. TOLOV)
001 Washington, DC 20305

200 Office of Naval Research
Code 427
001 Arlington, VA 22217

203 GIDEP Engineering & Support Dept
TE Section
P. O. Box 398
001 Norco, CA 91760

205 Director
Naval Research Laboratory
ATTN: Code 2627
001 Washington, DC 20375

206 Commander
Naval Electronics Laboratory Ctr
ATTN: Library
001 San Diego, CA 92152

207 CDR, Naval Surface Weapons Center
White Oak Laboratory
ATTN: Library, Code WX-21
001 Silver Spring, MD 20910

212 Command, Control & Comm Div
Development Center
Marine Corps Devel & Educ Cmd
001 Quantico, VA 22134

301 Rome Air Development Center
ATTN: Documents Library (TILD)
001 Griffiss AFB, NY 13441

307 HQ ESD (DRI)
L. G. Hanscom AFB
001 Bedford, MA 01731

314 HQ, Air Force Systems Command
ATTN: DLCA
Andrews AFB
001 Washington, DC 20331

403 CDR, US Army Missile Command
Redstone Scientific Info Center
ATTN: Chief, Document Section
001 Redstone Arsenal, AL 35809

404 Commander
US Army Missile Command
ATTN: DRSMI-RE (Mr. Pittman)
001 Redstone Arsenal, AL 35809

407 Director, Ballistic Missile Defense
Advanced Technology Center
ATTN: ATC-R, P.O. Box 1500
001 Huntsville, AL 35807

417 Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-MD
001 Fort Huachuca, AZ 85613

418 Commander
HQ Fort Huachuca
ATTN: Technical Reference Div
001 Fort Huachuca, AZ 86513

420 Commander
USASA Test & Evaluation Center
ATTN: IAO-CDR-T
001 Fort Huachuca, AZ 85613

421 Commander
HQ US Army Communications Cmd
ATTN: CC-OPS-SM
001 Fort Huachuca, AZ 85613

437 Deputy for Science & Technology
Office, Assist Sec Army (R & D)
001 Washington, DC 20310

438 HQDA (DAMA-ARP/DR.F.D.
VERDERAME)
001 Washington, DC 20310

455 Commandant
US Army Signal School
ATTN: ATSN-CTD-MS
001 Fort Gordon, GA 30905

475 CDR, Harry Diamond Laboratories
ATTN: Library
2800 Powder Mill Road
001 Adelphi, MD 20783

477 Director
US Army Ballistic Research Labs
ATTN: DRXBR-LB
001 Aberdeen Proving Ground, MD 21005

481 Harry Diamond Labs, Dept of Army
ATTN: DRXDO-RCB (Dr. J. Nemarich)
2800 Powder Mill Road
001 Adelphi, MD 20783

507 CDR, US Army Aviation Sys Command
ATTN: DRSAV-G
P. O. Box 209
001 St. Louis, MO 63166

512 Commander
Picatinny Arsenal
ATTN: SARPA-ND-A-4 (Bldg 95)
001 Dover, NJ 07801

515 Project Manager, Rembass
ATTN: DRCPM-RBS
001 Fort Monmouth, NJ 07703

517 Commander
US Army Satellite Comms Agcy
ATTN: DRCPM-SC-3
001 Fort Monmouth, NJ 07703

531 CDR, US Army Research Office
ATTN: DRXRO-IP
P. O. Box 12211
001 Research Triangle Park, NC 07709

532 CDR, US Army Research Office
ATTN: DRXRO-PH (Dr. R. J. Lontz)
P. O. Box 12211
001 Research Triangle Park, NC 27709

556 Commander, HQ MASSTER
Technical Information Center
ATTN: Mrs. Ruth Reynolds
001 Fort Hood, Tx 76544

563 Commander, Darcom
ATTN: DRCDE
5001 Eisenhower Ave.
001 Alexandria, VA 22333

564 CDR, US Army Security Agency
ATTN: IARDA-IT
Arlington Hall Station
001 Arlington, VA 22212

569 Commander
US Army Engineer Topographic Labs
ATTN: ETL-TD-EA
001 Fort Belvoir, VA 22060

602 Director, Night Vision Laboratory
US Army Electronics Command
ATTN: DRSEL-NV-D
001 Fort Belvoir, VA 22060

603 CDR/DIR, Atmospheric Sciences Lab
US Army Electronics Command
ATTN: DRSEL-BL-SY-S
001 White Sands Missile Range, NM 88002

604 Chief
Ofc of Missile Electronic Warfare
Electronic Warfare Lab, Ecom
001 White Sands Missile Range, NM 88002

606 Chief
Intel Materiel Dev & Support Ofc
Electronic Warfare Lab, Ecom
001 Fort Meade, MD 20755

680 Commander
US Army Electronics Command
000 Fort Monmouth, NJ 07703

1 DRSEL-PL-ST
1 DRSEL-NL-D
1 DRSEL-WL-D
1 DRSEL-VL-D
3 DRSEL-CT-D
1 DRSEL-TL-D
1 DRSEL-TL-DT

22 DRSEL-TL-MF
1 DRSEL-TL-E
1 DRSEL-MA-MP
2 DRSEL-MS-T1
1 DRSEL-GG-TD
2 DRSEL-PP-I-PI-1
1 DRSEL-GS-H
1 DRSEL-CG
2 DRSEL-PA
1 DRSEL-RD
1 USMC-LNO
1 TRADOC-LNO

701 MIT - Lincoln Laboratory
ATTN: Library - Room A-082
P. O. Box 73
001 Lexington, MA 02173

703 NASA Scientific & Tech Info Facility
ATTN: Acquisitions Branch (S-AK/DL)
P. O. Box 33
001 College Park, MD 20740

704 National Bureau of Standards
Bldg 225, PM A-331
ATTN: Mr. Leedy
001 Washington, DC 20231

705 Advisory Group on Electron Devices
201 Varick St, 9th Floor
001 New York, NY 10014

Hewlett-Packard Laboratories
1501 Page Mill Road
Palo Alto, CA 94304
001 ATTN: Dr. Leonard S. Cutler
001 ATTN: Mr. Donald L. Hammond
001 ATTN: Mr. Jack Kusters

Q-Tech Corp.
11529 Pico Blvd
Los Angeles, CA 90064
001 ATTN: Mr. William H. Fould

Bell Telephone Laboratories
555 Union Boulevard
Allentown, Pennsylvania 18103
001 ATTN: Mr. Warren L. Smith
001 ATTN: Mr. Ed Alexander

CTS Knights, Inc.
400 Reiman Avenue
Sandwich, Illinois 60548
001 ATTN: Mr. R. Hostetler
001 ATTN: Dr. D. E. Newell

Magnavox
2829 Maricopa Street
Torrance, CA 90503
001 ATTN: Mr. Walter Firth

Collins Radio Co.
5225 C Avenue, NE
Cedar Rapids, IA 52402
001 ATTN: Mr. Marvin Frerking

Frequency Electronics, Inc.
3 Delaware Drive
New Hyde Park, NY 11040
001 ATTN: Dr. Martin Bloch

McCoy Electronics Co.
Chestnut & Watts
Mt. Holly Springs, PA 17065
001 ATTN: Mr. L. W. McCoy

American Microsystems, Inc.
3800 Homestead Road
Santa Clara, CA 95051
001 ATTN: Mr. Chet Rutkowski

Crest Cumberland Inc.
101 Petersburg Road
Carlisle, Pennsylvania 17013
001 ATTN: Mr. George Bistline, Jr.

Bliley Electric Co.
2545 W. Grandview Boulevard
Erie, PA 16512
001 ATTN: Mr. Stanley Kaat

Colorado Crystal Corporation
2303 West 8th Street
Loveland, Colorado 80537
001 ATTN: Mr. Paul Bryan

Comtech Laboratory
16871 Noyes Avenue
Irvine, CA 92705
001 ATTN: Dr. William D. Beaver

Monitor Products Company, Inc.
P. O. Box 1966
Oceanside, CA 92054
001 ATTN: Mr. Donald R. Montgomery

M-Tron Industries, Inc.
East Highway 50, Box 638
Yankton, S. Dakota 57078
001 ATTN: Mr. Del Gaines

Northern Engineering Laboratories
357 Beloit Street
Burlington, Wisconsin 53105
001 ATTN: Mr. John Holmbeck

Ovenaire, Inc.
706 Forest Street
Charlottesville, Virginia 22901
001 ATTN: Mr. W. Galla

Mr. Benjamin Parzen
70-25 Yellowstone Boulevard
001 Forest Hills, NY 11375

Piezo Crystal Company
100 K Street
Carlisle, PA 17013
001 ATTN: Mr. W. Samuelson

Piezo Technology, Inc.
2400 Diversified Way
Orlando, FL 32804
001 ATTN: Dr. W. H. Horton

RCA
Building 17A3-1
Camden, NJ 08102
001 ATTN: Mr. Donald W. Nelson

Reeves Hoffman
400 W. North Street
Carlisle, PA 17013
001 ATTN: Mr. George Hoffman

RFL Industries
Powerville Road
Boonton, NJ 07005
001 ATTN: Mr. B. M. Kaufman

Saunders & Assoc.
6710 E. Camelback Road
Scottsdale, AZ 85251
001 ATTN: Mr. Jack Saunders

Statek Corporation
1233 Alvarez Street
Orange, CA 92668
001 ATTN: Mr. H. J. Staudte

Timing Systems, Inc.
135 Canal Street
Marblehead, MA 01945
001 ATTN: Mr. Plato Zorzy

Tyco Crystal Products
3940 W. Montecito
Phoenix, AZ 85019
001 ATTN: Dr. Virgil Bottom

Western Electric
1600 Osgood Street
North Andover, MA 01845
001 ATTN: Mr. Robert Pelrine

Electronic Crystal Corporation
2035 Washington Street
Kansas City, Missouri 64108
001 ATTN: Mr. J. J. Colbert

Electronic Research Corporation
10000 W. 75th Street
001 Overland Park, Kansas 66204

Erie Frequency Control
453 Lincoln Street
001 Carlisle, Pennsylvania 17013

John Fluke Mfg Co.
Box 7428
001 Seattle, Washington 98133

Frequency & Time Systems
Box 378
Danvers, MA 01923
001 ATTN: Mr. Robert Kern

General Electric Company
Mountain View Road
Lynchburg, Virginia 24502
001 ATTN: Mr. John H. Sherman, Jr.

Greenray Industries
840 W. Church Street
001 Mechanicsburg, Pennsylvania 17055

GTE Lenkurt Electric
1105 County Road
San Carlos, CA 94070
001 ATTN: Mr. F. Fastenau

Hewlett Packard Company
P. O. Box 301
Loveland, Colorado 80537
001 ATTN: Mr. G. E. Nelson

Hughes Aircraft
500 Superior Avenue
Newport Beach, CA 92663
001 ATTN: Mr. H. E. Dillon

Hughes Aircraft
Centinela & Jeale Streets
Culver City, CA 91304
001 ATTN: Dr. William Brammer

Keithley Instruments
28775 Aurora Road
Cleveland, Ohio 44139
001 ATTN: Mr. J. F. Keithley

Microsonics, Inc.
60 Winter St.
Weymouth, Massachusetts 02188
001 ATTN: Mr. Charles E. Hagen

Motorola
2553 N. Edgington Street
Franklin Park, Illinois 60651
001 ATTN: Mr. Dennis Reifel

DESC-EMM
Dayton, Ohio 45444
001 ATTN: Mr. Herman Anderson

RADC (ETSS)
LG Hanscom, AFB, MA 01731
001 ATTN: Mr. Alfred Kahan

Weinshel Engineering Company
Cloppers Road, P. O. Box 577
Gaithersburg, MD 20760
001 ATTN: Dr. Bruno Weinshel

USAECOM
ATTN: DRSEL-RD-ET-2
Fort Monmouth, NJ 07003
001 ATTN: Mr. Paul Leeds
001 ATTN: Mr. Joe Inserra

General Electric Company
Neutron Devices Dept.
P. O. Box 11508
St. Petersburg, FL 33733
001 ATTN: Dr. D. H. Ahmann
001 ATTN: Mr. B. E. Day
001 ATTN: Mr. J. M. Frank
001 ATTN: Dr. L. A. Kiley
012 ATTN: Mr. R. J. Ney
001 ATTN: Mr. R. D. M. Peters
001 ATTN: Mr. W. D. Wannamaker
001 ATTN: Technical Data Library

U. S. Department of Energy
Pinellas Area Office
P. O. Box 11500
St. Petersburg, FL 33733
002 ATTN: Mr. D. Ofte

U. S. Department of Energy
Technical Information Center
P. O. Box 62
027 Oak Ridge, Tennessee 37830

General Electric Company
Technical Information Exchange
R & D Center
P. O. Box 8
005 Schenectady, NY 12301

Sandia Laboratories
P. O. Box 5800
Albuquerque, NM 87115
001 ATTN: Mr. T. J. Young