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QUARTZ CRYSTAL RELIABILITY STUDIES

REPORT NUMBER 3

CONTRACT DA 36-039 SC-89199

ORDER NUMBER 1048-PM-62-93-93 (4805)

THIRD QUARTERLY PROGRESS REPORT

5 OCTOBER 1962 to 5 JANUARY 1963

U.S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY, FORT MONMOUTH, NEW JERSEY

INLAND TESTING LABORATORIES
COOK ELECTRIC COMPANY
1482 Stanley Avenue
Dayton 4, Ohio

QUARTZ CRYSTAL RELIABILITY STUDIES

REPORT NUMBER 3

CONTRACT DA 36-039 SC-89199

SIGNAL CORPS TECHNICAL REQUIREMENTS

NUMBER SCL-7003/84, 5 SEPTEMBER 1961

DEPARTMENT OF THE ARMY PROJECT NUMBER 991500401

THIRD QUARTERLY REPORT, 5 OCTOBER 1962 to 5 JANUARY 1963

The objectives of this study are:

1. - The determination of the causes of failure in quartz crystal units.
2. - The formulation of accelerated tests for the determination of "time to first failure", "mean time between failures", and "life time".
3. - The evaluation of such factors as elevated temperatures, and drive levels other than the recommended drive levels, in causing failure of quartz crystal units.
4. - The determination of a satisfactory definition of failure in terms of performance.

This report was prepared by Carleton E. Jones.

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Statement of Purpose

This study is an investigation of factors that produce failures of quartz crystal units. The work is divided into five distinct phases. The crystals being tested are separated into 20 Lots, for ease of handling and record keeping. Each Lot of crystals proceeds through the five Phases without regard to the status of the remaining Lots, thus more than one Phase may be active at any time, although for any one Lot of crystals, the sequence of Phases follows chronological order.

Phase I: The contractor is procuring, from industry, military quartz crystal units in the types and quantities specified in Signal Corps Technical Requirement SCL-7003/84. Each of these quartz crystal units is subjected to all preproduction tests required by Specification MIL-C-3098C, and such other tests as are required to establish that the crystal units are of a quality suitable for the study. All crystal units which fail these tests are eliminated from further study.

Phase II: The crystal units that conformed to all specification requirements during Phase I testing are subjected to tests as listed below.

(a) All crystal units that are normally operated under controlled temperature conditions are stored at their specified operating temperatures.

(b) One-fourth of the crystal units that are normally operated under non-controlled temperature conditions are stored at plus 85 degrees centigrade. The remaining three-fourths of these units are operated in oscillators at room ambient, one-

third of them at 25 percent of rated drive level, one-third at 100 percent of rated drive level, and one-third at 500 percent of rated drive level.

(c) Measurements of series resonant frequency and resistance are made at the end of each of the following periods of time after the start of the test: 24 hours, 125 hours, 225 hours, 500 hours, 1000 hours, 2000 hours, 3000 hours, 4000 hours, and 5000 hours.

Phase III: The frequency versus temperature characteristics of the crystal units will be redetermined.

Phase IV: Those crystal units which still meet the requirements of MIL-C-3098C at the end of Phase III will be divided into two lots, one of which will be subjected to shock tests, the other to vibration tests, as specified by the procuring activity. The frequency and effective resistance of the crystal units will then be redetermined.

Phase V: A final report will be prepared, analyzing the data generated in Phases I through IV with regard to: (a) determination of causes of failure; (b) the formulation of tests to determine "time to first failure", "mean time between failures", and "life time"; (c) the effects of elevated temperatures, and high and low drive levels in inducing failures; (d) a workable definition of failure in terms of crystal performance; and (e) determination of a reliability figure for quartz crystals.

Abstract

Phase I (preproduction testing of the crystal units) continues. Of the 20 Lots of crystals involved in this study, 13 have completed Phase I testing and are now in Phase II.

No problems of any significance have been encountered in performing either Phase I or Phase II tests. Slow delivery by the manufacturers has been the major factor slowing progress with the first phases of this study.

Publications, Lectures, Reports, and Conferences

During the period covered by this report, no publications were issued, and no lectures were delivered.

Monthly reports No. 5 and No. 6 were prepared and submitted on schedule, and the Second Quarterly Report was submitted, accepted, and distributed.

No formal conferences were held during this period. Mr. J. Stanley, USAERDL, visited the contractors plant 12 December 1962 to view the operation of the test program and discuss the procurement of the remaining crystals needed for the program. It was agreed that because of the apparent inability of manufacturer "A" to deliver the required 30 type CR-74/U crystals, other sources should be solicited to supply the units. Two other crystal suppliers were asked to bid on supplying these crystal units. One of the two suppliers indicated he could supply the units, and the arrival of a firm quotation from him is expected soon.

Factual Data

Phase I:

During the period covered by this report several partial shipments of crystals were received. Manufacturer A has now delivered all crystals ordered from him except the type CR-74/U samples. None of manufacturer A's CR-74's have been received, and it appears likely that another supplier may have to be found to supply these crystals.

Manufacturer B has now delivered all the type CR-32A/U and type CR-74/U crystal units ordered from him. Of the 120 type CR-67/U crystals ordered, 118 have been received, and of the 120 type CR-18A/U crystals ordered, 107 have been received.

A record of the results of the preproduction tests performed on the crystals supplied by manufacturer A is included in Appendix I, Table I. In those cases where it is indicated that a test was not applicable, this was because half of each type of crystals were subjected to the mositure resistance test and the other half to the aging test. Thus, Lots 1 and 2 were subjected to aging but not to moisture resistance, while Lots 3 and 4 were subjected to moisture resistance, but not to aging. For those crystal types which comprised only one Lot (the CR-32A/U and CR-74/U crystals), half of the Lot was subjected to aging and half to moisture resistance. Table II, in Appendix I gives the preproduction summary for the crystals supplied by manufacturer B.

The crystals still being subjected to preproduction tests will complete the tests in accordance with the following (approximate) schedule:

Lots 7 and 8 will complete preproduction testing 5 February 1963.

Lot 19 will complete preproduction testing 8 February 1963.

Lots 10, 14, and 18 will complete preproduction testing 45 days after receipt of the crystals required to complete the Lots.

Examinations of the crystal units that have failed during preproduction testing have led to the following conclusions as to the causes of the failures:

Sample number 120, Lot 4, which would not oscillate after subjection to the vibration test, was found to have a broken support wire (see Figure 1, Appendix II).

Sample number 21 of Lot 5, which would not oscillate after the immersion test, was re-subjected to the leakage test, and showed definite evidence of leakage. It is believed that there was probably some undetected leakage occurring when the crystal unit was initially subjected to the leakage test, and that additional water entered the crystal holder during the immersion test.

Samples A3 and A16 of Lot 6 would not oscillate at the conclusion of the aging test. Throughout the aging test the series resonant frequency of these two samples had been shifting in a negative direction at a relatively high rate, and the effective resistance had been increasing. By the end of the test, the effective resistance of each of the two units had increased to a value so high the crystal could not be made to oscillate in the standard test set (TS-683/TSM) at rated drive. The crystals would oscillate at approximately 300 percent of rated drive, but the series resonant frequencies of the units were well below the acceptable minimum frequency.

Samples 21 and 27 of Lot 9 failed to oscillate when tested after vibration. The crystal holders were opened and it was found that in each of these two units one of the support wires had broken off the pin in the base of the crystal holder. The break, in each case, was at the point at which the support wire was fastened to the pin. A photograph of these two units, (Figure 2) showing the broken support wires, is included in Appendix II of this report.

Samples 15, 19, and 28 of Lot 9 failed to oscillate after the leakage test. All three units had shown evidence of leakage during the leakage test.

Sample 25 of Lot 15 would not oscillate after the shock test. The crystal holder was opened and it was found that one of the support wires had broken loose from the quartz plate (see Figure 3, Appendix II). Sample 27 of this Lot would not oscillate after the salt spray test, and samples 20 and 28 would not oscillate at the conclusion of the aging test.

There were four failures in Lot 20 during preproduction testing. The glass holder of sample 25 fractured during the shock test, and sample 14 would not oscillate at the conclusion of the shock test. Samples 12 and 24 would not oscillate at the conclusion of the vibration test. A fifth sample, number 1, had to be removed from testing because the holder was accidentally broken while the unit was being mounted for the vibration test. A photograph illustrating the construction of these CR-74/U crystal units is included in Appendix II (Figure 4).

Efforts to ascertain the cause of failure are continuing on those crystal units for which no cause of failure was given in the above summary, and the results of these investigations will be included in Report Number 4.

Two tests were performed on the type CR-74/U crystals comprising Lot 20 that were not included in the specification (MIL-C-27222) covering these crystals. These tests were thermal shock and a special leakage test. The tests were performed as specified by the procuring agency. The thermal shock test consisted of immersing the crystals for a period of 15 seconds in a bath of water maintained at plus 95 degrees Centigrade. At the conclusion of the 15 seconds in the hot bath, the crystals were immediately transferred into a bath of water maintained at plus 5 degrees Centigrade. The crystals were left in the cold bath for a period of five minutes, then they were removed from the bath, dried, and closely examined, under magnification, for any evidence of cracks or other detrimental effects resulting from the thermal shock. No such evidence was discovered.

The special leakage test consisted of inserting the crystal holder into a high voltage field generated by a Tesla coil and observing whether any evidence of ionization could be detected within the crystal holder, which would indicate that the holder was no longer evacuated. No case of leakage was discovered.

Phase II:

Phase II testing, which includes storing crystal units at elevated temperatures, and also operating crystal units at 25, 100, and 500 percent of rated drive, is now being performed on Lots 1, 2, 3, 4, 5, 6, 9,

11, 12, 15, and 16. The oscillators used for operation of the crystals at the various drive levels are shown in Figure 5 and 6, and a schematic diagram of the oscillator circuit is shown in Figure 7, Appendix II. The circuit employed is an adaptation of the oscillator circuit employed in the standard crystal impedance meter (TS-683/TSM) used in testing these crystals.

In preparing the oscillators for use, the tuning and drive level was set in accordance with the procedures normally used to prepare the TS-683 crystal impedance meter for use in testing crystals to determine their parameters in accordance with specification MIL-C-3098C. For example, for testing a group of 30 type CR-18A/U crystals at 25 percent of rated drive, each individual oscillator was tuned, and the drive set across the required standard resistor, just as in using the crystal impedance meter. As the adjustment of each oscillator was completed, the resistor used to set the drive level was removed from the crystal socket, and one of the test crystals was plugged into the socket.

A daily check is made, using an R.F. probe and a multimeter, to determine whether each individual crystal is still oscillating. This makes it possible to pinpoint, within a single 24 hour period, the time of failure, should a crystal fail. The drive setting of each oscillator is checked each time the crystal is removed from the circuit for test measurements. The drive levels originally set for the oscillators have changed only slightly during operations to this date. All components employed in the oscillators were conservatively rated, and plate voltage was kept at a low level, to help ensure this stability.

Records of the change in frequency of the crystals with respect to time are being kept in terms of parts per million. The frequency measured for each crystal after the first 24 hours of Phase II testing was taken as the reference frequency for that crystal, and was assigned a value of 0. The difference, in cycles per second, between the reference frequency of the crystal and the measured frequency at any later time, divided by the reference frequency, expressed in millions of cycles per second, gives the frequency change, in parts per million, occurring between the two measurements. An increase in the measured frequency is recorded as a plus frequency change, a decrease as a minus frequency change.

The status of the various lots of crystals which were in Phase II testing at the close of this report period was as follows:

Lot 1

These 20 megacycle CR-18A/U crystals, which are being stored at plus 85 degrees Centigrade, completed approximately 2750 hours of storage through 5 January 1963. The maximum allowable frequency change for these units (the overall frequency tolerance per MIL-C-3098C) is plus or minus 50 parts per million.

During the first 1,000 hours in storage only one unit, number 13, had changed in frequency more than 50 ppm. That unit was minus 50.77 ppm at the conclusion of 1,000 hours storage. When the frequency was measured again, after 2,000 hours storage, a total of five units had frequency changes in excess of 50 ppm. Unit number 12 was minus 91.89 ppm, unit 13 minus 67.03 ppm, unit 17 minus 55.77 ppm, unit 23 minus 64.63 ppm, and unit 26 minus 50.62 ppm at that time. A complete record

of the frequency changes occurring in this Lot of crystals through the 2,000 hour test is given in Appendix I, Table III.

Lot 2

This Lot of crystals, of the same frequency and type as those in Lot 1, is being operated, at 25 percent of rated drive, in oscillators. The oscillators and test crystals are at room ambient conditions. Through 5 January 1963 this Lot completed approximately 2580 hours operation. One unit of this Lot (sample number 52) stopped oscillating after approximately 1430 hours operation. The sample was removed from test, and is being examined in an effort to assign a specific cause of failure.

Of the remaining 29 crystal units in this Lot, 17 units exhibited positive frequency shifts, and 11 units exhibited negative frequency shifts, at the end of 2,000 hours. One crystal unit has not changed in frequency since the measurement made at the conclusion of the first 24 hours of Phase II testing. A record of all frequency changes occurring in 2000 hours testing is presented in Table IV, Appendix I.

Lot 3

These 20 megacycle type CR-18A/U crystals are being operated, at 100 percent rated drive, in oscillators at room ambient conditions. In the interval between the 1,000 hour and the 2,000 hour frequency measurements, four units failed. These failure were:

Sample number 65 stopped oscillating after approximately 1504 hours of operation. It was determined that the crystal could be made to oscillate at a high drive level, but the equivalent resistance of the crystal had become so great that it would not oscillate in the

standard test set circuit, even at 400 percent of rated drive.

Sample number 67 was still oscillating at the conclusion of 2000 hours operation, but would not oscillate when tested after 24 hours of non-operating storage at plus 30 degrees Centigrade.

Sample number 79 stopped oscillating after approximately 1096 hours of operation.

Sample number 88 stopped oscillating after approximately 1768 hours of operation.

No definite cause of failure has yet been determined for samples 67, 79, and 88. The remaining 26 samples in this Lot were still operating within the allowable overall frequency tolerance (± 50 ppm) at the time of the 2000 hour frequency measurements. A record of the frequency changes occurring in this Lot is presented in Appendix I, Table 5.

Lot 4

These 20 megacycle CR-18A/U crystals are being operated in oscillators, at room ambient conditions, at 500 percent of the drive specified in MIL-C-3098C for crystals of this type and frequency. Through 5 January 1963, this Lot of crystals completed approximately 2555 hours of operation. There were no catastrophic failures during this period of operation.

Of the 29 crystal units in this Lot (one unit, number 120, failed during the preproduction tests), 17 had negative frequency shifts in excess of 50 parts per million at the conclusion of 2000 hours operation. A record of the frequency changes occurring during the first 2000 hours operation is given in Appendix I, Table VI.

Lot 5

These 50 megacycle CR-67/U crystals are being operated in oscillators, at room ambient conditions, at 100 percent of the drive level specified in MIL-C-3098/45. Through 5 January 1963 this Lot completed approximately 2507 hours of operation. Of the 29 units in this lot (sample number 20 failed the immersion test) 28 had changed in frequency less than the overall frequency tolerance of ± 25 parts per million during the first 2000 hours operation. The other unit, number 21, had changed minus 27.24 ppm at the end of 2000 hours operation. A record of the frequency changes of these crystals during 2000 hours operation is presented in Appendix I, Table VII.

Lot 6

This group of 50 megacycle CR-67/U crystals is being stored at a temperature of plus 85 degrees Centigrade. A total of 27 crystals are now in this Lot, as samples A3 and A13 failed the preproduction aging test, and sample A27 would not oscillate when tested after 225 hours in storage.

A record of the frequency changes occurring during the first 2000 hours of storage of this Lot of crystals is presented in Appendix I, Table VIII.

Lot 9

This group of 50 megacycle CR-32A/U crystals is being stored at the normal operating temperature specified for CR-32A/U crystals, plus 75 degrees Centigrade. A total of 25 crystals were put into storage, samples 15, 19, 21, 27, and 28 having failed during the performance of the preproduction tests.

The overall frequency tolerance for these crystals, per MIL-C-3098C, is plus or minus 20 parts per million. Through 1000 hours of storage, two samples, numbers 3 and 29, had frequency changes in excess of 20 ppm. After 2000 hours, 7 samples (numbers 3, 4, 6, 10, 11, 18, and 29) had frequency changes in excess of 20 ppm. A record of the frequency changes with time of this Lot of crystals is presented in Table XI, Appendix 1.

Lot 11

This Lot of 20 megacycle type CR-18A/U crystals, supplied by manufacturer B, completed approximately 980 hours of Phase II testing through 5 January 1963. These crystal units are being stored at a temperature of plus 85 degrees Centigrade. The overall frequency for these crystal units, per MIL-C-3098C, is plus or minus 50 parts per million. Through the 500 hour frequency measurements only one crystal had a frequency change in excess of that tolerance. That crystal, sample number 8, had shifted minus 146.25 ppm after 225 hours, and was minus 146.02 ppm at the 500 hour frequency measurement. A record of the frequency changes of this Lot of crystals is presented in Table XIII, Appendix 1.

Lot 12

This Lot of type CR-18A/U crystals is being operated, at 25 percent of rated drive, in oscillators at room ambient conditions. Approximately 900 hours of Phase II testing was completed on this Lot through 5 January 1963. None of the 30 crystals in this Lot had frequency changes in excess of the overall frequency tolerance of 50 parts per million at the conclusion of the first 500 hours of operation. No

catastrophic failures occurred during 900 hours of operation. The record of frequency changes with respect to time is presented in Table XIV, Appendix 1.

Lot 13

These type CR-18A/U crystals are being operated, at 500 percent of rated drive, in oscillators at room ambient conditions. The Lot completed 225 hours of Phase II testing 2 January 1963. Through 5 January 1963 there were no catastrophic failures in this Lot of crystals.

The overall frequency tolerance for these units (see MIL-C-3098C) is plus or minus 50 parts per million. At the 225 hour check, two crystals had changed in frequency more than 50 ppm. At that time, crystal number 74 was minus 183.40 ppm, and crystal number 83 was minus 56.50 ppm. A record of the frequency changes of each of the 30 crystals in this lot through 225 hours of testing is presented in Table XV, Appendix I.

Lot 15

This Lot of type CR-67/U crystals is being operated, at 100 percent of rated drive, in oscillators at room ambient conditions. This Lot completed approximately 900 hours of Phase II testing through 5 January 1963. The overall frequency tolerance for crystals of this type and frequency is plus or minus 25 parts per million.

Of the 26 crystal units comprising this Lot at the start of Phase II testing (4 units failed preproduction tests), 2 had exceeded this frequency tolerance after 125 hours operation, sample number 9 and sample number 11 each having frequency changes of minus 36.00 ppm. At the end of 225 hours, sample number 9 was minus 42.54 ppm, sample 11

was minus 33.34 ppm, and sample number 23 was minus 25.78 ppm. At the conclusion of 500 hours, 11 of the 26 crystals in this Lot had frequency changes in excess of 25 ppm. A complete record of the frequency changes occurring during 500 hours operation is presented in Table XVII, Appendix I.

Lot 16

This Lot of type CR-67/U crystals is being operated, at 25 percent of rated drive, in oscillators at room ambient conditions. During 500 hours of Phase II testing, there were no catastrophic failures, and no frequency changes in excess of the overall frequency tolerance of plus or minus 25 parts per million. The frequency changes occurring during 500 hours operation are shown in Table XVIII, Appendix I.

Lot 20

This Lot of type CR-74/U crystals is being stored at plus 85 degrees Centigrade. When put into storage 5 January 1963, there were 25 crystals in this Lot. Four crystals failed during the preproduction testing, and a fifth crystal was accidentally destroyed while it was being mounted for the vibration test.

Phases III, IV, and V:

The performance of these three Phases of the program cannot be initiated upon any Lot of crystals until the Lot completes Phase II. As each Lot of crystals completes Phase II, it will move immediately into Phase III, and at the conclusion of Phase III, be subjected to the tests comprising Phase IV.

Barring any unforseen troubles, Lot 1 should enter Phase III approximately 10 April 1963.

Conclusions

From a review of the data accumulated through this report period, some general trends can be detected, although with only 40 percent of Phase II completed on the crystal samples that have been in Phase II the longest period of time, any trend observed now may well be altered or even reversed by the conclusion of the test period.

For the type CR-18A/U crystal units now in Phase II, the average frequency change (in parts per million) per Lot was computed for each interval of the test sequence completed, with the following results:

Lot #	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.
1	0	+0.122	+0.124	-0.117	-7.034	-34.065
2	0	-0.073	-0.235	-0.408	-2.834	+1.328
3	0	-0.658	-5.765	-7.147	-15.698	-22.099
4	0	-4.045	-9.598	-16.875	-24.308	-54.938
11	0	-9.806	-8.817	-7.142		
12	0	-22.641	-21.991	-46.361		
13	0	+0.562	-16.321			

The conditions for these seven Lots of crystals are: Lot 1 is stored at +85°C; Lot 2 is oscillating at 25% of rated drive; Lot 3 is oscillating at 100% of rated drive; Lot 4 is oscillating at 500% of rated drive; Lot 11 is stored at +85°C; Lot 12 is oscillating at 25% of rated drive; and Lot 13 is oscillating at 500% or rated drive. The crystals in Lots 1, 2, 3, and 4 were supplied by manufacturer A, those in Lots 11, 12, and 13 were supplied by manufacturer B.

Six of the seven Lots exhibit a marked negative frequency shift. This in itself is not surprising, but the magnitude of the changes, particularly for Lots 1 and 12, is. The near quintupling of the average frequency change for Lot 1 in the interval from the 1000 hour to the 2000 hour checks is, at the moment, inexplicable. When the measurements made after 2000 hours were compared with those made after 1000 hours, it was felt that some error had been made in setting up the test equipment to perform the measurements, or that the equipment was not properly calibrated. The calibration of the instruments was checked and found to be correct. The measurements were then repeated, and the results agreed very closely with the original measurements.

The trend established by the frequency shifts occurring in Lot 4 agrees with what was expected for crystals subjected to high drive levels, but Lot 12 (at 25% drive) is showing a similar trend.

The average frequency change, in parts per million, for each Lot of type CR-67/U crystals now in Phase II was also computed. The results of these computations is tabulated below:

Lot #	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.
5	0	-0.733	-1.522	-2.822	-5.284	-9.903
6	0	+0.400	+0.326	-1.226	+0.005	-0.019
15	0	-3.343	-4.915	-30.333		
16	0	-0.416	-0.413	-0.583		

The conditions for these four Lots of crystals are: Lot 5 is operating at 100% of rated drive; Lot 6 is in storage at +85°C; Lot 15 is operating at 100% of rated drive; and Lot 16 is operating at 25% of

rated drive. The crystals in Lots 5 and 6 were supplied by manufacturer A, those in Lots 15 and 16 were supplied by manufacturer B.

The average frequency changes, in parts per million, for the CR-32A/U crystals in Lot 9, which are being stored at their reference temperature of +75°C, were: After 125 hours, -0.702; after 225 hours, +1.621; after 500 hours, -0.216; after 1000 hours, -5.754; and after 2000 hours, -19.436.

Program for the Next Interval

During the next Quarter, Phase I and Phase II testing will be continued, and investigation of the failed crystal units listed in the current report, as well as any units failing during the next interval, will be made. Identification of the plating metals used in the various failed crystals will be made.

With the additional data that will accrue during this interval, it is expected that some accelerated tests directed toward determining "time to first failure", "mean time between failures", and "life time" can be suggested.

Identification of Personnel

During this report period, three people have spent the majority of their working time on this contract. These are the Project Engineer, Mr. Jones, a technician, Mr. Switzer, and a second engineer, Mr. Roeger. A description of the background of Mr. Jones and Mr. Switzer was included in the First Quarterly Report. An outline of Mr. Roeger's training and experience is given below.

Through the end of this report period, Mr. Jones had performed approximately 1000 man-hours of work on this contract, Mr. Pease 470 man-hours (in designing and fabricating the test oscillators), Mr. Roeger 160 man-hours, and Mr. Switzer 973 man-hours.

Professional Record

ROEGER, EARL, JR. - Junior Engineer

Years Engaged in Profession - Since 1960

Academic Training

Mount Union College	B.S. Physics	1956-1960
University of Akron		1958

Employment Record

Dates	Company	Duties
1960 - Present	Inland Testing Laboratories	Engineer

Professional Experience

As an engineer at the Inland Testing Laboratories, is presently responsible for analyses of field failure data from the Army Equipment Record System. This includes statistical analyses to determine: reliability of equipments, components, and parts; probability of equipment and part availability; major problem areas in various electronic systems;

and maximum utility spare parts kits.

Has responsibility for the preparation of test procedures, and the supervision of laboratory technicians in the application of these procedures. Has designed test fixtures and chambers for vibration, shock, and variable-temperature testing of electronic and mechanical equipment, including solid-state converters, inverters, and audio amplifiers.

Prepares and edits test reports for submission to governmental agencies and private industry.

Security Clearance - Secret

APPENDIX I

Test Data

Note: Table numbers XII, XVI, XIX, XX, and XXI do not appear in the following data. These numbers are reserved for use on Lots of crystals that have not yet entered Phase II of this study.

TABLE I

Lot Nr.	Type	Nr. of Units Tested	Number of Failures (Preproduction Tests) Phase I							
			After Shock	After Vibration	After Low Temp. Storage	After Immersion	After Salt Spray	After Moisture Resistance	After Aging	Capacity
1	CR-18A/U	30	0	0	0	0	0	N.A.	0	0
2	CR-18A/U	30	0	0	0	0	0	N.A.	0	0
3	CR-18A/U	30	0	0	0	0	0	0	N.A.	0
4	CR-18A/U	30	0	1	0	0	0	0	N.A.	0
5	CR-67/U	30	0	0	0	1	0	0	N.A.	0
6	CR-67/U	30	0	0	0	0	0	N.A.	2	0
7	CR-67/U	30	0	0						
8	CR-67/U	30	0	0						
9	CR-32A/U	30	0	2	1	0	2	0	0	0
10	CR-74/U	30	No samples received from the manufacturer.							

Notes: All crystals listed were supplied by manufacturer "A".
N.A. indicates the test was Not Applicable
All failures recorded were catastrophic

TABLE II

Lot Nr.	Type	Nr. of Units Tested	Number of Failures (Preproduction Tests) Phase I							
			After Shock	After Vibration	After Low Temp. Storage	After Immersion	After Salt Spray	After Moisture Resistance	After Aging	Capacity
11	CR-18A/U	30	0	0	0	0	0	N.A.	0	0
12	CR-18A/U	30	0	0	0	0	0	N.A.	0	0
13	CR-18A/U	30	0	0	0	0	0			
14	CR-18A/U	30								
15	CR-67/U	30	1	0	0	0	0	N.A.	3	0
16	CR-67/U	30	0	0	0	0	0	N.A.	0	0
17	CR-67/U	30	0	0	0	0	0	0	N.A.	0
18	CR-67/U	30	0	0	0					
19	CR-32A/U	30	0							
20	CR-74/U	30	1	1	1	2	0	0		0

Notes: All crystals listed were supplied by manufacturer "B".
N.A. indicates the test was Not Applicable
All failures recorded were catastrophic

TABLE III - Phase II Testing, Lot 1, CR-18A/U

Unit Number	Frequency Change, Parts per Million, During Long Term Storage at 85°C								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
1	0	+0.50	+0.80	+0.80	-8.85	-29.71			
2	0	+1.41	+0.80	+0.70	-7.65	-11.96			
3	0	0	-0.40	-0.50	-14.21	-43.37			
4	0	0	-0.85	-0.40	-12.31	-26.36			
5	0	+0.30	+0.70	+0.85	-4.00	-6.85			
6	0	-0.70	-0.90	-1.31	-12.46	-38.82			
7	0	+0.40	+0.65	+0.50	-4.25	-20.41			
8	0	+0.25	+0.55	+0.40	-11.11	-36.62			
9	0	-0.55	-0.35	-0.20	-8.14	-41.12			
10	0	+0.40	-0.15	-0.50	-11.60	-13.91			
11	0	-0.30	-0.15	-0.05	+6.30	-13.96			
12	0	-0.10	-0.15	0	-17.56	-91.89			
13	0	+0.10	+0.25	+0.35	-50.77	-67.03			
14	0	+0.55	+0.30	+0.10	-16.81	-38.87			
15	0	-0.10	-0.85	-1.05	+2.55	-27.61			
16	0	0	0	0	0	-0.55			
17	0	+0.05	+0.15	+0.35	+3.60	-55.77			
18	0	0	+0.05	+0.05	+0.05	-0.55			
19	0	-0.10	-0.20	-0.35	-1.45	-40.97			
20	0	+0.05	+0.05	+0.15	-0.85	-23.36			
21	0	+0.10	+0.30	+0.35	-1.65	-5.25			
22	0	-0.10	-0.25	-0.60	+0.90	-46.37			
23	0	0	+0.15	+0.15	-2.12	-64.63			
24	0	+0.25	+0.50	+0.60	-12.41	-45.97			
25	0	+0.05	+0.25	+0.30	+2.05	-27.81			
26	0	-0.10	-0.35	-1.05	-8.95	-50.62			
27	0	+0.60	+1.10	+1.41	-1.45	-48.42			
28	0	+0.15	+0.85	+1.41	-5.35	-43.92			
29	0	+0.55	+0.90	+1.05	-5.00	-36.52			
30	0	0	0	0	-7.53	-22.76			

TABLE IV - Phase Testing, Lot 2, CR-18A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 25% drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
31	0	0	0	0	0	0			
32	0	+0.20	+0.40	+0.65	+1.41	+7.40			
33	0	+1.25	+1.15	+1.25	+1.25	+0.25			
34	0	-0.35	-0.50	-0.40	-3.15	+2.20			
35	0	-0.50	-1.60	-2.00	-6.75	-35.95			
36	0	+1.00	0	0	0	-0.70			
37	0	+0.10	+0.10	+0.30	+1.55	+3.55			
38	0	-0.20	+0.10	-0.05	-0.55	-10.55			
39	0	-0.15	-0.05	+0.05	-2.45	+6.90			
40	0	+0.55	+0.30	+0.30	-4.70	+23.96			
41	0	-0.10	-0.30	-0.60	+0.40	+0.40			
42	0	+0.05	+0.05	+0.05	+2.70	+8.05			
43	0	+0.25	+0.25	+0.30	+1.31	+0.80			
44	0	+0.10	+0.10	+0.10	-0.90	+3.60			
45	0	-0.45	-0.45	-0.30	-2.15	+17.36			
46	0	-0.15	-0.75	-1.00	-1.00	-1.50			
47	0	-0.70	-1.00	-1.00	-39.77	+0.45			
48	0	-0.50	-0.50	-1.00	-5.50	-3.00			
49	0	+0.70	+0.85	+0.60	+14.11	+8.95			
50	0	0	0	-0.35	-0.10	-3.35			
51	0	+0.15	+0.65	-0.30	+1.60	-1.90			
52	0	+0.70	+0.85	+1.15	-1.41	Failed			
53	0	-0.15	+0.05	-0.35	+0.65	-12.05			
54	0	-0.55	+0.20	+0.95	-3.05	+0.45			
55	0	-0.05	-0.95	-2.45	+10.05	+16.81			
56	0	-0.10	+1.50	+1.15	-0.75	-1.00			
57	0	-1.45	-2.35	-2.50	-13.01	-2.00			
58	0	-0.25	-1.05	-1.15	+3.85	-5.05			
59	0	-1.00	-2.45	-2.65	-11.81	+0.10			
60	0	-0.60	-1.85	-3.00	-27.76	+15.66			

TABLE V - Phase II Testing, Lot 3, CR-18A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 100% drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
61	0	+1.70	-1.45	-6.45	-17.15	-22.45			
62	0	-3.20	-6.30	-7.85	-20.70	-25.10			
63	0	-0.85	-3.10	-5.40	-17.90	-24.10			
64	0	-0.85	-2.45	-5.20	-19.00	-27.40			
65	0	-0.15	-2.45	-4.65	-17.90	Failed			
66	0	+7.00	-2.25	-5.65	-17.60	-46.35			
67	0	-12.70	-15.55	-5.25	-15.70	Failed			
68	0	-19.75	-42.60	-5.90	-16.25	-25.80			
69	0	+18.10	-2.60	-4.85	-15.40	-0.12			
70	0	+5.80	-2.15	-5.25	-16.15	-24.05			
71	0	-0.15	-2.85	-5.85	-15.70	-35.55			
72	0	+0.20	-2.55	-6.50	-15.50	-27.60			
73	0	+0.85	+2.30	+44.00	+35.40	+22.45			
74	0	+1.15	-2.35	-5.30	-13.70	-22.55			
75	0	-6.85	+17.60	+4.90	-3.75	-11.90			
76	0	-13.10	-12.40	-4.75	-14.50	-27.25			
77	0	+7.30	-3.20	-5.25	-14.50	-26.50			
78	0	-12.80	-85.75	-28.55	-26.30	-41.55			
79	0	-14.00	-23.00	-22.80	-19.80	Failed			
80	0	-2.15	-9.20	-12.80	-14.65	-35.75			
81	0	+34.50	+10.25	+6.95	-14.15	-29.75			
82	0	+21.30	-2.65	-7.35	-13.30	-44.15			
83	0	-17.50	-26.90	-25.20	-25.65	-23.10			
84	0	+1.00	-3.30	-6.70	-13.85	-27.40			
85	0	+1.25	-2.30	-6.25	-13.40	-34.95			
86	0	-2.30	-3.45	-9.15	-14.55	-31.85			
87	0	+0.45	-2.60	-7.50	-14.50	-26.60			
88	0	-15.50	-42.30	-46.80	-57.85	Failed			
89	0	+0.80	-9.50	-6.80	-13.75	-20.75			
90	0	+0.70	-2.60	-6.25	-13.60	-22.85			

TABLE VI - Phase II Testing, Lot 4, CR-18A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 500% drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
91	0	-2.45	-10.50	-16.20	-29.05	-76.85			
92	0	-6.55	-11.50	-16.50	-29.00	-79.50			
93	0	-5.50	-10.00	-20.00	-29.50	-80.30			
94	0	-6.50	-11.45	-20.75	-31.65	-83.40			
95	0	-5.45	-10.85	-18.55	-31.60	-80.65			
96	0	-6.10	-10.80	-16.70	-29.70	-85.25			
97	0	-6.75	-12.00	-17.50	-31.70	-81.95			
98	0	-2.55	-7.80	-12.00	-27.50	-78.95			
99	0	-5.10	-8.90	-19.40	-40.40	-48.50			
100	0	-5.75	-11.45	-15.00	-31.50	-81.90			
101	0	-6.10	-12.00	-16.10	-31.35	-82.10			
102	0	-5.80	-12.85	-19.65	-27.65	-87.10			
103	0	-0.15	-10.80	-14.85	-24.00	-36.05			
104	0	-13.55	-19.45	-31.95	-26.65	-12.80			
105	0	+1.95	-6.80	-12.35	-19.15	-25.75			
106	0	-1.65	-8.50	-20.75	-36.25	-45.45			
107	0	+1.50	-10.45	-18.25	-19.40	-78.25			
108	0	-6.40	-22.40	-29.80	-31.90	-33.25			
109	0	-2.60	-5.35	-11.85	-17.65	-26.70			
110	0	+2.20	-3.45	-16.05	-5.95	+4.65			
111	0	-10.90	0	-6.75	-6.45	-25.45			
112	0	-4.50	-11.10	-18.50	-19.05	-77.60			
113	0	-4.00	+0.25	-5.00	-7.75	-63.20			
114	0	-0.25	-12.75	-18.60	-19.45	-38.00			
115	0	-2.25	-9.40	-17.75	-17.75	-28.50			
116	0	-1.00	-10.90	-28.25	-40.00	-59.59			
117	0	-8.40	-6.50	-16.50	-26.75	-74.40			
118	0	-5.05	-11.70	-18.50	-23.80	-56.45			
119	0	-1.70	-8.55	-15.20	-16.70	-24.90			
120	Failed During Preproduction Tests								

TABLE VII - Phase II Testing, Lot 5, CR-67/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 100% Drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
1	0	+0.20	-2.58	-5.34	-10.66	-21.40			
2	0	-0.06	-2.00	-4.04	-7.90	-17.30			
3	0	-3.26	-2.36	-4.92	-4.10	-4.96			
4	0	0	-1.62	-3.86	-7.32	-8.64			
5	0	-1.76	-2.64	-4.80	-6.58	-9.60			
6	0	-0.10	-2.72	-2.94	-5.26	-15.50			
7	0	-0.40	-2.24	-5.40	-15.04	-15.34			
8	0	+0.16	-1.38	-4.16	-9.26	-13.40			
9	0	-2.28	0	-2.82	-3.50	-9.02			
10	0	+0.04	-1.62	-3.10	-3.50	-12.64			
11	0	+0.76	-2.34	-5.28	-8.22	-8.40			
12	0	+0.42	-1.86	-3.24	-10.80	-11.22			
13	0	+0.30	+1.36	-0.50	-1.66	-2.88			
14	0	-0.06	-2.04	-3.56	-4.28	-10.04			
15	0	-1.42	-3.56	-6.36	-7.80	-10.16			
16	0	+0.34	-1.46	-3.10	-3.56	-9.22			
17	0	+0.14	-2.38	-5.60	-6.86	-8.12			
18	0	-1.18	-1.68	-2.92	-2.42	-4.56			
19	0	-1.76	+2.00	0	-6.62	-7.34			
20	Failed Immersion Test								
21	0	-2.40	+1.50	+0.80	-1.58	-27.24			
22	0	-0.20	-1.92	-3.00	+3.30	-0.98			
23	0	-1.08	-0.18	0	-1.02	-12.48			
24	0	-0.46	-2.70	-3.94	-6.20	-7.50			
25	0	-2.00	-1.50	-1.70	-2.44	-5.64			
26	0	-0.02	-0.30	-0.30	-4.00	-5.92			
27	0	0	-3.00	-1.00	-2.04	-3.10			
28	0	+0.70	+4.78	+6.62	+4.52	+0.48			
29	0	-4.00	-5.72	-5.60	-14.36	-16.88			
30	0	-1.90	-4.00	-2.00	-4.10	-8.20			

TABLE VIII - Phase II Testing, Lot 6, CR-67/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Storage at 85°C								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
A1	0	-2.20	+1.28	-0.30	-2.74	-3.06			
A2	0	+0.32	+0.46	-3.02	-1.12	-1.72			
A3	Failed Aging Test								
A4	0	+2.08	+1.84	+2.48	-1.14	+1.00			
A5	0	+2.50	+2.00	+2.00	+1.34	+2.86			
A6	0	-1.86	-2.76	-3.70	-2.00	-4.68			
A7	0	+2.04	+2.36	+2.04	+1.74	+0.16			
A8	0	-6.00	-6.58	-7.56	-4.98	-5.72			
A9	0	+0.40	+1.42	+1.42	-0.94	-4.07			
A10	0	+2.92	+1.88	+0.76	+1.62	+0.76			
A11	0	+1.26	+2.10	+1.32	+0.58	+0.58			
A12	0	+0.16	+1.94	+1.30	+2.00	+1.62			
A13	Failed Aging Test								
A14	0	+2.10	+3.42	+0.94	+1.70	+1.42			
A15	0	-2.28	-2.14	-1.40	-0.30	-0.44			
A16	0	+0.70	+1.64	-3.10	+0.18	+0.92			
A17	0	-0.40	-0.30	-4.30	+18.40	+18.82			
A18	0	+1.60	+1.68	-0.14	+1.76	+3.86			
A19	0	+1.74	+0.36	-0.60	-0.14	+0.60			
A20	0	+3.41	+2.52	-1.94	+0.12	+0.48			
A21	0	-1.08	-4.38	-4.75	-2.62	-2.86			
A22	0	-0.38	-0.28	-0.12	-0.24	-0.16			
A23	0	+3.28	+2.56	+2.10	+1.18	+2.26			
A24	0	+0.42	-1.86	-2.58	-1.44	+0.44			
A25	0	-1.56	+0.54	-1.64	-1.42	-0.36			
A26	0	+0.98	+0.24	-1.52	+1.70	+1.30			
A27	0	+1.94	Failed						
A28	0	-2.98	-4.26	-16.90	-21.64	-21.56			
A29	0	+0.14	+0.96	+2.54	+7.80	+7.44			
A30	0	+1.56	+2.16	+1.08	+0.72	+0.52			

TABLE XI - Phase II Testing, Lot 9, CR-32A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Storage at 75°C								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
1	0	+1.38	+2.36	+1.60	+4.86	-17.76			
2	0	+1.14	+2.46	+2.08	+1.92	-9.34			
3	0	-2.18	-0.70	+0.70	-37.70	-73.08			
4	0	+0.60	+1.92	+0.36	-6.24	-29.42			
5	0	-0.02	+1.54	+0.70	-11.86	-13.88			
6	0	-5.60	-3.22	-2.82	-2.14	-23.16			
7	0	+0.76	+2.28	+0.84	-1.72	-9.20			
8	0	-2.64	-0.48	-1.32	-1.94	-18.20			
9	0	+0.66	+2.80	+1.02	-3.60	-19.38			
10	0	-2.80	+0.60	-3.06	-8.96	-22.80			
11	0	-4.12	-1.16	-4.00	-10.50	-23.36			
12	0	+0.58	+2.62	+2.22	-5.12	-17.20			
13	0	+1.06	+3.28	+2.10	-3.72	-13.16			
14	0	+2.28	+4.36	+2.48	-7.46	-19.84			
15	Failed Salt Spray Test								
16	0	-1.60	+0.48	-0.92	-11.86	-15.20			
17	0	-0.76	+1.78	+0.30	-4.72	-18.92			
18	0	-1.18	+0.78	-2.06	-11.04	-33.50			
19	Failed Salt Spray Test								
20	0	-4.00	-1.46	-2.30	-8.40	-17.98			
21	Failed Vibration Test								
22	0	-3.66	-1.18	-2.52	-7.42	-11.32			
23	0	+2.18	+5.70	+4.14	-2.10	-10.20			
24	0	+1.98	+5.52	+4.34	+11.46	+0.56			
25	0	+0.42	+2.54	+1.30	+3.18	-14.12			
26	0	+0.88	+3.60	+2.08	+11.56	+14.86			
27	Failed Vibration Test								
28	Failed Low Temperature Storage Test								
29	0	-4.20	-1.66	-3.96	-31.22	-63.74			
30	0	+1.28	+5.78	+2.10	+0.88	-6.60			

TABLE XIII - Phase II Testing, Lot 11. CR-18A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Storage at 85°C								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
1	0	-14.60	-26.00	-14.25					
2	0	-3.70	+3.00	+8.90					
3	0	-5.05	+0.25	+0.75					
4	0	-17.25	-14.15	-11.30					
5	0	-10.20	-4.75	-0.90					
6	0	-4.30	-0.65	+0.03					
7	0	-6.40	-1.65	-2.80					
8	0	-2.85	-146.25	-146.05					
9	0	-2.35	+1.60	+6.65					
10	0	-15.20	-10.10	-6.65					
11	0	-6.90	-0.02	+1.20					
12	0	-9.85	-5.25	-3.70					
13	0	-18.50	-15.40	-13.10					
14	0	-24.20	-20.90	-18.10					
15	0	-3.60	-1.30	+3.00					
16	0	-15.65	-8.30	-7.10					
17	0	-6.10	+1.35	+2.20					
18	0	-17.05	-13.50	-9.45					
19	0	-4.65	+0.25	+2.65					
20	0	-4.10	+0.55	+3.80					
21	0	-7.05	+2.40	+5.35					
22	0	-12.45	-4.90	-1.60					
23	0	-8.50	-5.55	-3.80					
24	0	-8.75	-5.30	-2.40					
25	0	-8.75	-4.90	-1.05					
26	0	-17.45	-9.35	-5.65					
27	0	-17.00	-10.15	-4.90					
28	0	-11.15	-4.30	+0.65					
29	0	-6.55	-1.40	+1.00					
30	0	-4.05	0	+2.35					

TABLE XIV - Phase II Testing, Lot 12, CR-18A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 25% drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
31	0	-30.65	-26.65	-44.65					
32	0	-11.30	-9.00	-25.95					
33	0	-21.50	-16.90	-36.30					
34	0	-6.95	+1.55	-20.75					
35	0	-21.35	-27.00	-58.45					
36	0	-11.05	-8.10	-27.10					
37	0	-22.85	-18.40	-37.10					
38	0	-47.15	-41.65	-59.85					
39	0	-31.20	-31.40	-47.10					
40	0	-32.05	-26.65	-49.20					
41	0	-9.90	-6.45	-24.55					
42	0	-24.55	-18.25	-39.30					
43	0	-28.75	-78.30	-146.45					
44	0	-30.25	-31.95	-54.75					
45	0	-40.15	-39.90	-61.65					
46	0	-33.50	-31.60	-51.40					
47	0	-21.45	-32.10	-56.50					
48	0	-31.25	-30.20	-48.90					
49	0	-62.30	-60.80	-86.90					
50	0	-4.80	-9.40	-28.45					
51	0	-15.20	-10.60	-34.45					
52	0	-10.15	-6.55	-31.95					
53	0	-37.75	-34.60	-57.55					
54	0	-9.10	-4.60	-31.15					
55	0	-8.35	-6.05	-32.75					
56	0	-14.70	-13.95	-35.20					
57	0	-19.15	-14.45	-45.05					
58	0	-14.85	-8.95	-37.50					
59	0	-11.10	-5.80	-43.80					
60	0	-15.95	-11.05	-40.15					

TABLE XV - Phase II Testing, Lot 13, CR-18A/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 50% Drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
61	0	-0.95	-2.35						
62	0	-0.95	-2.20						
63	0	+[illegible].60	-3.20						
64	0	-0.55	-1.70						
65	0	+0.25	+0.70						
66	0	+3.45	-2.35						
67	0	+4.85	-3.70						
68	0	-0.45	+2.05						
69	0	-0.70	-41.45						
70	0	-0.30	+3.75						
71	0	-0.85	-48.00						
72	0	-0.40	+2.40						
73	0	-0.75	-15.40						
74	0	+0.65	-183.40						
75	0	+0.45	+1.10						
76	0	+0.35	+0.45						
77	0	+0.55	+0.65						
78	0	+1.00	+2.70						
79	0	+0.25	-8.55						
80	0	-4.75	-27.85						
81	0	+0.85	-0.50						
82	0	+1.80	-39.85						
83	0	+0.40	-56.50						
84	0	+2.05	+2.40						
85	0	+0.80	+0.55						
86	0	-0.10	-13.95						
87	0	-0.25	+0.30						
88	0	+0.85	+0.90						
89	0	+1.45	-47.60						
90	0	+3.25	+0.05						

TABLE XVII - Phase II Testing, Lot 15, CR-67/U

Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 100% Drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
1	0	-0.94	-5.40	-49.90					
2	0	-1.92	-4.10	-50.18					
3	0	+0.22	+0.22	-8.72					
4	0	-11.96	-14.96	-60.92					
5	0	+1.32	+1.28	-8.02					
6	0	-0.76	-0.24	-9.66					
7	0	-0.56	-2.90	-10.12					
8	0	+5.20	+2.20	-4.14					
9	0	-36.00	-42.54	-89.38					
10	0	+7.20	+4.66	-4.42					
11	0	-36.00	-33.34	-84.76					
12	0	+20.00	+16.52	+10.46					
13	0	+6.00	+3.32	-5.42					
14	0	0	+1.28	-8.92					
15	0	0	-2.76	-49.12					
16	0	+1.00	-1.16	-11.86					
17	0	-1.26	-2.68	-14.64					
18	0	-0.62	-2.52	-54.24					
19	0	+1.50	-0.01	-10.04					
20	Failed Aging Test								
21	0	+0.50	-1.88	-48.10					
22	0	-1.08	+0.12	-12.08					
23	0	-22.84	-25.78	-42.40					
24	0	+3.14	+1.68	-8.68					
25	Failed Shock Test								
26	0	+0.50	-3.90	-55.42					
27	Failed Aging Test								
28	Failed Aging Test								
29	0	-20.52	-22.88	-79.40					
30	0	+0.46	-2.02	-9.12					

TABLE XVIII - Phase II Testing, Lot 16, CR-67/U

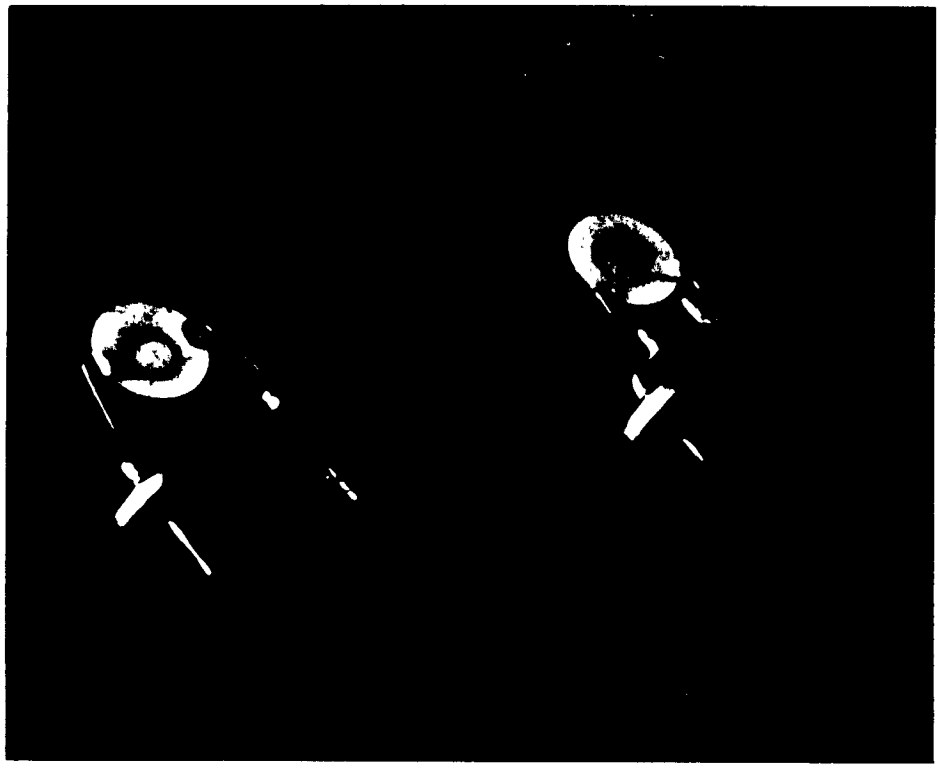
Unit Number	Frequency Change, Parts Per Million, During Long Term Oscillation at 25% Drive								
	24 hrs.	125 hrs.	225 hrs.	500 hrs.	1000 hrs.	2000 hrs.	3000 hrs.	4000 hrs.	5000 hrs.
A1	0	-0.02	+3.32	+5.36					
A2	0	-0.92	-0.64	-1.08					
A3	0	-0.90	-1.96	-2.42					
A4	0	-0.96	-1.00	-2.06					
A5	0	-1.30	-1.22	-1.46					
A6	0	-3.52	-3.32	-3.44					
A7	0	-1.52	-0.98	-0.24					
A8	0	-0.08	-0.30	-0.06					
A9	0	-0.32	-0.58	-1.62					
A10	0	-1.34	-0.38	-1.00					
A11	0	-0.76	+0.01	+0.08					
A12	0	-0.04	-1.26	-0.62					
A13	0	-0.34	-1.66	-2.54					
A14	0	+0.08	-0.62	-0.54					
A15	0	+0.50	-1.12	-2.16					
A16	0	+0.60	+2.00	+3.14					
A17	0	+1.38	+3.02	+5.52					
A18	0	-0.20	-0.98	-2.34					
A19	0	+0.46	+0.08	-2.50					
A20	0	+0.42	-1.58	-2.06					
A21	0	+0.44	+0.30	+1.10					
A22	0	-2.86	-2.34	-1.86					
A23	0	+1.32	-0.64	+0.20					
A24	0	+0.18	+1.94	+1.98					
A25	0	+0.70	-0.40	-2.08					
A26	0	-0.68	+0.22	-1.84					
A27	0	-0.44	+0.88	+2.92					
A28	0	-0.14	-1.24	-1.30					
A29	0	-1.10	-0.20	-2.36					
A30	0	-1.12	-1.74	-2.22					

APPENDIX II

Illustrations

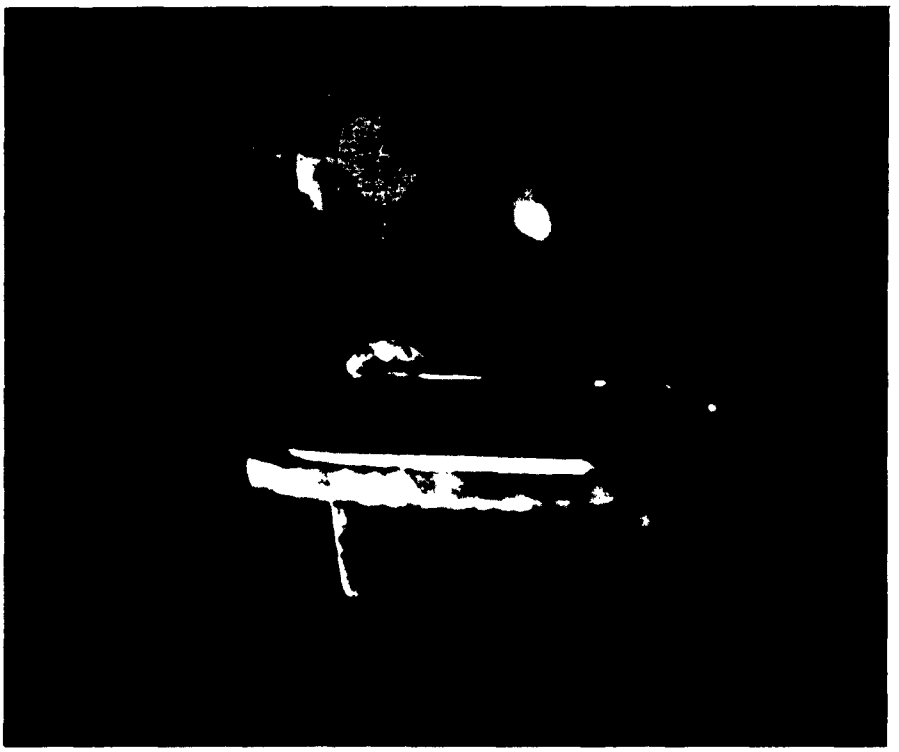
Shown above is sample number 120 of Lot No. 4, which sustained a broken support wire during the vibration test.

FIGURE 1



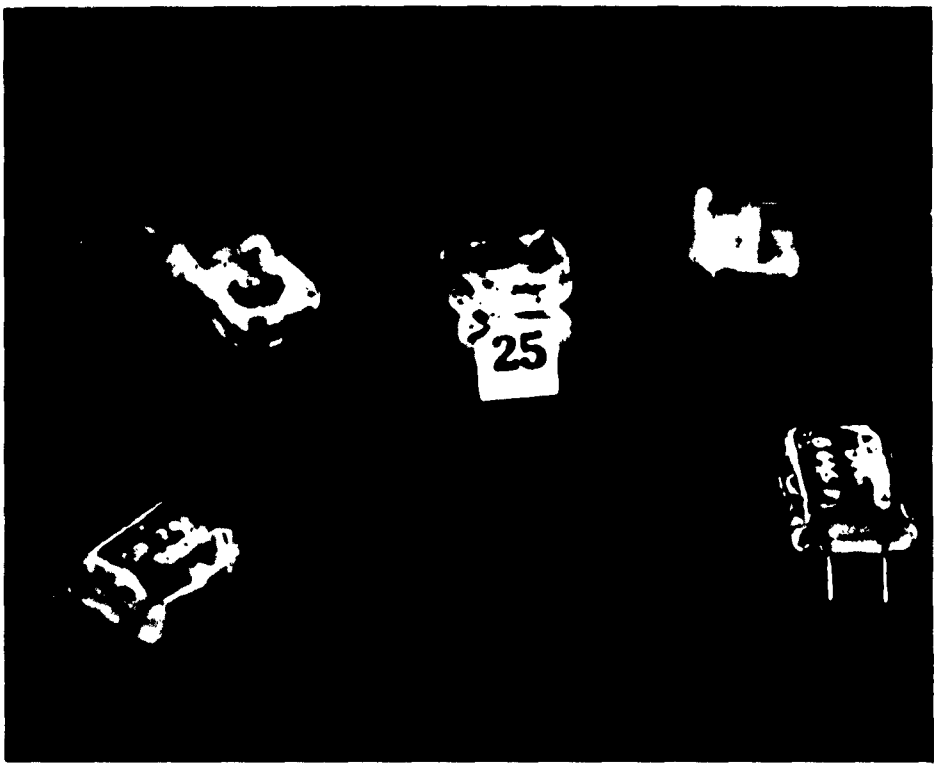
Shown above are samples number 21 (left) and 27 (right) of Lot No. 9 which sustained the damage illustrated during subjection to the vibration test.

FIGURE 2



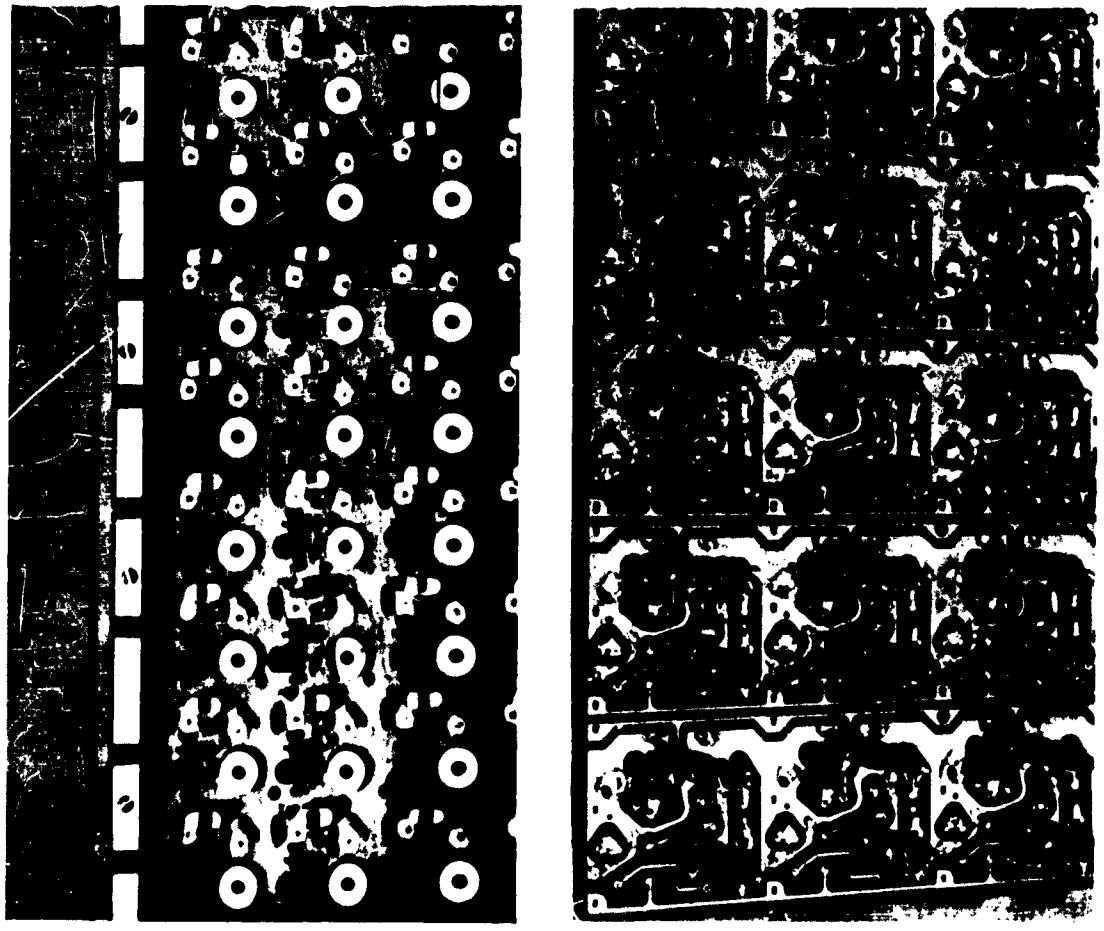
Sample No. 25 of Lot 15, shown above, received the damage illustrated during the shock test.

FIGURE 3



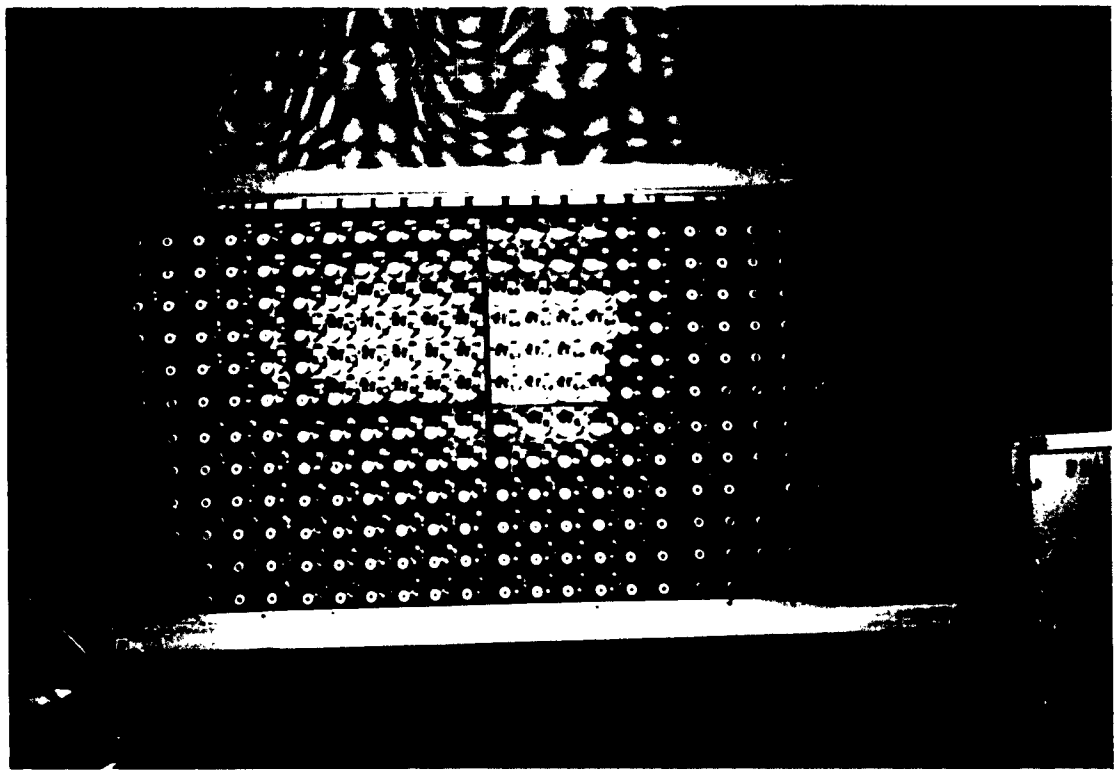
Type CR-74/U crystal units, showing Lot No. 20 samples that failed preproduction tests.

FIGURE 4



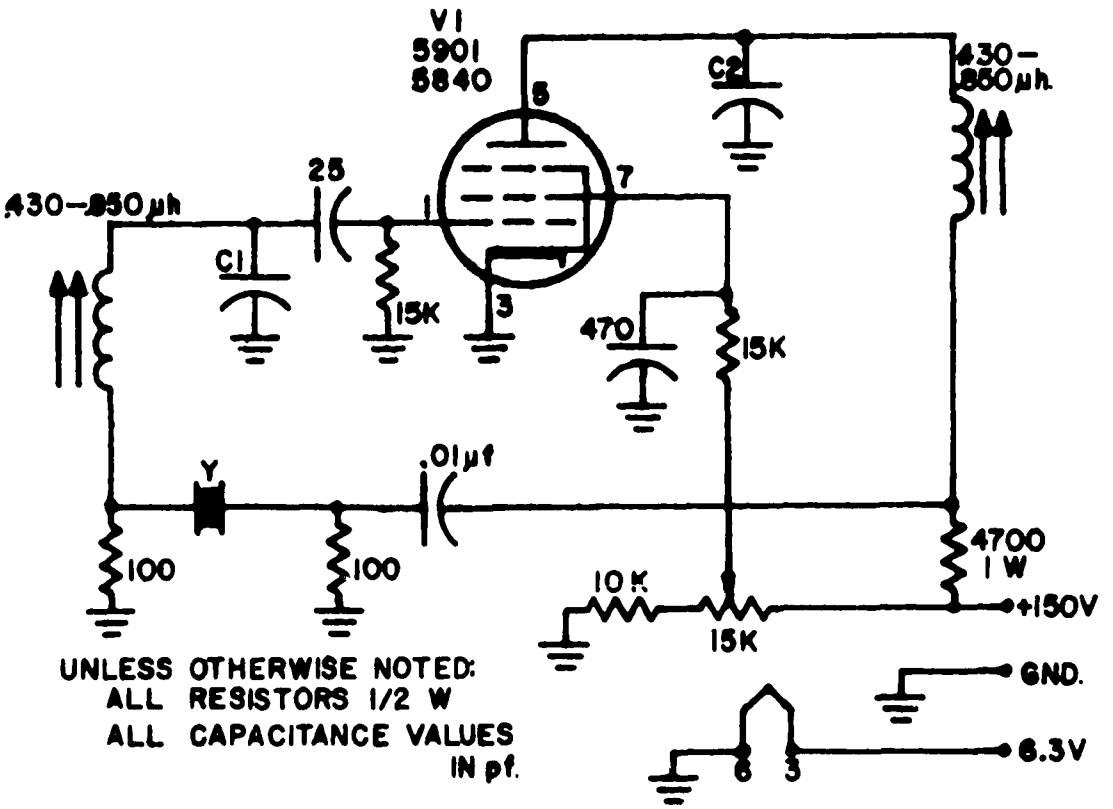
Partial front (on left) and rear views of typical printed circuit oscillator board used for life test oscillators.

FIGURE 5



Front view of bank of life test oscillators in operation.

FIGURE 6



CAP.	Y-20MC	Y-50MC
C1	91 pf	15 pf
C2	91 pf	15 pf

SCHEMATIC OF LIFE TEST OSCILLATOR CIRCUIT.

FIGURE 7

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and the development of the reliability test program
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Included are frequency change data for various periods
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