FR-1138

Prob.F2-6

REPORT NO. R-1138

DATE 25 March 1935

SUBJECT

Test of Model LJ Aircraft Crystal Frequency Indicator

(Type CHS-74015)

Serial No.11

BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

NRL Report No. R-1138
Test of Model LJ Aircraft Crystal Frequency Indicator

25 March 1935

NRL Report No. R-1138
Bu.Eng.Prob.F2-6

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Test of Model LJ Aircraft Crystal Frequency Indicator

(Type CHS-74015)
Serial No.11

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 12 Tables - 4 Plates - 15

Authorization: BuEng let.F42-1(9-7-W3) of 19 Sept.1934.

Date of Test: November 8, 1934 to January 28, 1935.

Prepared by:

H. F. Hastings, Assistant Radio Engineer

Reviewed by:

M. H. Schrenk, Associate Radio Engineer (Chief of Section)

A. Hoyt Taylor, Physicist, Supt. Radio Division

Approved by:

H. R. Greenlee, Captain, U.S.N., Director

Distribution: BuEng (4)
BuAero (2)

LF

Table of Contents

Appendices

AUTHORIZATION FOR TEST

1. This problem was authorized by Bureau of Engineering letter, ref.(a), and other additional references pertinent to this problem are listed as refs. (b) to (d).

Reference: (a) BuEng let.F42-1(9-7-W3) of 19 September 1934.
(b) Specifications RE 13A 489A
(c) NRL Report No. A-1045 of 10 April 1934, Test of Type CHS 74015 Crystal Frequency Indicator.
(d) NAS Report No. NASA Report RT-2 of 12 February 1935.

OBJECT OF TEST

2. The object of this test was to determine the mechanical and electrical characteristics of the Model LJ aircraft crystal frequency indicator as required by ref.(b).

ABSTRACT OF TEST

3. The mechanical features and workmanship were checked by careful inspection. The Model LJ equipment was set up with the RU-2 and RU-3 receivers to check its operating characteristics. The electrical characteristics were checked by measurements in the Laboratory. Temperature frequency characteristic data were taken of the self oscillator and the ten crystals over the range from -30°C to +50°C.

4. The equipment was then taken to the Naval Air Station, installed in the XRE-1 Bellanca cabin plane no.8938 and tests were conducted under actual flight operating conditions.

Conclusions

It is concluded:

(a) That the Model LJ aircraft crystal frequency indicator does not meet the requirements of the specifications and it is unsatisfactory for use in the Naval Service in its present condition.

(b) That the heterodyne oscillator frequency readings are unreliable.

(c) That the backlash in the gear drive mechanism is excessive and no accessible means for lubrication or adjustment is provided.

(d) That the zero beat zone is too wide.

(e) That the audio output is inadequate.

(f) That the zero correcting mechanism for the heterodyne oscillator does not cover a sufficient number of divisions to correct for all temperatures between -30°C and +50°C.

(g) That the crystal coupling condenser (C-4) is subject to corrosion.

(h) That some of the ground connections are improperly made through screws that make high resistance contact to the shield.

(i) That the equipment is one pound over weight.

(j) That the voltage rating of the by-pass condensers is too low.

(k) That three of the ten crystals are unsatisfactory.

(l) That the crystal oscillator is satisfactory for adjusting transmitters and receivers to the fundamental second, third, and fourth harmonic frequencies provided the crystals are satisfactory.

(m) That except for weight, size, and the convenience of setting a transmitter or receiver to the crystal frequencies and their harmonics, the Model LJ is surpassed by the Model LJ-1.

Recommendations

It is recommended:

(a) That a convenient and suitable means be provided to correct the backlash of the dial drive mechanism and to maintain the correction in accordance with par. 3-21 of specifications, ref. (b).

(b) That the index denoting the hundreds divisions be geared to the zero correcting device in such a manner that 100 divisions of the fine adjustment would equal one division of the coarse indicator; the total correction range to be $\pm$ 200 divisions instead of $\pm$ 50 divisions.

(c) That the voltage gain of the audio amplifier be increased to give the audio output required by pars. 3-6(d) and 3-18 of ref. (b).

(d) That 400 volt fixed condensers be used instead of the 200 volt type furnished.

(e) That the coupling between crystal and heterodyne be reduced so that the zero beat zone is not greater than 2 divisions at any frequency in the calibrated range.

(f) That the oscillator be made to maintain a constant frequency when subjected to severe shock and vibration.

(g) That all ground connections be made direct to the shield and not through screws used to support component parts.

(h) That a better grade of fiber washer be used to protect isolantite parts and binding posts, so that all parts will remain secure throughout the temperature and humidity changes called for by the specifications.

(i) That all tube clamping devices be so arranged that it is not necessary to twist them out of shape to have the adjustment screws line up with the access holes.

(j) That the crystal coupling condenser (C-4) be suitably protected against corrosion.

(k) That the crystals be held rigid in the wheel with sufficient clearance from the case to prevent scratching the paint.

(l) That the tube sockets be marked with the tube type number.

(m) That the serial numbers be engraved on the front panel and calibration chart to avoid assembly of the equipment with the wrong chart.

(n) That some form of bracket be provided to support the equipment when out of the case.

(o) That the spare parts be furnished with models sent to the Laboratory for test.

(p) That the volume control be made to uniformly vary the signal throughout its entire range without affecting the frequency of the crystal or heterodyne oscillators.

(q) That all crystals be ground in accordance with specifications. Three out of ten do not meet the requirements.

(r) That some means be provided to quickly attach and detach the calibration chart. Latches similar to the ones used to hold the equipment to the mounting base are suggested.

(s) That this equipment be considered unsatisfactory for use in the Naval Service until the above recommendations are complied with in a manner meeting the approval of the Bureau of Engineering.

DESCRIPTION OF MATERIAL UNDER TEST

5. The Model LJ aircraft crystal frequency indicator, Ser.No.11, was manufactured by the Hygrade-Sylvania Corporation and it consists of a crystal oscillator and a calibrated heterodyne oscillator. A 75 tube is used for the crystal oscillator. A 6A7 is used as a heterodyne oscillator and detector. A 37 is used as an audio output tube. The filament and plate supply is obtained by connecting the indicator cable to the junction box of a Model RU-2 or RU-3 receiver. Any one of ten crystals may be selected for direct check of a transmitter or receiver at their fundamental or harmonic frequencies. The heterodyne oscillator can be calibrated against any one of the crystal fundamentals or harmonics and a transmitter or receiver frequency checked at points remote to the crystal frequencies. A strip type calibration chart is mounted on top of the equipment.

METHOD OF TEST

6. The back lash was tested by moving the fine adjustment dial through the arc that caused no movement of the condenser shaft. The zero beat zone was checked by beating the heterodyne against both the crystal oscillator and a transmitter. This zone is equal to the total movement of the fine adjustment dial minus the back lash. The zero correcting device was checked from the temperature frequency characteristic curve of the heterodyne oscillator by noting the frequency change at different temperatures and attempting to reset the correcting device to compensate for that frequency change.

7. The audio output was measured for three different conditions as follows:

(a) The crystal oscillator beating with the standard signal generator.
(b) The heterodyne oscillator beating with the standard signal generator.
(c) The crystal oscillator beating with the heterodyne oscillator.

In each case the audio frequency power output was measured by a power output meter.

8. Temperature frequency characteristic data of the crystal and heterodyne oscillators were taken at each 10° from -30° to $+50^\circ$C. At $+10^\circ$ C the battery voltage was changed $\pm$ 10% and frequency changes of the crystal and self oscillators noted. For all other measurements and one set of readings at $+10^\circ$C the battery voltage was kept constant at 12 volts by charging the battery at the proper rate from the 110 volt d.c. line.

9. The radio frequency energy available between the output terminal and ground was measured by coupling the crystal frequency indicator direct to the receiver terminal and noting the output at 1,000 cycle beat. The standard signal generator was then substituted for the crystal frequency indicator and the necessary voltage supplied to give the same output indication. The voltage supplied equals that generated by the crystal frequency indicator.

10. Flight tests were conducted at the Naval Air Station, Anacostia, D.C., to determine the general operating characteristics of the equipment. Frequencies were measured by the crystal frequency indicator and the Naval Research Laboratory at the same time during flight. After the Model LJ equipment was adjusted to heterodyne the 6060 kilocycle carrier from W8XAL to give a beat note of about 800 cycles in the non-oscillating receiver, two successive landings were made on the field to determine the frequency shift due to vibration and shock.

11. The following instruments were used:

(a) General Radio Model LC-A standard signal generator, Ser.No.2.

(b) General Radio output power meter, Type 583-A, Ser.No.67.

(c) Special refrigerator assembled by the Naval Research Laboratory.

(d) Frequency standard measuring equipment, Model LF, Ser.No.1 exp. heterodyne frequency measuring equipment.

(e) Weston D.C. voltmeter, Model 45, Ser.No.41097, range 0 - 15, accuracy within 1/3 of 1% of full scale value at any part of the scale at 68°F in horizontal position. This instrument was used to measure the battery voltage.

(f) Weston D.C. ammeter, Model 45, Ser.No.30006, accurate to within 1/2 of 1% of full scale value at any part of the scale at 75°F. This instrument was used with a 50 mv shunt, Model 24, Ser.No.115618 to measure the filament current.

(g) Weston D.C. voltmeter, Model 564, Ser.No.1280 was used to measure the plate voltage.

(h) Weston milliammeter Model 1, Ser.No.32195, accurate to within 1/4% of full scale value at any part of the scale at 25°C was used to measure the plate current.

(i) General Radio beat frequency oscillator type 513-D, Ser.No.60.

DATA RECORDED DURING TEST

12. The data recorded during these tests is shown in the tables and plates of the appendix. Plates 1 to 10 show the temperature frequency characteristic of the crystals. Plates 11 and 12 show the temperature frequency characteristic of the self oscillator. Plate 13 shows the linear characteristic of the detector and audio amplifier. Plates 14 and 15 are photographs of the equipment.

13. Appendix 1 is a report of the flight tests made at the Naval Air Station, Anacostia, ref.(d) of this report. Table 1 shows the tabulated frequencies checked during flight test. Table 2 shows the tabulated power outputs. Table 3 shows the crystal data of three unsatisfactory crystals. Table 4 shows the radio frequency output.

DISCUSSION OF PROBABLE ERRORS

14. The accuracy of the measuring equipment used for these tests is as follows:

Standard signal generator	± 10%
Power output meter	± 5%
Temperature measurements	± 0.1%
Frequency measurements	± 0.001%
Low voltage readings	± 0.33%
Filament current	± 0.5%
Plate voltage readings	± 2%
Plate current readings	± 0.25%

RESULTS OF TESTS

15. No comment will be made on paragraphs of the specifications that are satisfactory. All other specifications will be listed in order and the defects noted.

1-1. This equipment can be satisfactorily installed on various classes of Naval aircraft. The operation is unsatisfactory as follows:

(a) The heterodyne oscillator changes frequency and at times stops oscillating due to vibration, shock, and difficulties inside of the sealed can containing the variable condenser, coil, and switch.

(b) Excessive back lash was observed varying between 10 and 15 dial divisions due to the fit of the worm drive and bevel gears. This should not exceed 2 divisions in accordance with specification 3-21. No easily accessible means for adjustment or lubrication of the gears is provided.

(c) The zero beat zone approximates 10 divisions in addition to the backlash.

(d) The zero correcting mechanism for the heterodyne oscillator is inadequate. It should cover ± 200 divisions instead of ± 50 divisions. The index denoting hundreds divisions should be geared to this zero correcting device in such a manner that one hundred divisions of the fine adjustment would equal one division. When making a reading, if the hundreds dial shows approximately 3450 divisions and the correction mechanism is set 50 divisions off, it is confusing to the operator whether the actual reading is 3400 or 3500. If the index moved as stated above this could not occur.

(e) The 355 and 375 kilocycle calibration points are not marked on the chart.

(f) The low grade fiber washers used to protect binding posts and isolantite parts shrink with changes in temperature and humidity. This causes: (1) loose input and output terminals; (2) one of the supporting screws on socket V-2 to make poor contact with the shield and the filament circuit which is grounded through this screw fails.

(g) The audio output is inadequate for direct calibration of transmitters under flight conditions at harmonic frequencies of the crystal frequency indicator. A coupling lead of 18 inches tightly twisted around the antenna is insufficient for proper audio output and it widens the zero beat zone too much. Less coupling with more audio frequency gain is necessary.

(h) The volume control does not uniformly vary the output. Zero signal spots occur at different points throughout the range.

(i) Three crystals are off frequency by 2 to 4 times the maximum specified allowance (544, 4135, and 4235 kilocycles). The 4135 kilocycle crystal also jumps frequency between -10°C and -20°C.

(j) One of the 200 volt by-pass condensers broke down during test. The voltage rating should be 400.

(k) The movable plates of the variable air condenser used with the heterodyne oscillator touch the stationary plates between 1000 and 2000 dial divisions. This is sealed in a can and it is difficult to inspect or correct outside of the factory.

1-2. The heterodyne oscillator is unsatisfactory for measuring frequencies of a transmitter or receiver due to the following reasons:

(a) See par.1-1(a).

(b) See par.1-1(b).

(c) See par.1-1(c).

(d) See par.1-1(d).

(e) See par.1-1(g).

(f) Excessive frequency variation with changes in temperature. The crystal oscillator is satisfactory except as noted below:

Three of the ten crystals are off frequency by 2 to 4 times the maximum allowed by the specifications. The 4135 kilocycle crystal jumps frequency between -10°C and -20°C. The audio output is low for measurements above 4235 kilocycles.

1-3. The equipment is complete except as noted below.

(3) Provision should be made to more easily detach the calibration chart for mounting elsewhere in the ship.

(5) The miscellaneous spare parts and accessories herein required should be furnished with the sample model for test. Tests were delayed when condenser C-7 failed.

2-2. See par.1-1(j)

2-3. The base clamping device for the type 38617 (6A7) heterodyne mixer tube is twisted around because of lack of proper alignment with screw driver access hole. Threaded inserts would be preferable to the nuts on these tube clamps. The crystal coupling condenser (C-4) is subject to corrosion due to use of unprotected brass and bronze material.

2-4. The workmanship is unsatisfactory as follows:

(a) See par.1-1(f).

(b) See par.1-1(e).

(c) See par.1-1(d).

(d) See par.1-1(b).

(e) See par.1-1(k).

(f) The inside of the case is subject to corrosion where the crystal holders rub the paint off.

(g) The tube sockets are not marked to indicate the type of tube to be used.

(h) Serial numbers are not engraved on the front panel and calibration chart to avoid assembling the equipment with the wrong chart.

(i) See par.1-1(a).

(j) The bracket that supports C-2 and C-7 cannot be removed and replaced without removing L-7. This bracket should be so shaped that it would support the weight of the equipment when out of the case.

2-5. Crystal coupling condenser (C-4) is subject to corrosion due to the use of unprotected brass and bronze material. See par.2-4(f).

2-7. This equipment was tested in temperatures ranging from -30°C to +50°C. When the temperature was dropped from +50°C to +10°C to comply with par.3-26 of specifications, the filament circuit failed as noted by par.1-1(f).

2-10. The following items entering into the construction of this equipment are not capable of operating continuously without damage:

(a) Condenser C-7 broke down during tests. The voltage rating is too low. See par.1-1(j).

(b) Crystal coupling condenser C-4 is subjected to damage from corrosion. See par.2-5.

(c) The crystal holders rub the paint off inside the case and corrosion takes place. See par.2-4(f).

2-11. No platform or acceleration testing equipment is available for this test in the Laboratory. The heterodyne oscillator changes frequency and stops oscillating at times due to vibration and shock. Flight tests were made at the Naval Air Station, Anacostia, D.C. See Appendix I, NASA Report RT-2.

2-13. See par.1-3 (5).

2-14. See par.2-4 (h).

2-15. See par.1-1 (f).

2-16. See par.1-1(a), 1-1(k), 2-4(f).

2-20. The oscillator grid and plate leads are not properly supported and isolated from other leads.

2-21. The best material known is used for this purpose.

2-25. See par.1-1(d).

2-26. None used.

2-31. Operation is safe, but performance is unsatisfactory as noted in pars. 1-1 and 1-2.

2-35. See par.2-3, 2-4(f).

2-37. Tubes could be changed much more readily if thumb screws or latches were used to hold the equipment in the case instead of round head screws.

2-39. The bracket supporting parts (C-2) and (C-7) cannot be removed and replaced without removing L-7.

2-40. The calibration curves show the frequencies increasing downward (toward the operator) rather than in the usual upward direction.

2-41. The 4135 kilocycle crystal jumps frequency between -10°C and -20°C.

3-1. See par.1-1(d).

3-2. See par.1-1(g).

3-4. This method is satisfactory, but the zero correcting device is inadequate for correcting the oscillator at all temperatures ranging between -30°C and +65°C. See par.1-1(d).

3-6. (b) The grid and plate leads to the heterodyne oscillator are not isolated or screened from other circuits.

(c) See Plate 13.

(d) The output circuit matches a 10,000 ohm impedance and all output powers were measured at this value. 20,000 ohm or 600 ohm phones are suitable at reduced output powers. See par.1-1(g). At 355 and 2102.5 kilocycles, the audio output was checked in three different ways:

(1) 1/2 volt from the standard signal generator, beating against the crystal oscillator.

(2) 1/2 volt from the standard signal generator, beating against the heterodyne oscillator.

(3) The heterodyne oscillator beating against the crystal oscillator.

Table 2 shows the results of this test.

3-11. The pressure and humidity could not be controlled. Temperature frequency curves were taken from -30°C to +50°C as shown by Plates 1 to 10 inclusive. Voltage variations as specified by par.3-26 do not alter the operation. Vibration does not alter their operation.

3-13. Three crystals are off frequency at +10°C as shown in Table 3.

3-15. (4) Temperature frequency characteristic data is shown on Plates 1 to 10 inclusive.

3-16. As shown by Plates 1 - 10 the change in frequency per °C is within the specified 0.005 %.

3-17. The temperature frequency characteristic of the high frequency range of the heterodyne oscillator is unsatisfactory. The frequency jumps between +10°C and +20°C. See Plate 12.

3-18. See par.1-1(g).

3-19. See Table 4.

3-20. All coils are contained in sealed cans. The temperature and humidity can be determined best by the naval inspector at the time of seal off in the factory.

3-21. See par.1-1(b).

3-22. The cable is satisfactory. At 12 volts the filament current is .6 amperes. At 200 volts plate supply the current drain is .006 amperes.

3-24. See par.1-1(e), 1-3(3).

3-25. See par.1-1(d).

3-26. (4) See Table 3.

3-27. (5) See Table 3.

3-28. The dimensions of this equipment are 8-13/16" wide, 8-7/16" deep, and 10-1/2" high.

3-29. The frequency indicator complete including tubes, calibration chart and mounting, shock absorbers, and detachable base but without crystals, weighs 11 lbs. and 6 oz. which is 1 lb. over weight.

Crystals weigh 1 lb. 2 oz.

Cable weighs 1 lb. 11 oz.

16. The following item by item summary of defects noted shows that the specifications are not complied with. This summary is classed in two groups, Mechanical and Electrical. The numbers on the left are those of paragraphs in ref.(b) which cover the points discussed.

Mechanical

1-1, 2-4, 2-15. The input and output terminals are loose due to shrinkage of the low grade fiber washers used behind the panel.

1-1, 2-4, 3-24. The 355 and 375 kilocycle calibration points are not marked on the chart.

1-1, 2-4 2-25, 3-4, 3-25. The zero correcting mechanism for the heterodyne oscillator is inadequate.

1-1, 2-4, 3-21 Excessive back lash was observed.

1-1, 1-2.	The zero beat zone approximates 10 dial divisions in addition to the back lash causing unsatisfactory measurements.
2-3.	The base clamping device for the type 38617 (6A7) heterodyne mixer tube is mechanically weak.
2-3, 2-5, 2-10, 2-35.	Crystal coupling condenser (C-4) is subject to corrosion due to use of unprotected brass and bronze material.
2-3, 2-4, 2-16.	The movable plates of the variable air condenser used with the heterodyne oscillator apparently touch the stationary plates between 1,000 and 2,000 dial divisions.
2-4, 2-15	All ground connections are not made direct to the shield.
2-4, 2-5, 2-10, 2-16, 2-35.	The crystal holders rub against the paint inside the case.
2-4	The gear drive mechanism is inaccessible for lubrication, cleaning, and backlash adjustment.
2-4	The tube sockets are not marked to indicate the type of tube used.
2-4, 2-14.	The serial numbers are not engraved on the front panel and calibration chart to avoid assembling the equipment with the wrong chart.
2-4, 2-11, 2-16.	The heterodyne oscillator changes frequency and stops oscillating at times under vibration and shocks.
2-4, 2-39	The replacement of condensers C-2 and C-7 cannot be readily accomplished without removing L-7.
3-29.	The equipment is one pound over weight.
1-3, 2-13	(par.5) The miscellaneous spare parts and accessories herein required were not furnished with the sample model for test.

Electrical

1-1, 3-2 3-18, 3-6(d).	The audio frequency output is inadequate.
1-1, 2-16	The operation of the heterodyne oscillator is not satisfactory.
1-1	The volume control does not uniformly vary the output signal. Zero signal spots occur at different points throughout the range.
1-1	The 355 kilocycle crystal failed to oscillate at times.
1-1, 2-2, 2-10, 2-18.	Condenser C-7 broke down during these tests.

2-4, 2-7 2-15.	The filament supply to the 75 and 37 tubes failed at times.
2-41.	The 4135 kilocycle crystal jumps frequency between -10°C and -20°C.
3-13, 3-26(4), 3-27(5).	At +10°C three crystals are off frequency.
3-17.	The temperature frequency characteristic of the high frequency range of the heterodyne oscillator is unsatisfactory.
1-2, 3-27.	The wide zero beat zone causes inaccurate readings.

17. The paragraphs of ref.(b) in which this equipment does not meet requirements are summarized as follows: 1-1, 1-2, 1-3, 2-3, 2-4, 2-5, 2-7, 2-10, 2-11, 2-13, 2-14, 2-15, 2-16, 2-18, 2-25, 2-35, 2-39, 3-2, 3-4, 3-13, 3-17, 3-18, 3-21, 3-25, 3-26, 3-27, 3-29.

CONCLUSIONS.

18. It is concluded:

(a) That the Model LJ aircraft crystal frequency indicator does not meet the requirements of the specifications and it is unsatisfactory for use in the Naval Service in its present condition.

(b) That the heterodyne oscillator frequency readings are unreliable.

(c) That the back lash in the gear drive mechanism is excessive and no accessible means for lubrication or adjustment is provided.

(d) That the zero beat zone is too wide.

(e) That the audio output is inadequate.

(f) That the zero correcting mechanism for the heterodyne oscillator does not cover a sufficient number of divisions to correct for all temperatures between -30°C and +50°C.

(g) That the crystal coupling condenser (C-4) is subject to corrosion.

(h) That some of the ground connections are improperly made through screws that make high resistance contact to the shield.

(i) That the equipment is one pound over weight.

(j) That the voltage rating of the by-pass condensers is too low.

(k) That three of the ten crystals are unsatisfactory.

(l) That the crystal oscillator is satisfactory for adjusting transmitters and receivers to the fundamental second, third, and fourth harmonic frequencies provided the crystals are satisfactory.

(m) That except for weight, size, and the convenience of setting a transmitter or receiver to the crystal frequencies and their harmonics, the Model LJ is surpassed by the Model LJ-1.

NRL Report R-1138 Appendix I

12 February 1935

NASA Report RT-2

Navy Department

U. S. Naval Air Station,

Anacostia, D. C.

. Report on

FLIGHT TESTS OF

MODEL LJ CRYSTAL FREQUENCY INDICATOR.

Number of Pages:	Text - 10; Appendix - 3; Plates - 2.
Authorization:	BuAero ltr. Aer-E-31-FAM, F42-1, F1-5(1) of 27 November 1934.
Dates of Test:	18 to 31 January, 1935.
Reported By:	M. P. Hanson, Assoc. Radio Engr.
Reviewed By:	R. M. Signer, Lieutenant, U.S.N. Radio Test Officer.
Approved By:	A. M. Montgomery, Commander, U. S. N. Commanding Officer.

Distribution:

NRL Anacostia, D.C. Station	(2).
BuAero- - - - - - - - - - - -	(2).
NAF Philadelphia, Pa. - - -	(1).
C.O. Files - - - - - - - - -	(1).
Radio Files - - - - - - - - -	(2).

TABLE OF CONTENTS

AUTHORIZATION

1. The tests reported herein were conducted under authority of BuAero ltr Aer-E-31-FAM, F42-1, F1-5(1) of 27 Nov., 1934, in accordance with the procedure outlined in BuEng ltr F42-1(11-8-W3) of 17 Nov., 1934, and in conformity with the procedure suggested by NRL under Appendix (A) herewith.

REFERENCES

2. The following references served as guides in conducting these tests:

(a) NRL's Proposed Flight Tests for Model LJ Frequency Indicator, Appendix (A) herewith.

(b) Instruction Book for Model LJ Crystal Frequency Indicator, supplied by Hygrade-Sylvania Corporation under Bureau Req.278-13X2 Cont. 32109, date June 30, 1933.

OBJECT OF TESTS

3. The object of these tests was to determine, from examination, installation, and actual flight operation, the relative suitability of the Model LJ equipment for service use aboard naval aircraft, as well as its compliance with certain requirements of the governing specification.

EQUIPMENT UNDER TEST

4. The equipment tested - Model LJ Frequency Indicator equipment, Serial No.11 - was supplied for this purpose by the Naval Research Laboratory. Manufactured by the Hygrade-Sylvania Corporation, Clifton, N.J., it consists of the following component parts:

(a) Frequency indicator chassis and case.
(b) Indicator mounting base.
(c) Calibration chart in housing.
(d) Shielded 5-conductor cable with plugs.
(e) Set of ten crystals in type 40001 holders.
(f) 1 vacuum tube, type 38617 (6A7)
(g) 1 vacuum tube, type 38075 ('75)
(h) 1 vacuum tube, type 38037 ('37)

5. Items (a), (b), (c), and (e), listed in the preceding paragraph, are shown on Plate 1 (herewith), while Plate 2 shows the inner top view of the indicator unit, item (a). The equipment is described in detail, with illustrations and circuit diagram, in the instruction book, reference (b) under paragraph 2. It employs a type 38075 tube as crystal-controlled oscillator, a 38617 tube as combination heterodyne oscillator mixer tube, and a detector, and a 38037 tube as impedance coupled audio amplifier which couples

to, the output headset jack through a .04 mfd condenser, without the use of an output transformer. The equipment is designed to cover the frequency range from 195 to 1500 kcs., and from 2,000 to 13,600 kcs; ten crystals are supplied, mounted in a turntable-rack, covering the following frequencies: 355, 375, 425, 440, 500, 516, 544, 4135, 4205, and 4235 kcs. The crystals are apparently of the X-cut type contained in air-gap type holders adjusted by the contractor. A selector switch gives the choice between crystal and heterodyne oscillation, or both for calibration purposes. Heater and plate voltage supply is derived from the spare outlet on a type CBY-23011-A or similar junction box, through the shielded cable supplied with the LJ equipment.

ABSTRACT OF TESTS

6. The model LJ equipment (Ser.No.11) was delivered by a representative of the Naval Research Laboratory 9 January, 1935. It was installed in XRE-1 Bellanca cabin plane No. 8938 on 21 January and was flight tested from 1140 to 1500 on 28 January, 1935, in conjunction with an installation comprising the following additional equipment: Model GO transmitter, Model RU-2 Receiver, Model NEA-1A engine driven generator, Mark V storage battery. Necessary completion of flight tests with other equipment (Model LJ-1 frequency indicator) and adverse flying weather caused some delay in the tests of the LJ equipment.

7. Details of the flight test procedure were arranged prior to the flight by verbal agreement with representatives of the Naval Research Laboratory in order to insure simultaneous precision frequency measurements at that place. Two-way radio communication was maintained with the Naval Research Laboratory during the flight. The tests in general followed the procedure suggested in sections 3-2, 3-3, and 3-30 at the end of Appendix (A). The model GO transmitter was successively adjusted to 8 different frequencies (from 355 to 12705 kcs), each of which was measured simultaneously in flight with the LJ equipment, and on the ground by the Naval Research Laboratory. Flight measurements of received frequencies were then made on signals from the Naval Research Laboratory, from the Naval Air Station, Anacostia, D.C., and from a Cincinnati high-frequency broadcast station, for comparison with simultaneous precision measurements by the Naval Research Laboratory. Two successive landings were then made to determine any effect of shock upon the frequency setting of the LJ equipment. Prior and subsequent to the flight tests, the equipment was carefully examined to indicate further its general suitability for service and flight use in aircraft.

SUMMARY OF CONCLUSIONS

8. The conclusions of this station, based upon the herein reported examination and tests of the model LJ crystal frequency indicator, are summarized as follows:

(a) The equipment does not meet the specification requirements.

(b) The equipment is useful and serviceable for adjusting radio transmitters and receivers directly to the frequencies of the contained crystals or their second harmonics.

(c) As a heterodyne frequency meter the equipment is not suitable for service use, because of excessive backlash and insufficient mechanical correction range of the indicator dial mechanism.

(d) If the equipments are reconstructed to remedy the faults set forth under (c) above, they would appear useful for adjusting radio receivers directly - and because of weak audio-frequency output, radio transmitters indirectly with aid of the receiver - to any frequency within the prescribed range of 195 to 1500, and 3000 to 13,600 kilocycles.

(e) The accuracy of the LJ equipment tested as a heterodyne oscillator was one-half of one percent when departing appreciably from the crystal calibration points. It is believed that if reconstructed as suggested in (d) above, and if supplied with a high-frequency crystal suitable for checking the upper region of high-frequency settings, a mean accuracy better than one-tenth of one percent may be expected.

(f) With the exception of its smaller size and weight, and its greater convenience directly on the crystal frequencies, the LJ equipment is surpassed in general utility and serviceability by the model LJ-1 equipment now being manufactured.

RESULTS OF FLIGHT TESTS

9. The following transmitter adjustments, and frequency measurements of transmitted and received signals in flight, were made between 1140 and 1500 on 28 January, 1935, and are compared with true frequencies as measured simultaneously, on the ground, by the Naval Research Laboratory. During this flight, the ambient temperature in the vicinity of the LJ frequency measuring equipment in the airplane varied between minus three and plus three degrees, Centigrade.

Adjustments of Model GO Transmitter:

Nominal Freq. Kcs.	Measured with LJ Kcs	True Freq. Kcs.	Error	Method
355	354.9	354.39	+.144%	Heterodyne
544	544.2	544.66	-.065%	Crystal direct
565	565.0	564.87	+.023%	Heterodyne
4135	4135.0	4135.80	-.019%	Crystal direct
6010	6080.0	6110.37	-.268%	Heterodyne
8210	8200.0	8208.50	-.104%	Heterodyne
8410	8410.0	8413.50	-.042%	Crystal, 2 harmonic
12705	12733.0	12667.60	+.567%	Heterodyne, third harmonic of 4235 kcs crystal not audible.

Nominal Freq. Kcs.	Measured with LJ Kcs.	True Freq. Kcs.	Error:	Method
Measurement of signals from NRL Transmitter (NKF):				
524	524.4	524.57	-.032%	Heterodyning reception
Measurement of signals from NAS, Anacostia Transmitter (NSF):				
6010	6039.5	6008.15	+.320%	Heterodyning reception
Measurements of signals from W8XAL, Cincinnati:				
6060	6093.5	6060.00	+.551%	Heterodyning reception

10. After adjustment of the LJ equipment to heterodyne the 6060 kilocycle carrier from W8XAL to give a beat note of about 800 cycles in the non-oscillating receiver, two successive landings were made on the field. These landings together with the intervening take-off resulted in a slight frequency shift not exceeding 100 cycles; a temporary additional frequency drift estimated at 100 cycles was observed during periods when the engine was idling and charging of the battery was interrupted. The shock mounting of the LJ equipment was sufficiently resiliant to give a substantially pure beat note under normal flight vibration, and appeared adequate for mechanical protection during landings and taxying.

11. Performance of the LJ equipment in flight was impaired by the following factors:

(a) The 355 Kcs. crystal failed to oscillate.

(b) Excessive backlash was observed, varying between 10 and 15 dial divisions; to reduce considerable possible error from this source, it was necessary to exercise care to take all readings in a numerically increasing direction of adjustment only.

(c) Excessive widths of zero beat zones up to 10 dial divisions were noted during measurements of transmitter frequencies with the LJ in heterodyne condition, which in combination with the excessive backlash served to impair the facility and accuracy of operation.

(d) The mechanical dial index correction feature was found totally inadequate in flight. Necessary corrections ranged between 90 and 160 divisions (up to 1.6 turns of the vernier dial), while any mechanical correction even approaching 50 divisions would become confusing on account of the resultant discrepancy between the movable unit index line and the reading of the fixed index line denoting the hundreds of divisions.

(e) Since the only high-frequency crystals supplied are 4135, 4205, and 4235 Kcs. only a very limited zone of self-calibration of the equipment is provided, with resultant loss of accuracy in other scale regions, as used for the 6 and 12 megacycle measurements taken in flight.

(f) The 355 and 375 Kcs. calibration check points were not found especially marked on the calibration chart.

(g) The audio-frequency output obtained from the LJ equipment during direct measurements of transmitted frequency above 3000 kcs. was generally inadequate. Thus, on 4135 kcs, with an 18 inch pickup lead connected to the LJ input post, only 0.4 milliwatt beat signal was obtainable into a 600 ohm headset, while at 8410 kcs only 0.07 milliwatts could be obtained-- and this only after twisting the 18 inch pickup lead tightly around the insulated lead connecting to a 20 ft. fixed external antenna. Still greater input coupling resulted only in undue widening of the zero beat zone. In the relatively quiet single-motored cabin plane it was still possible to check all transmitter frequencies directly with the LJ equipment, but in service use aboard patrol planes it would appear necessary to resort to an indirect method employing the receiver as an intermediary.

12. Suitable input to the receiver was obtained from the LJ equipment at all frequencies tested; the variable volume control on the LJ equipment was found to be a great convenience in establishing the desired strength of signal over a considerable latitude of coupling ranging from the pickup from the LJ output post alone, up to a coupling lead two feet in length placed adjacent to the receiver antenna lead.

EXAMINATION OF CONSTRUCTION

13. The dimensions and weights of the LJ frequency measuring equipment were found to be as follows:

Width: 8-13/16 inches, overall, including 1-1/8 inch projection of chart cranks.

Depth: 8-7/16 inches, overall, including 7/16 inch projection of connector plug shell in rear.

Height: 10-1/2 inches, overall, including shock mounting and chart unit; 7-1/4 inches without chart unit.

Length of Power Cable: 9 ft. 4 in., overall, including 2 plugs.

Weight of Complete Equipment: 14.125 lbs. including cable weight of 1.625 lbs.

14. The following defects in material and workmanship were noted in the equipment under test:

(a) 10 to 15 divisions mechanical backlash of reduction gear drive.

(b) The two binding posts marked "Input" and "Output" were loose and turned in panel, as result of shrinkage of low grade fibre washers used for insulation behind panel.

(c) The 355 kcs. crystal failed to operate in flight.

(d) The crystal calibration points for 355 and 375 kcs. are not marked on the chart.

(e) The base clamping device for the type 38617 (6A7) heterodyne mixer tube is twisted around because of lack of proper alignment with screw-driver access hole.

15. The equipment exhibits the following major defects and inadequacies in design:

(a). The mechanical dial correction is useful for corrections of less than 50 dial divisions, while corrections in excess of 150 divisions were found necessary.

(b) The audio frequency output is inadequate for the direct calibration of transmitters in usual flight conditions.

(c) In the "high-frequency" position, the upper frequency limit (dial reading 50.00) was insufficient, resulting in the following discontinuities in calibrated range:

3998.5 - 4,000 kcs.
7997 - 8,000 kcs.

16. The following features are noted from the standpoint of durability and corrosion resistance:

(a) The open crystal window in the front panel will admit excessive spray; it could readily be provided with a water shed.

(b) During rotation of the selector turntable, the crystal holders rub against the paint inside the case, with resultant likelihood of corrosion when the paint wears off.

(c) Internal adjustable crystal coupling condenser (C-4) is unplated copper or bronze, with brass adjusting screw subject to corrosion.

(d) Output tube cathode by-pass condenser (C-9), 20 mfd, is of the electrolytic type.

17. The following points are noted in connection with facility of maintenance and servicing:

(a) The gear drive mechanism is relatively inaccessible for lubrication, cleaning, and backlash adjustment.

(b) Marking of tube types alongside of sockets would facilitate replacement.

(c) Threaded inserts would be preferable to present separate nuts on tube base clamping devices.

(d) When removed from the case, the interior portion of the measuring equipment is subject to damage from resting upon connections under rear tube sockets. The clamp holding condensers C-2 and C-7 could readily be bent to serve as a protective supporting leg.

18. The following additional points are noted in connection with facility and accuracy of operation:

(a) The serial number of the equipment is shown on the case only, and not on the front panel nor on the chart unit; this may result in accidental interchange of major component parts and resultant confusion of accuracy.

(b) The direction of numerical increase of the unit dial reading (right to left) is not the natural one, and is in opposite sense to the increase in reading of the main (hundreds) dial, with possible confusion to the operator.

(c) The calibration curves show the frequencies increasing downward (toward the operator) rather than in the usual upward direction.

19. The following features of the model LJ equipment are considered to warrant favorable comment:

(a) Relatively small size and weight.

(b) Neat and compact layout of component parts.

(c) Well-marked interior component parts.

(d) Satisfactory shock mounting.

(e) High-grade soldering.

(f) Provision of crystal-calibrate-heterodyne switch.

(g) Provision of volume and sensitivity control knob.

(h) Use of elastic stop nut inserts in rear chassis and front of case; this use could be further extended to replace (inside case) four mounting nuts for chart unit.

COMPLIANCE WITH SPECIFICATIONS

20. The following items, referring to the specification extracts appended hereto appear not to be satisfactorily complied with:

ITEM	REASON
1-1	- Par.11, 14, and 15.
1-2	- Par.11, 14, and 15.
3-1	- Par.11, (d) and (g).
3-2	- Par.11, (g).
3-4	- Par.11, (d).
3-24	- Par. 15 (c); 14 (d). The calibration chart actually represents, in a single division, as much as 0.027% change in frequency, around 1500 and around 7700 kcs.

21. No information was supplied this station in regard to the frequency precision required of the equipment; the frequency error obtained with this equipment, as described in paragraph 9, appears excessive for satisfactory service use.

Proposed Flight Tests for Model LJ

Frequency Indicator.

Flight tests should be conducted to see that the following specifications are satisfactorily complied with:

1-1. This equipment is intended for and must be capable of satisfactory installation and operation on various classes of Naval aircraft.

1-2. Its paramount requirement shall be to measure the emitted frequency of any transmitter or to adjust any oscillating receiver to any desired frequency in the band 195 to 30,000 kilocycles, for which calibrations have been provided as hereinafter required, within the specified limits of accuracy.

2-11. The design must fulfill the demand that the equipment supplied operate successfully and without damage on a platform orientated any degree from the vertical up to and including 180 degrees in any direction. No damage to the equipment or vacuum tubes shall result from repeated landing of the plane in which it is installed. The equipment shall be designed to withstand a maximum acceleration of 8g (257.7 feet per second per second) applied in any direction.

2-16. The design of the equipment must insure freedom from damage and from faulty operation resulting from shock or vibration. ******

2-19. Suitable shock-proof mountings shall be provided to secure the equipment to the structure of the plane in such a manner as to comply with requirements of paragraphs 2-11 and 2-16. So-called "sponge rubber" and/or coil springs will not be acceptable as a shock absorbing medium, but may be used for damping. Where rubber is used provision must be made for easily replacing it with a minimum of disassembly.

2-20. All connections within the set shall be suitably supported to minimize changes in frequency or output or breakage due to severe vibration under flight conditions. Flexible stranded leads shall be used wherever practicable within the requirements of these specifications.

3-1. The measuring unit shall contain a crystal calibrator and heterodyne frequency meter and necessary controls, etc., as herein required within a single metal panel and container assembly. It shall be capable of use for calibrating transmitters and oscillating receivers by means of direct comparison with the crystal controlled oscillator, and by means of direct comparison with the heterodyne oscillator. In addition it shall be possible to correct the zero setting of the heterodyne oscillator by means of direct comparison between the heterodyne oscillator and the crystal controlled oscillator on the fundamental or harmonic frequencies of the crystal and heterodyne oscillators.

3-2. The method of adjusting the transmitter to a specific output frequency shall be zero beating the transmitter frequency with the proper heterodyne oscillator frequency and effecting the comparison by means of a pair of phones plugged into a suitable jack located on the front panel of the measuring unit.

3-3. The method of adjusting the receiver to a specific frequency shall be by zero beating the receiver frequency with the proper oscillator frequency as generated by the measuring unit and effecting the comparison by means of a pair of phones plugged into the receiver output jack.

3-4. The method of adjusting the zero setting of the heterodyne oscillator of the measuring equipment to agreement with the calibration shall be by zero beating the heterodyne oscillator with the crystal controlled oscillator and effecting the comparison by means of phones plugged into the jack on the front panel of the measuring equipment. When the heterodyne setting does not agree with the calibration for the particular crystal frequency selected, the heterodyne zero shall be capable of being reset mechanically to the proper point.

3-24. The measuring equipment shall be calibrated over the range 195 to 1500 kcs. and 3,000 to 13,575 kcs. The calibration chart shall be contained in a separate unit capable of mounting with the equipment or separately. This unit shall utilize a strip type of calibration and include means for turning the strip to the desired range as well as protecting the strip from the effect of tearing while unrolling, etc., or the effect of weather on any part thereof. Provision shall be made to read the calibration chart accurately and rapidly. The calibration chart and mounting shall be approved in detail by the Navy. The arrangement of the curves and divisions of calibration chart shall be such that one division represents not more than one condenser division or 0.01 per cent of the frequency at any part of the calibrated range. It will not be considered satisfactory to furnish a calibration of the fundamental ranges only and require multiplication by the operator to determine the harmonic frequencies. The calibration must be complete over the entire range specified above. The crystal frequencies must be marked plainly on the calibration chart at points near the intersection of the heterodyne calibration. In addition a card shall be mounted on the equipment showing the setting for important frequencies likely to be used but for which no crystals are available.

3-30. The shock absorbing mounting shall be so designed as to secure to a horizontal table or projection of the airplane fuselage. Provision shall be made to readily attach and detach the measuring equipment from the mounting base by means of the projections of four approved type shock absorbers. The shock absorbers shall, in combination with the rigid construction of the equipment, act to eliminate microphonics and other undesirable note characteristics at all frequencies.

3-31. All controls shall be capable of operation by one wearing heavy gloves.

The following tests should be made for frequency accuracy and stability:

3-2. Adjust the transmitter as described in this specification and record the frequency according to the CFI reading. When this adjustment has been made the transmitter frequency will be checked at the Laboratory to determine the accuracy of the setting. Record the temperature of the CFI at the time the reading is taken.

3-3. Adjust the receiver to zero beat with the incoming signal. Adjust the CFI to zero beat with the receiver. Shift the receiver to MCW and see that the CFI zero beats with the incoming signal. Record the frequency as indicated by the CFI. Record the temperature of the CFI.

3-30. Adjust the receiver to a constant frequency station with a beat of 1000 cycles approximately. Adjust the CFI to this same beat frequency. Shift the receiver to MCW and allow the CFI to serve as the heterodyne oscillator beating against the incoming signal.

Record any changes in beat frequency due to vibration of the CFI.

Use a fixed antenna and make this test while making landings and record any beat frequency changes.

All of the tests on this equipment have not been completed and it is requested that none of the parts be removed. This procedure insures proper test of the equipment as received from the manufacturer and avoids any possibility of altered calibration or operating characteristics.

Table 1

Frequencies checked during Flight Tests

	Normal Freq. kcs.	Measured Freq. with LJ	True Freq. kcs	% Error
Heterodyne	355	354.9	354.39	+ .144%
Crystal	544	544.2	544.66	- .085%
Heterodyne	565	565.0	564.87	+ .023%
Crystal	4135	4135.0	4135.80	- .019%
Heterodyne	6010	6084.0	6110.37	- .268%
Heterodyne	8210	8200.0	8208.50	- .104%
Crystal	8410	8410.0	8413.50	- .042%
Heterodyne	12705	12733.0	12667.60	+ .567%
N S F	6010	6039.5	6008.15	+ .520%
W8XAL	6060	6093.5	6060.00	+ .551%
N K F	524	524.4	524.57	- .032%

Table 2

Audio Power Output

for

Three Beat Frequency Conditions:

(1) crystal oscillator and standard signal generator; (2) self oscillator and standard signal generator; (3) crystal oscillator and self oscillator.

		100 cycles	200 cycles	500 to 3000 cycles
		At 355 Kilocycles		
(1)	Milliwatts output	7	7	12
(2)	" "	3	4	8
(3)	" "	5	8	10
		At 2102.5 Kilocycles		
(1)	Milliwatts output	5	7	9
(2)	" "	9	25	25
(3)	" "	7	20	30

Table 3

10°C these crystals are off frequency as tabulated.

Frequency Kcs.	Measured	Specified (Par.3-13)
544	+ .087%	± .02%
4135	+ .042%	± .01%
4205	+ .02%	± .01%

Table 4

The radio frequency output is in accordance with Par.3-19 as tabulated below.

Frequency Kcs	Heterodyne RF Output Microvolts	Crystal RF Output Microvolts
355	31,000	130,000
375	50,000	500,000+
425	4,350	500,000+
440	4,550	500,000+
500	3,000	242,000
516	17,000	400,000
544	16,000	425,000
4135	16,000	75,000
4205	14,000	40,000
4235	13,000	180,000
8270	125,000	100,000
8410	135,000	95,000
8470	90,000	500,000
12,405	360	55
12,705	415	400
12,615	400	90

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10°C
CRYSTAL
355 KC.

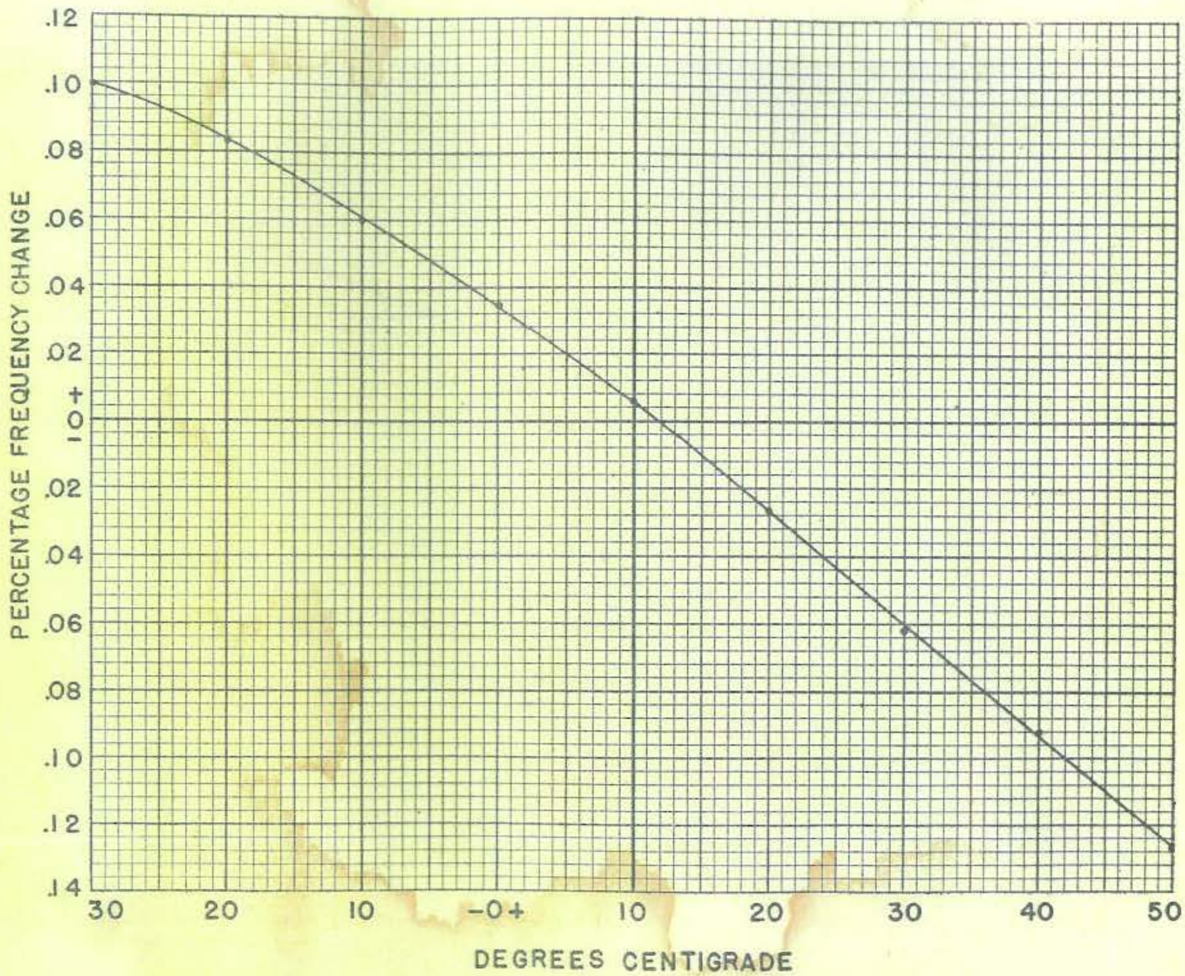


PLATE I

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10°C
CRYSTAL
375 KC.

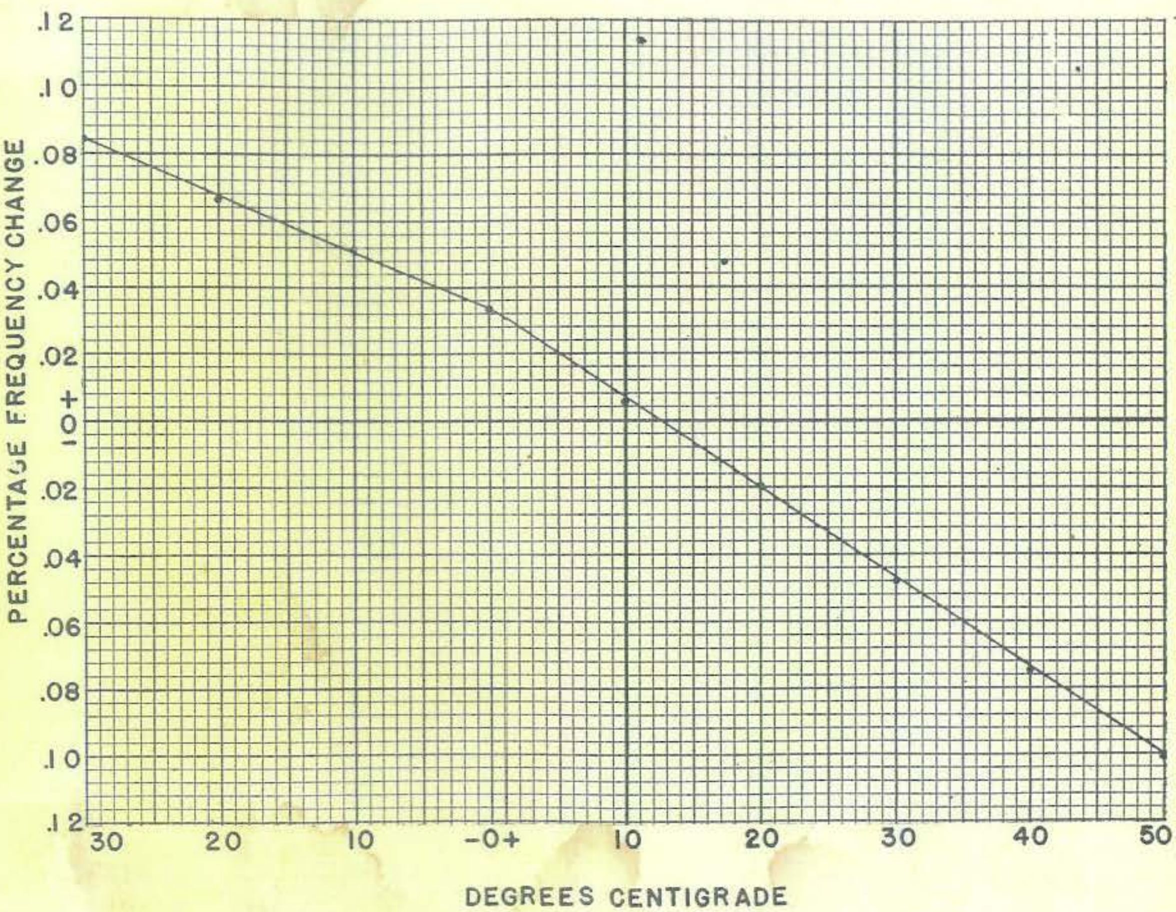


PLATE 2

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
425 KC.

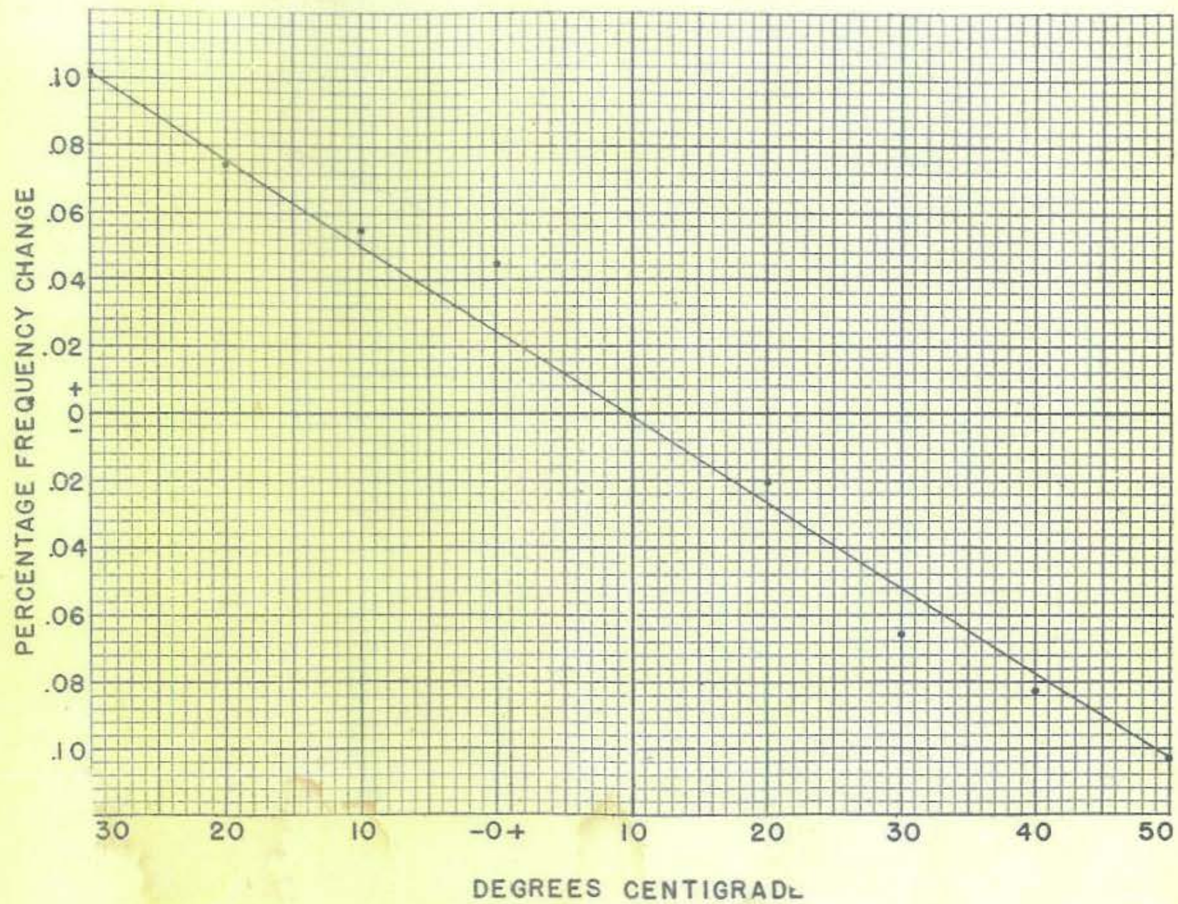


PLATE 3

CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
440 KC.

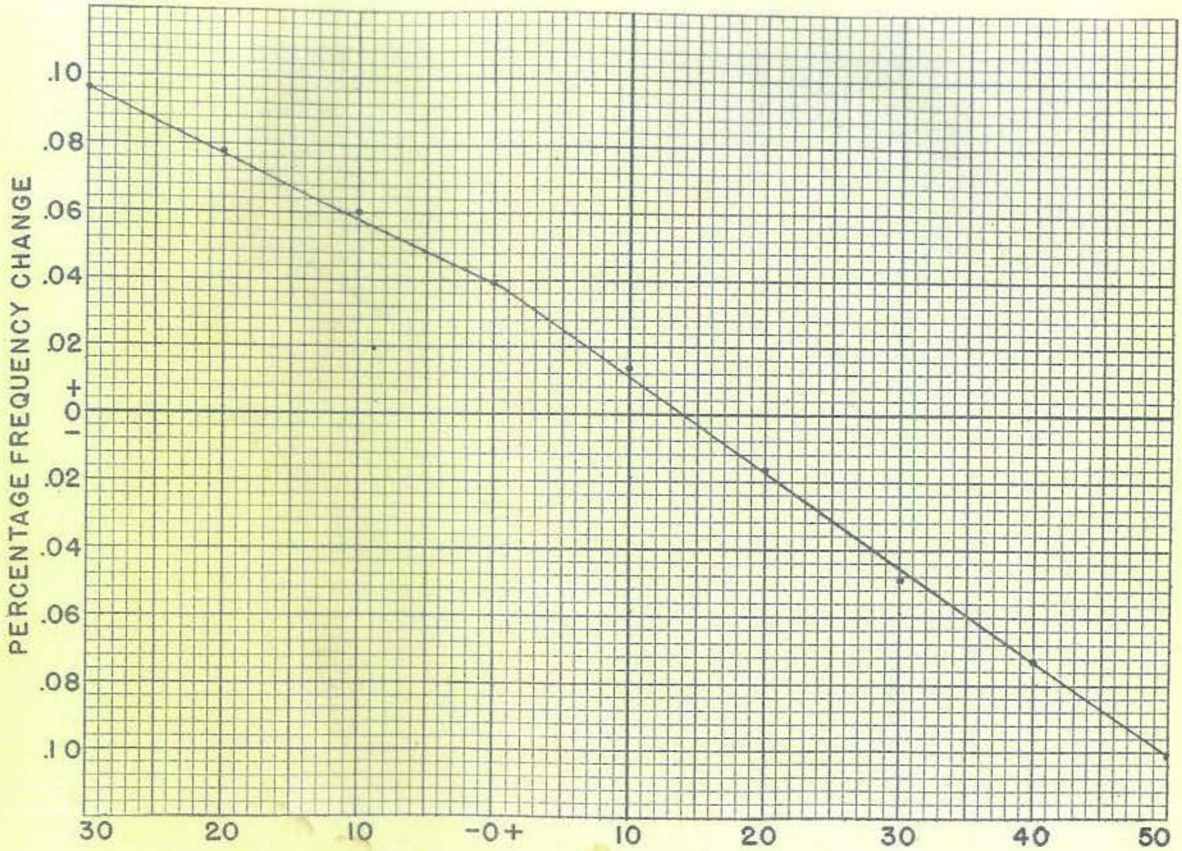


PLATE 4

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
500 KC.

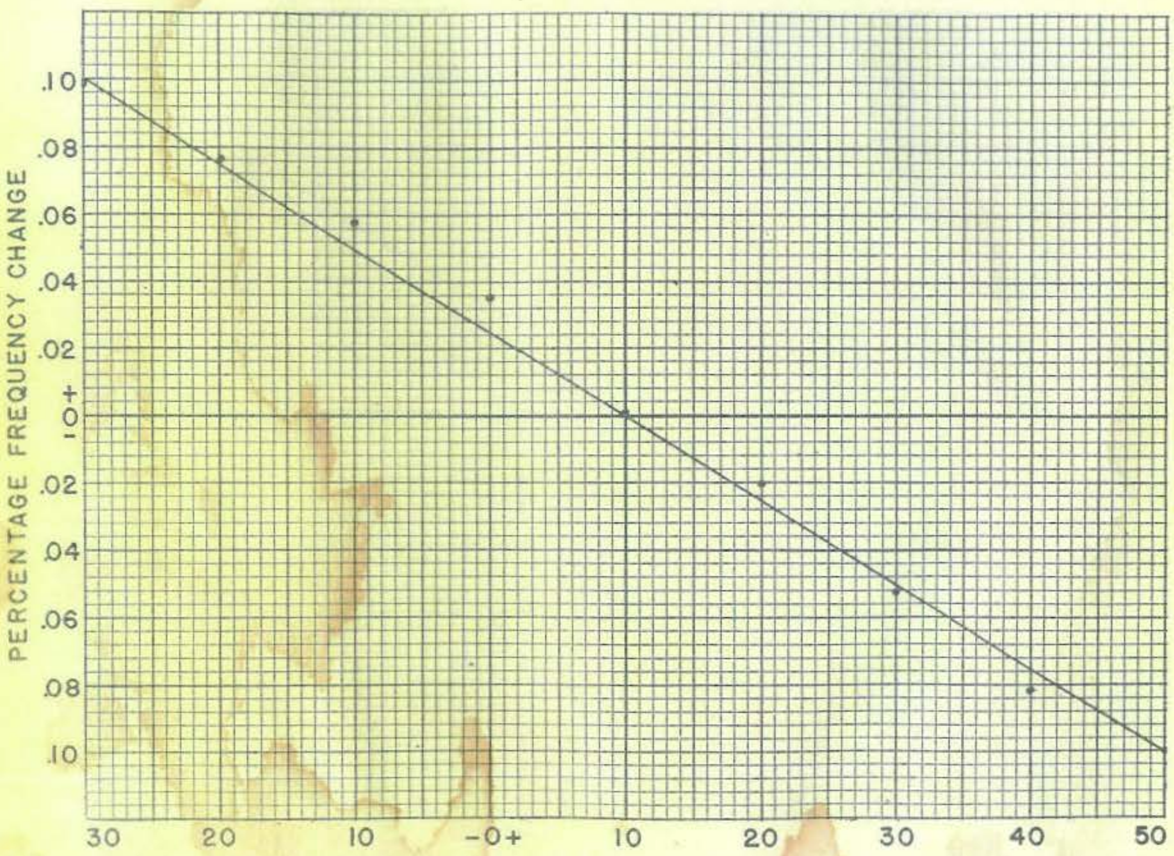


PLATE 5

TEMPERATURE–FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
516 KC.

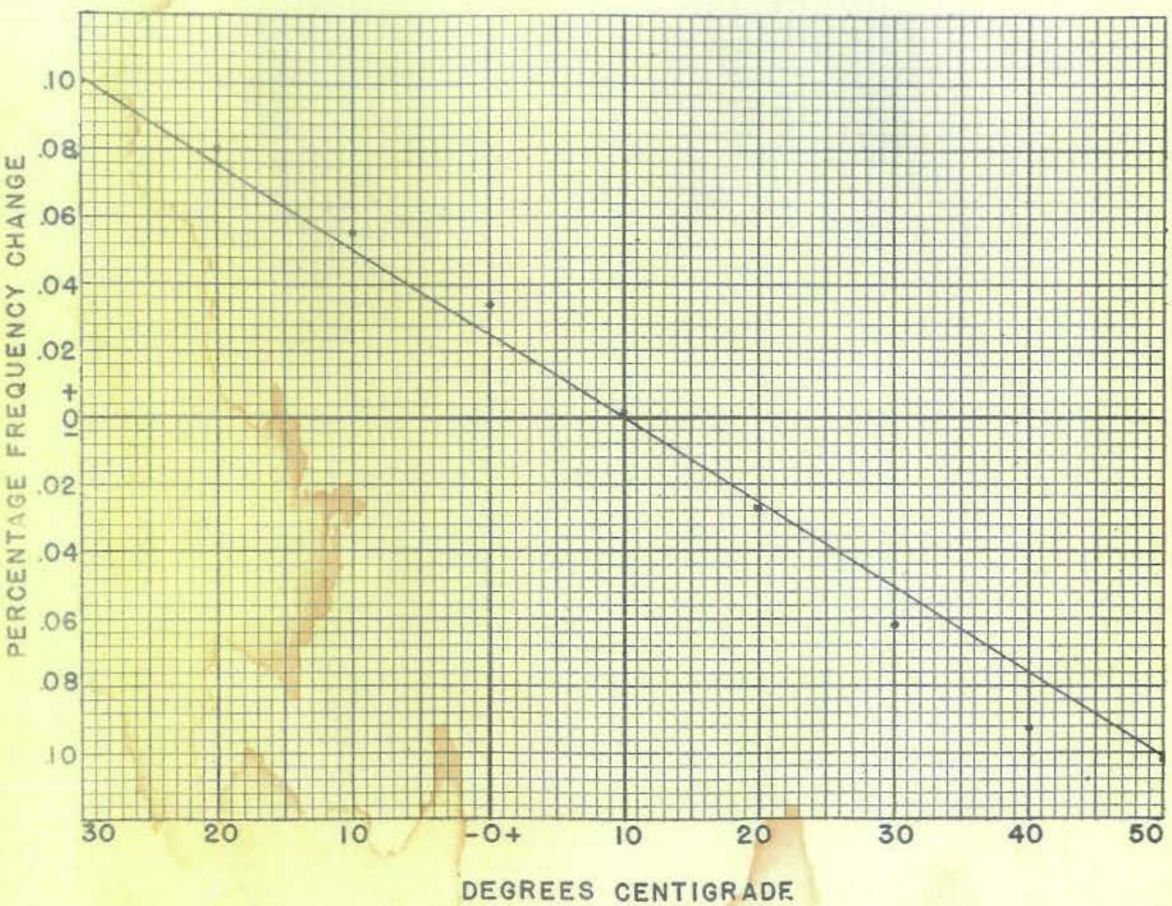


PLATE 6

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
544 KC.

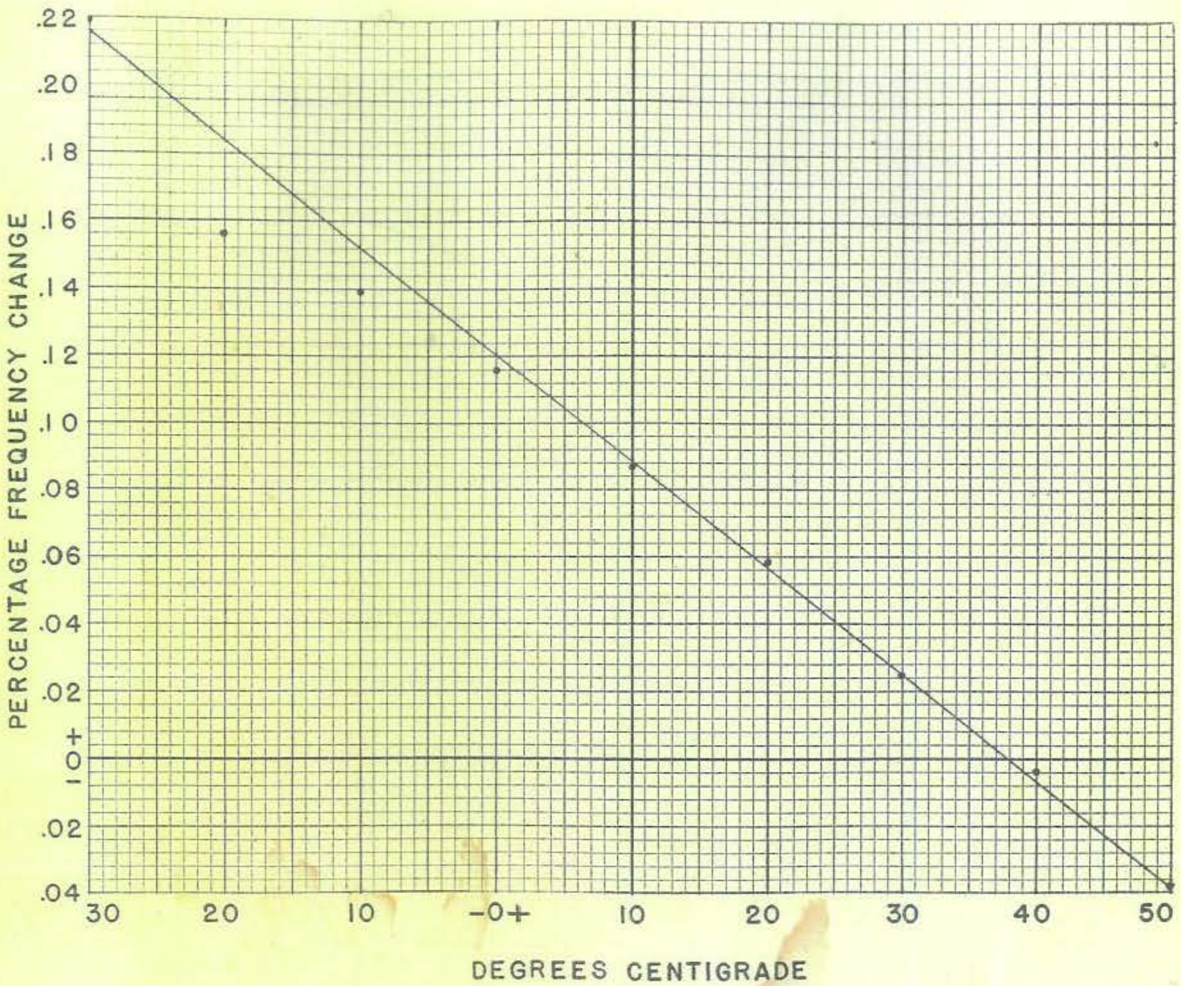


PLATE 7

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
4135 KC.

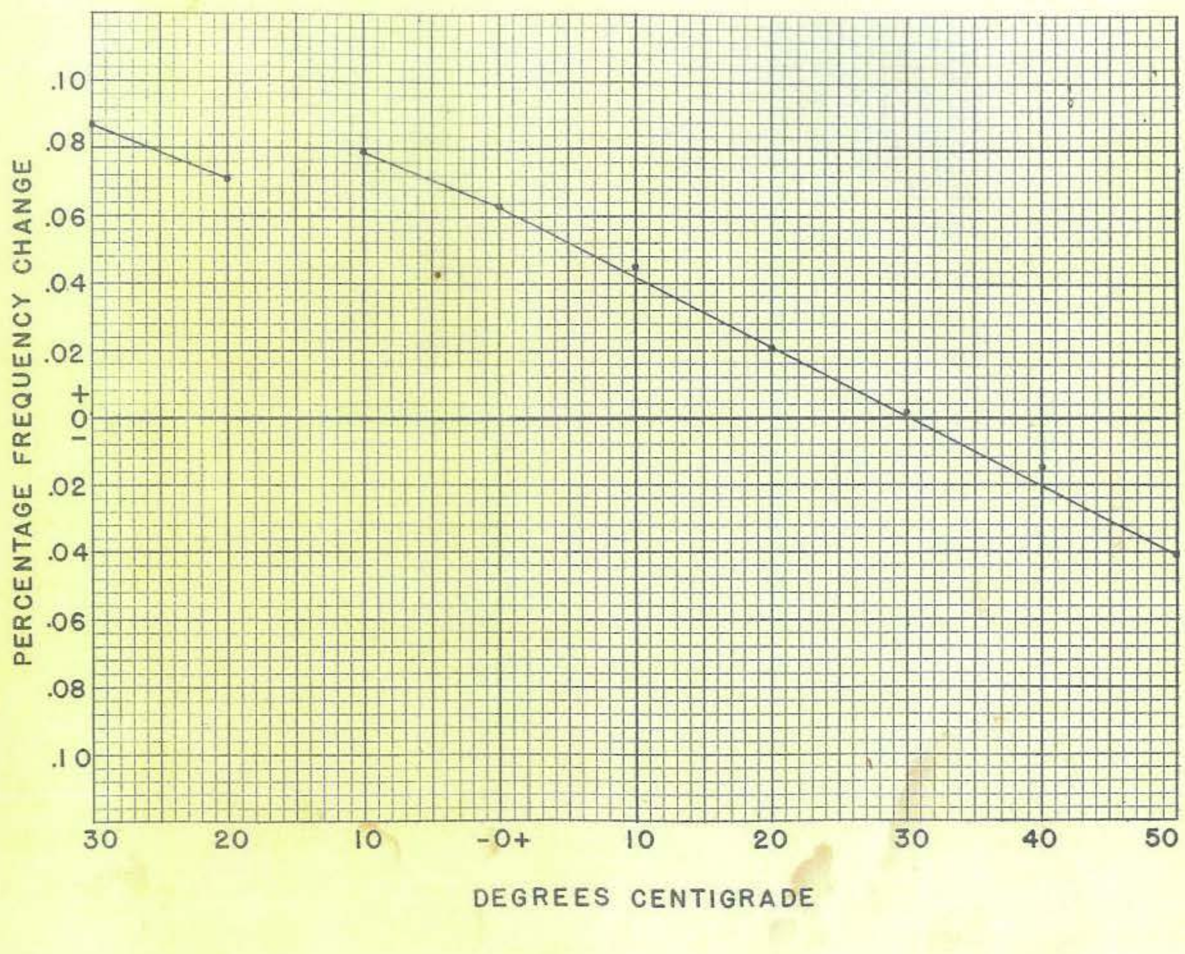


PLATE 8

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
4205 KC.

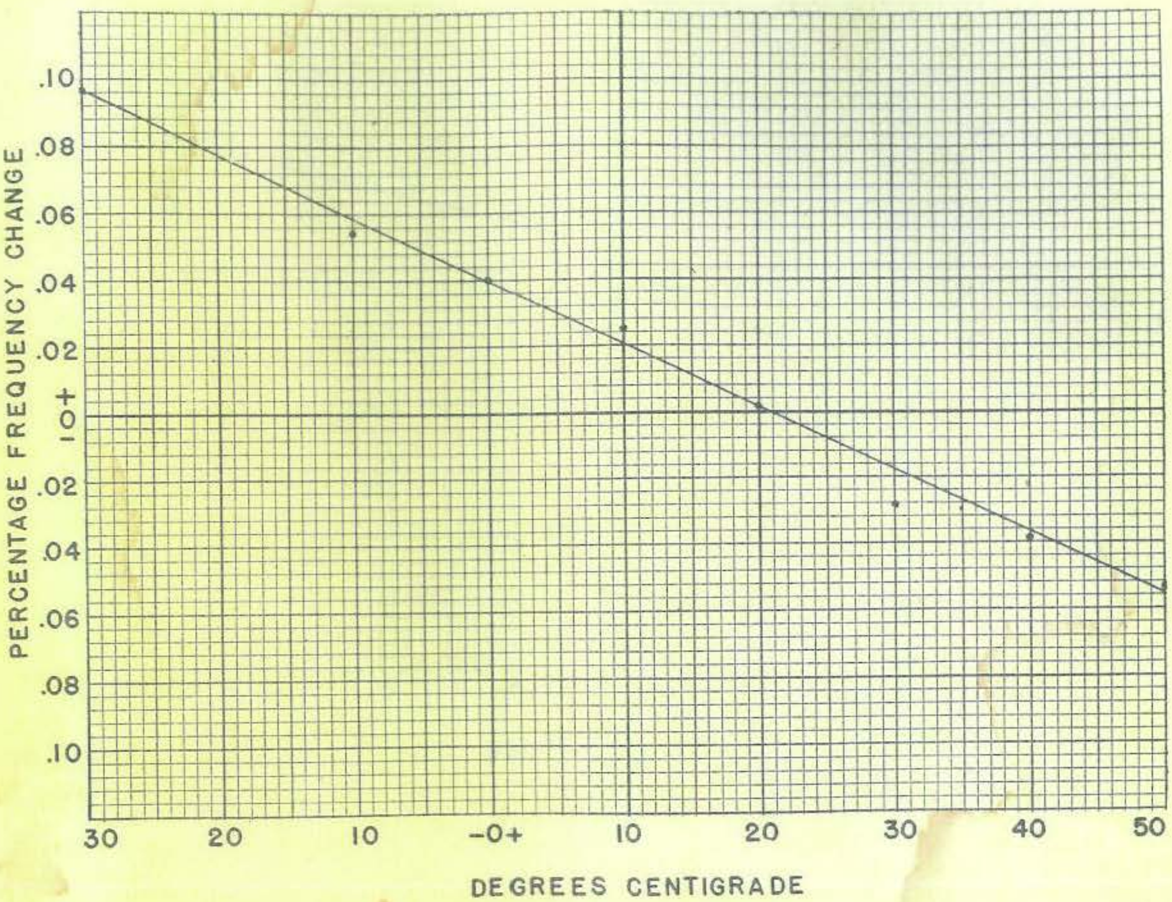


PLATE 9

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
CRYSTAL
4235 KC.

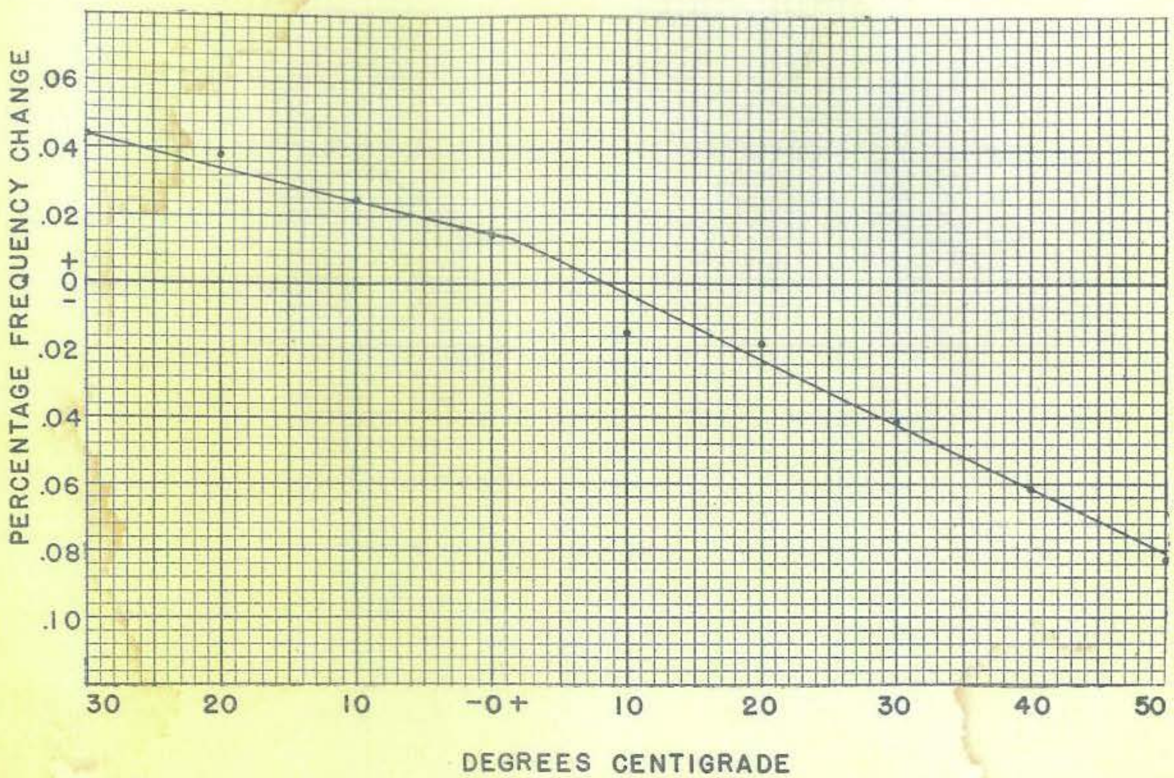


PLATE 10

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
SELF OSCILLATOR
330 KC.

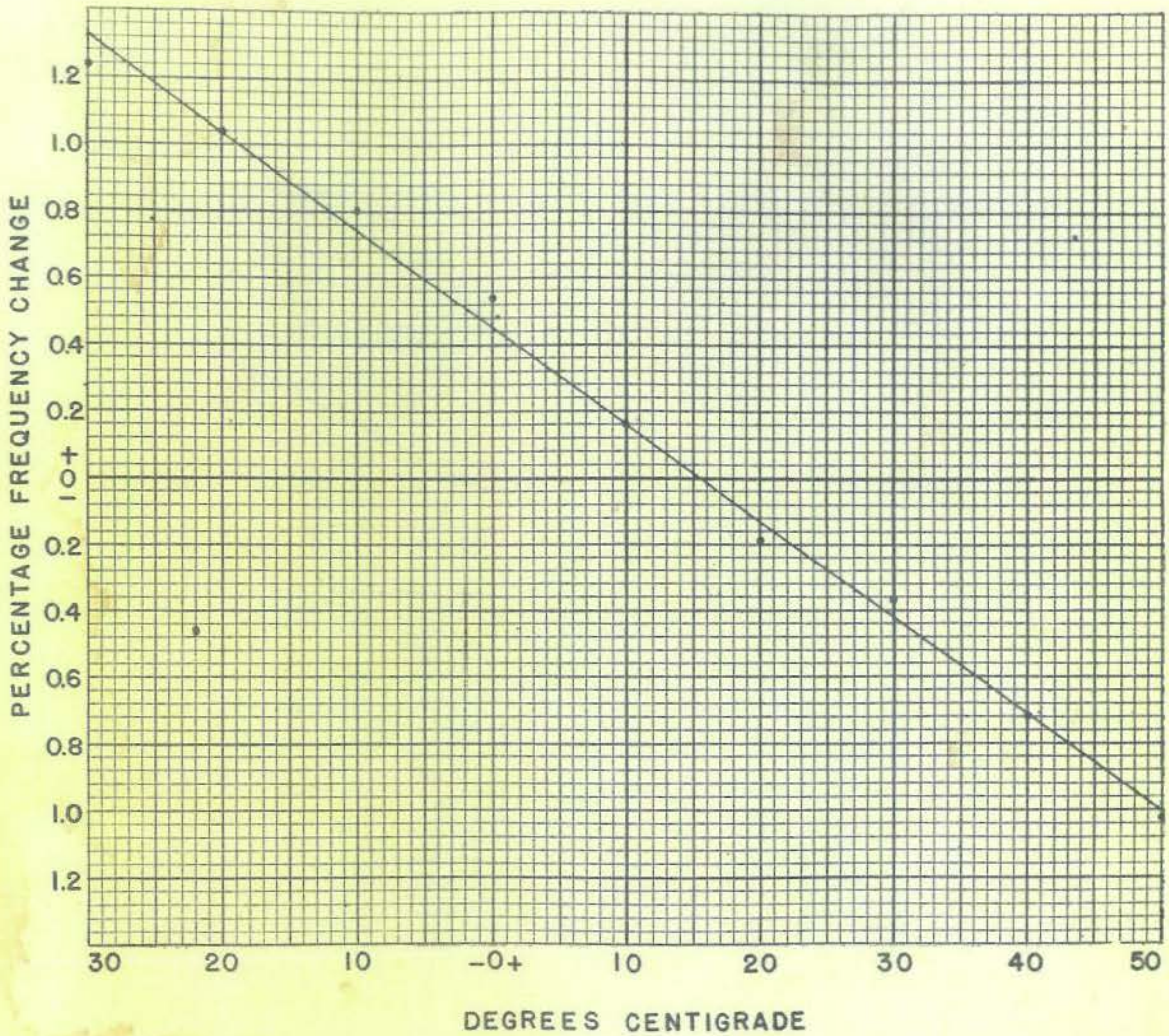


PLATE II

TEMPERATURE-FREQUENCY
CHARACTERISTIC
OF
MODEL LJ
CRYSTAL FREQUENCY INDICATOR
ASSIGNED FREQUENCY AT +10° C
SELF OSCILLATOR
3317 KC.

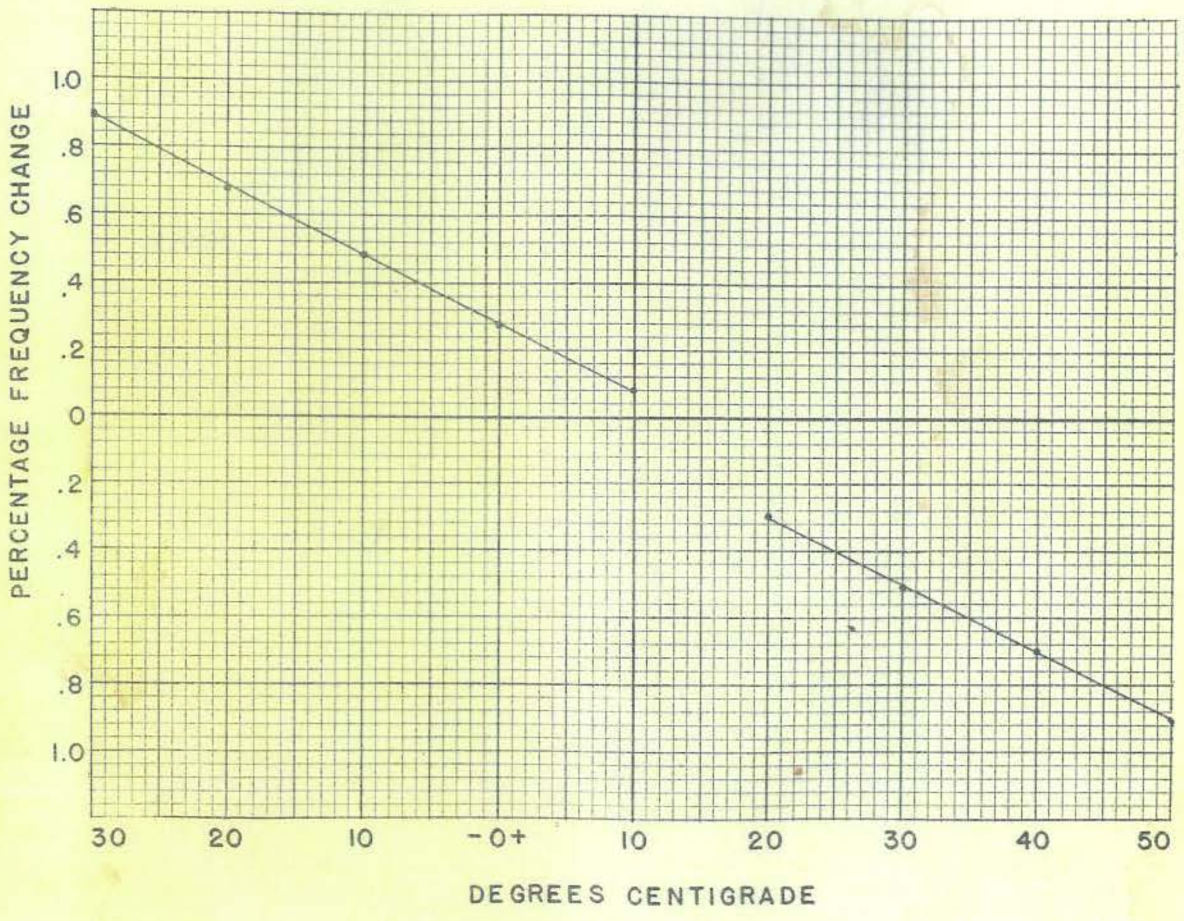


PLATE 12

LINEAR CHARACTERISTIC
OF
DETECTOR AND AUDIO AMPLIFIER
MODEL LJ
USING 1000 ∿ BEAT NOTE

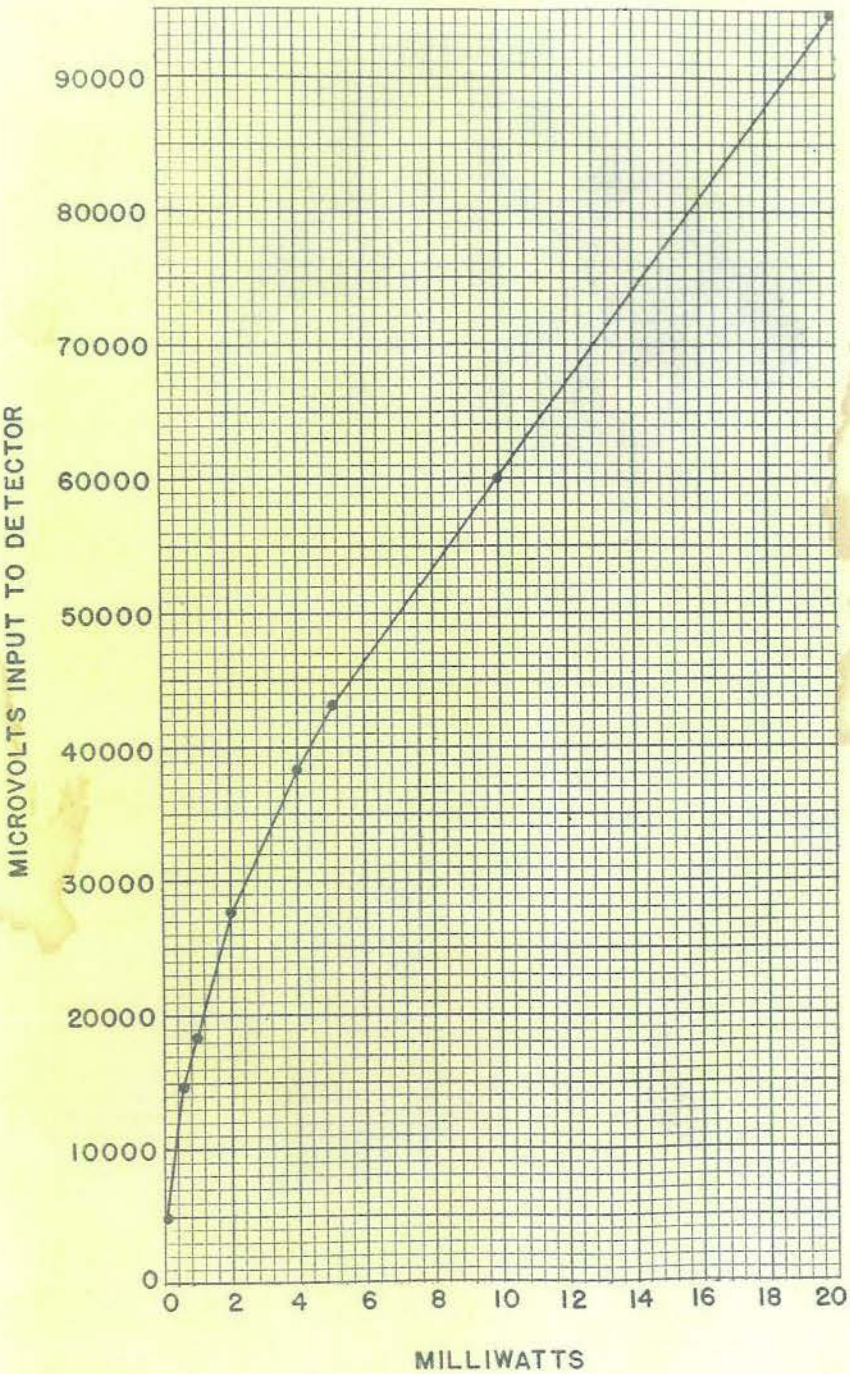
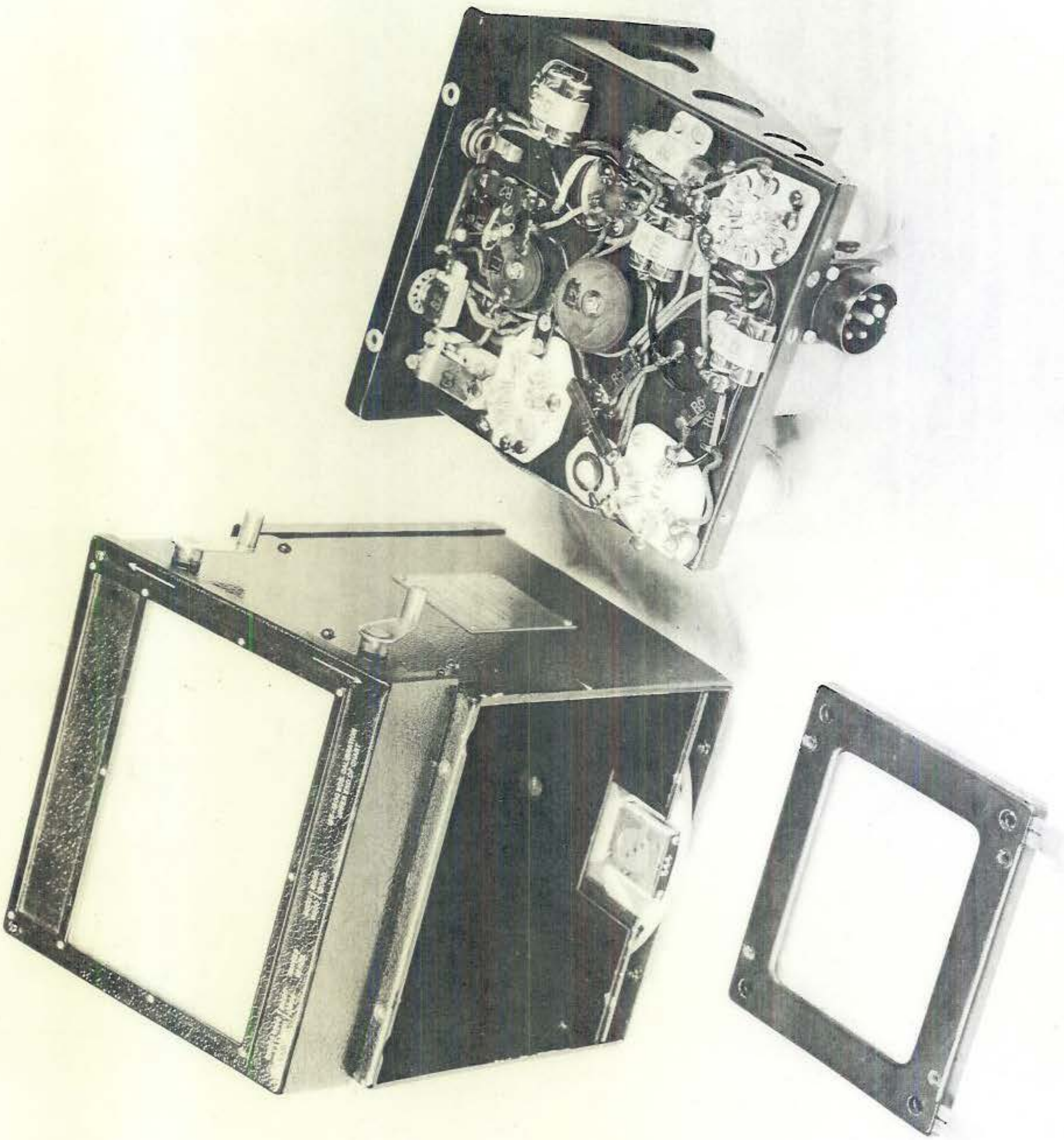
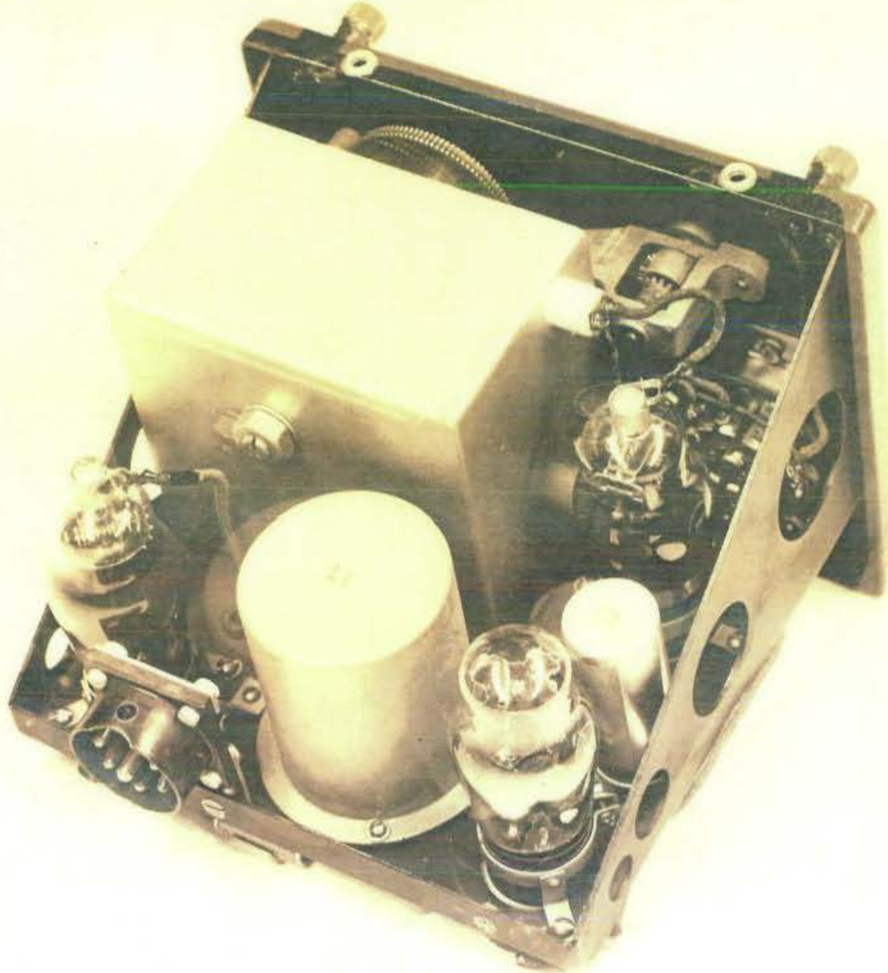


PLATE 13



AN-33116 Model LJ Crystal Frequency Indicator
(interior inverted) 31 January 1935.

PLATE 14



AN-33117 Model LJ Crystal Frequency Indicator,
Interior portion.   31 January 1935.

PLATE 15