DECLASSIFIED

F3-10

[redacted]

8

FR#1310

REPORT NO. R-1310

DATE 28 September 1936

Classification changed from CONFIDENTIAL
To UNCLASSIFIED
By authority of 1550-156/49 Dated 3-31-49
File No.

SUBJECT

TESTS OF MODEL LM FREQUENCY MEASURING EQUIPMENT

MANUFACTURED BY RADIO RESEARCH COMPANY

DECLASSIFIED by NRL Co[redacted]
Declassification Team
Date: 27 APR 2016
Reviewer's name(s): H. Do, P. HANNA

Declassification authority: NAVY DECLASS MANUAL, 11 DEC 2012, 02 SERIES

BUREAU OF ENGINEERING
OCT 2 1936
A C D F G
K N P W Y
De Df Dq Do Ds Dv
Yb Yd Ym Yo Yr Yt
ENCLS—AC—SC

BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

DISTRIBUTION STATEMENT A APPLIES
Further distribution authorized by UNLIMITED only.

4—7456

U. S. GOVERNMENT PRINTING OFFICE: 1933

DECLASSIFIED

[redacted]

28 September 1936

NRL Report No. R-1310
Bu.Eng.Problem F3-10

NAVY DEPARTMENT

BUREAU OF ENGINEERING

FR-1310

Report on

Tests of Model LM Radio Frequency Measuring Equipment - Manufactured by Radio Research Company.

Classification changed from CONFIDENTIAL
To UNCLASSIFIED
By authority of 1550-156/49
File No. Dated 3-31-49

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON DC

Number of Pages: Text - 20 Tables - 15 Plates - 7

Authorization: Bu.Eng.ltr. C-NOs-42429(9-16-W3) of 25 Sept. 1935.

Date of Tests: April 2, 1936 to June 2, 1936.

Prepared by:

H.F. Hastings, Asst.Radio Engr.

Reviewed by:

M.H. Schrenk, Assoc.Rad.Engr., Chief of Aircraft Section.

A.H. Taylor, Pr. Physicist, Supt., Radio Division.

Approved by:

H.M. Cooley, Captain, USN, Director.

Distribution:
Bu.Eng. (5)

ts

DECLASSIFIED

[redacted]

TABLE OF CONTENTS

Appendices

[redacted]

Table of Contents (Continued)

[redacted]

AUTHORIZATION

1. This problem was authorized by Bureau of Engineering letter, reference (a). Other additional references pertinent to this problem are listed as references (b) and (c).

Reference: (a) Bu.Eng.ltr.C-NOs-42429(9-16-W3) of 25 Sept. 1935.
(b) Specifications RE 13A 489C.
(c) N.A.S. Report ltr. F42-1/NA6(176) of 9 July 1936.

OBJECT OF TEST

2. These tests were conducted to determine the mechanical and electrical characteristics of the Model LM frequency measuring equipment as well as how suitable it may be for installation and operation in the Naval aircraft service as called for by reference (a), in accordance with the governing specifications, reference (b).

ABSTRACT OF TEST

3. The Model LM frequency measuring equipment was tested at the Laboratory for compliance with the governing specifications, reference (b). These tests covered the following:

(a) Mechanical, including

(1) Workmanship
(2) Size and weight
(3) Materials
(4) Shock mountings
(5) Controls

(b) Frequency ranges
(c) Power Output, including

(1) Audio beat frequency
(2) Radio frequency
(3) RF input required to produce the specified audio output.

(d) Frequency stability under conditions of

(1) Variation of receiver volume
(2) Change from transmit to receive position
(3) 10% change in supply voltage
(4) Reset from calibration
(5) Variation of ambient temperature from -30° to +50°C
(6) Vibration

(e) Tests of power supply, including

(1) Source
(2) Dynamotor regulation
(3) Ripple
(4) Improper filtration

[redacted]

(f) Tests for correction of calibration shift with time.

(g) Detector linearity.

(h) Tests to determine necessary RF coupling to receiver and transmitter without adjusting voltage or volume control.

(i) General inspection of the equipment to determine suitability for the Naval Service.

4. The equipment was transferred to the Naval Air Station, Anacostia, D.C., for flight tests at the conclusion of the Laboratory tests.

[redacted]

CONCLUSIONS

As a result of these tests, the following conclusions were reached.

(1) The model LM frequency measuring equipment does not entirely meet the requirements of the governing specifications.

(2) With slight modification, the equipment can be made to conform to the specifications and be made suitable for use in the Naval Aircraft Service.

(3) The equipment does not hold its calibration over a long period of time, particularly when subjected to numerous temperature cycles.

(4) An electrical corrector would be more desirable than the present mechanical zero corrector.

(5) The calibration chart is unique and simple. It is easy to read and should permit quite accurate reading. However, it should be made more rugged and should have an improved mounting to resist damage in service.

(6) All dial settings should be recorded in four figures to the left of the decimal, as 0459.6 instead of 459.6.

(7) The dial should be made larger and should be provided with finger holes instead of a crank, which is somewhat cumbersome in flight.

(8) The units and hundreds dials should be so marked to avoid confusion.

(9) Secondary crystal check points are very prominent and should be designated on the calibration chart to enable greater accuracy of setting the heterodyne oscillator.

(10) Stronger detents should be provided on all switches and the switch positions should be clearly marked.

(11) An RF attenuator is necessary for satisfactory operation.

(12) An audio filter is necessary in the power supply leads to prevent audio feedback to the receiver.

(13) The audio circuit may be so made as to allow the audio tube to oscillate and modulate the radio frequency oscillator. This should be provided to permit checking non-oscillating receivers.

(14) The power switch should have three positions, namely "Off", "Filament Only", "On".

(15) Since it is possible to mistake crystal harmonics for the proper frequency, it would be desirable to disconnect and ground the RF coupling post when the crystal is on.

(16) A right angle connector plug permitting adjustment to 90, 180 or 270 degrees from the locking pin position would facilitate installation in aircraft.

[redacted]

(17) The side of the frame should extend aft far enough to protect the equipment when it is removed from its case.

(18) Serial numbers should be stamped on the case and front panel to avoid possibility of interchanging units and calibration charts.

(19) A portable battery power supply should be developed to permit use of the indicator at places other than in the airplane.

(20) The output-input binding post now marked "ANT" should be marked "RF Cplg".

(21) An evacuated crystal holder is supplied which does not conform to the specifications. This holder should be approved since it assures much better crystal operation.

[redacted]

RECOMMENDATIONS

It is recommended

(1) That the Model LM frequency measuring equipment be accepted when the following recommendations have been complied with in a manner satisfactory to the Bureau of Engineering and provided they conform to the model in all other respects.

(2) That an electrical instead of mechanical calibration corrector be used, this corrector to be capable of keeping the dial divisions, between two adjacent major crystal check points, nearly the same for all changes in temperature, humidity, pressure, and voltage, so that all measured frequencies will be within the specified requirements (1-2)(1-4)(3-22)(3-26).

(3) That all parts and frequency determining circuits be properly aged to insure a constant calibration over a long period of time (1-2)(1-5)(3-25)(3-26).

(4) That secondary or intermediate crystal check points be designated as such on the calibration chart to insure more accurate measurements.

(5) That an RF attenuator be supplied so that proper coupling can be made without changing the coupling lead, receiver volume control or any voltage.

(6) That the calibration chart be made more rugged and with a mounting that will not cause excessive wear. All dial readings to be recorded in four figures to the left of the decimal and duplicate calibration charts supplied. The calibration memo chart should be mounted in a more convenient location.

(7) That the detent on the band switch be strengthened to prevent changing contact resistance and heavy dots be engraved on the panel marking the switch positions.

(8) That finger holes, instead of a handle, be used on the tuning dial and frequency shifts due to vibration, shock or pressure to the dial be eliminated.

(9) That serial numbers be stamped on the panel case and calibration chart.

(10) That an adequate filter to block all audio frequency feedback through the power supply leads be incorporated in this equipment.

(11) That the audio output tube be used as an audio modulator supplying approximately 40% modulation of the RF in the fundamental ranges.

(12) That the coupling post be disconnected from the circuit and grounded when the crystal is oscillating.

(13) That an adjustable position side entrance cable supply plug be furnished instead of the end entrance type.

(14) That the dial units and hundreds be properly marked with engraving and the hundreds index properly aligned.

(15) That the RF binding post be marked "RF CPLG" instead of "ANT".

(16) That the sides of the frame extend aft far enough to protect tubes and other parts if laid in any position out of the case.

(17) That an auxiliary battery power supply be developed to permit this equipment to be used for carrier deck, portable and laboratory measurements.

(18) That better water protection be provided around the dials and slip covers be furnished.

(19) That the operating instructions be simplified.

(20) That the equipment be so designed that the plate current decreases with decrease in the supply voltage to improve the plate voltage regulation and frequency stability.

(21) That the beat frequency remain constant for all settings when pressure is applied to the dial.

(22) That the vacuum crystal holder be approved for this equipment and careful inspection of parts and assemblies be required for each crystal prior to evacuation.

(23) That the crystal and heterodyne oscillator calibration be made at the same temperature (+10°C) as called for by special contract note.

(24) That a three-position power switch be supplied which will permit disconnecting the plate voltage without turning the filaments off.

(25) That the following specifications should be changed:

(2-37) Eliminate.
(2-40) To permit a tabulated book form of calibration and all dial readings should be recorded in four figures to the left of the decimal.
(2-45) To read "Condensers <u>of</u> the", not "<u>or</u>".
(3-1) To require an electrical corrector for the heterodyne oscillator that will keep the cycles per dial division nearly the same from -30° to +50°C. It shall be impossible to make a frequency check of a transmitter or receiver while the crystal is oscillating.
(3-6(d) So that the audio output tube can be switched to an audio modulator supplying approximately 40% modulation of the RF output in the fundamental ranges for receiver MCW checks. To require 30 MW at 100 cycles with a cut-off filter above 300 cycles and a sharp zero beat zone easily detected in flight.
(3-8) To require an evacuated, standard mounting base, crystal holder.
(3-12) To require 1000 kc. crystals for all indicators.
(3-13) To require a temperature of "+10°C" and not "+20°C".
(3-17) To require <u>0.001%</u> instead of <u>0.005%</u> per degree Centigrade from -30°C to +50°C.
(3-18) Insert (3-6-(d)) between "output" and "across".

[redacted]

(3-19) To require an RF attenuator which will permit reduction to 25 micro-volts at any frequency in the fundamental ranges and not vary the frequency.

(3-22) To require cables terminated in adjustable, side entrance cable, plugs, capable of being locked 90°, 180° or 270° from the locking pin position and five conductors. The negative plate supply to be conductively free from ground throughout the entire circuit.

(3-25) To require the heterodyne oscillator to maintain its calibration over long periods of time whenever the ambient temperature is returned to +10°C.

DESCRIPTION OF MATERIAL UNDER TEST [redacted]

5. The Model LM aircraft frequency measuring equipment was manufactured by the Radio Research Company, Washington, D.C.

6. The frequency range covered is from 195 kc. to 20,000 kc. by two fundamental ranges of 195 to 400 and 2000 to 4000 kc. corrected at numerous points by beating oscillator harmonics with the fundamental and harmonics of a 1000 kc. low temperature coefficient crystal. The tuning ranges are shifted by a two-position switch.

7. A Type 78 tube is used as an electron coupled heterodyne oscillator coupled to one of the grids of a Type 6A7 tube and the coupling post. The crystal oscillator is a part of the 6A7 circuit. This 6A7 tube is a mixer and detector. The audio output of this tube is amplified by the Type 76 output tube.

8. The power supply is furnished by the Models RU-2, RU-3 or RU-4 equipment.

METHOD OF TEST

9. The mechanical features were observed and defects noted for correction.

10. The size was determined by measurement and the weight with Toledo no-spring scales.

11. The frequency range was determined by checking the equipment with a Model LD-2 frequency standard and also by observing the points checked against the 1000 kc. crystal and harmonics.

12. The frequency stability was measured visually with the Model LK indicator under conditions of

(1) The receiver volume control changes.
(2) Manual to automatic position of receiver.
(3) Variation of input voltage from 10 to 16.
(4) Transmit-receive position.
(5) Changes in ambient temperature from -30°C to +50°C for crystal and heterodyne oscillator.
(6) Pressure on dial, switches and case.
(7) Reset from calibration.
(8) Variation of RF coupling using standard signal generator.

The audio power output was measured with a General Radio power output meter at different audio beat frequencies.

13. The radio frequency output was measured by coupling the indicator to a Model RAJ receiver and at a beat of 1000 cycles the receiver volume was set to a convenient level. The General Radio standard signal generator was substituted for the Model LM frequency indicator and adjusted at a beat of 1000 cycles. The standard signal generator attenuator was adjusted to give the same receiver power output. All receiver controls remained the same for

[redacted]

both measurements. Therefore, the standard signal generator output was equal to the frequency indicator output.

14. The power supply was tested by using a voltmeter and ammeter in the 12 volt circuit, also a voltmeter and ammeter in the plate voltage supply.

15. The plate current and voltage variations were measured when the supply voltage was adjusted for 10, 12, 14 and 16 volts, when the manual volume was set at maximum and minimum, shifting from automatic to manual and in transmit-receive positions. This test checks the voltage regulation at the indicator, which includes the dynamotor and necessary series resistors associated with the receiver, transmitter and indicator. Any change in current at one piece of this equipment varies the voltage at all three places.

16. The dynamotor ripple was checked by a power output meter and phones in a quiet room.

17. The radio frequency calibration was checked at the time the equipment was first received and about one month later by comparing the number of dial divisions required to move from one crystal check point to the next, and from the lowest to the highest crystal check points in each fundamental band to determine the ability of this equipment to holds its calibration.

18. During the flight tests, the Laboratory checked the frequency accuracy, set and reset, of a Model GF transmitter with the Model LM indicator by measuring the emitted signal with the Model LF frequency measuring equipment.

19. Backlash was checked by approaching a crystal check point both clockwise and counter-clockwise, noting the difference in dial settings. Also, a frequency check was made by adjusting the dial in a clockwise direction to a given beat frequency on the Model LK, then resetting to the same dial position in a counter-clockwise direction and observing the frequency difference with the Model LK equipment.

20. The wave form of the modulator in the modified Model LM and the percentage of modulation at several frequencies was checked with a cathode ray oscillograph.

21. The detector audio amplifier combination was checked for linearity by coupling the standard signal generator to the coupling terminal, varying the standard signal generator attenuator and recording the input voltage and audio power output at various levels.

22. The following instruments were used:

(a) Radio Research frequency measuring equipment, Model LK, Serial #2. Accuracy of frequency difference: ±2 cycles, 500 cycle scale; ±4 cycles, 1000 cycle scale; ±20 cycles, 5000 cycle scale.

(b) N.R.L. heterodyne frequency measuring equipment, Model LF, Serial #1. Accuracy .001%.

[redacted]

(c) General Radio Heterodyne Calibrator, Type RAG-74016, Model LD-2X, Serial #1. Accurate to 0.005%.

(d) General Radio beat frequency oscillator, Type 713-A, Serial #209. Harmonic content less than 2%.

(e) General Radio audio power output meter, Type 538-A, Serial #74. Accuracy better than .3 DB between 150 and 2500 cycles.

(f) N.R.L. refrigerator equipment.

(g) D.C. voltmeter, Weston Model #1, 0-15-30 volts, Serial #39629. Accuracy 1/2% at 25°C.

(h) D.C. ammeter, Weston Model #1, 0-1 amperes, Serial #42733. Accuracy 1/4%.

(i) D.C. voltmeter, Weston Model #45, 0-300-750 volts, Serial #15346. Accuracy 1/2% at 75°F.

(j) D.C. voltmeter, Weston Model #663, 0-100-250-500-1000 volts, Serial #825. Accuracy 2%.

(k) D.C. milliammeter, Weston Model #1, 0-50 mills, Serial #44781 and shunt. Accuracy 1/4% at 23°C.

(l) General Radio standard signal generator, Model LC-A, Serial #2. Accuracy ±5% of attenuator marking.

(m) Model RU-3 Aircraft Radio Corporation receiver, Serial #127, Type 46036.

(n) Model RAJ Aircraft Radio Corporation receiver, Serial #8.

(o) R.C.A. cathode ray oscillograph, Type TMV-122B, Serial #4222.

DATA RECORDED DURING TEST

23. The data recorded during these tests are shown in the plates and tables of the appendix and includes the following:

(a) Temperature frequency drift of crystals #10 and #11 associated with sets #4 and #5 over a temperature range from -30° to +50°C. See Table No. 3.

(b) Temperature frequency drift of the heterodyne frequency oscillator at various radio frequencies in the low and high bands of both indicators. See Tables Nos. 4, 11, 11a, 11b, 11c, 11d, 11e, and 11f.

(c) Calibration change due to temperature causing a change in the number of dial divisions for the complete calibrated range both high frequency and low. See Table 1.

(d) Power supply variations battery operated filament and audio grid bias at 10, 11, 12, 13, 14, 15 and 16 for 200, 225, 250 volts plate and the corresponding plate currents with and without crystal oscillator. See Table 2.

(e) Power supply variations dynamotor operated filament and audio grid bias at 10, 12, 14 and 16 volts for the corresponding plate volts of 170, 200, 235 and 270 and the plate currents crystal oscillator on and off. Also plate current and voltage due to volume control change is recorded at a constant dynamotor and filament supply of 16 volts. See Table 2a.

(f) Required accuracy of frequency readings from $-30^{\circ}C$ to $+50^{\circ}C$ or permissible error expressed in cycles and dial divisions for both indicators at various radio frequency settings and the total number of dial divisions required to cover the specified frequency ranges. See Table 5.

(g) Accuracy of frequency readings as checked by Naval Research Laboratory during the flight tests May 22 and 25, 1936, showing failure to comply with the frequency accuracy of .01% called for by the specifications. See Table 5a.

(h) Calibration shift of the heterodyne oscillator over a one month period of time taken at $+10^{\circ}C$ showing calibration error in divisions cycles and percentage at both times, also the permissible error. See Table 6.

(i) Calibration reset by capacity correction to make the dial divisions correspond to the original at $+27^{\circ}C$ showing the total divisions required to cover the range and the error between crystal check points after correction, also the average cycle per division at 14,000 kc. See Table 6a.

(j) Radio frequency output of the indicator at the fundamental, 2d, 3rd, 4th and 5th harmonics of the low frequency band, and the fundamental, 2d, 3rd and 4th harmonics of the high frequency band. See Table 7.

(k) Microvolts RF input required and the corresponding audio power output at 1000 cycles to show detector linearity. See Table 8, Plates 5, 6 and 7.

(l) Audio power output at all crystal check points in both bands with beat frequency adjusted to approximately 1000 cycles. See Table 9.

(m) Audio power output with 1/2 volt external RF supplied from the standard signal generator beating against the crystal frequency indicator at 200, 7000, 13500 and 20000 kc. with an audio output beat of 200, 1000 and 3000 cycles. See Table 10.

(n) Radio frequency required to produce the specified audio output at 2000, 13575 and 20000 kc. with 1000 cycle beat frequency. See Table 12.

(o) Frequency variation due to voltage changes at 2000 kc. and frequency shift due to voltage change caused by varying the volume control. See Table 13.

(p) All dimensions and weights. See Table 14.

(q) Photographs of the equipment, front view, completely assembled, rear view open, bottom view open and top view open. See Plates 1, 2, 3 and 4.

(r) Naval Air Station Report of Flight Tests. See Appendix I.

[redacted]

DISCUSSION OF PROBABLE ERRORS

24. The crystal temperature frequency variation measurements are accurate within ±2 cycles at 1000 kc.

25. The heterodyne oscillator temperature frequency variation measurements taken at several radio frequencies and different scales on the Model LK frequency equipment are accurate as follows:

±2 cycles	for	the	500	cycle	scale
±4 "	"	"	1000	"	"
±20 "	"	"	5000	"	"

26. The temperature measurements are accurate to within 1°C.

27. The standard signal generator attenuator accuracy becomes less as the frequency increases and it is approximately ±10% at 20,000 kc.

28. The accuracy of all instruments is listed under METHOD OF TEST, Page 4, Par. 22.

RESULTS OF TEST

29. Paragraphs of the specifications that require no comment will be omitted in this report.

2-5. All items entering into the construction of this equipment are reasonably resistant to the corrosive action of a moist sea atmosphere. No test was conducted with the models to subject them to such conditions.

2-7. The equipment supplied was not tested in all ambient temperatures between -32°C and +65°C. The refrigerator equipment cannot be relied upon to operate below -25°C or above +50°C. See Tables 3, 4, 11, 11a, 11b, 11c, 11d, 11e and 11f.

2-9. The equipment is contained in a closed metal cabinet with filament and plate power as follows: 16 volts max. at 0.70 amperes or 11.2 watts; 300 volts max. at 0.022 amperes or 6.6 watts. See Table 2. A total of 17.8 watts is dissipated in this closed cabinet, which helps to prevent collection of moisture. No special provision for ventilation is considered necessary.

2-11. This equipment has been subject to all tests called for by this specification during flight except the maximum acceleration of 8 g applied in any direction and no damage resulted. See Appendix 1. The crank handle may be a drawback in flight, causing an unbalanced dial. This handle is in the way of clothes and gloves.

2-13. All parts are not permanently and legibly marked for proper identification. Most important among these items are the equipment, case, crystal and Instruction Book. They should all be marked with the same serial number to avoid confusion with other units.

2-14. No nameplates were supplied with the samples.

DECLASSIFIED

2-15. The equipment does not operate entirely satisfactorily over the entire temperature range tested (-25°C to $+50^{\circ}$C). This unsatisfactory operation results in inaccurate frequency measurements beyond the allowance of specification (1-2) due to the cycles per division as calibrated changing with temperature. Over long periods of time the calibration gradually changes. In one month of time the temperature at which the calibration chart corresponds to the actual frequency shifts as much as 50°C. See Tables 1, 5 and 6. During the above mentioned time, the equipment was subjected to numerous temperature cycles from -25°C to $+50^{\circ}$C. Specific humidity measurements were not made, although operation in the refrigerator subjects the equipment to widely varying humidity conditions.

2-16. No apparent damage has resulted due to shock or vibration unless the shift in calibration temperature can partially be contributed to vibration. See Table 6. The audio transformer and audio choke leads are not crimped before soldering. Solder is depended on for mechanical strength contrary to this specification.

2-18. Throughout the temperature range of -29°C to $+50^{\circ}$C no cracking or flowing of compound used in associated parts of the equipment was observed.

2-19. The shockproof mounting supplied with this equipment conforms to the usual type used with similar equipment and is satisfactory in all respects except possibly at 8 g applied in any direction. No acceleration equipment is available in the Laboratory to make this test as called for by (2-11). See Appendix 1 for flight tests. In some cases it would be desirable to be able to mount the equipment by inclining the present base aft as much as 30° or in a modified face up position for suitable operation and good visibility.

2-20. All connections within the set have withstood the entire Laboratory and flight tests without injury due to vibration and shock.

2-21. The insulating material used in this equipment and wiring is reasonably safe from possible fire hazard. The metal case encloses the equipment so well that an external fire would not reach the equipment and an internal fire would not burn very long or get out of the case.

2-22. All vacuum tube sockets are of the single unit type.

2-23. No damage to vacuum tubes and other delicate devices resulted during the Laboratory and flight tests.

2-24. The vernier used for reading tenths of one division might be somewhat confusing. The index is not properly designated with an "arrow head" or "0"; there should be only nine tenths indicated by marks instead of ten tenths and they should be on the left side of the index. More simple operation may be accomplished by having a fixed index instead of the adjustable one furnished. The dial can be set to the desired nearest crystal check point according to the calibration chart and the calibrated oscillator brought to zero beat by an adjustable vernier condenser. By this method the cycles per division will be more uniform with temperature and the index will always be at the top of the dial, not 90° one way or the other.

2-24. (Continued) Some difficulty has been encountered by leaving the crystal turned on while making a measurement and beating the transmitter against the crystal harmonics instead of the self oscillator. This can and should be eliminated by disconnecting and grounding the coupling post during the time that the crystal is operating. This will assure measurement with the self oscillator at all times. The calibration chart should be marked with four figures to the left of the decimal point to avoid setting the equipment on the wrong frequency. Example:0429.5 instead of 429.5. These changes will simplify the operation of this equipment.

2-25. The dial index vernier is not properly marked, as pointed out in paragraph 2-24.

2-26. No electrical indicating instruments are used as a part of this equipment.

2-27. The adjustment dial rotates clockwise to increase frequency as specified. The hundred dial divisions, increasing numerically toward bottom rather than top, would be more desirable.

2-28. The equipment is properly housed in suitable grounded metal cabinets finished in the black wrinkle type. All surfaces have been treated to prevent corrosion. The attachment plug should be made with the cable at right angles to the plug and provision to rotate and lock the cable in any desired position. The plugs furnished will not cause shorts or shocks in contact with a flat metal surface. All latches are properly finished.

2-29. Tubes whose characteristics reach the specified limits are not available to make this test.

2-31. Safe operation is insured. Satisfactory operation within the limits of accuracy specified by (1-2) cannot be insured with the calibration and equipment in its present form. Crystal check points should be closer to each other in frequency with a better temperature or zero corrector device. See Tables 1, 5 and 6.

2-33. No body capacity effects are present.

2-34. The shielding is satisfactory.

2-35. The band change switch has a weak detent and the same contact resistance does not exist at all times. This causes slight frequency changes at times. This was quite noticeable at 400 kc. with indicator #4.

2-37. The access provided for replacement of tubes is poor. In this equipment it is desirable that it should be. It prevents exchanging or borrowing tubes for other purposes and in case of burnout it is advisable to make replacement on the carrier, not in flight. It is necessary to remove 13 screws and slip the unit out of its case to change tubes.

2-38. The audio transformer and choke coil assemblies are sealed off under slight evacuation and filled with an inert gas. No difficulty should ever result from humidity.

2-39. All parts are reasonably accessible to permit replacement when necessary.

2-40. The calibration chart is not in accordance with the governing specification but it is made in a very usable and desirable form. The covers should be better protected to prevent wear and the secondary and primary crystal check points marked in red throughout the entire range. The nearest primary crystal check point should be marked at the bottom of each page. All dial readings should be recorded in four figures to the left of the decimal point. Some errors in typing were noted and should be carefully checked in the production models.

2-41. The quartz crystals were ground so that the frequency did not jump and no spurious frequencies were detected from -30°C to +50°C. See Table 3, Serials 4 and 5.

2-43. The crystals are sealed in a vacuum and cannot be inspected optically. The operation is satisfactory.

2-44. No plug-in coils are used.

2-45. No electrolytic condensers are used in this equipment.

2-46. All parts in their final assembled form were subjected to numerous heating cycles from -25°C to +50°C and no apparent injury resulted to any of the parts. Temperatures of -32 and +65°C were not attained due to the temperature limit of the testing equipment.

3-1. The measuring unit contains a crystal calibrator and heterodyne frequency meter and necessary controls, except as noted in paragraph 2-24, housed in a single metal cabinet. It is capable of use for calibrating transmitters and oscillating receivers by means of direct comparison with the heterodyne oscillator. It is possible to check the zero setting of the heterodyne oscillator to correspond with the calibration at each crystal check point, but the accuracy of frequency measurements between check points depends on how near the operating temperature is to the temperature at which the cycles per division correspond to the calibration. Some form of corrector that will keep the dial divisions the same between crystal check points for all temperatures is desired. See Table 6.

3-2. It is possible to check a transmitter as described, but it would be very helpful to have an RF attenuator on the indicator to adjust the signal to a proper level for good check. It would be desirable to be able to adjust the RF output to values below 50 microvolts. See Table 7.

[redacted]

3-3. This method is possible with the Model LM equipment. It is somewhat difficult to get the receiver gain to the proper level and maintain frequency accuracy with the indicator due to the plate voltage variations at the indicator caused by varying the receiver volume control. See Table 7. This can be avoided by having an RF attenuator on the Model LM indicator and adjusting the level to suit the receiver, thus avoiding any plate voltage change of the indicator during a measurement.

3-4. This method of check is satisfactory, but the zero corrector device furnished will not adjust the oscillator in such a manner that the number of dial divisions remains the same between crystal check points at all temperatures specified. Therefore, the reset point is not proper for accurate frequency readings at remote points. See Table 6.

3-5. The measuring equipment contains a heterodyne oscillator and a crystal controlled calibrator. The heterodyne oscillator operates at two fundamental frequency ranges (195 kc. to 400 kc. and 2000 kc. to 4000 kc.). The ranges are changed by a single switch.

3-6. The circuits employed incorporate the following:

(a) <u>Crystal oscillator</u> with untuned plate inductance, and the crystal operates freely without spurious frequencies in the circuit. See Table 3.

(b) <u>The heterodyne oscillator circuit</u> for both ranges is accomplished by a single variable condenser. 5000 divisions are available throughout the entire tuning range. Approximately 4000 of these divisions are used to cover the desired range. This should remain the same for all temperatures. With a proper zero correction device, this is possible. See Table 6.

(c) <u>The detector</u> does not show a linear characteristic of input RF voltage when the output values lie between 0.06 milliwatts and 50 milliwatts with the beat signal at approximately 1000 cycles. See Table 8, Plates 5, 6 and 7. This is not considered an essential requirement.

(d) <u>The audio output circuit</u> is suitable for use with 600 ohm phones. The specified power output of

.003 watts at 200 cycles
.015 watts at 3000 cycles
.030 watts at 1000 cycles

has been greatly exceeded at all frequencies up to 20,000 kc. See Tables 9 and 10. It is not necessary to have a great deal of power output above 200 cycles. With all readings being taken at zero beat, the lower frequencies are much more desirable with a frequency cut-off device above 300 cycles. .030 watts would be more desirable at 100 cycles with not more than 0.001 watt above 300 cycles and a sharp zero beat zone under flight conditions.

[redacted]

3-7. All D.C. has been removed from the head telephones by an isolating transformer and reasonable care has been taken to prevent RF from getting on the phone cords from the indicator.

3-8. The crystal holder does not conform to the 40001-A crystal holder. It is radically different and evacuated, which is considered satisfactory and highly desirable to prevent moisture or changes in altitude from affecting the crystal. Careful inspection of parts should be made before assembly.

3-9. The crystal grid lead conforms to this specification.

3-10. Inspection of the crystal holder cannot be made after assembly and evacuation. They should be rigidly inspected before assembly.

3-11. The two crystals checked were ground to the proper frequency and the frequency remained practically constant over the entire temperature range as specified by 2-41, 3-15 and 3-16. See Table 3.

3-12. The crystal frequency chosen by the contractor is 1000 kc. In all future indicators, this same frequency and type of crystal holder should be required.

3-13. This specification calls for crystals to be ground at +20°C, but this has been amended by the schedule to +10°C, to correspond to the heterodyne calibration temperature. Due to the excellent temperature frequency characteristic of the crystals supplied with the samples, this is not a serious factor. The maximum variation over 79°C change was 52 cycles in 1000 kc. or 6.6 cycles for 10°C. See Table 3. If all crystals are ground to absolute frequency at +10°C, then the maximum specified variation from true frequency should not exceed plus or minus 40 cycles at 1000 kc.

3-14. The heterodyne crystal check points as indicated on the chart will not be mistaken, but they are widely separated and the possibility of inaccurate intermediate frequency measurements beyond .02% from 195 to 2000 kc. and .01% from 2000 to 20,000 kc. are possible with wide variations in temperature from that at which the heterodyne oscillator corresponds to the original calibration. This condition can be greatly improved or completely corrected by use of a capacity zero correction device on the heterodyne oscillator so that the dial divisions between crystal check points remain the same for all temperatures between -30°C and +50°C. See Table 6. For closer crystal check points, it would be desirable to use some of the secondary or intermediate crystal check points provided the first check is made at one of the primary points.

3-15. The crystals in the samples as operatively mounted in the equipment do not exceed .005% as specified. See Table 3.

(1) Vibration in refrigerator for hours at a time.
(2) Shaken violently by hand.
(3) Equipment in various positions.
(4) For temperatures ranging from -29°C to +50°C.

3-16. The temperature coefficient of the combined crystal, holder and circuit is less than 0.0001% per degree. See Table 3.

3-17. The temperature coefficient of each range of the heterodyne oscillator complies with this specification. At the poorest point, the percentage of frequency per degree Centigrade is .0015 and the specified allowance is .005%. See Table 4 and Table 11. While it is desirable to have a low temperature coefficient for a good indicator, it is much more essential that the frequency follow a straight line with temperature variation and at the same rate as interpreted in dial divisions at all frequencies covered by the entire fundamental band. In other words, it is essential that the total dial divisions, shown by the calibration chart to cover the entire fundamental ranges, should remain the same for all temperatures from -30°C to +50°C. If this condition exists or can be easily corrected at each temperature, the overall accuracy will be much better.

3-18. The input energy required to produce the specified audio output across the phones does not exceed 500 millivolts at any frequency. In fact, 130 millivolts is the maximum required at any frequency to produce 30 MW output at 1000 cycles, as called for by 3-6(d). See Tables 12 and 13.

3-19. The radio frequency energy available between the output terminal and ground exceeds 100 microvolts at all radio frequencies throughout the entire range of the instrument. See Table 7. In some respects, this excessive RF output causes difficulty. When setting a receiver to frequency, it is necessary to lower the gain control on the receiver to prevent blocking. This in turn varies the plate voltage on the indicator and it is necessary to go back to the nearest crystal check point and check the indicator and return to the desired frequency without any readjustment of the receiver volume during the process of measurement. It would be much more desirable to have an RF attenuator on the indicator output to adjust the level properly when the receiver is operating at normal reception level. This would also permit the operator to directly check any received signal by zero beating the indicator to the signal at a proper level without changing the indicator coupling by external length of lead.

3-20. The coils employed for the crystal controlled oscillator plate circuit and all elements of the heterodyne oscillator tuned circuit are not enclosed in containers sealed against moisture. This is satisfactory electrically and no difficulty was encountered during the tests. It is possible that high humidity and high temperature over long periods of time such as encountered in the tropics might cause trouble. If trouble does occur in service use, the general guarantee clause (1-5) will apply.

3-21. The variable elements of the heterodyne oscillator are connected to a dial assembly having 5000 effective readable divisions and approximately 4000 are used in the calibration. The spacing between adjacent marks is greater than or equal to 1/16th of an inch. At the highest calibrated frequency, one dial division is less than 3 kc. In other words, 4000 divisions equal 2000 kc. change in frequency. One division equals

[redacted]

0.5 kc. at 4000 kc., therefore one dial division equals 2 kc. at 16,000 kc. The backlash does not exceed 1% in either direction of the vernier. Electrically, this allowance represents 50 cycles in the low fundamental range and 500 cycles in the high fundamental range. See Table 6a. No dial stops are used.

It would be desirable to have the high frequency and low frequency calibration track so that 200 kc. equals 2000 kc., 400 kc. equals 4000 kc. and all intermediate points bear the same relation to each other with the calibration on the dial.

The vernier engraving for reading tenths of a dial unit are useful for laboratory and carrier deck work, but of no use in flight due to vibration.

The hundreds index marked is misaligned by 15 to 25 of the dial units and "Dial hundreds" should be engraved over the window.

The engraving (+Corrector-) over the dial should be changed to "Dial units".

3-22. The power supply to the measuring equipment is obtained through a three-conductor shielded cable 9 feet in length terminated at both ends in the same size and type of shielded plug, as specified. It would be desirable to have the indicator plug constructed so that the cable comes out of the side, with provision to adjust it in any one of three positions $\pm 90^{\circ}$ and 180° from the locking pin position.

The power supply variation with the Model RU-3 equipment varies to a greater extent than the values specified. See Table 2.

Specified	Measured
12-16 volts, .6 amps.	10-16 volts, .5 to .7 amps.
200-260 volts, 20 mills.	170-300 volts, 8.5 to 22 mills.

The plate voltage variations are not all due to the supply voltage varying from 10 to 16, but partially due to volume control variation.

These voltage changes vary the indicator voltage to such an extent that frequency readings exceed the specified allowance of .02% and .01% as called for by (3-26) unless the nearest crystal check point is adjusted to conform to the calibration and the frequency read without causing voltage changes in between calibration and reading. See Table 13.

The wide variations of plate voltage could be corrected to some extent if the negative power supply lead in the indicator was isolated from ground and returned back to the negative of the machine instead of through the common resistor in series with the receiver plate circuit.

The grid bias voltage for the last stage audio should remain more nearly constant with changes in the A voltage supply. This would prevent such great voltage variations of the plate supply to the indicator, because with lower filament supply the plate current would be less instead of greater.

A cathode resistor and bypass condenser on the audio stage would regulate this grid bias properly with changes in supply voltage and prevent large plate current variations.

3-23. The negative side of the 12 volt supply is bonded to the case in the equipment.

[redacted]

3-24. The measuring equipment is calibrated over the range 195 to 20000 kc. The chart is in book form and can be mounted with the equipment or kept externally. This book form of calibration is much more desirable than the strip type called for and can be read much more rapidly and accurately. It is not rugged enough and all details have not been finally approved. The crystal check points are plainly marked in red. A card is mounted on the equipment to record important frequencies, but the size and place of mounting are not the most convenient, as reported during the flight test installation. The operating instructions could be simplified by eliminating Paragraph VI and it would be convenient to have the circuit diagram and parts listed included. Duplicate books should be supplied.

3-25. The crystal calibration temperature and the heterodyne oscillator calibration temperature should be the same (+10°C) as called for by special contract note. The calibration of the heterodyne oscillator is reported to have been made at +22°C, but the temperature at which the total dial divisions correspond to the calibration is lower than -25°C. While it is possible to correct the index of the heterodyne oscillator to agree with the calibration chart at all crystal check points at all temperatures between -30°C and +50°C, it is impossible to make it agree with the calibration chart throughout this temperature range at points remote to the crystal check points. The inaccuracies at intermediate points exceed this specification due to a variation in the number of dial divisions between any two adjacent crystal check points with changes in temperature. In other words, the cycles per division change with temperature. By using a small electrical zero corrector instead of the mechanical corrector, it is possible to keep the cycles per division more nearly uniform throughout the specified temperature range. See Table 6.

3-26. The emitted frequency of the measuring equipment operating as a heterodyne oscillator is not within .02% of the absolute frequency in the range of 195 to 2000 kc. and not within .01% in the range 2000 to 20,000 kc. under all of the unfavorable conditions when the tubes have been lighted for ten minutes and resetting of the heterodyne oscillator to the nearest crystal check point. See Table 13. The greatest errors are caused by

(1) Variation of ambient temperature from -30 to +50°C. See Table 1.
(2) Changes in filament and/or plate voltage of 10%. See Table 13. Grinding errors should cause no difficulty if proper inspection is made before the equipment is accepted. If an electrical zero corrector is used, it should be possible to comply with this specification. See Table 6a.

The receiver volume control must be connected for manual, not AVC, operation and in one fixed position during the process of setting the indicator to the proper crystal check point and making a frequency measurement.
The accuracy of dial setting on the bench is one-tenth of one division and in flight one division.
The deviation of total dial divisions should not be greater than ±7.9 divisions for .02% in the low frequency band and ±5 divisions for .01% in the high frequency band. Actually, this is +25.1 divisions or

[redacted]

0.0636% in the low band and +15.3 or 0.0306% in the high band, resulting in such possible errors in frequency measurements at remote points from the crystal check points. This error can be reduced to meet the specifications as shown in Table 6a.

The overall errors in flight due to vibration, shock, calibration inaccuracies, temperature changes, ability to read the dial settings, etc., approximates 0.09% as a maximum decreasing to .001% near the crystal check points. The errors due to calibration change from the time of original calibration until April 15, 1936, resulted in -2.2 divisions and on May 20th the error had shifted to +11.9 divisions. At the same time, the errors in the high band were as follows: -1.3 divisions for 1st check and +11.5 divisions for the second check. See Tables 5, 5a, 6 and 6a. These errors can be reduced to a minimum by a proper zero or temperature correction device and meet the allowance of 0.02% and 0.01% as required by specifications (3-26).

3-27. The maximum overall dimensions of the measuring equipment, including all projections, mounting base, calibration chart and mounting, knobs, etc., do not exceed the specified allowance. See Table 15.

3-28. The weight of the indicator complete with tubes, calibration chart and mounting, mounting base, crystal and holder, shock absorbers and detachable base does not exceed 11 pounds. The cable does not exceed 1 pound 11 ounces. See Table 15. Additional allowance for weight may be necessary when the RF attenuator, audio filter and modulator combination is incorporated.

3-29. The shock mounting is in accordance with this paragraph.

3-30. All controls are capable of operation by one wearing heavy gloves, but the heterodyne oscillator dial handle is in the way and it is difficult to set the zero corrector ring without moving the dial. This handle should be eliminated and the dial increased in size, with a recess or finger hole for rapid movement of the dial.

3-31. This does not apply to the form of calibration furnished.

SUMMARY OF RESULTS

39. The results of tests on the Model LM frequency indicator at the Laboratory and in flight showed that this equipment could be made to conform to the specifications in a satisfactory manner. The defects and recommendations that follow were pointed out and discussed with the manufacturer at a conference held in the Navy Department June 4th, 1936.

(a) Defects

(1) The grid bias voltage for the last audio stage is obtained from the 12 volt storage battery. When the voltage is low, a low bias results and high plate current. When the voltage is high, the bias is high and the plate current low.

(2) The adjustment handle on the tuning dial is in the way when wearing heavy gloves (3-30) and slight pressures on the dial cause frequency shifts.

(3) Filament or plate voltage changes of 10% (3-26) cause excessive frequency shifts. In normal operation with the Model RU-3 receiver and varying the battery voltage from 10 to 16 (specifications 3-22), the plate voltage varies from 170 to 300.

(4) Varying the volume control from one limit to the other varies the plate voltage from 265 to 300 volts when the battery voltage is 16.

(5) The AVC operation causes the indicator to shift frequency as much as 500 cycles in 2000 kc., or .025%.

(6) The calibration shifts with time, causing radical frequency errors between crystal check points at all temperatures (specifications 3-25).

(7) The form of zero corrector device used causes errors greater than .02% in the low frequency band and .01% in the high frequency band.

(8) Indicator #4 showed constant fluctuation of frequency or small jumps during the 400 kc. temperature frequency run.

(9) The detent on the band switch is not strong enough to prevent frequency shifts due to different switch contact resistance. These contacts should be the same each time the switch is thrown.

(10) It is difficult to properly couple the indicator to a receiver.

(11) The calibration chart is not rugged enough to withstand the constant use.

(b) Recommendations

It is recommended:

(1) That a cathode resistor and by-pass condenser be supplied for bias voltage on the last audio stage to prevent large plate current variations when the supply voltage changes.

(2) That a better thrust bearing be provided on the tuning dial worm drive shaft to prevent movement of the variable condenser by pressure on the face of the tuning dial.

(3) That frequency shifts due to voltage changes be reduced to a minimum to prevent the indicator from shifting frequency by varying the volume, AVC operation or changes in the voltage source.

(4) That the negative B supply be kept free from ground as far as DC is concerned and the chassis bonded to associated equipment by one conductor in the cable.

(5) That present dial zero index correcting device be discarded and the index be made fixed with a small capacity calibration correction device.

(6) That the audio transformer leads be made mechanically tight to the lugs and not depend on the solder to hold them in place.

(7) That better switch contacts be provided and stronger detents to insure the same contact resistance each time the switch is thrown.

(8) That serial numbers be stamped on the panel and case to insure identification.

(9) That an output attenuator which will permit reduction of the RF output to less than 50 microvolts be located where the present power switch is now located, the power switch to be put at the bottom and center of the indicator and the handle removed. No calibration of the RF output will be necessary.

(10) That light metal covers and binders be used and the form of calibration furnished be accepted, although not in accordance with specification (3-24) and (3-31). The calibration should be at +10°C, as specified by (3-25).

(11) That the necessary switching and filter arrangement be incorporated to use the audio output tube as a 400 cycle modulator of approximately 40% modulation for the fundamental ranges of the RF oscillator.

(12) That the audio frequency produced while operating from the Model RU-3 power supply be eliminated by proper plate by-pass. The normal dynamotor ripple can be heard in a quiet room but it does not disturb operation of the equipment.

(13) That specification 3-8 be waived and the special vacuum crystal holders be accepted and one spare crystal provided for each 10 indicators.

(14) That careful inspection of all parts should be made prior to assembly of the crystal holder in accordance with specification 3-10, inspection of assembly being impossible after completion.

(15) That the normal temperature for grinding crystals (specification 3-13) and the heterodyne oscillator calibration (specification 3-25) should be the same instead of +20°C and +10°C, respectively. Suggest +10°C as called for by special contract note.

(16) That secondary crystal check points be marked at intermediate points to permit heterodyne oscillator check points nearer together and increase overall accuracy.

(17) That by eliminating the adjustable index and using a trimmer condenser for a zero correction device, more accurate frequency measurements can be made at any point. The calibration chart represents a definite number of dial divisions between crystal check points. If the number of divisions is kept the same for all temperatures, then the accuracy will be as good as the original calibration at all times. When measuring a frequency, if the dial is set according to the calibration at a crystal check point and zero beat obtained by adjusting the vernier condenser the number of divisions between crystal check points will remain nearly the same for all temperatures, provided the oscillator at any frequency without resetting has a good temperature frequency characteristic; 0.1% for 80°C is satisfactory. 0.05% would be more desirable.

(18) That, if practicable, the low frequency and high frequency calibration be made to track so that the same calibration and dial position for 200 kc. low frequency will be 2000 kc. high frequency and 400 kc. low frequency will be 4000 kc. high frequency. In addition, all equipment to be made so that the calibrations are interchangeable.

40. Certain features of the modified Model LM frequency indicator are desirable, but as a whole the RF attenuator calibration would be of little value unless the plate voltage and filament voltage could be kept constant and at the same value as supplied at the time of calibration.

41. The wave form of the audio oscillation using the output tube for a modulator is not considered important for rough receiver checks.

42. This equipment is capable of satisfactory installation and operation on various classes of Naval aircraft.

43. It is possible to measure the emitted frequency of any transmitter and adjust any oscillating receiver to any desired frequency in the band of 195 to 20,000 kcs., within an accuracy of 0.02% from 195 to 2000 kc. and 0.01% from 2000 to 20,000 kc. when the temperature does not vary more than plus or minus 20°C from that temperature at which the cycles per division correspond to the calibration chart and the voltages remain constant during the measurement. The specified accuracy is not possible from minus 30°C to +50°C with the temperature corrector device used in the models submitted.

44. The submitted models were complete except as noted below:

(a) The calibration is not contained in a suitable mounting to prevent excessive wear and no spare calibration is furnished.

(b) No spare parts were furnished with the models.

45. All power required to operate this equipment is obtained from the receiver junction box. The values of this supply are not in strict accord with paragraph 3-22. See Table 2.

CONCLUSIONS

46. As a result of these tests, the following conclusions were reached:

(1) The Model LM frequency measuring equipment does not entirely meet the requirements of the governing specifications.

(2) With slight modification, the equipment can be made to conform to the specifications and be made suitable for use in the Naval Aircraft Service.

(3) The equipment does not hold its calibration over a long period of time, particularly when subjected to numerous temperature cycles.

[redacted]

(4) An electrical corrector would be more desirable than the present mechanical zero corrector.

(5) The calibration chart is unique and simple. It is easy to read and should permit quite accurate reading. However, it should be made more rugged and should have an improved mounting to resist damage in service.

(6) All dial settings should be recorded in four figures to the left of the decimal, as 0459.6 instead of 459.6.

(7) The dial should be made larger and should be provided with finger holes instead of a crank, which is somewhat cumbersome in flight.

(8) The units and hundreds dials should be so marked to avoid confusion.

(9) Secondary crystal check points are very prominent and should be designated on the calibration chart to enable greater accuracy of setting the heterodyne oscillator.

(10) Stronger detents should be provided on all switches and the switch positions should be clearly marked.

(11) An RF attenuator is necessary for satisfactory operation.

(12) An audio filter is necessary in the power supply leads to prevent audio feedback to the receiver.

(13) The audio circuit may be so made as to allow the audio tube to oscillate and modulate the audio frequency oscillator. This should be provided to permit checking non-oscillating receivers.

(14) The power switch should have three positions, namely "Off", "Filament Only", "On".

(15) Since it is possible to mistake crystal harmonics for the proper frequency, it would be desirable to disconnect and ground the RF coupling post when the crystal is on.

(16) A right angle connector plug permitting adjustment to 90, 180 or 270 degrees from the locking pin position would facilitate installation in aircraft.

(17) The side of the frame should extend aft far enough to protect the equipment when it is removed from its case.

(18) Serial numbers should be stamped on the case and front panel to avoid possibility of interchanging units and calibration charts.

(19) A portable battery power supply should be developed to permit use of the indicator at places other than in the airplane.

(20) The output-input binding post now marked "ANT" should be marked "RF CPLG".

(21) An evacuated crystal holder is supplied which does not conform to the specifications. This holder should be approved, since it assures much better crystal operation.

[redacted]

APPENDIX I.

F42-1/NA6(176) U.S. NAVAL AIR STATION ANACOSTIA, D.C. GBHH/dg

JUL 9 1936

From: Commanding Officer.
To: Director, Naval Research Laboratory, Anacostia, D.C.

Subject: Aircraft Radio - Model LM Frequency Measuring Equipment - Report on Flight Tests of.

Reference: (a) BuEng. ltr., NOs-42429 (6-8-W3) dated 12 June 1936, with Enclosure (A).

Enclosure: (A) N.A.S., Anacostia, Memorandum - Comments on LM Frequency Meter Model, dated 3 June 1936.
(B) Copy of Radio Research Company's Drawing No. A-1811, showing LM Circuit Diagram; alterations at Anacostia are added.

1. This letter reports upon flight tests made with the LM frequency measuring equipment, as outlined during a verbal conference at this Station by representatives of the Naval Research Laboratory on 21 May 1936.

2. After general examination and bench test, the subject equipment was installed in O3U-1 airplane No. 8810, in conjunction with a model GF-3 transmitting and RU-4A receiving equipment. The equipment was flight tested on three flights aggregating 4-1/4 hours; it was then set up in the laboratory and modified by addition of a neon tube serving as visual zero beat indicator. The subject equipment is being retained for use in connection with flight tests of Model GO-2 and GP-3 equipments.

3. The frequency indicator unit embodies the following three fundamental circuits:

(a) An electron coupled oscillator system using a '78 tube. A band switch provides two fundamental frequency ranges, 200 to 400 kcs, and 2000 to 4000 kcs, respectively. A precision geared, temperature compensated tuning condenser is employed.

(b) A crystal controlled, fixed frequency oscillator circuit, rich in harmonics, employing a 1000 kc quartz crystal of very low temperature coefficient in an evacuated holder. A type 6A7 tube is used as a combined crystal oscillator, heterodyne mixer, and detector tube.

(c) A type 76 tube, for audio amplification, is impedance coupled to the plate of the 6A7 tube, and is connected through a step-down transformer to the output telephone jack, for use with a low impedance headset.

[redacted]

4. In place of a calibration curve or chart, a waterproofed book containing tabulated frequency settings is supplied, and normally carried in a stowage recess provided for it on the under side of the frequency meter unit.

5. On two flights (May 22 and 25, respectively) the transmitter was repeatedly adjusted, with the aid of the LM frequency meter, to successive nominal frequencies of 4385, 6690, and 7535 kcs, and the true frequency each time determined by measurement of the received frequency at the Naval Research Laboratory. The LM equipment in flight was also used to measure the frequencies of several received broadcast signals, in comparison with simultaneous precision laboratory measurements on the same signals.

6. On the first test flight, settings with the LM equipment were impaired by the occurrence of a spurious audio frequency howl whenever a zero beat setting was approached. With the aid of a representative of the contractor, this trouble was shown to be due to a 5000 ohm series resistor incorporated in the high voltage outlet on the GF-3 junction box, from which the LM derives its power. By the addition of a resistor and two condensers, the internal filtering in the LM equipment was sufficiently improved to provide satisfactory operation from the above imperfectly filtered supply.

7. The following table shows the results obtained during the flight tests; the call letters 52R were used by the radio test airplane.

Date	Transmitting Station	Measured Frequency, kcs: By LM in plane:	At N.R.L.:
5/22/36	52R	4385.0	4385.53
		"	4385.66
		"	4385.61
		"	4385.66
		"	4385.71
5/25/36	52R	4385.0	4385.66
		"	4385.61
		"	4385.61
		"	4385.91
		"	4385.91
5/22/36	52R	6690.0	6692.13
		"	6692.19
		"	6691.73
		"	6691.60
		"	6691.66
5/25/36	52R	6690.0	6691.96
		"	6691.86
		"	6692.26
		"	6691.86
5/22/36	52R	7535.0	7540.83
		"	7541.38
		"	7540.47
		"	7540.91
		"	7540.04

[redacted]

5/25/36	52R	7535.0	7539.50
		"	7538.98
		"	7539.06
5/25/36	52R	7535.0*	7535.37
		"	7535.37
		"	7535.20

*Using intermediate crystal check point.

5/22/36	W8XAL	6059.47	6059.62
		- -	6059.68
5/25/36	WMAL	629.75	630.00
5/25/36	WCAO	599.63	600.014

8. The greatest error observed during the flight tests is seen to occur on the 7535 kcs frequency. This was predicted by the Naval Research Laboratory on the basis of laboratory determination, chiefly due to a condenser capacitance error in traveling over the specific range from the regular 7000 kcs crystal check point to this test frequency. The greatly improved accuracy of the final 7535 kcs settings was accomplished by reference to an intermediate crystal check point on 7500 kcs. A large number of such auxiliary useful crystal check points were observed to be of sufficient intensity to be useful in flight.

9. General convenience of operation in flight, freedom from backlash, and precision of zero beat setting were found notably superior to any previously tested aircraft frequency measuring equipment. It appears, however, that further improvements may be effected in regards to numerous details, as set forth in Enclosure (A).

10. Subsequent both to the flight tests and to the Bureau of Engineering conference of 4 June 1936 reported in reference (a), this station conducted experiments by connecting a small neon tube (RU-3 spare) across the primary (high impedance) winding of the audio frequency output transformer in the subject equipment. Although the audio-frequency by-passing action was sufficient only to reduce the strongest beat notes by about 20 per cent, and therefore contributed only a small measure of aural protection to the operator, the value of this tube as a visual zero beat indicator was at once apparent. Without requiring insertion of the headset this tube makes possible extremely accurate zero beat settings with the equipment, by careful dial adjustment to a point in the middle of a glow (beat-note) zone where the glow suddenly ceases, or at least flashes at a slow rate (proportional to cycles per second off true zero beat). With the RU-3 receiver controls on MVC, the volume control knob was found to have a convenient vernier effect on the LM beat frequency.

11. The neon tube glow was found to be sufficiently bright to be readily visible in broad daylight when shaded from direct sunlight. The electrical sensitivity of this indicator was sufficient to give accurate response at all designated main crystal check frequencies, and to enable visual frequency adjustment of a model GF-1 transmitter, even with the power amplifier de-resonated and a therefore negligible antenna current.

[redacted]

12. The addition of a visual indicator tube is considered very advantageous from the standpoint of service application, since it will permit adjusting or monitoring of transmitter frequency in flight without the need for temporary abandonment of the operator's receiver watch, and also will enable accurate frequency settings despite ear fatigue on long flights, or under conditions of extreme noise as with planes warming up on the deck of a carrier.

13. In view of the above-mentioned advantages and the probable negligible additional cost, this station recommends that, in addition to the desirable changes pointed out in Enclosure (A), the production LM equipment be provided with the type of visual indicator described in this report. It is believed that the resulting equipment will represent a notable advancement not only in frequency measuring equipment for aircraft, but also will prove of great use for portable, laboratory, and shipboard applications.

14. For purposes of information and reference it is requested that this station be supplied with two copies of the Laboratory's final report on the subject equipment, when issued.

/s/ V.C. Griffin

Copies to: BuAero. (2)
BuEng. (1)
NAF Phila. (1)

DECLASSIFIED

[redacted]

ENCLOSURE (A)

Radio Test Section
U.S. Naval Air Station,
Anacostia, D. C.

3 June 1936.

GENERAL COMMENTS ON MODEL LM FREQUENCY METER MODEL

a. Intermediate harmonic check points (1500 & 7500 kcs) are of ample strength in flight to give good zero beat minima; about 0.3 div wide against 0.2 divisions for normal check points. Recommend adding such points for suitable frequency ranges.

b. No excessive bothersome signal strengths from LM observed in flight. The stronger the signal output from the phone jack, the narrower and more accurate the audible zero beat zone, hence consider a.f. attenuator undesirable for accuracy. Recommend that future specs require loss of a.f. output above 200 cycles, and maximum output below this, in order to sharpen audible beat zone without excessive signal at the higher frequencies to which ear and headsets are more sensitive.

c. Equipment initially had bothersome audio howl when near zero beat, when used with GF-3 model equipment (having 5000 ohm resistor in high voltage supply of junction box outlet); this was remedied by contractor's representative adding filter elements to LM.

d. Projecting crank handle is expected to be drawback in flight operation, easily causing accidental misadjustment, unbalance under vibration, and easily subjecting the precision drive to damage. Recommend its elimination. Eccentric finger holes may be substituted if believed desirable for rapid adjustment over wide range.

e. In certain positions of the corrector ring, the frequency dial was found to chafe against it while turning.

f. It was found necessary to vary length and proximity of r.f. coupling lead especially in measuring frequencies of widely different incoming signal intensities, and also in adjusting M.O. of transmitter only, as compared with transmitter completely resonated and emitting normally. A built-in r.f. attenuator is recommended. An improvised device of this nature was added externally between ANT coupling post and Ground, and was found to render operation more convenient, eliminating coupling lead changes.

g. The connecting cable projecting from the right side requires more space than available in most airplane mock-ups; urgently recommend providing cable with Anacostia 3-way right angle plug, adjustable so that cable may extend downward, to the rear, or upward. This will require turning outlet 90° counter-clockwise to bring latch forward.

h. Mounting and attachment method appears OK; additional provision for alternate horizontal mounting, with face up, would improve flight accessability in some cases. Many installations will require inclining present mounting aft as much as 30° in order to permit suitable operation and visibility.

i. Calibration memo chart on top of case will not be readable in most installations; recommend relocation on front panel, preferably of erasable enamel surface type similar to GF-3.

[redacted]

j. Chart not waterproof in present location on top.

k. Recommend name plate be attached on top of case; serial No. of each equipment, however, also to be shown conspicuously on front panel, as well as on calibration memo chart.

l. Eliminate engraving on panel " CORRECTION - -"; substitute "DIAL UNITS".

m. Engrave above window "DIAL HUNDREDS".

n. Hundreds dial on model is misaligned with respect to index mark, being between .15 and .25 divisions off.

o. Vernier engraving on corrector ring was found of no value in flight, both because of some parallax due to non-aligning surfaces, and due to difficulty in reading vernier during flight vibration. Recommend retention of vernier for non-flight use, however. Suggest filling only main index mark with white, adding small arrowhead; auxiliary vernier marks to be filled in omitting tenth mark altogether. Believe vernier should read in opposite direction, with main index at right, and marks spaced 9/10 rather than 11/10 unit divisions apart.

p. Hundreds dial reads in un-natural direction, with numerically increasing fingers towards bottom rather than towards top.

q. Suggest engraving heavy dots or lines marking switch positions for knobs on panel, in view of light clicker action and small arc of travel.

r. Suggest turning ON-OFF switch so as to be ON in the UP position, in keeping with standard aeronautical practices; the operator in many cases will be unable to read designations at this switch.

s. Instead of ANT, suggest marking RF binding post R.F. CPLG; this post does not connect to the airplane antenna.

t. Suggest suitable designation be marked on all internal components, and suitable marking of tube sockets. Mark crystals, incl ser. #.

u. When servicing with set on its back (out of case) full weight rests sidewise upon glass of two vacuum tubes; recommend protecting these tubes by leaving sides of metal frame square, rather than cutting off large portion.

v. Water shedding eaves strip recommended above main dial & corrector ring, extending above window. Also a water shedding butt strip across the front on top of the case, to prevent water from the top flowing inside.

w. Recommend waterproof slip covers be supplied with these equipments.

x. Consider supplying calibration books in duplicate; loss of one book or one page of same would seriously impair equipment.

y. Present calibration book mounting unsuitable, in that crackle paint scrapes against top of book, and book spiral binding wears groove in finish on case bottom. Felt on spring bottom is also undesirable from standpoint of impermanence under moisture. Recommend modifying spring mounting by eliminating felt, and by avoiding pressure of book or binding spring against crackle finish on case bottom.

z. Recommend showing all dial settings in book by four figures ahead of decimal point, to avoid confusion; thus instead of writing 459.6, show it as 0459.6, thus avoiding mistaken setting 4596.

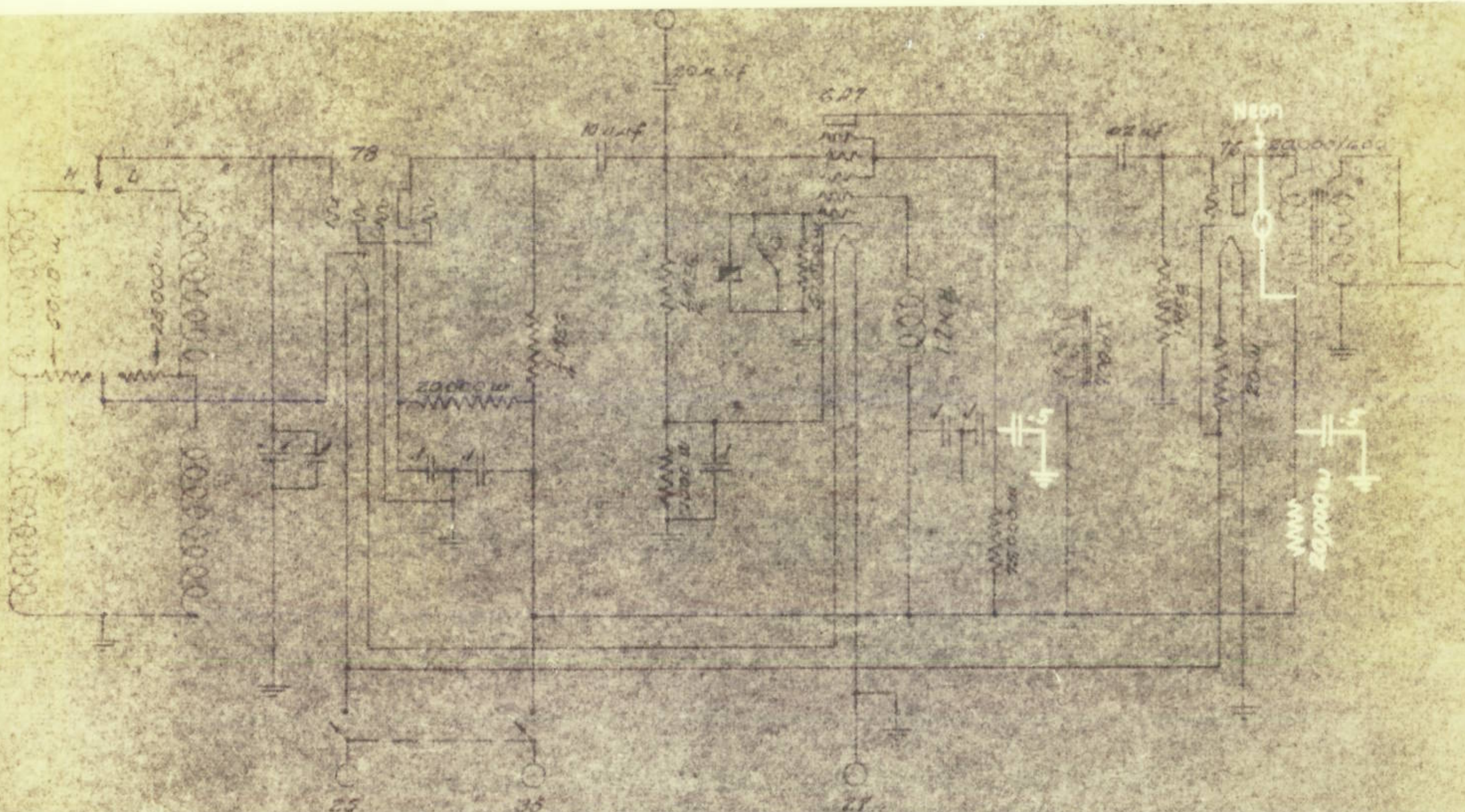
aa. A number of mistakes were found in printing of book; thus on p. 33, book reads 6958 instead of 6058 kcs.: on back cover, freq. range 540-560 kcs shown as 540-460.

bb. Book operating instructions should be simplified and revised; recommend eliminating last third of these instructions (par. VI).

cc. Recommend adding circuit diagram and parts list to calibration book, rendering separate instruction book unnecessary, if these books are supplied in duplicate. If not in duplicate, recommend separate instruction books in duplicate, and possibility of obtaining additional duplicate calibration books from contractor's original data, in case of loss or damage to calibration book.

dd. The LM equipment appears very promising for portable work also, such as for carrier deck use in setting VF squadrons on exact frequency, and for laboratory use. Recommend development and procurement of portable battery box and cable, not much larger than LM unit, to fasten under it with slide mounting, and with carrying strap extending around and above LM unit.

ee. This station concurs in the opinion that the mechanical method of dial correction is mechanically and from an accuracy standpoint inferior to the much simpler electrical correction method; recommend future specifications require the latter method.



Changes at N.A.S. Anacostia

[redacted]

NOTE: ALL DIMENSIONS PLUS OR MINUS ".005 UNLESS OTHERWISE SPECIFIED

RADIO RESEARCH Co., Inc.
WASHINGTON, D. C.

NAME	SCHEMATIC DIAGRAM CRYSTAL FREQUENCY IN
MATERIAL	
FINISH	
FIRST USED ON	NUMBER

[redacted]

TABLE 1.

CALIBRATION CHANGE WITH TEMPERATURE

Specifications 1-2, 2-15, 2-31.

200 to 400 kcs.	Serial #4 Total Dial Divs.	Serial #4 Dial Deviation	Serial #5 Total Dial Divs.	Serial #5 Dial Deviation	Max. permitted deviation from calibration
at calibration	4099.7	none	4122.9	none	
at +50°C	4124.8	+25.1	4148.1	+25.2	±7.9 div.
at +10°C	4111.8	+12.1	4139.1	+16.2	±18°C
at -25°C	4098.5	- 1.2	4126.2	+ 3.3	for 0.02%
2000 to 4000 kcs.					
at calibration	3875.2	none	3945.3	none	±5 div.
at +50°C	3890.5	+15.3	3964.3	+19.0	±20°C
at +10°C	3886.7	+11.5	3957.5	+12.2	for 0.01%
at -25°C	3880.4	+ 5.2	3954.8	+ 9.5	

TABLE 2.

POWER SUPPLY VARIATIONS
Specifications 1-4, 2-9, 3-22

E_p =		250 V.		225 V.		200 V.	
		without CO	with CO	without CO	with CO	without CO	with CO
E_F	I_F	I_p mills	I_p mills	I_p mills	I_p mills	I_p mills	I_p mills
10V	0.505A	18.5	19.5	15.25	15.8	12.0	12.5
11	.54	17.5	19.0	14.25	15.65	11.2	12.3
12	.575	16.5	17.5	13.25	15.0	10.5	11.6
13	.61	15.5	17.0	12.5	14.2	9.8	11.0
14	.64	14.5	16.5	11.75	13.5	9.5	10.5
15	.67	13.5	15.5	11.0	13.0	9.2	10.1
16	.7	13.0	15.0	10.75	12.5	9.2	9.8

Power Supply to Audio Output Tube E_F and E_G	I_F	I_p at 250 V. E_p	Indicator Plate Current Less Audio Output Tube without CO I_p	with CO I_p
10 V.	.25A	7 mills	11.5	12.5
11	.27	6	11.5	13.0
12	.29	5	11.5	12.5
13	.31	4	11.5	13.0
14	.32	3	11.5	13.5
15	.34	2	11.5	13.5
16	.355	1.5	11.5	13.5

[redacted]

TABLE 2a.

POWER SUPPLY VARIATIONS.
Specifications 1-4, 2-9, 3-22.

RU-3 Operation

E_F	E_p	CO on no beat I_p	CO on beat I_p
10 V.	170 V.	10 mills	12 mills
12	200	13	13.5
14	235	16	15.5
16	270	19	20.5

Volume Control Effect

E_F	E_p	I_p	Manual
16	265	17 mills	on
16	300	18.5	off

TABLE 3.

TEMPERATURE FREQUENCY CHECK
Specifications 2-7, 2-41, 3-6(a), 3-11, 3-13, 3-15, 3-16.

Crystal

	Indicator #4	Indicator #5
+20°C	--	+155 cycles
+10	+190 cycles	+163
- 0	+185	+175
-10	+187	+170
-20	+196	+172
-25	+200	+162
-29	+202	--
-20	+200	+160
-10	+195	+163
0	+190	+166
+10	+180	+172
+20	+178	+176
+30	+172	+182
+40	+158	+186
+48	+150	--
+50	--	+190

Temperature variation -		Cycles	Total	Per Degree
Indicator #4	78°C	-52	.0052%	.000066%
" #5	75°C	+35	.0035%	.000046%

[redacted]

TABLE 4.

SUMMARY TEMPERATURE FREQUENCY CHECK.
Specifications 2-7, 3-17, 3-26(5).

Heterodyne Oscillator

	KC	Temperature change	Cycles	Percent of Frequency	Allowed .005% per degree
Indicator #4	200	72°C	70	.035	.36%
	250	76	50	.02	.38
	300	75	265	.0884	.375
	300	77	235	.0783	.385
	400	79	775	.194	.395
	2000	75	735	.0267	.375
	3000	76	880	.0292	.38
	4000	75.2	4550	.114	.3775
Indicator #5	200	77	65	.0325	.385
	250	75	65	.026	.375
	300	75	160	.0534	.375
	400	78	435	.109	.39
	2000	73	415	.0207	.365
	3000	74	785	.026	.37
	4000	77	4700	.118	.385

Total drift for 80°C permits .4%, should not exceed .08% for good operation.

Temperature Frequency Drift for Average
1°C Change.

Heterodyne Oscillator

	Indicator #4		Indicator #5		
KC	Cycles	Percent	Cycles	Percent	Allowed
200	0.97	.00049	0.84	.00042	.005%
250	0.66	.00118	0.87	.00035	.005
300	3.05	.00102	2.13	.00072	.005
400	9.81	.00246	5.54	.00138	.005
2000	7.13	.00036	5.68	.00028	.005
3000	11.6	.00038	10.6	.00035	.005
4000	63.2	.0015	61.0	.00153	.005

Specified allowance should not exceed .001% per degree Centigrade.

[redacted]

TABLE 5.

REQUIRED ACCURACY OF FREQUENCY READINGS FROM
$-30^{o}C$ to $+50^{o}C$.

Specifications 2-15, 2-16, 2-31.

Maximum permitted error between any 2 crystal check points using mechanical connector.

Freq.	Cycles		Serial #4 Divisions		Serial #5 Divisions	
200 kcs.	80	-	1.6	-	1.61	-
250	100	100	2.0	2.0	2.01	2.01
333.3	133	133	2.7	2.7	2.72	2.72
400	-	160	-	3.2	-	3.22
Total	313	393	6.3	7.9	6.34	7.95
2000	400	-	0.77	-	0.784	-
2500	500	500	0.97	0.97	0.987	0.987
3000	600	600	1.16	1.16	1.18	1.18
3500	700	700	1.35	1.35	1.375	1.375
4000	-	800	-	1.54	-	1.57
Total	2200	2600	4.25	5.02	4.326	5.112

Frequency Range	Serial #4	Serial #5
200 to 400 kcs.	4099.7 div.	4122.9 divs.
2000 to 4000 kcs.	3875.2	3945.3

TABLE 5a.

ACCURACY OF FREQUENCY READINGS
Specifications 3-26.

Checked in Flight - May 22, 1936

Set by LM	Measured at NRL	- Cycles	Percent
4385 kcs.	4385.77 kcs.	770	.0175
6690	6692.19	2190	.0327
7535	7541.38	6380	.0846

Checked in Flight - May 25, 1936

Crystal checpoint	Set LM	Measured at NRL	Cycles	Percent
2000 kcs.	4385 kcs.	4385.91 kcs.	910	.0207
3500	6690	6691.96	1996	.0298
3500	7535.37	7535.37	370	.0049
4000	7535	7538.98	3980	.053

Maximum specified allowance = .01%

DECLASSIFIED

[redacted]

TABLE 6a.

CALIBRATION RESET BY CAPACITY CORRECTION.
Specifications 2-16, 2-31, 3-1, 3-4, 3-6b, 3-14, 3-17, 3-21, 3-25, 3-26.

HETERODYNE OSCILLATOR

Indicator Serial #4

Error and Reset to Calibration at +27°C.

KC	Dial Calibration	Dial at +27°C	Fixed Air Condenser Reset at +27°C
L.F. 400	4514.5	4545.0	4519.6
200	414.8	421.0	417.8
Total div.	4099.7	4124.0	4101.8
Error	0	+24.3	+2.1
Max.permitted error	±6.3	±6.3	±6.3
H.F. 4000	4363.9	4383.9	4361.5
2000	488.7	492.3	489.7
Total div.	3875.2	3891.6	3871.8
Calibration Error	0	+16.4	-3.4
Max.permitted error	±4.4	±4.4	±4.4

After Calibration Reset at +27°C

			Decreasing		Increasing	
	KC	Calibration	Dial Div.	Error	Error	Dial Div.
L.F. 1 div. = 49 cy.	200	414.8	414.0 reset	-.8	0	set
Permitted error is 80 cy. at 200 KC.	250	1435.1	1433.2 reset	-1.9	+.8	1435.9 reset
160 cy. at 400 KC.	333.3	3073.3	3071.2	-2.1	+1.5	3074.8 reset
	400	4514.5	set	0	+2.2	4516.7
H.F. 1 div. = 516 cy.	2000	488.7	488.6 reset	-.1	0	set
Permitted error is 400 cy. at 2000 KC.	2500	1487.6	1488.4 reset	+.8	0	1487.6
800 cy. at 4000 KC.	3000	2433.2	2433.6 reset	+.4	-1.1	2432.5 reset
	3500	3343.2	3373.7	+.5	-.4	3342.8 reset
	4000	4363.9	set	0	-.3	4363.6

3-21 Average cycles per division at 14000 kc.
2000
allowed 3000
Reset Accuracy
Specified allowance 1% of vernier or 500 cycles
at 4000 kc. measured 50 cycles increasing dial
measured 15 cycles decreasing dial

DECLASSIFIED

[redacted]

TABLE 7.

RADIO FREQUENCY OUTPUT
Specifications 3-2, 3-3, 3-19.

100 Microvolts required.

	L.F. Freq.		Microvolts
Fundamental	200 Kc.	=	500,000+
"	250	=	500,000+
"	333.3	=	500,000+
"	400	=	500,000+
2nd Harmonic	400	=	480,000
" "	500	=	500,000+
" "	666.6	=	205,000
" "	800	=	210,000
3rd Harmonic	750	=	165,000
" "	1000	=	310,000
" "	1200	=	350,000
4th Harmonic	1000	=	225,000
" "	1333.2	=	230,000
" "	1600	=	120,000
5th Harmonic	1666.5	=	100,000
" "	2000	=	110,000

	H.F. Freq.		Microvolts
Fundamental	2000 Kc.	=	310,000
"	2500	=	260,000
"	3000	=	250,000
"	3500	=	110,000
"	4000	=	105,000
2nd Harmonic	4000	=	105,000
" "	5000	=	60,000
" "	6000	=	58,000
" "	7000	=	50,000
" "	8000	=	75,000
4th Harmonic	8000	=	35,000
3rd Harmonic	7500	=	49,000
" "	9000	=	68,000
" "	10500	=	36,000
" "	12000	=	44,000
4th Harmonic	12000	=	33,000
" "	14000	=	33,000

[redacted]

TABLE 8.

DETECTOR LINEARITY
Specifications 3-6(c).

R.F. Input to Audio Output

Milliwatts	Microvolts Required Fundamental	 5th Harmonic	 Fundamental
...	200 Kc.	2000 Kc.	3000 Kc.
.06	2500	2500	2700
.1	3000	3500	3650
.2	4200	5500	5000
.3	5500	7000	6200
.4	6800	8500	7200
.5	7800	10000	8200
1.0	11000	13000	11600
2.0	15800	20000	17200
3.0	19200	24000	21200
4.0	23000	29000	25000
5.0	26000	32500	28000
10	35000	44500	37800
20	48000	60000	52000
30	58000	78000	68000
40	68000	95000	78000
50	75000	105000	88000

DECLASSIFIED

[redacted]

TABLE 9.

AUDIO POWER OUTPUT AT
CRYSTAL CHECK POINTS
Specifications 3-6(d), 3-18.

Low Range Oscillator
195 to 400 Kc.

Freq.	Output
200 Kc.	195 M.W.
250	230
333.3	250
400	225

High Range Oscillator
2000 to 4000 Kc.

2000 Kc.	430 M.W.
2500	260
3000	280
3500	195
4000	260

$E_f = 14$ $I_f = .645$ amps.

$E_p = 245$ $I_p = .00165$ amps.

TABLE 10.

"High Range Check" Standard Signal Generator
and Indicator Beating Against Each Other
Specification 3-18.

	200 cycles 3 M.W.	1000 cycles 30 M.W.	3000 cycles 15 M.W.
200 Kc.	40 M.W.	140 M.W.	150 M.W.
7000	60	150	150
13500	85	120	90
20000	70	85	55

500 Millivolts R.F. is allowed to produce standard output. 130 Millivolts is required at 20000 Kc.

[redacted]

TABLE 11.

TEMPERATURE FREQUENCY DRIFT
Specification 3-17, 3-26.

Heterodyne Oscillator
at 200 Kc.

Temperature	Indicator #4	Indicator #5
+20°C	157 cy.	117 cy.
+10	148	95
0	135	88
-10	141	89
-20	162	97
-25	164	106
-20	163	101
-10	164	94
0	170	91
+10	180	87
+20	191	94
+30	190	106
+40	195	130
+50	205	152
Spec. 3-26 Total	70 cy. or .035%	65 cy. or .0325%
Spec. 3-17 per 1°C	$\frac{70}{72}$ cy. or .0005%	$\frac{65}{77}$ cy. or .0004%

TABLE 11a.

TEMPERATURE FREQUENCY DRIFT
Specification 3-17, 3-26.

Heterodyne Oscillator
250 kc.

Temperature	Indicator #4	Indicator #5
+20°C	225 cy.	258 cy.
+10	187	259
0	175	262
-10	175	265
-20	180	270
-25	181	272
-20	179	272
-10	177	265
0	175	255
+10	182	237
+20	190	242
+30	191	266
+40	191	302
+50	192	
Spec. 3-26 Total	50 cy. or .02%	65 cy. or .026%
Spec. 3-17 per 1°C.	$\frac{50}{76}$ cy. or .00026%	$\frac{65}{75}$ cy. or .00035%

CONFIDENTIAL

TABLE 11b.

TEMPERATURE FREQUENCY DRIFT.
Specifications 3-17, 3-26.

Heterodyne Oscillator
at 300 Kc.

	Temperature	Indicator #4	Indicator #5
	+20°C	740 cy.	560 cy.
	+10	610	535
	0	600	565
	-10	635	565
	-20	710	645
	-25	735	630
	-20	725	630
	-10	715	625
	0	695	595
	+10	645	540
	+20	610	495
	+30	585	475
	+40	545	470
	+50	475	535
Spec. 3-26	Total	265 cy. or .0884%	175 cy. or .058%
Spec. 3-17	per 1°C	3.53 cy. or .00118%	2.33 cy. or .00078%

TABLE 11c.

TEMPERATURE FREQUENCY DRIFT.
Specifications 3-17, 3-26.

Heterodyne Oscillator
at 400 Kc.

	Temperature	Indicator #4	Indicator #5
	+20°C		+225 cy.
	+10	+500 cy.	+90
	0	+410	+135
	-10	+550	+270
	-20	+775	+455
	-25	+925	+600
	-20	+915	+585
	-10	+845	+520
	0	+645	+380
	+10	+485	+200
	+20	+300	+110
	+30	+180	-50
	+40	0	-110
	+50	-150	-165
Spec. 3-26	Total	1075 cy. or .27%	765 cy. or .191%
Spec. 3-17	per 1°C	14.3 cy. or .0036%	10.2 cy. or .0025%

DECLASSIFIED

CONFIDENTIAL

TABLE 11d.

TEMPERATURE FREQUENCY DRIFT
Specification 3-17, 3-26

Heterodyne Oscillator
at 2000 Kc.

Temperature	Indicator #4	Indicator #5
+20°C	+570 cy.	+680 cy.
+10	+480	+585
+5	+435	+570
0	+450	+590
-10	+565	+650
-20	+610	+695
-25	+595	+700
-20	+590	+690
-10	+615	+660
0	+760	+685
+10	+850	+675
+20	+905	+670
+30	+970	+730
+40	+920	+825
+50	+885	+985
Specs. 3-26 Total	535 cy. or .0267%	415 cy. or .0207%
Specs. 3-17 per 1°C	7.14 cy. or .000357%	5.53 cy. or .00028%

TABLE 11e.

TEMPERATURE FREQUENCY DRIFT
Specification 3-17, 3-26.

Heterodyne Oscillator
at 3000 kc.

Temperature	Indicator #4	Indicator #5
+25°C		+565 cy.
+20°C	+200 cy.	+640
+10	+800	+880
0	+860	+1200
-10	+720	+1300
-15	+700	+1350
-20	+680	+1340
-25	+720	+1325
-20	+730	+1310
-10	+725	+1275
0	+670	+1150
+10	+700	+1150
+20	+710	+950
+30	+770	+790
+40	+920	+725
+50	+1080	+810
Specs. 3-26 Total	880 cy. or .0292%	785 cy. or .026%
Specs. 3-17 per 1°C	11.6 cy. or .00038%	10.5 cy. or .00035%

[redacted]

TABLE 11f.

TEMPERATURE FREQUENCY DRIFT
Specifications 3-17, 3-26

Heterodyne Oscillator
at 4000 Kc.

Temperature	Indicator #4	Indicator #5
+20	800 cy.	1700 cy.
+10	200	1300
0	700	2150
-10	1550	2975
-20	2450	3825
-25	2700	4025
-20	2675	4050
-10	2575	3900
0	2300	3400
+10	1650	2600
+20	875	1650
+30	0	700
+40	-975	-75
+50	-1850	-650
Specs. 3-26 Total	4550 cy. or .114%	4700 cy. or .118%
Specs. 3-17 per 1°C	63.2 cy. or .0015%	61 cy. or .0015%

TABLE 12.

MEASURED RF INPUT REQUIRED TO PRODUCE SPECIFIED AUDIO OUTPUT
Specifications 3-18.

Indicator #4

At 5th Harmonic of 4000 Kc.
or 20,000 Kc.
Beat freq. = 1000 cycles
Audio output = 30 M.W.
R.F. Input = 130,000 microvolts

At 50th Harmonic of 400 Kc.
of 20,000 Kc.
Beat freq. = 1,000 cycles
Audio output = 5 M.W.
R.F. input = 500,000 microvolts

At 4th Harmonic
13,575 Kc.
1000 cycles
30 M.W.
50,000 microvolts

At 5th Harmonic
2,000 Kc.
1,000 cycles
30 M.W.
78,000 microvolts

[redacted]

TABLE 13.

FREQUENCY VARIATION DUE TO VOLTAGE CHANGES.
SPECIFICATIONS 3-22, 3-26(1).

At 5th Harmonic of 400 Kc. or 2000 Kcs.

E_f	E_p	Beat	Percentage
10	170	-1200 cy.	.0625%
12	200	-800	.04
14	235	-450	.0225
16	272	0	

FREQUENCY SHIFT DUE TO VOLUME CONTROL CHANGES.

2000 Kc.	Volume off	Shift manual to automatic	750 cy.	.0375%
2000 Kc.	" on	" " " "	250 cy.	.0125%
2000 Kc.	AVC operation	Grounding receiver ant. post	500 cy.	.025%
2000 Kc.	Manual "	Shift volume on to off	500 cy.	.025%

TABLE 14.

DIMENSIONS
Specifications 3-27.

Indicators #4 and #5

	Measured	Specified
Height	8-7/16"	10-7/8"
Depth	8-3/4" handle included	8-5/8"
Width	8"	8-3/4"

TABLE 15.

WEIGHT
Specifications 3-28.

	Measured	Specified
Indicator #4	10 lb. 10.5 oz.	11 lb.
Indicator #5	10 lb. 10.5 oz.	11 lb.
Cable #4	1 lb. 6 oz.	1 lb. 11 oz.
Cable #5	1 lb. 6 oz.	1 lb. 11 oz.
Total	12 lb. .5 oz.	12 lb. 11 oz.

Under weight - 10.5 oz.

[redacted]

1741

Naval Research Laboratory
Anacostia Station
Washington, D.C.

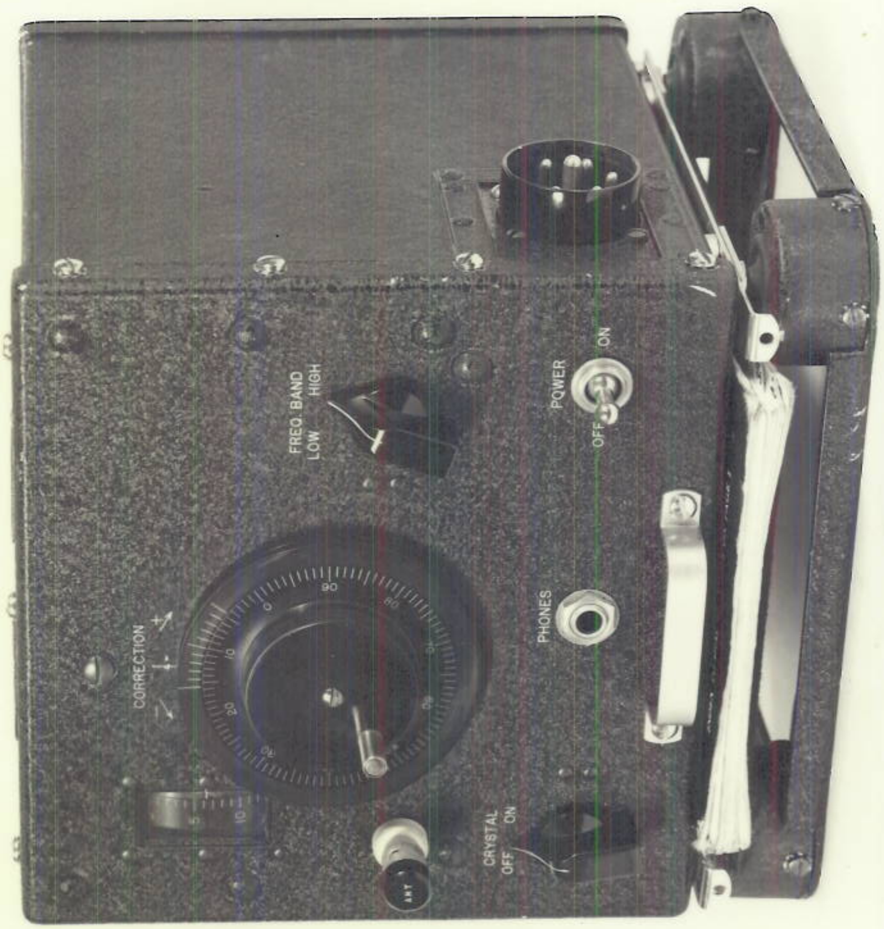


Plate 1

[redacted]

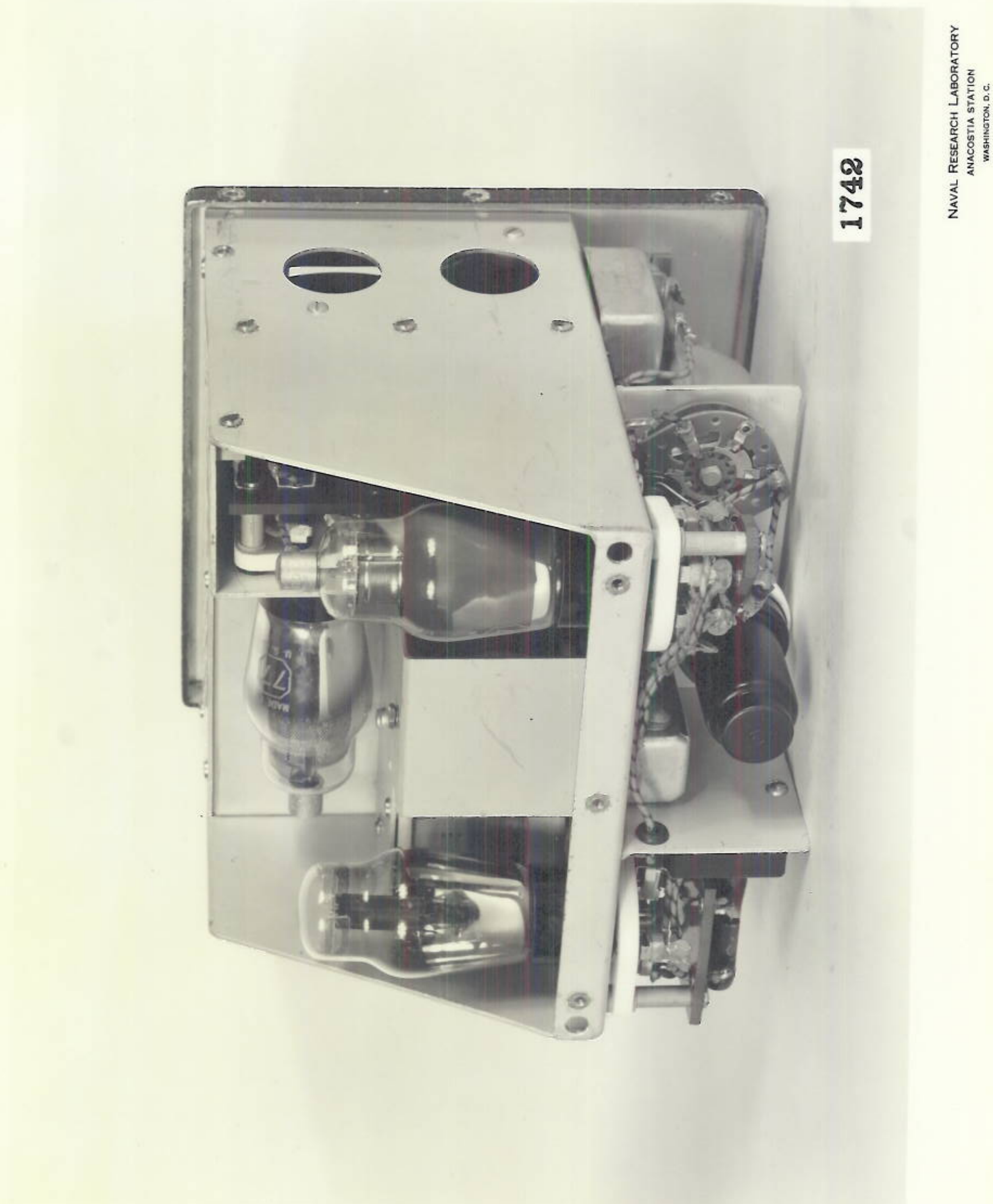
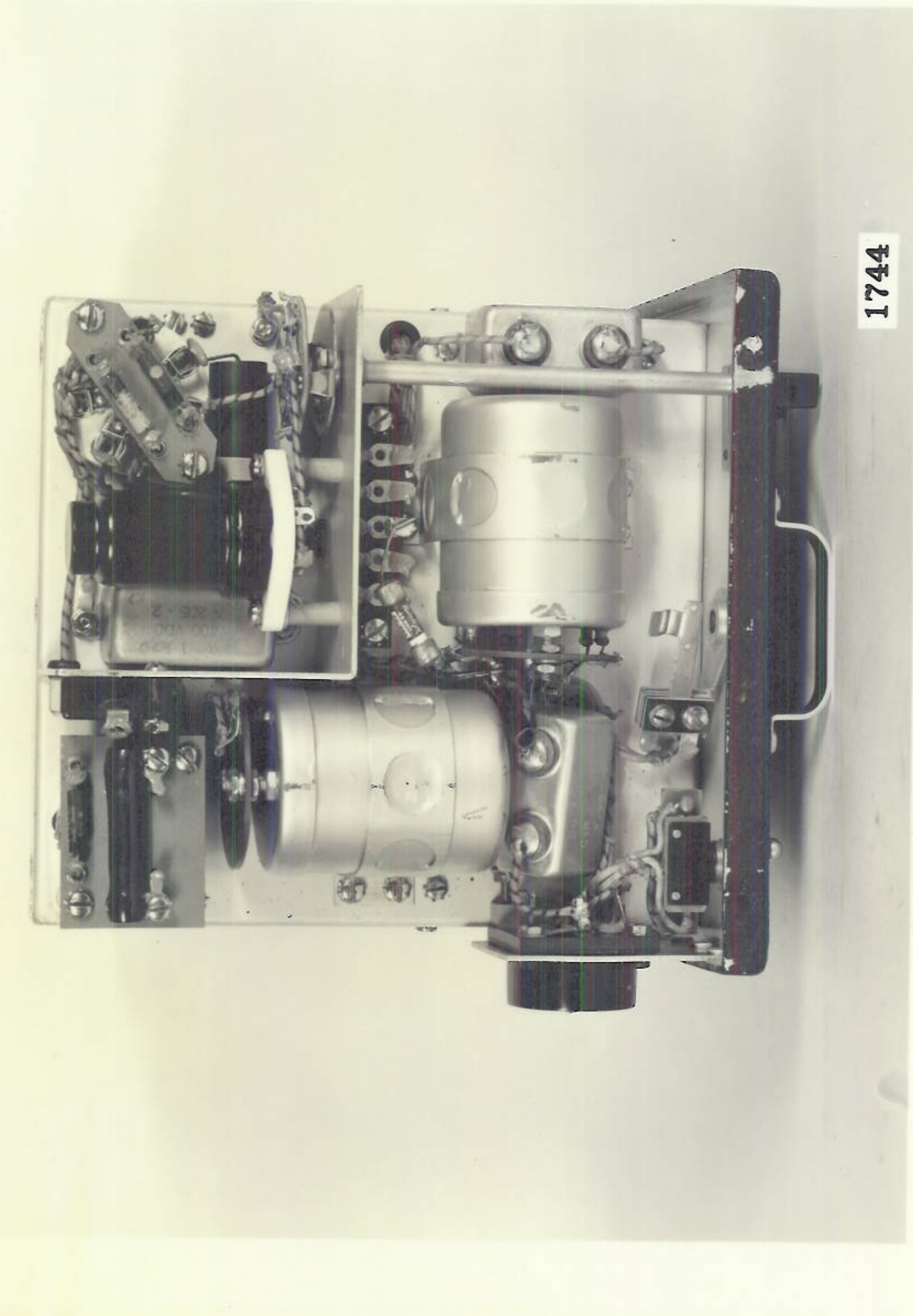


Plate 2

CONFIDENTIAL



NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

DECLASSIFIED

Plate 3

DETECTOR LINEARITY
FUNDAMENTAL 200 KC

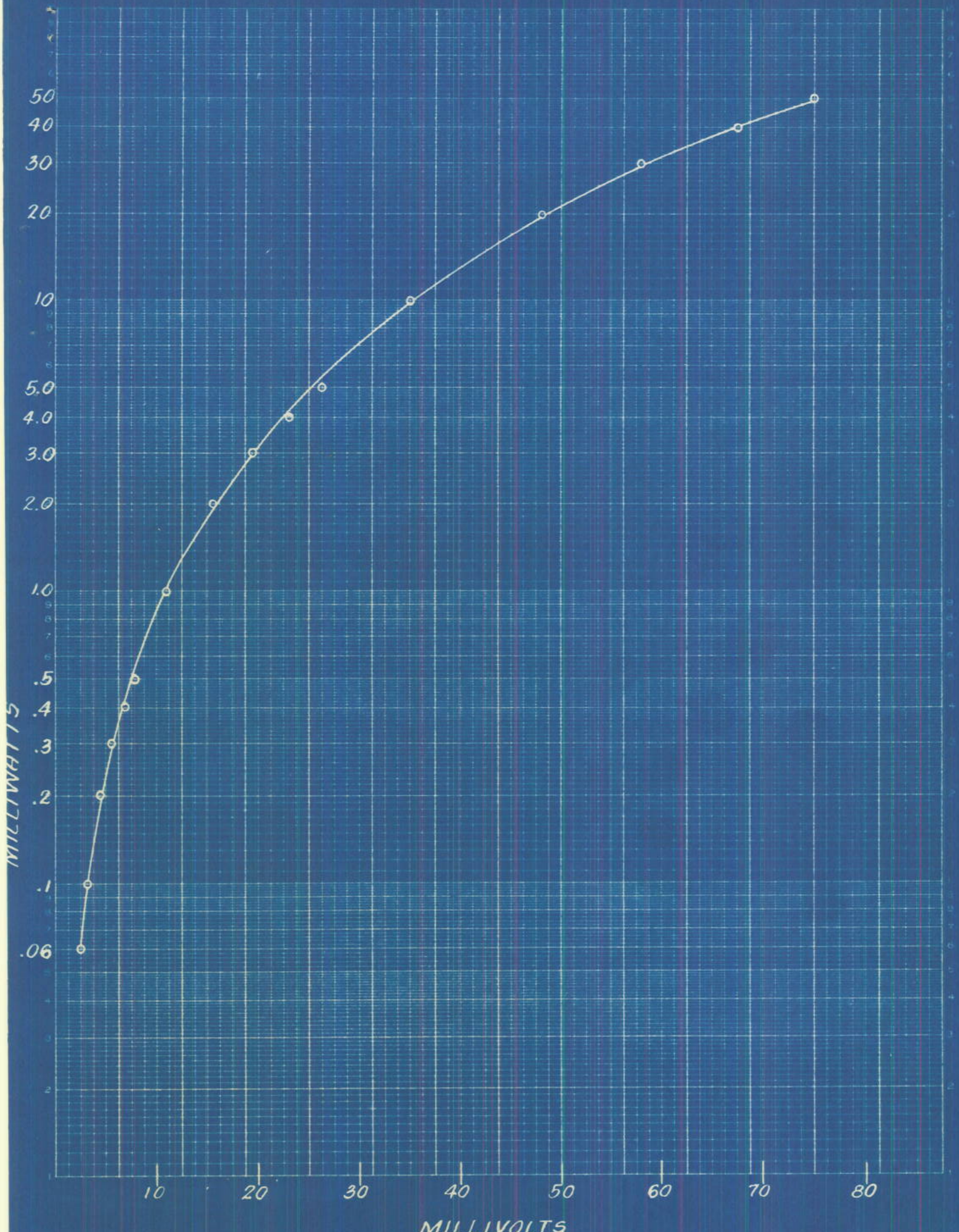


PLATE 5

DETECTOR LINEARITY

5TH HARMONIC 2000 KC.

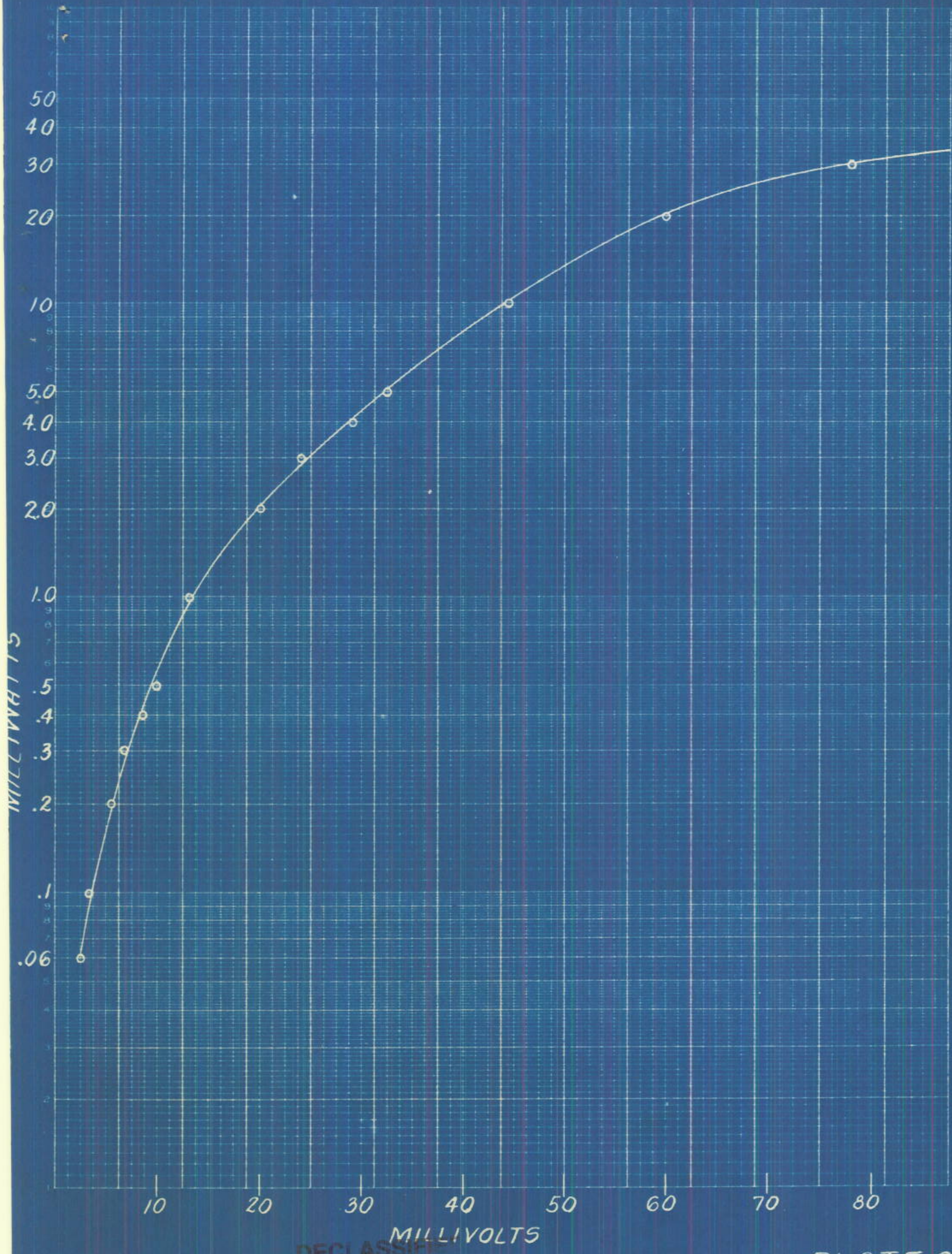


PLATE 6

DETECTOR LINEARITY
FUNDAMENTAL 3000 KC.

[redacted]

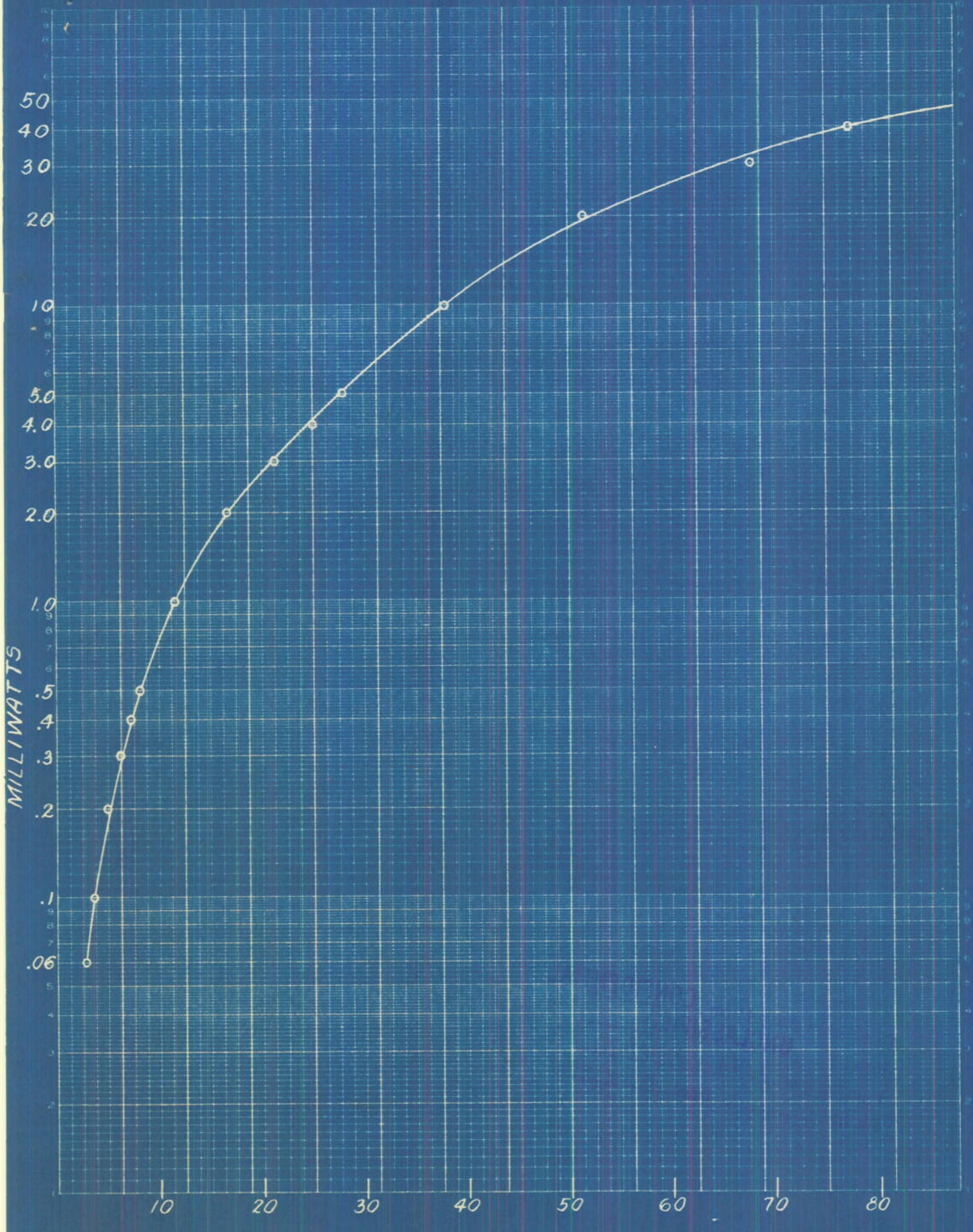


PLATE 7