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SUBJECT

Test of Model LM-2 Crystal Frequency Indicator

(Bendix Radio Corporation)



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NRL Report No. R-1427

NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report on
Test of Model LM-2 Crystal Frequency
Indicator
(Bendix Radio Corporation)

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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AUTHORIZATION

1. Test of the Model LM-2 Crystal Frequency Indicator was authorized by reference (a). Other pertinent references are listed as (b) to (j) inclusive.

- Reference:
- (a) Bueng.ltr. C-NOs-52637 (2-12-W8) of 19 Feb. 1937.
 - (b) Bueng.ltr. C-NOs-52637(2-12-W8) of 29 July 1937.
 - (c) Bueng. Specifications RE 13A 489D, dated 1 Oct. 1936.
 - (d) Bueng.ltr. F42-1(11-8-W3) of 17 Nov. 1934 to NRL, copy to NAS.
 - (e) NRL Conference of 24 June 1937.
 - (f) Bueng. Conference of 16 July 1937.
 - (g) Bueng. Conference of 11 Aug. 1937.
 - (h) Bueng. Conference of 3 Nov. 1937.
 - (i) NRL ltr. C-F42-1/74 of 7 Dec. 1937.
 - (j) NAS Report ltr. F42-1/74/NA6(342) of 9 Feb. 1938.

OBJECT OF TEST

2. These tests were conducted to determine the suitability of the subject equipment for use in naval service. Reference (d) was used as the governing specifications and additional tests were made for the purpose of revising specifications for future equipment.

ABSTRACT OF TEST

3. Tests made to determine the compliance of Model LM-2 Crystal Frequency Indicator with the governing specifications of reference (d) cover the following specific points.

- (a) Check mechanical features; general workmanship; materials used, corrosion resisting measures and adequacy of electrical circuits.
- (b) Power Consumption; radio frequency output; audio frequency output; detector linearity.
- (c) Variation of crystal frequency due to temperature and humidity.
- (d) Variation of self-oscillator frequency due to change of voltage, temperature and humidity.
- (e) Corrector range of new and revised model: determination of proper type of corrector.
- (f) Accuracy of emitted frequency throughout temperature range.
- (g) Effect of prolonged humidity upon the calibration.
- (h) Investigation of the performance of the voltage regulator.
- (i) Check of weights and dimensions of the equipment.
- (j) Suitability for flight operation was covered by Naval Air Station.

Conclusions

(a) The workmanship and material used in building the preliminary model LM-2 Crystal Frequency Indicator shows that the contractor has put forth an honest effort to produce good equipment. Arrangement of parts and wiring has been done neatly; mounting of component parts has been done rigidly and very few failures of a mechanical nature should develop in later service.

(b) Two particularly excellent features of the equipment are the drive mechanism of the heterodyne oscillator tuning condenser which showed practically no backlash at any time during the tests and the frequency stability of the crystal oscillator over wide ranges of temperature, humidity and voltage variations.

(c) The flexibility and accuracy of the instrument is of a high order, considering the space and weight limitations imposed upon it. Harmonic outputs are ample and under suitable conditions in the laboratory the useful range of the instrument can be extended far beyond the calibrated maximum of 20,000 kc.

(d) The additional calibration corrector on each range provides a workable solution for compensating the long time frequency shift due to humidity but a more satisfactory solution of the problem would be to design a circuit sufficiently free from the effects of humidity so that the additional correctors would be unnecessary.

(e) The incorporation of the voltage regulator will improve the operation of the instrument in case a violent change of voltage takes place between time of correcting calibration and making measurement. However, it is doubtful if this feature warrants the complications caused by the incorporation of the voltage regulator.

(f) The use of an automatic compensating condenser which corrects for the effects of temperature is only partially satisfactory in the present design. Undoubtedly the major change in frequency caused by temperature takes place in the inductors and the best reset accuracies are not attainable by correcting inductance shifts with compensating condensers. Furthermore, each range has its own inductance and one compensating condenser is expected to neutralize the frequency shifts occurring in either range. A fundamental improvement would result if inductances could be built with low temperature coefficients and the automatic compensating condenser eliminated entirely.

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Recommendations

(a) Model LM-2, Serial No. 3 Crystal Frequency Indicator should be considered satisfactory for naval service after the following recommendations and also the recommendations of the Naval Air Station have been complied with in a manner meeting the approval of the Bureau of Engineering.

(b) Instructions covering operation of modulation switch in calibration book should be printed in red and should state that crystal does not oscillate with modulation switch in "on" position.

(c) Provided the voltage regulator is incorporated in the model LM-2, the instruction book should indicate that the LM and LM-2 models are no longer interchangeable.

(d) Plating on audio transformer housing should be improved to prevent corrosion.

(e) Mounting of crystal inside of evacuated holder should be improved so that frequency does not jump when instrument is orientated 180°.

(f) The following changes in specifications should be made for future equipments:

- 1-2. Include voltage range and humidity range over which instrument must work.
- 2-5. Eliminate cadmium.
- 2-42. Eliminate method of making transformer housing non-corrosive.
- 3-4. Include humidity as well as temperature.
- 3-6(d) Audio output requirements should be raised to at least 60 milliwatts output with 500 millivolts input.
- 3-6(e) Radio frequency attenuator should reduce output to 100 microvolts.
- 3-14. Permit temperature coefficients of 0.003% per °C.
- 3-16. Audio output requirements should be increased. See Table 3.
- 3-17. Raise 100 microvolt requirement for radio frequency output to 5000.
- 3-18. Eliminate method of treating radio frequency coils for minimizing humidity effects.
- 3-20. Change voltage and current ranges. See Table 1.
- 3-23. Eliminate "with suitable key to their intensity".
- 3-25. Eliminate requirement for calibrating heterodyne at any specified temperature.
- 3-26. Change "output" to "calibration".
- 3-27. Clarify to indicate whether voltage changes are permitted after resetting heterodyne to calibration. Recommend that no variable be permitted between correcting calibration and making measurement.
- 3-29. Change weight requirements per Table 19.

MATERIAL UNDER TEST

4. The Model LM-2 Crystal Frequency Indicator manufactured by Bendix Radio Corporation consists essentially of a crystal oscillator used for frequency check points, a dual range calibrated self-oscillator used for interpolation purposes, and suitable detector and audio amplifier circuits.

5. The crystal oscillator possesses the distinctive feature of having a very low temperature coefficient 1000 kc crystal mounted in an evacuated holder which protects it from dust and moisture. The self-oscillator has two frequency ranges, the lower of which extends from 195 to 400 kilocycles and the upper from 2000 to 4000 kilocycles. These two fundamental ranges together with their second, fourth, and fifth harmonic provide continuous coverage over the range from 195 to 20,000 kc. A calibration book is provided which gives points every hundred cycles in the lower fundamental range and every kilocycle in the upper fundamental range and a manual corrector on the front panel of the calibrator restores the calibration to its true value before beginning a measurement.

6. A Navy Type 38077 vacuum tube is used as the self-oscillator in an electron coupled circuit. A type 6A 7 vacuum tube is used as both crystal oscillator and detector and a type 38076 vacuum tube is used in the audio amplifier.

7. The equipment as delivered to Bellevue was complete with calibration books, slip covers, shock proof mountings, five conductor shielded power cables and instruction book, but lacked spare parts.

8. Model LM-2, Serial Nos. 1 and 2 arrived at Bellevue on May 6, 1937. One of the above equipments was delivered to the Naval Air Station, Anacostia, on May 26, 1937. Serial No. 3 was received from the manufacturer on September 22, 1937, and was subsequently turned over to the Naval Air Station for flight tests on October 5, 1937.

METHOD OF TEST

9. For very precise measurements of frequency such as required to determine the shift of the crystal frequency due to change of temperature, a companion crystal oscillator was built which gave an audio beat note with the crystal to be measured. The audio note was then measured by means of a beat frequency oscillator, a cathode ray oscillograph and a 1000 cycle standard frequency derived from the Naval Research Laboratory primary frequency standard. Measurements are accurate within one cycle.

10. For variation of self-oscillator frequencies a beat between the self-oscillator and a crystal was fed to the visual indicating portion of the LK-1 drift indicator. Accuracy of measurement under worst conditions is about 25 cycles.

11. Corrector range determined by finding number of main dial divisions equivalent to corrector. Accuracy of measurement is about 2%.

12. Accuracy of emitted frequency was determined by selecting higher order harmonics than those regularly used for crystal check points, whose beat notes come at such a point in the calibration that they represented the maximum interpolation required in service. The settings for these secondary check points were noted and after correcting the calibration to a nearly crystal check point which appears in the calibration book in red the self-oscillator would be adjusted to its calibrated setting for the secondary check point and the resultant audio note divided by the order of self-oscillator harmonics producing it gave the error of the measuring equipment. An example will be carried through for the purpose of clarifying the above. On Serial No. 1 the crystal check point for 2250 kc comes at a setting of 1045.9. Use the manual corrector so that this setting is accurate. Then turn the dial to a setting of 1300.3 at which point, according to the calibration, we should have a frequency of 2375 kc. If the instrument is accurate we will be exactly on the zero beat setting resulting from the eighth harmonic of the self-oscillator ($2375 \times 8 = 19,000$) and the nineteenth harmonic of the crystal ($19 \times 1000 = 19,000$). If an audio note is present at the setting of 2375 kc the error of the instrument is given by the frequency of the audio note divided by eight which is the order of the self-oscillator harmonic producing the audio note at that point. The accuracy of this method of measurement is excellent, probably within five cycles at all times if the crystal is considered to be 1000 kc at all times. Measurements show that no serious error is introduced by the crystal but the settings made for reset accuracy tests are made under very inconvenient conditions and although extreme care is exercised it is possible that some settings may be in error by a few tenths of one division. Consequently, stray points are found which are beyond specification tolerance.

13. The effect of prolonged humidity upon the circuits of the LM-2 was determined in the following manner. The subject equipment was placed inside of the refrigerator and normal voltage was supplied to operate it. The manual corrector was turned anti-clockwise as far as possible and never moved throughout the entire test. With the corrector in this position the settings of six major crystal check points (top, bottom, and middle of each band) were recorded. An ordinary cooking hot plate of 1 kw rating was also placed inside the refrigerator and a beaker of water on the hot plate. The thermostat in the heater circuit of the refrigerator was set at $+50^{\circ}\text{C}$. and power was applied. The beaker of water soon reached the boiling point and saturated the air in the refrigerator. The temperature also stabilized at $+50^{\circ}\text{C}$. and this condition of $+50^{\circ}\text{C}$., 100% relative humidity was maintained continuously for 72 hours. Measurements were made twice a day simply by noting the settings where the major crystal check points were heard. After 72 hours, conditions were restored to normal, the equipment was dried out and the final calibration checked against the original settings to observe the permanent shift which had taken place. Power was applied for a short time when a measurement was being made.

14. Effectiveness of the voltage regulator was tested in two ways. First the frequency shift due to change of plate voltage was measured with and then without the voltage regulator. Then the shift in the settings of the major crystal check points due to change of plate voltage, with and without the voltage regulator, but in all instances in this test the lowest crystal check point on each range was corrected to calibration with the manual corrector and the departure from calibration of the other points due to plate voltage change was observed.

15. Audio outputs were measured with a General Radio Output Meter.

16. Radio frequency outputs were measured with a standard signal generator and a receiver by the substitution method.

17. Approximate percentage of modulation of the carrier was determined by substituting radio frequency carrier from a standard signal generator of the same voltage as the indicator output and then modulating the signal generator output to correspond to the modulation of the indicator. The signal generator can be modulated only in steps of 10% so the method is approximate.

18. Detector linearity was checked by plotting standard signal generator voltage input to indicator against audio power output of indicator.

19. The effect of humidity maintained only for a period of several hours was obtained in the large N.R.L. temperature control room at the same time that a similar test was being conducted on another piece of equipment. The method is to take the relative humidity down to a low value at the temperature at which the test is being made and permit the frequency to stabilize. Humidity is increased to about 95% while the temperature is held constant and the frequency shift is observed. Humidity is then reduced to a low value and the frequency shift again recorded.

20. Backlash was checked by approaching from clockwise and then anti-clockwise direction to a definite setting and observing the frequency difference on a visual indicator.

21. The following instruments were used for tests on the Model LM-2 crystal frequency indicator.

- (a) Model LK-1 frequency drift indicator. Accuracy of frequency difference; ± 2 cycles, 500 cycle scale; ± 4 cycles, 1000 cycle scale; ± 20 cycles, 5000 cycle scale.
- (b) General Radio crystal calibrator, Type CAF-74016, Model LD-2X, Serial No. 1. Accurate to 0.005%.
- (c) General Radio's beat frequency oscillator, type 713-A, Serial No. 209.
- (d) General Radio Output Meter, type 538-A, Serial 209.
- (e) N.R.L. Refrigerator.

- (f) N.R.L. Temperature Control Room
- (g) Model RU-4 Serial 427, aircraft Radio Corporation receiver.
- (h) National NC-100 receiver.
- (i) Crystal oscillator of Model LM-1, Serial No. 5 crystal Frequency Indicator, built by Bendix Radio Corp.
- (j) R.C.A . oscillograph, type TMV-122-B, Serial No. 4222.
- (k) General Radio Standard Signal Generator, Model LC-A, Serial No. 2. Accuracy 10%.

DATA RECORDED DURING TEST

22. Data was recorded on all tests and pertinent information is recorded in Tables 1 to 21 inclusive and Plato 1. Comments of Naval Air Station are given in appendix B.

DISCUSSION OF PROBABLE ERRORS

23. The accuracy of instruments is given in paragraph 21 but an error of greater importance than those introduced by the instrument is as follows. In the temperature coefficient data it is very difficult to separate frequency shifts due to temperature change from frequency shifts due to humidity unless equipment is available for controlling the humidity. From knowledge gained since the first temperature tests were made it is now known that the shift due to humidity would be minimized by starting a temperature run at the high temperature and going down but the capacity of the refrigerating equipment is too small to make such a test feasible. An error of this type would be most troublesome at a high L/C ratio circuit where the frequency shift was downward as the temperature increased. The top of the low range 400 kc fulfills these conditions and consequently too great a frequency drift is encountered at this point unless extreme care is exercised in the test. This is felt to be true in the case of Table 10 at 400 kc. At 4000 kc the error would be less due to the lower L/C ratio but in this case the temperature coefficient is reversed and consequently the data given is slightly better than the instrument actually rates.

RESULTS OF TEST

24. Paragraphs of the specifications which require no comment will be omitted.

- 2-2(4) Nameplates were not furnished with any of the preliminary models.
- 2-5 The 72 hour high humidity test indicated the presence of serious corrosion on the cadmium plated audio transformer housing. Fleet reports also indicate trouble due to cadmium plating of a nature which is not readily discovered in tests extending over a short time.

- 2-6 The switch used to turn the crystal on and off is made of magnetic material as is also the crystal holder. The crystal holder cover is the same as the envelope of a metal tube.
- 2-7 Tests show the operation of the equipment generally satisfactory throughout the temperature range but considerable difficulty was encountered due to high humidity. Humidity caused serious frequency shifts which did not seem to be a direct violation of the specifications inasmuch as the accuracy of the instrument remained practically unimpaired as long as the range of the calibration corrector was adequate to compensate for observed frequency variations. The first tests gave data as indicated in Table 11 but over a short period of time the shift due to change of humidity did not seem to exceed the range of the corrector but persistent reports coming in from the Fleet regarding the Model LM, complained about the failure of the corrector to restore the calibration to its true value. The phenomena of calibration drift was termed "aging" and various theories were advanced to explain the trouble. A remarkable similarity in the behavior of all units in the service was observed, the calibration always shifting in the same direction and always being more troublesome in the low frequency range. At this point the 72 hour, 100% humidity, 50° C. test was made and the phenomena taking place in service over a period of months was duplicated in the laboratory in a period of hours and it was definitely shown that the corrector range of serial Nos. 1 and 2 Model LM-2 was inadequate. Serial No. 3 was submitted with auxiliary screwdriver type correctors for each range, in addition to a manual corrector of better characteristic and this combination is adequate for the humidity conditions encountered. Corrector range is given in Table 12. The actual electrical phenomena involved in the action of humidity is the same as shunting the oscillating circuit with a resistance. Theoretical considerations fit the observed facts perfectly and the so-called "aging" phenomena which caused practically every Model LM instrument to drift out of calibration in the same direction during the summer months will reverse itself during the winter months and drift in the opposite direction. In Tables 16 and 17 are given the values for the so-called permanent shift due to the 72-hours of high humidity. This term, permanent shift, is merely relative and can be made of any desired value by drying the instrument sufficiently after the test. Model LM-2, Serial 1, has been subjected to two 72 hour humidity tests and been at the Laboratory all summer without any adjustment. During those tests it has drifted beyond the range of the manual corrector but on November 10 it possessed a calibration very close to the values submitted in the manufacturer's calibration book which records the settings taken sometime in May. As a matter of fact, the low range calibration has shifted slightly in the direction which would indicate that the effect of humidity upon the instrument is less now than it was at the time of calibration in May. Another instance of the calibration restoring itself in the winter months is the case of the Model LM-1, Serial No. 5, which has been at the Naval Research Laboratory during the summer months. During the summer the low

frequency range failed to correct properly but no adjustments were made. The instrument now corrects properly throughout the range. In view of the foregoing experience, the Laboratory feels confident that the auxiliary correctors of the Models LM and LM-2 will not have to be used oftener than twice a year. The Laboratory is not prepared to say which element of the oscillating circuit is affected by humidity but in view of the long range nature of the phenomena, the wax-impregnated coil is suspected. Further work might disclose a means of eliminating the effect of humidity to a point where the auxiliary correctors would no longer be necessary but at present they are considered a workable, although not totally, satisfactory solution.

- 2-11 180° orientation of the instrument caused the crystal to shift frequency about twenty-five cycles but the frequency returned to normal when the instrument was righted. No facilities are available for making the 8 g. tests.
- 2-14 No nameplates were provided with preliminary models and frequency ranges were not stamped on the interior of the cabinets.
- 2-25(3) Control knobs are secured to the shafts by a single set screw after filing a flat surface on the shaft. Filing of a flat surface on a shaft does not produce a workmanlike job.
- 2-36 The frequency band switch employs phenolic insulating material. This switch is at high radio frequency potential and the phenolic insulation may be responsible for some of the trouble due to humidity. It would be difficult to build a switch with ceramic insulation to substitute for the present type.
- 2-42 Cadmium plating on the metallic case of the hermetically sealed audio choke and transformer does not prevent corrosion satisfactorily.
- 2-44 & 2-45 Parts were not available for this test.
- 2-57 Main tuning dial and manual corrector knob are aluminum, painted black. Both are tied directly to the case and are at ground potential.
- 2-60 No test covering this point was made beyond the performance of the crystal which was satisfactory.
- 3-1 On serial No. 3 the switch that cuts the voltage regulator in and out of the circuit is not on the front panel but it is desirable to keep it mounted internally as it is at present. On serial Nos. 1 and 2 the switch was not incorporated in the equipment at all.

3-6(c) Detector linearity. Table 5.

- 3-6(d) Audio Output. Table 4. Measurements made with R.F. signal input of 500 millivolts instead of 700 millivolts due to limitations of the standard signal generator. Audio characteristic is given in Table 2.
- 3-6(e) The action of the attenuator has not been totally satisfactory due to the fact that all the attenuation is crowded at one end of the potentiometer. Furthermore, the requirement that the output be reduced below twenty-five microvolts at maximum attenuation is very difficult to check by Laboratory methods because the output depends upon the selection of the ground point to be used. Furthermore, in a service setup there will be R.F. coupling to the receiver through the power cable even if the voltage on the R.F. coupling post were reduced to zero. The attenuation provided by the control in its present form is sufficient to make the equipment workable. To make the attenuator action ideal would probably require a design similar to that used in standard signal generators, plus filtering of the power cable and the added performance is not considered commensurate with the difficulties encountered in achieving it.
- 3-6(f) Modulation of approximately 500 cycles has been provided.
- 3-7 Crystal is mounted in evacuated and sealed holder. Further inspection is impossible.
- 3-8 Crystal shifts frequency about twenty-five cycles when instrument is inverted.
- 3-11
- 3-12 Table 7.
- 3-14 Note 2-7. Data tables 9, 10 and 18, give temperature coefficients. 400 kc is the only point that gives trouble and this point is not serious. In regard to the temperature coefficient of the self-oscillator in a piece of equipment like the LM-2 indicator using the electrical calibration corrector which this equipment uses, the following facts are pointed out. The ideal condition is to have no change of frequency due to change of temperature at any point on the range but this is obviously impossible. The next best condition would be to have a reasonable temperature coefficient - 0.005% per degree would not be excessive - of such a nature that any frequency shift due to temperature could be corrected at all points in one frequency band with one adjustment of the corrector. This means that the frequency shift due to a given change of temperature should be twice the percentage at the high end of the band compared to the percentage shift at the low end of the band so as to correspond with the action of the corrector. Furthermore, and this is very important, the drift at the high and low end of the band must be in the same direction for the best accuracies. This is not true in the high frequency band of the Model LM-2. Table 9 shows the data. Now it would be

a very simple matter to increase the action of the compensating condenser to reduce the drift at 400 kc but the drift at 4000 kc would be increased and any increase in the drift at 4000 kc, even though it did not exceed specification 3-14, would vitiate the reset accuracies at that point so that specification 3-27 could not be met. The weakest point of the present self-oscillator design is the attempt to eliminate drifts due to temperature with a compensating condenser when such variations are due to changes in the inductance. The ideal design of an oscillator for Model LM-2 frequency indicator would incorporate a coil of low temperature coefficient preferably protected from effects of humidity, a condenser of low coefficient and no compensating condenser. At present there is no data available on the temperature coefficient of evacuated inductances and some serious difficulties may be encountered in their design but their use might prove feasible in future equipments.

- 3-15 See Table 4.
- 3-16 See Table 3.
- 3-17 See Table 6.
- 3-18 Impregnation of coils to eliminate effects of humidity have proved unsatisfactory.
- 3-19 Control meets specifications. Backlash was so slight as to be negligible in all the preliminary models.
- 3-20 See Table 1. The power cable is a five conductor shielded cable, nine feet in length, suitably terminated as per specifications.
- 3-21 The plug at the indicator end of the equipment is of the side entrance type which can be locked in position at intervals of 45°.
- 3-23 Calibration books are provided per specifications. Two minor changes are suggested: Paragraph 4 covering the action of the modulation switch should be printed in red and mention the fact that the crystal does not oscillate with the modulation switch in the "on" position and the red figure in the lower right hand corner of each page indicating intensity of crystal check point should be eliminated entirely.
- 3-27 Reset accuracy is generally satisfactory. See Tables 13, 14 and 15.
- 3-28 Dimensions are satisfactory. See Table 19.
- 3-29 Indicator is 13 oz. overweight. See Table 19.

25. In addition to the requirements of basic specifications, reference (d), the contractor has incorporated a voltage regulator which consists of two mean lamps in series with a dropping resistor. The plate voltage for the heterodyne oscillator is taken from the drop across these two voltage regulator tubes and consequently does not vary greatly regardless of the value of the supply voltage. Reference (i) contains the data covering the performance of the voltage regulator but for convenience it is repeated in Tables 20 and 21. The opinion of the Laboratory regarding the suitability of the voltage regulator is also contained in reference (i). This opinion is based upon additional data that was taken after the conference, reference (h), and provides a clarification of the opinion contained in the Naval Research Laboratory letter of 19 August 1937.

26. Deficiencies of submitted models noted during Laboratory tests are recorded below.

- (a) No nameplates were submitted with any of the preliminary models.
- (b) Housing of audio choke and transformer showed evidence of corrosion.
- (c) Crystal holder envelope is made of iron.
- (d) Frequency shift due to excessive humidity or long continued humidity was too great for corrector range of models as originally submitted. Serial #3 corrector was adequate.
- (e) Orientation of instrument through 180° arc caused crystal to shift about twenty-five cycles.
- (f) Control knobs are not secured to shafts in a workmanlike manner.
- (g) Frequency band switch employs phenolic insulation.
- (h) Ninety per cent of the action of the radio frequency attenuator takes place in a very few degrees of rotation.
- (i) Serial 1 and 2 showed temperature coefficients beyond specification limits at 400 kc. Serial No. 3 was close enough to be within limits of experimental error.
- (j) Impregnation of coils for purposes of eliminating humidity effects proved unsatisfactory.
- (k) LM-2 is 13 oz. overweight.
- (l) Incorporation of voltage regulator requires modification of junction box outlet.

CONCLUSIONS

27. The workmanship and material used in building the preliminary model LM-2 Crystal Frequency Indicator shows that the contractor has put forth an honest effort to produce good equipment. Arrangement of parts and wiring has been done neatly; mounting of component parts has been done rigidly and very few failures of a mechanical nature should develop in later service.

28. Two particularly excellent features of the equipment are the drive mechanism of the heterodyne oscillator tuning condenser which showed practically no backlash at any time during the tests and the frequency stability of the crystal oscillator over wide ranges of temperature, humidity and voltage variations.

29. The flexibility and accuracy of the instrument is of a high order, considering the space and weight limitations imposed upon it. Harmonic outputs are ample and under suitable conditions in the laboratory the useful range of the instrument can be extended far beyond the calibrated maximum of 20,000 kc.

30. The additional calibration corrector on each range provides a workable solution for compensating the long time frequency shift due to humidity but a more satisfactory solution of the problem would be to design a circuit sufficiently free from the effects of humidity so that the additional correctors would be unnecessary.

31. The incorporation of the voltage regulator will improve the operation of the instrument in case a violent change of voltage takes place between time of correcting calibration and making measurement. However, it is doubtful if this feature warrants the complications caused by the incorporation of the voltage regulator.

32. The use of an automatic compensating condenser which corrects for the effects of temperature is only partially satisfactory in the present design. Undoubtedly the major change in frequency caused by temperature takes place in the inductors and the best reset accuracies are not attainable by correcting inductance shifts with compensating condensers. Furthermore, each range has its own inductance and one compensating condenser is expected to neutralize the frequency shifts occurring in either range. A fundamental improvement would result if inductances could be built with low temperature coefficients and the automatic compensating condenser eliminated entirely.

TABLE 1

POWER CONSUMPTION OF MODEL LM-2
 FREQUENCY MEASURING EQUIPMENT
 SPECIFICATION 3-20 RE 13A 489D
 Serials #1 and 2

Filament Consumption

Ef	If	Specification
12	0.55	0.60 amperes
14	0.62	
16	0.69	

Plate Consumption

Ep	Voltage Regulator Load	Total Load
250	5.0 ma	16.0
300	7.0	22.0
350	9.0	26.5
400	11.0	31.5
450	12.5	36.0
480	14.0	37.0

Spec. Req. - Current not to exceed 20 milliamperes
 at 260 Volts Ep.

TABLE 2

MODEL LM #2 CRYSTAL FREQUENCY INDICATOR
 AUDIO CHARACTERISTIC

Specification: 3-6(d) of RE 13A 489D

Ep = 300;	Ef = 13.0;	Carrier f = 2000 kc
Audio Frequency Cycles	Milliwatts Output	
63	50	
120	100	
160	150	
255	190	
360	150	
480	100	
600	50	
1050	20	
1500	10	
2100	5	
2800	3	

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TABLE 3

AUDIO OUTPUT AT CRYSTAL HARMONIC CHECK POINTS

Specification: 3-16 of RE 13A 489D

Ep = 320; Ef = 14.0

Frequency	Output (Milliwatts)	
	Serial #1	Serial #2
200	160	160
222.2	140	125
250	180	180
300	125	125
333.3	180	180
375	140	140
400	170	170
2000	195	200
2250	140	150
2500	190	190
2750	120	120
3000	200	200
3250	110	110
3500	175	175
3750	35	50
4000	200	200

TABLE 4

AUDIO OUTPUT WITH 0.5 VOLT INPUT

Specification: 3-6(d) of RE 13Aa 489D

Ep = 300; Ef = 13.0

Frequency (kc)	Harmonic Order	Output (Milliwatts)	
		Serial #1	Serial #2
200	1	190	200
300	1	190	210
400	1	200	210
400	2	150	160
600	2	170	200
800	2	180	190
800	4	80	120
1200	4	150	190
1600	4	160	185
1600	5	150	160
2000	5	140	150
2000	1	190	190
3000	1	190	200
4000	1	200	210
4000	2	180	190
6000	2	180	160
8000	2	170	190
8000	4	200	190
12000	4	185	200
16000	4	170	190
16000	5	150	190
20000	5	120	170

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TABLE 5

DETECTOR LINEARITY OF LM #2

Specification: 3-6(c) of RE 13A 489D

300 Kc		Input (Millivolts)		3000 Kc		Output Milliwatts
Serial #1	Serial #2	#1	#2	#1	#2	
5	12	35	20	15	15	5
20	16	50	40	21	20	10
30	25	75	60	31	30	20
37	31	95	75	39	40	30
45	37	115	90	45	50	40
50	42	130	100	50	55	50

TABLE 6

RADIO FREQUENCY OUTPUT OF LM #2

Specification: 3-17 of RE 13A 489D

Frequency (Kc)	Serial #1 Volts
222	0.013
300	0.017
400	0.024
400	0.015
600	0.012
800	0.010
800	0.005
1200	0.010
1600	0.005
1600	0.004
2000	0.003
2000	0.011
3000	0.008
4000	0.006
4000	0.005
6000	0.007
8000	0.018
16000	0.005
20000	0.006

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TABLE 7

FREQUENCY DRIFT OF CRYSTAL OSCILLATOR
DUE TO CHANGE OF TEMPERATURE

Specification: 3-12 of RE 13A 489D

Temperature °C	Frequency Shift in Cycles	
	Serial #1	Serial #2
-27	760.5	764.5
-20	758.2	764.0
-10	757.0	763.0
0	757.1	761.0
+10	758.0	755.0
+20	760.0	752.0
+30	761.0	750.0
+40	761.7	749.5
+53	762.2	746.0
Totals	5.1	18.5
Spec. Req.	/°C	/°C

TABLE 8

MODEL LM #2 - CHANGE OF FREQUENCY
DUE TO CHANGE OF PLATE VOLTAGE

Ep	200 Kc	300 Kc	400 Kc	2000 Kc	3000 Kc	4000 Kc
250	50	30	50	275	840	360
300	55	40	70	310	980	600
350	58	50	82	340	1100	900
400	61	56	102	370	1160	1120
450	63	64	112	390	1210	1330
480	64	74	120	410	1360	1560
Total	14	44	70	135	520	1200

Frequency shift due to change of filament volts was not consistent over a number of trials but was always opposite in sign to the above results. When filament and plate were changed together in proportions representing service conditions, the frequency shifts were never serious.

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TABLE 9

FREQUENCY DRIFT OF SELF-OSCILLATOR
DUE TO CHANGE OF TEMPERATURE

Specification: 3-14 of RE 13A 489D

Serial #2

Temperature °C	Frequency Variation in Cycles					
	at 200 Kc	at 300 Kc	at 400 Kc	at 2000 Kc	at 3000 Kc	at 4000 Kc
-28	--	650	1478	2219	2430	250
-26	354	644	1440	2167	2395	50
-20	345	627	1412	2127	2435	350
-10	330	599	1300	2145	2750	1300
0	300	560	1160	2070	3080	2300
+10	183	500	1000	1980	3333	2550
+20	140	519	910	2246	3700	2450
+30	200	485	720	2400	3865	2100
+40	195	430	600	2348	3840	1250
+50	217	385	465	2270	3840	710
+55	245	376	--	2265		--
+65	295	--	--	--		--
Total	-214	-274	-1013	-285	+1445	+2500
Cycles/°C	2.4	3.3	13.0	3.4	18.5	32
Spec. Req.	4.0	6.0	8.0	40	60	80

TABLE 10

FREQUENCY DRIFT OF SELF-OSCILLATOR
DUE TO CHANGE OF TEMPERATURE

Specification: 3-14 of RE 13A 489D

Serial #1

Temperature °C	Frequency Variation in Cycles		
	at 300 Kc	at 400 Kc	at 3000 Kc
-25	605	1725	3500
-20	505	1650	3100
-10	448	1500	3250
0	385	1150	3400
+10	350	850	3300
+20	315	638	2850
+30	270	475	2375
+40	216	280	2100
+50	216	175	2050
+55	225	--	2125
Total	380	1550	1375
Cycles /°C	4.7	21	17.2
Spec. Req.	6.0	8.0	60

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TABLE 11

SUMMARY OF DATA SHOWING EFFECT OF RELATIVE
HUMIDITY ON FREQUENCY OF SELF-OSCILLATOR

SERIAL #1

Base Frequency Kc	Temperature ° C	Variation Cycles	%
200	30	220	0.11
400	30	1000	0.25
4000	30	3655	0.091
2000	0	130	0.0065
2000	30	1200	0.060
2000	50	2410	0.120

Humidity was varied from approximately 10% to 95% and back to 10% for all tests. Each test made separately over a time interval of about four hours.

TABLE 12

CORRECTOR RANGE

MODEL LM #2 - Serial Nos. 1 & 2

Frequency (Kc)	Corrector Range (Kc)
200	0.90
400	7.2
2000	9.0
4000	72.0

MODEL LM #2 - Serial No. 3

Frequency (Kc)	Manual Corrector (Kc)	Auxiliary Corrector (Kc)
200	0.500	4.8
400	4.0	38.4
2000	5.0	48.0
4000	40.0	384.0

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TABLE 13

ACCURACY OF EMITTED FREQUENCY - SERIAL #2

Specification: 3-27 of RE 13A 489D

Frequency (Kc)	Tolerance Cycles	Cycles Deviation from Absolute f		
		T = -30° C	T = +28° C	T = +50° C
200.000	40	-	-	-
210.526	42	+1	-2	-2
210.526	42	+12	+6	+6
222.222	44	-	-	-
235.294	47	+32	+15	+29
235.294	47	+2	+18	+12
250.000	50	-	-	-
277.777	55	+29	-6	-17
277.777	55	-38	+2	+4
300.000	60	-	-	-
315.772	63	+13	-22	-27
315.772	63	-56	-10	-13
333.333	67	-	-	-
357.143	67	+61	-3	-18
357.143	71	-35	+5	+19
375.000	71	-	-	-
384.615	76	+20	-10	+2
384.615	76	-36	-10	+5
400.000	80	-	-	-
2000.0	200	-	-	-
2125.0	212	-156	0	+27
2125.0	212	+75	0	-82
2250.0	225	-	-	-
2375.0	237	+55	+119	+103
2375.0	237	0	-54	-162
2500.0	250	-	-	-
2625.0	262	+69	+63	+110
2625.0	262	-200	+41	+87
2750.0	275	-	-	-
2875.0	287	0	0	+94
2875.0	287	-85	0	+94
3000.0	300	-	-	-
3125.0	312	+125	-130	0
3125.0	312	-162	0	-131
3250.0	325	-	-	-
3375.0	337	+344	+57	-50
3375.0	337	-58	+100	+237
3500.0	350	-	-	-
3625.0	362	+481	+130	+110
3625.0	362	-94	+62	+281
3750.0	375	-	-	-
3875.0	387	+312	+75	+75
3875.0	387	-400	-275	+200
4000.0	400	-	-	-

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TABLE 14

ACCURACY OF EMITTED FREQUENCY - SERIAL #1

Specification 3-27 of RE 13A 489D

Frequency (kc)	Tolerance Cycles	Cycles Deviation from Absolute f		
		T = -25°C	T = +27°C	T = +50°C
200.000	40	-	-	-
210.526	42	+34	-3	+20
210.526	42	-13	-6	-11
222.222	44	-	-	-
235.294	47	+29	-3	+10
235.294	47	-6	-3	+10
250.000	50	-	-	-
277.777	55	+10	-12	-23
277.777	55	0	+3	+6
300.000	60	-	-	-
315.772	63	+14	-18	-18
315.772	63	-47	-21	-18
333.333	67	-	-	-
357.143	71	+31	-12	-9
357.143	71	-21	-12	+5
375.000	75	-	-	-
384.615	77	+15	+9	+5
384.615	77	-49	-25	-12
400.000	80	-	-	-
2000.0	200	-	-	-
2125.0	212	+75	0	+115
2125.0	212	-81	-225	-147
2250.0	225	-	-	-
2375.0	237	0	+137	-165
2375.0	237	0	0	-20
2500.0	250	-	-	-
2625.0	262	-125	-65	-106
2625.0	262	+163	+156	+219
2750.0	275	-	-	-
2875.0	287	+112	+44	+69
2875.0	287	0	-50	+150
3000.0	300	-	-	-
3125.0	312	+87	-160	-117
3125.0	312	-31	+57	+120
3250.0	325	-	-	-
3375.0	337	0	-187	-63
3375.0	337	-72	-125	-55
3500.0	350	-	-	-
3625.0	362	-62	+62	-44
3625.0	362	-162	-75	+131
3750.0	375	-	-	-
3875.0	387	+81	-600	-712
3875.0	387	-112	-375	-600
4000.0	400	-	-	-

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TABLE 15

ACCURACY OF EMITTED FREQUENCIES SERIAL #3
Specification 3-27 of RE 13A 489D

Frequency KC	Tolerance Cycles	Cycles deviation from absolute	
		T = -24°C.	T = +50°C.
200.000	40	- - -	- - -
210.526	42	-20	-52
210.526	42	-4	-20
222.222	44	- - -	- - -
235.294	47	-8	-4
235.294	47	+12	-12
250.000	50	- - -	- - -
277.777	55	0	-9
277.777	55	-5	-9
300.000	60	- - -	- - -
315.772	63	+46	-5
315.772	63	-69	-14
333.333	67	- - -	- - -
357.143	71	+76	-8
357.143	71	-32	+28
375.000	75	- - -	- - -
384.615	77	+20	+16
384.615	77	-4	0
400.000	80	- - -	- - -
2000.0	200	- - -	- - -
2125.0	212	-280	-135
2125.0	212	0	0
2250.0	225	- - -	- - -
2375.0	237	-250	-200
2375.0	237	-50	-150
2500.0	250	- - -	- - -
2625.0	262	+150	+100
2625.0	262	-50	-100
2750.0	275	- - -	- - -
2875.0	287	+50	-300
2875.0	287	+50	+150
3000.0	300	- - -	- - -
3125.0	312	+360	0
3125.0	312	-190	0
3250.0	325	- - -	- - -
3375.0	337	+600	0
3375.0	337	-120	+160
3500.0	350	- - -	- - -
3625.0	362	+480	+40
3625.0	362	-320	+40
3750.0	375	- - -	- - -
3875.0	387	-80	-360
3875.0	387	-160	+70
4000.0	400	- - -	- - -

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TABLE 16

EFFECT OF PROLONGED HUMIDITY UPON CALIBRATION

Model LM #2 Serial No. 1

Base F KC	Departure from Calibration (Cycles)		
	After 8 hrs.	After 69 hrs.	Permanent Change
200	- 670	- 850	- 216
333.3	- 2100	- 3300	- 675
400	- 2900	- 6000	- 1065
2000	- 2800	- 4660	- 710
3000	- 6750	-13000	- 2300
4000	-14300	-30500	- 3180

TABLE 17

EFFECT OF PROLONGED HUMIDITY UPON CALIBRATION
COMPARISON OF SERIAL 1 WITH SERIAL 3.

Base F KC	Maximum Shift		Final Shift	
	Ser. 1	Ser. 3	Ser. 1	Ser. 3
200	- 580	- 832	- 280	- 240
333.3	- 2095	- 3020	- 1070	- 905
400	- 3300	- 6000	- 1730	- 2780
2000	- 2380	- 3600	- 1600	- 1080
3000	- 9100	-11380	- 4575	- 3220
4000	-19400	-37300	-11000	-7350

TABLE 18

SUMMARY OF TEMPERATURE DATA
Model LM #2 Serial No. 3

<u>T = -22°C.</u>	<u>T = +4°C.</u>	<u>T = +50°C.</u>	<u>Cycles Shift</u>
200.000	199.964	199.952	- 48
333.333	333.129	333.099	- 234
400.000	399.562	399.235	- 765
2000.000	1999.910	2000.675	+ 675
3000.000	3000.625	3002.740	+2740
4000.000	4001.348	4003.220	+3220

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TABLE 19

WEIGHT & DIMENSIONS OF MODEL LM #2

Specification 3-28 of RE 13A 489D

<u>Overall Dimension</u>		<u>Spec.</u>
Height	8-3/8	8-3/4
Depth	8-1/2	8-3/4
Width	8-1/8	8-1/4

Specification 3-29

<u>Weight Indicator</u> <u>Complete with Calibration</u>	<u>Spec.</u>
11 pounds 12 oz.	11 pounds
<u>Power Cable</u> 12 oz.	11 oz.
Total - 12 pounds 8 oz.	11 pounds 11 oz.

TABLE 20

PERFORMANCE OF LM-2 WITH AND WITHOUT VOLTAGE REGULATOR

: <u>Crystal check points LM-2, Ser. 1</u>							
: 150 volts : 300 volts : 420 volts							
Kcs.	Book	: With	Without	: With	Without	: With	Without
	Calibration	Regulator	Regulator	Regulator	Regulator	Regulator	Ref'tr
200.0	0347.7	0347.7	0347.7	0347.7	0347.7	0347.7	0347.7
222.2	0833.3	0832.3	0832.6	0832.6	0832.5	0832.3	0832.5
250.0	1403.1	1401.2	1401.4	1401.4	1401.6	1401.2	1401.4
300.0	2428.5	2424.2	2424.3	2425.0	2424.8	2424.9	2424.8
333.3	3130.3	3123.3	3123.3	3125.0	3124.8	3124.5	3124.6
375.0	4077.5	4065.6	4065.4	4069.1	4069.3	4068.5	4068.4
400.0	4707.5	4689.0	4688.7	4695.2	4695.0	4694.0	4695.2
2000	0523.5	0523.5	0523.5	0523.5	0523.5	0523.5	0523.5
2250	1045.9	1045.5	1045.3	1045.5	1045.9	1045.4	1045.5
2500	1553.9	1554.0	1554.0	1553.9	1554.1	1554.1	1553.6
2750	2054.5	2054.8	2054.9	2054.5	2055.2	2055.0	2055.0
3000	2548.5	2549.4	2549.8	2548.5	2549.2	2549.0	2549.1
3250	3047.4	3048.5	3048.9	3048.4	3048.7	3048.2	3048.3
3500	3561.1	3562.6	3562.6	3561.1	3562.3	3562.1	3561.9
3750	4094.1	4095.7	4096.0	4094.1	4095.8	4095.5	4095.1
4000	4654.6	4656.9	4656.8	4654.6	4656.5	4656.1	4655.8

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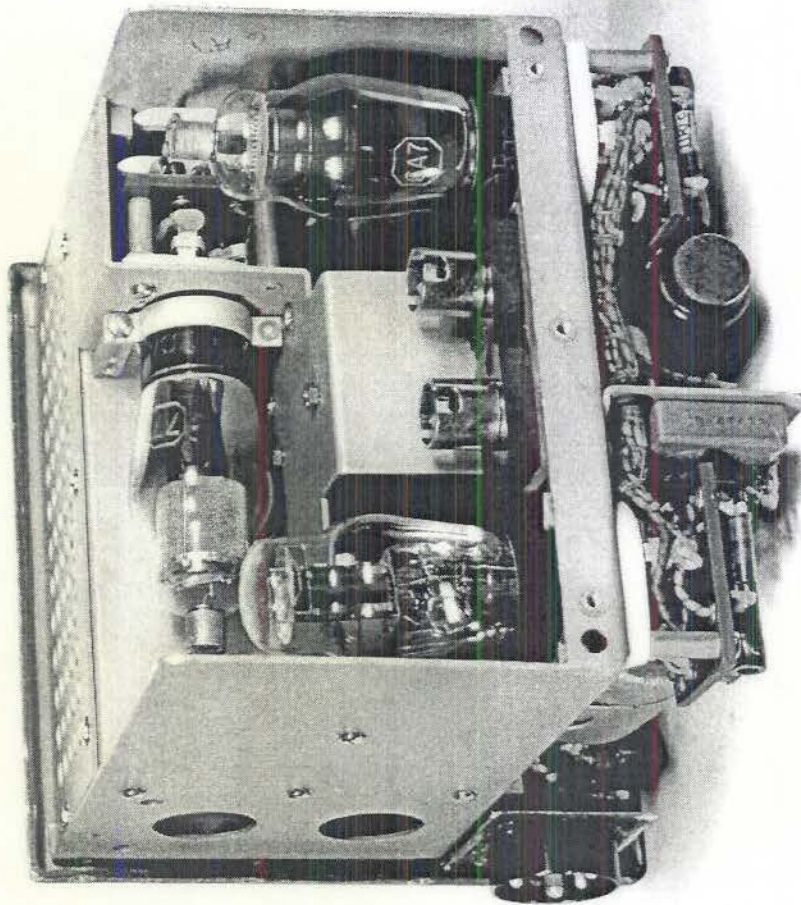
TABLE 21

FREQUENCY VARIATION DUE TO PLATE VOLTAGE CHANGE
WITH AND WITHOUT VOLTAGE REGULATOR

	200 Kc		333.3 Kc		400 Kc	
Plate	With	Without	With	Without	With	Without
Voltage	Regulator	Regulator	Regulator	Regulator	Regulator	Regulator
250	88	78	173	342	60	150
350	102	144	223	583	148	580
450	108	186	264	783	192	890
475	110	190	267	850	198	990
Total						
Shift	22	112	94	508	138	840

	2000 kc		3000 kc		4000 kc	
Plate	With	Without	With	Without	With	Without
Voltage	Regulator	Regulator	Regulator	Regulator	Regulator	Regulator
250	165	210	350	1600	300	380
350	230	550	620	2650	740	3000
450	278	795	780	3350	1340	4650
475	300	840	800	3500	1500	5000
Total						
Shift	135	630	450	1900	1200	4620

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Plate 2

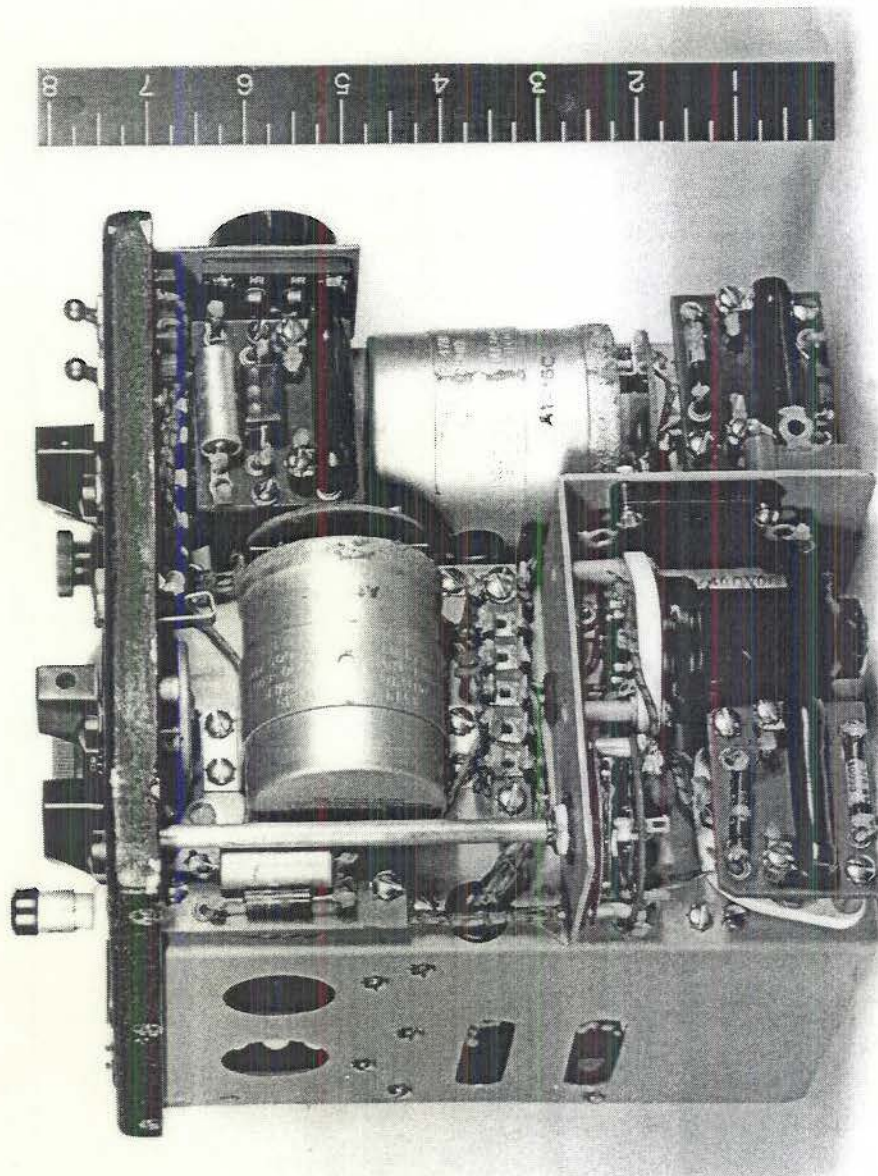


Plate 3

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U. S. NAVAL AIR STATION

ANACOSTIA, D. C.

F42-1/74/NA6(342)

Serial #38012

February 9, 1938

From: Commanding Officer.
To: The Director, Naval Research Laboratory.

SUBJECT: Aircraft Radio - Model XLM-2 Aircraft Crystal
Frequency Indicator, Report on tests of.

Reference: (a) BuEng. ltr. F42-1(11-8-W3) of 17 November,
1934.
(b) BuEng. Specification RE-13A 489D.
(c) BuEng. ltr. NOs52637 (2-11-W3) of 17 February,
1937.
(d) BuEng. ltr. C-NOs52637 (2-12-W8) of 19 Feb., 1937.
(e) BuEng. ltr. NOs52637 (7-16-W8) of 20 July, 1937
with Enclosure (A).
(f) BuEng. ltr. C-NOs-52637 (2-12-W8) of 29 July, 1937,
to Director, Naval Research Laboratory, copy with
Enclosure (A) to C.O., NAS, Anacostia, D. C.
(g) BuEng. ltr. C-NOs-52637 (2-12-W8) of 24 August,
1937, to Commandant, Washington Navy Yard, copy
with Enclosure (A) to C.O., NAS, Anacostia, D. C.
(h) BuEng. ltr. C-NOs-52637 (11-1-W3-30) of 8 Nov.,
1937, to Commandant, Washington Navy Yard, copy
with Enclosures to C.O., NAS, Anacostia, D. C.
(i) BuEng. ltr. C-NOs-42429 (11-13-W3) of 16 Nov.,
1937, to Commandant, Washington Navy Yard, copy
with Enclosure (A) to C.O., NAS, Anacostia, D. C.

Enclosure: (Herewith)
(A) Copy of Circuit Diagram.

1. This letter reports upon flight tests made with the model xLM-2 crystal frequency indicator, as outlined during a verbal conference at this station with a representative of the Naval Research Laboratory.

2. Serial No. 1 of the subject equipment reached this station on May 26, 1937. On June 21, 1937, Serial No. 1 was exchanged for Serial No. 2 with the Naval Research Laboratory. A deficiency in the calibration corrector circuit of Serial Nos. 1 and 2 required the submission of Serial No. 3, which reached this station on October 5, 1937, and was returned to the contractor (Bendix Radio Corporation) on January 7, 1938, via the Naval Research Laboratory. The subject equipments were given a general inspection and then installed in the XRE-2 airplane in conjunction with a model XGO-3 transmitting and model RE-4 receiving equipment.

-1- App.B

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Serial #38012

SUBJECT: Aircraft Radio - Model xLM-2 Aircraft Crystal
Frequency Indicator, Report on tests of.

3. The model xLM-2 crystal frequency indicator has three fundamental circuits:

- (a) An accurately calibrated, dual range self-oscillator, extending from 195 to 400 kilocycles and from 2000 to 4000 kilocycles. These two fundamental ranges together with the second, fourth, and fifth harmonics cover a continuous range from 195 to 20,000 kilocycles.
- (b) An extremely accurate crystal controlled oscillator using a low temperature coefficient crystal in an evacuated holder. The crystal oscillates at 1000 kcs. and provides check points for correcting the calibration of the self-oscillator.
- (c) Detector, audio amplifier, and output circuit designed for optimum operation at 250 cycles and suitable for feeding a low impedance headset. A switch is provided which converts the audio amplifier into a modulator so that modulated radio frequency outputs are available.

4. The heterodyne oscillator tube is a type 77, the crystal oscillator and detector is a type 6A7 and the audio amplifier is a type 76 tube.

5. The power supply for the model xLM-2 is derived from outlet 74 or 76 of any RU-3 or later model RU junction box or model GF junction box; it is necessary however to make modifications which put the dynamotor directly across terminals 26 and 36.

6. Overall dimensions of equipment:

Height.....8 3/8"
Depth.....8 1/2"
Width.....8 1/8"

An additional 2 1/2 inches are necessary on the width for inserting the power plug and 1/2 inch additional on the height for installation purposes. Weight of indicator, calibration book, and power cable is 12 pounds 8 ounces.

7. Operation of the model xLM-2 crystal frequency indicator was generally satisfactory in flight, but a number of deficiencies are recorded which should be corrected in production equipment. They are as follows:

Serial #38012

SUBJECT: Aircraft Radio - Model xLM-2 Aircraft Crystal
Frequency Indicator, Report on tests of.

- (a) Voltage Regulator: The incorporation of the voltage regulator requires modifications of the junction box power outlet and also requires the use of a five wire power cable, thus making LM and LM-2 equipments non-interchangeable. It is believed that the additional performance provided by the voltage regulator is insufficient to warrant making model LM-2 indicators non-interchangeable with model LM indicators. If model RAM receivers are supplied, a separate, additional modification is necessary for the operation of the LM-2 but the model LM could be used with the RAM without any modification.
- (b) Main Tuning Capacitor: The open construction admits dirt and metal chips between plates of capacitor. Suggest gold or silver plating in lieu of cadmium plating on capacitor plates to reduce tendency of dirt to adhere to plates. Difficulty encountered with model LM, Serial Nos. 207 and 303 at this station indicates that fringing of cadmium plated tuning condenser is so serious that the units had to be cleaned a second time ten weeks after original cleaning. To eliminate metal chips it will be necessary to prevent the screws on the chassis from rubbing against the inside of the cabinet as the chassis is inserted or withdrawn from the cabinet. To protect the main tuning capacitor against dirt it would be desirable to enclose the compartment in which it is installed. Consideration should be given to the use of a solid instead of a perforated top plate, and to close the holes in the sides.
- (c) Screwdriver Corrector Cover Plates: These should have suitable means for moving without likelihood of scratching finish of cabinet beneath. The engraving on these plates should be protected from tarnishing by use of corrosion resisting material for the plates themselves or by proper protection of the engraved portion.
- (d) Window Parallax Corrector: This at present allows for adjustment over plus or minus 2-1/2 divisions of the scale. Provision for adjustment over plus or minus one division of the scale is preferable. The slot in the adjusting screw is too narrow. Should be at least as wide as the slots in securing screws, so that a special screwdriver will not be necessary. To obviate the likelihood of mistaking the adjusting screw for a securing screw, it should be marked with an arrow, or other suitable distinguishing mark.

Serial #38012

SUBJECT: Aircraft Radio - Model xLM-2 Aircraft Crystal
Frequency Indicator, Report on tests of.

- (e) Calibration Chart: This should be lengthened to take advantage of available space and columns should be provided to give data for as many as ten frequencies, if practicable.
- (f) Fit of Front Panel: The front panel on the model overlaps the cabinet, hindering operation of one snap slide and removal of the calibration book. This condition should be corrected.
- (g) Main Tuning Condensor Cover Plate: The securing screw holes are misaligned. Should be corrected in production. Unplated brass inserts for securing this cover to the chassis should be replaced with aluminum inserts.
- (h) Grounding of Equipment: Grounding of equipment should be accomplished by placing pigtail jumpers across each rubber suspension, and the finish of the mounting plate should be scraped off beneath the mounting screws to provide a good ground to the plane structure.
- (i) Effect of Modulation Switch on Crystal Oscillator: The crystal will not oscillate with the modulation switch in the "On" position. Special note of this should be made in the instruction book under crystal operation and in paragraph 4, inside of calibration book cover.
- (j) Protection Against Corrosion: Inadequate protection against corrosion was noted in the following:
 - (1) Crystal switch shaft.
 - (2) Rotary plaque switch frames and detent springs.
 - (3) Steel washers and screws in plaque switch assemblies.
- (k) Volume Control: Too abrupt for good operation in flight. If practicable, the equipment should incorporate a tapered r.f. coupling control.
- (l) Assembly Clearances: Clearances between parts listed below are inadequate:
 - (1) Capacitor CD-4 and adjacent terminal.
 - (2) Output transformer terminal and audio choke can.

Serial #38012

SUBJECT: Aircraft Radio - Model XLM-2 Aircraft Crystal
Frequency Indicator, Report on tests of.

(m) Marking: The following are not properly marked:

- (1) Bottom terminal boards.
- (2) Tube sockets.

(n) Clip on Type 38077 Vacuum Tube (heterodyne oscillator):
The position of this clip should be reversed to give convenient access to the spring release.

(o) R.F. Coupling Binding Post: There should be positive means to prevent loss of this binding post.

(p) Securing of Control Knobs: To prevent loss of knobs, the set screws should work into slotted flats on the shaft, or other suitable protection should be provided.

8. Provided these deficiencies are corrected in production equipment to the satisfaction of the Bureau of Engineering, it is recommended that the model xLM-2 crystal frequency indicator be considered satisfactory for naval service.

9. It is requested that two copies of the Naval Research Laboratory's report be furnished to this station for information and future reference.

/s/ V. C. GRIFFIN

Copy to:
BuAero.
BuEng.
NAF Phila.



Schematic Diagram of Model AN-51137 1-27-38
 1M-2 Crystal Frequency Indicator.
 OFFICIAL NAVY PHOTOGRAPH
 NOT TO BE USED FOR PUBLICATION