

7 August 1936

NRL Report No. R-1295  
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FR-1295

NAVY DEPARTMENT  
BUREAU OF ENGINEERING

Report on  
Test of Modified Model LJ Aircraft Crystal Frequency  
Indicators - Manufactured by Hygrade  
Sylvania Corporation.

NAVAL RESEARCH LABORATORY  
ANACOSTIA STATION  
WASHINGTON, D.C.

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## AUTHORIZATION

1. This problem was authorized by Bureau of Engineering letter, reference (a). There are listed five additional references, (b) to (f) inclusive, pertinent to the problem.

Reference: (a) BuEng.let. F42-1(9-7-W3) of 19 Sept, 1934.  
(b) Specifications RE 13A 489A.  
(c) NRL Report No. A-1045 of 10 April 1934.  
(d) NRL Report No. R-1138 of 25 March 1935.  
(e) BuEng.let. F42-1(11-8-W3) of 17 Nov. 1934.  
(f) N.A.S. Anacostia ltr. F42-1/Na6(185) of 17 July 1936.

## OBJECT

2. The object of this test was to determine the extent of the improvements in two sample units modified in accordance with the findings of a prior test, ref. (d), on a production set. This report is therefore supplementary to ref. (c) and ref. (d).

## ABSTRACT OF TEST

3. A check was made of the changes in construction and performance of the two revised production units with reference to the recommendations of ref. (d). Mechanical changes were determined by inspection. Audio outputs and radio frequency variations with ambient temperature of a selected crystal and of the heterodyne oscillator in two selected settings were determined by measurement.

## CONCLUSIONS

- (a) The Model LJ frequency indicators as modified should be satisfactory for use in the Naval Service.
- (b) These modifications have in general corrected the defects noted in the report on tests of the earlier models as discussed in ref. (d).
- (c) The accuracy of setting the frequencies near 7500 kcs. is still poor when using primary crystal check points. The use of secondary crystal check points reduces these inaccuracies.

## RECOMMENDATIONS

As a result of these tests the following recommendations are made:

- (a) That the Model LJ frequency indicators as modified be considered satisfactory for use in the Naval Service and that all units be so modified.
- (b) That the secondary crystal check points be indicated on the calibration chart.
- (c) That the instruction books be revised to show all changes due to the modification.

## MATERIAL UNDER TEST

4. Two production Model LJ aircraft crystal frequency indicators, serials #24 and #60, were submitted by the contractor; with modifications to correct the objectionable features reported in ref. (d). The description of par. 5 of ref. (d) applies except that a Type 41 tube has replaced the Type 37 tube for the audio output stage. Plates 4 and 5 show the modified model.

## METHOD OF TEST

5. Modifications in mechanical construction were checked by inspection. Determination of the backlash and zero signal zone was made as follows. With a knowledge of the zero signal zone, measured in divisions on the fine adjustment dial over the angular rotation between where the signal disappears and reappears with angular motion continuous in one direction, the backlash is found by deducting the zero divisions from the total divisions of no signal when the dial is rotated forward and backward between the points where the signal just appears and where it just appears again. This reversed movement evidently includes both the backlash and the zero zone.

6. Audio output for the various conditions under test was measured by an output wattmeter with the output loading set at 600 ohms. An external signal of 1/2 volt was supplied from the standard signal generator and its exact frequency was adjusted to give an output note of the desired audio frequency as determined by beat comparisons with the audio oscillator.

7. Measurements to determine crystal frequencies and temperature drifts for the crystal and the self-oscillator were made by the Laboratory standard frequency equipment. Inasmuch as two previous tests of this type crystal frequency indicator had been made, only one crystal was checked for temperature drift. This was taken from  $-26^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$ . A determination of the frequency at  $+10^{\circ}\text{C}$  of the remaining crystals was considered sufficient. An exact determination was made also of the heterodyne drift from  $-26^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$  for a low frequency and for a high frequency setting.

8. The following instruments were used:

Weston D.C. voltmeter, Model 45, #15346, Range 0-300-750 V.  
Weston D.C. voltmeter, Model 1, #39709, Range 0-3-15-150 V.  
Westinghouse D.C. milliammeter, Type CX Range 0-50 m.a.  
Weston D.C. ammeter, Model 301, #202927, Range 0-1 amperes.  
General Radio Audio Oscillator Type 513-B #80.  
General Radio Standard Signal Generator, Model LC-A #2.  
General Radio Output Power Meter, Type 583-A #67.  
Temperature Control Box.

## DATA RECORDED

9. A summary of the data recorded is:

- (a) Zero zone and backlash for each crystal; Table 1.
- (b) Power requirements; Table 2.
- (c) Audio outputs of crystal frequency indicator:

- (1) Ser.#24, Crystal oscillator position with 1/2 volt input from standard signal generator; Table 3.

- (2) Ser.#24, Heterodyne oscillator position with 1/2 volt input from standard signal generator; Table 4.
- (3) Ser.#24, Crystal excitation for calibration with volume control set at the "calibrating" position; Table 5.
- (4) Ser.#60, Heterodyne oscillator with 1/2 volt input from standard signal generator; Table 6.
- (5) Ser.#60, Crystal oscillator with 1/2 volt input from standard signal generator; Table 7.
- (6) Ser.#60, Crystal excitation for calibration with volume set at the "calibrating" position; Table 8
- (d) Ser.#24 - Frequency temperature drift of 500 kcs. crystal -26°C to +50°C. Plate 1.
- (e) Ser.#24 - Crystal frequencies at +10°C. Table 9.
- (f) Ser.#24 - Heterodyne temperature drift at 500 kcs. -26°C to +50°C. Plate 2.
- (g) Ser.#24 - Heterodyne temperature drift at 4235 kcs. -26°C to +50°C. Plate 3.

PROBABLE ERRORS

10. An estimate of the limits of error in the various measurements is:

Audio power output	$\pm 10\%$
Temperatures	$\pm 0.1\%$
Radio frequencies	$\pm 0.001\%$
Audio frequencies	$\pm 2\%$
D.C. Voltages	$\pm 1\%$

RESULTS OF TEST

11. The general order of the recommendations of ref. (d) will be followed:

Backlash - A great improvement has been made in reduction of the backlash and null zone although no mechanical adjustment has been provided to effect or maintain a further correction. Table 1 gives the value of both for each crystal.

Zero Correction - No change has been made.

Audio Output - Tables 3 to 8 inclusive give the audio output for various conditions of operation; special care was taken to return to the same audio frequencies as the measurements were made for the various radio frequencies. The six audio frequencies at which audio outputs were taken for each radio frequency, forms a satisfactory picture of output performance, as 1000 cycles is very close to the maximum. Measurements have been taken for the crystal oscillator position and heterodyne oscillator position with 1/2 volt external input from a standard signal generator. Output measurements were taken also in the "calibrating" position provided to set the heterodyne with the crystal,

at the "calibrating" position of the volume control. This position of the volume control is turned well back so as to give a moderate coupling from the crystal oscillator and thus provides a more accurate setting of the heterodyne oscillator against the crystal oscillator.

Outputs are well above the minimums specified in par.3-6(d) of ref.(b) except for the third harmonics of 4135 in the heterodyne position. The increase of output over the previous units tested has been achieved by use of a type 41 output tube in place of the type 37 tube formerly employed.

Fairly complete data have been taken for the Ser.#24 unit while for the Ser.#60 the number of measurements were reduced.

In connection with the large difference between Ser.#24 and Ser.#60 on the "calibrating" position, Table 5 and Table 8, other checks show the variation in effect of the volume control for the same angular position to be the principal cause. This variation is not important as only a weak signal is required to check the heterodyne against the crystal and the volume control can be set to give the desired strength of beat signal for either a check against or for an external signal.

Fixed Capacitors - Inspection shows that the fixed capacitors in question have been replaced by new ones which are rated at 300 volts D.C. These should be satisfactory.

Coupling between Crystal and Heterodyne - As shown in Table 1, the null zone has been reduced to where it is considered satisfactory.

Oscillator Constancy under Shock - A test made at 544 kcs gave a shift of 60 to 100 cycles for the self-oscillator and of perhaps 20 cycles for the crystal oscillator when the crystal frequency indicator was hit smartly by the hand and rocked back and forth vigorously on its base. The change was determined by the departure from the 500 cycle note of the audio oscillator to which the output of the crystal frequency indicator had been adjusted by zero beat just prior to each test.

Ground Connections - Ground connections are made in three places through the bolts that hold the tube socket. Two fiber washers protect the Isolantite piece in each case and are thus interposed between the ground lead and the frame which forms the ground. This type of ground is unsatisfactory.

Fiber Washers - A test was made on one of the fiber washers noted above to determine its response to moisture. As removed from the set it measured .059" - .060" thick. After soaking in water for 16 hours this thickness increased to .081-1/2" - .082-1/2". The washer was then dried on top of a hot steam radiator for a half hour when it measured .060-1/2" - .061-1/2". No further shrinkage resulted from another half hour of drying.

Tube Clamps - Modifications have been made in the tube clamps so that there is now direct access to the tightening screws for using a screwdriver to set up on the socket or to free it.

Crystal Coupling Capacitor - A fixed capacitor of 15 mmfds has been substituted for the former adjustable fixed capacitor of 10 to 70 mmfds.

Mounting of Crystals - The crystal table now rotates with satisfactory clearances in all positions.

Marking of Tube Sockets - Designations V1, V2, and V3 are stenciled on the sockets with explanations of their meanings in the description book. The tube type applying has not been marked on the socket.

Bracket on Chassis - No additional bracket has been added to the rear of the chassis to support it when the chassis is out of the case.

Spare Parts to Accompany Test Sets - The two sets provided for these tests were received without spare parts.

Volume Control - There is considerable irregularity in the operation curves of the volume controls for both sets and there is also a marked divergence between the forms of the two curves. Some frequency effect accompanies the change of position of the volume control.

Crystal Accuracy - Plate 1 gives the results of a temperature frequency run made on the 500 kc crystal. All other crystals were checked satisfactorily for oscillations at each temperature measurement point. Measurements were made also of the frequency of all ten crystals at +10°C to determine their accuracy. All but two; namely, the 425 kc and 4135 kc crystals, were within the specified tolerance of ref. (b), par.3-26.

Power Requirements - Table 2 gives the power inputs at 200 volts and at 265 volts. The former was taken with a battery supply and the latter with a Type AD-5 Model 2941 dynamotor for a Model RU receiver but with the receiver not connected.

Instruction Book - The instruction books now issued will not be correct for sets modified in accordance with the changes made in units #24 and #60.

12. The results of the flight tests are given in Naval Air Station, Anacostia, letter, ref. (f), which forms Appendix A of this report. From these tests it will be seen that the modifications have made the indicator a useful piece of equipment. The frequencies at which flight tests of the accuracy of setting were made using the heterodyne oscillator were at points where the greatest inaccuracies were observed. These accuracies can be improved by using secondary crystal check points for setting the heterodyne oscillator.

## CONCLUSIONS

13. The Model LJ frequency indicators as modified should be satisfactory for use in the Naval Service.

14. These modifications have in general corrected the defects noted in the report on tests of the earlier models as discussed in ref. (d).

15. The accuracy of setting the frequencies near 7500 kcs. is still poor when using primary crystal check points. The use of secondary crystal check points reduces these inaccuracies.

TABLE 1

Backlash and Zero Zone for Each Crystal

CFI #24

<u>Kc Crystal</u>	<u>Null Divisions</u>	<u>Backlash Divisions</u>
4235	1/2	2-1/2
4205	1/2	2-3/4
4135	1/2	3
544	4-1/2	3
516	4	2-3/4
500	4	2-1/4
440	4	2
425	4	2-1/4
375	2	3
355	2	2-1/4

TABLE 2

Power Requirements - CFI #24

<u>Plate Volts</u>	<u>Plate Amps</u>	<u>FilVolts</u>	<u>Fil Amps</u>	<u>Remarks</u>
200	.013			Calibration Position
200	.0165			Heterodyne Position
265	.0275	11.32	.65	Calibration Position
274	.0222	11.32	.65	Crystal Position
266	.0270	11.32	.65	Heterodyne Position

The battery supply for all the above readings was 12.0 volts.

TABLE 3

## Milliwatts Audio Output-Crystal Position - CFI #24

KC Crystal	Kc SSG	Cycles Audio Frequency						
		100	200	500	1000	1500	2000	3000
355	355	16	68	200	210	145	95	33
	710	10	33	95	88	85	59	25
	1065	2.5	7	22	26	19	14	5.5
425	425	33	64	165	168		65	21
	850	9.5	35	110	120		62	29
	1275	7.5	13	39	43		18.5	10.5
500	500	23	65	185	200		103	50
	1000	3	19	30	102		58	25
	1500	1	4.5	22	28		16	7
544	544	17	58	205	210		115	55
	1088	7.5	36	114	135		76	35
	1632	4	19	64	75		40	18
4135	4135	7	25	72	85		48	21
	8270	18	3.8	14	18.5		9	4
	12405	.2	1.0	3.8	4.6		2.3	.9
4235	4235	5.5	20	60	85		49	22
	8470	1.0	4.4	15	17.5		9.5	4
	12705	.3	1.3	4.3	5.0		2.5	1.1

TABLE 4

Milliwatts Audio Output-Heterodyne Position

CFI #24.

Kc Het	Kc SEG	100	200	Cycles 500	Audio 1000	Frequency 1500	2000	3000
355	355	32	80	190	220	180	135	59
	710	35	80	205	225	175	125	52
	1065	22	50	40	155	120	85	33
425	425	24	54	112	100		52	27
	850	5.5	20	60	70		39	15
	1275	6	20	60	70		36	14
500	500	30	65	110	112		70	36
	1000	10	30	75	85		45	18
	1500	10	35	79	88		47	18
544	544	10	45	120	155		102	50
	1088	6	22	85	110		54	22
	1632	5	20	75	98		50	20
4135	4135	3.1	10	33	40		20	5.8
	8270	.08	.15	.8	16		.8	.3
	12405	.02	.10	.15	.2		.08	.03
4235	4235	5	14	57	65		34	13
	8470	.3	1.5	7.5	10		5	2.0
	12705	.2	.4	1.5	1.8		1.0	.4

TABLE 5

Milliwatts Audio Output in Calibration Position with Volume Control Set at "Cal" - CFI #24

Kc Crystal	Cycles Audio Frequency					
	100	200	500	1000	2000	3000
355	2.5	6.5	20	24	12	5
425	17	31	90	96	58	31
500	12	32	65	60	26	11
544	26	33	48	62	30	13
4135	7	24	60	64	26	9.5
4235	14	29	65	62	27	9.5

TABLE 6

Milliwatts Audio Output - Heterodyne Position - CFI #60

Kc Het	Kc SSG	Cycles Audio Frequency					
		100	200	500	1000	2000	3000
544	544	7	39	60	145	95	31
	1088	4.5	55	120	155	80	28
	1632	3.5	85	105	135	66	21
355	355	21	62	155	200	135	68
	710	7.5	55	190	210	110	31
	1065	3.5	55	100	135	70	25
4235	4235	1.5	13	32	50	25	9.5
	8470	.2	1.1	6.	8	4	1.7
	12705	.05	.4	2.1	2.7	1.3	.5

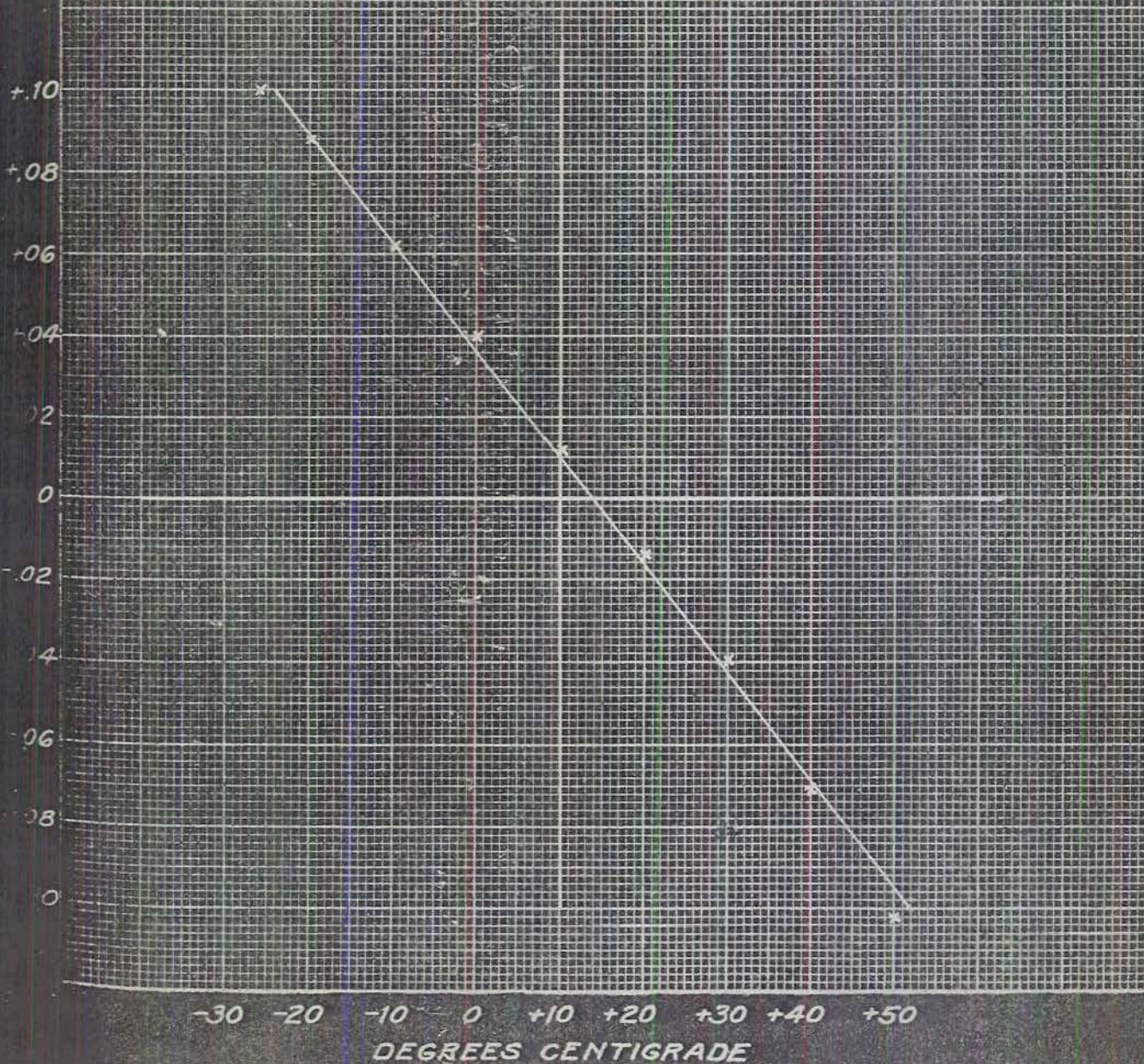
TABLE 9

Crystal Frequencies at +10°C.

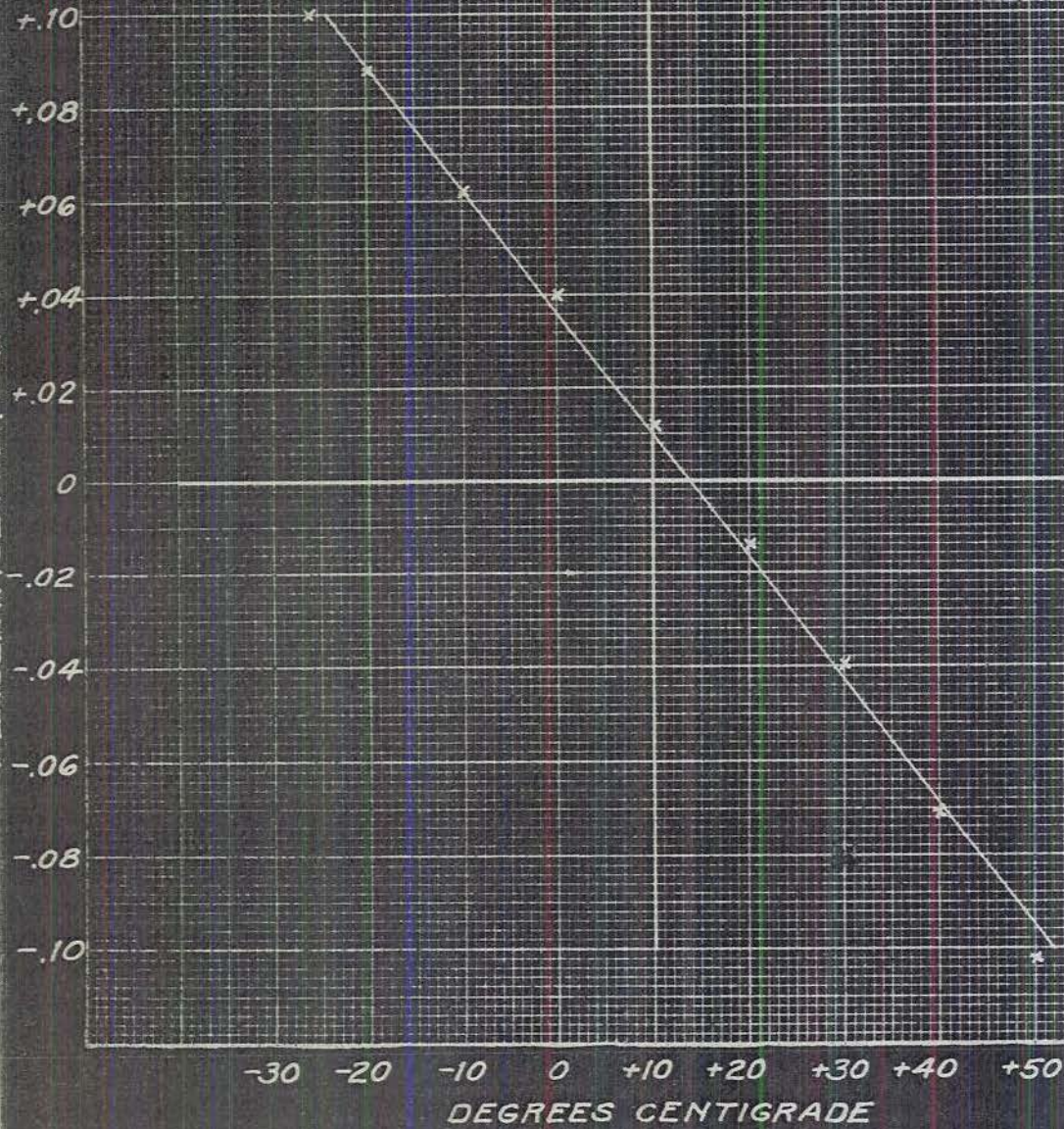
CFI #24

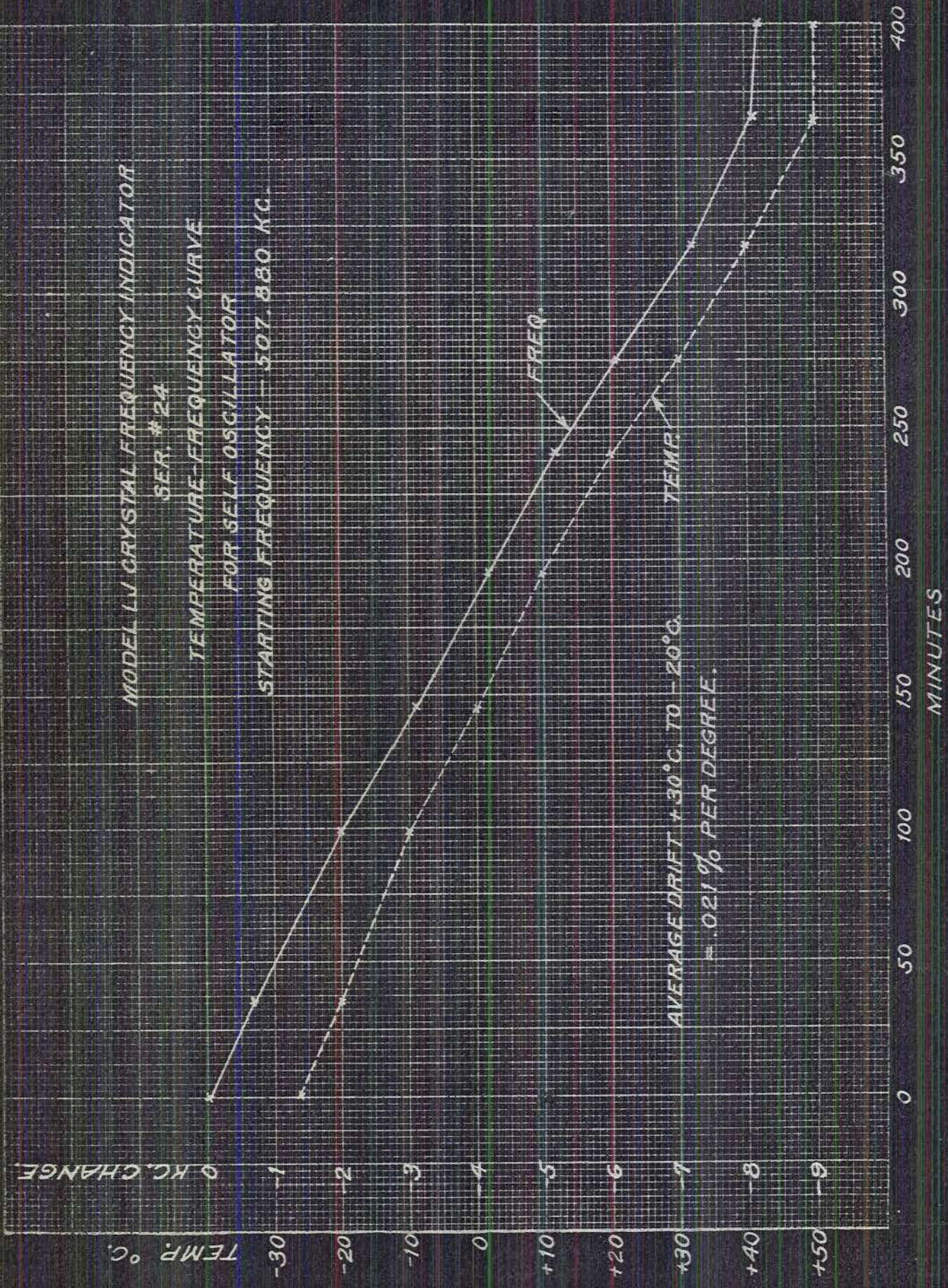
Crystal Kc	355	375	425	440	500
Measured Kc	355.012	375.055	425.175	440.038	500.053
% Deviation	.0034	.0149	.0401	.0086	.011
Crystal Kc	516	544	4135	4205	4235
Measured Kc	516.060	544.018	4136.1	4205.2	4235.3
% Deviation	.0116	.0033	.0266	.0048	.0071

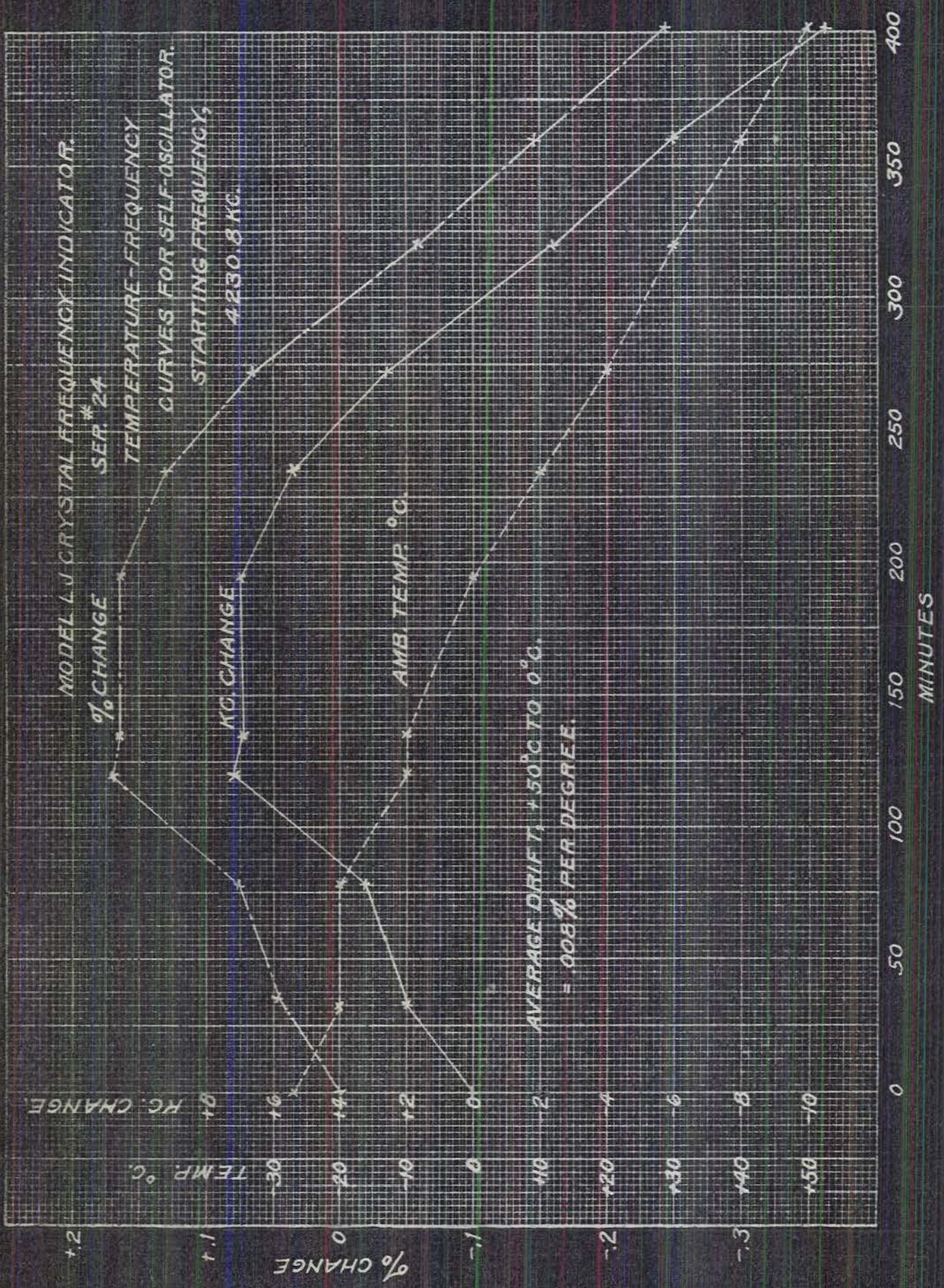
TEMPERATURE-FREQUENCY CHARACTERISTIC  
OF MODEL L-1  
CRYSTAL FREQUENCY INDICATOR,  
ASSIGNED FREQUENCY AT 110° C.  
CRYSTAL - 500 KC

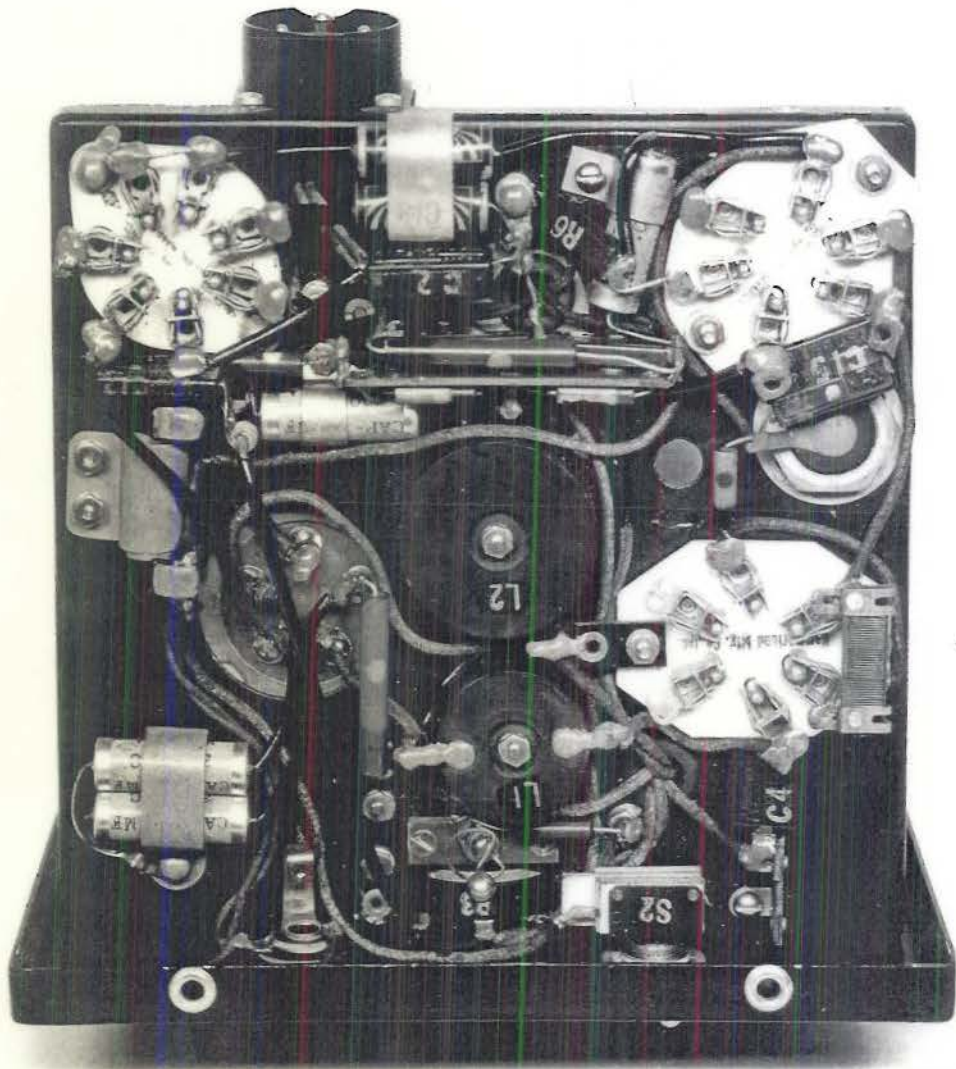


TEMPERATURE-FREQUENCY CHARACTERISTIC  
OF MODEL L-J  
CRYSTAL FREQUENCY INDICATOR,  
ASSIGNED FREQUENCY AT +10° C.  
CRYSTAL - 500 KG.





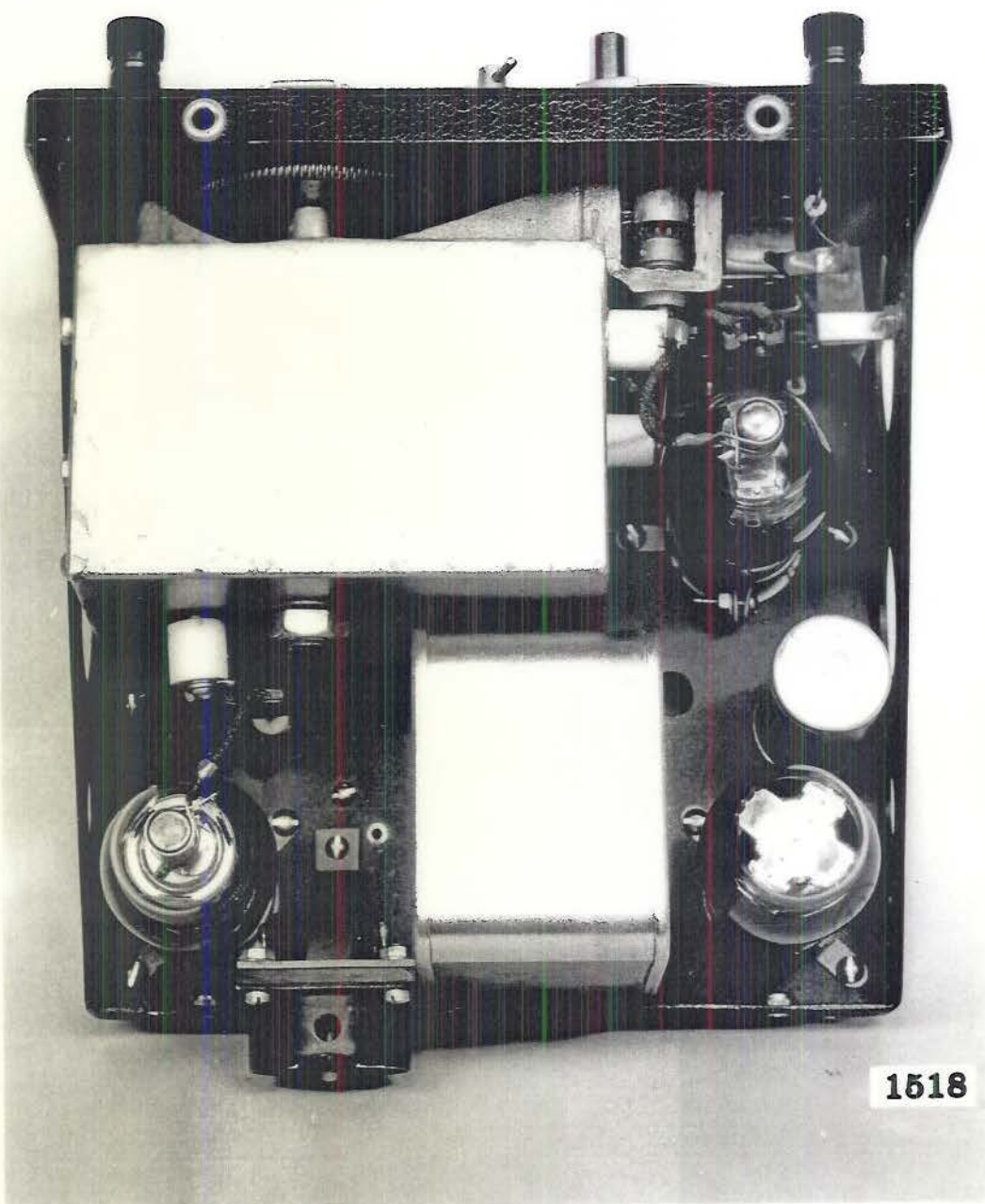




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NAVAL RESEARCH LABORATORY  
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PLATE 4



NAVAL RESEARCH LABORATORY  
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PLATE 5

copy

F42-1/NA6 (185)  
(Serial 36097)

U.S. NAVAL AIR STATION  
ANACOSTIA, D.C.

GEHH/dg

JUL 17 1936

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

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

References: (a) N.A.S., Anacostia, Report RT-2, dated 12 February 1935.  
(b) BuEng. ltr., NOS-32109 (3-30-W3) dated 14 August 1935, to  
N.R.L. with copy to N.A.S., Anacostia, D.C.

Enclosures: (A) N.A.S., Anacostia, "Comments on Revised Model LJ Frequency  
Meter", of 9 June 1936.  
(B) Photograph AN-34392, Rear view of original and modified units.  
(C) Photograph AN-34393, Bottom view of original and modified  
units.

1. Under authority of reference (b), representatives of the Naval  
Research Laboratory on 21 May 1936 delivered a contractor-modified model LJ  
equipment, Serial No. 60, for flight tests, and outlined verbally the  
procedure desired to enable most efficient cooperation with the Laboratory's  
ground measurement facilities.

2. The subject equipment was installed in O3U-1 airplane No. 8810  
on 26 May, 1936, in conjunction with a model GF-3 transmitting and RU-4A  
receiving equipment. The equipment was then tested on two flights, with a  
total flying time of 3 hours. Additional operating tests were conducted in  
the laboratory.

3. The following co-operative results were obtained during flight  
tests on 26 May 1936, the airplane with call letters 52R adjusting its  
transmitting frequencies with the revised LJ equipment in flight, while  
precision ground measurements on these transmissions were made at the Naval  
Research Laboratory; in addition, flight measurements were taken on several  
broadcasting stations of dependable known frequencies, by zero beating the  
LJ heterodyne against the broadcast carrier as received with the RU-4A  
equipment, in non-oscillating MCW position. The field strengths of the  
broadcasting stations selected represent widely different signal levels,  
being approximately 125 micro-volts per meter for WFIL, 1000 for WCAO, and  
100,000 for WMAL.

Transmitting Station:	Flight Measurement with LJ, kcs:	Ground Measurement at N.R.L., kcs:
52R	4235.0	4235.41 4235.38 4235.33

Appendix A, page 1.

F42-1/NA6 (185)  
(Serial 36097)

NAS ANACOSTIA, D.C.

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

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Transmitting Station:	Flight Measurement with LJ, kcs:	Ground Measurement at N.R.L., kcs:
52R	4385.0	4381.0 4381.3 4381.4
52R	6690.0	6681.36 6680.03 6680.86
52R	7535.0	7517.6 7518.3 7518.1
WMAL (630 kcs)	633.5	- -
WCAO (600 kcs)	601.6	- -
WFIL (560 kcs)	559.9	- -

4. The 4235 kcs measurements were taken directly against the crystal, which accounts for the relative accuracy. The 6690 and 7535 kcs measurements employed the heterodyne oscillator in a range considerably removed from the nominal crystal check points, and are not of satisfactory accuracy. Very much improved accuracy in this region was subsequently found obtainable by employing additional, less removed crystal check points, found to be present on frequencies equal to one and one-half times the nominal crystal frequencies.

5. The flight tests showed the general operation of the equipment, previously reported unsatisfactory under reference (a), to be improved to such an extent as now to render the equipment quite useful. Detailed comments upon performance, remaining defects, and recommendations are contained in Enclosure (A), which was prepared for the Bureau of Engineering conference on subject equipment held on 9 June 1936.

6. Enclosures (B) and (C) show rear and bottom views, respectively, of the interior of an original and of a modified unit, the latter being at the right in both views.

7. It is recommended that the existing LJ equipments be modified similarly, with additional compliance with items B, C, and D of Enclosure (A), and correcting, as far as practicable, the remaining minor defects outlined in Enclosure (A). The resulting equipment, while not measuring up to the latest standards and requirements for this class of apparatus, should prove of considerable value, especially for its intended use aboard patrol airplanes in conjunction with model GO radio installations.

F42-1/NA6 (185)  
(Serial 36097)

NAS, ANACOSTIA, D.C.

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

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8. For purposes of information and reference, it is requested that this Station be supplied with two copies of the Laboratory's report, when issued, pertaining to the subject equipment.

/s/ V. C. GRIFFIN

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Copies to: BuAero. (2)  
BuEng. (1)  
N.A.F. (1)

9 June 1936.

COMMENTS ON REVISED MODEL LJ FREQUENCY METERS

Defects Corrected:

1. Audio output is now satisfactory. During flight tests able to adjust M.O. of GF-3 transmitter, even with P.A. deresonated, in 8 M.C. band, either against heterodyne oscillator or direct against Crystal harmonic; and to 9050 kcs, against het. osc. Audio output is now sufficient to provide good inter-harmonic crystal calibration points in 6, 9, and 12 MC bands, where badly needed to avoid excessive error.
2. Excessive mechanical backlash plus excessive width of zero beat zone, which was about 20 degrees, has been corrected, zero beat zone now only 1 to 2 divisions.
3. Model tested did not exhibit previously required excessive mechanical correction range of more than 1/2 turn (or 50 divisions); only about 15 to 20 divisions of correction were ever required.
4. All crystal check points required by spec's have been marked on chart. (Additional inter-harmonics still desirable)
5. Rubbing of crystals against bottom of case has been eliminated.
6. Un-plated crystal coupling condenser replaced by fixed molded unit.
7. Binding posts now held secure by high-grade phenolic spacers.

Following defects still exist:

- a. Poor accuracy around 7500 kcs.
- b. R.F. attenuator near highest level shifts frequency somewhat.
- c. Crystals still difficult to see and not protected from spray.
- d. Tube clamps employ loseable nuts instead of threaded inserts.
- e. No tube types marked near the tube sockets.
- f. Serial numbers shown on case only; not on panel, chassis or chart.
- g. No revised circuit diagram or revised instruction book supplied.

RECOMMENDATIONS:

- A. In view of excellent correction of main defects, now rendering equipment quite useful especially for patrol plane squadrons, recommend alteration of remaining LJ equipments, with addition of following:
- B. Furnish new circuit diagrams and revise instruction books.
- C. Mark front panel externally, and calibration chart holder, prominently with Serial No.
- D. Add intermediate crystal check points to obtain required accuracy in 6, 9, 12, mc bands.

ENCLOSURE (A)