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NAVY DEPARTMENT

BUREAU OF ENGINEERING

REPORT ON

Test of the Preliminary Model LD-1 Combined Heterodyne Frequency Meter and Crystal Controlled Calibrator

Range 100 - 5000 kcs
for A.C. Operation

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
Washington, D.C.

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RESULTS OF TESTS

6. As requested in par.3 of ref.(a), comments will be made following the governing specifications ref.(b), paragraph by paragraph, with the numbering in the remainder of this division of this report corresponding to that used in these specifications.

I. INTRODUCTORY

1-1 through 1-4. The requirements of these paragraph stating the general nature and purpose of the equipment are met.

II. GENERAL

2-1. No comment.

2-2. Indicating instruments, fixed capacitors, etc., appear to be of the approved types. Commercial type 236 and 237 RCA tubes are used, as approved. See ref.(a), par.2(e).

2-3. The equipment is ruggedly constructed.

2-4. The workmanship is of the best.

2-5. Facilities for testing an equipment of this size at ambient temperatures of -1° to 45°C and at excessive humidities are not available. The equipment would apparently operate satisfactorily at an ambient temperature of 50°C except as to temperature control accuracy for short periods since it operates continuously at a controlled temperature of about 45°C without damage. It operates satisfactorily at an ambient temperature as low as 5°C.

2-6. All parts are protected from moist sea atmosphere as far as is practicable.

2-7 and 2-8. The use of iron, steel, and wood is reduced to a minimum.

2-9. The design of the electrical circuits and controls appears to be satisfactory.

2-10. Ample provision is made for ventilation and cooling.

2-11. The equipment was not heated above about 120°F, at which temperature no evidence was observed of compound flowing from capacitors or other units. Some fixed capacitors are mounted inverted while others are not.

2-12 through 2-14. These specifications are fulfilled.

2-15. The average change in heterodyne oscillator frequency due to inclining the equipment up to 45° was not greater than .002% except

when tilted backward when it was about 0.005%. However, at an angle of 30° from the normal, the average frequency change was less than 0.002% for all directions of tilt. This frequency stability is considered unusually good.

The operation of the crystal when tilted was not satisfactory, due both to the magnitude of the frequency change while tilted and also to the tendency for the crystal to stop oscillating when the equipment was inclined above about 20° in certain directions. The results observed are tabulated below.

Angle of tilt	% Crystal Freq. Change While Tilted For'd	Back	Right	Left
10°	0.002	0.005	0.002	0.005
15°	0.006	-	-	-
20°	Oscs. stopped	0.008	0.012	Oscs. stopped
30°	"	0.015	-	"

When the crystal stopped oscillating as noted, it usually was necessary, after the unit was restored to normal position to jar the equipment slightly to start oscillations.

In all the tilting tests except one, the crystal frequency returned to within about 0.001% of its previous value when restored to the normal position. In this one instance (the 20° right tilt above), the frequency was off 0.004% until the equipment was jarred, when the frequency again returned to its correct previous value.

2-16 and 2-17. The effect of gun fire cannot be simulated. Lock washers are used as required. The whole equipment is provided with a shock-proof type of mounting at the back as well as at the base and from the tests applied, it appears well designed to withstand vibration as encountered on shipboard. The crystal holder cannot be dislodged by shock. The vacuum tubes have rigid mountings. It is not known whether the tubes will function properly when subjected to the conditions of gun fire.

2-18. The circuits and operation are as simple as possible.

2-19. All controls and instruments are located on the front panel and are properly marked.

2-20. No body capacity effects are present.

2-21. All electrical instruments are of the 2-1/2" flush type.

2-22 and 2-23. Suitable name plates are affixed to the units and the operating voltage, frequency, etc., are marked thereon.

2-24. No spare parts were required for test.

2-25. The equipment has been operated continuously for a number of days without damage. Comments on accuracy will be given later.

2-26. The frequency, etc., increases with dial setting.

2-27. See Par.3-11.

III COMPONENT UNITS, CONSTRUCTION, PURPOSE, etc.

3-1. The equipment consists of a frequency measuring unit and a power unit with necessary accessories.

3-2. Either unit may be mounted above the other.

3-3. All power for operation is obtained from a 110 volt, 60 cycle source and a power cable is provided.

3-4. The cases of the units may be readily clamped together.

3-5. The equipment is complete and may be used for measuring a transmitter frequency or adjusting a receiver to any frequency between 100 and 25,000 kcs and the measuring unit can be recalibrated from the crystal every 20 kcs to 5,000 kcs.

3-6. A suitable black finish is used on the exterior.

3-7. All controls are located on the front panel.

3-8. The panels of the two units are perpendicular and lie in the same plane.

3-9. Suitable knurled screws are provided for securing the panels to the cases.

3-10. All circuit connections are made to the units when they are inserted into their cases.

3-11. The dimensions of the equipment are:

Height	33-1/4"
Width	17-1/4"
Depth	14-1/2"

The depth includes the shock-proof mounting device at the back and also the controls on the panel. The total weight of this model is 190 pounds. This overweight of 35 pounds appears to have been necessary to attain the unusual degree of heterodyne oscillator frequency stability with tilting, as mentioned in par.2-15, and also the overall ruggedness of this equipment. The variable condenser end plates are of steel and are perhaps 1/2" thick as well as the blocks by which they are clamped to the 1/4" panel. It is believed that the added weight is justified by the advantages resulting therefrom.

3-12. The equipment is properly shielded to prevent errors due to undesired couplings. An output transformer with taps for high or low impedance telephones is provided (which is satisfactory with both types of telephones). No determination of the presence of an internal static shield could be made.

3-13. The crystal compartment temperature is controlled to well within $\pm$ 0.1°C of 50° $\pm$ .5°C, except that the operating temperature rose on several occasions to 50.6°C. The cause for this appeared to be an imperfect contact in the thermostat circuit and operation was satisfactory after the Fahenstock clips to which the thermostat wires are connected were soldered to the screws which secure them.

The cabinet thermometer read below scale at perhaps 35°C at an ambient temperature of about 5°C with the auxiliary heater on and all tubes off. Ambient temperature during the tests varied only between 5° and 28°C.

3-14. Suitable fixed mercury thermostats are used. For the cabinet temperature control two thermostats in parallel are provided, one a 50° thermostat mounted on the inner shield of the cabinet in the compartment above the heterodyne oscillator (the strip heaters are mounted on the outside of this shield); the other thermostat has an operating point of 45°C and is mounted near the tubes toward the center of the same compartment. The cabinet thermometer is mounted in the same metal block with this thermostat.

An auxiliary heater is provided for rapidly bringing the cabinet up to operating temperature and for use when the ambient temperature falls below about 15°C. This heater is turned on manually.

A thermal fuse is included to protect against excessive temperatures in case of failure of the automatic temperature control system. The operating temperature of this fuse as mounted was not determined.

While these specifications do not require thermostats and thermometers of any given dimensions, it may be of interest to note that the thermostats furnished are 1/4" longer on the horizontal and 3/16" shorter on the vertical leg than the dimensions shown on sheet 12A

of specifications RE 13A 486. A thermostat conforming to the above drawing could be used in this model if the thermostat slot in the wood of the crystal box were recessed 1/4" more in the vertical direction.

The crystal thermometer is quite short, 3-3/8" on the horizontal and 2-13/16" on the vertical leg. The cabinet thermometer is 5-3/8" on the horizontal and 4-11/16" on the vertical leg, or about 5/8" longer in both dimensions than that shown on sheet 10A of specifications RE 13A 486, and could be replaced by one conforming to this drawing.

3-15. An emergency plug system is supplied to permit the operation of the equipment from a 6 volt and a 150 volt battery and heat supply from the 115 volt D.C. line. This emergency apparatus is quite satisfactory. See par.5-6 and 5-7.

3-16. A binding post is provided for grounding the case of the equipment and a .01 mfd capacitor rated at 700 volts is connected from each side of the supply line to the case.

3-17. The switch contacts have given trouble-free operation during the tests of the equipment and they appear to conform to the requirements of this paragraph. The manufacturer states that they are of cadmium plated phosphor bronze and brass.

3-18. Connection can be made to but one switch position at a time. It was observed, however, that when turning the band or coil switch from M to N or from O to N while the heterodyne oscillator was operating, some spurious oscillation occurred when the dial setting was between 1300 and 2000 divisions which was noticeable by a high pitched note in the phones (3 or 4 kcs). This condition would not occur if the tubes heated while the switch was on position N, but only when turned to this point, as mentioned. This note rendered use of the equipment impossible. It occurred with the crystal and multi-vibrator off or on and regardless of the audio amplifier gain. If the condenser is tuned below 1300 or above 2000 divisions this trouble ceases and does not recur at any setting.

3-19. Access doors are provided in both units as required.

3-20 and 3-21. All controls are suitably marked with lettering of the required size.

3-22. Indicating meters, thermometers and power and heat indicator lamps are provided.

3-23 through 3-25. Satisfactory verniers are provided where required and the main and vernier tuning dials are marked to divide the scale into 2500 divisions with 100 vernier divisions per main division.

3-26. The transformers could not be examined for type of waterproofing without damaging them.

3-27. Parts are as accessible for replacement as is practicable in such an equipment.

3-28. The overall maximum power input into both the units is approximately 390 watts, except that when the auxiliary heater is on together with all tubes and both heaters, the power is 475 watts. This power consumption would occur only when the ambient temperature is below 15°C.

3-29. The calibration data are typed on a long narrow strip of paper which is mounted in the manner of a scroll in a small container which is to be attached to the panel of the equipment. (Ref.(e), enclosure par.1) By means of a knob, any portion of the chart may be rotated so as to be visible through a window in the container. Columns are provided giving frequencies every 20 kcs throughout the range of the equipment (100 - 5,000 kcs) as well as dial settings, coil switch positions and kilocycles per division to be used in interpolation.

This form of calibration is quite convenient but, as submitted, the calibration is not considered satisfactory due to the fact that the assumption of a constant value of kilocycles per division over a 20 kc spread leads to errors in frequency measurement below about 2,000 kcs much larger than permitted. See comments under 4-13.

IV MEASURING UNIT

(a) Heterodyne Frequency Meter.

4-1. The frequency meter covers the range 100 to 5,000 kcs by the use of seventeen frequency bands.

4-2. The change of frequency with 6% change in supply voltage is negligible, and that due to changing tubes is considered satisfactorily low. The compensating condenser is available to correct for the tube effect.

Both the frequency meter and the audio oscillator employ the voltage compensated type of circuit.

4-3. The frequency drift of the heterodyne oscillator after the tubes have been turned on is in some observed instances within the allowed amount, while in others it exceeds this value. The drift does not "taper off" after 20 or 25 minutes of operation quite as required, and the greatest discrepancy is found in the last drift period as shown in the table below. The percent drift is given for consecutive 5 minute periods, the first period beginning 5 minutes after potential had been applied to the tubes.

Maximum frequency drift in % for 5 minute intervals

	Observed		Allowed
	Run 1	Run 2	
at 120 kcs:			
5 minutes	.0017	.0058	.014
10 "	.0033	.0017	.0067
15 "	.0017	.0017	.0017
20 "		.0008	.0008
at 800 kcs:			
5 minutes	.0035	.0038	.0025
10 "	.0033	.0063	.0023
15 "	.0028	.0024	.0015
20 "		.0032	.0009
at 4500 kcs:			
5 minutes	.0012	.0016	.0021
10 "	.0005	.0016	.002
15 "	.0009	.0024	.0015
20 "	.0002	.0056	.0005

These observations were made at an approximately constant ambient temperature of about 23°C

It is considered possible that some of this frequency drift is due to temperature rise in the heterodyne oscillator circuit compartment as a result of the operation of the ten tubes. On several occasions it was observed that the cabinet thermometer reading increased 2°C (from about 42° to about 44°C) during the first 25 minutes of tube operation. Whether the temperature of the heterodyne compartment which is below the tube compartment and separated from it by a metal shield can be affected by this rise is not known. But it is evident that the frequency drift varies with the cabinet heater cycle as shown graphically on Appendix 1, where the frequency is .0025% above or below a mean value, depending upon the portion of the cabinet heater cycle at which the observation is made.

4-4. From the slope of the kilocycles per division curve (appendix, plate 3) the usable portion of the condenser range is between 200 and 2250 divisions. On this basis, sufficient overlap does not exist in this model between these ranges: B-C, G-H, H-I, J-K, K-L, N-O, and Q-R. The frequency corresponding to 2250 divisions on H occurs at 35 divisions on I.

4-5. See comment on pars.3-5 and 4-2.

4-6. A suitable telephone jack is provided and in parallel with it a shielded outlet for a cable to the transmitter room. It is believed that two jacks would be preferable to the present arrangement, although this specification is complied with.

4-7. It is possible both to set an oscillating receiver and to measure the frequency of a received signal, as required, without damage, blocking, or loss of accuracy due to the operation of a transmitter in the same compartment with the equipment. No undesired effects were noted with the unit within five feet of a one k.w. transmitter operating at full power.

4-8. The equipment delivers many times the R.F. voltage required, for example, about 5,000 microvolts at 20 mcs, on the fourth harmonic of the heterodyne oscillator. A two position switch is provided to vary R.F. output, one position to be used below 5,000 kcs and the other, above.

The audio output on multiples of 100 kcs to 5,000 kcs is .05 milliwatts or more at 1,000 cycles, but at 350 cycles the output is not of this value above 3600 kcs. Between 3600 and 5000 kcs the audio output power at 350 cycles lies between .045 and .03 milliwatts as determined by voltage measurements across 20,000 ohms. The audio output on all multiples of 20 kcs, involving multivibrator harmonics, is .05 milliwatts or more at 1,000 cycles up to 3,000 kcs and at 350 cycles to 2,800 kcs. It is believed, however, that the audio output is sufficient for satisfactory use of the equipment.

A gain control is provided on the audio amplifier. The actual DB gain could not be measured in the assembled equipment. The calibrator coupling control is also a means of varying the audio output.

4-9. The calibration curve is linear, as required.

4-10 and 4-11. A compensating condenser is included which can be adjusted by unscrewing a hinged cover and using a screw driver, without any damage.

4-12. The tuning condenser is of rugged construction and the coils are well constructed and treated with some waterproofing compound. The equipment appears to be designed to minimize the effects of aging, hard usage, and climatic conditions.

4-13. With the calibration as given (only 20 kc points on all coils) the frequency meter cannot be set to an assured accuracy of 0.005% at all frequencies on frequency bands A to O (100 - 2600 kcs) but can be on bands P to R (2600 - 5000 kcs). But if a sufficient number of additional calibration points are given (which are available in the equipment and of satisfactory beat note strength) the equipment can

meet this specification above about 200 kcs, and below 200 kcs the assured accuracy is of the order of 0.01% if calibration points are given every 4 kcs.

The following table gives the % error observed in the measurement of certain frequencies. No backlash error is involved as all settings were made while increasing readings. No frequency drift with time is involved beyond that occurring in less than two minutes. The equipment had been operating normally a sufficient length of time before observations were made. The errors noted are those resulting from the assumption of a constant value of kilocycles per division along the condenser scale between adjacent 20 kc settings.

Freq. Band	Frequency Actual	Meas'd	% Error
A	110	109.79	-.19
E	250	249.85	-.06
E	270	269.93	-.028
H	510	509.88	-.023
J	750	749.94	-.008
J	753.33	753.23	-.013
J	755	754.89	-.013
J	770	769.92	-.010
J	786.67	786.67	.000
M	1570	1569.85	-.009
N	1850	1850.06	+.003
N	1930	1929.82	-.009
O	2230	2230.02	+.0009
O	2250	2249.85	-.007
P	2870	2869.93	-.002
P	2890	2890.03	+.001
Q	3530	3529.87	-.0037
Q	3550	3549.92	-.0023
R	4470	4469.96	-.001

The following table gives what is believed to be the maximum separation of calibration points in kilocycles in order to meet the accuracy of .005%.

Freq. Bands	Max.Freq.Diff. between calibration points for .005% accuracy.
A to C	less than 4 kcs (error with 4 kc points may be 0.01%)
D to E	4 kcs
F to G	5 kcs
H to J	6.67 kcs
K to O	10 "
P to R	20 "

Where points 4 kcs apart are given, harmonics of the heterodyne oscillator up to the fifth are used, beating with multivibrator harmonics. These beat notes are considered satisfactory where indicated in the preceding table as necessary; but it is not believed that on bands A to C (100 to 200 kcs) heterodyne harmonics of a higher order than the fifth are desirable for use.

By using these points the assured accuracy on bands A to C is 0.01% as previously stated.

4-14. See par.3-12 for comment on the output transformer.

4-15. A coupling post is provided together with a switch for increasing the R.F. output for use on harmonics of the heterodyne frequency meter.

4-16. A detector and 2 stage audio amplifier are provided.

4-17. The audio output of confusing beat notes is believed to be sufficiently low.

4-18. An audio oscillator having a frequency of about 435 cycles is provided and either the zero beat or matched tone method may be used in frequency measurement.

4-19. An auxiliary pair of dials which may be used to read the zero beat setting direct when the matched tone method is used, are provided in the form of rings mounted concentric with and outside of the main and vernier tuning dials. These are described in ref.(a), par.2(f). The original pair of dials was replaced by the contractor at this Laboratory due to binding after the heat had been applied to the cabinet for several days. See ref.(e) enclosure, par.(6). The improved dials also have similarly been bound so that one can be turned only with difficulty and the other one not at all. These uric formaldehyde dials lie against the heated panel of the unit with an auxiliary dial forming a snugly fitting ring around a tuning dial. Whether the binding is between these concentric dials or between the auxiliary dial and the panel is not known.

(b) Calibrator.

4-20 through 4-22. The unit contains a 100 kc crystal controlled oscillator and a 20 kc multivibrator which is controlled at one-fifth the crystal oscillator frequency with an adequate range of control. The adjustment of the multivibrator is simple.

4-23. The crystal frequency is within .001% of 100 kcs. See also par.2-15.

4-24 and 4-25. The crystal was not examined as the holder was sealed.

4-26. The holder is designed to minimize the effect of dust and moisture.

4-27. The design of the holder is not such as to insure against changes in frequency due to the roll of a ship. See comment on par.2-15.

4-28. A midget variable condenser shunted across the crystal is the only control on this circuit and the frequency change possible with this is 0.007% in either direction from a mean value.

4-29. A calibrator coupling control is provided as required.

4-30. Signal voltages from the equipment are satisfactory as well as the shielding and the coupling provided.

V. POWER UNIT

5-1. The power unit contains all essentials for operation of the equipment from a 110 volt, 60 cycle source.

5-2 and 5-3. The maximum power required does not exceed 490 watts. The average is less than 300 watts. See also par.3-28.

5-4. A voltmeter is connected across a part of the primary of the power transformer so as to read 85 volts at normal line voltage, with a red line on the meter at this point. A line voltage adjuster is provided with a ± 10% range.

5-5. An insulated cable is provided for connecting the power unit to the power supply. In the back inside of both the power and the measuring unit cases is mounted a strip carrying 15 spring plugs into which sockets on the units engage when the units are pressed into the cases. These sets of plugs are connected by insulated wires which pass through two metal conduits mounted on the outside of the cases. (See rear view picture.)

5-6 and 5-7. For emergency D.C. operation the above mentioned plug strips and conduits with the protecting metal covers for the strips are removed in one piece and are replaced by a similar emergency plug system wired for use with a 6 volt and a 150 volt battery. By shifting two resistor jumpers the relays are operable from the 110-

115 volt D.C. line and by removing a line fuse the transformer circuit is opened. The D.C. line is now applied in place of the A.C. supply.

During emergency D.C. operation, the heterodyne and mixer tube filaments are heated unless the A battery is removed since no switch is provided to open these circuits.

The holes in the protective cover of the D.C. emergency plug system for clamping it to the cabinets are not located accurately so that only a few of the securing screws can be used.

5-8. The power unit is removable from its case after the power cable has been pulled out of its socket.

5-9. A main heat power switch and a measuring unit power switch with indicator lamps on the panel are provided.

5-10. Both sides of the A.C. supply line are fused.

5-11. No extreme humidity or temperature tests were conducted on the power unit.

5-12. The power unit is suitable for use on a 110 or a 115 volt, 60 cycle line with ± 5% variation.

VI SPARE PARTS

6-1 and 6-2. The submission of spare parts was not required.

VII DATA REQUIRED

7-1. No comment. (Data to be submitted with bids.)

VIII MANUFACTURER'S DRAWINGS AND INSTRUCTION BOOKS

8-1 through 8-5. A preliminary instruction book with wiring diagrams of the complete equipment including installation drawings was submitted. Instructions are given on installation, operation, locating troubles, and theory of operation. A parts list is included.

The text of the instruction book is considered satisfactory in general. It is presumed that a table of contents will be inserted in the final book and that it will be proof read for errors.

The following comments on the preliminary book are made:

(1) On page 4, tube type should be 236 instead of 238.

(2) All mention of the color of the dials and their lettering should be made to conform to the type finally used.

(3) The first part of par. 2 on page 8 should be clarified.

(4) On page 8, par.1, the sign in the numerator of the fraction should be "-" instead of "=".

(5) On page 9 the equation near the top should be

$$S_x = S_1 + (f_o - f_1)\left[\frac{f_2 - f_1}{S_2 - S_1}\right]$$

(6) On page 9, in the equation near the bottom, S_o should be S_x and f_x should be f_o.

(7) On page 14, bottom, and page 15, top, the words "twice" and "half" should be interchanged.

(8) On page 18, pars.B, 3, and 5, instructions are given for making matched tone settings on opposite sides of zero beat by turning the tuning control down in one case and up in the other.

Inasmuch as the setting for a given frequency varies depending on the direction of rotation of the control from zero to 3 divisions at different points on the dial, it is believed that instructions for rotation in one direction (up) for all settings should be given.

The "backlash effect" varies in a nearly linear relation with condenser setting from 200 to 2200 divisions. At about 1600 divithere is no error. Below this setting the difference in setting with direction of rotation increases gradually to about 3 divisions at around 200 divisions with settings higher when rotating counterclockwise, while above 1600 divisions the difference increases to about 2, with the counterclockwise settings lower than the clockwise settings for the same frequency. A split gear with spring tension engages the worm, and the average backlash effect was observed to be somewhat greater after the contractor had replaced the original spring with a stronger one.

IX TESTS.

9-1. In summarizing, the equipment complies with all items of the specifications as far as could be determined except the following:

2-15, operation of the crystal with tilting.

3-11, The equipment is overweight by about 35 pounds.

3-13, the cabinet thermometer registers below 40°C in an ambient temperature of 5°C. This is not considered to be serious, since the crystal temperature remained constant.

3-18, spurious oscillation when switch is thrown to position N, if the condenser is set between 1300 and 2000 divisions.

4-1, insufficient overlaps. See comment also under 4-4.

4-3, heterodyne oscillator drift.

4-8, low audio frequency output at 350 cycles over a small part of the range. It is, however, believed that the equipment is satisfactory in this respect.

4-13 and 3-29, frequency measuring accuracy not within 0.005% at all points, and calibration points spaced 20 kcs apart are not sufficient below band P with this model.

4-19, improved auxiliary dials bind.

RECOMMENDATIONS

7. The following minor changes are recommended.

(a) The Fahenstock clips should be soldered to their screws, unless replaced by telephone tip plugs.

(b) Both the A.C. and D.C. plug systems would be more easily replaceable if the top were so labeled on the back of the protective cover of these parts.

(c) Unless backlash effect can be reduced to 0.5 divisions at all settings, the instructions should direct clockwise rotation of the tuning control for all settings.

(d) The two small plates indicating the resistor links to be shifted for D. C. operation can be made much more easily visible by being moved very slightly.

The small changes mentioned in enclosure to ref.(e) are acceptable in principle. It will be noted, however, that the new auxiliary dials put on the model were not satisfactory.

CONCLUSION

8. Except for the limitations mentioned in par.9-1, with respect to paragraphs 2-15, 3-18, 4-1, 4-3, 4-13 and 4-19 of the governing specifications, the equipment appears to be quite suitable for Naval use for the purpose for which it is intended.

FREQ. DRIFT TESTS OF LD-1 HETERODYNE FREQ. METER

— 800 KCS —

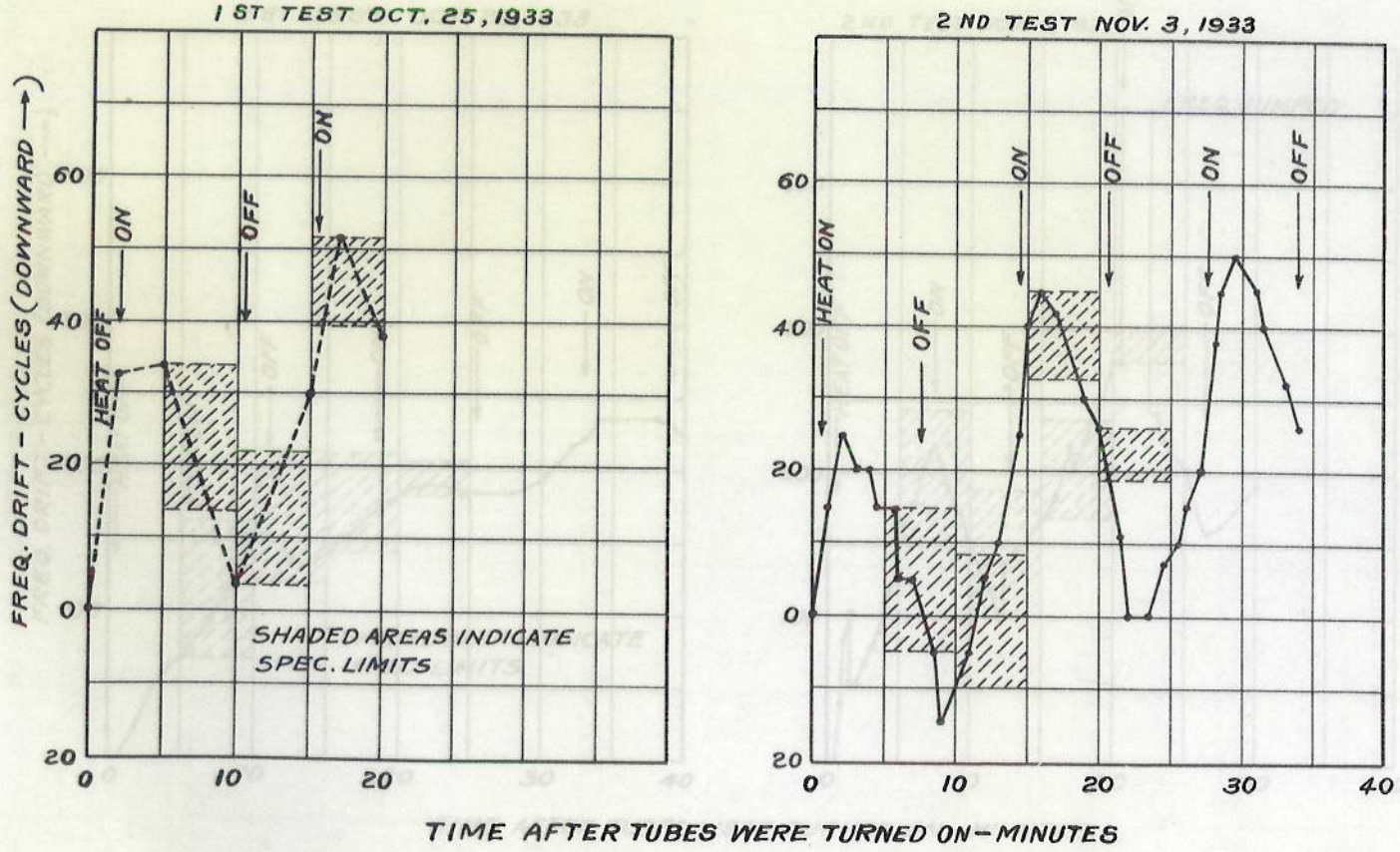


PLATE 1

FREQ. DRIFT TESTS OF LD-1 HETERODYNE FREQ. METER

— 4500 KCS. —

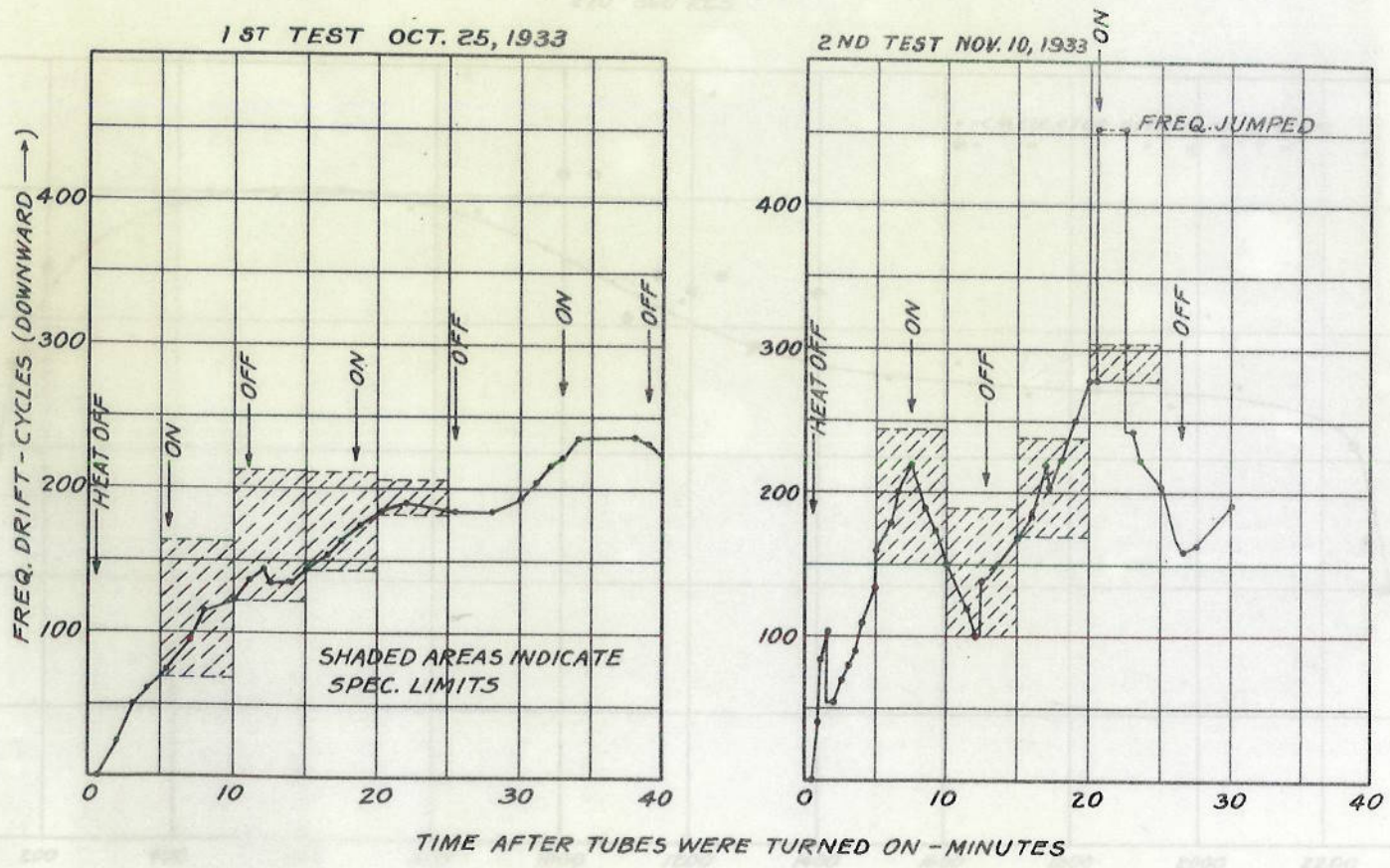


PLATE 2

LD-1 HET. FREQ. METER

KCS/DIV. CURVE FOR COIL J

670-860 KCS

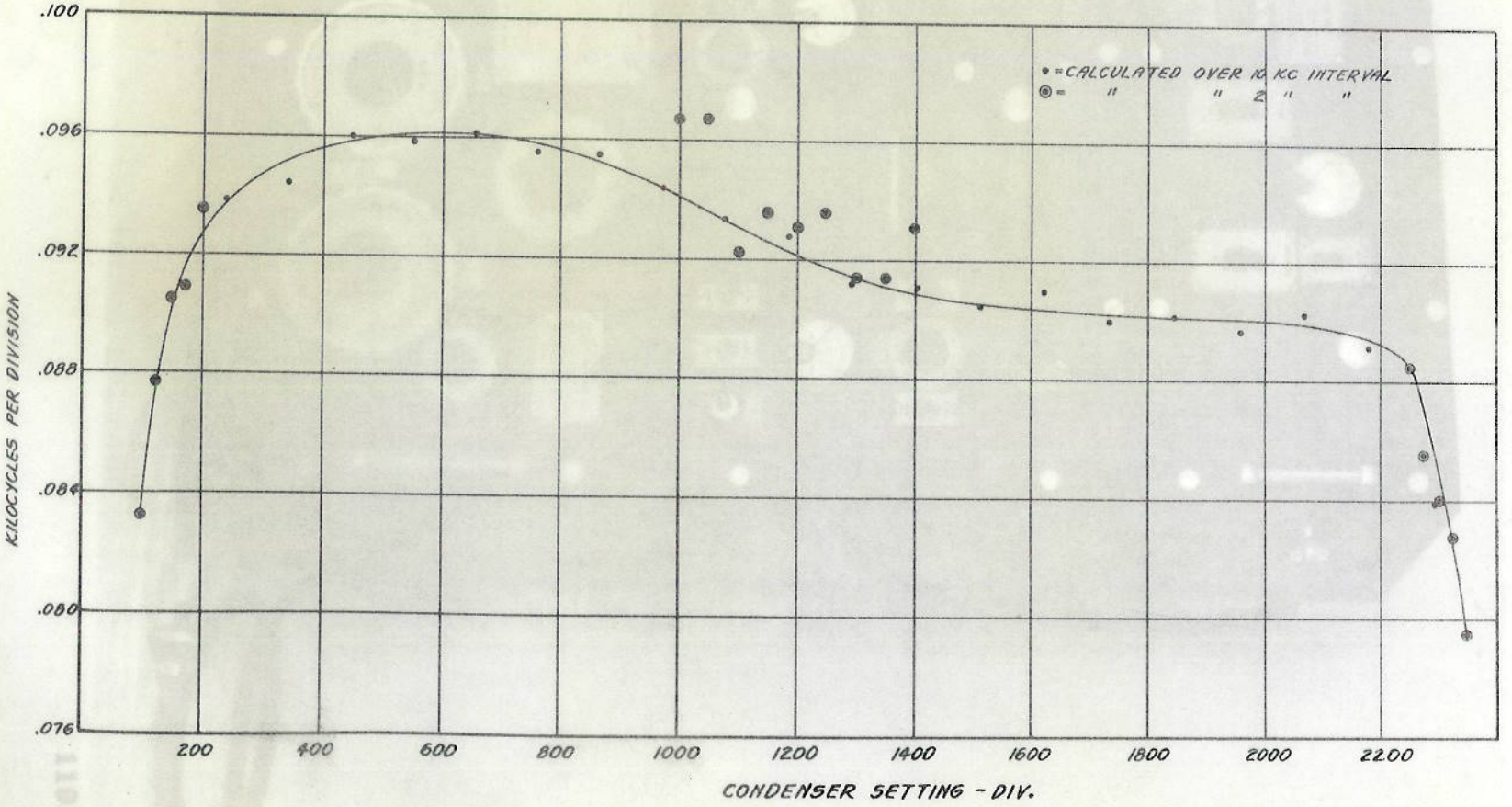
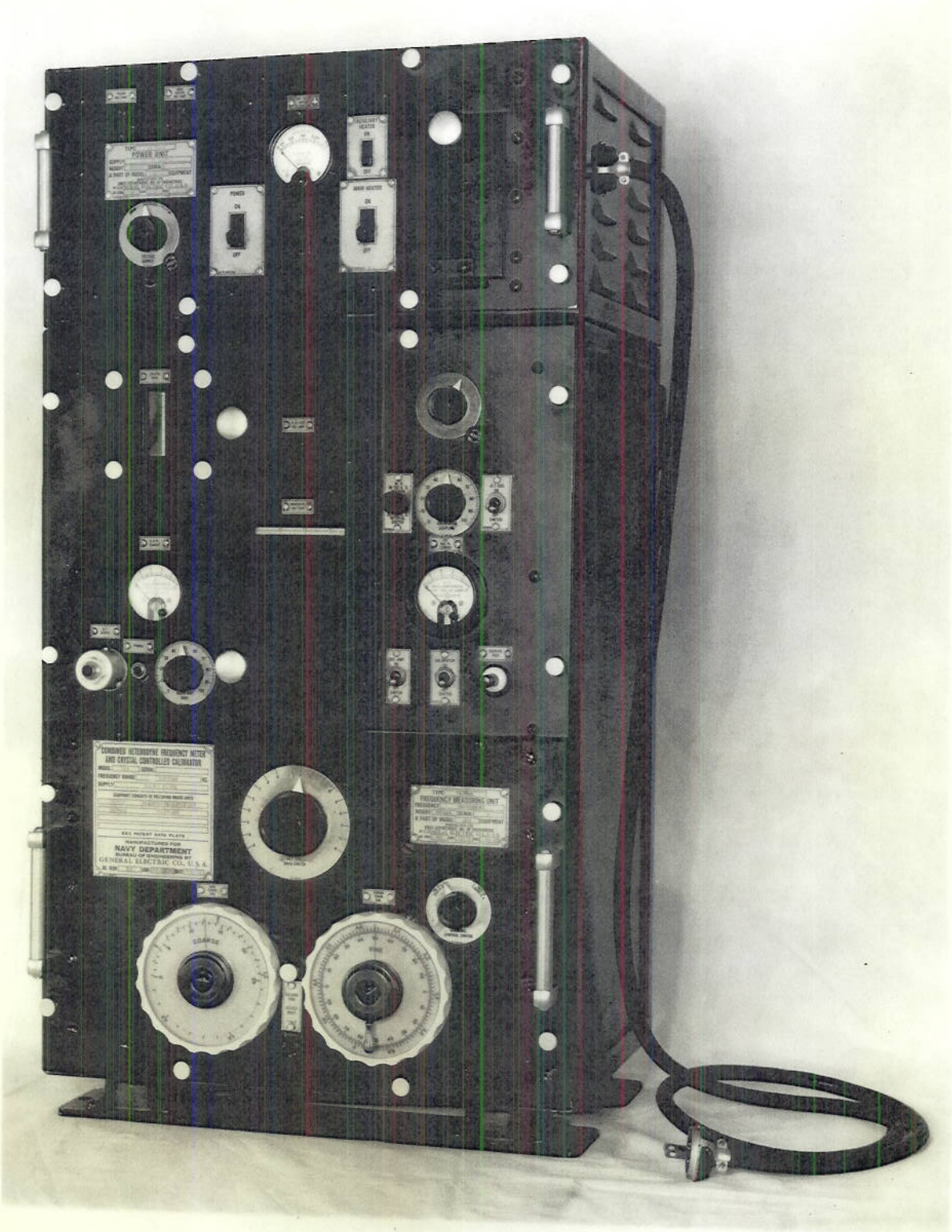


PLATE 3



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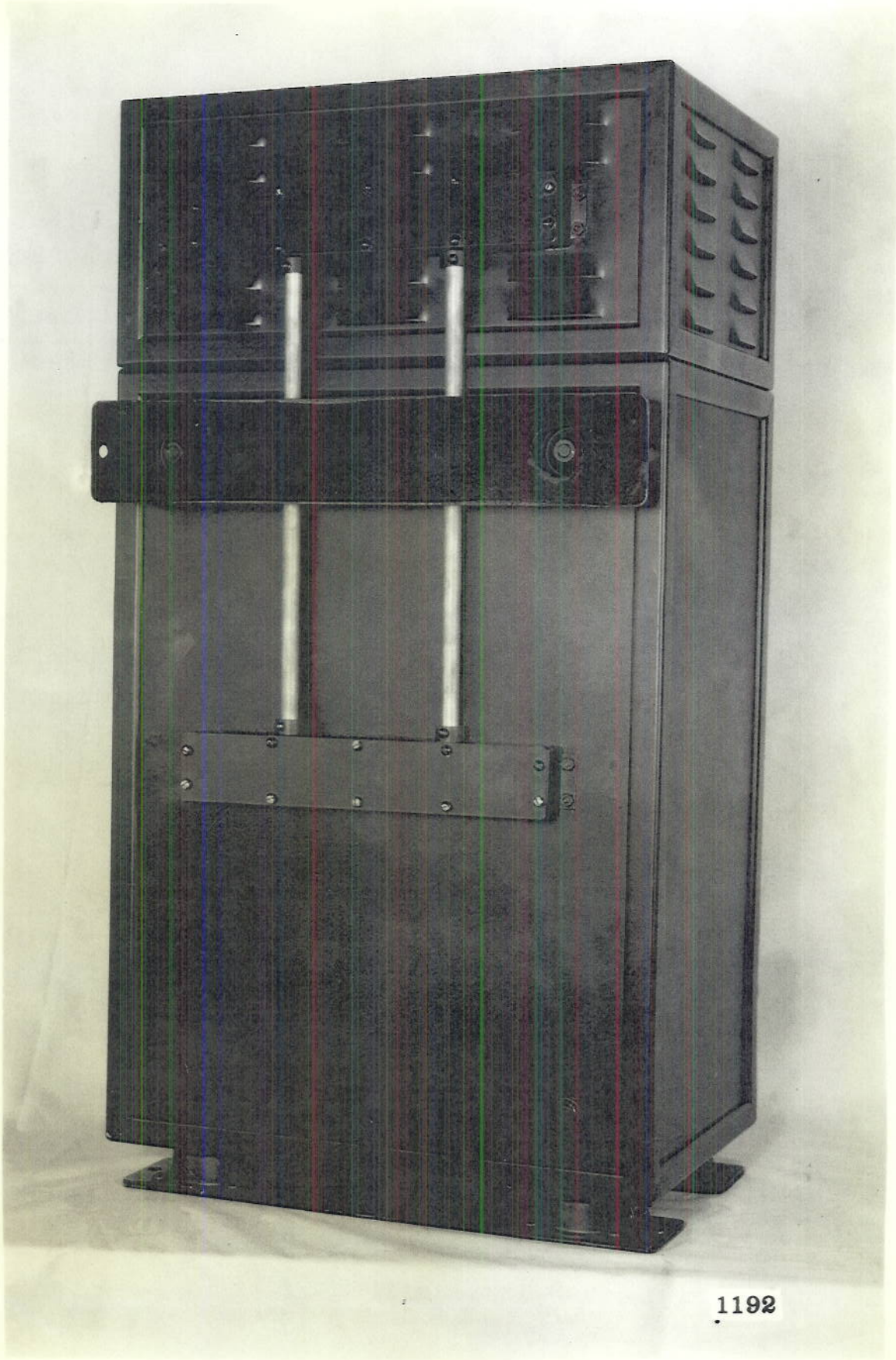
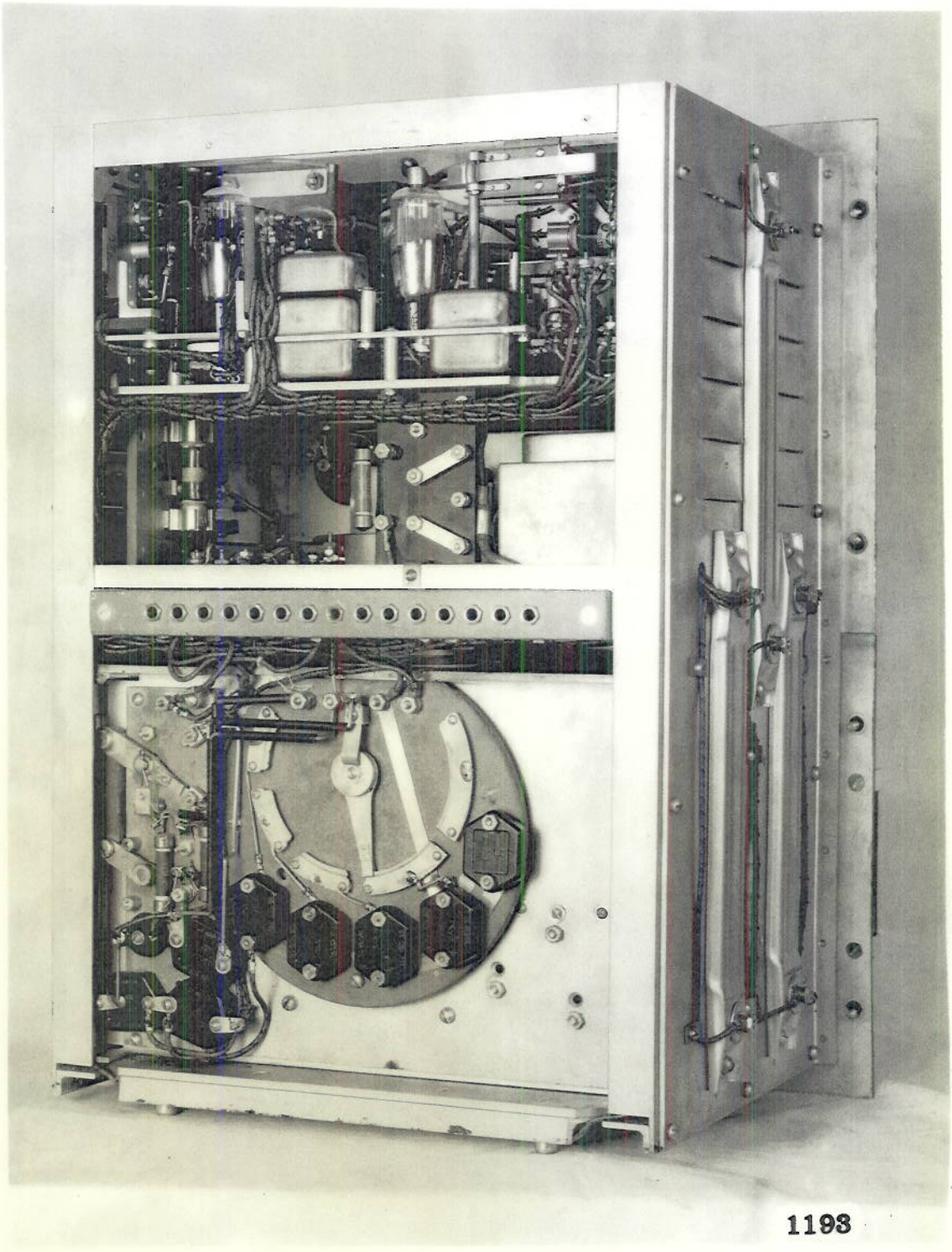
LD-1 - Preliminary Unit
Front View

Plate 4



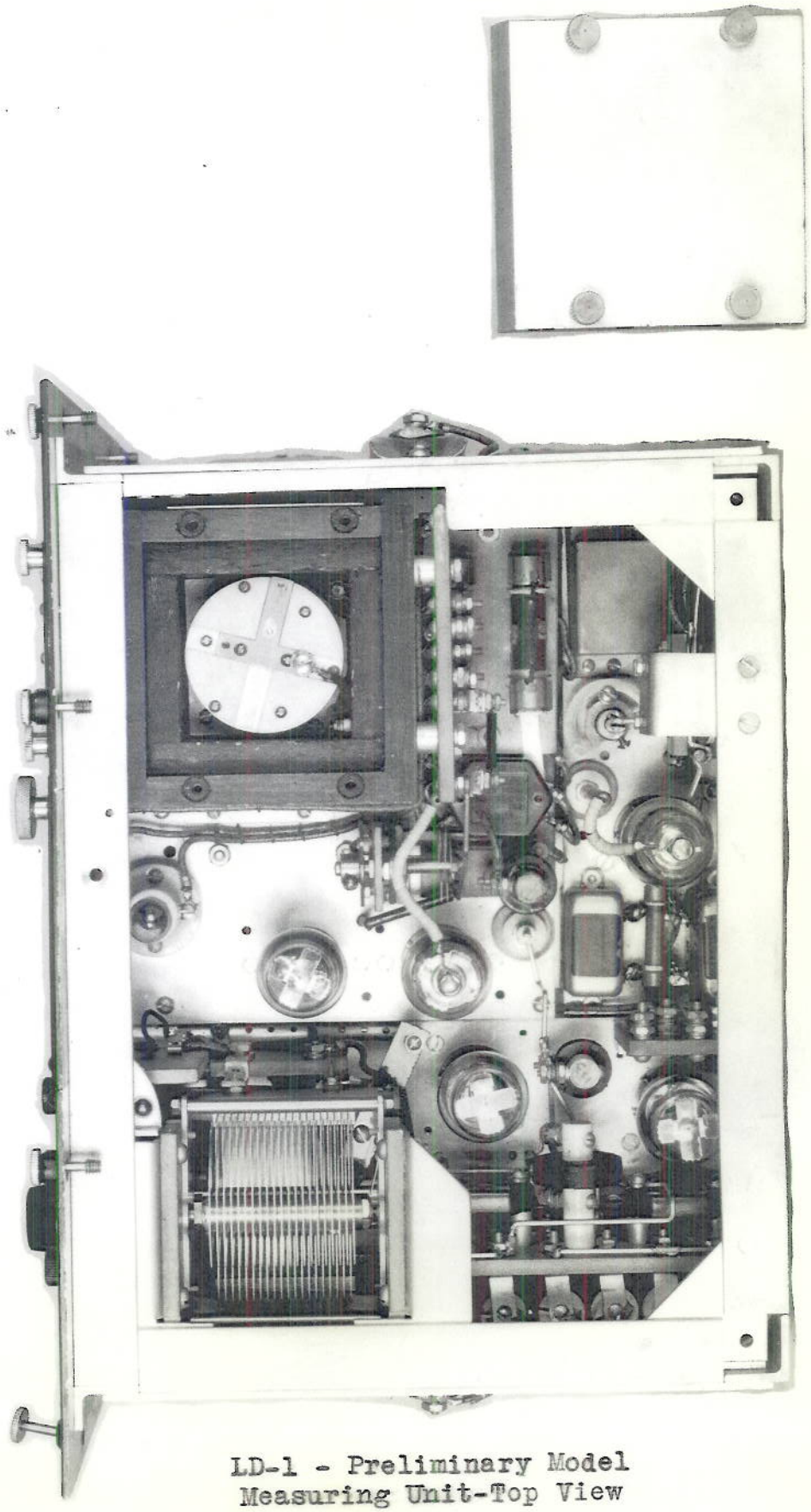
LD-1 - Preliminary Model
Rear View

Plate 5



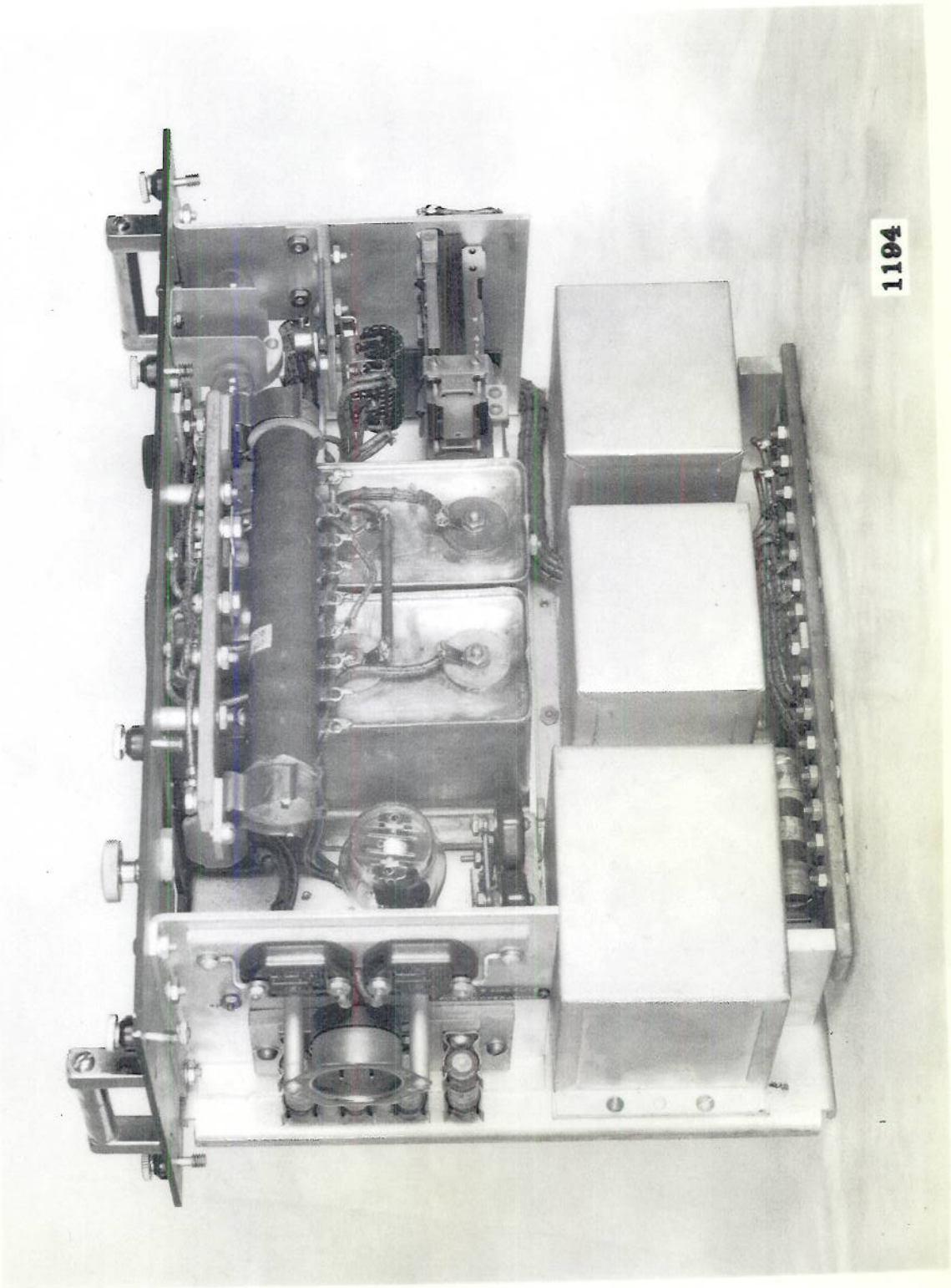
LD-1 - Preliminary Model
Measuring Unit - Rear View

Plate 6



LD-1 - Preliminary Model
Measuring Unit-Top View

Plate 7



LD-1 - Preliminary Model
Power Unit

Plate 8