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Report on

Preliminary Models

of

Model TBO Portable Transmitting and Receiving Equipment (U.S.Marine Corps)

under Contract NOs 43256

NAVAL RESEARCH LABORATORY
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AUTHORIZATION OF TEST

1. The tests herein reported were authorized by reference (a). Other pertinent data are listed as references (b) to (g).

Reference: (a) BuEng let.NOs-43256(10-18-W8) of 13 Dec.1935.
(b) Contract NOs-43256.
(c) Bureau of Engineering Specifications RE 13A 515A.
(d) BuEng let.NOs-43256(10-18-W8) of 3 Aug.1936.
(e) General Electric Test Data on TBO equipments.
(f) General Electric Descriptive Specifications covering TBO equipment.
(g) Preliminary Instruction Book.

OBJECT OF TEST

2. The object of the tests was to determine the following:

(a) The actual performance of the equipment with respect to contract requirements.
(b) Any departures from contract requirements.
(c) The nature of changes necessary to correct any departures from contract requirements.
(d) Recommendations regarding necessary or desirable improvements to meet service requirements.

ABSTRACT OF TESTS

3. The tests herein reported were conducted to determine the degree of compliance of the Model TBO equipments (preliminary models) with the mechanical and electrical requirements set forth in references (b) and (c). Specifically tests were conducted to determine the following:

Transmitter and Generator

(a) Frequency coverage and overlap.
(b) Test of power output, both crystal control and self excited master oscillator into various types of antenna constants, CW and voice.
(c) Power output tests at -30° C to +50° C. Frequency stability and overall efficiency were also observed under these conditions.
(d) Test of percentage modulation.
(e) Test of Frequency Stability under following conditions:
Variation of ambient temperature between 10 and 50° C.
Variation of relative humidity between 10% and 95%.
25% change in antenna constants.
10% variation in generator speed.
Variation due to change in keying speeds.
Variation due to change in percent modulation.
Variation due to vibration, pitch and roll.

(f) Check of calibration
(g) Test of resettability and determination of backlash.
(h) Clarity of emission.
(i) Generator voltage variation under following conditions:
Plus and minus 10% change in speed.
Key closed and key open.
0 to 90% modulation.
(j) Determination of mechanical input under various conditions.
(k) Operation during two hour locked key test.
(l) 100% overload of generator for 15 minutes.
(m) Range of communication, CW and Voice, under actual field conditions.
(n) Comparison of large and small antennas.
(o) Ability of equipment to withstand transportation and handling in the field.
(p) Check of mechanical and electrical characteristics.
(q) Ability to withstand 90% humidity at 40°C for 72 hours.
(r) Ability to withstand submersion for two hours.

Receiver

(a) Sensitivity (CW and MCW)
(b) Selectivity
(c) Maximum Noise Level
(d) Resonant Overload
(e) Fidelity
(f) Output with variation in temperature from +10°C to 50° C.
(g) " " " " humidity from low values to 75%.
(h) " " " " filament voltage of 10% from rated voltage.
(i) Output with change of any or all tubes.
(j) Stability with variation of input.
(k) " " " in battery voltages.
(l) " " " " humidity from low values to 75%.
(m) " " " " ambient temperatures between 10°C and 50° C.
(n) Stability with vibration from normal Service uses.
(o) Calibration and frequency coverage.
(p) Setting by calibration.
(q) Resettability.
(r) Overlap.
(s) Battery life.
(t) Wobbler range.
(u) Signal-Noise ratio.
(v) Sensitivity Control, range and linearity.
(w) Output impedance.
(x) Maximum undistorted output.
(y) Time constant.
(z) 72-hour humidity test.
(aa) Submergence test.
(bb) Image response.

Conclusions

(a) The general appearance of the TBO equipment is excellent and high grade materials have, in general, been employed in the construction. While a congested condition results in the transmitter-receiver unit and the accessory case due to the stringent weight and dimensional limitations, efforts have been made to retain as great accessibility as possible. Certain panel controls are capable of rearrangement to provide more convenient operating conditions and the power amplifier control requires additional refinement of adjustment.

(b) Receiver. The receiver is very compact and the parts are as accessible as can be expected considering the governing size and weight limitations. These features, combined with its employment of simple and effective circuits with high quality insulation and reasonably rugged construction, make it potentially adaptable for portable and field use. There are, however, certain performance and constructional features which will require modification for specification compliance. The most important of the performance shortcomings have to do with sensitivity and frequency stability. Constructional changes are required to overcome contact difficulties, the effect of panel distortion from manipulation on frequency stability, loosening of tubes in their sockets from transportation and vibration, greater clearance of the tube shields in the cabinet, corrosion of the cadmium plated parts, and the possibility of damage to unprotected trimmer condensers in chassis handling.

(c) Transmitter. The transmitter circuits are exceedingly compact and master oscillator power amplifier operation is secured through the use of a single tube. The efficiency of the circuits is high and may be controlled with ease and accuracy when the size and other structural limitations are considered. Crystal control operation produces excellent frequency stability, clearness of emission and good voice characteristics. These qualities are, naturally, less evident when self-excited operation is employed, but, notwithstanding, signals of good quality and intelligibility are obtained over the entire frequency range. The radio frequency power output appears to be slightly less than that stated in the governing specifications, but under actual service trials the equipment demonstrated its ability to maintain two-way communication over distances of 30 miles in the presence of severe disturbances and interference. Under favorable conditions of reception, 50 mile ranges should be possible.

(d) Antennas. The large type antenna furnished can readily be erected in territory where trees, poles, or other suitable objects are available. The small antenna, which may be erected under practically any conditions, is probably about 50% as efficient as a radiator as the large antenna. The mechanical construction of the small antenna must be improved before it can be considered satisfactory for service use.

(e) Generator, Hand Driven. The hand driven generator is an exceedingly rugged device, capable of continuous operation under extreme variations in temperature and humidity. It is efficient, easy to operate,

small and compact, and of light weight. It may readily be secured to a large variety of objects and is capable of withstanding severe overloads. The chain, which forms part of the securing arrangement, must be increased in strength.

(f) Accessory Box. The accessory box exceeds the size permitted by specifications. Even with this excess of space, a crowded condition results when all accessories are stowed. However, if proper care in packing is observed, all necessary items may be accommodated in the present dimensions.

(g) General. The method for securing covers on the transmitter-receiver unit and accessory box is inadequate and must be improved. With the present method of securing the covers, neither of the above mentioned units, accessory box and transmitter-receiver unit, are submergence-proof.

Recommendations

It is recommended:

(a) That an improved method for securing the telescopic sections of the small flagelliform antenna be provided and that the binding post on the ground stake be relocated 3" from the top of the stake; that the ground stake be increased in length to 17". (42a, 50a, 50c, 140, 143, 146)

(b) That an improved method be provided for securing the covers of the transmitter-receiver unit and the accessory box. (42b, 44, 85, 145)

(c) That binding posts of stronger construction be provided, particularly for the antenna connection; that binding posts be substituted for the microphone and hand key plugs and jacks. (42c, 50g, 93)

(d) That care be exercised to prevent cracked crystal holders being provided. (42d)

(e) That stronger chains of more suitable material be provided for securing hand driven generators to their supports.(42e, 50b, 106)

(f) That improved insulation be provided in the generator cable plugs and in the terminal sockets in the transmitter-receiver unit, and hand driven generator, and that an improved means be provided to prevent the entrance of water into these connections. (42b, 94, 127)

(g) That non-corrosive materials be used for all items used in the construction of the equipment. (44, 68)

(h) That the insulated button forming the handle of the telegraph key be fabricated from material which will not become soft and deformed when subjected to temperatures ranging up to 60° C. (48, 87)

(i) That proper precautions be taken to provide tube sockets which will prevent tubes from becoming loose under the influence of vibration and shock. (50b, 100)

(j) That tube shields be provided which will not interfere with the removal of the transmitter-receiver chassis from the case and which will permit removal of grid clips without injury to the soldered connections; also that improved means be provided for securing the shield around the oscillator coil and that greater clearance between shield and coil be provided. (50d, 50e)

(k) That gasketing material in the covers of the transmitter-receiver unit and accessory case be so designed that they will not become displaced when subjected to heat and humidity within the limits specified. (50i)

(l) That consideration be given to type approval of the vacuum tubes as used in this equipment. (54)

(m) That the antenna ammeter be connected into the high side of the antenna circuit. (60)

(n) That Navy type numbers be affixed to all component parts. (62)

(o) That the Bureau consider the advisability of permitting cover fasteners to be finished with crystalline lacquer (standard marine color) to decrease visibility of equipment in bright sunlight. (70)

(p) That the transmitter-receiver case be provided with the additional supports and mounting feet submitted by the manufacturer in the sample case. (78)

(q) That the Bureau consider the advisability of waiving the excess weight of the total equipment in the interest of increased strength, ruggedness, and improved operating characteristics. (78)

(r) That the size of the accessory box as submitted with the preliminary models be considered satisfactory, since any reduction in size would require that smaller batteries of less capacity be provided; that certain accessories be reduced in size beyond reasonable or safe limits or that a portion of the accessories be carried in an additional carrying device. (79)

(s) That an improved method be provided to insure that the transmitter-receiver unit and accessory case be watertight when submerged. (83, 95, 150)

(t) That a shield be provided for protection of the trimmer condensers from displacement by handling when removing chassis from the case. (88)

(u) That the contractor be authorized to furnish the bakelite encased type of microphone (Automatic Electric Company). (89)

(v) That the knurled head fasteners by means of which the transmitter-receiver unit is locked into its case be modified to permit these fasteners to be operated readily when the operator is wearing heavy gloves. (92)

(w) That the receiver tuning dial be given a dull finish to improve its visibility. (98)

(x) That the material in the friction contacts in the band switches and main tuning condenser be of silver. (100)

(y) That the front panel of the transmitter-receiver unit be constructed from 1/8" aluminum alloy in place of the present 3/32" sheet and that any additional means of securing rigidity which is feasible be applied to this unit to prevent panel distortion from affecting frequency of transmitter and receiver; that the increase in weight resulting from such modifications be authorized. (100)

(z) That the main receiver control be made more accessible to the operator by a rearrangement of the controls surrounding the receiver hand-wheel adjustment. (104)

(aa) That the Bureau consider the advisability of having instruction books printed on water-resisting cloth pages and covers and that the size of the instruction book be such that it will fit into the accessory box. (148)

(bb) That the padding in the "B" battery compartment of the accessory box be of a more durable material and secured at the top with a suitable binder. (149, 159)

(cc) That the "B" battery compartment be suitable to accomodate a standard size of the type of battery used. (161)

(dd) That the "clicker" device on the receiver band switch be improved. (175)

(ee) That the frequency stability and sensitivity of the receiver be improved to bring them within specification requirements. (181, 182, 193)

(ff) That the output transformer in the receiver be provided with an electrostatic shield and a center ground tap in the secondary winding. (185)

(gg) That the range of the frequency wobbler be reduced to come within specification limits. (190)

(hh) That the audio fidelity, which is at present very satisfactory for voice reception, and exceeds specification limits only between 200 and 310 cycles, be considered as acceptable inasmuch as its correction would probably involve greater weight and space requirements. (192)

(ii) That the output variation with change in ambient temperatures, which exceeds specification limits only at the high frequency end of band three and at the lower limit of the temperature cycle, be considered as meeting specification requirements, since the measurements are difficult to make and involve an appreciable tolerance which is estimated to be nearly enough to make the receiver pass this test. (198)

(jj) That the transmitter power output (r.f.) obtained with the preliminary models be considered satisfactory and that a high voltage generator current of 65 milliamperes be considered satisfactory. (204)

(kk) That the power amplifier band switch be approved. (205)

(ll) That the power amplifier tuning control be modified to permit more accurate adjustment of the power amplifier circuit. (208)

(mm) That the 40 watts power from the hand driven generator required to obtain full power output on CW transmission be approved. (221)

(nn) That the frequency stability of the transmitter in the region of 2000 kilocycles, especially when subjected to shock and roll and vibration, be improved. (234)

(oo) That the frequency stability characteristic of the transmitter when employing self-excited operation be considered satisfactory. (235)

(pp) That an improved method of providing stops on the vernier dial controls of the transmitter and receiver be provided and that precautions be taken to prevent loosening of parts in flexible couplings. (236)

(qq) That proper precautions be observed to prevent undue friction from occurring in the hand driven generator. (238)

(rr) That the "key open" efficiency of the hand driven generator be considered as satisfactory. (253)

(ss) That the Model TBO transmitting-receiving equipments be considered satisfactory for Naval use when the recommendations listed above have been complied with in a manner meeting the approval of the Bureau of Engineering.

MATERIAL UNDER TEST

4. The material under test consisted of two preliminary Models TBO portable transmitting and receiving equipments (Marine Corps).

5. Subject equipment was manufactured by the General Electric Company, Schenectady, New York, and was received at the Laboratory on 6 July 1936. The transmitter covers a rated frequency range of 2000 to 3500 kilocycles and the receiver a rated frequency range of 2000 to 8000 kilocycles.

6. Each complete Model TBO equipment consists of the following:

1 Transmitter-Receiver Unit, including

(a) Two quartz crystals and holders
(b) One set of six vacuum tubes as follows:

1 Type RCA 837
1 " " 1C6
4 " " 34

(c) One set tuning charts and curves

1 Hand-driven Generator, complete with clamp and two crank handles
1 Flagelliform "Small" Antenna, comprising

(a) 7 sections with 2 sets of 4 guy ropes
(b) 1 insulator section
(c) 1 grounding section
(d) 4 anchor stakes
(e) 1 canvas carrying-case for small antenna

1 Accessory Box containing the following:

(a) 1 each "A", "B", and "C" receiver batteries
(b) 1 "Large" Antenna System with reel and counterpoise
(c) 1 Microphone
(d) 1 Set Cables (receiver power and generator cable)
(e) 1 Telegraph Key
(f) 1 Set Spare Vacuum Tubes (6).

METHOD OF TEST

Transmitter and Generator

7. The equipment, when received, was carefully examined to determine whether any breakage had occurred during transportation and whether adequate precautions had been observed in preparing the apparatus for shipment.

8. The equipment was then placed into commission, particular attention being paid to the preliminary instruction books to determine whether they were complete and adequate. Receiver tests were made with Serial No.2 equipment, and transmitter tests with Serial No.3 equipment, except field tests where both equipments were used.

9. Power output determinations were accomplished through the medium of a 10 watt, 32 volt lamp and a calibrated photronic cell, the output of which was measured by a microammeter. The base of the lamp was removed to minimize capacity losses. Output determinations were also made by means of the I^2R method employing dummy antennas of various values of capacity and resistance.

10. Frequency changes and drifts were checked by means of Model LK and Model LH visual frequency indicating equipments.

11. Frequency coverage was determined by means of the Model LD-2 frequency measuring equipment.

12. Overall efficiency was determined by means of a suitable dynamometer and prony brake arrangement.

13. The percentage of modulation was determined by means of a cathode ray oscillograph.

14. The effect of vibration, roll, and pitch were determined by mounting the equipment on a test stand capable of tilting the equipment through an angle of 45° on either side of the vertical and also of producing controlled vibrations of various frequencies and amplitudes.

15. Temperature and humidity tests were conducted in the Naval Research Laboratory test chamber wherein it is possible to control these elements to the degree required by the governing specifications. Frequency measurements under these conditions were made by means of the Model LK and LH equipments.

16. Field tests were conducted in the vicinity of the Naval Research Laboratory and in nearby Virginia and Maryland.

Receiver

17. Radio frequency input voltages were obtained from a Standard Signal Generator Model LC-A, Serial No. 8, and a Model LN Alignment Oscillator, Serial No. 42. Audio frequency voltages were obtained from a General Radio Type 713-A Audio Oscillator, Serial No.141, used in conjunction with a General Radio Model 546A Microvolter, Serial No. 119.

18. Outputs were measured with an output meter of Laboratory construction, impedance 600 ohms, employing a Model 600 rectifier type voltmeter, also a General Radio Wave Analyzer Type 636A, Serial No.102.

19. The equipment used for the measurement of time constants was as follows:

General Radio Type 713-A Audio Oscillator, Ser.No.131.
General Radio Electron Oscillograph with Bedell Sweep Circuit, Type 687-B, Ser.No. 277.
Electronic Key of Laboratory construction.
Standard Signal Generator, Model LC-A, Ser.No.8.

A General Radio Type 617-A, Serial No. 30, interpolation oscillator was used in connection with frequency stability tests.

20. The tubes used in the receiver during tests were those furnished by the manufacturer with the equipments.

21. Sensitivity. Measurements of sensitivity were made in accordance with paragraphs 4-7(1) and 4-7(2) of reference (c).

22. Selectivity. Measurements of selectivity were made in accordance with paragraph 4-7(4) of reference (c).

23. Maximum Noise. Measurement of maximum noise was made with all receiver controls left as for sensitivity measurements, except the gain control, which was set for maximum gain.

24. Resonant Overload. Measurements of resonant overload were made with a CW input and all receiver controls adjusted as for CW sensitivity.

25. Audio Fidelity. Measurements of audio fidelity were made in accordance with paragraph 4-7(3) of reference (c).

26. Time Constant. The determination of the time constant was accomplished by applying impacts having a maximum amplitude of five volts through an electronic relay, to the input of the receiver, both separately and in parallel with an r.f. input from a Standard Signal Generator. The output of the receiver was viewed on the screen of a cathode ray oscillograph, and the duration of the impact noted as compared with the length of the image produced by the 30 cycle sweep voltage.

27. Output Impedance Characteristics. Measurements of output impedance were made by varying the input to produce standard output across various load impedances, and measured by a General Radio power output meter, Type 583-A, Serial No. 16.

28. Frequency Stability. Measurements of frequency stability were made by noting the change in beat note as indicated by a General Radio interpolation oscillator.

29. Accuracy of Resettability. The accuracy of resettability was measured by noting the change in output frequency by the use of an interpolation oscillator.

30. Sensitivity Control. The range and linearity were determined by varying the input to maintain standard output for all settings of the control from 0 to 270°, or maximum. Test was also made with constant inputs up to such a value as to produce maximum output, and noting the variation in output for settings of the sensitivity control down to the minimum readable with an output meter.

31. Image Response. Image response, both primary and secondary, was determined by noting the microvolts input required for standard output, with gain setting of receiver as for sensitivity measurements, at frequencies other than the resonant frequency setting of the receiver.

DATA RECORDED

32. The data recorded during the test of the Model TBO equipment is contained in Tables T-1 to T-18, and in Plates T-1 to T-10, appended hereto, for the transmitter and generator. Receiver data is contained in Tables R-1 to R-9, and Plates R-1 to R-31.

PROBABLE ERRORS IN RESULTS

Transmitter

33. Due to the difficulties inherent in radio frequency power measurements at low levels it is believed that the power output determinations are subject to errors of approximately ± 10%.

34. The determination of mechanical efficiency is subject to errors of about ± 5%.

35. Frequency measurements made through the medium of the Model LK and LH equipments are accurate to within five parts in one million.

36. Modulation measurements in the vicinity of 90% modulation should be considered accurate to within 5%.

37. Measurements of direct current values were made by means of precision type instruments of verified accuracy. Radio frequency measurements were made with instruments of the Model 425 type whose calibrations had been checked against precision standards to insure maximum accuracy.

Receiver

38. The estimated overall accuracy for the various tests made is given below:

Sensitivity	± 10%
Selectivity	± 10% input voltages
"	± .001% frequency variation
Maximum Noise Level	± 10%
Resonant Overload	± 5%
Audio Fidelity	± 0.5 dbs.
Output Variation	± 3.0 dbs
Frequency Stability	± 5% of cycles variation
Frequency Overlap	± 0.1%
Reset	± 10%
Frequency Wobbler Range	± 2%
Sensitivity Control	± 10%
Output Impedance	± 10%
Time Constant	± 10%

In estimating the overall accuracy of the results obtained, consideration is given to the manufacturer's rating of probable errors in the instru-

ments used, also the factors entering into the measurements involved. In all tests, great care was exercised in the manipulation of controls of the equipment under test, and the measurement equipment, and every effort was made to reduce errors in observations to a minimum.

RESULTS OF TESTS

39. The Model TBO equipments were received at the Naval Research Laboratory in an undamaged condition indicating that satisfactory precautions had been observed to protect the equipment during transportation.

40. In the following paragraphs of this report, reference is made to the governing specifications, RE 13A 515A, under which the equipments were constructed. Where no specific reference is made to any particular paragraph it is to be understood that the equipment under test complies with this paragraph and that no further explanatory remarks are considered necessary.

41. Section I. The Model TBO equipments as submitted meet the requirements of this introductory section of the specifications, except in the instances pointed out in the body of this report.

42. Par.2-3. Certain items of construction do not conform with the requirement that "This equipment must be ruggedly constructed of the best material known to be suitable for each specific employment." These items are as follows:

(a) "Small" antenna of the flagelliform type. The telescopic lengths of this antenna are secured together by means of internal threads and a spring arrangement. These threads failed in several sections during service tests. The binding post on the ground stake is not of sufficient strength and should be relocated as to position. (A detailed account of these weaknesses will be found under paragraphs 140 and 143.)

(b) The entire assembly of cover clamps is weak and unsatisfactory. (See Par.3-1(1)).

(c) The insulated type of binding post used for the antenna connection is of frail construction. The Isolantite portion of this post cracked and the entire terminal became loose so that it turns in the panel. The insulating portion of this terminal must be strengthened before it will be satisfactory for service use. The design of this terminal must be such that it will take the strain of the antenna lead without breaking or becoming loose. These terminals are of the type where the cap portion must be depressed to enable a wire to be inserted or removed, depending upon a spring for this action.

(d) Quartz crystal No. 714710, Type SP, Frequency 2076.0 kilocycles, was received with a crack in the isolantite insulation near the ground terminal.

(e) The chains by means of which the generators are secured to a support, such as trees, posts or pipes, broke several times during the course of the tests. This occurred in spite of precautions being taken to insure that no undue strain was imposed upon the chain. These chains are fabricated from a rather soft material which has tendency to permit the links to open. More durable chains of tempered material and possibly a larger cross section must be furnished before this portion of the equipment can be considered suitable for service use.

(f) The connection socket and cable plug in the hand driven generator is insulated by means of a brown phenolic insulation. During field tests a drop of water penetrated this socket, short circuiting the 500 volt output and causing the insulation to become charred. The flexible rubber covering over the cable terminal was in place at the time the failure occurred. It is recommended that all high voltage connections be insulated by means of high grade ceramic insulation which will not char if short circuits occur.

Other items used in the construction of this equipment are subject to criticism and will be discussed under appropriate paragraph headings in the body of this report.

43. Par.2-4. In general, the workmanship employed in the assembly of the TBO equipment is of good quality and high grade materials have been used. Such items as require improvement or modification will be discussed in detail under appropriate paragraph headings of the governing specifications.

44. Par.2-5. The following items used in the construction of this equipmont are constructed of materials which do not possess the maximum resistance to the corrosive effect of a moist sea atmosphere:

(a) Cover clamps
(b) Jack supporting brackets used for key and microphone connections which are of steel and show considerable signs of corrosion.
(c) Condensers in receiver, Nos.221 and 228.
(d) Nameplates which are of magnetic material.
(e) Various cadmium plated items which show signs of corrosion, especially the steel-clad paper condensers in the receiver, the contact prongs of the transmitter tube sockets and variable condenser Item 309. Tests at this Laboratory have not included the 200-hour 20% salt spray test. If these tests are desired, it is recommended that separate unassembled parts be furnished for this test.

45. Par.2-6. As pointed out under par.2-5 above, certain items have been constructed of corrosive steel where it would be possible to substitute stainless steel or other types of corrosion resisting metal.

46. Par.2-7. The equipment was tested over a range of temperature between the limits of approximately -30° C and +60° C. No signs of failure or breakdown were noted during these tests. A detailed account of these tests will be found under pars.4-9(28-a), Test No. 14 and 4-8(16-c).

47. Par.2-8. No casulties from overload were noted during the tests other than that reported under par.2-3(f) above, wherein a short circuit occurred at the generator output terminals and charred the insulation. Comments with regard to suitability of controls for field use are given under appropriate headings in this report.

48. Par.2-9. No provision is made for ventilation and cooling other than that provided by radiation from the metal case of the equipment. However, during numerous key locked tests for periods as long as 6 or 7 hours no signs of overheating were noted either in the transmitter-receiver cabinet or in the hand driven generator. In general, it was noted that the temperature of the cabinet was approximately 5° C higher than the ambient temperature. In this connection it is desired to call attention to the fact that the insulating material from which the button on the telegraph key is fashioned became soft at a temperature of 50° C and became deformed. Since the telegraph key is likely to be subjected to the direct rays of a tropical sun, it is recommended that the handle or button be fabricated from some other type of insulating material which will not soften or flow at these temperatures.

49. Pars.2-11, 2-12, 2-13, 2-14. The tests required under these paragraph headings for component parts have not been made, as no separate parts were furnished. Should the Bureau desire that these tests be made, it is requested that several samples of each type of capacitor, resistor, audio transformer and chokes be furnished.

50. Par.2-18. The equipment was repeatedly placed in various positions, such as lying on its sides, upside down, etc., without damage. During repeated dismantling and setting-up, including transportation by motor truck and in the hands of the operating personnel, the following failures and defects were noted:

(a) The threads in the joints of the flagelliform antenna failed.
(b) The 1-C-6 tube repeatedly became loose in its socket, causing non-operation of the receiver.
(c) The binding post on the antenna ground stake broke off.
(d) The tops of the metallic shield surrounding the receiver tubes became deformed from contact with the top of the case.

(e) The shield surrounding the second oscillator coil in the receiver shifted position sufficiently to short circuit this coil.
(f) The chain on the hand driven generator broke on several occasions.
(g) The antenna binding post cracked and became loose in the panel.
(h) The cover fasteners failed to operate properly.
(i) The round flexible gaskets in the cover of the transmitter and accessory case pulled out. This was apparently caused by heat, tending to make the gaskets soft and sticky.

Since no acceleration equipment is available for testing equipment of this nature, acceleration tests were not conducted.

51. Par.2-19. As pointed out under par.2-18, faulty, operation resulted from vibration and shock during handling due to tubes becoming loose in their sockets and from a displaced shield in the receiver shorting out a portion of the circuit.

52. Par.2-20. Vacuum tubes, quartz crystals and, in fact, all component parts of the equipment are rigidly mounted within the case. Flexible mountings within the space limitations would be impracticable, if not entirely impossible. The fact that the 1-C-6 tube repeatedly became loose in its socket indicates the necessity for some means of preventing this action.

53. Par.2-21. All vacuum tube sockets are of the single unit type.

54. Par.2-22. The following vacuum tubes are employed in the Model TBO equipment:

Transmitter: 1 type RCA-837

Receiver: 1 type RCA-1C6
4 type RCA-34

In addition, the equipment is so designed that a spare socket is provided within the transmitter-receiver case for carrying a spare tube of each type. Under the terms of par.2-2 which states "Vacuum tubes not contained in this list will be acceptable only if ample evidence is provided to indicate that they will be satisfactory in the Naval Service", the manufacturer asks approval of the types of tubes used for the reasons outlined on pages 11 - 15 inclusive of their descriptive specifications, ref.(f). During the course of these tests, no tube failures occurred and no troubles with the tubes were encountered.

55. Par.2-24. The equipment is entirely shielded on all six sides and is so designed that the shielding may be connected to ground.

56. Par.2-25. The design and control of the circuits employed in the TBO equipment has been made as simple as the requirements of the governing specifications permit.

57. Par.2-26. The following control devices, switches, terminals, etc., are mounted on the front panel of the equipment:

Send-Receive Switch
P.A. Band Switch
Antenna Coupling Switch
Crystal - M.O. Selector Switch
CW - Voice Switch
M.O. Tuning Control
P.A. Tuning Control
Receiver filament - Transmitter Cathode Switch
Receiver plate voltage switch
CW - MCW Switch
Receiver Tuning Control
Filament Rheostat
Wobbler Control
Sensitivity Control
Antenna Trimmer Control
Receiver Band Selector Switch
Antenna Terminal
Ground Terminal
Head Telephone Terminals
Microphone Jack
Key Jack
Transmitter Power Terminal Socket
Receiver Power Terminal Socket

The above controls permit the receiver and transmitter to be adjusted to any frequency within the specified range. Transmitter controls are black, while receiver controls are red, permitting ready identification. No provision is made for break-in operation. With the send-receive switch set to the "receive" position, it is possible to apply power to the master oscillator and thus adjust the receiver to zero beat with the transmitter crystal, which permits of rapid and accurate calibration of these fixed points.

58. Par.2-27. All control shafts are grounded to the panel of the equipment.

59. Par.2-28. All tuning controls are so designed that values of settings increase numerically with increase of the final controlled effect. The master oscillator tuning control on the transmitter and the tuning control on the receiver are of the thumb wheel type. The thumb wheel is secured in a vertical position and as the wheel is rotated downwards the dial numbers increase.

60. Par.2-29. Two meters are mounted on the front panel of the transmitter. The d.c. meter is supplied with switches so that it is possible to read transmitter tube cathode current, receiver filament current and receiver plate voltage. The other instrument is an r.f. ammeter, range 0 to 1.5 amperes and is connected in the ground side of the antenna circuit. Since previous experience has indicated that

an antenna ammeter in the ground side cannot always be relied upon to give maximum deflection when maximum power is being supplied to the antenna, an additional r.f. ammeter was connected in the high side of the circuit; that is, the second meter was connected to the antenna binding post. Observations showed that the external antenna ammeter always gave maximum deflection when maximum power was being delivered to the dummy antenna, either lamp load or resistance load with a suitable series capacitor. It was also noted that the panel ammeter, connected in the ground side, frequently gave larger deflections when the power delivered to the antenna was, say seven watts, than it would when the power delivered was, say nine watts. During these tests the antenna constants remained fixed. The only adjustments made were those of P.A. tuning and antenna coupling. It is recommended, therefore, that the antenna ammeter be removed from the ground side and be connected into the circuit between the antenna blocking condenser, item 320, and the antenna terminal.

61. Par.2-30. The electrical indicating instruments furnished are of the 2.5 inch size, flush mounted. The d.c. instrument is bypassed by a suitable capacitor.

62. Par.2-32. Navy type numbers have not been affixed to all component parts in the preliminary model.

63. Par.2-34. Symbol numbers to correspond with the wiring diagram are provided on the various component parts in the transmitter-receiver assembly where size of the parts permit. The small size of the equipment, the compact assembly of same and the diminutive size of some component parts prohibit this method of identification throughout the equipment.

64. Par.2-35. Every effort has been made to permit replacement of parts without extensive disassembly. However, the restricted dimensions of the equipment prohibit ready accessibility in all cases.

65. Par.2-36. Such items of construction as do not comply with the requirement that "safe operation and satisfactory performance are assured" are listed individually under appropriate paragraph headings of the specifications.

66. Par.2-37. Operating personnel cannot come into contact with any potentials in the equipment unless the chassis were removed from the case while the equipment is in operation. The safeguards provided are considered adequate for the protection of personnel.

67. Par.2-38. The nameplates and panel markings provided on the TBO equipment are satisfactory, except non-magnetic material is recommended for nameplates.

68. Par.2-39 to 2-43. No trouble was experienced during any of the tests due to faulty wiring. Some traces of corrosion were noted as described under par.2-5 of the specifications.

69. Pars.2-39 to 2-43. The tests called for under these paragraphs have not been made in connection with the preliminary model. If the Bureau desires these tests to be conducted, appropriate wire samples and samples of treated aluminum or alloys should be submitted to the Naval Research Laboratory.

70. Par.2-44. All snaps, catches, screws,etc., which are manipulated in normal service have been plated with a dull finish. The manufacturer submitted an extra transmitter-receiver case to illustrate various methods of finishing the cover catches and methods for increasing the rigidity of the case. Two of the cover catches were finished with olive drab lacquer similar to that which is used for finishing the case. These lacquered catches have the advantage of a dull finish which prevents reflections in bright sunlight which may be a desirable characteristic while the equipment is being used by field patrols. It is believed that the finish on these catches will withstand wear and since the lacquer in no way interfered with the operation of the catches, it is recommended that the Bureau consider the advisability of adopting this type of finish in the interests of decreased visibility. If the Bureau desires the tests called for under par.2-45 to be conducted at the Naval Research Laboratory, it will be necessary for the manufacturer to submit suitable samples of these various component parts.

71. Par.2-46. (See also Test No.21). Both preliminary models, Ser.No.2 and 3, were subjected to a relative humidity of approximately 90% at 40° C for a period of 72 hours. Receiver tests were conducted with Ser.No.2 and transmitter tests with Ser.No.3.

Transmitter. During the course of this test the transmitter was operated at hourly or two hour intervals during the daylight hours for a period long enough to make the necessary observations. These periods of operation were generally of about two minutes duration. The transmitter was adjusted for operation at 2772 kilocycles, crystal control. Plate T-10 attached hereto is a graphic record of the test, wherein power output, frequency, temperature and relative humidity are plotted against time. After the equipment had been subjected to the required 72 hours at 90% humidity, the equipment was placed into operation and the key locked for one hour. Referring to Plate T-10 it will be noted that the power output at the end of the one hour key locked period was 8.4 watts while during the test the power level was 7.8 watts. The frequency of emission remained substantially constant during the test, rising about 55 cycles during the last hour of operation. No signs of breakdown or non-operation were observed during the entire test. The Model TBO transmitter, therefore, meets all the requirements of par.2-46 and Test No. 21.

Receiver. Receiver sensitivity was measured at the top and bottom of each frequency band just previous to and after the completion of the humidity bath. The sensitivities were found at the end of this test to comply with the governing specifications. (See Table R-10)

72. Par.2-47. The immersion tests called for under this paragraph have not been made. Should the Bureau desire that these tests be made at the Naval Research Laboratory, suitable component parts should be furnished.

73. Par.2-49. The exterior surfaces of the transmitter-receiver cabinet and the accessory box are finished with baked crystalline wrinkle finish of a color corresponding to "Marine Standard Lacquer".

74. Par.2-50. The exterior of the generator unit is finished with a dull baked enamel of a color corresponding to "Marine Standard Lacquer".

75. Par.2-51. The front panel of the transmitter-receiver unit is finished in black crystalline wrinkle finish. Panel markings and control designations have been engraved upon the front panel.

76. Par.2-52. The "Small" antenna, constructed from stainless steel, has been given a protective coating of crystalline baked enamel corresponding in color to Marine Standard Lacquer. The ground stake fittings are finished with a dull finished plating.

77. Par.2-53. No head telephones were supplied with the preliminary models. Page 2 of Contract Notes under paragraph designation 3-5(3)/7-4 states that no head telephones shall be furnished under the subject contract. Sufficient space is available in the accessory case to pack one pair of head telephones, although an exceedingly congested condition results and extreme care must be exercised not to damage the various parts.

78. Par.2-54. The weights of the various parts of the Model TBO equipment are listed in Table T-1. It will be noted that the specified weight of the total equipment has been exceeded by 2 lbs. 10 oz. (exclusive of the instruction book). The weight of one pair of head telephones is included in the weight of the accessory box. The manufacturer submitted a sample transmitter-receiver case in which additional stiffening members had been applied in order to strengthen the case. These additional supports increase the weight of the case by about 5 ounces. The extra rigidity imparted by their presence is such that it is recommended that all equipments be fitted with the additional braces and the extra weight allowance be permitted. Part of the additional weight is due to 4 small feet, designed to raise the case above the fasteners. These feet are a distinct advantage with the present type of fasteners.

79. Par.2-55. The dimensions of the various units are listed in Table T-1. It will be noted that the height dimension of the accessory box has been exceeded by 4 inches. Even with its present dimensions the accessory box is very crowded when all necessary items are packed. There appears to be no possibility of decreasing the size of any of the accessories sufficiently to permit them being carried in a 4 inch high case. One dimension of the transmitter-receiver case is exceeded by 1/16 inch. It is recommended that this excess be approved. The dimensions of the generator are considerably less than those permitted by the specifications.

80. Par.2-57. As pointed out under par.2-55, the dimensions of the accessory box have been increased so that the cubical contents exceed the specification requirements by approximately 60%.

81. Par.2-58. Each equipment was supplied with two tuning charts, each capable of recording ten transmitter settings and ten receiver settings. The paper charts are secured between two pieces of transparent celluloid material rendering the charts waterproof, although they become somewhat deformed when subjected to varying temperatures and high humidity. Settings may be recorded in either ink or pencil and old calibrations can readily be erased and new calibrations recorded in their place. These charts are secured inside the cover of the transmitter-receiver unit under a heavy square of celluloid material.

82. Par.2-59. Each equipment is provided with three calibration charts for the receiver and one calibration chart for the transmitter. These charts are prepared in a manner similar to the tuning charts referred to above under par.2-58. The accuracy of these charts will be discussed under par. 4-9-30 and Test No. 15 (transmitter) and under pars. 3-1-15, 4-8-32 and Test No. 7 (receiver). The charts are secured on the inside of the cover of the transmitter-receiver case.

83. Par.2-61. The accessory box, complete with all accessories, the hand driven generator and the transmitter-receiver case (with transmitter-receiver unit removed) were submerged in fresh water for a period of two hours. The transmitter-receiver chassis was removed from the case before submergence since the deformation of the securing clamps by means of which the cover is held in place indicated that it was very doubtful whether the case would be watertight and it was not desired to subject this unit to unnecessary damage. At the end of the two hour period the equipment was removed from the fresh water, the exterior dried off and the covers removed. It was found that the transmitter-receiver case had leaked about two ounces of water while the accessory case contained about six ounces of water. The "A" and "B" batteries had absorbed enough water to soak the treated paper covers and the terminals came away at the slightest touch. Various other items capable of absorbing moisture became water logged, such as the cordage, tube cartons, etc. The hand driven generator operated satisfactorily after immersion although a few drops of water were found in one of the crank holes. It was also noted that the cover plates which protect the generator socket are lined with oiled paper to serve as gaskets. Although no water penetrated this cover, it was observed that the oiled paper had become badly marred due to the rubbing action when the cover plate is swung into and out of position. It is recommended that cloth-inserted packing be used at this point. Previous to the immersion test the packing was carefully examined and arranged to give maximum protection. However, due to the deformation of the holding clips, it is believed that insufficient tension was placed on the cover, thus permitting water to penetrate to the interior of the cases. Thus, it will be seen that only the hand driven generator successfully withstood the immersion test.

84. Par.2-62. If the proper form of gasketing material is available, replacements can readily be accomplished and the preliminary instruction book outlines clearly the method to be followed in replacing worn out material and the source and proper catalogue designations for obtaining new material.

85. Par.3-1(1). The transmitter-receiver assembly is housed in a case of corrosion resisting steel. The front of the case is removable and forms the only opening in the case. As pointed out under par.2-61 above, the case is not submergence proof when the front cover is in place. The cover fasteners are not effective in maintaining watertightness. It requires but a relatively slight blow with a hard object on the fasteners to make their spring tension ineffective. The brackets on the box are not sufficiently rigid to assure that the fasteners will not become disconnected therefrom if subjected to such handling as may be expected in the service for which this equipment is intended. The fasteners are of magnetic material which may be corrosive, although but slight traces have resulted from the tests to date. The springs within the fasteners are not visible without destruction of the fastener and if they are of corrosive material they may soon become entirely ineffective in maintaining watertightness. One fundamentally objectionable feature is that the fasteners protrude from a flat-sided box and are therefore subjected to injury from transportation, handling, and even from normal use of the equipment. It would appear that a better design would be one in which the cover fasteners are set into indentations in the box walls so that the box will sit on any flat surface without strain on the fasteners. This would probably call for major rearrangement or a larger box. The new design should be changed to remove the present difficulty of obtaining sufficient grip to facilitate easy opening. The thickness of the box material is .023", which cannot be expected to stand rough treatment.

86. Par.3-1(2). The hand key furnished is of the standard type.

87. Par.3-1(3). As required by the "Contract Note", page 2, the transmitter key is mounted by means of attachment buttons at the left top of the case in such a manner that the case may be used as an arm rest by the operator. The key is provided with a flexible cord and is fitted with a plug which may be inserted in a suitable jack in the front panel of the equipment. As pointed out under par.2-9, the insulating button which forms the handle of the telegraph key softens at high temperatures and becomes deformed. A button of suitable material should be substituted for that now furnished.

88. Par.3-1(4). The chassis was easily removable from the cabinet at the start of tests but after the field tests there was sufficient distortion of the box that the box top gave enough pressure on the top of the panel to require that the box be held by a second individual to permit removal of the chassis. Also, after the box latches became more free from use, they have a tendency to extend over the face of the panel at the bottom, preventing chassis withdrawal unless the box is placed with the panel up. Both of these objections should be in a large measure overcome by the use of the special box bearing Serial No. 1 which has extra reinforcing members and metal feet at the bottom to take the weight of the box off of the latches. The "goat" tube shields of the receiver portion have a tendency to strike the panel flange upon withdrawal, particularly if slightly distorted from use. Greater clearance should be provided which can be accomplished with a different type of tube shield. The 4 trimmer condensers located at the bottom right hand end of the chassis are unprotected and are in such a position that the fingers of the one withdrawing the chassis may accidentally displace or even short circuit the delicate plates without knowledge of so doing. These condensers must be protected.

89. Par.3-1(5). Two types of microphones were submitted with the Model TBO equipment. One type, provided with an aluminum handle and a bakelite mouth piece was given preliminary tests in October 1935, the results of which were reported to the Bureau of Engineering in Naval Research Laboratory letter S67/51, S67/60 of 18 October 1935. The second microphone is entirely enclosed in a cylindrical bakelite case and is apparently manufactured by the Automatic Electric Company. Extensive comparison tests were made of the two types of microphones and invariably the Automatic Electric Company microphone gave superior results. While the speech quality of both microphones is good, the Automatic Electric Company microphone is more sensitive and 90% modulation can be obtained more readily while the operator speaks in a normal tone of voice. With the Automatic Electric Company microphone it is not necessary to hold the lips directly against the mouthpiece, as is usually necessary with the aluminum handle General Electric Company) microphone. The Automatic Electric Company microphone is fitted with a non-locking switch, fits the hand comfortably and may be operated while the person using it is wearing heavy gloves. The Automatic Electric microphone was subjected to a temperature of -20°C and operated satisfactorily at that temperature. It was then removed from the refrigerator and immediately became encased in frost but still functioned normally. Later, as the frost melted and condensation took place, the entire microphone became covered with moisture, including the inside of the mouthpiece, but normal operation was consistently maintained. Previous to this test the microphone had been subjected to a number of heat cycles ranging between 10 and 50° C and one as low as -30°C, without any noticeable ill effect upon the microphone. It is recommended, therefore, that the Automatic Electric Company type of microphone be supplied with Model TBO equipments.

90. Par.3-1(6). The controls located on the front panel of the equipment are listed under par.2-26 and the meters under par.2-29. No modulation control is provided and actual service tests indicated that such a control is not necessary.

91. Par.3-1(7). The receiver has the required controls located on the front panel. See list of controls under par.2-26.

92. Par.3-1(8). Access to the transmitter-receiver is accomplished by removing the chassis from the case. Four knurled head metal screws are provided for securing the chassis in the case and these may be used for withdrawing the chassis. They are of the non-removable Type. It is recommended that the round heads on these screws be enlarged and modified in order to permit a better grip to be obtained. With the present size screws it is difficult to obtain a sufficiently firm grip to unscrew these devices, particularly when the operator's hands are encased in heavy gloves.

93. Par.3-1(9). The contract notes and the governing specifications state that binding posts located at the bottom of the front panel shall be provided for making microphone and headset connections. Microphone connections are now made by means of a plug and jack arrangement. The headset connects to a spring grip type of binding post which is satisfactory in its present condition. A possible objection would result

from the use of a corrosive spring in their construction. The material used is not known and can be studied only after destruction of the binding post, which has not been done. Non-corrosive springs must be used in this construction. The key connections are also made by means of plug and jack devices, as pointed out under par.3-1(3) above. During the course of extensive tests no difficulties were encountered with the plug and jack connections. However, it is believed that in service use under adverse conditions, such as operation in muddy, dusty, or snow covered locations, the jack holes are likely to permit the entrance of foreign materials and the plugs themselves accidentally become dirty or wet, causing failure of these circuits. It is recommended, therefore, that the key and microphone connections be made through the medium of suitable binding posts.

94. Par.3-1(10). The battery cables connect to the battery box with rubber-covered cables having a plug at each end which fit into a receptacle on the receiver panel and to a similar one on the side of the battery box. The plugs have the female members for connection to banana type male contacts in the panel or box receptacles. These cables are removable when not in use and the receptacle in the battery box can be covered with a rubber-gasketed cover to maintain watertightness. The receiver is covered by the rubber-gasketed main cover when in place for transportation. An attempt has been made to make these plugs and receptacles spraytight by the use of a rubber sleeve which can, with some difficulty, be slid over the junction of the plug and receptacle, also covering the lock button and hole which prevents the plug from becoming accidentally disconnected when in use. This sleeve is probably quite effective in its present condition, but, if like most rubber, its effectiveness will be of limited duration in the presence of heat and sunlight. The generator cables are similar to the battery cables described above. As pointed out under par.2-3(f), a failure of the phenolic insulating material in the generator socket and the plug connection to this socket occurred due to a drop of water penetrating the socket. The generator cable and socket connections should be insulated by means of a high grade ceramic insulation to prevent recurrence of this breakdown.

95. Par.3-1(11). The transmitter-receiver unit, packed for field transportation, was submerged for a period of two hours in fresh water and, as pointed out under par.2-61, sufficient water entered the unit to cause injurious results. This requirement of the specification is not met.

96. Par.3-1(12). The coarse adjustment portion of the master oscillator and receiver dials are calibrated in 10 divisions and the vernier dials on these controls are divided into 100 divisions. The power amplifier control is calibrated from 0 to 100. The wobbler control has a zero center calibration with graduations at 5 and 10 on either side. This should be satisfactory if the wobbler action is limited to the specified range. Finer graduations are, however, recommended if used with the present wobbler range.

97. Par.3-1(13). The tuning gears for the receiver and master oscillator circuits are of the worm and wheel type. The wheel is in two sections with spring take-up to reduce back-lash and to provide adjustment for spot wear. The ratio is 20:1. The worm is of magnetic material and its corrosive qualities are unknown. If corrosive, the manipulation of the tuning dial will be questionable after stowage for long periods in moist salt atmosphere. The degree of back-lash present in these controls is discussed in detail under pars.4-8(29) and 4-9(31).

98. Par.3-1(14). The dials and indicating devices are visible with light at a 60° angle except for the thumb wheel dials. These dials are difficult to read as the figures are on a conical surface at a plane about 40° from that of the panel, while the graduations are on a plane parallel to the panel. In the case of the receiver tuning, the wheel is glossy and red with yellowish numerals giving reflection at many angles. If the graduated part of the tuning wheel as well as the part where the numbers are located were dull in finish, it would be much easier to read.

99. Par.3-1(15). The calibration curves have been plotted in accordance with the specifications, except that there is a break in the calibration for receiver No.2 between 5 and 6 on band 1, resulting in no calibration from 2903 to 2913 kilocycles. The calibration charts have been made on cross-section paper which is sealed in celluloid. This appears to give good protection from moisture and soiling with use, but it was observed that the charts become noticeably buckled from the various cycles of humidity and temperature as required by the specifications. The extent to which this will be effective with continued service is not known, but it is not believed to be enough to outweigh the moisture protection afforded over plain paper charts.

100. Par.3-1(16). Transmitter: No trouble was experienced in the transmitter unit which could be attributed to friction or pressure contacts. However, a slight pressure on the front panel of the equipment frequently caused a violent frequency change when operating with self-excited master oscillator control. The panel of the transmitter-receiver unit is constructed from 3/32" aluminum sheet. It is believed that if this thickness were increased to 1/8", the resulting increase in rigidity would tend to overcome a large portion of this trouble. Any additional support which could be arranged for the panel would also be helpful. This naturally would increase weight somewhat, but it is felt that the addition of a few ounces is necessary in this connection for satisfactory operation.

Receiver: The same detuning difficulty was experienced with the receiver circuits from pressure on the panel and should be remedied either by a thicker panel or mechanical decoupling of the tuning condensers from the panel and controls. The friction or pressure contacts consist of band switches, tube contacts, power cable contacts, condenser rotor contacts, volume control and rheostat slider contacts and contacts between shielding components. The band switches have made satisfactory contact throughout these tests. The rotor consists of an arm about 1/8" diameter with a hemispherical end which makes contact on

springs mounted on an isolantite ring which surrounds the control shaft. The flat spring contacts are permanently secured to the ring at one end, while the free end is made to move radially outward from the shaft center as the contact arm comes into contact. A groove is pressed into the spring end so that the switch rotor will be somewhat self-centering and to provide a positioning click. The rotor arm is connected to a circular disc upon the edge of which rests a flat spring contact with right angle end bend to give the conventional type of wiping contact. All of these contact parts appear to be silver-plated. It has been the experience of the Laboratory, however, that silver-plated friction contacts on frequently operated switches lose their plating sooner or later, depending upon their use and the thickness of the plate, and give a contact of uncertain, if not varying, resistance. All reliable receiving equipment of recent purchase has been equipped with solid or coin silver contact points either silver soldered or brazed on the contact members, both movable and fixed. The tube socket contacts are unsatisfactory, particularly for this type of portable service. All tubes had worked at least part way out of their sockets upon delivery. The first oscillator tube in Serial No.3 could not be made to function except intermittently. A new tube was inserted and it functioned for a time and then failed to oscillate. A third tube was used and the first two measured for electrical constants and were found to be within reasonable limits. Upon further investigation, the difficulty was found to be in poor socket contact. On other occasions when the equipment was sent out for field tests, considerable difficulty was experienced in obtaining normal receiver operation. This was generally traced to poor tube socket contacts. On the return from a field test, the tops of all of the so-called "goat" tube shields were found to be mashed and the tubes were, in two cases, completely out of their sockets. The shield distortion was the result of having withdrawn the chassis from the case in the field with the tubes partly out of their sockets, in which case the tube shields struck the turned over edge at the top of the case. In relatively few cases after transportation on field tests has the equipment been in operating condition until after the chassis has been removed and the tubes pushed into place. The "goat" type of tube shield is not considered satisfactory. They are not only flimsy and awkward to handle, but do not permit the removal of the grid cap terminal leads without the aid of some form of tool or by pulling the terminal off by its wire connection, which is bad practice. It is possible that the socket contact difficulties can be traced to these shields as the contact from the shield to the chassis is through two opposing springs making pressure on the tapered surface of the shield and with vibration these compressing springs may cause the tubes to rise out of the sockets. The power cables depend upon the so-called banana type of contact. This type of contact has given satisfactory service when not abused. The male members, which are the most susceptible to injury resulting in failure, are well protected, and both the male and female members are assembled into sturdy plugs and receptacles.

101. Par.3-1(17). Transmitter: During the course of the tests reported herein, no trouble was experienced from radio frequency contacts in the transmitter unit. As pointed out in previous paragraphs of this report, the contacts in the generator connections require improvement, binding posts of an improved type are required for the antenna connection,

and the plug and jack connections for the hand key and microphone should be replaced with suitable binding posts.

Receiver: (See preceding paragraph.) All friction contacts employed possess considerable self-cleaning properties. The band switch is not fundamentally of self-cleaning type as the contactor is spherical in shape and may have a tendency to ride on non-conducting particles or films. The pressure provided would, however, greatly reduce this possibility. The variable condenser contacts have the least self-cleaning properties of any and are not considered as being in accordance with best engineering practice for receivers operating in the subject frequency range. The contact consists of a flat spring, forked at the free end to straddle the rotor shaft and fit between two collars spaced slightly more than the thickness of the spring. By bending the forked end, it is possible that the spring contacts both collars, one with greater tension than the other due to the normal tension on the spring from its anchorage. This type of contact is not definitely self-cleaning and the collection of dust and other foreign matter has been known to produce a variable resistance contact in similar construction. The spring appears to be silver-plated and the collars are of non-magnetic material which appears to be cadmium plated stainless steel. These contact surfaces for both the spring and the collars should be the equivalent of solid silver to assure continued satisfactory operation. The back end of the rotor shaft rotates on a single steel ball bearing which is magnetic and may rust.

102. Par.3-1(18). Variable resistors used in the TBO equipment are of the wire wound type.

103. Par.3-1(19). Dummy sockets are provided for one of each of the types of tubes employed. These sockets are duplicates of the sockets used in the transmitter and receiver and may not provide sufficient locking qualities to assure that they will not come out of the sockets and become damaged in transportation. (See par.3-1(16).)

104. Par.3-1(20). The receiver main tuning control consists of a horizontal axis vertical motion thumb wheel. The location of the thumb wheel is between the "CW - MCW" toggle switch and the "Ant. trimmer" knobs which are located directly above and below the thumb wheel respectively, while the lock for the main tuning condenser is at the right of the wheel. This control being thus surrounded, is greatly limited as to accessibility. The thumb wheel action is rather stiff and tuning is slow, as it averages from 3 to 4 thumb movements to make a complete turn of the thumb wheel. This wheel would be difficult to adjust in cold weather with gloved hands. The greatest interference results from the position of the "CW - MCW" switch, although the main dial lock also provides considerable obstruction.

105. Par.3-2(1). When secured to a suitable support, the generator furnished with the TBO equipment is suitable for hand operation by one man.

106. Par.3-2(2). The generator is provided with a removable clamping device consisting of two fixed jaws. A chain is provided by means of which the generator may be secured to a support and an adjustable tension device is provided by means of which the chain may be tightened to firmly secure the generator in a position for operation. However, as pointed out under par.2-3(e), the chain provided has not sufficient strength to resist breakage when the tension device is operated normally. Stronger chains of suitable material must be provided before the mounting device can be considered suitable for service use.

107. Par.3-2(3). The clamping device is so designed that it will permit the use of a support ranging from 1-1/2" to 18" in diameter, either round or square. During the tests conducted the generator was secured to both metallic objects and to trees and posts.

108. Par.3-2(4). When the clamping device is removed the generator may be bolted to a wooden or metallic support.

109. Par.3-2(5). Operation of the generator is accomplished by means of two hand-cranks with a 6-1/4" operating radius. The cranks are mounted diametrically opposite each other, spaced 180° apart and rotate through 360°.

110. Par.3-2(6). The hand cranks are readily detachable and yet are securely held in place during operation by means of a recessed ball and socket catch.

111. Par.3-2(7). The normal operating speed of the hand cranks is 60 r.p.m. and when turned at this approximate speed the generator offers minimum resistance. The generator is fitted with an automatic voltage regulator by means of which the voltage output is held substantially constant when the speed of rotation varies between the limits of 54 to 66 r.p.m.

112. Par.3-2(8). The hand crank handles are provided with free running hand grips to insure against chafing the operator's hands and are of a suitable diameter to prevent cramping of the figers.

113. Par.3-2(9). Single race ball bearings are used in the generator. During extensive tests no additional lubrication was provided and post trial inspection revealed no signs of wear or other derangement. A plentiful supply of lubricant was still available for both bearings and gears.

114. Par.3-2(10). No visual speed indicator is provided in connection with the generator, nor is a device of this type necessary. As pointed out under par.3-2(7) above, ± 10% variation in speed has no effect upon the output voltage due to the action of the automatic voltage regulator.

115. Par.3-2(11). Post trial inspection revealed no appreciable signs of gear wear. The pinions employed appear to be case hardened, while the gears are, of somewhat different temper to obviate wear. The accuracy of the gears is attested by the free running characteristics of the generator and the entire assembly is housed in an oil tight cover.

116. Par.3-2(12). The audible noise produced by the generator is of very low amplitude and does not interfere with the reception of weak signals.

117. Par.3-2(13). The generator is watertight and provision is made for easy disassembly. All removable parts are secured with plated screws to distinguish them from screws which are not subject to removal.

118. Par.3-2(14). Brushes are readily accessible by removing watertight cover plates held in position by two screws.

119. Par.3-2(15). Double brushes are inserted in each brush rigging, the proper tension being secured through the medium of coil springs securely fastened to a cap held in place by a set screw. No signs of undue wear were noted at the conclusion of the tests.

120. Par.3-2(16). The direction of rotation is denoted by prominent arrows cast integral with the generator housing. The arrows were colored red.

121. Par.3-2(17). The generator plug receptacles do not project beyond the generator case and are provided with watertight covers. As stated in the foregoing paragraphs of this report, improved insulation should be provided in these receptacles and an improved gasket should be provided on the watertight cover.

122. Par.3-2(18). The generator complies with the requirements of par.2-61.

123. Par.3-3(1). The generator and batteries are connected to the transmitter and receiver unit by means of heavy flexible rubber covered cables, fitted with plugs for insertion into receptacles. (See par.3-1(10).)

124. Par.3-3(2). The generator cable is 10 feet long and the battery cable 3 feet long.

125. Par.3-3(3). The cables are connected to the generator and accessory box by means of detachable plugs. The plugs are fitted with readily detachable locking devices.

126. Par.3-3(4). The cables are equipped with the female portion of the connector plug. This plug consists of a cylindrical stainless steel housing over a molded composition plate which contains the female jack contacts. The cable end of the housing is drawn in to give a close fit around a flanged sleeve which in turn fits tightly around the cable.

The flanged end fits inside of the housing and the body of the sleeve is threaded. A nut and washer is furnished which, when tightened, secures the housing to the sleeve and thence to the cable. A set screw holds the jack contact plate into the housing. The jack plate is engraved with numerals adjacent to the jacks to identify the several conductors. The locking buttons in this assembly are of magnetic material but have not rusted during the period of these tests. They should be of non-corrosive material or difficulty will be experienced with their operation.

127. Par.3-3(5). The plugs are fitted with a soft rubber sleeve for the purpose of rendering them waterproof. However, as tests in the field revealed and further tests in the Laboratory verified, it is possible for water to enter the generator plug and receptacle. During the tests the soft rubber sheath was forced against the generator housing as securely as possible but water still penetrated the receptacle. In order to avoid permanent breakdown, the use of non-charring insulation, as recommended in the foregoing paragraphs, is indicated. The battery cable plugs are considered as sprayproof but not waterproof, if immersed. Rubber sleeves are provided to keep moisture from entering the lock button holes and can be slid over the junction of the plug and receptacle.

128. Par.3-3(6). The plug receptacles are recessed and do not project beyond the outside surface of the generator and accessory box.

129. Par.3-3(7). The terminals in the battery and generator cables are so arranged that they are not interchangeable and the plugs are provided with positioning devices so that they can be inserted only in the proper position.

130. Par.3-3(9). All cables are shielded, the shielding being connected to the metal cable shell which in turn makes contact with the generator case and the cases of the transmitter receiver unit and accessory box which may be connected to the ground stake. The shielding is of the internal type protected by a coating of flexible rubber.

131. Par.3-3(10). No cable failures occurred during the tests herein described and the cables appear to be of a quality which will insure long life.

132. Par.3-4(1). Two antenna systems are supplied with the equipment, designated as the "small" and "large" antennas.

133. Par.3-4(2). A counterpoise constructed from four 20 foot lengths of flexible antenna wire is provided, which may be laid out star shaped upon the surface of the earth. An additional two foot length of wire is connected to the mid point of the counterpoise for securing it to the ground stake while a similar 5 foot length is provided for making connection to the ground terminal of the transmitter-receiver unit.

134. Par.3-4(3). The antenna and counterpoise wire is similar to Model "J" aircraft antenna wire.

135. Par.3-4(3) to (6). A double type reel of light weight and small size is furnished for stowing the antenna (large) and counterpoise. This reel proved suitable during the field tests if ordinary care were exercised to prevent the wire from becoming entangled.

136. Par.3-4(7a). The large antenna is so designed that it is suitable for securing to trees, poles, buildings, etc. Sufficient lengths of cordage of light weight are provided which may be secured to the ends of the flat top portion of the antenna. During field tests it was found that by weighting the end of the cord the weight could be thrown over a suitable projection, such as the limb of a tree, and the antenna raised into place.

137. Par.3-4(7b). The antenna is complete with suitable insulators, counterpoise and securing devices for attaching the wire to the insulators.

138. Par.3-4(7c). The flat top portion of the antenna is 40 feet long to the center of which is attached a 25 foot down-lead.

139. Par.3-4(7d). The counterpoise provided may be used with both the large and small antenna systems.

140. Par.3-4(8a). The small antenna is of the flagelliform type wherein the various sections telescope and permit the entire assembly to be erected in a vertical position. An ingenious method of securing the several sections together has been provided but unfortunately after several field trials this method of locking failed. The various portions are inserted in each other and are fitted with internal threads and with a spring device which locks the sections together. In disassembling the antenna the sections must be held apart with considerable force while they are unscrewed. Apparently with each operation a small section of thread has a tendency to break off of flatten out until finally the entire thread is destroyed and there remains no means of securing the sections together. It is recommended, therefore, that some other means be provided for securing the various sections of the antenna together. It is believed that an arrangement of ordinary internal and external pipe threads will prove to be most suitable.

141. Par.3-4(8b). The antenna is constructed of corrosion resisting steel which combines mechanical strength and minimum weight.

142. Par.3-4(8c). The total length of the antenna above the insulator is 24 feet 8 inches.

143. Par.3-4(8d). The antenna is erected by driving a metallic stake into the earth. This stake is fitted with a ball top and a binding post for providing connection to the transmitter-receiver unit. An insulated section fitted with a socket then rests upon the ground stake. This section is insulated by means of a 7/8" diameter mycalex rod, 1-1/2" long. The antenna proper then is slipped into place over the insulated section. The lowest section of the antenna proper is fitted

with a binding post by means of which connection may be made to the transmitter-receiver unit through the medium of an insulated wire. The ground stake is approximately 14" in length (overall). Immediately below the ball top is located the binding post. When the stake is driven secure into hard earth it is necessary to strike the top of the stake with a heavy object in order to remove it. This action subjects the binding post to injury and during field tests the binding post was broken off. It is recommended that the binding post be lowered three inches and that the ground stake be increased in length to 17 inches. This would be of great aid when the antenna must be erected in loose or sandy soil.

144. Par.3-4(8e). The antenna is sufficiently flexible to prevent breaking from its own weight and withstood the force of strong gusty winds during field tests. A suitable guying system is provided. Double guys are used near the center and at the bottom of the top section. The guys are secured to metallic pegs furnished with the equipment.

145. Par.3-4(8f). No section of the antenna exceeds 44" in length.

146. Par.3-4(8g). The weight of the small antenna, complete with canvas carrying bag, is 6 pounds 12 ounces. The specifications permit a weight of 4 pounds. It is feared, however, that any considerable reduction in the weight of this structure will militate against reliable service in the field.

147. Par.3-5(1) and (2). The accessory box is constructed of stainless steel. The lid is completely detachable and is secured by means of ten snap fasteners. The objections pointed out in preceding paragraphs with respect to the inadequacy of the cover fasteners on the transmitter-receiver unit apply also to the fasteners on the accessory box.

148. Par.3-5(3). The accessory box contains the following items:

1 - "A" battery (2 cells)
1 - "B" battery
1 - "C" battery (2 units)
1 - Battery cable
1 - Generator cable
1 - Antenna-counterpoise reel complete
1 - Telegraph key and cord
1 - Microphone and cord
1 - Spool containing guys and insulators for large antenna.
1 - 837 tube
4 - 34 tubes
1 - 1C6 tube
1 - Small antenna lead-in
2 - Hand cranks

No head telephone sets were furnished, but sufficient space is available for the stowage of one such set. No tools were provided with the preliminary model. The instruction book in its preliminary form will not

fit into the accessory box. In order to be accommodated in the accessory box the instruction book will have to be of small size and probably of unusual dimensions. In this connection it is recommended that the Bureau consider the advisability of having the instruction book bound in limp covers and printed on cloth treated in a manner to make it water resistant. The hard usage under varying climatic conditions in exposed locations to which field equipment will be subjected will undoubtedly cause the destruction of an ordinary paper instruction book in a short period of time.

149. Par.3-5(4). The battery compartments within the accessory box are provided with insulation adequate to prevent short circuiting of the batteries. The padding in the "B" battery compartment is of a loose felted material which is insecurely fastened to the box wall. This condition makes it difficult to replace "B" batteries, as this material leaves the box and rolls up under the battery when the battery is inserted. A more durable material securely fastened at the top, preferably by a metallic binder, is required. Careful packing, in accordance with the instructions of the manufacturer permits the stowage of all accessories with the exception of the instruction book.

150. Par.3-5(5). The accessory box in its present form is not submergence-proof as described under par.2-61 above. There are no external projections other than the snap fasteners and the receptacle cover plate securing screws.

151. Par.3-5(6). A schematic circuit diagram is attached to the inside of the cover under a waterproof shield of transparent material.

152. Par.3-5(7). It is possible to connect the battery cable when the accessory box is closed.

153. Par.3-5(8). A watertight cover is provided for the battery cable plug receptacle.

154. Par.4-1. The generator and batteries as specified in reference (c) supply all power necessary for the operation of the receiver and transmitter.

155. Par.4-2. The transmitter-receiver case is at ground potential, and the chassis makes positive electrical connection with the case by means of the panel-securing screws and nuts.

156. Par.4-3. All tests were made with fresh batteries which did not fall below 90% of the open circuit specified voltages for sensitivity and selectivity measurements, nor below 83% where continuous operation up to 7 and 8 hours was necessary.

157. Par.4-4. Test of operation was made with exactly 75% of specified voltages. The receiver was found to function satisfactorily but with a reduction in sensitivity of the order of 3 to 1.

158. Par.4-5. Normal "B" battery voltages as obtained from the specified battery equipment were used.

159. Par.4-6(1). Batteries are placed in the accessory box and provision is made for connection to the plug receptacle. The padding furnished in the "B" battery compartment is not properly secured at the top. Insertion of the battery is made difficult as the material rolls up, obstructing its passage. The padding should be positively secured at the top with some form of clamp which will protect the edge to prevent its destruction with use.

160. Par.4-6(2). The "C" battery is also placed in the accessory box, as designated in Contract Note, reference (b).

161. Par.4-6(3). The batteries furnished with the equipments are as follows:

"A" Battery - 2 Burgess No. 4FH, 1-1/2 V.,2-5/8" x 2-5/8" x 4-5/16".
"B" Battery - 1 Burgess No. B72BP, 108 V., 2-1/2" x 6-3/8" x 7-3/4".
"C" Battery - 2 Burgess No. 5540, 7-1/2 V.,13/16" x 3" x 3-15/16".

The dimensions given are all overall to include binding posts. During tests, replacement "B" batteries were ordered by type number and dimensions as shown above. Batteries were furnished bearing the same type number (B72BP), but having a height of 7-11/16", not including the binding posts, the overall height being 8-1/4". With this additional height, the batteries would not fit in the compartment provided in the accessory box.

162. Par.4-6(4). For the purpose of expediting battery life test, a substitute method was used as allowed by par.6-2(Test 9) of reference (c). The receiver was operated continuously for 7 to 8 hour periods for a total of 46.5 hours operation on one set of batteries. At the end of the 46.5 hours operation, "B" battery voltage was 85% of rated open circuit voltage, and "A" batteries would still maintain the normal 360 milliampere output for CW operation.

163. Par.4-7(1), (2), (3), (4). These paragraphs cover definitions of CW sensitivity, MCW sensitivity, audio fidelity and selectivity, respectively, the requirements of which were adhered to without deviation throughout the tests.

164. Par.4-8(1). The requirements of this paragraph are met.

165. Par.4-8(2). The frequency range of 2000 to 8000 kilocycles is amply covered without hiatus.

166. Par.4-8(3). A minimum number of controls are used, and tuning is accomplished by a single control.

167. Par.4-8(4). An antenna trimmer is provided for alignment of the first tuned circuit for the particular antenna used. Only one input is used for all antennae.

168. Par.4-8(5). The receiver is of the superheterodyne design and employs a total of five vacuum tubes, of two types, all of which are of the two volt series.

169. Par.4-8(6). The tuning range is covered in three bands.

170. Par.4-8(7). Band switching is accomplished by a single control located on the front panel.

171. Par.4-8(8). The overlap of adjacent bands meets specification requirements and is shown in Table R-1, which also shows the frequency range covered.

172. Par.4-8(9). The kilocycles per division are reasonably linear, the only variation being at the extreme ends of the bands where overlap occurs. These overlap frequencies, however, may be obtained in one of the bands on a portion of the curve that is fairly linear. The working range of the bands, including overlap, is covered from 0 to 100 divisions of a 100-division dial.

173. Par.4-8(10). The filament rheostat varies the filament current to all receiver vacuum tubes, and the control also operates a switch to cut off all battery power.

174. Par.4-8(11). The CW-MCW switch opens and closes the filament circuit of the audio oscillator and also opens and closes a compensating resistor in parallel to the filament rheostat, so that operation of the switch only is required to place the receiver in condition for CW or MCW reception.

175. Par.4-8(12). The band switch incorporates a "clicker" device which, however, is of insufficient positive action to readily distinguish whether the band switch stops on contact or between contacts. Also, the proper position of the switch when on contact does not line up with the engraving for No. 1 of the three bands.

176. Par.4-8(13). The sensitivity control is capable of reducing the voltage gain of the receiver 60 decibels, as shown on Plate R-10. The angular rotation of the sensitivity control versus audio output in decibels has linear relationship within the limits of $\pm$ 15 decibels with respect to average value, as shown on Plates R-11 and R-12.

177. Par.4-8(14). The sensitivity control operates in such a manner that the noise level is reduced in substantially direct proportion to a CW signal, as shown on Plate R-13, and without introducing appreciable extraneous noises in the audio output. The maximum noise level is shown on Plate R-31 for CW reception. When the CW oscillator is "off" and receiver in condition for MCW reception, with the sensitivity control at maximum, the noise throughout the entire frequrange is too small to be accurately measured with an output meter.

178. Par.4-8(15). Continuous variation in output, with a constant input, is shown on Plates R-11 and R-12, except for an irregular sector between 200 and 220°. This may be due to a defect in the winding of the particular resistor under test, which shows some roughness near the sector from 200 to 220°.

179. Par.4-8(16)(A). With a change in input from 0.5 microvolts to such values as to produce 8 milliwatts output, and with the receiver adjusted for CW reception with optimum gain, no appreciable change in the frequency of the audio output is noted.

180. Par.4-8(16)(B)(a). Output frequency change with variation in filament voltage from 100% to 90% is shown in Table R-2 and meets specification requirements. Frequency change with variation in plate voltage from 100% to 90% is shown in Table R-3 and meets specification requirements, except at 7500 kilocycles, where the change is .055% of the signal frequency. The reference frequency is taken as the incoming signal frequency as interpreted by manufacturers on page 56 of reference (f).

181. Par.4-8(16)(B)(b). With the receiver adjusted for optimum sensitivity, and with a CW input sufficient to give an output of approximately 6 milliwatts, the variation in frequency with variation in humidity between the limits of small values, and 75% at 50° C is shown on Plates R-23, R-24, R-25 and R-26. Specification requirements are not met.

182. Par.4-8(16)(B)(c). With the receiver adjusted for optimum sensitivity, and with a CW input sufficient to give an output of approximately 6 milliwatts, the variation in frequency with variation in ambient temperatures between the limits of 10° C and 50° C is shown on Plates R-17, R-18, and R-19. Specification requirements are not met. In reference (f), page 56, the contractor states that specification requirements cannot be guaranteed, but agrees to meet a value of 0.005% per degree Centigrade, which would be the equivalent of 0.2% for a temperature change of 40° C as compared with 0.05% required by the specifications. It is found, however, that neither the specification requirements nor the contractor's agreement has been met.

183. Par.4-8(16)(B)(d). Placing the receiver on a vibration table, with vibrations of the order of 1200 per minute, a chirping signal was produced which returned to normal with the cessation of vibrations. While on the table and under vibration, a signal picked up with an antenna could be read during slow transmission. Microphonics due to normal service use are not believed to be serious.

184. Par.4-8(17). Output impedance characteristics are shown on Plate R-15. Maximum output is obtained with an output load of 2000 ohms which, however, is but 1.35 decibels up from a load of 600 ohms.

185. Par.4-8(18). The output circuit of the receiver has an output transformer, by means of which all d.c. potentials are removed from the output. Neither the wiring diagram nor the Preliminary Instruction Book, reference (g) shows that the output transformer has an electrostatic shield; therefore, there may be some radio frequency potentials in the output. The secondary of the output transformer does not have a grounded center tap, and it is probable that the opposite sides of the lines are not of substantially the same instantaneous potential with respect to ground and that the intent of the specifications has not been met.

186. Par.4-8(19). Twenty-five volts at a resonant frequency of 2200 kilocycles was applied to the input of the receiver without harmful effect. The impedance of the input circuit involved is calculated to be of a value that will not permit sufficient current to flow to cause injury to the component parts of the circuit with 25 volts applied at any frequency within the range of the receiver.

187. Par.4-8(20). Microphonic noises are as low as can be expected from the types of tubes used, and the construction of the case in which they are contained. They are considered to have been kept at a reasonable minimum.

188. Par.4-8(21). The intermediate frequency is 1520 kilocycles, which meets specification requirements.

189. Par.4-8(22). The audio beat oscillator is adjusted to produce an audible signal of approximately 1,000 cycles; however, it was found that maximum sensitivity at 1,000 cycles was not obtained with the oscillator wobbler at a zero setting in all cases, the average optimum setting on receiver Serial No.3 being -5, while on Serial No. 2 it was approximately at 0.

190. Par.4-8(23). The frequency wobbler is provided with a zero center scale, and varies the audio beat oscillator tuning as shown in Table R-4, which is in excess of the specification limits.

191. Par.4-8(24). Selectivity is shown on Plates R-3, R-4 and R-5, and is well within specification requirements, as amended by contract note, reference (b).

192. Par.4-8(25). Audio fidelity is shown on Plate R-14 and does not meet specification requirements as to a flat response of $\pm$ 3 decibels between 200 and 3000 cycles with respect to a 1000 cycle reference frequency. Between 310 and 3000 cycles the specification requirements are met, while at 200 cycles the response is 4.8 decibels down from the 1000 cycle response.

193. Par.4-8(26). CW sensitivity is shown on Plate R-1 and MCW sensitivity on Plate R-2. CW sensitivity, which was taken throughout with the audio oscillator wobbler at zero center scale setting, does not meet specification requirements except at the upper end of band 1. MCW sensitivity meets specification requirements in bands 1 and 2, and all except the upper half of band 3. It will be noted that with 1,000 cycles modulation the MCW sensitivity is within specification limits throughout the entire range of the receiver.

194. Par.4-8(27). With impacts having a maximum amplitude of 5 volts to simulate static surges applied to the receiver input, and the output measured by the customary cathode ray method as described under METHOD OF TESTS, the reduction in sensitivity was found to persist .001 second after cessation of the input surges, which meets specification requirements.

195. Par.4-8(28). The audio system of the receiver is not used for modulating the transmitter from a microphone input.

196. Par.4-8(29). The accuracy of resettability is shown in Table R-5 and is found to be within specification limits.

197. Par.4-8(30). With a CW input modulated 30% at 400 cycles, the output of the receiver was measured with a General Radio wave analyzer for harmonic content, with the results as shown in Table R-6. On a wattage basis, the percent of total harmonics is within specification limits.

198. Par.4-8(31)(a). With the receiver adjusted for optimum sensitivity, and with a constant input, the variation in output with variation in ambient temperature between the limits of 10°C and 50°C is shown on Plates R-20, R-21 and R-22. During these tests the percentage of humidity was maintained at a low value. Specification requirements are met for all except at 7500 kilocycles when the temperature dropped to 10° C. Since output measurements were made at various audio frequencies, an average curve as shown by the dotted line on Plate R-22 is believed to be a more nearly correct representation of the output variation.

199. Par.4-8(31)(b). With the receiver adjusted for optimum sensitivity, and with a constant input, the variation in output with variation in humidity from low values to 75% also up to 95% is shown on Plates R-27, R-28, R-29, and R-30. Specification requirements are met for all. As in the case of the preceding paragraph, outputs were measured at various audio frequencies, and the heavy dips are believed to be due to this condition, and should not be taken into consideration. The dips, however, are still within specification limits.

200. Par.4-8(31)(c). With the receiver adjusted for optimum sensitivity, and with a constant input, variation in output due to variation of filament voltage of 10% is shown in Table R-2, and is well within specification limits.

201. Par.4-8(31)(d). With the receiver adjusted for optimum sensitivity, and with a constant input, variation in output with change of any or all tubes is shown in Table R-7 and is within specification limits.

202. Par.4-8(32). Under normal operating conditions, and using the calibration curves furnished with the equipment, the receiver was set to various frequencies with the results as shown in Table R-8. The actual output frequency is shown which is compared with the normal 1000 cycle frequency to determine the percentage of variation from correct setting. Specification requirements are met under these conditions.

Image Response. The response of the receiver to frequencies other than resonant frequency is shown in Table R-9. An input of 420 microvolts at the intermediate frequency of 1520 kilocycles will produce standard output of 6 milliwatts, and an input of 575 microvolts at the primary image frequency, 5240 kilocycles will produce a 6 milliwatt output. The input required for standard output at resonance under the above conditions was 14 microvolts, the resonant frequency used being 2200 kilocycles.

203. Par.4-9(1). The transmitter employs a single vacuum tube of the pentode type, Type 837. The circuit is such that master oscillator power amplifier performance is obtained by the use of this single tube.

204. Par.4-9(2). The transmitter is capable of supplying approximately 9 watts CW and 3 watts voice to an antenna system over the frequency range of 2000 to 3500 kilocycles. An examination of Table T-2 reveals, however, that to obtain in the neighborhood of 9 watts CW and 3 watts Voice requires that the high voltage generator current be in the region of 60 to 65 milliamperes rather than at the 50 milliampere level at which the generator is rated. However, the generator furnished is entirely capable of withstanding a 65 milliampere output continuously without trouble, since during the course of these tests it was operated at the 65 milliampere level for many successive 7 hour key locked periods. Furthermore, the difficulty in making accurate radio frequency power measurements at 3 to 10 watt levels subjects the measurements to errors of at least 10%. In no case is it necessary to exceed a generator output wattage of 40 watts to obtain maximum operation at the 65 milliampere level. Par.4-9(22) of the governing specifications permits 40 watts for MCW operation and 30 watts for CW operation. In actual practice these limits are reversed; i.e., CW operation requires 40 watts and MCW 30 watts or less. In addition, field tests indicated that the equipment is capable of producing excellent signals at distances up to 30 miles which were readable in spite of serious interference from local static. In view of the foregoing, it is recommended that the Model TBO equipment as submitted for test be considered as meeting the output requirements of the governing specifications. The output was free from lilt and no objectionable harmonics or unwanted radiations were noted. In order to obtain an approximate comparison of the relative efficiency of the large antenna as compared with the small antenna, a series of field strength measurements were made. The results of these tests are illustrated in Table T-3. It must be borne in mind, however, that field strength measurements of this nature are not entirely reliable, due to local conditions, distortions in the field strength pattern, angle of radiation, etc. Still these measurements undoubtedly give a fair indication of the results which may be expected, and to a large extent this opinion was verified by field trials. It will be noted that in general the large antenna is approximately twice as efficient as the small antenna, that very little difference was noted between the use of a counterpoise or a straight ground, and that insulating the counterpoise had no appreciable effect as compared with an uninsulated counterpoise.

205. Par.4-9(3). The frequency range of 2000 to 3500 kilocycles is covered without resorting to plug-in coils. However, the power amplifier circuit is provided with a three point band switch. Actually this control tends to tune both the power amplifier stage and the antenna circuit and in view of the fact that the master oscillator circuit covers the entire range without the use of a band change switch, it is recommended that the arrangement of circuits as furnished be considered satisfactory and as meeting the spirit of the specifications.

206. Par.4-9(4). The transmitter unit accommodates two crystals simultaneously, either of which may be selected at will by means of a selector switch. This same selector switch permits operation of the self-excited master oscillator circuit.

207. Par.4-9(5). The crystal-master oscillator selector switch is located on the front panel of the transmitter unit.

208. Par.4-9(6). The number of controls provided for the operation of the transmitter is considered to be a practical minimum for obtaining the type of operation required by the governing specifications. The tuning controls are provided with locks. The power amplifier tuning control is operated by means of a small knob and dial which furnishes direct drive of a variable capacitor. The adjustment of the power amplifier circuit requires an accurate adjustment for maximum output and frequency accuracy when employing master oscillator control. It is therefore recommended that some form of simple vernier drive be provided on this control.

209. Par.4-9(7). Tests were conducted wherein the transmitter master oscillator dial setting was determined from the calibration chart. This setting was approached alternately from a clockwise and counterclockwise direction and the divergence from the actual frequency desired noted. Table T-4 illustrates the results of these tests. It will be noted that the equipment complies with the specification requirements in this respect.

210. Par.4-9(8). The frequency range specified, i.e., 2,000 to 3,500 kilocycles, is covered by the continuously variable master oscillator control. The extreme frequency limits which this control covers between the minimum and maximum setting are indicated in Table T-5.

211. Par.4-9(11) and (12). The quartz crystals furnished are of the low.temperature coefficient type. The four crystals furnished with the two equipments operated satisfactorily during the course of these tests. The frequency variation at 2076 kilocycles per degree Centigrade, between the limits of 10 to 50° C, is 0.00016%, as is illustrated in Plate T-1. The variation at 2772 kilocycles is 0.00021% per degree is shown in Plate T-2.

212. Par.4-9(13). The two crystals are mounted within the transmitter unit by means of substantial spring clips.

213. Par.4-9(14). No trace of spurious frequencies were observed during the course of these tests, the crystals producing pure fundamental output only.

214. Par.4-9(15). The frequency of the crystals was checked while they were operating in the equipment at full power output at an ambient temperature of 25° C. All crystals were found to be within 100 cycles of the specified frequency.

215. Par.4-9(16). A Send-Receive switch is provided on the transmitter-receiver unit for the purpose of switching the antenna

from the transmitter to the receiver, and vice versa for alternate transmission and reception. No break-in relays are provided in the TBO equipment.

216. Par.4-9(17). Actual tests demonstrated that the transmitter is capable of being keyed up to 30 words per minute and is capable of being modulated up to 90% over the audio frequency range of 200 to 3000 cycles.

217. Par.4-9(18). A CW-MCW switch is provided for making all the necessary adjustments for transferring from one type of emission to the other. The receiver audio system is not employed in connection with the transmitter circuits.

218. Par.4-9(19). No modulation control is provided on the TBO equipment. The transmitter is so designed that normal speech impinging upon the microphone held close to the lips of the operator will produce approximately 90% modulation of the carrier.

219. Par.4-9(20). A single 837 vacuum tube is employed in the transmitter, the filament of which operates at 12.6 volts, d.c.

220. Par.4-9(21). As previously stated, the receiver audio system is not employed in connection with the transmitter voice circuits.

221. Par.4-9(22). As pointed out above under par.4-9(2), the generator output does not exceed 40 watts for CW operation and for voice operation the power required is approximately 30 watts or less. This type of operation does not strictly comply with the specification requirements, but since the maximum power of 40 watts is not exceeded under any circumstances (except misadjustment or faulty tuning) it is believed that the spirit of the specifications is complied with and it is recommended that the equipment receive approval in this respect.

222. Par.4-9(23). The transmitter is completely shielded with respect to external objects and the internal shielding is sufficient for satisfactory operation.

223. Par.4-9(24). Two suitable meters of the 2.5" diameter flush type are provided on the panel for tuning operations.

224. Par.4-9(25). A suitable switch is provided so that the one d.c. meter may be used for checking transmitter and receiver currents and potentials.

225. Par.4-9(26). The meters were subjected to high humidity at high temperature and to numerous heat cycles without showing any signs of injury or faulty operation.

226. Par.4-9(27). An experienced operator can adjust the transmitter accurately to any given frequency for which a calibration is available in less than one minute.

227. Par.4-9(28a). The frequency change occurring when the transmitter is subjected to changes in ambient temperatures between the limits of 50° and 10° C was determined for two types of control and on four frequencies, as follows:

Crystal Control, 2076 kilocycles
Crystal Control, 2772 "
Self Excited MO, 2000 "
Self Excited MO, 3500 "

Plate T-1 illustrates the test conducted at 2075 kilocycles wherein it will be noted that the maximum frequency change encountered was 136 cycles, or 0.0065%. Plate T-2 illustrates the test conducted at 2772 kilocycles, the maximum frequency shift due to temperature change was 236 cycles or 0.0085%. Plate T-3 covers the test conducted at 2000 kilocycles, self-excited master oscillator, wherein the maximum frequency shift was 2600 cycles, or 0.13%. Plate T-4 covers the test conducted at 3500 kilocycles, self excited master oscillator, wherein the maximum frequency shift due to temperature variation was 6315 cycles, or 0.18%. It will be noted that during all tests the relative humidity was held to values below 25% and that the temperature was held constant for one hour at each 10° point in an attempt to permit the transmitter to stabilize at these points. In the case of crystal control the frequency drifted downward as the temperature decreased; with self-excited master oscillator the frequency of the transmitter increased as the temperature decreased.

228. Par.4-9(28b). The frequency changes encountered when the relative humidity of the atmosphere surrounding the equipment was varied between the limits of approximately 10% and 95% were determined for crystal control operation and self excited master oscillator operation, as follows:

Crystal Control, 2075 kilocycles
Crystal Control, 2772 "
Self Excited MO, 2000 "
Self Excited MO, 3500 "

Plate T-5 illustrates the test conducted at 2076 kilocycles and it will be noted that changes in relative humidity had a negligible effect, the maximum frequency change noted being 12 cycles, or 0.0005%. Plate T-6 covers the test conducted at 2772 kilocycles, crystal control. The maximum frequency change encountered during this test was 82 cycles, or 0.0029%. The frequency change during the first hour of the test accounted for practically the entire change and may have been due to heating in the transmitter rather than due to any effect of humidity. Plate T-7 illustrates the test conducted at 2000 kilocycles, self excited master oscillator. The maximum frequency change attributable to humidity effects is 1780 cycles or 0.089%. Plate T-8 covers the test conducted at 3500 kilocycles, wherein the maximum frequency change noted was 4140 cycles, or 0.118%. When using crystal control the humidity has little effect upon the frequency. With self excited master oscillator the frequency varies inversely as the humidity. In all tests the temperature was maintained substantially constant at 50° C.

229. Par.4-9(28c). The frequency change due to 25% variation in antenna constants is illustrated in Table T-6. The tests covered both crystal control and self excited master oscillator.

230. Par.4-9(28d). Within normal limits of speed of rotation it is impossible to cause the voltage of the hand driven generator to vary appreciably. Therefore, this requirement of the specifications was interpreted to mean the frequency change encountered when the speed of rotation of the hand driven generator was varied between the limits of ± 10%, or 54 r.p.m. to 66 r.p.m., normal speed being 60 r.p.m. Table T-7 reveals the results of this test. At no frequency, either crystal control or self excited master oscillator, did a 10% speed variation affect the output frequency.

231. Par.4-9(28e). The variations in frequency caused by variations in keying speed are illustrated in Table T-8 appended hereto.

232. Par.4-9(28f). Frequency changes due to variation in the percentage modulation between limits of 0% and 90% are illustrated in Table T-9. Only in the region of 2000 kilocycles, self excited master oscillator, did the level of modulation affect the carrier frequency. It will be noted that due to the resulting distortion at 2,000 kilocycles the carrier frequency shifted 308 cycles or 0.015%. At the other frequencies tested no frequency shift could be discerned.

233. Par.4-9(28g). The Model TBO equipment, Ser.No.3, was secured to a test stand and subjected to vibration and to roll and pitch through an angle of 45° on either side of the vertical, at a rate of 6 r.p.m. Table T-10 reveals the results of these tests. Vibration or inclination from the vertical had no effect upon crystal controlled operation, but did have an appreciable effect upon self excited operation. However, at all times while the equipment was being subjected to vibration, or pitch and roll, a readable signal could be obtained in a nearby receiver. At 2000 kilocycles, while being subjected to roll and pitch, the beat note in the Model RAB test receiver varied sufficiently so that it passed through zero beat when the original adjustment gave about a 1,000 cycle note.

234. Par.4-9(28 summary). Table T-11 summarizes the frequency changes due to the various conditions outlined in this paragraph of the specifications. The transmitter complies fully with the requirements of the specifications with regard to stability for crystal control operation.

235. Par.4-9(29). The stability characteristics of the TBO transmitter, self excited operation, are illustrated in Plates T-3, T-4, T-7, T-8 and Tables T-6 to T-11 inclusive. From Table T-11 it will be seen that the stability requirements for self-excited operation have been exceeded by a small degree. Due to the arduous nature of some of the tests and the difficulty in making precise measurements, it is recommended that the self excited frequency stability of the TBO equipment be considered as satisfactory and complying with the requirements of the governing specifications. The specifications limit the total frequency variations from all causes to 0.3%. The actual figure determined during the tests is 0.33%, or an excess of approximately 10%.

236. Par.4-9(30). Table T-12 covers tests conducted in accordance with this paragraph of the specifications (Test No. 15). When employing crystal control the calibration curves are entirely adequate for accurate settings of the master oscillator dial and over the range of settings where the crystal will oscillate it is difficult to drag the crystal frequency as much as 100 cycles in 2000 to 3000 kilocycles. When employing the self excited master oscillator the settings obtained from the calibration chart complied with the specification requirement of 0.1% accuracy, except in the region of 2000 kilocycles where this figure was slightly exceeded. During the tests called for by Tests No.15 and 16 which together with the tests conducted under par.4-9(7) of the specifications (See Table T-4) also constitute a measure of the back-lash inherent in the master oscillator control, it was noted that the required degree of reset could be obtained if during these tests the control was not rotated far enough to come up against the stop at either end. The master oscillator control operates a variable capacitor through the medium of a 20 to 1 gear reduction and a universal joint. The stop is on the condenser itself and consists of a pin inserted in the condenser shaft which strikes upon a protruding member when the limit of rotation is attained. Even though the control is rotated in a manner which permits the stop to be struck lightly a serious shift in the calibration occurs, as is illustrated in Table T-13. From this table it will be noted that touching the stop alternately on the high and low end, frequency differences as great as 33 kilocycles in 3500 kilocycles, or 0.9% are encountered. The universal joint, or flexible coupling, used consists of an isolantite ring across which two flexible metallic strips are connected at right angles. In order to make connection to the drive shaft and the driven shaft, collars with set screws, are secured to the flexible cross members. Apparently these collars are turned down at one end until a thin section is obtained, which is inserted in a hole in the center of the cross members and then peened over. No signs of soldering or brazing could be detected at the point of peening or riveting. It is believed that the mechanical shift occurs at this point. It is recommended that this assembly, as well as the similar one in the receiver, be so modified that the stop is located before the flexible coupling so that the condenser itself is not required to suffer strain and that if joints similar to those described above are employed, that they be securely brazed or soldered.

237. Par.4-9(31). When employing crystal control the transmitter is capable of being reset with an accuracy greater than 0.02%. See Table T-14. Although no specification value is given for self excited master oscillator, a test was conducted to determine the resettability of the transmitter under this condition. Table T-14 shows the results of this test.

238. Par.4-10(1). During the course of these tests the generator was subjected to numerous 7 and 8 hour periods of continuous operation at full load and even at loads somewhat in excess of the rated load. (See comments under par.4-9(2). During these periods the generator was required to operate at temperatures ranging from +50° C to -30° C and was subjected to long periods of humidity as high as 95% (relative). During the major portion of the tests an electro-mechanical drive was employed. It is estimated that the generator was in service equal to

many months of hand driven operation. During this period the generator required no actual upkeep and post trial inspection revealed no signs of wear or lack of lubrication. As pointed out under previcus paragraphs of the specifications, the chain by means of which the generator is secured to a support is unsatisfactory and must be corrected. The insulating material employed in the terminal socket in unsatisfactory. It was also discovered that the end plate covering the armature shaft in Generator No.2 fitted too tightly against the bearing. Loosening this cap reduced the input power required by 7 watts. Care must be exercised to avoid this condition in production equipment.

239. Par.4-10(2). The generator is capable of supplying all necessary d.c. power, properly filtered, for the operation of the transmitter, including the modulating system.

240. Par.4-10(3). Table T-15 summarizes the results of tests conducted to determine the voltage regulation of the generator under the following conditions:

(a) Variation in generator speed of 10%
(b) Key up to keying at 30 w.p.m.
(c) Variation in modulation of from 0 to 90% modulation of the carrier at 1,000 cycles.

It will be noted that the voltage variations of the low voltage end were entirely negligible, while the total combined variation of the 500 volt supply was 3.5% for all conditions of test. Specifications permit a 10% variation. Modulation measurements were made at 400 cycles, due to the lack of a suitable 1000 cycle source at the time of test. Later 1000 cycle modulation was employed and found to give results similar to those obtained at 400 cycles.

241. Par.4-10(4). Reference to Table T-2 reveals that the mechanical efficiency of the generator is between 52 and 58%; i.e., the electrical power output of the generator is approximately 55% of the mechanical input to the generator.

242. Par.4-10(5). The generator is capable of delivering 100% overload for a period of 15 minutes without injury or undue heating. See Table T-16 appended hereto.

243. Section V. Instruction Books. Attention is invited to comments under par.148. The instruction books in their preliminary form were satisfactory for placing the equipment into commission, but are not adequate for the use of service personnel.

244. Par.6-2, Test 1. This is covered by pars. 42 to 153 inclusive, in the discussion of specification requirements under Section II "General" and Section III "Mechanical Requirements".

245. Par.6-2, Test 2. Receiver Sensitivity, see par.193.

246. Par.6-2, Test 3. Receiver Selectivity, see par.191.

247. Par.6-2, Test 4. Receiver Fidelity, see par.192.

248. Par.6-2, Test 5. Receiver Stability, see par.179-183, inclusive.

249. Par.6-2, Test 6. Receiver Output, see par.197-201, inclusive.

250. Par.6-2, Test 7. Receiver Calibration, see par.202.

251. Par.6-2, Test 8. Receiver Resettability, see par.196.

252. Par.6-2, Test 9. Battery Life, see par.162.

253. Par.6-2, Test 10. Receiver Overlap, see par.171.

254. Par.6-2, Test 11. See pars. 165, 171, 205,210.

255. Par.6-2, Test 12a. See par.204.

256. Par.6-2, Test 12b.(a) An additional test was conducted to determine the action of the transmitter when subjected to an ambient temperature of -30° C. The transmitter was operated at a frequency of 2772 kilocycles crystal control. During the course of the test which lasted for approximately 8 hours record was made of the ambient temperature, the output frequency of the transmitter, the power output of the transmitter and the mechanical efficiency of the generator. These data are plotted against time in Plate T-9. It will be noted that the mechanical efficiency of the generator dropped from about 50% at +30°C. to about 30% at -30° C. The frequency of the transmitter changed 900 cycles over the range of temperature, or 0.032%. The power output decreased from 8.4 watts to 7.6 watts. No signs of failure, either electrical or mechanical, were noted during the course of this test.

(b). The specifications require a test conducted at 60° C with 90% relative humidity. This test was not actually conducted. The test chamber wherein tests of this nature are conducted uses ammonia as the refrigerant, which must also be employed in regulating the degree of humidity. 50° C is the maximum temperature at which it is safe to operate the system with ammonia present; operation at higher temperatures is like to cause severe casualties to both personnel and materiel. Without the use of ammonia the control of humidity is lost and it is likely that the test chamber would have become saturated, or the percentage of humidity would have to have been held at a point much lower than that required by the specifications. For these reasons this test was omitted. However, as illustrated in Plates T-5 to T-8, inclusive, it will be observed that the equipment was operated for several hours at 50° C with relative humidities as high as 95%. Hence it is believed safe to assume that the equipment will withstand the 60° 90% humidity test without failure. It may also be pointed out that human beings could not exist for any length of time in an atmosphere of this nature.

257. Par.6-2, Test 13. Tests of percentage modulation were conducted at 2000 kilocycles and 3500 kilocycles, master oscillator control, and at 2772 and 2076 kilocycles, crystal control. 90% modulation of good quality was readily obtained by three different operators. In all tests of voice modulation, good quality of speech was obtained. As pointed out in previous paragraphs of this report, the Automatic Electric Company microphone is to be preferred to the other type of microphone submitted by the manufacturer.

258. Par.6-2, Test 14. See Tables T-6 to T-11 inclusive and Plates T-1 to T-8 inclusive appended hereto and comments made under pars.227 to 235 inclusive.

259. Par.6-2, Test 15. See Tables T-12 and T-13 and comments under par.236.

260. Par.6-2, Test 16. See Table T-14 and comments under par. 237.

261. Par.6-2, Test 17. See Table T-2 and comments under par.204.

262. Par.6-2, Test 18. See Table T-15 and comments under par,240.

263. Par.6-2, Test 19. The key open efficiency of the hand driven generator; efficiency at 30 words per minute keying and efficiency at 90% modulation were determined and the results of these tests are listed in Table T-17. The key open efficiency was determined as approximately 45% under $\pm$ 10% variation in hand crank speed. The specifications require 50% efficiency under these conditions. While no accurate determinations of efficiency at 30 w.p.m. keying were possible, it is calculated that the efficiency was in the nieghborhood of 50%. At 90% modulation the efficiency is approximately 55%. As pointed out previously in this report, it is believed that efficiency measurements of this character are subject to a 5% error, and hence it is recommended that the generator be considered as complying with the requirements of the specifications as outlined under Test No. 19.

264. Par.6-2, Test 20. A two hour locked key test was conducted at 2772 kilocycles, crystal control. The results of this test are summarized in Table T-18. From this data it will be noted that during the test the mechanical efficiency never fell below 50%, the output watts required from the generator did not exceed 37.3; the radio frequency output from the transmitter actually had increased at the end of the two hours to a value of 9.3 watts from a starting level of 8.7 watts and the maximum frequency change noted was 73 cycles or 0.0026%. It may therefore be stated that the Model TBO equipment successfully withstood the two hour locked key test. In this connection it may be pointed out that the equipment was actually subjected to many key locked tests of 7 and 8 hours duration (see tests relative to temperature and humidity) and successfully withstood the strains imposed by these tests.

265. Par.6-2, Test No.21. A 72 hour humidity test was conducted in accordance with par.2-46 and in accordance with the instructions outlined in ref.(d). For the results of this test see Plate T-10 and comments under par.2-46. During this test the transmitter-receiver chassis was partially removed from the case.

266. Par.6-2, Test No.22. See discussion under par.83.

267. Par.6-2, Test No.23. Additional receiver tests made, but not specifically designated, are covered as follows:

Image Response, See par.202.
Time Constant, See par.194.
Output Impedance, See par.184.
Resonant Overload, See Plates R-6, 7, 8, 9.
Maximum Noise Level, See par.177.
Signal plus Noise vs.Noise, See par.177.
Range and Linearity of Sensitivity Control, See par.176.
Setting by Calibration, See par.202.
Frequency Wobbler Range, See par.190.

Field tests were conducted with both equipments. The frequency of transmission was 2076 and 2772 kilocycles, crystal control, and 2000 and 3500 kilocycles, self excited master oscillator. Both voice and CW signals were observed and tests were conducted at distances of 5, 10, 20, and 30 miles. Large and small antennas were employed during all tests, both for transmission and reception. After a slight amount of experience, it was possible for a group of four men to place the equipment into operation, that is, erect both antenna systems, secure the motor generator to a support, connect the various units and be on the air in a period of about 15 minutes. Naturally, the time for installation will vary due to the character of the ground, accessibility of suitable trees, posts, buildings, etc. During the most extensive field tests Equipment No.2 was operated in nearby Virginia and Set No.3 in nearby Maryland. At ten miles signals of strength 4 to 5 were obtained under all conditions of operation, i.e., voice or CW, at any frequency and with both large and small antennas. At twenty miles the use of the large antennas showed a decided superiority, especially on certain frequencies. During these tests afternoon static was very severe and the tests were conducted in the presence of local thunderstorms. Set No.2 was caught in a sudden local shower at one location which was instrumental in causing the failure of the generator socket insulation previously referred to. During the 30 mile range test, static of terrific intensity was present. In spite of this, CW signals could be copied when the large antenna was employed at both ends of the circuit. Voice communication was unreliable under these conditions. In general, it may be stated that the Model TBO equipments will give satisfactory operation up to distances of 50 miles under good conditions of reception. Severe interference in the form of static is likely to cut this distance in half. Voice communication should be reliable up to 30 miles under good conditions and up to 15 or 20 miles when atmospheric conditions are less favorable. It appears that approximately one-half the range may be expected when employing the small antenna as compared with the large antenna. The

operation of the hand driven generator was not particularly tiring for short periods of time. In the majority of cases, after personnel had become somewhat acquainted with the equipment, contact was established with practically no preliminary calling. No. 2 equipment suffered a receiver casualty during the field tests, the nature of which is described under par.50(e). (NOTE: In this connection the almost constant failure of 1C6 tube socket should be emphasized.)

268. Section VII. Spare Parts. No spare parts were provided with the preliminary model (tubes excepted) under the terms of the governing contract.

SUMMARY OF DEFECTS

269. A summary of the defects noted and such items as require modification or correction are listed below: (NOTE: The numerals enclosed in parentheses refer to the paragraphs of this report under which these items are discussed in detail.)

(a) (42(a), 50(a), 50(c), 140, 143, 146) Telescopic joints of "small" antenna failed; ground stake binding post should be relocated; ground stake should be increased 3" in length; small antenna assembly exceeds specification weight.

(b) (42(b), 44, 85, 145) Cover-securing clamps are unsatisfactory.

(c) (42(c), 50(g), 93) Antenna binding posts of stronger construction should be supplied; binding posts should be substituted in place of plug and jack connections.

(d) (42(d) Cracked crystal holder.

(e) (42(e), 50(b), 106) Chains on generators lack strength.

(f) (42(f), 94, 127) Generator cable and socket insulation inadequate.

(g) (44, 68) Non-corrosive materials have been used in construction of several items.

(h) (48, 87) Hand key button should be fabricated from more suitable material.

(i) (50(b), 100) Tube sockets inadequate under influence of vibration and shock.

(j) (50(d), 50(e) Tube shields and shielding of second oscillator coil (receiver) are unsatisfactory.

(k) (50(i) Cover gaskets become loose under influence of temperature.

(l) (54) The vacuum tubes employed have not been selected from types specified in RE 13A 346.

(m) (60) Antenna ammeter should be connected in high side of circuit.

(n) (62) Navy type numbers have not been affixed to component parts in the preliminary model.

(o) (63) Resistor mountings are not marked to indicate the Navy number of the resistor units required.

(p) (78) Combined weight of equipment exceeds specification requirements.

(q) (79) Dimensions of accessory box exceed specification limitations.

(r) (83, 95, 150) Equipment is not submergence-proof.

(s) (88) Chassis not capable of easy removal from the case without scraping or binding, due to fasteners extending over face of the case, protrusion of "goat" type tube shields, and insufficient reinforcing of case to prevent distortion. The trimmer condensers are not sufficiently protected from disarrangement in removing chassis from the case.

(t) (92) Knurled head securing screws for holding transmitter-receiver unit in chassis require modification.

(u) (98) Receiver tuning dial is not satisfactory with respect to visibility.

(v) (99) The calibration curves furnished with Serial No.2 receiver are not complete for one of the bands.

(w) (100) Silver-plated friction contacts in band switches and tube socket contacts are not satisfactory. "Goat" type shields on receiver tubes are not satisfactory and are believed to contribute to the existing tube socket contact failures.

(x) (100) Front panel of equipment requires additional rigidity.

(y) (101) The variable condenser contacts are not considered satisfactory for Naval service.

(z) (104) Receiver main control is somewhat inaccessible.

(aa) (149, 159) The padding in the "B" battery compartment of accessory box is not suitably fastened.

(bb) (161) Replacement "B" batteries furnished under the battery manufacturer's type number were of a different size than the batteries supplied with the equipment and would not fit in accessory box, although bearing the same type number.

(cc) (175) The "clicker" device on the band switch of the receiver is not sufficiently positive in action.

(dd) (181) Frequency stability of receiver with variation in percentage of humidity is not within specification limits.

(ee) (182) Frequency stability of receiver with variation in ambient temperatures is not within specification limits, nor is it within the limits which contractor agreed to meet in ref.(f).

(ff) (185) The opposite sides of the phone cords are not of substantially the same instantaneous potential with respect to ground.

(gg) (190) The range of the frequency wobbler exceeds specification limits.

(hh) (192) Audio fidelity of receiver is not within specification requirements.

(ii) (193) Sensitivity of receiver, both CW and MCW, is not within specification limits.

(jj) (198) Receiver output variation for temperature cycle exceeds specification limits at the upper end of band 3 at 10° C.

(kk) (204) Transmitter fails to comply with power output requirements; excess generator current at 500 volts required.

(ll) (205) Band switch provided on Transmitter PA circuit in violation of specifications.

(mm) (234) Effect of roll and pitch at 2000 kilocycles, master oscillator, interferes with reception.

(nn) (235) Frequency stability requirements of specifications for self- excited master oscillator transmitter operation are exceeded.

(oo) (236) Calibration chart for transmitter fails to comply with specification requirements at 2000 kilocycles; method of providing stops on master oscillator control unsatisfactory.

(pp) (238) Undue friction caused by end plate on generator shaft of No. 2 hand driven generator.

(qq) (253) "Key Open" efficiency of generator does not meet specification requirements.

CONCLUSIONS

270. The general appearance of the TBO equipment is excellent and high grade materials have, in general, been employed in the construction. While a congested condition results in the transmitter-receiver unit and the accessory case due to the stringent weight and dimensional limitations, efforts have been made to retain as great accessibility as possible. Certain panel controls are capable of rearrangement to provide more convenient operating conditions and the power amplifier control requires additional refinement of adjustment.

271. Receiver. The receiver is very compact and the parts are as accessible as can be expected considering the governing size and weight limitations. These features, combined with its employment of simple and effective circuits with high quality insulation and reasonably rugged construction, make it potentially adaptable for portable and field use. There are, however, certain performance and constructional features which will require modification for specification compliance. The most important of the performance shortcomings have to do with sensitivity and frequency stability. Constructional changes are required to overcome contact difficulties, the effect of panel distortion from manipulation on frequency stability, loosening of tubes in their sockets from transportation and vibration, greater clearance of the tube shields in the cabinet, corrosion of the cadmium plated parts, and the possibility of damage to unprotected trimmer condensers in chassis handling.

272. Transmitter. The transmitter circuits are exceedingly compact and master oscillator power amplifier operation is secured through the use of a single tube. The efficiency of the circuits is high and may be controlled with ease and accuracy when the size and other structural limitations are considered. Crystal control operation produces excellent frequency stability, clearness of emission and good voice characteristics. These qualities are, naturally, less evident when self-excited operation is employed, but, notwithstanding, signals of good quality and intelligibility are obtained over the entire frequency range. The radio frequency power output appears to be slightly less than that stated in the governing specifications, but under actual service trials the equipment demonstrated its ability to maintain two-way communication over distances of 30 miles in the presence of severe disturbances and interference. Under favorable conditions of reception, 50 mile ranges should be possible.

273. Antennas. The large type antenna furnished can readily be erected in territory where trees, poles, or other suitable objects are available. The small antenna, which may be erected under practically any conditions, is probably about 50% as efficient as a radiator as the large antenna. The mechanical construction of the small antenna must be improved before it can be considered satisfactory for service use.

274. Generator, Hand Driven. The hand driven generator is an exceedingly rugged device, capable of continuous operation under extreme variations in temperature and humidity. It is efficient, easy to operate, small and compact, and of light weight. It may readily be secured to a large variety of objects and is capable of withstanding severe overloads. The chain, which forms part of the securing arrangement, must be increased in strength.

275. Accessory Box. The accessory box exceeds the size permitted by specifications. Even with this excess of space, a crowded condition results when all accessories are stowed. However, if proper care in packing is observed, all necessary items may be accommodated in the present dimensions.

276. General. The method for securing covers on the transmitter-receiver unit and accessory box is inadequate and must be improved. With the present method of securing the covers, neither of the above mentioned units, accessory box and transmitter-receiver unit, are submergence-proof.

Table T-1

Model TBO Equipment
Ser.No. 3
(Preliminary Model)

List of Weights and Dimensions

Data as per Pars. 2-54 and 2-55 of Specifications RE 13A 515A

Accessory Case, complete (including head telephones)	27 lbs. 8 oz.
Small antenna complete in case	6 " 12 "
Transmitter-Receiver, complete with cover and charts, but minus spare tubes	27 " 2 "
Hand driven generator, without handles	21 " 4 "
Total Weight -	82 lbs.10 oz.

Accessory Case:
Length - 16"
Height - 8"
Width - 8"

Transmitter-Receiver Case (Exclusive of fasteners)
Length - 16"
Height - 8"
Depth - 10-1/16"

Hand Driven Generator:
8-5/8" x 8-5/8" x 6-3/8"

Small Antenna in carrying bag:
3" dia. x 44" long

Specification Requirements:

Weights: Total weight - 80 lbs.
Any one unit - 30 lbs.

Dimensions:
Accessory Case: 4 x 10 x 16
Transmitter-Receiver: 8 x 10 x 16
Generator: 6-1/4 x 8-3/4 x 9

Table T-2
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No.12
Determination of R.F.Power Output and Mechanical Efficiency

Type of Emission	Freq. kcs.	Photo Cell	R.F. Watts Output	H.V. Gen. E	H.V. Gen. I	L.V. Gen. E	L.V. Gen. I	Generator Output Watts	Watts Input to Generator	Mechanical Efficiency Percent		Remarks
CO - CW	2076	60	7.9	500	63	12.7	.66	39.9	72.4	55	63	MA Generator
CO - CW	2076	22	6.0	502	50	12.7	.66	33.5	64.3	52	50	output
CO - Voice	2076	5	2.8	510	47	12.8	.66	32.5	58.8	55	63	level (CW)
CO - Voice	2076	-	2	517	37	12.9	.67	27.6	53.0	52	50	"
CO - CW	2772	122	10	498	65	12.7	.66	40.8	72.4	56	65	"
CO - CW	2772	40	7	502	50	12.7	.66	33.5	61.5	55	50	"
CO - Voice	2772	5	2.8	514	37	12.8	.66	27.8	51.0	55	65	"
CO - Voice	2772	-	2	512	31	12.8	.66	24.4	47.3	52	50	"
MO - CW	3500	122	10	500	60	12.75	.66	38.5	66.5	58	60	"
MO - CW	3500	72	8.4	505	50	12.8	.66	33.7	60.5	56	50	"
MO - Voice	3500	10	3.2	511	37	12.8	.66	27.7	51.1	55	60	"
MO - Voice	3500	1	2	515	32	12.8	.66	25.0	48.6	52	50	"

NOTE: 10 watt lamp used as antenna load.

Table T-3

Model TBO Equipment
Ser.No. 3
(Preliminary Model)

Comparative Efficiency of "Small" Antenna
as compared with "Large" Antenna.

Ground and Counterpoise Condition	MV per Meter Field Strength Large Antenna	MV per Meter Field Strength Small Antenna	% Eff.	Freq. Kcs
CP Grounded	3.47	1.97	56.8	2076
CP Insulated	3.24	1.70	52.5	2076
Ground only	3.71	2.00	53.8	2076
CP Grounded	4.79	2.27	47.4	2772
CP Insulated	4.12	1.76	42.7	2772
Ground only	4.31	1.38	32.0	2772

Field strength measurements made at distance of 3,000 feet.

"CP Grounded" denotes that the counterpoise was resting on the surface of the earth and connected to the ground post.

"CP Insulated" denotes that the counterpoise was secured to 18" long maple dowels, 12" above the surface of the earth; no ground connection employed.

"Ground only" denotes that no counterpoise was used; ground stake being used as the ground connection.

Table T-4
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test as per Par.4-9(7) of Specifications RE 13A 515A
Reset by Calibration Chart, alternately Clockwise and Counterclockwise.

Direction of approach	Frequency kcs	Divergence Cycles	Percent
3500 kilocycles			
Clockwise	3502.545	2545	0.072
Counterclock	3500.975	975	0.028
Clockwise	3502.350	2350	0.067
Counterclock	3501.400	1400	0.040
Clockwise	3502.425	2425	0.069
Counterclock	3501.550	1550	0.044
3000 kilocycles			
Clockwise	2997.400	2600	0.086
Counterclock	3001.100	1100	0.036
Clockwise	2997.400	2600	0.086
Counterclock	3000.900	900	0.030
Clockwise	2997.650	2350	0.078
Counterclock	3001.150	1150	0.038
2500 kilocycles			
Clockwise	2497.550	2450	0.098
Counterclock	2498.750	1250	0.050
Clockwise	2497.550	2450	0.098
Counterclock	2498.500	1500	0.060
Clockwise	2497.700	2300	0.092
Counterclock	2498.650	1350	0.054
2000 kilocycles			
Clockwise	1996.950	3050	0.152
Counterclock	1997.500	2500	0.125
Clockwise	1997.100	2900	0.145
Counterclock	1997.500	2500	0.125
Clockwise	1996.850	3150	0.157
Counterclock	1997.650	2350	0.117

Divergence permitted by specifications: 0.25 %

Table T-5
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)

Test No. 11

Frequency Coverage of Transmitter Circuits

Frequency kcs	M.O. Setting	P.A. Setting	P.A. Band	Antenna Coupling
1782.646	000	1	1	3
2202.500	260	31	1	3
2202.813	260	15	2	3
2598.824	434	21.5	2	4
2369.650	601	42	2	4
2368.936	601	21	3	4
3402.750	770	45	3	4
3904.190	1000	31	3	6
3904.656	1000	40.5	3	5

Transmitter adjusted for full power output into 10 watt lamp load.

Table T-6
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)

Test No. 14-c

Frequency Change due to 25% Variation of Antenna Constants

Type of Emission	P. A. Ip	Ant. I	Ant.Cap. uuf	Ant. Res. ohms	Frequency kcs	Freq. Cycles	Change %
MO - CW	63	0.60	225	25	3500.000		
MO - CW	70	0.60	300	25	3499.825	175	0.005
MO - CW	66	0.55	300	25	2000.000		
MO - CW	63	0.52	225	25	1999.938	62	0.0031
CO - CW	63	0.52	225	25	2076.000		
CO - CW	67	0.55	300	25	2076.002	2	0.0001
CO - CW	65	0.60	300	25	2772.000		
CO - CW	60	0.52	225	25	2772.011	11	0.0004

Table T-7
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)

Test No. 14-d

Frequency change due to ± 10% Variation in Generator Speed

Type of Emission	Frequency at Normal	Frequency at -10%	Frequency at +10%	Frequency Cycles	Change %
CO - CW	2772	2772	2772	0	0
CO - CW	2076	2076	2076	0	0
MO - CW	2000	2000	2000	0	0
MO - CW	3500	3500	3500	0	0

Table T-8
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)

Test No. 14-e

Frequency change due to variation in keying speeds

Type of Emission	Frequency at 30 wpm	Frequency at 10 wpm	Frequency Cycles	Change %
CO - CW	2272.000	2271.997	3	0.0001
CO - CW	2075.997	2076.000	3	0.0001
MO - CW	2000.000	2000.034	34	0.0017
MO - CW	3500.130	3500.000	130	0.0037

Table T-9
Model TBO Transmitter, Ser.No. 3 (Preliminary Model)

Test No. 14-f

Frequency change caused by variation of modulation between limits of 0% and 90%

Type of Emission	Frequency at 0% Modulation	Frequency at 90% Modulation	Frequency Cycles	Change %
MO-Voice	3500.000	3500.000	0	0
MO-Voice	1998.154	1998.462*	308	0.015
CO-Voice	2076.000	2076.000	0	0
CO-Voice	2772.000	2772.000	0	0

*Note: At 2000 kilocycles, master oscillator (self-excited) operation, the maximum modulation obtainable without serious distortion was 75%. 90% modulation showed considerable distortion and carrier shift.

Table T-10

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No. 14-g
Frequency change caused by vibration and roll and pitch.

Frequency & type of Emission	Frequency change due to Vibration		Roll & Pitch	
	Cycles	Percent	Cycles	Percent
2000 - MO	150	0.0075	1600	0.08
3500 - MO	400	0.0114	600	0.017
2076 - CO	0	0	0	0
2772 - CO	0	0	0	0

NOTE: The equipment was subjected to a period of ten minutes vibration at each frequency and to a period of ten minutes roll and pitch at each frequency.

Table T-11

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No. 14
Summary of Tests 14-a to 14-g covering Frequency Stability

Test No.	2076 kcs Cry. Control	2772 kcs Crys. Control	2000 kcs Self Exc.	3500 kcs Self Exc.
14-a	0.0065%	0.0085%	0.13%	0.18%
14-b	0.0005%	0.0029%	0.089%	0.118%
14-c	0.0001%	0.0004%	0.0031%	0.005%
14-d	0	0	0	0
14-e	0.0001%	0.0001%	0.0017%	0.0037%
14-f	0	0	0.015	0
14-g Vib	0	0	0.0075	0.0114
Roll	0	0	0.08	0.017
Arithmetical Sum	0.0072	0.0119	0.3263	0.3351
Permitted by Specifications	0.05%	0.05%	0.3%	0.3%

Table T-12

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No.15
As per Par.4-9(30) of Specs. RE 13A 515A
Test of Calibration Chart

CRYSTAL CONTROL

When using crystal control the master oscillator control should be adjusted for optimum output. Any variation within reason from this setting has a negligible effect upon the frequency and in all cases it is well within the 0.05% permitted by the specifications.

SELF EXCITED M. O.

Trial No.	Frequency kcs	Divergence Cycles	Percent
	3500 kcs		
1	3500.975	975	0.028
2	3501.400	1400	0.040
3	3501.550	1550	0.044
	3000 kcs		
1	3001.100	1100	0.036
2	3000.900	900	0.030
3	3001.150	1150	0.038
	2500 kcs		
1	2498.750	1250	0.050
2	2498.500	1500	0.060
3	2498.650	1350	0.054
	2000 kcs		
1	1997.500	2500	0.125
2	1997.500	2500	0.125
3	1997.650	2350	0.117

The above results were obtained by approaching all settings from one direction (counterclockwise).

Permitted by specifications: 0.1%

Table T-13

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)

Effect of M.O.condenser stop on calibration

Contact with Stop	Frequency kcs	Difference in Frequency Cycles	Percent
High	3501.600		
Low	3503.300	1700	0.048
High	3478.600	24700	0.70
Low	3502.500	23900	0.94
High	3469.370	33130	0.94
Low	3502.000	32630	0.93

After each contact with the stop the same dial setting was repeated; approach to the setting was clockwise in all cases.

Table T-14

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No.16
As per Par. 4-9(31) of Specs. RE 13A 515A

Resettability of Transmitter

CRYSTAL CONTROL

Once a setting has been determined for a given crystal, approaching this setting from either direction causes no measurable difference in frequency.

SELF EXCITED M.O.

Direction of approach	Frequency kcs	Difference in Frequency Cycles	Percent
	3500 kcs		
Clockwise	3499.850	150	0.0042
Counterclock	3500.250	250	0.0071
Clockwise	3499.350	650	0.0185
Counterclock	3500.450	450	0.0128
Clockwise	3499.500	500	0.0143
Counterclock	3499.350	650	0.0185
	3000 kcs		
Clockwise	2999.850	150	0.0050
Counterclock	2998.250	1750	0.0580
Clockwise	2999.650	350	0.0116
Counterclock	2999.000	1000	0.033
Clockwise	2999.450	550	0.0183
Counterclock	2998.150	1850	0.062
	2500 kcs		
Clockwise	2499.750	250	0.01
Counterclock	2496.450	3550	0.142
Clockwise	2499.650	350	0.014
Counterclock	2496.550	3450	0.138
Clockwise	2499.750	250	0.01
Counterclock	2496.500	3500	0.14
	2000 kcs		
Clockwise	1999.750	250	0.0125
Counterclock	2000.400	400	0.02
Clockwise	1999.650	350	0.0175
Counterclock	2000.300	300	0.015
Clockwise	1999.450	550	0.0275
Counterclock	2000.350	350	0.0175

Table T-15

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No.18
Generator Voltage Variation

18(1) Variation due to change in generator speed of ± 10%.

Normal Speed		+10% Speed		-10% Speed		Max.Change Volts		Percent Change	
L. V.	H. V.	L. V.	H. V.	L. V.	H. V.	L. V.	H. V.	L. V.	H. V.
12.8	497.5	12.9	502.5	12.8	500	0.1	5	0.78	1.0

18(2) Variation between key up and keying at 30 words per minute.

Voltage key up		Voltage at 30 wpm		Maximum Change Volts		%	
L. V.	H.V.	L.V.	H.V.	L.V.	H.V.	L.V.	H.C.
12.65	518	12.65	510	0	8	0	1.5

18(3) Variation between 0% and 90% modulation (400 cycle input)

Voltage at 0% Modulation		Voltage at 90% Modulation		Maximum Change Volts		Percent	
L.V.	H.V.	L.V.	H.V.	L.V.	H.V.	L.V.	H.V.
12.65	517.5	12.7	512	0.05	5.5	-	1

Permitted by specifications: 10% voltage change for any or all of above conditions.

Table T-16

Model TBO Transmitter, Ser.No.3.(Preliminary Model)
Test as per Par. 4-10-5 of Specs. RE 13A 515A.
100% Overload Test

Normal Load: HV - 500 volts; 0.05 amp. = 25.0 watts
LV - 12.8 volts; 0.8 amp. = 10.24 watts

100% Overload: HV - 50 watts
LV - 20.48 watts

Time	Amb. Temp.°C	Gen. Temp. °C	Watts input to Gen.	Watts output from Gen.	Mech. eff.
1330	31	33	118.5	70.48	60%
1345	31	37	118.5	70.48	60%

Post trial inspection showed no overheating or other signs of damage.

Table T-17

Model TPO Transmitter, Ser.No. 3 (Preliminary Model)
Test No.19
Determination of mechanical input at ± 10% speed variation.

19(1) Key Open Efficiency.

Gen. RPM	Gen E. HV	Gen I HV	Gen E LV	Gen I LV	Generator Output watts	Watts Input to Gen.	Mech Eff.
54	525	17	12.75	0.66	17.4	38	45
60	525	17.5	12.75	0.66	17.6	40.6	43
66	525	17.5	12.8	0.66	17.7	41	44

19(2) Efficiency at 30 words per minute.

No reliable measurements could be made under keying conditions due to the constant fluctuation of all meters in the various circuits. It was calculated that the efficiency was in the neighborhood of 50%.

19(3) Efficiency at 90% Modulation.

54	520	38	12.75	0.66	28.4	55	52
60	515	37.5	12.75	0.66	27.7	54	52
66	515	37.5	12.8	0.66	27.8	55.5	51

Specification requirements: 50% efficiency

Table T-18

Model TBO Transmitter, Ser.No. 3 (Preliminary Model)
Test No.20
Two hour locked key test, Crystal Control,2772 kc.

Time	Frequency	P.A. Ip	Ant. Cur.	Watts Output	Gen E HV	Gen E LV	Gen I HV	Gen I LV	Watts Input to Generator	Generator output watts	Mechanical Efficiency
1400	2772.773	63	.59	8.7	500	12.6	55	655	64.8	35.8	55%
15	.795	64	.59	8.7	505	12.7	55	660	64.8	36.2	56
30	.812	64	.59	8.7	505	12.7	55	660	64.8	36.2	56
45	.823	64	.60	9.0	510	12.7	56	660	74.8	37.0	50
1500	.830	64	.60	9.0	510	12.7	56	660	73.5	37.0	50
15	.837	64	.60	9.0	510	12.8	56	660	73.5	37.1	50
30	.841	64	.61	9.3	512	12.8	56	660	74.8	37.2	50
45	.844	64	.61	9.3	512	12.8	56	660	73.5	37.2	50
1600	.846	64	.61	9.3	514	12.8	56	660	73.5	37.3	50

Transmitter operating into 25 ohm dummy antenna of 150 uuf.

Maximum frequency change - 73 cycles or 0.0026%.

Ambient temperature held constant at 28° C

Humidity held constant at 50%.

Generator speed held constant at 60 r.p.m.

No. 2 generator used during this test.

Table R-1

Model TBO Receiver

Frequency Range and Overlap
See Par.171

Band	Frequency kcs.	Overlap
1	1975 - 3282	
2	3105 - 5180	5.5%
3	4905 - 8170	5.4%

Table R-2

Model TBO Receiver
See Par.180 and 200.
Frequency Stability and Variation in Output with Change from 100% to 90% of Open Circuit Filament Voltage.

Freq. kcs.	E_{f1}	E_{f2}	Cycles Output for E_1	Cycles Output for E_2	Output E_1	Output E_2
2200	2.84	2.556	1000	1161	1.89	1.24
3500	2.84	2.556	1000	1298	1.89	1.24
4800	2.80	2.52	971	1976	1.89	1.28
7500	2.80	2.52	1000	2791	1.89	1.08

Table R-3

Model TBO Receiver

Frequency Stability with Variation in Plate Voltage from 100% to 90%
See Par.180

Freq. kcs.	E_1	E_2	Output Cycles for E_1	Output Cycles for E_2
2200	92	82.8	1086	684
3500	92	82.8	1000	375
4800	92	82.8	1021	1021 + 861 through 0
7500	92	82.8	981	981 + 3138 through 0

Table R-4

Model TBO Receiver

Frequency Wobbler Range
See Par.190

Freq. Kcs	Cycles -10	Cycles 0	Cycles +10	Total Range Cycles	
2200	3056 through 0	3664		6720	
2200		3730 through 0	1887	5617	12337
4100	3637 through 0	2985		6622	
4100		2175 through 0	3555	5730	12352
7500	2790 through 0	3854		6644	
7500		3097 through 0	2460	5557	12201

Table R-5

Model TBO Receiver

Accuracy of Resettability
See Par.196

Freq. Kcs.	Tuning	1st Adj.	Reset From H.F.	Reset From L.F.
2200	1 - 53.5	1000 cycles	1042 cycles	765 cycles
3500	1 - 93.9	1000	1253	561
4800	7 - 43.1	1000	692	574
7500	7 - 32.1	1000	1823	187

Table R-6

Model TBO Receiver

Measurement of Harmonic Content of Output
Input Modulated 30% at 400 Cycles
See Par. 197

	Output-Rectifier VM		Output, Wave Analyzer 400cycles		800 cycles		1200 cycles	
Freq.kcs	Volts	mw	Volts	mw	Volts	mw	Volts	mw
2200	1.89	6	1.71	4.86	.36	.216	.04	.002
	2.19	8	2.115	7.44	.47	.370	.04	.002
3500	1.89	6	1.71	4.86	.36	.216	.04	.002
	2.19	8	2.115	7.44	.47	.370	.04	.002
4800	1.89	6	1.71	4.86	.36	.216	.04	.002
	2.19	8	2.115	7.44	.47	.370	.04	.002
7500	1.89	6	1.8	5.4	.36	.216	.04	.002
	2.19	8	2.02	6.8	.32	.170	.12	.024

Table R-7

Model TBO Receiver

Variation in Output with Change of Any or All Tubes.
Constant Input and Receiver Adjusted for Standard Conditions.
See Par. 201

		Changes					
Freq.	Orig.Tubes	1C6	34IF	34 Det.	34 CW Osc.	34 Audio	All
2200	6 mw	6.8	4.4	14.8	9.8	5	6
3500	6 mw	4.9	3.6	11	7.4	5	6
4800	6 mw	3.4	3.8	8.8	6.8	3.3	4.2
7500	6 mw	3.5	5.5	11	7.8	5	5.5

Table R-8

Model TBO Receiver

Setting to Frequency by the Use of Calibration Curves
furnished with the Equipment.
See Par.202

Freq.	Tuning	Model LN Setting	Audio Output in Cycles
2200	1 - 59.5	212.2 E	2500
3500	1 - 95.5	49.5 E	4000
4800	7 - 51.5	125.1 F	4950
7500	7 - 37.5	230 F	6000

Table R-9

Model TBO Receiver

Receiver Response to Frequencies Other than Resonant Frequency
Frequency of Receiver Resonance 2200 kilocycles
First Oscillator 3720 kilocycles - Intermediate Frequency - 1520
See Par.202

Input Frequency	Microvolt input for std.output 6 mw	Remarks
1520	420	Intermediate Freq.
2200	14	Resonant Freq.
2280	80,000	
2630	6,700	
2970	40,000	
4480	72,000	
4800	46,000	
5240	575	Primary Image
5900	4,000	
6320	53,000	
9000	6,000	
9660	3,800	
12580	4,300	
13220	75,000	
16200	60,000	
16820	71,000	
19780	75,000	

Table R-10

Model TBO Receiver

Receiver withdrawn 2" from case, and subjected to relative humidity of 90% at 38° C for 72 hours.
See Par.71

Band	Freq.	Sensitivity just prior to test	Sensitivity at completion of test
1	2112.5	13.9	22.5 *
	3235	7.83	7.8
2	3285	16.4	14.
	5085	13.9	8.9
3	5170	14.1	13.5
	8020	11.3	12

* Noise, characteristic to rotating machinery, prevailed during this measurement.

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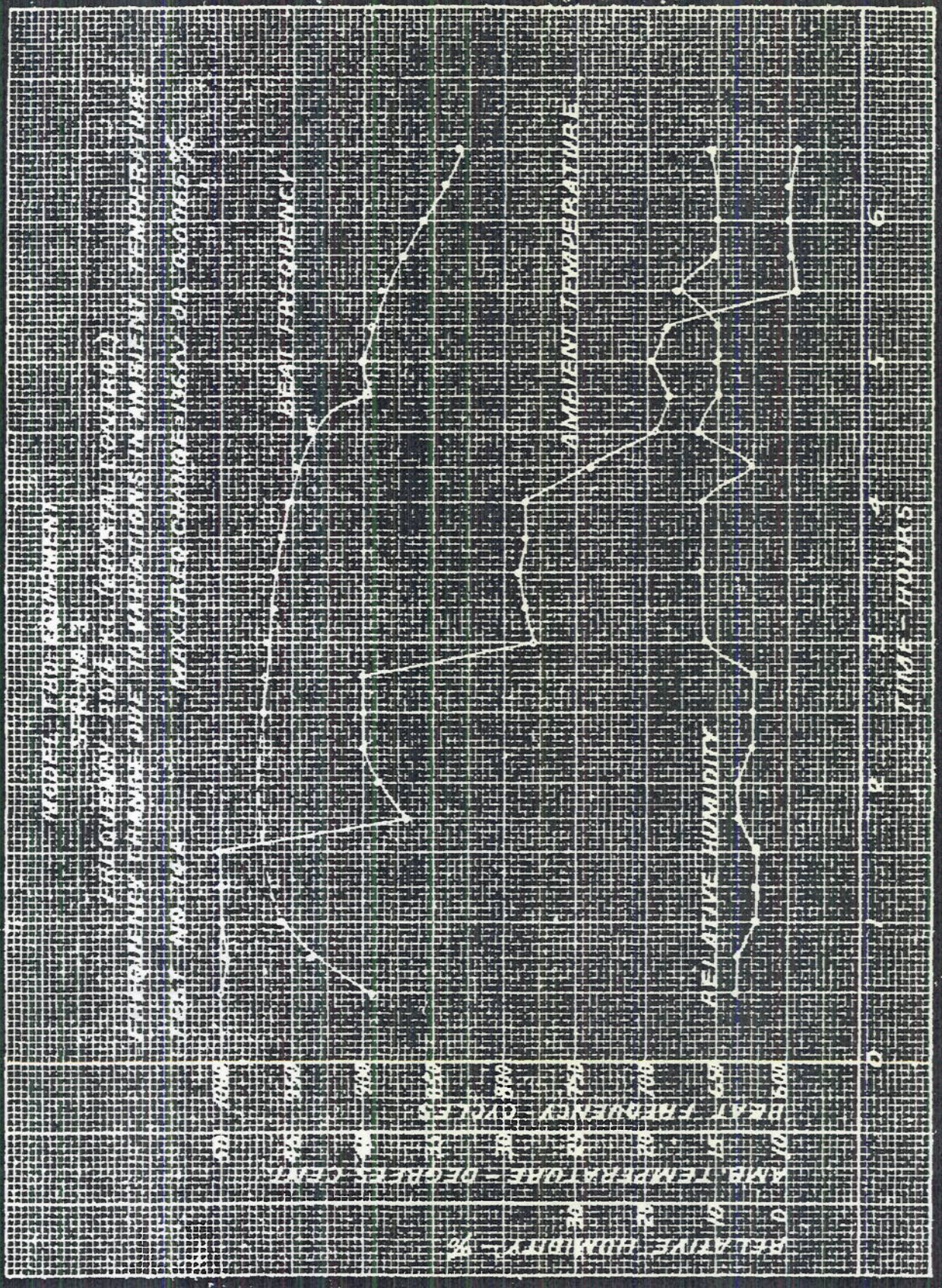


PLATE T-1

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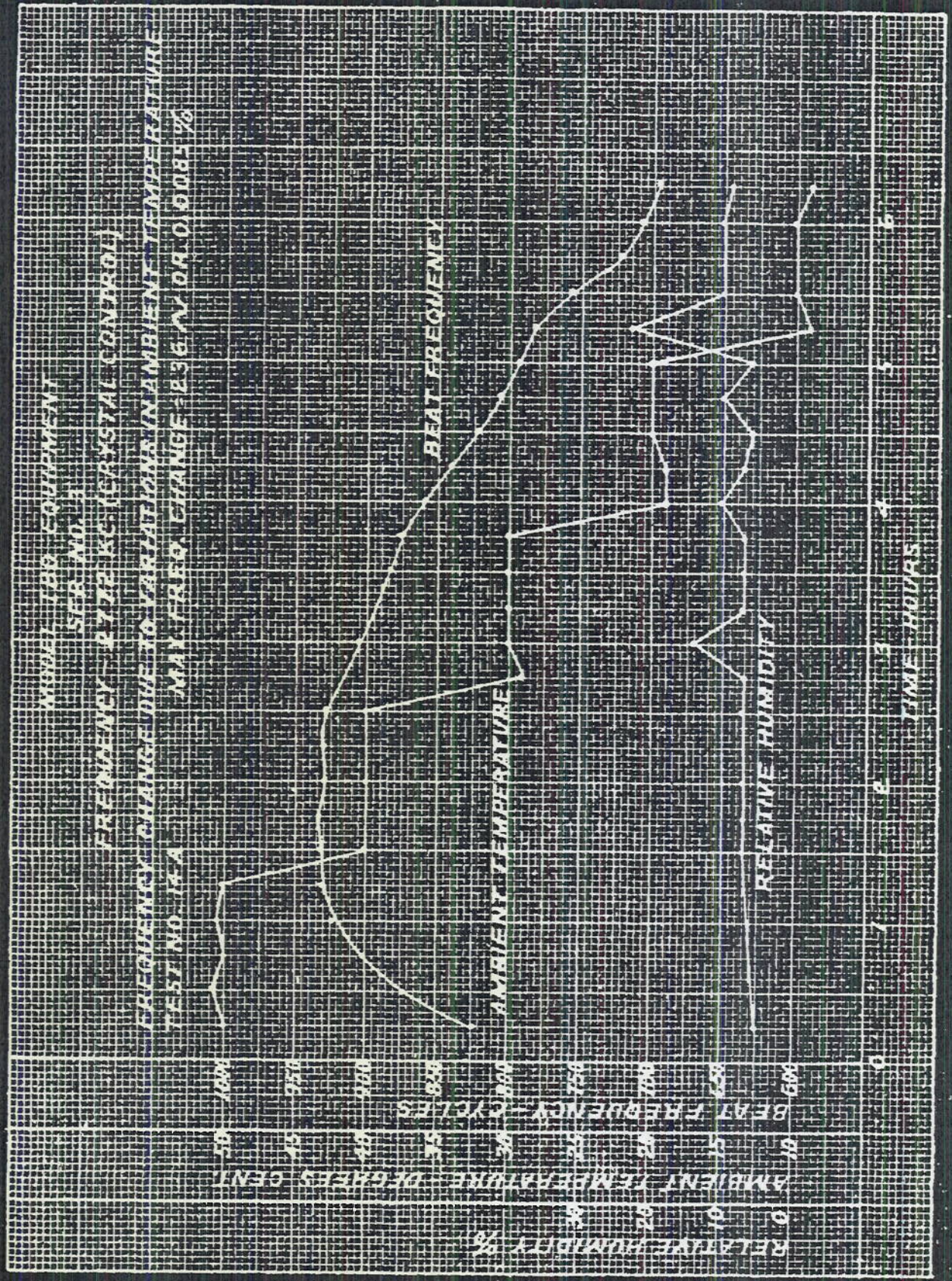


PLATE T-2

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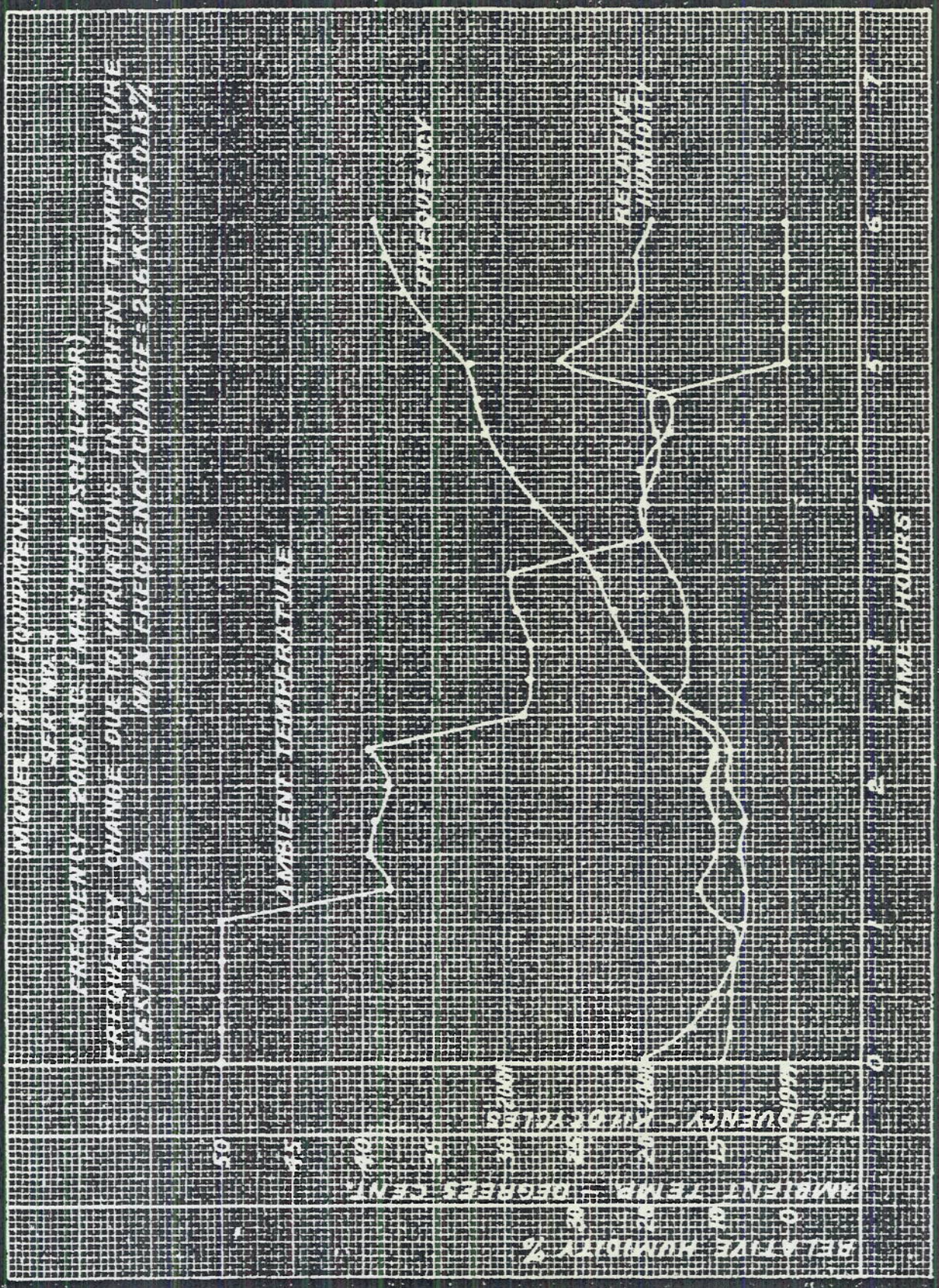


PLATE T-3

N. R. L. 34A

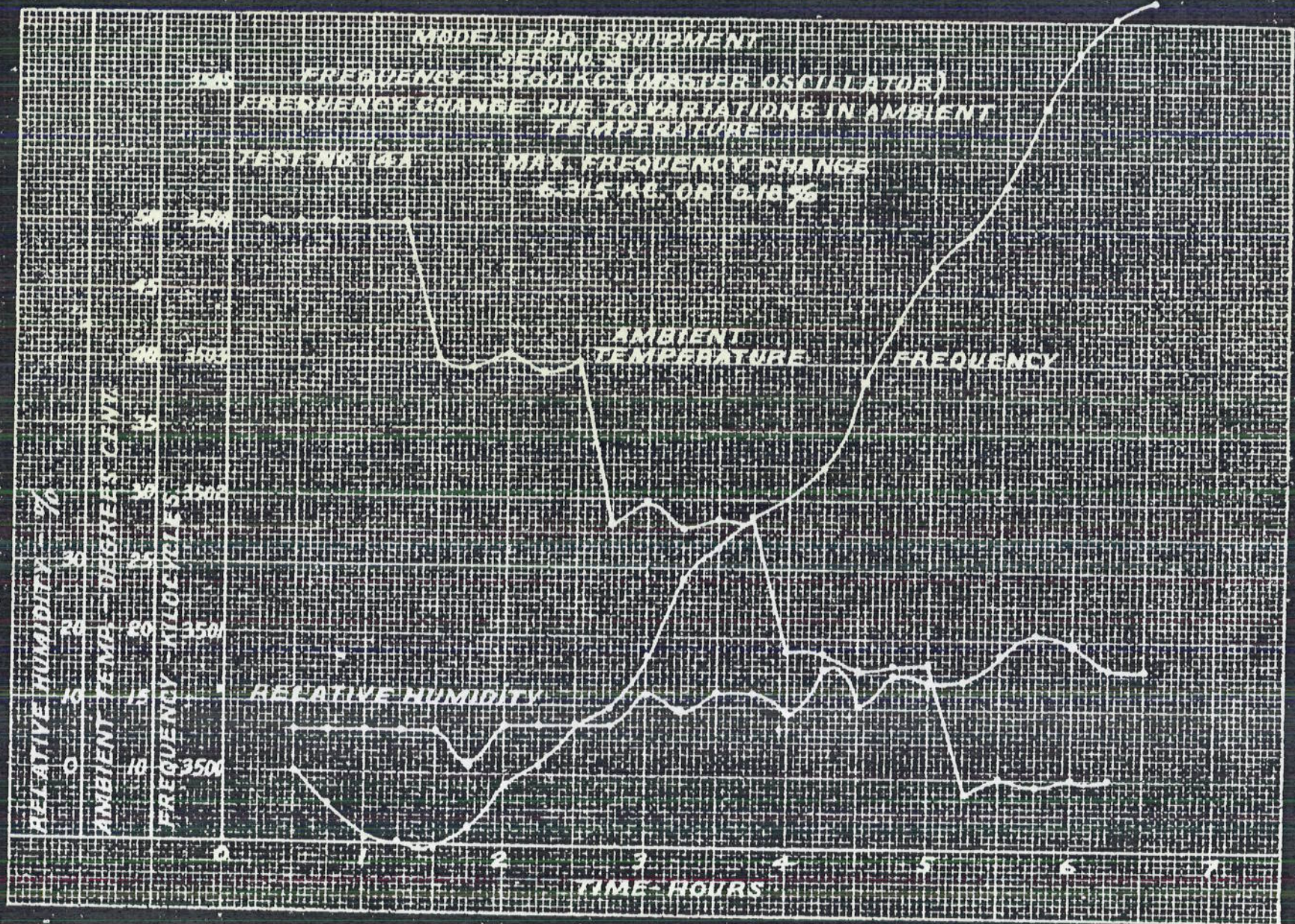


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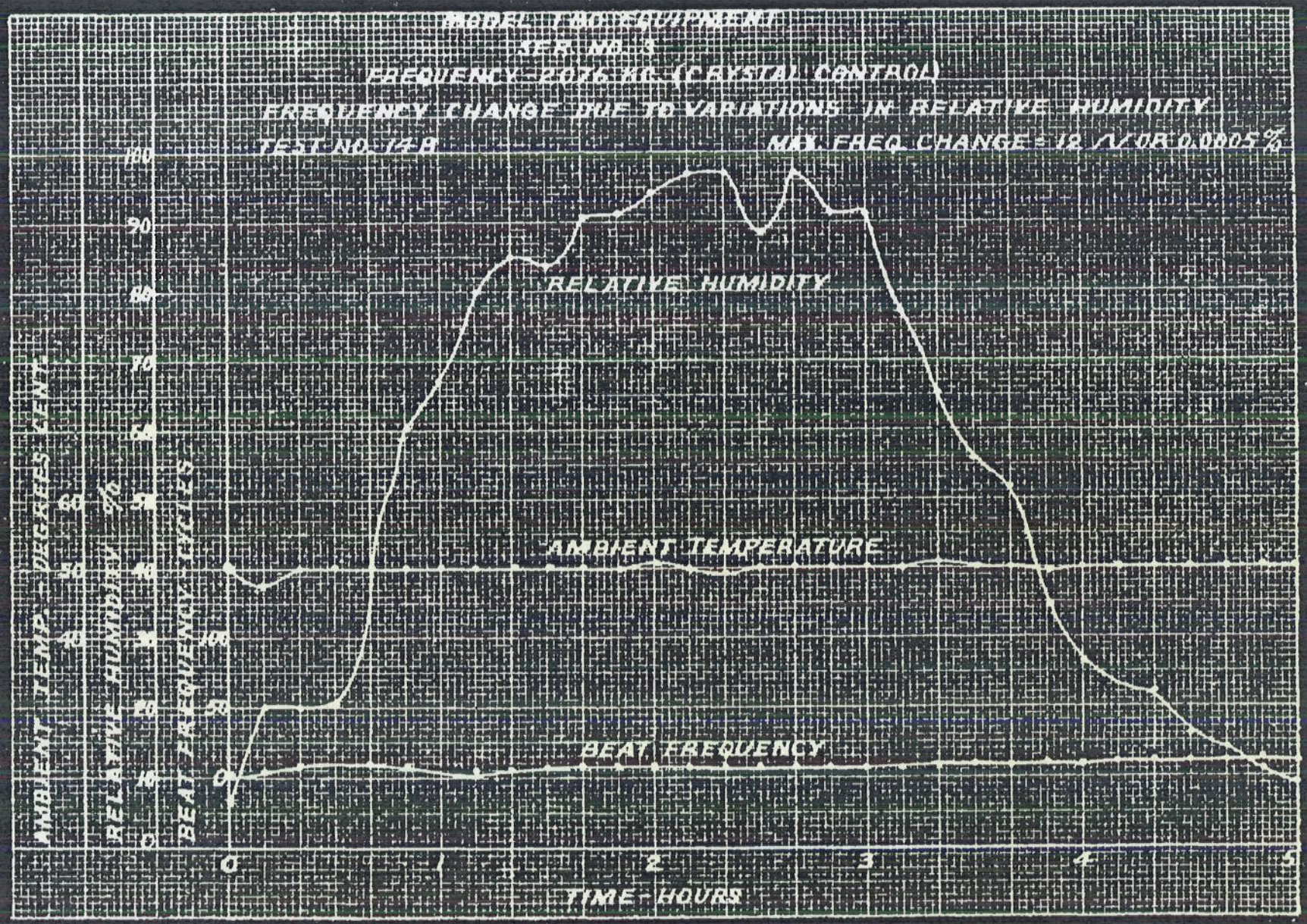


PLATE T-5

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PLATE T-6

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DATE

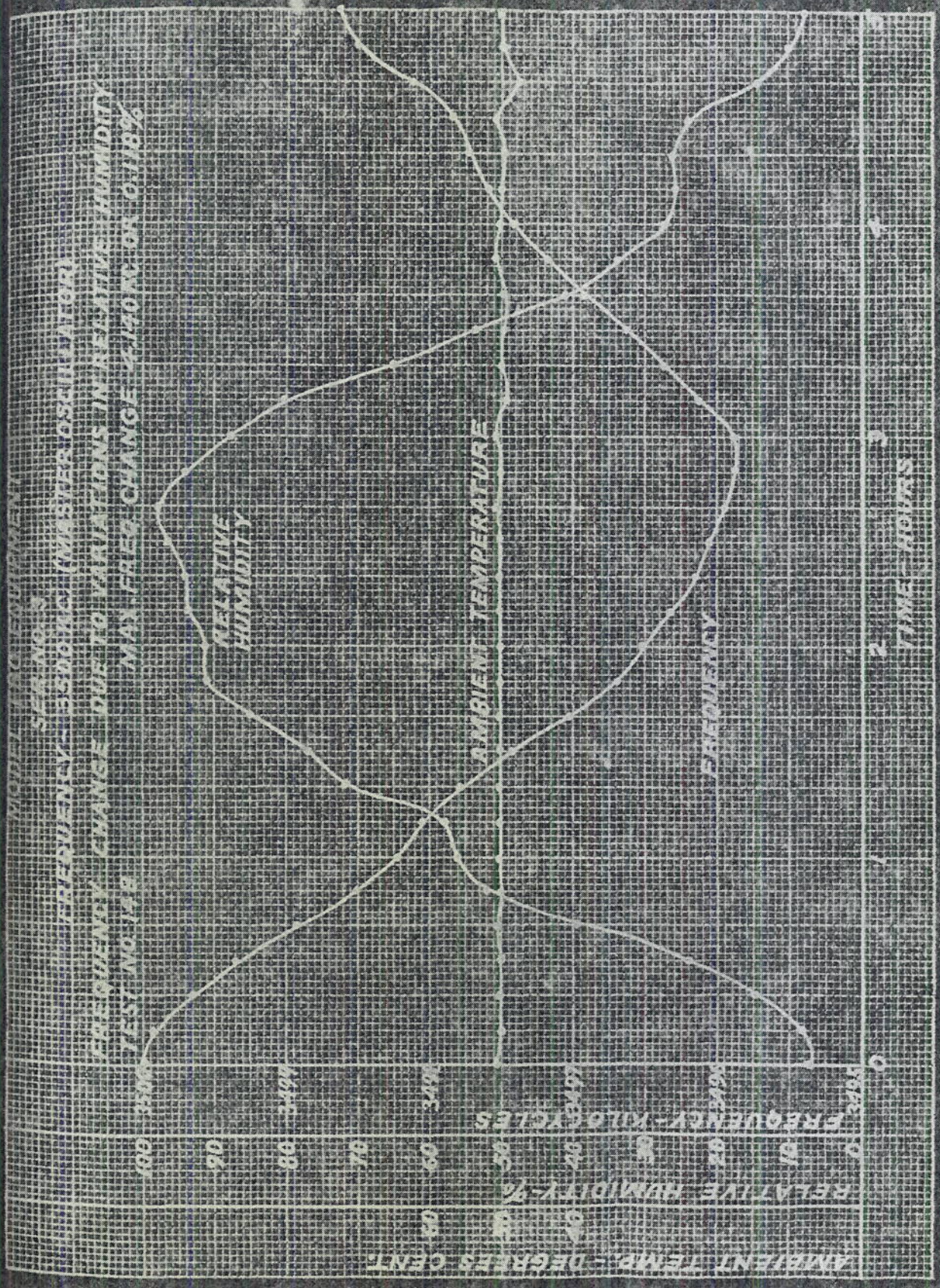


PLATE T-8

N. R. L. 31A

N. R. L. 31A

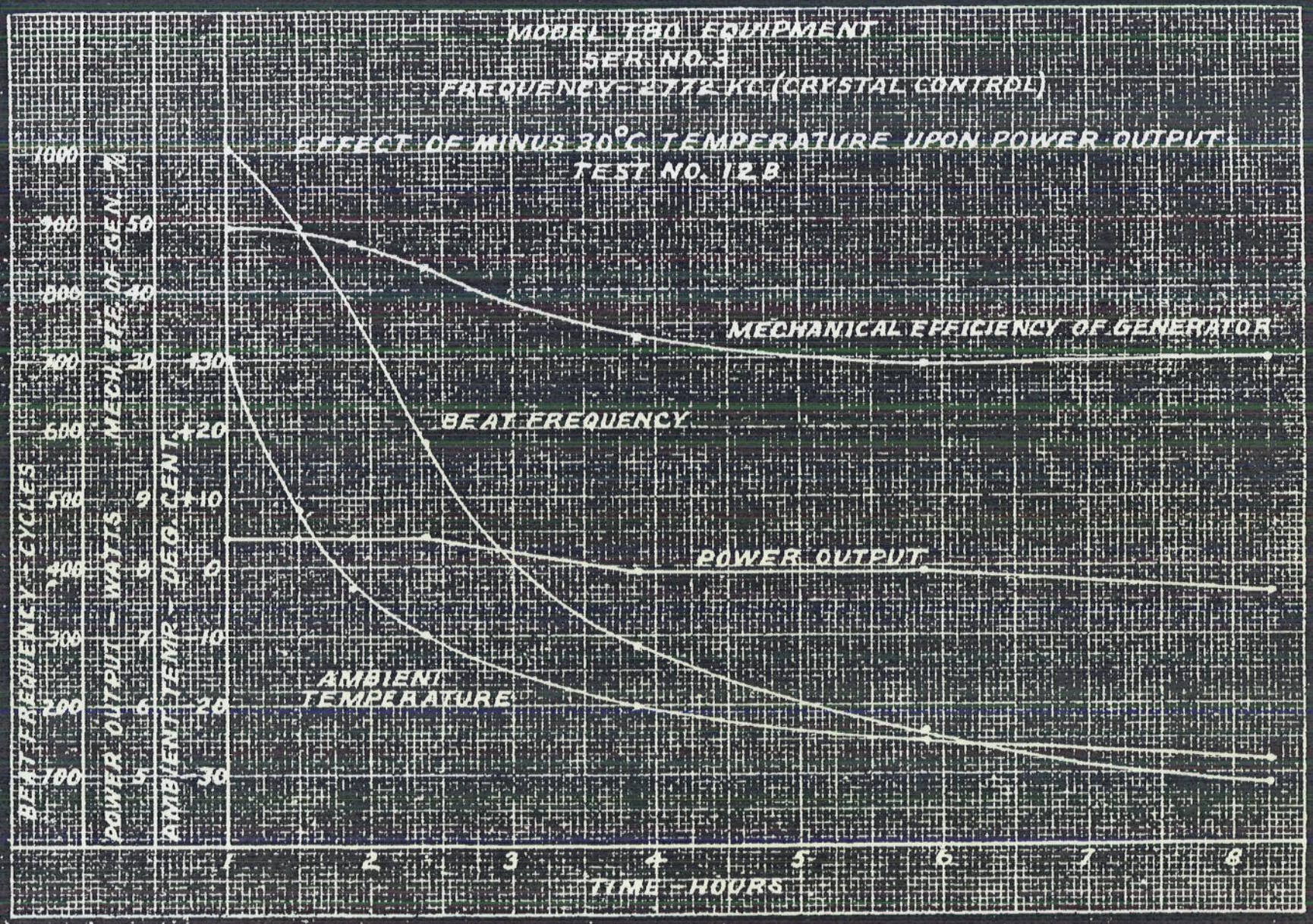


PLATE T-9

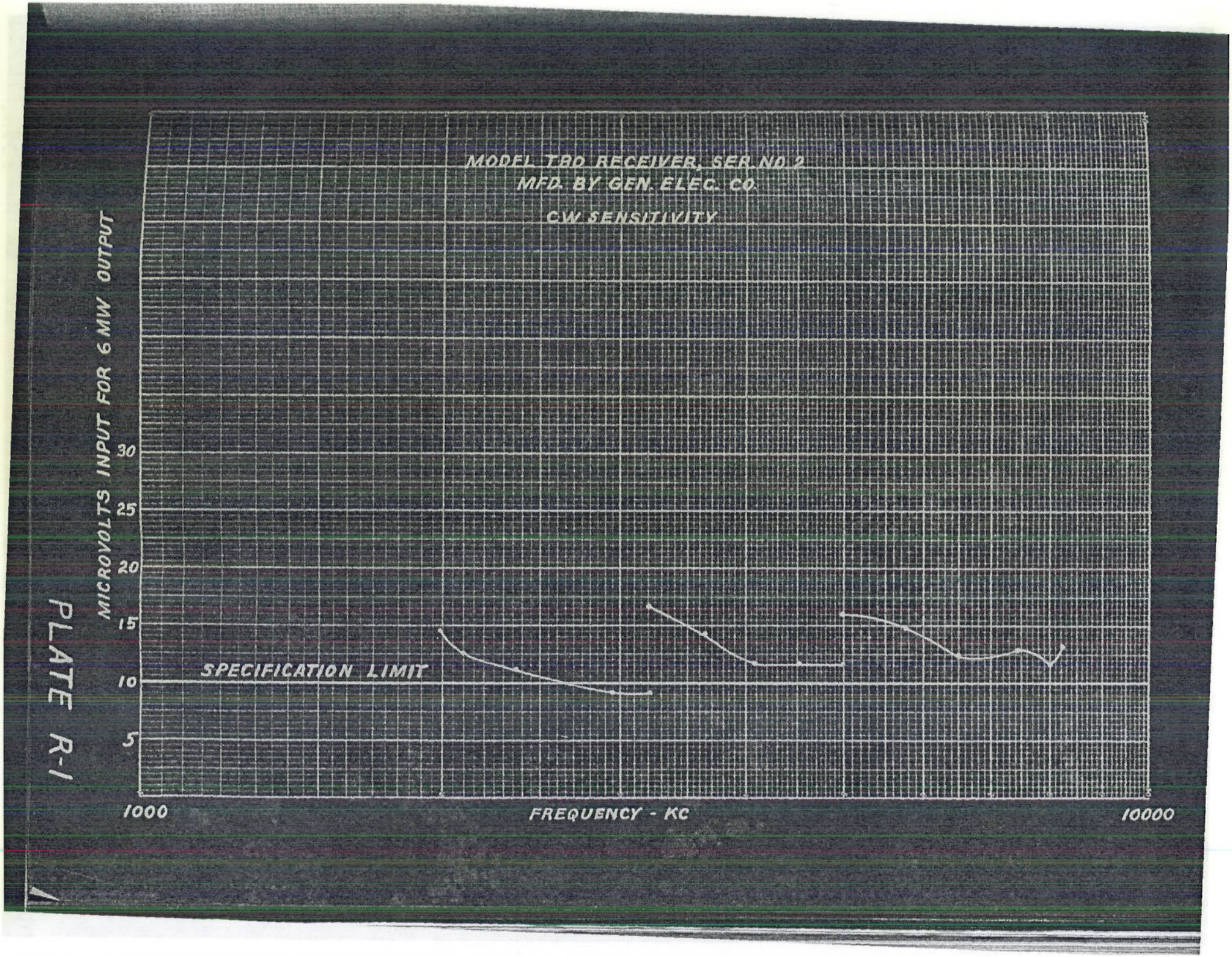

MODEL TBD RECEIVER, SER. NO. 2
MFD. BY GEN. ELEC. CO.
C.W. SENSITIVITY
MICROVOLTS INPUT FOR 6 MW OUTPUT
30
25
20
15
10
5
SPECIFICATION LIMIT
1000
FREQUENCY - KC
10000

PLATE R-1

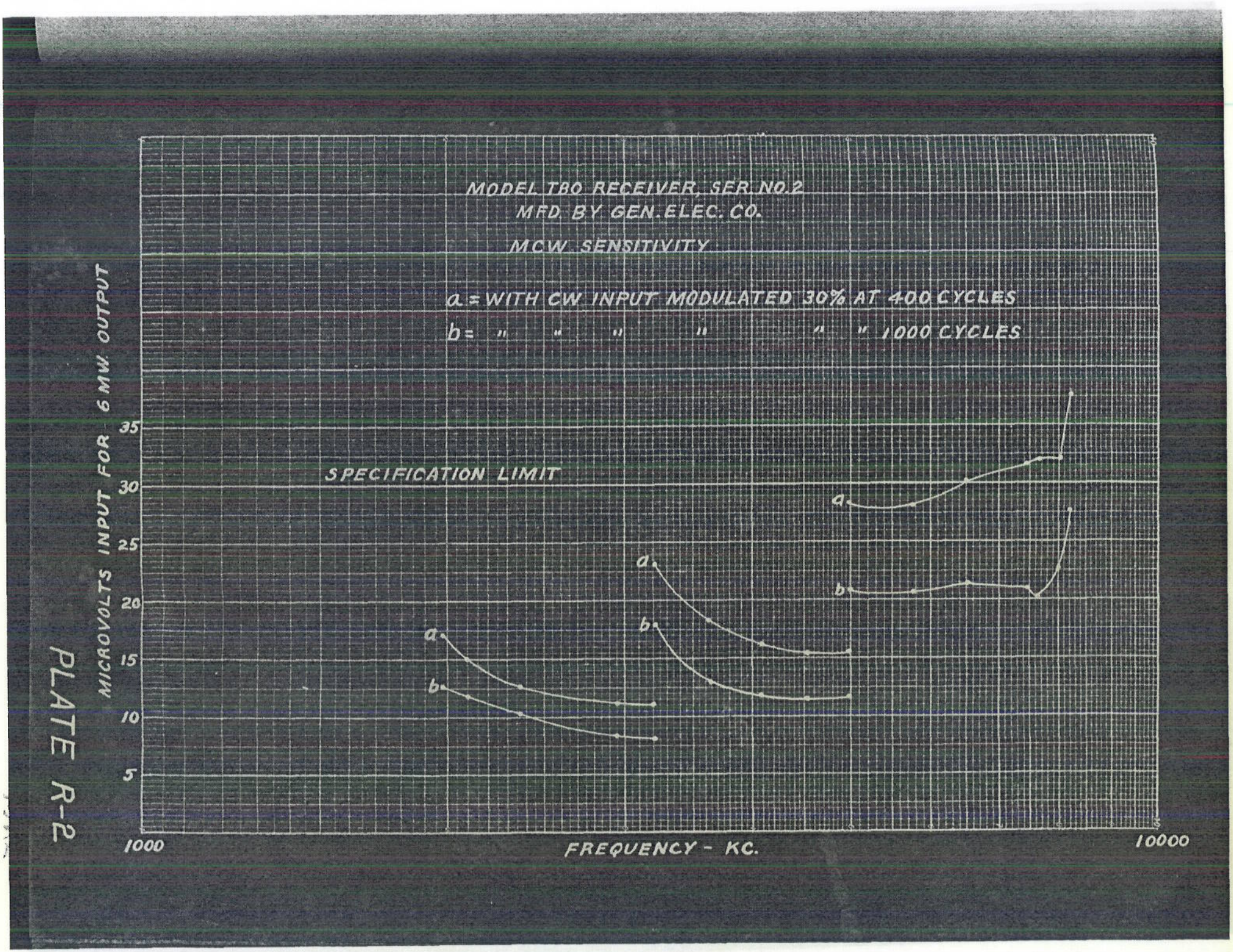

MODEL T80 RECEIVER, SER NO. 2
MFD. BY GEN. ELEC. CO.
MCW SENSITIVITY
a = WITH CW INPUT MODULATED 30% AT 400 CYCLES
b = " " " " " " 1000 CYCLES
SPECIFICATION LIMIT
MICROVOLTS INPUT FOR 6 MW OUTPUT
35
30
25
20
15
10
5
a
b
a
b
a
b
1000
FREQUENCY - KC.
10000

PLATE R-2

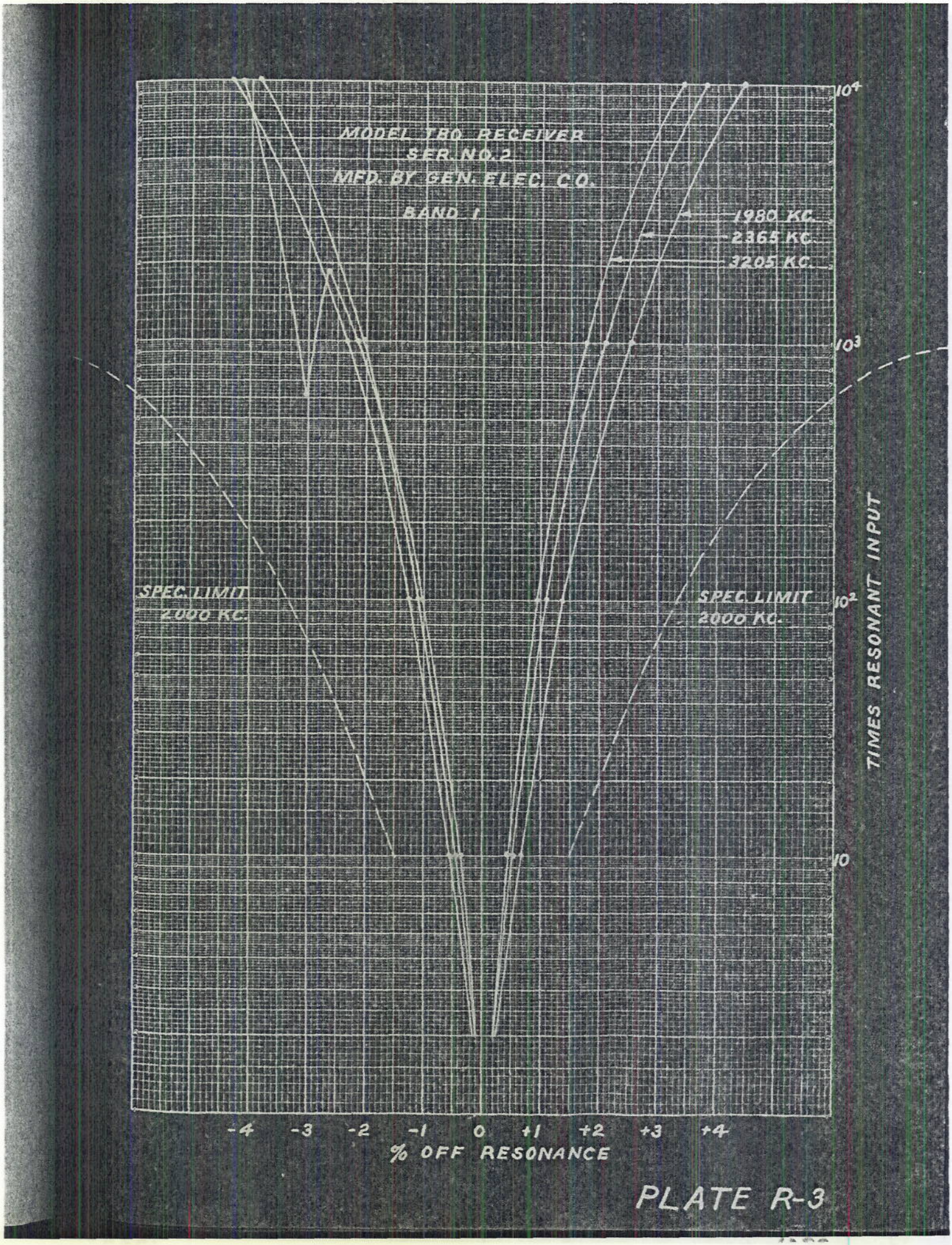

MODEL TBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
BAND 1
1980 KC.
2365 KC.
3205 KC.
SPEC. LIMIT
2000 KC.
SPEC. LIMIT
2000 KC.
10⁴
10³
10²
10
TIMES RESONANT INPUT
-4 -3 -2 -1 0 +1 +2 +3 +4
% OFF RESONANCE

PLATE R-3

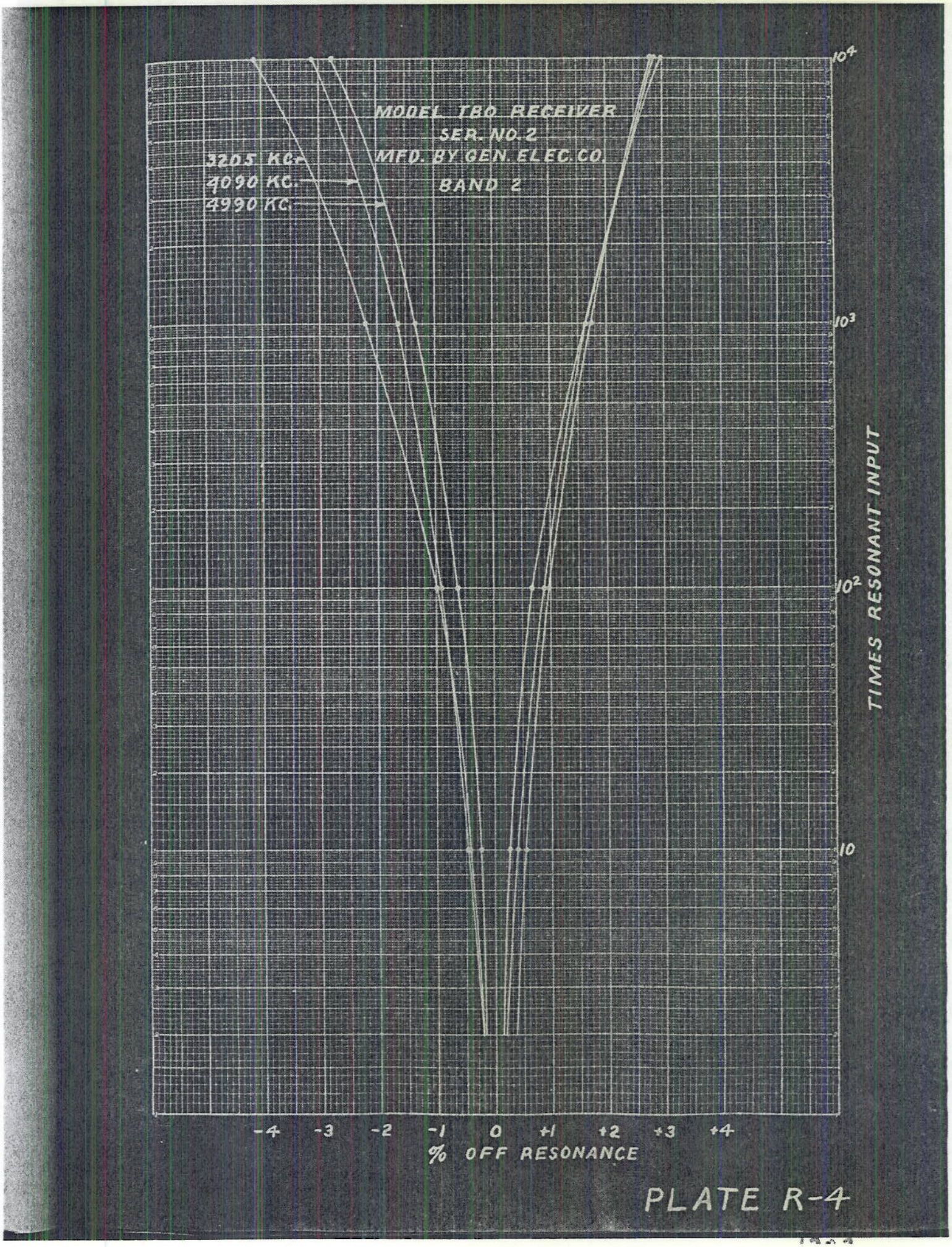

MODEL TBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
BAND 2
3205 KC.
4090 KC.
4990 KC.
10⁴
10³
10²
10
TIMES RESONANT INPUT
-4 -3 -2 -1 0 +1 +2 +3 +4
% OFF RESONANCE

PLATE R-4

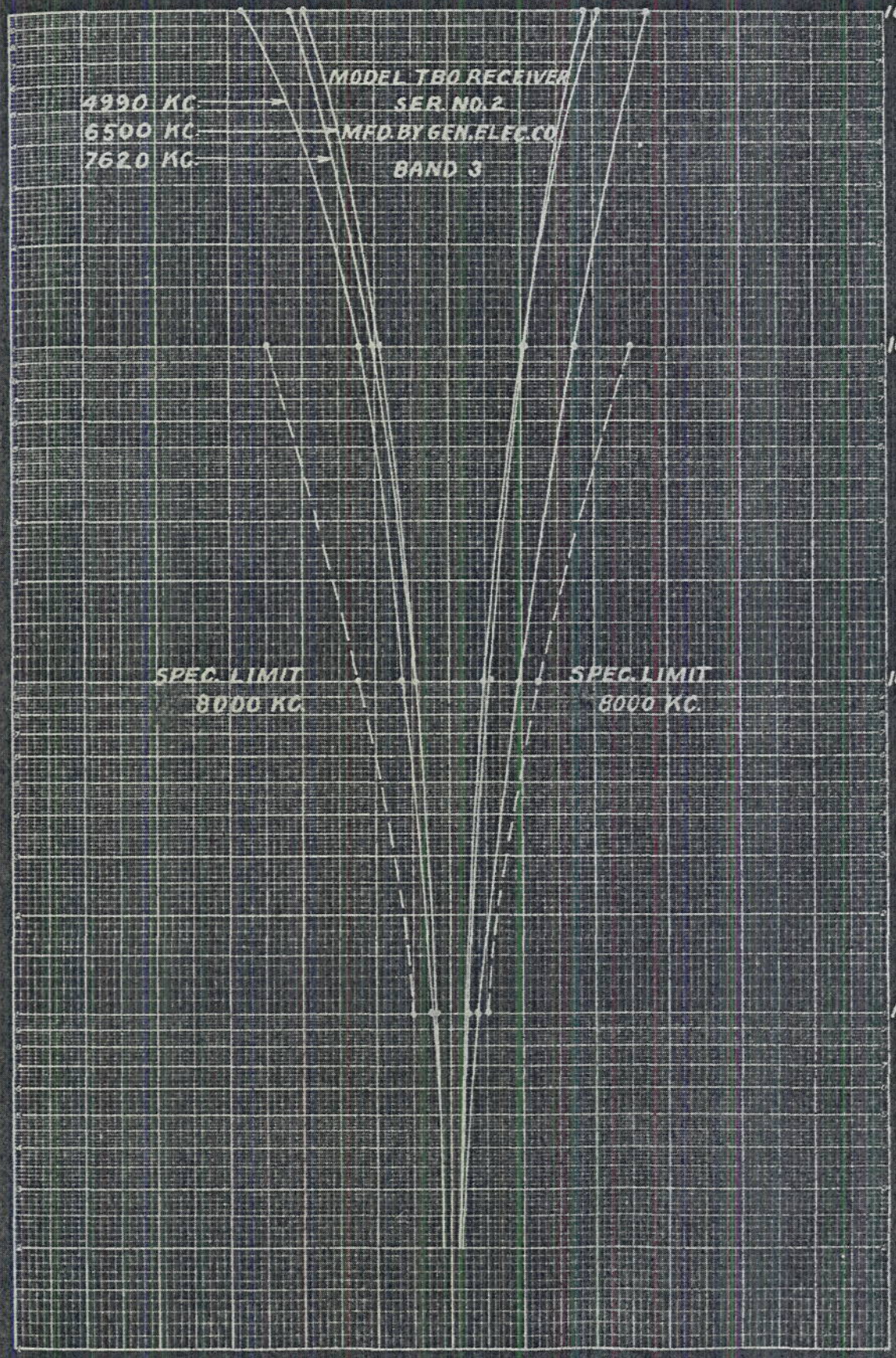
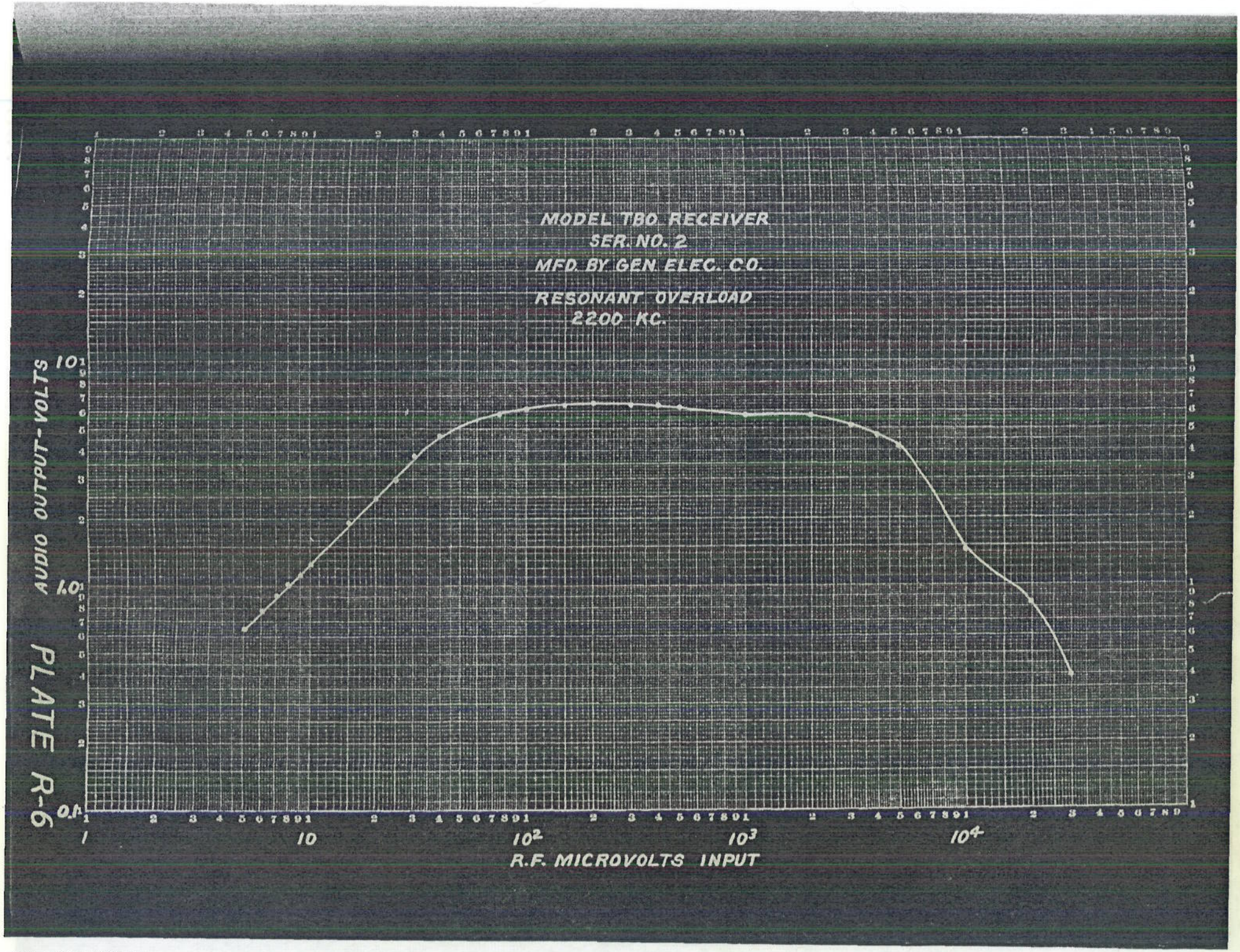
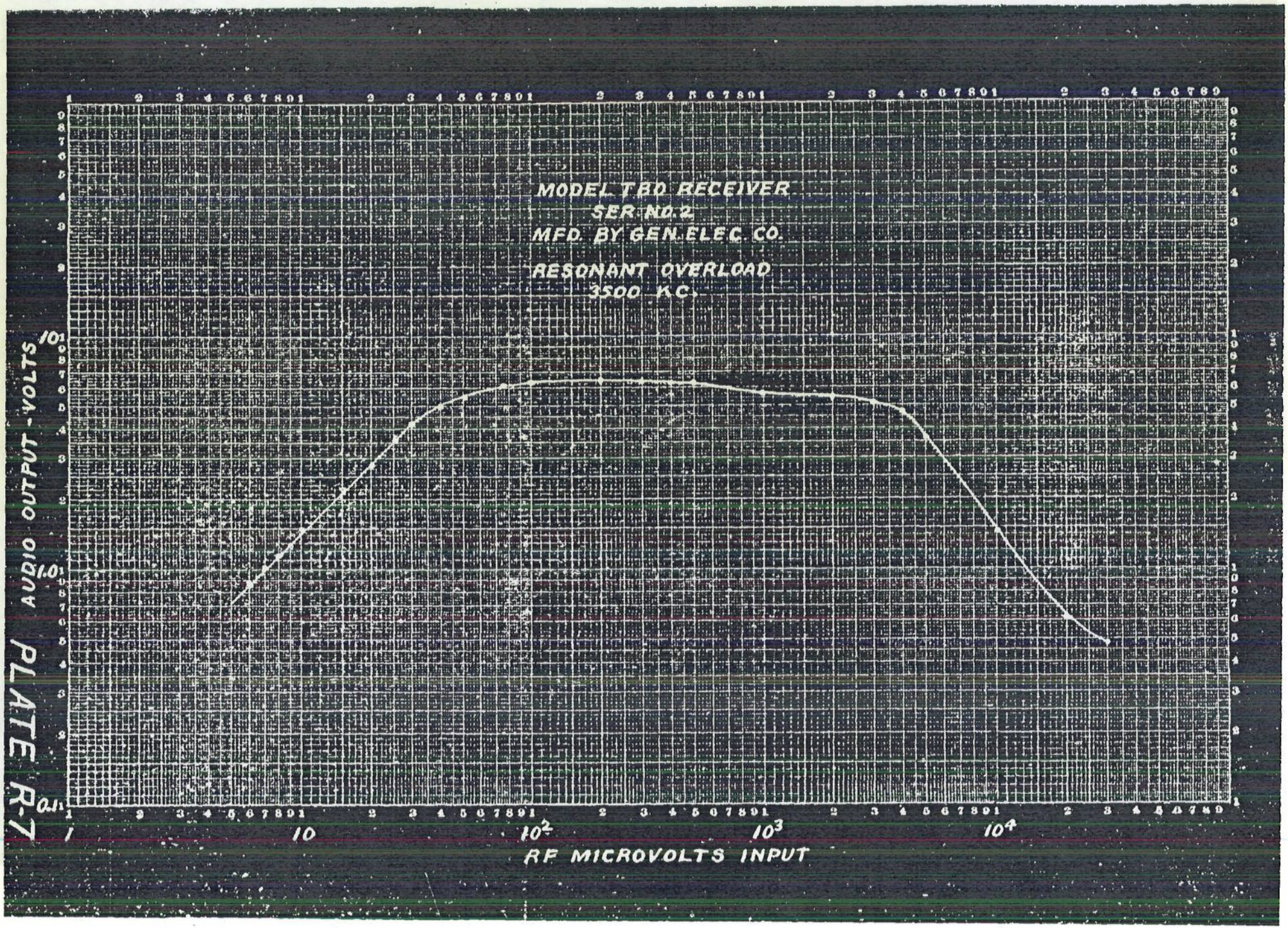
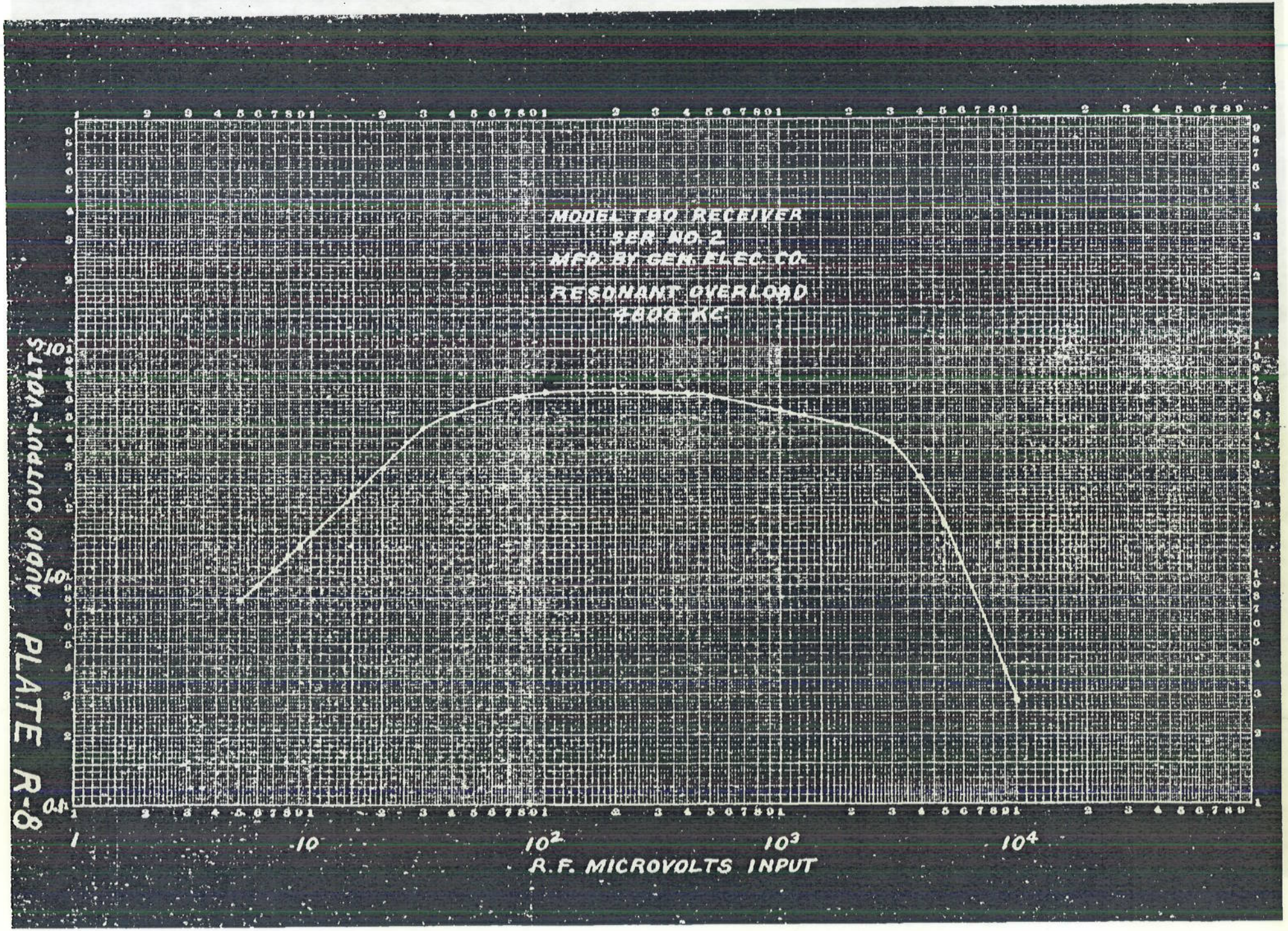
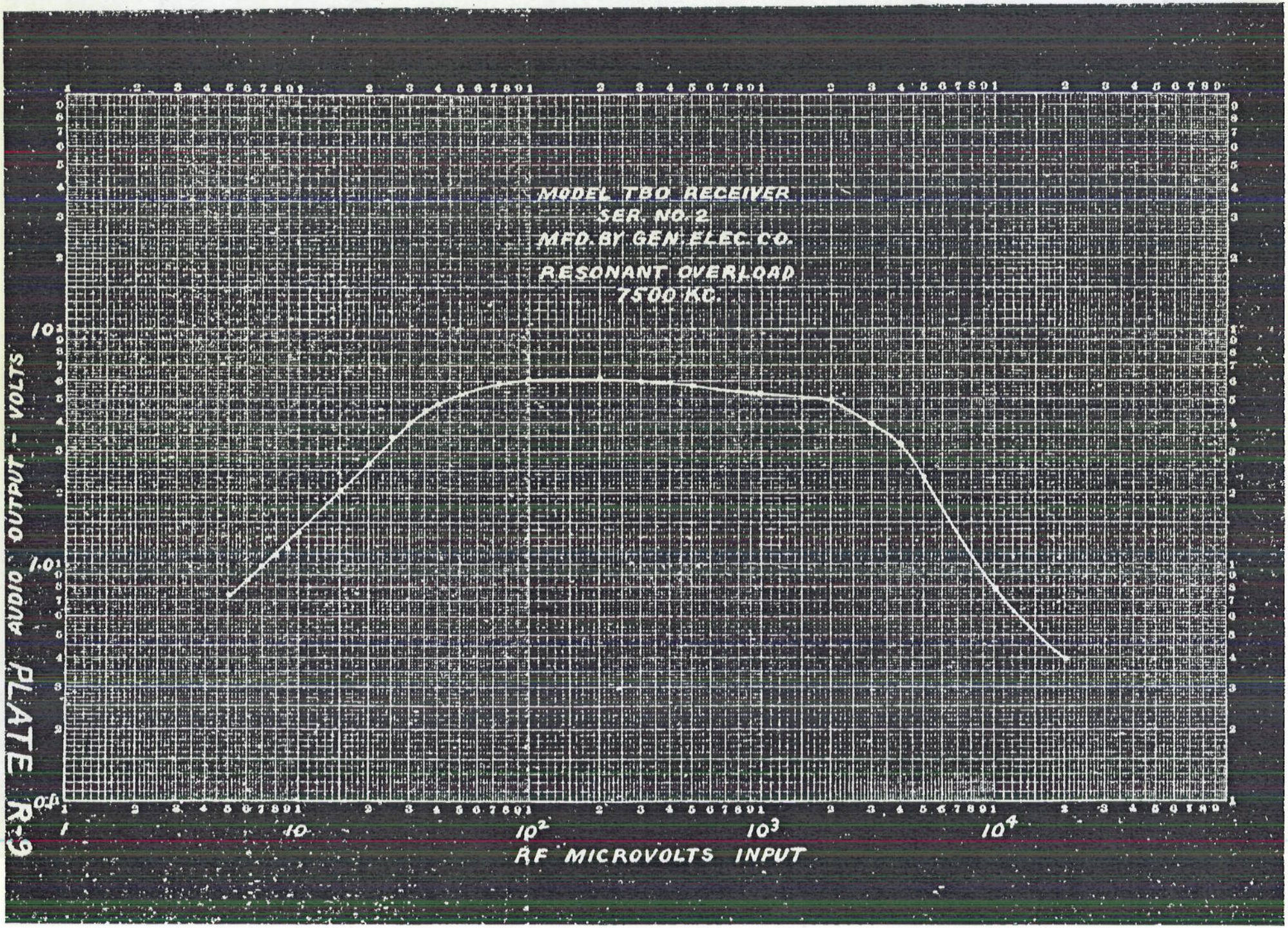

MODEL TBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
BAND 3
4990 KC.
6500 KC.
7620 KC.
SPEC. LIMIT
8000 KC.
SPEC. LIMIT
8000 KC.
10⁴
10³
10²
10
TIMES RESONANT INPUT
-4
-3
-2
-1
0
+1
+2
+3
+4
% OFF RESONANCE

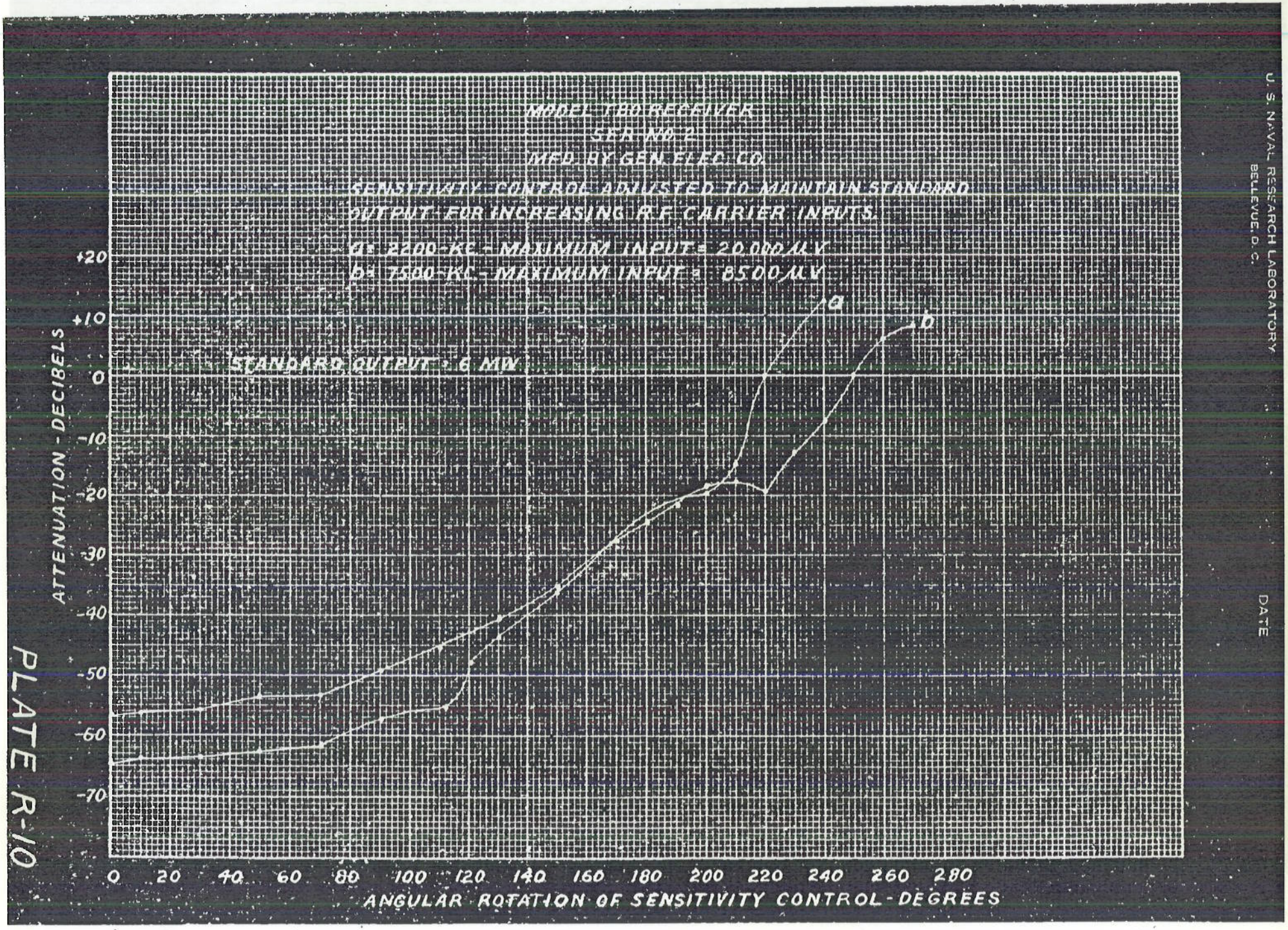
PLATE R-5

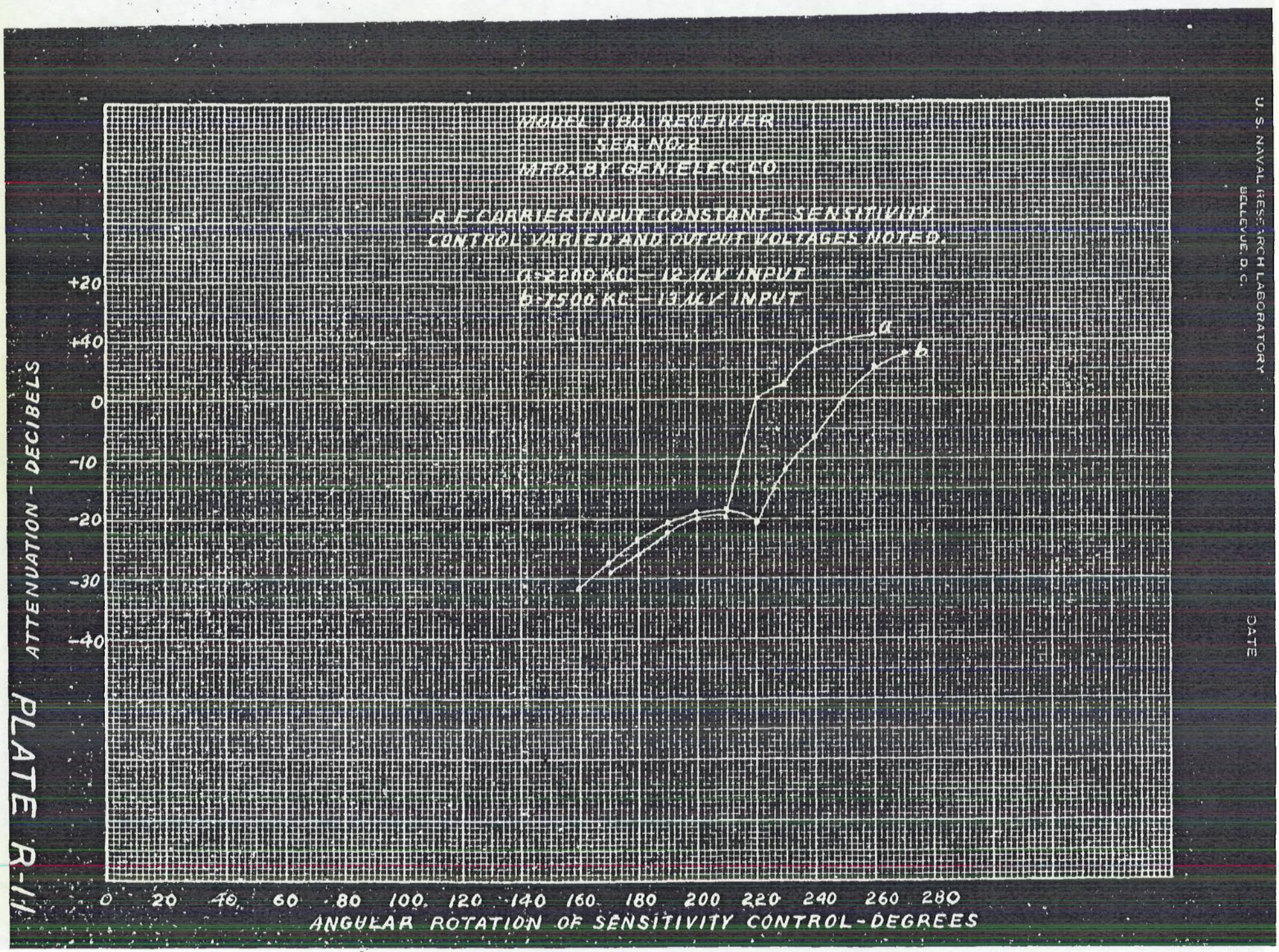

MODEL TBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
RESONANT OVERLOAD
2200 KC.
AUDIO OUTPUT-VOLTS
PLATE R-6
1
10
10²
10³
10⁴
R.F. MICROVOLTS INPUT


MODEL TBD RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
RESONANT OVERLOAD
3500 K.C.
PLATE R-7 AUDIO OUTPUT - VOLTS
RF MICROVOLTS INPUT
1
10
10²
10³
10⁴


MODEL T90 RECEIVER
SER NO. 2
MFD. BY GEN. ELEC. CO.
RESONANT OVERLOAD
4800 KC
AUDIO OUTPUT-VOLTS
PLATE R-8
1
10
10^2
10^3
10^4
R.F. MICROVOLTS INPUT


MODEL TBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
RESONANT OVERLOAD
7500 KC.
PLATE R-9 AUDIO OUTPUT - VOLTS
RF MICROVOLTS INPUT
1
10
10^2
10^3
10^4


MODEL 180 RECEIVER
S.E.R. NO. 2
MFD. BY GEN. ELEC. CO.
SENSITIVITY CONTROL ADJUSTED TO MAINTAIN STANDARD
OUTPUT FOR INCREASING R.F. CARRIER INPUTS
a = 2200-KC - MAXIMUM INPUT = 20,000 μV
b = 7500-KC - MAXIMUM INPUT = 8500 μV
STANDARD OUTPUT = 6 MW
a
b
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
ATTENUATION - DECIBELS
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ANGULAR ROTATION OF SENSITIVITY CONTROL - DEGREES
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE
PLATE R-10


MODEL 1180 RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
R.F. CARRIER INPUT CONSTANT — SENSITIVITY CONTROL VARIED AND OUTPUT VOLTAGES NOTED.
a-2200 KC. — 12 μV INPUT
b-7500 KC. — 13 μV INPUT
+20
+40
0
-10
-20
-30
-40
a
b
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ANGULAR ROTATION OF SENSITIVITY CONTROL - DEGREES
PLATE R-1.1
ATTENUATION - DECIBELS
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE

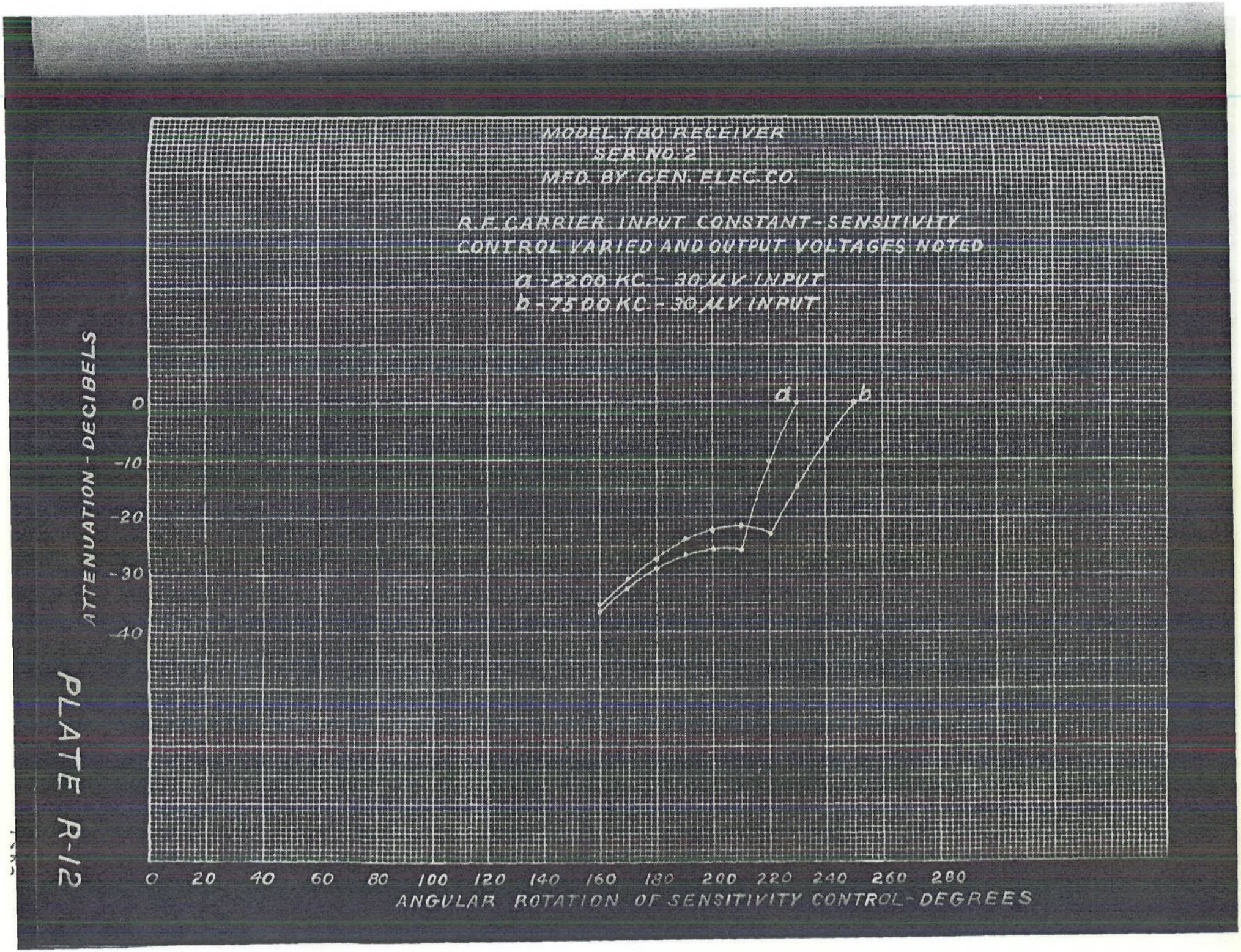

MODEL T80 RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
R.F CARRIER INPUT CONSTANT - SENSITIVITY CONTROL VARIED AND OUTPUT VOLTAGES NOTED
a - 2200 KC. - 30 μV INPUT
b - 7500 KC. - 30 μV INPUT
ATTENUATION - DECIBELS
0
-10
-20
-30
-40
a
b
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ANGULAR ROTATION OF SENSITIVITY CONTROL - DEGREES

PLATE R-12

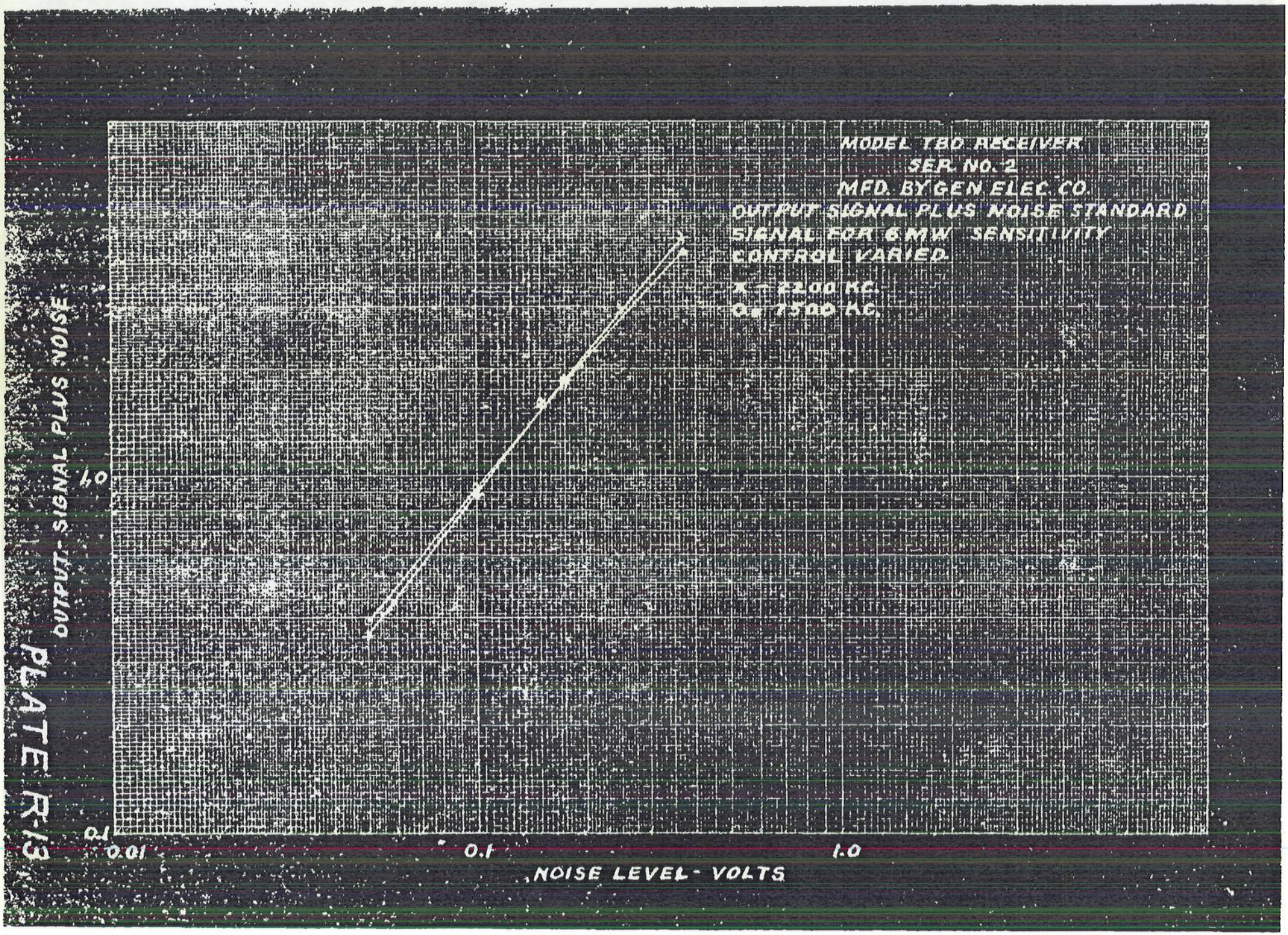

MODEL TBD RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
OUTPUT SIGNAL PLUS NOISE STANDARD
SIGNAL FOR 6 MW SENSITIVITY
CONTROL VARIED.
X = 2200 KC.
O = 1500 KC.
OUTPUT - SIGNAL PLUS NOISE
40
0.1
0.01
0.1
1.0
NOISE LEVEL - VOLTS

PLATE R-13

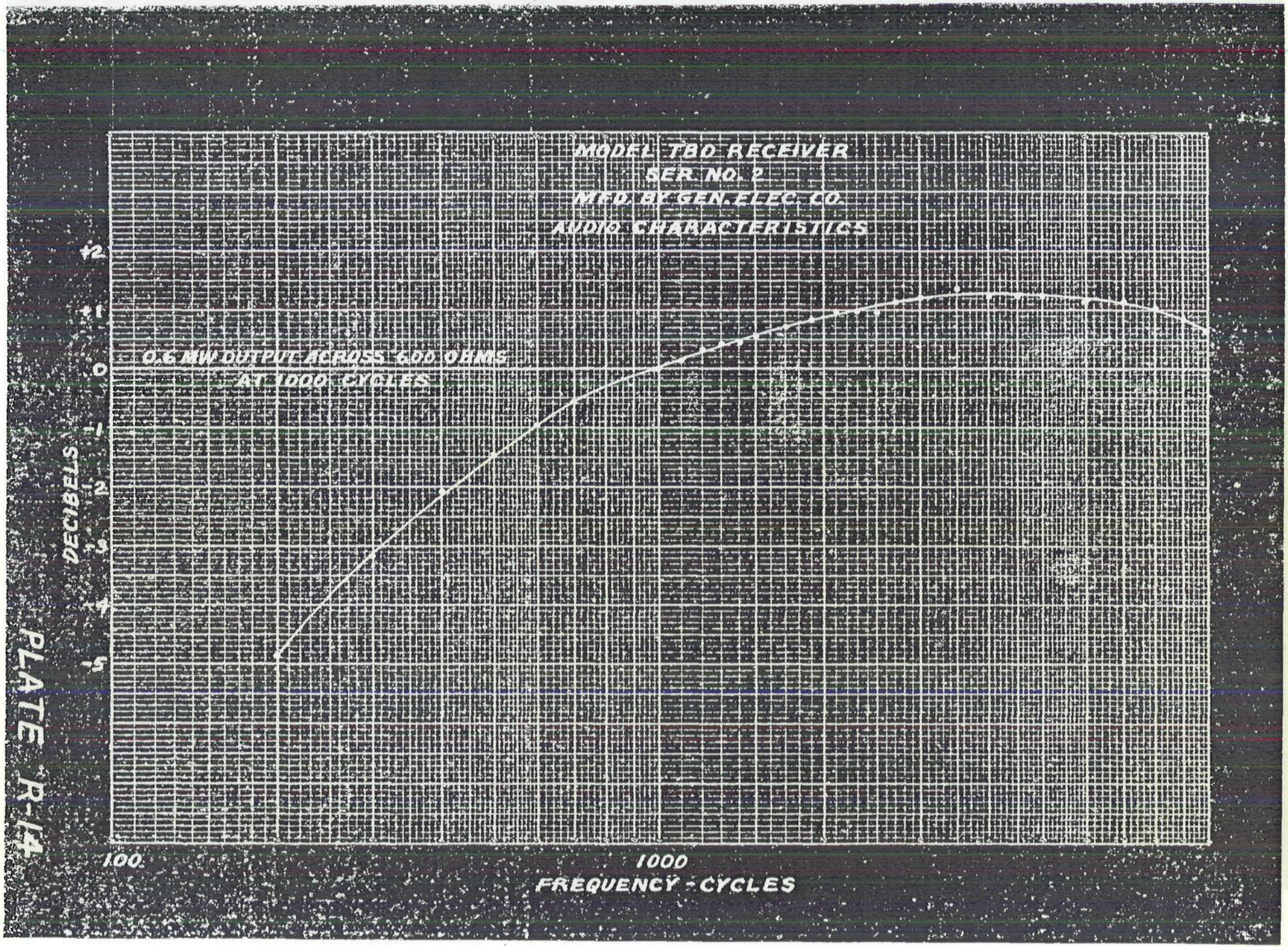
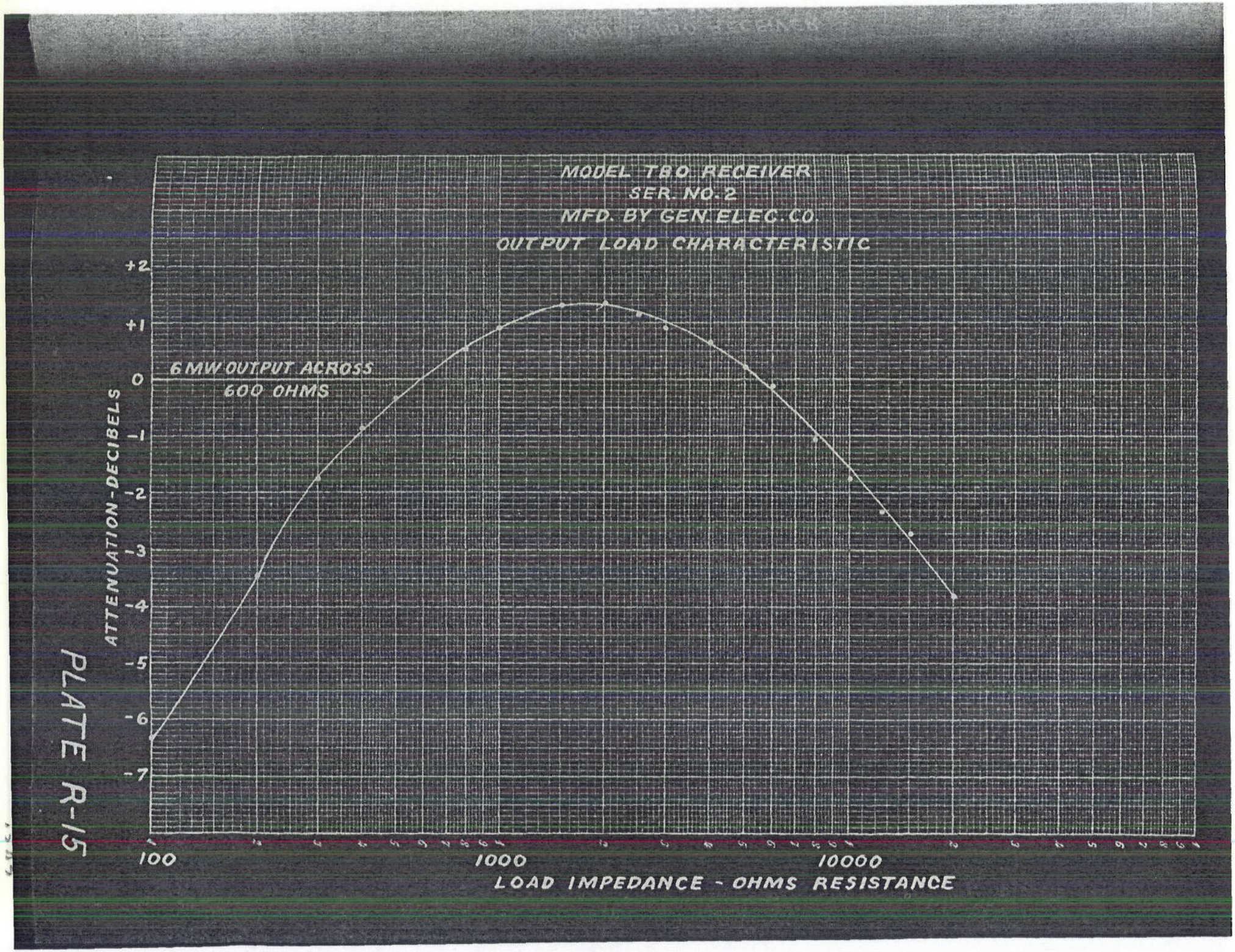

MODEL TBD RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
AUDIO CHARACTERISTICS
0.6 MW OUTPUT ACROSS 600 OHMS
AT 1000 CYCLES
+2
+1
0
-1
-2
-3
-4
-5
DECIBELS
100
1000
FREQUENCY - CYCLES

PLATE R-14


MODEL T80 RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO
OUTPUT LOAD CHARACTERISTIC
6 MW OUTPUT ACROSS
600 OHMS
ATTENUATION-DECIBELS
+2
+1
0
-1
-2
-3
-4
-5
-6
-7
100
1000
10000
LOAD IMPEDANCE - OHMS RESISTANCE
PLATE R-15

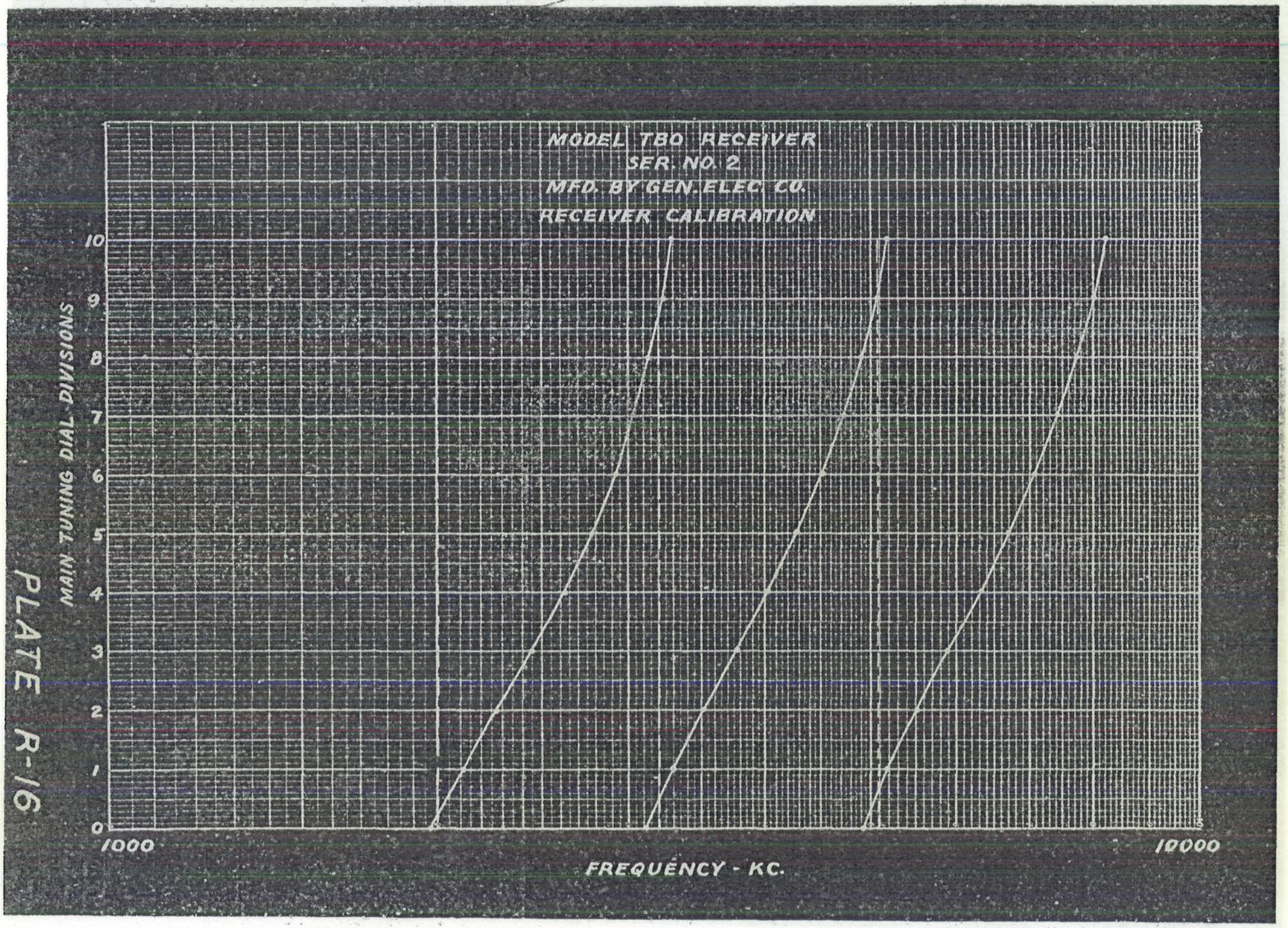

MODEL TBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
RECEIVER CALIBRATION
MAIN TUNING DIAL DIVISIONS
0
1
2
3
4
5
6
7
8
9
10
1000
10000
FREQUENCY - KC.

PLATE R-16

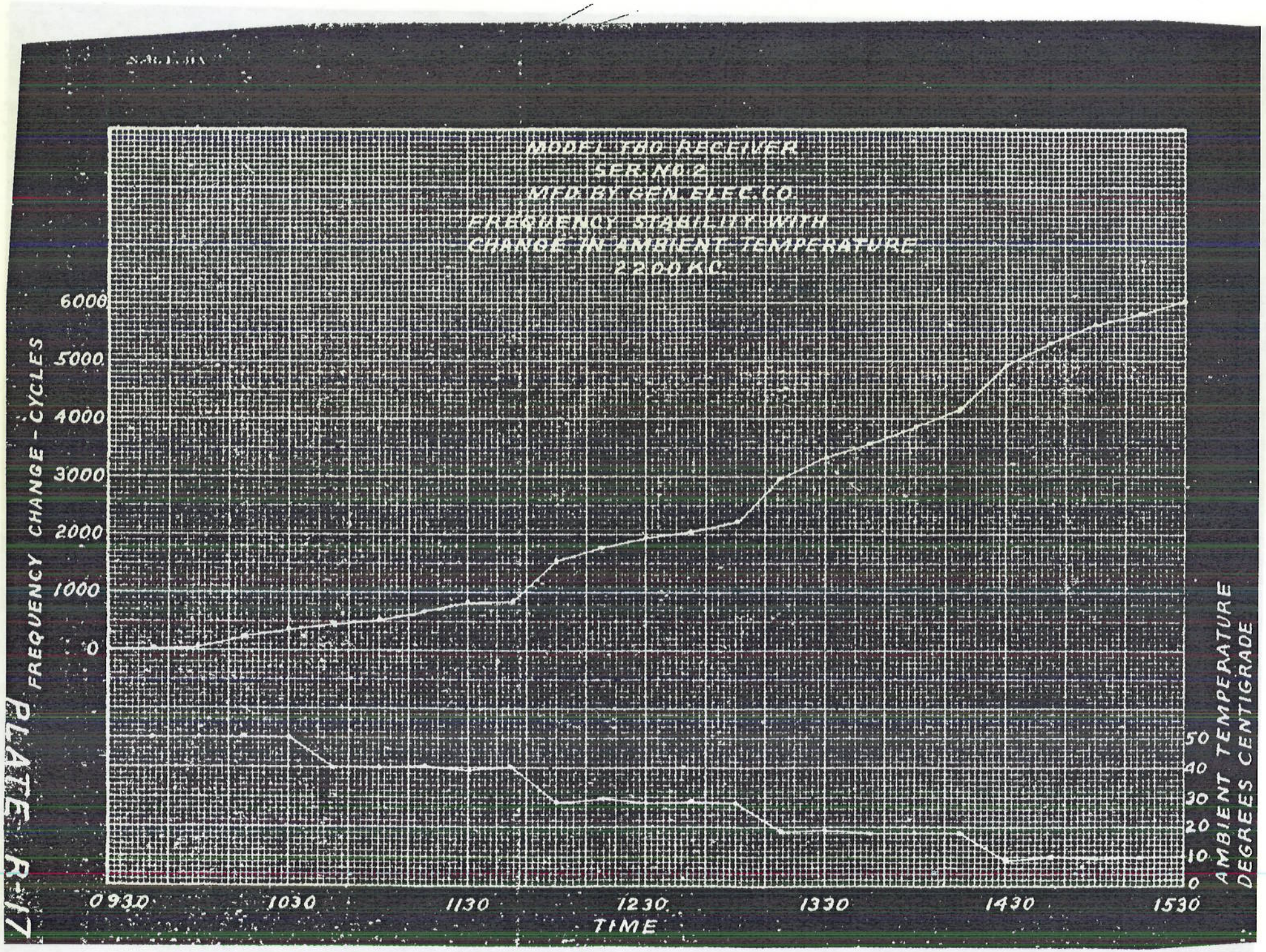
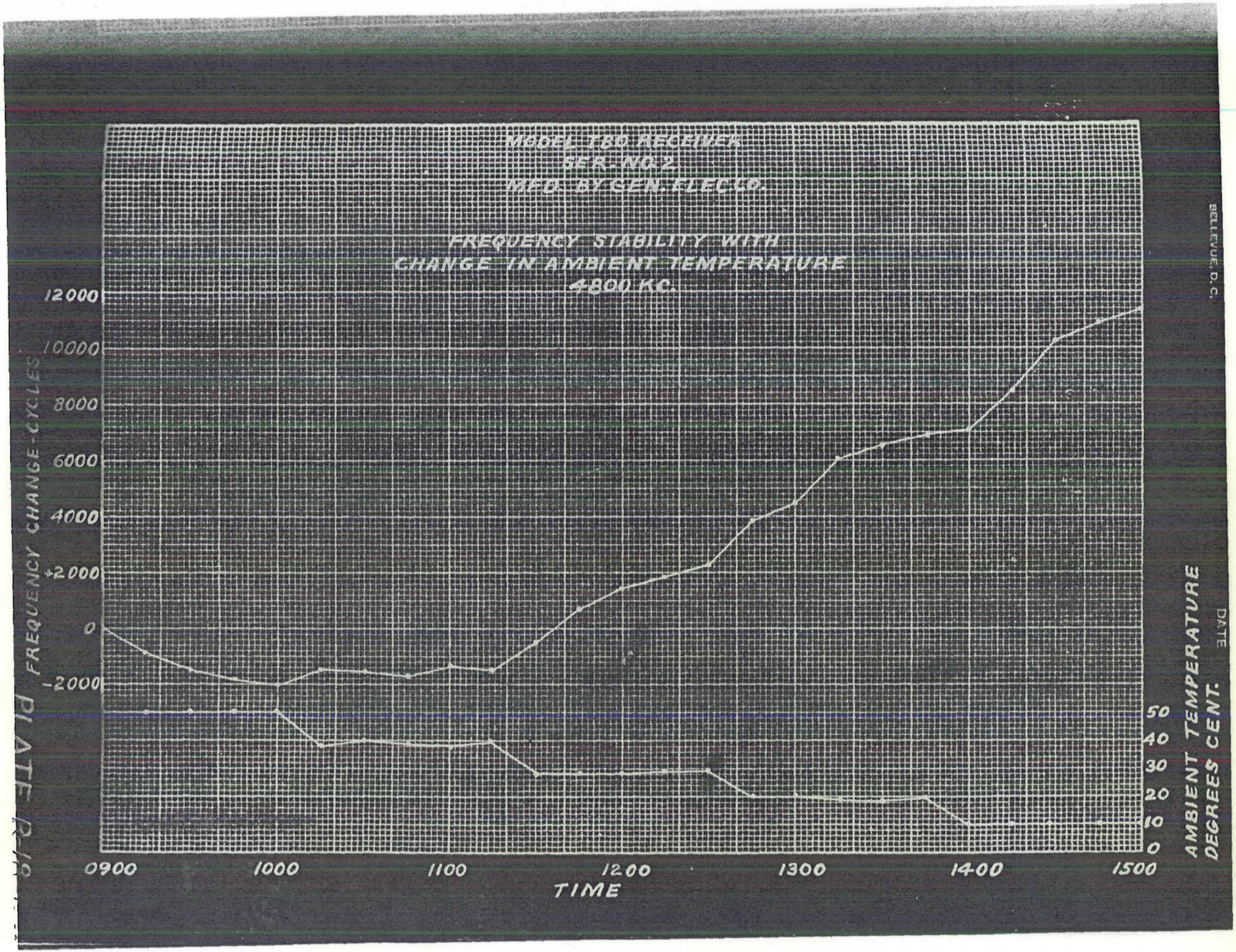

MODEL FBO RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
FREQUENCY STABILITY WITH
CHANGE IN AMBIENT TEMPERATURE
2200 KC.
FREQUENCY CHANGE - CYCLES
6000
5000
4000
3000
2000
1000
0
0930
1030
1130
1230
1330
1430
1530
TIME
AMBIENT TEMPERATURE
DEGREES CENTIGRADE
50
40
30
20
10
0

PLATE R-17


MODEL 180 RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
FREQUENCY STABILITY WITH
CHANGE IN AMBIENT TEMPERATURE
4800 KC.
12000
10000
8000
6000
4000
+2000
0
-2000
FREQUENCY CHANGE-CYCLES
PLATE
0900
1000
1100
1200
1300
1400
1500
TIME
50
40
30
20
10
0
AMBIENT TEMPERATURE
DEGREES CENT.
BELLEVUE, D.C.
DATE

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

AMBIENT TEMPERATURE
DEGREES CENT.

50 40 30 20 10 0

1530
1430
1330
1230
1130
1030
0930

TIME

FREQUENCY CHANGE-CYCLES

32000 28000 24000 20000 16000 12000 8000 +4000 0 -4000

MODEL TR-1 CRYSTAL
SERIAL NO. 2
MEDIUM ENERGY ELECTRODE
FREQUENCY STABILITY WITH
CHANGE IN AMBIENT TEMPERATURE
7500 KC

PLATE R-19

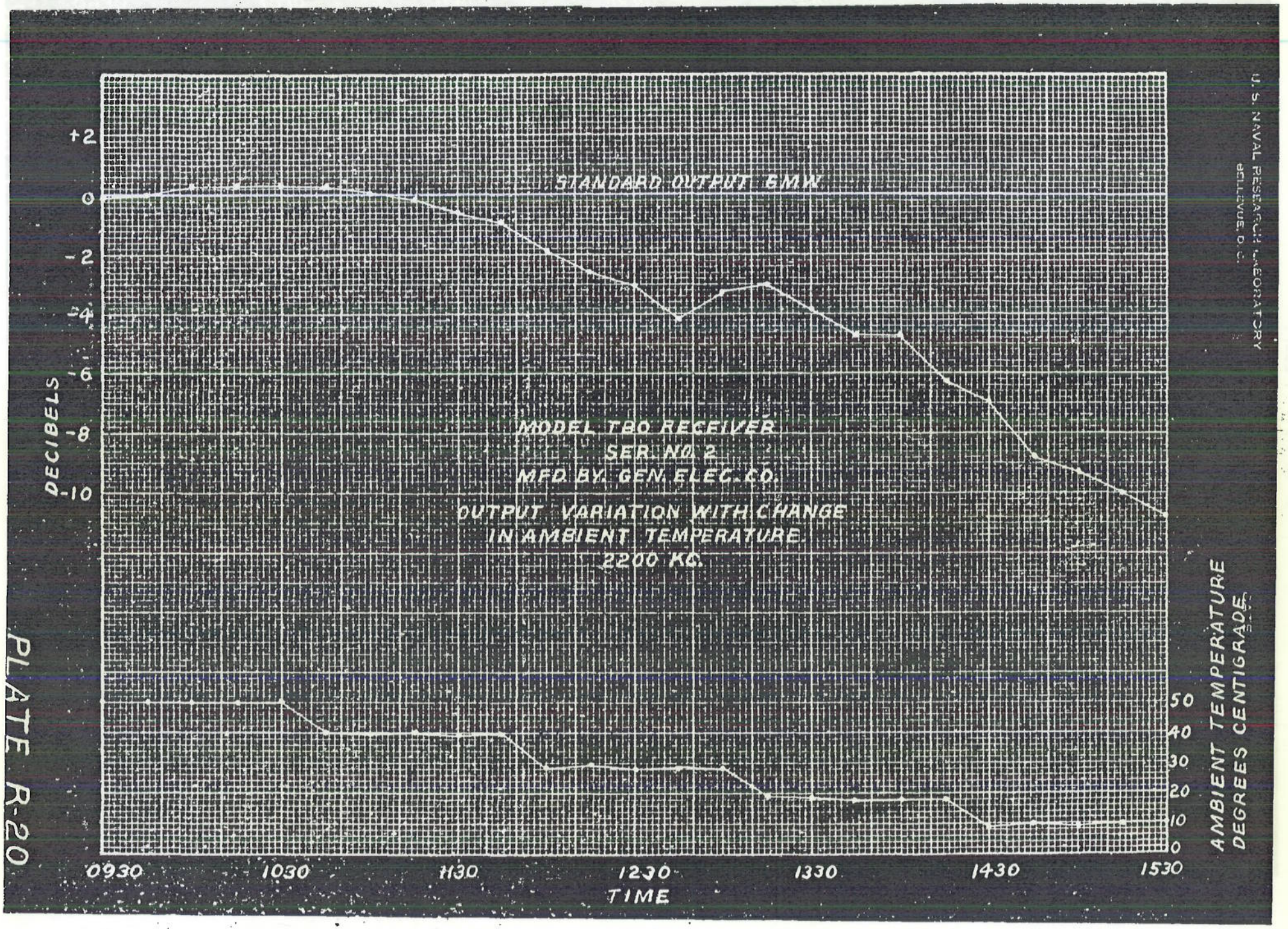

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
STANDARD OUTPUT 6MW
MODEL TBO RECEIVER
SER. NO. 2
MFD. BY. GEN. ELEC. CO.
OUTPUT VARIATION WITH CHANGE
IN AMBIENT TEMPERATURE
2200 KC.
DECIBELS
+2
0
-2
-4
-6
-8
-10
0930
1030
1130
1230
1330
1430
1530
TIME
AMBIENT TEMPERATURE
DEGREES CENTIGRADE
50
40
30
20
10
0

PLATE R-20

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

PLATE R-21

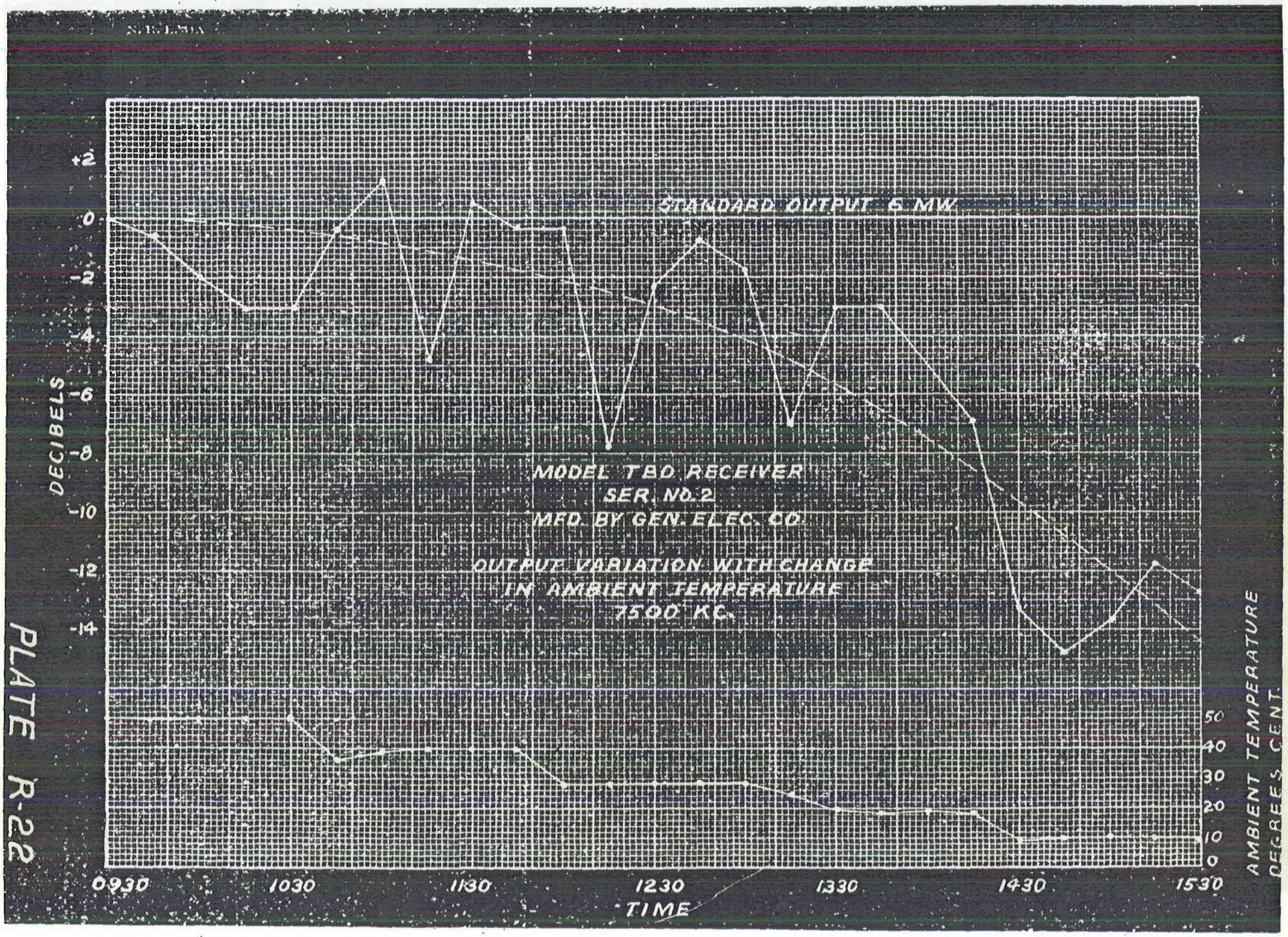
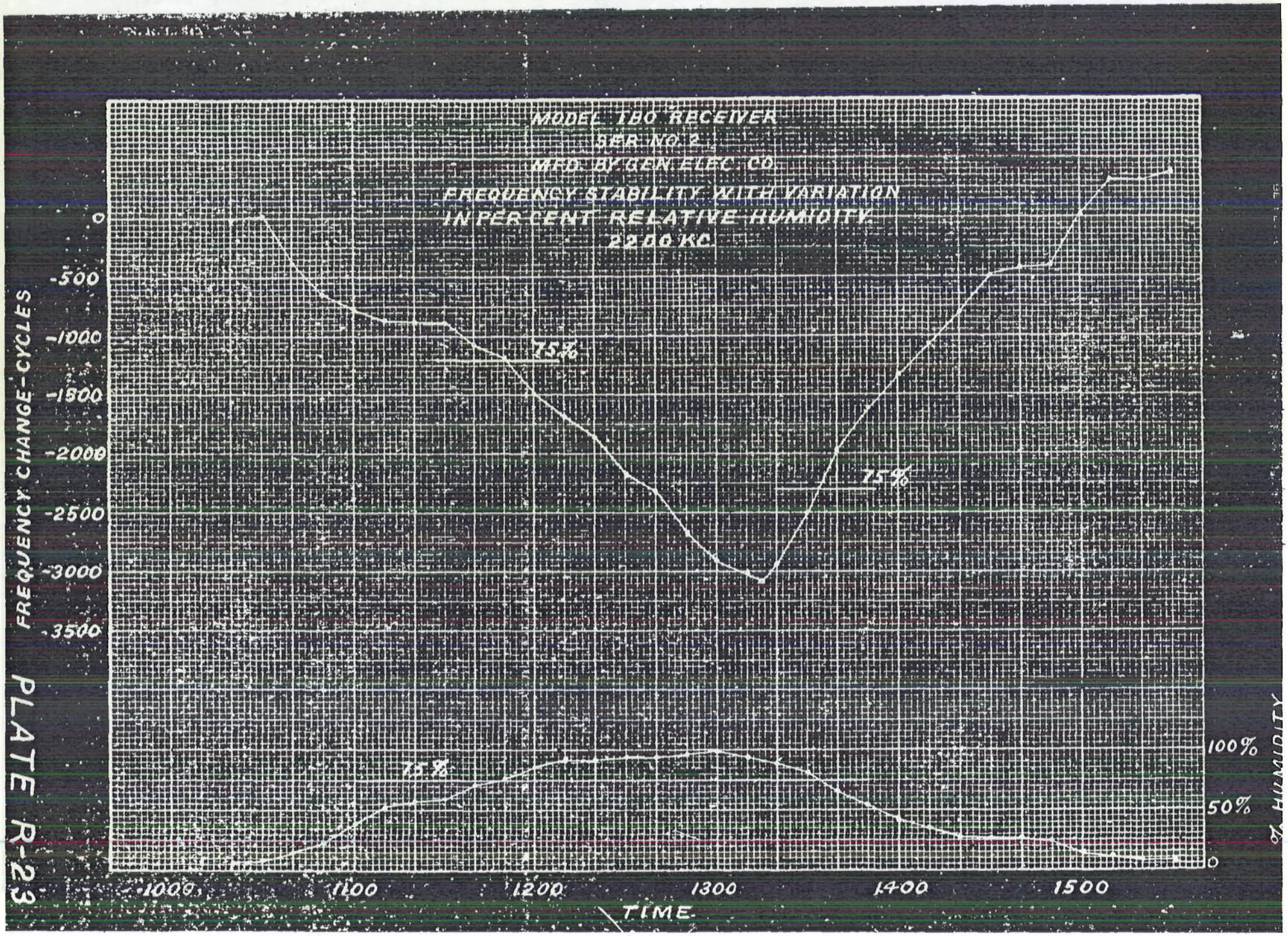
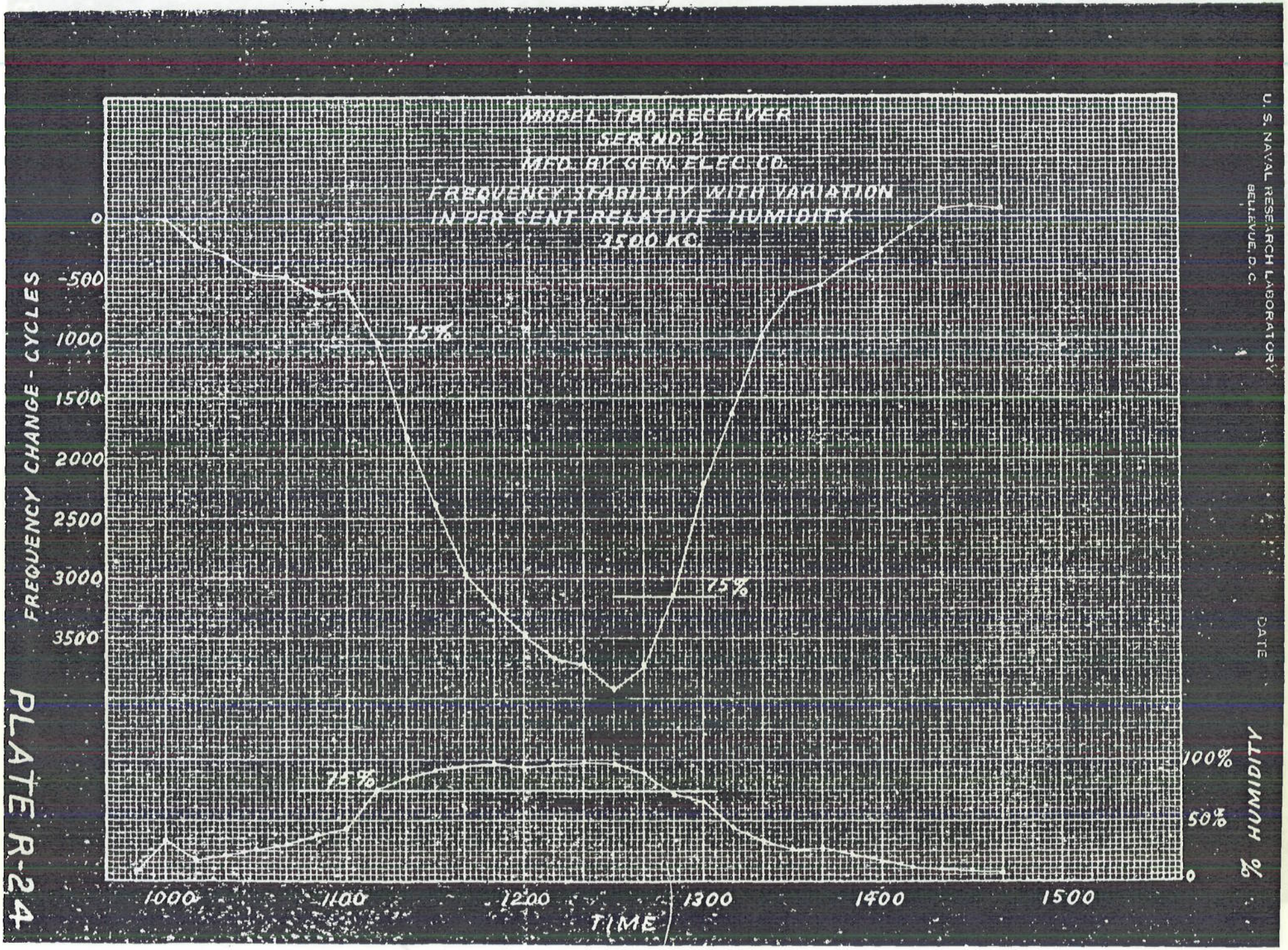
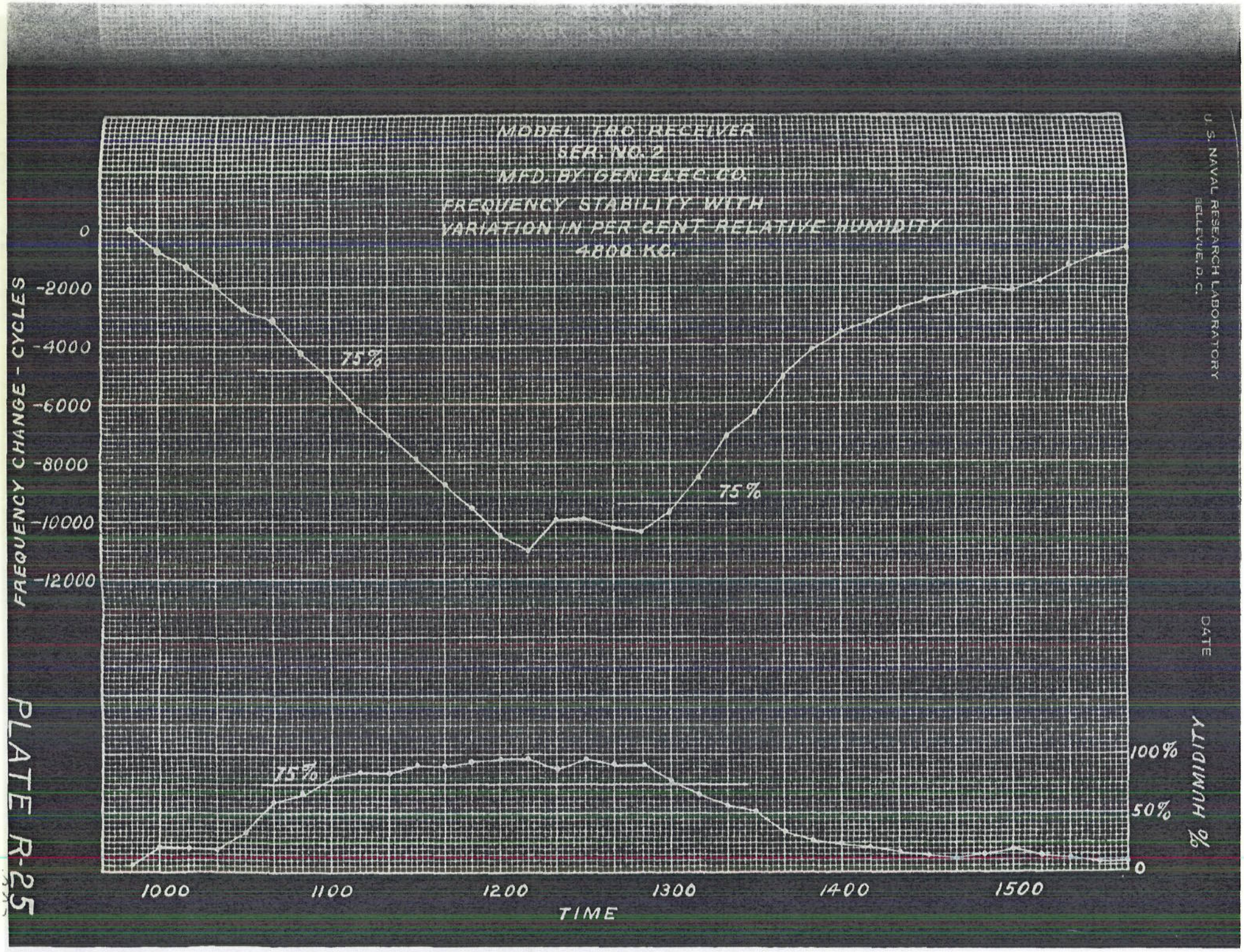
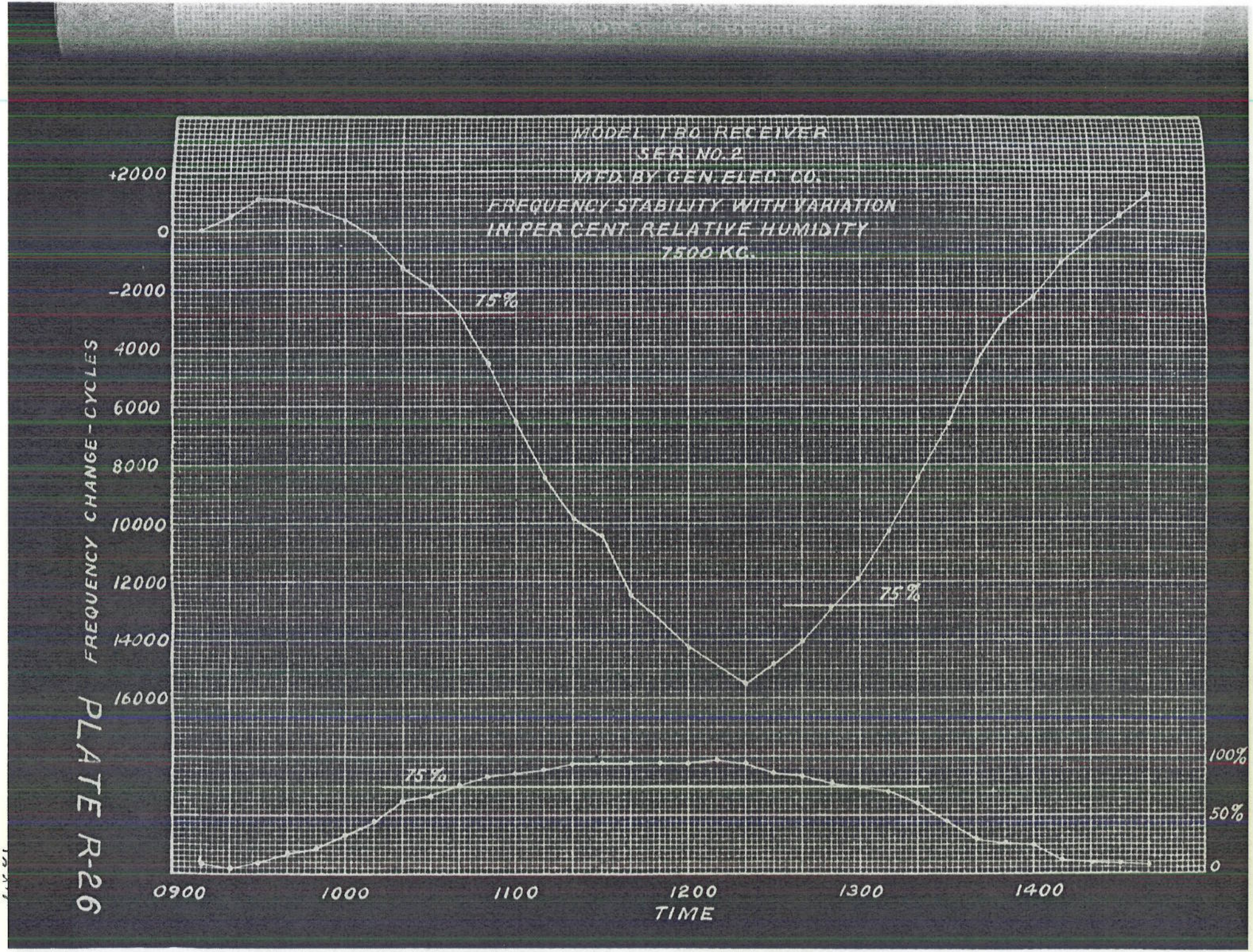

STANDARD OUTPUT 6 MW.
MODEL TBD RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
OUTPUT VARIATION WITH CHANGE
IN AMBIENT TEMPERATURE
7500 KC.
DECIBELS
+2
0
-2
-4
-6
-8
-10
-12
-14
0930
1030
1130
1230
1330
1430
1530
TIME
AMBIENT TEMPERATURE
DEGREES CENT.
50
40
30
20
10
0

PLATE R-22


MODEL 180 RECEIVER
SER NO 2
MFD BY GEN ELEC CO
FREQUENCY STABILITY WITH VARIATION
IN PER CENT RELATIVE HUMIDITY
2200 KC
75%
75%
75%
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
PLATE R-23
FREQUENCY CHANGE-CYCLES
100%
50%
0
% HUMIDITY
1000
1100
1200
1300
1400
1500
TIME


MODEL T80 RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
FREQUENCY STABILITY WITH VARIATION
IN PER CENT RELATIVE HUMIDITY
3500 KC.
FREQUENCY CHANGE - CYCLES
0
-500
1000
1500
2000
2500
3000
3500
75%
75%
75%
1000
1100
1200
1300
1400
1500
TIME
100%
50%
0
HUMIDITY %
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE
PLATE R-24


MODEL T&O RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
FREQUENCY STABILITY WITH
VARIATION IN PER CENT RELATIVE HUMIDITY
4800 KC.
0
-2000
-4000
-6000
-8000
-10000
-12000
FREQUENCY CHANGE - CYCLES
75%
75%
75%
100%
50%
0
% HUMIDITY
1000
1100
1200
1300
1400
1500
TIME
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.
DATE
PLATE R-25


MODEL T-80 RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
FREQUENCY STABILITY WITH VARIATION
IN PER CENT. RELATIVE HUMIDITY
7500 KC.
+2000
0
-2000
4000
6000
8000
10000
12000
14000
16000
FREQUENCY CHANGE - CYCLES
75%
75%
75%
100%
50%
0
0900
1000
1100
1200
1300
1400
TIME
PLATE R-26

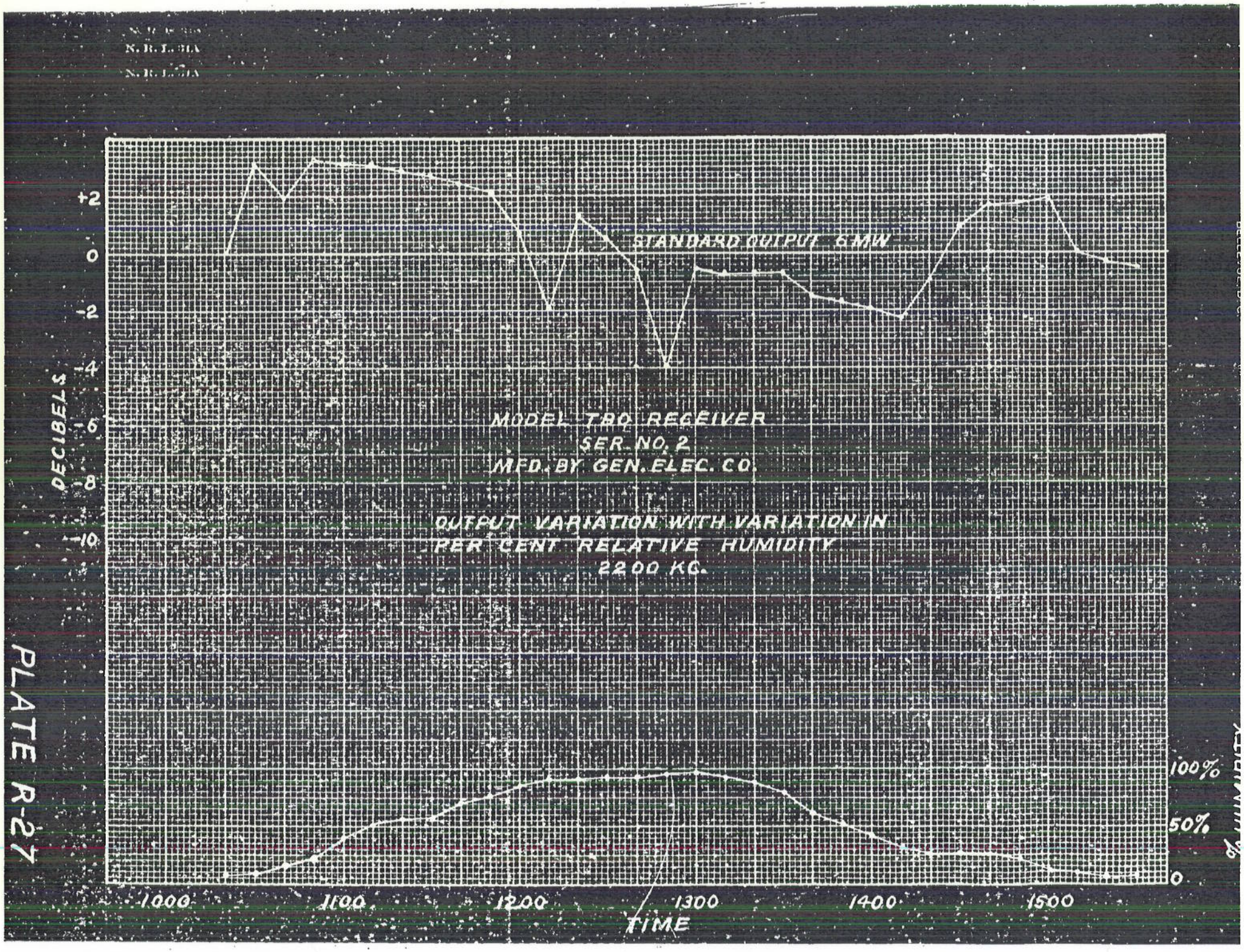

STANDARD OUTPUT 6 MW
MODEL TBQ RECEIVER
SER. NO. 2
MFD. BY GEN. ELEC. CO.
OUTPUT VARIATION WITH VARIATION IN
PER CENT RELATIVE HUMIDITY
2200 KC.
DECIBELS
+2
0
-2
-4
-6
-8
-10
1000
1100
1200
1300
1400
1500
TIME
100%
50%
0
% HUMIDITY

PLATE R-24