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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Test of

Model CXL Radio Transmitting Equipment

(Contractor: Graybar Electric Co.,Inc.)
(Manufacturer: Western Electric Co.)

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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AUTHORIZATION OF TEST.

1. The tests herein reported were authorized by references (a) and (b). Other pertinent data used in connection with the tests of the Model CXL Equipments are listed as references (c) to (h) inclusive.

Reference: (a) BuEng. Restricted letter NOs-42972 (12-23-W8) of 28 Dec. 1935.
(b) BuEng. Restricted letter NOs-42972 (12-23-W8) of 18 Jan. 1936.
(c) BuEng. Restricted Specs. RE 13A 507A.
(d) Contractor's Descriptive Specification.
(e) Test data on CXL Equipment.
(f) Test data on D-98294 Quartz Plates.
(g) Preliminary Instruction Book covering Model CXL Equipment.
(h) NRL. letter S67/72 of March 5, 1936 to Bureau of Engineering.

OBJECT OF TEST.

2. The object of the tests was to determine the general suitability of the CXL equipments for service use afloat, with particular attention to any new features or special advantages over other types of superfrequency apparatus, and to obtain information with a view of formulating recommendations for the improvement of future equipment of this type.

ABSTRACT OF TESTS.

3. The tests herein reported were conducted to determine the general suitability of the CXL Equipment for service use and to formulate recommendations for the improvement of future equipment of this type. Specifically, tests were conducted to determine the following:

(a) Ability to withstand handling and shipment.
(b) Check of mechanical or physical construction and assembly; general workmanship; corrosion resisting methods employed and adequacy of electrical circuits.
(c) Power output; power required from supply lines.
(d) Physical suitability of antenna systems and transmission lines and electrical efficacy of same.
(e) Quality of emitted signals; lilt; undesirable modulations; key clicks; keying speeds; break-in operation and adequacy of antenna filters to prevent sub-harmonic radiations.
(f) Check of dimensions and weight.
(g) Check of protective circuits.
(h) Determination of modulation characteristics.

(i) Frequency stability and accuracy under following conditions:

(1) Key locked operation.
(2) Variation of supply line voltage.
(3) Variations in ambient temperature.
(4) Variations in humidity up to 100%.
(5) Change of vacuum tubes.
(6) Effect of vibration.
(7) Effect of inclination and shock.
(8) Effect of power output control.

(j) Check of power equipment.

CONCLUSIONS.

(a) The external appearance of the equipment is excellent and high grade materials have been used in the construction. The internal wiring is orderly, well secured and of good quality. No lead sheathed wire is employed, but this lack of shielding appears to have no ill effects upon the operation of the equipment judging by the tests conducted at the Naval Research Laboratory.

(b) No access to the interior of the transmitter proper is afforded through the front panel. The provision of front panel access should be given serious consideration in the event additional equipment of this nature is secured in the future. The removal of side and rear shields whenever minor ajustments or replacements are required necessitates providing additional space on board ship and prevents the installation of the equipment with its back flush against a bulkhead.

(c) In future equipment of this nature it would be exceedingly desirable to provide increased flexibility and time saving methods when shifting frequencies. The possibility of providing remotely controlled adjustable antennas is worthy of investigation in order to eliminate the necessity of the operating personnel going aloft each time the transmitter frequency is changed. In general, it may be stated that future procurements of superfrequency equipment should be required to conform as nearly as possible with the requirements found necessary and desirable in high frequency and intermediate frequency shipboard equipment as represented by the latest issues of Bureau of Engineering specifications.

(d) The equipments furnished are capable of producing the required power output and yet permit the various component parts to operate at safe and reasonable levels. The voice circuits are capable of excellent speech reproduction and, in general, exceed the contractual requirements with respect to modulation, distortion, fidelity and noise level. The radio frequency stability and accuracy reflects a high degree of engineering skill and the effects of potential variations, temperature variations, humidity variations over wide limits, shock, roll and pitch have been reduced to negligible values. Certain changes in physical or mechanical construction are indicated, however, to prevent severe vibration from interfering with the normal operation of the equipment.

(e) The equipment demonstrated its ability to function satisfactorily over long periods of key locked full power operation and no operational failures occurred during the course of the tests reported herein.

(f) Compliance with the terms of the governing contract wherein it was required that the manufacturer incorporate two distinct types of keying for telegraph operation; two modulating frequencies for telegraph operation; automatic voice control of the carrier; inclusion of the receiver within the transmitter frame; use of a single antenna for transmission and reception and the accompanying provision for break-in operation, naturally increases the complexity of the apparatus.

This in turn influences the design, construction, installation, operation and maintenance requirements. Should actual operations within the Fleet under service conditions indicate that certain features could be dispensed with without impairing the efficiency of the equipment or curtailing the benefits derived from its operation, future apparatus of this type could undoubtedly be simplified to a considerable extent.

(g) It is further concluded from the results of actual transmission tests conducted that too great reliance should not be placed in such transmission tests when they are conducted under conditions which vary widely from the conditions surrounding actual service operations afloat. Due to the fact that superfrequency communications are greatly influenced by the immediate terrain, the altitude of transmitting and receiving antennas, ground conditions, noise levels and so forth, the results obtained on shore will not be representative of the results which may be expected from shipboard installations.

RECOMMENDATIONS:

It is recommended:

(a) That information be obtained covering the various shipments of CXL equipment to determine whether plywood packing cases are suitable for the shipment of heavy units. (Par. 17)

(b) That in future equipments the actual type number of the tube be included in the marking near the tube socket. (Par. 25b)

(c) That proper precautions be observed to insure that tubes can be inserted in their respective sockets without encountering interference from bayonet pins. (Par. 25c)

(d) That the possibility of improving connections to type 305-A vacuum tubes (or similar tubes) be thoroughly investigated with a view of preventing the possibility of short circuits. (Par. 25d)

(e) That existing CXL equipments operating from 230 volt supplies be modified to prevent the destruction of remote indicator lamps and that this condition be guarded against in future production. (Pars. 25e & 120)

(f) That all circuits be equipped with proper fuses and that wiring diagrams clearly show the location of such fuses. (Par. 25f)

(g) That all controls in all equipments be clearly marked with the designations conforming to the wiring diagram and instruction book markings. (Par. 25g)

(h) That suitable means be provided for energizing receivers when withdrawn from their normal operating position, in order that servicing operations may be conducted. (Pars. 25h & 110)

(i) That proper precautions be observed to insure against voltage breakdowns. (Pars. 25i & 25k)

(j) That proper provisions be incorporated in the equipment to prevent vibration from adversely affecting operation. (Pars. 25j, 40, 66 and 107)

(k) That in future equipment steps be taken to provide increased accessibility. (Pars. 25L, 31 and 96)

(l) That future equipment using motor generators be so designed that the individual output potentials may be varied at will without affecting the output of companion generators and that greater output voltage stability be insured. (Par. 25m)

(m) That all variable controls be adjustable from the front panel by means of approved knobs and fittings and that future equipments be provided with improved means for accomplishing frequency changes. (Pars. 44, 45 and 86)

(n) That every effort be made to prevent the generation of spurious oscillations in all circuits of the equipment. (Par. 71)

(o) That the need of by-pass units on DC meters be determined from service operation tests and if found necessary, that all equipments be provided with such units. (Par. 94)

(p) That suitable informative nameplates be provided near the lubricating devices on motor generators. (Par. 134)

(q) That protective fuses be provided at the generator terminals of high tension lines in order to afford maximum protection against short circuits and overloads. (Par. 135)

(r) That errors in instruction books be corrected and that additional information be provided covering motor generator equipment. (Par. 138)

(s) That particular attention be paid to the results of service tests with existing equipment with a view of determining the feasibility of simplifying future equipment along the lines suggested in paragraph 145 of this report.

MATERIAL UNDER TEST.

4. The material under test consisted of the following:

2 - Model CXL Radio Transmitting and Receiving Equipments, Serial Nos. 13 and 14. Serial No. 13 is designed to operate from a 230 volt, d.c. power supply, while Serial No. 14 operates from 115 volts d.c. Each complete equipment consists of the following component units:

1 - CW-52052 Radio Transmitter
1 - CW-46047 Radio Receiver
3 - CW-23075 Remote Control Units
1 - Type CC-21116 Generator
1 - Type CC-21190 Motor and 1 Type CA-021188 Motor starter for the 115 volt power supply and 1 Type CC-21191 Motor and 1 Type CA-021189 Motor starter for 230 volts d.c. power supply.
2 - E5A Hand Telephone Sets
2 - 396A Chest Set Transmitters
Vacuum tubes, quartz crystals and spare parts.
Antenna installation and transmission line equipment.

5. The Model CXL equipments were manufactured by the Western Electric Company under Contract NOs-42972 with the Graybar Electric Company. The transmitter has a nominal output rating of 50 watts over the range of 30 mc. to 60 mc. The carrier frequency is controlled by means of quartz crystals which are adjusted to operate at one-sixth (1/6th) of the output frequency. The transmitter is capable of voice transmission and MCW telegraph transmission. When using MCW it is possible to select a modulating frequency of either 750 cycles or 1000 cycles. Two types of telegraphic transmission are provided; it is possible to key the carrier or the carrier may be permitted to radiate continuously and keying be accomplished by controlling the audio oscillator.

6. The Model CXL Transmitter and Receiver equipment was received at the Naval Research Laboratory on January 22, 1936. The antenna equipment for use in connection with the transmitters was received on February 28, 1936.

METHOD OF TEST.

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. Upon receipt of the necessary wiring diagrams and instructions (received January 31, 1936) the equipment was placed into commission, particular attention being paid to the adequacy of the instructions and diagrams and the methods provided for making the necessary connections.

9. Power output determinations were accomplished through the medium of a 60 watt lamp and a calibrated photronic cell. The lamp was energized through a short length of concentric transmission line and precautions were taken to insure proper impedance matching.

10. Frequency changes and drifts were determined by means of a modified LH drift indicator which utilized one of the spare crystals furnished with the CXL equipments.

11. The CXL equipment was installed in the temperature controlled test room and the temperature coefficient of the transmitter was determined between the limits of zero degrees Centigrade and plus 50 degrees Centigrade. The effect upon frequency of variations in relative humidity from a low value up to 100% was also determined.

12. Modulation investigations were made by means of the cathode ray oscillograph.

13. The ability of the equipment to withstand vibration and the roll and pitch of a vessel in a heavy sea was determined by mounting the equipment upon a special test stand whereby vibration and inclination could be applied in a manner simulating that encountered afloat.

14. Range tests were conducted up to a distance of approximately 10 miles. In order to accomplish these tests one of the receivers was mounted in a truck.

DATA RECORDED.

15. Complete data was recorded on all tests conducted and this information is contained in Tables 1 to 7 and Plates 1 to 9 inclusive appended hereto.

PROBABLE ERRORS IN RESULTS.

16. Every effort was made to minimize errors in the results of the tests reported herein. Meters employed in making current and voltage measurements were of the precision type of verified accuracy. The method employed for determining frequency drifts at superfrequencies appears to be trustworthy to within about 10 cycles, or less. Extreme precautions were exercised to prevent high frequencies from affecting the results obtained during oscillographic determinations of modulation and special care was taken to prevent errors from this source while determining the audio response and distortion characteristics of the equipment under test. No great reliance can be placed in the range test data collected, as explained in the body of this report.

RESULTS OF TESTS.

17. The Model CXL equipment was received in good condition, no damage or breakage having been incurred enroute. The packing cases in which the equipment was enclosed were sheathed with one-eighth (1/8") inch thick plywood secured to frames of 3/4" thick pine. In view of

the difficulties which are being encountered in connection with the shipment of radio transmitting equipment wherein damage has been incurred even when the packing cases were of exceptionally rugged construction, it is believed that cases constructed of thin plywood do not afford the necessary degree of protection. However, since the shipment received at the Naval Research Laboratory was in no way injured, it may be desirable to obtain reports on the other equipments shipped under this contract before deciding whether plywood packing cases are unsuitable for future shipments.

18. In the following paragraphs of this report reference is made to the governing specifications, RE 13A 507A, under which this equipment was 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.

19. Par. 1-1. Due to the wide difference in conditions surrounding transmission and reception at superfrequencies over land and over water, no definite conclusions as to the ultimate ranges which may be expected from shipboard installations could be arrived at from the tests conducted at the Naval Research Laboratory. Therefore, it is believed that range data upon which reliance may be placed must be obtained from tests conducted in the Fleet.

20. Par. 1-2. The requirements of this paragraph relative to the avoidance of interference with other communications on board ship could not be determined with any degree of accuracy through the medium of laboratory tests. Such information can only be obtained from the results of service operation afloat.

21. Par. 1-3. The equipment as furnished was complete in all respects for the radiation of tone modulated telegraph signals or voice modulation and provided for the reception of either type of signal.

22. Par. 1-4. The quartz crystals supplied with the CXL equipments, serials No. 13 and 14, were ground to the specified frequency with exceeding accuracy so that no difficulty was experienced in obtaining the necessary beat note adjustments. If all crystals furnished on this contract are the equal of the crystals supplied with the two equipments under test, no difficulty should be experienced in the reception of signals from any one or all transmitters on a common adjustment of all receivers.

23. Par. 1-6. Two hundred feet of concentric transmission line was furnished with each CXL equipment. For test purposes the contractor provided a special cable, properly terminated, to facilitate servicing of the receiver.

24. Par. 2-2. The Model CXL equipments are of rugged construction. The main framework and cross members are fabricated from hard aluminum alloy 2" x 2" x 1/8" with heavy gusset plates spot welded at the corners. The materials used have been carefully selected to insure their suitability for the specific purpose they serve. Certain forms of

construction have been employed which should be modified in any future construction. These items will be discussed in detail under appropriate paragraph designations.

25. Par. 2-3. In general, the workmanship employed throughout the entire equipment is of excellent quality and high grade materials have been used. However, certain items were noted where corrections or improvements may be made.

(a) In equipment Serial No. 13 the aluminum shielding enclosing the radio frequency circuits was drilled in such a manner that it was difficult to remove or insert the screws. This was remedied by slotting the screw holes. This shielding fitted in a satisfactory manner on equipment Serial No. 14.

(b) The tube sockets in the transmitter are marked VS1B, VS2B, etc., making it necessary to refer to the apparatus list in the instruction book to determine what type of tube should be inserted in each socket. It would be desirable to have the type number of the tube marked near the socket as is done in the case of the receiver.

(c) It was necessary to remove the bayonet pins from the bases of the 305-A vacuum tubes in order to insert them in sockets V4A and V5A. These sockets are fitted with locking clamps to prevent the tube from coming loose under the influence of vibration. Either the design of the locking clamp should be modified to permit the insertion of a tube having the bayonet pin or the bayonet pins should not be fitted into the tube base. Forcibly removing this bayonet pin is very likely to injure the tube.

(d) Connections to the type 305-A plate, screen and filament terminals are made by means of "Fahnstock" clips and bare stranded wire. A slight derangement of these clips or wires would cause the tube elements to short circuit. Some means should be provided to prevent the possibility of such short circuiting. It must be stated, however, that during the roll and vibration tests no difficulties or trouble was noted from this source.

(e) The remote control light or indicator on Transmitter Serial No. 13 is so wired that 230 volts potential is impressed across the lamp, causing it to burn out immediately. Provision must be made to reduce this voltage to a safe operating value.

(f) The field circuit of the 800 volt generator supplied with equipment Serial No. 14 was not provided with a fuse, the fuse clips being left empty.

(g) Although controls P1B and D1B were legibly marked in Serial No. 13, these markings were not provided in Equipment Serial No. 14.

(h) Upon receipt of the equipment no provision had been made for energizing the receiver when it was withdrawn from the shielded case in which it is normally housed. In order to facilitate servicing operations a suitable flexible cable is necessary. This cable was subsequently provided by the contractor on March 30, 1936.

(i) The plate leads to vacuum tubes V1A, V2A and V3A pass through holes in the vertical shield of the R.F. unit. These leads are insulated with isolantite beads. However, if one bead should become broken or the lead should stretch slightly, a short circuit could readily develop at the point where the lead passes through the shield. Suitable insulated grommets should be provided to protect the leads at this point.

(j) The clips used for making connection to the grids of the receiver tubes are of a type which are affected by vibration. Vibration causes these clips to loosen up sufficiently so that they come in contact with the metal tube shield, placing the receiver in a non-operative condition. This condition should be remedied by supplying a vibration proof grid clip or by insulating the tube shield above the grid cap. On May 11, 1936 the Naval Research Laboratory received 24 complete shields, with caps, from the Western Electric Company, which were billed with the notation "Material to replace incorrect material furnished on original shipment". These replacement shields are identical with those furnished originally and hence will not obviate the difficulties reported. Information is requested as to what disposition should be made of these shields.

(k) A voltage breakdown occurred in the plate circuit of vacuum tube V3A. This failure occurred in the plate tank compartment of the R.F. assembly and apparently was due to the fact that the plate lead had been tightly jammed between a grounded metal member and an insulated member, thus injuring the insulation.

(l) If it were necessary to effect any repairs to the meter switches K1A, K2A or K3A, which are located in the meter compartment, it would be necessary to dismantle the grid and plate potentiometer assembly. The shield covering the meter compartment cannot be entirely removed unless the potentiometer assembly is first removed.

(m) As described in detail in reference (h) the output voltage of the motor generators does not repeat accurately for the same setting of the field rheostats.

26. Par. 2-4. The equipment is so designed that it operates satisfactorily in any ambient temperature between the limits of zero and 51.5 degrees Centigrade. The influence of temperature upon the frequency stability of the equipment will be discussed below.

27. Par. 2-5. The entire equipment is constructed of corrosion resisting materials or from materials which are protected against the effects of moisture. No ill effects were noted after subjecting the equipment to high humidities.

28. Par. 2-6. The use of iron and steel, except for electro magnetic purposes, has been reduced to a minimum.

29. Par. 2-7. Radio frequency circuits and high voltage circuits have been insulated through the medium of isolantite. Phenolic insulating material has been used only in such instances wherein no suitable substitute is available or where it is not subjected to high frequencies or high voltage.

30. Par. 2-9. During the course of these tests no signs of overheating or breakdown were noted in any portion of the equipment. The high voltage circuits of both generators are fused with adequate fuses. The 60 cycle supply from the motor slip rings is fused as is the incoming 115 or 230 volt line. An overload relay is provided in the negative return of the 800 volt generator. This relay can be adjusted to operate at about 800 m.a. current, while the normal full load current required by the transmitter is approximately 600 m.a. The overload relay is of the spring actuated type.

31. Par. 2-10. No interlock system for the purpose of preventing accidental contact with high voltage has been provided since the CXL equipment is not fitted with access doors. All access to the transmitter is obtained by removing the side and back shields.

32. Par. 2-11. The sides and top of the transmitter are covered with perforated shielding which readily permits natural circulation of air. During the numerous locked key tests at full power, in ambient temperatures as high as 50 degrees Centigrade, no indications of overheating were observed.

33. Par. 2-12. No signs of leakage were noted from any units which might contain compounds.

34. Par. 2-13. The equipment was subjected to numerous "key locked" full power tests without signs of overheating or injury to any part. In addition the equipment was keyed at the rate of one hundred words per minute with satisfactory results.

35. Par. 2-14. During the course of these tests no evidence was noted which indicated that the various items entering into the construction of the equipment were incapable of continuous operation.

36. Par. 2-15. The Model CXL equipment was adjusted for full power operation, key locked. The antenna or transmission line terminals were then short circuited and also open circuited. The equipment incurred no damage during this test and the power amplifier tubes showed no signs of overheating. Table No. 1 appended hereto covers the data collected during this test.

37. Par. 2-16. The various vacuum tubes in the CXL equipment operate within the limitations set forth in the manufacturer's specifications. Certain of the tubes employed in this equipment are not covered by Navy Tube Specifications. In the case of the W. E. 300-A tube the manufacturer recommends a plate voltage of 300 volts with the maximum set at 350 volts. In the CXL equipment operating at full power the plate voltage impressed upon this tube is 325 volts. In the case of the W. E. 305-A tube, the recommended plate voltage is 800 with a maximum of 1000 volts. Under full power conditions this tube is subjected to a plate voltage of 825 in the CXL equipment.

38. Par. 2-17. (a) In general, it may be stated that the equipment is so designed that safe and satisfactory operation are secured. Such items of construction or operation which do not definitely comply with the governing specifications or such features wherein improvements may be wrought, are discussed separately under appropriate paragraph headings in this report.

(b) In order to obtain data on the actual transmission characteristics of the CXL equipment the receiver supplied with Serial No. 13 was mounted in a truck to serve as a mobile receiving station. Certain minor adjustments or additions were necessary in order to permit the receiver to operate when removed from the transmitter frame, such as blocking the antenna relay in the receiver; blocking the A.C. power supply relay in the position for normal operation; installing auxiliary switches for the operation of the "Codan" noise suppressor and the selection of voice or telegraph operation and the addition of a telephone jack for connecting to the receiver output. The receiving collector consisted of a half wave doublet supported about sixteen feet above the ground. This antenna was so constructed that its plane could be varied from horizontal to vertical. Energy from the antenna was lead to the receiver input by means of an 80 ohm twisted pair transmission line.

(c) When using voice control of the carrier, at the transmitter, it was noted that considerable care had to be exercised to obtain the proper adjustment of the voice control feature, in order that the first words of a sentence or the first syllables of a word would not be missed. The most satisfactory adjustment was obtained when the sensitivity control was adjusted to a point just below the value where the carrier would remain on constantly in the absence of speech input. If the sensitivity of the carrier control was reduced below this point to any degree the carrier would not be turned on in sufficient time to transmit the first word or the first syllables of a word.

(d) Listening tests in the field were made under three different conditions of operation of the transmitters. All tests were made with

the two transmitters, Serial Nos. 13 and 14, tuned to 45.9 and 35.9 MC respectively. The three conditions of operation were:

(1) Transmitting antennas adjusted for maximum loading of the power amplifier and modulated at approximately 30%.

(2) Transmitting antennas adjusted for maximum loading of the power amplifier and modulated at approximately 100%.

(3) Transmitting antenna adjusted for maximum radiation as determined by means of a diode detector located at various points around the antenna. Modulation adjusted to 100%.

(e) When operating under condition (1), tests were made at distances of 3.5 and 6.5 miles (airline) to the Northeast of the transmitter. At 3.5 miles the 35.9 MC carrier produced signals of excellent quality. Automobiles and trucks passing on nearby roads caused bad interference from ignition. This interference was readily noticeable when the automobiles approached to within 200 feet of the receiver. Planes passing over also caused interference due to ignition and rapid fading from reflected waves. This interference was strong enough at times to override the signal and cause it to be unreadable on both voice and telegraph. The 45.9 MC carrier gave very similar results except that the signal strength was somewhat higher and less interference from automobile ignition was noted.

(f) Condition of operation: (1), distance 6.5 miles. At this location a high tension power line traversed the area in which the receiver was located. The noise level on both carrier frequencies was very high and satisfactory reception could not be obtained on either frequency, either voice or telegraph. Both frequencies were subject to bad fading. The signal level was too low to take advantage of the "Codan" device.

(g) Tests made under Condition (2), 100% modulation. At 3.5 miles the results were similar to those reported under paragraph (e) above, while at 6.5 miles a definite improvement was noted over the previous tests conducted with 30% modulation.

(h) Tests made under Condition (3). At 6.5 miles the signal strength was greatly improved over previous tests and satisfactory communication was possible on 45.9 M.C. The increase in signal strength permitted the gain of the receiver to be reduced to a point where ignition interference did not bother reception. The signal on 35.9 MC was also greatly improved and was superior to that obtained at 45.9 MC.

(i) Although every effort was made to obtain conclusive results the wide variations between receiving and transmitting conditions encountered on shore as compared with those obtaining afloat emphasize the fact that very little reliance can be placed upon the results obtained at the Laboratory as an index of the results which may be expected afloat. The physical conditions surrounding the laboratory tests prevented the elevation of the transmitting antennas and the receiving antenna to the desired or

necessary height; poor ground conditions prevailed at the transmitter which prevented the obtaining of the proper impedance matches. The terrain surrounding the transmitter is such that hills and other obstacles intervened between transmitter and receiver as soon as the distance of separation exceed a mile or more. Thus it is only possible to repeat the belief or opinion that the ultimate decision as to the suitability of this type of equipment must be based upon the results of tests conducted aboard the various vessels of the Fleet.

39. Par. 2-18. The equipment was mounted on a test stand, complete with motor generator and automatic starter, and subjected to the motion of a ship in a heavy sea. Thus the equipment was inclined at angles of forty-five degrees from the vertical at a rate of six cycles per minute. The stand is equipped with a turntable, so that the equipment was inclined in a fore and aft direction and from side to side. Plates No. 1, 2 and 3 are views of the CXL equipment installed on the test stand. The heavy preventer lines were rigged in such a manner that they did not help support the equipment, but would take the strain should the regular base fittings fail. During this inclination test no damage was incurred by any portion of the equipment and the output frequency remained constant. The motor generator equipment continued to function normally and no variations in output voltage were noted.

40. Par. 2-19. The test stand shown in plates No. 1, 2 and 3 is so arranged that the equipment mounted upon it may be subjected to vibrations of various periods and amplitudes. During the vibration test it was noted that at certain periods of vibration various parts comprising the transmitter assembly vibrated excessively. The compartment containing the antenna transfer relays and the antenna filter, which is clearly illustrated in Figure 3 of the Instruction Book, vibrated sufficiently to interfere with the operation of the antenna relays, causing the signals, both voice and telegraph, to be badly garbled. A representative of the Manufacturer attempted to adjust these relays to prevent this action, but no satisfactory adjustment could be arrived at. In order to overcome the ill effects of vibration it will be necessary to strengthen the mounting of the antenna relay compartment. At present this compartment is secured only on its upper end which permits too great a latitude of movement. The same criticism applies to the construction of the radio frequency compartment. This unit is suspended entirely from the front panel and vibrates excessively at certain periods. Although the vibration of this unit did not interfere with the normal operation of the equipment it is believed that additional braces should be provided, in order to prevent damage which is likely to occur if vibration persisted for a considerabl period of time. Vibration also affected the receiver causing it to cease operation. This difficulty was traced to the grid clips used for making connections to the grids of the vacuum tubes. The clips moved up sufficiently to short to the tube shields. As pointed out in paragraph 25 (j) above, this condition should be remedied by supplying vibration proof clips or by insulating the tube shield above the grid cap.

41. The above tests indicate the importance of avoiding such forms of construction which will permit component parts to whip about as is the case when rather flexible objects are secured at one end only.

42. Par. 2-20. The vacuum tubes and crystals contained in the CXL equipment are flexibly mounted to protect them against damage from vibration. No failures of these parts were experienced when the equipment was subjected to severe vibration.

43. Par. 2-21. The design and control of the circuits of the CXL equipment are believed to be the simplest possible within the requirements of the governing specifications. It may be pointed out, however, that should service tests indicate the feasibility of dispensing with certain requirements, considerable simplification of controls and circuits could be attained. As examples the following items are mentioned:

(a) Removing the receiver from the transmitter unit and permitting the former to operate as an independent unit would permit considerable simplification. The need for the complicated input filter would be obviated; the number of connections to the receiver would be reduced; relays in the receiver could be dispensed with and the antenna transfer relay system could be dispensed with. The size of the transmitter unit could be reduced and the transmitter wiring would be greatly simplified.

(b) The retention of only one type of telegraphic signalling, either "keyed carrier" or "keyed modulation", would further simplify the equipment.

(c) Should service tests indicate that only one frequency of modulation for telegraphic signalling would suffice, simplification in both transmitter and receiver could be obtained by the elimination of one of the modulating frequencies.

The above suggestions are not made with a view of recommending that existing equipments be modified but rather that these elements be given consideration in the event that new or additional equipment is contemplated.

44. Par. 2-22. All controls and indicating devices on the front panel have been clearly and pleasingly marked for identification and operation by means of photo etched plates which are readily readable at a distance of twenty-four inches or more. The following variable controls are not located on the front panel, but are contained within the transmitter unit, access being obtained by removing the side or back shields.

(a) P-2-B, AF Oscillator Output Control
(b) D-1-B, AF Oscillator Frequency Control Switch
(c) P-1-B, Input Control Potentiometer
(d) P-4-B, Sidetone Level Control

The fact that these controls are not located on the front panel presents no serious drawback if the policy of operation is such that once the necessary adjustments are made it is intended that these adjustments remain fixed more or less permanently. If frequent readjustment are

desirable or necessary these controls should be accessible from the front of the panel. In any future equipment of this type it is recommended that all variable or adjustable controls be located on the front panel.

45. Par. 2-23. All control shafts and bushings have been grounded or insulated. The following control knobs or handles are provided on the front panel. Not all of these controls are fully insulated, as indicated in the following lists.

Fully Insulated control knobs:
- Grid Bias Voltage Control
- Filament Voltage Control
- Plate Voltage Control
- Power Control Switch

Telegraph Key Switches, Insulated Handles:

Meter Controls:
- Grid Current, "V2A" - "V1A" - "V3A"
- Grid Current, "V4A" - "V4A + V5A" - "V5A"
- Plate Current, "V4A" - "V4A + V5A" - "V5A"
- Plate Current, "V2B" - "V3B"
- Plate Current, "V4B" - "V4B + V5B" - "V5B"

Receiver Switch "Voice Local - Tone Local - Remote"

Receiver Switch "Local On - Off - Remote"

Transmitter Test Key "Voice - Remote - Tone"

Transmitter Keying Switch, "Key Carrier - Key Modulation"

The following controls consist of bakelite knobs with a metal insert which also forms the pointer:
- Transmitter Control Switch
- Receiver Sensitivity Control
- Transmitter Carrier Control Sensitivity

The following control consists of an all metal toggle switch handle:
- Noise Suppressor Control

The following controls are of the "Screw Driver Type" and consist of small metal plates recessed in the front panel. Both the control and the locks are operated by means of a screw driver. These controls are not insulated.
- "A" Oscillator Plate Tuning
- "B" Harmonic Generator Grid Tuning
- "C" Harmonic Generator Plate Tuning
- "D" R.F. Amplifier Plate Tuning
- "E" Mod. Amplifier Grid Tuning
- "F" Mod. Amplifier Plate Tuning
- "G" Antenna Coupling Adjustment

The following test jacks are provided on the front panel of the transmitter:
- Hand Set Test Jack
- Monitor Jack

The following controls are provided on the front panel of the receiver and are accessible through the door in the bottom of the front panel of the transmitter:

Audio Filter Toggle Switch "In-Out"
Receiver Sensitivity Control
Audio Filter Selectro Switch "750 cycles - 1000 cycles"
Four tuning jacks

During the tests of the CXL equipments no trouble was experienced due to stray high frequency fields while adjusting non-insulated controls.

46. Par. 2-24. All electrical meters are of the flush type with bakelite case. Two small indicating lights (red) of the telephone type are provided to indicate when the transmitter is on and when the receiver is on. All indicating instruments are located on the front panel.

47. Par. 2-25. Appropriate name plates of the photo etched type have been firmly secured to the transmitter unit. The same type of name plates are supplied with the receiver and remote control units. The Motor Generator Equipment and the Automatic Starter are provided with heavy brass name plates.

48. Par. 2-28. The dimensions and weight of the CXL equipment are listed in Table No. 2 attached hereto.

49. Par. 2-29. The component parts of the equipment will pass through a door or hatch of the dimensions specified without further disassembly.

50. Par. 2-30. The equipment was subjected to ten percent plus and minus variations in line voltage without incurring any damage. Satisfactory operation was obtained during these tests.

51. Par. 2-31. "Lord" type mountings have been used to protect delicate parts from shock. These units may be readily replaced with similar units with a minimum amount of disassembly.

53. Par. 2-33. Condensers of the electrolytic type have not been used in the construction of the CXL equipment.

54. Par. 2-35. The front panel of the transmitter is finished with crystalline lacquer. The side, top and back shields of the transmitter are flat black. The inner metal surfaces retain their original aluminum color. The starter panel is finished in black while the motor generator unit is painted a dark bluish gray.

55. Par. 2-36. The entire equipment is electrically shielded and the shields are maintained at ground potential.

56. Par. 2-37. The number of friction and pressure contacts has been kept to a minimum. Removable coils in the high frequency compartment are soldered into place. No contact trouble was experienced during the course of the tests.

57. Par. 3-1-1. The master oscillator circuit utilizes a single vacuum tube, Type WE-306-A, the controlling element being a piezo electric crystal. The frequencies of the transmitter crystals are:

6075.000 kc
7661.660
9300.000

Each crystal holder is provided with a nameplate carrying the following information:

Contract Number
Type Number of Transmitter
Crystal Serial Number
Frequency of Crystal
Output Frequency of Transmitter

58. Par. 3-1-2. The second stage of the transmitter uses a type WE-306-A tube as a harmonic generator, wherein the frequency is multiplied three fold, having been already doubled in the special master oscillator circuit. Thus all frequency multiplication is accomplished in two stages.

59. Par. 3-1-3. The third circuit, a fundamental radio frequency amplifier, employs a Type WE-305A tube.

60. Par. 3-1-4. The modulating amplifier stage employs two Type WE-305A tubes in push pull.

61. Par. 3-1-5. The output of the modulating amplifier is coupled into a concentric transmission line by means of an adjustable coupling coil.

62. Par. 3-1-6. The audio frequency circuits used as a speech amplifier consist of three stages, the first stage using a 76 tube; the second stage employs two WE-300-A tubes in push pull while the final audio stage uses two 38145 tubes in push pull. Transformer coupling is used throughout.

63. Par. 3-1-7. An audio frequency tone oscillator is provided which employs a type 76 tube and provision is made for modulating the telegraphic output of the transmitter at either 750 cycles or 1000 cycles. The audio oscillator is contained within the transmitter frame and either frequency of modulation may be selected at will through the medium of a selector switch.

64. Par. 3-2. Two hundred feet of concentric transmission line is furnished with each equipment. This line is of the copper-isolantite type.

65. Par. 3-3. Each CXL equipment is supplied with half wave doublets in the form of aluminum alloy tubing. Three such radiators are supplied, one for each output frequency. These doublets may be secured to a heavy aluminum alloy tube which in turn is provided with fastenings for securing the entire assembly to a yard or similar structure. All necessary

fittings have been provided except such special bolts as may be required for securing the assembly to the yardarm. Provision is made for varying the coupling between the antenna and the transmission line to obtain the proper match and to compensate for the effect of nearby objects. The transmission line is terminated by means of an isolantite insulator and provision is made for filling the transmission line with dry gas under pressure. All fittings and parts are rugged and have been designed to withstand the effects of moisture and weather.

66. Par. 3-4. Electro-mechanical relays have been provided in the transmitter to transfer the antenna and transmission line from the transmitter to the receiver for alternate transmission and reception on the same antenna. These relays perform their function satisfactorily, except, as pointed out in paragraph 40 above, in the presence of severe vibration.

67. Par. 3-5. The transmitter is capable of delivering 50 watts of carrier power (CW). This was determined by loading the transmitter output into a 60 watt lamp and determining the dissipation by means of photronic cell measurements. In order to obtain this power it is essential that the load characteristics be accurately adjusted and that optimum values be employed.

68. Par. 3-6. It is possible to obtain complete modulation (100%) of the carrier power with less than 5 per cent total distortion. Reference to Plate No. 4 reveals the fact that at 100% modulation the total distortion measured was 2.8%. These measurements were made with an output frequency of 36.4 M.C. and a modulating frequency of 400 cycles. The audio frequency characteristic of the Model CXL equipment is shown in plate No. 5 attached hereto. It will be noted that the frequency response between 100 and 5000 cycles is flat to within less than plus and minus one decibel. This data represents the response of the equipment from the input to the microphone circuit to the final carrier output. Plate No. 9 shows the carrier noise determined at various degrees of modulation between 10% and 100%. It will be noted that the noise is approximately 50 db down at 100% modulation.

69. Par. 3-7. Reference (c) requires that "The speech input level for proper 100 per cent modulation shall be approximately (minus) 20 decibels based on a zero decibel level of 6 milliwatts. The speech input impedance shall be 200 ohms". Measurements indicated that the input impedance is approximately 200 ohms and hence a zero level of 6 milliwatts would require an input voltage of 1.095 volts, or 0.109 volts for the minus 20 DB level. With the gain control full on it was determined that in order to obtain 100% modulation an input voltage of approximately 0.560 volts was required, or about 6 DB down from zero level. While this condition is not in strict accordance with the governing specifications it is entirely practicable and satisfactory and it is recommended that it be considered so. A more sensitive input circuit, especially where voice control of the carrier is employed, would result in serious interference from extraneous noises in the vicinity of the microphone. With the present adjustment of the equipment a normal tone of voice is capable of producing 100% modulation without difficulty and in actual service it is believed that an even less sensitive adjustment will normally be used.

70. Par. 3-8. (a) The CXL equipment is provided with a system of vacuum tube keying utilizing two W.E. 300-A tubes. Tests were undertaken to determine the efficacy of this type of keying. A type XJ-1 receiver was used for the key click investigation. Since no provision is made in the CXL transmitter for keying without modulation, tests were made with the transmitter signal modulated. The signal impressed on the receiver antenna terminal from the transmitter was varied from a few millivolts (measured) to several volts (estimated). The receiver was operated both as for C.W. and as for I.C.W. reception, and tuned through a wide range of frequency, volume and regeneration adjustments, both with and without an antenna. Under no receiving conditions could any key clicks be detected through the modulation signal of the transmitter. The presence of this modulation, however, prevented reception of other signals over quite a tuning range, this being a function of the receiver selectivity, and any key clicks which may have been hidden by the modulation would cause less interference than the modulation itself. It may be stated therefore that the method of keying employed in the CXL equipment reduces key clicks to a point where no interference is caused to other communications.

(b) The antenna circuit of the CXL equipment is provided with a filter for the purpose of reducing harmonic and sub-harmonic radiations. Tests were conducted at the output frequency of 45.9 MC to determine the degree of interference which might be encountered from sub-harmonic radiations. The frequencies which might be expected to cause interference would be roughly 7, 15, 22, 30 and 38 MC. A sensitive receiver was set up at a distance of about 500 feet from the transmitter antenna, with the following results:

Rec'd M.V. Input	Frequency
-	7.662
-	15.324
1500	22.986
-	30.648
-	38.310
plus 100,000	45.970

When the receiver was removed to a distance of 3.5 miles, no other frequency beside the fundamental, 45.970 MC, could be detected. Hence it may be stated that satisfactory provisions have been incorporated into the CXL equipment for the suppression of unwanted sub-harmonics. No equipment was available to determine the degree of energy radiated in true harmonics, that is, at frequencies in excess of 60 MC.

(c) No signs of lilt in the emitted signal could be detected and no undesirable modulations which could be attributed to the transmitters were observed.

71. Par. 3-9. The output frequency of the transmitter is completely controlled by means of piezo-electric crystals and only one frequency is emitted at one time. Three crystals are supplied as follows:

6075.000 KC
7661.660
9300.000

A spare crystal is provided for each frequency. It was noted that under certain conditions it was possible to obtain a spurious frequency or oscillation in the output stage of the CXL equipment. This was encountered at the highest output frequency, i.e., 55.8 MC. The spurious frequency could readily be eliminated by proper adjustment of the output circuit and the antenna coupling circuit.

72. Par. 3-10. The piezo-electric crystals are supplied in holders of a suitable type which can readily be removed or inserted in the transmitter. No spurious frequencies were noted.

73. Par. 3-11. The piezo-electric crystals supplied are of the low temperature coefficient type. Over the range of zero degrees to 50 degrees Centigrade the maximum change in frequency noted at 0.0046 percent (2125 cycles at 45.9 M.C.). The governing specifications require a frequency constancy over this range of ambient temperatures of plus or minus 0.025 per cent. No means have been provided for maintaining the temperature of the crystals at a constant value.

74. Par. 3-12. The design of the transmitter is such that only one crystal can be installed at one time.

75. Par. 3-14. The crystals in the CXL equipment are worked at a low power level and no ill effects were noted during the course of these tests which indicated that the crystals were being worked beyond a safe limit.

76. Par. 3-15. The carrier frequency of the CXL equipment is maintained constant to better than 0.025 per cent, as itemized in paragraphs 77 to 83 below.

77. Par. 3-16.(a)(e) The deviation of the crystal from its assigned frequency would constitute the major error in initial calibration. The maximum deviation from the assigned frequency noted was approximately 0.0008 percent. The various crystals of the same frequency were ground with such extreme accuracy that it was difficult to obtain an audible beat note between two crystals even at the third harmonic.

78. Par. 3-16 (b). Errors in setting to the desired frequency. It is possible to "drag" the crystal frequency within small limits while tuning the master oscillator circuit. However, there is one point of tuning which gives most efficient results and greatest output and this can readily be ascertained by observing the various plate and grid currents of the master tube and the succeeding stages. Thus the error in setting to the desired frequency may be considered negligible.

79. Par. 3-16 (c). Variations in ambient temperature. Reference to Plate No. 6 reveals that the largest variation in output frequency when operating at 45.9 M.C. was 2125 cycles, or 0.0046%, over the temperature range of zero to 50 degrees Centigrade.

80. Par. 3-16 (d). Variations in supply line voltage. The supply line voltage was varied between the limits of minus 10 percent and plus 10 percent (from 207 volts to 253 volts) are tabulated in Table No. 3.

The maximum frequency change observed during this test which was conducted at an output frequency of 45.9 M.C. was 101 cycles or 0.00022%.

81. Par. 3-16 (e). Variations in humidity. At an output frequency of 45.9 M.C. the humidity of the test room containing the CXL equipment was varied between the limits of approximately 8% and 100% relative at an ambient temperature of 35 degrees Centigrade. The maximum frequency variation which could be ascribed to variations in relative humidity was 150 cycles or 0.00032%. This test is illustrated in Plate No. 7 attached hereto.

82. Par. 3-16 (f). Control of power output. The power output of the CXL equipment was varied between the limits of approximately 100% and 25%, with the results indicated in Table No. 4. The maximum frequency change recorded during this test which was conducted at an output frequency of 45.9 MC was 405 cycles or 0.00088%. Additional information was obtained as to the effect of varying the grid field rheostat and the plate field rheostat independently. This data is presented in Table No. 7 attached hereto.

83. Par. 3-16 (g). Change of vacuum tubes. The maximum variation in frequency noted due to changing tubes in the master oscillator circuit was 237 cycles at an output frequency of 45.9 MC., or 0.0005%. The maximum frequency change noted when changing tubes in the harmonic generator circuit was 24 cycles, or 0.00005%. Table No. 5 gives the detailed results of this test.

84. Par. 3-16. A summary of the above tests shows that the maximum frequency change due to all causes listed in paragraph 3-16 of the governing specifications, even when added arithmetically without consideration of sign, totals 0.00732% whereas the specifications permit an algebraic limit of 0.025%. Another source of frequency error not covered by the above summary consists of the drift noted immediately after the transmitter is started. This starting drift appears to be dependent upon the ambient temperature surrounding the transmitter. This phenomena is illustrated in Plates No. 6, 7 and 8. Plate No. 6 reveals that during the first forty minutes with an ambient temperature of 50 degrees Centigrade, the drift was approximately 1800 cycles at 45.9 MC. Plate No. 7 shows that during the first thirty minutes at an ambient temperature of 35 degrees Centigrade the starting drift was 435 cycles. Plate No. 8 reveals that at an ambient temperature of 25 degrees Centigrade it required approximately two hours to reach equilibrium and during this period the frequency drifted approximately 115 cycles. Thus it appears that at normal room temperatures only a small change in frequency will be encountered while at higher temperatures the starting drift will reach considerable magnitudes.

85. Par. 3-17. No interference from the oscillating master oscillator was noted in the receivers during the course of these tests. It should be pointed out that due to the fact that it was impossible to separate the two equipments by more than a few yards, the incoming signals from the transmitter which were being received always were of high amplitudes. Thus if the oscillating master was actually radiating a small amount of energy it would be insufficient to interfere with the

powerful incoming signal. It is the understanding of the Laboratory that some evidence of interference to weak signals was noted in the tests of the CXL equipments in the Fleet. In order to overcome this interference the manufacturer equipped the antenna relay circuits with small R.F. chokes and carefully shielded the break in the transmission line within the relay compartment. The material for making these modifications was supplied by the manufacturer and the two CXL equipments, Serials No. 13 and 14, have been modified in accordance with the contractor's instructions.

86. Par. 3-18. By means of seven tuning controls located on the front panel of the transmitter it is possible to adjust the equipment for operation on the frequency selected and for which a suitable crystal is available. The adjustment range of the panel controls, however, is limited so that it is also necessary to change the inductors in the various circuits when shifting frequency by more than a few megacycles. Access to these inductors is obtained by removing the shielding enclosing the R.F. compartment. The coils are soldered into place so in order to effect their removal it is necessary to unsolder the connections and then re-solder these connections when the proper coils are inserted. A number of these connections are rather inaccessible so that frequency changes cannot be accomplished readily. With the present arrangement it requires several hours for the average operator to effect a frequency change. Soldering irons of special size and shape would greatly facilitate this operation. In future equipments of this nature it would be very desirable to provide an improved method for changing the coil systems.

87. Par. 3-19. Each control on the panel is identified by suitable nameplates located near the control.

88. Par. 3-20. It is possible to shift from one type of transmission to another without readjusting the voltage controls. When shifting from one frequency to another, it is necessary to remove all voltages from the equipment in the interests of safety to personnel and apparatus.

89. Par. 3-21. The CXL equipments are provided with a system of antenna transfer relays for switching the antenna from the transmitter to the receiver when the key is open or when the carrier is removed, and from the receiver to the transmitter whenever the key is closed and the carrier is radiating. Due to the physical limitations surrounding the tests at the Laboratory actual break-in communication could not be tested. However, the small amount of energy radiated by the master oscillator circuit indicates that break-in operation will be satisfactory whenever the incoming signal is of sufficient intensity to permit the making of good copy.

90. Par. 3-22. No difficulties or interference to reception were noted during the tests which could be attributed to the motor generator.

91. Par. 3-23. Suitable indicating instruments have been provided on the panel of the transmitter to facilitate adjustment of the various circuits in the equipment.

92. Par. 3-24. The dimensions of the transmitter assembly, which includes the receiver and the tone oscillator, are shown in Table No. 2.

93. Par. 3-25. The transmitter is thoroughly shielded, both internally and externally. The rear shield of the transmitter consists of two sections secured by means of thumb screws. The thumb screws are so designed that they cannot be lost, being secured permanently to the shielding.

94. Par. 3-26. None of the electrical indicating instruments have been fitted with by-pass units to protect them against damage due to stray radio frequency potentials. Although none of these meters suffered injury during the course of these tests it cannot be definitely stated that no injury will occur if the CXL equipments are operated in the vicinity of other radio transmitters on shipboard.

95. Par. 3-27. The transformers contained in the CXL equipment were subjected to numerous key locked tests, including tests at ambient temperaturs of 50 degrees Centigrade, without signs of overheating or failure.

96. Par. 3-28. The transmitter is so constructed that its foundation pedestal bolts to the deck by means of eight half inch bolts. The adequacy of this type of mounting was demonstrated by the roll and pitch tests described in paragraph 39 above. The replacement of vacuum tubes and crystals and the adjustment of circuits, relays and auxiliaries must be accomplished by removing the side and back shields. No access doors are provided in the panel of the transmitter and none of the assemblies are removable from the front of the panel.

97. Par. 3-29. The equipment is provided with a plate overload relay and the arrangement of the circuits is such that plate potentials cannot be impressed upon the tubes in the absence of grid bias potential. The generator which furnishes the grid bias potential also acts as the excitor for the plate generator. Filament supply is obtained from slip rings on the motor.

98. Par. 3-30. The number of relays and contactors used in the CXL equipment has been kept at a minimum commensurate with the performance characteristics specified in the governing contract.

99. Par. 3-31. High voltage d.c. is prevented from reaching the antenna system by an insulated antenna coupling unit and additionally by the capacitors contained in the antenna interference filter. The voltage rating of the capacitors in the interference filter is not known since they are encased in a protective aluminum cover.

100. Par. 3-32. The modulator equipment is incorporated in the transmitter assembly and the dimensions do not exceed the limitations specified in paragraph 3-24 of RE 13A 507A. (See Table No. 2).

101. Par. 3-35. Provision has been made in the CXL equipment for effecting tone transmission at either 750 cycles or 1000 cycles. 90% modulation of the carrier is readily obtainable.

102. Par. 3-36. Provision is made whereby both transmitter and receiver may be controlled from the transmitter panel or from the remote control stations. At the remote control stations when using voice modulation the carrier can be controlled only through the medium of the automatic carrier control, while at the transmitter the test key may be thrown to the voice position which turns on the carrier and maintains the carrier as long as the test key is in the voice position. While this type of operation is being employed the automatic carrier control is non-operative and reception is impossible until the test key is returned to the central position.

103. Par. 4-1. While reference (c) specifies receiving equipment suitable for table mounting, the Bureau of Engineering in subsequent correspondence (BuEng. ltr. C-NOs-42972 (7-8-W8) of 9 November 1935 to INM, New York) authorized the inclusion of the receiver in the transmitter frame. The receiver is located in the bottom compartment of the transmitter, access being possible through a hinged door in the front panel.

104. Par. 4-2. The receiver is so designed that it makes possible reception of voice or tone modulated signals in the frequency range of 30 to 60 megacycles.

105. Par. 4-3. This requirement of the specifications was modified by the correspondence referred to in paragraph 103 above. The receiver, at present, is designed for use only when housed in the space provided for it in the transmitter assembly. With certain modifications it could readily be adapted for use at an independent fixed receiving point.

106. Par. 4-4. The receiver is complete for taking radio frequency signals from the antenna and converting them to audio frequency signals in the head telephones. The receiver utilizes the same transmission line and antenna as the transmitter through the medium of antenna or break-in relays.

107. Par. 4-5. All connections within the receiver have been securely anchored and supported to minimize changes in frequency or output and to prevent breakage under the influence of vibration. Flexible stranded conductor has been used wherever possible. As pointed out in paragraph 40 above, however, vibration interfered with the operation of the receiver, causing the grid clips on certain tubes to short against the shields.

108. Par. 4-6. The wiring within the receiver is color coded to facilitate servicing operations and testing. The receiver was subjected to ambient temperatures of 50 degrees Centigrade and to relative humidities of 100% at 35 degrees Centigrade with no visible ill effects upon the operation of the equipment.

109. Par. 4-7. Vacuum tubes and crystals are rigidly mounted within the receiver, but the entire receiver is flexibly mounted within the transmitter frame through the medium of "Lord" mountings. All vacuum tube sockets are of the single or individual type, no gang sockets being employed in the equipment.

110. Par. 4-8. Access to the inside of the radio receiver is provided by removing the receiver chassis from the transmitter frame. The receiver, when in place, is held securely by means of latches and two heavy securing rods. As pointed out in paragraph 25 (h) above, no means was provided for energizing the receiver when it was withdrawn from the transmitter. Such a cable was provided at a later date and is considered necessary for the proper servicing of the receiving equipment.

111. Par. 4-9. Complete shielding is provided for the receiver when it is installed in the transmitter. The dimensions of the receiver proper are as follows:

Height: 7-1/2"
Width : 20"
Depth : 12"

112. Par. 4-10. The receiver operates from a 110 volt, 60 cycle, single phase source, but requires an additional source of d.c. potential of approximately 50 volts for the operation of the antenna relay and the power supply relay. This additional requirement was necessitated by the change authorizing the location of the receiver within the transmitter unit and by virtue of the fact that the transmitter and receiver employ the same antenna. The A.C. power required for operation of the complete receiver is 61.5 watts.

113. Par. 4-11. The tuning of the receiver to any frequency within the range of 30 to 60 megacycles is accomplished through the medium of two plug-in coil systems, the various circuits of which may be adjusted by means of knob controls behind a removable shield on the front of the receiver. Four tuning jacks have been provided into which a suitable range d.c. meter may be plugged to aid in the alignment of the receiver circuits.

114. Par. 4-12. The conversion oscillator is designed for crystal controlled operation only, as required by "Contract Note".

115. Par. 4-13. The receiver is so designed that it accommodates one crystal holder at one time. The crystal holders employed in the receiver are identical with those used in the transmitter. Three crystals, enclusive of spares, are furnished with each receiver and each holder is marked with the following information:

Contract Number
Navy Type number of receiver
Crystal serial number
Frequency of crystal
Frequency of receiver (incoming signal)

116. Par. 4-14. The frequencies of the receiver crystals supplied are as follows:

8303.330 KC
9941.660
10075.000

Although operating at frequencies in excess of 7 MC, all crystals performed satisfactorily and gave no evidence of inherent defects due to the high frequencies of operation.

117. Par. 4-15. The receiver crystals furnished are of the low temperature coefficient type, requiring no temperature control.

118. Par. 4-19. The output of the receiver is so arranged that it is possible to listen to incoming signals by means of a headset or hand set plugged into the panel of the transmitter or at any of the three remote control units.

119. Pars.4-20 to 4-30. Due to the fact that suitable test equipment for operation in the range of 30 to 60 MC was not available, detailed tests could not be conducted in accordance with the requirements outlined in these paragraphs. The receiver functions in a satisfactory manner and is provided with automatic volume and gain control, carrier operated device, anti-noise, audio frequency filter circuits for 750 and 1000 cycles, manually operated level and sensitivity control circuits and the necessary switches and relays for permitting local or remote control and the selection of either voice or telegraph operation. It was found that the "Codan" device was very advantageous when receiving in locations where high noise levels were encountered and where the signal amplitude was sufficiently great to permit the use of this device. The use of the 750 cycle and 1000 cycles filters are useful in reducing the ratio of noise to signal. In this connection it may be pointed out the the action of the filters is not sufficiently sharp to exclude 1000 cycles when the 750 cycle filter is used, or vice versa, the 1000 cycle filter does not exclude the 750 cycle signal. Thus it would be impossible to operate two transmitters on the same carrier frequency, one transmitting intelligence at 750 cycles and the other at 1000 cycles, and separate the signals at the receiver. The receiver employs a circuit of the superheterodyne type.

120. Pars. 5-1 to 5-9. The equipment as supplied meets the requirements of these paragraphs of the specifications. However, as pointed out in paragraph 25(e) above, the remote indicator light on Transmitter Serial No. 13 (230 volts supply) is so wired that this lamp is subjected to the full line voltage of 230 volts, causing the lamp to burn out.

121. Par. 5-10. Three remote control units are supplied with each equipment. When these remote control units are installed adjacent to the standard control unit called for in paragraph 5-3 of the governing specifications, it is possible to control the transmitter, including the starting and stopping of same from such a remote point. The telephone remote control unit is ruggedly constructed of the size and weight listed in Table No. 2 attached hereto and is suitable for either table or bulkhead mounting. This unit affords a secure rest for a combination hand set, a plug receptacle for the combination hand set, a plug receptacle for the chest type microphone and a plug receptacle for head telephones. A toggle switch is provided for transmitter control by means of which it is possible to select telegraph operation or telephone operation by means of either the chest set or hand set. A toggle switch is provided for receiver control by means of which it is possible to select either telephone or telegraph operation. When returned to the central position this switch turns the receiver off. The telephone remote control unit is also provided with an indicator light for informing the operator whether the receiver is on or off. This indicator lights when the receiver is turned on from any location, i.e., from the transmitter panel or from any of the remote telephone stations.

122. Par. 5-11. Each equipment is provided with two chest type microphones and two combination hand sets. These microphones are not equipped with "press-to-talk" switches, it being understood that this requirement was eliminated by correspondence subsequent to the submission of the original specifications.

123. Par. 6-1. The power equipment supplied with the CXL equipments is designed to assure safe and satisfactory operation, with the exceptions noted under paragraph 25(m) above.

124. Par. 6-3. The equipment was subjected to line voltage changes from 10% below to 10% above normal without damage or overheating being noted in the power supply.

125. Par. 6-4. The power equipment was subject to full power key locked transmitter load for periods as long as seven hours at ambient temperatures ranging between zero and 50 degrees Centigrade without overheating or showing signs of breakdown.

126. Par. 6-5. The total power required from the supply mains for operation of the transmitter and all auxiliaries is listed in Table No. 6. The amount of power thus drawn is considered a satisfactory minimum and in accordance with good engineering practice.

127. Par. 6-6. The motor generator equipment supplied is of the two unit, four bearing type. The generator armature is of the double type, two armatures being carried on a single shaft 22 inches long. One armature furnishes the grid potential, 200 volts, while the other supplies plate potential at 800 volts.

128. Par. 6-7. The design of the equipment furnished does not resort to the connecting of two armatures in series to obtain the necessary direct current voltages.

129. Par. 6-8. The flexible coupling between motor and generator is of rugged construction and capable of withstanding the intermittent stresses caused by keying the transmitter and is capable of operating satisfactorily under full load service conditions.

130. Par. 6-9. The motor and generator units are mounted on a rigid bed plate of sufficient strength to prevent misalignment under the conditions encountered in the Naval Service. The construction is such that it is possible to remove either the motor or the generator, or both, without removing the bed plate from its normal foundation.

131. Par. 6-10. The motor and generator frames are securely grounded to the bed plate, which in turn may be grounded to the station ground. Terminals are housed in metal boxes or receptacles firmly anchored to the motor and generator frames and are of sufficient strength to withstand the application of a 250 pound weight without bending or causing misalignment.

132. Par. 6-11. The weight and dimensions of the motor generator equipment are listed in Table No. 2 appended hereto.

133. Par. 6-12. The motor and generators are equipped with self-aligning ball bearings.

134. Par. 6-13. This paragraph of the specifications requires that suitable nameplates shall be secured in a prominent position, specifying the Navy designation for the proper lubricant. Such nameplates have not been provided. Grease cups have been provided for lubricating purposes.

135. Par. 6-15. This paragraph of the specifications was modified by the "Contract Note" to the extent that "The use of protective fuses located at the motor generator will not be required where low potentials of 500 volts or less are involved". The output of the 200 volt and 800 volt generators are fused with suitable fuses located in the transmitter unit, only the field fuse being located at the generator terminals. Thus the location of the 800 volt fuse is not in accordance with the governing specifications.

136. Par. 6-16. Motors and motor starters are supplied for operation on 115 volts or 230 volts as specified in the contract. However, no provision has been made whereby it would be possible, by changing suitable connections, to operate a 115 volt motors and starters at 230 volts, or vice versa.

137. Par. 7-1. Spare parts have been provided with each transmitter in accordance with the specifications. These parts are contained in a suitable rugged container, each item being clearly marked and its location within the spare parts box clearly indicated in the instruction book and on the inside cover of the spare parts box.

138. Sec. 9. The preliminary instruction books submitted with the CXL equipments have been assembled in a finished and pleasing manner and, in general, are complete and wholly adequate for the purpose intended. The instruction book would be improved, however, if more complete information and wiring diagrams of the motor generator equipment were provided. The following typographical errors were noted:

Under "Tuning Procedure", Page 10, 2nd column.
Tube designations V5B, V6B should be V4B, V5B
Tube designations V3B, V4B should be V2B, V3B

Under "Tuning Procedure", Page 10, 1st column.
Res. R2.1C is not provided with a band; this
designation should read R2.2C, Band No. 3

Figure 16 in instruction book.
Secondary windings of transformer T1A are referred to as T1B.
Transformer T1A is a filament transformer, while T1B is the
1st AF Amplifier input transformer.

139. A summary of the defects noted and such items as do not comply with the requirements of the governing specifications, together with suggested changes which it is believed will improve the performance of the Model CXL equipments, are listed below. The numerals enclosed in parentheses refer to the paragraph of this report under which these items

are discussed in detail.

(a) (17) Use of thin plywood packing cases should be investigated before authorizing use of such construction for future shipments.

(b) (25a) Ill fitting interior shielding furnished on Equipment Ser. No. 13.

(c) (25b) Addition of tube type number near socket would be of assistance to personnel.

(d) (25c) Bayonet pins should not be provided in the bases of 305-A vacuum tubes, or the tube sockets provided should be modified.

(e) (25d) Means for improving connections to plate, screen and filament of 305-A vacuum tubes should be investigated.

(f) (253) (120) Potentials impressed upon the remote indicator lamps of 230 volt equipment to be reduced to a safe operating value.

(g) (25f) Proper fuses to be supplied in field circuits of motor generators.

(h) (25g) Controls P1B and D1B not marked in Equipment Serial No. 14.

(i) (25h) (110) Means should be provided for energizing receivers when withdrawn from transmitter frame.

(j) (25i) More adequate protection should be provided for plate leads where they pass through metal shielding.

(k) (25j) Means should be provided for preventing grid connections to receiver tubes from short circuiting to metal tube shields.

(l) (25k) Insulation failure encountered due to improper positioning of plate lead.

(m) (25l) Improved accessibility to meter compartment should be provided.

(n) (25m) Greater voltage stability of motor generator output desirable.

(o) (31) (96) In future equipment, access to the interior of the equipment should be provided through the front panel.

(p) (40) (66) (107) Transmitter construction should be improved to prevent vibration from interfering with operation of the equipment.

(q) (44) All variable controls should be of the front of panel type.

(r) (45) Panel controls of the non-insulated type have been provided.

(s) (69) Speech input level required does not conform with governing specifications (No remedial action recommended).

(t) (71) Spurious oscillations encountered under certain conditions of adjustment.

(u) (86) Future equipments should be provided with improved means for accomplishing frequency changes.

(v) (94) No by-pass units supplied on d.c. meters.

(w) (134) Nameplates have not been provided at points of lubrication.

(x) (135) Protective fuses are not located at the generator terminals.

(y) (136) Motor starting equipment operates at one potential only.

(z) (138) Instruction book errors should be corrected.

CONCLUSIONS.

140. The external appearance of the equipment is excellent and high grade materials have been used in the construction. The internal wiring is orderly, well secured and of good quality. No lead sheathed wire is employed, but this lack of shielding appears to have no ill effects upon the operation of the equipment judging by the tests conducted at the Naval Research Laboratory.

141. No access to the interior of the transmitter proper is afforded through the front panel. The provision of front panel access should be given serious consideration in the event additional equipment of this nature is secured in the future. The removal of side and rear shields whenever minor adjustments or replacements are required necessitates providing additional space on board ship and prevents the installation of the equipment with its back flush against a bulkhead.

142. In future equipment of this nature it would be exceedingly desirable to provide increased flexibility and time saving methods when shifting frequencies. The possibility of providing remotely controlled adjustable antennas is worthy of investigation in order to eliminate the necessity of the operating personnel going aloft each time the transmitter frequency is changed. In general, it may be stated that future procurements of superfrequency equipment should be required to conform as nearly as possible with the requirements found necessary and desirable in high frequency and intermediate frequency shipboard equipment

as represented by the latest issues of Bureau of Engineering specifications.

143. The equipments furnished are capable of producing the required power output and yet permit the various component parts to operate at safe and reasonable levels. The voice circuits are capable of excellent speech reproduction and, in general, exceed the contractual requirements with respect to modulation, distortion, fidelity and noise level. The radio frequency stability and accuracy reflects a high degree of engineering skill and the effects of potential variations, temperature variations, humidity variations over wide limits, shock, roll and pitch have been reduced to negligible values. Certain changes in physical or mechanical construction are indicated, however, to prevent severe vibration from interfering with the normal operation of the equipment.

144. The equipment demonstrated its ability to function satisfactorily over long periods of key locked full power operation and no operational failures occurred during the course of the tests reported herein.

145. Compliance with the terms of the governing contract wherein it was required that the manufacturer incorporate two distinct types of keying for telegraph operation; two modulating frequencies for telegraph operation; automatic voice control of the carrier; inclusion of the receiver within the transmitter frame; use of a single antenna for transmission and reception and the accompanying provision for break-in operation, naturally increases the complexity of the apparatus. This in turn influences the design, construction, installation, operation and maintenance requirements. Should actual operations within the Fleet under service conditions indicate that certain features could be dispensed with without impairing the efficiency of the equipment or curtailing the benefits derived from its operation, future apparatus of this type could undoubtedly be simplified to a considerable extent.

146. It is further concluded from the results of actual transmission tests conducted that too great reliance should not be placed in such transmission tests when they are conducted under conditions which vary widely from the conditions surrounding actual service operations afloat. Due to the fact that superfrequency communications are greatly influenced by the immediate terrain, the altitude of transmitting and receiving antennas, ground conditions, noise levels and so forth, the results obtained on shore will not be representative of the results which may be expected from shipboard installations.

Table No. 1

MODEL CXL RADIO EQUIPMENT

ANTENNA SHORT CIRCUITED AND OPEN CIRCUITED

Test as per paragraph 2-15 of Specifications RE 13A 507A

(Output Frequency - 49,970 KC)

Antenna Circuit	P. A. Ip	P.A. Ig	Ep	Eg
Normal	165	9	890	200
Shorted	205	4	890	200
Open	150	15	890	200

The power amplifier tubes showed no signs of becoming overheated during this test.

Table No. 2

MODEL CXL RADIO EQUIPMENT

DIMENSIONS AND WEIGHTS

Data as per paragraph 3-24 of Specifications RE 13A 507A

Unit	Height	Width	Depth
Transmitter	72-1/2"	25-1/2"	19"
Remote Control Unit	9"	8-1/8"	5-1/8"
Automatic Starter	22-1/2"	13-1/4"	12-1/4"
Motor-Generator	15"	50-1/2"	16"

The above are overall dimensions.

Unit	Weight
Transmitter	520 lbs.
Remote Control Unit	7
Motor Generator	559

Table No. 4

MODEL CXL RADIO EQUIPMENT

CONTROL OF POWER OUTPUT

Test as per paragraph 3-16-f of Specifications RE 13A 507A

Output Watts	Percent Power	Frequency kc	Plate Volts	P.A. Ip	Grid Volts
47.5	100	45,970.800	900	174	200
37.5	79	45,970.980	840	150	204
25.0	53	45,971.175	710	120	214
12.5	26	45,971.205	700	110	215

Maximum frequency change: 405 cycles
0.00088%

Table No. 5

MODEL CXL RADIO EQUIPMENT

CHANGE IN FREQUENCY DUE TO CHANGE OF VACUUM TUBES

Test as per paragraph 3-16-g of Specifications RE 13A 507A

Master Oscillator Circuit

Tube No.	Frequency Kc
556	45,970.800
561	.935
425	.698
896	.812
513	.770

Maximum change: 237 cycles
0.0005%

Harmonic Generator Circuit

881	45,970.806
425	.806
513	.782

Maximum change: 24 cycles

Note: Master Oscillator Circuit employs Type WE 306-A tubes; Harmonic Generator Circuit also employs Type WE 306-A tube. Each tube was permitted to heat for 10 minutes before frequency readings were taken.

Table No. 6

MODEL CXL RADIO EQUIPMENT

POWER REQUIRED FROM SUPPLY LINES

Test as per paragraph 6-5 of Specifications RE 13A 507A

(1) Starting Power:

Line Voltage:	219 volts
Line Current:	18.5 amps.
Watts:	4051

(2) "Idle Running" Power:

Plate Volts:	900
Grid Volts:	200
Filament Volts:	110
Line Volts:	224
Line Current:	7
Watts:	1568

(3) Full Power, Key Locked, CW.

Output Power:	46.5 watts
Plate Volts:	900
Grid Volts:	200
P. A. Ip	170 ma
Line Volts:	222
Line Current:	8.2 amps.
Watts:	1820

(4) Full Power, 100% Modulation:

Ip, V4B & V5B	135 MA
Plate Volts	900
Grid Volts	200
Ip V4A & V5A	170 MA
Line Volts:	223
Line Current:	8.2
Watts:	1828.6

Table No. 7

MODEL CXL RADIO EQUIPMENT

VARIATION OF MOTOR GENERATOR FIELD RHEOSTATS

Effect of varying Grid Generator Field Rheostat alone

Grid Volts	Plate Volts	Output Watts	P.A. Ip	Frequency kc
175	810	35.0	144	45,970.800
185	810	35.0	144	800
195	822	36.5	146	806
205	838	37.5	150	809
215	855	39.4	154	818
225	870	40.0	156	821

Effect of varying Plate Generator Field Rheostat alone

Plate Volts	Grid Volts	P.A. Ip	Output Watts	Frequency kc
780	208	134	32.0	45,970.800
800	206	142	34.5	812
820	204	145	35.8	824
840	203	149	37.5	833
860	202	156	40.7	845
880	200	160	44.1	851
900	196	166	45.4	863

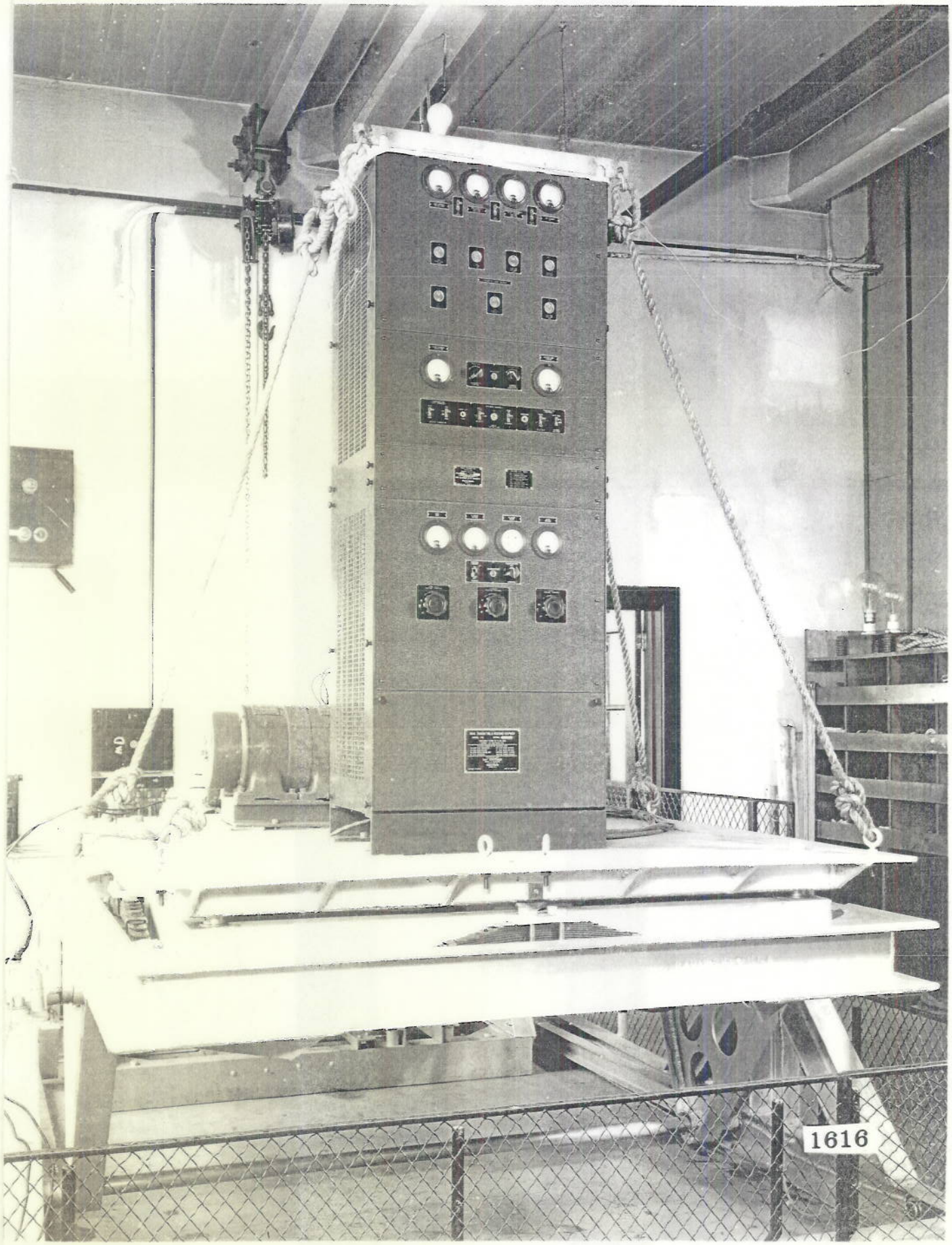

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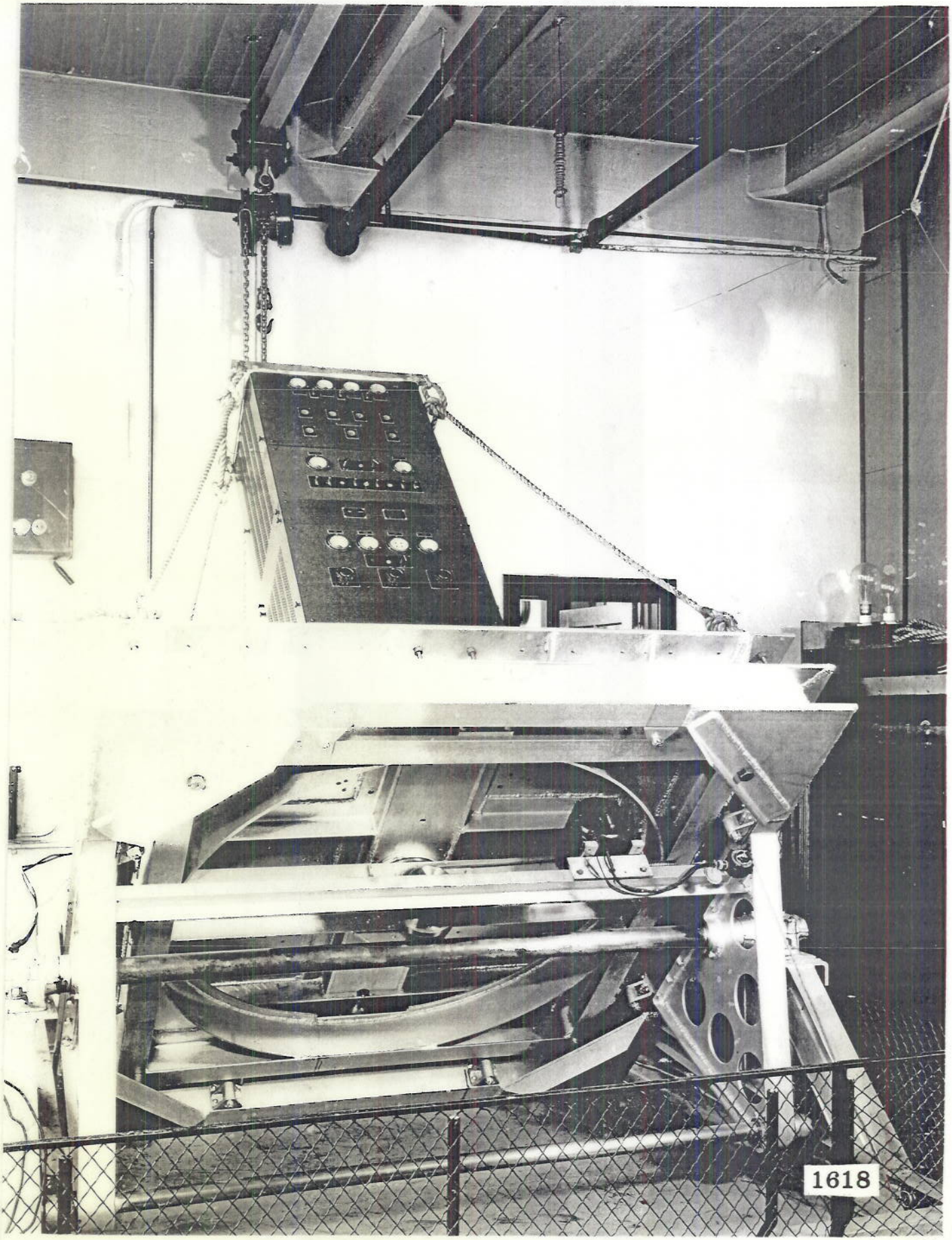
Plate 2



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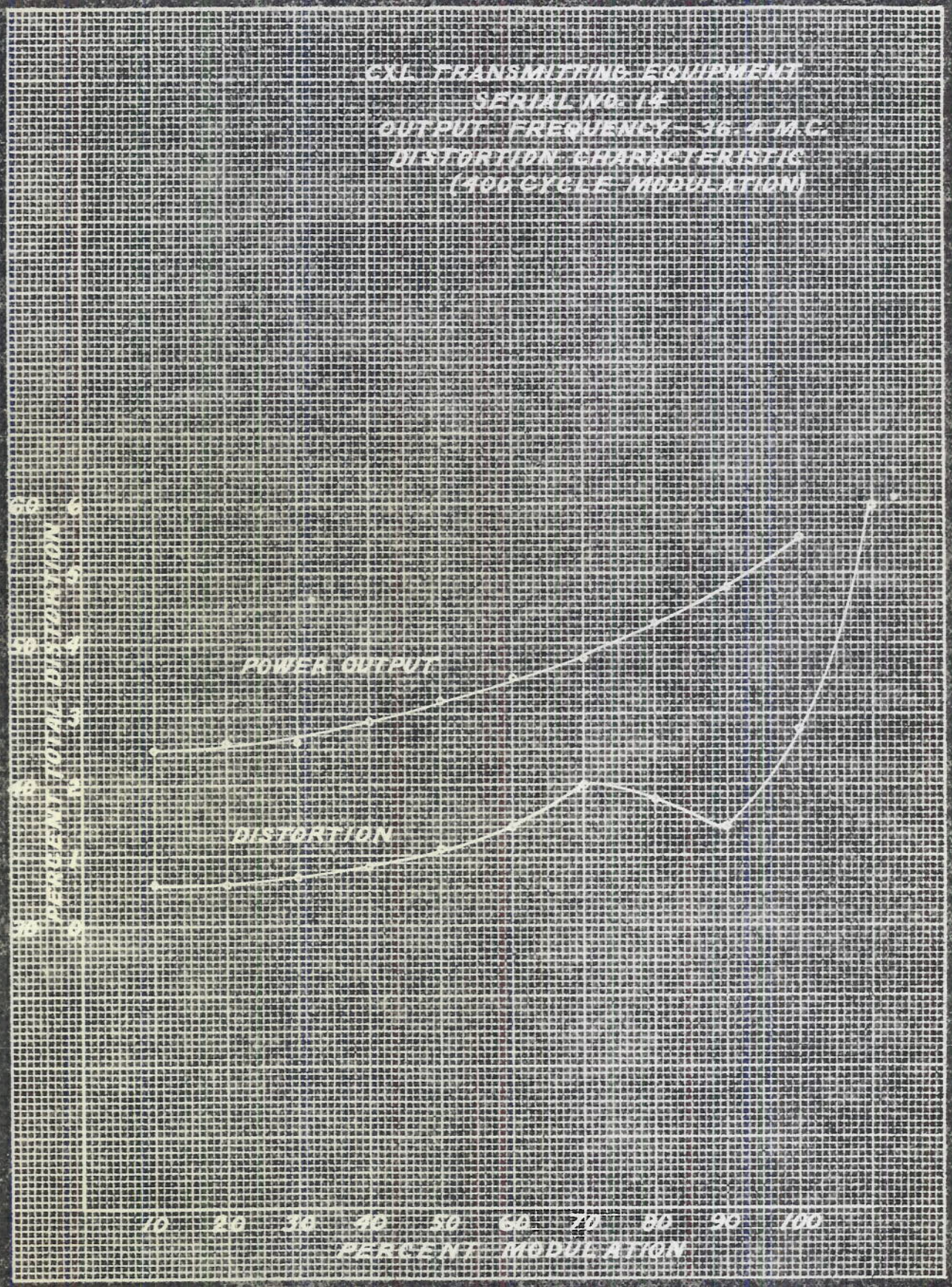
DATE



N. R. L. 31A

PLATE 4

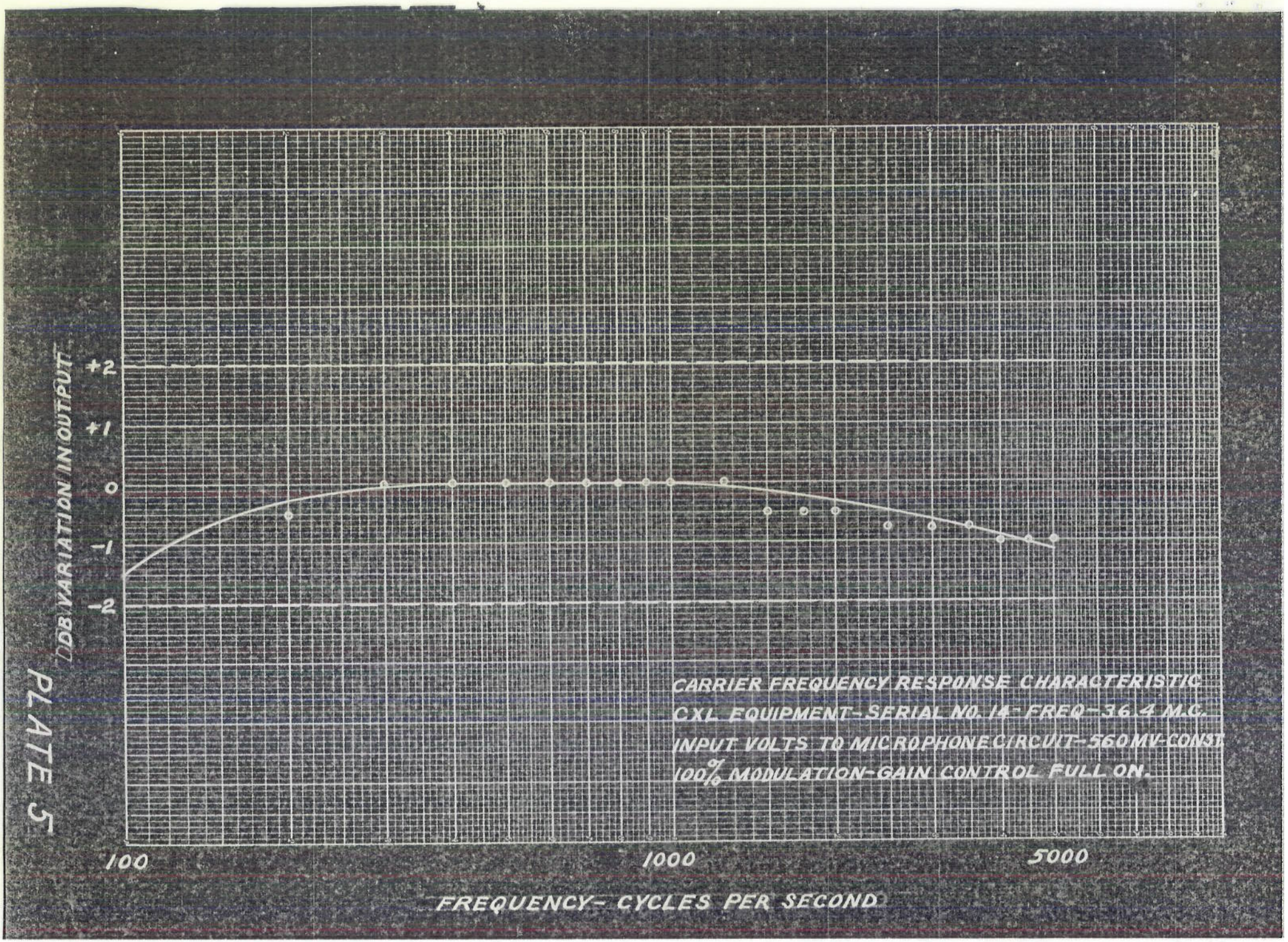
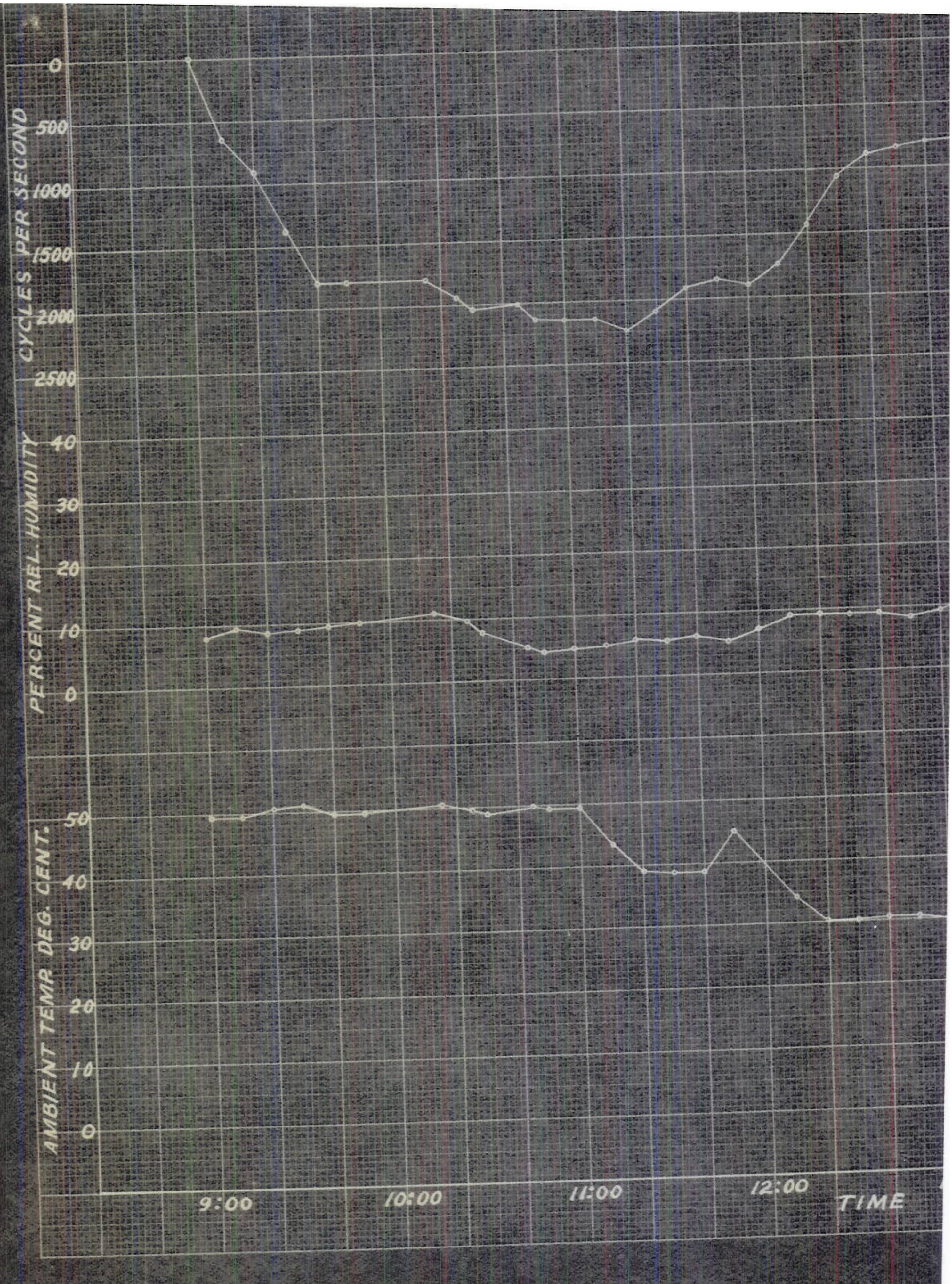
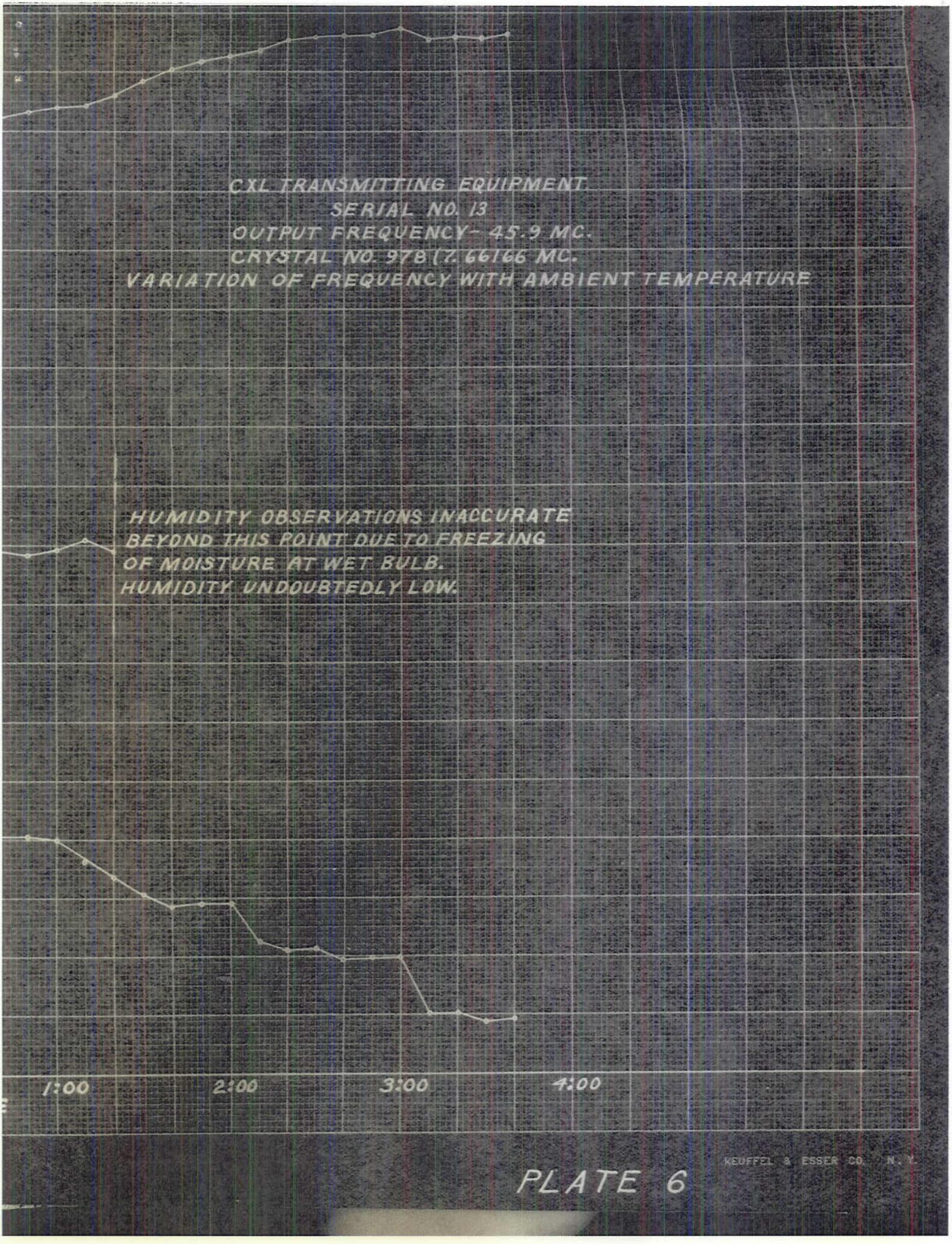
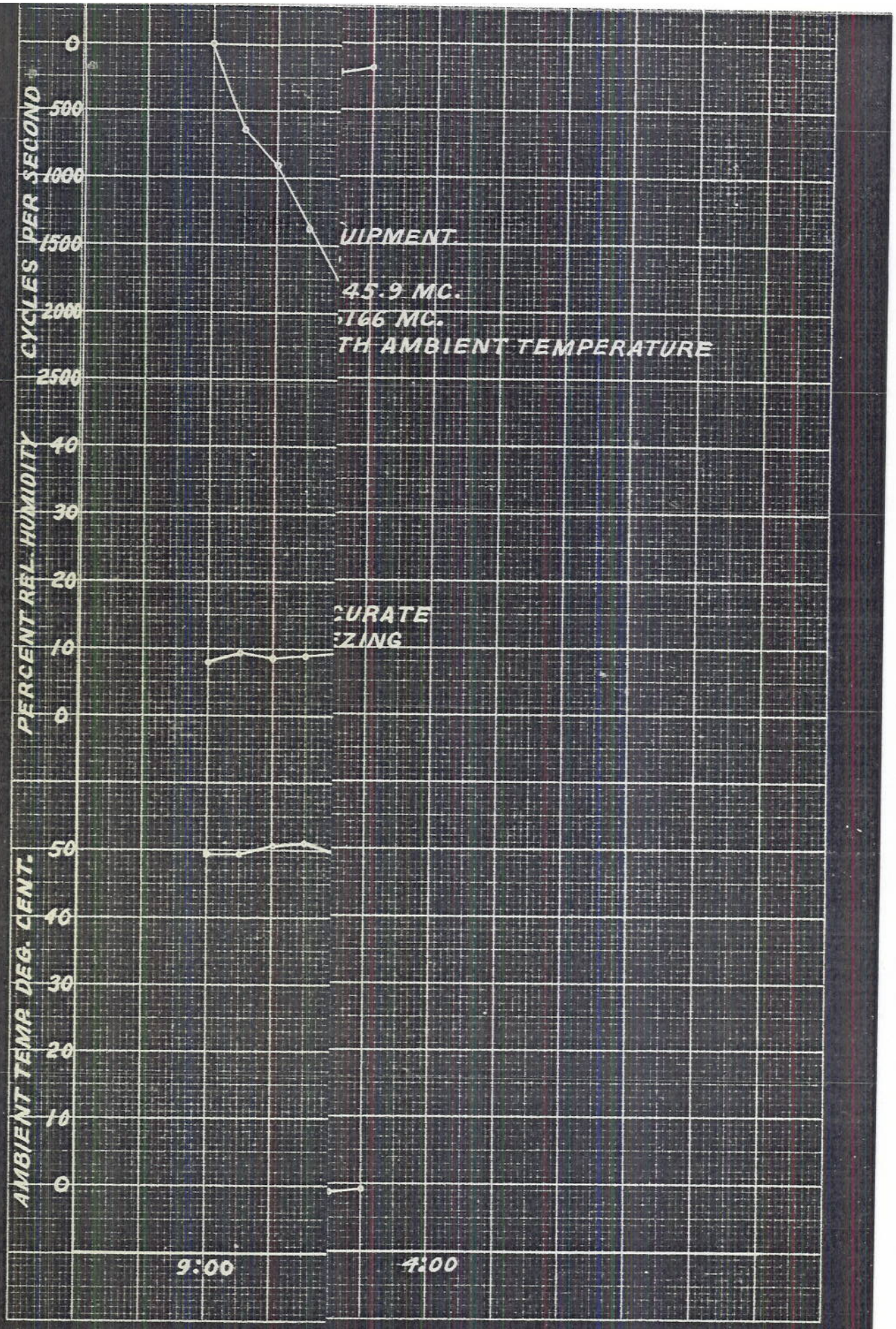


PLATE 5
DB VARIATION IN OUTPUT
+2
+1
0
-1
-2
100
1000
5000
FREQUENCY- CYCLES PER SECOND
CARRIER FREQUENCY RESPONSE CHARACTERISTIC
CXL EQUIPMENT-SERIAL NO. 14- FREQ-36.4 M.C.
INPUT VOLTS TO MICROPHONE CIRCUIT-560 MV-CONST
100% MODULATION-GAIN CONTROL FULL ON.


CYCLES PER SECOND
0
500
1000
1500
2000
2500
PERCENT REL. HUMIDITY
40
30
20
10
0
AMBIENT TEMP. DEG. CENT.
50
40
30
20
10
0
9:00
10:00
11:00
12:00
TIME


CXL TRANSMITTING EQUIPMENT
SERIAL NO. 13
OUTPUT FREQUENCY- 45.9 MC.
CRYSTAL NO. 978 (7.66166 MC.
VARIATION OF FREQUENCY WITH AMBIENT TEMPERATURE
HUMIDITY OBSERVATIONS INACCURATE
BEYOND THIS POINT DUE TO FREEZING
OF MOISTURE AT WET BULB.
HUMIDITY UNDOUBTEDLY LOW.
1:00
2:00
3:00
4:00
KEUFFEL & ESSER CO. N.Y.
PLATE 6



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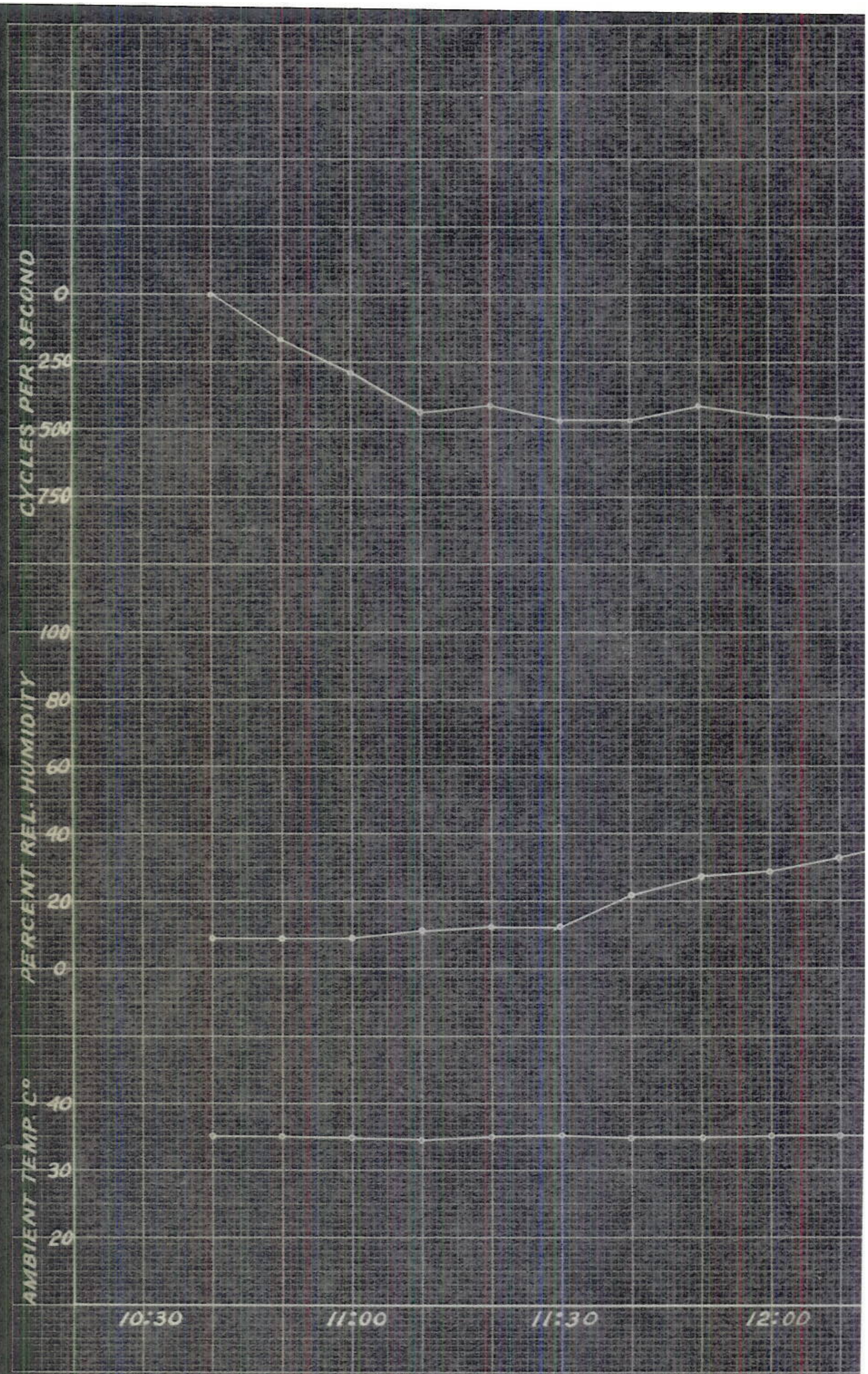
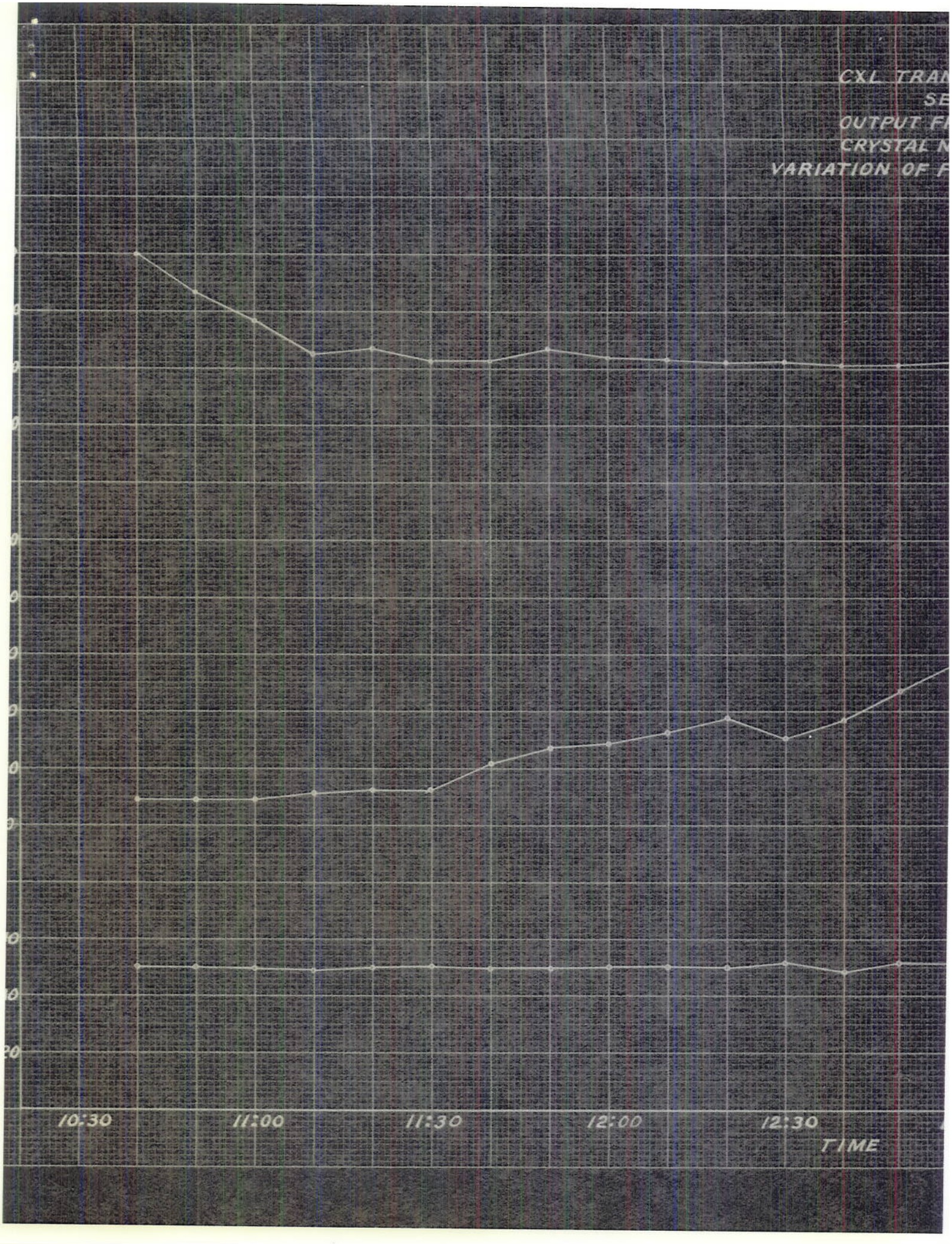
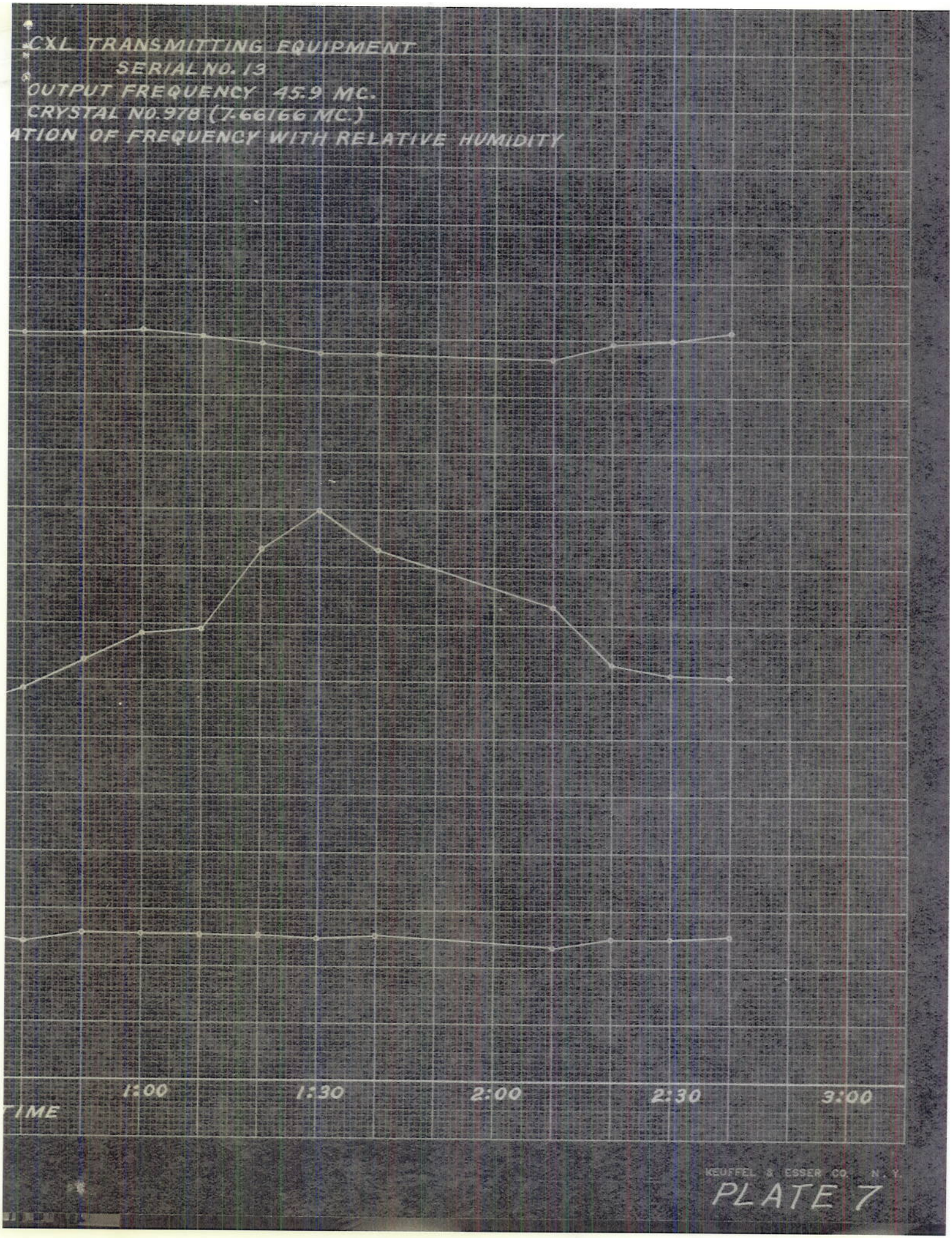
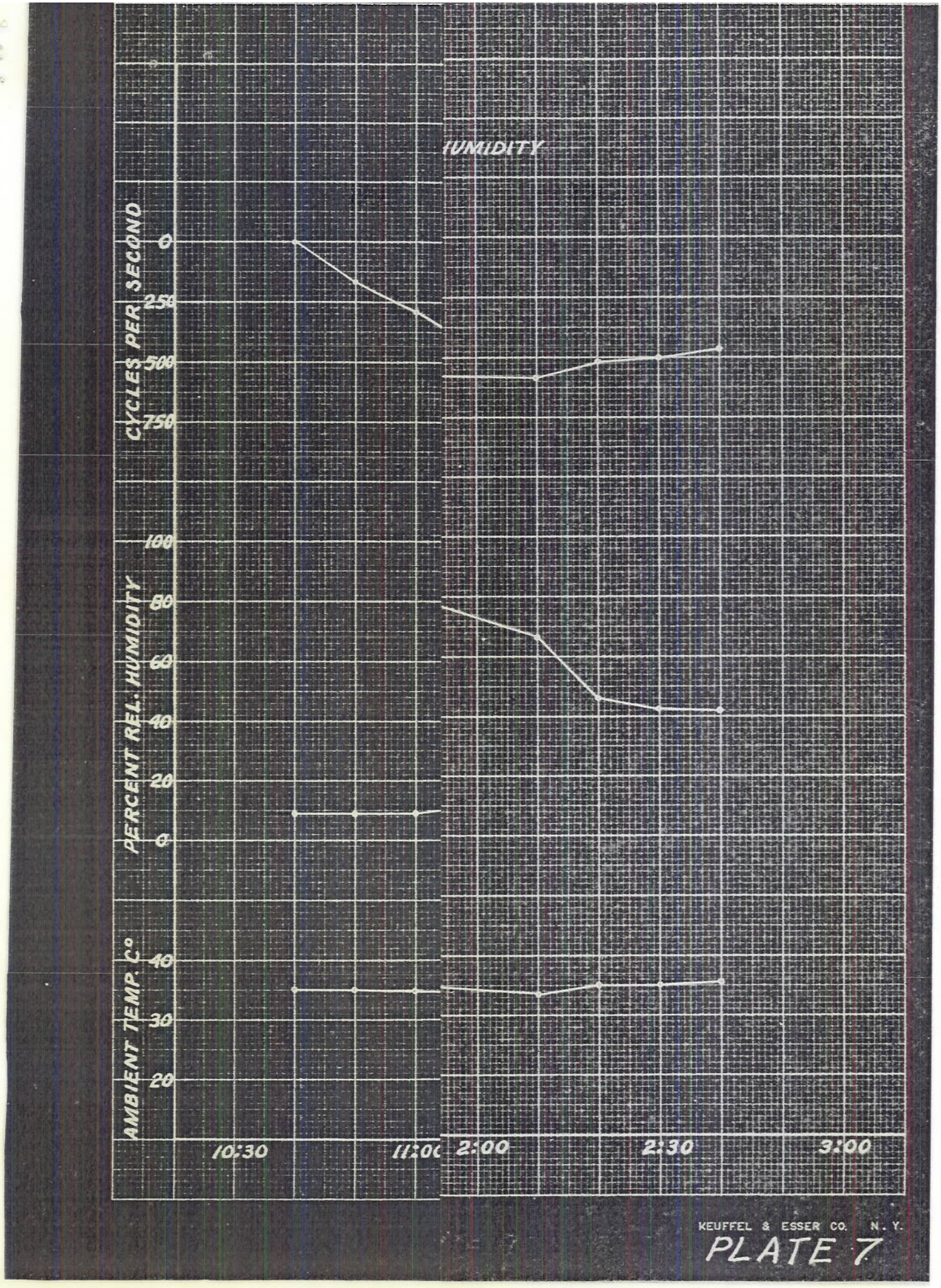


CYCLES PER SECOND
0
250
500
750
PERCENT REL. HUMIDITY
100
80
60
40
20
0
AMBIENT TEMP. C°
40
30
20
10:30
11:00
11:30
12:00


CXL TRA
SE
OUTPUT F
CRYSTAL N
VARIATION OF F
10:30
11:00
11:30
12:00
12:30
TIME


CXL TRANSMITTING EQUIPMENT
SERIAL NO. 13
OUTPUT FREQUENCY 45.9 MC.
CRYSTAL NO. 978 (7.66166 MC.)
ATION OF FREQUENCY WITH RELATIVE HUMIDITY
1:00
1:30
2:00
2:30
3:00
TIME
KEUFFEL & ESSER CO. N. Y.
PLATE 7

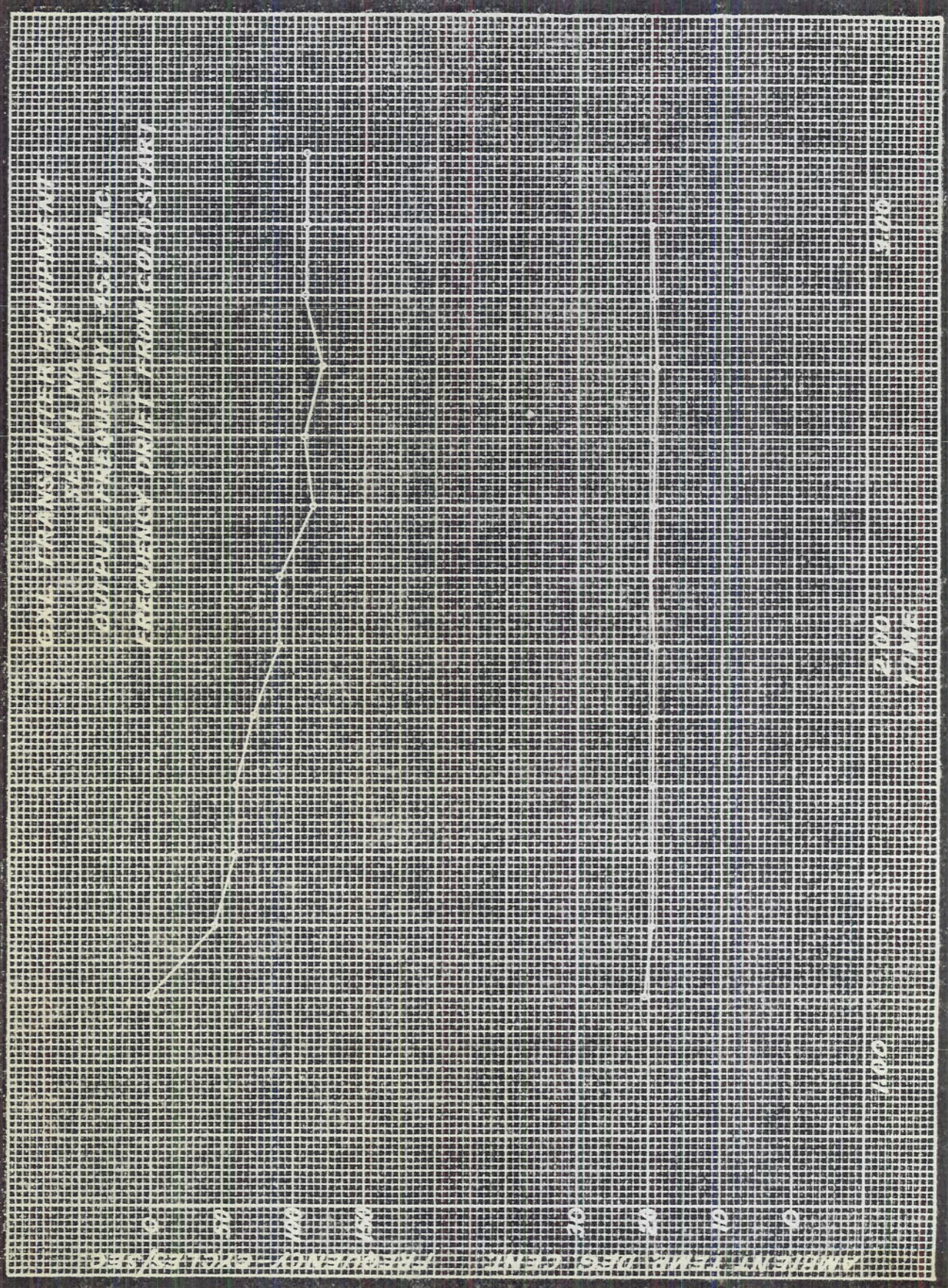


KEUFFEL & ESSER CO. N. Y.

PLATE 7

BELLEVUE, D. C.

DATE



N. R. L. 31A

PLATE 8