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REPORT NO. R-2299

DATE 3 June 1944

FR-2299

SUBJECT

Report on Test of
Experimental Model of an Electronic
Chronometer, Serial No. 3

DECLASSIFIED by NRL Contract

Declassification Team

Date: 11 AUG 2016

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Declassification authority: NAVY DECLASS
GUIDE, 11 DEC 2012, PGS 6-7, PARA 3(2)

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AND REFERENCE TO
S24/7(380-FCK)

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JUN 3 1944

To: Superintendent, U.S. Naval Observatory

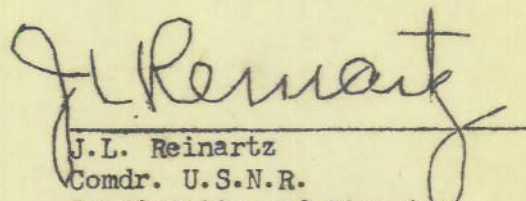
Subj: Electronic Chronometer - Examination and Test of -
Problem N13T.

Ref: (a) U.S. Naval Observatory letter Op-29-MO/y S24-7(04)
of 23 March 1944.

Encl: (H.W.)
(A) NRL Report R-2299 dated 3 June 1944
(5 copies)

1. Enclosure (A) is a report covering the results of tests conducted at the Naval Research Laboratory on an experimental model, serial 3, of an electronic chronometer manufactured by Thomas B. Gibbs and Co. of Delavan, Wisconsin.

2. The report recommends that certain modifications be made in the design of the resilient mounting system for the equipment. If requested to do so, the Naval Research Laboratory will be pleased to cooperate in effecting this redesign.


J.L. Reinartz
Comdr. U.S.N.R.
By direction of Director
Naval Research Laboratory

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3 June 1944

NRL Report No. R-2299
Prob. No. N13T

NAVY DEPARTMENT

Report on Test
of
Experimental Model of an
Electronic Chronometer, Serial No. 3

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 15 Tables - 16 Plates - 26

Authorization: U.S. Naval Observatory ltr Op-29-MO/y
S24-7(04) dated 23 March 1944 to NRL.

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Distribution: U.S.N. Observatory (5)

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ABSTRACT

An experimental model of an Electronic Chronometer, Serial No. 3, manufactured by Thomas B. Gibbs and Co. of Delavan, Wisconsin was subjected to tests at the Naval Research Laboratory during the period from 27 March 1944 to 27 April 1944. These tests included temperature tests, humidity tests, and electrical and mechanical inspection. The results of the tests are discussed in detail.

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AUTHORIZATION

1. The tests herein reported were authorized by reference (a). Pertinent Naval specifications are listed in references (b) to (d).

Reference: (a) U. S. Naval Observatory ltr
Op-29-MO/y S24-7(04) dated
23 March 1944 to NRL.
(b) BuShips specification RE 13A 554D.
(c) BuShips specification RE 13A 372J.
(d) BuShips specification RE 13A 488E.

CONCLUSIONS

2. The results of the tests conducted on the subject equipment lead to the following conclusions:

- a. Access to the equipment for servicing or replacement of component parts is limited. This condition arises not only from the manner in which the individual component parts have been installed, but also from the general construction of the cabinets and their mountings.

- b. The rate of the chronometer changed when the ambient temperature was varied. In the absence of specified limits, no conclusion can be reached as to whether or not the amount of variation was excessive. However, it is believed that the temperature control system for the quartz crystal frequency control should be modified to maintain the crystal temperature within a much smaller range of temperatures than at present.

- c. The rate of the chronometer varied when the equipment was exposed to a relative humidity approaching saturation.

- d. The chronometer will not operate accurately if the equipment is exposed to radio-frequency power from external sources.

- e. The method of marking component parts does not conform to the pertinent Navy specification for radio equipment.

- f. The workmanship and type of components does not meet the requirements demanded in radio equipment intended for shipboard service.

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RECOMMENDATIONS

3. The results of the tests conducted on the subject equipment lead to the following recommendations:

a. The housing of the equipment should be modified in the manner recommended in paragraph 34 of this report. In effecting this modification care should be taken to achieve a design that will provide adequate accessibility for maintenance and the replacement of component parts and proper protection against shock and vibration.

b. The temperature control system for the quartz crystal should be improved so that it will maintain the temperature of the crystal within plus or minus 0.1°C in the range from 59° to 61°C . The control system should be capable of maintaining this accuracy when the ambient temperature is varied over the range of 0°C to 50°C .

c. The equipment should be provided with filtering circuits and shielding to prevent malfunctioning of the circuits due to stray radio-frequency fields.

d. The component parts should be provided with identification and other markings in the manner recommended in paragraphs 12 to 14, inclusive, of this report.

e. Component parts should be revised as recommended in paragraphs 27 to 33, inclusive, of this report.

f. It is recommended that the suggestions made in paragraphs 48 to 52, inclusive, relative to the elimination of electrical defects, be adopted.

g. It is recommended that the equipment be provided with an instruction book of the type suggested in paragraph 53 and that the defects on the schematic diagrams discussed in paragraphs 54 to 59, inclusive, be eliminated.

EFFECT OF AMBIENT TEMPERATURE

Effect of Operation at a Constant Ambient Temperature

4. In order to determine whether the "rate" of the chronometer would remain constant, the equipment was allowed to operate at essentially constant ambient temperatures for extended periods. The temperatures which were maintained during these tests and the duration of each test are summarized as follows:

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Duration (Hours)	Ambient Temperature (°C)	Data Appear In	
		Table	Plate
7.00	23 to 25	1	1
8.25	26 to 27.5	2	2
8.25	24 to 26	3	3
8.00	35	4	4
8.25	35	5	5
8.25	35	6	6
8.00	50	7	7
8.25	50	8	8
8.25	50	9	9
6.75	0	10	10

The results of these tests are summarized in Table 16. The data listed in this table were obtained by graphical differentiation of the data presented in Plates 1 to 10, inclusive. Referring to Plate 16, the following may be observed:

a. The rate varied with ambient temperature. The maximum rate was plus 0.828 second per day and the minimum rate was plus 0.388 second per day. The difference between these rates (0.828 - 0.388) is plus 0.44 second per day, which is equivalent to a difference in the frequency of the crystal-controlled oscillator of 0.447 c.p.s. This is equivalent to 5.28 parts per million.

b. The rate varied although the ambient temperature remained constant. As illustrated in Plate 16, at an ambient temperature of 50°C, the rate varied between 0.828 and 0.547 second per day.

Variation in Ambient Temperature

5. The equipment was placed in operation in an ambient temperature of 50°C. After a period of approximately 1 hour, the ambient temperature was slowly reduced so that at the end of a period of 6.25 hours after the start of the test, it was 0°C. This ambient temperature was maintained for 1.25 hours. The data for this test are listed in Table 11 and are presented graphically in Plate 11. Another test was then made in a manner similar to that just described, except that the ambient temperature was initially adjusted to 0°C and then gradually increased to 50°C. The data for this test are listed in Table 12 and are presented graphically in Plate 12. The following was observed:

a. Referring to Plate 11, the rate was negative during one period of the test (1030 to 1145). This was the first occasion during the tests that a negative rate was observed.

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b. The test presented in Table 12 was made to obtain further information concerning the negative rate observed in the preceding test. However, except for the inconclusive first portion of the test period, the rate was positive.

6. Since the ambient temperature at which the rate changed from positive to negative was not revealed by the preceding attempts, a test was made over a narrower range of ambient temperatures, from 20°C to 35°C. The data for this test are listed in Table 13 and are presented graphically in Plate 13. Referring to this plate, it may be seen that the rate was negative for a short period at the start of the test but was positive during the remainder of the test.

7. In a further effort to determine the temperature at which the rate changed from positive to negative, the ambient temperature was varied as shown in Table 14 and presented graphically in Plate 14. Plate 14 shows that during one part of the test the rate was negative and that during another part it was positive. However, the temperature at which the reversal occurred was not identified.

Crystal Holder and Oven

8. It was noted that the crystal oven label indicates that the crystal frequency is correct at 51°C. Experience has shown that this is too low a temperature to provide a sufficient margin for adequate temperature control when the ambient temperature is 50°C. It is recommended that the equipment be provided with a crystal oven that will maintain the crystal temperature to within plus or minus 0.1°C of a temperature in the range of 59° to 61°C, inclusive.

Leakage of Potting Compound

9. Following the temperature tests, it was found that wax had melted and leaked from the grid transformer assembly for the type ClB tubes and also from the 4.0 µf capacitor (Part No. 10, Power Supply). In addition, the wax on each of the grid circuit resistors for the type ClB tubes had melted and collected in a drop at the bottom of the resistor. The design should be modified to eliminate this leakage, since the manner in which wax is used in these instances does not conform to the requirements of paragraph 2-2(1) of reference (b).

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EFFECT OF HUMIDITY

10. As shown by the data listed in Table 15 and presented graphically in Plate 15, when the relative humidity was increased to 97 per cent from an initial value of 30 per cent, the rate changed from plus 31 milliseconds per hour to plus 35 milliseconds per hour.

EFFECT OF STRAY RADIO-FREQUENCY FIELDS

11. Investigation revealed that the stray radio-frequency field emanating from a nearby low power radar transmitter caused malfunctioning of the multivibrators in the Frequency Standard Generator, thereby causing a sudden increase in the rate of error. An example of the result of this condition is shown in Plate 3. It is recommended that the chronometer equipment be provided with adequate filter circuits and shielding.

MARKING AND IDENTIFICATION

12. The symbols used to represent component parts in the schematic diagram differ from those customarily used in instruction books for Naval equipment. These differences are as follows:

a. The tube symbols are semi-pictorial diagrams. These symbols should be replaced by the type customarily used in schematic diagrams. The tube elements shown in the schematic diagram should be numbered to agree with the tube socket terminal numbers.

b. The relay symbols are of a type ordinarily used on power control diagrams. These symbols should be replaced by the type customarily used in schematic diagrams for Naval radio equipment.

c. The triangular symbol used to indicate grounded points should be replaced by standard parallel line ground symbol.

13. The "part designation" symbols required by paragraph 4-5(1) of reference (b) have not been provided. It is recommended that these symbols be provided and that they be located adjacent to their corresponding component. In addition, fuse holders should be marked with the current and voltage ratings of the fuses to be employed therein.

14. In a number of instances where component parts such as capacitors and transformers have two or more terminals, no numbers have been stamped adjacent to the terminals to permit

their identification. It is recommended that such numbers be provided and that these numbers also appear on the schematic diagram.

WIRING AND WORKMANSHIP

15. A number of instances were noted in which the workmanship or design was not adequate. The following examples were recorded:

a. Two holes which were intended for mounting the power transformer assembly to the rectifier subchassis could not be used because they were mislocated.

b. Four tapped holes were found near the holes by which the rectifier subchassis is bolted down. These holes apparently had been intended to be used in bolting down the subchassis but had been mislocated.

c. The burr was not removed from the tapped hole by which the chain for the connector cap assembly is secured.

d. One of the bolts holding the Amphenol connector for the d-c supply line was found to have been clipped to the proper length. This left a burred end on the bolt.

16. In a number of instances, an excessive amount of solder has been used to solder resistors to their terminal boards. An example of this is found in resistor number 33.

17. The resistor number 39 is a small tab type unit in which the resistance wire is wound on a hollow ceramic tube and covered with vitreous enamel. The power rating is estimated to be 5 watts. The resistor has been mounted on a bolt which passes through the chassis and the hole through the center of the resistor and is secured by a nut. This nut has been soldered in place. This type of resistor does not conform with the provisions of paragraph 16-3 of reference (c). However, if permission to use this type of resistor is granted, the method of mounting should be modified, since it will be difficult to remove the soldered nut when replacing the resistor. The 10,000-ohm, 10-watt resistor (Part No. 20) is a similar type of resistor. This resistor also has tab type terminals and its use is therefore contrary to the provisions of paragraph 16-3 of reference (c). This resistor also is mounted by a center-bolt and, although the nut is not soldered in place, this method of mounting is objectionable because the center-bolt also is used to fasten a tube socket to the chassis. Thus, in order to replace the tube socket, it is first necessary to remove the resistor.

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18. There are three resistors connected directly to the tube sockets in the rectifier subchassis. This method of installing resistors renders the replacement of sockets difficult and, in addition, makes the resistors difficult of access. It is recommended that these resistors be secured to a mounting board and connected to the tube sockets by suitable wiring.

19. The bakelite strips used for mounting resistors 31 and 33 are unsatisfactory for the following reasons:

a. The resistor strips are supported on bolts in a manner which will permit them to become loose.

b. The use of the single bolt at each end of the resistor strip does not provide sufficient support. It is recommended that these strips be supported on suitable brackets.

c. The bakelite used for these resistor strips is only 1/16 inch thick and is therefore not sufficiently rigid.

d. Flat strips of metal riveted to the bakelite are used as resistor terminals. It is recommended that these be replaced by round terminal lugs.

20. There are two cables connected between the Amphenol connectors on the cover of the Frequency Standard Generator and terminals on the chassis of this unit. Although the cover can be removed, the presence of these cables prevents it from being placed more than a limited distance from the chassis. It is recommended that the need for these cables be eliminated by relocating the Amphenol connectors on the side of the chassis.

21. All of the soldered joints in the wiring have been made incorrectly, since solder is depended upon for mechanical strength; that is, the wire has not been wrapped around the terminal previous to soldering.

22. The wiring in the rectifier chassis has been installed in an unworkmanlike manner. The wiring covers the tube sockets and is not properly secured to the chassis. It is recommended that the wiring be laced into cables and then clamped to the chassis.

23. Solid wire has been used for connecting circuits in the Frequency Standard Generator. In many instances there are long lengths (8 inches) of this wire that are secured only at the ends. Thus, the wire is susceptible to damage by vibration. It is recommended that this solid wire be replaced by stranded wire and that the wire be clamped to the chassis.

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24. The leads to the plate cap connectors for the type ClB tubes are not readily replaceable since they enter the transformer through a hole in the center of the terminal stud. Thus, if the lead breaks on the inside of the terminal stud, it may be necessary to dismantle the transformer in order to effect repairs. It is recommended that the leads connecting the terminals on this transformer to the plate caps of the type ClB tubes be terminated with soldering lugs at the transformer.

25. The connecting lead of resistor number 38 is connected to the connecting lead of capacitor number 10 by means of a soldered eyelet; that is, one lead was inserted in the eyelet from one direction and the other lead from the other direction and the remaining space in the eyelet was then filled with solder. Since this type of joint depends upon solder for mechanical strength, it does not conform with the requirements of paragraph 2-5(1) of reference (b).

26. Resistor number 36 is installed in a manner that requires it to be removed before the adjoining capacitor to which it is directly connected can be replaced. It is recommended that this resistor be mounted on a resistor strip and connected to the capacitor terminals by suitable wiring.

COMPONENT PARTS

27. Two separate transformers are used to excite the grids of the type ClB tubes. Since the voltages applied to these grids are 180 degrees different in phase, it is recommended that these two transformers be replaced by a single transformer having suitable secondary windings.

28. The two power transformers (Parts No. 22 and No. 23) and the inductor (Part No. 24) are housed in a common container. Should one of these units fail, the others must also be replaced. It is recommended that these transformers and the inductor each be housed in a separate container.

29. Paragraphs 3-4(1) and 3-4(2) of reference (b) require that the capacitors used in Navy radio equipment be of the type specified by reference (d). The following capacitors used in the equipment do not conform to these specifications:

a. The two by-pass capacitors on the primary side of the power transformer (non-standard shape and size).

b. The eight "tiny mite" capacitors--Parts Nos. 6, 7, 8, 9 (incorrect dimensions and have pigtail connectors).

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- c. The three 0.01 μ f capacitors--Part No. 11 (incorrect dimensions, and have pigtail connectors).
- d. The two "Sola" 0.1 μ f capacitors--Part No. 10 (no Navy type number appears).
- e. The dual 1 μ f capacitors--Part No. 13 (no Navy type number appears).
- f. The 1 μ f metal cased capacitor--Part No. 14 (wrong type of terminals).
- g. The 4 μ f metal cased capacitor--Part Nos. 10 and 12 (no Navy type number appears).
- h. The 0.5 μ f metal cased capacitor--Part Nos. 11 and 16 (no Navy type number appears).

It is recommended that the capacitors now used be replaced by a type specified in reference (d).

30. The two fuses for the battery circuit are located on the top of the rectifier chassis so that it is necessary to remove the cover of this unit when changing fuses. It is recommended that the equipment be designed so that these fuses are readily replaceable.

31. It is recommended that holders for spare fuses be provided adjacent to the two fuses for the battery circuit.

32. The a-c and d-c power supply lines are not provided with fuses. It is recommended that fuses be placed in each side of these lines.

33. The fuse located in the Frequency Standard Generator unit is accessible only after the cover of this unit has been removed. It is recommended that the fuse holder be located in a position that will permit the fuse to be replaced quickly.

MECHANICAL DEFECTS

34. The following items were noted concerning the construction of the cabinets and the manner in which they are supported on flexible mountings:

- a. The frameworks which support the Power Supply and the Frequency Standard Generator require excessive deck area. It is suggested that the two units be mounted in a single cabinet and that this cabinet be supported on resilient mounts. The equipment should be designed so that it can be

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mounted on either a vertical or horizontal surface. Should these modifications be made, the recommendations suggested in paragraph 34(b to f) may not apply.

b. The Power Supply unit is retained in its mounting frame by gravity alone. It is recommended that suitable knurled-head thumbscrews be provided to secure this unit to its mounting frame. These screws should be of the captive type.

c. No handles have been provided on the Frequency Standard Generator, the Power Supply unit, or on the rectifier subchassis. These assemblies are therefore difficult to remove from their respective mountings. Handles should be provided on these units to aid in their removal.

d. The five bolts by which the rectifier chassis is held in the Power Supply unit pass upward through the bottom of the Power Supply unit and thread into tapped holes in the chassis. The heads of these screws are located on the underside of the Power Supply unit and are not readily accessible when this unit is in its mounting frame, since there is a space of only 2.5 inches between the underside of this unit and the surface to which the mounting frame is secured. In addition, it is considered that the five 8-32 steel machine screws by which the rectifier is secured do not provide sufficient strength to insure that this chassis will remain in place. It is recommended that these screws be replaced by six 1/4-inch captive, knurled-head thumbscrews, and that floating nuts be provided to receive the screws. These securing devices should be arranged so that it will be possible to remove the rectifier chassis without the necessity of reaching under the Power Supply unit to release the screws.

e. The Frequency Standard Generator is held in place in its mounting frame by bolts which thread into tapped holes in the side of the cabinet. In addition to the tapped holes, the bolts are also secured by nuts and lock washers located inside the cabinet. It is extremely difficult to remove or replace the nuts and lock washers on the bolts located at the corners. It is recommended that the present bolts be replaced by captive, knurled-head thumbscrews and that the cabinet be provided with floating nuts to receive these screws.

f. Although vibration tests were not made on the subject equipment, examination indicated that the resonant period of both of the units was within the range of ship vibrational frequencies; that is, below 1500 cycles per minute. It is recommended that the flexible mounting system be redesigned to place the resonant frequency of the equipment above 1500

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cycles per second. The resilient mounting should be installed in a plane passing through the center of gravity of the assembled equipment. It is possible to apply the mounts to only the base of the equipment providing the maximum weight is concentrated at the bottom of the assembly.

35. The following items were observed concerning the accessibility of the component parts for replacement or testing:

a. The underside of the sockets for the type 6H6 and the VR105-30 tubes and the nuts on the mounting bolts for these sockets are extremely difficult to reach for servicing operations or replacement. The most practical method of obtaining access to these components involves the removal of the case holding the grid transformers for the type ClB tubes. This incurs an additional difficulty, since the limited space available for access to the securing nuts for the case makes replacement of the unit difficult. It is recommended that these sockets be made more accessible without the need for partial disassembly of the equipment. Access to the underside of the 2N030 relay socket, the underside of the socket for the type 6N7GT/G tube, the 10,000-ohm potentiometer, the three composition resistors (Parts 17, 18, 19) and a number of terminals on the power transformer is severely limited until the grid transformer assembly is removed.

b. A number of the terminals on eight tube sockets and one of the securing bolts for each of these sockets are concealed under a resistor mounting strip. This condition renders replacement of any of the sockets more difficult than should be necessary, since such a replacement would involve removal and replacement of the resistor strips and the unsoldering of many extra connections. It is recommended that the resistor terminal strips be rearranged to permit ready access to the tube sockets.

c. There are two 0.1 μ f capacitors (Part No. 10) secured between a terminal board and the surface to which this terminal board is secured. Because of this condition, it is difficult to replace the capacitors. These capacitors should be relocated in a manner that will eliminate this difficulty.

d. Access to the two 0.14 μ f capacitors (Part No. 9) included in the case containing the grid transformers of the rectifier unit cannot be obtained until the cover of this unit has been unsoldered. This is considered to be an impractical operation and in the event that one of these capacitors fails, it would be necessary to replace the complete transformer-capacitor assembly.

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e. A number of resistors (Part No. 33) are mounted between the underside of a bakelite terminal strip and the chassis of the Frequency Standard Generator in a manner which makes them replaceable only with difficulty and after an unnecessary expenditure of time. There is no space remaining on the accessible side of this terminal strip for mounting these resistors. It is recommended that the resistor strips be redesigned to eliminate this difficulty.

36. The chassis of the rectifier unit and the Frequency Standard Generator, which are constructed of 1/16 and 3/32-inch thick steel plate, respectively, are not sufficiently rigid. It is recommended that these chassis be made of sheet aluminum 1/8 inch thick.

37. The cabinet for the Frequency Standard Generator is constructed of steel 1/32 of an inch thick. This cabinet is not sufficiently rigid.

38. The welds of the steel chassis in the equipment were broken at several points. Better workmanship is necessary.

39. The chain which forms the keeper for the connector cap on the Amphenol plug of the Power Supply unit is secured to the cabinet by a machine screw. This machine screw fits into a tapped hole in the cabinet. However, the metal of the cabinet is too thin to permit this type of construction and it is recommended that the machine screw be held by a nut.

40. The sockets for the type ClB tubes should be provided with anti-stress washers as required by paragraph 4-3(21) of reference (b).

41. The heads of the mounting bolts for the two capacitors (Parts Nos. 10 and 11) are covered by the power transformer assembly (Part No. 23). Thus, unless the transformer has been removed, it is not possible to manipulate the head of these screws when removing or replacing the capacitors. It is recommended that the mounting bolts be made accessible.

42. The two bypass capacitors on the primary of the power transformer have been mounted by soldering them to thin metal lugs which in turn are bolted to the chassis. This method of mounting is unsatisfactory, since it depends upon solder for mechanical strength.

43. It is recommended that all of the vacuum tubes and the Amperite relay be provided with base clamps to retain them in their sockets. It is recommended that Birtcher Type 926 clamps of the proper size be used for this application.

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44. It is recommended that the brass parts which are used in the voltage test jack and on the mounting bolt for the inductor (Part No. 45) be plated to protect them against corrosion.

45. The calibration of the chronometer dial which indicates seconds is not expanded sufficiently to permit measurements to an accuracy of 1/10 of a second. It is recommended that the dial provided for the sweep second hand be calibrated with 1/10-second divisions.

46. The center of rotation of the sweep second hand was found to be in a different position than the center of the calibrated circle. This mislocation permits an error of 2/10 of a second in reading the sweep second hand. It is recommended that the sweep second hand and its calibration be located with respect to each other in a manner which will eliminate this error.

47. It is recommended that the top of the Frequency Standard Generator chassis be provided with test points to permit the operation of individual stages to be observed when the equipment is being serviced. These test points should be connected to appropriate circuits in a manner that will permit the waveforms of the various stages to be observed by means of an oscilloscope.

ELECTRICAL DEFECTS

48. When the crystal oscillator ceases to oscillate, the multivibrators continue to operate and power continues to be supplied to the chronometer. Thus, the chronometer continues to run, but since the multivibrators are not being controlled, the rate of error will become extremely erratic. It may be desirable to design the equipment so that the chronometer will ~~not~~ stop when the crystal ceases to oscillate.

49. Paragraph 4-1(6)A of reference (b) requires that ceramic insulation be used on vacuum tube sockets, capacitors, and inductors used in radio-frequency circuits. Since phenolic insulation has been used on all of the vacuum tube sockets on the variable capacitor (Part No. 23) and on the inductors (Parts Nos. 44 and 45), it is recommended that these parts be replaced by components having ceramic insulation.

50. It is recommended that the equipment be provided with an indicator light to indicate the cycling of the crystal oven heater.

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51. It is recommended that the equipment be provided with a voltmeter to indicate the battery voltage. This is necessary to permit the operator to monitor the condition of the battery.

52. For the reasons listed below, it is recommended that the storage battery in the equipment be removed from its present position and located in a compartment containing other storage batteries used aboard ship:

a. The battery generates gases which will be harmful to the remainder of the equipment.

b. Special precautions must be taken to prevent the gases from causing an explosion.

c. The battery requires special maintenance which can be obtained if it is located adjacent to other batteries subject to periodic inspection and maintenance.

INSTRUCTION BOOK AND SCHEMATIC DIAGRAM

53. No instruction book was provided with the equipment. It is recommended that an instruction book be provided, containing information necessary for installation, operation, maintenance, servicing, and the procurement of replacement parts.

54. The capacitor (Part No. 18) has an additional capacitor connected across it, but this capacitor is not shown on the schematic diagram. It is recommended that these two capacitors be replaced by a single capacitor of the correct value. If this is not feasible, and it is necessary to retain the two capacitors, then both capacitors should be shown on the schematic diagram. The above remarks also apply to capacitor (Part No. 19).

55. The two capacitors which are connected between the power transformer primary and the chassis of the rectifier unit are not shown on the schematic diagrams supplied with the equipment. This error should be corrected.

56. The resistor (Part No. 39) is actually 100 ohms, but the schematic diagram indicates it to be 200 ohms. This discrepancy should be corrected. The capacitor (Part No. 15) has a capacity of 4 μ f but the schematic diagram indicates that it has a capacity of 3.5 μ f. This discrepancy should be corrected.

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57. The capacitors (Parts Nos. 17 to 20, incl.) are marked with incorrect capacity values on the schematic diagram. A capacitor which is actually 1000 μ pf is marked 1000 μ f. These errors in marking the schematic diagram should be corrected.

58. It is recommended that wiring diagrams, in addition to schematic diagrams, be provided with the equipment. It is recommended that a functional diagram showing both voltages and waveforms at various points in the circuits be provided.

59. The designations used to identify component parts do not conform with the requirement of paragraph 4-5 of reference (b). It is recommended that the present method of identification be replaced by the method specified in the reference.

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TABLE 1

ELECTRONIC CHRONOMETER
OPERATION AT ROOM TEMPERATURE
(Part 1)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 Min.
			Amps. ac	Watts ac		Sec.	Millisec.	
0915	24.5	48.0	1.70	84	39.0	0.0	14	
0930	23.0	47.5	1.70	84	39.8	0.0	19	5
0945	23.0	47.0	1.65	80	39.0	0.0	22	3
1000	23.2	47.9	1.65	80	39.2	0.0	28	6
1015	23.2	48.0	1.87	87	39.5	0.0	32	4
1030	23.3	48.1	1.70	84	40.4	0.0	39	7
1045	23.3	48.1	1.72	85	40.5	0.0	44	5
1100	23.3	48.0	1.70	84	40.3	0.0	48	4
1115	23.3	48.0	1.69	83	40.0	0.0	53	5
1130	23.3	48.0	1.75	85	40.0	0.0	58	5
1145	23.4	48.2	1.70	83	40.0	0.0	64	6
1200	23.5	48.2	1.76	86	40.0	0.0	69	5
1215	23.5	48.3	1.70	84	40.0	0.0	73	4
1300	24.0	48.5	1.70	84	40.5	0.0	93	
1315	24.2	48.6	1.70	84	40.2	0.1	98	5
1330	24.2	48.6	1.69	83	40.5	0.1	103	5
1345	24.2	48.6	1.72	84	40.5	0.1	109	6
1400	24.2	48.5	1.77	87	40.5	0.1	115	6
1415	24.2	48.6	1.62	80	40.0	0.1	121	6
1430	24.4	48.6	1.70	84	40.0	0.1	126	5
1445	24.5	48.8	1.68	83	40.5	0.1	131	5
1500	25.0	48.9	1.76	87	40.5	0.1	136	5
1515	25.0	49.0	1.67	83	40.0	0.1	140	4
1530	25.2	49.0	1.67	83	40.0	0.1	146	6
1545	25.4	49.1	1.67	83	40.0	0.1	151	5
1600	25.5	49.2	1.70	84	40.5	0.1	156	5
1615	25.5	49.3	1.75	86	40.5	0.1	162	6

- Note 1. Input Supply Volts = 115 volts ac.
2. All rates are positive.

* Oven temperature measured on external surface of ceramic crystal oven.

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TABLE 2
ELECTRONIC CHRONOMETER
OPERATION AT ROOM TEMPERATURE
(Part 2)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	<u>Input Supply</u>		Bat. Volts dc	<u>Chronometer Time Gained</u>		Rate Millisec. Per 15 min.
			<u>Amps. ac</u>	<u>Watts ac</u>		<u>Sec.</u>	<u>Millisec.</u>	
0800	27.5	50.2	1.65	81	40.0	1.5	15	
0815	27.0	50.0	1.65	80	39.5	1.5	23	8
0830	26.6	50.0	1.70	84	39.5	1.5	28	5
0845	26.6	49.9	1.65	81	39.5	1.5	33	5
0900	26.5	49.8	1.67	82	39.2	1.5	40	7
0915	26.4	49.6	1.70	82	39.0	1.5	47	7
0930	26.0	49.2	1.68	83	39.5	1.5	52	5
0945	26.0	49.0	1.70	84	39.5	1.5	58	6
1000	26.0	49.2	1.69	83	39.0	1.5	64	6
1015	26.0	49.2	1.74	85	39.0	1.5	70	6
1030	26.0	49.3	1.67	83	39.5	1.5	75	5
1045	26.0	49.6	1.75	86	40.0	1.5	81	6
1100	26.0	49.6	1.67	81	40.0	1.5	88	7
1115	26.2	49.9	1.70	83	39.7	1.5	93	5
1130	26.5	50.0	1.70	84	40.0	1.5	99	6
1145	26.6	49.9	1.70	84	40.0	1.6	106	7
1200	26.5	50.0	1.70	83	40.0	1.6	113	7
1215	26.7	49.9	1.70	83	40.0	1.6	119	6
1300	27.0	50.0	1.72	85	40.5	1.6	138	
1315	27.0	50.0	1.70	83	40.2	1.6	144	6
1330	27.0	50.0	1.70	83	40.0	1.6	150	6
1345	27.0	50.0	1.70	84	40.0	1.6	156	6
1400	27.2	50.1	1.76	87	40.0	1.6	162	6
1415	27.2	50.2	1.70	83	40.0	1.6	170	8
1430	27.5	50.0	1.70	83	40.0	1.6	175	5
1445	27.5	50.2	1.70	83	40.2	1.6	181	6
1500	27.0	50.4	1.70	83	40.4	1.6	187	6
1515	27.5	50.4	1.67	83	40.5	1.6	194	7
1530	27.4	50.5	1.70	84	40.5	1.7	200	6
1545	27.0	50.3	1.70	83	40.0	1.7	206	6
1600	27.0	50.3	1.70	84	40.0	1.7	213	7
1615	27.0	50.4	1.75	85	40.2	1.7	220	7

- Note 1. Input Supply Volts = 115 volts ac.
2. All rates are positive.

* Oven temperature measured on external surface of ceramic crystal oven.

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TABLE 3

ELECTRONIC CHRONOMETER
OPERATION AT ROOM TEMPERATURE
(Part 3)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
			Amps. ac	Watts ac		Sec.	Millisec.	
0800	26.0	49.6	1.64	81	40.2	2.0	12	
0815	25.0	48.9	1.90	92	40.0	2.0	17	5
0830	25.2	48.9	1.68	81	39.7	2.0	22	5
0845	24.0	48.2	1.67	81	39.2	2.0	27	5
0900	23.8	47.7	1.73	84	39.5	2.0	31	4
0915	24.0	47.9	1.80	87	39.0	2.0	37	6
0930	24.0	48.0	1.75	84	39.0	2.0	44	7
0945	24.5	48.4	1.70	83	39.0	2.0	48	4
1000	24.0	48.2	1.72	84	39.2	2.0	52	4
1015	24.2	48.5	1.71	83	39.5	2.0	58	6
1030	25.0	48.9	1.70	81	39.2	2.0	62	4
1045	24.8	48.9	1.75	84	39.3	2.0	67	5
1100	24.5	48.6	1.80	87	39.5	2.0	70	3
1115	25.0	48.8	1.76	85	40.0	2.0	75	5
1130	25.0	49.0	1.65	81	40.0	2.0	80	5
1145	25.0	49.0	1.82	89	38.5	2.0	84	4
1200	25.0	49.1	1.81	89	40.0	2.0	90	6
1215	24.0	48.3	1.76	86	40.5	2.0	94	4
1315	25.0	49.0	1.74	85	41.0	2.1	113	
1330	25.0	49.0	1.60	78	40.5	2.1	117	4
1345	25.0	49.2	1.80	88	40.0	2.1	123	6
1400	25.0	49.5	1.74	85	40.0	2.1	126	3
1415	25.0	49.0	1.75	82	39.5	2.1	133	7
1430	24.6	48.9	1.72	83	39.5	2.1	137	4
1445	24.5	48.7	1.68	82	40.0	2.1	141	4
1500	25.0	48.9	1.72	84	40.0	2.1	146	5
1515	25.0	48.9	1.74	83	40.0	2.1	153	7
1530	25.0	49.0	1.70	83	39.0	2.1	161	8
1545	25.0	49.0	1.78	87	40.0	2.1	173**	12
1600	25.0	49.2	1.78	86	40.0	2.1	178	5
1615	25.5	49.2	1.64	88	40.5	2.1	186	8

Note 1. Input Supply Volts = 115 volts ac.

2. All rates are positive.

* Oven temperature measured on external surface of ceramic crystal oven.

** Erratic time increase caused by a local radar pretriggering equipment multivibrators.

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TABLE 4

ELECTRONIC CHRONOMETER

OPERATION AT A 35°C AMBIENT TEMPERATURE

(Part 1)

Time Hours	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min
		Amps. ac	Watts ac		Sec.	Millisec.	
0815	55.0	1.78	86	39.0	0.1	5	
0830	55.0	1.78	86	39.7	0.1	11	6
0845	55.0	1.70	83	40.0	0.1	17	6
0900	55.3	1.74	85	40.0	0.1	22	5
0915	55.0	1.66	81	40.0	0.1	29	7
0930	55.2	1.79	86	40.0	0.1	34	5
0945	55.0	1.71	83	39.8	0.1	41	7
1000	55.0	1.71	83	39.6	0.1	47	6
1015	55.0	1.71	82	39.5	0.1	52	5
1030	55.0	1.72	83	39.5	0.1	58	6
1045	55.0	1.70	83	39.8	0.1	64	6
1100	55.0	1.80	87	39.6	0.1	70	6
1115	55.0	1.73	84	39.5	0.1	75	5
1130	55.0	1.80	87	39.9	0.1	81	6
1145	55.0	1.78	86	40.0	0.1	87	6
1200	55.0	1.88	82	40.0	0.1	93	6
1215	55.2	1.74	84	40.0	0.1	98	5
1300	55.0	1.72	84	40.0	0.2	117	
1315	55.0	1.81	87	40.0	0.2	123	6
1330	55.0	1.80	87	40.0	0.2	128	5
1345	55.0	1.80	86	40.0	0.2	133	5
1400	55.1	1.70	83	40.0	0.2	140	7
1415	55.0	1.75	85	40.0	0.2	145	5
1430	55.0	1.78	86	40.0	0.2	151	6
1445	54.9	1.74	85	40.0	0.2	156	5
1500	55.0	1.76	85	40.0	0.2	163	7
1515	55.0	1.72	84	39.5	0.2	169	6
1530	55.0	1.75	84	39.2	0.2	175	6
1545	55.0	1.74	84	40.0	0.2	181	6
1600	55.0	1.82	88	40.0	0.2	186	5
1615	55.0	1.70	82	40.0	0.2	192	6

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive.

* Oven temperature measured on external surface of ceramic crystal oven.

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TABLE 5

ELECTRONIC CHRONOMETER

OPERATION AT A 35°C AMBIENT TEMPERATURE

(Part 2)

Time Hours	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
		Amps. ac	Watts ac		Sec.	Millisec.	
0800	55.0	1.64	80	40.2	0.9	4	
0815	55.0	1.78	86	39.5	0.9	11	7
0830	55.0	1.68	81	40.0	0.9	17	6
0845	55.0	1.70	83	39.2	0.9	23	6
0900	54.9	1.75	85	39.5	0.9	29	6
0915	55.0	1.70	82	40.0	0.9	37	8
0930	55.0	1.73	84	40.0	0.9	42	5
0945	55.0	1.70	82	40.0	0.9	48	6
1000	55.0	1.70	83	40.0	0.9	55	7
1015	55.0	1.71	83	40.0	0.9	61	6
1030	55.0	1.68	82	40.0	0.9	67	6
1045	55.0	1.76	86	40.0	0.9	73	6
1100	55.0	1.72	84	39.5	0.9	78	5
1115	55.0	1.80	88	40.0	0.9	84	6
1130	55.0	1.79	87	40.0	0.9	90	6
1145	55.0	1.73	84	40.0	0.9	96	6
1200	55.0	1.76	86	40.5	1.0	101	5
1215	55.0	1.71	83	40.0	1.0	106	5
1245	55.0	1.70	83	40.0	1.0	117	
1300	55.0	1.78	86	40.0	1.0	121	4
1315	55.0	1.76	86	39.2	1.0	127	6
1330	55.0	1.79	82	39.0	1.0	132	5
1345	55.0	1.70	83	39.5	1.0	138	6
1400	55.0	1.71	83	39.5	1.0	142	4
1415	55.0	1.69	82	39.2	1.0	147	5
1430	55.0	1.70	83	39.0	1.0	151	4
1445	55.0	1.68	81	39.1	1.0	157	6
1500	55.0	1.70	82	39.5	1.0	161	4
1515	55.0	1.69	81	39.5	1.0	165	4
1530	55.0	1.68	82	39.0	1.0	170	5
1545	55.0	1.69	82	39.5	1.0	175	5
1600	55.0	1.69	82	39.0	1.0	180	5
1615	55.0	1.74	84	39.8	1.0	186	6

Note 1. Input Supply Volts = 115 volts ac.

2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 6

ELECTRONIC CHRONOMETER

OPERATION AT A 35°C AMBIENT TEMPERATURE

(Part 3)

Time Hours	Oven Temp.* °C	Input Amps. ac	Supply Watts ac	Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
					Sec.	Millisec.	
0800	55.0	1.70	80	40.0	1.3	3	
0815	55.0	1.76	86	39.1	1.3	9	6
0830	55.0	1.71	82	39.5	1.3	15	6
0845	55.0	1.74	83	39.5	1.3	22	7
0900	55.0	1.71	83	39.5	1.3	28	6
0915	55.0	1.72	83	39.5	1.3	33	5
0930	55.0	1.76	86	39.5	1.3	39	6
0945	55.0	1.73	84	40.0	1.3	44	5
1000	55.0	1.80	87	40.0	1.3	50	6
1015	55.0	1.73	84	40.0	1.3	56	6
1030	55.0	1.68	82	39.7	1.3	62	6
1045	55.0	1.72	83	39.5	1.3	66	4
1100	55.0	1.77	86	39.7	1.3	71	5
1115	55.0	1.75	85	39.5	1.3	78	7
1130	55.0	1.80	88	40.0	1.3	83	5
1145	55.0	1.71	83	40.0	1.3	89	6
1200	55.0	1.64	80	40.1	1.3	95	6
1215	55.0	1.75	84	39.3	1.4	100	5
1300	55.0	1.75	85	39.5	1.4	117	
1315	55.0	1.74	84	40.0	1.4	123	6
1330	55.0	1.73	84	40.0	1.4	128	5
1345	55.0	1.71	83	40.0	1.4	133	5
1400	55.0	1.70	83	40.0	1.4	139	6
1415	55.0	1.73	84	40.0	1.4	145	6
1430	55.0	1.71	83	40.0	1.4	150	5
1445	55.0	1.71	83	40.0	1.4	156	6
1500	55.0	1.73	85	40.0	1.4	162	6
1515	55.0	1.74	85	40.0	1.4	168	6
1530	55.0	1.80	88	40.0	1.4	175	7
1545	55.0	1.84	90	40.0	1.4	180	5
1600	55.0	1.82	87	40.0	1.4	187	7
1615	55.0	1.84	89	40.5	1.4	193	6

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 7

ELECTRONIC CHRONOMETER

OPERATION AT A 50°C AMBIENT TEMPERATURE

(Part 1)

Time Hours	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
		Amps. ac	Watts ac		Sec.	Millisec.	
0815	57.5	1.70	83	38.5	2.2	3	
0830	59.7	1.70	83	39.0	2.2	12	9
0845	59.9	1.66	81	39.5	2.2	20	8
0900	60.0	1.69	82	39.1	2.2	28	8
0915	60.0	1.68	82	39.0	2.2	37	9
0930	60.1	1.65	80	39.3	2.2	45	8
0945	60.0	1.74	85	39.1	2.2	53	8
1000	60.0	1.66	81	39.1	2.2	61	8
1015	60.0	1.73	84	39.0	2.2	68	7
1030	60.0	1.70	83	39.3	2.2	75	7
1045	60.0	1.70	82	39.0	2.2	83	8
1100	60.0	1.71	83	39.0	2.2	92	9
1115	60.0	1.69	82	39.0	2.3	100	8
1130	60.0	1.71	83	39.3	2.3	106	6
1145	60.0	1.60	78	39.5	2.3	115	9
1200	60.0	1.64	81	39.0	2.3	123	8
1215	60.0	1.70	83	39.2	2.3	130	7
1300	60.0	1.74	84	39.0	2.3	153	
1315	60.0	1.67	82	39.5	2.3	162	9
1330	60.0	1.68	82	39.5	2.3	170	8
1345	60.0	1.70	83	39.4	2.3	178	8
1400	60.0	1.70	83	39.3	2.3	184	6
1415	60.0	1.68	82	39.2	2.3	192	8
1430	60.0	1.74	84	39.0	2.4	200	8
1445	60.0	1.68	82	39.5	2.4	207	7
1500	60.0	1.70	83	39.4	2.4	215	8
1515	60.0	1.68	82	39.5	2.4	222	7
1530	60.0	1.56	76	40.0	2.4	231	9
1545	60.0	1.67	82	39.4	2.4	238	7
1600	60.0	1.69	83	39.5	2.4	246	8
1615	60.0	1.67	82	39.0	2.4	253	7

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 8

ELECTRONIC CHRONOMETER

OPERATION AT A 50°C AMBIENT TEMPERATURE

(Part 2)

Time Hours	Oven Temp.* °C	<u>Input Supply</u>		Bat. Volts dc	<u>Chronometer Time Gained</u>		Rate Millisec. Per 15 min.
		<u>Amps.</u> ac	<u>Watts</u> ac		<u>Sec.</u>	<u>Millisec.</u>	
0800	59.5	1.64	80	39.5	2.9	5	
0815	60.0	1.67	82	39.4	2.9	13	8
0830	60.0	1.71	83	39.2	2.9	22	9
0845	60.1	1.63	80	39.6	2.9	30	8
0900	60.0	1.69	83	39.1	2.9	37	7
0915	60.0	1.71	84	39.1	2.9	45	8
0930	60.0	1.66	81	39.5	2.9	53	8
0945	60.0	1.66	81	39.0	2.9	59	6
1000	60.0	1.68	82	39.0	2.9	67	8
1015	60.0	1.68	82	39.0	2.9	75	8
1030	60.0	1.69	83	39.0	2.9	83	8
1045	60.0	1.74	85	39.0	2.9	90	7
1100	60.0	1.66	81	39.5	2.9	97	7
1115	60.0	1.71	83	39.2	3.0	102	5
1130	60.0	1.70	83	39.8	3.0	108	6
1145	60.0	1.71	83	39.9	3.0	114	6
1200	60.0	1.71	83	40.0	3.0	121	7
1215	60.0	1.60	78	39.7	3.0	128	7
1245	60.0	1.71	83	39.2	3.0	140	
1300	60.0	1.68	82	39.3	3.0	148	8
1315	60.0	1.71	83	39.2	3.0	155	7
1330	60.0	1.75	84	39.4	3.0	162	7
1345	60.1	1.68	82	39.5	3.0	168	6
1400	60.1	1.70	82	39.5	3.0	175	7
1415	60.0	1.67	81	39.4	3.0	181	6
1430	60.0	1.71	84	39.5	3.0	189	8
1445	60.0	1.71	84	40.0	3.0	195	6
1500	60.1	1.66	81	40.7	3.1	202	7
1515	60.0	1.69	82	39.3	3.1	208	6
1530	60.0	1.68	82	39.4	3.1	215	7
1545	60.0	1.63	80	39.7	3.1	223	8
1600	60.0	1.67	82	39.5	3.1	230	7
1615	60.0	1.70	83	39.5	3.1	237	7

- Note 1. Input Supply Volts = 115 volts ac.
2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 9

ELECTRONIC CHRONOMETER

OPERATION AT A 50°C AMBIENT TEMPERATURE

(Part 3)

Time Hours	Oven Temp.* °C	<u>Input Supply</u>		Bat. Volts dc	<u>Chronometer Time Gained</u>		Rate Millisec. Per 15 min.
		<u>Amps.</u> ac	<u>Watts</u> ac		<u>Sec.</u>	<u>Millisec.</u>	
0815	60.1	1.66	81	39.2	3.6	8	
0830	60.0	1.67	82	39.0	3.6	15	7
0845	60.0	1.73	84	39.0	3.6	21	6
0900	60.0	1.66	81	39.3	3.6	33	12
0915	60.0	1.64	80	39.5	3.6	39	6
0930	60.0	1.73	84	39.1	3.6	45	6
0945	60.0	1.64	80	39.5	3.6	51	6
1000	60.0	1.70	83	39.5	3.6	58	7
1015	60.0	1.72	84	39.0	3.6	65	7
1030	60.0	1.69	83	39.0	3.6	70	5
1045	60.0	1.69	82	39.5	3.6	77	7
1100	60.0	1.69	82	39.3	3.6	83	6
1115	60.0	1.67	81	39.0	3.6	90	7
1130	60.0	1.70	83	39.2	3.6	95	5
1145	60.0	1.62	79	39.5	3.7	101	6
1200	60.0	1.66	81	39.4	3.7	108	7
1215	60.0	1.70	83	39.0	3.7	115	7
1230	60.0	1.62	79	40.0	3.7	123	8
1245	60.0	1.67	82	39.0	3.7	129	6
1300	60.0	1.67	82	39.0	3.7	137	8
1315	60.0	1.73	84	39.0	3.7	145	8
1330	60.0	1.70	83	39.5	3.7	153	8
1345	60.0	1.75	86	39.3	3.7	162	9
1400	60.0	1.67	82	39.5	3.7	170	8
1415	60.0	1.69	83	39.5	3.7	178	8
1430	60.0	1.68	82	39.0	3.7	183	5
1445	60.0	1.68	82	39.5	3.7	192	9
1500	60.0	1.65	80	39.6	3.7	198	6
1515	60.0	1.70	83	39.1	3.8	206	8
1530	60.1	1.70	83	39.4	3.8	215	9
1545	60.1	1.66	81	39.5	3.8	223	8
1600	60.0	1.66	81	39.4	3.8	231	8
1615	60.0	1.65	81	39.5	3.8	237	6

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 10

ELECTRONIC CHRONOMETER

OPERATION AT A 0°C AMBIENT TEMPERATURE

Time Hours	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
		Amps. ac	Watts ac		Sec.	Millisec.	
0930	41.5	1.86	90	40.0	4.2	9	
0945	40.5	1.77	86	39.5	4.2	15	6
1000	40.5	1.86	90	40.0	4.2	22	7
1015	40.6	1.86	90	40.2	4.2	30	8
1030	40.5	1.90	92	40.0	4.2	38	8
1045	40.3	1.84	89	40.4	4.2	45	7
1100	40.4	1.78	86	40.0	4.2	50	5
1115	40.2	1.87	90	40.5	4.2	57	7
1130	40.4	1.70	83	40.8	4.2	64	7
1145	40.3	1.86	89	40.4	4.2	70	6
1200	40.4	1.89	90	40.5	4.2	76	6
1215	40.5	1.76	85	40.5	4.2	81	5
1230	40.6	1.71	83	40.7	4.2	86	5
1245	40.6	1.82	87	40.4	4.2	92	6
1300	40.5	1.75	84	40.0	4.2	99	7
1315	40.5	1.89	91	40.5	4.3	105	6
1330	40.5	1.83	88	40.0	4.3	112	7
1345	40.5	1.85	89	40.5	4.3	117	5
1400	40.2	1.86	91	40.5	4.3	123	6
1415	40.5	1.80	87	40.0	4.3	128	5
1430	40.5	1.94	94	40.3	4.3	135	7
1445	40.5	1.76	84	40.8	4.3	142	7
1500	40.5	1.78	86	40.5	4.3	148	6
1515	40.5	1.90	92	40.5	4.3	156	8
1530	40.4	1.86	90	40.5	4.3	162	6
1545	40.5	1.78	86	40.8	4.3	169	7
1600	40.5	1.75	84	40.4	4.3	175	6
1615	40.5	1.90	91	40.5	4.3	181	6

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 11

ELECTRONIC CHRONOMETER
EFFECT OF AMBIENT TEMPERATURE VARIATION
(Part 1)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
			Amps. ac	Watts ac		Sec.	Millisec.	
0845	50.0	58.5	1.68	82	39.2	4.8	8	
0900	50.0	59.6	1.71	83	39.0	4.8	14	6
0915	50.0	59.8	1.71	83	39.1	4.8	20	6
0930	50.0	60.0	1.63	80	39.4	4.8	25	5
0945	50.0	60.0	1.68	82	39.5	4.8	29	4
1000	50.0	60.0	1.67	82	39.2	4.8	33	4
1015	47.5	59.0	1.73	84	39.5	4.8	37	4
1030	45.0	58.0	1.68	82	39.4	4.8	37	0
1045	42.5	57.1	1.67	82	39.2	4.8	34	-3
1100	40.0	56.2	1.76	86	39.0	4.8	31	-3
1115	37.5	55.3	1.70	83	39.3	4.8	30	-1
1130	35.0	54.3	1.71	83	39.3	4.8	28	-2
1145	32.5	53.3	1.67	82	39.7	4.8	27	-1
1200	30.0	52.5	1.68	82	39.6	4.8	31	4
1215	27.5	51.5	1.74	85	39.5	4.8	40	9
1230	25.0	50.5	1.73	85	39.5	4.8	46	6
1245	22.5	49.2	1.77	86	39.5	4.8	54	8
1300	20.0	48.6	1.83	89	39.5	4.8	62	8
1315	17.5	47.5	1.76	86	39.8	4.8	68	6
1330	15.0	46.3	1.80	87	40.0	4.8	74	6
1345	12.5	45.6	1.89	91	40.0	4.8	81	7
1400	10.0	44.2	1.84	89	40.0	4.8	89	8
1415	7.5	43.5	1.85	89	40.0	4.8	98	9
1430	5.0	42.5	1.72	83	40.5	4.9	103	5
1445	2.5	41.4	1.75	85	40.0	4.9	110	7
1500	0.0	40.5	1.78	86	40.4	4.9	115	5
1515	0.0	40.0	1.85	89	40.3	4.9	121	6
1530	0.0	40.0	1.87	90	40.0	4.9	125	4
1545	0.0	40.0	1.81	87	40.5	4.9	128	3
1600	0.0	40.0	1.76	85	40.5	4.9	133	5
1615	0.0	40.0	1.90	92	40.5	4.9	137	4

- Note 1. Input Supply Volts = 115 volts ac.
2. All rates are positive except where indicated otherwise.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 12

ELECTRONIC CHRONOMETER
EFFECT OF AMBIENT TEMPERATURE VARIATION
(Part 2)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
			Amps. ac	Watts ac		Sec.	Millisec.	
0830	0.0	42.5	1.83	88	39.2	5.0	0	
0845	0.0	40.5	1.84	89	39.8	5.0	0	0
0900	0.0	40.5	1.75	85	40.5	5.0	1	1
0915	0.0	40.0	1.88	90	40.4	5.0	7	6
0930	0.0	40.0	1.88	90	40.0	5.0	17	10
0945	0.0	40.0	1.87	90	40.0	5.0	24	7
1000	2.5	40.7	1.85	89	40.0	5.0	32	8
1015	5.0	41.6	1.79	86	40.4	5.0	40	8
1030	7.5	42.8	1.88	90	40.4	5.0	46	6
1045	10.0	43.6	1.79	84	40.0	5.0	50	4
1100	12.5	44.8	1.90	91	40.0	5.0	57	7
1115	15.0	45.9	1.71	82	40.2	5.0	61	4
1130	17.5	46.6	1.74	84.5	40.5	5.0	65	4
1145	20.0	47.9	1.72	83	40.5	5.0	70	5
1200	22.5	49.0	1.73	84	40.0	5.0	75	5
1215	25.0	50.0	1.73	84	40.2	5.0	78	3
1230	27.5	51.0	1.80	87	40.0	5.0	81	3
1245	30.0	52.0	1.73	83	39.7	5.0	87	6
1300	32.5	52.8	1.78	86	39.7	5.0	90	3
1315	35.0	53.9	1.66	80	39.6	5.0	95	5
1330	37.5	54.9	1.84	90	39.7	5.0	98	3
1345	40.0	56.0	1.77	86	39.5	5.1	102	4
1400	42.5	56.9	1.73	84	39.5	5.1	105	3
1415	45.0	58.0	1.77	86	39.6	5.1	109	4
1430	47.5	58.8	1.70	83	39.5	5.1	112	3
1445	50.0	60.0	1.68	82	39.5	5.1	115	3
1500	50.0	60.0	1.66	81	39.5	5.1	118	3
1515	50.0	60.0	1.65	80	39.6	5.1	123	5
1530	50.0	60.0	1.69	83	39.5	5.1	131	8
1545	49.6	60.0	1.77	86	39.4	5.1	138	7
1600	50.0	60.0	1.67	82	39.5	5.1	146	8

- Note 1. Input Supply Volts = 115 volts ac.
2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 13

ELECTRONIC CHRONOMETER

EFFECT OF AMBIENT TEMPERATURE VARIATION

(Part 3)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
			Amps. ac	Watts ac		Sec.	Millisec.	
0915	25.0	50.0	1.80	87	39.2	5.7	3	
0930	25.0	50.0	1.72	84	39.5	5.7	3	0
0945	25.0	50.0	1.74	85	40.0	5.7	1	-2
1000	25.0	50.0	1.80	87	39.6	5.7	0	-1
1015	25.0	50.0	1.70	83	39.6	5.7	3	3
1030	25.0	50.0	1.73	84	39.9	5.7	12	9
1045	25.0	50.0	1.73	84	39.9	5.7	20	8
1100	25.0	50.0	1.72	83	39.8	5.7	26	6
1115	20.0	49.5	1.81	88	40.0	5.7	33	7
1130	20.0	48.6	1.83	89	40.0	5.7	41	8
1145	20.0	48.5	1.68	82	40.5	5.7	48	7
1200	20.1	48.6	1.69	82	40.3	5.7	55	7
1215	30.0	51.2	1.69	82	40.2	5.7	62	7
1230	30.0	51.9	1.79	86	40.2	5.7	67	5
1245	30.0	51.8	1.93	94	39.5	5.7	73	6
1300	30.0	51.9	1.65	80	40.5	5.7	77	4
1315	30.0	51.9	1.73	84	39.7	5.7	80	3
1330	30.0	52.0	1.72	84	39.7	5.7	83	3
1345	35.0	53.5	1.74	85	39.5	5.7	87	4
1400	35.0	53.8	1.76	86	39.5	5.7	89	2
1415	35.0	54.0	1.74	85	39.7	5.7	91	2
1430	35.0	54.0	1.63	80	40.0	5.7	95	4
1445	35.0	54.0	1.73	84	40.0	5.7	98	3
1500	25.0	52.0	1.79	87	40.0	5.8	101	3
1515	25.0	50.0	1.74	85	39.5	5.8	105	4
1530	25.0	50.0	1.69	83	40.0	5.8	108	3
1545	25.0	50.0	1.74	85	39.5	5.8	113	5
1600	25.0	50.0	1.72	84	40.0	5.8	117	4

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive except where indicated otherwise.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 14

ELECTRONIC CHRONOMETER
EFFECT OF AMBIENT TEMPERATURE VARIATION
(Part 4)

Time Hours	Amb. Temp. °C	Oven Temp.* °C	Input Supply		Bat. Volts dc	Chronometer Time Gained		Rate Millisec. Per 15 min.
			Amps. ac	Watts ac		Sec	Millisec.	
0830	22.7	48.5	1.69	83	39.5	5.9	15	
0845	30.0	49.8	1.70	83	39.5	5.9	19	4
0900	32.4	51.3	1.68	82	39.5	5.9	23	4
0915	36.0	54.6	1.70	83	39.5	5.9	26	3
0930	47.5	57.3	1.68	83	39.5	5.9	26	0
0945	50.0	59.5	1.70	83	39.5	5.9	24	-2
1000	50.2	59.7	1.66	81	39.5	5.9	21	-3
1015	50.0	60.0	1.71	83	39.0	5.9	19	-2
1030	50.0	59.9	1.66	81	39.5	5.9	19	0
1045	50.5	60.4	1.67	82	39.5	5.9	17	-2
1100	50.0	59.8	1.68	83	39.5	5.9	14	-3
1115	50.0	60.0	1.67	82	39.2	5.9	13	-1
1130	50.0	60.0	1.64	81	39.5	5.9	12	-1
1145	50.0	59.8	1.67	82	39.0	5.9	11	-1
1200	50.0	59.8	1.65	81	39.5	5.9	13	2
1215	50.0	59.8	1.66	81	39.2	5.9	16	3
1230	50.0	59.7	1.68	82	39.5	5.9	20	4
1245	29.0	54.5	1.74	85	39.0	5.9	24	4
1300	20.0	50.5	1.70	83	39.0	5.9	23	-1
1315	20.0	48.8	1.72	84	39.5	5.9	21	-2
1330	25.0	49.4	1.69	83	39.5	5.9	19	-2
1345	25.0	49.4	1.70	83	39.5	5.9	18	-1
1400	40.0	56.0	1.77	86	39.0	5.9	25	7
1415	21.0	50.0	1.77	86	39.2	5.9	30	5
1430	19.4	47.5	1.76	86	39.5	5.9	36	6
1445	20.0	47.0	1.71	83	40.2	5.9	41	5
1500	50.0	57.0	1.74	85	39.5	5.9	45	4
1515	50.0	57.0	1.71	83	39.5	5.9	50	5
1530	50.2	60.0	1.70	83	39.7	5.9	53	3
1545	50.0	59.7	1.64	80	39.7	5.9	50	-3
1600	50.0	60.0	1.69	82	39.5	5.9	49	-1
1615	50.0	59.8	1.64	81	39.5	5.9	48	-1

- Note 1. Input Supply Volts = 115 volts ac.
2. All rates are positive except where indicated otherwise.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 15

ELECTRONIC CHRONOMETER

EFFECT OF HUMIDITY VARIATION AT 40°C AMBIENT TEMPERATURE

Time Hours	Rel. Hum. %	Oven Temp.* °C	<u>Input Supply</u>		Bat. Volts ac	<u>Chronometer Time Gained</u>		Rate Millisec. Per 15 min.
			<u>Amps.</u> ac	<u>Watts</u> ac		<u>Sec.</u>	<u>Millisec.</u>	
0915	40	56.5	1.72	83	40.1	0.4	28	
0930	33	58.6	1.66	81	40.0	0.4	34	6
0945	29	59.2	1.70	83	40.1	0.4	43	9
1000	29	59.5	1.70	83	40.0	0.4	50	7
1015	29	59.6	1.70	83	40.0	0.4	62	12
1030	29	59.5	1.71	83	39.8	0.4	67	5
1045	97	59.5	1.68	82	40.0	0.4	76	9
1100	97	59.6	1.71	83	40.0	0.4	86	10
1115	97	59.7	1.71	83	40.0	0.4	93	7
1130	97	59.7	1.72	84	40.2	0.5	102	9
1145	97	59.7	1.72	84	40.2	0.5	111	9
1200	97	59.7	1.69	83	40.5	0.5	120	9
1215	97	59.7	1.71	83	39.6	0.5	130	10
1230	97	59.7	1.67	81	40.5	0.5	140	10
1245	97	59.7	1.74	85	40.0	0.5	148	8
1300	29	59.7	1.70	83	40.0	0.5	157	9
1315	29	59.7	1.70	83	40.0	0.5	166	9
1330	29	59.7	1.80	87	40.0	0.5	175	9
1345	29	59.7	1.72	83	40.0	0.5	184	9

- Note 1. Input Supply Volts = 115 volts ac.
 2. All rates are positive.

* Oven temperature was measured on external surface of ceramic crystal oven.

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TABLE 16

ELECTRONIC CHRONOMETER

VARIATION IN AMBIENT TEMPERATURE - SUMMARY

Table No.	Temp. °C	Rate in Milliseconds/Hour			Equivalent Rate for 24 hrs. (Seconds) (Note c)		
		Average for test period (Note a)	Maximum during test period (Note b)	Minimum during test period (Note b)	Average	Maximum	Minimum
1	23 to 25	21.3	21.3*	21.3*	0.522	0.522	0.522
2	26 to 27	24.9	24.9*	24.9*	0.597	0.597	0.597
3	24 to 26	19.2	22.7	16.2	0.460	0.546	0.388
4	35	23.4	23.4*	23.4*	0.560	0.560	0.560
5	35	22.0	27.0	17.0	0.528	0.648	0.480
6	35	25.3	25.3*	25.3*	0.607	0.607	0.607
7	50	31.3	31.3*	31.3*	0.750	0.750	0.750
8	50	27.2	34.5	25.1	0.652	0.828	0.602
9	50	28.6	31.7	22.7	0.687	0.760	0.547
10	0	25.3	31.0	24.1	0.607	0.743	0.580

* Variation in rate was too small to measure with available apparatus.

Note a. Average rate is based on time gained during test period (7 to 8 hours).

b. Maximum and minimum rates were obtained by graphical differentiation of data on tables 1 to 10.

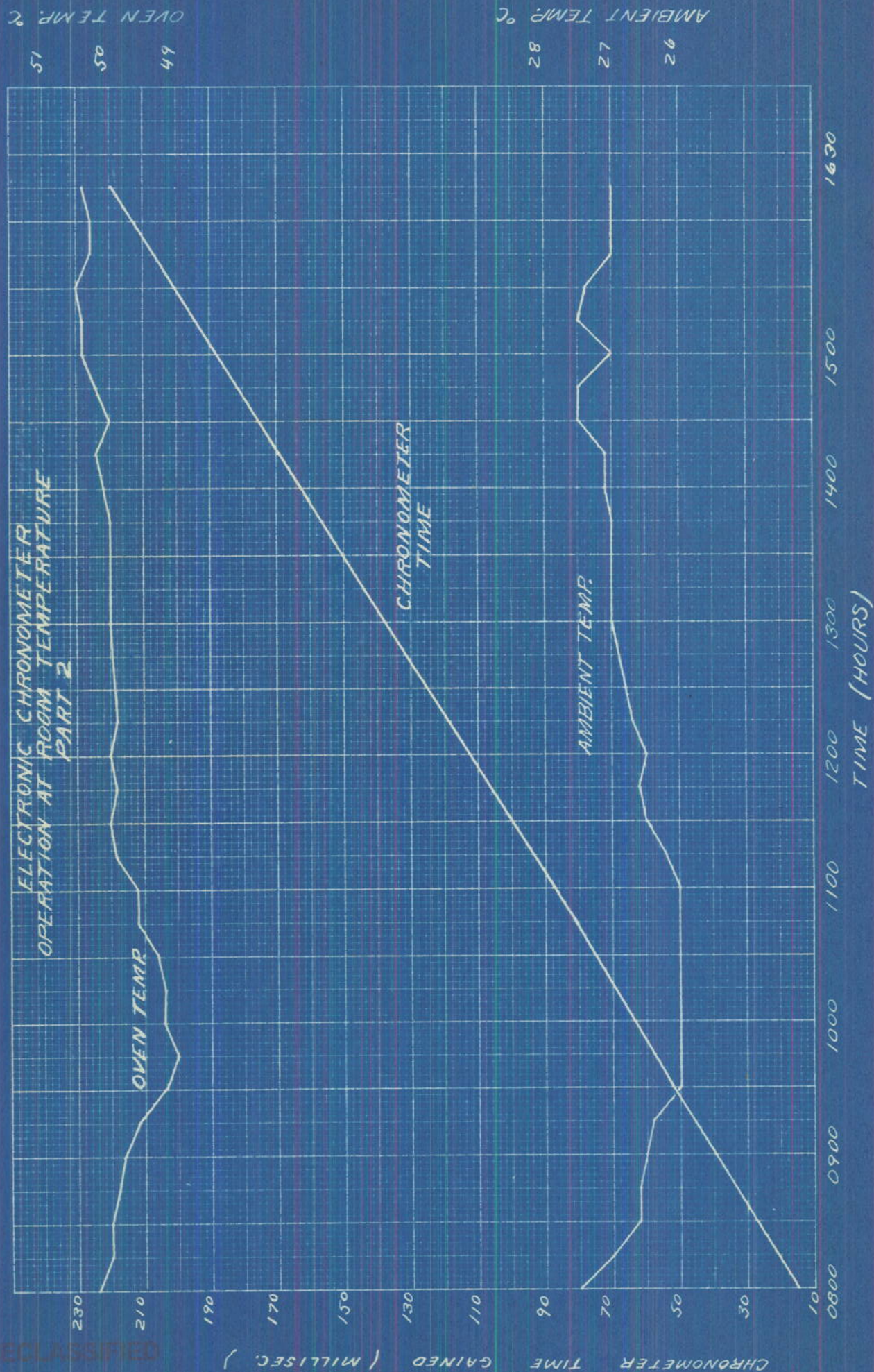
c. Equivalent rate for 24 hours = (Rate In Milliseconds/Hour) (24/1000)

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CHRONOMETER TIME GAINED (MILLISEC.)

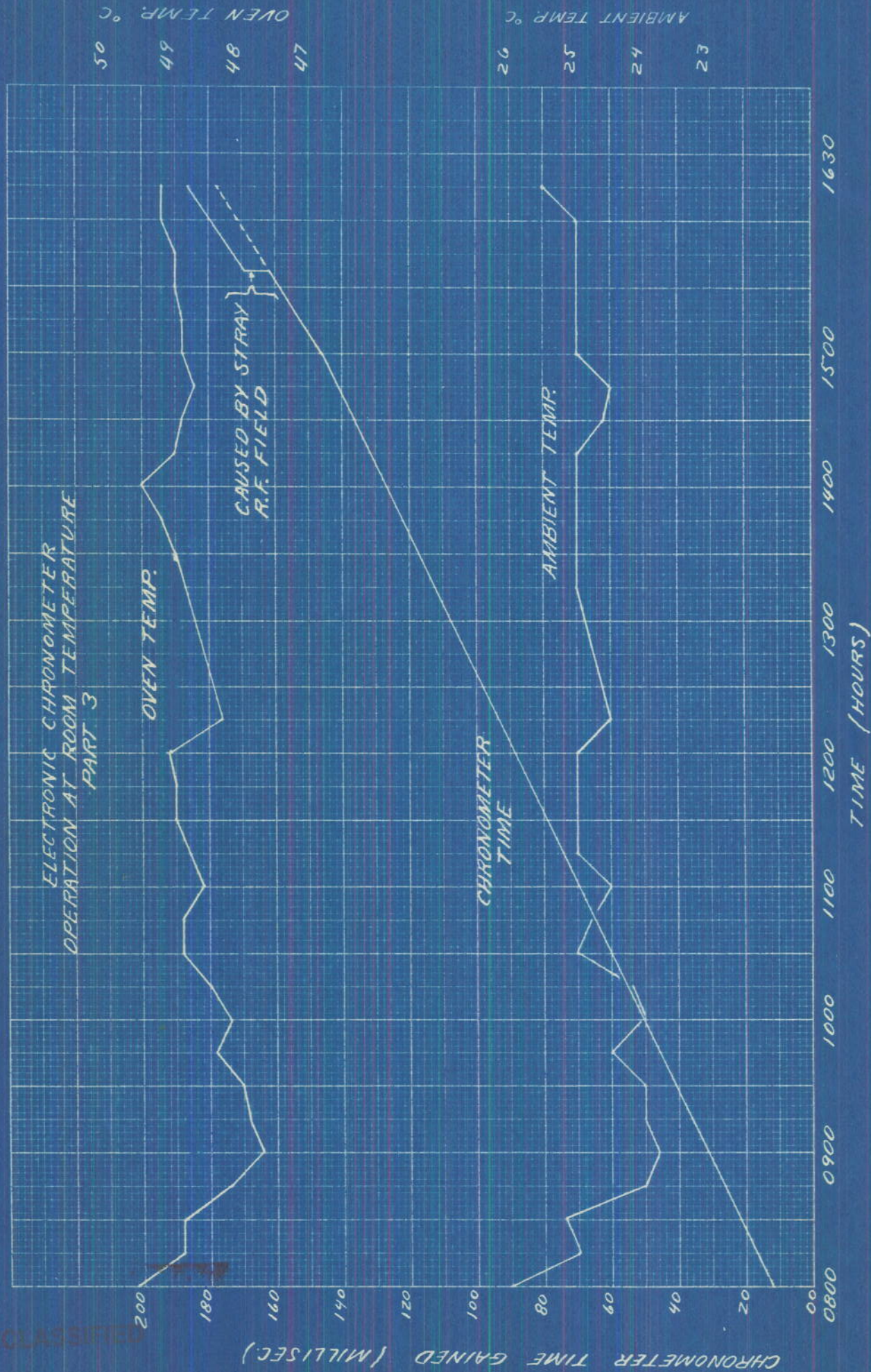


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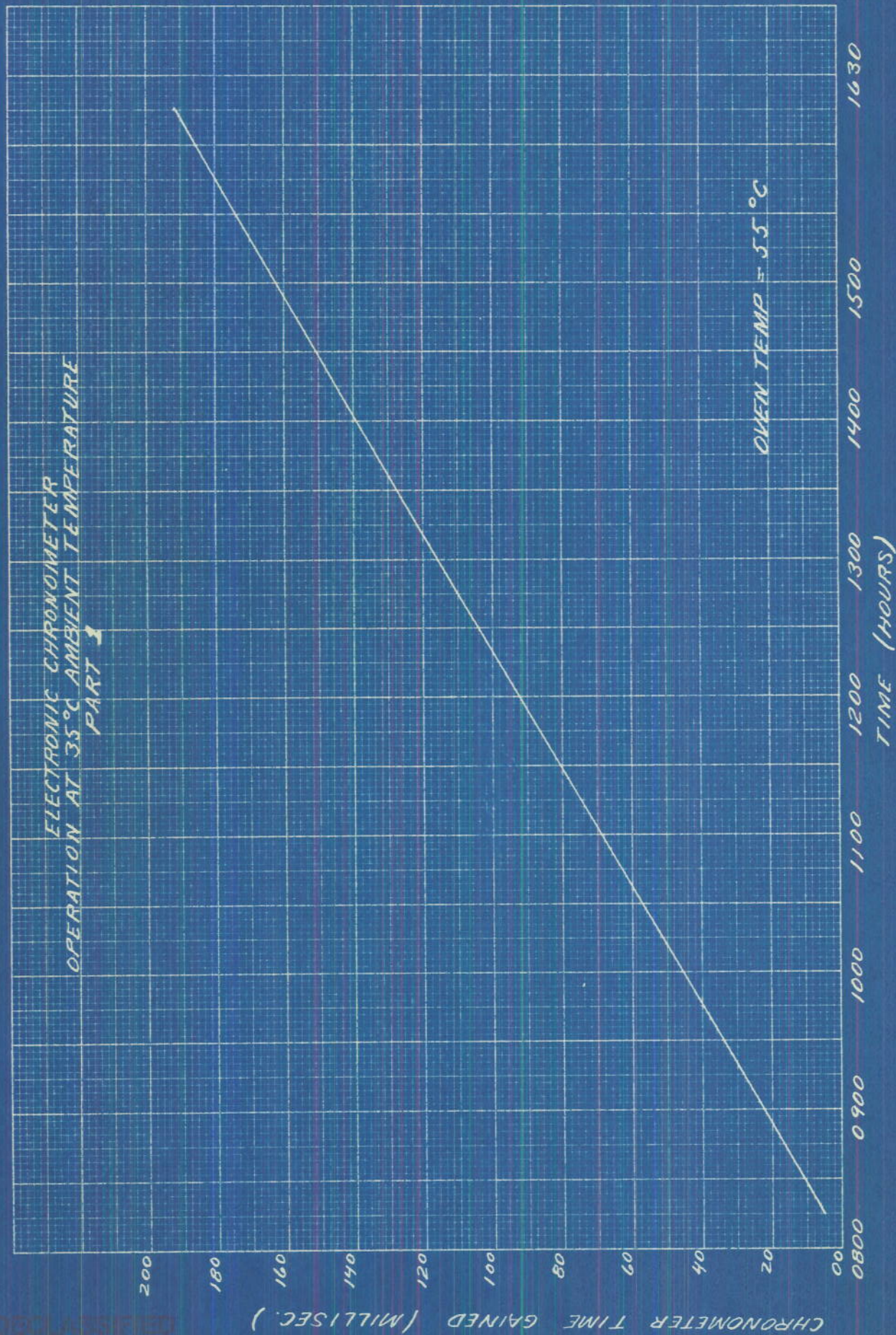


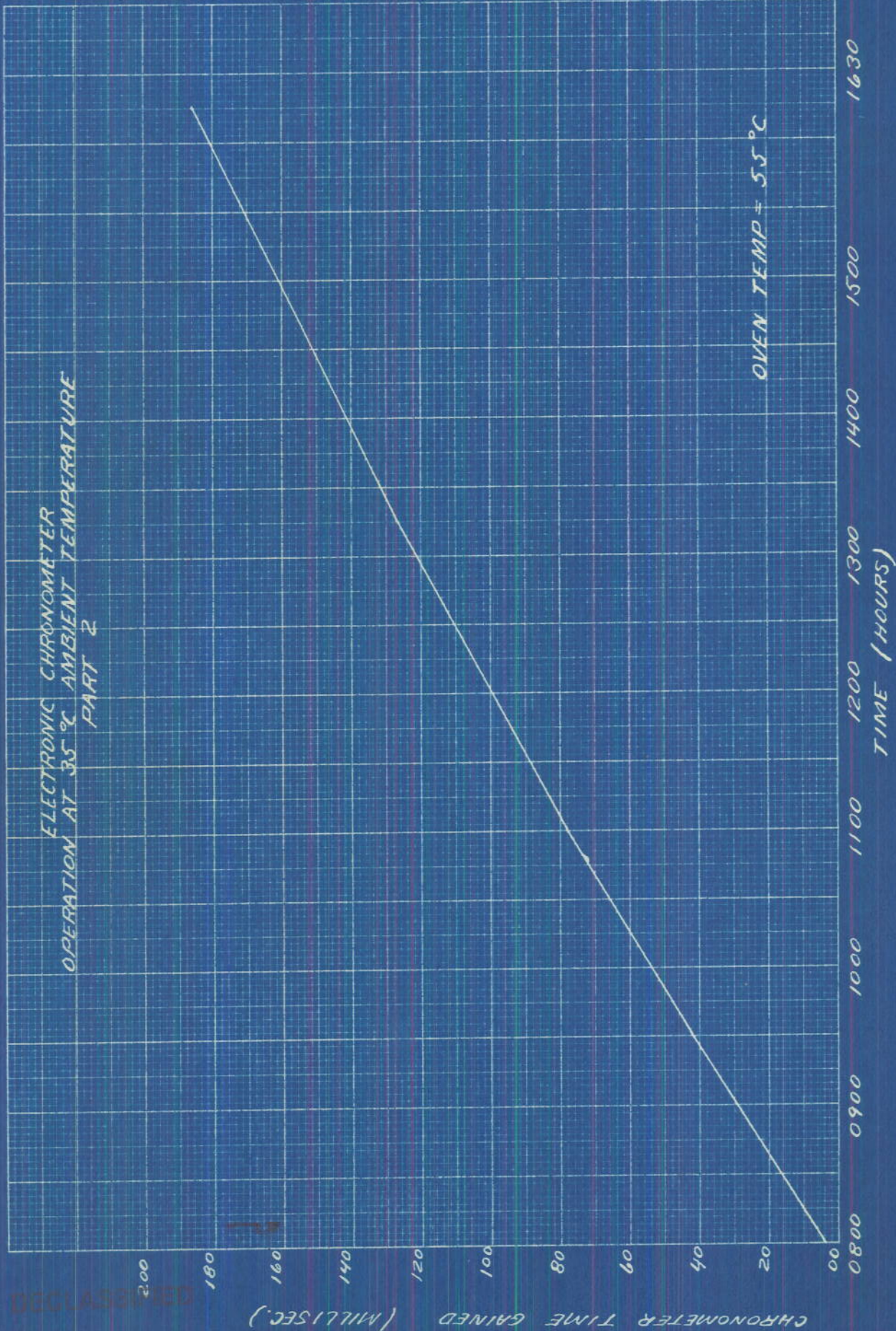
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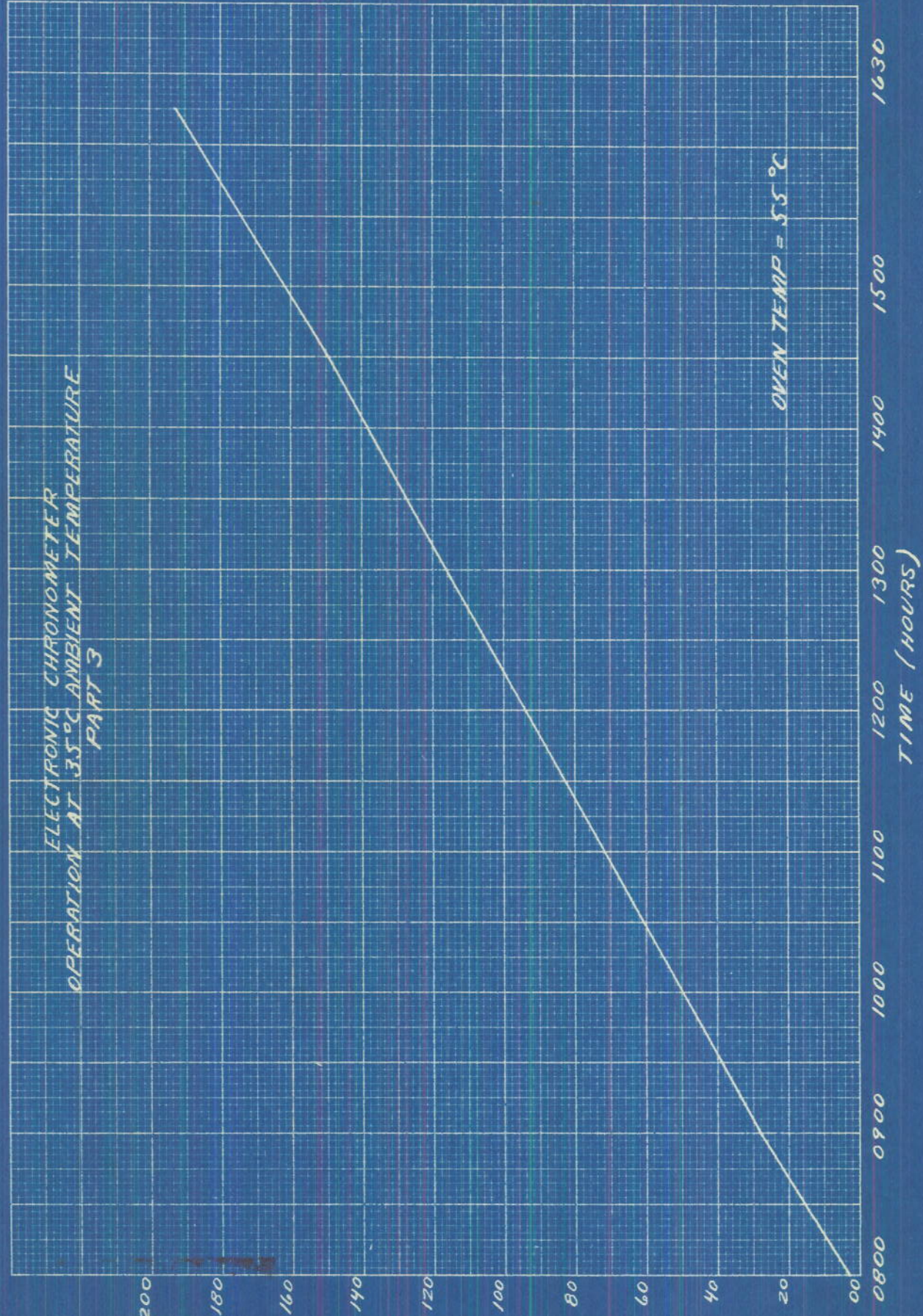






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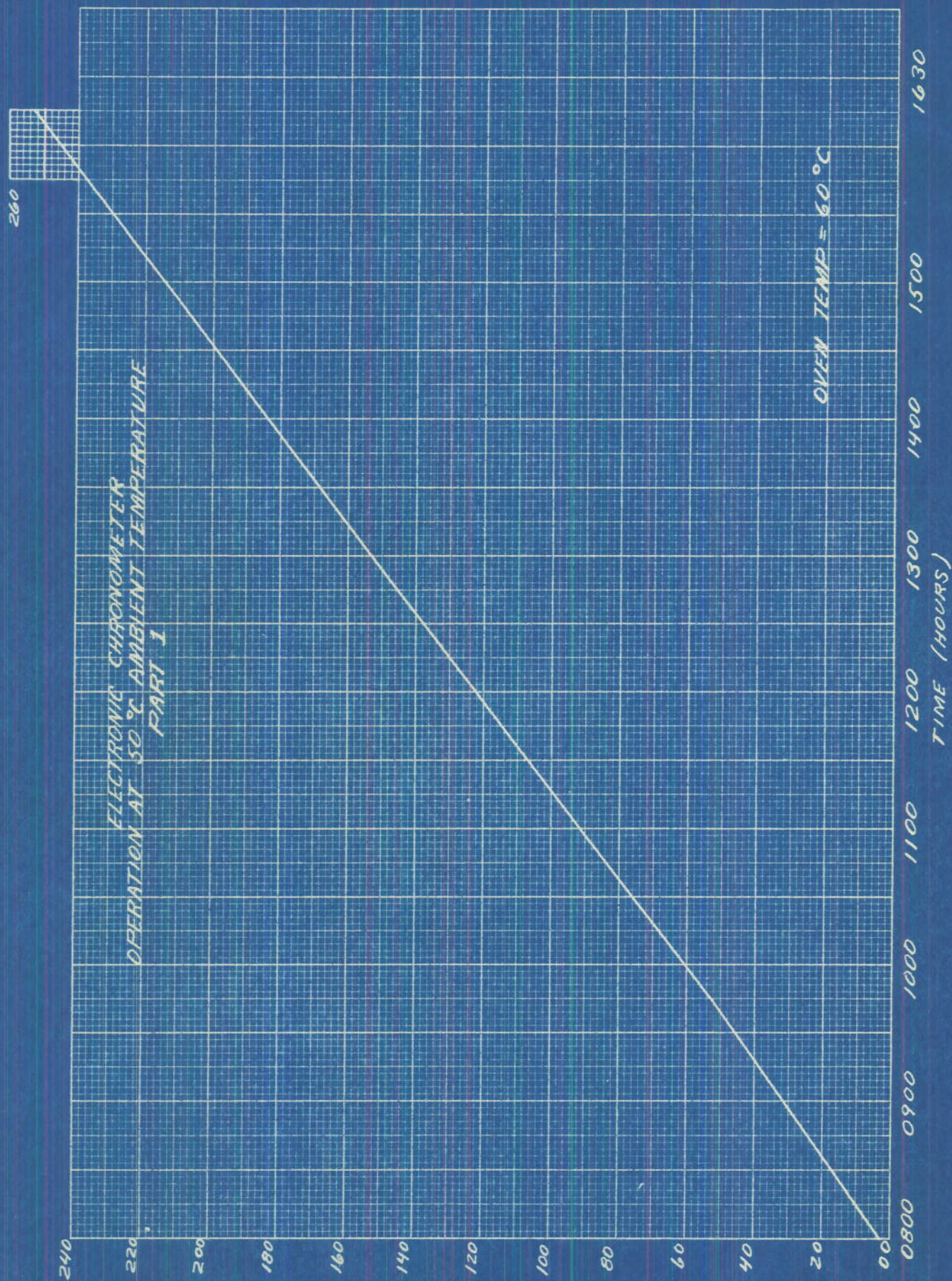
CHRONOMETER TIME GAINED (MILLISEC.)





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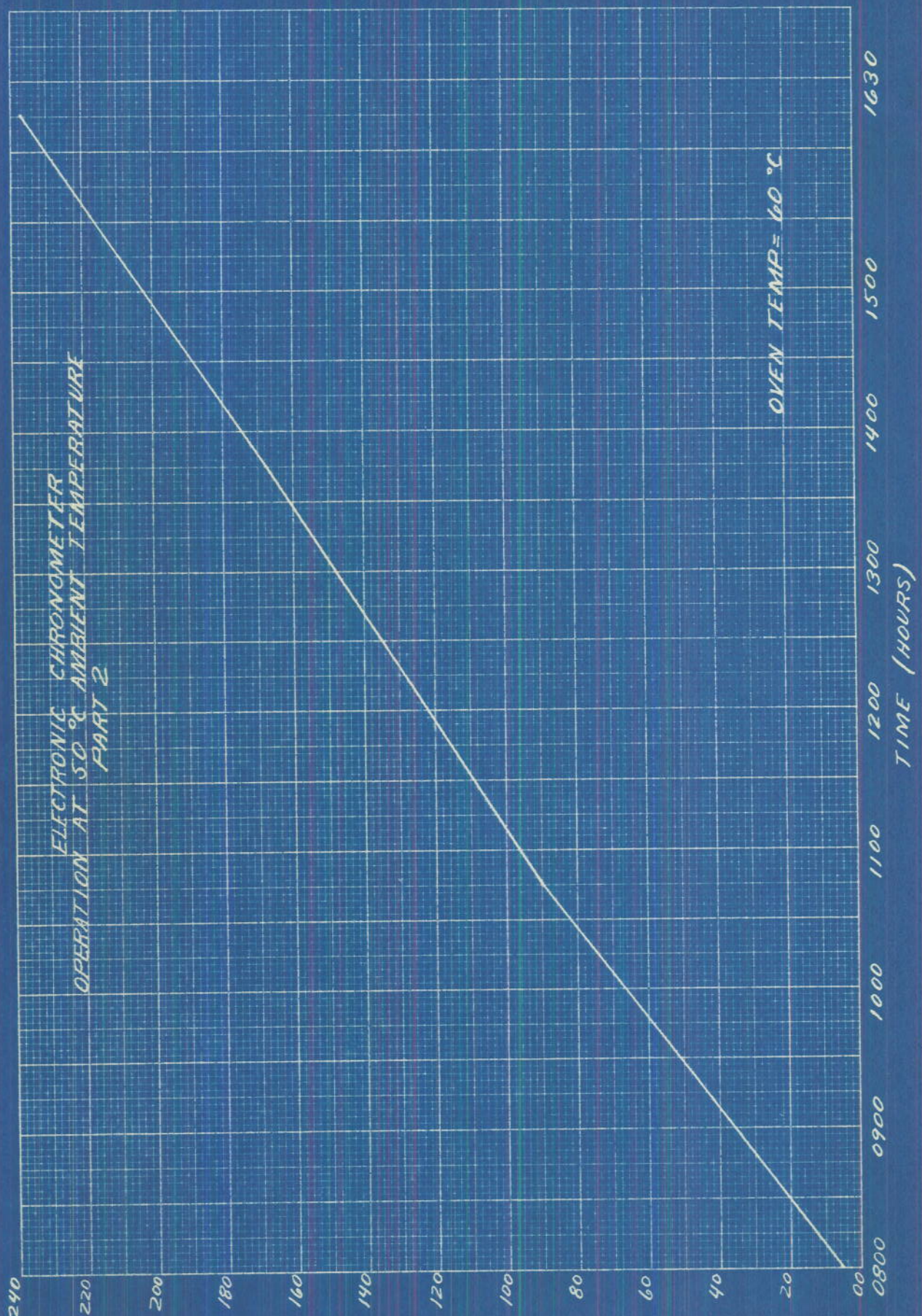
CHRONOMETER TIME GAINED (MILLI SEC.)





DECLASSIFIED

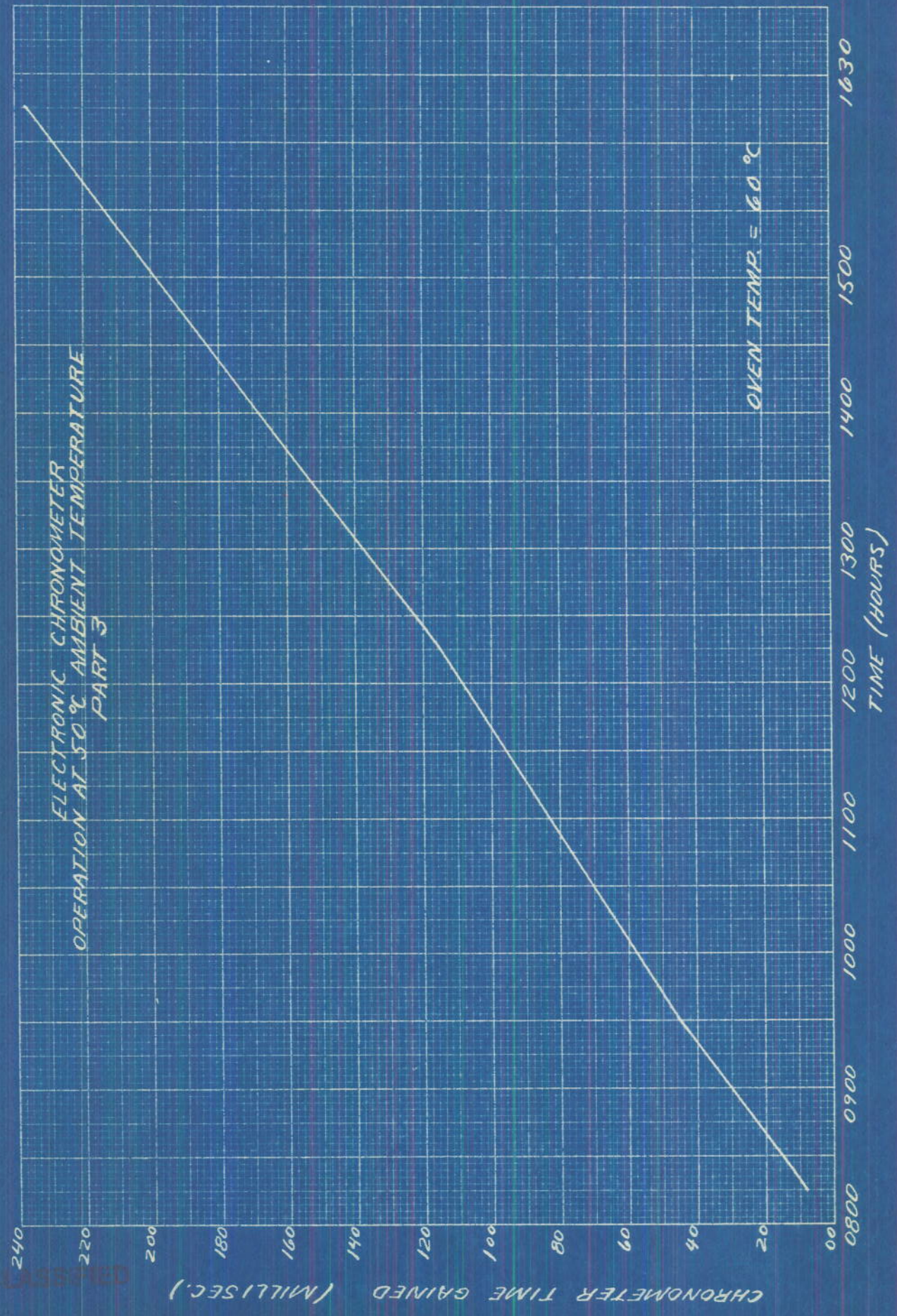
CHRONOMETER TIME GAINED (MILLI SEC.)



NO. 3110, 20 DIVISIONS PER INCH, 120 BY 120 MILLIMETERS. LUDLOW BOOK COMPANY, PRINTED IN U.S.A.

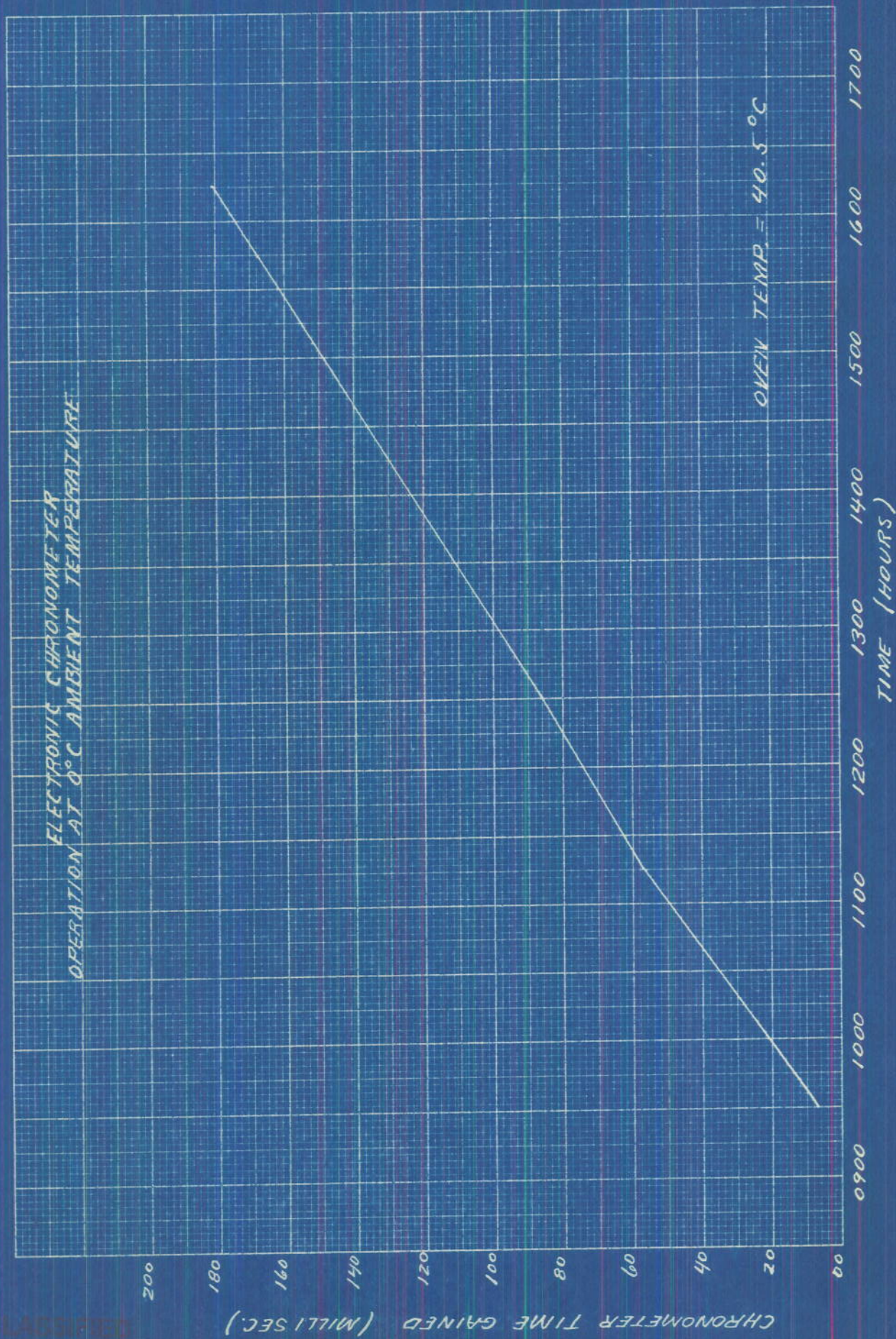


DECLASSIFIED



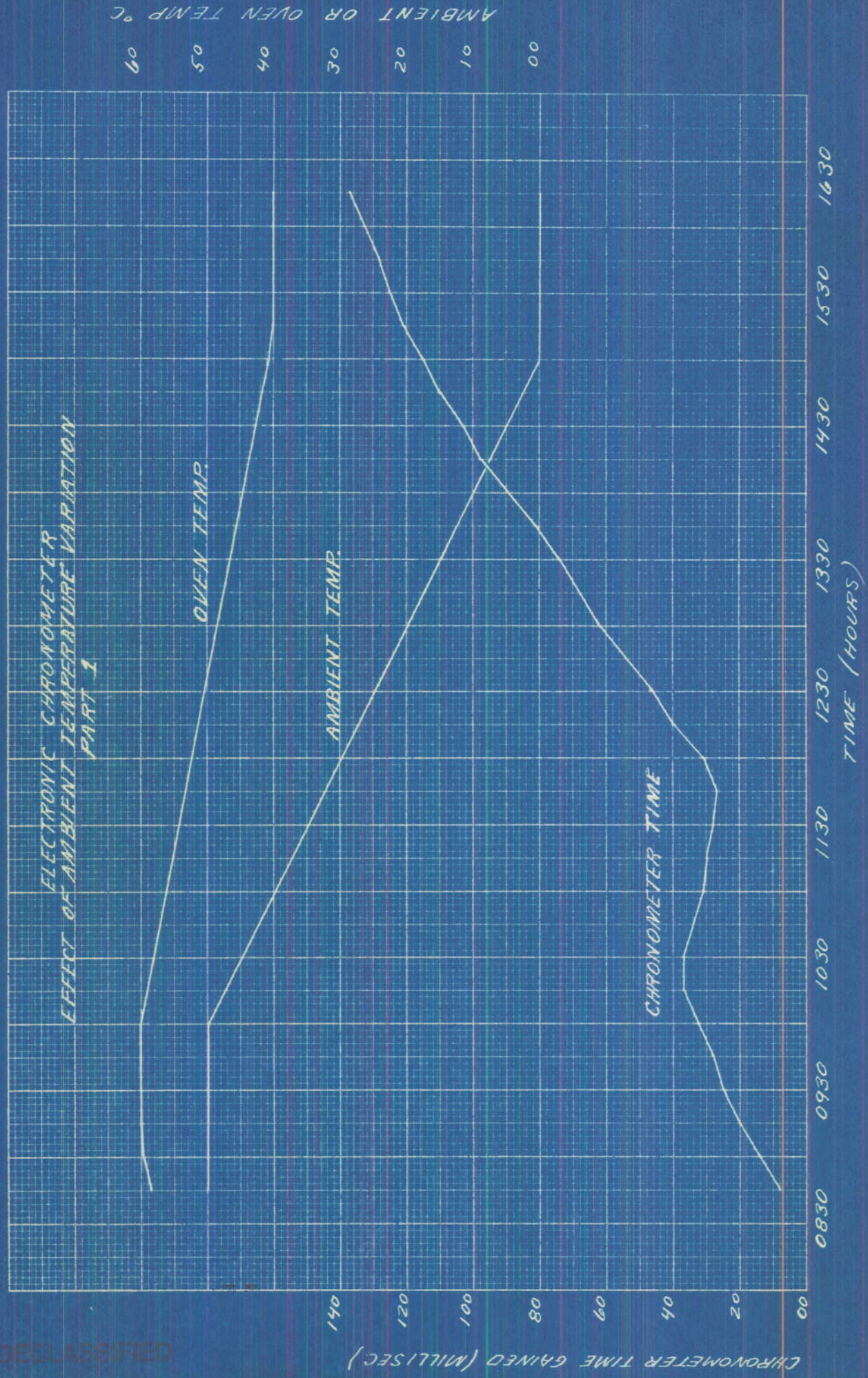


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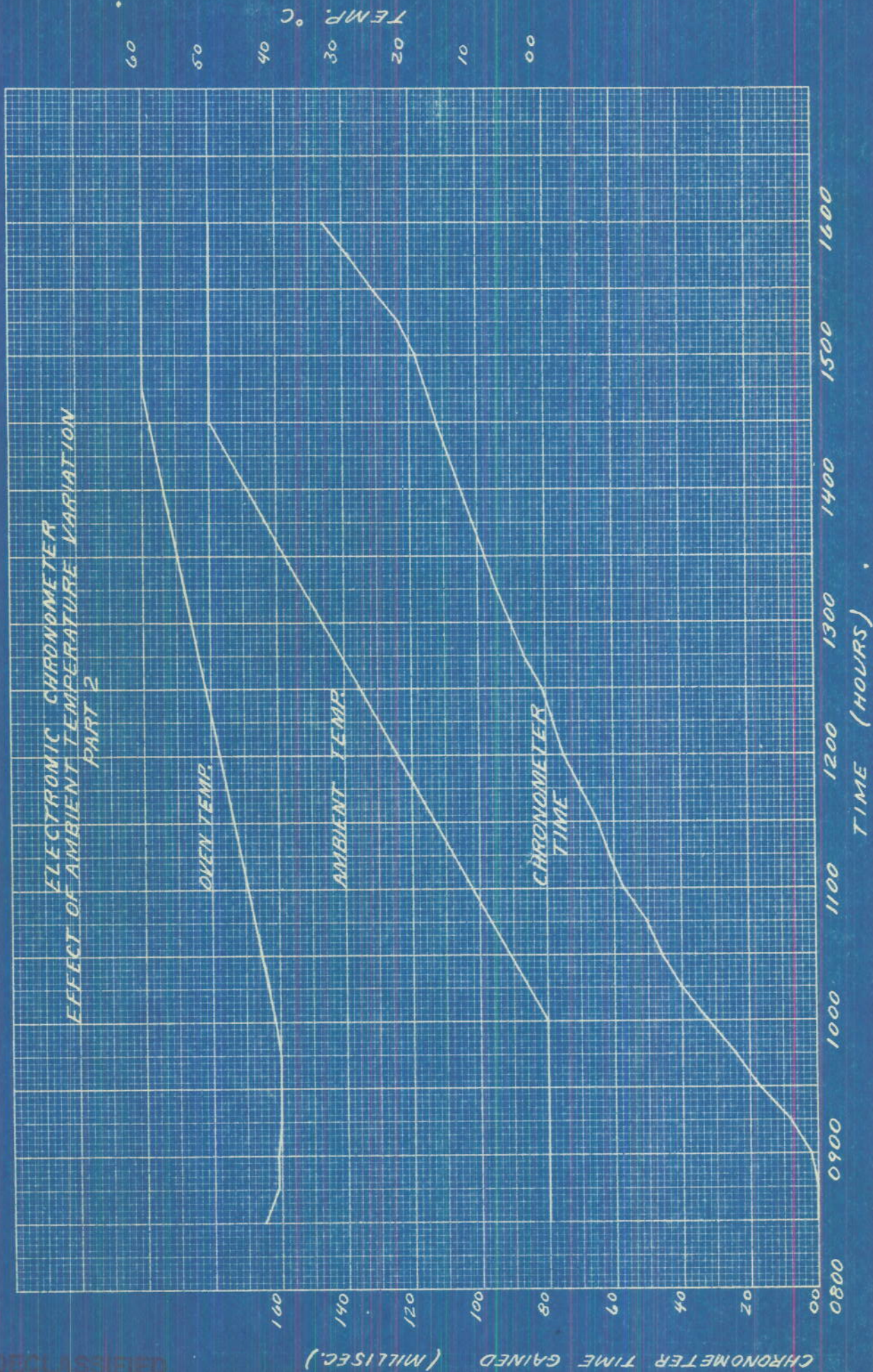


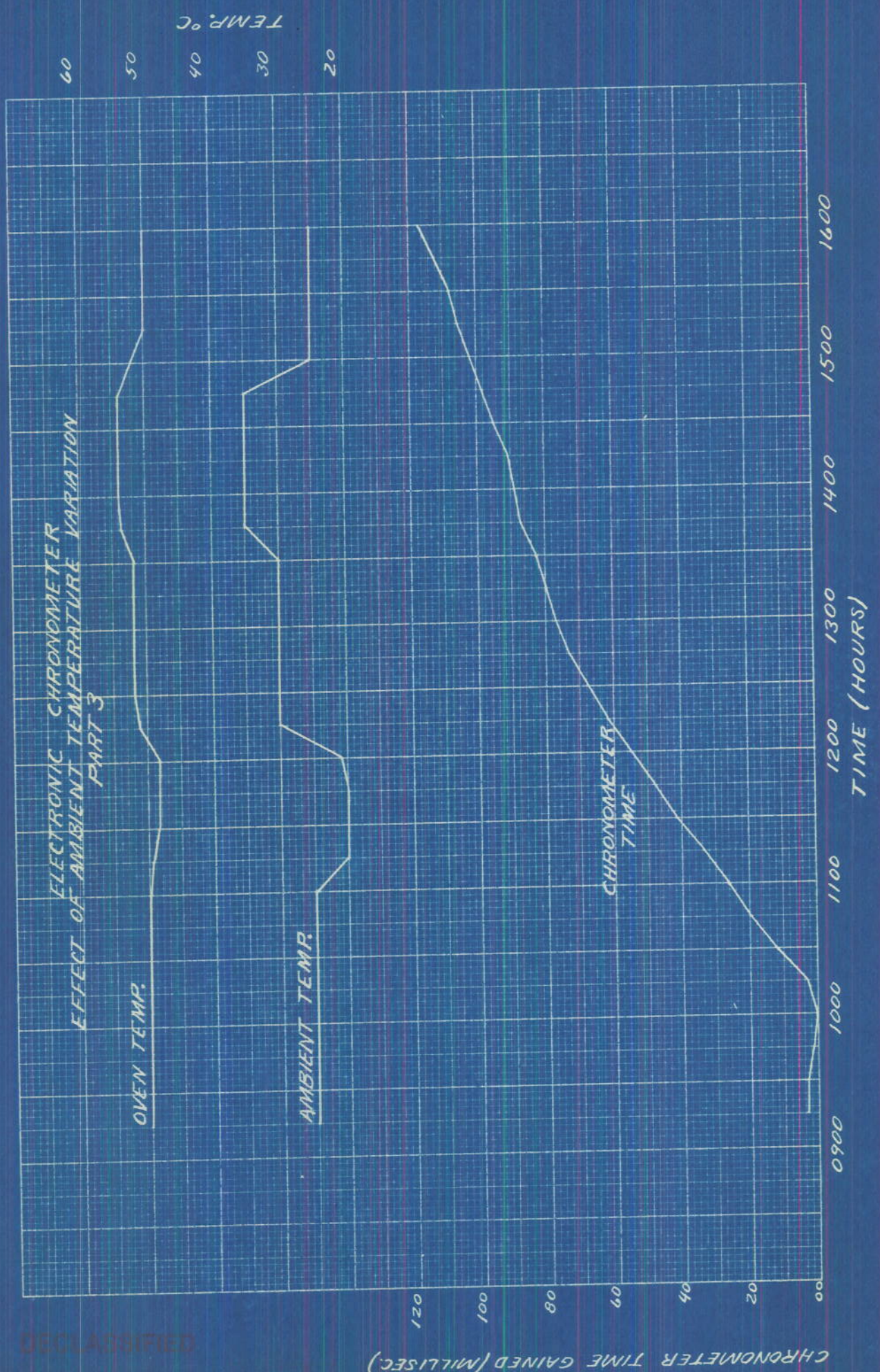


DECLASSIFIED



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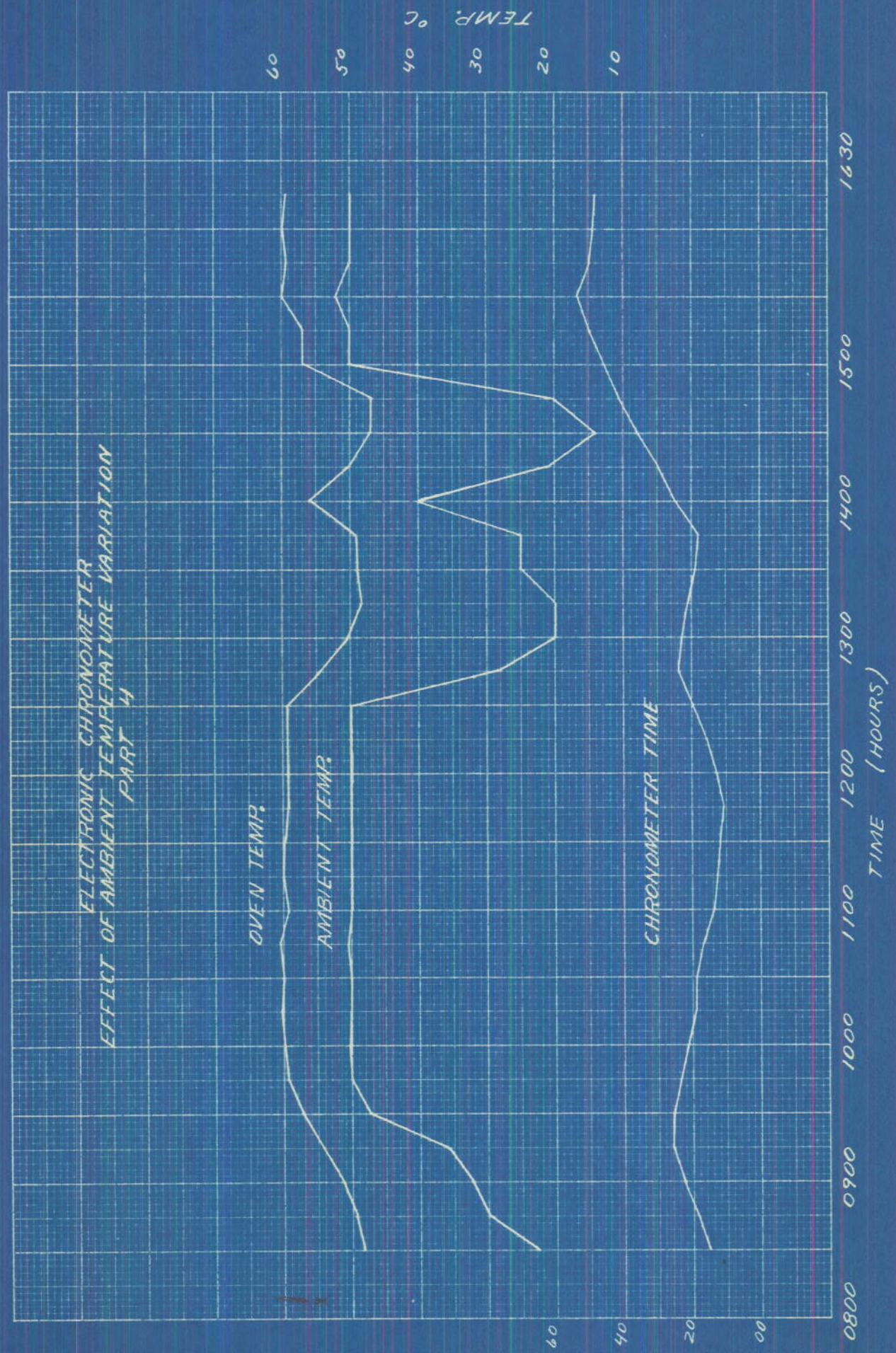
DECLASSIFIED

CHRONOMETER TIME GAINED (MILLISEC.)



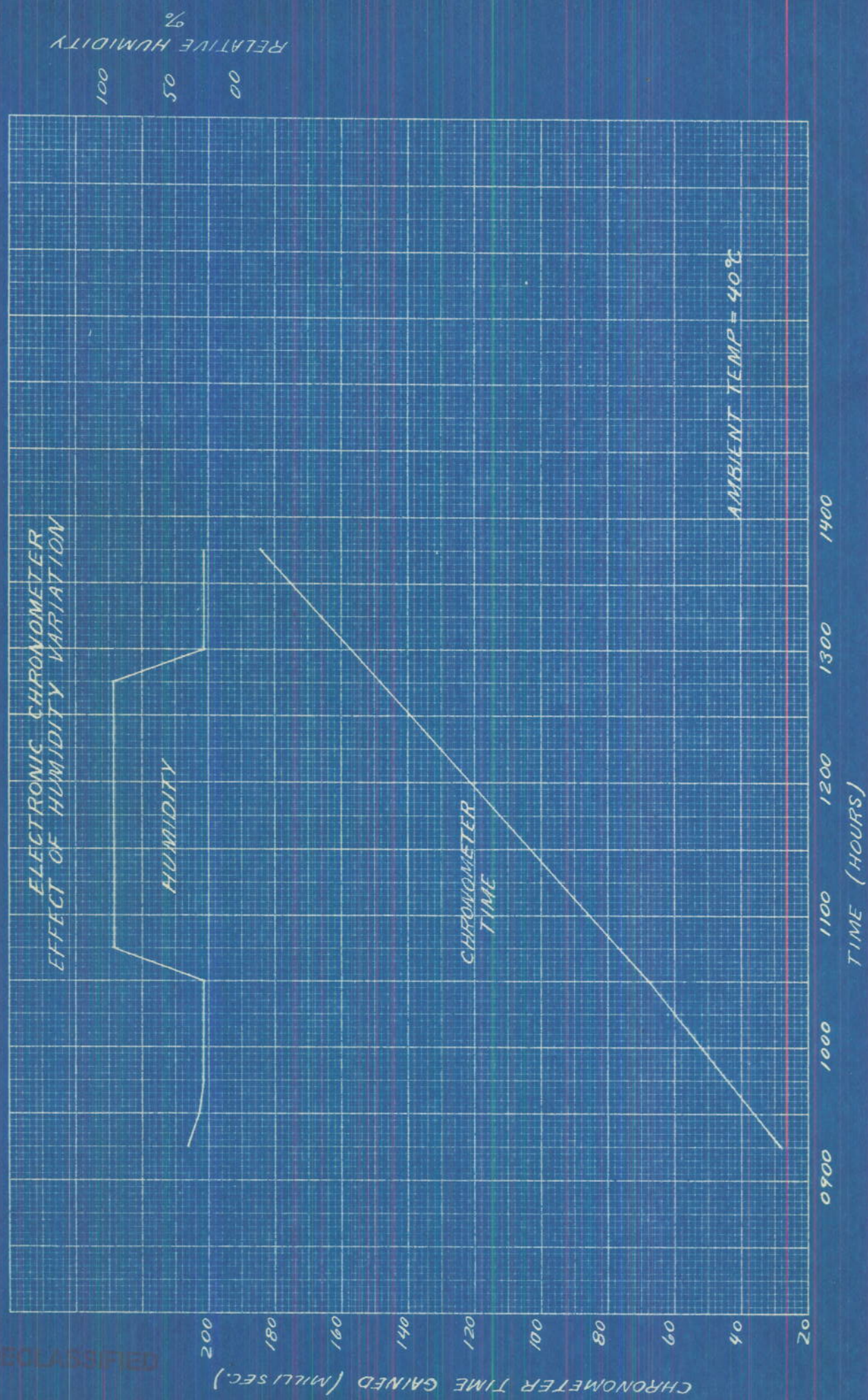
DECLASSIFIED

CHRONOMETER TIME GAINED (MILLISEC.)





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ELECTRONIC CHRONOMETER VARIATION IN RATE WITH AMBIENT TEMPERATURE

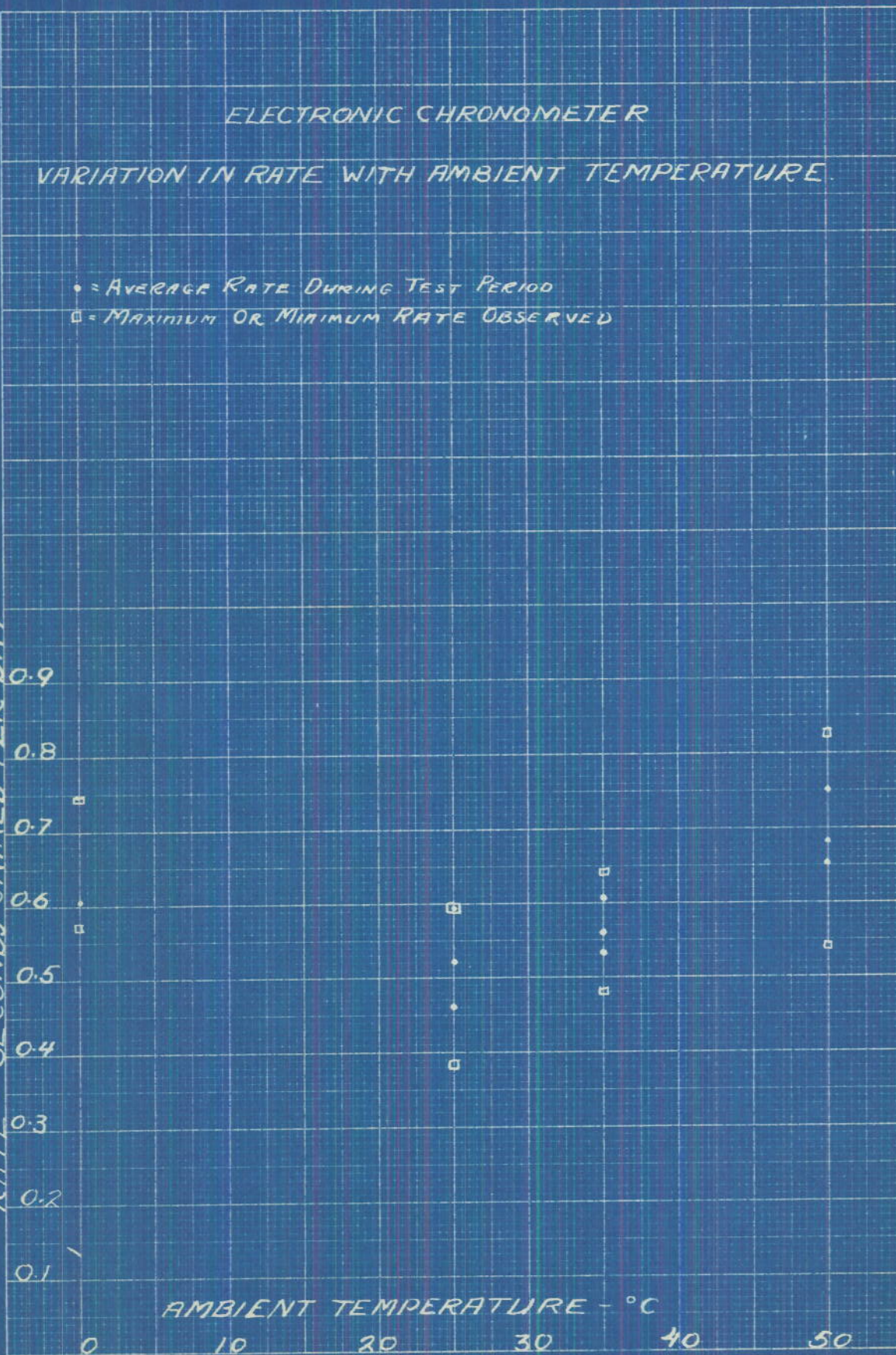
• = AVERAGE RATE DURING TEST PERIOD
□ = MAXIMUM OR MINIMUM RATE OBSERVED

RATE - SECONDS GAINED PER DAY

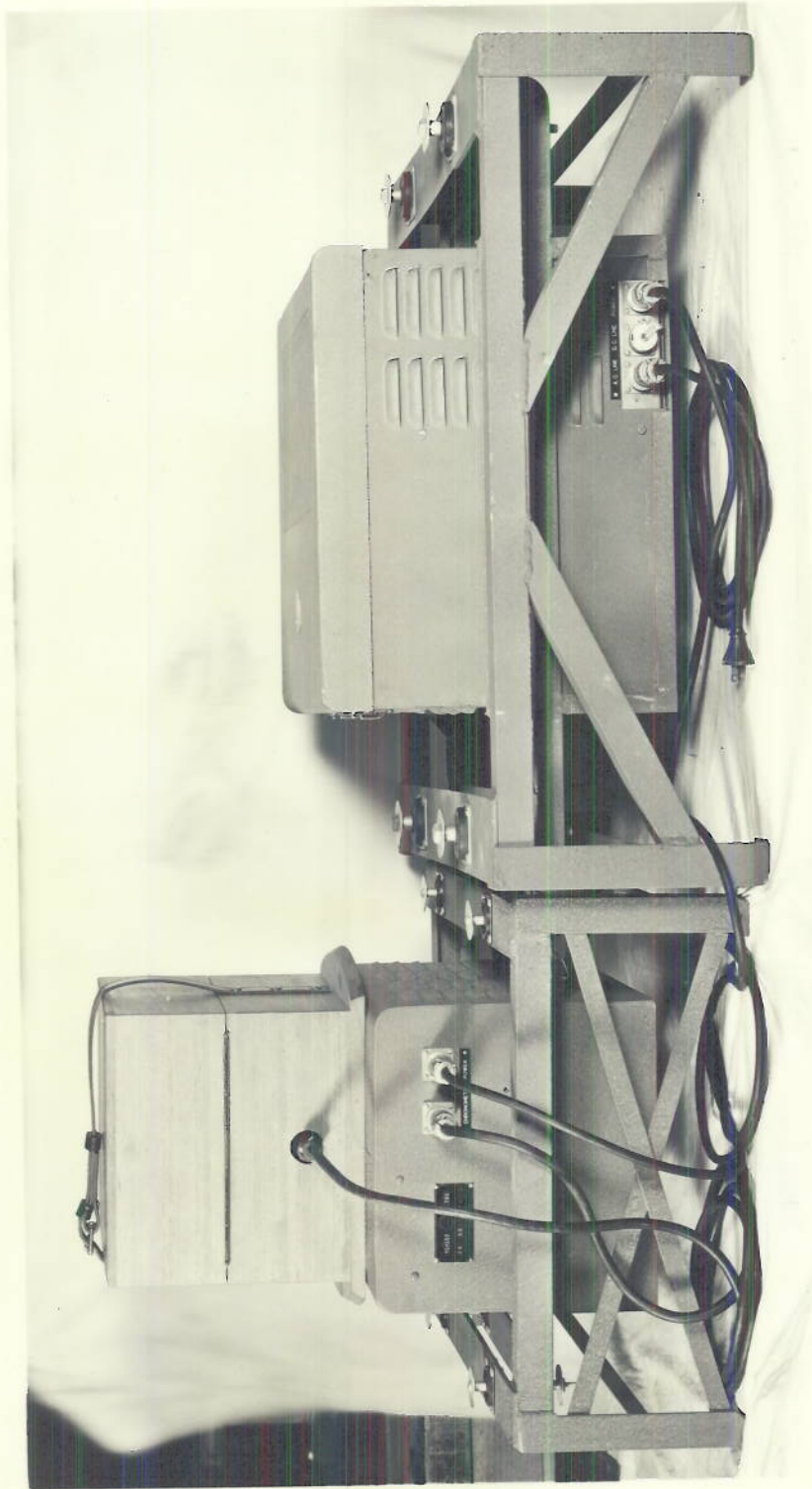
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

AMBIENT TEMPERATURE - °C

0 10 20 30 40 50



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PLATE 17

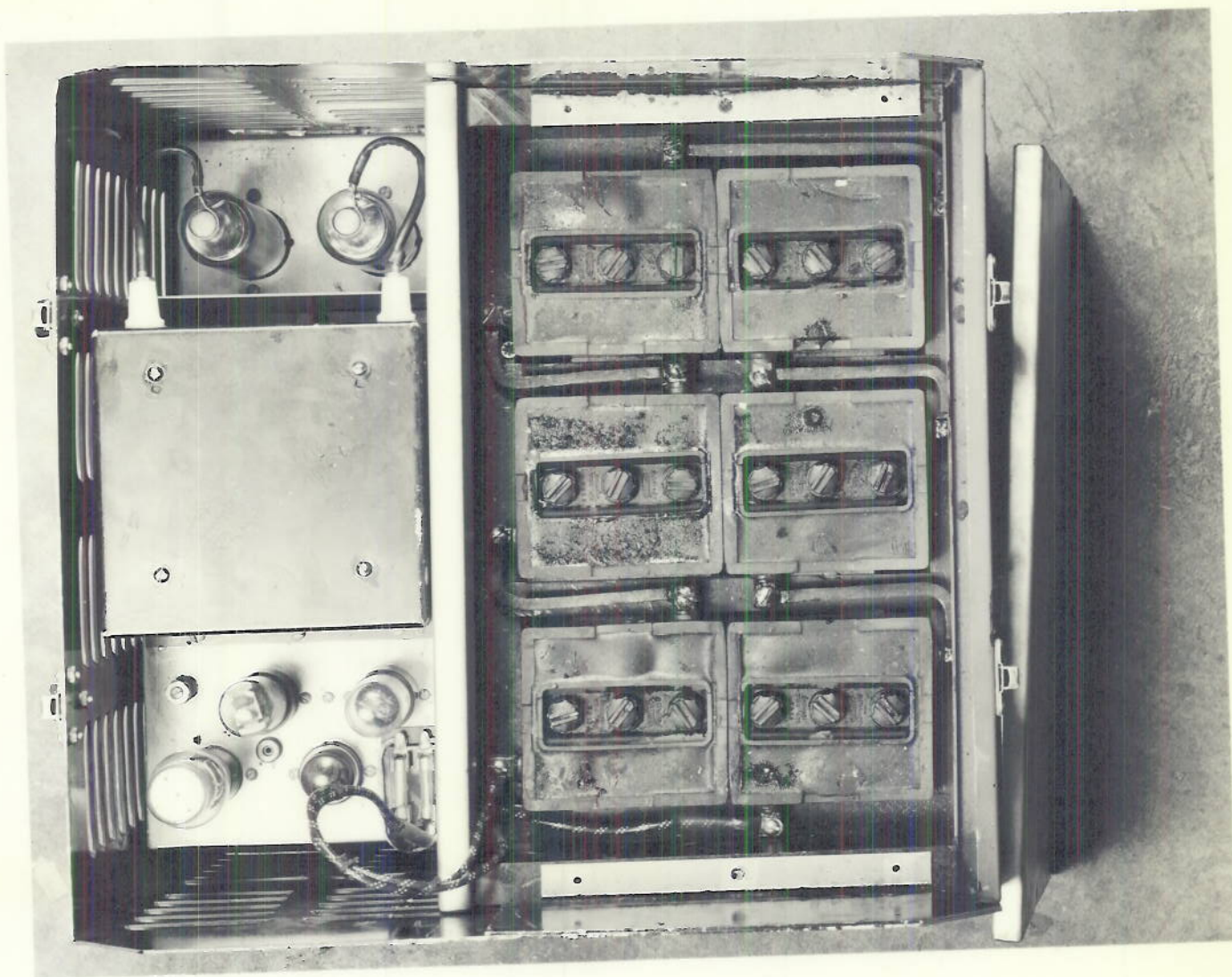
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PLATE 18

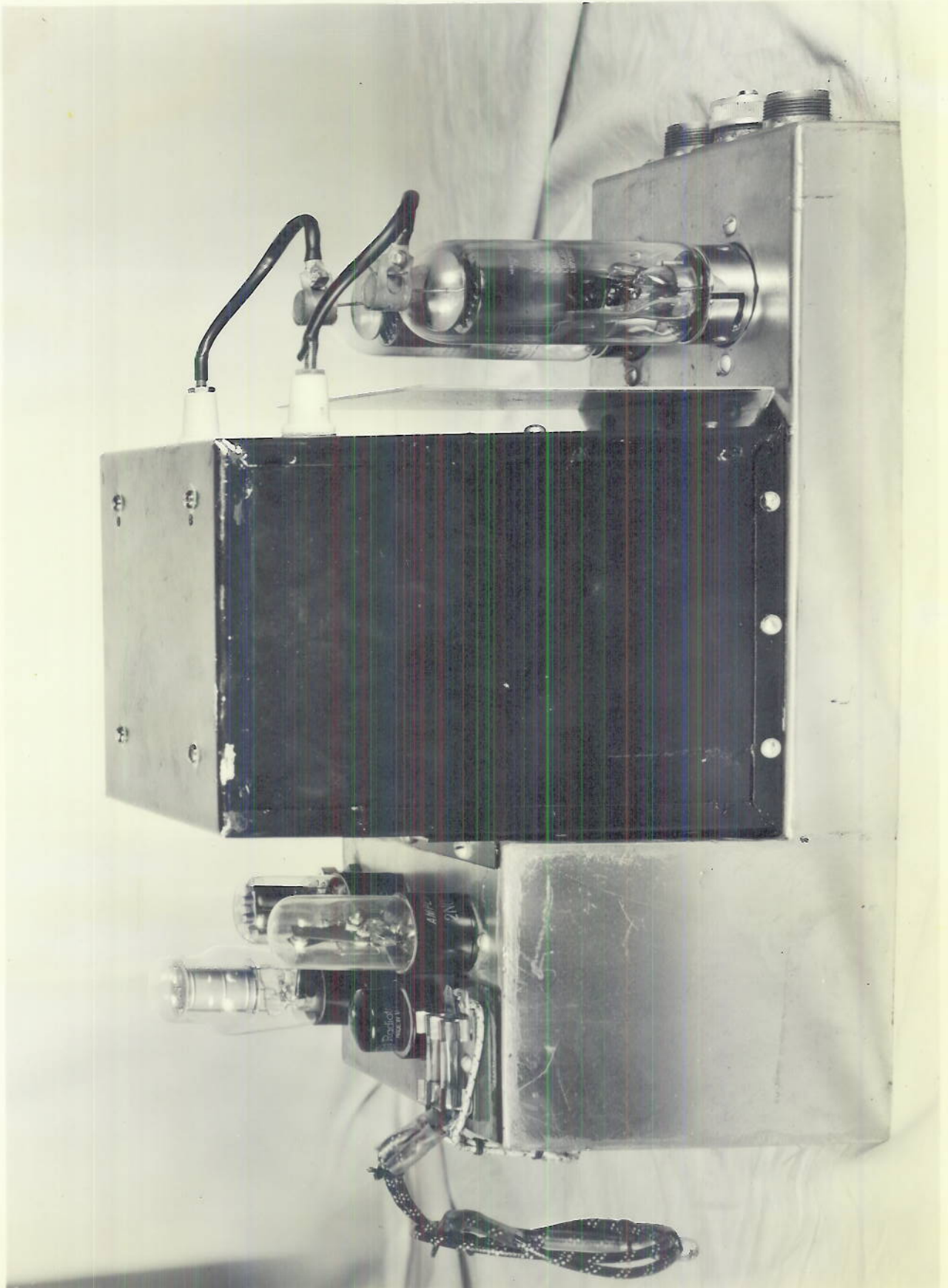
DECLASSIFIED



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PLATE 19

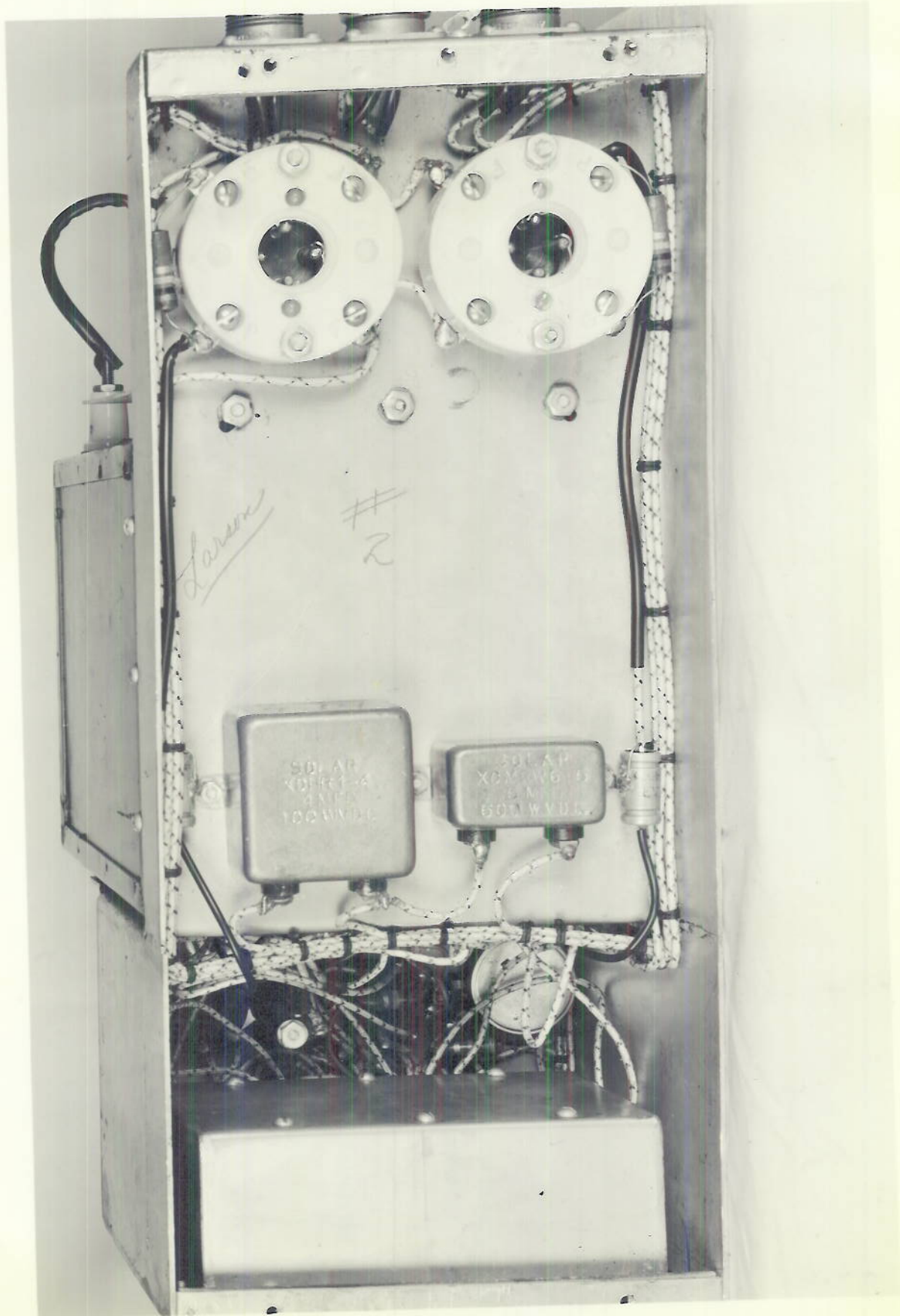
DECLASSIFIED



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PLATE 20

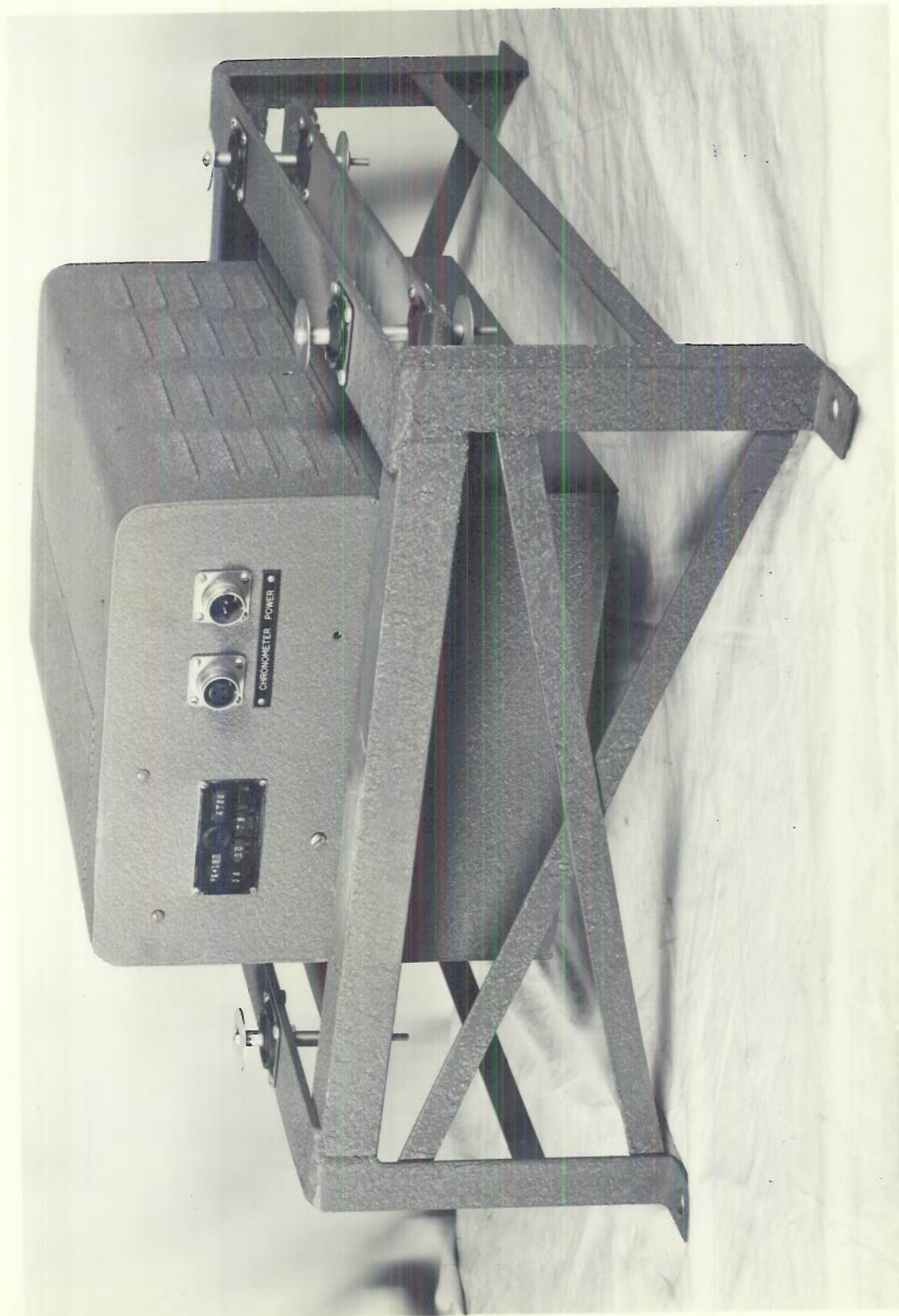
DECLASSIFIED



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PLATE 21

DECLASSIFIED



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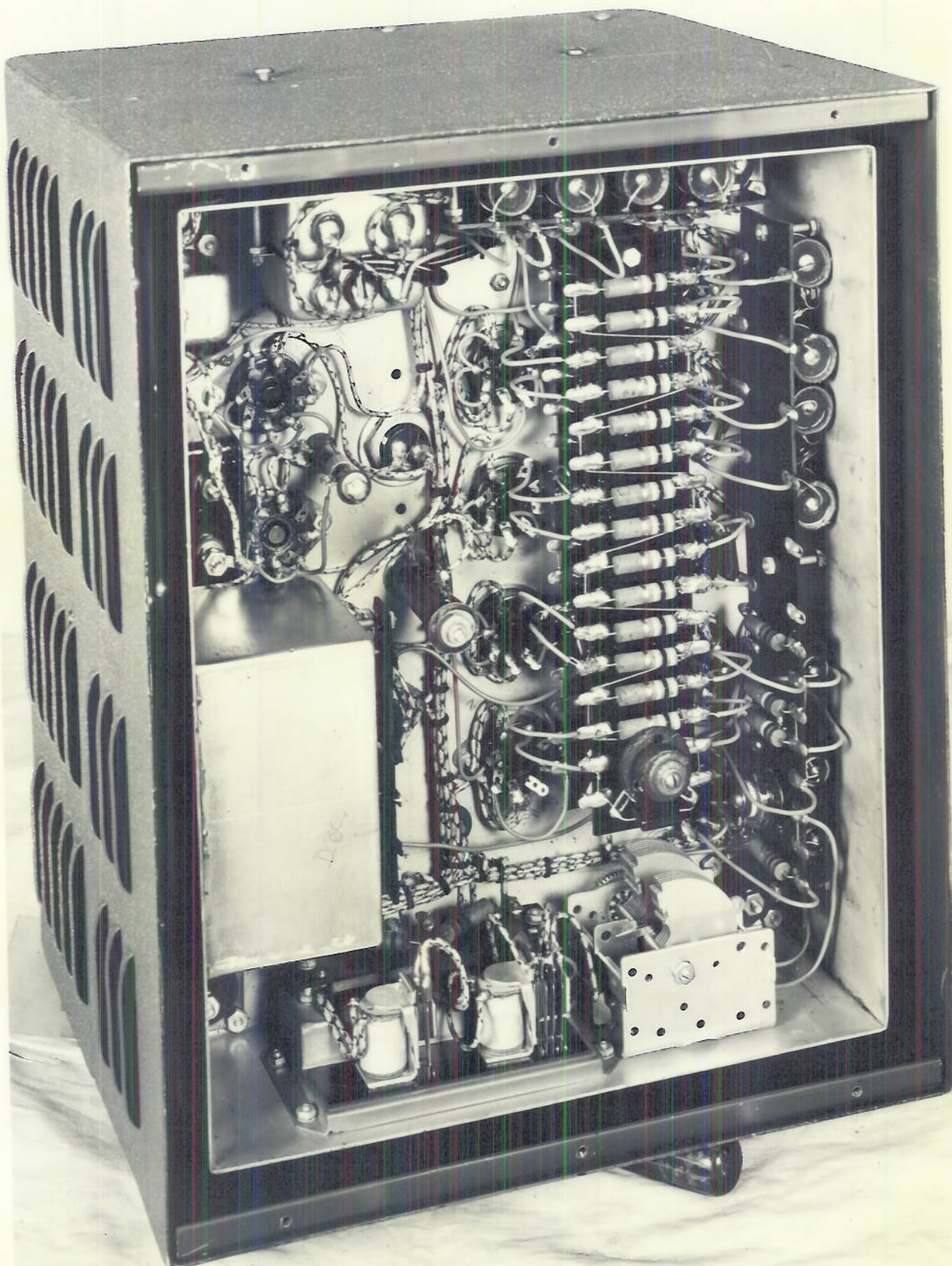
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PLATE 23

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PLATE 24

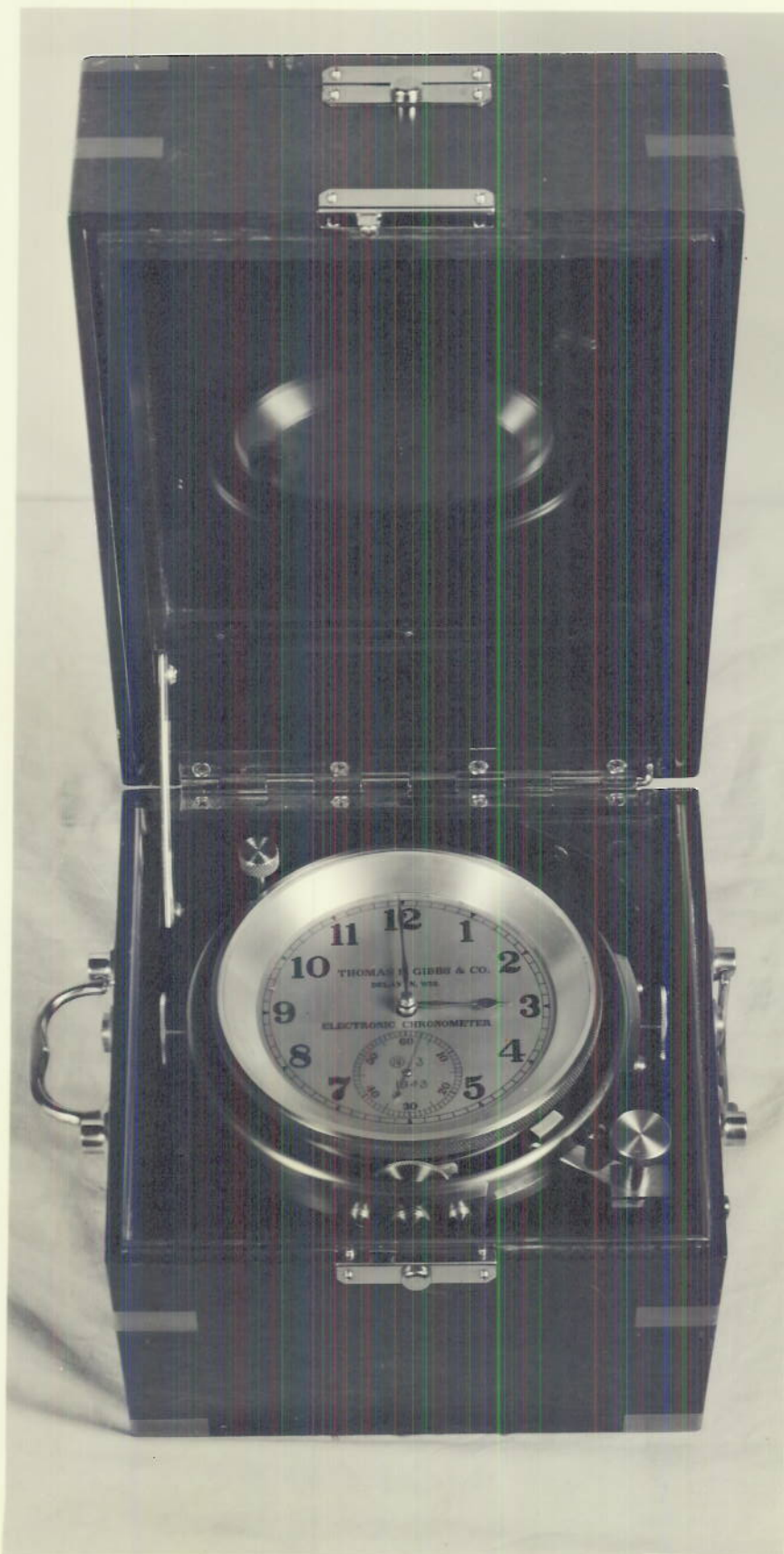
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PLATE 25

DECLASSIFIED



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PLATE 26