REPORT NO. R-1233

DATE 20 January 1936

SUBJECT

Report of

Electrical Characteristics and Performance

of General Electric Type FP-164 Time

Relay Electronic Relay

by

K. M. Soukaras

NAVAL RESEARCH LABORATORY

WASHINGTON 25, D. C.

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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of

Electrical Characteristics and Performance of General Electric Type FP-16A Time Delay Electronic Relay.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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Distribution:
BuEng.(5)

mbe

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Appendices

AUTHORIZATION

1. Tests authorized by reference (a) form the subject matter of this report concerning an electronic device manufactured by the General Electric Company and designated by them as type FP-164 "Time Delay Electronic Relay". References (b), (c) and (d) are informative on matters relevant to the origin of the present problem.

Reference: (a) BuEng.ltr. NOs-35693 (11-25-W8) of 11 Sept. 1935.
(b) BuEng.ltr. NOs-35693 (11-25-W8) of 10 Dec. 1934 to I.N.M. Schenectady, N.Y.
(c) I.N.M. Schenectady, N.Y. ltr. C-35693(223), C-36484 (132) of 23 Nov. 1934 to BuEng.
(d) General Elec.Co's ltr. of Nov.13, 1934 to I.N.M., Schenectady, N.Y. on contracts NOs-35693 and NOs-36484.

OBJECT OF TEST

2. The object of this investigation was to study the operation of the General Electric Type FP-164 vacuum tube time delay relay with its associated circuit, to ascertain its electrical performance in this circuit, to obtain its mechanical and electrical characteristics, and to determine its suitability for use in Naval Service equipment.

ABSTRACT OF TESTS

3. The time delay characteristics of four samples of the subject tube were obtained at ambient temperatures of 0°C, 25°C and 50°C. The subject tube is normally used in series with a suitable copper oxide rectifier. The subject tube's performance with and without the oxide rectifier, and its tendency to "arc-back", were determined. The volt-ampere characteristic of the copper oxide rectifier and its forward resistance at normal current were determined for temperatures at 0°C, 25°C and 50°C. Oscillographic records showing supplied voltage and output current, with the oxide rectifier in series with the subject tube, were obtained at 25°C. The heater voltages used were those determined by the manufacturer and displayed on the base of the tubes. At the conclusion of the essential tests, the heater voltage for one tube was changed on purpose, and a new characteristic obtained. The samples were subjected to vibration for one minute and the resulting effect on the tube's performance determined.

CONCLUSIONS

(a) The subject tube holds promise of material possibilities for Navy use but at its present stage of development it is not entirely satisfactory particularly for shipboard use. The tests of four samples indicate that the time delay period is a function of the heating of the cathode. However, once the heater voltage is determined for a certain time delay period falling within a predetermined range of time, there is no positive assurance that the delay will be repeated for the same time. One tube which had a time delay of 33 minutes one day at a certain temperature, showed a delay of 55 minutes the next day at nearly the same temperature. This, however, is not true for all tubes investigated. One tube had very nearly the same delay of 33 minutes for temperatures of 0°C, 25°C, and 50°C.

(b) One of the four samples was entirely unreliable from the beginning of the tests. It appears that the short spacing between anode and cathode is such that in the case of this tube an intermittent short circuit occurs as soon as the cathode is heated sufficiently, within a few minutes, to emit electrons. The subject tube is a high vacuum tube. In all such tubes the drop within the tube is normally high. The desire to make a low drop tube may have influenced the design to the extent of having the anode very near the cathode. In such cases a strong vibration may short-circuit the tube.

(c) No tendency to "arc-back" was experienced in 3 of the 4 samples. The fourth sample was a bad tube and was not tested.

(d) Of the three good tubes, two can be used without the copper oxide rectifier. The third tube yields a comparatively small average current due to its incomplete rectification. With the oxide rectifier the efficiency of rectification is increased.

(e) The oxide rectifier is useful in the operation of the subject tube in two respects: (1) It eliminates the possibility of arc-back due to the comparatively high inverse resistance of the oxide rectifier. (2) It increases the rectification efficiency of the subject tube. The inverse resistance of the oxide rectifier was found to be particularly high at 0°C.

(f) The identification of the subject tube, including the heater voltage and serial number designations, as displayed on the base, is subject to erasure and fading and is therefore unsatisfactory.

RECOMMENDATIONS

(a) It is recommended that the subject tube be re-designed with an increased spacing between anode and cathode in order that safer and more reliable operation be insured.

(b) The identification of the subject tube, including the heater voltage and serial number designations, should be stamped in a legible and permanent manner with no possibility of erasure.

4. Description of Tube.

(a) The subject tube is fundamentally a diode or half-wave rectifier, the design of the elements of which is such as to provide a delayed time function of current. The time delay property of this tube is a result of the unique construction of its cathode which consists of a solid mass of nickel metal in the form of a hollow right circular cylinder enclosing a helical heater. See Plates 1 and 2. Attached to and surrounding the cathode mass, and extending on the lower end beyond the height of the mass, is a thin metallic sheet forming a concentric cylinder, near the border of which, on the inner surface, is a layer of barium oxide coating of small width. An additional thin cylinder of metal surrounds the cathode and is separated from it by spacers consisting of indentations on the external cylinder, the purpose being to make this cylinder perform the function of a heat reflector. On top of the cathode mass and welded thereto is a double cap on which one end of the helical heater terminates. This cap provides a return circuit for the heater to the base pin and also acts as a heat reflector. Thus one end of the heater and the cathode are electrically connected together inside the tube.

(b) The anode consists of a circular disc of metal with a center hole, permitting the lower end of the heater to pass through on its way to the proper base pin. Surrounding this disc and electrically connected thereto is a narrow, thin, circular ribbon of metal which is concentric with and is enclosed by the layer of barium oxide coating to which previous reference was made. The separation of the anode and the oxide coating is small, thereby subjecting the tube to the possibility of an electrical short circuit between anode and cathode, in the case of violent vibration of the tube elements.

(c) The manner in which the subject tube produces its time delay is as follows: The cathode mass is heated, indirectly in large part by radiation, and directly in small part by conduction from the heater. The oxide coating, which is the main source of electrons, is heated indirectly in small part by radiation from the heater, and in larger volume directly by conduction from the cathode mass. The size of the mass, and the available heat energy, as determined by the heater voltage applied, provide a gradual heating of the coating and, hence, a gradual increase in the emission of electrons from the coating.

(d) Plate 1 is a photograph of the tube showing its parts and assembly. Plate 2 shows a vertical cross-section of the essential inner structural arrangement of the elements of the subject tube.

5. Description of Apparatus. Plate 3 is a photograph of the experimental set-up of the apparatus for conducting the various tests. The essential items consist of the following:

(a) A 220-6.5 volt, single-phase, 60 cycle per second, 500 watt transformer, for supplying power to the tube.

(b) A suitable resistor of 750 ohms recommended by the manufacturer.

(c) A control relay, manufacturer's type CR 810-1265H-143. This relay is so adjusted as to be energized by the rectified direct current when it reaches its normal value of 40 milliamperes.

(d) A copper oxide rectifier, manufacturer's type [illegible] This oxide rectifier input, 39 volt - 65 milliamperes output. is used in series with the subject tube, the negative potential end of the rectifier being connected to the anode of the tube. The purpose of the rectifier is, presumably, to protect the subject tube from any tendency it may have to "arc-back". Another equally important circuit function was found for the oxide rectifier and will be disclosed in its proper place in this report.

(e) A variable filament rheostat capable of carrying the normal heater current of 12 amperes.

6. Diagram of Connections. Plate 4 shows the circuit connections used in obtaining the time delay characteristics and the supply voltage and output current wave forms of the subject tube.

METHOD OF TEST

7. (a) The procedure employed in obtaining the desired data was as follows: With the tube cold at room temperature the primary supply voltage was adjusted to exactly 220.0 volts, the heater voltage to that marked on the base of the tube, and the rise of the rectified current against time noted. In this case time was determined by the use of a stop watch, indicating minutes and seconds, from the instant of closing the supply switch.

(b) The subject tube was given a vibration test for one minute with no voltages applied. More data were obtained after this test.

(c) To obtain the time delay characteristics at ambient temperatures of 0°C and 50°C it was necessary to place the apparatus inside an automatic temperature controlled compartment.

(d) The tendency of the subject tube to "arc-back" was determined by operating the tube without the copper oxide rectifier in the circuit.

(e) Inasmuch as the copper oxide rectifier is required for the normal operation of the subject tube, the determination of the properties of the former are evidently desirable. The volt-ampere characteristic of the oxide rectifier was obtained using direct voltages and its forward resistance at 40 milliamperes was determined from its characteristic at ambient temperatures of 0°C, 25°C and 50°C. The inverse rectifier resistance was also determined at these temperatures for voltages corresponding to the normal circuit current of 40 milliamperes. The volt-ampere characteristic for 0°C and 50°C was obtained with the rectifier enclosed within the temperature controlled compartment which of necessity enveloped the rectifier with darkness. It is tacitly assumed here that the photoelectric effect of the copper oxide rectifier under the described conditions of test was small.

DATA RECORDED DURING TESTS

8. The data obtained during the tests are plotted and shown as graphs on Plates 6 to 23 inclusive. Plates 10 to 23 show the time delay characteristics of the subject tube under conditions indicated on the plates. Plates 7 to 9 show the volt-ampere characteristics of the copper oxide rectifier at three different temperatures.

9. Plate 5 shows the supply voltage and output current wave forms of the subject tube with the copper oxide rectifier in series at 25°C.

PROBABLE ERROR IN RESULTS

10. The accuracy of the data obtained throughout the tests is well within 1%.

11. The accuracy with which the oscillograph records can be read and measured is about 5%. However, in these tests only the waveforms of the voltage and current are desired and not their actual magnitudes.

RESULTS OF TEST

12. The results of the tests are shown in table form on Plate 6 and in graph form on Plates 7 to 23 inclusive.

13.(a) Tube No. 111, heater voltage 5.1 volts, had an initial time delay, at 30°C, of 31 minutes and 33 seconds before the one minute vibration test. After the vibration test the same tube required 55 minutes to reach a saturation current of 39.0 milliamperes without the relay closing. The specification requirement is that the initial delay period fall within the range 28 to 35 minutes.

(b) After a 5-minute-off period the time required for the relay to pick up was 15 minutes and 30 seconds both before and after the vibration test. The specification requires that this time be from 8 to 15 minutes.

(c) After the vibration test and at 0°C, the same tube required 45 minutes and 23 seconds to reach a saturation current of 34 milliamperes. After a 5-minute-off period the time was 26 minutes for the same current. In either case the relay did not close since its adjustment was for normal current of 40 milliamperes.

(d) At 48.5°C the time was 45 minutes and 30 seconds for a saturation current of 32 milliamperes. After a 5-minute-off period the time was 29 minutes.

14. Tube No. 112, E_H = 5.0 volts had, before the vibration test, an initial delay period of 34 minutes at 25°C. After a 5-minute-off period the delay was 14 minutes and 30 seconds. The data for this tube were taken after many trials in the majority of which the tube proved to be very unreliable. It was found that after a heating of 2 to 3 minutes the tube shorts itself with the current instantly rising to about 73 milliamperes. The control relay contacts opened and closed rapidly, indicating that the anode and cathode made and broke contact cyclicly with the same frequency, with the current rising and falling correspondingly. This condition occurred when the tube received a jar of some sort and in other instances with no apparent cause.

15.(a) Tube No. 113, E_H = 4.6 volts required 28 minutes and 35 seconds to actuate the control relay at 40 milliamperes and at a temperature of 25°C. After a 5-minute-off period it required 15 minutes.

(b) At 48.5°C the initial delay period was 55 minutes for a saturation current of 36 milliamperes. After a 5-minute-off period it required 34 minutes for a current of 35 milliamperes.

(c) At 0°C the time required to reach a saturation current of 37 milliamperes ... after a 5-minute-off period. 35 minutes.

16.(a) For tube No. 118, E_H = 4.5 volts, the initial time delay was 35 minutes and 41 seconds before the vibration test and 26 minutes 31 seconds after the vibration test, the data taken at 25°C. After a 5-minute-off period the delay was ten and one half minutes.

(b) At 48.5°C the initial delay was 33 minutes 50 seconds, and after a 5-minute-off period the delay was 15 minutes 52 seconds.

(c) At 0°C the initial delay was 32 minutes 17 seconds, and after a 5-minute-off period the delay was 14 minutes 44 seconds.

17. Tube No. 113, E_H = 4.6 volts was operated on purpose at E_H = 5.1 volts and a new time delay characteristic obtained at 48.5°C. Under this operating condition the initial time delay was 23 minutes and 48 seconds to make relay pick up at 40 milliamperes. After a 5-minute-off period it required 9 minutes and 18 seconds to actuate the relay. This test shows that the same tube which failed to meet requirements with a heater voltage of 4.6 volts was satisfactory when the heater voltage was increased to 5.1 volts.

18. Plate 5 shows the oscillograms of supply voltage and rectified current with the subject tube and oxide rectifier in series. The current wave form for tubes No. 111 and 112 is a normal half-wave rectified current with the negative half-cycle completely suppressed. The wave form for the rectified current of tube No.118 shows that the rectification is not complete. No oscillographic record was made for Tube No. 112 due to its instability and the danger of burning out the oscillographic element. However, the rectified current waveform for this tube was viewed under favorable conditions in a cathode ray oscillograph and found to be very similar to that of tube No.118, that is, the rectification was incomplete.

19. The copper oxide rectifier was removed from the circuit and the tubes operated at 25°C ambient temperature. Tube No. 113 required 52 minutes to reach a saturation current of 36 milliamperes. Tube No. 111 required 40 minutes to reach a current of 32 milliamperes. On the other hand the current for tube No.118 remained constant at 12.4 milliamperes at the end of 34 minutes of operation. Incidentally this is the tube the oscillogram of which shows incomplete rectification. However, although with the copper oxide rectifier in series this tube functions the best relative to the other tubes, without the oxide rectifier it is the least satisfactory. This proves that the copper oxide rectifier plays an important circuit function, namely, to increase the rectification efficiency of the time delay tube in addition to the protection it affords the tubes from any tendency to arc back, inasmuch as the inverse rectifier resistance of the oxide rectifier is high. It has been calculated to be as follows: At 0°C, very high, approaching infinity; at 25°C, 46,000 ohms; at 48.5°C, 5,800 ohms. Hence, the forward and inverse resistances of the copper oxide rectifier are a function of the temperature and decreasing with increasing temperatures. No arc-back occurred in any of the tubes, the oxide rectifier having been removed from the circuit.

20. The control relay employed, manufacturer's type CR 3810-1265H-143, was found to chatter, after the current reached 32 milliamperes in the case

of those tubes showing incomplete rectification. This indicates that strong alternating components of the current flow through the relay winding and when aided by any sudden vibration the relay is apt to close its contacts prematurely. For this reason such a relay cannot be used on shipboard but may be used on shore stations.

21. The current increases steadily with time for tubes No. 111 and 113. Tube No. 118 produces a dip in current, small but definite, during the first 11 minutes of heating. The current becomes unsteady between 2.5 and 6.0 milliamperes after which it continues normally.

CONCLUSIONS

22. The subject tube holds promise of material possibilities for Navy use, but at its present stage of development it is not entirely satisfactory, particularly for shipboard use. The tests of four samples indicate that the time delay period is a function of the heating of the cathode. However, once the heater voltage is determined for a certain time delay period falling within a predetermined range of time, there is no positive assurance that the delay will be repeated for the same time. One tube which had a time delay of 33 minutes one day at a certain temperature, showed a delay of 55 minutes the next day at near the same temperature. This, however, is not true for all tubes investigated. One tube had very nearly the same delay of 33 minutes for temperatures of 0°C, 25°C and 50°C.

23. One of the four samples was entirely unreliable from the beginning of the tests. It appears that the short spacing between anode and cathode is such that in the case of this tube an intermittent short circuit occurs as soon as the cathode is heated sufficiently, within a few minutes, to emit electrons. The subject tube is a vacuum tube. In all such tubes the drop within the tube is normally high. The desire to make a low drop tube may have influenced the design to the extent of having the anode very near the cathode. In such cases a strong vibration may short-circuit the tube.

24. No tendency to "arc-back" was experienced in 3 of the 4 samples. The fourth sample was a bad tube and was not tested.

25. Of the three good tubes, two can be used without the copper oxide rectifier. The third tube yields a comparatively small average current due to its incomplete rectification. With the oxide rectifier the efficiency of rectification is increased.

26. The oxide rectifier is useful in the operation of the subject tube in two respects: (a) It eliminates the possibility of arc-back due to the comparatively high inverse resistance of the oxide rectifier. (b) It increases the rectification efficiency of the subject tube. The inverse resistance of the oxide rectifier was found to be particularly high at 0°C.

27. The identification of the subject tube, including the heater voltage and serial number designations, as displayed on the base, is subject to erasure and fading and is therefore unsatisfactory.

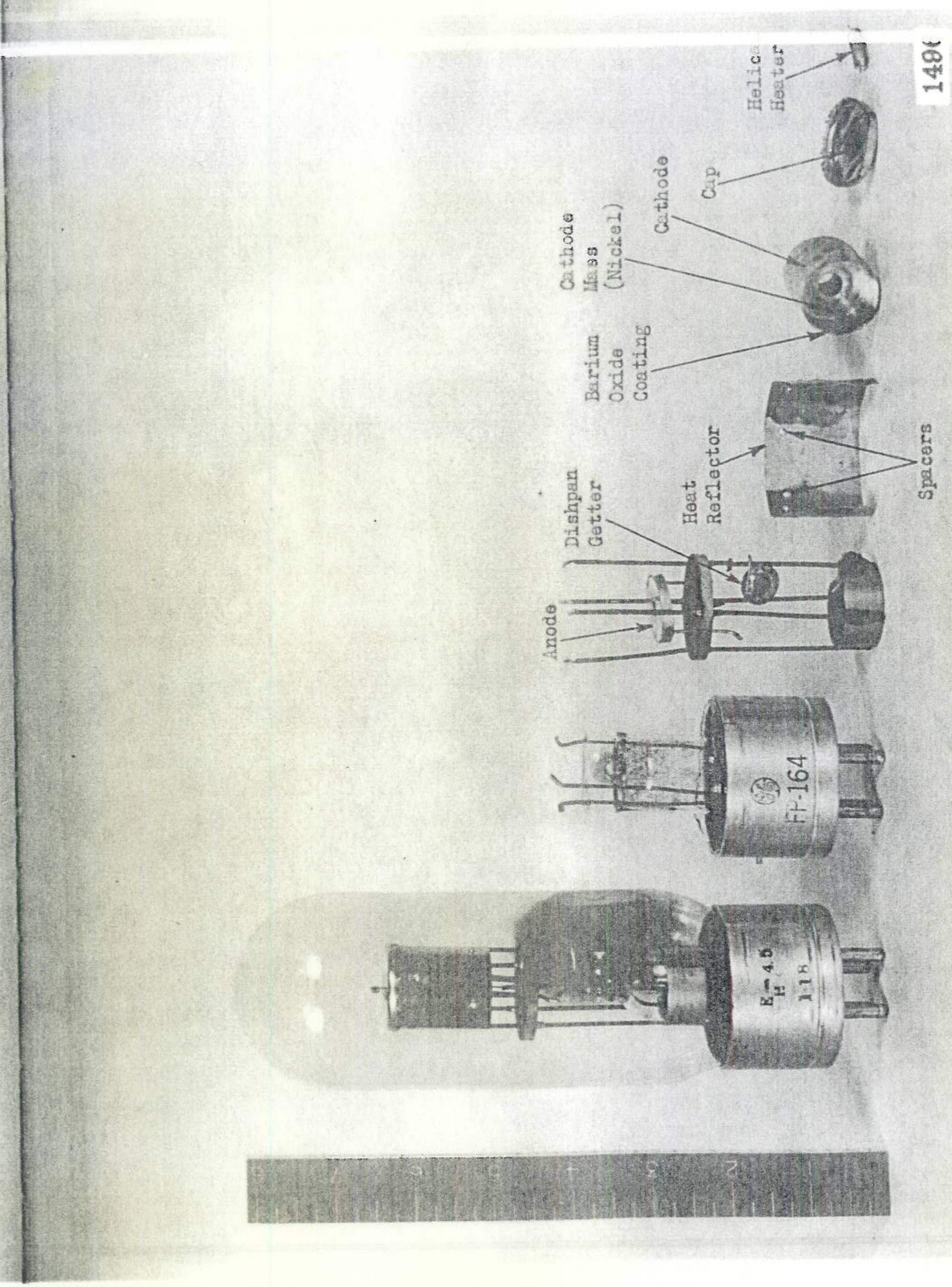

Anode
Dishpan Getter
Heat Reflector
Spacers
Barium Oxide Coating
Cathode Mass (Nickel)
Cathode
Cap
Heater
FP-164

PLATE I

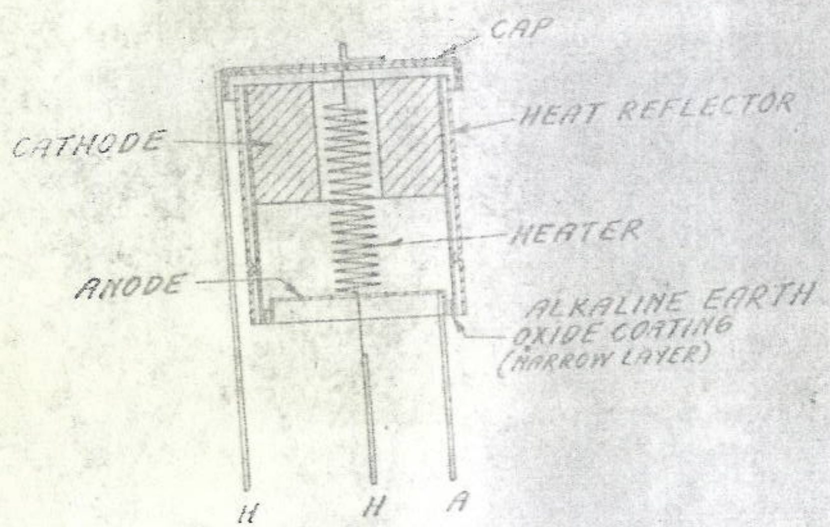

CAP
HEAT REFLECTOR
CATHODE
HEATER
ANODE
ALKALINE EARTH
OXIDE COATING
(NARROW LAYER)
H
H
A

PLATE 2

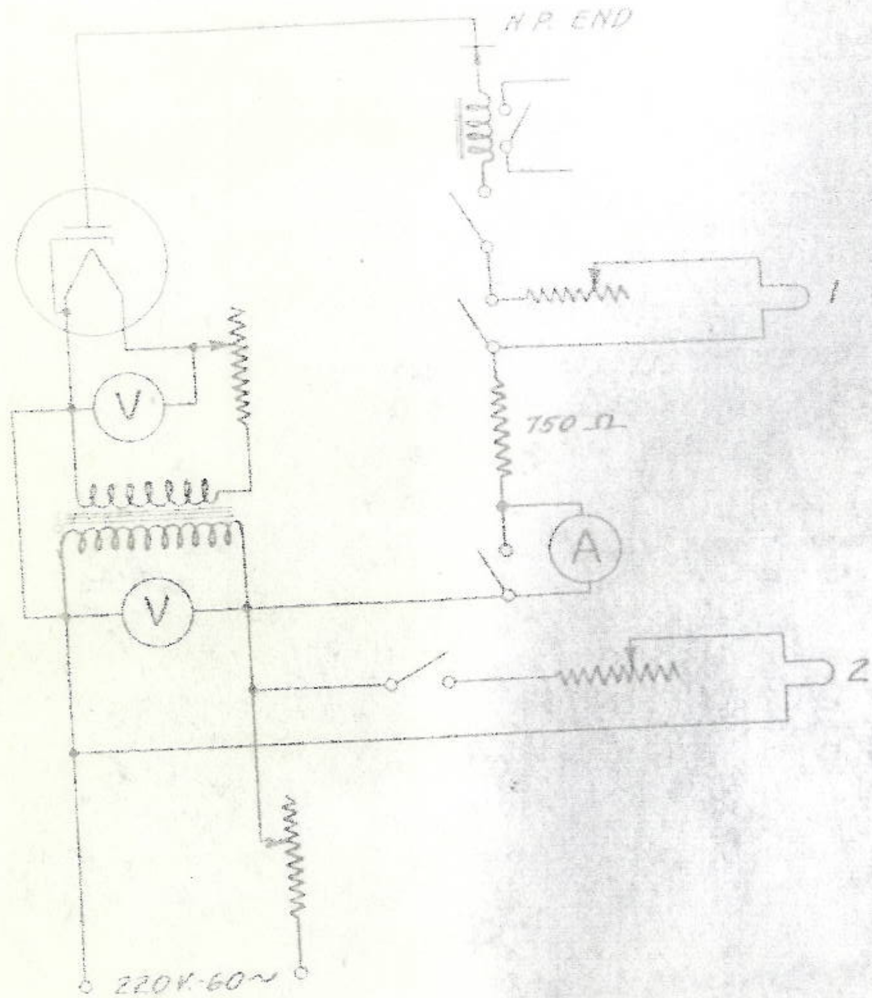


DIAGRAM OF CONNECTIONS USED IN OBTAINING THE TUBE CHARACTERISTICS AND OSCILLOGRAMS

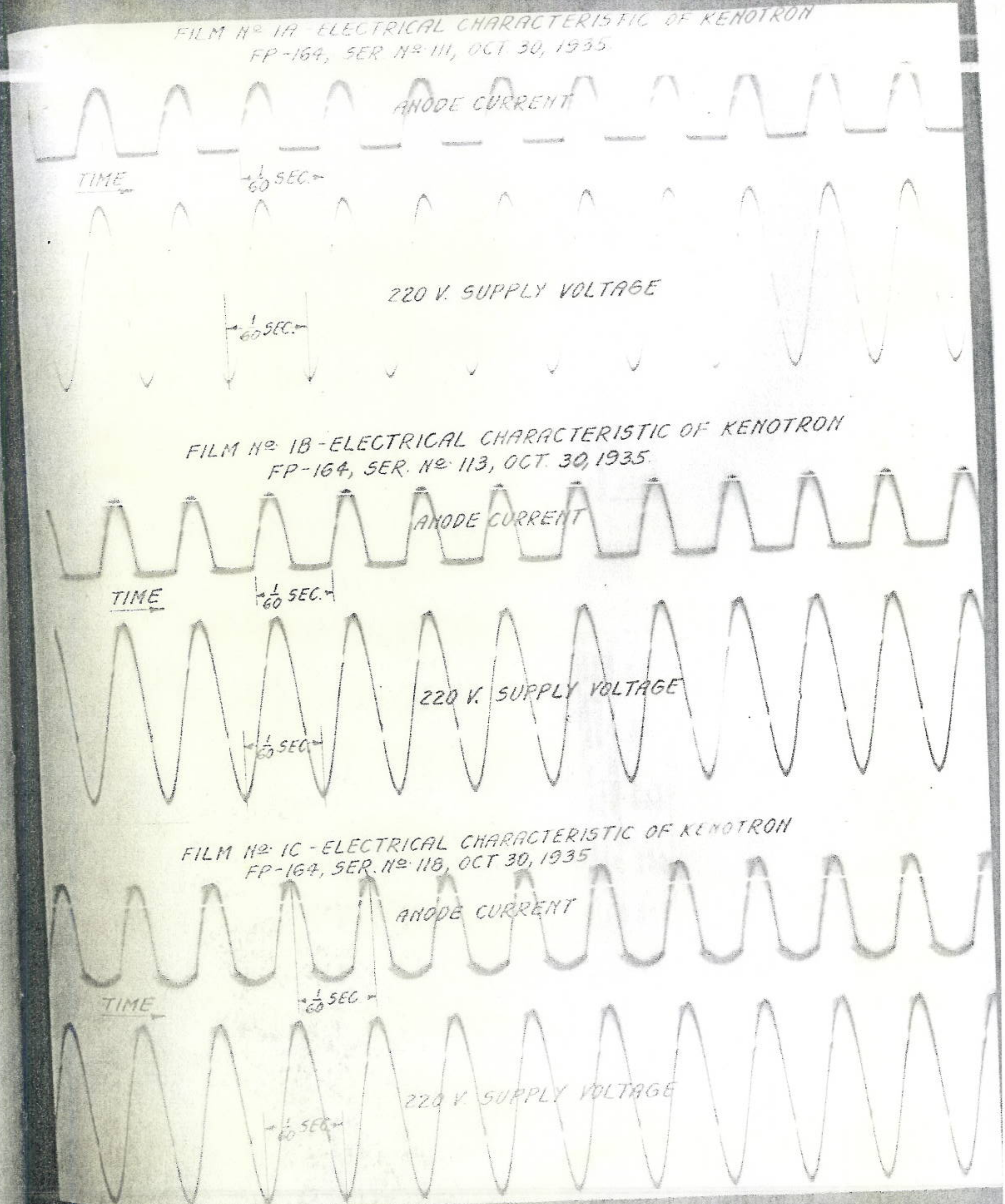

FILM Nº 1A - ELECTRICAL CHARACTERISTIC OF KENOTRON
FP-164, SER. Nº 111, OCT. 30, 1935
ANODE CURRENT
TIME
1/60 SEC.
220 V. SUPPLY VOLTAGE
1/60 SEC.
FILM Nº 1B - ELECTRICAL CHARACTERISTIC OF KENOTRON
FP-164, SER. Nº 113, OCT. 30, 1935
ANODE CURRENT
TIME
1/60 SEC.
220 V. SUPPLY VOLTAGE
1/60 SEC.
FILM Nº 1C - ELECTRICAL CHARACTERISTIC OF KENOTRON
FP-164, SER. Nº 118, OCT 30, 1935
ANODE CURRENT
TIME
1/60 SEC
220 V. SUPPLY VOLTAGE
1/60 SEC.

PLATE 5

General Electric Time Delay Electronic Relay Vacuum Tube Device Type FP-164.

Summary of Characteristics versus Temperature, before and after vibration tests on tubes.

Time given in minutes and seconds required to actuate control relay General Electric Type CR 2810-1265B-143 at its rated current of 40.0 milliamperes, d.c.

Conditions: - Temperature, 25 degrees Centigrade, before Vibration Tests.

Tube Number	Heater Volts	Initial Time Delay	After 1 Minute Off	After 2 Minutes Off	After 3 Minutes Off	After 4 Minutes Off	After 5 Minutes Off	Curves on Plate Number
111	5.1	31-33	7-54	11-06	14-02	15-52	15-30	10
112	5.0	34-03					14-30	12
113	4.6	28-35	6-22	7-0	9-56	12-33	14-55	14
118	4.5	35-42	5-25	6-20	8-24	9-35	10-25	16

Conditions: - Temperature, 25 degrees Centigrade, after vibration tests.

Tube Number	Heater Volts	Initial Time Delay	After 1 Minute Off	After 2 Minutes Off	After 3 Minutes Off	After 4 Minutes Off	After 5 Minutes Off	Curves on Plate Number
111	5.1	> 55	6-47	13-0	12-43	17-12	15-30	11
112	5.0	34-14	7-19	10-40	12-10	13-46	[illegible]	13
113	4.6	35-17	6-42	9-34	14-49	[illegible]	14-32	15
118	4.5	26-31	4-27	6-54	8-37	9-44	10-44	17

Conditions: - Temperature 48.5 degrees Centigrade, after vibration tests.

Tube Number	Heater Volts	Time required to reach the indicated saturation current. Initial Time Delay	Saturation Current in Ma	Time Delay After 5 Minutes Off	Saturation Current in Ma	Curves on Plate Number
111	5.1	45-30	32.0	29-30	33.0	19
113	4.6	55-0	36.0	34-0	35.0	21
118	4.5	33-50	40.0	13-52	40.0	22

Conditions: - Temperature Zero degrees Centigrade, after vibration tests.

Tube Number	Heater Volts	Time required to reach the indicated saturation current. Initial Time Delay	Saturation Current in Ma	Time Delay After 5 Minutes Off	Saturation Current in Ma	Curves on Plate Number
111	5.1	45-23	34.0	26-0	34.0	18
113	4.6	54-0	37.0	35-0	37.0	20
118	4.5	32-17	40.0	14-44	40.0	22

PLATE 6

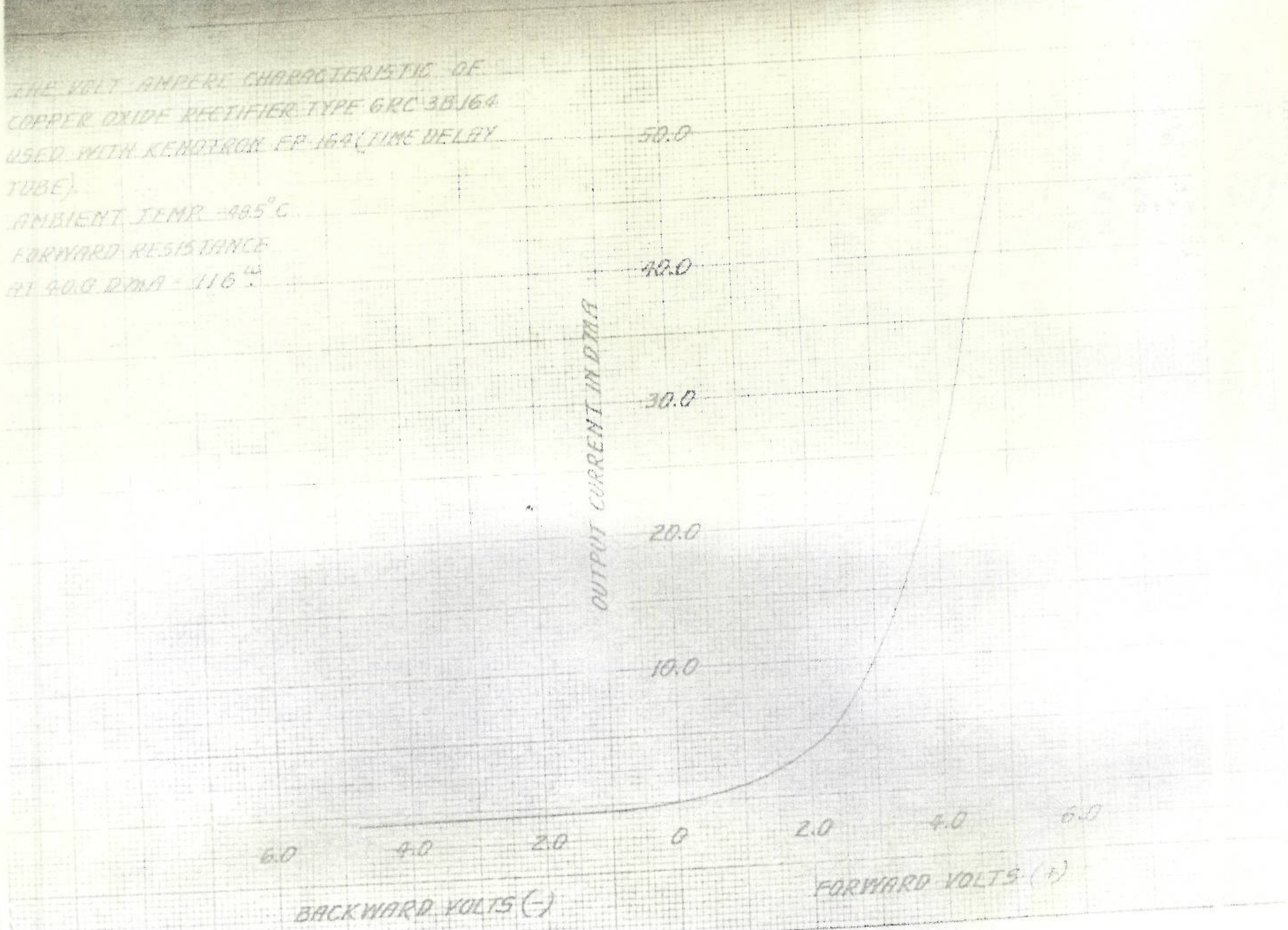
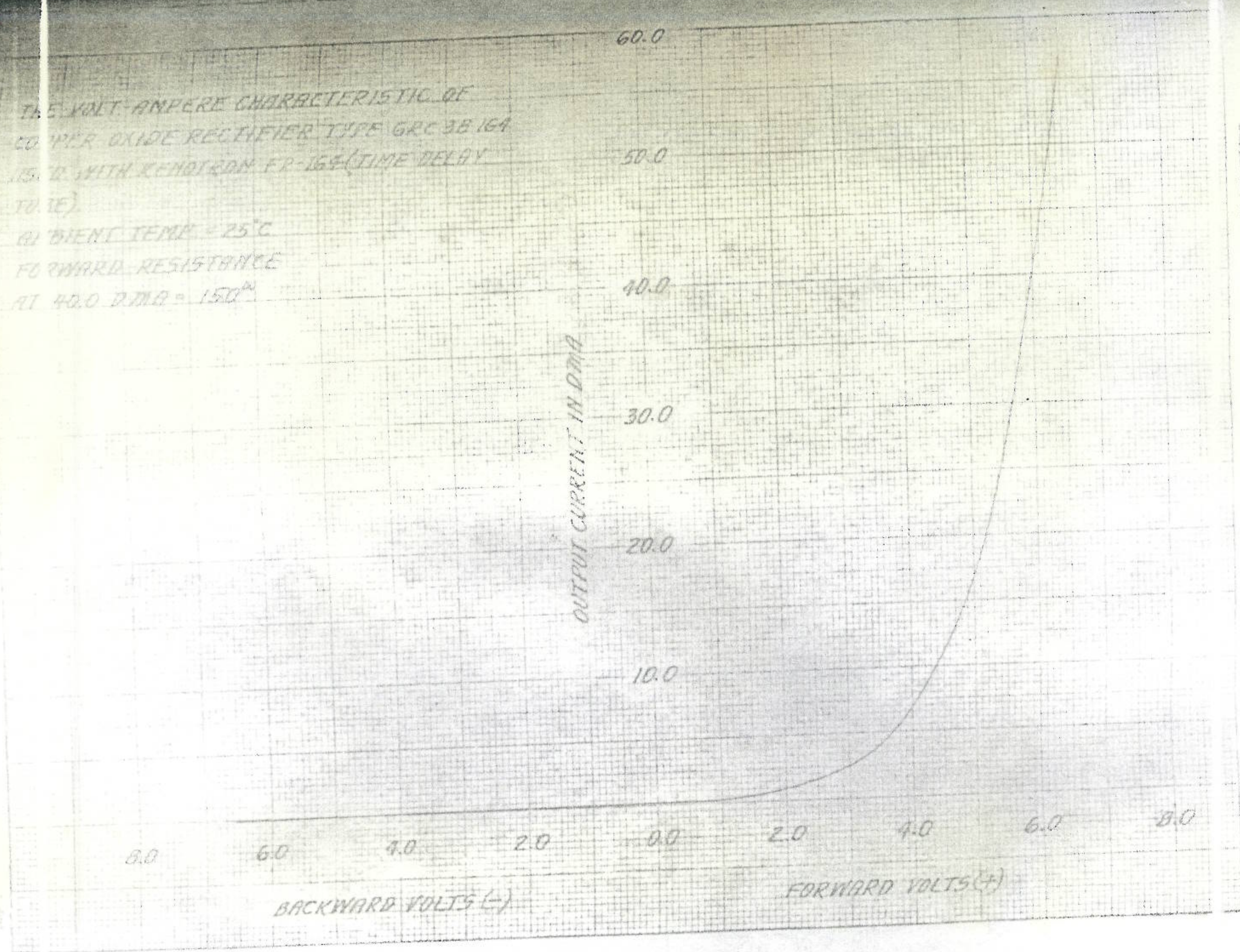

THE VOLT AMPERE CHARACTERISTIC OF
COPPER OXIDE RECTIFIER TYPE GRC 3BJ64
USED WITH KENOTRON FP 164 (TIME DELAY
TUBE).
AMBIENT TEMP. 48.5°C
FORWARD RESISTANCE
AT 40.0 DMA - 116 ω
OUTPUT CURRENT IN DMA
50.0
40.0
30.0
20.0
10.0
6.0
4.0
2.0
0
2.0
4.0
6.0
BACKWARD VOLTS (−)
FORWARD VOLTS (+)

PLATE 7

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

DATE

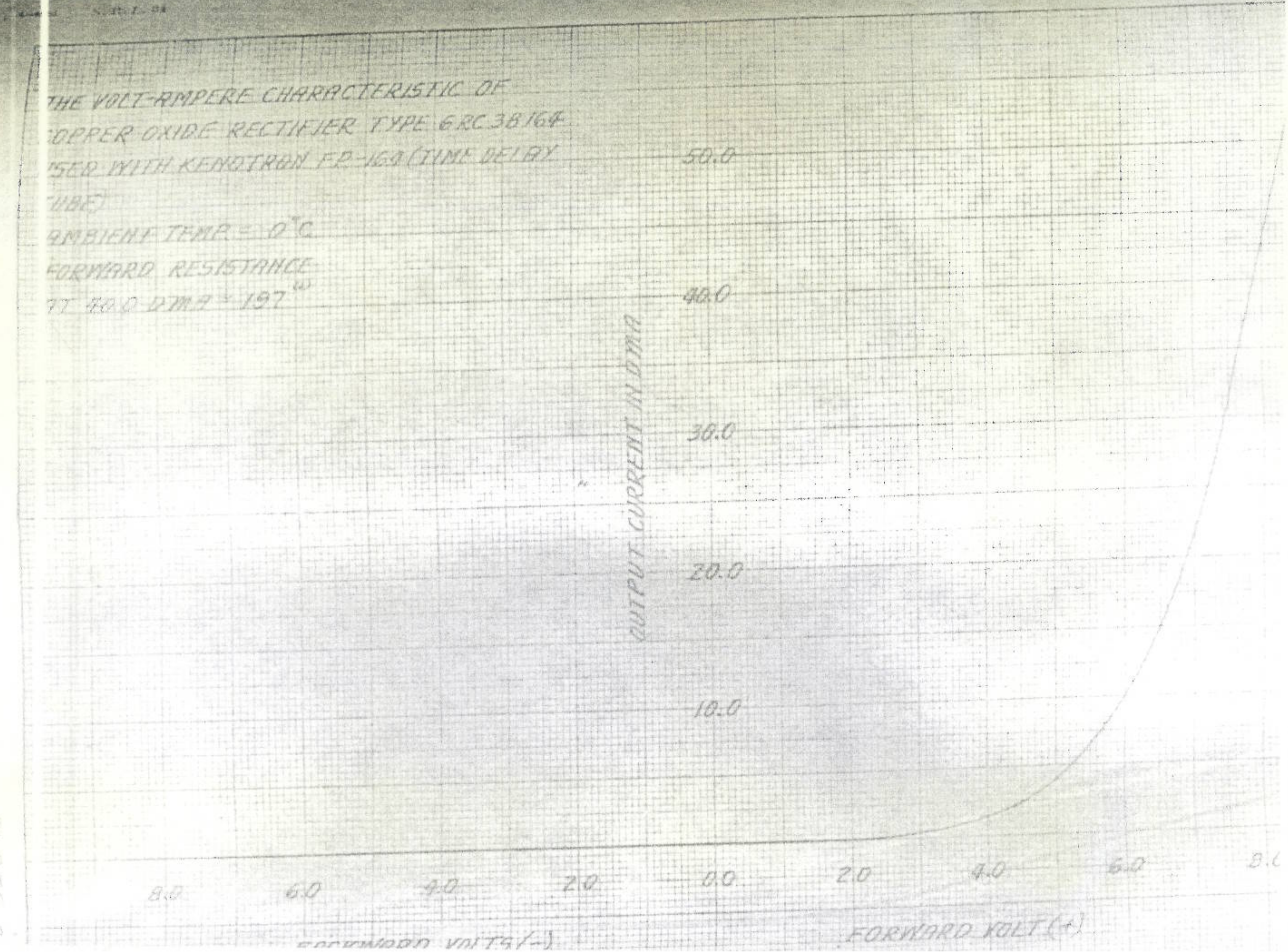


SHEET

PLATE 8

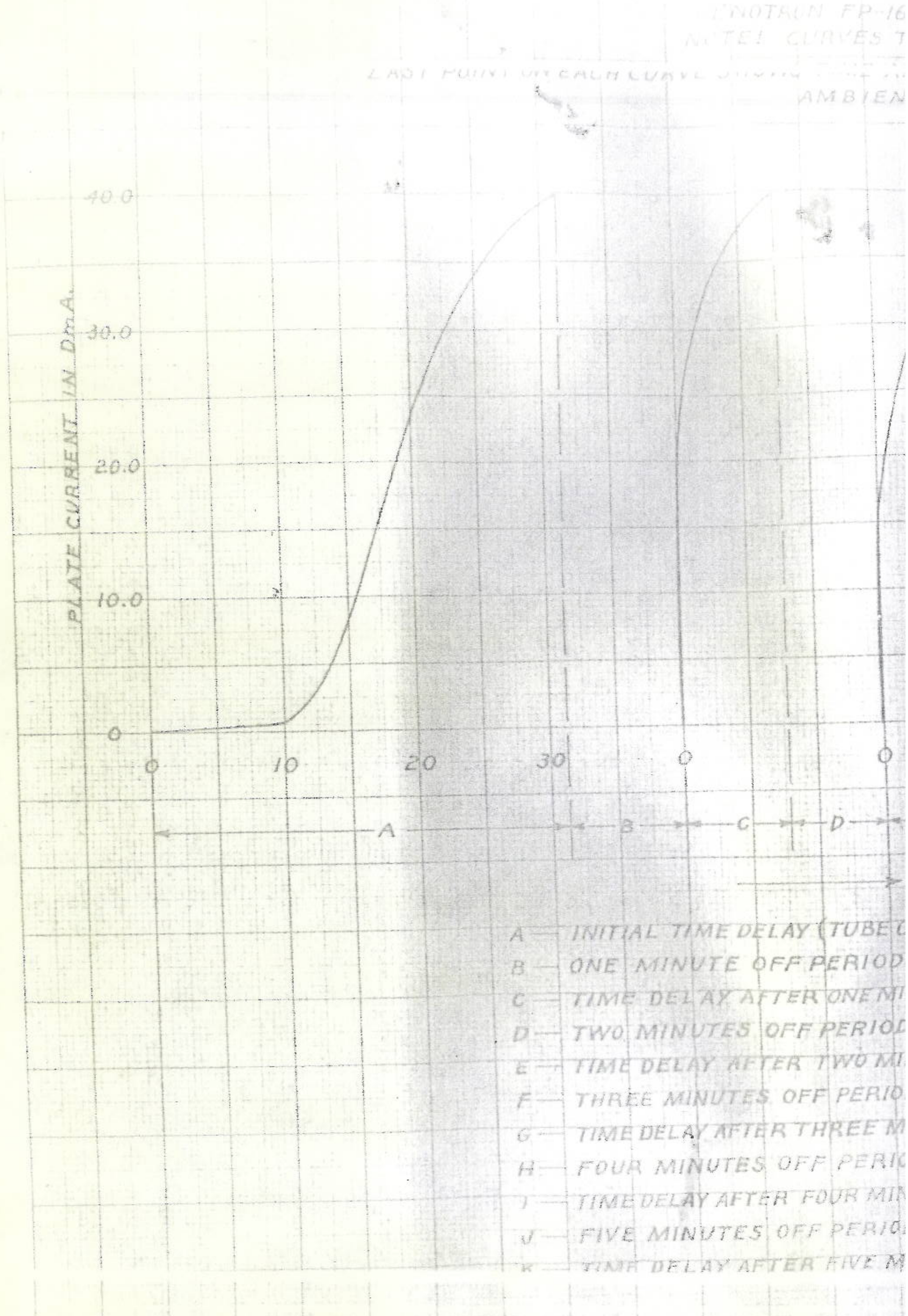
U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE



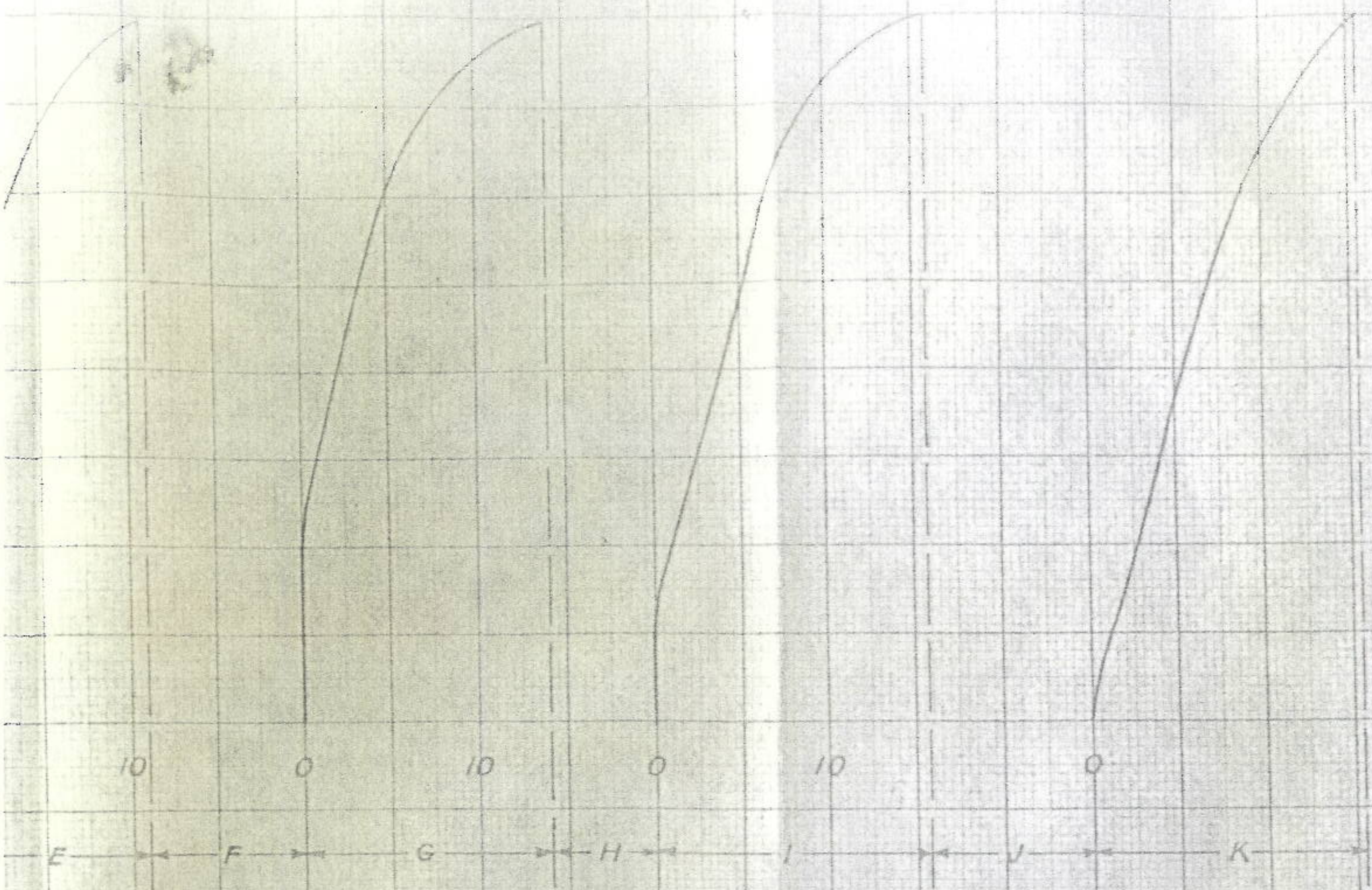
SHEET

PLATE 9


AMBIEN
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0
0
10
20
30
0
0
A
B
C
D
A — INITIAL TIME DELAY (TUBE
B — ONE MINUTE OFF PERIOD
C — TIME DELAY AFTER ONE
D — TWO MINUTES OFF
E — TIME DELAY AFTER TWO
F — THREE MINUTES OFF
G — TIME DELAY AFTER THREE
H — FOUR MINUTES OFF
I — TIME DELAY AFTER FOUR
J — FIVE MINUTES OFF
K — TIME DELAY AFTER FIVE

4. SER NO. III E_H = 5.1 VOLTS
AKEN BEFORE VIBRATION TEST

ND CURRENT REQUIRED TO ACTUATE CONTROL RELAY
T TEMPERATURE: 30°C.



TIME IN MINUTES

DLD): TIME = 31'—33" I_P = 39.8 DmA.

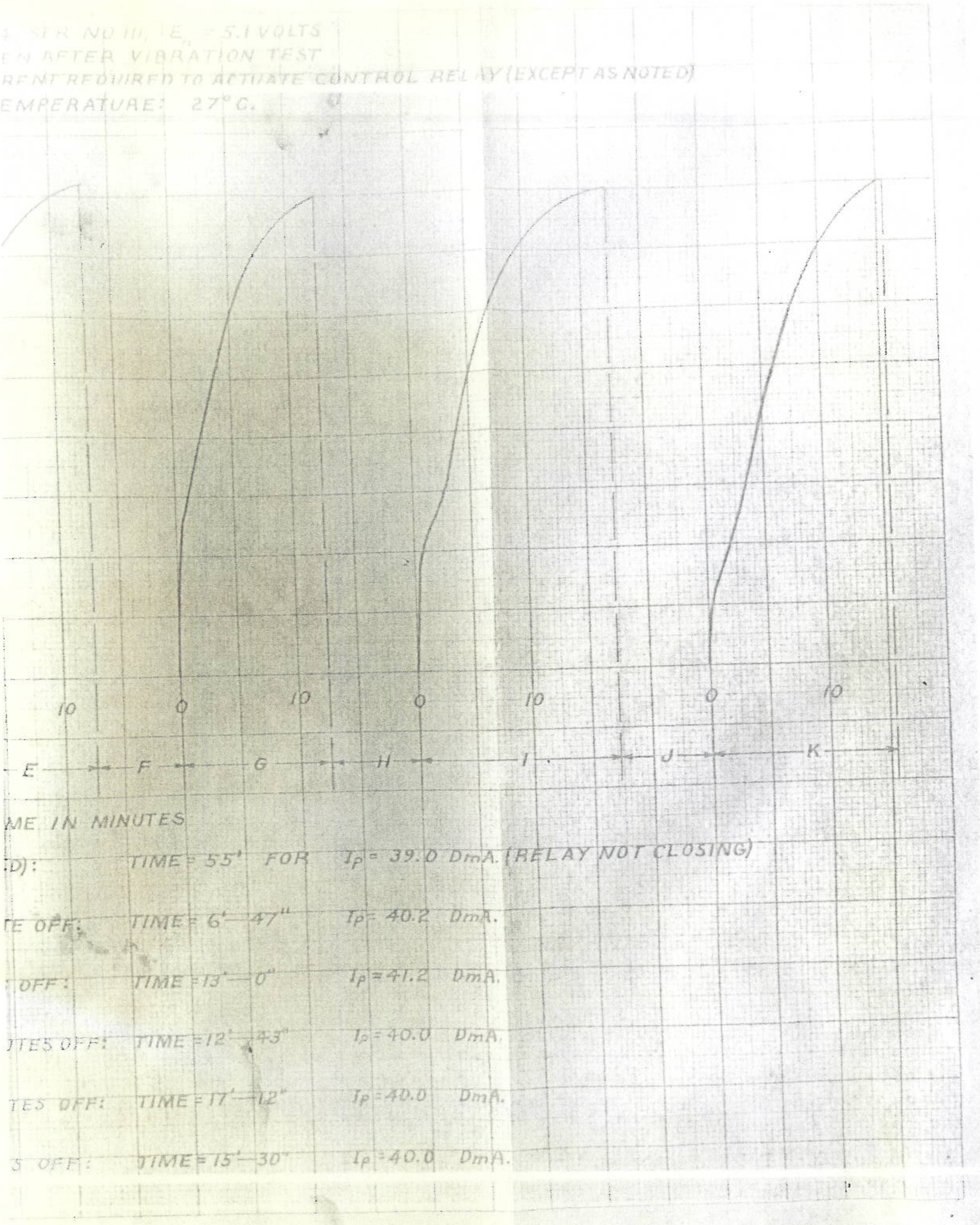
UTE OFF: TIME = 7'—54" I_P = 39.4 DmA.

UTES OFF: TIME = 11'—06" I_P = 39.6 DmA.

IUTES OFF: TIME = 14'—02" I_P = 39.7 DmA.

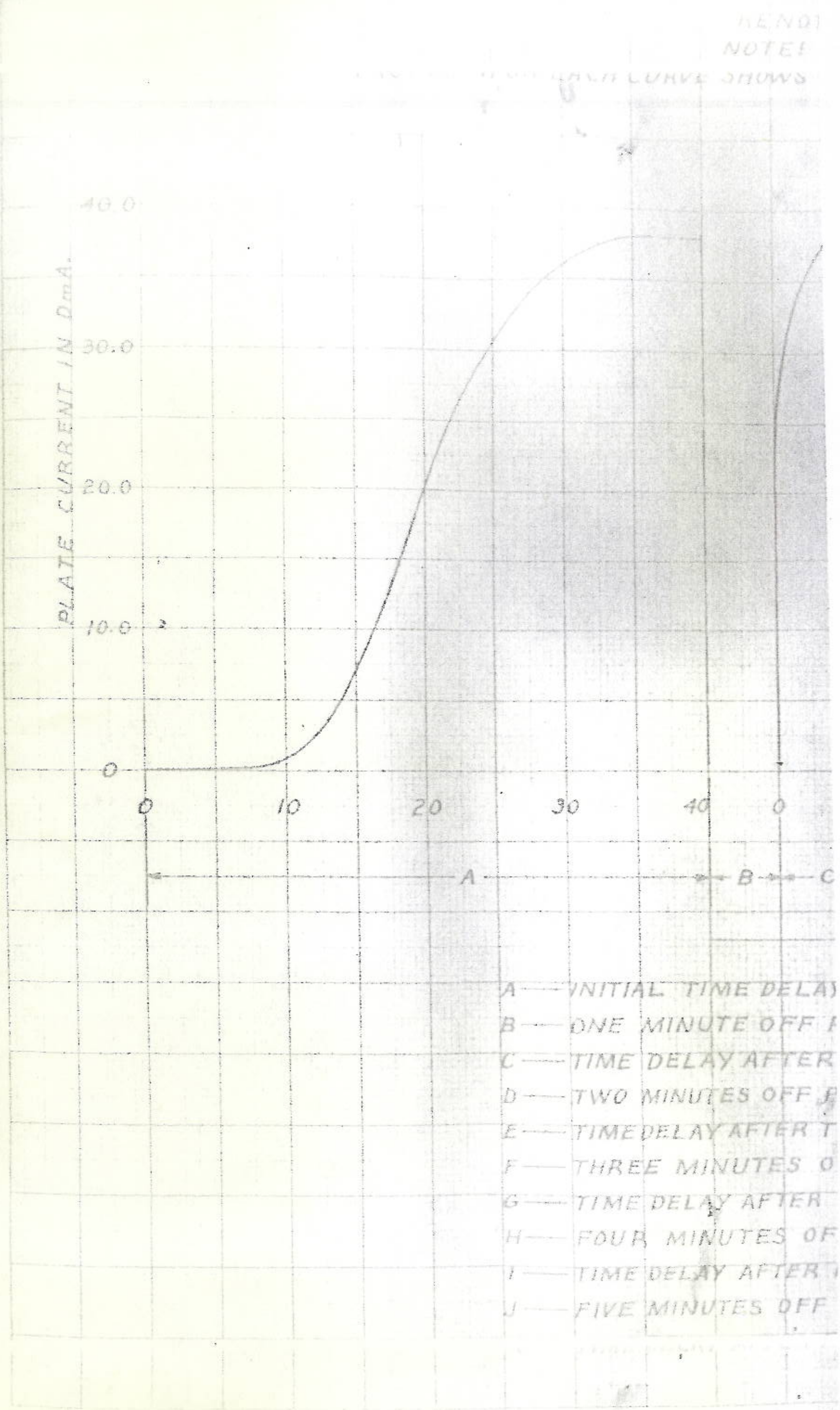
TES OFF: TIME = 15'—32" I_P = 39.8 DmA.

UTES OFF: TIME = 15'—30" I_P = 39.4 DmA.



SER NO III, E_H = 5.1 VOLTS
EN AFTER VIBRATION TEST
RENT REQUIRED TO ACTUATE CONTROL RELAY (EXCEPT AS NOTED)
EMPERATURE: 27°C.
10
0
10
0
10
0
10
E
F
G
H
I
J
K
ME IN MINUTES
D): TIME = 55' FOR I_P = 39.0 DmA. (RELAY NOT CLOSING)
E OFF: TIME = 6'—47" I_P = 40.2 DmA.
OFF: TIME = 13'—0" I_P = 41.2 DmA.
TES OFF: TIME = 12'—43" I_P = 40.0 DmA.
TES OFF: TIME = 17'—12" I_P = 40.0 DmA.
S OFF: TIME = 15'—30" I_P = 40.0 DmA.
KEUFFEL & ESSER CO. N.Y.

PLATE II



NOTE
EACH CURVE SHOWS
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0
0
10
20
30
40
0
A
B
C
A — INITIAL TIME DELA
B — ONE MINUTE OFF
C — TIME DELAY AFTER
D — TWO MINUTES OFF
E — TIME DELAY AFTER
F — THREE MINUTES
G — TIME DELAY AFTER
H — FOUR MINUTES OF
I — TIME DELAY AFTER
J — FIVE MINUTES OFF

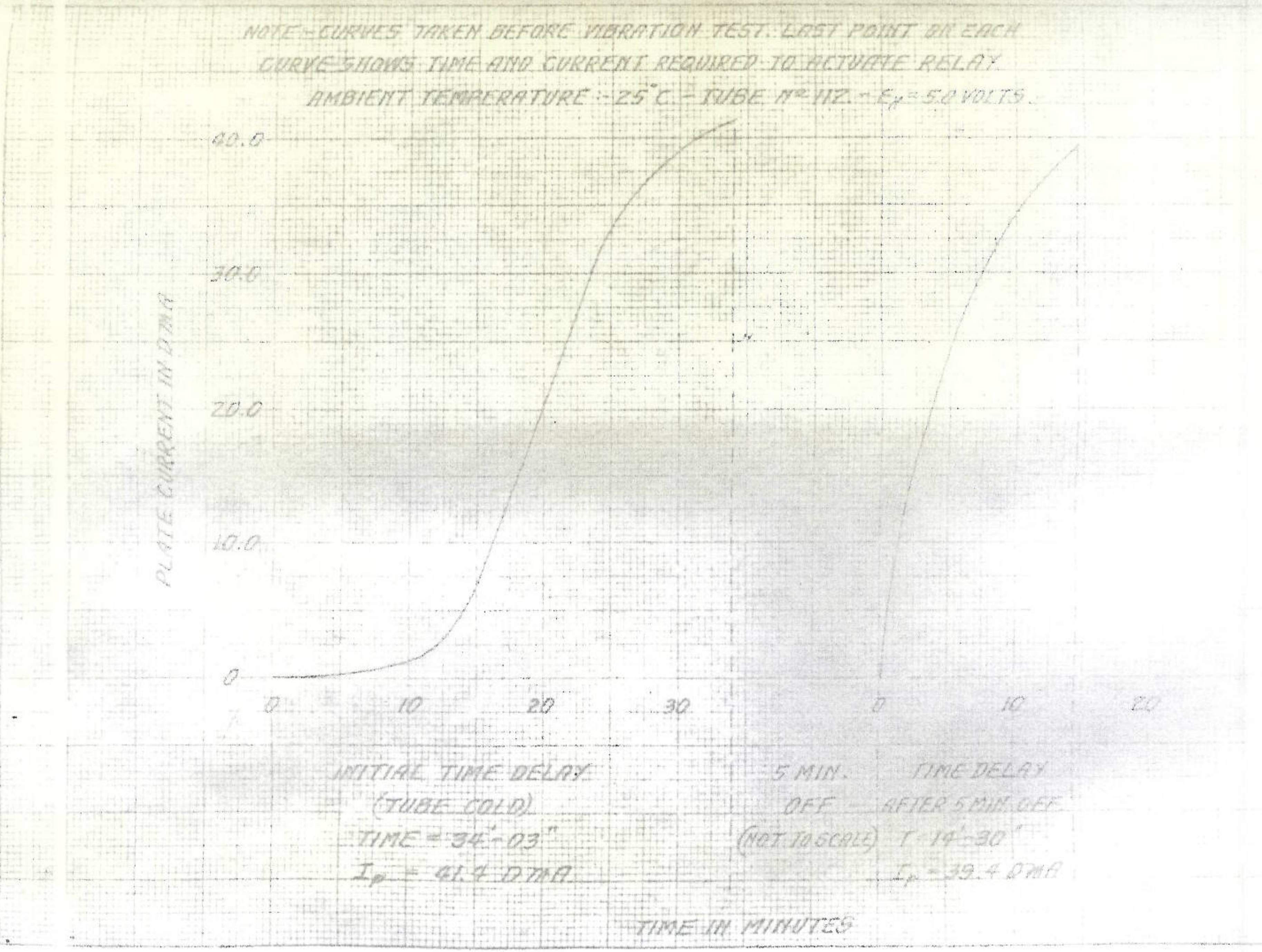
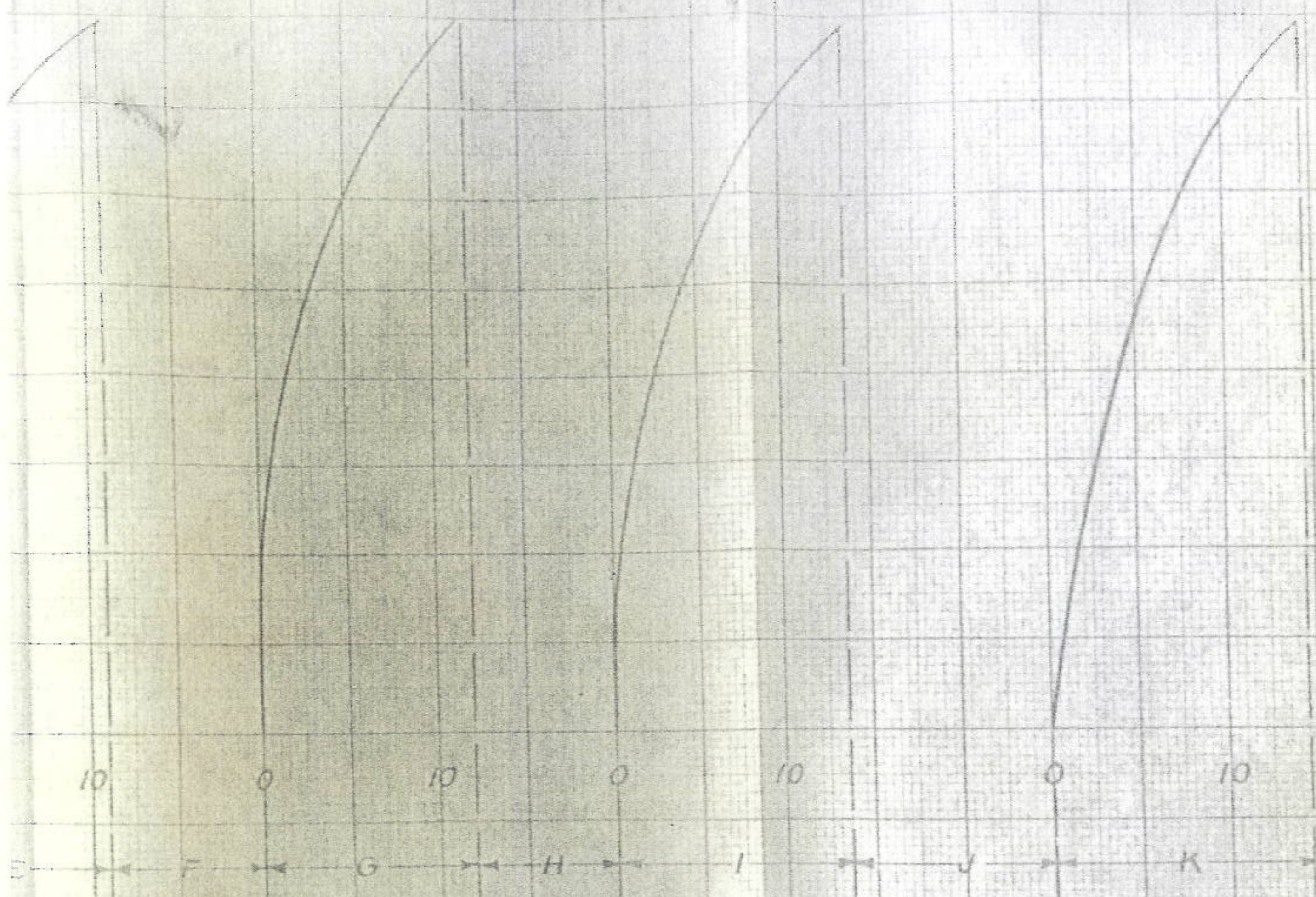

NOTE - CURVES TAKEN BEFORE VIBRATION TEST. LAST POINT ON EACH
CURVE SHOWS TIME AND CURRENT REQUIRED TO ACTUATE RELAY.
AMBIENT TEMPERATURE - 25°C - TUBE Nº 112 - Ef = 5.0 VOLTS.
40.0
30.0
20.0
10.0
0
PLATE CURRENT IN D.M.A.
0
10
20
30
0
10
20
INITIAL TIME DELAY
(TUBE COLD)
TIME = 34'-03"
Ip = 41.4 DMA
5 MIN.
OFF
(NOT TO SCALE)
TIME DELAY
AFTER 5 MIN. OFF
T 14'-30"
Ip = 39.4 DMA
TIME IN MINUTES

PLATE 12

4, SER. NO. 112, E_f = 5.0 VOLTS.
KEN AFTER VIBRATION TEST.
AND CURRENT REQUIRED TO ACTUATE CONTROL RELAY
EMPERATURE 24° C.



E IN MINUTES

TIME = 34' — 14" I_p = 39.7 DmA.

OFF: TIME = 7' — 19" I_p = 39.7 DmA.

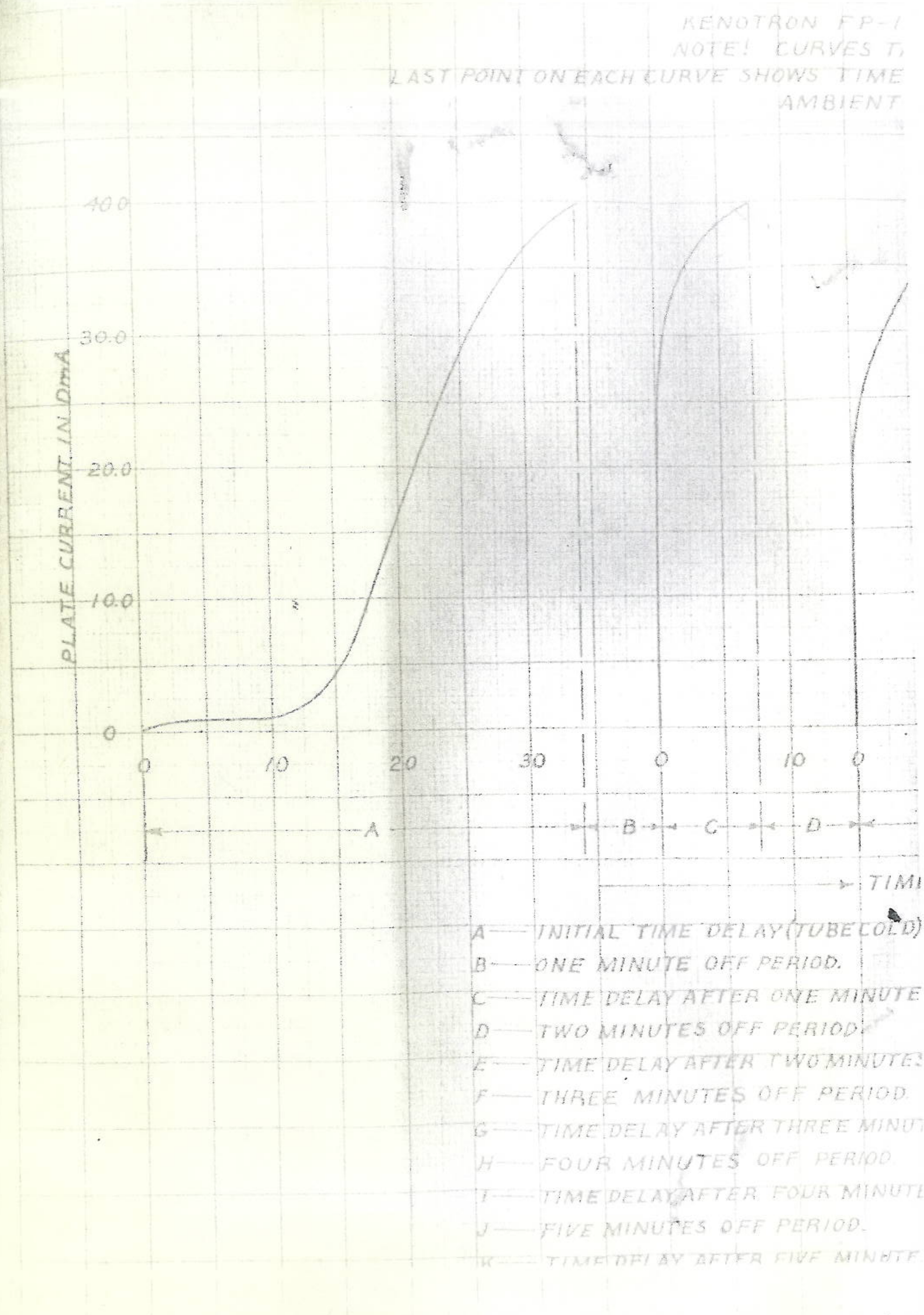
OFF: TIME = 10' — 40" I_p = 39.7 DmA.

ES OFF: TIME = 12' — 10" I_p = 39.7 DmA.

S OFF: TIME = 13' — [illegible] I_p = 39.7 DmA

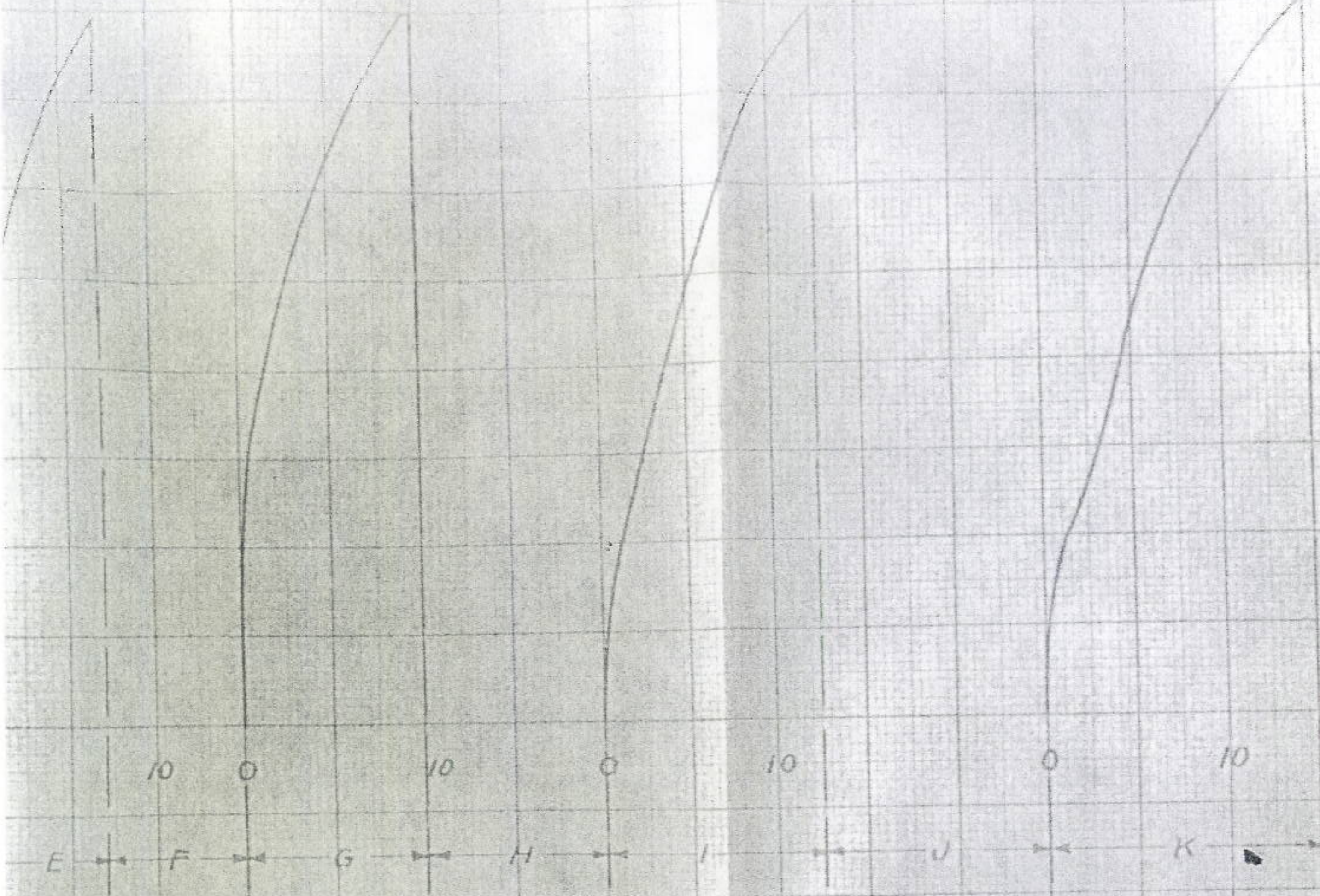
OFF: TIME = 14' — 33" I_p = 39.7 DmA.

PLATE 13



KENOTRON FP-1
NOTE! CURVES T
LAST POINT ON EACH CURVE SHOWS TIME
AMBIENT
PLATE CURRENT IN DmA
40.0
30.0
20.0
10.0
0
0
10
20
30
0
10
0
A
B
C
D
TIM
A — INITIAL TIME DELAY (TUBE COLD)
B — ONE MINUTE OFF PERIOD.
C — TIME DELAY AFTER ONE MINUTE
D — TWO MINUTES OFF PERIOD.
E — TIME DELAY AFTER TWO MINUTES
F — THREE MINUTES OFF PERIOD.
G — TIME DELAY AFTER THREE MINUT
H — FOUR MINUTES OFF PERIOD
I — TIME DELAY AFTER FOUR MINUTE
J — FIVE MINUTES OFF PERIOD.
K — TIME DELAY AFTER FIVE MINUTE

SER. NO 113, E_H = 4.6 VOLTS
KEN BEFORE VIBRATION TEST
AND CURRENT REQUIRED TO ACTUATE CONTROL RELAY
MPERATURE: 25° C.



TIME = 28' — 35" I_p = 40.0 DmA.

OFF: TIME = 6' — 22" I_P = 39.6 DmA.

OFF: TIME = 7' — 0" I_P = 39.6 DmA.

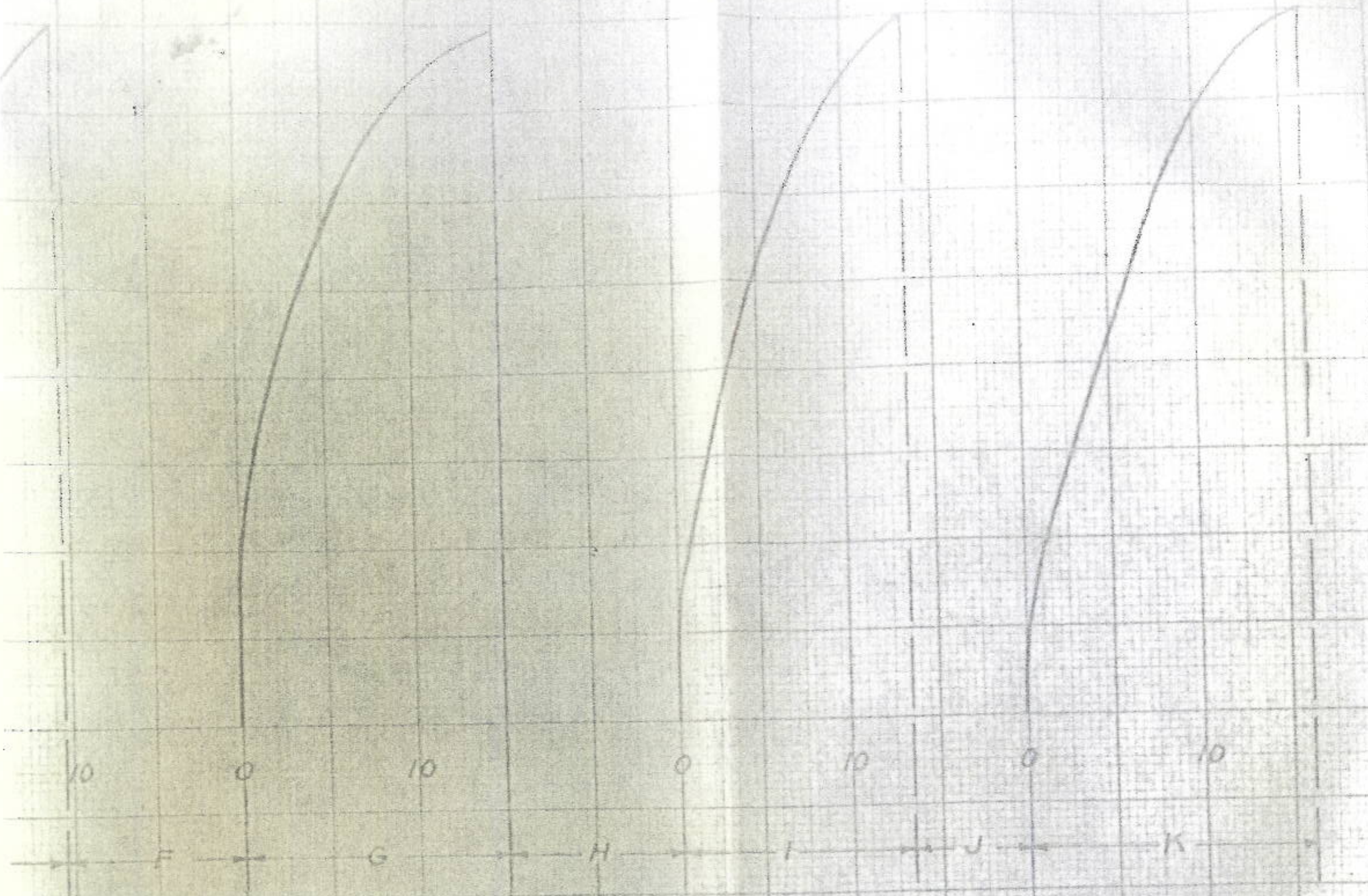
S OFF: TIME = 9' — 54" I_P = 39.6 DmA.

S OFF: TIME = 12' — 33" I_P = 39.6 DmA.

S OFF: TIME = 14' — 55" I_P = 39.8 DmA.

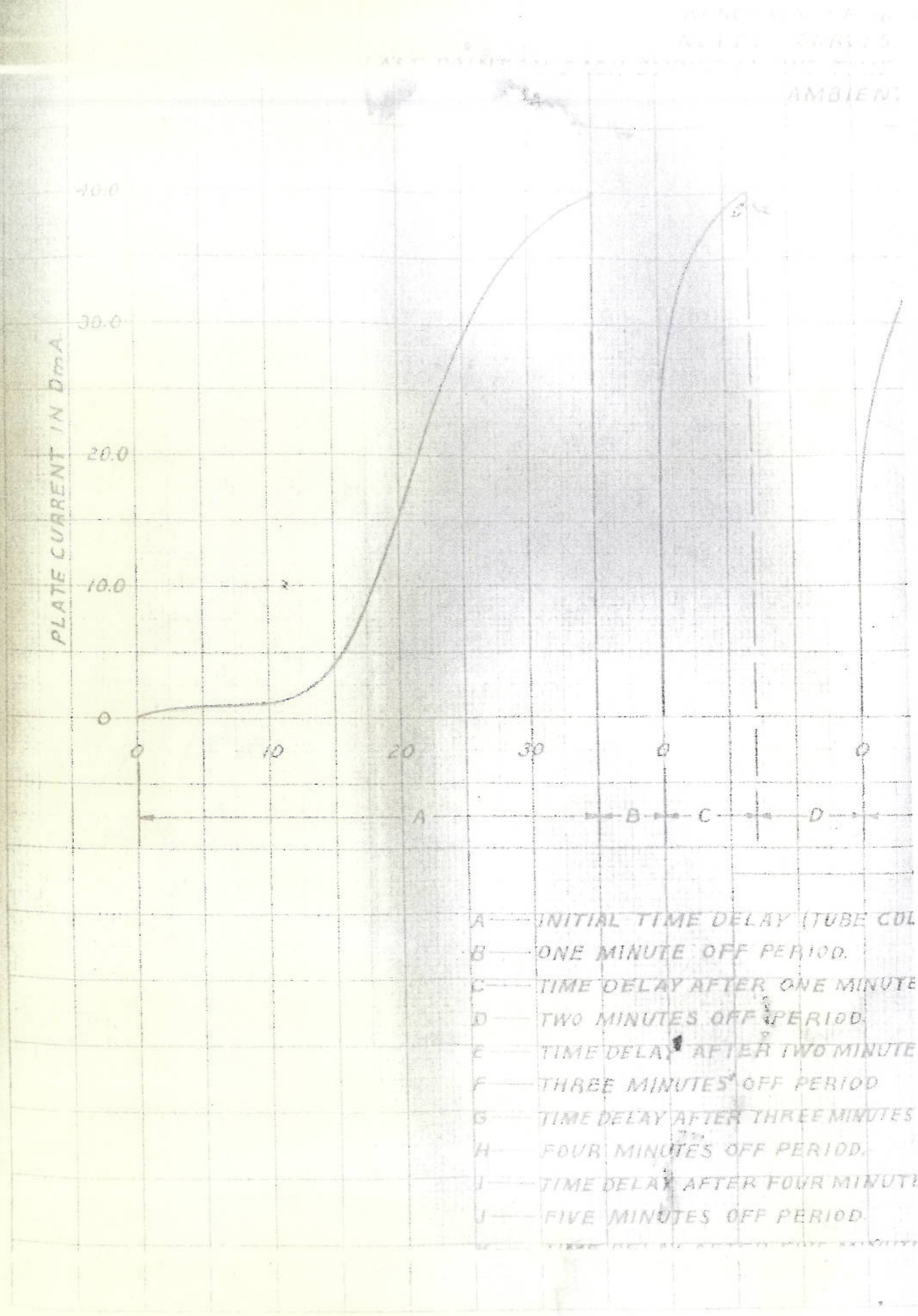
PLATE 14

DER NO. 13 E_h = 4.6 VOLTS
KEN AFTER VIBRATION TEST
D CURRENT REQUIRED TO ACTUATE CONTROL RELAY
EMPERATURE: 23° C.



TIME IN MINUTES

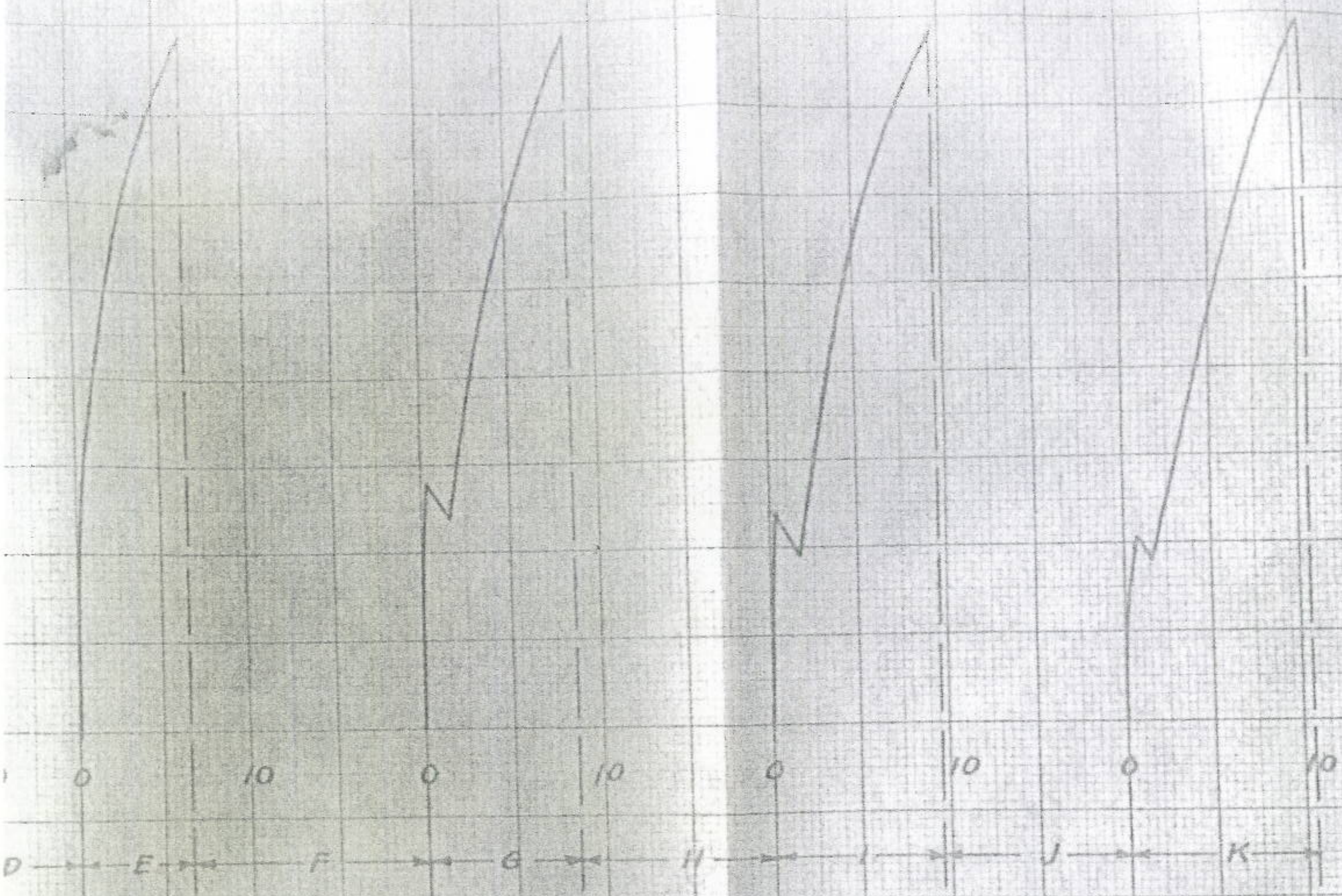
	TIME = 35' – 17"	I_p = 40.0	DmA.
FF:	TIME = 6' – 42"	I_P = 40.0	DmA.
OFF:	TIME = 9' – 34"	I_P = 39.8	DmA.
FF:	TIME = 14' – 49"	I_P = 39.8	DmA.
OFF:	TIME = 13' – 15"	I_P = 39.8	DmA.
OFF:	TIME = 14' – 54"	I_P = 40.0	DmA.



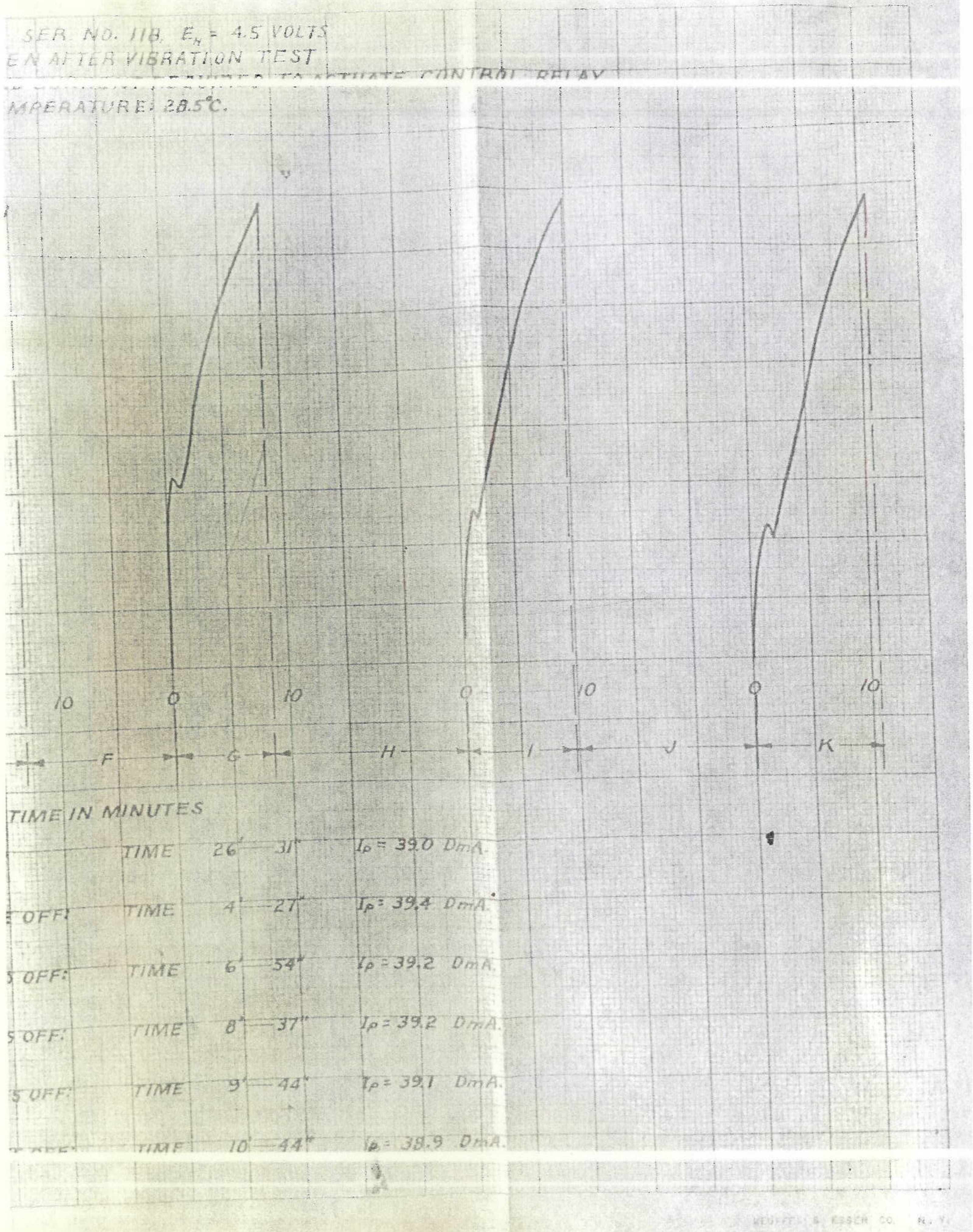
AMBIENT
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0
0
10
20
30
0
0
A
B
C
D
A — INITIAL TIME DELAY (TUBE COL
B — ONE MINUTE OFF PERIOD.
C — TIME DELAY AFTER ONE MINUTE
D — TWO MINUTES OFF PERIOD.
E — TIME DELAY AFTER TWO MINUTE
F — THREE MINUTES OFF PERIOD
G — TIME DELAY AFTER THREE MINUTES
H — FOUR MINUTES OFF PERIOD.
I — TIME DELAY AFTER FOUR MINUTE
J — FIVE MINUTES OFF PERIOD.

SER. NO. 118, E_H = 4.5 VOLTS.
EN BEFORE VIBRATION TEST.

EMPERATURE: 30° C.

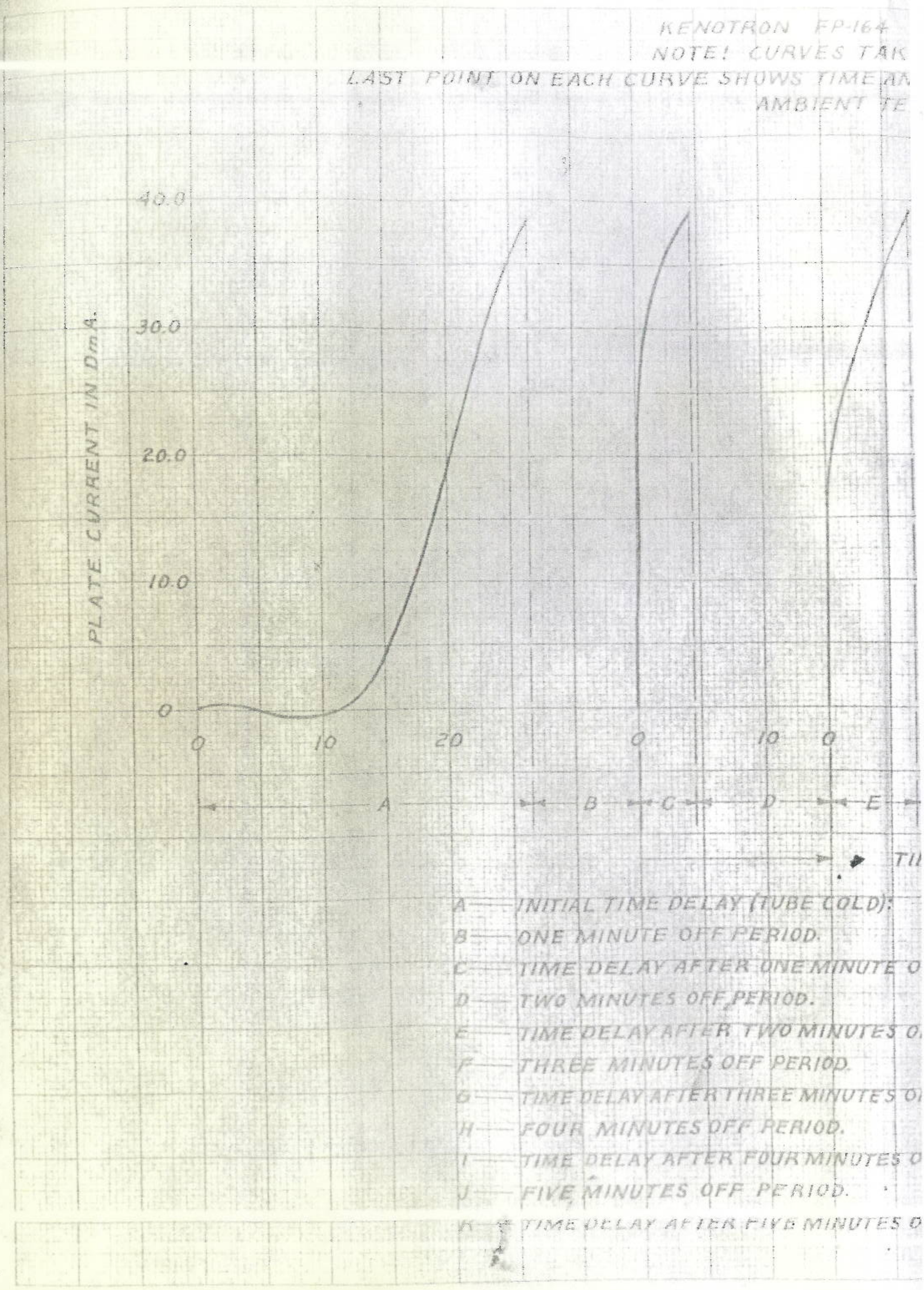


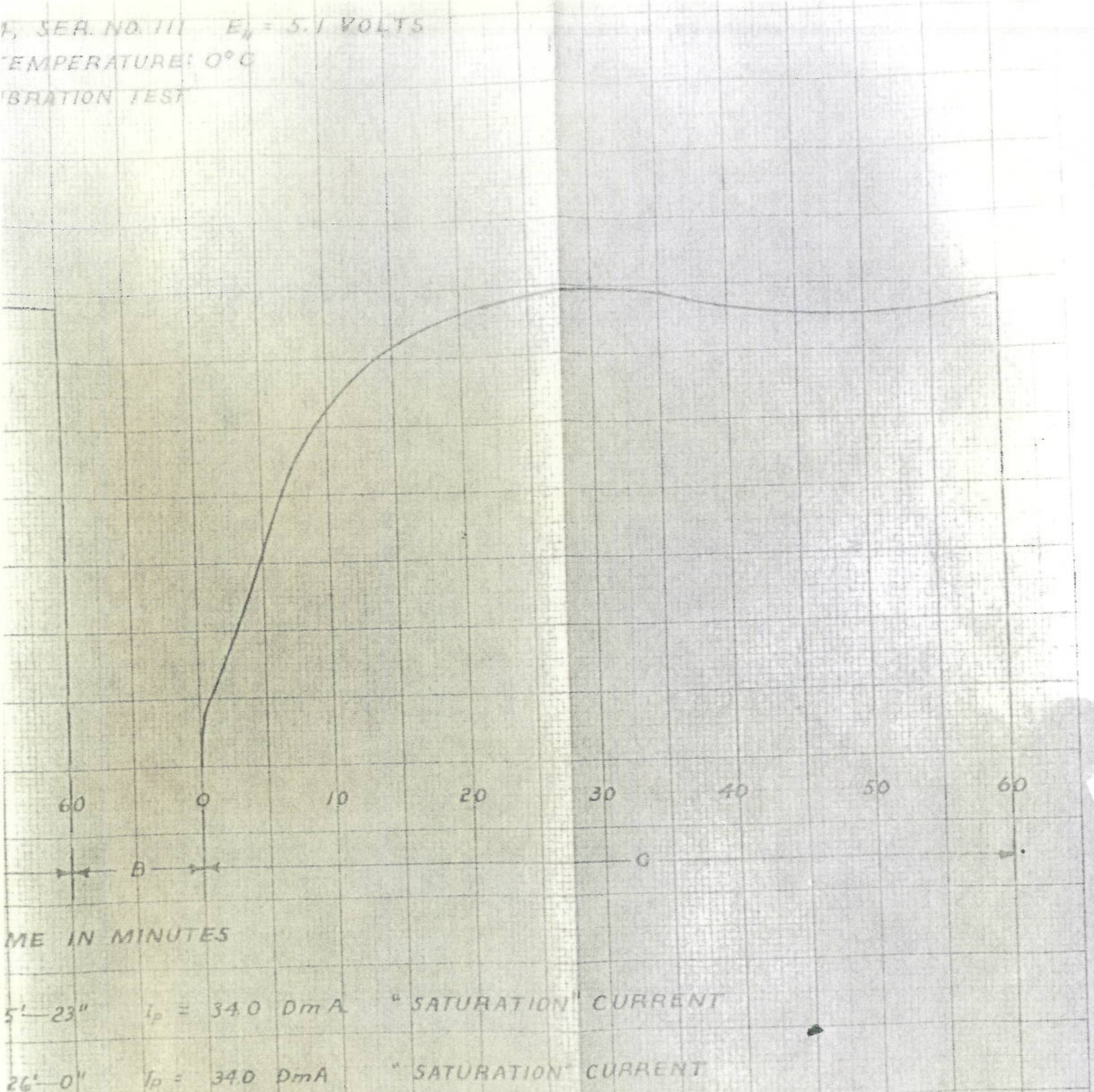
	TIME = 33' — 41"	I_P = 39.6 DmA
FF:	TIME = 5' — 25"	I_P = 39.2 DmA
OFF:	TIME = 6' — 20"	I_P = 38.8 DmA
TES OFF:	TIME = 8' — 24"	I_P = 39.2 DmA
UTES OFF	TIME = 9' — 35"	I_P = 39.3 DmA



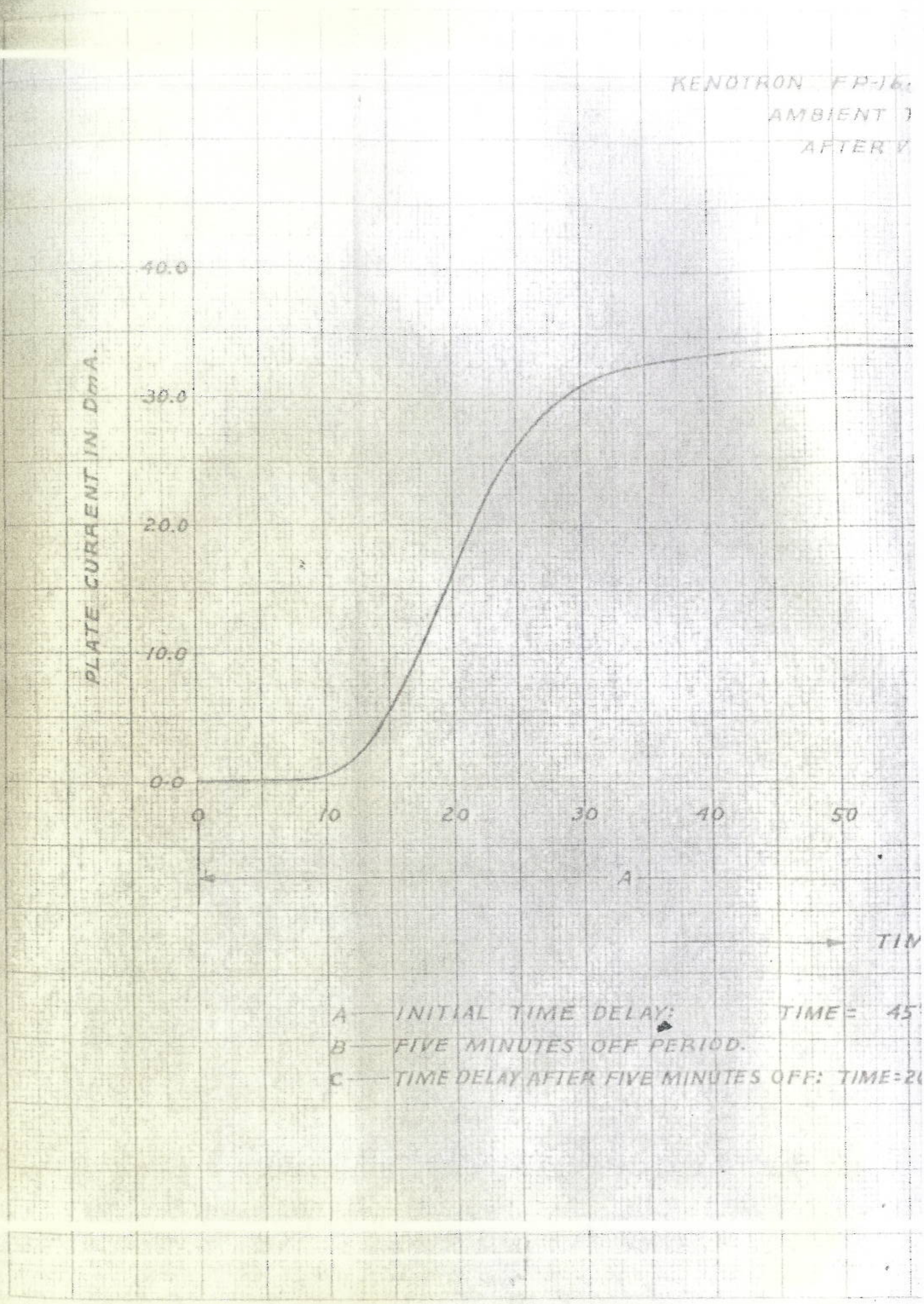
SER. NO. 11B. E = 4.5 VOLTS
EN AFTER VIBRATION TEST
CONTROL RELAY
MPERATURE: 28.5°C.
10
0
10
0
10
0
10
F
G
H
I
J
K
TIME IN MINUTES
TIME 26' 31" Ip = 39.0 DmA.
E OFF: TIME 4' 27" Ip = 39.4 DmA.
S OFF: TIME 6' 54" Ip = 39.2 DmA.
S OFF: TIME 8' 37" Ip = 39.2 DmA.
S OFF: TIME 9' 44" Ip = 39.1 DmA.
TIME 10' 44" Ip = 38.9 DmA.
KEUFFEL & ESSER CO.

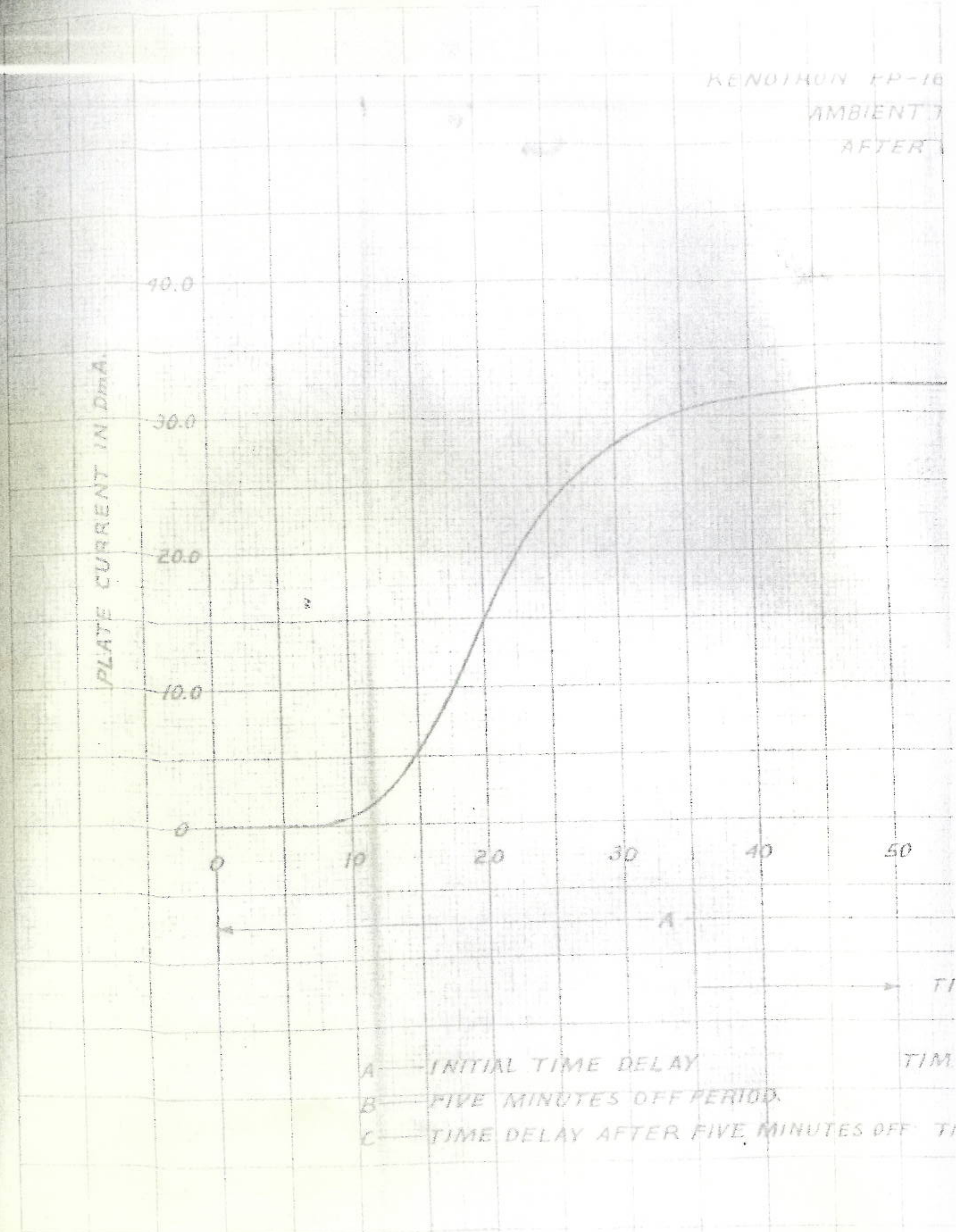
PLATE 17


KENOTRON FP-164
NOTE! CURVES TAK
LAST POINT ON EACH CURVE SHOWS TIME AN
AMBIENT TE
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0
0
10
20
0
10
0
A
B
C
D
E
TI
A — INITIAL TIME DELAY (TUBE COLD):
B — ONE MINUTE OFF PERIOD.
C — TIME DELAY AFTER ONE MINUTE O
D — TWO MINUTES OFF PERIOD.
E — TIME DELAY AFTER TWO MINUTES O
F — THREE MINUTES OFF PERIOD.
G — TIME DELAY AFTER THREE MINUTES O
H — FOUR MINUTES OFF PERIOD.
I — TIME DELAY AFTER FOUR MINUTES O
J — FIVE MINUTES OFF PERIOD.
K — TIME DELAY AFTER FIVE MINUTES O



KEUFFEL & ESSER CO. N.Y.


KENOTRON FP-16
AMBIENT
AFTER
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0-0
0
10
20
30
40
50
A
TIM
A—INITIAL TIME DELAY: TIME= 45
B—FIVE MINUTES OFF PERIOD.
C—TIME DELAY AFTER FIVE MINUTES OFF: TIME=2


KENOTRON FP-16
AMBIENT T
AFTER
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0
0
10
20
30
40
50
A
TI
A—INITIAL TIME DELAY
TIM
B—FIVE MINUTES OFF PERIOD
C—TIME DELAY AFTER FIVE MINUTES OFF
TI

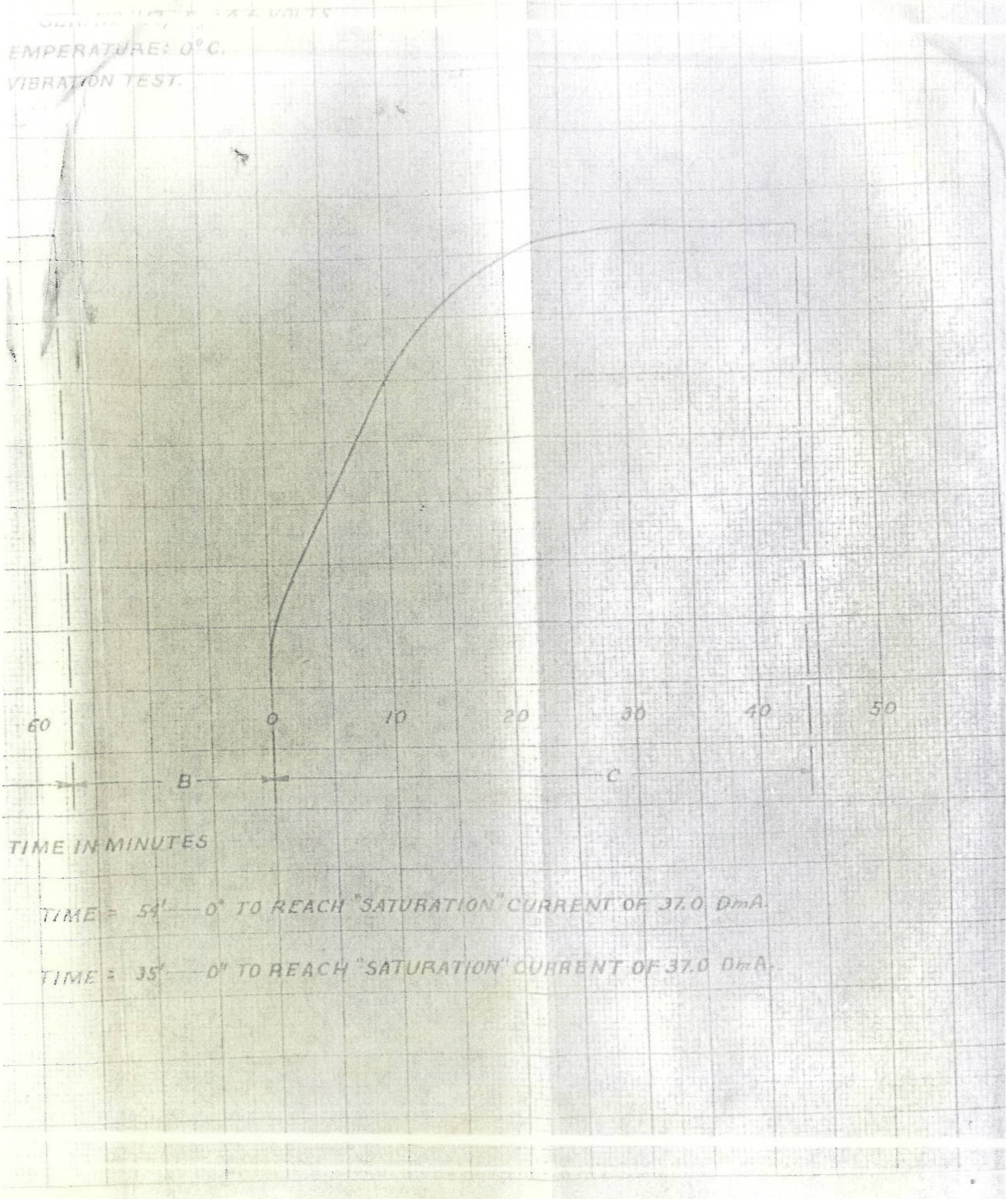
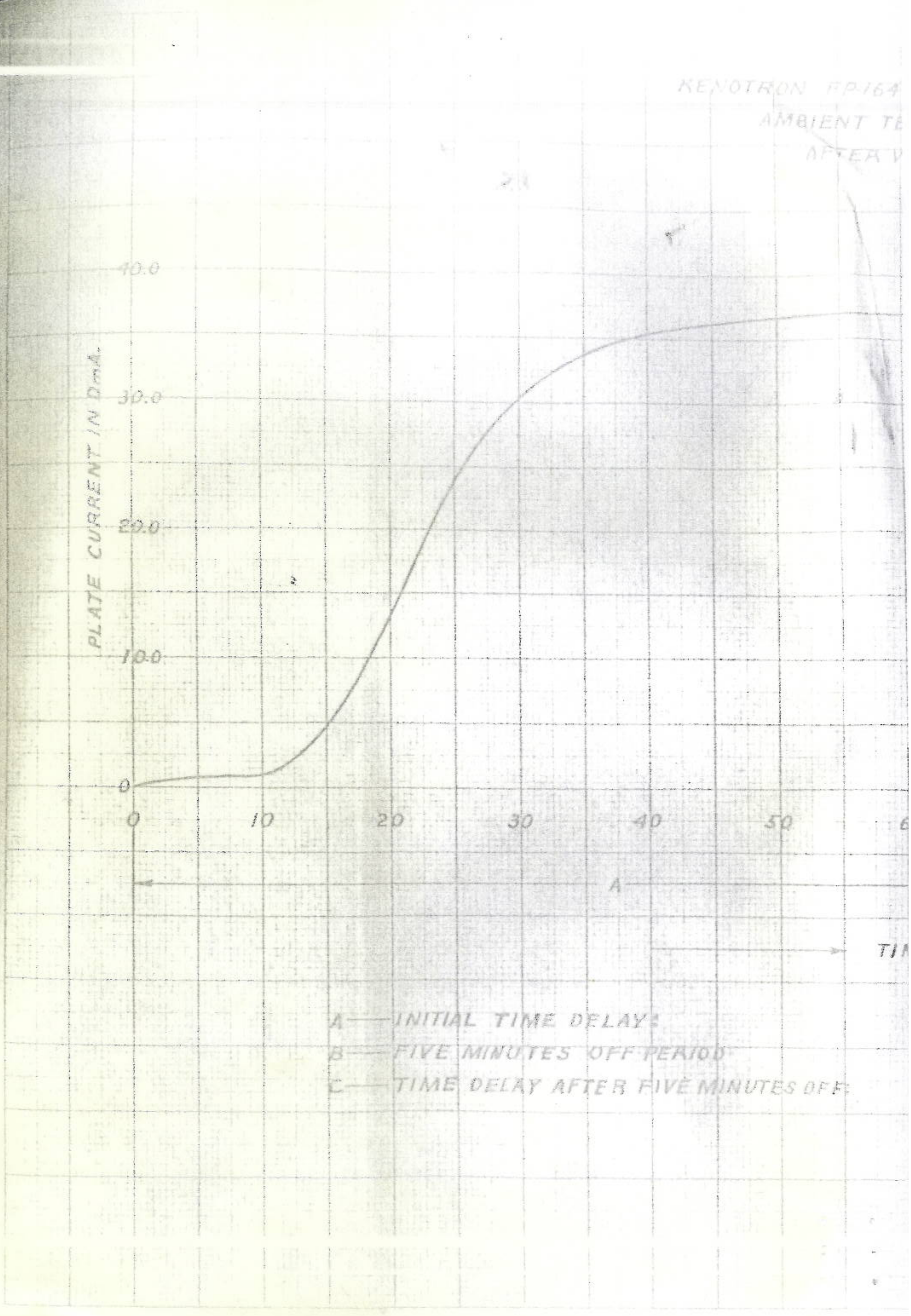
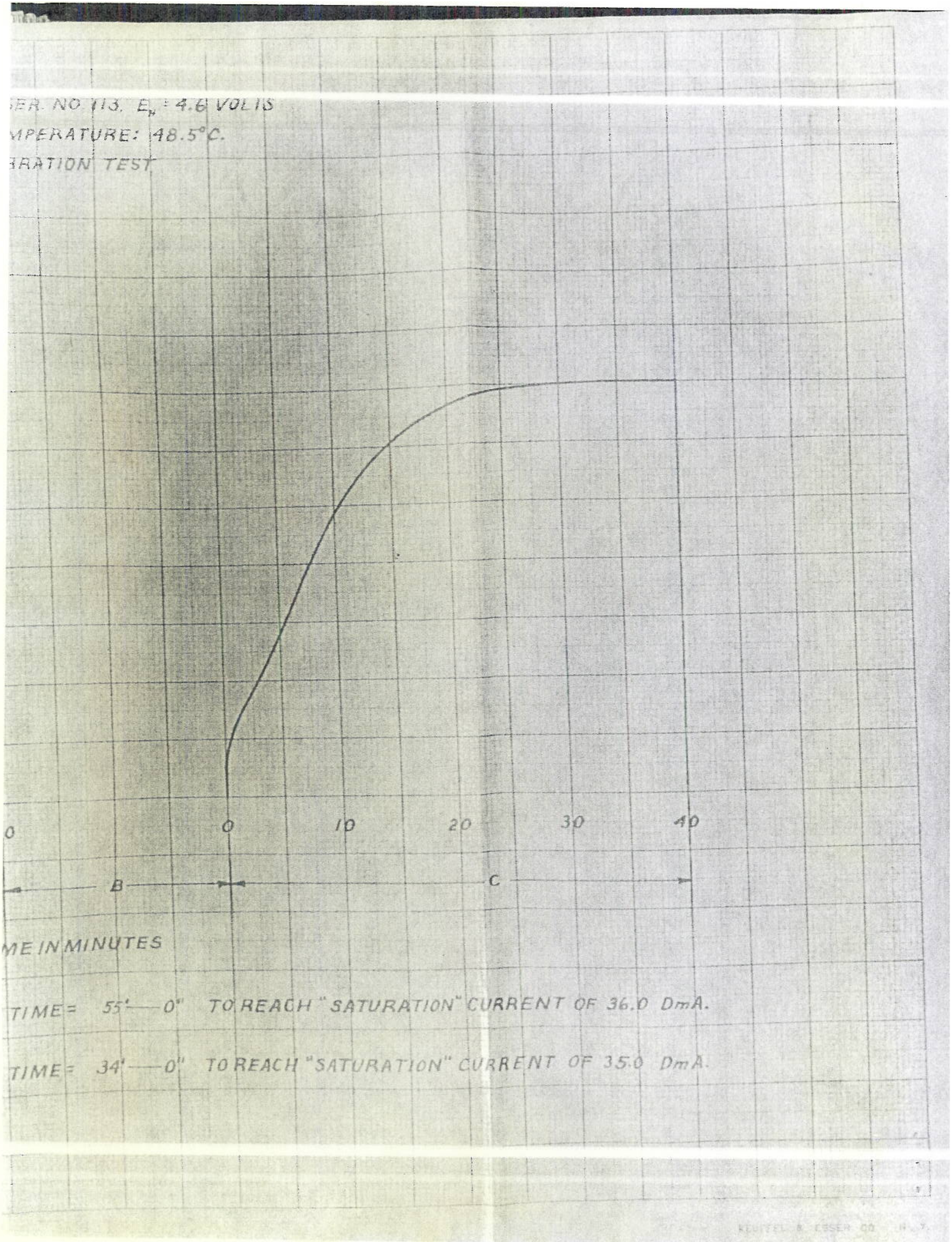
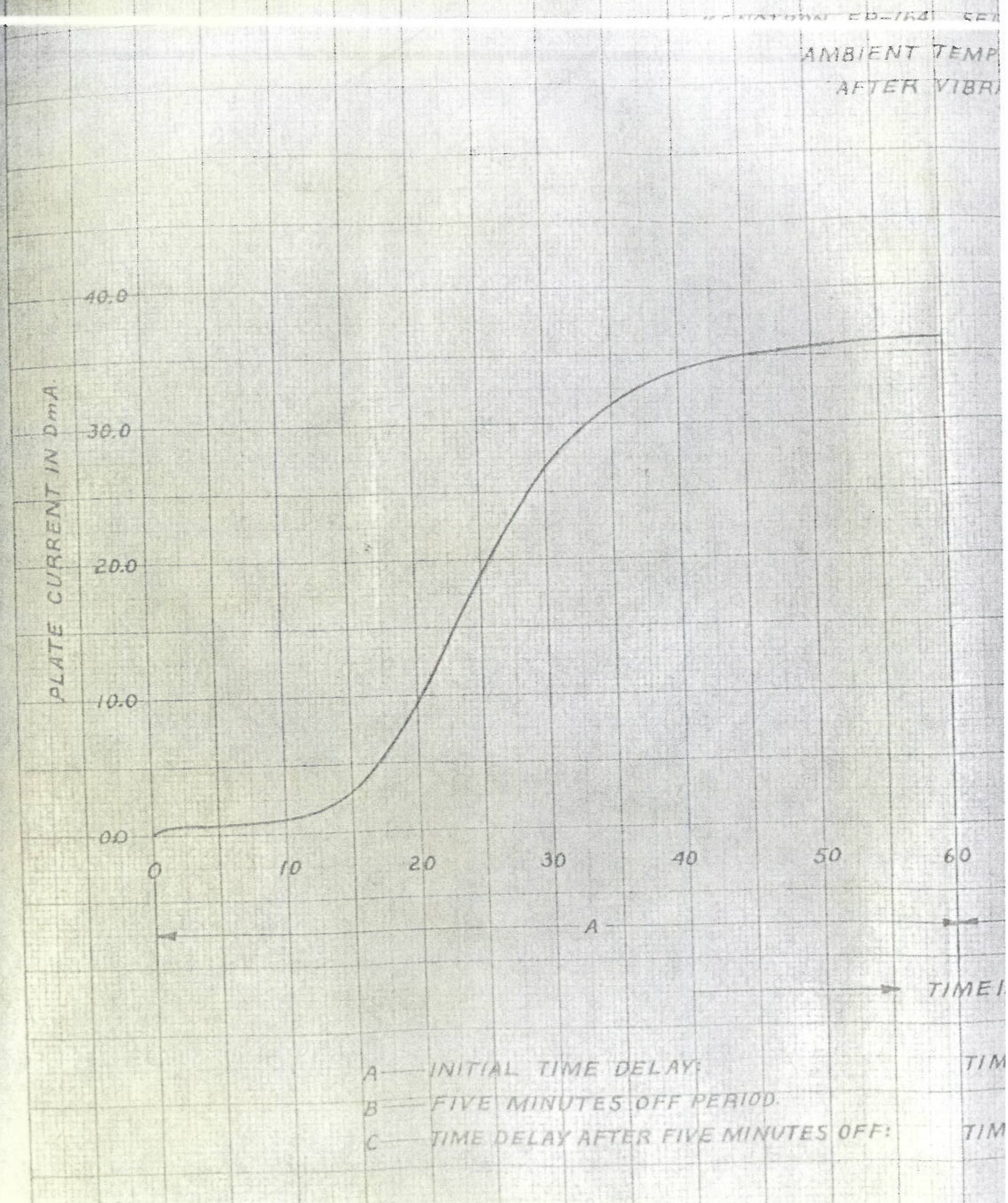

EMPERATURE: 0° C.
VIBRATION TEST.
60
0
10
20
30
40
50
B
C
TIME IN MINUTES
TIME = 54' — 0" TO REACH "SATURATION" CURRENT OF 37.0 DmA.
TIME = 35' — 0" TO REACH "SATURATION" CURRENT OF 37.0 DmA.

PLATE 20

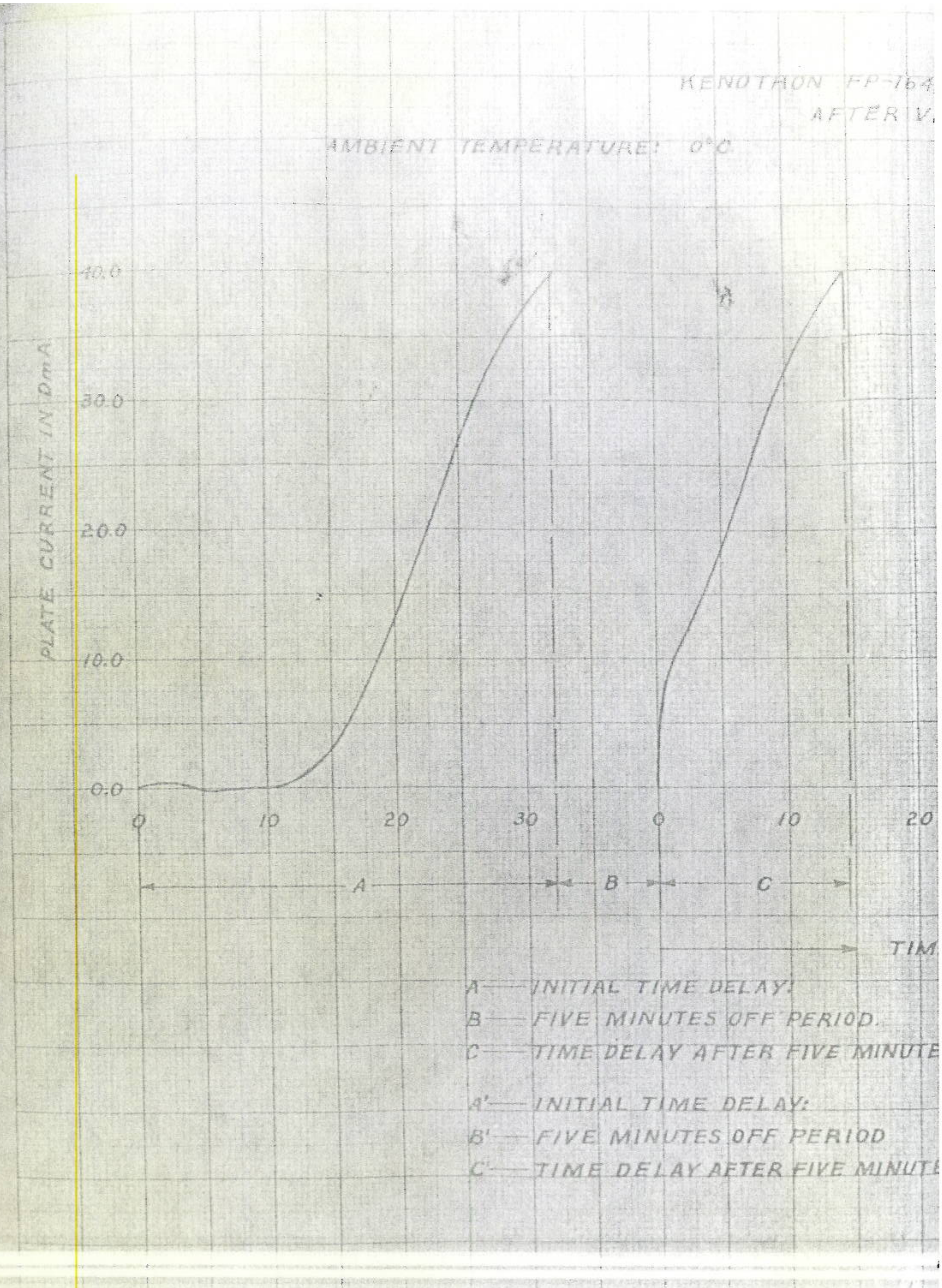

KENOTRON FP-164
AMBIENT TE
AFTER V
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0
0
10
20
30
40
50
A
A — INITIAL TIME DELAY.
B — FIVE MINUTES OFF PERIOD
C — TIME DELAY AFTER FIVE MINUTES OFF.



ER. NO 113. E_{μ} = 4.6 VOLTS
MPERATURE: 48.5°C.
BRATION TEST
0
0
10
20
30
40
B
C
ME IN MINUTES
TIME = 55'—0" TO REACH "SATURATION" CURRENT OF 36.0 DmA.
TIME = 34'—0" TO REACH "SATURATION" CURRENT OF 35.0 DmA.

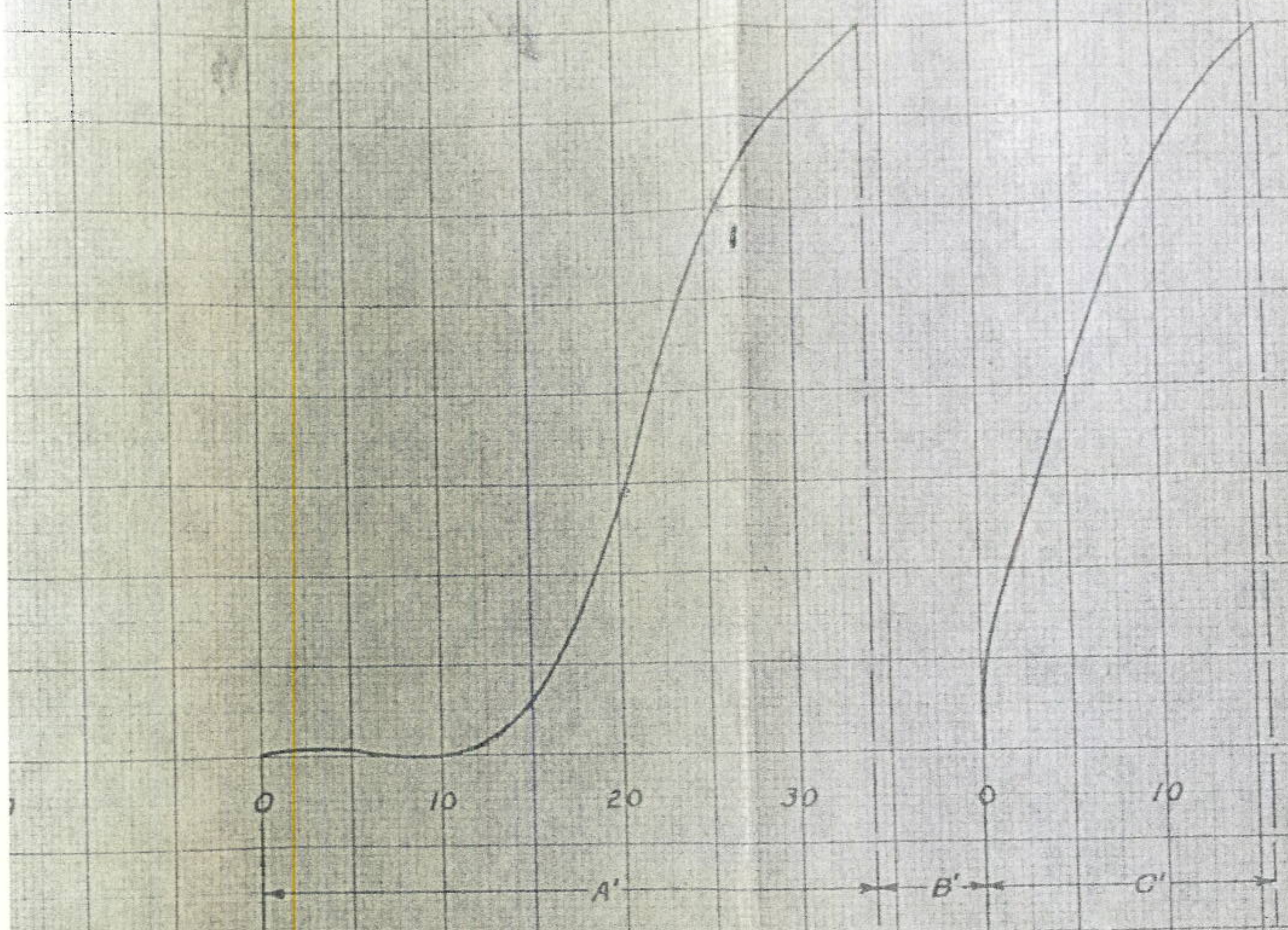


AMBIENT TEMP
AFTER VIBR
PLATE CURRENT IN DmA.
40.0
30.0
20.0
10.0
0.0
0
10
20
30
40
50
60
A
TIME I
A — INITIAL TIME DELAY:
B — FIVE MINUTES OFF PERIOD.
C — TIME DELAY AFTER FIVE MINUTES OFF:
TIM
TIM


KENOTRON FP-164
AFTER V
AMBIENT TEMPERATURE: 0°C
PLATE CURRENT IN DmA
40.0
30.0
20.0
10.0
0.0
0
10
20
30
0
10
20
A
B
C
TIM
A — INITIAL TIME DELAY:
B — FIVE MINUTES OFF PERIOD.
C — TIME DELAY AFTER FIVE MINUTE
A' — INITIAL TIME DELAY:
B' — FIVE MINUTES OFF PERIOD
C' — TIME DELAY AFTER FIVE MINUTE

IBRATION TEST

AMBIENT TEMPERATURE: 48.5°C.



ME IN MINUTES

TIME = 32' — 17" I_p = 40.0 DmA.

ES OFF: TIME = 14' — 44" I_p = 40.0 DmA.

TIME = 33' — 50" I_p = 40.0 DmA.

ES OFF: TIME = 15' — 52" I_p = 40.0 DmA.