NATIONAL BUREAU OF STANDARDS REPORT

5492

Investigation of General Electric Company Type 3 Water-Activated Batteries for Air-Sea Rescue and In-Flight Fueling Lights

By
Wade H. Askew
Naval Aircraft Lighting Group
Photometry and Colorimetry Section
Optics and Metrology Division

Test 21N-32/56

Sponsored by
Lighting Section, AE-821
Bureau of Aeronautics
Department of the Navy
Washington, D.C.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Inquiries regarding the Bureau's reports should be addressed to the Office of Technical Information, National Bureau of Standards, Washington 25, D. C.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
0201-20-2300	October 1957	5492

Investigation of
General Electric Company
Type 3 Water-Activated Batteries
for
Air-Sea Rescue
and
In-Flight Fueling Lights

By
Wade H. Askew
Naval Aircraft Lighting Group
Photometry and Colorimetry Section
Optics and Metrology Division

Test 21N-32/56

Sponsored by
Lighting Section, AE-821
Bureau of Aeronautics
Department of the Navy
Washington, D.C.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Investigation of
General Electric Company
Type 3 Water-Activated Batteries
for
Air-Sea Rescue
and
In-Flight Fueling Lights

By
Wade H. Askew

1. INTRODUCTION

This report covers results of an investigation into certain characteristics of water-activated batteries, primarily to obtain information upon which to determine whether their use would be practical in air-sea rescue work, and for lighting aircraft in-flight fueling equipment. In the air-sea rescue aspect, it has been proposed that this type battery be used by the survivor of a crash at sea to power a signal light. For in-flight fueling, it has been proposed that water-activated batteries be used to light the drogue of the tanker plane. Due to shelf aging, and the reduction in capacity as the temperature is lowered, dry cells would have limited reliability for these purposes. (A representative curve showing the relationship between dry cell capacity and temperature is shown in Figure 1.) Because of the stretching and flexing of the long length of hose connecting the drogue with the fuel supply tanks, the use of wires along, or imbedded in, the hose to obtain power directly from the plane's electrical system for lighting the in-flight fueling equipment is considered undesirable.

At a conference of representatives of the Bureau of Aeronautics and the National Bureau of Standards, it was decided that the batteries should be tested to obtain information on the following:

(1) Output capacity when activated by tap water and when activated by salt water (3.5% by weight of NaCl).

(2) Effect of exposure to salt spray and to humidity as outlined in sections 4.4 and 4.5 respectively of Specification MIL-T-5422C(ASG).

(3) No-load deterioration during activation.

(4) Life in a make-and-break-circuit in which a 5-watt lamp load is operated in a duty cycle of 1/2 second ON and 2 1/2 seconds OFF. (A type 1839 lamp was selected for this test.)

(5) Life in a make-and-break circuit in which a lamp load of approximately 10 wattseconds is applied during a time interval of 1/3 second and repeated every 3 seconds. Also the effective intensity and power consumption during the flash. (A type 1134 lamp was selected for this test.)

(6) Effect of high and low ambient temperatures during activation.

(7) Gases evolved during activated life of the battery.

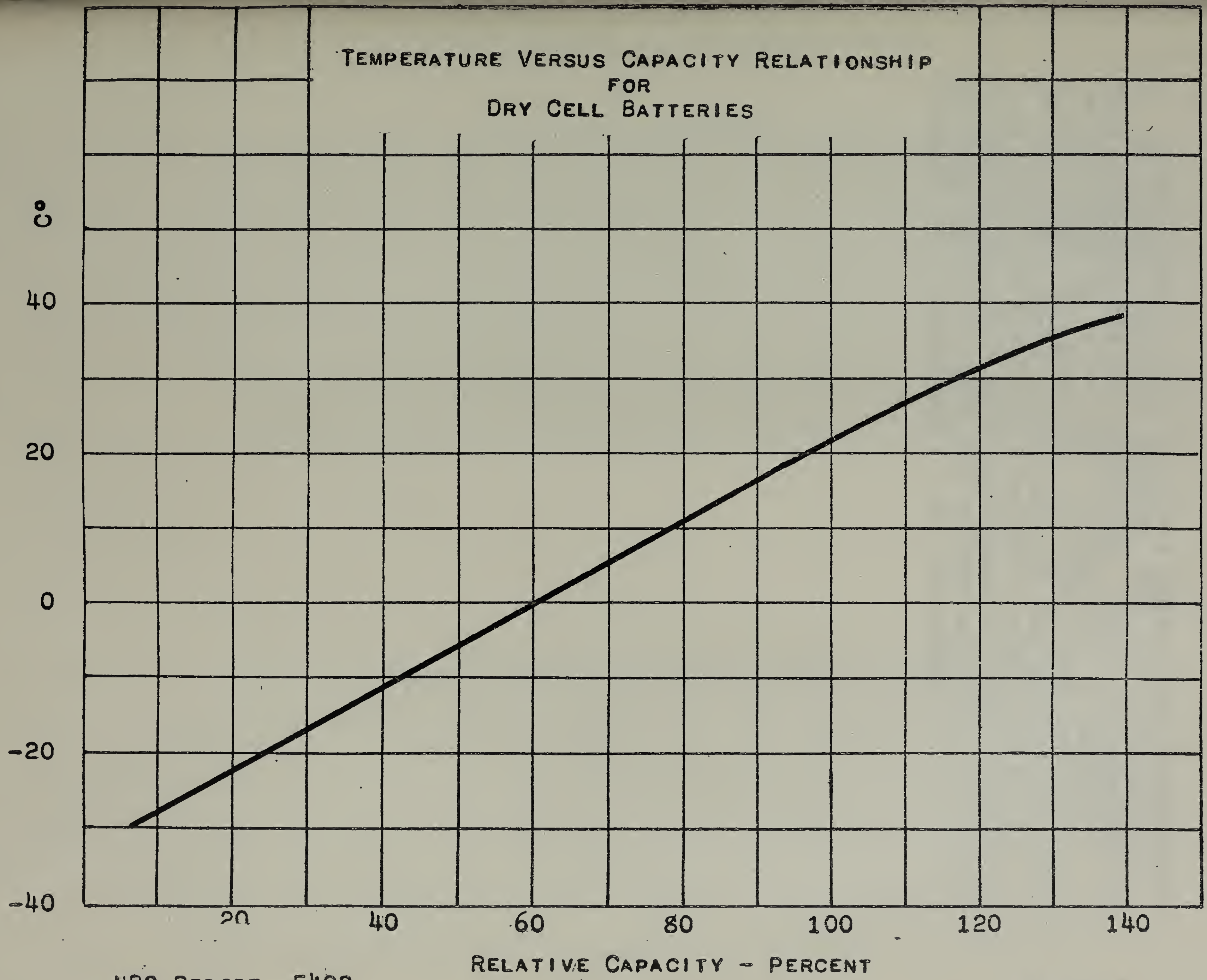

TEMPERATURE VERSUS CAPACITY RELATIONSHIP
FOR
DRY CELL BATTERIES
C°
40
20
0
-20
-40
20
40
60
80
100
120
140
RELATIVE CAPACITY - PERCENT

FIGURE 1

2. TYPE OF BATTERY USED FOR INVESTIGATION

The batteries used in these tests were manufactured by the General Electric Company, and are designated as Type 3 water-activated batteries. They are rated by the manufacturer at 6.3 volts, 1.5 amperes, 90 minutes. A unit weighs 8 ounces and measures approximately 6" x 2 3/8" x 1/2". At the top of the battery (the end from which the electrical terminals emerge) and also at the bottom, is a hole approximately 3/16" in diameter, allowing water to enter the battery and gases to escape. Figure 2 is a photograph of the batteries.

General Electric Co.
Type 3 Water-Activated Battery

NBS Report 5492

FIGURE 2

3. TEST PROCEDURE AND RESULTS

Except where otherwise indicated the tests were conducted under the following general conditions:

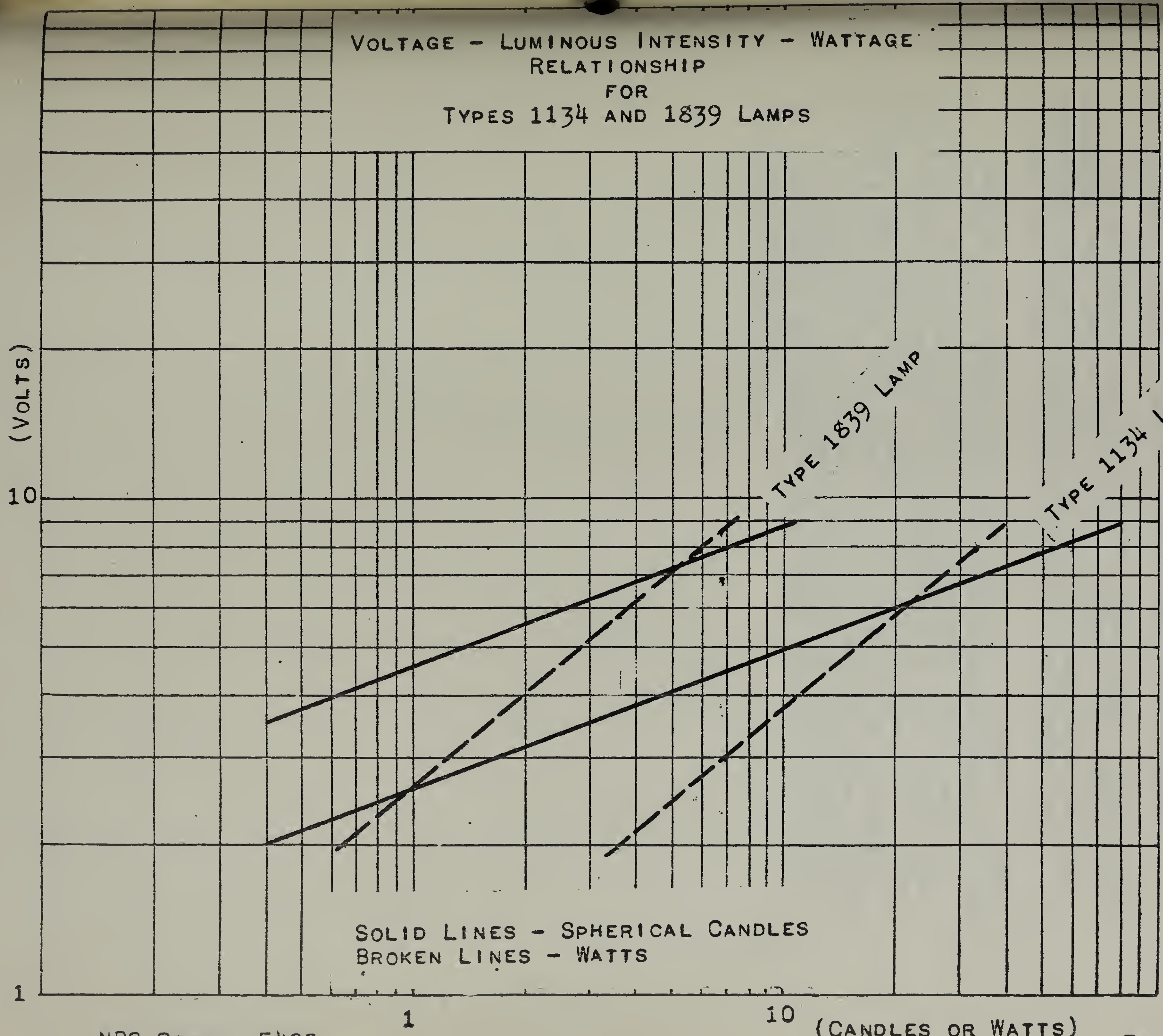
Altitude and Ambient Temperature - Approximately sea level and 25°C.

Activating Solution and Battery Position - The batteries were completely immersed in two liters of tap water, and the battery was maintained in the vertical position, i.e., the position in which the terminal leads are up.

The methods of testing and the results obtained under the different phases of the investigation are given in the paragraphs which follow.

3.1 Characteristics of Types 1134 and 1839 Lamps.

Before conducting tests on the batteries, the voltage-intensity-wattage relationship for the types 1134 and 1839 lamps was determined from a maximum of 9 volts down to the voltage at which the luminous intensity was about 0.4 spherical candle. The results of this test are shown by the curves in Figure 3.


VOLTAGE - LUMINOUS INTENSITY - WATTAGE
RELATIONSHIP
FOR
TYPES 1134 AND 1839 LAMPS

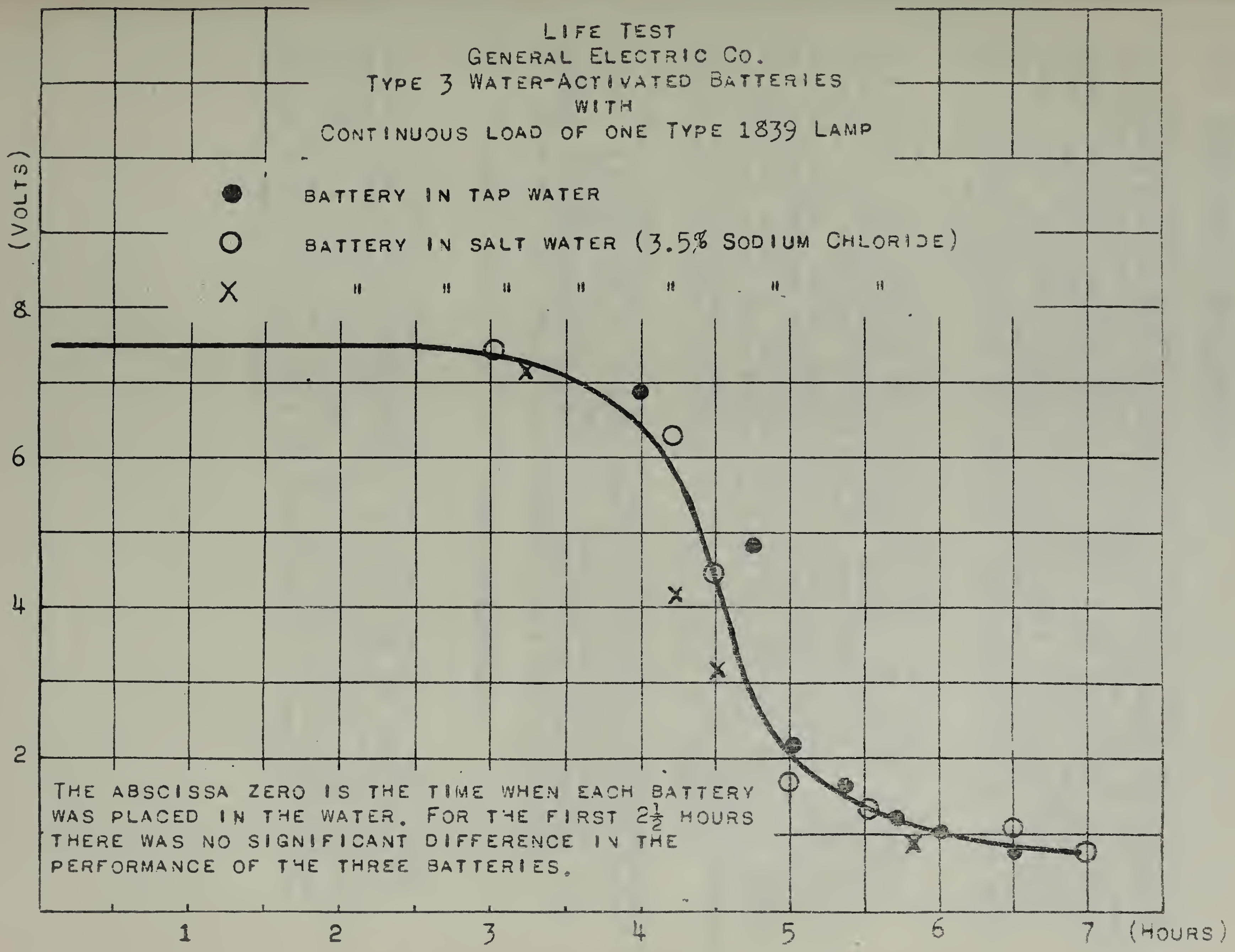
SOLID LINES - SPHERICAL CANDLES
BROKEN LINES - WATTS

FIGURE 3

3.2 Output Capacity in Tap Water and in Salt Water

Two batteries were placed in salt water (3.5% sodium chloride) and one in tap water, a Type 1839 lamp was connected to each battery, and the voltage was measured frequently during the active life of the batteries.

Results of these tests are shown in Figure 4, where voltage of the batteries is plotted against time. During the first 2 1/2 to 3 hours of activation there was no significant difference in performance of the three batteries, and the power output was fairly constant. After about 3 1/2 hours the power output decreased sharply. The differences in rate of drop between the three batteries is thought to be caused primarily by variations of the individual batteries rather than the type of water used for activation.



LIFE TEST
GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERIES
WITH
CONTINUOUS LOAD OF ONE TYPE 1839 LAMP

THE ABSCISSA ZERO IS THE TIME WHEN EACH BATTERY WAS PLACED IN THE WATER. FOR THE FIRST $2\frac{1}{2}$ HOURS THERE WAS NO SIGNIFICANT DIFFERENCE IN THE PERFORMANCE OF THE THREE BATTERIES.

FIGURE 4

3.3 Salt Spray and Humidity.

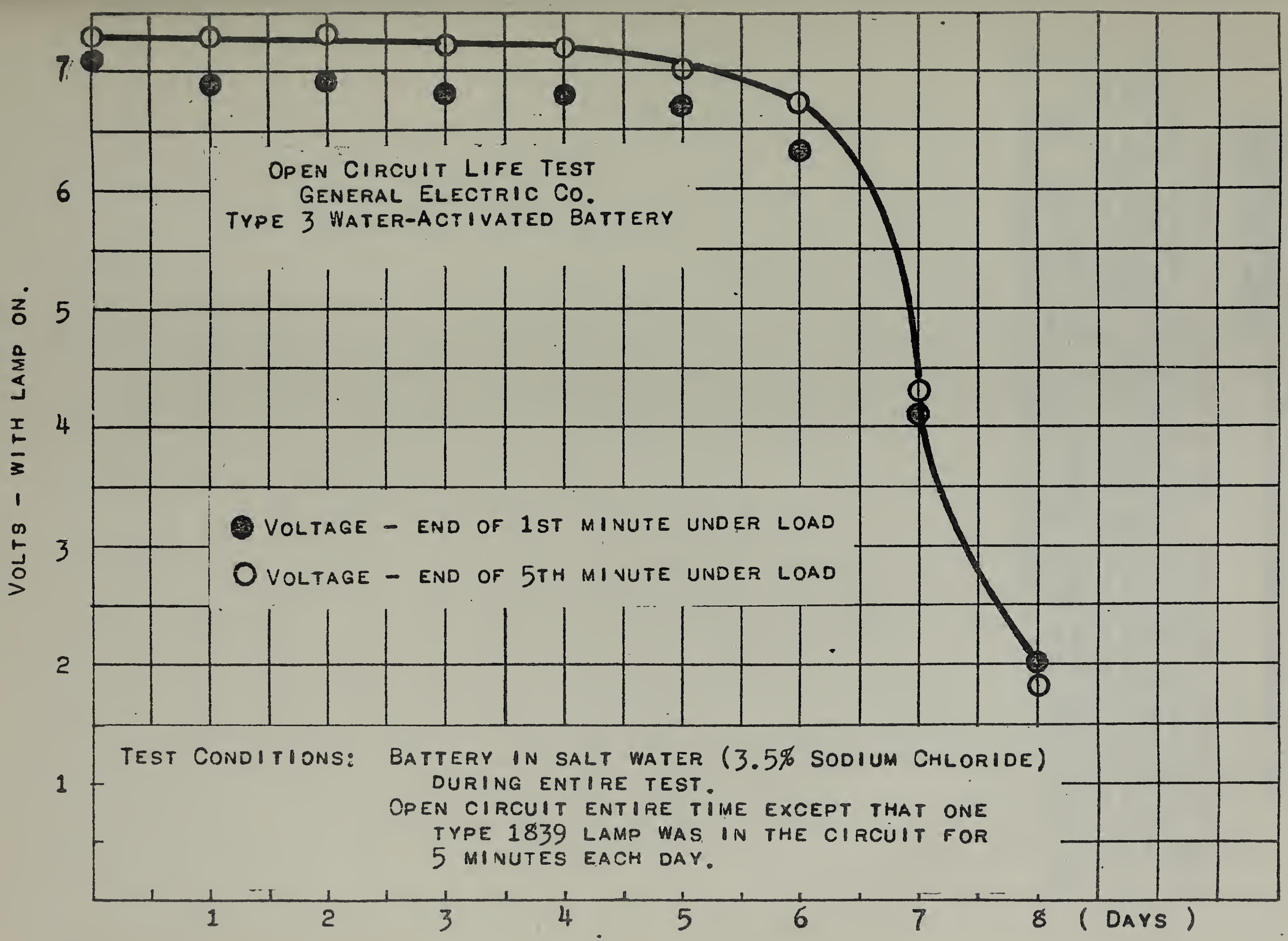
Two batteries were subjected to salt spray as outlined in Specification MIL-T-5422C(ASG), and two were subjected to the humidity test as shown in Figure 4 (page 14) of the same specification, except that the first four hours of the specified humidity test (involving lower and higher temperatures than occur in the repeated cycles) were omitted. Throughout these tests a recording voltmeter was connected across the battery terminals to indicate the generation of any significant voltage.

The salt spray test had no apparent effect on the batteries, but during the humidity test the outer plastic jacket of the batteries developed small splits in several places. No evidence of an E.M.F. was indicated during either of the tests. After completion of the tests each battery was activated and subjected to a life test while carrying a continuous load of one Type 1839 lamp. Except for the small variations previously found between individual batteries, the electrical power generated was the same as for batteries which had not been subjected to salt spray or humidity.

Two additional batteries were subjected to the humidity test. At the end of 5 days there was evidence of case rupture. Without further testing, these batteries were forwarded to the manufacturer for examination and comment. At the time of this report no comments have been received.

3.4 No-Load Deterioration During Activation.

The battery used in this test was kept in salt water during the entire test period. It was in an open circuit except for 5 minutes each day, during which time it was connected to a Type 1839 lamp. The voltage across the battery was read each day at the end of the 1st and the 5th minute during which the lamp was in the circuit. Results of the test are shown in Figure 5.



OPEN CIRCUIT LIFE TEST
GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERY

TEST CONDITIONS: BATTERY IN SALT WATER (3.5% SODIUM CHLORIDE) DURING ENTIRE TEST.
OPEN CIRCUIT ENTIRE TIME EXCEPT THAT ONE TYPE 1839 LAMP WAS IN THE CIRCUIT FOR 5 MINUTES EACH DAY.

FIGURE 5

3.5 Output Capacity with Intermittent Load of One Type 1839 Lamp.

A battery activated in salt water was connected in a make-and-break circuit in which a load of one Type 1839 lamp was operated in a duty cycle of 1/2 second ON and 2 1/2 seconds OFF. This cycle was continued for the practical active life of the battery, during which time the voltage was measured at frequent intervals while the lamp was ON. The voltage versus time curve for this phase of the investigation is shown in Figure 6.

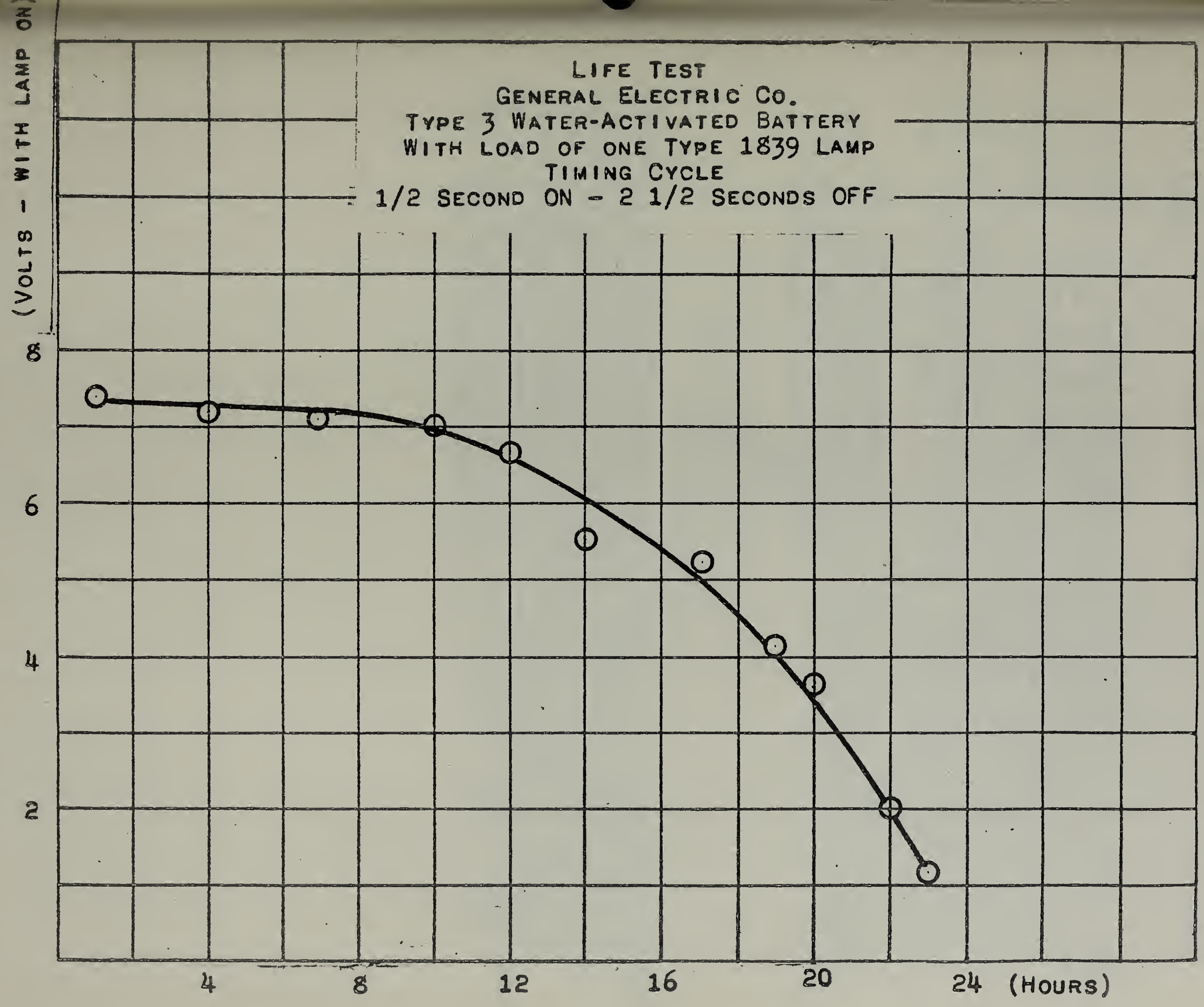

LIFE TEST
GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERY
WITH LOAD OF ONE TYPE 1839 LAMP
TIMING CYCLE
1/2 SECOND ON - 2 1/2 SECONDS OFF
(VOLTS - WITH LAMP ON)
8
6
4
2
4
8
12
16
20
24 (HOURS)

FIGURE 6

3.6 Life Test With an Intermittent Load of One Type 1134 Lamp.

For this test a battery, activated by salt water, was connected in a make-and-break circuit with a Type 1134 lamp. The duty cycle of the circuit was approximately 1/3 second ON and 2 2/3 seconds OFF. Time distributions of voltage, current, and light output were measured at frequent intervals during the test. The power versus time relationship and the energy consumed during the ON period were computed from measurements made 5 minutes, 2 1/2 hours, and 4 1/2 hours after the start of the test and are shown in Figure 7.

The effective intensity of the flashing light was computed by the method described in NBS Report 4554, "Computation of the Effective Intensity of Flashing Lights", whereby I_e is maximized in the formula

$$I_e = \frac{\int_{t_1}^{t_2} I\,dt}{0.2 + (t_2 - t_1)}$$

where I_e is the effective candlepower, I is the instantaneous intensity in candles at the time t; and t_1 and t_2 are the times in seconds at the beginning and at the end of the portion of the flash being considered. In Figure 8, the computed effective intensity of the flashing lamp is plotted against the time from the start of the test. For comparison, the figure also shows the intensity obtained from a Type 1839 lamp burning continuously.

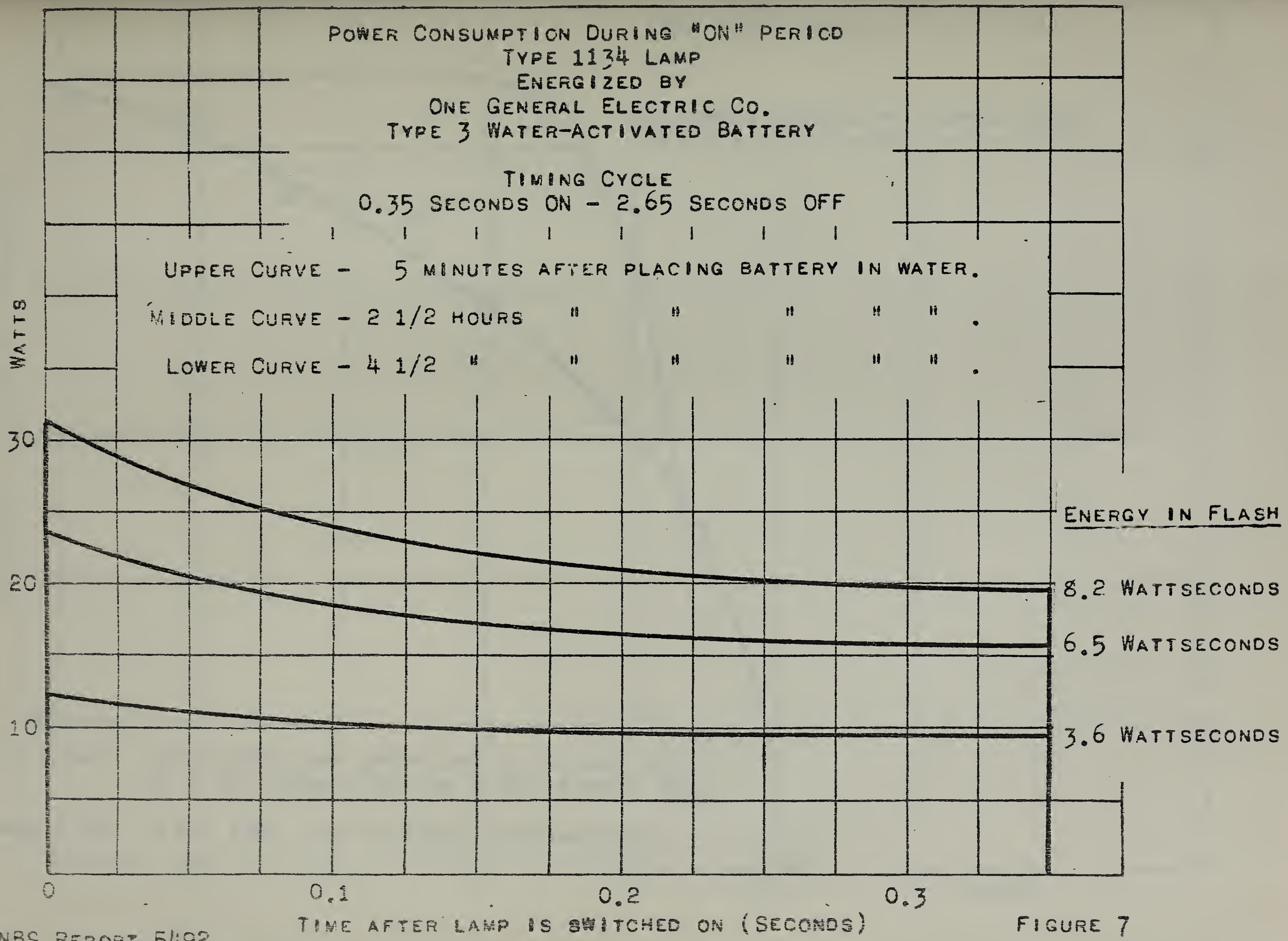
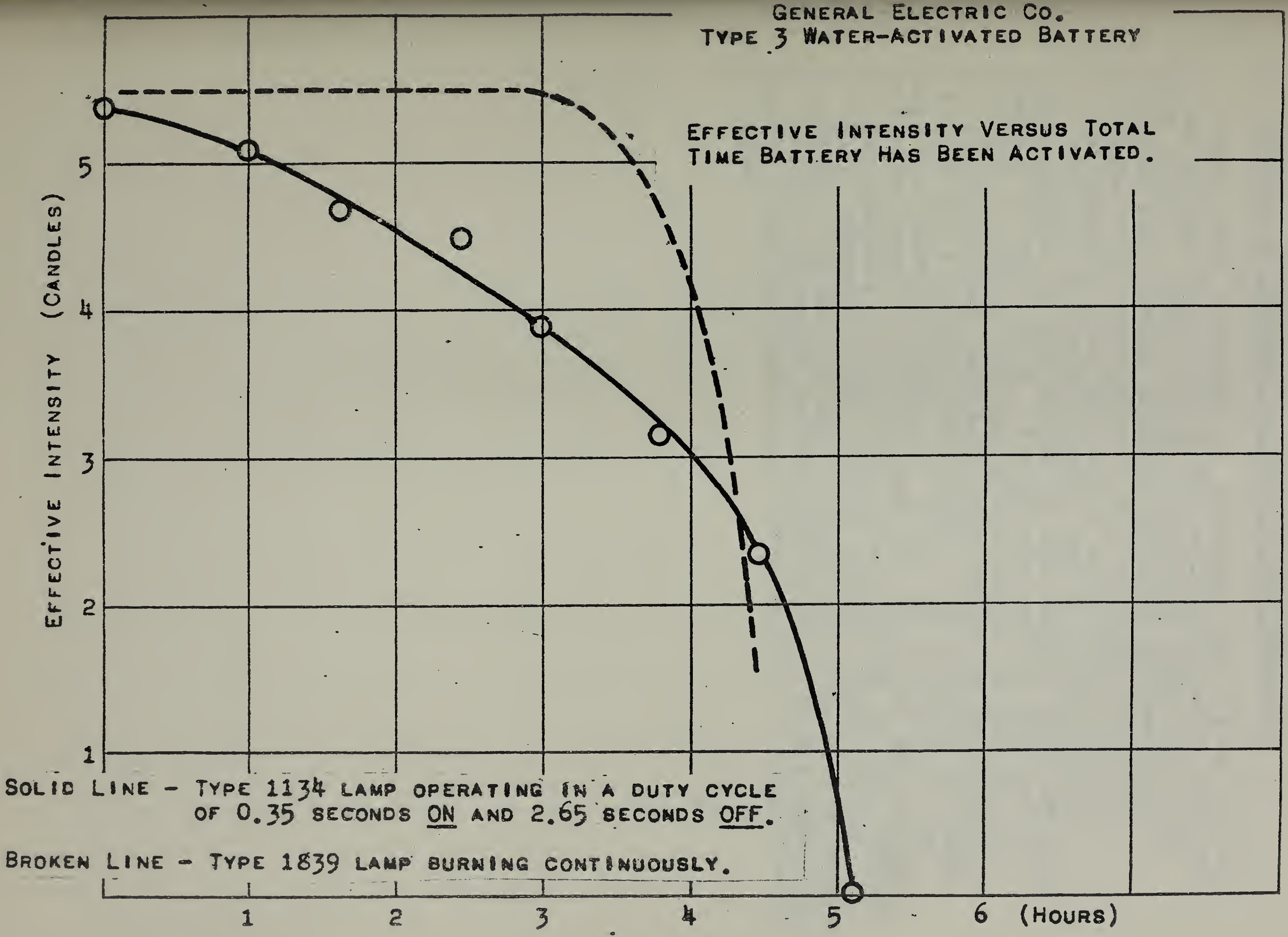
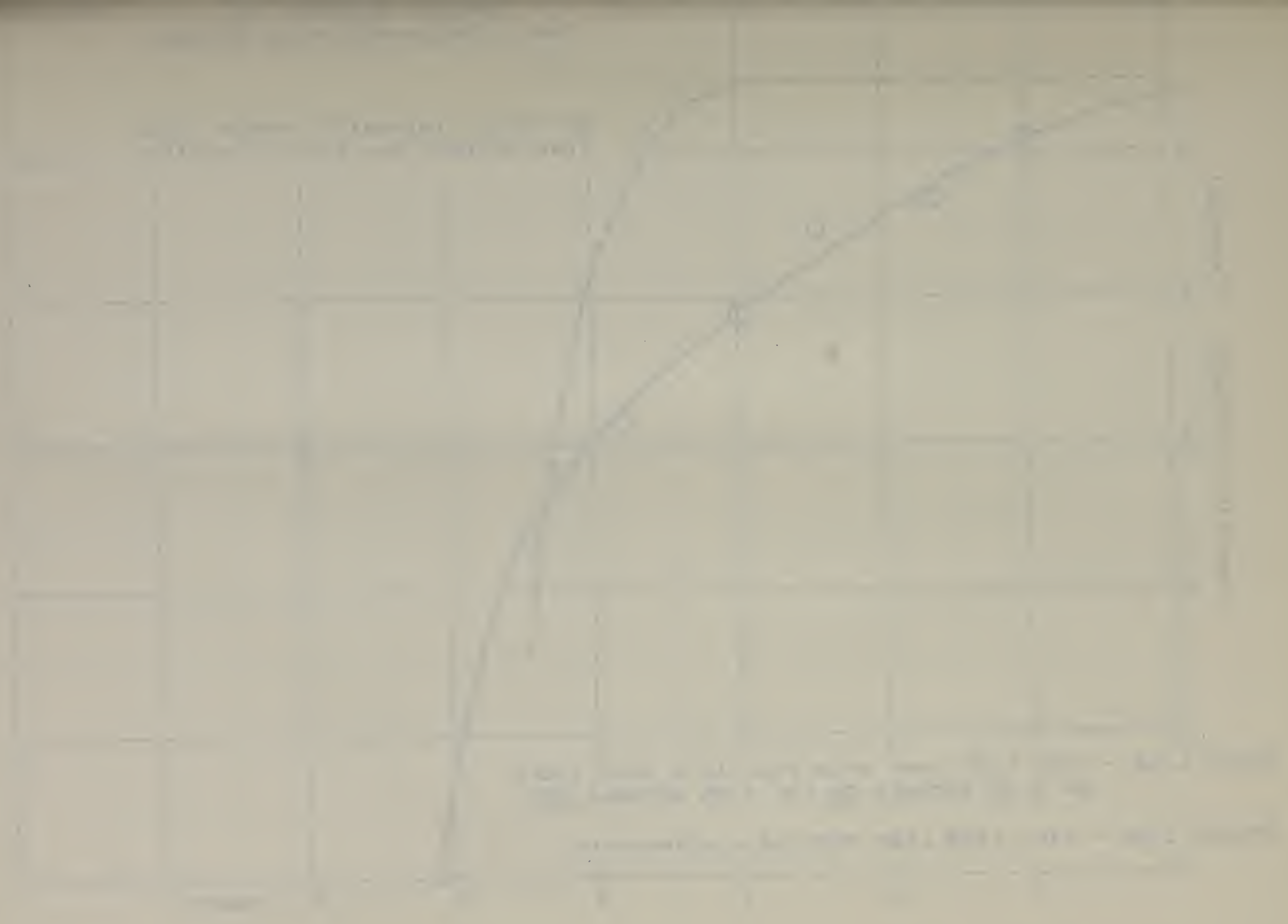

POWER CONSUMPTION DURING "ON" PERIOD
TYPE 1134 LAMP
ENERGIZED BY
ONE GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERY
TIMING CYCLE
0.35 SECONDS ON - 2.65 SECONDS OFF
UPPER CURVE - 5 MINUTES AFTER PLACING BATTERY IN WATER.
MIDDLE CURVE - 2 1/2 HOURS " " " " " .
LOWER CURVE - 4 1/2 " " " " " " .
WATTS
30
20
10
0
0.1
0.2
0.3
TIME AFTER LAMP IS SWITCHED ON (SECONDS)
ENERGY IN FLASH
8.2 WATTSECONDS
6.5 WATTSECONDS
3.6 WATTSECONDS

FIGURE 7



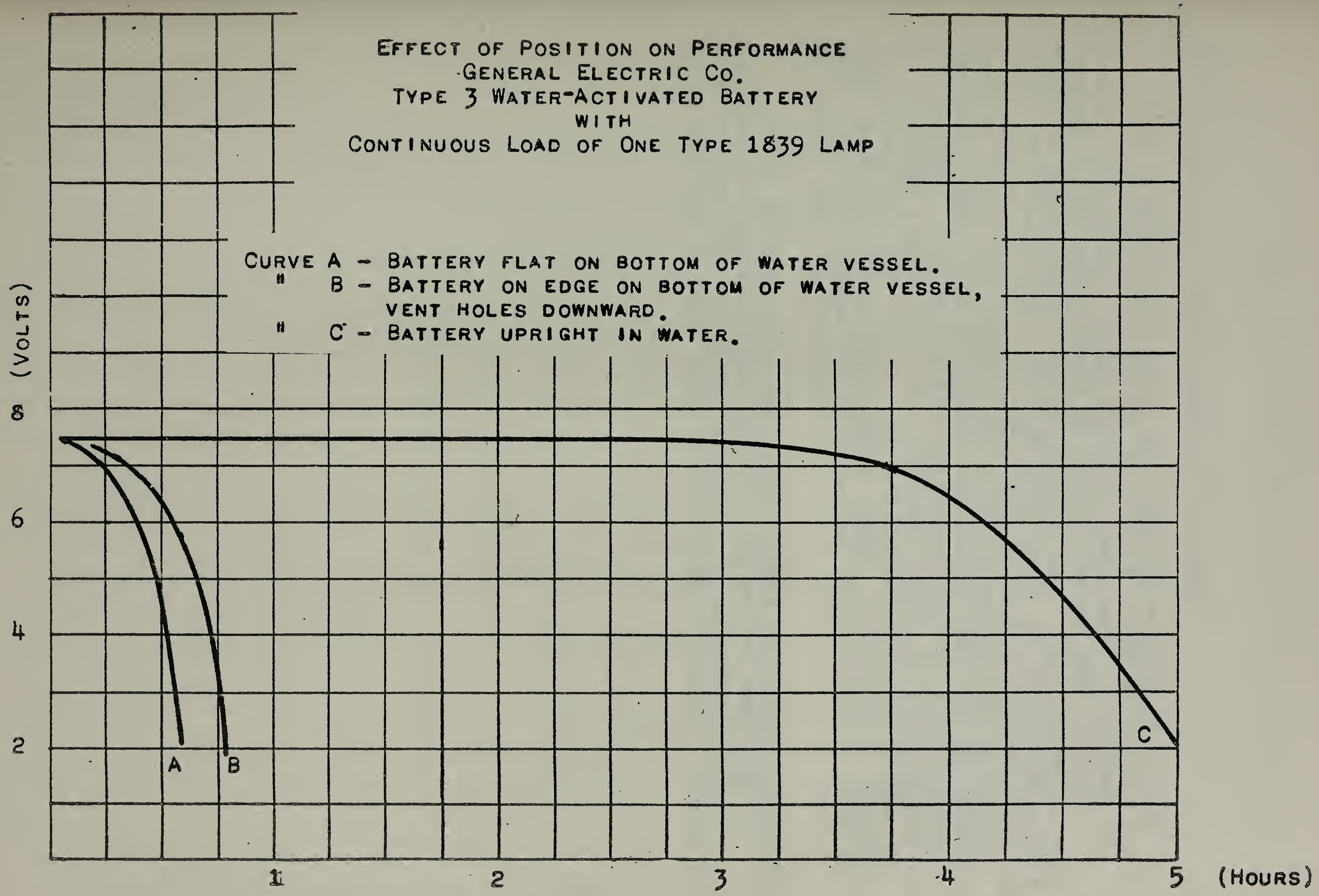
NBS REPORT 5492

FIGURE 8



3.7 Effect of Battery Position on Performance.

Tests were conducted to determine the effect of different battery positions in the activating water upon the power output. Using a load of one Type 1839 lamp, the batteries were tested in three mutually perpendicular positions - (1) vertically, i.e., terminal leads up, (2) horizontally with one of its broad sides lying on the bottom of the water vessel, and (3) horizontally, lying edgewise on the bottom of the vessel, with the vent openings at the bottom. A separate battery was used for each test. Before setting the batteries in the (2) and (3) positions they were held under water in the vertical position (1) for about one minute. The results of these tests are shown in Figure 9. After the voltage of the batteries tested in the (2) and (3) positions had dropped to approximately 2 volts they were returned to the vertical position, whereupon they quickly resumed their initial potential. In the (2) and (3) positions some of the evolved gas becomes entrapped in the battery case, thus limiting the amount of battery plate area which can come in contact with the water.



EFFECT OF POSITION ON PERFORMANCE
GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERY
WITH
CONTINUOUS LOAD OF ONE TYPE 1839 LAMP

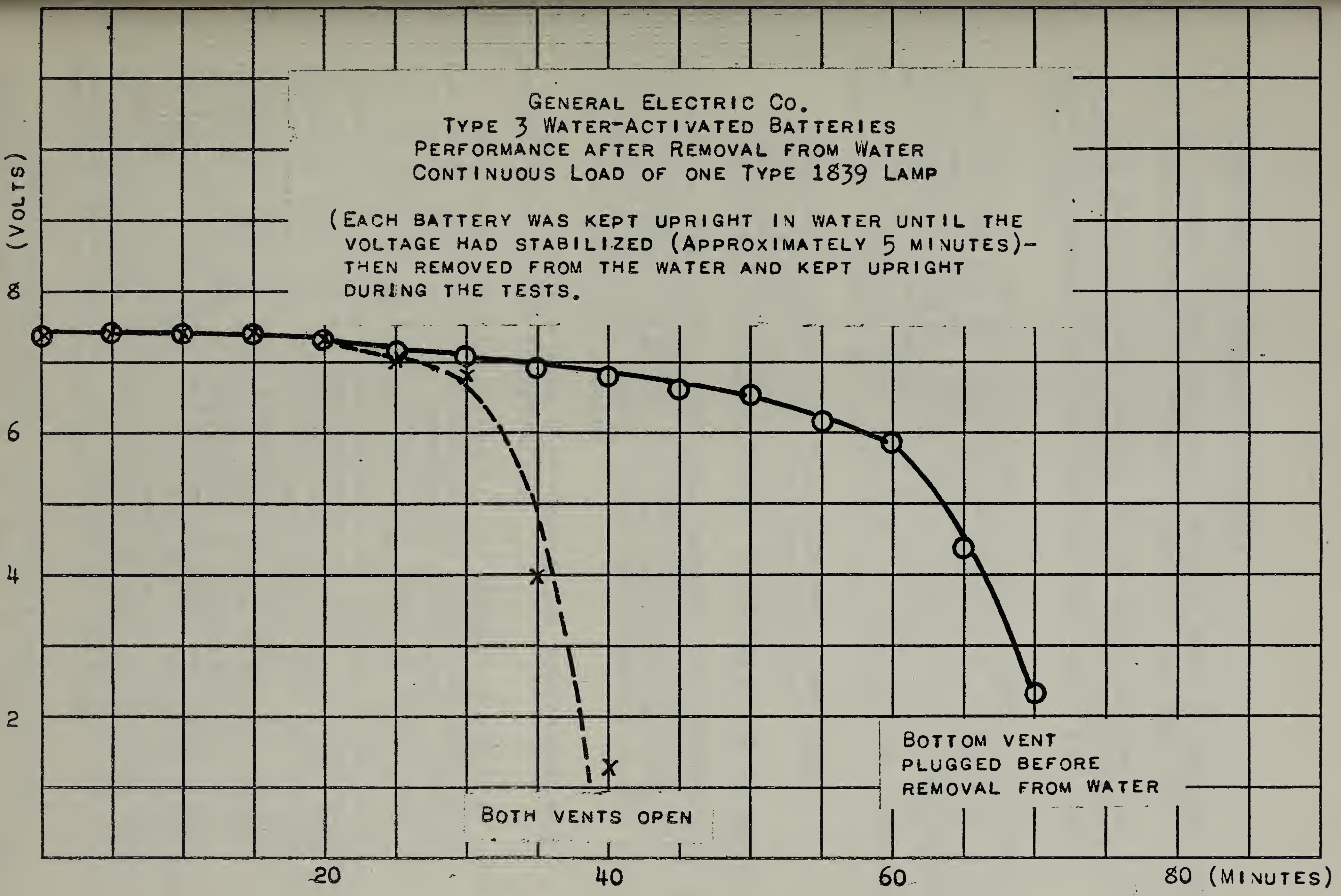
CURVE A - BATTERY FLAT ON BOTTOM OF WATER VESSEL.
" B - BATTERY ON EDGE ON BOTTOM OF WATER VESSEL, VENT HOLES DOWNWARD.
" C - BATTERY UPRIGHT IN WATER.

FIGURE 9

3.8 Performance After Removal from Water

For lighting the in-flight fueling equipment it may not be practical to keep the batteries in water during the fueling operation. Consequently, tests were conducted to determine the performance of the batteries upon removal from the water after initial activation. Two batteries were used for these tests. A type 1839 lamp was connected across each battery and the batteries were placed in water until the voltage output had stabilized (approximately five minutes). Before removal from the water the bottom vent of one battery was plugged. The batteries were then removed from the water and the EMF across each was recorded until it had dropped to approximately two volts. The batteries remained in the upright position throughout these tests. The results (Figure 10) show that the plugged battery lasted about twice as long as the one which was not plugged.

After removal from the water, these batteries apparently continue to operate until most of the water remaining in them is used up. At high altitudes it is probable that a large portion of this water would be lost through evaporation.



GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERIES
PERFORMANCE AFTER REMOVAL FROM WATER
CONTINUOUS LOAD OF ONE TYPE 1839 LAMP

(EACH BATTERY WAS KEPT UPRIGHT IN WATER UNTIL THE VOLTAGE HAD STABILIZED (APPROXIMATELY 5 MINUTES)–THEN REMOVED FROM THE WATER AND KEPT UPRIGHT DURING THE TESTS.

FIGURE 10

3.9 High and Low Temperature Tests

All tests of the batteries at high and low temperatures were conducted with a continuous load of one Type 1839 lamp.

The batteries were tested in tap water at 70°C and in a mixture of ice and tap water (0°C). The performance at these temperatures was substantially the same as at room temperature.

Since use of the batteries at temperatures below 0°C precludes the use of tap water alone as the activating liquid, tests were conducted using several different materials for lowering the freezing point of the water. First each mixture was tried at room temperature to determine whether the activating mixture itself would affect the battery performance. The mixtures so tested were as follows:

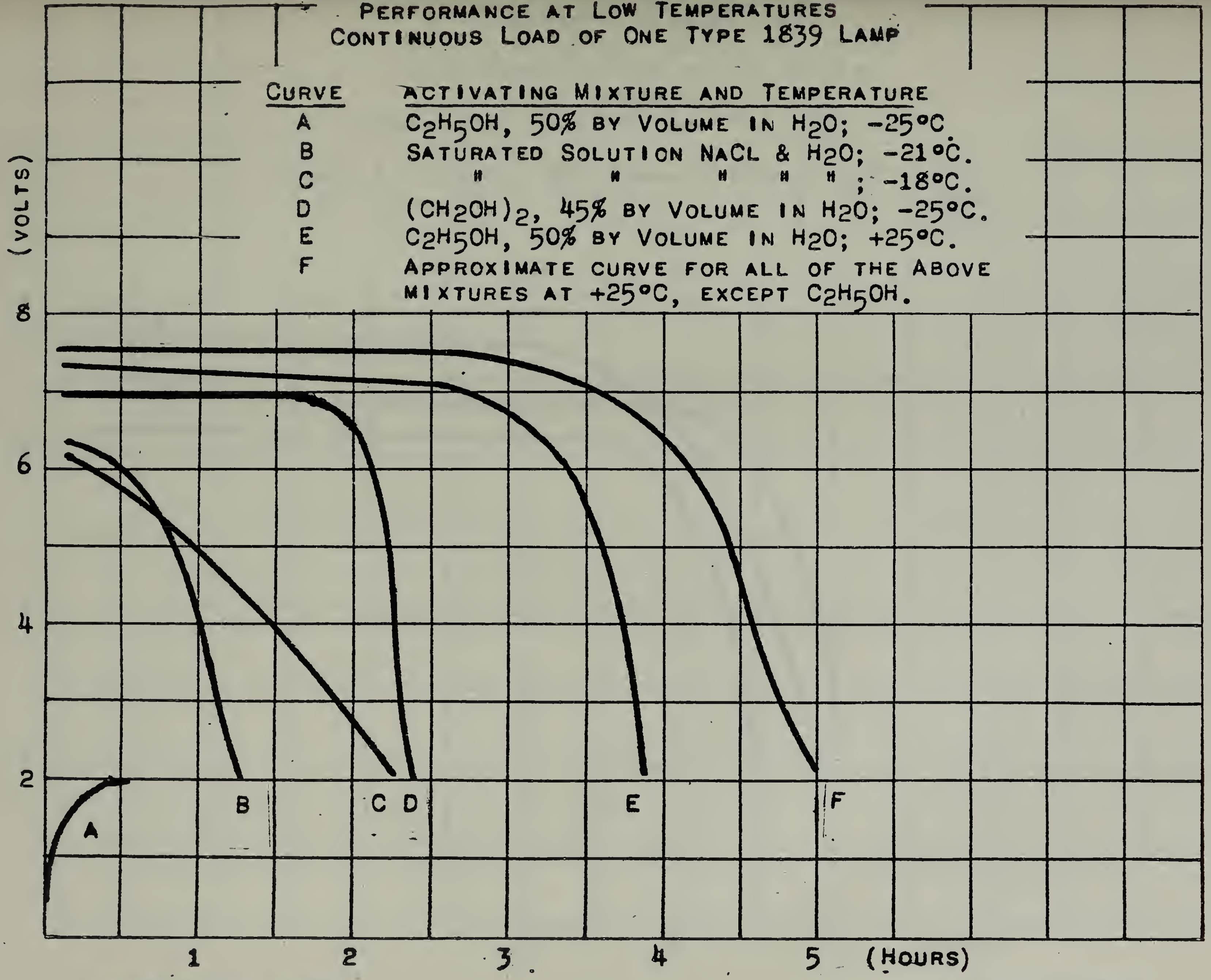
Saturated solution of sodium chloride and water
Ethylene glycol, 45% by volume, in water
Ethyl alcohol, 50% by volume in water
Calcinated calcium chloride, 340 grams/liter of water

Except for the alcohol and water mixture, the performance of the batteries was similar to that obtained with tap water. With the alcohol mixture there was approximately a 20% decrease in the time during which the potential across the lamp remained above 2 volts.

These mixtures were then tested for activation characteristics at low temperatures.

A battery was activated in the alcohol mixture at -24°C, and over a period of 25 minutes the E.M.F. did not exceed 2 volts. The test was therefore discontinued. Activation in the ethylene glycol mixture was tried at -25°C, and the active life of the battery was about 50% of that at room temperature. Battery performance was tested in the sodium chloride solution at temperatures of -21°C (the approximate freezing point of a saturated solution of NaCl) and then at -18°C, and in both cases the performance fell off considerably from that at room temperature. However, in a mixture of water, and ice sprinkled with sodium chloride, which mixture maintained a temperature of approximately -9°C during the test, the battery performance was nearly equal to that at room temperature. Tests were conducted with calcium chloride solution at temperatures of -25°C and -35°C, and in both cases the active life of the battery was about the same as it was at room temperature, although there was some reduction in the maximum voltage obtained.

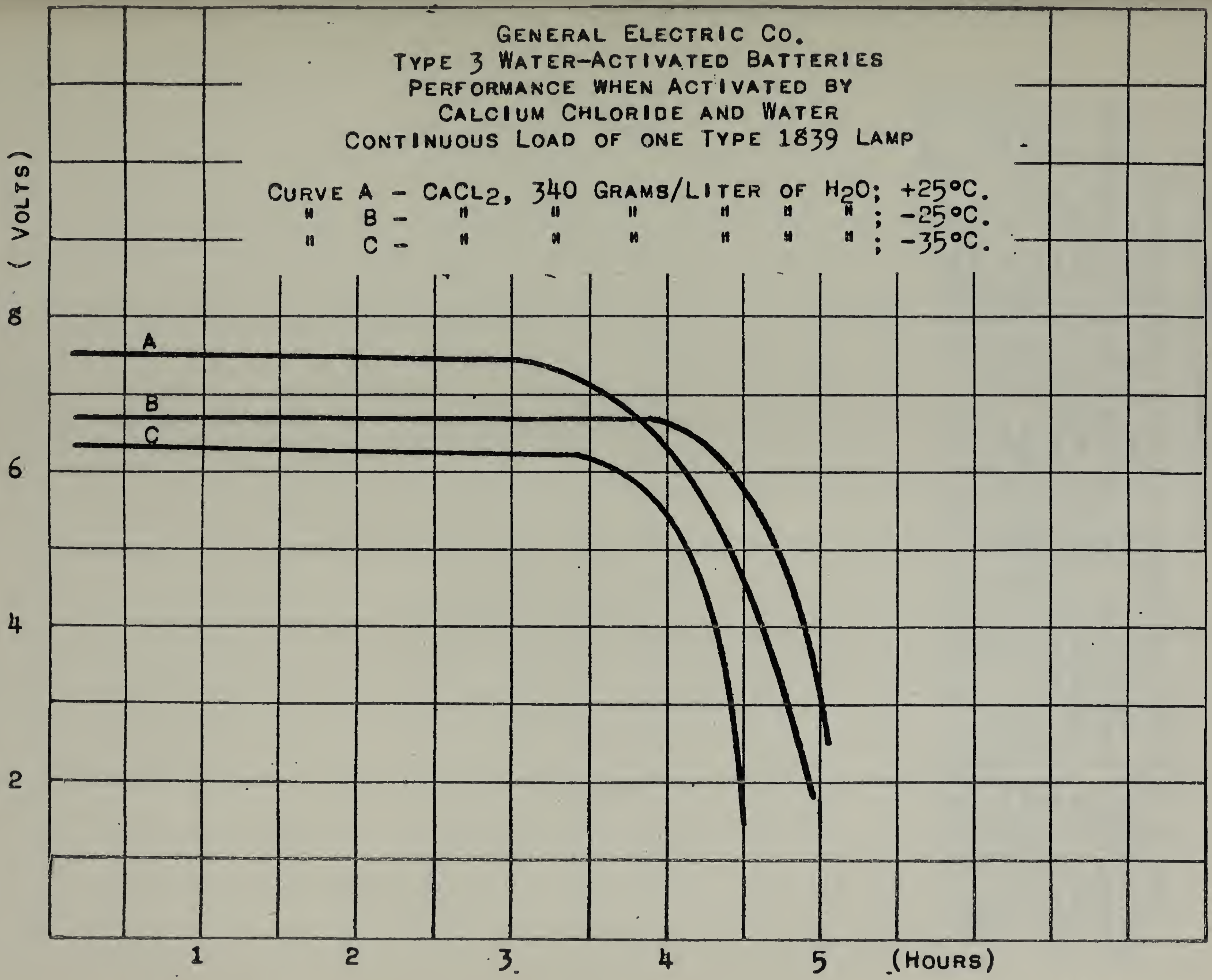
Curves showing battery performance under the low temperature test conditions are shown in Figures 11-A and 11-B.



GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERIES
PERFORMANCE AT LOW TEMPERATURES
CONTINUOUS LOAD OF ONE TYPE 1839 LAMP

CURVE	ACTIVATING MIXTURE AND TEMPERATURE
A	C_2H_5OH, 50% BY VOLUME IN H_2O; -25°C.
B	SATURATED SOLUTION NACL & H_2O; -21°C.
C	" " " " " ; -18°C.
D	$(CH_2OH)_2$, 45% BY VOLUME IN H_2O; -25°C.
E	C_2H_5OH, 50% BY VOLUME IN H_2O; +25°C.
F	APPROXIMATE CURVE FOR ALL OF THE ABOVE MIXTURES AT +25°C, EXCEPT C_2H_5OH.

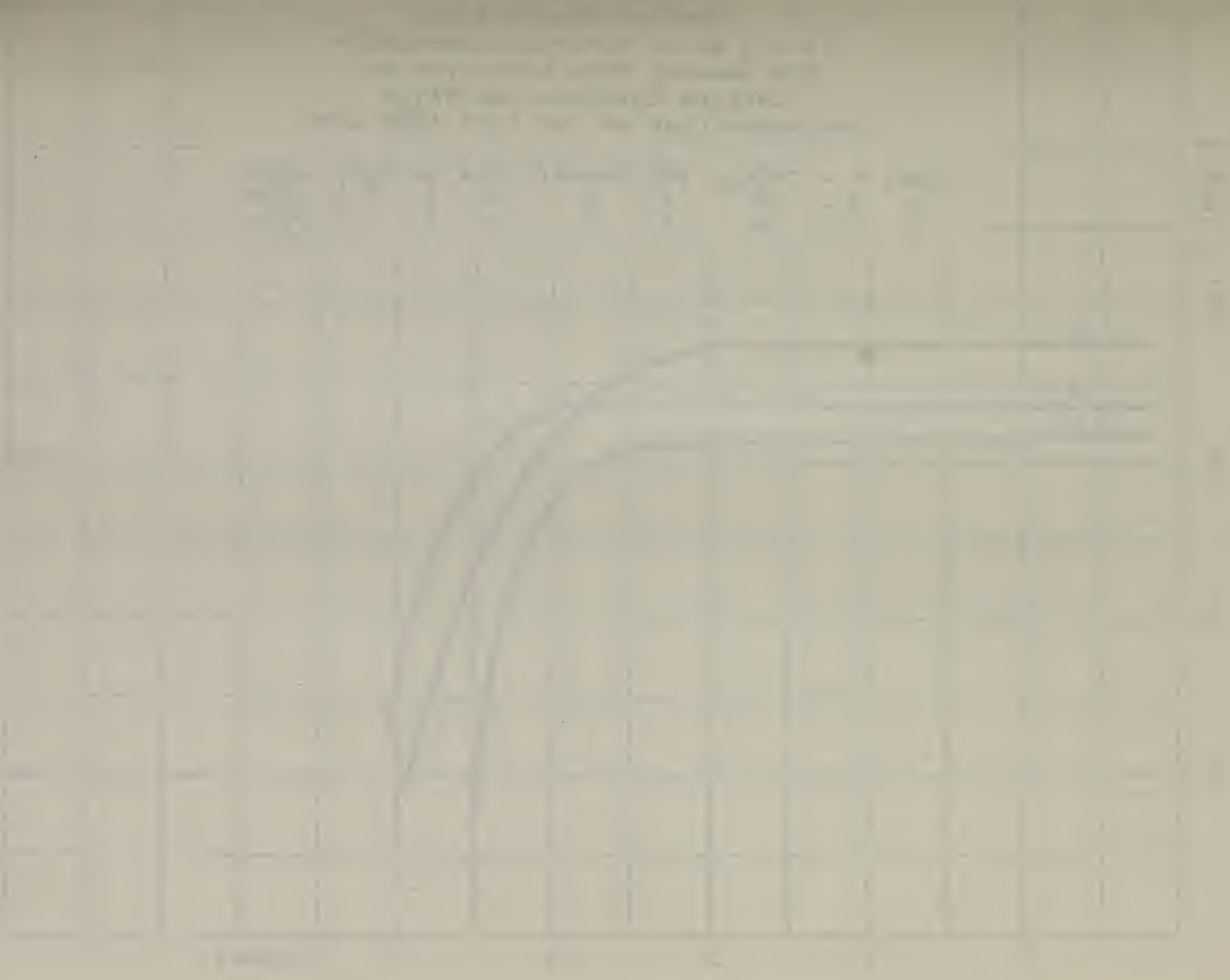
FIGURE 11-A



GENERAL ELECTRIC CO.
TYPE 3 WATER-ACTIVATED BATTERIES
PERFORMANCE WHEN ACTIVATED BY
CALCIUM CHLORIDE AND WATER
CONTINUOUS LOAD OF ONE TYPE 1839 LAMP

CURVE A - $CaCl_2$, 340 GRAMS/LITER OF H_2O; +25°C.
" B - " " " " " " ; -25°C.
" C - " " " " " " ; -35°C.

FIGURE 11-B.



3.10 Evolvement of Hydrogen

Consultations with the Chemistry Division of this Bureau indicate that nearly all of the gas evolving from activation of this type battery is hydrogen. The amount of gas given off by one battery remaining in the water until all visible evidence of evolvement ceased was measured and found to be approximately 12 liters when corrected to a pressure of 760 MM Hg and a temperature of 25°C. Volumetric concentrations from approximately 4% to 75% of hydrogen in air are considered explosive mixtures.

4. DISCUSSION

4.1 Air-Sea Rescue Operations

With a Type 1839 lamp, which consumes approximately 5.5 watts at 7.5 volts, the Type 3 water-activated battery will last under continuous load for between 4 and 5 hours before the illumination decreases to 0.5 scp at approximately 3.5 volts (Figures 3 and 4). However, as shown in Figure 5, the activated battery will last for approximately 7 days in a stand-by or no load condition, and as such would be useful for short periods of power demand if, for example, the light is to be used only in signaling nearby searching aircraft. Also, as shown in Figure 6, the battery could be used for approximately 20 hours in a flashing circuit with the same type lamp. It is probable that a thermal flasher could be designed to operate in the circuit and still enable the light to be flashed at a useful rate throughout one night.

A study of Figure 8 shows that most of the battery's potential power output is wasted in flashing the heavy-filament (Type 1134) lamp. The effective intensity of the 1134 flashing once every three seconds is considerably less than the intensity of the steady-burning Type 1839. Considerable power is wasted each time the heavy filament is heated to incandescence, and the large surge current through the cold filament apparently causes an accelerated electrochemical reaction as evidenced by the rapid evolvement of gas from the battery, and by the gradual rather than abrupt reduction of evolvement when the lamp circuit is opened.

4.2 In-Flight Fueling

Use of water-activated batteries for lighting the in-flight fueling equipment would present a number of problems. For example, there is the matter of keeping the battery supplied with water. As shown in Figure 10, at sea level the battery can power the Type 1839 lamp for approximately 35 minutes after removal of the battery from the water. If the battery is maintained in an upright position this period can be practically doubled by sealing the bottom vent, but in either case, the period of useful activity is rather limited. There may be practical ways of supplying water to the battery, such as an enveloping container of water or a wicking arrangement for getting the water into the battery from a surrounding absorbent material which would be soaked in water to start the activation. Of course the amount of water lost through evaporation will increase with altitude.

4.3 General

The low ambient temperatures at the in-flight fueling altitudes preclude the use of water alone. The batteries will operate fairly satisfactorily in a calcium chloride solution at temperatures at least as low as -35°C.

Based on results of this investigation, the utility of water activated batteries for lighting in-flight fueling equipment appears doubtful. However, the fact that operation can be obtained at low temperatures by the use of anti-freeze mixtures, indicates a possible use by survivors of a crash on ice floes, or in cold waste lands.

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major field laboratories in Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside front cover of this report.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Application Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering.

Radio Standards. Radio Frequencies. Microwave Frequencies. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.


NBS