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Supplement to 183-53-53

THE MC-193 AND MC-193A NICKEL-CADMIUM BATTERY

F. D. Hess

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ABSTRACT

This memorandum supplements the Technical Memorandum No. 183-53-53 on the Development and Evaluation of the MC-193 Nickel-Cadmium Battery by giving the most recent information that has been gathered on the storage, maintenance, and testing of the battery.

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August 24, 1954

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THE MC-193 AND MC-193A NICKEL-CADMIUM BATTERY

I SUMMARY

A. Purpose of this Report

Since the Technical Memorandum on the Development and Evaluation of the MC-193 Nickel-Cadmium Battery was published in November, 1953, the completion of long-term tests and the gathering of information on battery performance has made a supplementary report on the same subject desirable.

The present report is not a final treatment of the battery as a whole, but a series of studies of certain problems that have arisen in connection with its maintenance and use.

B. Water Loss on Storage (Abstract)

In a dry climate, the MC-193 battery should be watered prior to use if stored more than 16 months at room temperature (75°F), or if stored more than 4 months at 125°F. In a humid climate, these storage times can be extended to 48 months at room temperature and 12 months at 125°F.

C. Crazing of Plastic Cell Cases (Abstract)

The crazing of cell cases is caused by stresses resulting from wedging the cells in the battery case. Crazing has not appeared to weaken the cell walls nor result in loss of electrolyte during the first 21 months of storage. The effect of additional storage time will continue to be studied.

D. Environmental Tests (Abstract)

The assembly comprising the MC-291 battery box and MC-193 battery were tested for resistance to vibration, shock, linear acceleration, humidity, salt, and rain. While one MC-193 battery case was bowed by the shock test, the battery itself gave satisfactory discharges following all tests.

The specified storage test for the battery is 22 days at 125°F. This was compared to a test intended to represent severest known actual storage conditions with respect to temperature, namely, cycling between 90°F and 140°F at 100 per cent relative humidity. The latter test showed somewhat higher capacities after 22 days, indicating that the test at 125°F provides a margin of safety in evaluating the battery for high temperature storage.

An equation of battery capacity in terms of temperature was developed, based on data derived from the storage of seventy-two batteries.

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E. Quality Control Analysis (Abstract)

An analysis is presented of types of defects found in new and stockpiled batteries. Variations in inspection practice make it difficult to detect trends in data, and the recent increase in Class "D" defects may be ascribed to closer inspection, particularly of electrolyte levels. One battery from stockpile failed to pass the discharge test after ten days' storage at 125°F.

II WATER LOSS ON STORAGE (Detailed Discussion)

A. Summary

In a dry climate the MC-193 battery cell loses water by evaporation at the following approximate rates

TABLE I

	Grams Per Day per Cell	Fl. Oz. Per Day per Cell
Room Temperature	0.014	0.0005
125°F	0.060	0.0020

Estimating that a battery will not perform efficiently if more than 15 per cent of its electrolyte has been removed, it should be watered prior to use if stored more than 16 months at room temperature, or if stored more than 4 months at 125°F.

These figures are for desert conditions. In a humid climate they can be extended to 48 months at room temperature and 12 months at 125°F.

In addition to temperature and humidity the rate of water loss depends on the type of battery (MC-193 or MC-193A) and the state of charge. To minimize water loss, the battery should be stored in the discharged condition.

B. Previous Tests[1].

Tests made on cell cases with sealed vents, filled to the mark with electrolyte, indicated water losses as follows:

[1] Technical Memorandum on the Development and Evaluation of the MC-193 Nickel-Cadmium Battery, p. 25. Technical Memorandum 183-53-53.

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TABLE 2

	Grams Per Day per Cell	Fl. Oz. Per Day per Cell
Room Temperature	0.012	0.0004
125°F	0.043	0.0014

This is an acceptable check on the figures first cited, as the test assemblies were not identical. The first figures duplicate closely the actual battery assembly.

C. Test Procedure

An MC-193 and an MC-193A battery were broken down into their component cells. Six cells from each battery were stored and weighed at 30-day intervals under the following conditions

1. Room Temperature (70 - 80°F)
   125°F

2. Charged
   Discharged

3. Relative Humidity near zero.

A second MC-193A battery was stored at 125°F and 50 per cent relative humidity. This battery received a booster charge every 10 days, and its cells were weighed at 30-day intervals as before.

A record was made of cell cases showing signs of crazing or surface cracking of the plastic in order to see if crazed cells lost more electrolyte than uncrazed cells.

Finally at the conclusion of the test, electrolyte was withdrawn from one cell in each batch of six, and the potassium hydroxide and potassium carbonate contents determined.

The average losses for each group are listed below in tabular form and are also shown in Graph No. 1.[1]

---

[1] Appendix I, Graph I.

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TABLE 3

Type of Battery	Condition of Charge	Storage Temperature	Weight Loss Grams per Day per Cell
MC-193	Discharged	RT	0.011
MC-193A	Discharged	RT	0.014
MC-193	Charged	RT	0.015
MC-193A	Charged	RT	0.017
MC-193	Discharged	125°	0.055
MC-193A	Discharged	125°	0.058
MC-193	Charged	125°	0.060
MC-193A	Charged	125°	0.068
MC-193A	Booster Charge every ten days	125° (50% R.H.)	0.022

D. Evaluation of Results

1. The last battery listed, which was stored at 50 per cent Relative Humidity, had an evaporative loss only one third as great as the same type battery stored at zero Relative Humidity. This permits a corresponding extension of the minimum safe watering period for a battery stored in a humid climate, as compared to a battery stored in a dry climate.

2. The weight loss for the MC-193A battery ran 16 per cent higher than for the MC-193. The reason for this is not known. It tends, however, to confirm the hypothesis that the loss of moisture is through the cell walls rather than through the vents, since the MC-193A vents at a higher internal pressure than the MC-193.

The differential for each temperature and state of charge is

TABLE 4

State of Charge	Temperature	Percentage Increment in Wt. Loss of MC-193A over MC-193
Discharged	RT	25.0%
Discharged	125°	9.4%
Charged	RT	17.4%
Charged	125°	12.[illegible]%

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3. The weight loss for charged cells ran 19 per cent higher than for discharged cells. This is due to the fact that charged cells are warmed slightly above their ambient temperature by internal discharge. The differential is shown below:

TABLE 5

Type of Battery	Temperature	Percentage Increment in Wt. Loss of Charged over Discharged Cells
MC-193	RT	26.9%
MC-193	125°	12.9%
MC-193A	RT	19.2%
MC-193A	125°	16.5%

4. Crazed cells showed only a 1 per cent greater weight loss than uncrazed cells. This figure is believed to be negligible, statistically, and agrees with observations on crazing to be found in Section III.

5. Standard deviation for weight loss of all cells examined was 11.5 per cent.

E. Carbonation

Analysis of the electrolyte after storage was not very informative, since no comparative analysis had been made before storage: The following table shows the percentages of potassium hydroxide and potassium carbonate after 90 days storage. The last column shows the per cent potassium present in the form of the carbonate. This figure is appreciably higher for batteries stored in the charged condition at an elevated temperature, leading to the speculation that the carbonation might occur due to oxidation of organic matter, possibly the cellophane separator, by the positive plate.

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TABLE 6

Type of Battery	Condition of Charge	Storage Temperature	Per Cent Potassium Hydroxide	Per Cent Potassium Carbonate	Per Cent Equivalents Potassium as Carbonate
MC-193	Discharged	RT	25.1	9.8	23.9
MC-193A	Discharged	RT	24.5	8.8	22.5
MC-193	Charged	RT	20.1	9.1	26.9
MC-193A	Charged	RT	18.2	7.2	24.1
MC-193	Discharged	125°	25.1	10.5	25.3
MC-193A	Discharged	125°	23.3	9.8	25.3
MC-193	Charged	125°	22.6	13.9	33.3
MC-193A	Charged	125°	21.4	11.9	31.1
MC-193A	Booster Charge every ten days	125° (50% R.H.)	18.7	13.6	37.0

III CRAZING OF PLASTIC CELL CASES (Detailed Discussion)

A. Summary

Some battery cells, particularly in older batteries, exhibit a condition known as crazing in which fine surface cracks appear on the plastic cell case.[1]

These cracks appear almost invariably along one end of the cell case - that end which is next to the battery case. They extend in the form of an inverted V from the center of the case toward the edges. They are on the outside of the case and penetrate about halfway through.[2]

A consideration of the stresses to which the cell is subject shows that this type of crazing would result in relieving a strain imposed from above. The location of the crazing on the outer cell face indicates that crazing is caused by the driving of the nylon retaining wedges into place along the outer, upper rim of the battery case. For the sake of appearance this condition should be corrected, however, there is no evidence that it affects battery performance. A different method of wedging may be required to eliminate crazing.

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[1] Appendix 2, Photograph 1.

[2] Appendix 2, Photograph 2.

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B. Effects of Crazing

Since these surface cracks do not extend into the inside surface of the cell, they should not permit any leakage of electrolyte. This is borne out by the experimental evidence. A test of seventy cells stored for 90 days at room temperature and 125°F showed a water loss from crazed cells only 1 per cent higher than from uncrazed cells.[1]

Furthermore, the presence of surface cracks does not appear to weaken the cell in ability to withstand internal pressure.

Tests[2] were performed to determine the pressure at which crazed Bakelite C-11 cell cases sustain damage detrimental to battery performance. It was desired that these cells be exploded by pressure inside a normal battery where the battery case and cells act as a clamp.

C. Procedure

Six crazed Bakelite C-11 cell cases were obtained from a single battery. The regular rubber vent mechanism was reinforced by winding rubber bands around it in order that the cell case would sustain the pressure necessary to explode it. The six cells, with the filler screw removed, were placed in another Ni-Cad battery and the entire battery was charged. By charging the entire battery, cell pressure is built up in each individual cell with the result that a much tighter clamp is available. With a cell fully charged, any further charge will produce pressure in the cell.

A pressure meter recently calibrated was screwed into the vent filler, sealing the cell from any leakage. Using a single cell charger, the cell was charged at a 10 ampere rate until it exploded.

D. Results

TABLE 7

Unit	Pressure at which Cell Exploded	Position of Cell Failure
No. 1	85 PSI	Along uncrazed side
No. 2	68 PSI	Along uncrazed side
No. 3	65 PSI	Along crazed side
No. 4	55 PSI	Along uncrazed side
No. 5	55 PSI	Along crazed side
No. 6	60 PSI	Along uncrazed side

[1] This report, Section II

[2] Memo, Neeld to Bird, dtd. 22 January 1954.

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E. Conclusions

From the six units tested it appears that crazing to the extent noticed to date does not weaken the Bakelite C-11 cell case.

IV ENVIRONMENTAL TESTS (Detailed Discussion)

A. The MC-291, MC-193 Assembly

This is an abstract from a report by the Environmental Test Division on the Nickel-Cadmium battery and battery box assembly. Those sections of the report concerning the MC-291 battery box only, have been omitted.

1. Object of Test. - These tests were performed as a quality check of the MC-291, MC-193 assembly with respect to vibration, shock, linear acceleration, humidity, salt, and rain.

2. Summary of Results. - Three MC-291's failed the vibration tests because of broken thermostats. The MC-193 clamp was bowed during the shock test. The MC-291 latch opened during the shock test. The MC-291's and the MC-193's passed all other tests.

3. Procedure. - Four MC-193's, Lot Nos. 353, 381, 382, R.S. No.7473, and four MC-291's were supplied. One MC-291, MC-193 assembly was subjected to each of the following tests: Vibration, shock, linear acceleration, humidity, salt, and rain. Before and after each test the MC-291 was given a functional test which consisted of a heater resistance check at +50°F and a high-potential check (203 volts d-c) at +90°F. The specification calls for a heater resistance of 7.0 to 7.7 ohms at +50°F, and at least 1 megohm at +90°F, except after humidity, rain, or salt - then it should be at least 500 ohms at +90°F. The MC-193's were given an initial charge and discharge test, charged before and discharged after each test.

Vibration test A was performed according to SCS-7, procedure I, paragraph 4.7.2, and consisted of a resonant survey along each of the three major axes, one hour of vibration at resonance, and one hour of cycling. With respect to the MC-291, the vibration at resonance in the longitudinal axis was at 300 cps for 30 minutes, and at 75 cps for 30 minutes, in the vertical axis at 115 cps for 30 minutes, and at 95 cps for 30 minutes, and in the transverse axis at 95 cps for 60 minutes. At no time was there any single severe resonant point, but rather a range of frequencies through which resonances occurred. The frequencies considered the worst were used for the resonant vibration. The cycling was from 10 to 73 cps with a constant double amplitude of 0.036 inch, and from 73 to 500 cps at a constant acceleration of 10 g.

Vibration test A caused a thermostat failure in the SA-42 heater blanket of the MC-291. Therefore, vibration tests B and C were performed and two more assemblies were vibrated in a manner similar to vibration test A. However, alterations of test conditions, making the test

much more severe, were as follows:

a. The assembly was at a cold temperature (-60°F) at the start of vibration in order to monitor the thermostats for chatter when closed.

b. The MC-193's had been previously vibrated; it was felt that any used MC-193 would have practically the same effect as a new one.

The shock tests consisted of 100-g acceleration of 0.005 second duration in both directions of the vertical axis of the MC-291, and 30-g accelerations of the same duration in both directions of both the longitudinal and the transverse axes.

The linear acceleration of 50-g for one minute was applied along all three axes.

The humidity test consisted of ten 48-hour SCEL exposure cycles.

The salt-spray test was a 50-hour test conducted in accordance with MIL-E-5272 (USAF), section 4.6.

The rain test was a 2-hour test with a simulated rainfall of 4 ± 1 inch per hour.

4. Results. - All units supplied were in good condition. Six cells needed addition of distilled water to bring the electrolyte level up to where it was visible in the windows.

At the completion of vibration test A, the heater resistance of the SA-42 heater blanket in the MC-291 was too high at +50°F. One thermostat was broken internally. The thermostat elements are supported by the two leads which have two 90-degree bends in each. The leads broke at the bend, destroying the thermostat. It was determined that powder inside the thermostat was a combination of the materials inside the thermostat and was produced by the mortar and pestle action occurring between the element, insulation, and case during vibration. Operable thermostats when opened did not have powder. One of the end thermostats did have a high contact resistance (1 ohm) which was attributable to the powder.

At the completion of vibration tests B and C, both MC-291's had three broken thermostats (top, bottom, and one end) which broke internally at the bend in the leads. However, as pointed out in Procedure, the assemblies were cold at the start of vibration and this condition undoubtedly reduced the flexibility of the leads. The MC-193 clamp in each case broke, one severely, the other slightly, thus increasing the amplification of the MC-193 in the MC-291. This breaking, not observed before in batteries used as fillers, could also be attributed to the cold temperatures.

The chatter encountered was meaningless because it was probably caused by the making and breaking of the broken leads of the thermostats.

Table 8 shows the discharge results of the MC-193's. Table 9 shows MC-193 breakage during vibration tests B and C.

The MC-193 discharge results were satisfactory following all tests. The cells turned blackish during vibration, as usual, with no harmful effect on battery capacity. With the MC-291 in the inverted position, the clamp was bent when subjected to a 100-g shock. During the same drop, the latch of the MC-291 came unhooked. The MC-291 passed all the functional tests except vibration, as mentioned above.

Test Conducted by W. E. BOSKEN - 1611-2

TABLE 8

Results of MC-193 Discharge

Battery No.	Time of Discharge to 25.2 Volts: Before Testing (min)	Test	After Testing (min)
DG 8562 E3	8.73	Vibration	9.67
DG 13349 H3	8.15	Shock	8.42
DG 13138 G3	8.23	Linear Acceleration	9.03
DG 8332 E3	8.75	Humidity	6.93
DG 13138 G3	(See linear acceleration)	Salt	9.23
DG 13138 G3	(See linear acceleration)	Rain	8.53

Discharge: 30-volt units, 1.07-ohm resistance, room temperature

Minimum requirement: One minute to 25.2 volts

TABLE 9

MC-193 Breakage During Vibration Tests B and C

Battery No. 1

History: One previous 6-hour vibration (SCS-7)

1. The top of clamp broke at both ends on the side without flanges (up side in the MC-291).

2. Broke wedge holder part of clamp on the side with flanges (down side in the MC-291).
   The cells were then insecurely held in the clamp.

3. Electrolyte spilled over bottom of box.

4. Six connecting straps broke.
   One large strap broke completely.
   One large strap cracked at one end.
   Three small straps broke completely (both ends).
   One small strap broke at one end.

5. Three nuts came off terminals.

Battery No. 2

History: Vibrated by manufacturer.

1. The top of clamp broke at one end on the side without flanges (up side in the MC-291).

B. Twenty-two Day Storage Tests at Elevated Temperature

1. Summary. - Specifications[1] for the Nickel-Cadmium battery call for a charged storage test of 22 days' duration at 125°F ±2°, after which the battery should have a minimum discharge time of 2 minutes through a constant 1.07 ohm resistance load, with the battery temperature at 80°F.

Tests have been conducted to determine whether this storage time and temperature are realistic in terms of the actual environmental conditions to which the battery is subject.

The conclusion, on the basis of the evidence presented here, is that the test is valid and yields results that are on the conservative side.

[1] Dwg. 119837, Issue A, Design Information for the MC-193A Ni-Cad Battery Unit, Para. 1.2.2.1.

Consideration was also given to the fact that the military use of the battery permits charged storage times up to 44 days.[1] It is evident that there is a gap between the 22 days' storage time that the vendor must "build into the battery" and the permissible field storage time. In future production, the vendor could allow the quality of the battery to be degraded to such an extent that while it would still meet the specifications of Dwg. 119837, it could no longer satisfy the allowed storage time of Tables I and II of the Preparation and Application Manual.

Studies are now being made by 5131 and 5311 on current battery storage data to determine what corrections should be made to the production test requirements in order to insure no degradation of battery performance in future production batteries.

2. Test Procedures. - Consultation with Department 5130 established these facts:

   a. The extreme high temperature limits that the battery would reasonably be expected to meet over a 90-day period are a high of 140°F and a low of 90°F during twenty-four hours.

   b. A twenty-four hour temperature cycle could be simulated in the laboratory, regulating the temperature as a sine wave function between the limits of 140°F and 90°F.

Accordingly, two fully-charged batteries were stored for twenty-two days at 100 per cent relative humidity, using the above temperature cycle. They were then discharged, 8 cells at a time, through a 0.357 ohm resistor. Average discharge times to 8.4 v, equivalent to 25.2v for a full battery, are given here, compared to the average discharge time of 72 battery cells stored 22 days at 125°F.

TABLE 10

	Discharge Time
Battery No. 5808	5 min. 57 sec.
Battery No. 5958	5 min. 42 sec.
Average for batteries stored at 125°F	3 min. 50 sec.

In addition, a test was conducted by the Field Forces Department in which two batteries were stored for 90 days under desert storage conditions. They were then discharged through a 1.8 ohm resistor with the following results:[2]

---

[1] SC-2637B (Tm), Preparation and Application Manual for MK 2 Power Supply, 23 December 1953. Table II gives 44 days as the storage time for the 90° - 140° diurnal cycle.

[2] Ltr., C. F. Bild, 5311, to N. L. Vinson, 1732, dtd. 18 May 1954, Ref. Sym: 5311-(44).

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TABLE 11

Battery Number	Time to 25.2 v	Time to 24.0 v
8726	6.0 min	17.75 min
8267	7.5 min	19.75 min

These results should be somewhat higher than those obtained by discharge through a 1.07 ohm resistor. However, they demonstrate the ability of the battery to carry the required load after a storage period which was probably in excess of that allowed under Table II.

3. Conclusion. - A charged storage test for the Ni-Cad battery of 22 days at 125°F, followed by a two-minute minimum discharge period through 1.07 ohms to 25.2 v, is a realistic and conservative appraisal of the battery's ability to withstand high temperature storage.

Other data studied by the Department 5130[1,2] yielded substantially the same conclusion.

C. Equation of Battery Capacity in Terms of Temperature.

1. Summary. - Since the publication of Tables I and II in SC-2637B(Tm)[3] giving the maximum allowable charged storage time for the Nickel-Cadmium battery at elevated temperatures, more extensive tests[4] have been run, permitting the development of an equation for the capacity of batteries in charged storage at various temperatures.[5]

Due to time limitations, storage tests on twenty-four batteries at 70°F and 90°F have not yet been completed. Each storage test reported herein has been made at a fixed temperature, and further study must be made to relate these tests to the fluctuating temperatures actually experienced by the battery in storage. This report, therefore, is limited to the prediction of the charged capacity of batteries in storage at fixed temperatures of 90°F and above.

---

[1] Storage Life of Ni-Cad Batteries under High Temperatures. Technical Memorandum 18-54-51, February 23, 1954.

[2] Maximum Temperature Patterns in Hot Climates. Technical Memorandum 80-54-51, June 4, 1954.

[3] SC-2637B(Tm) Preparation and Application Manual for Mk 2 Power Supply.

[4] Interim Report of Temperature - Storage Tests of MC-193 Nickel-Cadmium Batteries, Bosken to Bild, dtd. 29 June 1954, Ref. Sym: 1611, Project No. ET-1720-A.

[5] Technical Memorandum, 75-54-51, dtd. July 21, 1954, Title: "Analysis of MC-193 Nickel Cadmium Battery Storage Tests," C. R. Clark - 5131-1 and F. P. Hudson, 5131.

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The allowable storage periods for the temperatures considered were:

TABLE 12

Temperature	Allowable Storage Period
165°F	4 days
140°F	14 days
125°F	34 days
110°F	85 days
90°F	130 days[1]

Expressed in equation form:

$$y = 8.045 - 1.780\, e^{-1.104\left(\frac{18000}{T+460} - 28.5\right)} x - 2.21$$

y = capacity in minutes (down to 25.2 voltage level thru 1.07 ohm load)

T = temperature, degrees Fahrenheit

x = storage time in days

2. Procedure. - Forty-eight batteries were charged for one hour at 37.4 volts, stored overnight with the ambient temperature at 50°F, and discharged. They were allowed to stand in the shorted condition for at least 24 hours, after which a sample of electrolyte was withdrawn from three cells in each battery for analysis. They were then recharged, and electrolyte samples taken from the batteries to be stored at 125°F and 110°F. After standing for 24 hours at room temperature, the batteries were placed in storage at the test temperature.

Upon completion of the required storage time, a pair of batteries was kept with the ambient temperature at 50°F overnight then discharged in lots of 8 cells to give the test data for capacity. Finally, electrolyte samples were removed from the batteries stored at 165° and 140°F.

[1] This value obtained by extrapolation.

3. Results. - Expressed as permissible storage times for the various test temperatures, the results are given in tabular and equation form in the summary and graphically in Appendix 1.[1]

The graphs are based upon the actual test data and would not coincide exactly with storage times calculated from the capacity-storage equation. Some revision of Tables I and II in the Preparation and Application Manual may be required when all storage tests have been completed. More information is needed to give the relation between storage at a constant temperature and when subject to diurnal temperature changes.

V QUALITY CONTROL ANALYSIS (Detailed Discussion)

A. General

Procurement and stockpiling of the Nickel-Cadmium battery are sufficiently advanced to permit a limited determination of trends in quality control.

This section is a compilation and evaluation of battery defects noted by various sources, principally Inspection Department II, the Quality Assurance and Surveillance Departments, and the Environmental Test Division. Some laboratory test results are given, but corrective measures are not in the scope of the present report.

B. Classification of Defects List

A consideration of the manner in which defects affect battery performance has resulted in the following grading system:

Class A - Very Serious (Demerit Value of 100)

1. Failed discharge test.
2. Crossed polarity.
3. Improperly connected.
4. Intercell connector missing.
5. Shorted battery leads.
6. Broken wire or unsoldered connection.

Class B - Serious (Demerit Value 50)

1. Loose metal inside cells.
2. Loose intercell connector strip.
3. Cell cracks in lower part of cell.

[1] Appendix 1, Graphs 2, 3, 4, 5, and 6.

Class C - Moderately Serious (Demerit Value 10)

1. Cell cracks in upper portion of cell.
2. Leakage at terminals.
3. Stripped threads in vent.
4. Split filler neck.
5. Damaged insulation.
6. Loose rib due to poor spot welding.
7. Damaged connectors.
8. Leaky cell.
9. Hardware corroded.

Class D - Not Serious (Demerit Value 1)

1. Loose cable clamp.
2. Plastic locking wedge too long.
3. High or low electrolyte.
4. Hardware (scratches and mars).
5. Poor plating on connector.
6. Connector burnt (plastic insulator).
7. Vent screws loose.
8. Plastic tubing damaged.
9. Connectors need paint.
10. Dirty units or dried potassium carbonate on units.
11. Burred edges.
12. Loose lock nut.
13. Cracked dust cover.
14. No polarity markings on cell.
15. Bent frame.

C. Evaluation of Specific Defects

Certain parts of this grading system require explanation.

1. The subject of crazed cell cases has been considered in Section III of this report. As it was concluded that crazing (distinct from cracking) to the extent noted to date did not impair battery performance in any way, no defect classification was assigned to it.

2. Carbonation of the electrolyte is not believed to degrade cell performance until a concentration of about 60 per cent (in equivalents of the total potassium content) is reached.[1] Some of the cells reported in Section V may exceed this value, though no impairment in battery capacity was detected.

[1] Bell Telephone Laboratories. Memorandum for Record-Carbonation of the Electrolyte of Nickel-Cadmium Storage Batteries - Case 38421-3, dtd. 20 May 1953.

Further testing is projected in which unactivated cells will be filled with electrolyte containing varying amounts of potassium carbonate. Cycling and storage characteristics may then be determined on cells whose histories are known.

3. Stain, Discoloration, Incrustation. - Occasionally stainless steel filling screws are observed to have a thin film of brown rust over the surface. Though no corrective measure need be taken, this rust may be removed by burnishing with crocus cloth.

   Discoloration and incrustation on the exterior nickel fittings result from the normal entrainment of small amounts of electrolyte from the cell vents. This is sometimes referred to as corrosion, but should properly be called incrustation, as the metal does not appear to be attacked. As it may be detrimental to battery performance, it is removed by washing with cold water and a stiff brush.

4. Blue crystalline growths on the nickel plated nuts have been observed in two batteries. One of these was in tropical storage; the other was stored for several months at 125°F and 50 per cent relative humidity.

   This has been ascertained to be copper carbonate, formed when the nickel plate on the nuts flakes off and exposes the copper undercoating. It is evidence of a poor plating job, but would have a negligible effect on battery performance.

D. Defects Found in The Inspection of New Batteries

A survey was made of 12,308 batteries examined by the Inspection Division. The monthly incidence of each class of defect is tabulated below, and appears in graph form in Appendix 1.[1]

TABLE 13

Month	Number of Batteries Examined	Percent Showing Defects	Percent of Each Class Defect A	B	C	D
1953						
July	923	16.5	0.0	1.2	6.6	8.7
Aug.	1588	12.4	0.0	1.2	3.3	7.9
Sept.	1576	17.2	0.1	1.6	1.9	14.1
Oct.	1955	14.0	0.5	1.0	3.1	8.6
Nov.	1221	17.1	0.8	1.6	4.4	10.2
Dec.	1102	20.1	0.4	2.0	1.3	16.8

[1] Appendix 1, Graph 2

TABLE 13 (cont)

Month	Number of Batteries Examined	Percent Showing Defects	Percent of Each Class Defect A	B	C	D
1954						
Jan	780	19.6	0.3	1.3	4.1	15.9
Feb.	852	14.7	0.5	0.7	2.7	14.2
Mar.	1029	33.4	0.7	2.4	9.3	41.5
Apr.	976	26.5	0.3	1.5	5.6	32.9
May	306	31.7	0.3	1.6	8.5	30.1

NOTE: Since some batteries exhibit more than one defect, Columns 4, 5, 6 and 7 will generally add up to more than Column 3.

Referring to the table, it would appear that the percentage defective batteries increased sharply in March, 1954. It is doubtful, however, whether this should be ascribed to an actual increase in defects rather than the improved detection of defects brought about by more rigid inspection methods. For example, in the first month listed (July, 1953), nine categories of defects are given. By April, 1954, this has increased to fifteen categories, indicating an improvement in inspection practice.

Furthermore, it will be noted that a major part in the defect increase is due to the greater number of Class D defects, particularly high and low electrolyte levels. For the month of March, 1954, 39 per cent of the total number of defects listed are ascribed to the level of electrolyte.

With reference to Graph 7, Appendix 1, it will be noted that in some instances a summation of defects by classes (A, B, C, D) will exceed the total percentage of defective batteries. This is because many batteries are found with two or more defects.

E. Examination of Batteries Returned From Sites

A program was initiated to make a thorough examination, on a sampling basis, of batteries in the various Sites.

A total of twenty batteries are to be returned from the Sites to Sandia Corporation semi-annually. However, the first lot of batteries checked under this program came from the Sandia reserve. The second lot came from Sites A, B, C and D (five batteries from each Site).

1. Summary of Results

a. First Lot - Batteries From Sandia Reserve

All batteries passed all electrical tests, except that one battery (No. 15) was five seconds below the required discharge time following the cold storage test.

b. Second Lot - Batteries From Sites

The carbonation of the electrolyte increases with age.

One battery did not have one set of the wedges which hold the cells in place. All but two of the batteries showed incrustation (white crystalline solid) at the terminals.

One battery yielded very low comparative discharge time following the high-temperature test.

One cell was found to be defective. Mr. W. M. Evans, 5521, performed the post mortem and reported dirt in the separator material, probably causing an internal short. The discharge results following all other tests were satisfactory.

2. Procedure. - Batteries were visually inspected for packaging defects or damage to the units. The units were inspected to determine whether (1) the cells were held tightly in place, (2) the cell connections were secure, (3) the cable leads were satisfactory, and (4) the the electrolyte level was satisfactory. Electrical tests consisted of:

Test 1. Charge-discharge capacity.
Test 2. Retention of charge - high temperature.
Test 3. Cold.
Test 4. Maximum voltage.
Test 5. Vibration.

Test 1 -- Each battery unit (20) was fully charged, allowed to stand for 24 hours, and then discharged. The battery must be capable of supplying a minimum of 7.2 minutes of capacity to the end voltage of 25.2 volts. For a full charge using a Signal Corps battery charger PP 775/U, ten batteries were charged in parallel at 37.4 volts for 100 minutes, or until the current was less than one-half ampere per battery. Discharge was at room temperature into a constant 1.07 ohm resistance to an end voltage of 25.2 volts.

Test 2 -- Each battery unit (20) was fully charged, stored for ten days at +125°F, cooled to room temperature, and discharged. The battery must then be capable of supplying a minimum of 4.0 minutes to the 25.2 volt end voltage.

Test 3 -- Each battery unit (20) was fully charged, allowed to stand for eight hours at -65°F, warmed to room temperature, and discharged. The battery must then be capable of supplying a minimum of 7.2 minutes to the 25.2 volt end voltage.

Test 4 -- Each battery unit (20) was fully charged, allowed to stand for one hour at room temperature, and then discharged into a 2-ohm resistance. The voltage at 15 seconds was recorded. The voltage should be no more than 30.5 volts at the battery terminals.

[redacted]

Test 5 -- Different vibration test procedures were used for the two twenty-battery lots.

Of the first lot (Sandia reserve), four battery units were fully charged and vibrated for one hour in each of the three principal axes for each of the following conditions (total of nine hours):

1. From 10-30-10 cps in 5 minute cycles with 0.109-inch constant double amplitude.

2. From 30-60-30 cps in 5 minute cycles with 0.054-inch constant double amplitude.

3. From 60-300-60 cps in 5 minute cycles with a constant acceleration of 5 g.

Of the second lot (batteries from Sites), four battery units were fully charged and vibrated according to SCS-7.

Batteries must be capable of supplying a minimum of 7.0 minutes to the 25.2-volt end voltage if discharged later than 30 hours after charge.

3. Results

a. First Lot - Batteries from Sandia Reserve

Visual inspection revealed no defects except that about 8 per cent of the cells were low on electrolyte. Distilled water was added to these. They are shown in Table 14, together with the battery serial numbers. The discharge results are shown in Table 15. The only discharge below specification was battery No. 15 after the cold test, and this was only 5 seconds below the specification. This battery had the lowest discharge time after tests 1 and 2.

The results of the maximum voltage test are shown in Table 15. Most of these were slightly high (0.1 to 0.3 volts) at 15 seconds.

The results of the analysis for carbonation in the electrolyte and the specific gravity of the electrolyte are shown in Table 16. There was no apparent correlation between the extent of carbonation and the battery capacity, but one cell from each battery is not indicative of the capacity of the 24-cell battery. This analysis established a zero point for the extent of carbonation under storage conditions.

b. Second Lot-Batteries from Sites

Visual inspection revealed corrosion on cell terminals, some cells low on electrolyte, and one battery devoid of one set of the cell clamping wedges. These are shown in Table 14, together with the battery serial numbers.

[redacted]

The discharge results are shown in Table 15. The only discharge below specifications was Battery No. 20 after the high temperature test. This battery contained one defective cell which was post mortemed by the consultant, who reported "dirt" in the separator material which was the probable cause of the short, but he is forwarding the cell to the Materials Test Laboratory for examination.

The results of the maximum voltage test are shown in Table 15. Several of these were high but only slightly (0.1 volt).

The results of the analysis for carbonation in the electrolyte are shown in Table 17. These are interesting in that a trend of increasing contamination with age of battery seems apparent. The higher percentages do not seem to have any significant effect on battery capacity.

Test Conducted by W. E. Bosken. 1611-2

[redacted]

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TABLE 14

Serial Numbers of MC-193's Tested

Code Number	From Site	Serial No.	Cells Low on Electrolyte*	Number of Corroded Terminals
1		DG 5555 C3	None	Not Recorded
2		DG 6798 D3	None	Not Recorded
3		DG 8184	None	Not Recorded
4		DG 6598 D3	None	Not Recorded
5		DG 4992 B3	1, 4, 8 and 20	Not Recorded
6		DG 5514 C3	10, 14 and 20	Not Recorded
7		DG 6759 E3	7, 8, 20** and 24	Not Recorded
8		DG 6724 D3	None	Not Recorded
9		DG 5241 B3	19	Not Recorded
10		DG 8015 E3	None	Not Recorded
11		DG 6331 D3	None	Not Recorded
12		DG 5558 C3	3	Not Recorded
13		DG 5592 C3	4, 5, 6 and 23	Not Recorded
14		DG 6760 E3	8 and 17	Not Recorded
15		DG 6151 E3	3, 4, 6, 11, 12, 13, 16, 18, 20 & 24	Not Recorded
16		DG 6282 D3	19 and 21	Not Recorded
17		DG 7839 D3	None	Not Recorded
18		DG 7989 E3	None	Not Recorded
19		DG 6542 D3	None	Not Recorded
20		DG 4763 B3	13, 16 and 18	Not Recorded
21	B	DG 9552 F3	None	4
22	B	DG 13459 H3	None	6
23	B	DG 9511	1	0
24	B	DG 13380 H3	None	10
25	B	DG 10773 F3	8	7
26	D	DG 7735 D3	None	1
27	D	DG 11937 F3	1	1
28	D	DG 12007 F3	1	5
29	A	DG 4489 A3	None	9
30	A	DG 6825 E3	3	10
31	A	DG 6371 D3	None	6
32	A	DG 5457 C3T	None	16
33	D	DG 7584 D3	None	0
34	D	DG 6047 C3	None	2
35	A	DG 5308 B3	None	1
36	C	DG 12243 H3	None	4
37	C	DG 9726 F3T	1	35
38	C	DG 4044 A3	None	1
39	C	DG 3879 A3	3	2
40	C	DG 12176 H3	None	20

*Cells are numbered one at the positive terminal through twenty-four at the negative terminal.

**Terminal corroded. spewed at terminal during charge.

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[redacted]

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TABLE 15

Complete Discharge* Times of MC-193's Tested

Battery No.	Discharge No. 1 Min.	1 Sec.	2 Min.	2 Sec.	3 Min.	3 Sec.	4 Volts	5 Min.	5 Sec.	6 Min.	6 Sec.
1	8	56	7	16	8	37	30.5			9	30
2	8	39	6	46	7	33	30.6			8	00
3	8	55	7	36	8	23	30.7			9	17
4	8	27	6	55	8	04	30.8	8	46	8	49
5	8	32	7	48	8	48	30.7			8	56
6	9	04	7	14	8	21	30.7	9	35	9	30
7	9	00	6	56	8	07	30.7			8	51
8	8	44	7	52	8	07	30.8			8	59
9	8	45	7	35	8	51	30.6			9	07
10	8	51	7	25	8	13	30.8			9	12
11	8	57	7	40	8	24	30.6			9	22
12	9	15	7	18	8	46	30.6			9	22
13	9	09	7	34	9	03	30.5			8	36
14	8	31	7	05	7	55	30.5+			8	52
15	8	08	6	22	7	07**	30.4			8	45
16	9	07	7	42	8	16	30.6			9	18
17	9	00	6	44	8	14	30.6			9	15
18	9	03	6	48	8	03	30.6	9	23	9	15
19	8	53	7	17	8	04	30.6			9	09
20	8	47	7	37	9	08	30.6	9	57	9	39
21	8	23	7	18	8	19	30.5	8	07		
22	7	59	7	28	8	14	30.4				
23	8	10	7	04	8	07	30.5				
24	8	15	7	00	7	54	30.5				
25	8	20	6	51	7	50	30.5				
26	8	16	7	30	8	42	30.5				
27	8	32	7	24	8	26	30.6	7	51		
28	8	17	6	57	8	28	30.5				
29	8	21	7	33	9	02	30.6				
30	9	07	7	16	8	35	30.5				
31	8	45	7	19	8	48	30.6				
32	8	50	7	09	8	59	30.6				
33	8	48	7	00	9	00	30.6	8	45		
34	8	08	6	26	8	08	30.5				
35	9	00	6	22	8	24	30.4				
36	8	35	7	42	8	46	30.6				
37	8	25	7	07	8	34	30.6				
38	8	44	6	45	9	35	30.6				
39	8	35	7	06	9	31	30.6	9	23		
40	8	54	3	30***	-	--	----				

*Discharge: 1.07 constant resistance - Room Temperature - End Voltage 25.2 volts.
**Below specification by 5 seconds.
***Failed: Removed from test and given to Mr. W. M. Evans, 1521, for post mortem (at least one defective cell).

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Table 15 (cont)

Discharge No. 1 - Immediate Charge - Discharge Capacity Test
Discharge No. 2 - Following 10 days at +125°F
Discharge No. 3 - Following cold storage test
Discharge No. 4 - Voltage at 15 seconds - 2 ohm load
Discharge No. 5 - Following vibration test
Discharge No. 6 - Following conditioning charge

TABLE 16

Results of Analysis for Carbonation and Specific Gravity

Battery No.	Per Cent K_2CO_3	Specific Gravity
3	6.9	1.21
5	12.0	1.23
9	13.2	1.24
10	7.8	1.25
13	11.6	1.26
14	7.0	1.25
15	9.2	1.25
16	6.7	1.24
19	8.2	1.23

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TABLE 17

Electrolyte Analysis

Battery No.	Per Cent K_2CO_3 Cell 4	Per Cent K_2CO_3 Cell 24	Specific Gravity Cell 4	Specific Gravity Cell 24
21	13.8	11.5	1.249	1.257
22	9.6	9.9	1.238	1.233
23	13.4	10.5	1.240	1.221
24	11.1	10.0	1.244	1.261
25	10.4	11.6	1.216	1.227
26	11.1	11.0	1.250	1.255
27	10.6	9.9	1.231	1.242
28	10.1	13.4	1.252	1.267
29	27.7	24.9	1.266	1.238
30	10.3	11.7	1.244	1.249
31	9.9	11.7	1.221	1.222
32	13.8	13.4	1.260	1.274
33	11.8	11.8	1.265	1.268
34	12.7	13.4	1.260	1.244
35	25.4	24.7	1.243	1.244
36	11.2	10.1	1.244	1.260
37	13.8	15.8	1.227	1.250
38	26.9	25.7	1.258	1.246
39	26.8	27.1	1.231	1.243
40	8.6	10.1	1.211	1.238

F. D. HESS - 5311

D. L. LAWSON - 5311

Case No. 435.03
August 24, 1954

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[redacted]

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APPENDIX 1

Graphs

Number

1 Water Loss vs Storage Time

2 Discharge Time vs Storage Time (165°F.)

3 Discharge Time vs Storage Time (140°F.)

4 Discharge Time vs Storage Time (125°F.)

5 Discharge Time vs Storage Time (110°F.)

6 Storage Temperature vs Useful Life

7 Per Cent Defective Batteries per Month

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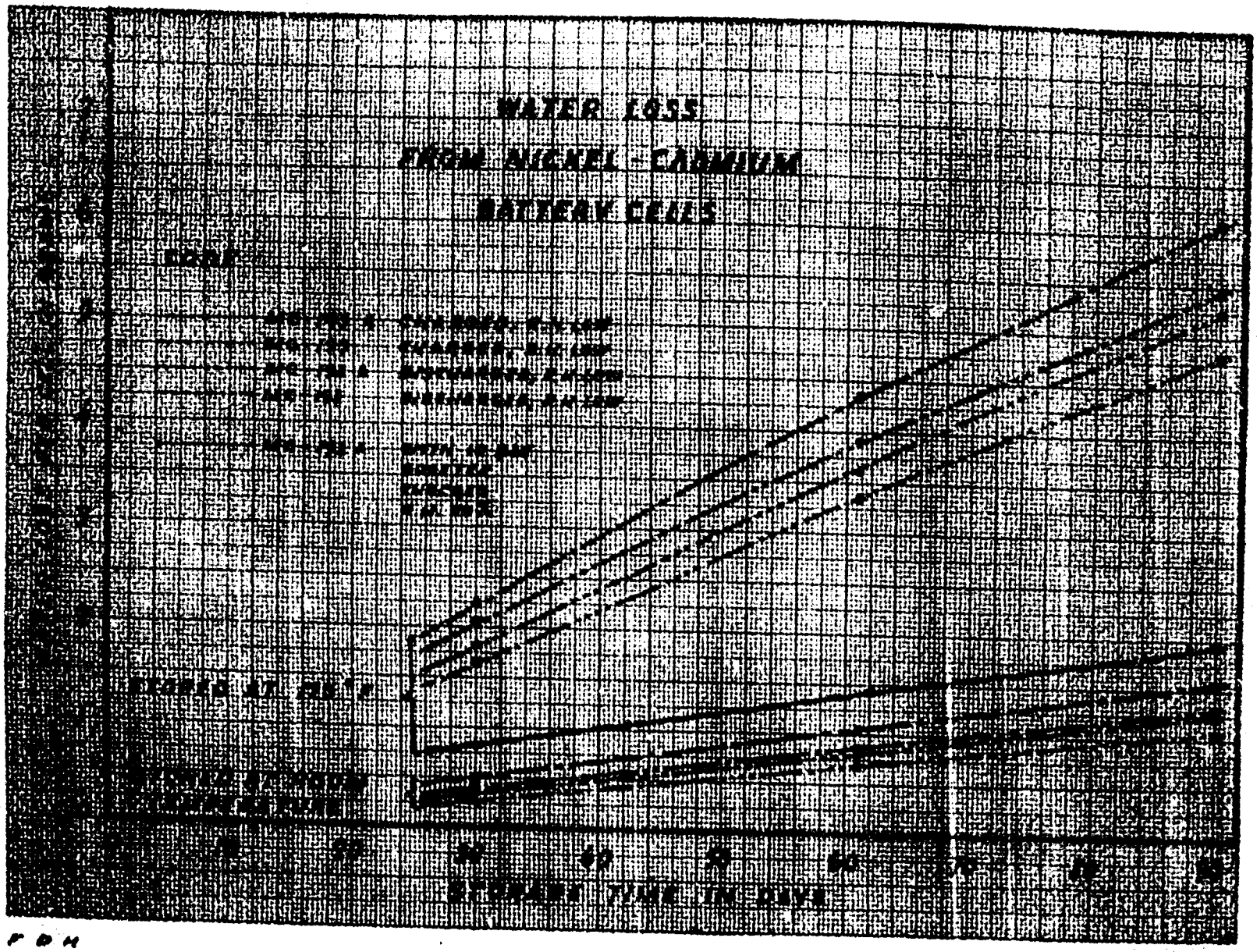
[redacted]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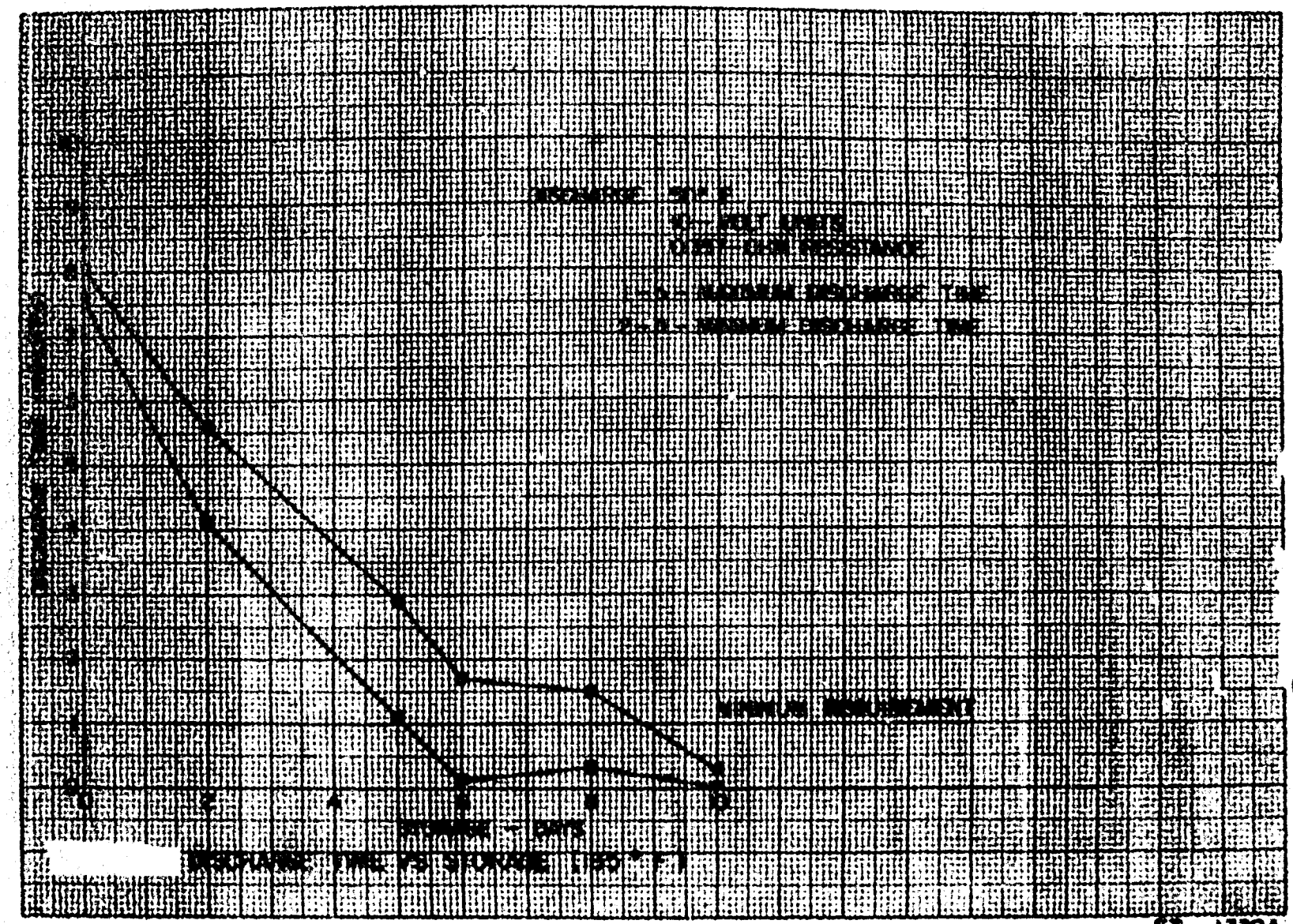
FROM NICKEL - CADMIUM
BATTERY CELLS
CODE
STORAGE TIME IN DAYS

F D H

29 - 6 - 56



ET – 1720A
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3-23-54 JFM

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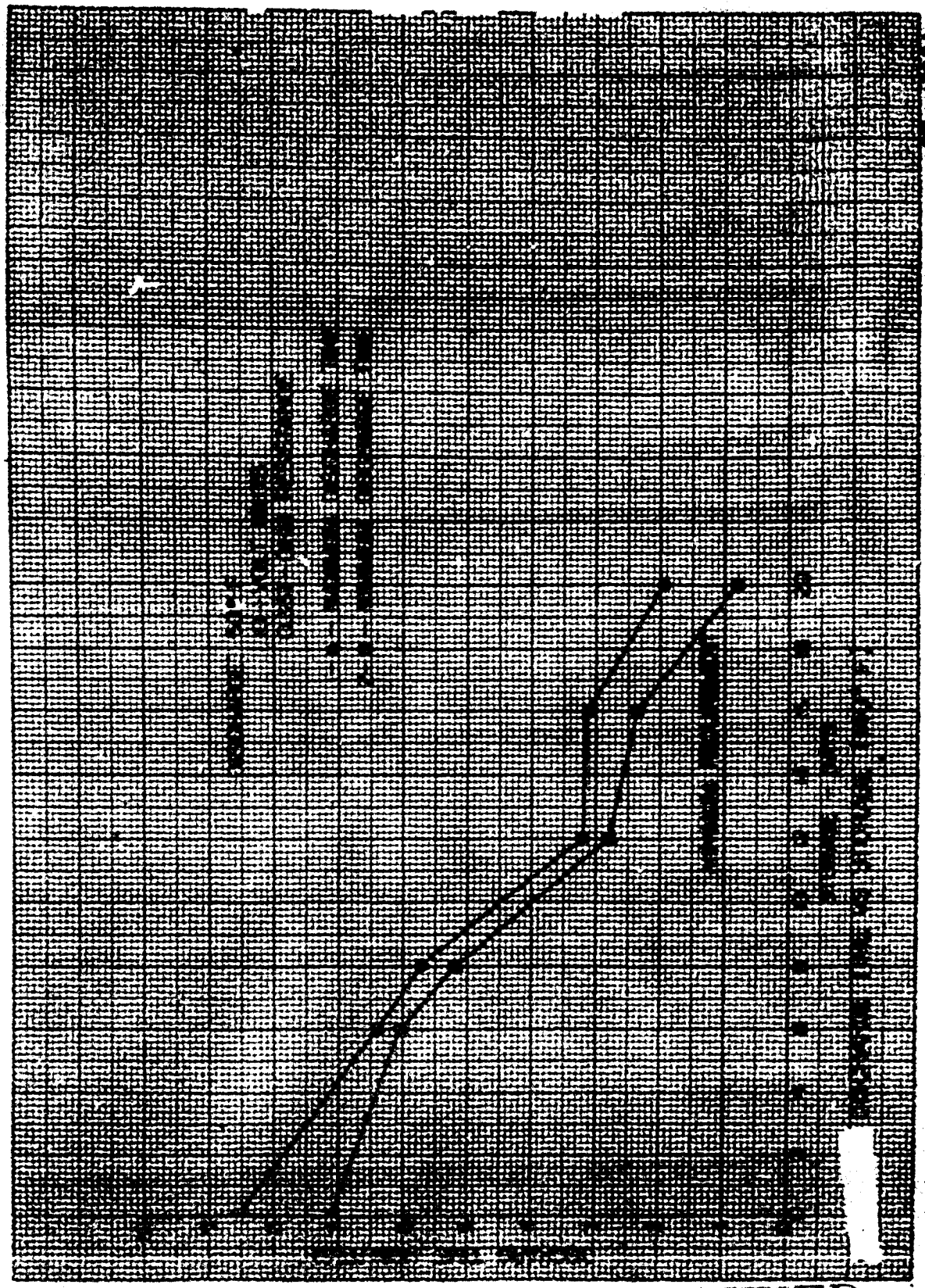

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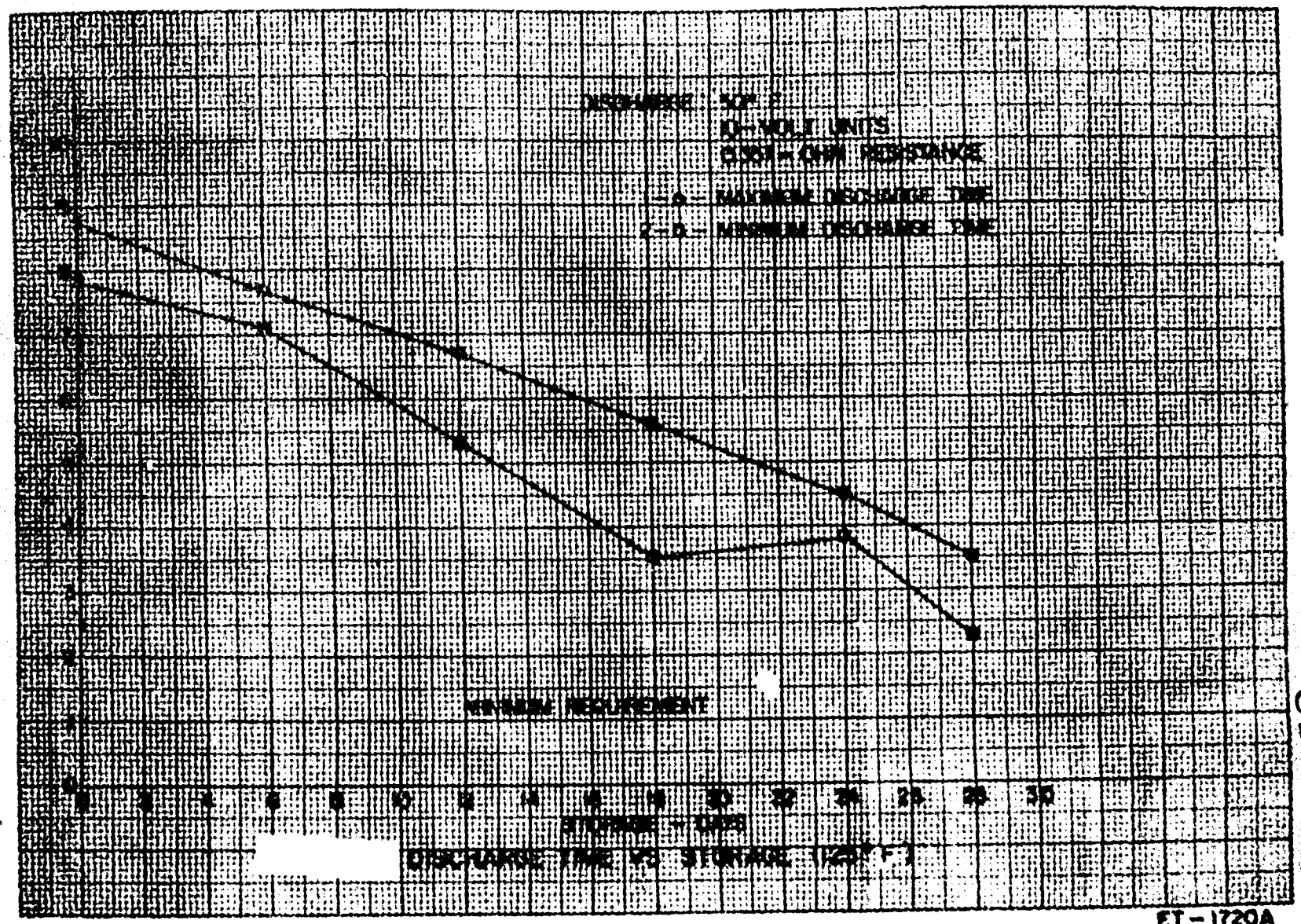

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3-23-64 JFK

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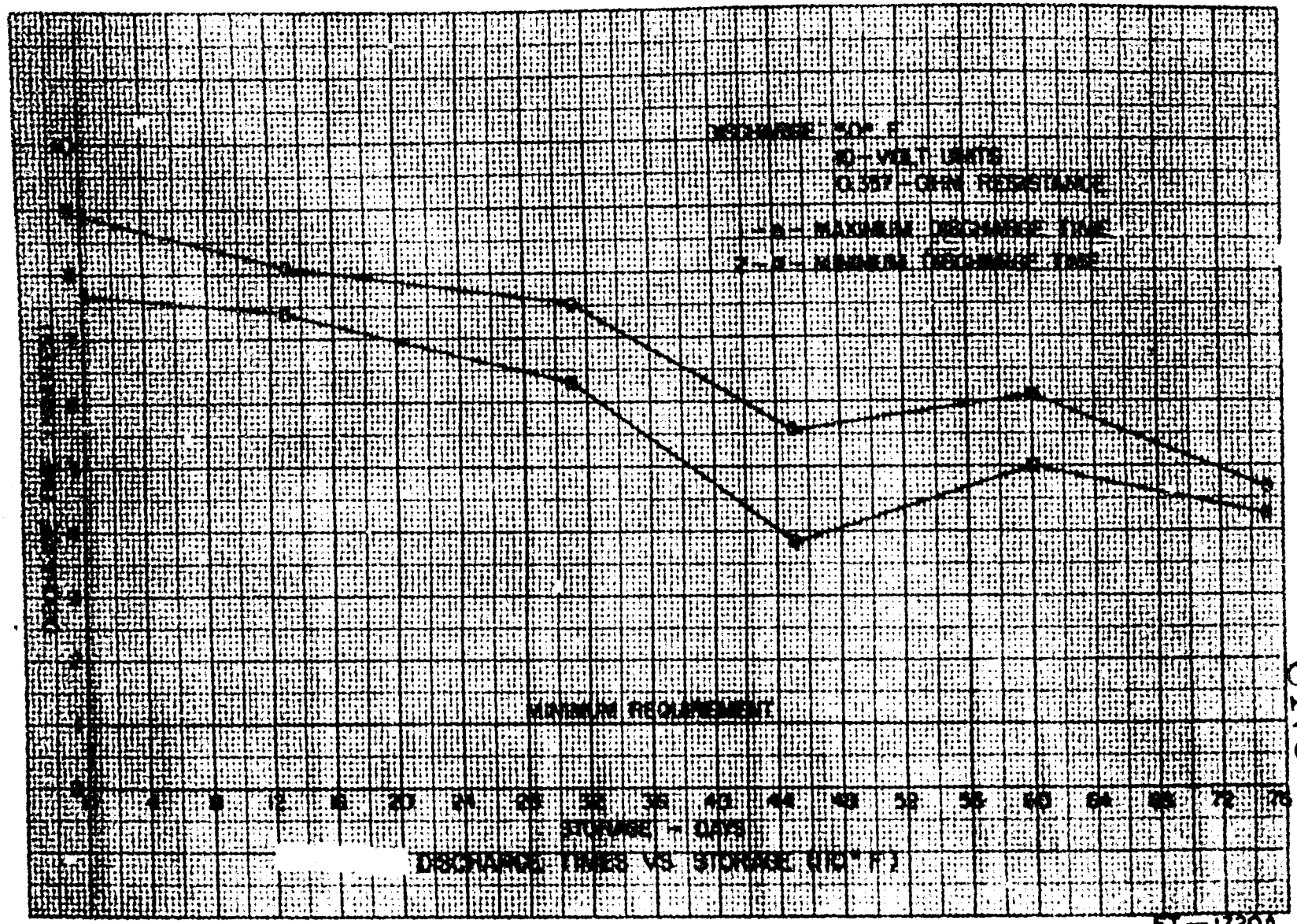

DISCHARGE TIMES VS. STORAGE (110° F)

ET—1720A
REF SYM—1611
3-24-54 JFM

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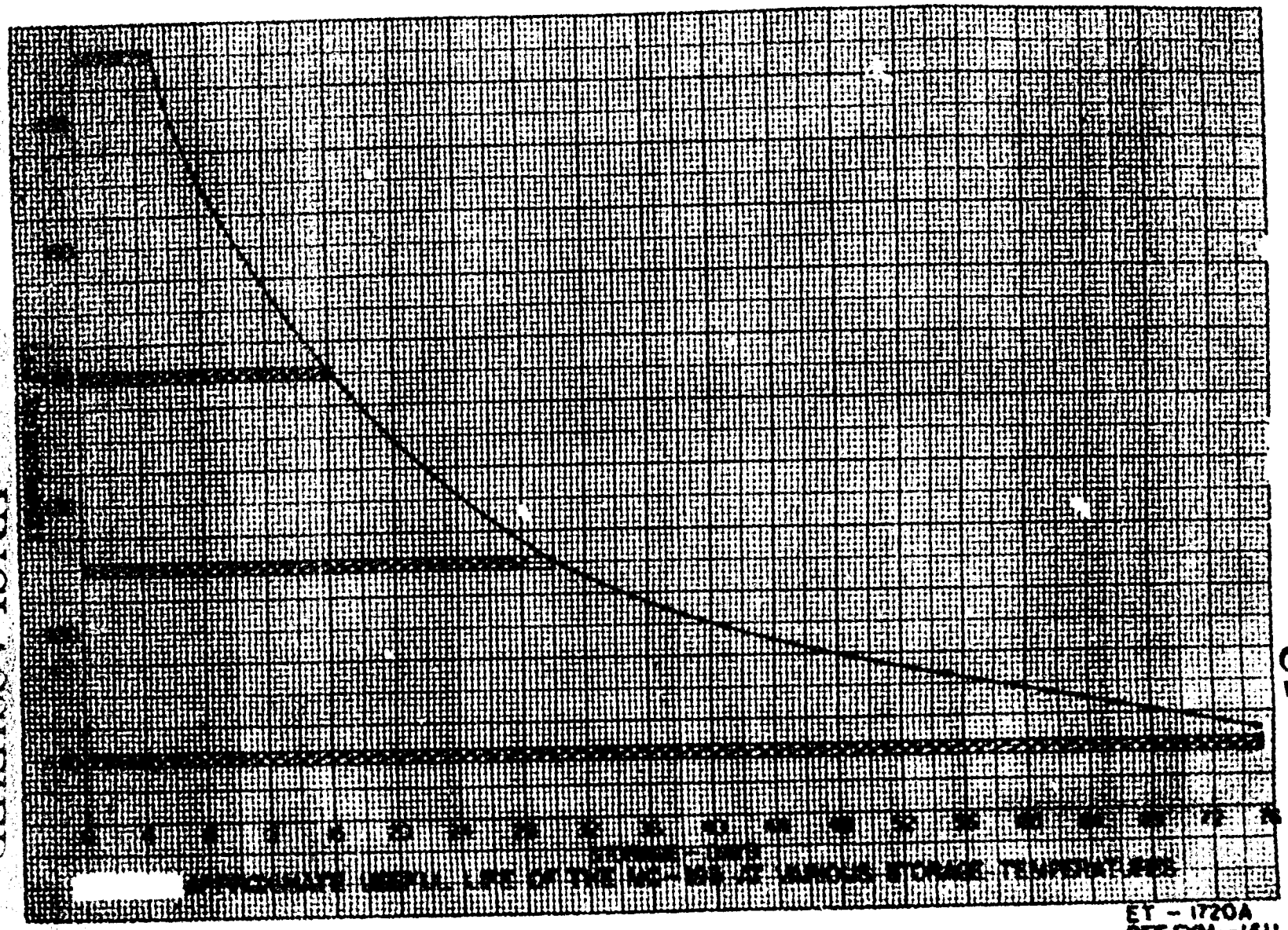

[redacted] APPROXIMATE USEFUL LIFE OF THE [redacted] AT VARIOUS STORAGE TEMPERATURES

ET - 1720A
REF SYM - 1611
3-25-54 JFM

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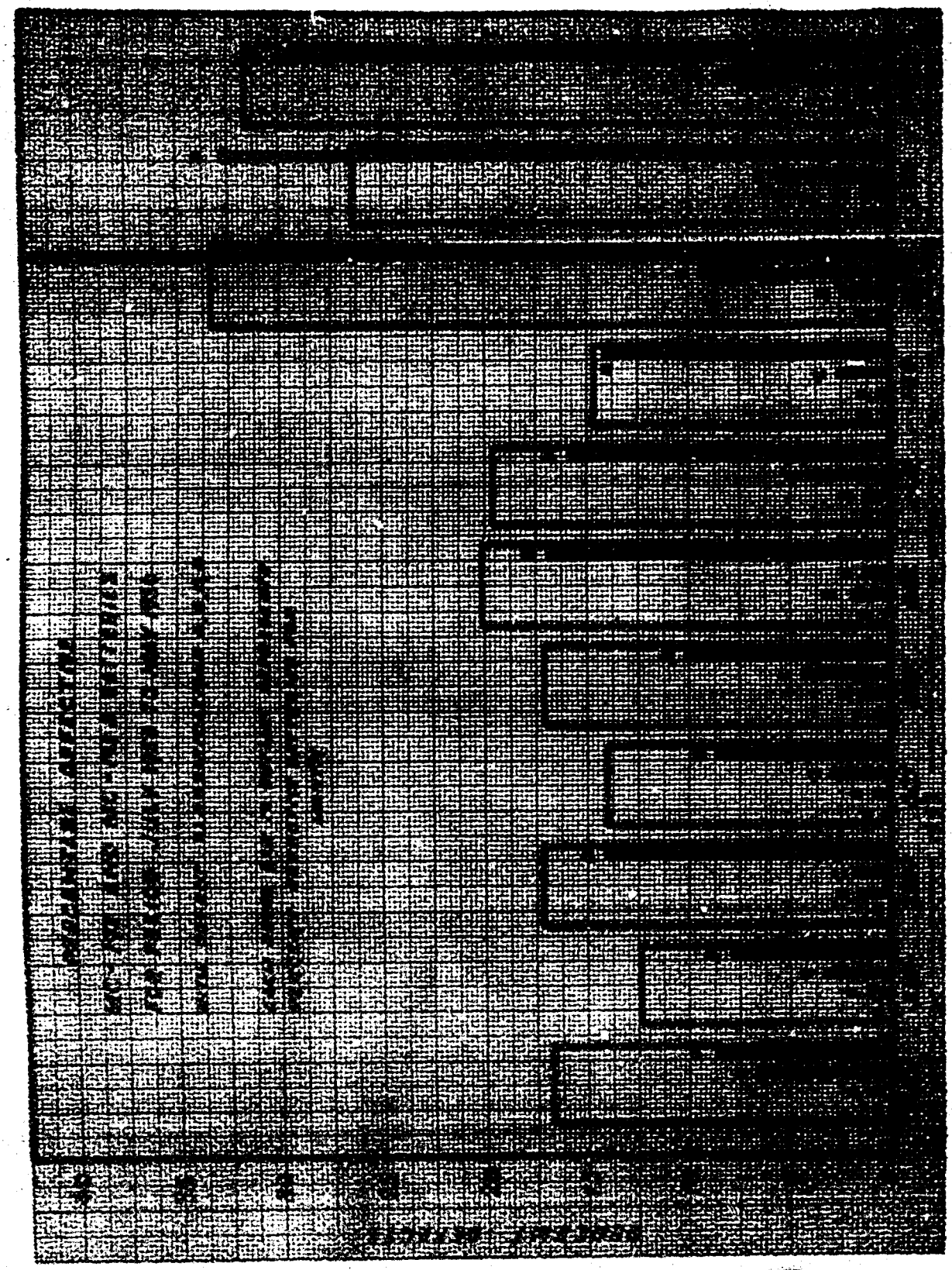
[redacted]



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APPENDIX 2

Photographs

Number

1 Cell, Showing Crazing

2 Cell Cross Section, Magnified, Showing Crazing

3 MC-193 Battery After Shock

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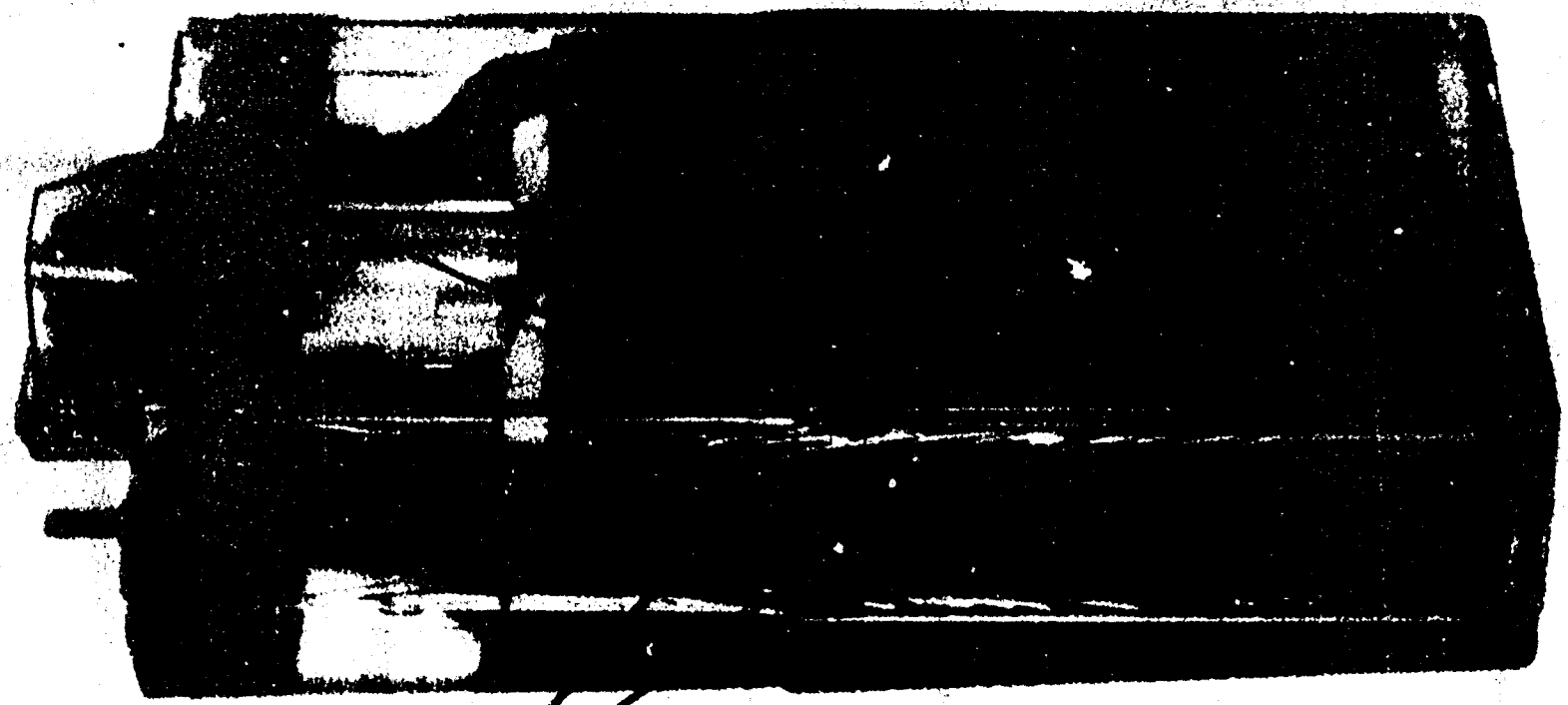
MC-193 CELL



CRAZING

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[redacted]

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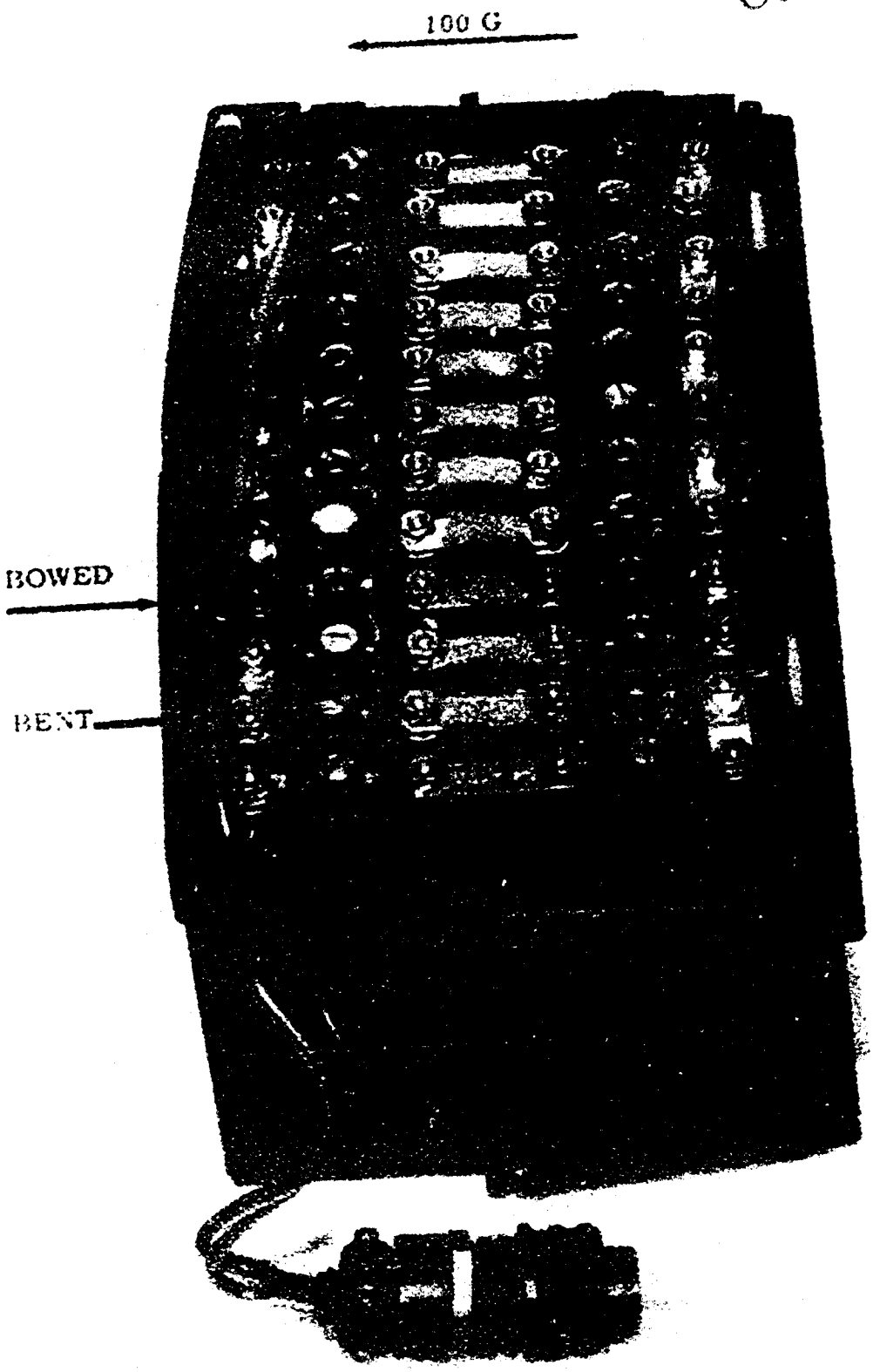

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MC-193 AFTER SHOCK

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