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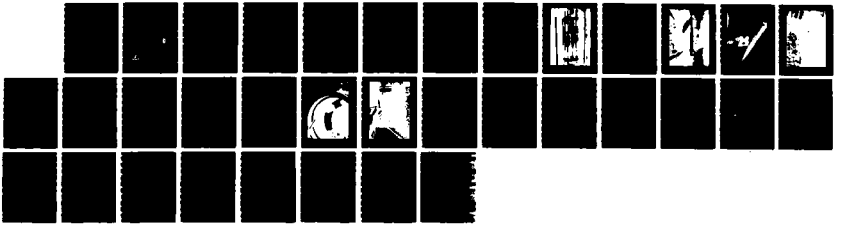

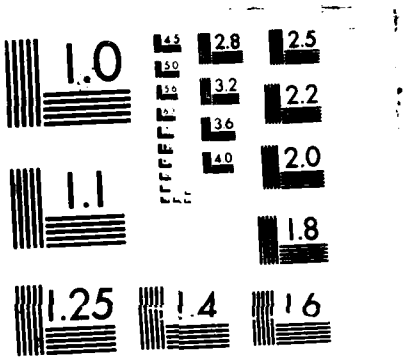

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NSWC TR 85-22

AD-A180 134

SAFETY TESTS OF ADC MK 3

BY R. F. BIS J. BARNES S. BUCHHOLZ F. DeBOLD P. DAVIS
L. KOWALCHIK

RESEARCH AND TECHNOLOGY DEPARTMENT

15 JANUARY 1985

NAVAL SURFACE WEAPONS CENTER

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An Li/So_2 battery is used to provide power for an Acoustic Countermeasure ADC Mk 3. This report presents results of a test program to determine if the ADC Mk 3 is safe for fleet use.

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FOREWORD

A lithium/sulfur dioxide (Li/SO_2) battery is used to provide power for an Acoustic Countermeasure ADC Mk 3. This report presents results of a test program to determine if the ADC Mk 3 is safe for fleet use.

Approved by:

Jack R. Dixon

JACK R. DIXON, Head
Materials Division

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ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

A technical evaluation and safety analysis have been conducted on an Acoustic Countermeasure ADC Mk 3. The ADC Mk 3 submarine decoy is stored on submarines between the pressure hull and outer hull. In the launch configuration a gas generator(containing a propellant) launches the decoy. However, in the shipping configuration the gas generator is separated from the launch container. The purpose of this report is to describe the results of a test program requested by the Naval Sea Systems Command (NAVSEA) (as required by Reference 1) and conducted by the Naval Surface Weapons Center (NSWC). The tests were conducted to determine if the unit is safe to handle, ship, and deploy as configured.

The ADC Mk 3 power supply consists of 55 high-rate LO26SH cells manufactured by Duracell USA. The battery has 3 strings in parallel. Each string has 17 cells in series. A second power supply of four cells in series is in the same pack. A schematic and a photograph of the battery are shown in Figures 1 and 2, respectively. All fuses are of the fast blow type and have the values shown in Figure 1. The three thermal fuses are designed to open at 77°C. In addition, the ADC Mk 3 unit was supplied with a "Roberts" type pressure relief valve set at 10 psi. The "Roberts" type is a spring-loaded, resealing pressure relief valve.

Abuse conditions were generated by:

1. Forced discharge at 21 amperes with all fuses in place.

2. Heating of the battery to 500°C at a rate of 20°C/minute.

3. Short circuiting (all fuses bypassed).

4 Forced discharge at 21 amperes (all fuses bypassed).

5. Charging (all fuses and diodes bypassed) after removal of approximately 50 percent of the battery capacity. The charging voltage was limited to the open circuit voltage of the battery pack. This test was conducted with the Mk 3 inside the launcher with end cap mounted. This test was used to simulate a diode failure.

6. Forced discharge (all fuses bypassed) at 21 amperes inside launcher as configured for shipping. The end cap is replaced with a plastic dust cover in this configuration.

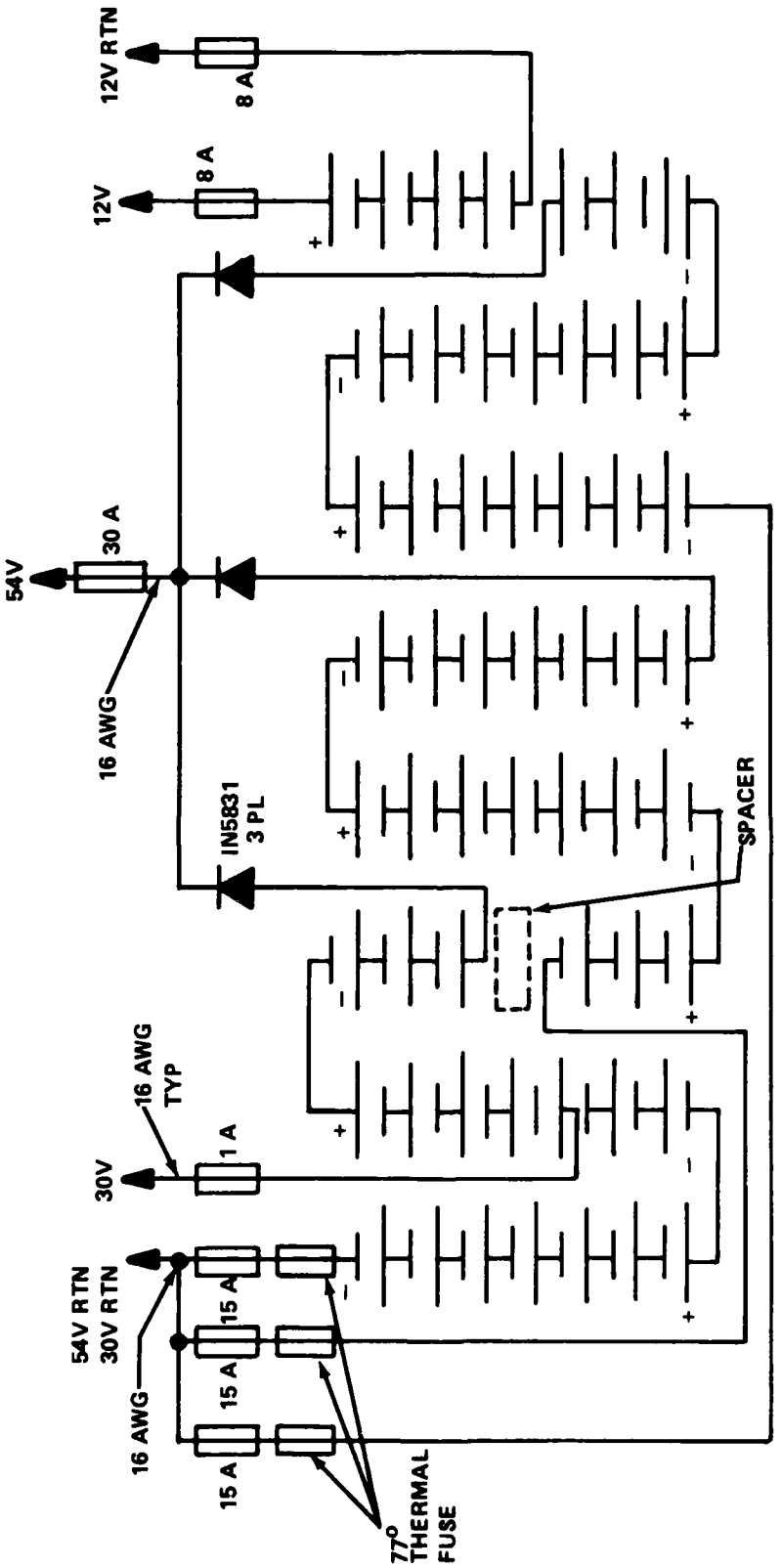

FIGURE 1. SCHEMATIC OF ADC MK 3 Li/SO_2 BATTERY

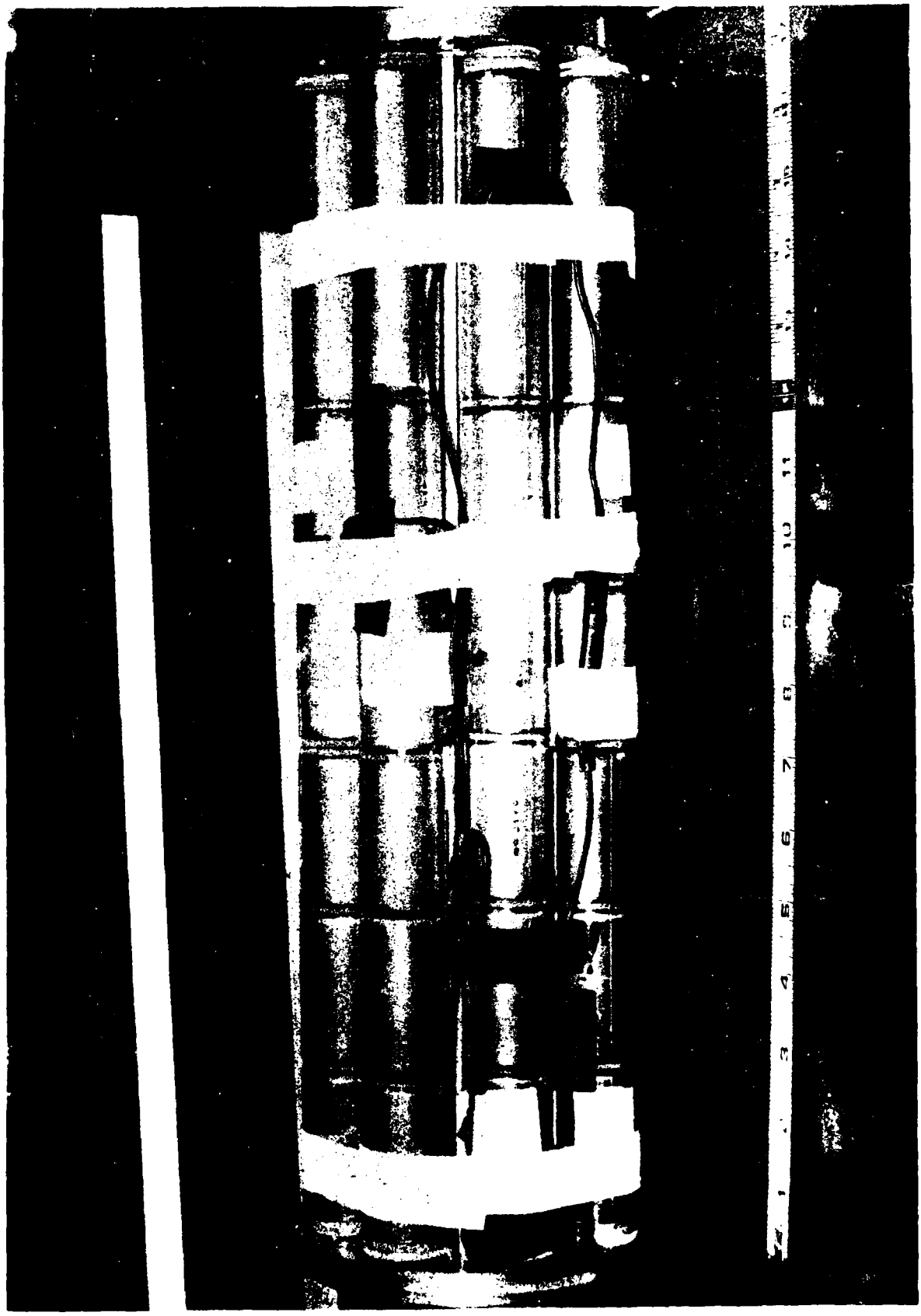

FIGURE 2. PHOTOGRAPH OF ADC MK 3 Li/SO_2 BATTERY

7. Forced discharge (all fuses bypassed) at 21 amperes inside launcher as configured for launch.

Photographs of the ADC Mk 3, the ADC Mk 3 in the launcher as configured for shipping, and the ADC Mk 3 in the launcher as configured for launch are shown in Figures 3 through 5, respectively.

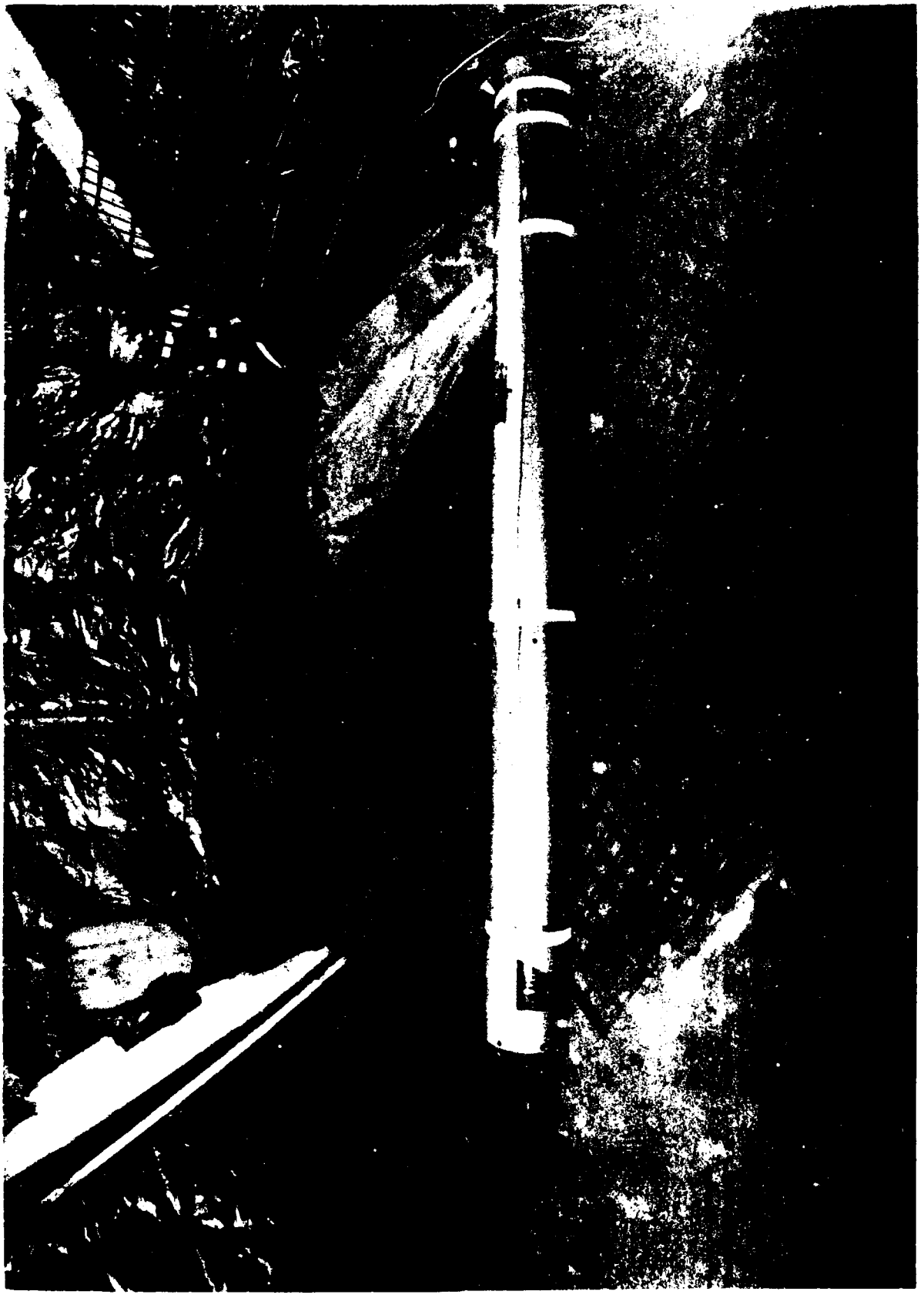

FIGURE 3. PHOTOGRAPH OF ADC MK 3 UNIT OUTSIDE LAUNCH CONTAINER

FIGURE 4. PHOTOGRAPH OF ADC MK 3 LAUNCH CONTAINER AS CONFIGURED FOR SHIPPING (DUST COVER IS IN PLACE ON RIGHT HAND END.)

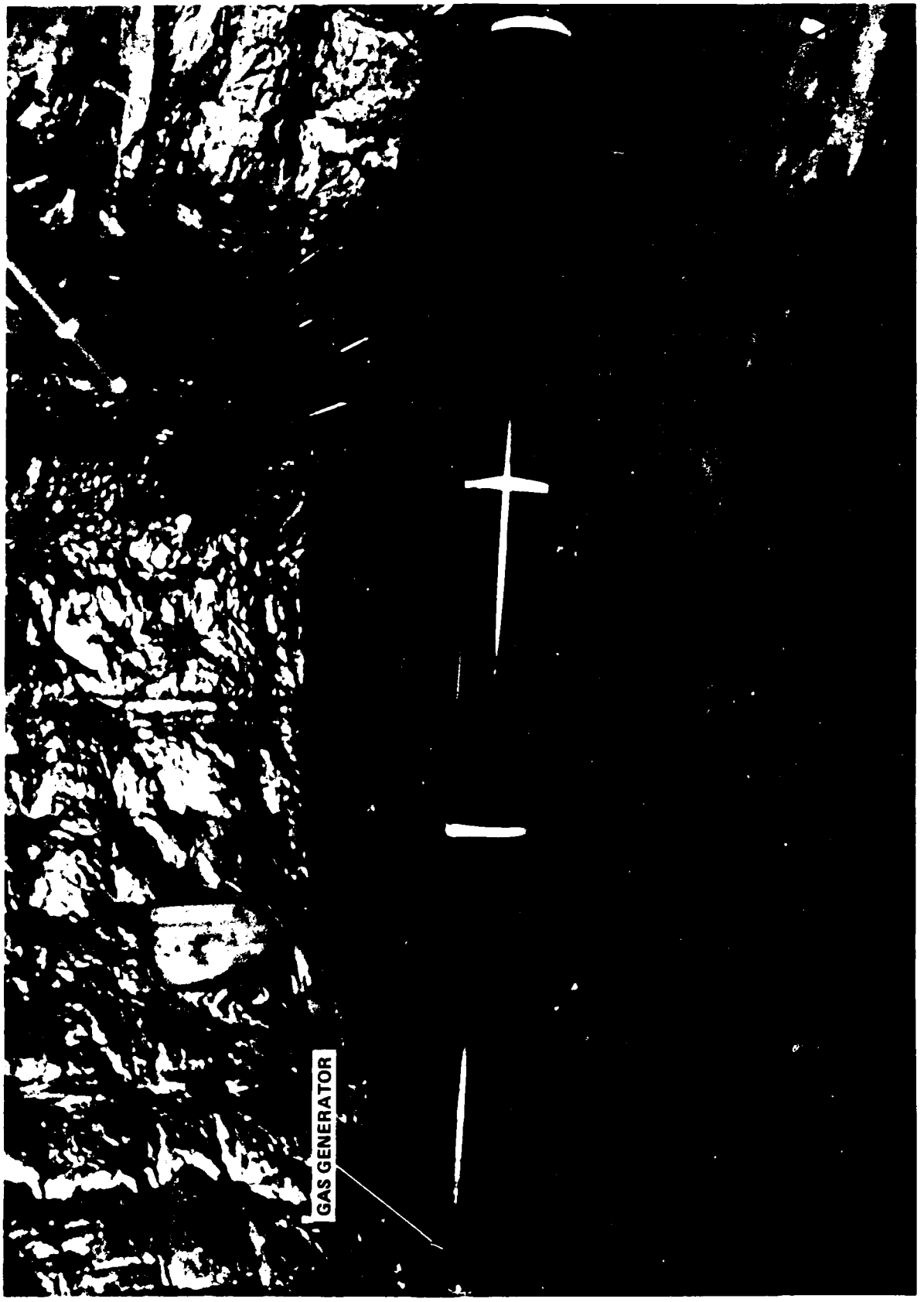

FIGURE 5. PHOTOGRAPH OF ADC MK 3 AS CONFIGURED FOR LAUNCH (THE ADC MK 3 UNIT IS INSIDE LAUNCH CONTAINER.)

CHAPTER 2

EXPERIMENTAL

The experimental program was conducted as follows:

1. With the battery inside the ADC Mk 3, a forced discharge at 21 amperes was carried out using a dc power supply. All electrical and thermal fuses were in place for this test. The purpose of this test was to determine if the safety devices functioned before thermal runaway took place. Voltages, pressures, currents, and temperatures were monitored throughout the run. Only one test was performed.

2. With the battery inside the ADC Mk 3, three Briskheat^{R} tapes were wrapped around the battery. All fuses were bypassed for this test. Each heat tape was controlled by a separate Variac. Voltages, pressure, and temperatures were monitored throughout the run. Temperature rise during this test was between 15°C and 20°C per minute. This test was performed once.

3. The complete battery was short circuited inside the ADC Mk 3 as configured for shipping. The impedance of the short circuit was 0.02 ohm. All fuses and diodes were bypassed for this test. Pressure, temperature, current, and voltage were monitored throughout the run. This test was performed once.

4. Three forced discharges were carried out at approximately 21 amperes in three different configurations:

   a. The battery inside the Mk 3

   b. The Mk 3 inside the launcher in the shipping configuration

   c. The Mk 3 inside the launcher as configured for launch

Pressure, temperature, current, and voltage were monitored throughout the run. This test was run once in each configuration described above.

5. A charging test was conducted on a battery that had approximately 50 percent of its capacity removed. There was no incubation period. During this test the charging voltage was limited to the open circuit voltage of the battery. This test was conducted with the Mk 3 inside the launcher as configured for launch. Current, voltage, pressure, and temperature were monitored throughout the run. All fuses and diodes were bypassed for this test. This test was performed once.

Pressures were measured using a PSI 100 pressure transducer. Type K thermocouples were used to measure the temperature at several points on the battery, ADC Mk 3, and launch tube.

Video tapes were made of all tests and are on file at NSWC, White Oak.

CHAPTER 3

RESULTS AND DISCUSSION

Test Number 1 was a forced discharge of the battery inside the ADC Mk 3 unit. All fuses were in place for this test. A plot of temperature, pressure, current, and voltage versus time is shown in Figure 6. Initially, the discharge current was set at 23 amperes. The battery was not discharged at 30 amperes due to a power-supply current limitation of 24.5 amperes. After approximately one minute, the power supply circuit breaker opened and the current dropped to 18 amperes. Repairs were completed and at 19 minutes the power supply was again supplying current. The current at this point was 24.5 amperes, or approximately 8.2 amperes per parallel string. At 37.5 minutes the battery circuit opened. At this time the maximum battery temperature recorded was 68.1°C which is near the set point of 70°C of the thermal fuses. A post-mortem indicated that two of the three thermal fuses opened. In addition, the 15-ampere electrical fuse in the leg which had the thermal fuse intact also opened. This is consistent with the fact that after the two thermals opened, all the current (23 amperes) passed through the leg with a thermal fuse and a 15-ampere fuse. No ventings were observed during this test.

Test Number 2 was the heating of the complete battery pack at approximately 10°C/minute inside the ADC Mk 3. Voltage, temperature, and pressure were monitored throughout the run. Pressure measurements indicated the venting of cells about at 19 minutes (e.c. = 150°C) into the run continuing up to 44 minutes. At no time did the pressure exceed 15 psig. Temperature, voltage, and pressure versus time are plotted in Figure 7. Figure 8 shows the "Roberts" pressure relief valve inside the tail section of the ADC Mk 3 before testing. Figure 9 shows the tail section after venting has taken place through the relief valve.

Test Number 3 consisted of shorting the battery inside the ADC Mk 3 with all fuses and diodes bypassed. The value of the impedance resistance of the short circuit was 0.02 ohm. A summary of the data is presented in Figure 10. The current originally rose to 94 amperes. After two minutes the battery opened due to a high current failure of the connecting tabs. The battery vented producing approximately 8 psig at which point the "Roberts" valve opened. The maximum temperature observed was about 200°C. As in previous tests, the "Roberts" valve kept the pressure below 15 psig in the ADC Mk 3 unit.

Test Number 4 consisted of a forced discharge at a constant current of 22.5 amperes of the battery inside the ADC Mk 3 as configured for shipping. All fuses and diodes were removed for this test. Venting commenced at approximately 40 minutes at which time the temperature rose rapidly to 500°C. The maximum pressure was 10 psig. The "Roberts" valve operated properly in this case also. A summary of the data is presented in Figure 11.

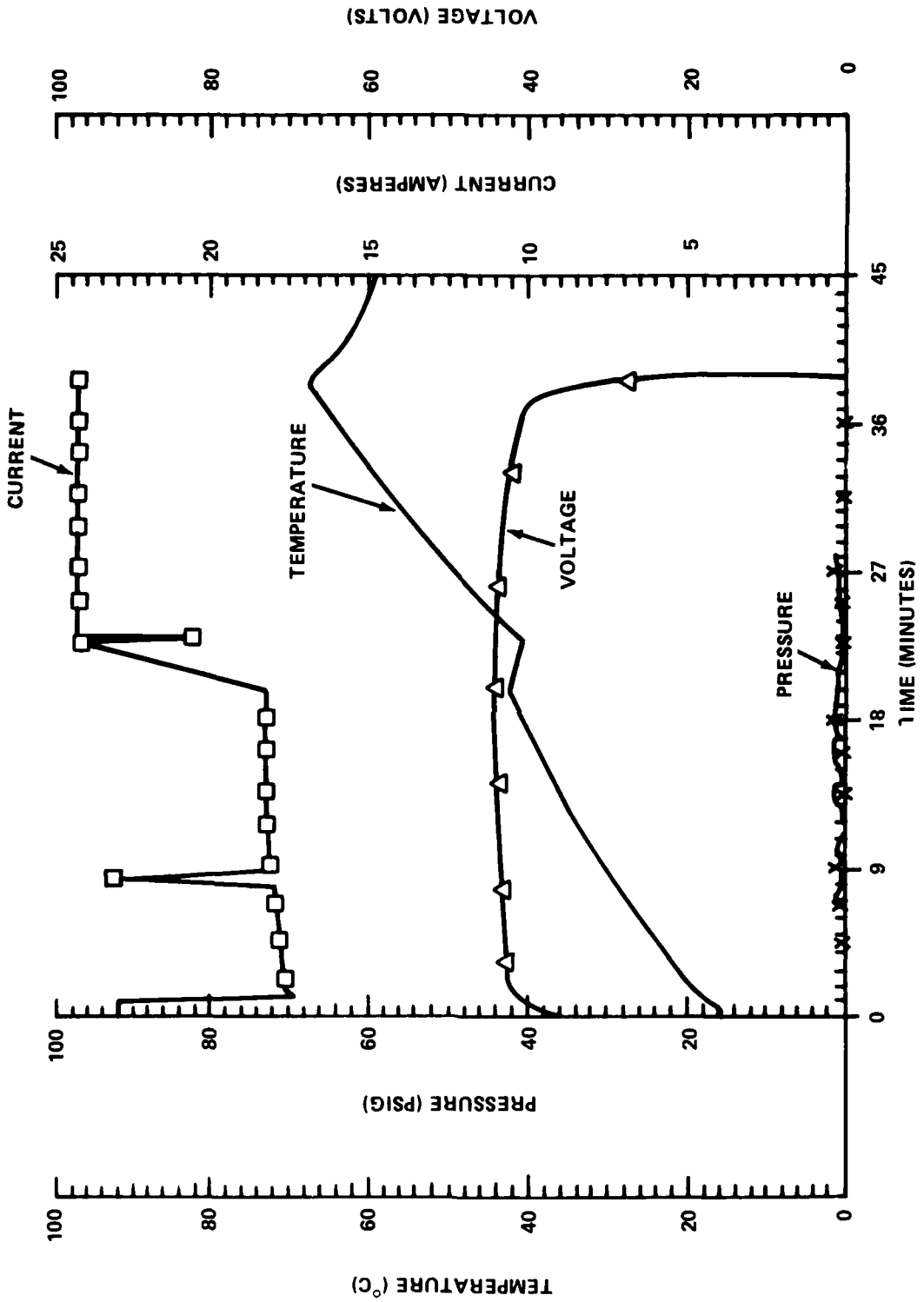

FIGURE 6. FORCED DISCHARGE OF LITHIUM BATTERY INSIDE ADC MK 3 UNIT (CURRENT, VOLTAGE, PRESSURE, AND TEMPERATURE ARE PLOTTED AS A FUNCTION OF TIME. ALL SAFETY DEVICES WERE PRESENT IN THE BATTERY.)

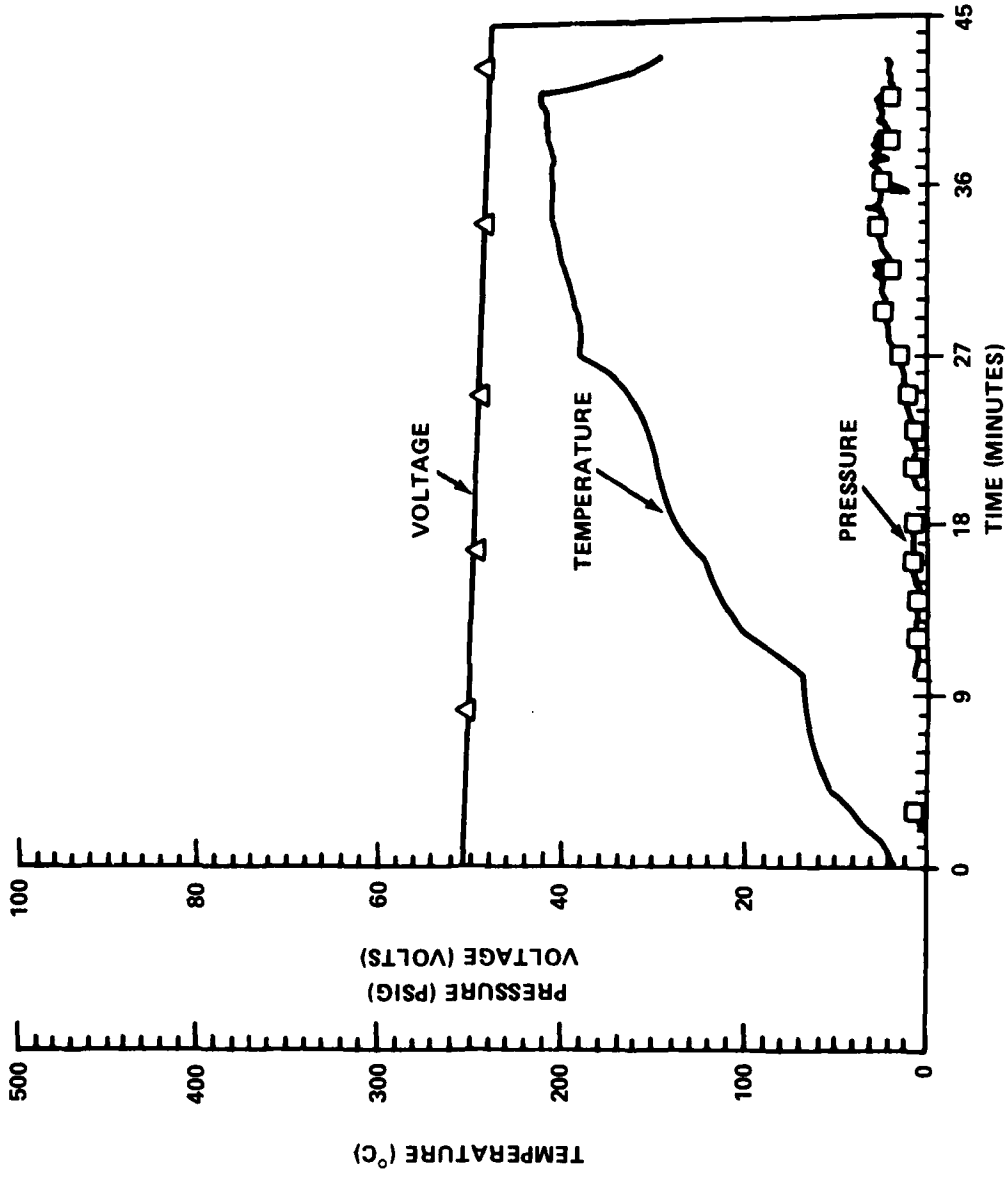

FIGURE 7. HEAT TAPE TEST ON ADC MK 3 (VOLTAGE, PRESSURE, AND TEMPERATURE ARE PLOTTED AS A FUNCTION OF TIME.)

FIGURE 8. PHOTOGRAPH OF "ROBERTS" PRESSURE RELIEF VALVE IN ADC MK 3 TAIL SECTION

FIGURE 9. PHOTOGRAPH OF ADC MK 3 TAIL SECTION AFTER VENTING (THE BLACK MATERIAL IS A RESIDUE FROM VENTING AFTER HEATING OF THE BATTERY.)

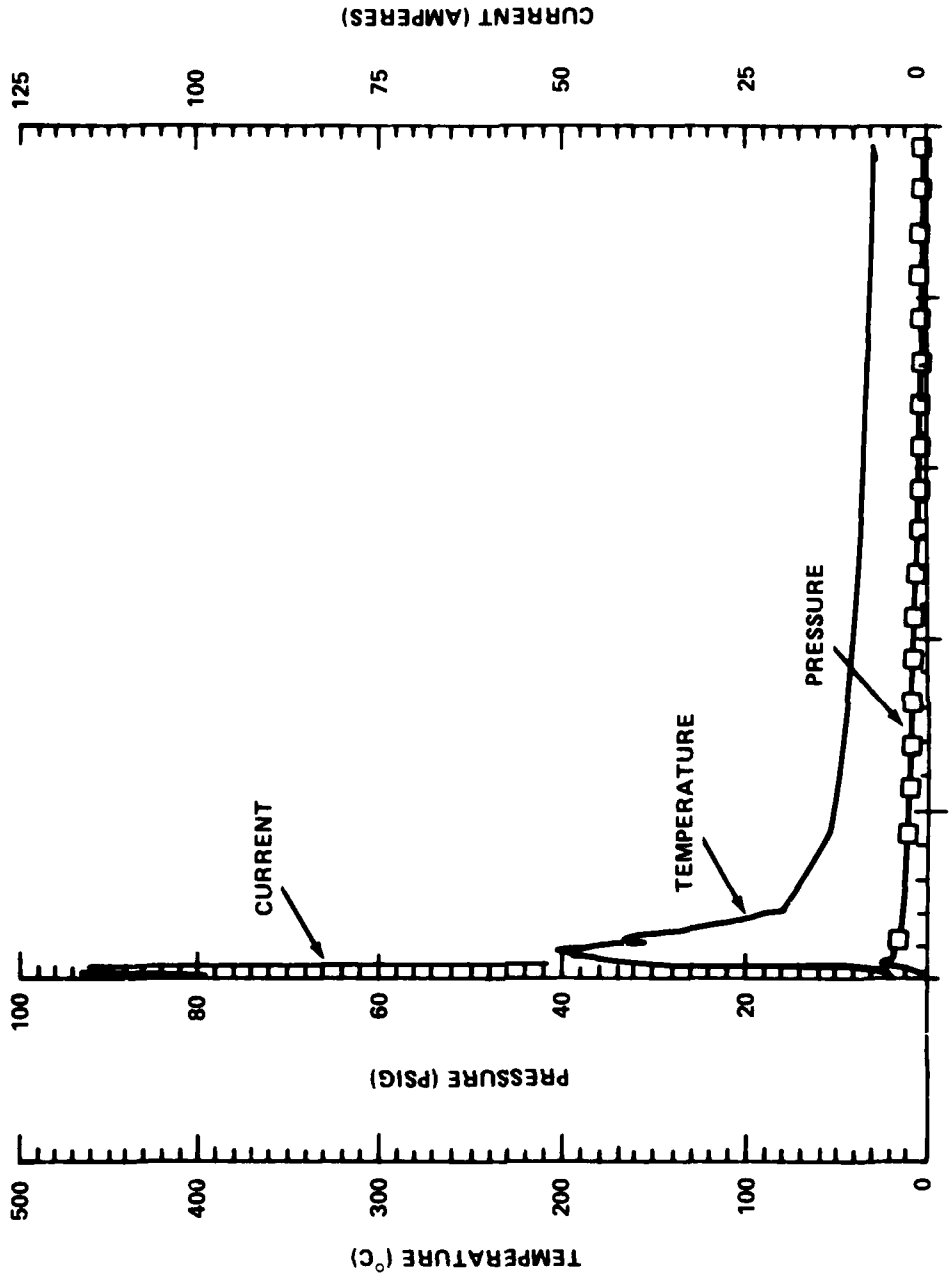

FIGURE 10. SHORT CIRCUIT ON ADC MK 3 BATTERY INSIDE THE ADC MK 3 UNIT (ALL PROTECTIVE DEVICES SUCH AS FUSES OR DIODES WERE REMOVED FROM THE BATTERY FOR THE TEST. THE PLOT SHOWS CURRENT, PRESSURE, AND TEMPERATURE.)

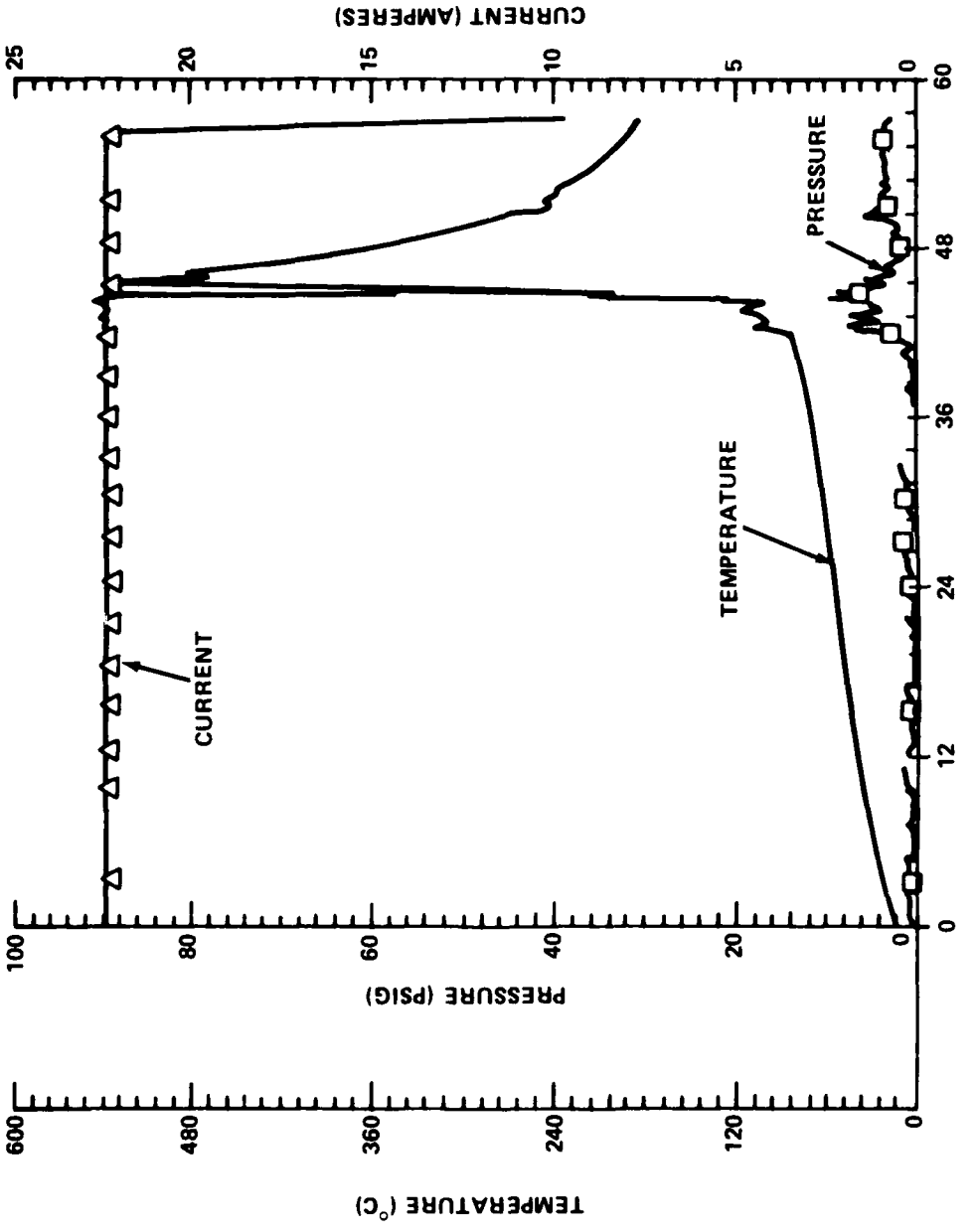

FIGURE 11. CONSTANT CURRENT DISCHARGE AT 22.5 AMPERES OF THE ADC MK 3 BATTERY (AS CONFIGURED FOR SHIPPING SEE FIGURE 4)(ALL SAFETY DEVICES WERE REMOVED FOR THIS TEST. CURRENT, PRESSURE, AND TEMPERATURE ARE PLOTTED AS A FUNCTION OF TIME.)

Test Number 5 consisted of a charging test of the full battery pack after removal of approximately 50 percent of the capacity. The capacity was removed at a constant current of 21.5 amperes. Charging commenced with the current and voltages limited to 21.5 amperes and 52 volts, respectively. These limits were set at the electrical fuse value and the open circuit voltage of the battery. The charging current fell from 3.0 amperes to approximately 100 milliamperes in 10 minutes. The test was terminated after four hours. No venting occurred during this test. A summary of the charging test data are presented in Figure 12.

The charging current and voltage were subsequently increased to 21.5 amperes and 64 volts, respectively. After approximately 20 minutes, an explosion occurred which blew off the end cap and dislocated or shifted the target. The explosions of individual cells continued for three minutes. It should be emphasized that charging current was no longer being applied to the cells that exploded after the initial explosion. The highest temperature recorded was 50°C.

Test Number 6 was a forced discharge of the battery in the launcher with the plastic dust cover in place. The battery vented quietly after about 50 minutes into the test. Smoke appeared around the dust cover. The pressure never rose above a few psig. No adverse reactions were observed. The maximum temperature recorded was approximately 350°C. A summary of this test is presented in Figure 13.

Test Number 7 was a forced discharge in the launcher with the gas generator attached. The battery vented mildly and caused no adverse effects to the unit. The pressure in the launcher reached 120 psig because of the lack of a pressure relief valve. However, the gas in the launcher was contained without incident. A summary of this test is presented in Figure 14.

Test Number 8 used the battery which was forced discharged during Test Number 1. The test was conducted on the battery outside the ADC Mk 3 unit. All fuses were bypassed for Test Number 8. The battery was first discharged completely by placing a 5-ohm resistor across the output terminals. A summary of the discharge is presented in Figure 15. The battery was then charged with a power supply. The voltage and current were limited to the open-circuit voltage (52V) and fuse value of 30 amperes, respectively. The observed currents were in the milliamp range during this test. This test was terminated after approximately 80 minutes. No ventings occurred during this phase. The power supply voltage was then increased to 150 volts to increase the charging current. The current increased to about 1/2-ampere and remained at that level for two minutes. The current then climbed to 13 amperes and cells started to vent. Voltage was then lowered to 52 volts. Current and voltage were erratic. Several violent ventings occurred and the battery burned. A summary of this charging test is presented in Figure 16.

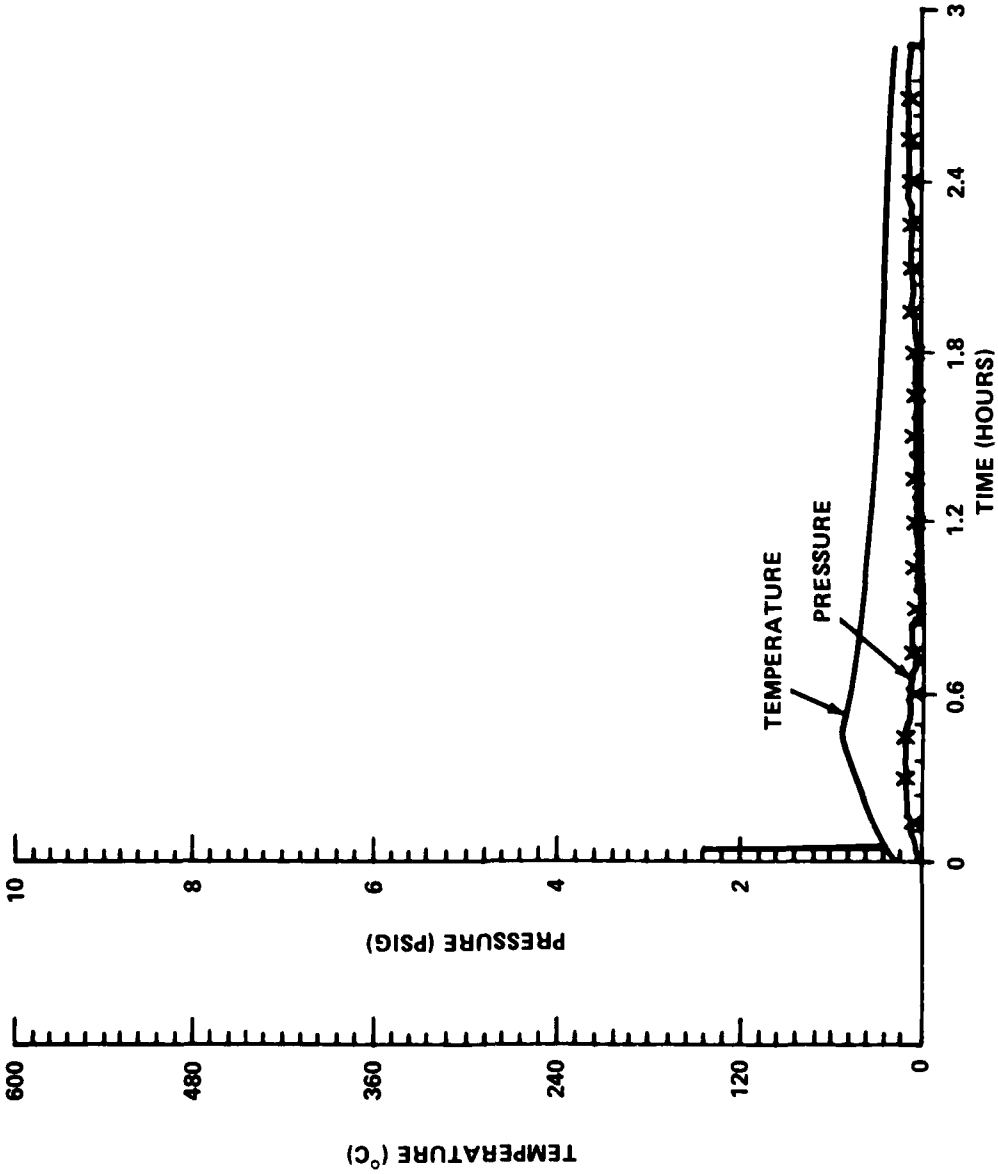

FIGURE 12. CHARGING OF ADC MK 3 LITHIUM BATTERY AS CONFIGURED FOR SHIPPING AFTER 50 PERCENT OF THE CAPACITY HAD BEEN REMOVED AT 21.5 AMPERES (THE VOLTAGE AND CURRENT WERE LIMITED TO 52 VOLTS AND 21.5 AMPERES, RESPECTIVELY.)

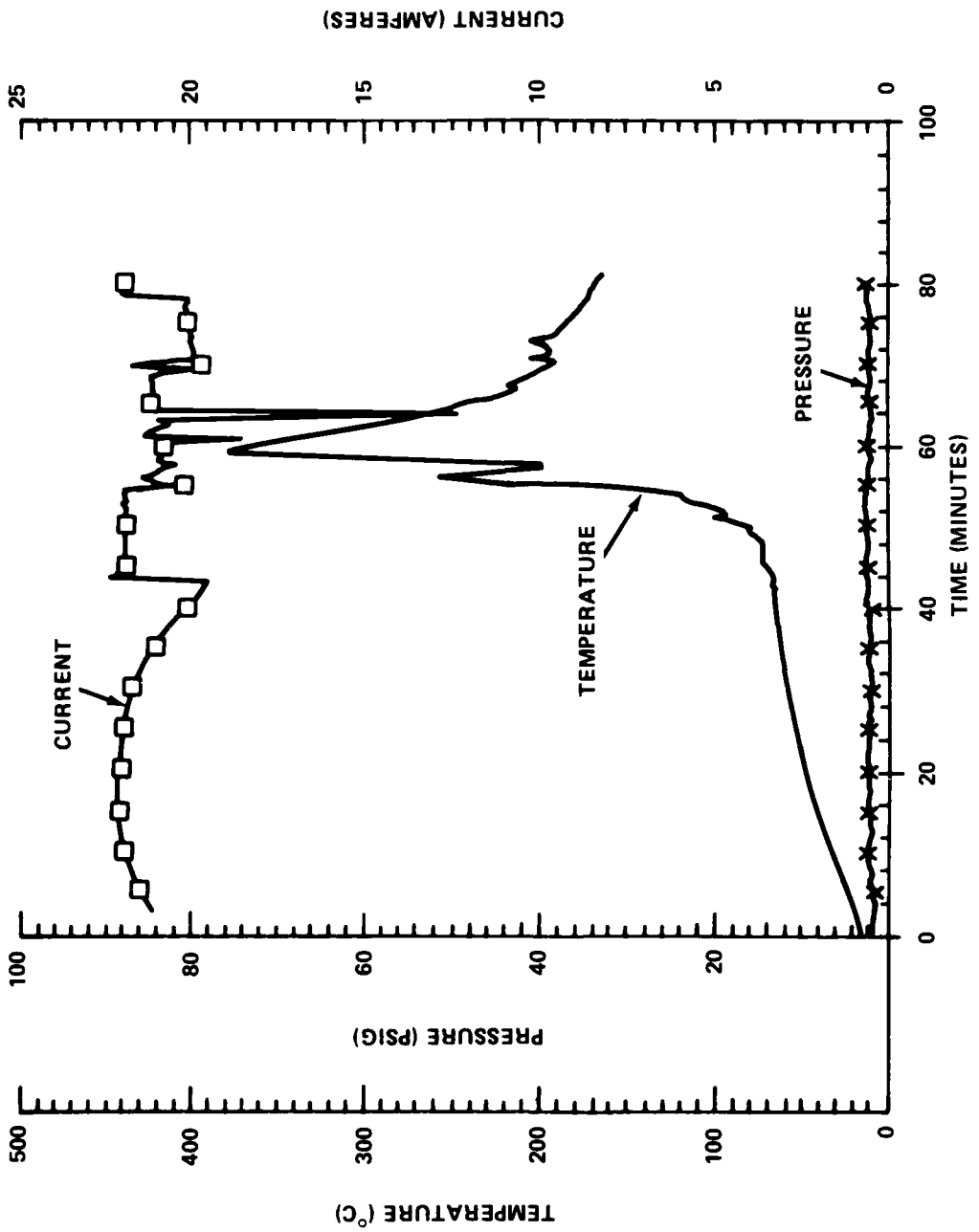

FIGURE 13. CONSTANT CURRENT DISCHARGE AT 21.5 AMPERES OF THE ADC MK 3 LITHIUM BATTERY AS CONFIGURED FOR SHIPPING (NO PROTECTIVE DEVICES WERE IN THE BATTERY. CURRENT TEMPERATURE, AND PRESSURE ARE PLOTTED AS A FUNCTION OF TIME.)

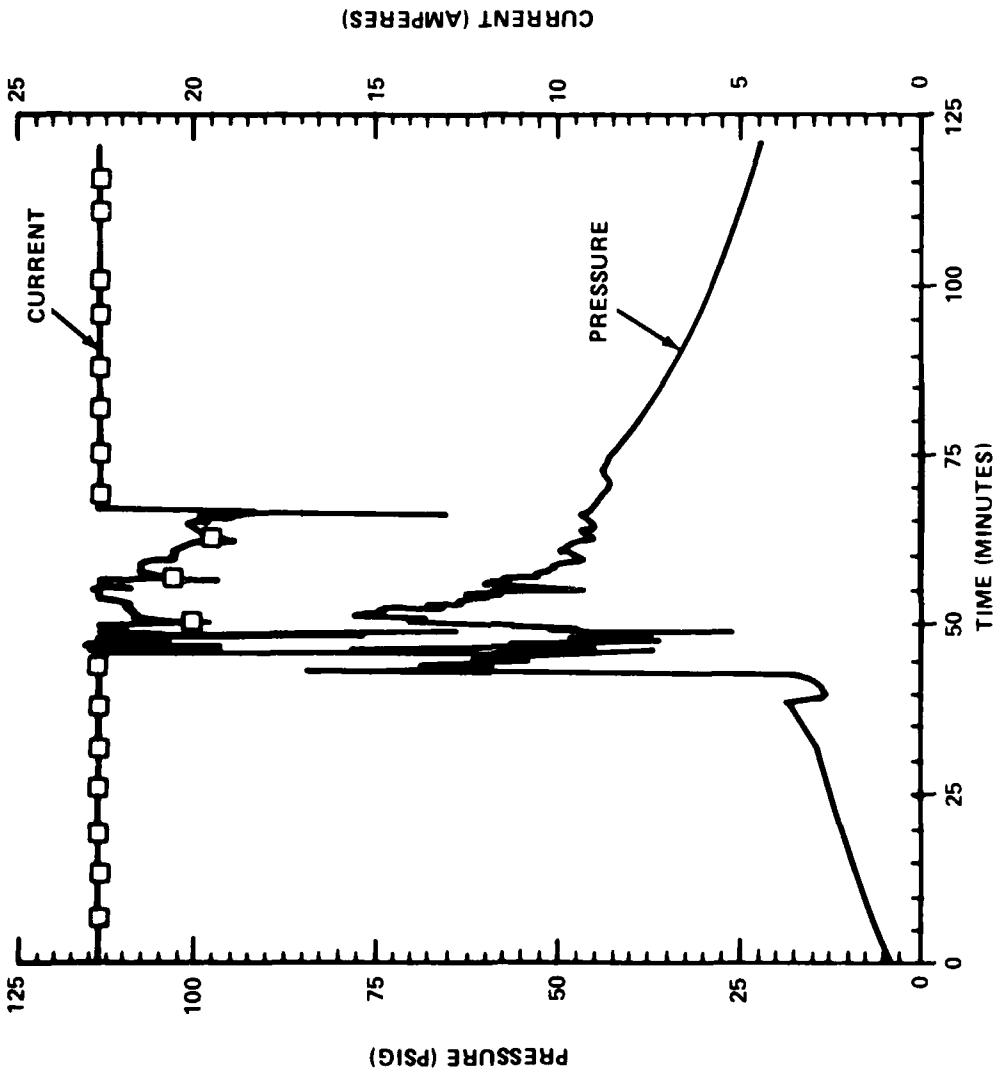

FIGURE 14. CONSTANT CURRENT DISCHARGE AT 22.5 AMPERES OF ADC MK 3 INSIDE LAUNCHER AS CONFIGURED FOR LAUNCH (SEE FIGURE 5)(ALL BATTERY PROTECTIVE DEVICES WERE REMOVED. CURRENT AND PRESSURE ARE PLOTTED AS A FUNCTION OF TIME.)

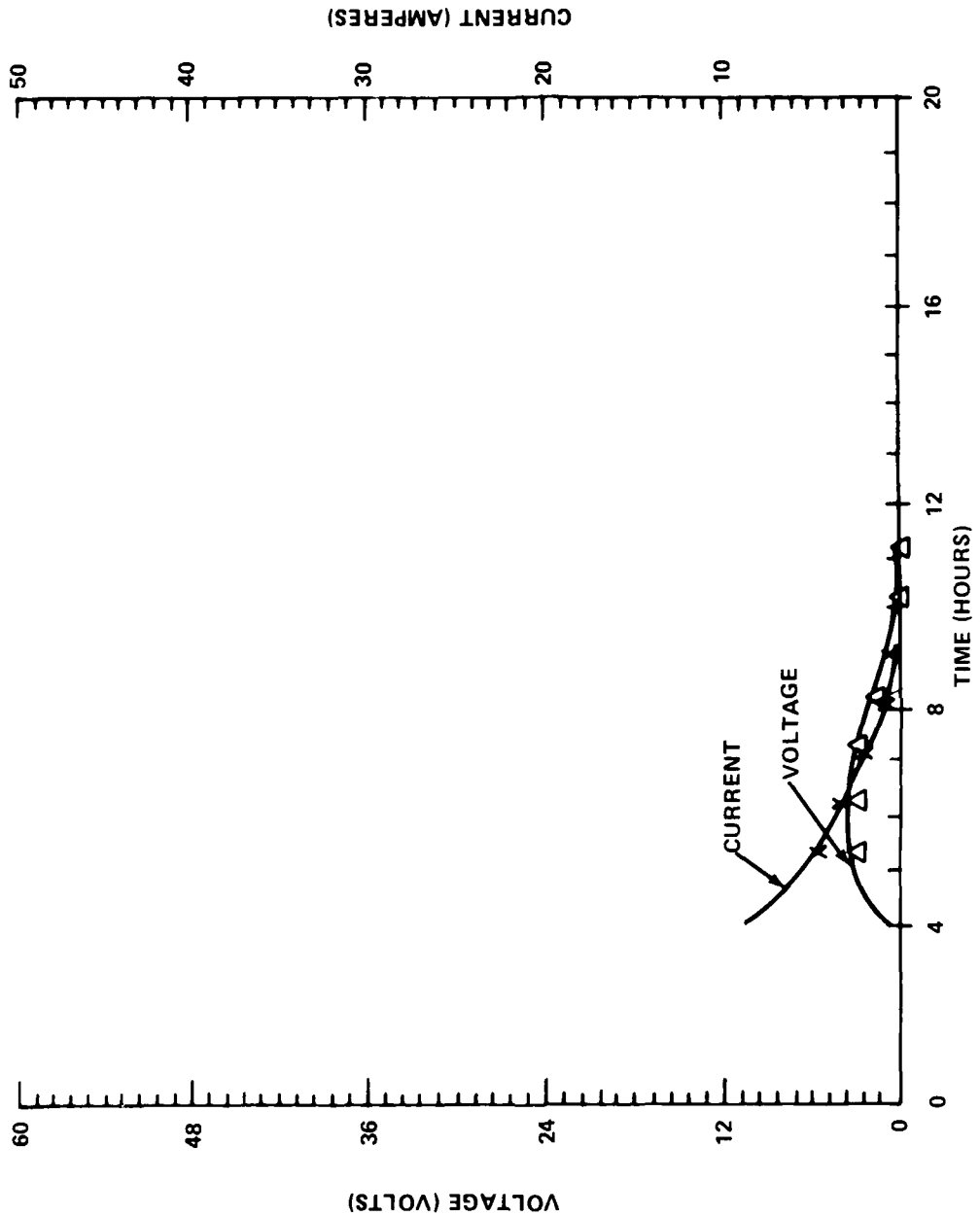

FIGURE 15. CONSTANT LOAD DISCHARGE OF ADC MK 3 BATTERY OUTSIDE UNIT USING A 5-OHM RESISTOR (THE CURRENT AND VOLTAGE ARE PLOTTED AS A FUNCTION OF TIME.)

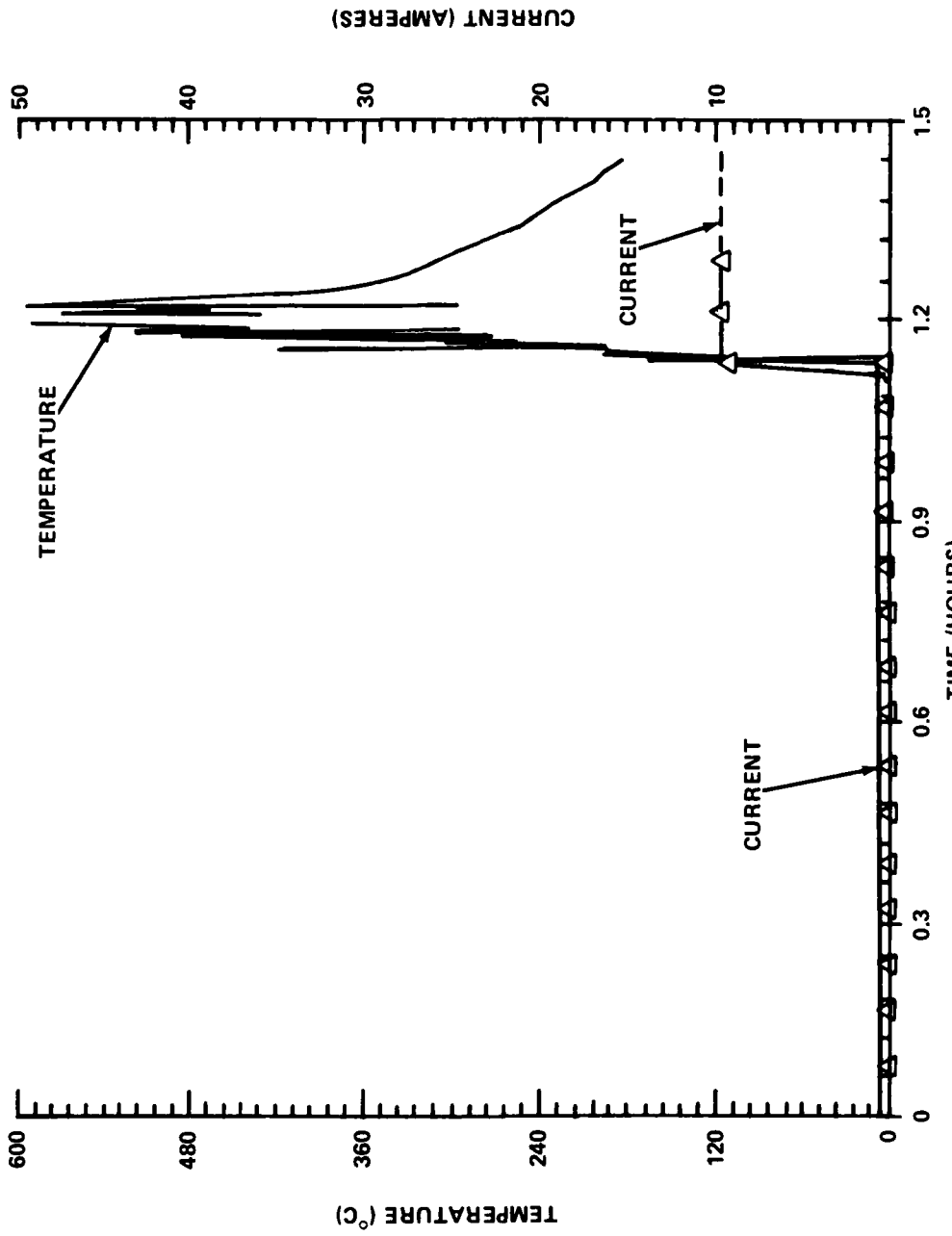

FIGURE 16. CHARGING OF BATTERY PREVIOUSLY DISCHARGED AS SHOWN IN FIGURE 15 OUTSIDE ADC MK 3 (THE CURRENT AND TEMPERATURE ARE PLOTTED AS A FUNCTION OF TIME. VOLTAGE AND CURRENT WERE VARIED DURING THIS TEST AS DESCRIBED IN THE TEXT.)

CHAPTER 4

SUMMARY AND CONCLUSIONS

A complete safety review, in accordance with NAVSEAINST 9310.1A, has been completed on the ADC Mk 3 in both the shipping and launch configurations. A total of seven tests were performed on the ADC Mk 3. The tests included:

1. Forced discharge at 21 amperes with all fuses in place.

2. Heat tape (all fuses bypassed).

3. Short circuit (all fuses bypassed).

4. Forced discharge (all fuses bypassed).

5. Charging (all fuses bypassed) at 21.5 amperes inside launcher after removal of approximately 50 percent of the battery capacity. The voltage was limited to the open circuit voltage of the battery pack.

6. Forced discharge (all fuses bypassed) at 21 amperes inside launcher as configured for shipping.

7. Forced discharge (all fuses bypassed) at 21 amperes inside launcher as configured for launch.

Tests 1 through 5 were performed on the ADC Mk 3 unit outside the launcher.

Test 1 resulted in the complete battery open circuit by opening two thermal fuses and one electrical fuse. There was no venting. Tests 2 through 5 inclusive resulted in ventings and small pressure increase of less than 5 psig.

Gas was properly released through the "Roberts" pressure relief valve supplied with the ADC Mk 3. No external fire or flame was observed. Test 6 resulted in the escape of gas at the dust cover. No measurable pressure rise in the launch tube was observed. Test 7 resulted in a pressure in excess of 110 psig in the launch tube. According to information provided by the contractor, this pressure is more than 50 percent of the yield pressure of the launch tube and exceeds the requirement of NAVSEAINST 9310.1A. Furthermore, Test 7 did not result in temperatures high enough to cause initiation of the gas generator.

Based on the results described above we conclude that the ADC Mk 3 is acceptable for service use in the shipping configuration. In the launch configuration, it is recommended that a means of pressure relief be provided in the launch tube. After pressure relief is provided in the launch tube, the redesign should be resubmitted to NSWC for review and, if necessary, units supplied for retesting.

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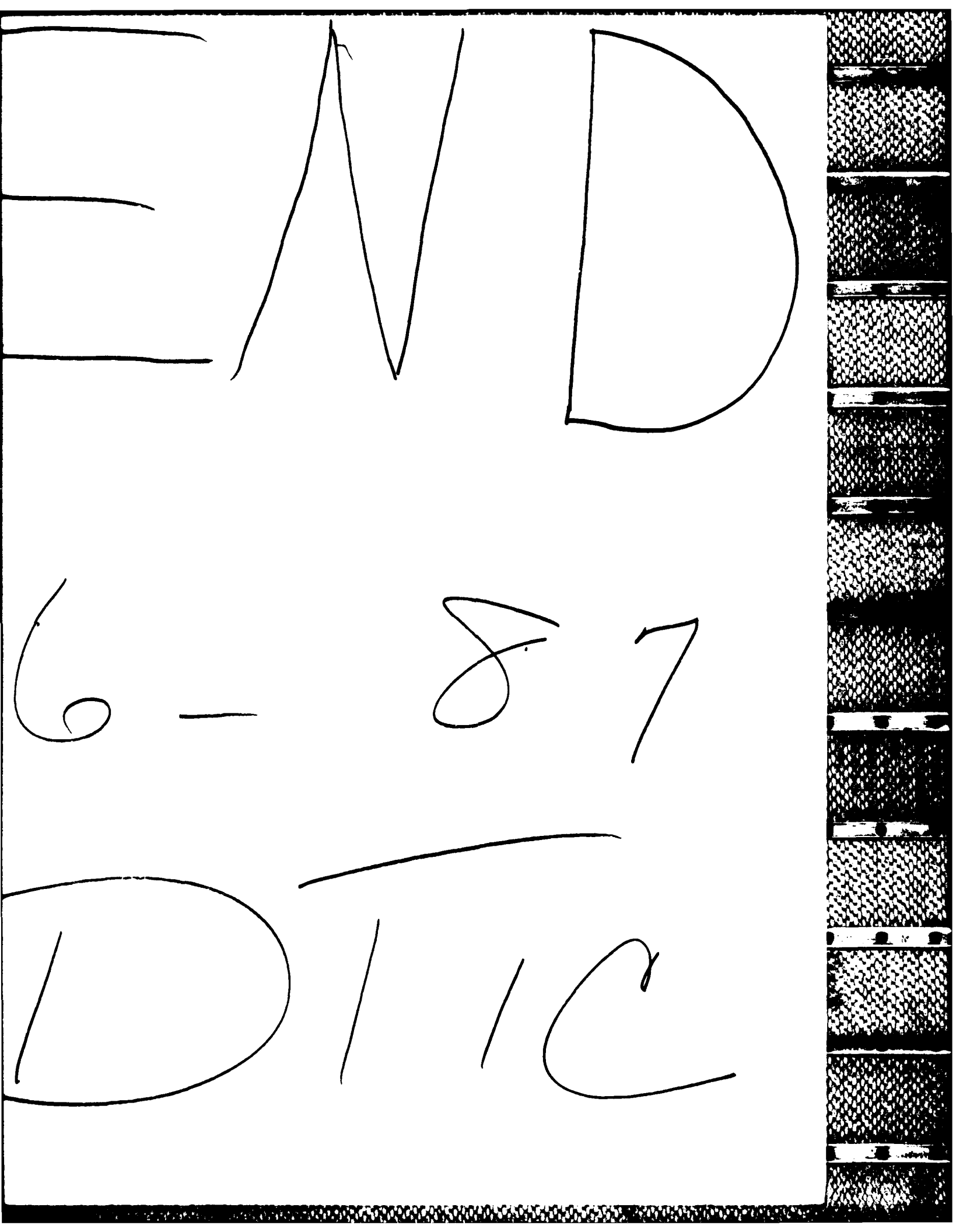
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