TM 11-6140-203-14-1

TECHNICAL MANUAL

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT,
AND GENERAL SUPPORT MAINTENANCE MANUAL

AIRCRAFT AND NONAIRCRAFT NICKEL-CADMIUM BATTERIES (GENERAL)

HEADQUARTERS, DEPARTMENT OF THE ARMY
14 OCTOBER 1980

WARNING

DANGEROUS CHEMICALS ARE USED IN NICKEL-CADMIUM BATTERIES

The electrolyte used in nickel-cadmium batteries contains potassium hydroxide (KOH), which is a caustic chemical agent. Serious and deep burns of body tissue will result if the electrolyte comes in contact with the eyes or any part of the body. Use rubber gloves, rubber apron, and protective goggles when handling the electrolyte. If accidental. contact with the electrolyte is made, use ONLY clean water and immediately (seconds count) flush contaminated areas. Continue flushing with large quantities of clean water. Seek medical attention without delay for the eyes.

EXPLOSIVE GASES ARE GENERATED BY NICKEL-CADMIUM BATTERIES

Hydrogen and oxygen gases are generated in explosive proportion while the nickel-cadmium battery is being. charged and discharged. Charge the nickel-cadmium battery in a well-ventilated area to reduce concentrations of explosive gases. Turn off the battery charger before connecting or disconnecting the nickel-cadmium battery to prevent arching. Do not use matches or an open flame in the charging area. Arcs, flames, or sparks in the charging area will ignite the gases and cause an explosion. The battery box cover must be removed and the battery case vent plug (if used) must be open when charging.

DO NOT MIX SULPHURIC ACID AND KOH

The electrolyte used in nickel-cadmium batteries reacts violently to the sulphuric acid used in the more common lead-acid types of batteries. DO NOT add sulphuric acid electrolyte to the battery; the mixing of the acid and KOH electrolytes will cause a violent reaction which could result in the splattering of the mixture into the eyes and onto the skin. Every effort must be made to keep nickel-cadmium batteries as far away as possible from lead-acid batteries. Do not use the same tools and materials such as screwdrivers, wrenches, syringes, hydrometers, and gloves for both types of batteries. Any trace of acid or acid fumes will permanently damage nickel-cadmium batteries on contact.

BATTERY SHOP SAFETY PRACTICES

Nickel-cadmium battery maintenance personnel should be thoroughly trained in the use of charging, discharging, and test procedures. The employment of properly trained personnel in the maintenance of nickel-cadmium batteries cannot be overemphasized. The nickel-cadmium battery shop must be used ONLY to maintain nickel-cadmium batteries. Anything associated with lead-acid batteries should never come in contact with nickel-cadmium batteries, including acid fumes. In addition to the equipment required to maintain nickel-cadmium batteries; the nickel-cadmium battery shop should have adequate ventilation; deluge shower, eyewash fountain, and fire extinguisher.

TIGHTENING TERMINAL SCREWS AND STUDS

Be extremely careful when tightening terminal screws and studs. Bodily injury and damage to the equipment may result if the torque wrench accidently causes a short circuit.

FIRE FIGHTING SAFETY PRACTICE

CO_2 is an acceptable fire extinguishing agent once a fire has developed. In no case should CO_2 be directed into a battery compartment to effect cooling or displace explosive gases. The static electricity generated by the discharge of the extinguishers could explode hydrogen/oxygen gases trapped in the battery compartment.

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REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS

You can help improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in back of this manual direct to: Commander, US Army Communications and Electronics Materiel Readiness Command, ATTN: DRSELME-MQ, Fort Monmouth, New Jersey 07703. In either case, a reply will be furnished direct to you.

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*This manual supersedes TM 11-6140-203-15-1, 1 December 1969, including all changes.

LIST OF ILLUSTRATIONS

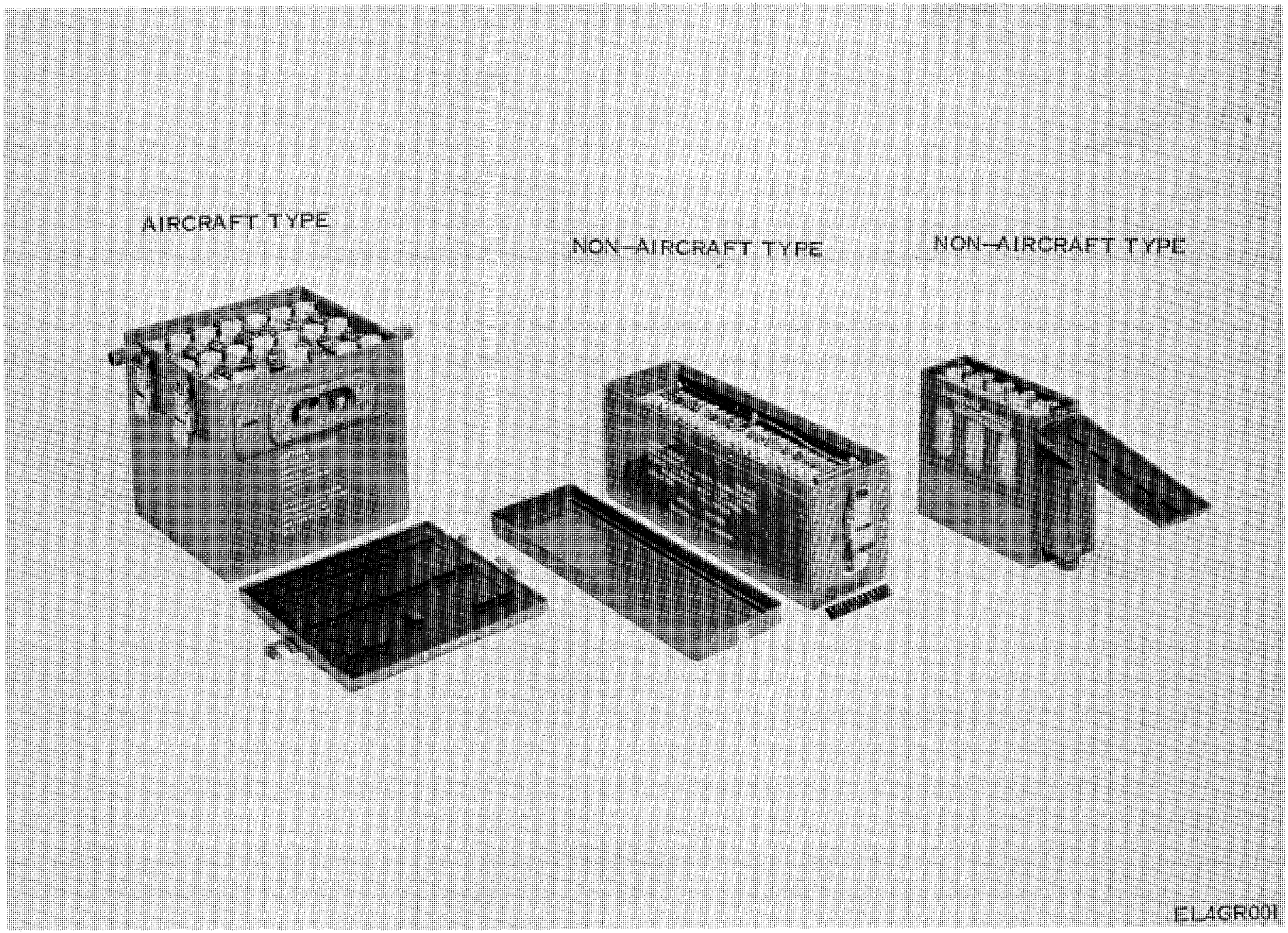

Figure 1-1. Typical Nickel-Cadmium Batteries.

CHAPTER 1

INTRODUCTION

1-1. scope

The full series of publications covering vented nickel-cadmium batteries is made up of four manuals: TM 11-6140-203-14-1, TM 11-6140-203-14-2, TM 11-6140-203-14-3, and DMWR 11-6140-203. This manual covers the description, functioning, operational characteristics, serviceability and general servicing information of aircraft and nonaircraft type vented nickel-cadmium batteries, Refer to TM 11-6140-203-14-2 for specific data and maintenance and repair instructions for each of the aircraft nickel-cadmium batteries. Refer to TM 11-6140-203-14-3 for specific data and maintenance and repair instructions for each of the nonaircraft nickel-cadmium batteries.

1-2. Indexes of Publications

a. DA Pam 310-4. Refer to the latest issue of DA Pam 310-4 to determine whether there are new editions, changes, or additional publications pertaining to this equipment.

b. DA Pam 310-7. Refer to DA Pam 310-7 to determine whether there are modification work orders (MWO's) pertaining to this equipment.

1-3. Maintenance Forms, Records, and Reports

a. Reports of Maintenance and Unsatisfactory Equipment. Department of the Army forms and procedures used for equipment maintenance will be those prescribed by TM 38-750, The Army Maintenance Management System.

b. Report of Packaging and Handling Deficiencies. Fill out and forward DD Form 6 (Packaging Improvement Report) as prescribed in AR 735-11-2 (NAVSUPINST 4440.127E/AFR 400-54/MCO 4430.3E/DSAR 4140.55)

c. *Discrepancy in Shipment Report (DISREP) (SF 361).* Fill out and forward Discrepancy in Shipment Report (DISREP) (SF 361) as prescribed in AR 55-38/NAVSUPINST 4610.33B/AFR 75-18/MCO P4610.19C and DLAR 4500.15.

CHAPTER 2

FUNCTIONING OF NICKEL-CADMIUM BATTERIES

Section I. GENERAL

2-1. Purpose and Use

Vented nickel-cadmium (Ni-Cad) batteries derive their name from the composition of their plates; nickel oxide on the positive and metallic cadmium on the negative. They are "vented" in that gases generated during the charging process can be expelled from the cells in a controlled manner. They are used to provide a source of direct current (dc) power in both aircraft and nonaircraft applications. The following characteristics provide major advantages over other storage batteries.

a. Vented nickel-cadmium batteries will maintain a relatively steady voltage when being discharged at high currents.

b. Vented nickel-cadmium batteries can be charged and discharged at a high rate current without causing permanent damage to the battery.

c. Vented nickel-cadmium batteries can stand idle in any state of charge (fully charged, partly charged or discharged) without any damage.

d. Vented nickel-cadmium batteries can withstand extremely cold temperatures without damage.

e. Vented nickel-cadmium batteries can withstand high levels of vibration and shock without failure.

f. Vented nickel-cadmium batteries are composed of individually replaceable cells.

g. Vented nickel-cadmium batteries have a long service life under severe conditions of use.

2-2. Construction

a. Batteries. The term "battery" is generally used to describe a unit consisting of one or more cells. Cells are the basic building blocks of a battery. A battery can be a single cell which has terminals and is insulated and is ready for use; but usually a battery is a series combination of individual cells assembled in a case containing a connector and proper insulation. Each cell has a nominal voltage of 1.20 volts; however, the actual operating voltage of a cell will range from 1.2 to 1.3 volts. A nominal 6-volt battery will contain 5 cells connected in series and a nominal 24-volt battery will contain 19 or 20 cells.

b. Principal Parts and Materials. The principal parts and materials used in the vented cells of the nickel-cadmium battery are shown in figure 2-1 and are described in paragraphs (1) through (5) below.

(1) *Plates* (electrodes). The sintered plates of nickel-cadmium cells are made by a process in which carbonized nickel powder is sintered at high temperature to a metal carrier. The welding together of the individual grains of nickel powder onto the carrier, results in a highly porous structure known as a *plaque.* Positive (nickel) electrodes are formed by soaking the plaque in nickel salts and then subjecting the salt-impregnated plaque to electric current. Negative (cadmium) electrodes are formed by the same processes except that cadmium salts are used. Plates are formed by cutting the plaque to size and welding a nickel tab to a corner for connection purposes.

(2) *Electrolyte.* The electrolyte is normally, by weight, a 30 percent solution of potassium hydroxide (KOH) in distilled water. It provides a path for conducting the current that flows between the positive and negative plates. The electrolyte does not take part in the chemical react on in nickel-cadmium batteries, but acts as an ion carrier. The specific gravity of the electrolyte, which is approximately 1.300, remains the same whether the battery is charged or discharged. Therefore, specific gravity measurements cannot be used to determine state-of-charge as is the case with lead-acid batteries.

(3) *Separator.* The separator is a continuous thin porous multiluminate of nylon and either cellophane or plastic, that keeps the positive and negative plates from coming into contact with each other and causing a short. The layer of cellophane or plastic, also has the added function of preventing oxygen generated on overcharge from coming into contact with the negative electrode and lowering the end-of-charge voltage. Before 1979 (except for BB-433A/A, which is prior to 1978) all aircraft and nonaircraft batteries contained cellophane separators. After 1979 (1978 for the BB-433A/A) most aircraft nicad batteries used plastic film separators such as "Permion" or "Celgard:" These plastic film separators have greater resistance to degradation and longer life than cellophane, greatly reducing the possibility of "thermal runaway."

(4) *Cell assembly.* The cell is assembled into its final form by welding the tabs of the negative plates to one terminal post and the tabs of the positive plates to a second terminal post. Once assembled, it is inserted into a plastic case (nylon for aircraft batteries and nylon on Acrylonitrile-Butadine-Styrene (ABS) for nonaircraft batteries) and fitted with a cover and vent assembly that permits the terminal posts to project through the top of the case. After the cover is sealed to the case, electrolyte is added.

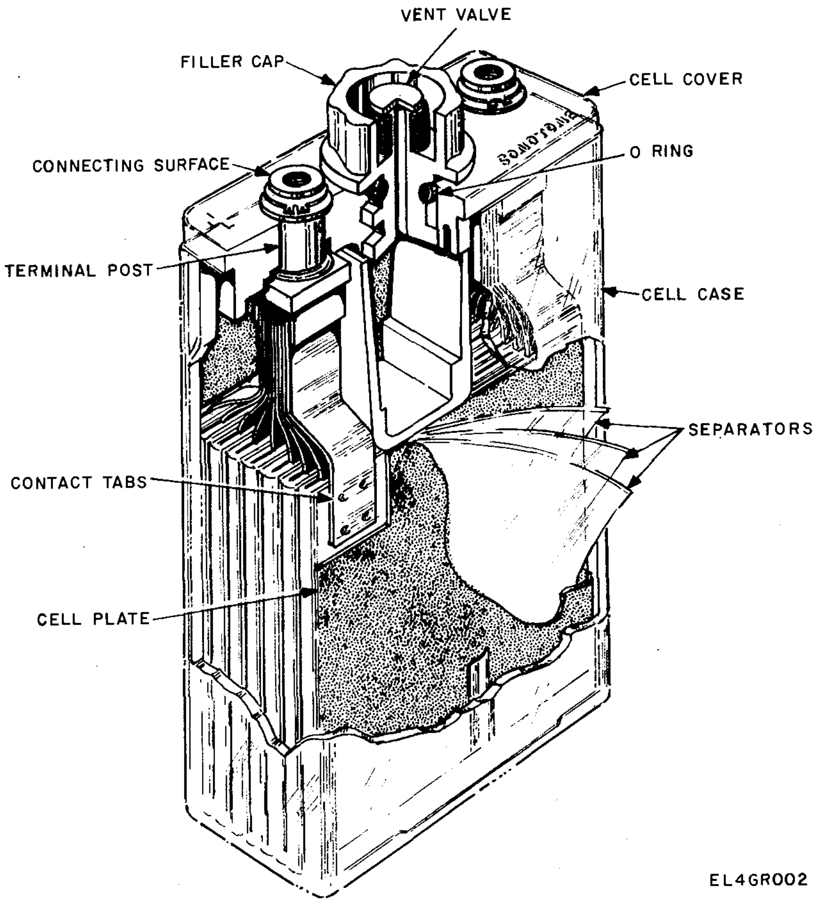

Figure 2-1. Construction of a Typical Vented Sintered-Plate-Nickel-Cadmium Cell.

(5) *Cell vent.* Each cell is equipped with a vent plug and filler cap. These vents may be either a one-piece or a two-piece assembly. The cell vent can be removed for cleaning and adjustment of electrolyte level. When excessive gases develop in a cell during charge, they escape through the vent hole. The vent relieves gas pressure by remaining closed until a pressure of at least 2 psi is reached and will open at a pressure below 10 psi. Except when releasing gas, the vent remains sealed to prevent electrolyte leakage, the entry of foreign material into the cell or contamination of the electrolyte by exposure of air high in carbon dioxide content. When a two-piece cell vent is used, the vent valve may be removed for shipping and replaced by a shipping screw. Before putting the battery into service the slipping screw *must be* removed and replaced by the vent valve.

2-3. Electrochemical Action

The exact chemical reactions that occur within a cell of the nickel-cadmium battery during charge and discharge are open to question, particularly with regard to the reduced and oxidized states of the active materials. However, the essential operation can be described. Figure 2-2 illustrates the essential electrochemical actions.

a. Charge. When charging current is applied to the cell, the cadmium-oxide material of the negative plates gradually loses oxygen and becomes metallic cadmium and the nickel-oxide active material of the positive plates is brought to a higher state of oxidation. These changes continue in both sets of plates as long as the charging current is applied, or until the active materiels at the plates have been completely converted. The cell emits gas toward the end of this process because of the decomposition of the water component of the electrolyte as hydrogen at the negative plates and oxygen at the positive plates. The electrolyte conducts current between the plates of opposite polarity and reacts to produce the electrochemical changes without producing any significant change in its own overall chemical composition. Thus, the measurement of specific gravity of the electrolyte gives no indication of the state of charge in a nickel-cadmium cell. Because the charging of the nickel-oxide positive electrode is not 100 percent efficient, an overcharge of 20 to 40 percent is usually required to bring the battery to full capacity.

b. Discharge. During discharge, the chemical reaction is reversed. The positive plates gradually return to a state of lower oxidation, while the negative plates simultaneously regain lost oxygen. During the discharge process, the chemical energy is released as electrical current through the discharge load. The rate at which the chemical energy is converted is determined principally by the resistance of the load to current flow. A load with a very low resistance could cause such a high current that the cell might be damaged or destroyed.

2–4. Summary of General Information

a. Individual nickel-cadmium cell nominal voltage is 1.2 volts while actual voltage is between 1.20 and 1.30 volts.

b. Active materials of a nickel-cadmium cell are nickel oxide on the positive plate and metallic cadmium on the negative plate.

c. Nickel-cadmium cell plates are separated by a thin porous multilaminate of plastic materials.

d. Electrolyte used in the nickel-cadmium cell is a 31 percent by weight solution of potassium hydroxide in distilled water.

e. Specific gravity of the electrolyte is the same whether the nickel-cadmium cell is charged or discharged. However, the electrolyte level rises during charge and lowers during discharge.

f. The vent valve on the nickel-cadmium cell must be capable of venting excessive gases.

g. The value of charging voltage used depends on the number of cells connected in series.

h. The value of charging current depends on the ampere-hour rating of the storage battery.

Section II. OPERATING CHARACTERISTICS

2–5. Electrical Characteristics

a. Voltage. Regardless of size or shape, the voltage of a single nickel-cadmium cell is nominally 1.20 volts based on the plateau voltage at a 5-hour discharge rate but a number of voltage levels other than this maybe encountered as the voltage varies depending on the rate of charge or discharge, state of a charge, and temperature. Battery voltages higher than this are obtained by connecting integral multiples of a suitable number of cells in series. Accordingly, a 6-volt nickel-cadmium battery consists of five cells connected in series; a 12-volt battery contains 10 cells similarly connected, a 24-volt battery contains either 19 or 20 cells serially connected. The quantity of cells a specific battery contains is listed in chapter 2 of TM 11-6140-203-14-2 or TM 11-6140-203-14-3 for aircraft and nonaircraft nickel-cadmium batteries respectively.

b. Open Circuit Voltage. Open circuit voltage is the voltage of a cell without a load. At room temperature, this voltage is 1.25 to 1.35 volts for a fully charged battery, depending on how long the cell has been standing after charge. Elevated temperatures will lower the measure open circuit voltage.

c. Closed Circuit Voltage. Closed circuit voltage is the voltage of a cell with a load applied. The value depends on the size of the load, the electrical capacity of the cell, the temperature, and the length of time on discharge.

d. Plateau Voltage. Plateau voltage is the cell voltage during the relatively flat portion of the discharge curve. This voltage depends on the discharge rate and, in most applications, is about 1.2 volts.

2–6. Capacity

Sintered-plate Ni-Cad cells are capable of delivering almost full capacity over a wide range of discharge rates and temperatures. However, battery capacity can be influenced by the primary factors of discharge rate and temperature and secondary factors such as storage, age, and previous charge history of the battery.

a. Rated Capacity. The capacity rating of a nickel cadmium battery is that capacity measured in ampere-hours at a specified rate of discharge, discharge temperature, and voltage end point.

(1) *Aircraft batteries are* normally rated at the 1-hour discharge rate; i.e., a 30-Ah battery is discharged at 30 amperes, at 20°C (68°F) to an end point voltage of 0.9 volt/cell. However, in the past other rating systems have also been employed. Thus, a battery which is rated at 30 Ah at the 1-hour rate could also have a rated capacity at 34 Ah at the 2-hour rate (17A) to an end-point of 1.0 volt/cell.

(2) *Nonairaft batteries* for communications use are normally rated at the 5 hour-discharge rate, i.e., a 14 Ah battery is discharged at 2.8 amperes at 20°C (68°F) to an end point voltage of 1.0 volt.

b. Actual Capacity.

FOR ALL PRACTICAL PURPOSES, THE CHARGE-DISCHARGE REACTION MAY BE WRITTEN AND ILLUSTRATED AS FOLLOWS:

$$2\,\mathrm{Ni(CH)_3} + \mathrm{Cd} \rightleftharpoons 2\,\mathrm{Ni(OH)_2} + \mathrm{Cd(OH)_2}$$

CHARGED ←→ DISCHARGED

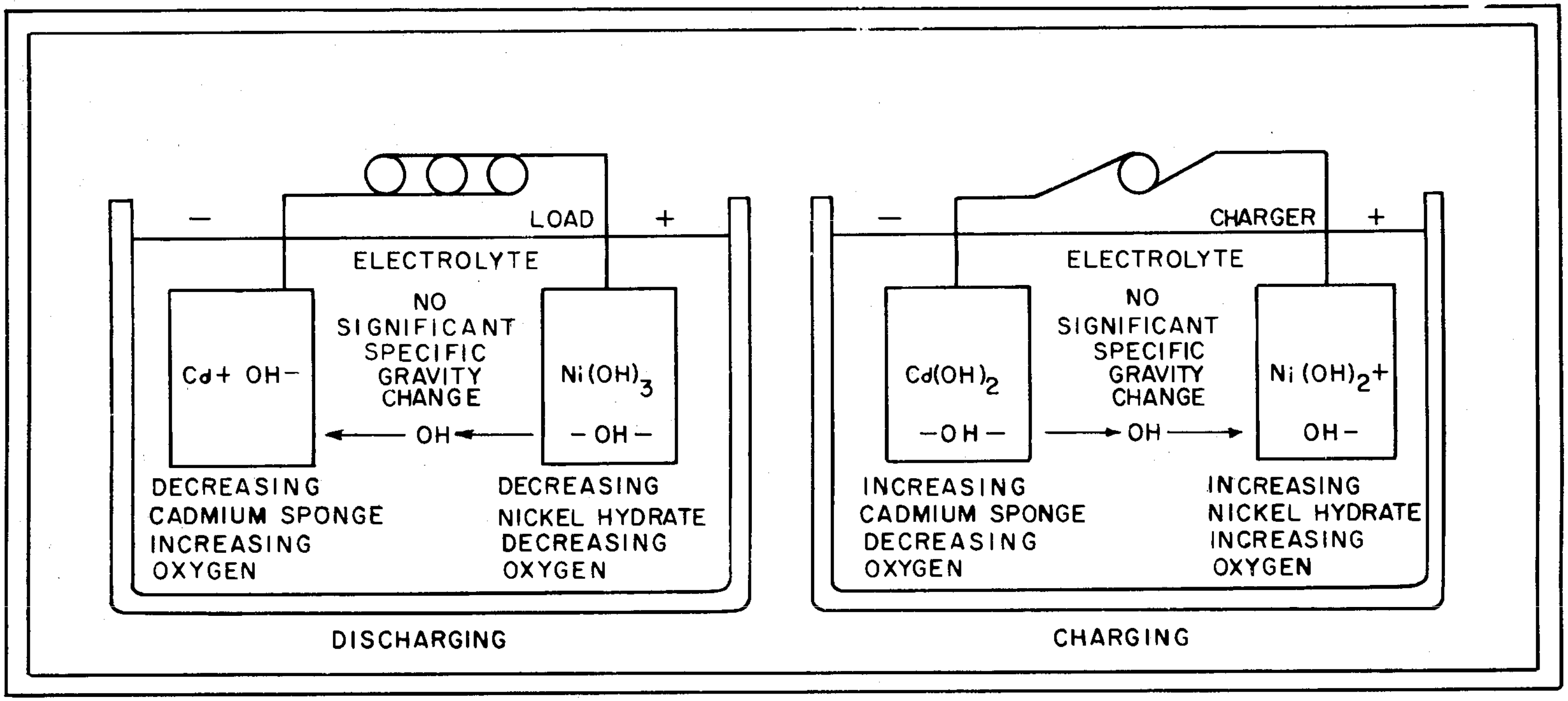

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Figure 2-2. Electrochemical Action in a Nickel-Cadmium Storage Battery.

(1) *Aircraft batteries.* The actual capacity obtained from aircraft type batteries after a full charge normally exceeds the rated capacity by 25 to 40 percent. When the actual capacity falls below rated capacity, the battery is considered unacceptable.

(2) *Nonaircraft batteries.* The actual capacity obtained from new communication type batteries after a full charge normally exceeds the rated capacity by 15 to 30 percent. Actual capacity falls with cycling, and when it reaches 60 percent of rated capacity after many hundreds of cycles it is considered unacceptable.

2–7. Discharge Characteristics

a. Discharge Rate. The nickel-cadmium battery is capable of delivering very high discharge currents relative to its size. Figure 2-2 shows the capacity and voltage obtained during discharges of a 30 ampere-hour aircraft type cell over a wide range of discharge rates at normal temperature. The lowest usable voltage for proper cell operation in noncranking applications is considered to be approximately 1.0 volt (equivalent to 19 volts for a 19-cell battery). The curves in figure 2-3 show that an increase in current demand from 8 amperes to 100 amperes will only slightly decrease the capacity output of the storage battery. However, the individual cells are still capable of delivering current in excess of their rated ampere-hour capacity. As the current demand is increased to 300 amperes, the cells are degraded until their capacity has dropped to approximately 24 ampere-hours, which is approximately a 20 percent reduction over the rated capacity of 30 ampere-hours. As the current demand is increased to 500 amperes, the cell can no longer deliver usable current for noncranking load because the cell voltage has dropped below the minimum acceptable level. However, for engine cranking loads, cell voltages as low as 0.6V are acceptable. The curves of figure 2-3 show that the aircraft type cells are capable of sustained current drains up to 10 times their rated capacity before the voltage level drops below 1.0 volt. Nonaircraft type cells are usually designed for lower rate applications and therefore will be limited to approximately one-half the current levels of the high-rate aircraft type cells. Curve A of figure 2-3 is a typical discharge curve for a 19-cell aircraft battery discharged at the one and two hour rates.

b. Discharge Temperature. Nickel-cadmium cells are capable of sustaining high current drains and good performance at temperatures as low as 0°F. However, sustained high current at temperatures below 0°F will result in a reduced cell performance because the increased internal resistance of the cell lowers the closed circuit voltage. The effective capacity of a cell will decrease when it is subjected to high current demands and extreme temperatures. This is shown in figure 2-4 where battery capacity and voltage is compared at the 5-minute rate at 80°F and –22°F. The preferred operating temperature for typical vented nickel-cadmium

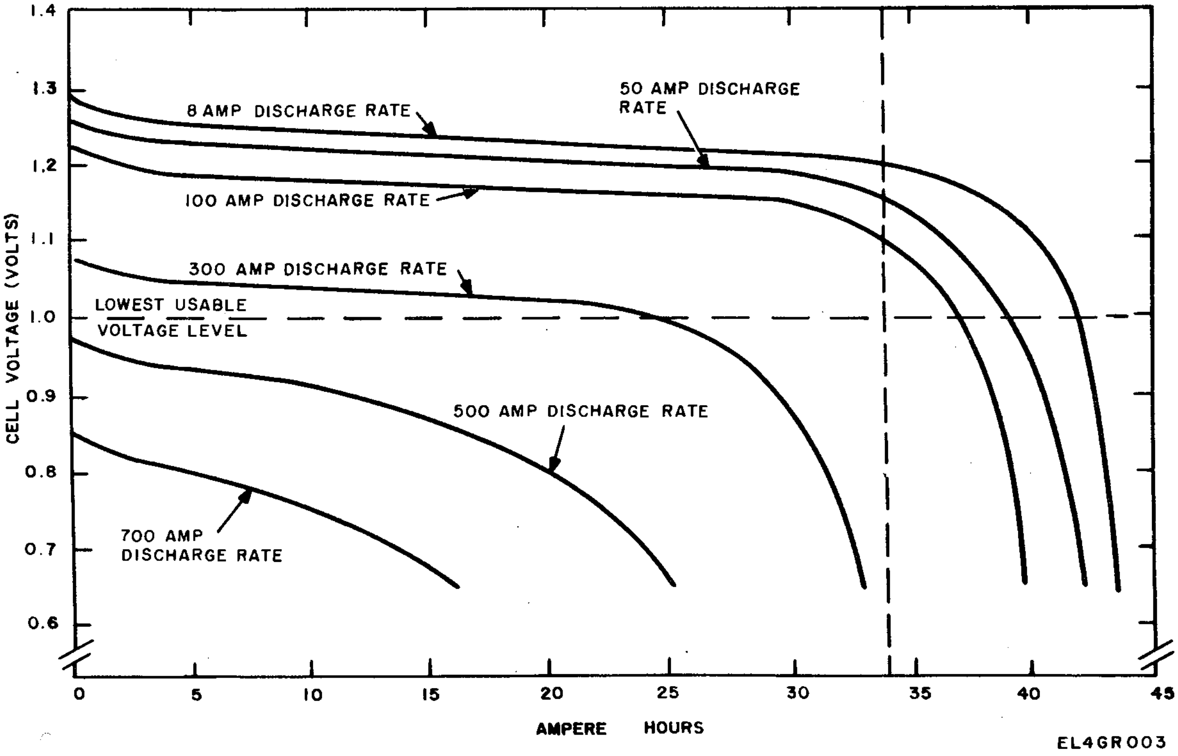
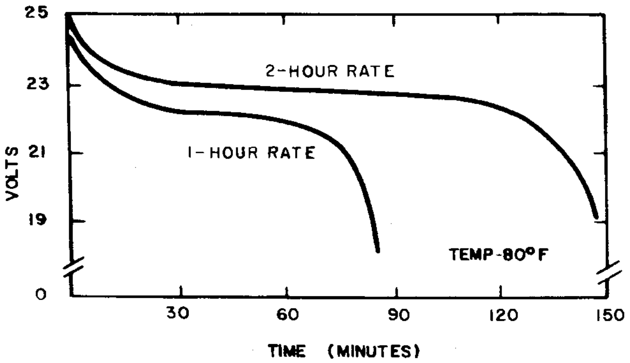


Figure 2-3. Effects of Discharge Rates on Capacity of a 24-Volt, 30-Ampere-Hour Nickel-Cadmium Battery.

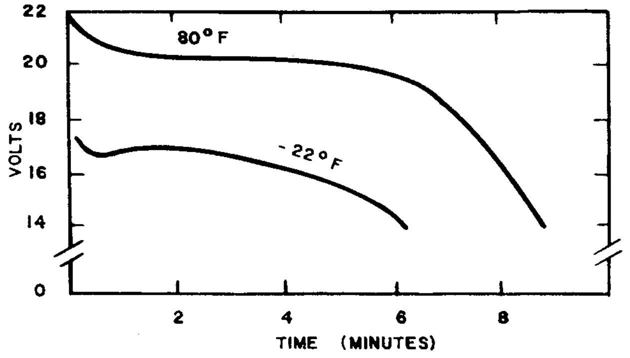
cells is the range from 0°F to 100°F, with the optimum temperature range being 50°F to 90°F. An increase or decrease in temperature from the optimum range causes a corresponding reduction in cell capacity. Vented nickel-cadmium batteries, however, may be discharged at temperatures as low as – 65°F if discharge rates are limited. Figure 2-5 indicates available battery capacity as a function of temperature. The information given in figure 2-5 should be considered only a guide because cell design and battery size will affect low temperature discharge performance considerably. Discharging at high rates for sustained periods will cause large increases in battery temperature. Batteries should be allowed to cool to approximately room temperature after high rate discharge before starting to recharge.

2–8. Charge Characteristics

A nickel-cadmium battery is capable of accepting charge at rates many times its rated capacity for a short period. However, once the battery is fully charged the rate of current input must be limited to prevent excessive loss of water, spewage of electrolyte and overheating. Control of charging current or voltage and tone is necessary to prevent excessive overcharge while still providing full capacity. The characteristics of the various charging methods follow. In general, the constant potential charge provided by the aircraft bus does not provide a full charge.



A. TYPICAL DISCHARGE CURVE AT NORMAL TEMPERATURE (80°F)



B. LOW TEMPERATURE DISCHARGING (5-MINUTE RATE)

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Figure 2-4. Comparison of Typical Discharge Characteristics of a 19-Cell Nickel-Cadmium Battery at Normal and Low Temperature.

a. Constant Potential. Constant-potential (CP) charging applies a fixed voltage to the cell. The resulting charge current is determined by the applied voltage level, the state-of-charge of the cell and its temperature. Figure 2-6 shows a typical constant potential charging curve of a partially discharged battery in an aircraft. As shown by the figure, very large amounts of current are input for a short period of time until the back voltage of the battery rises as it nears full charge. Adjustment of the constant potential setting of the aircraft bus with temperature is required to match the characteristics of the battery.

b. Modified Constant Potential. Frequently, battery charging equipment used for charging nickel-cadmium batteries cannot tolerate the very high currents which would be drawn in the initial stages of charging at constant potential. In such cases, current-limiting devices or electrical resistances are commonly connected between the battery and its charging source. Because these practices supply a fixed voltage when the battery is fully charged, but reduced voltage in the initial stage of charging, they are called *modified* constant potential charges. The limitation of charging current during initial stages of charging current lengthens the time required to completely charge the battery. Current can also be limited by manually reducing the voltage for the first few minutes of charge. For constant potential charging rates for aircraft nickel-cadmium batteries, refer to chapter 5, TM 11-6140-203-14-2. For constant potential charging rates for nonaircraft nickel-cadmium batteries, refer to chapter 5, TM 11-6140-203-14-3. A typical modified constant potential charging curve is shown in figure 2-6.

c. *Constant Current.* The constant current method of charge is not limited by the back voltage of the battery and as such will provide a full charge irrespective of battery temperature. A typical constant current charging curve is shown in figure 2-7. The figure indicates that the battery voltage rises sharply as a 100 percent state-of-charge is reached. Charging current is still applied, however, to achieve the desired 20 to 40 percent overcharge. When automatic equipment is employed, charging can be done at high rates; i.e., the 1-hour rate, until the voltage rise takes place. At this point the constant current value can be reduced to the 3- to 5-hour rate in order to provide the required overcharge at a low enough rate to prevent spewage of electrolyte. The length of the overcharge period is normally timed. If automatic equipment is not accessible, the entire charge must be run at a rate which will be safe for overcharge. These charging rates are provided with each specific battery.

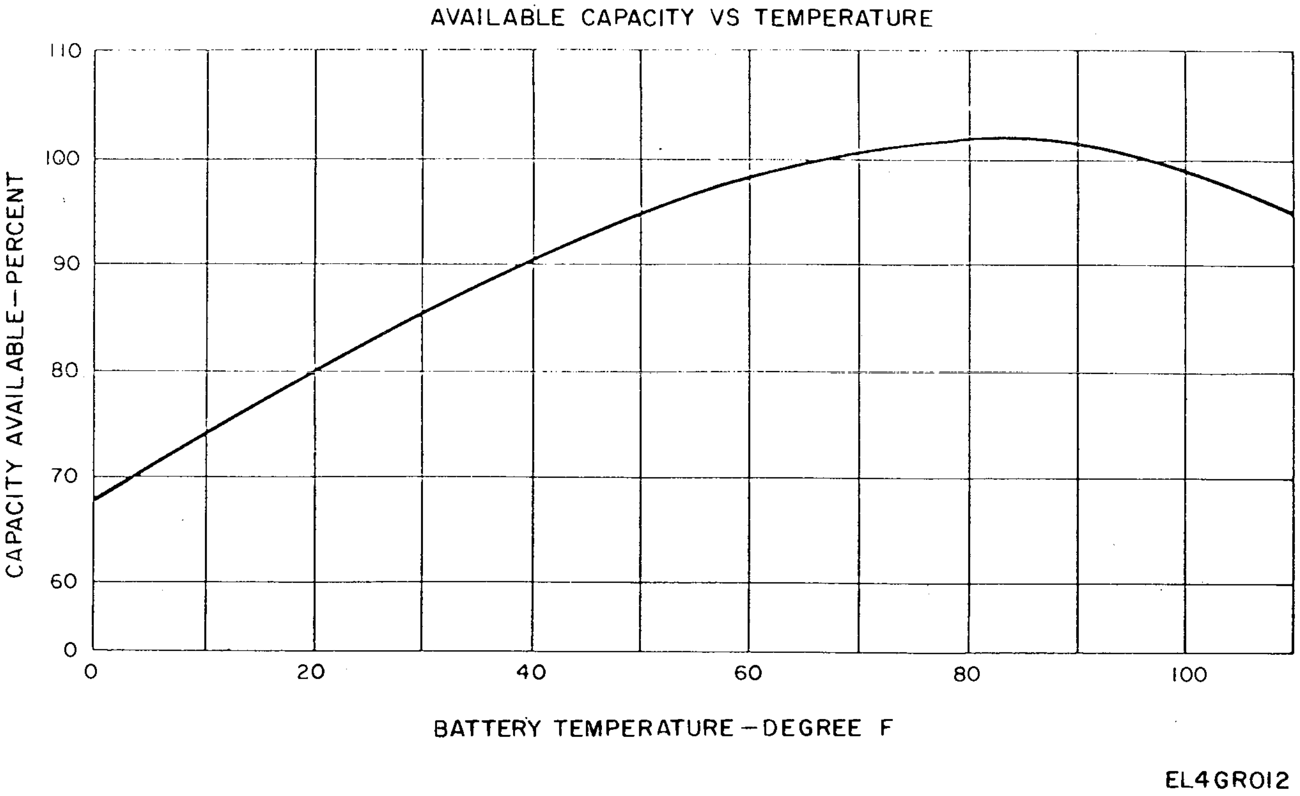

Figure 2-5. Temperature-Capacity Relationship

d. Pulse Charging. Several types of automatic charging equipment are available which provide the charging current in the form of high current pulses interspersed with periods of no current or discharge. In general, these charges function in the same manner as automatic constant current types, in that the current level is reduced when the battery voltage rises to provide a controlled overcharge. Because of the nature of the pulse charge and the automatic controls employed, it is usually possible to charge at very high rates. Charge time of 1 hour is typical. One type of charge analyzer that can charge 24-volt batteries in 1 hour is the AN/USM-432. Figure 2-8 gives its front panel layout.

e. Charging of New or Unformed Batteries. Batteries which have never been cycled have a different charge voltage characteristic than used batteries. This occurs because the cadmium electrode in a new battery may have a large excess of uncharged cadmium oxide which must be formed by overcharging. Thus, the sharp voltage rise seen in figure 2-7 does not occur during the first cycle. Up to 150 percent overcharge may be required to reach full charge. Because of this condition, care must be taken when charging at very high rates with automatic pulse or constant current charging equipment, since the voltage level required to reduce the charging current is not reached. This can result in overheating of the batteries and spewage of electrolyte out of the cell vents. It is recommended that new batteries be charged at a current no higher than the 2-hour rate for the first cycle and the charge should be continued until the voltage reaches at least 1.50 volts per cell. When charging a new battery, the voltages of all the individual cells should be checked periodically for either very high or low values.

f. Standby or Trickle Charging. Because the self-discharge of a nickel-cadmium battery is approximately 1.2 percent per day at normal temperatures, standby charging is required to maintain its full rated capacity. For standby charging in the temperature range of 60°F to 90°F, use a current equal to 3 ma per ampere-hour rated capacity or a constant potential of 1.35V/cell. Batteries on standby charge must be regularly checked to ensure adequate electrolyte level.

2–9. Charge Efficency

Charge efficiency is the ratio of ampere-hours available on discharge to ampere-hours returned to a bat-

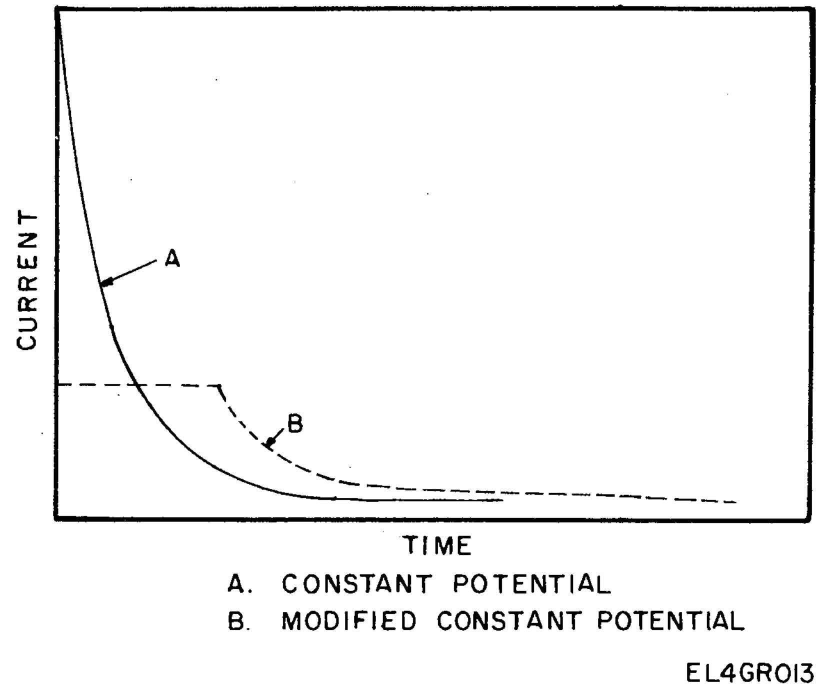

Figure 2-6. *Typical Constant Potential Charging Curve.*

tery during charge. This ratio is always less than 1; therefore, excess charge must always be returned to the battery after discharge to restore rated capacity. The total charge necessary may be as low as 110 percent, or much greater, depending on the temperature and cell characteristics. It is generally recommended that the nickel-cadmium battery be charged (constant current) for a time that will give at least 125 percent of the previously discharged ampere hours. *For example,* a 20-ampere-hour battery that is fully discharged should be recharged at constant current until at least 1.25 times 20 ampere-hours are restored, or at least 25 ampere-hours are returned. In general, a 40 percent overcharge is recommended, particularly when cell imbalance has occurred, charge rates are at the 5-hour rate or lower, and the temperature is above 90°F.

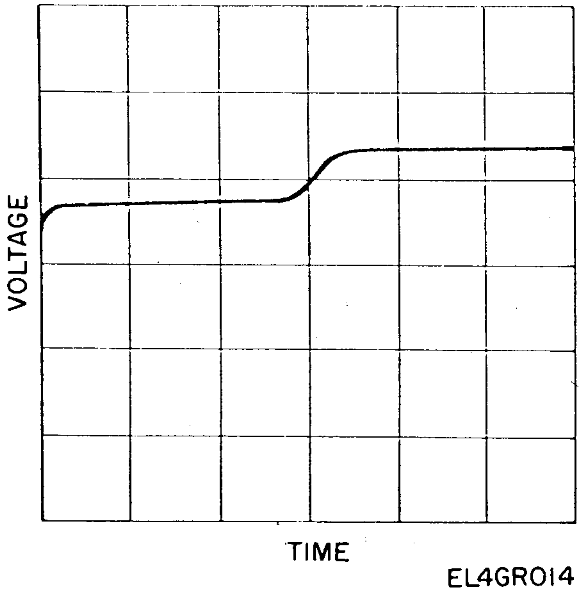

Figure 2-7. Constant Current Charging Curve.

2–10. Gassing

During charge, the tendency of nickel-cadmium cells to gas increases with temperature rise and the charge state. Cell gassing characteristics will also vary somewhat among manufacturers, cell types and for various other reasons. A certain amount of gassing is necessary for a battery to become fully charged. The danger is in excessive or violent gassing, leading to possible explosion, loss of electrolyte, or damage to the battery. Monitor the charging procedure to insure that excessive or violent gassing is controlled by reducing charging current or charging voltage.

2–11. Electrolyte Level

An inherent characteristic of nickel-cadmium battery cells is that the electrolyte is absorbed within the plates and separators to a point where it is not visible from the top of the cells when at a low state of charge or in a discharged condition. When the battery is recharged, the electrolyte level rises and reaches its maximum height at full charge. Ideally, the electrolyte level should be checked on a fully charged battery that has been *at rest* for at least 30 minutes and not exceeding 2 hours. The correct level of electrolyte is ¼-inch above the top of the plates of a fully charged cell that has been at rest for the prescribed period of time. Refer to TM 11-6140-203-14-2 and TM 11-6140-203-14-3 respectively for rest time limitations for specific aircraft and nonaircraft nickel-cadmium batteries. Observing the rest time limitations before checking the electrolyte level is an absolute must to insure that the cell is not overfilled or underfilled. However, some modification in electrolyte level height or rest time after charging may be required depending on the equipment used for charging and the environment the battery will see in use (voltage regulator setting and temperature). In general, the constant current (CC) chargers used in the battery shop will produce a higher apparent level of electrolyte than a constant potential (CP) charger, since the CC charger normally charges to a higher end-of-charge voltage. If this is the case, then it maybe necessary to increase the rest time after charge from 30 minutes to up to 2 hours and/or increase the electrolyte to $\frac{5}{16}$-inch above the top of the plates. These changes in electrolyte level should only be made if absolutely necessary and only in cells containing adequate head space over the plates.

2–12. Foaming

Foam may sometimes be noticed in cells during charge. It normally does not indicate a defect and is harmful only if it results in excessive overflow. Foaming is more likely to occur after adding water and should disappear after a few cycles of operation. Continued foaming indicates contaminated electrolyte and the cell should not be used until thoroughly checked for damage. When electrolyte is lost due to foaming in *new* cells, add 31 percent KOH electrolyte to the cell rather than water. After the first two charge cycles, only distilled water should be added.

2–13. Summary of Operation Characteristics

a. Cell capacity decreases when discharged at high currents.

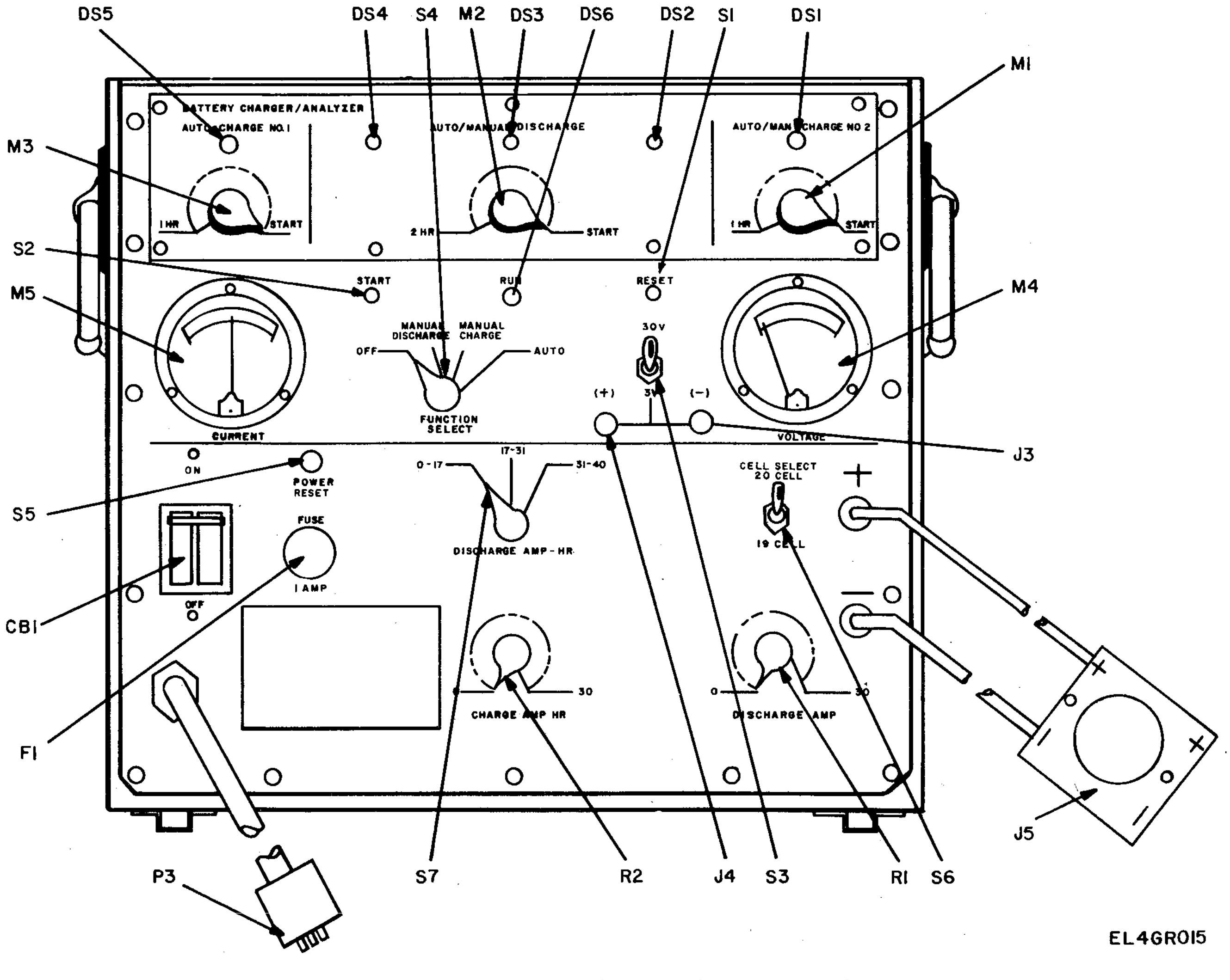

Figure 2-8. AN/USM-432, Charger/Analyzer, Front Panel Layout.

b. Cell capacity decreases at temperatures lower than 20°F or higher than 100°F.

c. Voltage level of nickel-cadmium batteries remains essentially constant until approximately 90 percent of its capacity has been delivered.

d. Nickel-cadmium batteries should be charged for at least 125 percent of previously discharged ampere-hours to be at approximately full charge state.

e. Electrolyte is not visible from the top of the cells when the cell is at a low state of charge. When charged properly and rested for a minimum of 30 minutes and a maximum of 2 hours, the electrolyte level should be ¼-inch above the top of the plates.

f. The electrolyte level should be checked when the nickel-cadmium battery is fully charged and has been at rest for a minimum of 30 minutes and a maximum of 2 hours.

g. Refer to TM 11-6140-203-14-2 and TM 11-6140-203-14-3, respectively, for rest time limitations for aircraft nickel-cadmium and nonaircraft nickel-cadmium batteries.

Section III. FACTORS AFFECTING SERVICEABILITY

2–14. Temporary Loss of Capacity

An important characteristic observed in nickel-cadmium batteries is temporary loss of capacity or “sleepiness” (also referred to as the “memory effect”). When this temporary loss occurs, the battery is unable to deliver the designed capacity. The loss of capacity is a result of shallow discharge cycles. For instance, when a battery is continually discharged, as for example, to a depth of only 20 percent of full charge, its voltage-time curve begins to drop abnormally near the 20-percent discharge point. The effect is that 80 percent of the capacity has become temporarily inactive.

a. Causes. The loss-of-capacity effect is more common when recharging a battery across a constant potential bus, such as in aircraft, than when charging with constant current. The loss of capacity is usually an indication of an imbalance between the cells because of differences between individual cells in temperature, charge efficiency, and self-discharge rate. Imbalance can be verified by a periodic check of individual cell voltages after the battery has shown a sharp rise in voltage while being charged by the constant current method, or after current has dropped and essentially stabilized during constant potential method. The individual voltage of each cell under full charge should be 1.5 volts or more when the cell is at room temperature (about 70° F). A variation of more than 0.10 volt between cells after completion of charge is an indication of imbalance and that the lower voltage cells need to be additionally charged to reach equalization. Usually, a deep cycle discharge at the 10-hour rate of 0 volt followed by a recharge of the battery is sufficient to equalize the cells. Figure 2-9 shows a battery discharge equalization fixture and a list of available fixtures. Another cause of capacity loss is a growth of the grain size of the active material within the battery plates. This type of effect is normally associated with very low rates of discharge particularly at high temperatures.

b. Consequences. The temporary loss-of-capacity effect should not be taken lightly. Even though a battery may appear to be giving satisfactory performance, it may deliver only a portion of its rated capacity if required during an emergency. *For example,* during a test being conducted on 19-cell, 34-ampere-hour, 24-volt nickel-cadmium batteries, 30 were given a capacity test. The average capacity measured on 30 batteries was less than 15-ampere-hours, or less than half of the rated capacity; two of the batteries delivered only 2-ampere-hours each. It is clear that the condition of the batteries would not be ideal under emergency conditions. To minimize the loss-of-capacity problem, nickel-cadmium batteries should be serviced periodically and given a deep cycle discharge to 0 volt.

2–15. Thermal Runaway

Thermal runaway is a condition in which the current for a fully charged nickel-cadmium battery rises out of all proportion to the impressed voltage.

a. Cause. Since runaway occurs in an overcharged state after the battery is fully charged, the excess charging energy is dissipated as heat and electrolysis of water. Continued overcharging under certain conditions has the effect of reducing the internal battery resistance so that it draws a higher current from the impressed voltage. As the temperature of the battery increases, the effective internal resistance continues to decrease and the current becomes progressively greater. This process continues and eventually destroys the battery unless it is properly protected by a cutout device.

b. Effect of Temperature and Voltage. Thermal runaway primarily depends on temperature and charging voltage; therefore, the higher the charging voltage, the less the temperature required to effect the runaway condition, or the higher the temperature, the less charging voltage required. Battery temperature should never exceed 120°F.

c. Effect of Battery Separator Material. Most thermal runaways in the past have been caused by the breakdown of the cellophane, film separator, so that oxygen generated on overcharge could reach the cadmium electrode, thereby lowering its voltage and increasing the current from a constant potential source. Plastic film separators such as “Permion” or “Celgard” used in many Army nickel-cadmium batteries since

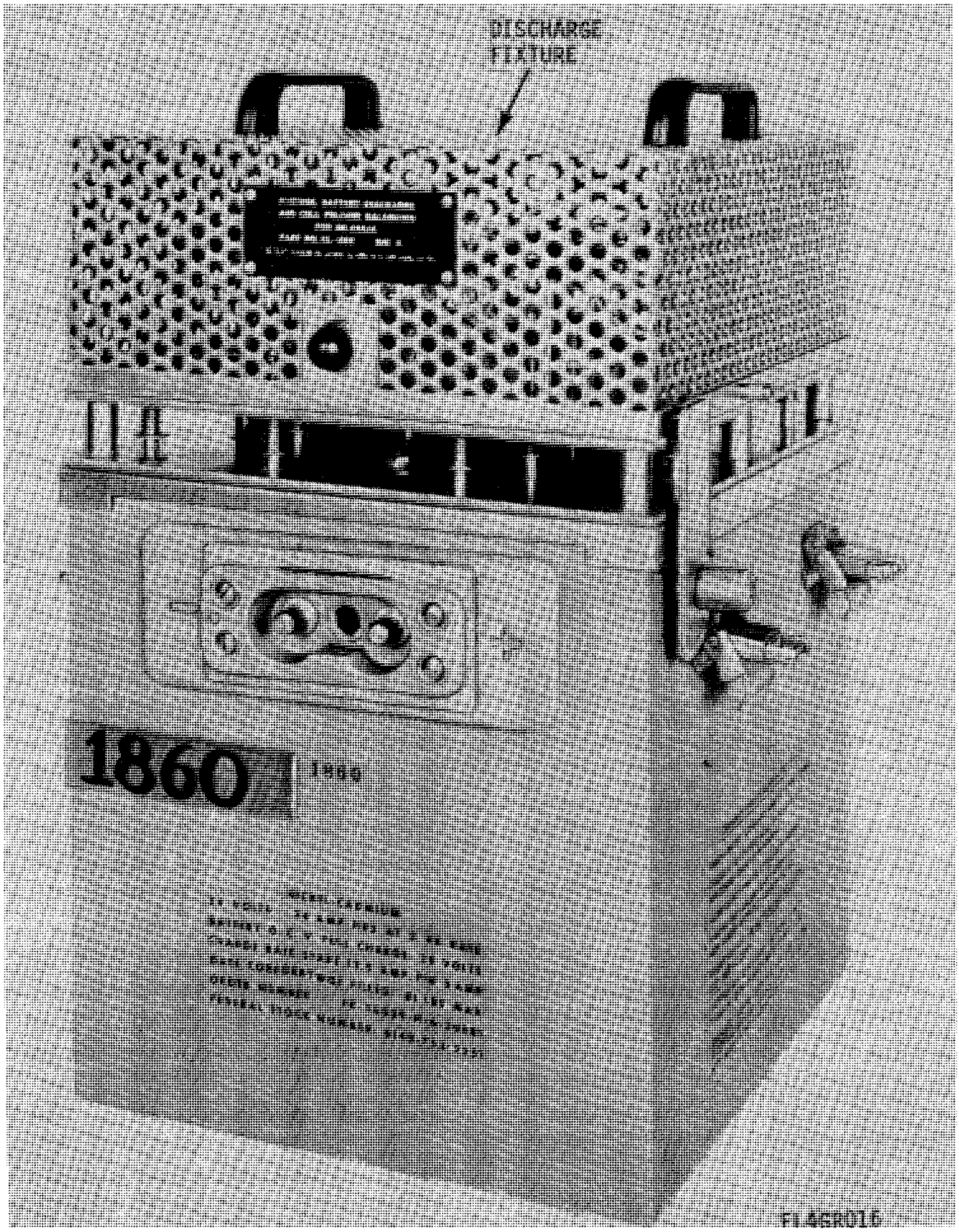

Figure 2-9. Battery Discharge Equalization Fixture (Typical Setup).

1979 will not break down in the alkaline environment of the cell as did cellophane, and therefore thermal runaway is much less likely with these materials. However, even with these new improved plastic materials, overheating and spewing of electrolyte can occur if excessively high potentials and temperatures are encountered.

d. Detecting Thermal Runaway. Thermal runaway may occur if the batteries are charged for long periods at high charging voltages or high temperatures. Thermal runaway may be detected by the following signs

(1) Battery temperature shows a significant rise at the end of charge (approximately 130°F).

(2) When the constant potential charging method is used, the current gradually increases rather than gradually decreases.

(3) If the constant current charging method is used, runaway will be indicated by a decrease of battery voltage with time rather than an increase as is usual.

2–16. Extreme Temperature Operation

The nickel-cadmium battery displays a much greater low temperature operation capability than the lead-acid battery. Usually, design specifications list the operating temperature range as – 65°F to + 165°F. Its output capacity will be considerably degraded at both extremes.

a. *Charging.* Charging at low temperatures requires more time and higher charging voltages than at normal temperatures. In general, the lower the battery temperature, the longer the time required for charging. Conversely, charging at high temperatures requires lower charging voltages.

b. Discharge Voltage. The voltage decreases with an increase in discharge rate and a decrease in temperature.

2-17. Summary of Factors Affecting Serviceability

a. Shallow discharge cycles result in temporary loss of capacity and an imbalance of cells within a nickel-cadmium battery.

b. Slow deep cycle discharge to *0* volt followed by charge is necessary to equalize cells within a nickel-cadmium battery.

c. Cells containing plastic film separators are more resistant to thermal runaway than cellophane separated ones.

d. Nickel-cadmium battery temperature rise above 130°F may cause thermal runaway.

e. Charging at low temperature requires more time and/or higher charging voltage.

Section IV. GENERAL SERVICING FEATURES

2-18. Care of Battery

Nickel-cadmium batteries are rugged and provide long life. However, they require proper handling and maintenance if they are to deliver designed output and are to have a maximum useful life. Certain general handling techniques and precautions must be observed.

a. The electrolyte in nickel-cadmium batteries contains potassium hydroxide and distilled water. Chemically, this is the exact opposite of an acid. Lead-acid batteries use sulphuric acid. Take every step possible to keep the nickel-cadmium batteries as far away as possible from the lead-acid type batteries. Do not use the same tools and materials (screwdrivers, wrenches, syringes, hydrometers, gloves, apron, etc.) for both batteries. Anything associated with the lead-acid type battery (even air) must never come in contact with the nickel-cadmium battery or the electrolyte. Even a trace of sulphuric acid fumes from a lead-acid battery mixing with the electrolyte for the nickel-cadmium battery may result in damage to the nickel-cadmium battery.

b. If separate battery shops are not possible, setup bench facilities at opposite ends of the battery shop. Mark each area of the battery shop clearly. Keep tools and materials separate. The nickel-cadmium area should be free of all contamination. Markings that identify the tools and materials for use with nickel-cadmium batteries will insure that contamination will not occur. Painting the color *blue* is recommended on the tools and materials used with nickel-cadmium batteries. Painting the color *pink* is recommended on the tools and materials used with lead-acid batteries. The use of properly trained personnel in the maintenance of nickel-cadmium batteries is most important. In addition, strict adherence to the maintenance procedures prescribed for nickel-cadmium batteries is equally important. The authority responsible for battery maintenance must insure that all battery maintenance personnel are qualified and fully aware of proper safety precautions. Figure 2-10 illustrates the equipment layout of a typical nickel-cadmium battery shop.

c. If a shortage of tools exists and it becomes necessary to use the same tools for both types of batteries, be absolutely sure to wash and rinse the tools with plenty of clean, hot water after they are used on either type. Use plenty of strong soap. Potassium hydroxide will give the tools a very slippery, soapy feeling. To speed up the cleaning, if available, use a mild solution of vinegar to wash the tools. Dip the tools in the vinegar solution, rinse in warm tap water, and then rinse in distilled water.

d. When working around batteries, use the apron, gloves, and goggles or face-shield provided. If you spill any potassium hydroxide on your skin, immediately flood the area with cold water and seek medical aid.

CAUTION

> *Do not* use a wire brush. *Do not* attempt to clean the battery shops with solvents, acids, or any chemical solvents because the batteries are constructed with plastic cells which would be damaged by contact with such chemicals. Keep open flames and metal objects, such as tools, etc., away from the exposed parts of the battery. If objects are accidentally dropped across the terminals, a short circuit could cause damage to one or more cells.

e. The white powder found on top of the cells and cell connectors is potassium carbonate and is formed when the potassium hydroxide reacts with the carbon dioxide in the air. Potassium carbonate deposits in the dry state are nonconductive and when in contact with nickel or nickel-plated material is noncorrosive. When moisture is added to the powder, which occurs with drastic humidity changes, an electrical leakage path is established. Also, if the potassium carbonate comes in

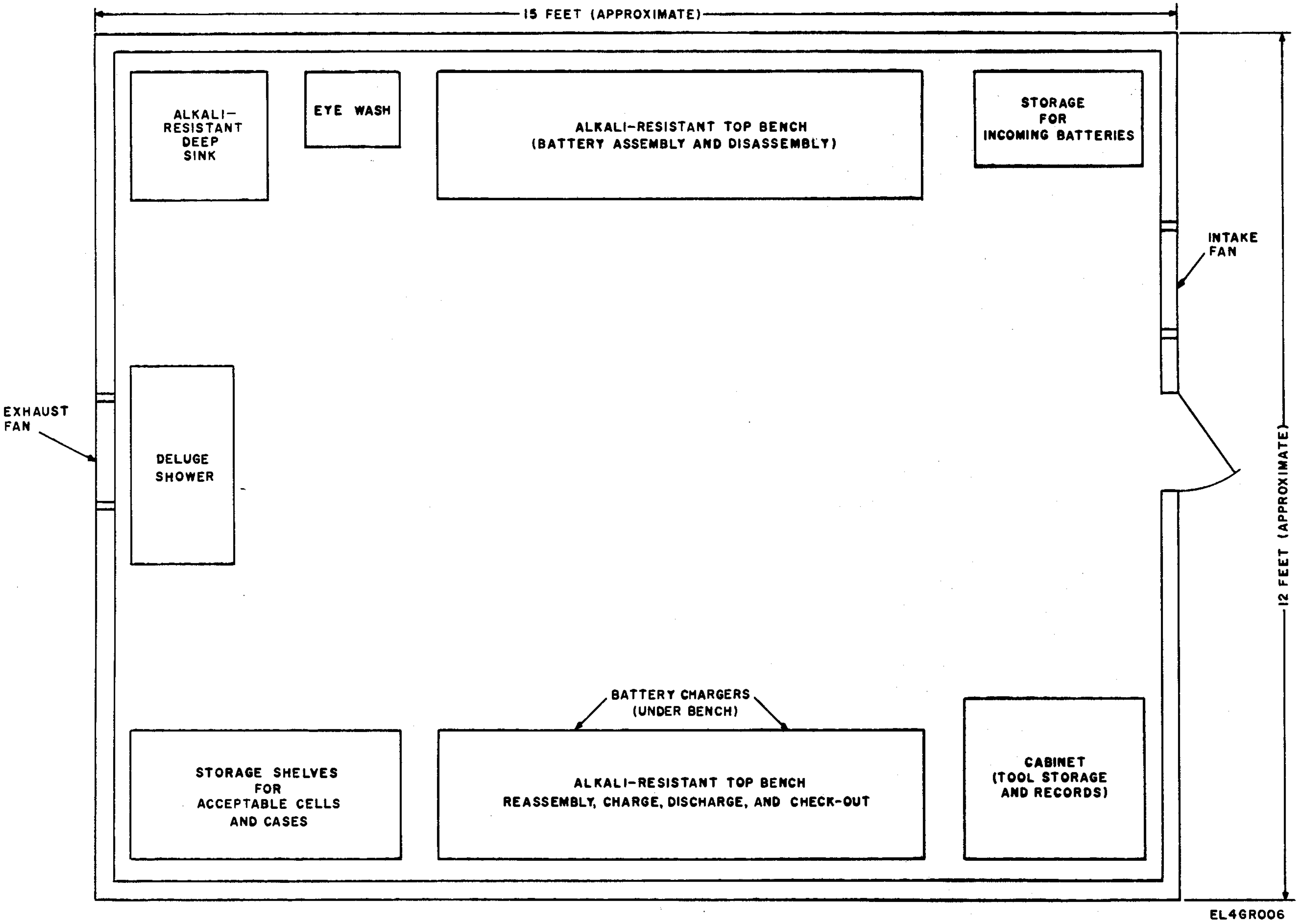

Figure 2-10. Typical Nickel-Cadmium Battery Shop Equipment Layout.

contact with copper, which could occur if the nickel-plating is scratched, corrosion will set in. For these reasons, the battery must be carefully cleaned and kept free of potassium carbonate deposits.

f. The potassium carbonate deposits, when dry, may be removed with a nylon brush. Be sure that the filler caps are secured before brushing. Any foreign matter can contaminate the battery. If necessary, the tops of the batteries may be flushed with water. Be sure that the filler caps are tightly closed before flushing with water. Batteries must be thoroughly dry before use.

g. Do not attempt to determine the state of charge of a nickel-cadmium battery by a voltage check or by a specific gravity check of the electrolyte. The electrolyte is not Changed by the chemical reaction which takes place in the battery; the specific gravity is the same whether the battery is charged or discharged. An indication of the approximate state of charge is the amount of current the battery draws when it is connected to a constant potential charger. The higher the state of charge, the less current the battery will draw.

2-19. Determining State of Charge

The actual state of charge of a nickel-cadmium battery is difficult to determine. It cannot be determined by the specific gravity of the electrolyte since it does not change during battery charge and discharge. The methods described in *a* and *b* below may be used for a general determination of charge condition. However the most accurate method is to fully recharge the battery before use if it has been charged and is on standby for any length of time.

a. *Battery Current Drawn From Constant Potential Source.* A common method of checking the state of charge is to connect the battery across a constant potential charging source and observe the charging current drawn by the battery as indicated by an ammeter in series with the battery. The charging-source voltage would normally be 1.5 volt times the number of cells; *for example, 28.5* volts for a 19-cell, 24-volt battery at 70°F. If the current drops to 1 or 2 amperes or less within 5 minutes, the battery can be assumed to be in a near state of full charge.

b. Voltmeter Reading With Battery Under Load. Since the discharge voltage of a nickel-cadmium battery is essentially constant until the battery is approximately 90 percent discharged, voltmeter readings across the terminals while the battery is under load are not too reliable. Figure 2-11 shows a typical voltage discharge curve under moderate load, and illustrates the problem associated with voltmeter readings. A reading of approximately 24 volts may mean that the battery is almost fully charged (point 1 on the curve) or almost totally discharged (point 2 on curve).

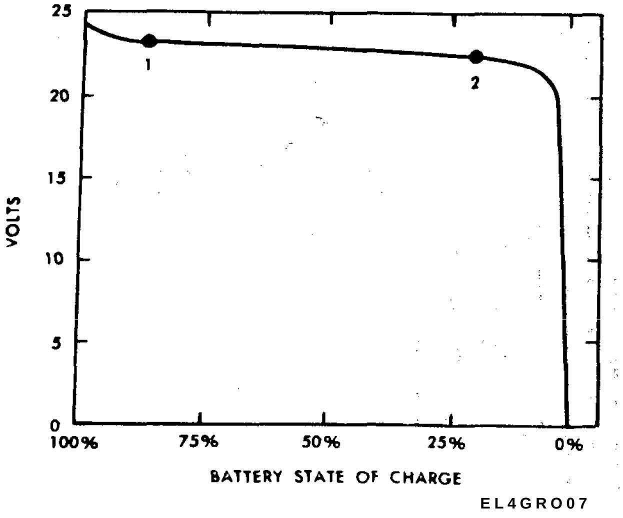

Figure 2-11. *Typical Discharge Voltage Curve Under Moderate Load for Nickel-C!admium Battery.*

2-20. Periodic Maintenance Cycling

Figure 2-12 shows the maintenance sequence that should be performed at direct support or general support categories. For aircraft nickel-cadmium batteries, maintenance shown in flow chart is required every 100 flight hours or every 120 days (whichever shall occur first). For nonaircraft nickel-cadmium batteries, maintenance shown in flow chart is required quarterly or every 100 cycles (whichever shall occur first). The periodic maintenance cycle should result in the rebalancing of all cells in the battery, the reactivation of inactive plate material, and the replacement of defective cells. In addition, the battery as returned to the user contains the proper electrolyte level and a full charge.

2-21. Adjustment of Electrolyte Level

The proper height and method for adjusting the electrolyte level has caused considerable confusion in the past. This has been because of the wide variety of charging methods, conditions of use, and available head space within each size and type of nickel-cadmium cell. Refer to TM 11-6140-203-14-2 or TM 11-6140-203-14-3 for detailed procedures covering the battery being serviced.

a. *Checking Electrolyte Level.* Because a nickel-cadmium cell contains large amounts of electrolyte below the top of the plates, the fact that electrolyte is not visible in the partially discharged state is not necessarily cause for alarm. When a battery has been charged on an aircraft bus, the electrolyte should be visible above the cell plates immediately after the charge is ended. If not, the electrolyte level in the cell

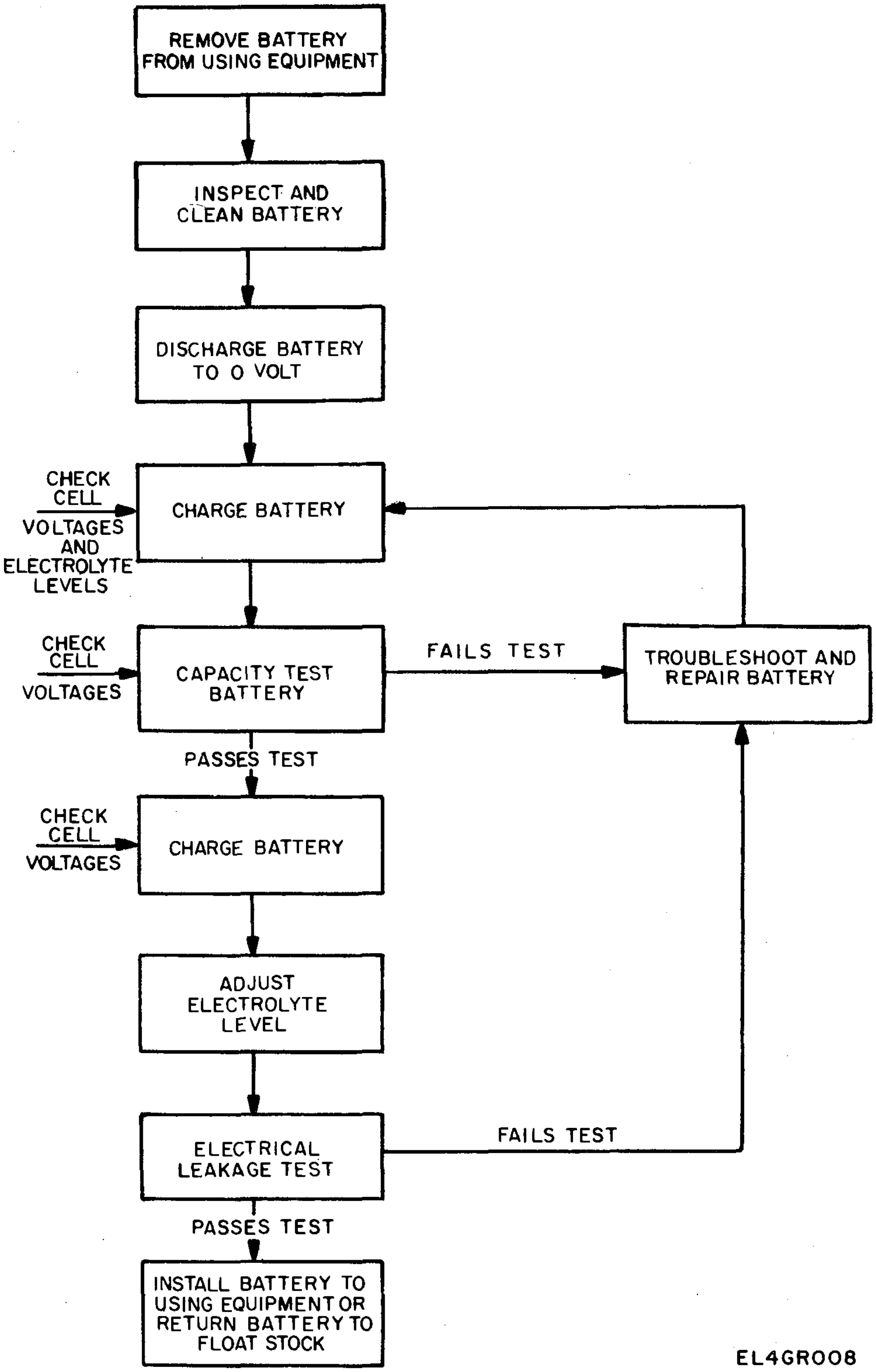

Figure 2-12. Maintenance Flow Chart (Every 100 Flight Hours or120 Days for Aircaft Nickel-Cadmium Batteries; Quarterly or Every 100 Cycles for Nonaircraft Nickel-Cadmium Batteries).

is low and must be adjusted using distilled water following the procedure given in *c* below. Adjustment of electrolyte level is not authorized at the organizational (AVUM) level.

NOTE

> A low setting of the aircraft voltage regulator will result in the battery being only partially charged and therefore an apparent low level of electrolytes.

b. Adjusting Electrolyte Level. The electrolyte level of cells in a nickel-cadmium battery should not be adjusted when the state of charge is unknown. The level of the electrolyte should be adjusted after the battery has been completely charged and *allowed to rest for at least 30 minutes.* The procedure is exactly the opposite of that for lead-acid batteries in which the electrolyte level is adjusted by adding water before placing the battery on charge, or whenever the electrolyte level is low. An inherent characteristic of nickel-cadmium cells is that when they are in a low or discharged condition, the electrolyte is absorbed within the plates and separators to a point where it is not visible from the top of the cells. When the battery is recharged, the electrolyte level rises. At full charge, the electrolyte level is at its maximum.

c. *Adding Distilled Water or Electrolyte (KOH).* If distilled water or electrolyte (KOH) is added to nickel-cadmium cells while the battery is in the aircraft or vehicle and the state of charge is unknown, electrolyte may boil or spew through the filler caps as the battery receives its charge from the power bus. The potassium hydroxide contained in the electrolyte may eventually plug the vent valve of the filler caps. If the vent valves become plugged, pressure builds up in the cells and gas accumulates. If sufficient pressure builds up, the cell will rupture. The electrolyte may then flow over the top of the cells and down into the case bottom between the cells. The overflow of electrolyte eventually starts corrosion and may cause a short circuit between the cell connectors. This chain of events, particularly the accumulation of hydrogen, can lead to an explosion. An igniting spark could be caused by a loose cell connection or a short circuit between the cell connectors resulting from the spewed electrolyte. Electrolyte (KOH) should only be added to a new cell on its initial charge or if large amounts of electrolyte have spewed out of a cell.

d. Check State of Charge. Before adjusting a suspected low electrolyte level, cycle the battery in the shop to assure that it is fully charged. Conversely, never allow electrolyte to fall below the cell level indicators (if used) when the battery is in a charged condition. Low electrolyte levels in the charged condition will cause the cells to heat up, resulting in their ultimate destruction.

2-22. Summary of General Servicing Features

a. Nickel-cadmium batteries must be kept away from lead-acid batteries to avoid contamination.

b. State of charge cannot be determined with a specific gravity check of electrolyte in nickel-cadmium batteries.

c. Adjust electrolyte level only when the nickel-cadmium battery is fully charged and allowed *to rest for at least* 30 *minutes.* If level is low, use only distilled water.

CHAPTER 3

SHIPMENT, STORAGE, AND DEMOLITION TO PREVENT ENEMY USE

Section I. SHIPMENT AND STORAGE

3-1. Repacking for Shipment or Storage

a. Battery Discharging. The battery should be fully discharged prior to packing for shipment or storage. Discharge the battery as specified in paragraph 5-7, TM 11-6140-203-14-3.

b. Material Requirements. For material requirements, use the original packing material, or equal.

c. *Packaging.* The exact procedure for packaging batteries for shipment and storage depends on materials available and conditions under which the batteries are to be shipped or stored. If the original packaging materials are available, package the batteries as shown in figures 3-1 and 3-2. If the original packaging materials are not available, use sturdy cartons and barrier material to protect the batteries.

3-2. Storage

Nickel-cadmium batteries can be stored for indefinite periods of time without deterioration. After storage, the battery should be prepared for service as specified in paragraph 5-5, TM 11-6140-203-14-2 for aircraft nickel-cadmium batteries or paragraph 5-5, TM 11-6140-203-14-3 for nonaircraft nickel-cadmium batteries.

Section III. DEMOLITION OF MATERIEL TO PREVENT ENEMY USE

3-3. Authority for Demolition.

Demolition of the equipment will be accomplished only upon the order of the commander. The destruction procedures outlined in paragraph 3-4 will be used to prevent further use of the equipment.

3-4. Methods of Destruction.

Use any or all of the following methods to destroy the battery:

WARNING

> The electrolyte used in the nickel-cadmium battery contains a caustic chemical agent. Serious flesh burns will result if the electrolyte comes in contact with any part of the skin. Before destroying cells, empty all electrolyte to prevent spattering when smashing.

a. *Smash.* Smash the battery case, battery boxes, and cells.

b. Burn. Burn the battery box liners, the gaskets, and the technical manuals.

c. *Dispose.* Bury or scatter the destroyed parts in slit trenches or foxholes, or throw them into streams. Scatter the connectors, cells, wire harnesses, and boxes.

d. *Other.* Use anything immediately available for destruction of this equipment.

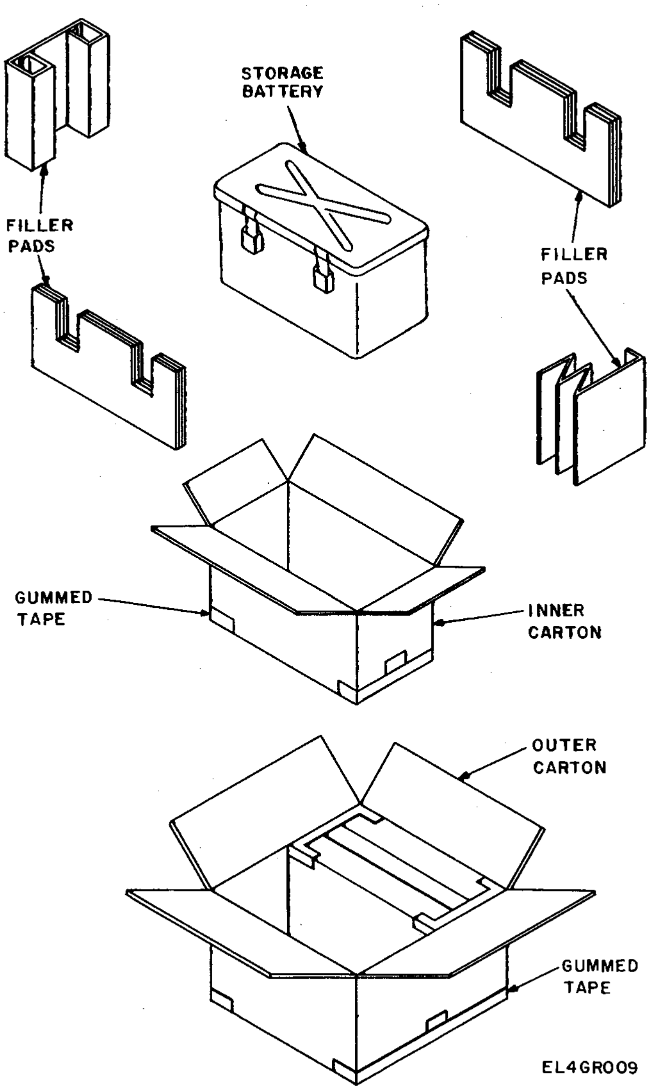

Figure 3-1. Typical Single Nickel-Cadmium Battery, Packaging Diagmm.

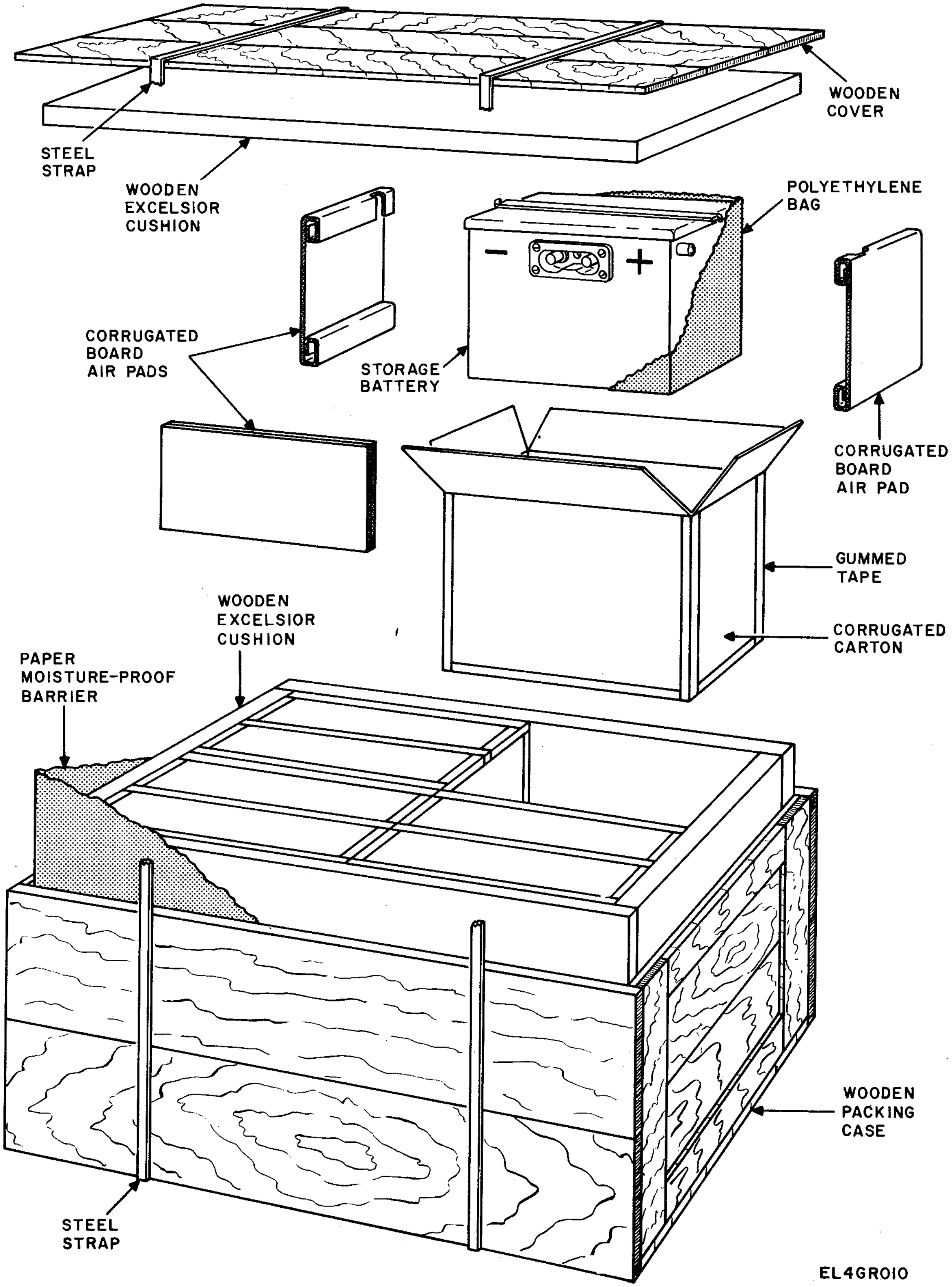

Figure 3-2. Typical Multiple Nickel-Cadium Batteries, Packaging Diagram.

APPENDIX A

REFERENCES

DA Pam 310-4	Index of Technical Publications: Technical Manuals, Technical Bulletins, Supply Manuals (Types 7, 8, and 9), Supply Bulletins, and Lubrication Orders.
DA Pam 310-7	US Army Index of Modification Work Orders.
SB 11-573	Painting and Preservation Supplies Available for Field Use for Electronics Command Equipment.
TB 43-0118	Field Instructions for Painting and Preserving Electronics Command Equipment Including Camouflage Pattern Painting of Electrical Equipment Shelters.
TM 11-6130-413-12	Operator's and Organizational Maintenance Manual for Battery Charger-Analyzer AN/USM-432.
TM 11-6140-203-14-2	Operator's, Organizational, Direct Support, and General Support Maintenance Manual for Aircraft Nickel-Cadmium Batteries.
TM 11-6140-203-14-3	Operator's, Organizational, Direct Support, and General Support Maintenance Manual for Nonaircraft Nickel-Cadmium Batteries.
TM 38-750	The Army Maintenance Management System (TAMMS).
TM 740-90-1	Administrative Storage of Equipment.
TM 750-244-2	Procedures for Destruction of Electronics Materiel to Prevent Enemy Use (Electronics Command).

GLOSSARY

Ampere-hour–An ampere-hour is a unit of measure for battery capacity obtained by multiplying the current flow in amperes by the time in hours during which the current flows.

Charge–Charge is an electrochemical process by which electrical energy in the form of direct current (forced through the battery in a direction opposed to the discharge current) is converted to chemical energy.

Cycle–A cycle is one charge period followed by one discharge period.

Discharge-Discharge is an electrochemical process in which chemical energy is converted into electrical energy in the form of direct current flowing out of the battery into an external circuit.

Discharged battery—A discharged battery is one in which continued passage of charging current produces no further appreciable conversion of electrical energy into chemical energy.

Fully charged battery—A fully charged battery is one in which continued passage of charging current produces no further appreciable conversion of electrical energy into chemical energy.

Normal discharge rate–Normal discharge rate is the steady amount of current which a battery will provide over a given time before the voltage drops to a predetermined point (1.0 volt per cell). The normal rate is expressed in the length of time this current can be provided by the battery. Nickel-cadmium batteries are generally rated at the 2-hour rate for aircraft type or at the 5-hour rate for nonaircraft type.

Rated capacity—Rated capacity is the capacity in ampere-hours which a charged battery will deliver continuously at its normal (2-hour for aircraft type or 5-hour for nonaircraft type) rate. The capacity of a battery or the total amount of electrical energy a cell can deliver depends entirely on the amount of active material it contains. (To increase the capacity of a battery, therefore, a greater number of plates or larger or thicker plates must be used in each cell, with enough electrolyte to provide a conducting path for the current flowing between the positive and negative plates.)

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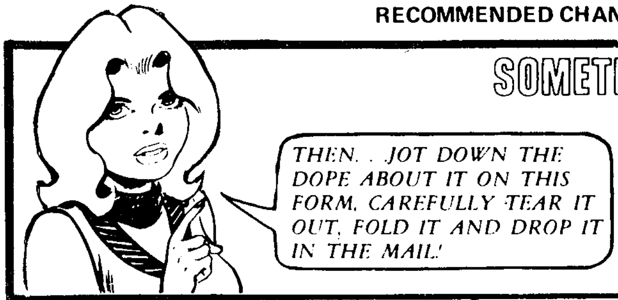

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BE EXACT PIN-POINT WHERE IT IS				IN THIS SPACE TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT:
PAGE NO	PARA-GRAPH	FIGURE NO	TABLE NO	
2-25	2-28			Recommend that the installation antenna alignment procedure be changed throughout to specify a 2° IFF antenna lag rather than 1°. REASON: Experience has shown that with only a 1° lag, the antenna servo system is too sensitive to wind gusting in excess of 25 knots, and has a tendency to rapidly accelerate and decelerate as it hunts, causing strain to the drive train. Hunting is minimized by adjusting the lag to 2° without degradation of operation.
3-10	3-3		3-1	Item 5, Function column. Change "2 db" to "3db." REASON: The adjustment procedure the the TRANS POWER FAULT indicator calls for a 3 db (500 watts) adjustment to light the TRANS POWER FAULT indicator.
5-6	5-8			Add new step f.1 to read, "Replace cover plate removed in step e.1, above." REASON: To replace the cover plate.
		F03		Zone C 3. On J1-2, change "+24 VDC to "+5 VDC." REASON: This is the output line of the 5 VDC power supply. +24 VDC is the input voltage.

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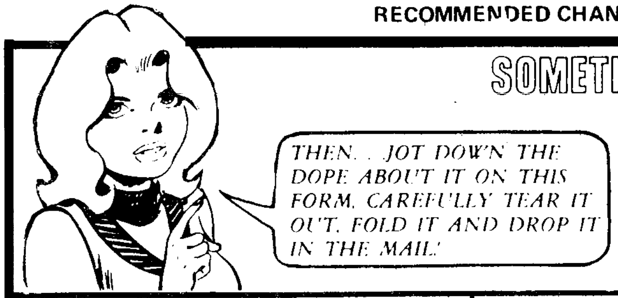

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THE METRIC SYSTEM AND EQUIVALENTS

NEAR MEASURE

Centimeter = 10 Millimeters = 0.01 Meters = 0.3937 Inches
1 Meter = 100 Centimeters = 1000 Millimeters = 39.37 Inches
1 Kilometer = 1000 Meters = 0.621 Miles

EIGHTS

Gram = 0.001 Kilograms = 1000 Milligrams = 0.035 Ounces
1 Kilogram = 1000 Grams = 2.2 lb.
1 Metric Ton = 1000 Kilograms = 1 Megagram = 1.1 Short Tons

LIQUID MEASURE

1 Milliliter = 0.001 Liters = 0.0338 Fluid Ounces
1 Liter = 1000 Milliliters = 33.82 Fluid Ounces

SQUARE MEASURE

1 Sq. Centimeter = 100 Sq. Millimeters = 0.155 Sq. Inches
1 Sq. Meter = 10,000 Sq. Centimeters = 10.76 Sq. Feet
1 Sq. Kilometer = 1,000,000 Sq. Meters = 0.386 Sq. Miles

CUBIC MEASURE

1 Cu. Centimeter = 1000 Cu. Millimeters = 0.06 Cu. Inches
1 Cu. Meter = 1,000,000 Cu. Centimeters = 35.31 Cu. Feet

TEMPERATURE

5/9(°F - 32) = °C
212° Fahrenheit is evuivalent to 100° Celsius
90° Fahrenheit is equivalent to 32.2° Celsius
32° Fahrenheit is equivalent to 0° Celsius
9/5C° + 32 =°F

APPROXIMATE CONVERSION FACTORS

TO CHANGE	TO	MULTIPLY BY
Inches	Centimeters	2.540
Feet	Meters	0.305
Yards	Meters	0.914
Miles	Kilometers	1.609
Square Inches	Square Centimeters	6.451
Square Feet	Square Meters	0.093
Square Yards	Square Meters	0.836
Square Miles	Square Kilometers	2.590
Acres	Square Hectometers	0.405
Cubic Feet	Cubic Meters	0.028
Cubic Yards	Cubic Meters	0.765
Fluid Ounces	Milliliters	29.573
its	Liters	0.473
arts	Liters	0.946
allons	Liters	3.785
Ounces	Grams	28.349
Pounds	Kilograms	0.454
Short Tons	Metric Tons	0.907
Pound-Feet	Newton-Meters	1.356
Pounds per Square Inch	Kilopascals	6.895
Miles per Gallon	Kilometers per Liter	0.425
Miles per Hour	Kilometers per Hour	1.609

TO CHANGE	TO	MULTIPLY BY
Centimeters	Inches	0.394
Meters	Feet	3.280
Meters	Yards	1.094
Kilometers	Miles	0.621
Square Centimeters	Square Inches	0.155
Square Meters	Square Feet	10.764
Square Meters	Square Yards	1.196
Square Kilometers	Square Miles	0.386
Square Hectometers	Acres	2.471
Cubic Meters	Cubic Feet	35.315
Cubic Meters	Cubic Yards	1.308
Milliliters	Fluid Ounces	0.034
Liters	Pints	2.113
Liters	Quarts	1.057
ers	Gallons	0.264
ms	Ounces	0.035
ograms	Pounds	2.205
Metric Tons	Short Tons	1.102
Newton-Meters	Pounds-Feet	0.738
Kilopascals	Pounds per Square Inch	0.145
lometers per Liter	Miles per Gallon	2.354
meters per Hour	Miles per Hour	0.621