

**ROYAL CANADIAN AIR FORCE**



**DESCRIPTION AND MAINTENANCE  
INSTRUCTIONS**

**AIRCRAFT**

**NICKEL CADMIUM**

**STORAGE BATTERIES**

**TYPE MA4, MA5, MA300H, CA-10N**

(This EO replaces EO 40-5EA-2 dated 1 Aug 62)

ISSUED ON AUTHORITY OF THE CHIEF OF THE DEFENCE STAFF

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## PART 1

## INTRODUCTION

## GENERAL

1 This EO is the reference for instruction, operation, service and field repair of 24 volt, 19 cell vented nickel-cadmium batteries used in service aircraft. The specific batteries treated in this EO are listed by military type or other identification in Table 4-1.

2 It is a design intention that, with proper battery care, the service life of a nickel-cadmium battery should approximate the life of the aircraft. The introduction of this type of equipment will afford the benefits of high battery reliability and long life. However, nickel-cadmium batteries are costly equipment, and a high degree of technical proficiency and maintenance efficiency is required to meet the design objective.

3 The shop recharging of nickel-cadmium aircraft batteries is to be carried out by an ETechA NCO, or under the supervision and direct responsibility of an ETechA NCO. Personnel engaged in the maintenance and supervision of this equipment are to familiarize themselves with this EO.

4 The subject nickel-cadmium batteries are classed as repairable equipment and a suitable depth of repair may be carried out by field units having a nickel-cadmium battery charging shop as per EO 40-1-13B. Nickel-cadmium batteries which are beyond the capability of field units to repair are to be returned through normal supply channels.

5 Nickel-cadmium batteries are supplied by the manufacturer already filled with the proper electrolyte, and are stored in that condition. Used serviceable batteries which are no longer required at a unit are to be re-conditioned and repackaged for storage.

6 An RCAF E133 log book is to be raised by field units for each aircraft nickel-cadmium

battery for the purpose of recording details of maintenance and repair carried out in the battery shop.

7 Other publications relating to this subject are:

(a) EO 40-1-13B - General Requirements - Charging Room for Alkaline Batteries.

(b) EO 00-80-4/13 - Safety Precautions.

(c) EO 65C-30CA-2 - Technical Manual, Charger-Analyser Type PCA-130.

(d) EO 40-5A-2 - Description and Maintenance Instructions, Aircraft Storage Batteries, Lead-Acid.

8 Other references and acknowledgments:

(a) Defence Research Chemical Laboratories (DRCL) Report 344.

(b) DRCL Report 315, Some Chemistry of the Nickel-Cadmium Battery, by Dr. EJ Casey, Defence Research Chemical Laboratories, Ottawa.

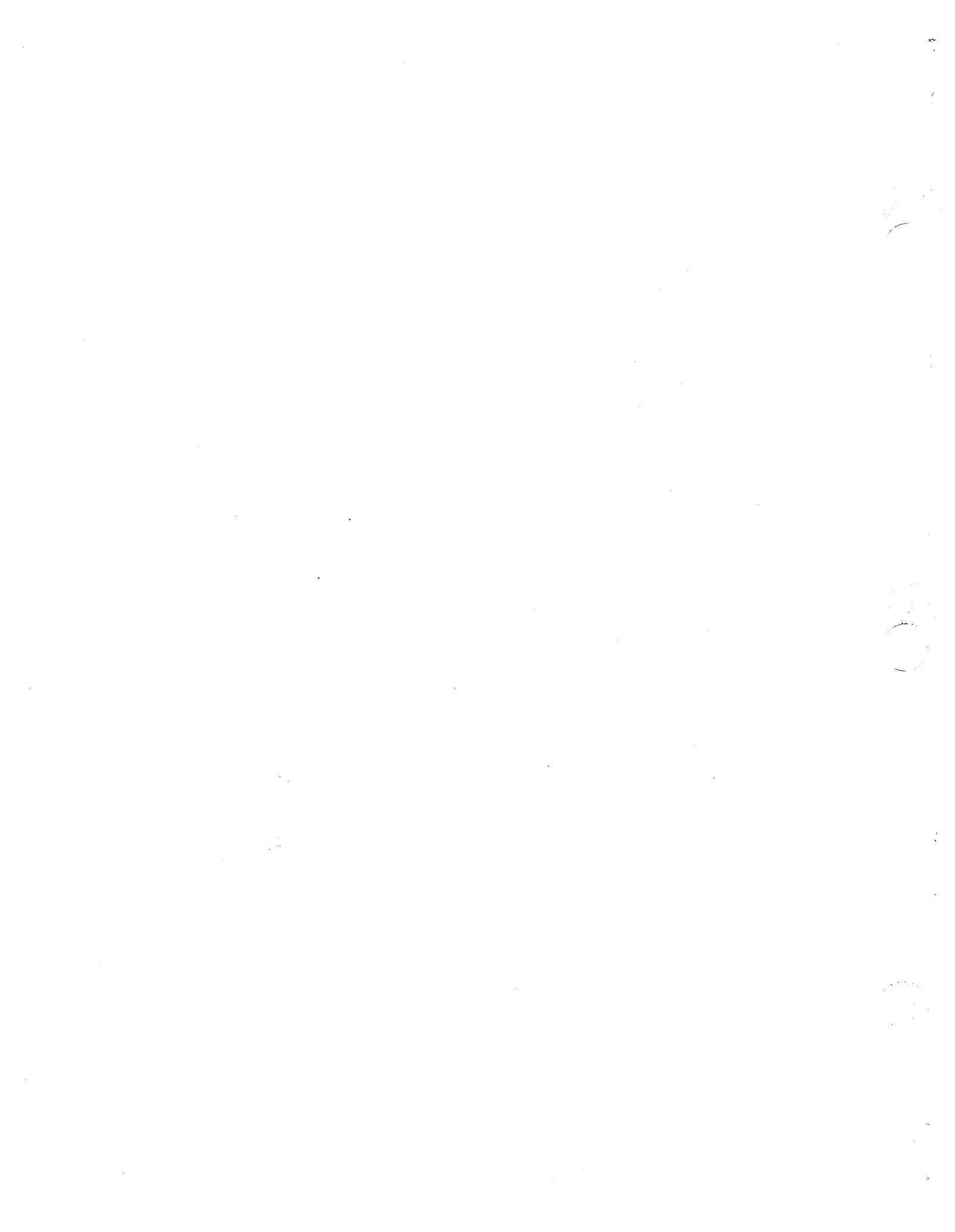
(c) Sonotone Corporation Instruction Manual BA-89.

(d) Electro-Chemical Energy Sources by RW Schult and WT Stafford in Electro-Technology July 1961.

(e) Aircraft Electrical Practice by Lewis F Wainwright, Odhams Press 1961.

(f) USAF TO 8D2-3-1, Aircraft Nickel-Cadmium Storage Batteries.

(g) The Charge-Discharge Process of the Nickel-Oxide Electrode, by Dr. F Kornfeil, in Proceedings of 12th Annual Battery Research and Development Conference.



**PART 2****GENERAL INFORMATION****SECTION 1****DESCRIPTION****GENERAL**

1 Nickel-cadmium batteries are available in the following construction:

(a) Thin sintered plate type.

(1) Vented Batteries - For high rate discharge and low temperature application, for example, as replacements for conventional aircraft and ground vehicles batteries.

(2) Sealed Batteries - These batteries are available mainly in primary cell sizes. An hermetical seal eliminates the need for either water or electrolyte addition. They are used essentially in applications such as satellites, where maintenance free operation is a requirement.

(b) Pocket Plate Batteries.

(1) Conventional type batteries for moderate rate and normal temperature applications such as, industrial, railway and marine.

2 Nickel-cadmium batteries are categorized as alkaline batteries by virtue of the composition of the electrolyte, but not all alkaline batteries are of the nickel-cadmium type.

3 Nickel-cadmium batteries for use with 24 volt aircraft systems normally consist of 19 individual replaceable cells, connected in series, and placed within a container, see Figure 2-1. The nominal open-circuit voltage of each cell is 1.3 volts.

4 Nickel-cadmium batteries derive their name from the composition of their plates; a nickel oxide for the positive plate, and metallic cadmium for the negative plate. As in other wet cell batteries, the cell is the fundamental unit of the nickel-cadmium battery, see Figure 2-2.

**CONSTRUCTION**

5 The nickel-cadmium battery has a very rugged construction. A fine mesh nickel screen is the basic unit into which is sintered carbonyl nickel powder. We now have a porous plaque of high mechanical strength. The active materials, nickel salts for the positive plate and cadmium salts for the negative plate, are then vacuum impregnated into the pores of the plaque. Current is passed through the plates in the presence of electrolyte to convert the nickel and cadmium salts into their final form as nickel and cadmium hydroxides. Figure 2-3 gives a descriptive illustration of the construction of the battery cell.

6 The principal elements of the nickel-cadmium cell are as follows:

(a) The Plate - The plates of nickel-cadmium batteries are made of nickel powder sintered to a nickel wire screen. Sintering is a solid state diffusion process by which fine metal powder is fused together at high temperatures to form a porous plate. The active materials are then electro-chemically deposited within the pores of the plate. The process in effect multiplies the apparent surface area, resulting in the effective surface area being many times greater. The porosity of the plate also facilitates absorption of the electrolyte, which then easily comes in contact with the active materials.

(b) The Separators - The separators are made of nylon cloth and cellophane, and are used to separate and insulate the plates, while allowing access of electrolyte. Alternating positive and negative plates, and the separators, are assembled very closely together and form the cell core.

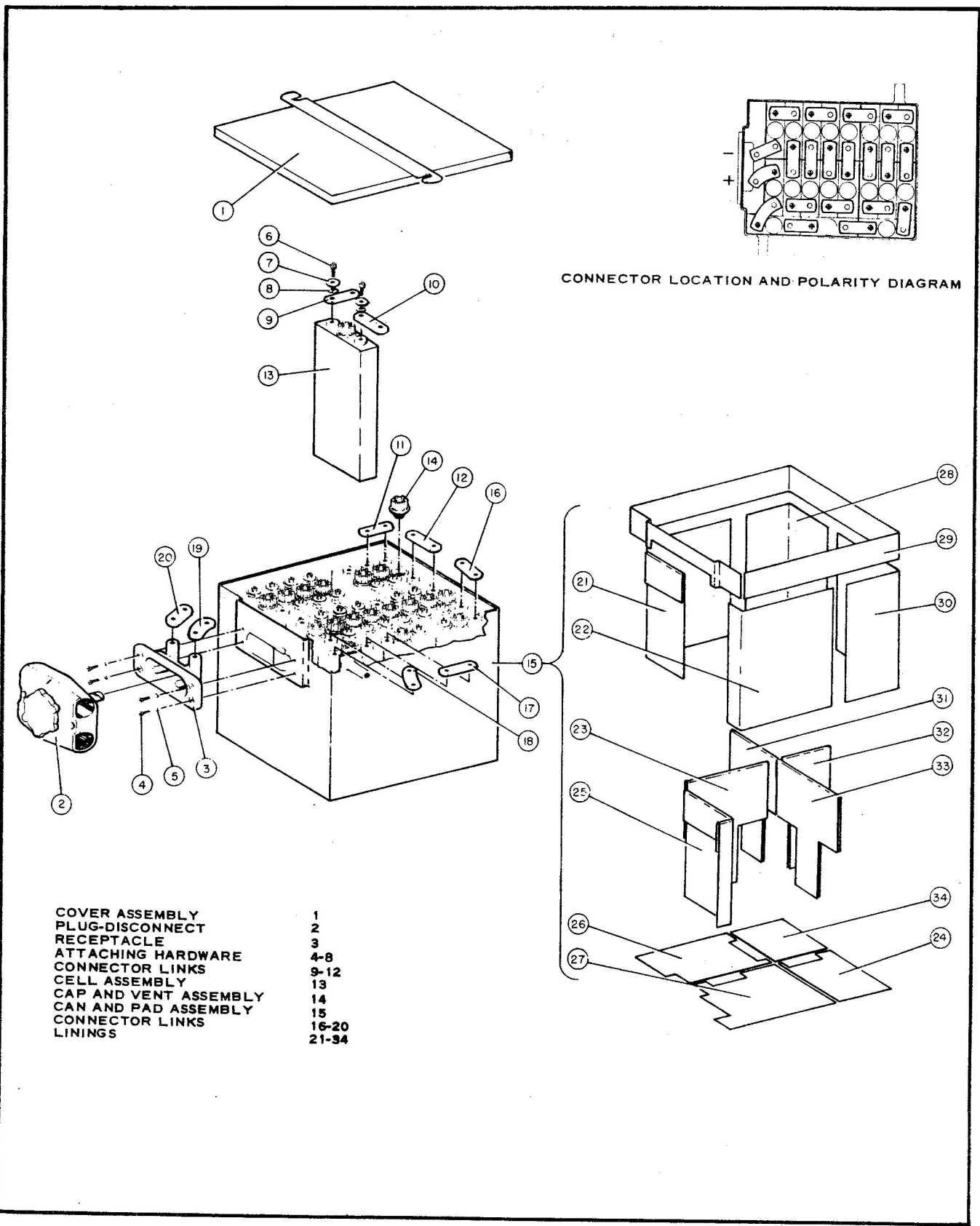
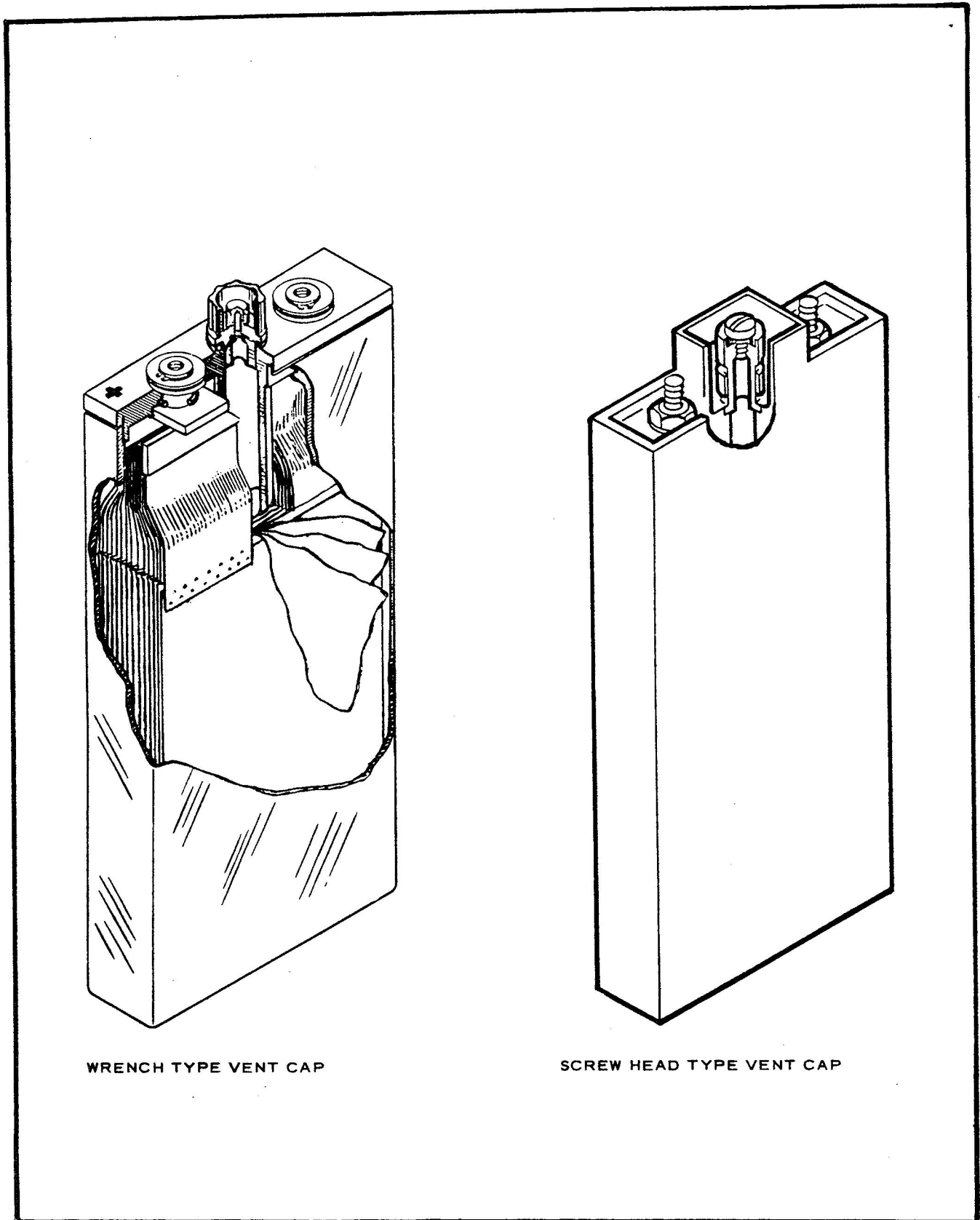


Figure 2-1 Exploded View of Type MA-4 Battery





WRENCH TYPE VENT CAP

SCREW HEAD TYPE VENT CAP

Figure 2-2 Cutaway View, Nickel Cadmium Cell

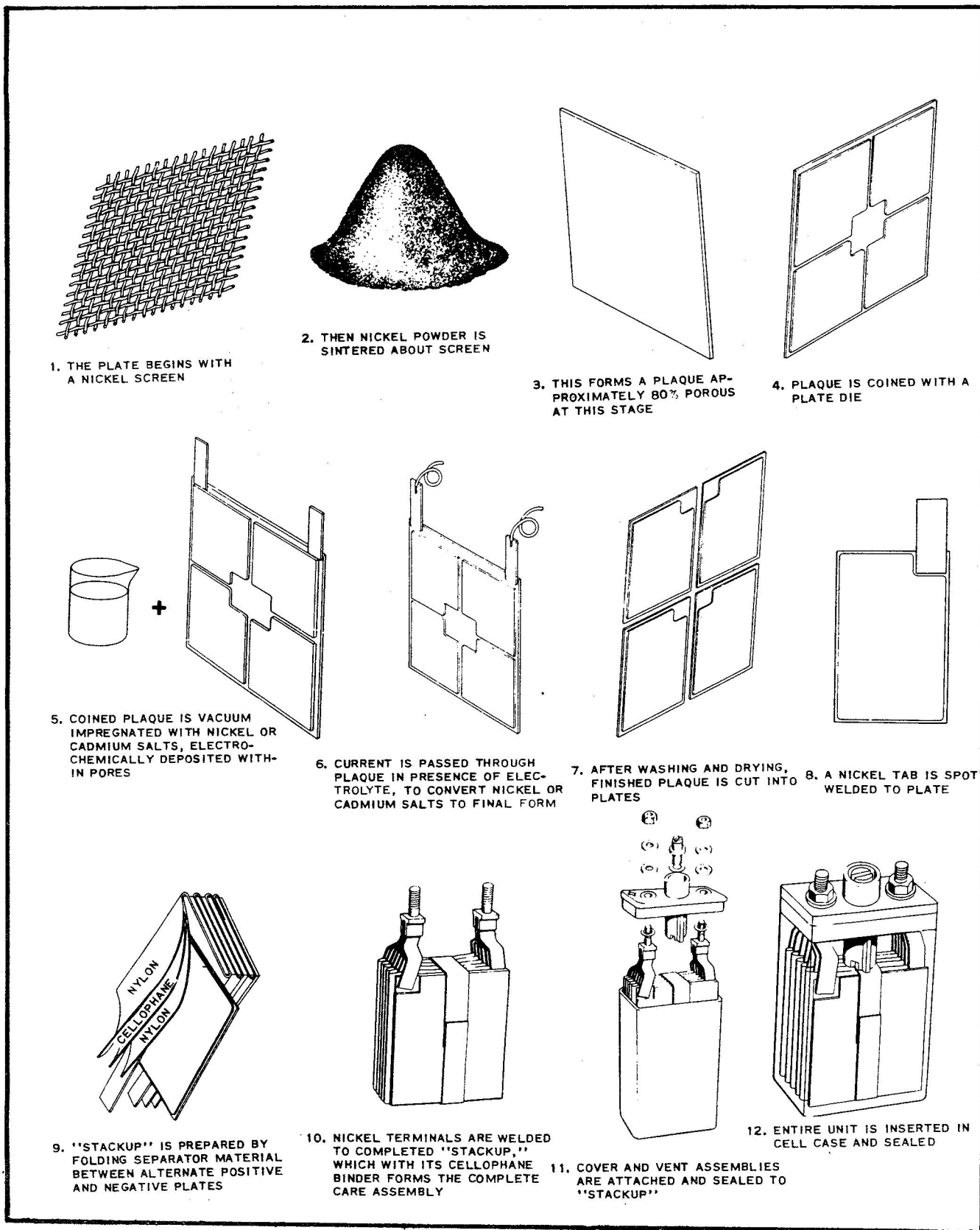


Figure 2-3 Construction of Nickel-Cadmium Sintered Plate and Cell

(c) The Electrolyte - The electrolyte used in nickel-cadmium batteries is a solution of 30 percent by weight of Potassium hydroxide (KOH) in distilled water. The electrolyte provides a conductive path for the current. While it is an agent of the charge and discharge processes, its density and composition is not altered as a result of the chemical reactions, and the electrolyte concentration remains essentially constant regardless of the state of charge of the battery. The KOH electrolyte in the battery should contain less than 5 percent by weight of potassium carbonate ( $K_2CO_3$ ) impurity. Electrolyte for replacement should contain less than one percent  $K_2CO_3$ .

(d) The Cell Container - The cell container may be of molded nylon, polystyrene, suitable plastic or metal. It houses the cell core.

(e) The Cell Vent - Each cell is equipped with a vent plug which serves as a gas relief vent if its rated pressure is exceeded. When removed, access is gained inside the cell, for verifying and topping up electrolyte level as required. When in place, its rubber expansion collar permits the release of gas when gas pressure exceeds approximately 5 psi.

## DEFINITIONS

7 The usual electrical definitions and values apply to the use and maintenance of nickel-cadmium batteries. The following definitions are given to amplify, or to describe special aspects:

(a) Ampere Hour - An ampere-hour is a unit of measure for battery capacity and is obtained by multiplying the current flow in amperes by the time in hours in which the current is delivered.

(b) Discharge Rate - The discharge rate is the average amount of current which a battery will provide over a given time before its ON-LOAD voltage drops to the predetermined value of 1.00 volt per cell. The discharge rate is expressed for convenience as a multiple (or fraction) of the nominal rated-capacity. That is a "one C" (1 C), or one hour rate of discharge for a 35 ampere-hour battery would be a discharge rate of 35 amps for one hour. Similarly, a 22 AH battery being discharged at 2C would be discharged at 44 amperes. Generally, the higher the discharge rate the lower the available capacity.

(c) Rated Capacity - Military types of nickel-cadmium batteries are rated at the two hour rate of discharge to an end voltage of 19.0 volts. If a battery is stated to have a nominal capacity of 35 AH when fully charged, it would be capable of delivering  $35/2 = 17.5 = 1/2C$ . amps for two hours to an end voltage of 19.0 volts at room temperature (70 to 80°F). Types developed in the US as Commercial e. g. the CA-10N, are initially rated at the five hour rate, and appropriate adjustments are made when transposing this capacity into the equivalent two hour rate. Although two batteries may have the same nominal capacity they may vary in their ability to deliver current at various rates of discharge dependent on their internal design. A high-rate battery has many thin plates a design which allows for good output capacity at high rates of discharge, even at low temperatures. A low-rate battery has fewer and thicker plates which allow for good capacity at long low rates of discharge.

(d) Charge - Charge is an electro-chemical process by which electrical energy in the form of direct current (forced through the battery in a direction opposite to that of the discharge current) is converted to chemical energy.

(e) Discharge - Discharge is an electro-chemical process in which chemical energy is converted into electrical energy in the form of direct current flowing from the battery through an external circuit.

(f) Cycle - A battery cycle consists of one discharge followed by one charge.

(g) Charged Battery - A charged battery is one in which continued passage of charging current produces no further appreciable conversion of electrical energy into chemical energy. To fully charge a nickel-cadmium battery it is necessary to replace 120-140% of the capacity removed from the battery during the previous discharge. If the battery is fully discharged, then 120% to 140% of the nominal capacity must be replaced in the battery during charge. The nickel-cadmium battery may be considered to be charged if any of the following conditions exists:

(1) After a constant potential charge, the charge current has dropped to a low trickle for a period of approximately one hour during which the battery voltage remains constant.

(2) During a constant-current charge, the cell voltages have reached 1.6 volts/cell and have remained there for at least one hour.

(3) On open circuit, the battery voltage is above 1.28 volts per cell.

(h) Discharged Battery - A discharged battery is one in which all the chemical energy has been expended and it is no longer possible to receive useful conversion of chemical energy to electrical energy. Normally the battery may be discharged at 1/2C down to an on-load voltage of 1.00 volt per cell before it is considered to be fully discharged. However, if extremely high discharge rates are being used, for example 10C to 15C (6 to 4 minute rate) then the discharge may be carried down to as low as 0.74 volts/cell (on load) before the battery is considered discharged. On open circuit, if a battery has an average voltage of 1.25 volts/cell or less, it may be considered to be discharged.

(j) Stand-by Service - This refers to an installation in which the battery STANDS-BY, ready to furnish power during interruption in the normal DC power supply. For example, the battery in an aircraft stands-by to power certain emergency equipment if the normal source of DC power fails in flight.

(k) Cell Unbalance - Is a condition which is induced mainly as a result of repeated deep-cycling at constant-potential recharge. Under these conditions, some cells may not recharge fully, and will have a lower charge level than the other cells in the battery. If deep-discharges repeat, some cells may then undergo a period of polarity reversal, thereby further inhibiting their ability to absorb a good charge during subsequent constant-potential recharging. Since batteries installed in aircraft are effectively connected into a Constant-Potential recharging system, there is a need of periodical constant-current charging, or

battery reconditioning, so that cell-unbalance can be corrected through a controlled over-charge.

(m) Polarity Reversal - Can take place in an unbalanced cell, when the battery is undergoing deep discharge. In such a case, the unbalanced cell will become discharged first, but the other cells are still passing the battery discharge current through the discharged cell, which has then the effect of charging the latter backwards and inducing polarity reversal in it.

(n) Controlled Overcharge - Is that normal overcharge given a battery during charging to ensure that the battery is fully charged. In constant current charging, the battery is given a controlled overcharge of up to 40% of its rating.

(p) Uncontrolled Overcharge - Takes place in a battery and can produce thermal runaway and damage if the Constant Charging Potential is too high, or if the Constant current Charge is unduly prolonged.

(q) Thermal Runaway - Is a destructive condition which can occur under UNCONTROLLED OVERCHARGE in both vented and sealed batteries, but more especially in sealed, batteries.

## CHARACTERISTICS AND PROPERTIES

8 Nickel-cadmium batteries possess several aspects and characteristics which functionally distinguish them from other storage batteries, and which have to be understood in order to enable safe and economical application.

9 Table 2-1 lists and contrasts the advantages/disadvantages of sintered-plate nickel-cadmium batteries:

ADVANTAGES	DISADVANTAGES
<p>Long Life - A long life can be expected, with numerous usage cycles. Individual cells are replaceable, enabling economical and convenient repairs in cases of failure of individual cells. Cells can be easily connected and disconnected, however connector maintenance is necessary to ensure connector cleanliness, security and tightness.</p> <p>Stable Density of Electrolyte - The density of the electrolyte is stable under normal operating conditions, and does not require Specific Gravity readings to be taken.</p> <p>Voltage/Charge Characteristics - The voltage level varies little except at extremes of full-charge and full-discharge, providing a stable voltage under varying state-of-charge conditions.</p> <p>Temperature/Performance - The battery, with 30% KOH, can withstand without damage temperatures down to -54°C (-65°F). Since electrolyte concentration does not vary with state of charge, the freezing point stays at a fixed minimum. The battery voltage remains relatively steady under load even at temperatures down to -40°C (-40°F).</p> <p>Voltage/Load Characteristics - The nickel-cadmium battery maintains a relatively stable voltage under varying load conditions, due to its very low internal resistance.</p> <p>Storage Life - Nickel-cadmium batteries can stand idle or in storage, in any state of charge, for indefinite periods, without suffering physical damage. They do not require re-fresher charges while in storage. When no longer required in an application, they can be cleaned, repackaged, and returned to storage.</p>	<p>High Initial Cost - The cost of nickel-cadmium batteries is considerably higher than that of lead-acid batteries, and effective maintenance is required to enable its operational advantages to be realized. Also, cell interchangeability means numerous exposed, removable connections which have to be kept cleaned and tightened. Handling care is required to prevent intercell sparking.</p> <p>Electrolyte Contamination - The KOH electrolyte contaminates easily, both in the cells and in containers, unless it is kept covered at all times. KOH electrolyte has an affinity for carbon dioxide (CO<sub>2</sub>) in ambient air, causing a reaction which produces potassium carbonate (K<sub>2</sub>CO<sub>3</sub>) and derates battery capacity and performance. Due to high plate porosity, the cell electrolyte is not easily replaced.</p> <p style="text-align: center;"><u>NOTE</u></p> <p>The stable density characteristic of the electrolyte means that the battery State-of-Charge cannot be ascertained by S. G. readings.</p> <p>Voltage/Charge Relationship - The stable voltage/charge characteristic of the battery means that its state of charge cannot be easily determined from its voltage reading, unless sufficiently precise measuring instruments are available.</p> <p>Temperature/Performance Characteristics - High ambient temperatures may induce thermal runaway under certain charge conditions. (See Theory of Operation).</p> <p>Voltage/Load Characteristics - It is not easy to determine the state of charge by the battery voltage. Also, because of very low internal resistance, very high discharge currents can occur under short-circuit conditions, which can be hazardous to personnel and damaging to equipment. During maintenance, precautions have to be taken to prevent intercell shorting, which can ignite ambient combustible gases.</p> <p>Storage Life - While nickel-cadmium batteries retain their charge better than some other battery types when stored in the charged state, some self-discharge does take place, especially at higher temperatures.</p>

Table 2-1 Nickel-Cadmium Batteries - Characteristics and Properties



**SECTION 2****DEVELOPMENT****GENERAL**

1 Whereas some conventional nickel-cadmium batteries, e.g. the pocket-plate (or JUNGNER) type, had been used in some special airborne applications, their use was limited due to their high weight per ampere-hour, and their relatively high internal resistance.

2 During the Second World War, Germany developed a nickel-cadmium battery in which the positive and negative plates were made of sintered nickel, and used such a battery in their FOCKE-WULF aircraft. The sintering process had the effect of considerably enlarging the effective plate area, thereby allowing a decrease in battery weight and internal resistance. The chemical changes taking place in the sintered-plate battery are essentially the same as in the pocket-plate battery.

**SINTERED-PLATE BATTERY TYPES**

3 There are two basic types of sintered-plate nickel-cadmium batteries:

(a) The VENTED type, in which the cell incorporates a pressure-vent in the cell cap. These vents open when the cell internal pressure exceeds ambient pressure by approximately 5 psi.

(b) The SEALED type, in which the cell cap nominally seals the cell. Normal operation is possible in a sealed condition, because the gases evolved at one plate are theoretically absorbed in the other. However, under some conditions of operation, such as during overcharge, sealed batteries are more sensitive to thermal-runaway. Some sealed-type batteries which have been developed for aircraft have incorporated a thermal protective relay.

**TYPES USED IN CANADA**

4 Only the VENTED-TYPE of sintered-plate nickel-cadmium aircraft battery is used in service aircraft.





## SECTION 3

## THEORY OF OPERATION

## GENERAL

1 The basic theory applicable to storage batteries as energy-conversion devices in which the conversion process is reversible, also applies to nickel-cadmium batteries. General considerations regarding battery voltage, capacity, rating and processes also apply.

## CELL VOLTAGE

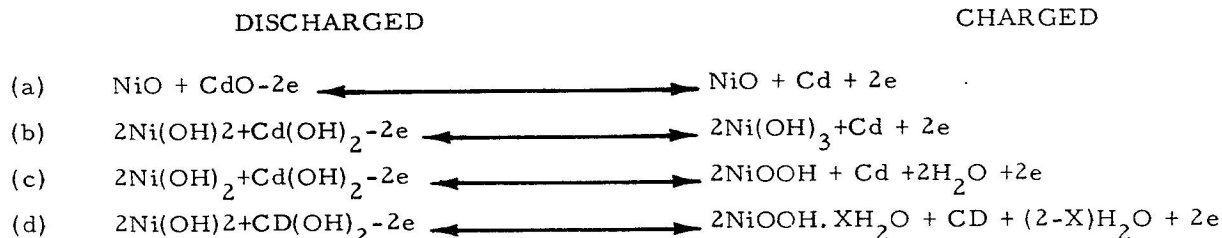
2 In nickel-cadmium batteries, the potential difference developed between the positive and negative plates, is nominally 1.3 volts. The cell-voltage goes up to 1.6 volts per cell when nearing end of charge. However, during normal use, and due to the low internal resistance allowed by the sintered plates, the cell voltage remains steady under varying load-conditions, at 1.28 to 1.30 volts per cell. Normally, the battery may be discharged at average rates down to an on-load voltage of 1 volt/cell.

3 At very high discharge rates, the discharge may be continued down to 0.74 volts/cell on load before the battery may be considered discharged. However, if the battery is discharged below 1 volt/cell at average rates, risks increase of inducing cell unbalance in some cells.

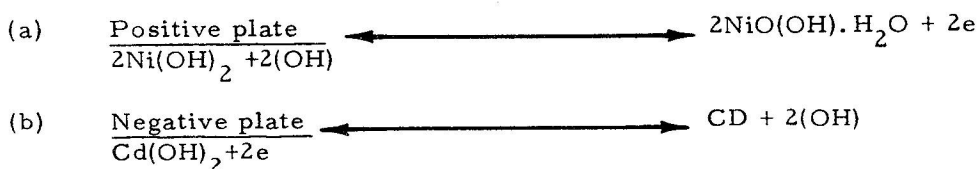
## CELL CHEMISTRY

4 The theoretical electro-chemistry of the

9 The principle of operation may be represented by any of equations (a), (b), (c), (d):



10 The plate reactions for equation (d) are as follows:



nickel-cadmium system is rather complex, and attempts at simplifications tend to lead to discrepancies.

5 A knowledge of the electro-chemical processes that occur in this type of battery is not necessary for its satisfactory operation and maintenance. However, an idea of the chemical changes may be of interest and the following is included for information.

## PLATE CHANGES DURING CHARGE

6 When a charging current is applied, the negative plate changes, losing oxygen and becoming metallic cadmium. The positive plate is brought to a higher state of oxidation by the charging current. This is not a simple oxide, but rather a hydroxyl oxide (NiOOH).

## PLATE CHANGES DURING DISCHARGE

7 During discharge, the negative plate is oxidized to cadmium oxide, and the positive plate is reduced to a lower nickel oxide.

## ELECTROLYTE CHANGES

8 The electrolyte, while it remains essentially constant in concentration, does enter into the electro-chemical reactions by virtue of effecting electron-transfers.

11 Equation (a) is an oversimplification but is easy to understand as it indicates the oxidation process of the electrodes, while electrons are produced. Equation (b) indicates that the oxidation steps actually produce hydroxides. Equations (c) and (d) are more nearly correct from an electrochemical viewpoint. In equation (c), the term  $2\text{H}_2\text{O}$  suggests a change takes place in the electrolyte density, although this is too small to be detected by a hydrometer reading. Actually the greater part of this  $2\text{H}_2\text{O}$  term is bound up as water of hydration in the positive plate. The quantity of water bound up in the nickel electrode is  $\text{XH}_2\text{O}$  as shown in equation (d), where X may be any number from 0 to 2. The resulting water change which is left to alter the electrolyte S.G. slightly is therefore  $(2-X)\text{H}_2\text{O}$ . Readers desiring further information on the electro-chemistry of these reactions are directed to the references given in Part 1.

### ELECTROLYTE DENSITY VERSUS CELL PERFORMANCE

12 In the sintered plate nickel-cadmium battery, performance is optimized when the density of the KOH electrolyte is at 1.280 to 1.300. This is obtained when KOH concentration is 30% by weight.

13 Refer to Figure 3-1 for a diagram of the behaviour of KOH in water solutions as a function of temperature and concentration. Since the density of the electrolyte does not vary with the state of charge, risks of battery freezing are therefore not increased when the battery is in a discharged state.

### BATTERY CYCLING

14 A cycle is one discharge followed by one charge. A cycle may be classed as shallow or deep. A shallow discharge consists of a partial discharge and charge whereas a deep cycle consists of a full discharge where all or nearly all the available capacity is drained from the battery, followed by a full charge.

15 The nickel-cadmium battery operates best when it is cycled reasonably frequently on a cycle of moderate discharge followed by a full charge that replaces 120% to 140% of the capacity removed.

### DESCRIPTION OF RUNAWAY

16 THERMAL RUNAWAY is a condition which occurs in nickel-cadmium batteries, especially those of the sealed type, under conditions of uncontrolled overcharge. However, it can also occur in the vented-type batteries if left on overcharge for long periods at high charge voltages.

17 Runaway occurs in a fully charged battery, in the overcharge stage, when the current rises out of all proportion to the impressed charge voltage. There is a decrease in internal resistance at that stage, so the battery accepts a higher current for the same impressed voltage. Since the battery is fully charged, the greater portion of the current accepted is dissipated as heat, which has the effect of further decreasing internal resistance, leading to still increasing charge current.

18 Runaway is dependent on charging voltage and temperature. Under constant-potential charging, the higher the temperature, the lower the voltage setting required to produce runaway. Similarly, on constant current charging, if a battery is kept on charge longer than is necessary to restore 140% of the capacity previously used, runaway conditions can develop as a greater portion of the charging current dissipates in the form of heat.

19 Runaway is undesirable and dangerous in that it causes rapid electrolyte boil-off and eventual destruction of the battery if continued for a sufficient length of time. Runaway conditions can be detected by temperature, voltage, or current rates, as detailed elsewhere in this EO.

**PART 3****OPERATION AND SERVICE****SECTION 1****OPERATIONAL ENVIRONMENT****GENERAL**

1 The Nickel-Cadmium battery operates successfully over a range of temperatures from  $-40^{\circ}\text{C}$  to  $54.4^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$  to  $130^{\circ}\text{F}$ ). It is possible to operate the Nickel-Cadmium battery at temperatures above  $54.4^{\circ}\text{C}$  ( $130^{\circ}\text{F}$ ) for short periods of time. It is not a recommended procedure because of the possibility of thermal runaway, and of possible deterioration of the cellophane of the nylon cloth-cellophane separator at temperatures above that point.

**LOW TEMPERATURE OPERATION**

2 Nickel-cadmium batteries have reasonably good low-temperature characteristics provided the proper electrolyte, if the proper concentration, is used. It is essential for optimum low-temperature performance that the battery electrolyte be 30% KOH by weight and contain less than 5% by weight  $\text{K}_2\text{CO}_3$  (potassium carbonate) impurity, see Figure 3-1.

3 The freezing point of the nickel-cadmium battery remains constant regardless of the state of charge since the density of the electrolyte remains essentially constant. This ensures resistance to freezing damage, and fair performance down to  $-65^{\circ}\text{F}$  provided the electrolyte purity and concentration are adequate.

**LOW TEMPERATURE CAPACITY**

4 A nickel-cadmium battery in good condition and fully-charged should deliver 50% of

its rated capacity at  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ) at the one-hour rate of discharge (1C) to an end voltage of 19.0 volts.

**CHARGING AT LOW TEMPERATURE**

5 Nickel-cadmium batteries will accept a charge at temperatures down to  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ). At low temperatures, the charging period required to bring the battery to full charge is longer and requires a slightly higher charge potential.

**VOLTAGE CHARACTERISTICS AT LOW TEMPERATURES**

6 The discharge voltage characteristic and capacity of the nickel-cadmium battery decrease with a decreasing temperature and/or an increase in discharge rate.

7 Although the total ampere-hour output is less after low-temperature charge and low-temperature discharge than it is after normal-temperature charge and low-temperature discharge, the discharge characteristic is usually higher after the low-temperature charge.

**SLEEP EFFECT**

8 If the battery voltage drops sharply on low temperature discharge to a value below 12 volts and stays there for several minutes before slowly rising, the battery is said to have a "sleep effect". Sleep effect is usually caused by a low KOH concentration and/or a high  $\text{K}_2\text{CO}_3$  concentration in the electrolyte. This condition can be rectified by means of special procedures to replace the battery electrolyte with fresh, pure 30% KOH electrolyte containing less than one percent  $\text{K}_2\text{CO}_3$ .

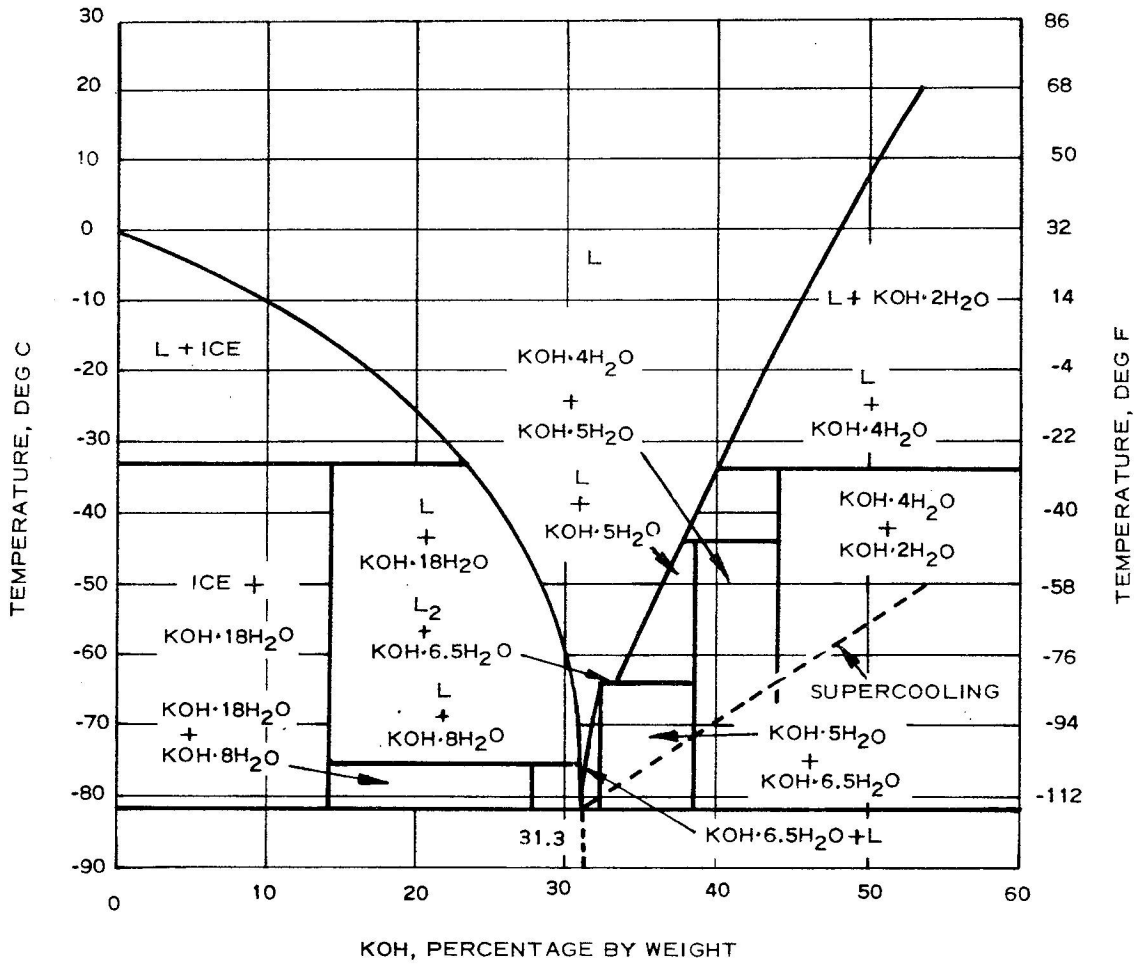


Figure 3-1 Solid-Liquid Equilibria In The System KOH - H<sub>2</sub>O

## SECTION 2

# INSPECTION

### PRIMARY INSPECTION

1 The Primary Inspection may be carried out as follows with the battery on board the aircraft, and can serve as a preflight inspection:

(a) Visually check the battery and cells for evidence of damage or distortion. Check battery and connections for security.

(b) Visually check for cleanliness. White salts deposits and electrolyte spillage may indicate high electrolyte levels, or improper voltage regulator setting.

(c) Check the battery voltage on open circuit to determine the state of charge. If the open circuit voltage is 24.3 volts or above, as determined by a voltmeter having one percent accuracy, the battery may be considered to be 80% charged.

2 If after carrying out the above, the state of charge of the battery is in doubt, the battery should be further checked using the Charge Acceptance Check, or the Discharge Voltage Check, as given below. Alternately, the battery should be replaced, or removed for a refresher charge.

### REFRESHER CHARGE

3 This is a constant potential charge or a constant-current charge given in the battery shop. The battery is fully charged, and the electrolyte level is checked and adjusted. If cell unbalance is suspected, a major inspection is carried out.

4 This charge-inspection routine is carried out when the state of charge of the battery is in doubt but does not warrant a full reconditioning procedure. It is advisable to give the battery a refresher charge whenever the battery sits idle for long periods of time or when the state of charge of the battery is in doubt. When an aircraft undergoes prolonged maintenance or inactivity, its battery should be given a refresher charge just prior to the aircraft being returned to service.

### MAJOR INSPECTION

5 Major inspections of nickel-cadmium batteries are required at specified intervals, determined by the nature of service they are subjected to. They are at such times to be removed from the aircraft for constant-current charging and other reconditioning.

6 Such battery major inspections are normally to take place at each aircraft periodic inspections, or at a frequency to be determined by User Commands according to the requirements of particular utilizations.

7 Battery major inspections are to be carried out in the battery shop and are to follow the procedures given for BATTERY RECONDITIONING, see Part 4.

### PRE-INSTALLATION INSPECTION

8 Reconditioned Battery - When installing a reconditioned battery in an aircraft, carry out the following:

(a) Ensure the battery is in a satisfactory state of charge.

(b) Ensure the battery is clean and dry, and that the internal links and connectors are secure.

(c) Ensure that the aircraft battery hold is clean, and that the battery attachment hardware in the aircraft is secure.

(d) Ensure that the aircraft venting system is in good condition, i.e. free from kinks, corrosion or other damage.

### INSTALLATION

9 Installation of a New Battery - Prior to original installation of a new battery in aircraft, the following procedures are to be carried out:

(a) Check battery case, cover and cells for damage or distortion.

(b) Check cell vents and cell cases for cleanliness - that there is no electrolyte spewage or white salt ( $K_2CO_3$ ) deposits which may cause intercell shorting or blocked vent plugs.

(c) Check battery and cell voltages to determine state of charge and whether there are any low or unbalanced cells.

(d) Check that all terminal post connections are secure and tight, and that cell polarity of the battery is in correct sequence.

(e) Give the battery a refresher charge or a conditioning cycle.

(f) Check electrolyte level and adjust if necessary. On receipt of a battery from storage, its electrolyte level may not be visible above the top of the plates, due to extensive absorption in plates. This condition may prevent the battery from accepting an initial charge. In such a case, top up cells with distilled water, but only to a level flush with top of plates. The highest electrolyte level will occur immediately at the end of charge, when it should be at least 1/4" but not more than 3/8" above level of plates.

10 Conditioning Cycle - Before placing a new battery into aircraft service, it is advisable to give the battery a conditioning cycle. A conditioning cycle consists of:

(a) Placing the battery on a constant-current charge at the five hour rate up to an end-voltage of 1.60 volts/cell maintained for one hour, see Table 4-1.

(b) Discharging the battery at the five-hour rate to an end voltage of 1.00 volt/cell, while recording the current and time elements. This constitutes a capacity check, see Table 4-1.

(c) Recharging the battery.

11 Applying a conditioning cycle to a new battery will ensure that it is fully charged, and will correct slight unbalance of cells that might have developed in storage. Also, it will provide an opportunity to check the electrolyte levels at end of charge and discharge and allow for proper adjustment.

### BATTERY STATE OF CHARGE UNKNOWN

12 If the state of charge of a battery is unknown, and it is not possible to discharge the battery down to 19 volts prior to charge, then the battery may be placed on a constant-current charge at the five-hour rate until the proper overcharge voltage is reached, i.e. 1.55 to 1.60 volts/cell, or 29.5 to 30.5 volts (on-charge voltage). Continue the overcharge for at least one hour, but no more than two hours. This constitutes a refresher charge.

**SECTION 3****SERVICING****GENERAL**

1 Nickel-cadmium batteries are supplied by the manufacturer in a charged condition, and containing the proper electrolyte. However since self-discharge takes place in storage, new batteries may be assumed on receipt to be in a discharged, or partly discharged condition. Therefore new batteries require servicing prior to installation, see Section 2, paragraphs 9 to 11.

2 Stand in Discharged State - New batteries, as well as discharged or partly discharged batteries may be stored indefinitely at reasonable temperature without suffering damage or physical deterioration. Discharged or partly discharged nickel-cadmium batteries may be returned to storage for subsequent issue and normal conditioning and service.

**CHECKING STATE OF CHARGE**

3 Occasions will arise where it is needed to determine the state of charge of a battery. Since in a nickel-cadmium battery the electrolyte density does not vary with the state of charge, the specific-gravity of the electrolyte does not give any indication. Also because of the low internal-resistance of the sintered plates, the voltage/load relationship varies only slightly, and requires an accurate instrument to detect.

4 Charge Acceptance Check - The best indication of the state of charge of a nickel-cadmium battery is the amount of current it draws when connected to a constant-potential bus. The higher the state of charge, the lower the charging current will be. This charge acceptance method of charge verification is given as follows:

(a) Connect a metered 28.5 constant potential supply to the battery.



Ensure proper ammeter protection against high surge currents.

(b) Note the charge current. If the battery is fully-charged, or nearly so, the initial current will be only one C to two C, and will drop off to a trickle current in less than 3 minutes. A battery in which the initial draw does not exceed two C may be assumed to have 80 percent capacity or more. If the battery is fully discharged, the initial surge current will be up to six C, and take between one-half to one hour to subside to a trickle current.

5 This charge acceptance characteristic is the preferred method of charge verification of nickel-cadmium batteries. In applications where this method of ascertaining the state of charge is frequently required, methods of carrying out same in-situ, if desired, may be developed locally, utilizing existing resources as much as possible. The battery charging current is the current draw after the aircraft battery is connected, less the current drawn when the battery is disconnected.

6 When carrying out a state of charge check utilizing the charge acceptance method, the 28.5 Volt Constant-Potential source may be left ON for a sufficient period necessary to bring the battery up to the desired state of charge.

7 The Open Circuit (OC) Voltage Check - The open-circuit (OC) voltage of a nickel-cadmium battery may be checked by using an accurate voltmeter (1% accuracy). A reliable reading may be obtained following 16 hours stand after charge, once the spurious charge voltages have subsided. If a battery supplies a small load for a short time after charge, such as happens in normal aircraft installations, the spurious charge voltages may be considered as having disappeared.

8 If the OC voltage of the battery is 24.3 volts or more, then the battery may be assumed to have retained at least 80% of its nominal capacity.

9 The Discharge Voltage Check - This is a precision on-load voltage check carried out, utilizing a volt-meter of 1% accuracy. Because of the slight slope of the nickel-cadmium discharge curve, see Figure 3-2, accuracy is essential in carrying out this check.

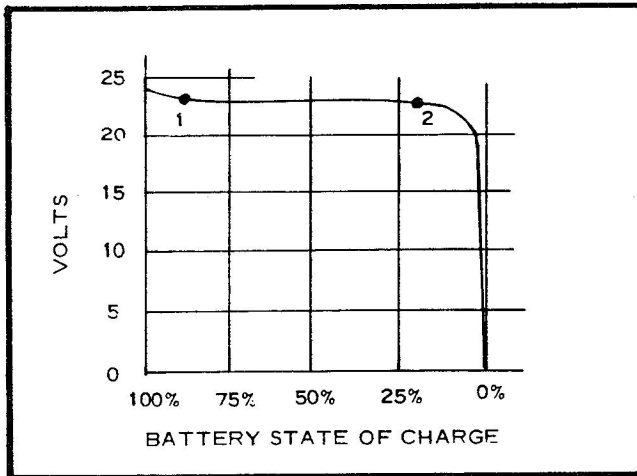


Figure 3-2 Typical Discharge Voltage Curve Under Moderate Load

10 Discharge the battery at normal temperature at the one-hour rate (i.e. one C). If the voltage remains above 22.9 volts after 3 minutes, then the battery may be considered to have retained at least 50% of its capacity.

### LOW ELECTROLYTE LEVEL

11 If it is noticed that the electrolyte level

is low in a battery installed in the aircraft, the battery IS NOT to be topped-in in-situ. A low-electrolyte level may then be primarily an indication of a low state of charge, and topping up the battery without first determining the state of charge can easily lead to excess electrolyte and spewage after the battery has recharged, and equipment damage and maintenance problems can ensue. Therefore, when a condition of low-electrolyte level is noted, the battery is to be removed from the aircraft for shop maintenance.

### OVERHEATING OF CONNECTORS

12 When checking nickel-cadmium batteries, whether installed in aircraft or not, particular care is required to verify that the battery internal linkages and intercell connectors do not show evidence of discoloration of heating.

### CLEANLINESS AND VENTING

13 Batteries in use, and the compartments in which they are housed in aircraft are to be kept clean, and free from acid contamination. The aircraft venting systems are to be kept in a clean and operating condition.



## PART 4

## CARE AND MAINTENANCE

## SECTION 1

## THE KOH ELECTROLYTE

**WARNING**

Potassium hydroxide electrolyte used in nickel cadmium batteries is very corrosive. If any is spilled on clothing, hands or other material it should be flooded immediately with cold water or boric acid solution. Consult Unit Medical Officer if the eyes are involved. Rubber gloves, aprons and face shields should be worn when handling potassium hydroxide.

**GENERAL**

1 The potassium hydroxide electrolyte (30% KOH) used in nickel-cadmium batteries is a solution of potassium hydroxide and pure distilled water, having a specific gravity of 1.280 to 1.320. It should be pure, and stay below 5% potassium carbonate ( $K_2CO_3$ ) contamination. Batteries are supplied in the filled condition with the correct electrolyte, electrolyte density does not normally require field checking. Electrolyte requirements by Field Units will be generally limited to topping up. Electrolyte is stocked in one-pint plastic bottles in the RCAF as Stock No. 6801-21-806-3954.

2 KOH Electrolyte Preparation - While in the RCAF ready-mixed pure 30% KOH is supplied as above, the procedure for its preparation is given for information. The proportion is 3.67 lb. of potassium hydroxide to one gallon of pure distilled water. The electrolyte is mixed in a glass or plastic container, by slowly pouring the potassium hydroxide into the water. Only KOH pellets of low  $K_2CO_3$  (i.e. 1% or less) content should be used. A glass or nylon rod is used to stir.

**WARNING**

NEVER POUR WATER INTO POTASSIUM

HYDROXIDE. Heat is generated so rapidly that the electrolyte is thrown on the person.

The resultant solution should have a specific gravity of approximately 1.30. Check with an appropriate hydrometer. If electrolyte is prepared in advance of use, it is to be stored in tightly sealed non-metallic containers so as to minimize exposure to atmosphere.

**ELECTROLYTE CONTAMINATION BY CO<sub>2</sub>**

3 Potassium hydroxide electrolyte has a high affinity for carbon dioxide ( $CO_2$ ) in ambient air. The reaction  $2KOH + CO_2 \rightleftharpoons K_2CO_3 + H_2O$  takes place hence a potassium carbonate contaminant is produced in the electrolyte when KOH contacts the atmosphere. Therefore, the main electrolyte concern, in the case of nickel-cadmium battery maintenance, is that of limiting contamination by  $CO_2$  in ambient air.

**CONTROL OF ELECTROLYTE CONTAMINATION BY CO<sub>2</sub>**

4 To reduce such contamination to a minimum, the following field procedures are to be followed:

- (a) Remove cell vent cap only when necessary to verify electrolyte level and to top up cells.
- (b) Cell vent caps are to be in place on the cell during charging and other shop maintenance.
- (c) Electrolyte bottles which are used for topping up must not be left open with the cap off longer than necessary.

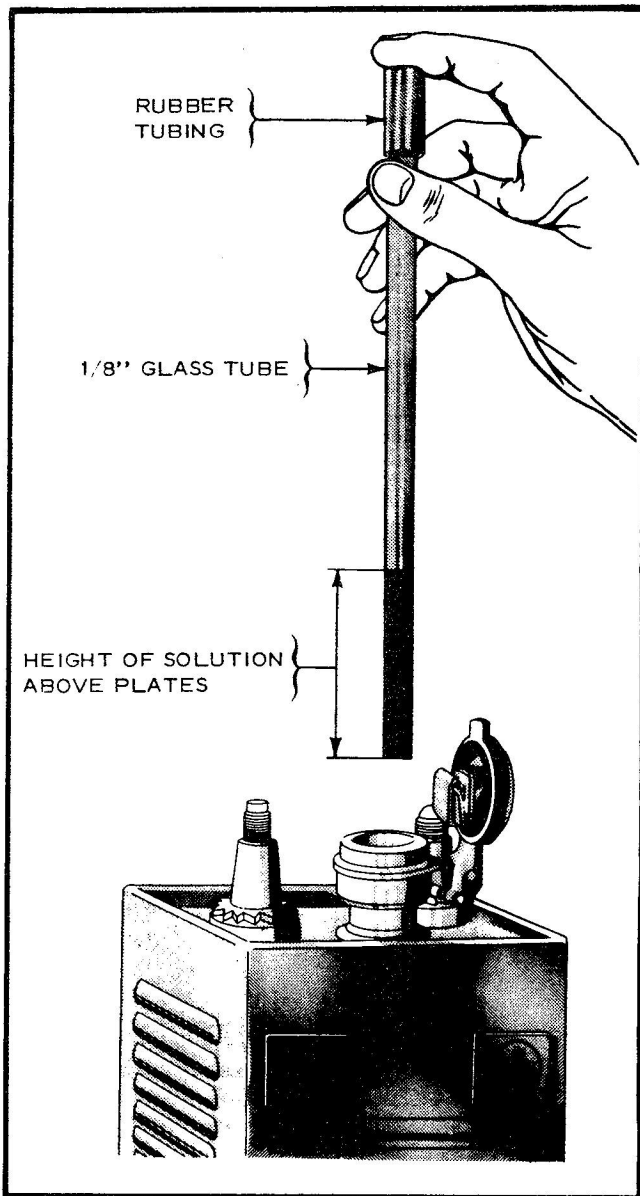


Figure 4-1 Method of Determining Height of Electrolyte Above Plates

5 In conventional type nickel-cadmium batteries, contaminated KOH electrolyte can be replaced easily. However, in sintered-plate batteries, so much of the electrolyte is retained within the plates that field replacement is not practical.

7 If electrolyte contamination is suspected in a sintered plate battery, e.g., as a result of low performance at high-rate discharge, or at low temperature, the battery is to be returned for repairs, with tag stating "Suspect Electrolyte Contamination, Reference this EO".

## ELECTROLYTE LEVEL

8 It is essential to maintain the proper electrolyte level for optimum performance. Too high an electrolyte level can cause excessive gassing and electrolyte spewage during charging, particularly on constant current charging. Too low an electrolyte level can cause high internal resistance and poor performance. Adjust the electrolyte level only 1/2 hour to 2 hours after end of charge, so as to avoid underfilling or overfilling, which can result in low electrolyte levels, or in electrolyte spewage. However if prior to charge the electrolyte level becomes no longer visible above the level of the plates, then the level should be adjusted so as to be just level with the tops of the plates.

### CAUTION

Do not use water labeled "water for batteries". This is distilled water shipped in carboys that may have been used for sulphuric acid. This water will ruin nickel-cadmium batteries.

Do not top up electrolyte level when the battery is discharged, or when the state of charge is unknown.

9 The electrolyte level should be at least 1/8" above the tops of the plates at all times. The highest electrolyte level will be immediately at the end of charge at which time the level should be at least 1/4" but not more than 3/8" above the tops of the plates. If the level cannot be seen easily a glass tube must be used to determine the level. Select a tube approximately 6" long, with an inside diameter of 1/8", and open at both ends. Remove cell vent caps and insert the tube as far as it will go. Place a finger over the open end and withdraw the tube, see Figure 4-1.

10 Only distilled water or dilute KOH should be added to the battery electrolyte for topping-up purposes. Normally, distilled water is to be used. However, if electrolyte spewage or loss occurs, as evidenced by large amounts of white powder around the vent caps, topping-up should be carried out using a half and half mixture by volume of pure distilled water and 30% KOH. Such a mixture should be made in limited quantities only, and requires protection from ambient CO<sub>2</sub> just as 30% KOH does.

11 During discharge and in prolonged storage more of the electrolyte is absorbed into the plates, and the level drops, however on subsequent recharge the electrolyte level rises to its proper level again.

12 Recurring low-electrolyte levels in a cell may be an indication of cell unbalance.

### **GASSING AND SPEWAGE**

13 Provided that a battery is fully discharged prior to giving it a full constant-current charge, and provided the battery contains the correct amount of electrolyte, then excessive gassing and spewage does not occur.

14 Excessive gassing and spewage on charge may be due to one of the following:

- (a) High end of charge currents.
- (b) High electrolyte levels.
- (c) Battery only partially discharged prior to full charge.
- (d) Prolonged overcharging.

### **PREVENTION OF CONTAMINATION BY ACID**

15 Care is to be taken that Nickel-Cadmium batteries do not become contaminated with sulphuric acid, or hydro-sulphuric electrolyte. The possibility exists of heavy acid fumes con-

taminating alkaline batteries, hence the latter should not be brought in the vicinity of lead-acid batteries when these are being charged.

16 To minimize possibilities of electrolyte contamination between nickel-cadmium batteries and lead-acid batteries and vice versa, equipment utilized for maintenance of lead-acid batteries, e.g., gloves, aprons, are not to be used in connection with nickel-cadmium batteries at any time. Electrolytes must be clearly labelled.

17 Alkaline electrolytes such as potassium hydroxide (KOH) are chemical bases, and when these come in contact with an acid, water and salt is produced. It must be realized that when a distilled water container and a syringe are used for topping up a lead acid battery, both the water and syringe are acid-contaminated, then if the same syringe or water bottle is utilized for topping up an alkaline cell, battery contamination and neutralization occur. In this case, the reaction  $2\text{KOH} + \text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O} + \text{K}_2\text{SO}_4$  takes place, producing water and potassium sulphate. Such limited neutralization is not explosive or dangerous, but it has the effect of destroying battery capacity, hence prejudicing high value equipment.

18 In instances of limited holdings of nickel-cadmium batteries when a nickel-cadmium battery charging room as per EO 40-1-13B is not accessible or justified, improvised charging practices are to be such that contamination does not take place.



## SECTION 2

# CHARGING

### GENERAL

1 The vented sintered plate nickel-cadmium battery is readily adaptable to the standard charging systems. These include the following standard methods:

- (a) Constant current.
- (b) Constant potential.
- (c) Modified constant potential.
- (d) Float charging.

2 In addition, some pulse-charge methods have been developed, which require special equipment. The PCA130 charger-analyser is one such device, and is to be utilized for processing aircraft nickel-cadmium batteries at all units for which its scaling is authorized.

3 Units not scaled with special equipment are to carry out charging as per the constant-current method or the constant-potential method, as applicable, utilizing standard equipment. Table 4-2 lists special equipment required in addition to equipment normally utilized in battery shops.

4 Personnel carrying out and supervising the recharging of nickel-cadmium batteries are to familiarize themselves with signs of incipient thermal runaway developing in batteries under charge and are to be alert as to its presence and meaning in order that battery damage may be minimized.

5 Signs of Incipient Runaway - Thermal runaway developing in a battery under charge may be detected by the following signs:

- (a) A significant rise in temperature of the battery at the end of charge (above the level of 37.8°C (100°F)).
- (b) Under Constant-Potential charging, a gradual rise in current with time can be noted, instead of the normal current fall-off.
- (c) Under Constant-Current charging, a fall in battery voltage with time can be noted, instead of the characteristic rise in voltage occurring with time at end of charge.

6 If signs of runaway are detected early, the charge is to be immediately terminated and the battery allowed to cool. If there is no evidence of battery damage, the battery is to be given a reconditioning cycle, or a reconditioning check, as may be required, prior to returning it to service.

7 Charging with Reversed Polarity - Accidental charging with a reversed polarity, if detected quickly, will not damage the battery, but is to be avoided. In the event of accidental recharging with a reversed polarity, a battery reconditioning cycle is to be carried out.

### CONSTANT CURRENT CHARGING

8 To obtain optimum performance from a nickel-cadmium battery, it is essential to replace 120% to 140% of the capacity withdrawn in the previous discharge, or if the battery is fully discharged, to replace 120% to 140% of its nominal capacity. This is best achieved by the constant current method.

9 Constant-current charging is the preferred shop charging method, whenever a charger-analyser is not available.

10 Under constant-current charging, the charging voltage level is controlled so as to maintain a steady charging current over the appropriate time period for the battery under charge, see Table 4-1. This procedure ensures sufficient overcharge current to fully charge the battery and to correct slight cell unbalance. For example, a 34 ampere hour battery multiplied by 140 percent of its rated capacity (34 x 1.40) equals approximately 48 ampere hours.

11 Constant current charging may be accomplished by using a rectifier or motor-generator type power source, in which provisions exist to adjust the voltage to the value required to maintain the desired charge-current. Normally, constant-current charging should be accomplished through use of the standard TUNGAR chargers, by manipulating the voltage taps so as to maintain the current at the required value.

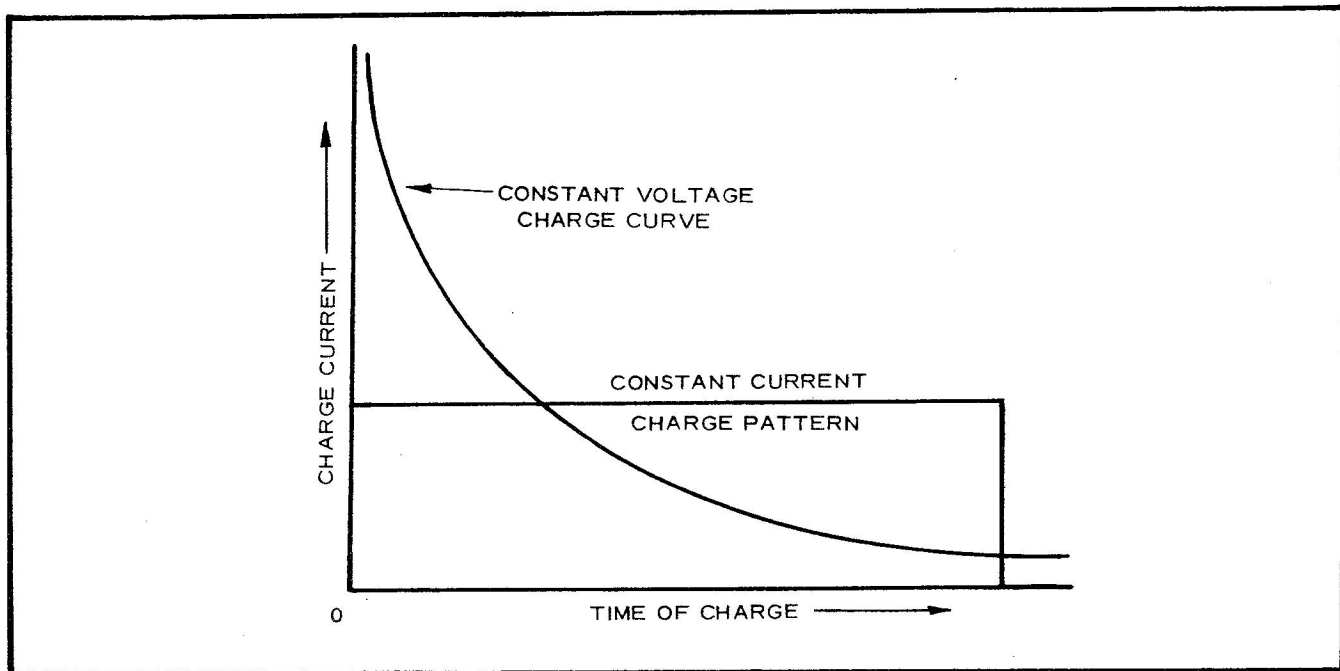


Figure 4-2 Relative Charge Patterns for Constant-Current and Constant-Potential

12 A record of the average charging current for applicable intervals has to be kept for each battery undergoing charge. Personnel carrying out constant-current charging operations shall maintain such a record, and shall monitor the charge time so as to ensure conditions likely to induce thermal runaway do not occur.

13 Prior to constant-current charging, it is desirable to fully discharge the battery down to its on-load voltage of 19 volts, or 1 volt/cell. The battery is then charged at a constant rate for a period of time sufficient to fully charge the battery. The initial draw is usually considerably less than for the constant-potential method and as a consequence it requires a longer length of time to fully recharge the battery. The end of charge voltage is not limited, as in the case of the constant-potential charge and as a result each cell is given the same amount of charge, thus rectifying any cell unbalance.

14 A convenient rate of constant-current charging is the 5 hour rate maintained for 7 hours. The battery may be charged at lower rates (for example, a 10 hour rate for 14 hours) however a longer charging time will be required to give the battery the necessary 20% to 40% overcharge to ensure a fully charged battery.

15 A higher rate of constant-current charging is not recommended unless an automatically controlled pulse charger is used which is capable of progressively monitoring the charging program. A device of this type should prevent excessive gassing and stop the charge when the battery is fully charged.

16 During the main portion of the charge the cell volts will be between 1.40 - 1.45 volts/cell or 26.6 - 27.6 volts for a 19 cell vented Ni-Cd battery. At the end of charge, during the overcharge portion, the voltage will rise to 1.55 - 1.60 volts/cell or 29.5 - 30.5 volts for the battery.

17 When charging at the 5 hour rate the battery should be kept on charge for at least one hour after the 29.5 on-charge volts is reached, but not exceeding two hours. This ensures proper controlled overcharge, without risks of uncontrolled overcharge.

18 State of Charge Unknown - If the state of charge of a battery is unknown and it is not possible to discharge the battery prior to charge, then charge the battery at the five hour rate until the overcharge voltage is reached i.e. 1.55 - 1.60 volts/cell, or 29.5 to 30.5 volts for battery on-charge voltage. Continue the overcharge for at least one hour but not more than two hours. This constitutes a refresher charge.

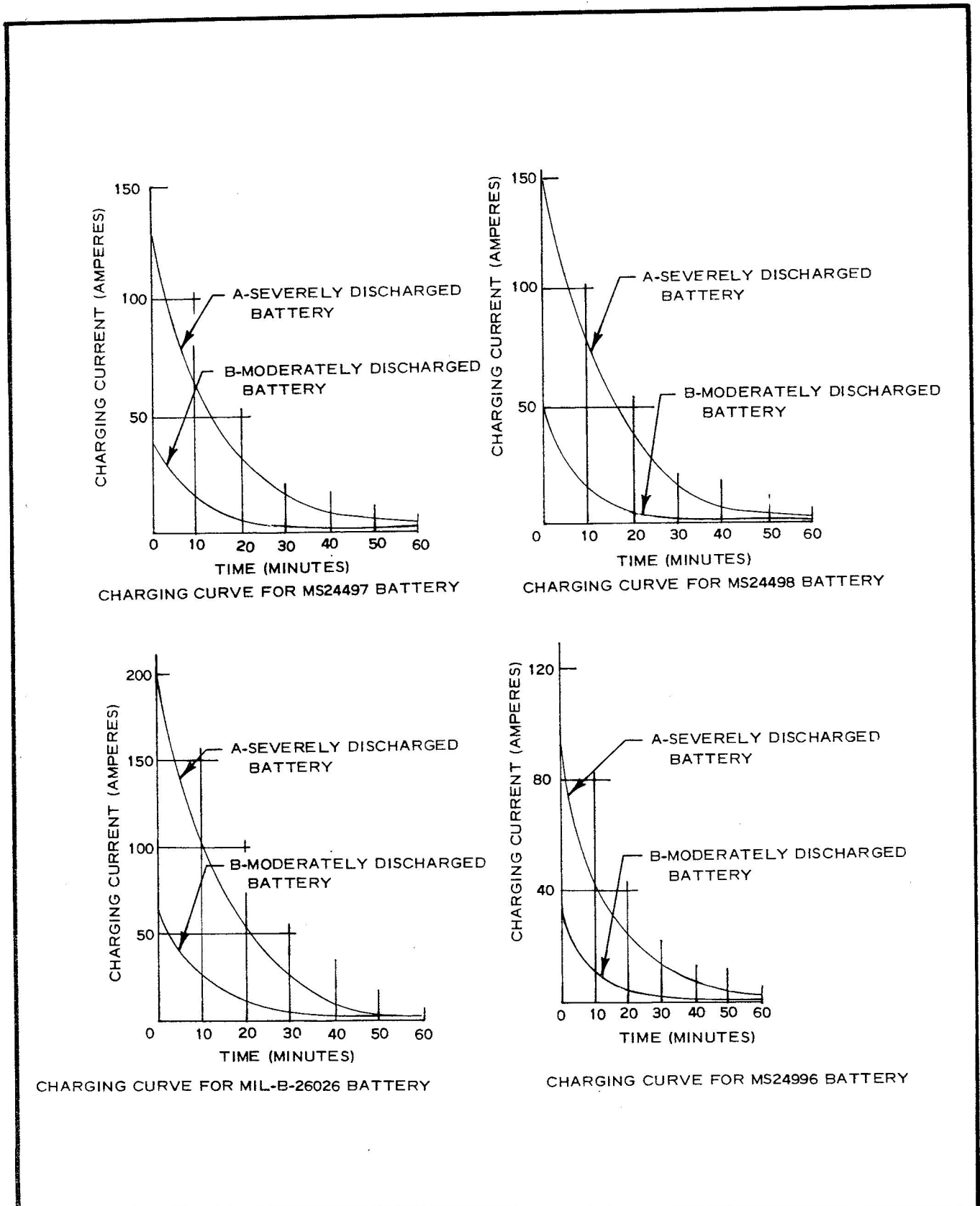


Figure 4-3 Typical Charging Curve at 28.5 Volts Constant Potential

## CONSTANT POTENTIAL CHARGING

19 The constant potential method takes advantage of the rapid recharge capability of nickel-cadmium batteries.

20 Constant potential charging can be effected from any constant potential source regulated at 28.5 volts to 29 volts (for a 24 volt 19 cell battery), and able to absorb the high initial charging currents drawn by the battery under charge. Motor-Generator sets, Rectifiers, APU's etc. may be used where necessary to accomplish such a charge. Parallel charging is not recommended.

21 Charge Pattern - When charging batteries by the constant potential method, the charging current is automatically regulated by the battery. Batteries cannot be overcharged by this method if the charging voltage is maintained at the correct value. Refer to Table 4-1 for correct constant potential charging voltages. The charging current of a severely discharged battery generally will follow curve A in Figure 4-3. Notice that the current starts at a high value but quickly decreases as the battery gains its charge. The current will finally level out at approximately 5 amperes. The values of current and time in curve A illustrate a battery which has been discharged to the greatest degree which would normally be encountered in the aircraft. The peak current and time will be proportionately less for a battery which is less severely discharged as shown in curve B. Initial charging currents can be from 40 to 200 amperes depending on the particular battery being charged. The current will gradually decrease to 5 amperes in approximately 30 minutes depending on state of charge of the battery when placed on charge.

22 At initial charge rates of 100 amps (approximately 4C) and 28.5 to 29 volts constant potential a 22 AHR (MS24497 type) battery will be fully charged in from 1/2 hour to 1 hour.

23 The voltage regulation should be set at 28.5 volts for optimum performance. A setting of less than 28.5 volts will result in under-charging the battery. A higher setting will cause overcharging and result in excessive gassing, loss of electrolyte and possible run-away.

24 The main advantage of constant potential charging is that it will effect a rapid recharge with a minimum of gassing and electrolyte loss. Constant potential charging is, in general, the type of charging given the battery on board the aircraft. The disadvantage of constant potential charging is that, over a period of time, there is a progressive loss of capacity since the battery does not receive its 120-140% overcharge which is essential to maintain 100% capacity. Hence, a requirement exists to give the battery a reconditioning charge each periodic inspection, whenever possible.

25 The larger the output capacity in amperes, of the charging unit, the sooner the charge will be completed. Ni-Cd batteries can accept an initial charge current of approximately six times their rated capacity (6C) as an initial charge current. It should be noted that the initial surge current will be quite high (approximately 6C) for a fully discharged battery and drops off exponentially with time.

26 It is advisable that the battery open circuit voltage be at least 19.0 volts or more at the start of constant potential charging or otherwise very high initial current surges will result. If the open circuit voltage is below 19.0 volts, then charge at low rate until the battery voltage reaches 19.0 volts before commencing constant potential charging. Normally 3 to 5 minutes of low-rate charging should bring the battery voltage to 19.0 volts.

27 Verification of Full-charge State - To ensure the battery is fully charged, an ammeter having a 0-25 to 0-50 ampere scale may be connected in series with the battery and the source of power. The ammeter can be connected in the circuit when the charging current is 10 amperes or less as indicated by the generator test stand ammeter.



Do not connect a 0-25 or 0-50 ampere scale ammeter in series with the battery when the battery is initially connected to a constant potential charging source. Initial high charging current will permanently damage the ammeter.

28 The charging process should be continued until the current flow decreases to 1.0 - 0.5 amperes.



29 When conducting constant potential charging, personnel are to ensure that the voltage setting is not higher than authorized, so as not to induce thermal runaway.

### **MODIFIED CONSTANT POTENTIAL CHARGING**

30 The modified constant potential charge incorporates the advantages of both the constant potential and constant current methods. The rapid charge capability of the constant potential method is utilized by initially charging the battery at a constant potential of 28.5 volts. When the battery terminal

volts reach 28.5 volts and the charging current drops to the five hour rate then the charge is continued by the constant current method at the five hour rate for one hour. The battery should be at least 20% overcharged.

### **FLOAT CHARGING**

31 Fully charged batteries may be floated across a line voltage of approximately 1.4 volts per cell or 26.6 volts for a 19 cell battery. The voltage setting will vary slightly with ambient temperature and utilization rate of the float circuit.



**SECTION 3****BATTERY RECONDITIONING****GENERAL**

1 It may become necessary to recondition the nickel-cadmium batteries at periodic intervals for any of the following reasons:

- (a) Prolonged constant potential cycling.
- (b) Battery or cell damage.
- (c) Erratic characteristics.

**RECONDITIONING PROCEDURES**

2 Reconditioning of Nickel-Cadmium batteries is to be carried out as follows:

- (a) Check battery case, cover on cells for evidence of damage or distortion. Replace any damaged or distorted cells, see Table 4-3.
- (b) Check all cell vents and cell cases for cleanliness. Signs of excessive electrolyte spillage or white salt deposits ( $K_2CO_3$ ) may indicate intercell shorting or blocked vent plugs. Clean cells and case with clear water if required and brush off white deposits with a stiff, non-conductive brush.
- (c) Check that all terminal post connections are secure.
- (d) Check that polarity of cells is in the correct sequence.
- (e) Check battery volts and individual cell volts to determine the state of charge and whether there are any low or unbalanced cells. Weak or unbalanced cells may not appear obvious on an open circuit check. Cells may be considered unbalanced if they exhibit a voltage variation of 0.05 volts or more. Unbalance of cells can best be detected on charge or on load, when nearing end of charge or discharge.
- (f) Check electrolyte level and adjust if necessary. The electrolyte level should be at least 1/8" above the tops of the plates at all times. However, after periods of prolonged storage the electrolyte becomes absorbed in the plates and the resultant dryness can cause

high internal resistances which make normal charging difficult. Addition of pure distilled water up to the tops of the plates should then rectify this condition.

(g) Further to the above, during reconditioning of a nickel-cadmium battery, the recharging and capacity-checking are normally to be carried out as follows:

- (1) Discharge the battery at the one hour rate down to 0.6 volts per cell for each cell.

NOTE

Should the battery exhibit signs of unbalanced cells, it will be necessary to discharge the cells down to a common reference point, i.e. 0.6 volts per cell. During discharge, some cells may reach 0.6 volts sooner than others, and continue falling in voltage towards 0.00 volts. This is permissible provided the cells are not then discharged past the 0.00 point, at which time reversed polarity would be induced.

Care is therefore to be exercised to avoid reversing the polarity of the cells by overdischarging the battery. It may in some instances be necessary to discharge cells individually to avoid overdischarging. Slight overdischarging is not physically harmful to the battery, but is to be avoided.

- (2) Recharge the battery by the constant current method, see Table 4-1 at the 5 hour rate for 7 hours. Check cell voltages to determine that all cells maintained 1.60 volts/cell for at least the last hour of charge.
- (3) Discharge the battery at the 5 hour rate down to an end voltage of 1.0 volts/cell - check individual cell-volts for weak cells at end of discharge and determine if the battery delivered its nominal rated capacity. If it did, recharge as per (2) above and return to service.

(4) If in (3) above the battery did not deliver its rated capacity, repeat steps (2) and (3).

(5) If following the second low-rate discharge the battery delivers its full nominal capacity to 19.0 end-volts on-load, and the cells appear to be well balanced, then the battery may be recharged and returned to service.

(6) If the battery still fails the capacity test after these procedures, some cells may be defective and require cell removal, and reconditioning, (see Field Repairs). If such repairs are impossible or unsuccessful, the cell, or battery, is to be returned for repairs.

(h) The battery may be charged at 28.5 volts constant-potential to determine its charge acceptance as follows:

(1) Check if any individual cells are low in voltage (below 1.50 volts/cell) at the end of charge.

(2) Discharge the battery at the one hour rate down to an end voltage of 19.0 volts. Check to determine that the battery is capable of delivering its nominal rated capacity and check individual cell volts at end of discharge to determine if any weak cells or cell unbalance exists.

(3) If the battery accepts a charge satisfactorily by the constant potential method, delivers its rated nominal capacity at the two hour rate and does not have any weak cells, then the battery may be considered to be acceptable.

(4) If the battery fails to accept charge by the constant potential method, or fails to deliver at least 90% of its nominally rated capacity when discharged at the two hour rate, then give the battery two constant current conditioning cycles as per (g) above.

## MISCELLANEOUS

### CLEANING

3 A nickel-cadmium battery, and the compartment in which it is installed, must be free from any traces of acid. Do not paint nickel-cadmium batteries. Do not attempt to clean the battery tops with solvents, acids or any

chemical solutions as they may injure the plastic case as well as the battery itself.

4 The battery ordinarily requires only external cleaning of the case and cell tops. Should the battery require cleaning for the removal of dust or of potassium carbonate deposits, or for electrolyte spillage, or for any other reason, it is advisable to flush the top of the batteries with water. Flushing with distilled water is preferred, but ordinary tap water suffices. A stiff brush may be used to clean any stubborn dirt particles.



Do not use wire brush or severe arcing will occur. Make sure vent plugs are closed during the entire cleaning operation. Make sure cell tops are dry before returning battery to use.

### VENTING

5 Each battery incorporating a venting system is equipped with a steel vent tube, which is to be connected to the sump jar system in the aircraft on installation. This vent tube is to be kept clean and free from obstruction.

### TROUBLE-SHOOTING

6 For trouble-shooting procedures refer to Table 4-3 for probable cause and remedy.

### TOOLS

7 In addition to the tools and equipment generally used in battery shops, the special tools and equipment listed in Table 4-2 are required for Nickel-Cadmium Battery Shops.

8 In addition to the above, cell pullers are required, which may be manufactured locally as per Figure 4-4.

9 Tools for the repair and maintenance of the Nickel-Cadmium battery should be kept separate from those used for lead-acid batteries so as to avoid any possible contamination. ACID will ruin nickel-cadmium batteries and conversely ALKALI will ruin lead-acid batteries.

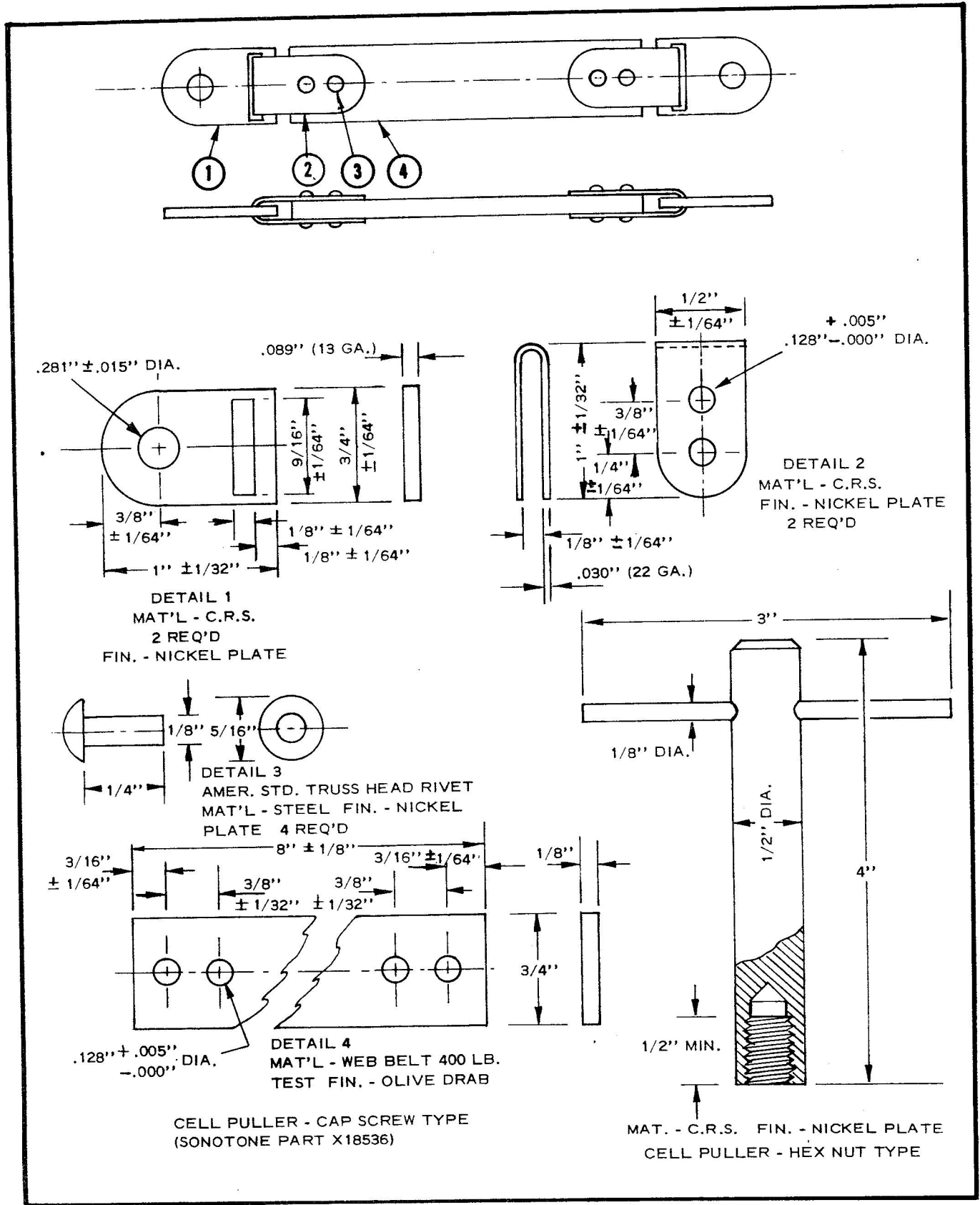


Figure 4-4 Cell Pullers

Class 6140 Stock No. STOCK NO.	TYPE	VOLTS	NOMINAL CAPACITY Amp. Hrs.	CAPACITY TEST				CHARGING RATES			CELL. TERMINAL TORQUE VALUES		NOTE
				TWO HOUR DISCHARGE RATE Amps	FIVE HOUR DISCHARGE RATE Amps	MINIMUM END VOLTAGE	CONSTANT CURRENT Time Amps Hrs	CONSTANT POTENTIAL Volt Reg Setting	Sonotone and Gould Ft/lb.	Gulton Ft/lb.			
00-578-7524	MA-4 (MS24497-1)	24	22	11	4.4	5	19	4.4	7	28.5-29.0	6	12	
00-578-7525	MA-5 (MS24498-1)	24	34	17	7.0	5	19	7.0	7	28.5-29.0	6	12	
00-617-0084	MA-300H	24	3.6	1.8	0.7	5	19	0.7	7	28.5-29.0	1.5		
21-803-9425	CA-10N	24	11	5.5	2.6	5	19	2.2	7	28.5-29.0	6		
	24H120 (Part 16962-5)	1.3	22	11	4.4	5		4.4	7				u/o MA-4
	(Part 18191-6)	1.3	34	17	7.0	5		7.0	7				u/o MA-5
	3H120 (Part 22378-1)	1.3	3.6	1.8	0.7	5		0.7	7				u/o MA-300H
	10H120 (Part 15495)	1.3	11	5.5	2.6	5		2.2	7				u/o CA-10N

Table 4-1 General Information - Batteries and Cells

TOOL	PURPOSE
Wrench 5/32 Allen Head (5120-00-198-5392)	To secure or release intercell connectors and terminals
Wrench Plastic Vent Plug  Wrench Cell-Cap Part 16979 (5120-21-809-9490)  Wrench Cell-Cap Part 16515 (5120-21-809-9491)	To secure and release vent plugs.  To use on MA4 and CA-10N  To use on MA5
Glass Tube, 1/8" dia. 6" long	To measure electrolyte levels
Syringe Hypodermic, with blunted insulated tip (21GM/6-6880 Syringe Hypo 5CC) (21GM/6-4335 Needle Hypo)	To withdraw electrolyte samples.
Brush, fiber, stiff (7920-21-554-1000)	To brush off white salt deposits on cells and terminals.
Voltmeter,  Scale:    0-2 volts Accuracy: 1%  Voltmeter,  Scale:    0-35 volts Accuracy: 1%	To read cell volts in values of 0.02 volts          To read battery voltage in values of 0.1 volts
Torque - Wrench, 0-20 ft.-lb.	Refer to Table 4-1
Parafilm Roll  (Fisher Chemical Catalog #13-374, or equivalent)	To seal under screw-cap of electrolyte bottles.
6810-21-806-3954 Electrolyte 30% KOH by weight (less than 1% K <sub>2</sub> CO <sub>3</sub> contaminant)	To top up cells after electrolyte loss
Cell Puller, Insulated (Local Manufacture)	To remove cells

Table 4-2

FAULT	PROBABLE CAUSE	REMEDY
High internal resistance.	(a) Low electrolyte level. (b) Prolonged storage. (c) Loose intercell connections and terminals.	(a) Check electrolyte level and if necessary adjust. (b) Recondition with constant current charging and low rate (5 hr) discharges for at least two cycles. (c) Check all intercell connections and terminals and tighten if loose.
Poor low temperature performance.	(a) Improper electrolyte - either low potassium hydroxide (KOH) or high potassium carbonate ( $K_2CO_3$ ) concentration. (b) Loose intercell connection and terminals.	(a) Check electrolyte by analysis for low KOH and/or high $K_2CO_3$ then flush out the old electrolyte and replace with new (30% KOH and less than 1% $K_2CO_3$ electrolyte). (b) Tighten connections.
Defective Battery (a) Cracked cells. (b) Distorted cells. (c) Melted cells.	(a) Excessive mechanical abuse. (b) Exposure to high temperatures (above 160°F) for prolonged periods. (c) Runaway - which may be due to: (1) High charging voltage 30.0 volts for prolonged periods 3 hrs. (2) High temperature environment. (3) Low electrolyte level.	(a) Replace cells and check cause of mechanical abuse. (b) Remove battery from high temperature environment and replace distorted cells. (c) Replace cells. (1) Check and adjust voltage regulator. (2) Check that temperature is maintained below 54.4°C (130°F).
Low electrolyte level.	(a) High voltage regulator setting. (b) Prolonged constant current charging. (c) Normal loss with time.	(a) Check and adjust voltage regulator top-up electrolyte. (b) Restrict constant current charging to reconditioning, periodic intervals and for time periods in accordance with Part 3, Section 3, para. 11. (c) Top electrolyte with distilled water.

Table 4-3 (Sheet 1 of 2) Trouble Shooting



FAULT	PROBABLE CAUSE	REMEDY
Low Capacity.	<p>(a) Discharged battery.</p> <p>(b) Prolonged constant potential cycling.</p> <p>(c) Low voltage regulator setting.</p> <p>(d) Weak cells, cell unbalance, discharge the battery at the 1 hour rate and check individual cell voltages to see if any cells drop out before the 19.0 volts cut-off.</p> <p>(e) Prolonged storage - 6 months or longer.</p>	<p>(a) Recharge.</p> <p>(b) Recharge - by constant current method until battery receives 40% overcharge. Battery may need one or two constant current cycles.</p> <p>(c) Reset voltage regulator.</p> <p>(d) Recharge - by constant current method until battery receives 40% overcharge. If any cells have not reached or maintained 1.60 volts/cell for at least one hour of charge then charge these cells individually for another two hours.</p> <p>(e) Recharge by constant current method for at least two cycles. Discharge the battery at five hour rate to 1.0 volts/cell between charge cycles. Check electrolyte levels and top up with distilled water or dilute KOH if necessary.</p>
Electrolyte Spillage and/or White salt deposits on vent plugs and terminals	<p>(a) High electrolyte level.</p> <p>(b) High voltage regulator setting.</p> <p>(c) Prolonged constant current charging.</p> <p>(d) Cracked cell.</p>	<p>(a) Check and if necessary adjust electrolyte level.</p> <p>(b) Check and reset Voltage Regulator.</p> <p>(c) Follow constant-current charging instructions properly.</p> <p>(d) Replace cell. For all above faults wash cells and case with distilled water, wipe clean and re-assemble. Soak and wash vent plugs in distilled water and replace.</p>

Table 4-3 (Sheet 2 of 2) Trouble Shooting



**PART 5****FIELD REPAIRS****BATTERY REPAIRS AND  
TROUBLE-SHOOTING**

1 Nickel cadmium batteries may have local repairs effected on them for any of the reasons outlined in Table 4-3 which are within the ability of field units to carry out.

2 A major advantage of nickel cadmium batteries is that they can be disassembled for replacement of faulty components. However, they should be disassembled only to the extent necessary for replacement of components.

**WARNING**

Use extreme care when working around the top of cells. Do not drop any un-insulated tool onto the top of the battery. Severe sparking will result and both the tool and cell terminals can be badly burned. It is suggested that electrical tape be used to insulate all tools used in battery maintenance.

**REMOVAL OF DEFECTIVE CELLS**

3 When a defective cell is found, the entire battery shall be discharged and the defective cell replaced. To do this, proceed as follows:

(a) Using an allen or socket type wrench of correct size, remove nuts or recessed head screws which hold intercell connectors to a definite cell.

(b) Remove intercell connectors and other loose hardware. Retain for re-installation.

(c) Using a vent cap wrench or screwdriver (on some batteries), loosen the vent caps on all cells in the battery. This will relieve the pressure within the cell which might expand each cell tightly against cells on either side. After all cells have been vented, tighten the caps snugly.

(d) Using a locally fabricated cell puller, see Figure 4-4, secure to cell terminals of cell to be removed, and carefully pull cell out of battery case.

4 When removing a cell from the battery, the cell sides require support during cell handling, charging and shipping, as applicable. For this use, a suitable box or a support made of wood or other suitable material is to be locally manufactured, of adequate size to ensure a snug fit for the type of cell in use at Field Units. A cell-size wooden block is also required to install in the battery while the removed cell is absent.

5 The cells are closely packed in the battery case in such a manner that they make a very snug fit. The cells tend to swell a little on charge and shrink slightly on discharge, therefore, for easy removal of cells it is recommended that the battery be fully discharged before cell removal is attempted.

**REPLACEMENT OF CELLS**

6 When cells are being replaced in a battery they should be in the same state of charge as the battery itself so as to prevent cell unbalance. Whenever individual cells are being tested, they should be securely clamped on the sides, to ensure proper charging and in particular, to prevent bulging of cell walls. Neutral Vaseline applied to the sides of the cell cases will help to ease both insertion and removal of cells. Reconnect the intercell connectors, ensuring all washers are re-installed. Tighten all ALLEN screws on hex nuts to appropriate torque values given in Table 4-1.

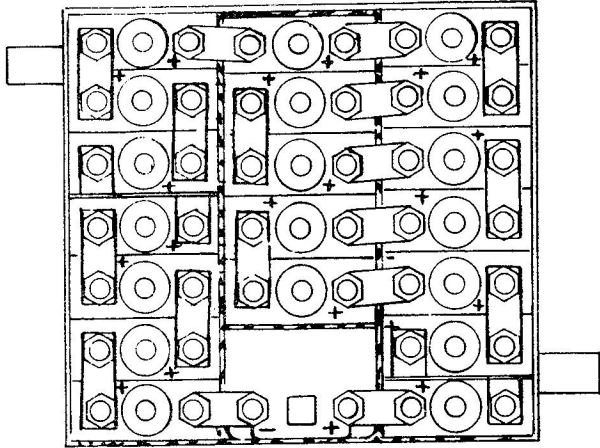
**CAUTION**

Care is to be taken that cells are not re-installed in a battery with their polarity reversed. Ensure proper sequence and correct terminal torque values.

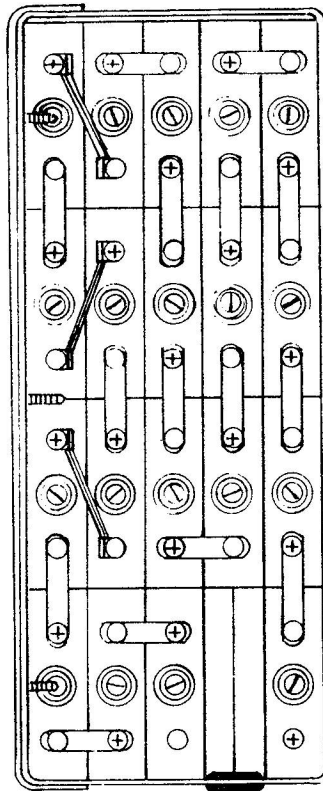
**CORRECTION OF CELL UNBALANCE**

8 Cell unbalance may occur in nickel-cadmium batteries as a result of:

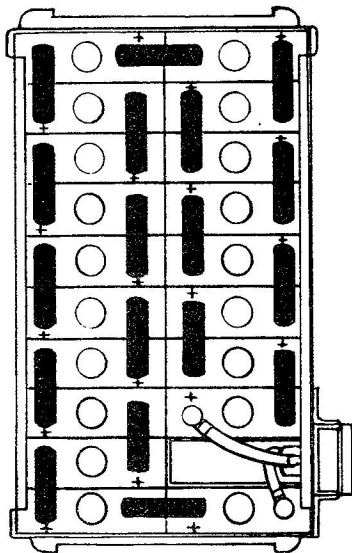
(a) Deep discharging of the battery.



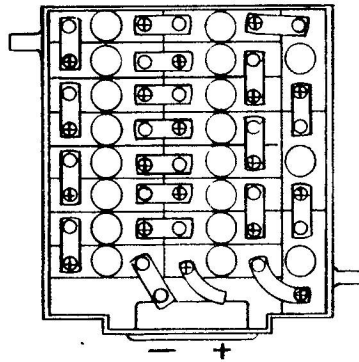
TYPE MA-5



TYPE MA-300H



TYPE CA-10N



TYPE MA-4

Figure 5-1 Connector Location and Polarity Diagrams

- (b) Prolonged battery storage.
- (c) Numerous battery cyclings limited to constant-potential recharging.

9 Minor conditions of cell unbalance are normally remedied by reconditioning the battery with one constant current charge followed by one discharge and another constant-current charge. The controlled overcharge portion of these charges then corrects minor unbalances.

10 Cells are considered in a state of unbalance when they exhibit a voltage variation of 0.05 volts or more during charge and discharge, particularly when nearing the end of these processes. Cell unbalance, unless quite pronounced, cannot be detected from its open-circuit voltage. Therefore, periodic checks of individual cell voltages are required during charge or discharge of the battery.

11 If cell unbalance is detected in one or more cells, and if the controlled overcharge of the battery reconditioning procedures fails to correct this, these unbalanced cells may be disconnected and removed for individual cell reconditioning.

12 A low electrolyte level in a cell may be an indication of unbalance of that cell.

### RECHARGING OF INDIVIDUAL CELLS

13 Nickel-Cadmium cells requiring individual recharge are to be processed as follows at units having suitable capability:

- (a) Discharge the cell at the five hour rate. An individual cell can be discharged below the one volt cell voltage. When nearing end of discharge, the process can be hastened by utilizing a jumper to directly short out the cell terminals.
- (b) Connect the cell to a suitably metered and protected two-volt supply, in series with a variable resistor suitably rated to control the applicable cell charge current as per Table 4-1.
- (c) Charge cell at appropriate current for suitable time as given in Table 4-1 under the constant-current charging rate.
- (d) Repeat (a), (b) and (c).

(e) Discharge cell at five hour rate down to 1 volt on load, ensuring the cell delivers its rated capacity.

14 If procedure above is successful, the cell may be installed in a battery in the same state of discharge. Install cell in series with other cells, ensuring polarity sequence is correct. Refer to Figure 5-1.

15 If procedure above is unsuccessful, tag the cell with all pertinent information and return it for repairs.

### ANALYSIS OF ELECTROLYTE

16 The KOH electrolyte should be clear and colourless. It should be 30% KOH by weight, and contain less than 5% potassium carbonate ( $K_2CO_3$ ).

17 When the degree of purity of the electrolyte in a battery is in doubt, it may be advisable to obtain electrolyte samples for chemical analysis. Similarly, in batteries where insufficient electrolyte is available to obtain a specific gravity reading, it may be necessary to have the electrolyte analysed to determine its concentration.

### REMOVAL OF ELECTROLYTE SAMPLES

18 Prior to removal of electrolyte samples, it is advisable that the battery be placed on charge until the overcharge state is reached. Since the highest electrolyte level is at the end of charge and since the level falls during discharge or storage, the above procedure should ensure that there is a sufficient volume of electrolyte available for a sample.

19 The sample may be removed using a 5ml hypodermic syringe having a blunted, insulated tip. The sample should be placed in a small (2 oz) suitable glass or plastic vial, sealed with parafilm and a secure screw or crimp top. A sample size of 1 or 2 mls is sufficient, however, the larger the sample, the more accurate the analysis will be.

20 After removal of the sample, replace the volume of liquid removed from the cell with a similar volume of replacement electrolyte - 30% KOH, containing less than 1%  $K_2CO_3$  impurity.



**PART 6****SAFETY PRECAUTIONS**

1 This Part lists safety precautions and instructions to be observed in the operation of nickel-cadmium batteries and related installations and equipment.

**NATURE OF HAZARDS**

2 The hazards which may be encountered when using nickel-cadmium batteries against which precautions must be taken are:

**ELECTROLYTE**

(a) The electrolyte (30% solution of KOH) is a highly active chemical, and is very corrosive and destructive when in contact with metal, wood and other materials. It also can injure body tissue SEVERELY.

**CHARGING**

(b) It is generally acknowledged that nickel-cadmium batteries can be charged with the minimum of gassing. However to avoid the possibility of excessive gassing and spewing of electrolyte during the charging cycle (in particular the overcharge period) strict adherence to the charging procedures recommended by the battery manufacturer or other recognized agencies must be followed. THIS IS MOST IMPORTANT IN THE CASE OF SEALED CELLS, where gases, in excess of the recombination capacity of the plates, can be evolved, and since the gases cannot escape, this eventually results in either cell rupture or in an explosion, in the extreme case. On extended overcharge vented batteries liberate both hydrogen and oxygen. This gas mixture on its own, or in combination with air may form explosive mixtures. Therefore battery maintenance and charging operations should ALWAYS be performed in well ventilated areas where NO SMOKING regulations are in effect. Under certain discharge conditions, i. e., in the case of deep discharge of multiple cell batteries some cells might be driven into reversal with the subsequent liberation of hydrogen gas. This also is an explosion hazard but can be prevented by good ventilation and taking the precaution not to discharge the battery below a terminal voltage equivalent to 1 volt-cell (low rate) and 0.6 volts cell (high

rate). Nickel-cadmium batteries can be charged either at constant current or at constant potential.

**SHORTING**

(c) Nickel-cadmium batteries, in particular the thin, sintered plate type, are capable of very high discharge currents (approximately 30 C i. e. 30 times rated capacity (AH) in amperes) when short circuited. Such currents are not only destructive to the battery but also can BURN PERSONNEL AND DAMAGE TOOLS AND OTHER EQUIPMENT. To avoid accidental short circuits, all tools used with the battery or in its vicinity should be suitably protected by insulating tape or varnish. The battery cover is to be kept on the battery as much as possible.

**PRECAUTIONS**

3 Precautions to be observed when handling nickel-cadmium batteries may be summarized as follows:

(a) Keep flames and sparks away from the vicinity of vented nickel-cadmium storage batteries. No smoking in battery rooms.

(b) Charge batteries, in particular vented batteries, in well-ventilated area only.

(c) Make certain that the charge is turned off when making or breaking connections in the charging circuit or at the battery. Where possible, break electric connections at points remote from the battery.

(d) When using tools around a battery, take care not to short-circuit the battery or cell terminals. Battery technicians should remove rings and wrist watches while handling these batteries.

(e) Only brushes with bristles of non-conducting materials, viz. nylon, should be used for cleaning batteries and cell terminations and intercell connectors.

(f) Make no repairs to battery while current is flowing through it.

4 In the event of personnel contamination by alkaline electrolyte the following antidotes are recommended:

(a) Internal - Give large quantities of water and weak acid solution, such as vinegar, lemon juice, or orange juice. Follow with a demulcent, such as white of egg, olive oil, starch water, mineral oil or butter. Keep body warm.

(b) External - Wash the affected area with a large quantity of water as promptly as possible. Neutralize with lemon juice, vinegar, or a weak solution of boric acid. If electrolyte has affected the eyes, wash them with a weak solution of vinegar, with olive oil, or with a saturated solution of boric acid, and consult Unit Medical Officer.

Before you shoot the juice to the battery there're some safety pointers you want to keep in mind.

When a vented nickel-cadmium battery is charged to its full capacity, hydrogen and oxygen gases escape through the vented battery plugs that're left on during charging. A mixture of about four per cent of these fumes can be ignited by a direct short. A wrench dropped across the terminals of the battery may be all that's needed to make the electrolyte boil up a storm and give you an explosion.



### **DO IT- SAFELY**

*BUT IF YOU FOLLOW THESE SAFETY POINTS THAT APPLY TO THE CHARGING OF ALL BATTERIES PLUS ANY DIRECTIONS SUPPLIED WITH YOUR CHARGER THERE'S NO SWEAT !*

1. Always charge, and if possible, discharge batteries in a well ventilated area to prevent a collection of explosive gases.
2. Be sure all terminal connections to the battery are tight to guard against sparks.
3. No smoking in the battery room ... could set off lingering fumes.
4. Use only tools that have the least amount of metal showing which will also guard against sparks.

Figure 6-1 Safety Pointers



**PART 7****STORAGE AND DISPOSAL****STORAGE**

1 Nickel - cadmium batteries can be stored in any state of charge, and stand idle for considerable periods, without physical damage, provided they are kept in a cool, dry atmosphere.

2 Contrary to other common types of storage batteries, nickel - cadmium batteries do not form on discharge any substance which deteriorates the plates. Hence a used nickel - cadmium battery can stand in a discharged state for undetermined lengths of time without inhibiting its capacity to absorb a charge. No periodic refresher charges are necessary while the battery is in storage.

3 However, while standing, or in storage, a charged nickel - cadmium battery may undergo a gradual self-discharge. The electrolyte level will drop as the electrolyte retracts into the plates during prolonged storage. The battery will appear quite dry and may exhibit high internal resistance characteristics on first subsequent recharge. To return the battery to service add just sufficient replacement electrolyte or distilled water to moisten the plates and bring the electrolyte level up to the top of the plates. Then place the battery on a conditioning cycle.

4 Storage Temperature - The lower the

temperature, the better the battery will retain its charge when in idle storage or stand-in service. At normal room temperature, they may normally retain their charge for approximately six months.

5 Storage Racks - Batteries should never be piled on top of one another. Suitable, non-tippable storage racks are to be utilized.

6 Battery covers are to be in place when a nickel - cadmium battery is in temporary storage, so as to minimize possible hazards due to metallic objects contacting cell terminals and causing sparking and shorting.

**DISPOSAL**

7 Used serviceable nickel - cadmium batteries which are no longer required at a unit are to be suitably packaged, tagged, and returned to serviceable SD stocks.

8 Nickel - cadmium batteries and cells which are repairable are to be reconditioned at units having suitable facilities. When they are beyond the repair capability of field units, they are to be returned for repairs.

9 If a nickel - cadmium battery or a nickel - cadmium cell is damaged beyond repair, it is to be reported to AMCHQ for disposal.

