KS-15578 NICAD BATTERIES

ENGINE STARTING

1. GENERAL

1.01 This section covers KS-15578 engine starting storage batteries of the nickel-cadmium (Nicad) type.

1.02 The section is reissued to raise float voltage slightly, list the E-type cells, drop insistence on distilled water, and call for a 100 per cent charge at installation and annually thereafter.

1.03 Information has been obtained from field experience, laboratory tests, and literature on the subject. While cells of this construction have been manufactured in this country only since 1946, and used in the Bell System only since 1947, it is believed that experience will confirm all unchecked data given herein.

1.04 KS-15578 batteries with the letter E in the list number have actual capacity on the nameplate. KS-15578 batteries without the E in the list number (prior to late 1955) were incorrectly rated. They have appreciably less capacity (possibly 20 per cent less) than the value marked on the nameplate. It is proposed, however, that this error be disregarded by the maintenance forces and that nameplate rating be assumed to be correct when applying any instructions in this or other sections where per cent of capacity is a factor.

1.05 These batteries will gas only on charge and then only at potentials over 1.33 volts per cell. At potentials up to 1.47 volts per cell, the gassing is negligible. The gas given off is the same as given off by lead-acid cells, namely, a mixture of hydrogen and oxygen. Since this is explosive, the same antiexplosion precautions apply to these cells as to lead-acid cells.

1.06 The alkaline electrolyte is corrosive and attacks most animal and vegetable products including clothing, the skin, and paint, as well as some metals including aluminum and zinc but excluding iron, steel, and nickel. It attacks glass very slowly (Pyrex-type glass almost negligibly), so exposure of glass other than the Pyrex type or of porcelain should be for as short duration as practicable, and glass or porcelain objects should be washed in water after any exposure to electrolyte. Since the acid resistant paint used on battery racks is not protection from the alkaline solution, extra care is necessary to avoid exposure of such paint to electrolyte. Boric acid is used to neutralize spilled electrolyte, but it should not be applied to the metal containers as it will promote rusting. Saturated solution or crystals of boric acid should also be used to neutralize electrolyte spilled on the hands or clothing. For splashes on the face, wash in boric acid solution. For splashes in the eye, douse with the same solution, or use an eye cup if available.

1.07 The outer surfaces of cell containers are electrically live. They should not touch each other or be grounded. Only taped or otherwise insulated tools should be used when working on the cells, and no metal objects should be laid on the cells.

1.08 Soda or sulfuric acid even in small quantity is detrimental to the cells. Hydrometers or thermometers that have been used in lead-acid cells should not be used with Nicads.

2. DESCRIPTION

2.01 Cell containers are made of nickel-plated steel, painted on the outside with asphalt varnish. Each cell is fitted with a spring-loaded vent cap which should be kept closed to reduce the contact of the electrolyte with air. Shipping vent plugs are to be discarded. They may be removed by using a pair of pliers and a combined rocking and turning motion. Cells are usually mounted in wooden crates called trays (see Fig. 1). These are painted with asphalt varnish and are arranged to prevent adjacent cells from touching each other. Cells are shipped filled and with a layer of oil over the electrolyte to reduce contact of the electrolyte with air.

2.02 In a fully charged state, the positive plates contain nickel hydroxide in a high state of oxidation and the negative plates contain finely divided cadmium metal. In a discharged cell, the positives contain nickel hydroxide in a low state of oxidation and the negatives, cadmium hydroxide. The electrolyte, which is a solution of chemically pure caustic potash, KOH, takes no apparent part in the chemical reactions. Changes in specific gravity at the positive and negative plates cancel out so as to leave the electrolyte unchanged in specific gravity both on charge and discharge.

2.03 The voltage per cell is less than on lead-acid cells so that more Nicad cells are required for any required voltage. The usual comparison of number of cells for different nominal battery voltages are as follows:

Nom Volts	Number of Cells Lead Acid	Nicad
6	3	5
12	6	10
20	10	16
22	11	18
24	12	20
32	16	25
34	17	27
48	23	38

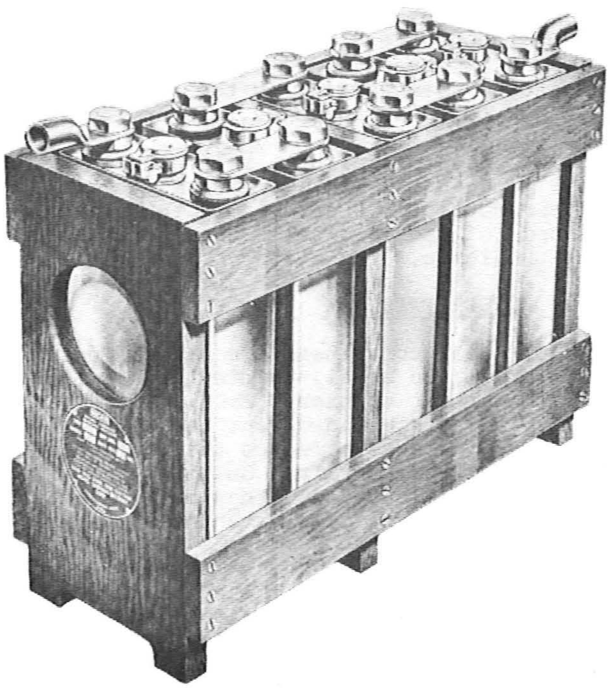

Fig. 1 - Assembly

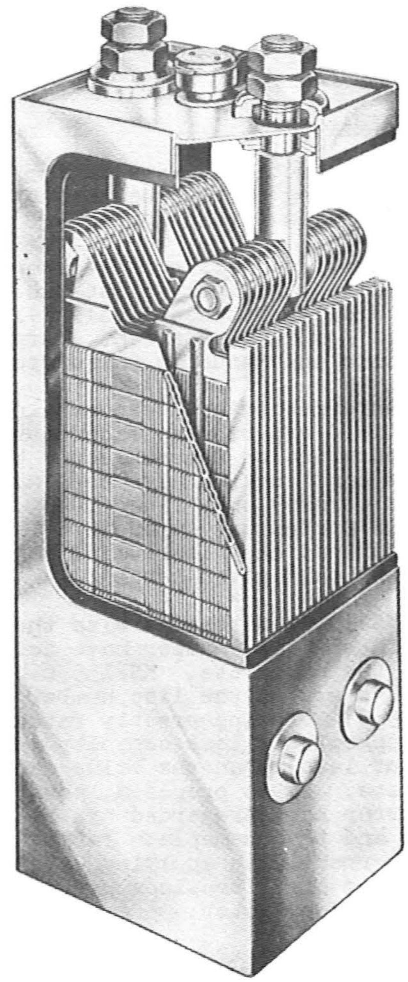

Fig. 2 - Construction

2.04 Table A shows the voltage characteristics of E-type cells at various rates. These batteries may be discharged safely at any current rate even that caused by a short circuit on the cells. See 2.06.

2.05 Float should be held between 1.40 and 1.45 volts per cell. Where there is no voltage regulator, voltage should be corrected frequently by small changes in charger setting until correct value is obtained. Thereafter, voltage should be noted often enough to assure that proper float is being maintained.

2.06 The battery should be charged at installation, annually, and whenever the battery fails to start the engine or there is other evidence of undercharge. Unless otherwise specified, this charge should be 100 per cent of nameplate capacity rating. Charging rates as high as twice the 5-hour rate (capacity divided by 5) are satisfactory provided temperature is not excessive (see 2.09), and provided gassing does not cause overflow of the cells. Low rates within the capability of the furnished charger are usually satisfactory but, in some cases of very deep discharge at low discharge rates, higher charge values from one to two times the 5-hour discharge rate may be necessary. Final voltages would be from 1.75 volts at low rates to 1.85 volts at high rates. Open-circuit voltage is about 1.30 volts per cell.

Table A - Discharge Charateristics of E-type Cells at Heavy Rates of Discharge and to Various End Voltages

Voltage of Cell at End of Discharge

Discharge Currents

Amperes Expressed in Terms of "C" Which Is the Nameplate Ampere-hour Capacity of the Cell at the 5-hour Rate of Discharge

Disch Sec.	1.00v	0.95v	0.90v	0.85v	0.80v	0.75v	0.70v	0.65v	0.60v	0.55v	0.50v
1	3.05xC	3.50xC	3.92xC	4.35xC	4.77xC	5.36xC	6.12xC	6.93xC	7.22xC	7.71xC	8.50xC
2	2.98	3.42	3.85	4.31	4.70	5.25	5.94	6.70	7.03	7.53	8.11
5	2.86	3.30	370	4.20	4.61	5.15	5.82	6.61	6.91	7.32	7.92
10	2.78	3.22	3.66	4.12	4.57	5.06	5.52	6.43	6.62	7.14	7.72
15	2.73	3.17	3.60	4.05	4.47	4.90	5.30	6.20	6.32	6.81	7.63
20	2.69	3.13	3.52	3.92	4.31	4.73	5.13	5.75	5.93	6.42	7.04
30	2.64	3.08	3.30	3.50	3.80	4.23	4.68	5.13	5.31	5.83	6.24
45	2.59	3.03	3.23	3.42	3.61	3.93	4.40	4.90	5.12	5.44	5.83
60	2.56	3.00	3.20	3.40	3.50	3.80	4.30	4.85	5.08	5.24	5.55
90	2.38	2.75	3.00	3.25	3.45	3.65	4.10	4.60	4.81	5.05	5.23

2.07 Table A shows the expected discharge characteristics of the cells with an E in the list number. Example, it should be possible to discharge a 120-ampere-hour battery (list 6E) for 90 seconds at 360 amperes with voltage falling no lower than 0.90 volts per cell.

2.08 Nicad cells are rated at the 5-hour rate. Their capacities are almost the same at all rates from the 3- to the 20-hour rate. Their internal resistance is about the value of 0.15 divided by the rated ampere-hour capacity. For engine starting, service depends on the short time cranking ability of the battery at high discharge rates rather than on the 5- or 8-hour capacity. This explains why the 5-hour capacities of Nicads may be less than the 8-hour capacities of lead-acid batteries for the same service. Nicads do not enjoy this advantage on central office and PBX service where lower discharge rates are usual. The approximate capacities of Nicads at different temperatures are as follows:

Temperature Degrees F	Percentage of 5-hour Capacity
100	105
77	100
32	95
0	70
-10	60

2.09 Electrolyte temperatures from -20F to +115F are satisfactory. For short periods, as during a special charge, temperatures up to 145F can be tolerated. Temperatures down to -40F do no damage other than temporarily reducing the capacity.

2.10 The efficiency of a storage battery on cycle operation is the ratio of the output of the battery to the input required to restore the initial state of charge under specified conditions of temperature, current rate, and final voltage. The efficiency of interest is the ampere-hour efficiency. This represents the electrochemical effectiveness of the cell. It is the current output times hours of discharge, divided by the current input times hours of charge to restore the cell to full charge. For Nicad cells, the required recharge is usually specified as 140 per cent of the discharge. In addition to the discharge-charge inefficiency, there are long term losses due to local action.

2.11 Distilled water or any other water approved for use in lead-acid batteries may be used for leveling. Water containers should be kept clean and stoppered. No water container should be used that has previously held acid or other chemicals. Condensed steam from boilers in which water softeners were used may be unsatisfactory.

2.12 Electrolyte levels as measured from the top of the plates are as follows:

KS-15578 List No.	Electrolyte Level Max (Inches)	Min (Inches)
1	1	1/2
2 to 7	1-3/4	3/4
8 to 9	2	3/4
10	3	3/4
1E	1-1/4	1/2
2E to 7E	1-1/2	3/4
8E to 10E	1-3/4	3/4

A transparent tube is furnished with each battery for measuring electrolyte level and noting that there is still oil on top of the electrolyte. The tube is inserted through a vent hole until stopped by the top of the plates. The top of the tube is then closed with the finger and the tube lifted to show the electrolyte and oil. Spillage should be avoided. If the top of the plates have been exposed to air, add water immediately to cover the plates.

2.13 The thickness of the oil layer is not critical and need not be measured. It is expected to be about 1/16 inch to 1/4 inch thick. It is a pure mineral oil, and oil on hand for use in countercells is satisfactory for this application also.

2.14 Cells may be shipped with electrolyte at any specific gravity from 1.160 to 1.300 at the discretion of the battery manufacturer. The higher specific gravity is preferred for very cold locations and the lower for warm locations. The theoretical permissible drop in specific gravity during life is about 50 points but the field is not expected to keep records or check this item. There is no appreciable change in specific gravity during charge or discharge. In case of spillage necessitating the addition of water in quantities listed below, new electrolyte should be ordered for the entire cell. Cells will suffer no harm while waiting for the new electrolyte.

KS-15578 List No.	Excess Spillage Per Cell (Pints)
1 & 1E	1/4
3 & 5	1/2
3E & 5E	1/2
2,6 & 7	3/4
2E,6E & 7E	3/4
8 & 8E	1
9 & 9E	1-1/4
10 & 10E	1-1/2

2.15 Theoretically, the electrolyte will fail ultimately and need to be replaced due to carbonation caused by absorption of carbon dioxide from the air and from water used for leveling. The vent caps and the layer of oil over the electrolyte reduce exposure of the electrolyte to the air to a minimum. The recommended operating routine uses practically no water. As a result, the rate of carbonation is so low, about 2 per cent per year, that replacement of electrolyte because of carbonation is no longer considered a normal hazard. Cells when shipped are specified to have not over 15 per cent carbonation. They will give good service up to 60 per cent carbonation. At higher values, the discharge voltage and cell capacity will both decrease until at 80 per cent carbonation the cell will have only one-third normal capacity.

2.16 Nicads may be substituted for lead-acid cells, using the same control equipment and with no adjustments other than the slight change in float voltage. They could be used with less expensive plants in some cases, but for the present, the same plants are being used to make the two types of batteries interchangeable. The less expensive controls would be acceptable because Nicads are much less critical of maintained voltage and are not harmed by overcharge. High charge rates that do not heat electrolyte excessively and do not cause excess water loss cause no harm. High discharge rates, even those present on a short circuit on the cell, cause no harm. Standing for long periods either partially or wholly discharged causes no permanent damage to the battery.

2.17 Cells should be kept dry and clean, using a dry cloth to avoid dampness that might encourage rusting of the container. If cells come with grease or petroleum smeared on containers or terminals, it should be wiped off to discourage the collection of dust and an unsightly appearance of the battery. In some cases, a white crystalline deposit has appeared around some of the terminals due to leaks in the seal around the posts. This deposit does not corrode any of the parts and does no harm except to the battery appearance. It should be wiped off with a dry cloth. The nut over the seal should be tightened to stop the leakage.

2.18 While the nickel plated copper intercell connectors used have none of the cold flow experienced with the lead alloy or lead-coated copper intercell connectors of lead-acid cells, connections of nickel-cadmium cells should be inspected ocasionally for tightness, using an insulated wrench.

2.19 Nicads installed within a year of shipment from the factory should receive an initial charge equal to 100 per cent of nameplate rated capacity. This charge should be at as high rate as practicable but not in excess of twice the 5-hour discharge rate. See 2.06. Where time exceeds a year, special recommendations should be obtained from the battery manufacturer.

2.20 When for any reason cells have been shipped dry with solution in separate containers, a more extensive initial charge is required. After pouring the solution to minimum level, allow cells to sit approximately 12 hours before the start of the initial charge. Then charge at as high current rate as feasible but not to exceed the 5-hour discharge rate (capacity divided by 5) until 140 per cent of the 5-hour capacity of the battery has been applied. This would be a charge of 7 hours if at the 5-hour rate. Allow the battery to sit for several hours, preferably 12 hours, and repeat the above 140 per cent charge. During charging, reduce the rate if necessary to prevent the temperature of the solution exceeding 115F. After completion of the total 280 per cent of charge, fill to the maximum level with the provided solution.

2.21 Operation and maintenance are being covered in the associated engine sections. They are quite simple as indicated below:

(a) Give full capacity initial charge.

(b) Hold voltage at specified float value, usually 1.40 to 1.45 volts per cell.

(c) Maintain electrolyte level within prescribed maximum and minimum limits. Level should be checked annually, but addition of water should seldom be required.

(d) Keep connections tight.

(e) Keep exterior of cells and containers clean and dry.

(f) Give a full capacity charge annually and if battery fails to crank engine.

(g) Neutralize spilled electrolyte with boric acid.

(h) Unless required locally, records need not be maintained.

3. ADVANTAGES AND DISADVANTAGES

3.01 The advantages of Nicad compared with lead-acid cells seem to be as follows:

Long life

No equivalent of sulfation

Great mechanical strength

No corrosive spray

No swelling of plates

No buckling of plates

Very low water consumption

No gassing on discharge

Low rate of self-discharge

Not damaged by low temperatures

No shedding of active materials

Simple and inexpensive maintenance

No deterioration of plate separators

No specific gravity or other records necessary

May be operated at high or low temperatures

Not damaged by remaining idle in any state of charge or discharge

Lower trickle rates

3.02 The disadvantages seem to be as follows:

Higher cost

More space occupied

Difficulty of replacing deep discharges removed at low rates

Impossibility of checking state of charge by specific gravity readings

Lower efficiency

Possibility of need for electrolyte renewal on services other than float or engine starting

Containers being metal and live offer some hazard