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AEROSPACE INFORMATION REPORT

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MAINTENANCE OF BATTERIES AND BATTERY CHARGING AND SERVICING FACILITIES

1. SCOPE:

This SAE Aerospace Information Report (AIR) covers, and is restricted to, hands-on servicing/maintenance of industrial lead acid batteries used solely for motive power and exclusively for ground support equipment (GSE). It does not address or pertain to automotive-type SLI (starting-lighting-ignition) batteries or any other types of batteries (such as nickel-cadmium, zinc, or lithium batteries) which may be on-board airport GSE for either motive power or auxiliary uses. Similarly, the battery servicing and charging facilities described herein are those intended exclusively for industrial lead acid batteries.

1.1 Purpose:

This AIR is intended to provide basic information on proper procedures and facilities for handling, charging, and otherwise servicing and maintaining motive power lead acid batteries used in airport GSE. Adherence to these guidelines can help maximize battery life and performance, as well as the overall efficiency and effectiveness of electric GSE at airports. This document also describes (physical) battery servicing facilities in the airport environment.

2. REFERENCES:

1. "Battery-Powered Industrial Trucks...For Cost-Effective Materials Handling," Lead Industries Association, Inc., New York, 1983

2. "A Primer on the Lead Acid Battery," Lead Industries Association, Inc., New York, 1978

3. "Battery-Powered Ground Equipment...Economical Solution to Soaring Fuel Costs, Lead Industries Association, Inc., New York, 1981

2. (Continued):

4. "How to Plan an Efficient Charging Room Layout," Modern Materials Handling Magazine, Cahners Publishing Company, November 1980

5. Mayer, Michael, "Cutting Maintenance on Lead Acid Batteries," Lead Development Association, London, November 1984

6. Healy, Rick, "Battery Shop Safety," The Battery Man Magazine, Independent Battery Manufacturers Association, Largo, Florida, April 1987

7. "Material Handling (Industrial Truck) Battery Chargers," Standards Publication PV 6-1976, and "Determination of Capacity of Lead Acid Industrial Storage Batteries for Motive Power Service," Standard Publication IB 2-1974, National Electrical Manufacturers Association, Washington, D.C.

8. Exide Corporation, "Instructions for Installation, Operation, and Maintenance of Lead Acid Batteries in Motive Power Service," Sec. 28.00, January 1985, and "Charging Rooms Planning Guide," November 1980

9. GNB Incorporated, "Instruction, Maintenance, and Service Manual - Motive Power Batteries and Chargers," April 1984

10. General Battery Corporation, "Industrial Battery Service Manual," July 1980

11. Simmons-Rand Corporation, "Installation, Use, Maintenance, and Repair of Mine Power Storage Batteries," January 1985

2.1 Applicable Documents:

This document is based on, and should be both complemented and supplemented by, the detailed instructions/recommended practices and procedures of the manufacturers and/or suppliers of batteries, chargers, vehicles, and servicing/maintenance facility components. Similarly, this document should be considered in the context of applicable federal, state, and local health, safety, fire, and other pertinent regulations, which are predominant. In particular, Occupational Safety and Health Administration (OSHA) Regulations 1926.403 and 1910.178 specify the federal requirements concerning safe care and charging of storage batteries. These two OSHA regulations are detailed (excerpts) in 7.4(a.) and 8.1(a.-d.).

2.2 Definitions:

The following words and terms are most often associated with industrial lead batteries, and should be familiar to personnel responsible for proper battery maintenance:

AMPERE (AMP or A): A unit of measurement of electrical current. The current forced through a resistance of 1 Ω by a potential of 1 V is equal to 1 A.

AMPERE-HOUR (A·h) CAPACITY: The amount of electricity that can be drawn from a battery; dependent upon the number or size of the plates in each cell.

CONNECTORS: Molded strips of lead that connect the posts over the top of the cover, where multiple cells are used.

CURRENT: The flow of electricity, normally expressed in amperes.

CYCLE: One discharge and one charge of a battery. Life cycle is the number of times a battery can be discharged-charged before it fails to respond and is no longer serviceable.

DEEP DISCHARGE: Removal of the rated energy capacity of a battery; in practice, it is suggested that a maximum 80% depth-of-discharge be considered the maximum deep discharge level of a battery, even if it is rated at 100% discharge.

DIRECT CURRENT (DC): Where the positive and negative polarity remains in the same relative position (does not reverse). This is characteristic of the current delivered by batteries, whereas household current, for example (utility electricity) is AC (alternating current).

ELECTROLYTE: Battery fluid, generally a sulfuric acid-water solution.

ENERGY DENSITY: The ratio of battery energy content in watt-hours to battery weight or volume.

HYDROMETER: An instrument used to measure electrolyte density or specific gravity.

KILOWATT-HOUR (kW·h) CAPACITY: A unit of measurement of a battery's rated energy capacity.

RATED CAPACITY: The ampere-hours of discharge that can be removed from a full charged battery at a specific constant discharge rate, a specified discharge temperature, and a given cutoff voltage.

SPECIFIC GRAVITY: Weight of the electrolyte compared to an equal volume of water alone. A battery's specific gravity indicates its state-of-charge.

2.2 (Continued):

VOLT (V): A unit of electromotive force; each battery cell produces approximately 2 V.

VOLTMETER: An instrument for measuring battery cells' voltage output.

WATT (W): A unit of power; the product of volts x amps. A battery's total power is measured in watts.

WATT-HOUR (Wh): The measure of energy or work accomplished; the product of the rate of work in watts and the time in hours, or the product of ampere-hours x average voltage.

3. LIMITATIONS:

This document is intended as a basic battery maintenance guideline only, and should not supersede battery of charger manufacturers' detailed installation, handling, charging, and maintenance instructions. Service-related problems with batteries, chargers, vehicles, and components that cannot be solved on the job or in on-site maintenance shops should be referred only to the manufacturers or their authorized representatives.

4. GENERAL BACKGROUND:

Battery-powered, or electric, GSE is utilized throughout the world by major passenger airlines, regional carriers, fixed-base operators (FBOs), air cargo lines, and the military. It may be used in conjunction with, or in place of, fossil-fuel-powered GSE.

The most widely used types of electric GSE on airport ramps are pushout (tow) tractors, baggage tractors, belt loaders, and cargo transporters and loaders. Many forklift trucks used in off-ramp baggage handling areas are also battery-powered. Cabin-service vehicles, personnel carriers, and other types of GSE may also be battery-powered. A wide range of battery sizes are available to equip these vehicles.

4.1 Electricity Demands:

In most instances, airport terminals do not require the installation of additional electric capacity or utility power lines to provide sufficient electricity for battery charging.

4.2 Battery-Vehicle Ratios:

Generally, users of electric GSE achieve effectiveness with one battery per vehicle, but sometimes two batteries per vehicle is preferred, which permits one battery to charge while the other is in use.

4.3 Charging Regimes:

There are basically two regimes for charging batteries:

a. Opportunity
b. Demand

The opportunity method is for active vehicles meaning charging batteries on the vehicle (no removal of battery required) whenever there is a lull in the vehicles' duty cycles. The other method is demand charging, meaning charging batteries when they have reached a maximum 80% depth of discharge (even though they may be rated at 100% depth of discharge), as indicated by the vehicles' dashboard-mounted gauges and/or by actual battery capacity testing with instruments. Whenever possible, battery charging should be performed at night, when activity is normally slow at airports and the significant economies of off-peak-generated electricity may be realized. Details regarding charging regimes may be found in 7.2.

5. BATTERY PRINCIPLES:

5.1 General Electrochemistry:

When two dissimilar materials, in this case lead peroxide and elemental lead, are immersed in a solution of sulfuric acid and water (known as the electrolyte) within a battery, an electromotive force of approximately 2 V per cell is generated. Batteries attain their maximum voltage rating by grouping many cells together, thus creating batteries of 24 V (12 cells), 36 V (18 cells), 48 V, 72 V, and so on.

5.2 Discharge Cycle:

The electrolyte reacts with the lead peroxide in the positive plates and the elemental lead in the negative plates to form lead sulfate on both sets of plates. At the same time, the oxygen from the lead peroxide is disassociated from the positive plates and combines with the hydrogen from the sulfuric acid to form water. As this reaction continues, both the positive and the negative plates become less and less dissimilar, and the sulfuric acid becomes more and more diluted; eventually, the battery becomes discharged in this manner. This reaction, coupled with the pounds of lead and the pounds of sulfuric acid, produce the rated capacity of the battery, which may be measured in kilowatt hours (kW·h) or ampere hours (Amp hours or A·h). The energy available from a battery at any given time is affected by the rate at which energy is discharged from the battery.

5.3 Charge Cycle:

By introducing an electric current back into the battery via connecting it to a properly-sized charger, the same chemical reaction that is responsible for discharge is reversed and the battery is charged. In other words, the positive plates are restored to lead peroxide, the negative plates to elemental lead, and the electrolyte to its original concentration.

6. BATTERY MAINTENANCE PROCEDURES:

The following procedures should be followed whenever handling batteries, whether during normal charging, regularly scheduled periodic maintenance, or specific repair situations:

a. Shut off all incoming power and disconnect the battery from the charger before servicing batteries or chargers. Assure that all other connections are clean, tight, and well insulated.

b. Keep batteries cool and dry. Never store, use, or charge batteries near open flames, sparks, smoking materials, or sources of excessive heat or moisture.

c. Check fluid (water-acid electrolyte) level periodically if using a battery requiring regular maintenance. If necessary, add only approved water (usually distilled or low-mineral-content water), filling each cell (through its opening) to no more than the manufacturers' recommended level, or via the single-point watering port on batteries constructed in this manner. Water should be added when the battery is fully charged, otherwise, expansion may cause corrosive and potentially harmful acid to spill over during the charging cycle; also, hydrogen gassing levels could exceed the norm.

NOTE: This level-checking and, if necessary, "topping up" of the electrolyte refers only to traditional vented, liquid electrolyte batteries. Sealed batteries (often called reduced-maintenance or maintenance-free batteries) obviously do not require much, if any, regular user maintenance. It is not advisable for users to add sulfuric acid to batteries; in infrequent instances when test readings indicate insufficient electrolyte concentration, consult manufacturers' instructions.

d. Protective clothing, including eye shields (preferably full face shields) and aprons are required during topping-up procedures. If electrolyte accidently comes in contact with the skin, flush promptly with water. Battery maintenance areas are also required to be equipped with certain safety devices - a fire extinguisher, an eye wash basin, and a shower. It is also highly recommended that a placard of basic on-the-job safety procedures be clearly displayed in all battery charging/maintenance areas.

e. Do not overcharge batteries. Follow manufacturers' guidelines. Overcharging can be just as damaging to batteries as undercharging.

f. Adequate ventilation (especially above batteries) is mandatory when charging to allow dilute gases to escape and be disposed of safely (hydrogen gas is liberated during the charging cycle and is explosive). Simple hoods above battery-chargers and exhaust blowers-vents often suffice.

6. (Continued):

g. Monitor battery condition regularly and record the electrolyte specific gravity (hydrometer reading) and voltage output (voltmeter reading) of each cell. Check these readings against the norms, promptly investigating the cause of large and/or frequent variations from the norms as specified by the manufacturers. A well-organized maintenance record book should be kept so that all personnel involved can access accurate, up-to-date, battery information quickly. Good record-keeping may also prove invaluable should warranty claims need to be made or should major repairs be indicated. Specific gravity readings for battery cells are as follows:

(1)	Full charge:	1.275 to 1.300 (some high gravity batteries might have readings in excess of 1.300)
(2)	Medium charge:	1.240 to 1.275
(3)	Low charge:	1.200 to 1.240
(4)	Fully discharged:	1.100

h. Keep vent plugs tightly in place and free of foreign matter when batteries are in service or charging.

i. Clean external battery case periodically with sodium bicarbonate (household baking soda) and water solution; use a stiff scrub brush if corrosion is heavy on the battery casing. It is preferable to allow battery to dry thoroughly before placing back in service, but some types of batteries can be used immediately after washing.

CAUTION: Avoid ingestion of cleaner into the battery.

NOTE: Sealed lead acid batteries, because they are unvented, should not require external case maintenance, except for removal of dirt/dust that might accumulate on the batteries from the environment.

j. Never place objects (especially metal) adjacent to the battery terminals (side or top), to avoid accidental discharge.

6.1 Special Battery Maintenance:

While routine battery charging and maintenance is normally handled by drivers and related personnel, certain special maintenance and repairs may also be done in-house. These would include many trouble-shooting tasks that can normally be handled by trained on-site technicians. Some of the most common are as shown in Table 1.

TABLE 1 - Troubleshooting Tasks

Condition	Possible Cause	Possible Solution
Low Specific Gravity	Overwatering	Do not overfill
	Insufficient charge	Extend charge
	Internal short	Repair/replace cell
Excessive Water Needs	Overcharging	Check charger size/time
	Cell leakage	Repair/replace cell
	Overheating	Cool and ventilate and check charger
High Cell Temperatures	Overcharging	Shorten charge time and check charger
	Battery overworked	Reduce working time or increase the size of battery
Poor Vehicle Performance	Battery undersized or bad battery cell	Use larger battery and check battery for bad cell

7. BATTERY CHARGING PROCEDURES:

Batteries need to be charged for the same reason that fuel tanks need to be refilled. Modern, automatic, solid-state chargers and color-coded connector cables make the charging process almost foolproof.

7.1 Charge Times:

Generally, a battery requires charging when it reaches approximately the 80% depth-of-discharge level, most often indicated by the battery state-of-charge meter (usually dashboard-mounted) dipping into the danger zone. Although many batteries are rated for 100% depth-of-discharge, experience has proved that full discharge can negatively affect a battery's life and cycle capability. Experienced users will soon determine, on average, how long a given vehicle's battery will last in terms of either hours of actual work, or on a per-shift basis. Intervals between charging will vary depending upon vehicle use, atmospheric conditions, and battery age. Most of the newer electric GSE have function lockout and/or visual indicating mechanisms which encourage charging at the proper time while enabling the vehicle to be driven safely to the nearest charging area.

7.2 Charging Regimes:

As stated previously, there are essentially two charging regimes: demand charging and opportunity charging.

a. Demand Charging: This is the most practiced method, and also the most acceptable method from the battery manufacturers' standpoint.

b. Opportunity Charging: This is often the most convenient method from the users' standpoint.

c. Either of the above methods may be practiced, either exclusively or in combination. Suffice to say, it might take 6 to 8 h to deliver a full charge to a fully discharged battery being demand charged; conversely, it might take only a few minutes to re-energize a partially discharged battery. In either case, automatic charges reduce the possibility of human error and incorrect charging. However, care should be taken to ensure that the best suited automatic control is chosen for the charging regime intended.

d. Equalization Charging: Modern chargers can also be set to deliver an equalizing, or trickle, charge to batteries; that is, they can equalize the voltage in all cells even when the battery as a whole is fully charged. Equalization charging is highly recommended and should aid in prolonging the life of batteries.

7.3 Battery Charging Facilities: All of the following must be considered:

a. Location Factors - Many factors must be considered in determining the location of, and requirements for, battery handling facilities, i.e., centralization (standardization and control) versus decentralization (random placement of facilities and chargers). Both centralized and decentralized systems are, and may be, used depending upon the following factors:

(1) Determination of battery population and location
(2) Space - physical and floor load parameter
(3) OSHA (and other applicable) requirements/regulations
(4) Travel distances
(5) Personnel
(6) Number of facilities designated for charging only; no servicing

b. Utilities Required:

(1) Clean water and drains
(2) Sufficient electric power
(3) Adequate ventilation
(4) Approved acid disposal system

c. Capital Equipment, Related Materials: As a general rule, the following items are part of a comprehensive charging facility, but modifications are common depending upon whether batteries are charged while on-board vehicles or battery changing (physical removal and replacement) is practiced:

(1) Battery hoist
(2) Battery racks
(3) Chargers
(4) Charger racks
(5) Maintenance tools
(6) Approved water sources
(7) Water hose(s)
(8) Battery washing station
(9) Minor repair equipment/parts/spare parts storage
(10) Eye wash and deluge shower
(11) Spreader bar
(12) Storage container
(13) Ventilation system
(14) Personnel protective clothing
(15) Floor markings
(16) "No Smoking" signs/general safety placards
(17) Manufacturers' maintenance manuals (batteries, chargers)