Battery Room Ventilation and Safety

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Credit: 5 PDH

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BATTERY ROOM VENTILATION AND SAFETY

It is common knowledge that lead-acid batteries release hydrogen gas that can be potentially explosive. The battery rooms must be adequately ventilated to prohibit the build-up of hydrogen gas. During normal operations, off gassing of the batteries is relatively small. However, the concern is elevated during times of heavy recharge or the batteries, which occur immediately following a rapid and deep discharge of the battery.

Often the HVAC designers underestimate the worst case for dangerous hydrogen accumulation, and often display reassuring calculations proving that no danger really exists. But dismissing such a critical safety issue is not a safe or responsible way to deal with it. Instead, we should be prepared to face the likely possibility of hydrogen build up, clearly identify the conditions when the risk is highest, and design systems that protect us from explosive levels in a fail-safe way.

This course describes the hazards associated with batteries and highlights those safety features that must be taken into consideration when designing, constructing and fitting out a battery room. It provides the HVAC designer the information related to cost effective ventilation. The course is only for reference and anyone using this course should rely on state and local codes that may apply. Advice on specific ventilation rates required must be sought from the battery suppliers.

This course is applicable to facility professionals, architects, electrical, mechanical and HVAC engineers, controls engineers, contractors, environmentalists, energy auditors, O& M professionals and loss prevention professionals.

The course is divided into 5 chapters:

1. Fundamentals of Lead-acid Battery
2. Rules and Regulations
3. Ventilation Calculations
4. Battery Room Design Criteria
5. Preparation and Safety – Do’s and Don’t’s

Once you complete your course review, you need to take a multiple-choice quiz consisting of twenty five (25) questions based on this document.

CHAPTER -1

FUNDAMENTALS OF LEAD-ACID BATTERIES

The function of the battery is to store electricity in the form of chemical energy and when required to convert it to electrical energy. Electrical energy can be produced from two plates immersed in a chemical solution. When several are linked, they give a higher capacity.

Battery cells can be divided into two major types:

- Primary cell: It is one that cannot be recharged and is discarded at the end of its life.
- Secondary cell: It is one that is rechargeable.

Examples of primary cells include carbon-zinc (dry cell), alkaline-manganese, mercury-zinc, silver-zinc, and lithium cells (e.g., lithium-manganese dioxide, lithium-sulfur dioxide, and lithium-thionyl chloride). Examples of secondary cells include lead-lead dioxide (lead-acid), nickel-cadmium, nickel-iron, nickel-hydrogen, nickel-metal hydride, silver-zinc, silver-cadmium, and lithium-ion.

Lead-acid battery

Lead-acid battery is a type of secondary battery which uses a positive electrode of brown lead oxide (sometimes called lead peroxide), a negative electrode of metallic lead and an electrolyte of sulfuric acid (in either liquid or gel form). The overall cell reaction of a typical lead-acid cell is:

$$\underset{\text{Lead}}{Pb} + \underset{\text{Lead oxide}}{PbO_2} + \underset{\text{Sulphuric acid}}{2H_2SO_4} \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} \underset{\text{Lead sulphate}}{2PbSO_4} + \underset{\text{Water}}{2H_2O}$$

The three major contributors to Lead-acid battery chemistry are lead, lead dioxide, and sulfuric acid. Unfortunately pure lead is too soft to withstand the physical abuse; about 6% antimony is added to strengthen it. Historically, antimony added to the lead grids, acted as a catalyst and made out gassing (loss of hydrogen and oxygen during use) worse, and frequent water replenishing was required. So battery manufacturers looked for another material that could strengthen the lead grids. Calcium was added to both the positive and negative electrodes. It reduced out gassing enough to allow manufacturers to claim they are building "maintenance-free batteries".

Alkaline battery (Nickel-Cadmium battery)

An alkaline storage battery has an alkaline electrolyte, usually potassium hydroxide (KOH), and nickel oxide (nickel oxy-hydroxide) as positive electrode and metallic Cadmium as negative electrode. The overall cell reaction is:

$$\underset{\text{Cadmium}}{Cd} + \underset{\text{Nickel oxyhydroxide}}{2NiOOH} + \underset{\text{Water}}{2H_2O} \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} \underset{\text{Cadmium hydroxice}}{Cd(OH)_2} + \underset{\text{Nickel hydroxide}}{2Ni(OH)_2}$$

The nominal cell voltage = +1.2V

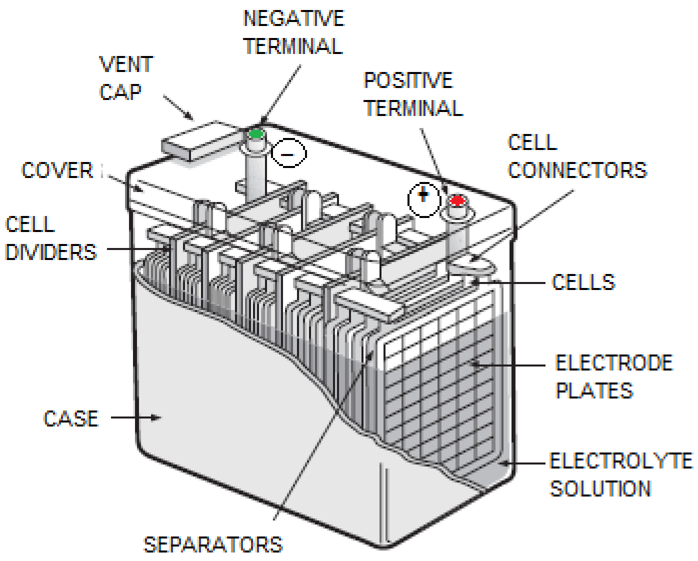
When compared to lead-acid batteries, Nickel Cadmium loses approximately 40% of its stored energy in three months, while lead-acid self-discharges the same amount in one year. Lead-acid work well at cold temperatures and is superior to the lithium-ion when operating in sub-zero conditions.

The Lead-acid battery is the most popular type used and we will focus on it in this course.

Components of Lead-Acid Battery

The Lead-acid Battery basically consists of the following four (4) components:

1. Case
2. Terminals
3. Plates
4. Electrolyte



A RECHARGEABLE BATTERY

Case

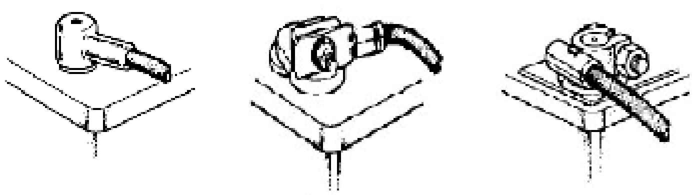
The battery case is constructed of insulating, acid resistant material usually plastic or hard rubber and has a number of compartments or cells. A 12-volt battery has 6 cells. Recesses in the bottom of the cells collect the sediment that falls from the plates. This prevents the sediment from bridging the plates and causing an internal short-circuit. The top of the plate assembly is enclosed by a moulded one-piece cover which is sealed to the main case. Each cell has a removable plug to facilitate topping up and testing. These plugs are vented to allow for the escape of gases produced during charging.

Terminals

Positive pole: shown '+' usually red in color and is the larger of the two.

Negative pole: shown '–' usually black or green and is the smaller of the two.

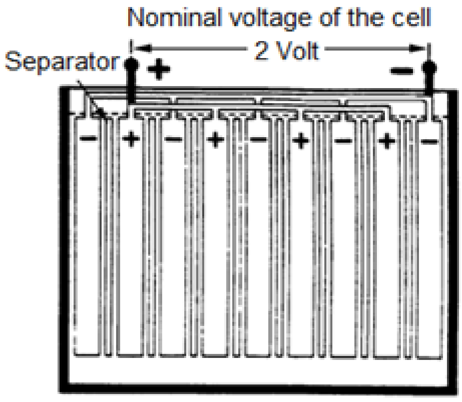
Battery connectors: Various types of connectors are shown below:



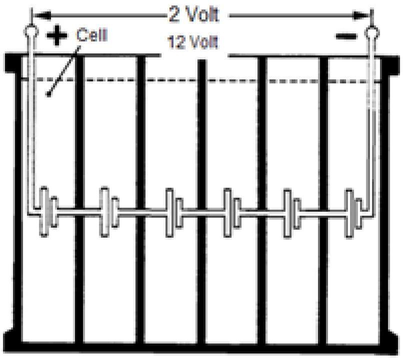
Die Cast (Helmet) Type | Flat Type | Clamp Type

Plates

Batteries are composed of one or more cells; each cell has a number of positive and negative plates with separators fitted between them. The total number of plates per cell is normally not less than seven, usually starting and finishing with a negative plate.



The surface area of the plates in a cell determines its current capacity. In a lead-acid battery, the plates are assembled so there is always one extra negative plate. The plates are close to each other but do not touch, which would cause a short-circuit.



One set of plates is connected to the negative side of a DC source, the other to the positive side. Direct current is applied to the plates, changing them chemically, until the battery is ready for service.

The nominal voltage of a cell is 2 volts. Cells connected in series make a battery, and the number of cells determines its nominal voltage. The accepted, or nominal, voltage of a cell does not depend on the size of the cell. The size of the cells determines the discharge capacity (current capacity) of the entire battery.

Each cell has its own vent cap designed to relieve excess pressure and allow gases to escape. It also keeps the dust and dirt out of cells and contains electrolyte solution inside the battery cell.

Electrolyte

The battery is filled with electrolyte, which is a mixture of 35% sulfuric acid and 65% de-ionized water. The separators between the plates are porous to allow the circulation of the electrolyte, and the chemical action to take place. When the cell is functioning, the acid reacts with the plates, converting chemical energy into electrical energy. Electrical current flows from one pole of the battery, through the circuit, and back to the battery.

Discharging

In a fully-charged battery the positive plates are made of lead peroxide and the negative plates are spongy lead. During discharge or use:

- Sulphur in the acid combines with the plates to form lead sulphate; and
- The oxygen and hydrogen released combine to form water, which dilutes the electrolyte.

As the battery is discharged, or used, the acid concentration decreases and becomes weaker (dilute) until the battery cannot produce an electrical current. This makes it possible to tell the state of charge by seeing how weak the electrolyte is. A hydrometer is used to measure the strength of the electrolyte. Both negative and positive plates become lead sulphate as the battery is discharged by use. The resulting lead sulphate is bulkier than spongy lead or lead peroxide, so if the battery is discharged too quickly the plates will buckle and some paste will fall out. This shortens the life of the battery.

Note, the strength is generally expressed in terms of specific gravity, which is weight of the electrolyte compared to the weight of an equal volume of pure water.

Charging

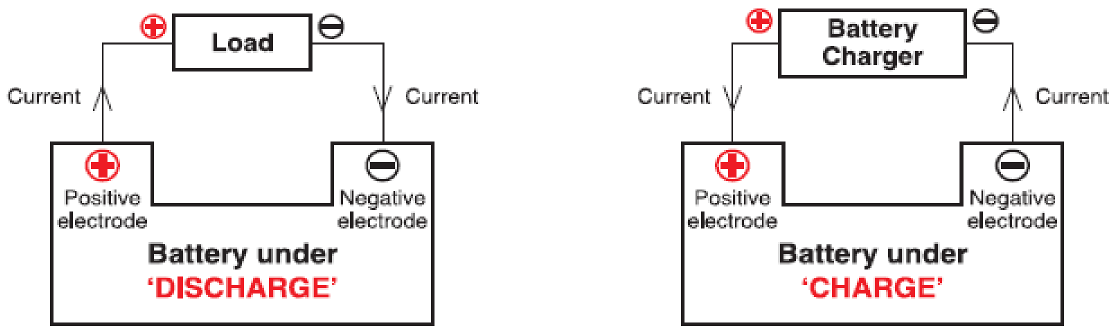
To charge a battery, a current must be forced back through it. So a positive voltage must be applied to the positive terminal, and negative to the negative terminal. Also the voltage must be high enough to overcome the battery voltage and drive sufficient current into the battery. About 14 Volts is adequate, for a 12V battery.

- Oxygen in the electrolyte combines with the lead sulphate of the positive plate to become lead peroxide;
- Sulphate is released from both plates, which is converted to sulfuric acid and the concentration of the electrolyte is restored; and
- The negative plate becomes spongy lead.

Charging is thus the reverse of discharging, and the plate materials return to their original forming of lead peroxide for the positive plates and spongy lead for the negative plates. The sulfuric acid (H_2SO_4) concentration becomes highest when the cell is fully charged.

Battery Operation

The diagrams below show the basic operation of a rechargeable battery under discharge and charge conditions. The positive terminal is the cathode during discharge, but it is the anode during recharge. Remember, the terms “anode” and “cathode” properly apply to function, not structure. The anode of a device is the terminal where current flows in from outside. The cathode of a device is the terminal where current flows out. A useful mnemonic is ACID: Anode Current into Device.



Key Facts

Lead-acid batteries do not lend themselves to fast charging and, with most types, a full charge takes 14 to16 hours.

A Lead-acid battery must always be stored at full state-of-charge. Low charge causes sulfation, a condition that robs the battery of performance. Adding carbon on the negative electrode reduces this problem but this lowers the specific energy.

TYPES OF LEAD-ACID BATTERIES

Lead-acid batteries are the most widely used energy reserve for providing direct current (DC) electricity, primarily for uninterrupted power supply (UPS) equipment and emergency power system (inverters). There are two basic cell types: Vented and Recombinant Valve Regulated Lead-acid (VRLA) Batteries.

Vented Lead-acid Batteries

Vented Lead-acid Batteries are commonly called “flooded” or “wet cell” batteries. These have thick lead-based plates that are flooded in an acid electrolyte. The electrolyte during charging emits hydrogen through the vents provided in the battery. This reduces the water level and therefore periodic addition of distilled water is required. Also since the hydrogen released to the surroundings is highly flammable and explosive; these types of batteries must be installed in a sufficiently ventilated room. Most industry codes specify 6 air-changes per hour in the battery room. We will learn more on ventilation later in this course.

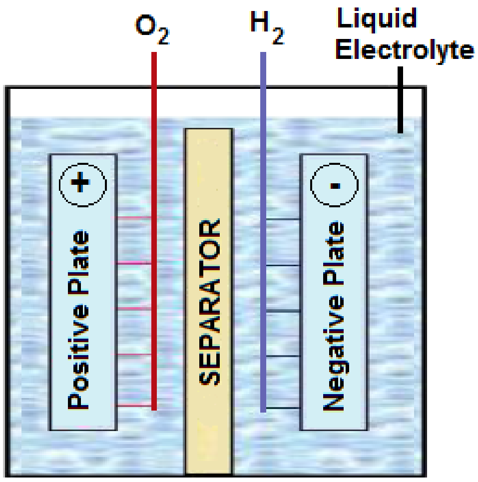
Recombinant Valve Regulated Lead-acid (VRLA)

Recombinant cells have a starved or gelled electrolyte. The oxygen generated from the positive electrode during charging diffuses to the negative electrode producing water:

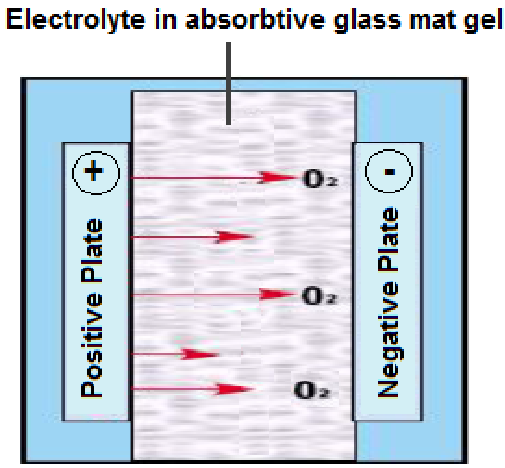
$$Pb + H_2SO_4 + \frac{1}{2}O_2 \rightarrow PbSO_4 + H_2O$$

The recombination reaction suppresses hydrogen evolution at the negative electrode, thereby allowing the cell to be sealed. In practice, the recombination efficiency is not 100% and a pressure relief valve regulates the internal pressure at a relatively low value, generally below 10 psig. For this reason, sealed lead-acid cells are often called “valve-regulated lead-acid” (VRLA) cells.

The diagram below shows a comparison between vented battery gassing and VRLA battery recombination.



VENTED BATTERY



VRLA BATTERY

Comparison of Flooded v/s Sealed Batteries

Both the vented and the VRLA batteries work on the principle of chemical reactions between positive and negative plates. But there are some key differentiating characteristics:

1. In flooded cell batteries the electrolyte is in liquid form, while in VRLA batteries it is immobilized in a gel or absorbent glass mats.
2. The flooded cell batteries release hydrogen continuously during charging while the VRLA batteries release hydrogen only when overheated and/or overcharged. The flooded cell batteries emit approximately 60 times more hydrogen than comparably rated VRLA batteries.
3. The flooded cell batteries require dedicated ventilation system to maintain hydrogen concentration below the lower explosive limit. VRLA batteries have lesser risk and these can be housed without mechanical ventilation. Supplier guidance must be applied.
4. The flooded cell batteries should be installed in dedicated rooms physically separated from other areas. Room construction shall be designed to meet the required fire resistance rating for the application. VRLA batteries have lesser risk and can be used in the same room as the equipment they support.
5. VRLA batteries are prone to failure condition known as “thermal runaway.” It is a condition when the heat generation rate inside the battery is faster than the heat dissipation. To prevent the failure and the battery dry out, the safety

valves open and the battery vents hydrogen until temperature and/or voltage are reduced. This condition can be triggered by charger over-voltage. Flooded cell batteries are immune to thermal runaway condition.

6. Flooded lead-acid batteries can be charged at high voltage settings which improve performance. VRLA batteries are usually set to a lower voltage limit, which shelters the battery but produces poor performance. Check with your battery vendor for guidance.
7. VRLA batteries usually have lower up-front costs but have a shorter lifetime than wet-cell, usually around five years. Flooded cell batteries require more advanced maintenance but have a longer lifetime, up to 20 years.

BATTERY TERMINOLOGY

Batteries are rated in terms of their nominal voltage and ampere-hour capacity.

Battery Capacity

The ampere-hour (AH) capacity is the unit used in specifying the storage capacity of a battery. While a battery that can deliver 10 A for 10 hours can be said to have a capacity of 100 AH, that is not how the rating is determined by the manufacturers. A 100 AH rated battery most likely will not deliver 10 A for 10 hours. Battery manufacturers use a standard method to determine how to rate their batteries. Their rating is based on tests performed over 20 hours with a discharge rate of 1/20 (5%) of the expected capacity of the battery per hour. So a 100 ampere-hour battery is rated to provide 5 A for 20 hours. The efficiency of a battery is different at different discharge rates. When discharging at 5% an hour, the battery's energy is delivered more efficiently than at higher discharge rates. To calculate the 5% discharge rate of a battery, take the manufacturer's ampere-hour rating and divide it by 20.

C-rate

C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. 1C rate means that the discharge current will discharge the entire battery in 1 hour; 0.1C means 10% transfer in one hour, or full transfer in 10 hours; 5C means full transfer in 12 minutes, and so on.

State of Health

The state-of-health of a battery is the percentage of its capacity available when fully charged relative to its rated capacity. For example, a battery rated at 30 AH, but only capable of delivering 24 AH when fully charged, will have a state-of-health of 24/30 x100 = 80%. Thus, the state-of-health takes into account the loss of capacity as the battery ages.

Voltage Rating

The voltage rating is based on the number of cells connected in series and the nominal voltage of each cell (2.0 V for lead-acid type and 1.2 V for nickel-cadmium). Twelve-volt lead-acid batteries will have six cells in series.

Reserve Capacity (RC)

This is defined as the time in minutes for the battery voltage to fall to 10·5 volts with a constant load of 25 Amps at a temperature of 25°C.

Cycle Life

The cycle life of a battery is defined as the number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria. Cycle life is estimated for specific charge and discharge conditions. The actual operating life of the battery is affected by the rate and depth of cycles and by other conditions such as temperature and humidity.

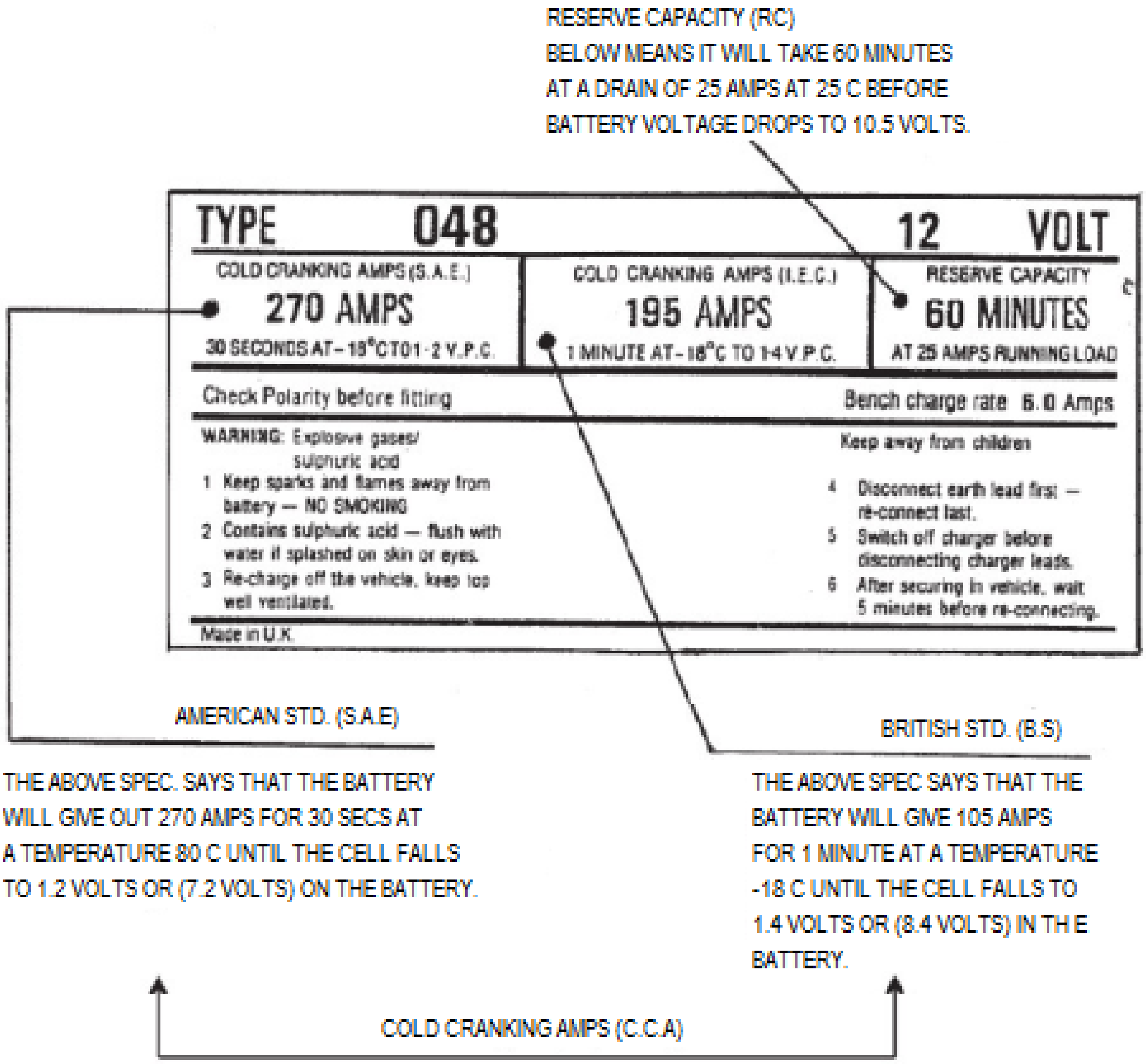
State of charge

The concentration (strength) of sulfuric acid within the electrolyte varies with the state of charge. This changes the density or specific gravity of the electrolyte, which can be measured with a hydrometer. A hydrometer is a scale that indicates the density readings of an electrolyte.

State of Charge	Density
Fully charged	1.280
Half charged	1.200
Discharged	1.120

Since temperature also has a small effect on density, the graph below would be a more accurate way of finding the state of charge.

Typical label on a Battery



Batteries Classification

Batteries can be classified either as starter batteries or deep cycle batteries.

The starter battery is designed to provide a momentary high power burst, for example cranking an engine. The deep-cycle battery, on the other hand, is built to provide continuous power, for example motive power for a wheelchair or golf car. The deep cycle means that the battery is fully discharged and then recharged. From the outside, both batteries look alike; however, there are fundamental differences in design.

The starter battery has many thin plates in parallel to achieve low resistance with high surface area. The deep-cycle battery has thick plates for improved cycling abilities. The starter battery is made for high peak power and does not allow deep cycling, whereas the deep-cycle battery has a moderate power output but permits cycling.

BATTERY SIZING

Battery banks can be sized based on the greater of either load demand or generation input.

Sizing Battery Banks Based on Loads

To estimate the battery requirements on load, you must first calculate the amount of power you will draw from the batteries. This power draw is then translated into ampere hours (Ah); the unit of measure to express battery capacity.

To calculate ampere current drawn by the load expressed in watts, use the following equation:

$$A = W/V \text{ (where W = watts and V = volts DC)}$$

Battery capacity in ampere hours (Ah) is than calculated by multiplying the current drawn by the load by the length of time it will operate.

Example:

A usable capacity of 460 Ah @ the 100 hr rate would be able to sustain a 4.6 amperes load (460/100) for 100 hours for full discharge.

A battery with a capacity of 350 ampere-hours should provide 17.5 amperes (350/17.5) for 20 hours.

Example:

Suppose a 12-V automotive battery is rated at 36 Ah. If a 100-W, 12-V bulb is connected across this battery; how long will the bulb stay aglow, assuming the battery has been fully charged?

Current drawn = Watts/Volts = 100/12 = 8.33 amps

Battery capacity = 36 Ah

Time the battery will sustain for full discharge = 36/8.33 = 4.32 or 4 hours 20 minutes.

Sizing Battery Banks Based on Generation

If renewable energy sources (solar, wind, hydro, etc.) are going to be used for battery charging, then the amp-hours of the battery bank needs to be 5 times the size of the charging source. For example, if you have a solar photovoltaic panel that can produce 100-amps DC, then size the battery bank to a minimum 500 amp-hours. This is because the batteries aren't just used for storage; they are also a buffer for all the charging energy which is brought into them.

Renewable energy sources require using charge controllers. Some charge controllers cannot respond quick enough to prevent over-voltage conditions in rapidly changing input levels (i.e., wind gusts or grid power interruptions). Small battery banks cannot absorb large spikes in input power that can occur under those conditions. Larger sized battery banks can provide a buffer to prevent equipment damage until the charge controllers take over.

Sizing your Battery Charger

Using the right battery charger is the first step in protecting and maintaining your expensive deep cycle battery bank.

Know the size in amp hours of your battery bank. If you under-estimate the required charging capacity of your battery bank, the charger will take longer to charge your batteries. If you over-estimate the required charging capacity, the charger may deliver too much current. Excessive charging current can cause battery overheating, accelerated water loss in flooded type batteries, and damaged batteries. Many battery manufacturers recommend a maximum charging rate of 20% of the amp hour capacity of the battery. For example, a 220 a/h battery bank (a small golf cart battery bank) should be charged at 44 amps per hour.

The Cardinal Rule of Battery Charging

Do not mix battery types (gel, flooded or AGM). Mixing battery types will cause incorrect charging, reduced battery life, and possible damage to the battery bank if charged by an incorrect charge setting.

FACTORS AFFECTING BATTERY LIFE

There are four primary factors that affect battery life. These are ambient temperature, battery chemistry, cycling and service.

Ambient temperature

The rated capacity of a battery is based on an ambient temperature of 25°C (77°F). Any variation from this operating temperature can alter the performance of the battery. Battery capacity is diminished at low temperatures. Higher room temperatures will shorten the expected battery life.

Battery chemistry

Batteries are electrochemical devices whose ability to store and deliver power slowly decreases over time. Batteries should always remain in charged state. If allowed to remain in the discharged state for a prolonged time period, the battery becomes damaged by “sulfation”. It is important to periodically equalize your batteries. Equalization is an overcharge performed on flooded cell batteries after they have been fully charged. Equalization causes water in the cells to evaporate.

Cycling

During a utility power failure, the battery power is used. Once utility power is restored, the battery is recharged for future use. This is called a discharge cycle. At installation, the battery is at 100 % of rated capacity. Each discharge and subsequent recharge reduces the relative capacity of the battery by a small percentage. The length of the discharge cycle determines the reduction in battery capacity.

Lead-acid batteries can only undergo a set number of discharge/recharge cycles before the chemistry is depleted. Once the chemistry is depleted, the cells fail and the battery must be replaced.

Maintenance

Service and maintenance of the batteries is critical to the reliability and the battery life. Without regular maintenance, the battery may experience heat-generating resistance at the terminals, improper loading, reduced protection and premature failure.

A gradual decrease in battery life can be monitored and evaluated through voltage checks, load testing or monitoring. Periodic preventive maintenance extends the battery string life by preventing loose connections, removing corrosion and identifying bad batteries before they can affect the rest of the string.

SAFETY AND HEALTH HAZARDS

There is always a possibility of explosion by arcing/sparking around the battery terminals due to Hydrogen and Oxygen presence from the charging process, acid burns, spillages, overcharging and toxic fumes. Under extreme conditions, certain types of batteries can explode violently. A battery explosion is usually caused by the misuse or short-circuit malfunction of a battery.

The hazards associated with the battery work can be grouped into the following major categories:

1. Electrical hazards;
2. Fire and explosion hazards;
3. Chemical hazards; and
4. Other related hazards.

Electrical hazards

There are two major electrical hazards in connection with the battery work, namely, electric shock and short-circuit of live electrical conductors.

1. Electric shock may occur when one makes direct contact with the exposed battery terminals stayed at different potential or with the exposed conductor of

cables or conductive parts connected with the battery, resulting in the passing of electric current through the body of the victim.

2. Short-circuit of the battery terminals or other electrical conductors stayed at different potential would cause a high current flow. The sudden release of energy stored in the battery in a short time and under an uncontrolled manner may cause a flashover and explosion, thus resulting in the rupture of battery housing, spillage of electrolyte, melting down of battery terminals or other metal parts, and subsequent splashing of molten metal, etc.
3. Overcharging, which is charging a battery beyond its electrical capacity, can also lead to a battery explosion, leakage, or irreversible damage to the battery. It may also cause damage to the charger or device in which the overcharged battery is later used. Batteries liberate hydrogen when they are overcharged even slightly (because of hydrolysis of the water in the electrolyte).

Fire and explosion hazards

When the charging operation is close to completion, explosive gas may be generated from the battery due to the action of electrolysis of water contained in the electrolyte solution.

$$\underset{\text{water}}{2H_2O} \xrightarrow[\text{electrolysis}]{} \underset{\text{hydrogen}}{2H_2\uparrow} + \underset{\text{oxygen}}{O_2\uparrow}$$

The gases produced are hydrogen and oxygen. The former is much lighter than the air and would accumulate in the air space above the electrolyte solution inside the battery. These gases may also leak through the battery vents and disperse to the surrounding of the battery room or workplace.

Hydrogen gas when mixed with oxygen or air can be explosive. Any spark or naked flame present may cause a fierce explosion of the explosive mixture. Sparks may be generated by electrostatic discharge, abrasion of some metals, normal switching or abnormal tripping of electrical equipment, etc. A smouldering burn may turn into a blaze in the presence of enriched oxygen. Any combustibles in the vicinity, which is not ignited in the air normally, may ignite by itself in the presence of enriched oxygen.

Chemical hazards

The chemicals and materials commonly used in rechargeable batteries are hazardous to health. Workers may suffer from skin burn or eye injury caused by spillage or splashing of electrolyte if they mishandle or improperly maintain the battery. It is important to practice precautionary measures such as maintaining adequate ventilation, using safety/protective gear, housekeeping and maintaining personal hygiene.

Other related hazards

There are other work related hazards associated with the battery work. These include, but not limited to, the following:

- Falling from height when handling battery installed at high level;
- Tripping due to tangling of electric cables during charging of battery or hand tools placed on the floor; and
- Musculoskeletal disorders resulting from the improper handling of batteries that are usually heavy.

Environmental Issues

The legal requirements for lead-acid batteries in relation to “end of useful life” are such that they should be disposed in a manner that is appropriate to the current laws and regulations within the state. The storage of the batteries has to be such that it conforms to the safety rules and regulations. The collection of used batteries has to be by an approved recycling company. Contact your local waste disposal company for further details.

CHAPTER – 2

RULES AND REGULATIONS

There are many different rules, regulations and standards affecting stationary battery selection, installation, operation and maintenance. Some of these address the battery while others address the battery room or other associated equipment. The following is intended to be a brief listing and discussion of these various rules and standards and not a legal interpretation.

The first and most familiar are the IEEE standards. The Institute of Electrical and Electronics Engineers has detailed requirements on the installation and maintenance of batteries. These standards are a consensus by manufacturers and any interested users as to the best method to get safe reliable operation of a stationary battery system. They are not laws. Listed below are IEEE's specific recommendations on storage batteries.

1. **IEEE – 450:** "Recommended Practice for Maintenance, Testing and Replacement of Large Lead Storage Batteries for Generating Stations and Substations"

   Maintenance inspection procedures are explained along with the proper parameters for various tests. Replacement criteria along with record keeping are detailed.

2. **IEEE – 484:** "Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations"

   Many aspects of safety, mounting alarms, Nuclear IE classification, installation criteria and procedures and record keeping are described in this section.

3. **IEEE – 485:** "Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations"

   This particular section defines loads and duty cycle, and details the sizing of large stationary batteries, cell selection, determining battery size, etc.

4. **IEEE – 635:** "Standard for Qualification of Class IE Load Storage Batteries for Nuclear Power Generating Stations"

5. **IEEE – 537:** "Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems"
6. **IEEE – 1105:** "Recommended Practice for Maintenance, Testing and Replacement of Ni-Cad Storage Batteries for Generating Stations and Substations"
7. **IEEE – 1187:** "Recommended Practice for Installation of Valve Regulated Lead-acid Batteries" Same as equivalent practice for wet cells.
8. **IEEE – 1188:** "Recommended Practice for Maintenance and Testing of Valve Regulated Lead-acid Batteries" Same as equivalent practice for wet cells.
9. **IEEE – 1189:** "Recommended Practice Guidelines for Sizing Valve Regulated Lead-acid Batteries" Same as equivalent for wet cells.

OSHA (Occupational Safety and Health Administration)

OSHA (Occupational Safety and Health Administration) rules are concerned only with the safety of employees. They are laws, administered by the states based on uniform federal law.

OSHA 1925.403 (A) General Requirements -

1. Batteries of the non-seal type shall be located in enclosures with outside vents or in well ventilated rooms, so arranged as to prevent the escape of fumes, gases, or electrolyte spray into other areas.
2. Ventilation shall be provided to ensure diffusion of the gases from the battery to prevent the accumulation of an explosive mixture.
3. Racks and trays shall be substantial and treated to be resistant to the electrolyte.
4. Floors shall be of an acid resistant construction or be protected from acid accumulations.
5. Face shields, aprons, and rubber gloves shall be provided for workers handling acids or batteries.
6. Facilities for quick drenching of the eyes and body shall be provided within 25 feet of the work area for emergency use.

7. Facilities shall be provided for flushing and neutralizing spilled electrolyte, for fire protection, for protecting charging apparatus from damage by trucks, and for adequate ventilation for dispersal of fumes from gassing batteries.

OSHA 1910.178 subparagraph (g) – “Changing and Charging Storage Batteries”

This particular section deals more with motive power battery usage than with stationary battery installations, but several paragraphs may still apply.

1. Facilities shall be provided for flushing and neutralizing spilled electrolyte, for fire protection, for protecting charging apparatus from damage, and for adequate ventilation for dispersal of fumes from gassing batteries.

2. When racks are used for the support of batteries, they should be made of materials nonconductive to spark generation or be coated or covered to achieve this objective.

3. Precautions shall be taken to prevent open flames, sparks or electric arcs in battery charging areas. Tools and other metallic objects shall be kept away from the top of uncovered batteries. Smoking shall be prohibited in the charging area.

The National Electrical Code (NEC)

The National Electrical Code (NEC) is also a law, enforced by the local electrical inspectors. The NEC has very limited mention of stationary batteries. Selections that mention back up power, emergency lighting, and/or telecommunications are as follows:

1. **701-4 (c):** Battery Systems Maintenance.

   Where battery systems or unit equipment are involved (including batteries used for starting, control or ignition in auxiliary engines), the authority having jurisdiction shall require periodic maintenance.

2. **701-5 (d):** Written Record.

   A written record shall be kept of such tests and maintenance.

3. **480-1 through 480-9 Storage Batteries**

   This section provides a definition of what a battery is, and describes the types of batteries and how they are designed. It also lists other codes to reference.

Sealed and wet cells are described along with ventilation, load requirements, and other topics.

4. **480-6 Separation of 250 VDC**

   A separation of air between voltages higher than 250 VDC is required. Typically, the rack design meets this requirement.

The Uniform Building Code (UBC)

The Uniform Building Code (UBC) is one of the three major building codes used in the United States but the UBC has been adopted more readily than the other two. UBC addresses two issues regarding storage battery installations: seismic qualifications and spill containment for materials that are health hazards.

1. **1994 UBC 1630 -** "Lateral Forces on Elements of Structures, Nonstructural Components and Equipment Supported by Structures"

   This particular section of the UBC code has been adopted as the standard for design by many vendors. It covers the design and development of storage battery racks and trays.

2. **UBC 307 -** Requirements for Group H Occupancies

   This section references a table which describes the requirements of a spill containment system for lead-acid storage batteries. Basically, the UBC code is used as the foundation of the 1994 Uniform Fire Code Article 64.

3. **UBC 307 1.1** General

   Group H Division 7 (term is defined below) occupancies shall include buildings or structures, or portions thereof, that involve the manufacturing, processing, generation or storage of materials that constitute a high fire, explosion or health hazard. For definitions see table 3-E and divisions.

4. **UBC 307 1.2 -** Multiple Hazards

   When a hazardous material has multiple hazards, all hazards shall be addressed and controlled in accordance with the provisions of this chapter.

5. **UBC Division 7**

   Occupancies having quantities of materials in excess of those listed in Table 3-E that are health hazards, include:

   Corrosives – Liquids in excess of 500 gallons

6. **UBC 307.2.3 -** Construction, Height and Allowable Area

   UBC 307.2.3 Spill Control: When required by the Fire Code, floors shall be recessed a minimum of 4 inches or shall be provided with a liquid-tight raised sill, with a minimum height of 4 inches so as to prevent the flow of liquids to adjoining areas. Except for surfacing, the sill shall be constructed of noncombustible material, and the liquid-tight seal shall be compatible with the material being stored. When the liquid-tight sills are provided, they may be omitted at door openings by the installation of an open-grate trench which connects to an approved drainage system.

UFC

The Uniform Fire Code was developed through the cooperation of local and state fire department officials with other agencies to create a uniform code of regulations for local authorities. The UBC code references local Fire Code for spill-containment situations.

If the local authority does not have a fire code, the UFC code may be used as a reference; in some states, this is required.

Specifically, the UFC code Article 64 requires six items for storage battery installations.

These items are:

1. **64.104 (c) Occupancy Separation**

   Battery systems shall be located in a room bounded by an occupancy separation having a minimum one-hour fire-resistive rating, exterior walls, roof or foundation of the building.

2. **64.104 (d) Spill containment**

   Each rack of batteries, or group of racks, shall be provided with a liquid tight 4-inch deep spill-control barrier which extends at least 1 inch beyond the battery rack in all directions.

3. **64.104 (e) Neutralization**

   An approved method to neutralize spilled electrolyte shall be provided. The method shall be capable of neutralizing a spill from the largest lead-acid battery to a pH between 7.0 and 9.0.

4. **64.104 (I) Ventilation**

   Ventilation shall be provided in accordance with the Mechanical Code. Unless the ventilation is designed to limit the maximum concentration of hydrogen to .8 percent of the total volume of the room in accordance with nationally recognized standards, the rate of ventilation shall not be less than 1 cubic foot per minute per square foot.

5. **64.104 (g) Signs**

   Doors into rooms or buildings containing stationary lead-acid battery systems shall be provided with approved signs. The signs shall state that the room contains lead-acid battery systems, that the battery room contains energized electrical circuits, and that the battery electrolyte solutions are corrosive liquids.

6. **64.104 (h) Seismic Protection**

   Battery systems shall be seismically braced according to the building code.

DOT

The Department of Transportation regards lead-acid batteries as hazardous material, not hazardous waste. Lead-acid batteries are subject to all DOT regulations applicable to the packaging, labeling and transporting requirements noted in the Code of Federal Regulations, 40 CFR 106-180, which further define the packaging, placarding and transporting of hazardous materials.

1. **Requirements for Recyclable Materials, 40 CFR - 261.5**

   Hazardous wastes that are recycled are subject to the requirements for generators, transporters and storage facilities of paragraphs (b) and (c) of this section, except for the materials listed in paragraphs (a) (2) and (a) (3) of this section. Hazardous wastes that are recycled will be known as "recyclable materials."

2. **Subpart G, Spent Lead-acid Batteries being reclaimed**

   The regulations of this subpart apply to persons who reclaim spent lead-acid batteries that are recyclable materials ("spent batteries"). Persons who generate, transport, or collect spent batteries, or who store spent batteries but do not reclaim them are subject to regulations under Parts 262 through 266 or Part 270 or 124 of this chapter, but are not subject to the requirements of Section 3010 of RCRA.

3. **172.101 Hazardous Materials Table**

   Provides a complete listing of hazardous materials, the classes or division of those materials, as well as specific identification and labeling procedures, and other special provisions.

4. **173.159 Batteries, Wet**

   (a-c) Explains the proper packaging of batteries based on their weights and dimensions.

   (d-h) Explains the proper packaging of wet non-spillage batteries.

Awareness of and attention to the above regulations can increase safety and reliability of stationary battery systems and avoid legal problems for the user. This was only a summary extract from relevant stipulations. For full regulation details, refer to the appropriate regulatory agency website.

CHAPTER - 3

VENTILATION CALCULATIONS

Hydrogen is produced during battery charging. If hydrogen gas is allowed to accumulate in an enclosed area, it is readily ignitable and may result in an explosion. The likelihood of this happening depends on the number of batteries, their charge rate, the size of the room, and the ventilation available for the room. This danger can be eliminated by monitoring hydrogen build-up and providing adequate ventilation. Battery manufacturers should be able to provide exact gassing rate, charging voltage and charging currents for the type of battery installed.

How much hydrogen does a battery emit?

As a rule of thumb, when the battery is about fully charged, each charging ampere supplied to the cell produces about 0.0158 cubic feet of hydrogen per hour from each cell. This rate of production applies at sea level, when the ambient temperature is about 77ºF, and when the electrolyte is "gassing or bubbling."

The battery rooms must be adequately ventilated to keep the concentration of hydrogen gas within safe limits. Some codes suggest that the battery rooms shall be ventilated at a minimum rate of 1.5 cubic feet per minute per square foot, with care to ensure proper air distribution to and within the battery storage area. Other organizations such as NFPA, ASHRAE and IS provide the following guidelines:

- NFPA 76: Standard for the Fire Protection of Telecommunications Facilities 2009 Edition Fan capacity should be 1 CFM per sq.ft. of floor space.
- NFPA 111: Standard on Stored Electrical Energy Emergency and Standby Power Systems, 2005 recommends a minimum of 2 air-changes per hour to remove gasses generated by vented batteries.
- ASHRAE Guideline 21P: 1 CFM per charging amp, no less than 6 air-changes per hour
- IS: 1332: Battery Room - 12 air-changes per hour

Note there is lot of variations among various standards; one standard lists 12 air-changes per hour, whereas another lists 6 air-changes per hour, and another lists 2 air-changes per hour. It only leads one to believe that the air changes method is flawed and can result in grossly oversizing or undersizing the ventilation system. The author has worked on numerous telecom and offshore projects where he observed that the ventilation requirement for battery rooms varied from 2 air-changes per hour in one project; while in another similar project, the requirement was as high as 6 air-changes per hour. This may sounds irrational but we will demonstrate this with examples later in this course.

BATTERY ROOM VENTILATION

The National Fire Protection Association lists the lower explosive level (LEL) of hydrogen as 4% by volume.

What does this mean?

LEL is the point at which hydrogen can combust. For example the air in a box with a volume of 100 cubic feet containing 4 cubic feet of hydrogen gas would be expected to ignite when exposed to a spark or open flame. This can be disastrous.

Below is a picture depicting the extent of damage due to a ventilation failure.

To ensure safety, most regulations such as the Uniform Fire Code and the International Fire Code stipulate a maximum hydrogen concentration below the level of 1% or 25% of the lower explosion limit in a battery room.

Ventilation Method

The following steps shall be followed:

Step 1: Calculate Hydrogen Release

Amount of hydrogen release during normal float condition for a flooded battery is given as:

$$H = N * I * k$$

Where:

- H = Hydrogen generated, in cubic feet per hour (ft^3/hr).
- k = 0.0158 ---- [A typical lead-acid power battery will generate approximately 0.0158 cubic feet of hydrogen per cell per hour at sea level, when the ambient temperature is about 77ºF, and when the electrolyte is "gassing".]
- N = Number of cells per battery ---- [Note: A single cell is normally 2 volts DC. Therefore, a 6-volt battery normally has 3 cells, and a 12-volt battery normally has 6 cells.]
- I = Charge current, amperes

Step 2: Calculate Room Volume

A room with a flat roof has a volume of:

$$RV = w \times l \times h$$

Where,

- RV = Room volume
- w = Room width
- l = Room length
- h = Room height

Step 3: Determine Critical Volume

The critical volume is the maximum permissible hydrogen concentration to limit the value to below 1% and is given by:

CV = RV * PC

Where,

- CV = Critical volume in ft^3
- RV = Room volume in ft^3
- PC = Maximum permissible hydrogen concentration to limit the value to below 1%.

Step 4: Time to reach Critical Level of Hydrogen Concentration

$$t = \frac{CV}{H}$$

Where,

- t = time to produce critical level of hydrogen, hrs
- CV = critical volume, ft^3
- H = hydrogen generated in ft^3/hr

Step 5: Determining the Ventilation Rate

$$Q = \frac{H \frac{ft^3}{hr} * \frac{1\ hr}{60\ min}}{PC\ \%}$$

Where,

- Q = Minimum required ventilation airflow rate, in cubic feet per minute (cfm).
- H = Hydrogen generated, in cubic feet per hour (ft^3/hr).
- PC = Percent concentration of hydrogen allowed in a room is limited to one percent.

Step 6: Fan Sizing

Add a 25% safety margin in Step 5. This safety factor is to allow for hydrogen production variations with changes in temperature, charge controller failure, and reduction in net volume of battery room due to battery equipment and fixtures. It also allows for deterioration in ventilation systems. As such:

$$Q_A = Q \times FS$$

Where,

- Q_A = The actual volumetric ventilation rate, in cubic feet per minute (cfm)
- FS = Factor of safety, usually 25%.

Step 7: Determine Air changes per hour

$$ACH = \frac{Q_A\left(\frac{ft^3}{min}\right) * 60\left(\frac{min}{hr}\right)}{RV\left(ft^3\right)}$$

Where,

- Q_A = Actual ventilation rate in CFM
- ACH = Air changes per hour
- RV = Room Volume in cu.-ft

EXAMPLE - 1

A 60-cell lead-acid battery, located in a room having a volume of 2000 cubic feet, is being charged at 50 amperes. The ventilation system is designed to provide three air-changes each hour. Determine the rate of hydrogen production and the adequacy of the air exchanges required for ventilation.

Solution:

Hydrogen Production Rate

Hydrogen (H_2) production in cubic meters per hour is: H = N * I * k

50 amps * 60 cells * 0.0158 ft^3 /cell/hour = 47.4 ft^3 /hour

Critical Volume

Critical volume, based on 1 percent by volume is:

2000 ft^3 * 0.01 = 20 ft^3

Time taken to reach 1% hydrogen concentration

20 ÷ 47.4 = 0.42 hour (25.2 minutes)

The ventilation system must clear the 2000 ft^3 room within 0.42 hour (25.2 minutes) before the batteries can produce 20 cubic feet of hydrogen.

Ventilation Required

$$Q = \frac{H\frac{ft^3}{hr} * \frac{1\ hr}{60\ min}}{PC\ \%}$$

$$Q = \frac{47.4\frac{ft^3}{hr} * \frac{1\ hr}{60\ min}}{0.01}$$

Q = 79.5 ft^3

Fan Sizing

Q_A = Q x FS

Q_A = 79.5 x 1.25

Q_A = 99.38 ft^3

Actual Air-Changes

Room Volume = 2000 sq.-ft.

$$ACH = \frac{Q_A\left(\frac{ft^3}{min}\right) * 60\left(\frac{min}{hr}\right)}{RV\ (ft^3)}$$

ACH = 99.38 * 60 / 2000 = 2.98 say 3 air changes per hour.

Three air-changes each hour provide one air change in 20 minutes, which is quicker than the 25.2 minutes required. Critical hydrogen concentration will not be reached with continuous operation of the ventilation system.

Alternate Shortcut Method:

During normal battery charging, up to 47.4 ft^3 per hour hydrogen gas may be released. To achieve a 1% hydrogen concentration, this must be mixed with 99 times its volume of air, or 78.21 ft^3/min [47.3 x 99/60 = 78.21ft^3/min].

Add 25% safety factor: 78.21 x 1.25 =97.76 ft^3/min

ACH = 97.76 * 60 / 2000 = 2.93 say 3 air-changes per hour.

EXAMPLE - 2

Same condition as previously mentioned in Example 1, except that the battery is located in a smaller room size of 1000 ft^3.

Hydrogen Production Rate

Hydrogen (H_2) production in cubic meters per hour is: H = N * I * k

50 amps * 60 cells * 0.0158 ft^3 /cell/hour = 47.4 ft^3 /hour

Critical Volume

Critical volume, based on 1 percent by volume is:

1000 ft^3 * 0.01 = 10 ft^3

Time taken to reach 1% hydrogen concentration

Time to produce critical level of 1 percent hydrogen (10 cubic feet) in the 1000 cubic-feet battery room is:

10 ÷ 47.4 = 0.21 hour (12.6 minutes)

The ventilation system must move 1000 cubic feet (the room volume), with the 10 cubic feet of hydrogen contained within, before the 0.21 hour (12.6 minutes) elapses.

$$Q = \frac{H\frac{ft^3}{hr} * \frac{1\ hr}{60\ min}}{PC\ \%}$$

$$Q = \frac{47.4\frac{ft^3}{hr} * \frac{1\ hr}{60\ min}}{0.01}$$

Q = 79.5 ft^3/min

Fan Sizing

Q_A = Q x FS

Q_A = 79.5 x 1.25

Q_A = 99.38 ft^3/min

Actual Air-Changes

Room Volume = 1000 sq.-ft.

$$ACH = \frac{Q_A\left(\frac{ft^3}{min}\right) * 60\left(\frac{min}{hr}\right)}{RV\left(ft^3\right)}$$

ACH = 99.38 * 60 / 1000 = 5.96 say 6 air-changes per hour.

Six air-changes each hour provide one air-change in 10 minutes, which is quicker than the 12.6 minutes required. Critical hydrogen concentration will not be reached with continuous operation of the ventilation system.

Conclusions

We see from Examples 1 and 2, that the ventilation sizing is a function of hydrogen production rate. In both cases, for similar battery equipment, Example 1 demands 3 air-changes, whereas Example 2 demands 6 air-changes. The air-change is dependent on the size of the room and it increases for a smaller battery room volume. This proves that the air-changes provided by various standards should be used only as a guidance when precise information about batteries and charger characteristics is not fully known.

Lower ventilation rates than necessary is a safety issue while over ventilation is a waste of energy, especially where the battery rooms are provided with mechanical air-conditioning to reduce temperature extremes.

EXAMPLE - 3

Per manufacturer specification, one fully charged lead-acid battery cell at 77°F will pass 0.24 amperes of floating current for every 100 ampere-hour cell capacity when subject to an equalizing potential of 2.33 volts. Each cell has a nominal 1,360-amphere hour’s capacity at the 8-hour rate. Calculate the ventilation rate for a battery room consisting of 182-cell battery and 3 battery banks. Assume the battery room has dimensions of 20’ (l) x 15’ (w) x 10’ (h).

Solution:

$$I = \frac{FC}{100} * Ah$$

Where,

- I = Charging current, amperes

- FC = Float current per 100 ampere-hour. FC varies with battery types, battery condition, and electrolyte temperature.
- Ah = Rated capacity of the battery in Ampere hours.

$$I = \frac{0.24\ \text{amp}}{100\ \text{amp-hr}} * 1360\ \text{amp hr}$$

I = 3.264 amps

N = 182 cells /battery * 3 battery banks = 546 cells

k = 0.0158 ft^3/amp hr cell

H = 3.264 * 0.0158 * 546

H = 28.16 ft^3/hr

Determine Ventilation required:

$$Q = \frac{28.16\,\frac{ft^3}{hr} * \frac{1\ hr}{60\ min}}{0.01} = 46.93\,\frac{ft^3}{min}$$

Apply safety factor

Q_A = 46.93 * 1.25 = 58.66 ft^3/min

The ventilation system should be capable of extracting 58.66 cubic feet per minute.

Room Volume = 20 x 15 x 10 = 3,000 cubic feet

$$ACH = \frac{58.66\,\frac{ft^3}{min} * 60\,\frac{min}{hr}}{3000\ ft^3} = 1.17\,\frac{AC}{hr}$$

Results Summary

Ventilation Requirements: There will be 28.16 cubic feet of hydrogen gas produced per hour in a room with a volume of 3000 cubic feet. As an industry standard, the maximum percentage of hydrogen gas allowed within a room should not exceed 1%. This can be estimated by comparing the volume of the room to the amount of hydrogen that could potentially be produced within an hour. If the level in your battery room exceeds 1% after one hour of charging, normally forced ventilation would be recommended. Based on the numbers provided, the room would be at 28.16/3000 = .0094% after 1 hour, which is less than 1%. Therefore, theoretically the forced ventilation may be avoided but is highly recommended due to uncertainties of building geometries, high points, and inadequate or blocked openings for natural ventilation.

Exhaust Fan Requirements: Two exhaust fans (one working + one standby) are recommended, each rated for 58.66 cubic feet per minute. The air in the room will need to be completely exchanged every 1.17 hours or 70 minutes to maintain a safe level of hydrogen gas.

EXAMPLE - 4

In above example, how much time it will take to build 1% concentration of gas with no ventilation? Assume 1000 cu-ft of room volume is covered by battery equipment.

Volume of the room = 3000 cu ft

Volume taken by the batteries infrastructure = 1000 cu ft

Net volume = 2000 cu ft

Allowable maximum gas accumulation: 1% of 2000 cubic feet = 20 cubic feet

Hours to build a 1% concentration of gas in the unoccupied volume assuming no air exchange: 20 cubic feet ÷ 28.16 cubic feet per hour = 0.71 hours or 42 days

VENTILATION CALCULATION (Metric Units per British Standard BS 6133:1985)

The following is an extract from BS 6133:1985 – Safe operation of lead-acid stationary cells and batteries. In order to be certain that the ventilation of the battery room is adequate to keep the average concentration of hydrogen gas in the room within safe limits, it is necessary to be able to calculate the rate of evolution of hydrogen. Hydrogen is evolved during a recharge or freshening charge of the battery when the voltage rises above 2.30V per cell. During this period when the cells are gassing freely, it is recommended that the concentration of hydrogen gas within the battery room is limited to an average of 1%, except in the immediate vicinity of the cell tops. This is only one quarter of the normally accepted safe limit of 4% hydrogen, but in view of the potential hazard with stationary batteries, this additional safety margin is fully justified.

The following method may be used to calculate the ventilation requirements of a battery room. 26.8Ah input to a fully charged cell will liberate 8 g of oxygen and 1 g of hydrogen. One (1) g of hydrogen occupies a volume of 12 liters at 20°C and at a pressure of one standard atmosphere. Therefore 26.8Ah input will evolve 12 liters of hydrogen. Therefore the volume of hydrogen evolved from a battery per hour:

$$H = \frac{\text{no. of cells} * \text{charge current} * 12\ \text{l}}{26.8}$$

H = no. of cells * charge current * 0.45 l

H = no. of cells * charge current * 0.00045 m^3

The volume of hydrogen found by the above calculation can be expressed as a percentage of the total volume of the battery room, and from this, the number of changes of air per hour to keep the concentration of hydrogen below 1% can be calculated.

EXAMPLE - 5

Consider a battery of 120 cells with charge current of 17 amperes. The battery is installed in a double tier, double row terraced arrangement in a room of 4m x 2m x 3m. Determine the ventilation rate to limit hydrogen concentration to less than 1%.

Rate of hydrogen produced, H

$$H = 120 \times 17 \times 0.00045 = 0.92\ m^3/hr$$

Maximum permissible concentration of hydrogen, PC = 1%

Ventilation required, Q

Q = H/PC

Q = 0.92/0.01 = 92 m^3/hr

Fan Capacity

$Q_A = Q \times 1.25$

$Q_A = 92 \times 1.25 = 115\ m^3$

Room Volume, RV = 4 x 2 x 3 = 24 m^3.

Air changes per hour

ACH = QA/RV

ACH = 115/24 = 4.79

Therefore to keep the concentration of hydrogen gas at a maximum of 1%, the air in the room will need to be changed 4.79 times per hour, or about five times per hour.

Ventilation Design Criteria

The battery room ventilation design criteria include:

1. Design mechanical systems to maintain ventilation rates in accordance with NFPA 70E.

2. Battery room shall be ventilated at high points for removal of accumulated hydrogen. Ideally the battery room exhaust ventilation shall have both high-level exhaust for hydrogen and low-level exhaust for electrolyte spills (acid fumes and odors). Distribute one-third of the total exhaust flow rate to the high-level exhaust to ventilate all roof pockets. Locate low-level exhaust at a maximum of 1-ft above the floor.
3. Hydrogen gas from battery rooms shall be extracted to a safe area, i.e. outdoors, or to an area where the gas will always dissipate into the atmosphere without possible danger of the gas accumulating in any part of that area.
4. The ventilation system for the battery room shall be separate from ventilation systems for other spaces. Air recirculation in the battery room is prohibited.
5. Exhaust air through a dedicated exhaust duct system if the battery room is not located on an outside wall. Ductwork shall be fabricated from fiberglass reinforced plastic (FRP) or polyvinyl chloride (PVC).
6. Design ventilation systems to maintain concentrations of hydrogen gas in the battery room below 1 percent concentration.
7. Design the makeup (replacement) air volumetric flow rate equal to approximately 95 percent of the exhaust flow rate to maintain the battery room under negative pressure and prevent the migration of fumes and gases into adjacent areas.
8. Makeup air can be transferred from a Class 1 or Class 2 area in the facility as defined in ASHRAE 62.1 or supplied directly. If supplied directly, it shall be filtered.
9. The air inlets shall be no higher than the tops of the battery cells of the lower tier if more than one tier is present.
10. Provide means for balancing air flow to ensure a negative pressure relationship. Exhaust all air directly to the outdoors.

Fans and Motors

The battery room shall be ventilated by means of two exhaust fans (one working + one standby). The standby fan should start automatically in case the other fails, Each fan shall have an independent failure alarm.

The fan shall be mounted as high as possible in the wall, but not below the level of the light fittings.

Fans will have non-sparking wheel construction and motor shall be explosion proof type. Use AMCA 201, Type B spark resistant construction. Fans shall preferably be roof-mounted with an upwardly directed discharge. Where a roof-mounted ventilator cannot be used, a wall mounted axial type extract fan with back draught dampers shall be used.

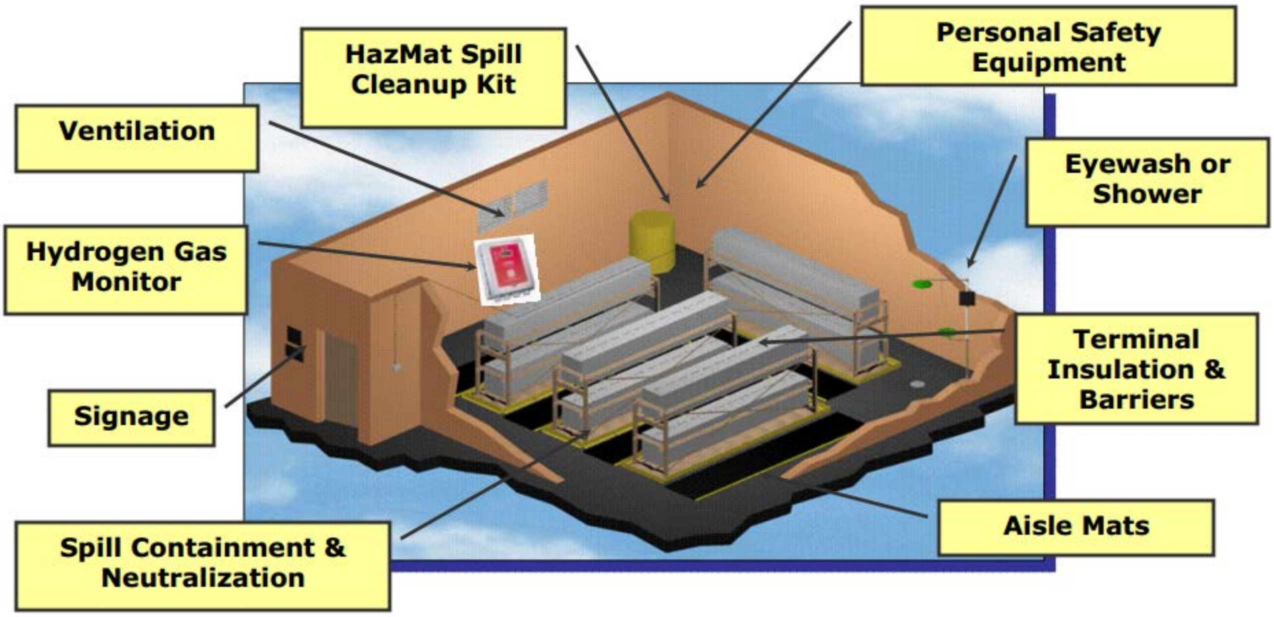
Note:

The ventilation calculation discussed is for flooded cell batteries. VRLA batteries do have relief vents but these do not function unless they are forced into a failure mode. The requirements of a ventilation system must be coordinated with the supplier's recommendations as well the requirements of a fire prevention and suppression system.

CHAPTER - 4

BATTERY ROOM DESIGN CRITERIA

There are many critical design issues that must be taken into consideration when planning, designing and constructing a safe and reliable battery room. Many of the model building codes and recognized standards such as IEEE, OSHA, NEC, and NFPA Life Safety Codes outline the requirements for the design and installation of battery rooms. They provide guidance on the performance criteria for the various systems as well as requirements for equipment related to these. This section provides some important elements for guidance.



General

1. Comply with NFPA 70E Article 320.6 (2004 Edition) for battery room design and NFPA 70E Article 480 for battery room ventilation requirements.
2. Occupational Safety and Health Standards (OSHA) require battery installations to have environment control and ventilation. Other mandatory regulation standards may include Title 29 Code of Federal Regulations (CFR) Parts 1910 &1926 and Title 40 Code of Federal Regulations Protection of Environment.
3. Provide a battery enclosure that is commercially manufactured, designed and UL listed for battery containment. It should have an integral electrolyte spill containment.

Architectural Requirements

1. The positioning of the battery room must be in a close proximity to the load centres (UPS modules). Proper code clearances must be maintained in and around battery racks for required maintenance support and life safety systems. Egress aisles, exit ways, and maintenance aisles must also be maintained.
2. Provide the occupancy separation requirements specified in NFPA/Uniform Fire Code. When more than one battery type (chemistry) is employed, each type of battery shall be located in a separate room with each room individually meeting the occupancy separation requirements and with no direct access between the rooms. Services not associated with the battery room shall not pass through the room. The battery room shall not be used for access to other spaces. Battery rooms shall not be used for material storage, such as storage of office supplies, cleaning supplies, or spill control equipment; design a separate space for these materials.
3. Consider an overhead hoist or equivalent portable material handling equipment for the handling of batteries.

Floors Construction

1. Expansion joints shall be avoided.
2. Floor finish in all battery rooms and enclosures shall be slip-resistant and acid or alkali resistant as appropriate for the battery chemistry employed. The floor shall be given a protective coating of acid-resistant, non-skid ceramic floor tiles or an approved acid-resistant epoxy coating applied in accordance with the manufacturer's specifications.
3. When the battery room is located at ground level, the floor shall comprise a concrete surface bed laid on compacted earth. When the battery room is situated above ground level, the floor shall comprise a reinforced concrete slab.
4. Due to the mass of the batteries, the floor shall be absolutely stable. Subsidence of the floor at points of load shall not take place, as this will cause

settling and tilting of the batteries with consequent straining of the battery connection.

Walls

1. Walls shall be continuous from floor to ceiling and be securely anchored. The walls of lead-acid or nickel cadmium battery rooms shall be protected against electrolyte splashes, by applying an approved light colored, acid resistant enamel paint.
2. Windows shall not be provided in battery rooms.

Ceilings

1. The ceilings should be flat to ensure that the release of hydrogen gas cannot be trapped in pockets.
2. Skylights and false ceilings shall not be used.
3. Ceilings shall be given the same paint treatment as walls.

Doors

1. The battery room door shall have the applicable fire and security rating and shall be not less than 800 mm wide and 2000 mm high. The door shall have one leaf that opens outwards.
2. The inside surfaces of the door shall be protected by an approved light-colored, acid resistant paint.

Structural Issues

1. Due to the weight of lead-acid batteries, column and floor loading can quickly become a problem. Flooded wet cell batteries racked two or three tiers high in a limited floor area can easily impress a 250 to 450 lbs/sq-ft floor loading on the structural floor which will transfer to column and footers.
2. The battery mounting rack or cubicle should be of robust construction to withstand the battery loading. It should also be suitably treated for resistance to the corrosive electrolyte. Obtain the battery rack from the same manufacturer that supplies the battery.

Fire Resistance Ratings

Battery rooms that are attached to or within another building shall comply with the following:

1. Battery rooms should be isolated from each other using fire compartmentalized rooms, and away from each other, from other equipment and from staffing areas by a fire wall rated at two hours.
2. Individual battery rooms should be treated as separate zones for fire detection and suppression purposes.
3. Any duct, pipe, conduit, cable or other equipment that penetrate a wall, floor or ceiling, having a fire resistance rating, shall be fire stopped with a fire resistant material, such that the fire resistance of the wall, floor or ceiling will not be negatively affected.

Plumbing

1. Every battery room should have a combination eye wash/deluge shower station to provide a means of decontaminating personnel exposed to and contaminated by battery acid. OSHA ANSI Z358.1 Standard requires eyewash/shower within 25 feet of battery work.

    - Plumbed shower stations: 30 gpm

- Wall-mount stations: 0.4 gpm for 15 min.
- Eyewash bottles (1 qt.)

2. Where there is not enough space for civil extensions to accommodate an industrial emergency shower, it shall be located outside the battery room next to the door. The shower drain shall be connected to the battery room drain system.

MECHANICAL REQUIREMENTS

Temperature Control

1. For optimal battery performance, the battery room temperature should be maintained at a constant 77°F. Temperatures below 77°F increase the battery's life but decrease its performance during heavy discharge. In room temperatures above 77°F, battery performance increases but its life decreases.
2. Comply with the following IEEE documents for temperature control criteria, as appropriate for the selected battery type:
   - IEEE Std. 484-2002, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-acid Batteries for Stationary Applications.
   - IEEE Std. 1106-2005, IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications.
   - IEEE Std. 1187-2002, IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-acid Storage Batteries for Stationary Applications.

Ventilation

Battery rooms shall be designed with an adequate exhaust system which provides for continuous ventilation of the battery room to prohibit the build-up of potentially explosive hydrogen gas. During normal operations, off gassing of the batteries is relatively small. However, the concern is elevated during times of heavy recharge of the batteries, which occurs immediately following their rapid and deep discharge.

The dual explosion proof fan shall be installed with a remote alarming capability to report a hydrogen gas build up and abnormal operating conditions.

Refer to Section 2 for details.

ELECTRICAL REQUIREMENTS

1. All electrical equipment or fittings installed in a battery room must be intrinsically safe to reduce the risk of arcing, flashing or ignition.
2. The ventilation fans shall be provided with the single-phase squirrel-cage induction type motors suitable for direct-on-line starting. These shall be Class I Division II 'non-sparking' motors.
3. Battery rooms shall be equipped with a centralized Emergency Power-Off (EPO) system than can disconnect power to the load centres (UPS common battery bus or individual UPS modules). This EPO system enables the facility management team to quickly isolate a battery system experiencing problems and thereby mitigating a potentially dangerous situation. An EPO device should be located at all egress points from the room and be tied into the central alarm system and monitored.
4. Article 480-9 of the National Electric Code requires a disconnecting means which shall be provided for all ungrounded conductors derived from stationary battery systems over 50 volts.
5. All battery racks and cabinets associated with UPS systems should have NEC code green wire grounds linking all battery racks.
6. Type AC, NM, NMC, NMS and UF cables shall not be used in battery rooms. No flexible metal conduit or flexible metallic tubing shall be used. Connections to battery terminal posts, including intercell connections, shall minimize strain on the battery posts.

Lighting

1. Illuminance levels in the battery room shall be designed to meet IESNA Lighting Handbook recommendations with a minimum illumination level of 300 lux (30 fc). The lighting design shall consider the type of battery rack and the physical battery configuration to ensure that all points of connection, maintenance and testing are adequately illuminated.

2. The entire lighting installation within the battery room shall consist of explosion proof luminaires which shall be designed in such a way that all possible sources of ignition, such as arcs, sparks and excessive surface temperatures, can be closely controlled and the probability of an explosion occurring is reduced to an acceptably low level.
3. The luminaires shall not be mounted directly over the battery stands and shall be positioned in parallel with the battery stands. This precaution will facilitate maintenance on the fittings, and will also minimize the obvious dangers of working over the cells.
4. Battery room lighting fixtures shall be pendant or wall mounted and shall not provide a collection point for explosive gases. Fixtures shall offer lamp protection by shatterproof lenses or wire guards. Fixtures in battery rooms for vented cells shall be constructed to resist the corrosive effects of acid vapors. Luminaires and lamps shall provide minimal heat output in general and shall provide minimal radiant heating of the batteries. Fixture mounting shall not interfere with the operation of lifting devices used for battery maintenance.
5. Lighting track shall not be installed in battery rooms.
6. Receptacles and lighting switches should be located outside of the battery area.

Monitoring and Instrumentation

1. Provide alarms and instrumentation to measure battery voltage, battery current, ground detection for ungrounded systems and ventilation fan failure/run status.
2. The ventilation system shall include sensors (differential pressure switch) for initiating alarm signals to the central control room in the event of ventilation system failure.
3. Consider the hydrogen gas detection and alarm system interlocked to the exhaust fans. Local codes usually do not require hydrogen and other gas detectors to be installed in dedicated battery rooms. If used, hydrogen detectors should be set to alarm at a maximum of 2% concentration. The

detectors should be installed at the highest, draft-free location in the battery compartment or room where hydrogen gas would accumulate.

4. Article 480-9 of the National Electric Code requires each vented battery cell to be equipped with a flame arrester designed to prevent destruction of the cell attributable to an ignition of gases outside the cell.

Cable Entry Facilities

1. Where the cable entry is through the floor, the following shall be adhered to:
    a. The cable opening shall be adjacent to the wall and stands where applicable.
    b. PVC or cement cable pipes curved to the bending radius of the cable shall be cast into the floor in such a way that the entry of the cables into the battery room is perpendicular to the floor.
    c. To prevent fluids or foreign matter from entering the pipe, its upper end shall project at least 50mm above the finished floor surface.
2. For any other form of cable entry, the following shall be adhered to:
    a. These cable entries shall be either vertically from the floor above, if applicable, or horizontally (at a satisfactory height) through one of the battery room walls.
    b. A separate entry, as near as possible to the battery terminals, shall be provided for each battery bank.
    c. These entries shall be kept sealed with vermiculite or equivalent material, to prevent hydrogen transfer before and after installation of the cables.

CHAPTER - 5

PREPRATION AND SAFETY

Objective

Inspect and test a battery.

Safety check

- Make sure that the access is good and any covers or cab are secure and cannot fall.
- Always make sure that you wear the appropriate personal protection equipment before starting the job.
- Remember that batteries contain acid and it is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are working on.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your supervisor.

Points to note

- Batteries come in many sizes and power ratings, so always check the rating of the battery you are servicing. The rating provides a testing benchmark for battery performance.
- The hydrometer used to measure the specific gravity of the electrolyte must be handled carefully and safely.
- Store the hydrometer in a safe receptacle before and after use. Small amounts of electrolyte in the hydrometer can leak out and damage the vehicle paintwork.

Do not remove electrolyte from one cell to another when testing; this will cause incorrect readings

1. **Check and adjust fluid level:** A sealed or low-maintenance battery has no removable cell covers, so you cannot adjust or test the fluid levels inside However, some of these do have visual indicators that provide information on the status of the charge and condition of the battery cells. Each manufacturer provides details of these visual indicators so refer to these when undertaking an inspection. If the battery is not a sealed unit, it will have removable caps or bars on top. Remove them, and look inside to check the level of the battery fluid, which is called the electrolyte. If the level is below the top of the plates and their separators inside, add distilled water or water with a low mineral content until it just covers them. Be careful not to over-fill the cells as they could boil over when charging.
2. **Conduct specific gravity test -** There is a relationship between the state of battery charge and the strength of the electrolyte. As the battery becomes discharged, the specific gravity (SG) of the electrolyte becomes lower. The SG of the electrolyte is measured by means of a hydrometer. This instrument consists of a glass tube, with a rubber bulb fitted on one end. Inside the tube, there is a float, which is calibrated from 1.130 to 1.300. To carry out a specific gravity test on a battery, the hydrometer must be designed for battery testing. First step should be to put on all the required personal protection equipment (PPE). Remove all vent caps from the battery to be tested. Draw some of the electrolyte into the hydrometer until the float is floating clear of the bottom of the outer tube. Take a reading from the scale on the float. This reading indicates the density of the electrolyte in that cell. Replace the electrolyte in the same cell, and repeat the process for all the remaining cells. The readings for each cell should be approximately the same.

   The figure you have now is an overall state of charge for the battery. A very low overall reading of 1130 or below indicates a low state of charge. A high overall reading of about 1280 indicates a high state of charge. The reading from each cell should be the same. If one or two cells are very different from the rest, this indicates that there is a deficiency in the battery.

   Indications from specific gravity readings are as follows:

   - 1.260 - 1.280: Battery fully charged

- 1.190 - 1.210: Battery approximately half charged
- 1.110 - 1.130: Battery fully discharged

NOTE: The hydrometer should always be washed out with clean water after use and stored safely.

DO's & DON'T's

Battery Charging

Only rechargeable type battery can be charged. Never charge a primary battery as that may cause an explosion or fire.

The followings are the precautions to be taken to prevent gas explosion, electric faults and other accidents during battery charging:

a. Battery charging should be done in a location that is specifically designated for that purpose;

b. The location designated for charging and storing batteries needs adequate ventilation for the dispersal of the fumes generated from gassing batteries;

c. Never smoke or allow sparks or flames near the batteries. It should be borne in mind that explosive gases may not only be evolved when battery charging is in progress. Some gas bubbles generated during charging would stick on the electrode plates of the battery, and they would be released slowly from the battery for some time subsequent to the charging operation. As such, it should be assumed that explosive gases are always present in the space surrounding the battery top;

d. Suitable and adequate lighting should be provided and maintained for the battery room and the workplace. The lighting and electrical appliances used in those areas having foreseeable hazard of accumulation of explosive gases should also be of the explosion proof type;

e. The battery charger should be suitably rated and protected against electrical faults. The cable connection terminals should be properly shrouded to prevent an accidental short-circuit of the conductor parts and to prevent electric shock;

f. The battery charger should be switched off or disconnected from its power supply before making connection with battery cables for battery charging, and disconnection of battery cables after battery charging;

g. Make sure that the voltage used to charge the system never exceeds the system design while charging. For instance if you connect two 12-volt batteries in 'series' for charging, you should use the 24-volt setting on the charger; however, if you connect the same two batteries in 'parallel', you should only use the 12-volt setting on the charger.

h. Check that the polarities of terminals of the battery and the battery charger are correct before connecting the two for charging. The positive (+ve) terminal of the battery should be connected to the positive (+ve) terminal of the charger, and the same applies to the negative (-ve) side. Always use the markings on the battery to determine the positive and negative terminals. Never simply use the color of the cables to determine the positive or negative terminals.

i. Due to the large charging current, any sudden breaking of the charging circuit while battery charging is in progress, may generate sparks at the point of breaking. The charger cables should therefore be firmly and securely fixed or clamped in place on the cable terminals and connections before switching on the charger. Do not disturb the cable terminations and connections while battery charging is in progress, or when a battery is on load. Switch off the battery charger or the loads of a battery circuit first, if any work on the battery cable terminations and connections is required;

j. Charging cables and other electric cables should be properly placed. Do not leave these cables tangling freely on the floor to prevent tripping over;

k. Hand tools and electric tools, which might give rise to sparks, should not be used in the vicinity of the battery being charged;

l. If you need to remove a battery, always remove the ground terminal from the battery first. Make sure all accessories are off so you don’t cause a spark;

m. Never charge a frozen battery.

Points to note

- Slow charging a battery is less stressful on a battery than fast charging is.
- Always remove the negative battery terminal while changing a battery to reduce risk to the electronically intensive equipment's (UPS). Use a 'memory minder' to retain electronic settings.
- Dangers of excessive voltages (voltage peaks) produced by the incorrect use of battery chargers, thereby causing damage to electronic control units or related electronic components.

Cleaning of battery

The battery should be regularly cleaned to remove dirt or salt encrusted around vent cap openings or on the surface of the battery. The battery can be cleaned by wet towels if it is not too dirty. Otherwise, it should be moved to a designated area with proper drainage and the dirt or salt can then be rinsed out with water.

Do not use chemicals or other solvents as cleaning agent. Also do not use high-pressure water jet to wash the batteries.

All covers and caps of the cells should be tightly closed before cleansing to prevent any seeping of water into the battery.

Handling of battery

Batteries are heavy and may cause musculo-skeletal disorders for the workers if they do not handle the batteries properly. Suitable lifting points and mechanical lifting equipment should be provided and made use of.

Suitable working platform or other suitable means of support and suitable lifting equipment should be provided to allow making access to and handling of batteries installed at high level.

The weight of batteries should also be taken into account in the design and construction of the platform and support if the batteries are to be loaded onto the platform and support temporarily.

When handling batteries, care should be taken to avoid spillage of electrolyte. The battery should be kept in an upright position and the vent caps should be closed tight.

Electrical safety

a. To avoid electrical hazards associated with the battery work, i.e. short-circuit and electric shock, the following general principles should be taken:

   - To avoid getting an electric shock, the worker has to take due care to avoid making contact with the battery terminals directly or through other conductive parts, such as the battery cables connected with the terminals, indirectly.
   - To avoid short-circuiting the battery, it should not allow any bridging of battery terminals of different potential by conductive metal parts, both directly or indirectly to form a closed circuit, should not be allowed.

b. The battery cables and terminals should be suitably rated and sized to avoid any overheating and overloading problem. The bolted connection of the cables and terminals should always be kept tight. It is preferred to have the battery cable connections standardized by using plug and socket type connection units to facilitate easy connection with the battery charger or other batteries. Terminals of the connection units should preferably be of the recessed type so as to minimize the exposure of conductive metal parts.

c. The battery cables should be suitably insulated and protected against short-circuit and earth fault. The cable terminations should be properly shrouded to prevent accidental contact with the exposed conductive metal parts.

d. The workers, who carry out the battery work, should be well aware of the electrical hazards involved. They should take necessary precaution to avoid accidental short-circuits and earth fault in the course of their work.

e. The battery top should always be kept dry and clean to avoid short-circuiting of the battery terminals or any leakage of current between the terminals caused by the dirt accumulated on the battery top.

f. Do not place any conductive parts or metal tools on the battery top.

g. All the hand tools used on batteries should be of the insulated and single ended type. They should be checked regularly to ensure the integrity of the insulation. A numerical check should be made on the number of tools after working on batteries. In general, always put the insulation cover or cap of battery terminals, if any, in place to avoid unnecessary exposure of the bare metal terminals. If the insulation covers or caps are to be removed to facilitate work, the extent and duration of exposure of the terminals should be minimized as far as practicable. In this respect, an insulation plate or barrier may be put on top of the battery to screen off the exposed metal terminals temporarily.

h. Do not expose batteries and battery chargers to rain or dripping water, such as water from condensate of air conditioning systems, to prevent short-circuiting.

i. Thoroughly check the electric cables for the battery and chargers periodically. There should not be any insulation cover damage that would expose the inner cable conductor, reduction of effective cross-sectional area of cable conductor due to breaking of some conductor strands, sign of overheating such as discoloring or charring of cable insulation cover, etc. Any defective battery cables should be repaired or replaced immediately to avoid any short-circuits or earth faults.

j. Warning notice regarding electrical hazards should be prominently posted in the workplace where the battery, battery charger and associate electrical equipment are installed.

k. The batteries and the connected cables should be suitably placed and arranged so as to avoid any short-circuiting of the battery terminals directly, or via the cables indirectly. In that respect, sufficient clearance should be allowed between the battery terminals and cable connections of different potential.

l. Provide non-slip rubber insulating matting in front of all charging benches to protect personnel from electric shock and slipping hazards.

Battery electrolyte

Electrolytes used in rechargeable batteries are sulfuric acid for a lead-acid battery and potassium hydroxide for a nickel-cadmium battery. Both of the electrolytes are corrosive and would cause irritation and severe burns if they incidentally come into contact with skin or eyes. The consequence could be very serious.

To prevent electrolytes from coming into contact with workers, the following precautions should be taken:

a. Anyone working in and around batteries should wear proper personal protection equipment (PPE) such as face shields, gloves, footwear and aprons. The PPE should be made of materials resistive to acids and alkali, e.g. rubber or nitrile gloves, rubber aprons, etc.;

b. All the PPE should be washed thoroughly after use and stored properly in a cool and dry place. They should not be exposed to direct sunlight. Check whether there are any defects in the PPE every time before use;

c. Top up the electrolyte with distilled water slowly. Do not overfill to prevent spillage;

d. In topping up electrolyte, only distilled water should be added to the electrolyte but not the electrolyte itself. In case the specific gravity of the electrolyte is still low and could not be raised to a normal level after repeated charging of the battery and electrolyte has to be added, only properly trained and experienced personnel should be allowed to do so; and

e. Do not add water or electrolyte when the battery is being charged.

A violent chemical reaction may result if strong acid (e.g. sulfuric acid) and strong alkaline solutions (e.g. potassium hydroxide) come into contact with each other. The chemical reaction would release lots of heat and may cause boiling and splashing of the solutions.

To avoid the above undesirable chemical reaction, never mix the lead-acid batteries and alkaline batteries together. In this respect, it is recommended that:

a. Different types of batteries should be installed in different rooms, or in different areas of the room with suitable segregation;

b. Suitable warning notice or labels should be posted at conspicuous place to alert the workers should different types of batteries be installed in the same room or area;

c. Different sets of maintenance tools such as hydrometers, funnels, etc., should be dedicated for different electrolytes. Otherwise, the tools should be thoroughly cleansed with water immediately after use; and

d. Workers should be assigned to work on one type of battery at a time, and as far as possible. Otherwise, suitable washing facilities should be provided to enable the worker to thoroughly clean his hands and his protective clothing after working on one type of battery and before working on another type.

Spill Containment Issues

Spill containment must be provided to adequately contain potential acid spills from cracked or leaking batteries. Adequate quantities of absorbent materials and acid neutralizing agents should be maintained in the room for use in spill containment and clean-up operations. If you don’t already have one, consider getting a “Spill Kit”. Then a suitable neutralizing agent should be applied to neutralize the electrolyte:

a. In case of acid spillage, neutralize with a weak alkali, e.g. soda ash, sodium carbonate or sodium bicarbonate;

b. In case of alkali spillage, neutralize with a weak acid, e.g. boric acid.

If the spillage is minor and if proper floor drain is available, one may consider diluting the electrolyte spillage by ample amount of water. But before taking such action, he should consider also the possible adverse effects of the acid or alkaline solution on the drainage facilities and other downstream facilities and the environment. Depending on the scale of electrolyte spillage, he may need to solicit experts to deal with the spillage properly.

One should properly wear suitable personal protective equipment such as gloves, apron, face shield, safety shoes, etc. before he manages the electrolyte spillage.

If it is necessary to store electrolytes in the workplace, they have to be kept in proper containers and storerooms and be suitably labelled. The labels should include the following information in text and relevant symbols:

a. Identity of the substance – chemical name(s) or common name(s);
b. Hazard classification and symbols;
c. Indication of the particular risks inherent in the substance; and
d. Indication of the required safety precautions.

Lead, Cadmium, Nickel and their compounds

Chemicals used to make the cell electrode plates including metals such as lead, cadmium and nickel and their compounds, are toxic and would impose a health hazard to the workers if they incidentally enter the worker's body. Therefore, as part of the general precautionary measures to protect against the chemical hazards, workers working on batteries should wear suitable personal protective equipment such as gloves. They should also observe good personal hygiene practices such as refraining from eating, drinking and smoking in the workplace as well as thoroughly washing their hands and faces when taking breaks, before eating and drinking, and after work.

Since hazardous chemicals are contained inside the battery, the worker should avoid breaking up or damaging the battery casing, which would expose the battery's internal active materials. The battery operator would be vulnerable if he touches or somehow ingests or inhales the active materials. Strict personal hygiene precautions should be taken and proper PPE should be worn in extreme cases where damage to the battery does occur, and the active materials are exposed.

It is essential that all obsolete or damaged batteries, battery casings, containers, electrolyte, electrode plates, and other components that contain hazardous chemicals such as acid, alkali, lead, nickel, cadmium and their compounds, etc. be properly collected, labelled and stored for subsequent disposal in accordance with the relevant legislative requirements and guidelines issued by the relevant authorities. They should never be mixed with and disposed of as normal domestic waste.

Housekeeping

Good housekeeping in the workplace is essential in ensuring the safety and health of workers. It is found from past experience that having bad housekeeping is in fact the fundamental cause of many accidents that involve battery work.

The following should be noted for good housekeeping in the workplace:

a. Loose materials or tools should be placed in boxes or proper containers instead of being left on the floor freely.

b. Sufficient working space should be allowed. Access ways and emergency exits should always be properly maintained and kept clear from obstructions.

c. Suitable and adequate general lighting and ventilation should be provided and maintained in the workplace. The area of installation work should be well lit with an illumination level suitable for the specific work task.

d. Battery rooms should not be used as storerooms, particularly for storing combustible or flammable materials.

e. Battery rooms and the workplaces should always be kept clean, tidy and dry. Rubbish and waste produced should be removed regularly.

f. Personal belongings of the workers should be kept in lockers instead of being scattered around the workplace.

Fire protection

- Suitable and adequate number of fire extinguishers and other fire fighting equipment should be made available in the workplace. This equipment should also be kept in readily accessible locations.
- It should be noted that a water type fire extinguisher may not be suitable, as it may short-circuit the batteries. A 10-pound class C fire extinguisher should be located just inside the battery room door.
- The locations of the fire extinguishers and other fire fighting equipment should be made known to the workers.

- The workers should be trained on the proper use of fire extinguishers and other fire fighting equipment.
- The workers should only try to control the fire when small and manageable. Otherwise, they should evacuate from the workplace immediately and contact the local fire department and other emergency services.

First aid

An emergency shower and an eyewash station must also be located near the area in case a worker’s body or eyes are accidentally in contact with the electrolyte.

If the electrolyte comes into contact with the skin, it should be washed out with plenty of clean water immediately. If the electrolyte splashes into the eye, flood the eye immediately with plenty of clean water, preferably from an eye wash bottle. Following the washing of skin or eyes, get medical attention immediately.

The eye wash bottles should be checked periodically to ensure that they are not expired, the solutions not cloudy, and the seals not broken. The bottles should be replaced regularly in accordance with the manufacturer's instructions. The emergency showers should be turned on regularly to prevent development of rust or accumulation of dirt in the shower and pipework due to prolonged lack of usage.

If the electrolyte is swallowed, vomiting should not be induced. It is essential that the worker be made to drink plenty of water, and medical attention should be sought immediately.

Design and Application Tips to Ensure Maximum Service

The performance and service life of these batteries can be maximized by observing the following guidelines:

1. Heat kills batteries. Avoid placing batteries in close proximity to heat sources of any kind. The longest service life will be attained where the battery temperature does not exceed 77°F.
2. Since a battery may generate ignitable gases, do not install it close to any equipment that can produce electrical discharges in the form of sparks.
3. When the battery is operated in a confined space, adequate ventilation should be provided.

4. The battery case is manufactured from high impact ABS plastic resin. It should not be placed in an atmosphere of, or in contact with organic solvents or adhesive materials.
5. Correct terminals should be used on battery connecting wires. Soldering is not recommended although it may be unavoidable in certain cases.
6. When there is a possibility of the battery being subjected to heavy vibration or mechanical shock, it should be fastened securely and the use of shock absorbent material is advisable.
7. When connecting the batteries, free air space must be provided between each battery. The recommended minimum spacing between batteries is 0.2 inches (5mm) to 0.4 inches (10mm). In all installations, consideration must be given to adequate ventilation for the purposes of cooling.
8. When the batteries are to be assembled in series to provide more than 100V, proper handling and safety procedures must be observed to prevent accidental electric shock.
9. When cleaning the battery case, ALWAYS use a water dampened cloth but NEVER use oils, organic solvents such as petrol, paint thinners etc. DO NOT even use a cloth that is impregnated or has been in contact with any of these or similar substances.
10. Do not attempt to dismantle the battery. If accidental skin/eye contact is made with the electrolyte, wash or bathe the affected area immediately with liberal amounts of clean fresh water and seek IMMEDIATE medical attention.
11. DO NOT INCINERATE batteries as they are liable to rupture if placed into a fire. Batteries that have reached the end of their service life can be returned to special facilities for safe disposal.
12. Touching electrically conductive parts might result in an electric shock. Be sure to wear rubber gloves before inspection or maintenance work.
13. The use of mixed batteries with different capacities, of different ages or of different manufacturers, which may have been subjected to different uses, is liable to cause damage to the battery itself and/or the associated equipment.

14. To obtain maximum life, batteries should never be stored in a discharged state.

15. In order to obtain maximum working life, when the batteries are used in a UPS system, the following is advised:

    a. Where the DC input exceeds 60 volts, each battery should be insulated from the battery stand by using suitable polypropylene or polyethylene material.

    b. In high voltage systems, the resistance between the battery and the stand should always be greater than 1 Megohm. An appropriate alarm circuit should be incorporated to monitor any current flow.

Summary

Ventilation systems for stationary batteries must address human health and safety, fire safety, equipment reliability and safety, as well as human comfort. The ventilation system must prevent the accumulation of hydrogen pockets greater than 1% concentration.

Flooded lead-acid batteries must be provided with a dedicated ventilation system that exhausts outdoors and prevents circulation of air in other parts of the building. VRLA batteries require comparatively lower ventilation, usually enough to remove heat and gases that might be generated.