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(Revision of IEEE Std 484-1987)

IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications

Sponsor

IEEE Standards Coordinating Committee 29 on Stationary Batteries

Approved 10 April 1996

IEEE Standards Board

Abstract: Recommended design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of vented lead-acid batteries are provided. Required safety practices are also included. These recommended practices are applicable to all stationary applications. However, specific applications, such as emergency lighting units and semiportable equipment, and alternate energy applications, may have other appropriate practices and are beyond the scope of this recommended practice.
Keywords: alarms, assembly, data collection, float operation, flooded cells, freshening charge, installation design criteria, installation procedures, instrumentation, internal ohmic measurements, mounting, precautions, protective equipment, receiving and storage, resistance readings, seismic, testing, vented lead-acid batteries, ventilation

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Introduction

(This introduction is not part of IEEE Std 484-1996, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.)

Stationary lead-acid batteries play an ever-increasing role in industry today by providing normal response and instrument power and backup energy for emergencies. This recommended practice fulfills the need within the industry to provide common or standard practices for the design of battery installations and the battery installation procedures. The methods described are applicable to installations and battery sizes using vented lead-acid batteries. The installations considered herein are designed for float operation with a battery charger serving to maintain the battery in a charged condition as well as to supply the normal dc load.

This recommended practice may be used separately, and when combined with IEEE Std 450-1994, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications, and IEEE Std 485-1983, IEEE Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations, will provide the user with a general guide to sizing, designing, placing in service, maintaining, and testing a vented lead-acid battery installation. As a recommended practice, this document presents procedures and positions preferred by the IEEE.

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IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications

1. Scope

This recommended practice provides recommended design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of vented lead-acid batteries. Required safety practices are also included. This recommended practice applies to all stationary applications. However, specific applications, such as emergency lighting units and semiportable equipment, and alternate energy applications, may have other appropriate practices and are beyond the scope of this recommended practice.

The portions of this recommended practice that specifically relate to personnel safety are mandatory instructions and are designated by the word *shall*; all other portions are recommended practices and are designated by the word *should*.

Sizing, maintenance, capacity testing, charging equipment, dry charged cells, and consideration of other types of batteries are beyond the scope of this recommended practice.

2. References

This recommended practice shall be used in conjunction with the following publications:

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).[1]

IEEE Std 450-1995, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications (ANSI).

IEEE Std 485-1983, IEEE Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations (ANSI).

[1]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

3. Definitions

The following definition applies to the subject matter of this recommended practice. For other definitions, refer to IEEE Std 100-1992 and other documents referenced in clause 2.

3.1 vented battery: A battery in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries are commonly referred to as "flooded." *Syn:* vented cell.

4. Safety

The safety precautions listed herein shall be followed during battery installation. Work on batteries shall be performed only by knowledgeable personnel with proper, safe tools and protective equipment.

4.1 Protective equipment

The following equipment for safe handling of the battery and protection of personnel shall be available:

a) Goggles and face shields
b) Acid-resistant gloves
c) Protective aprons and overshoes
d) Portable or stationary water facilities for rinsing eyes and skin in case of contact with acid electrolyte
e) Bicarbonate of soda mixed approximately 0.1 kg/L (1 lb to 1 gal) of water to neutralize acid spillage
f) Class C fire extinguisher
g) Adequately insulated tools
h) Lifting devices of adequate capacity, when required

NOTES
1—The use of bicarbonate of soda to neutralize acid spills may result in production of a hazardous waste. Users should be aware of their responsibilities for handling waste. Compliance with appropriate local, state, and federal governmental regulations in this matter is recommended.
2—Some battery manufacturers do not recommend the use of CO_2 Class C fire extinguishers due to the potential of thermal shock.

4.2 Precautions

The following safety precautions shall be followed prior to and during installation:

a) Ensure that metal racks are connected to ground in accordance with applicable codes.

b) Inspect all lifting equipment for functional adequacy.

c) Restrict all unauthorized personnel from the battery area.

d) Prohibit smoking and open flame, and avoid the chances of arcing in the immediate vicinity of the battery.

e) Keep the top of the battery clear of all tools and other foreign objects.

f) Ensure that illumination requirements are met.

g) Ensure unobstructed egress from the battery area.

h) Ensure that the battery area is ventilated during charging.

i) Avoid the wearing of metallic objects such as jewelry while working on the battery.

j) Avoid excessive tilting of the cells so as to prevent spillage.

k) Neutralize static buildup by having personnel contact the nearest effectively grounded surface just before working on the battery.

5. Installation design criteria

Considerations that should be included in the design of the battery installation depend upon the requirements or function of the system of which the battery is part. The general installation design criteria for all vented lead-acid batteries are provided in the following subclauses.

5.1 Location

a) Space and floor supports allocated for the battery and associated equipment should allow for present and future needs. Calculations should be performed to ensure that floor loading capabilities are not exceeded.

b) The location should be as free from vibration as practical.

c) The general battery area should be clean, dry, and well ventilated (see 5.4), and provide adequate space and illumination for inspection, maintenance, testing, and cell/battery replacement. Space should also be provided to allow for operation of lifting equipment, addition of water, and taking measurements (e.g., temperature, specific gravity, etc.).

d) The battery should be protected against natural phenomena such as earthquakes, winds, and flooding, as well as induced phenomena such as fire, explosion, missiles, pipe whips, discharging fluids, and CO_2 discharge.

e) The optimum cell electrolyte temperature is 25 °C (77 °F) and is the basis for rated performance. A location where this temperature can be maintained will contribute to optimum battery life, performance, and cost of operation. Extreme ambient temperatures should be avoided because low temperatures decrease battery capacity, while prolonged high temperatures shorten battery life and increase maintenance cost. Installation in a location with an ambient below the optimum temperature will affect sizing. Refer to IEEE Std 485-1983.

f) The location and arrangement of cells should result in no greater than a 3 °C (5 °F) temperature differential between cells at a given time. Avoid conditions that result in spot heating or cooling, as temperature variations will cause the battery to become electrically unbalanced.

g) Portable or stationary water facilities should be provided for rinsing spilled electrolyte. Provisions for neutralizing, containing, and safely disposing of acid electrolyte in accordance with governmental regulations should be included.

h) The charger and main power distribution center should be as close as practical to the battery, consistent with item j) below.

i) Illumination in the battery area should equal or exceed the interior lighting recommendations in figure 11.1 of [B1].[2]

j) Nearby equipment with arcing contacts shall be located in such a manner as to avoid those areas where hydrogen pockets could form.

[2]The numbers in brackets preceded by the letter B correspond to those of the bibliography in clause 8.

5.2 Mounting

a) The most common practice is to mount cells on a steel rack with acid-resistant insulation between the cells and the steel of the rack. Metal racks should be connected solidly to the grounding system if grounding is part of the design requirements and applicable codes. The cells may also be mounted on adequately insulated supports secured to a floor or base.

b) Not more than two tiers or two steps should normally be considered for large batteries; this choice of rack results in a minimum temperature differential between cells and will facilitate maintenance. A three-tier rack is acceptable provided the requirements of 5.1 item f) are met, and maintenance is not adversely affected.

c) Cells in clear jars are usually mounted so that one edge of each plate is plainly visible for inspection and so that the electrolyte withdrawal tubes or vent plugs are easily accessible.

d) Electrical connections to the battery and between cells on separate levels or racks should be made so as to minimize mechanical strain on battery posts.

5.3 Seismic

Where applicable building codes require seismic protection, the racks, cabinets, anchors, and installation thereof shall be able to withstand the calculated seismic forces. To minimize the effect of seismic forces, the battery should be located at as low an elevation as practical. The following criteria should be observed regarding mounting:

a) All cells should be restrained. Side and end rails with spacers between cells is one method that can be used to prevent loss of function due to a seismic event.

b) Where more than one rack section is used, the rack sections should be rigidly joined, or the adjacent end cells in each rack should be connected with flexible connectors as provided by or recommended by the manufacturer. Connections between cells at different levels of the same rack should also be flexible.

c) Racks shall be firmly connected to the building structure as specified by using approved fastening techniques such as embedded anchor bolts or racks welded to structural steel face plates (sized to accommodate a range of battery rack sizes).

CAUTION

Anchoring a rack to both the floor and the wall may cause stress due to conflicting modes of vibration.

5.4 Ventilation

The battery area shall be ventilated, either by a natural or mechanical ventilation system, to prevent accumulation of hydrogen. The ventilation system shall limit hydrogen accumulation to less than 2% of the total volume of the battery area. The location should be free of areas that might collect pockets of hydrogen. Maximum hydrogen evolution rate is 1.27×10^{-7} m^3/s (0.000269 ft^3/min) per charging ampere per cell at 25 °C (77 °F) at standard pressure. The worst-case condition exists when forcing maximum current into a fully charged battery.

A battery area that meets the above ventilation requirements should not be considered a classified (hazardous) location; thus special electrical equipment enclosures to prevent fire or explosion should not be necessary.

5.5 Instrumentation and alarms

The following general recommendations for instrumentation and alarms apply to the battery installation only. Requirements for the charger, dc system design, etc., are beyond the scope of this recommended practice.

Each battery installation should include the following instrumentation and alarms:

a) Voltmeter
b) High and low battery voltage alarm
c) Ground detector (for ungrounded systems)
d) Instrumentation to measure current through the battery (refer to 4.5 of IEEE Std 450-1995).

The preceding recommendations for instrumentation and alarms could be satisfied by equipment in the dc system.

6. Installation procedures

See clause 4 for safety precautions to be followed.

6.1 Receiving and storage

6.1.1 Receiving inspection

Upon receipt, and at the time of actual unloading, each package should be visually inspected for apparent damage and electrolyte leakage. If either is evident, a more detailed inspection of the entire shipment should be conducted and results noted on the bill of lading.

Cell repair or replacement should be instituted as required. Record receipt date and inspection data results.

6.1.2 Unpacking

a) When lifting cells, a strap and strap spreader should be used, if applicable.

b) Always lift cells by the bottom, never by the cell posts.

c) Check electrolyte levels for evidence of leakage and to ensure that the plates are covered; any cell should be replaced if the electrolyte level is approximately 13 mm (0.5 in) or more below the top of the plates. If the level is less than approximately 13 mm (0.5 in) below the top of the plates, add electrolyte of appropriate strength, or water, and fill to cover the plates.

d) All cells with visible defects such as cracked jars, loose terminal posts, or improperly aligned plates, shall be repaired or replaced.

6.1.3 Storage

a) Cells should be stored indoors in a clean, level, dry, and cool location; extremely low ambient temperatures or localized sources of heat should be avoided.

b) Cells should not be stored for more than the time period recommended by the manufacturer, without applying a charge to the battery; in all cases, a period of three months storage is allowable between charges if the recommendations of item a) above are followed.

c) For charging during storage or special conditions, the battery manufacturer should be consulted. Record dates and conditions for all charges during storage.

6.2 Assembly

6.2.1 Rack assembly

The assembly of the rack should be in accordance with the manufacturer's recommended procedure.

6.2.2 Cell mounting and connections

The following sequence should be used:

a) Lift the individual cells onto the rack following the procedures outlined in 6.1.2 items a) and b). Mount the cells in accordance with the manufacturer's recommendations. Do not apply lubricant on rack rails unless approved by the manufacturer(s).

b) Remove shipping plugs and install flame arrestor vent plugs.

c) Check cell polarity for positive to negative connections throughout the battery.

d) Unless otherwise instructed by the manufacturer, clean all terminal posts and connecting hardware areas showing evidence of corrosion, dirt, or acid with a nonmetallic brush or pad; then coat all areas with a thin film of manufacturer's approved corrosion-inhibiting compound.

e) The intercell connector contact surfaces should be cleaned by rubbing gently with a nonmetallic brush or pad; care should be exercised in cleaning to prevent removal of the plating. Apply a thin film of manufacturer's approved corrosion-inhibiting compound to all contact surfaces.

f) Make intercell connections using manufacturer's approved connectors (normally furnished with the battery).

g) When more than one intercell connector per cell post is required, mount the intercell connectors on opposite sides of the post for maximum surface contact.

h) Tighten both ends of connection bolts to the battery manufacturer's recommended torque values. Use a second wrench for counter torque.

i) Clean all cell covers and containers; for dust and dirt, use a water-moistened clean wiper; for electrolyte spillage, use a bicarbonate of soda and water-moistened wiper. Do not use hydrocarbon-type cleaning agents (oil distillates) and strong alkaline cleaning agents, which may cause containers and covers to crack or craze.

j) Read the voltage of the battery to ensure that individual cells are connected correctly (i.e., the total voltage should be approximately equal to the number of cells multiplied by the measured voltage of one cell). If the measurement is less, recheck the connections for proper polarity.

k) For future identification, apply individual cell numbers in sequence beginning with number one at the positive end of the battery; also add any required operating identification.

l) Read and record intercell connection resistance and the method of measurement to determine adequacy of initial installation and as a reference for future maintenance requirements (see clause 7). Review records of each connection detail resistance measurement; remake and remeasure any connection that has a resistance measurement more than 10% or 5 $\mu\Omega$, whichever is greater, over the average for each type of connection (i.e., intercell, intertier, interrack). See annex A for detailed procedures.

m) When items a) through l) above have been satisfactorily completed, make connections from the battery to the charger in preparation for the freshening charge.

6.3 Freshening charge, data collection, and testing

6.3.1 Freshening charge sequence

Since a battery loses some of its charge during shipment and storage, a freshening charge should be applied after installation and before connection to the system. Follow the manufacturer's recommendation for application and duration. Typically this consists of the following:

a) Prior to applying the charge, read and record the open circuit voltage of all cells, and the electrolyte temperature and specific gravity of every tenth cell. Select the cell with the lowest specific gravity as a pilot cell for the freshening charge.

b) Inspect all cells to ensure that the electrolyte level is above the top of the plates. If required, add enough electrolyte to cover the plates.

c) Apply the freshening charge per the manufacturer's recommendations. If the freshening charge voltage exceeds the system voltage limit, perform the freshening charge offline from the dc system.

d) Read and record at least once per day during the freshening charge: battery voltage individual cell voltage, electrolyte temperature of every tenth cell, and the specific gravity and electrolyte temperature of the pilot cell.

e) Return charger to float voltage.

6.3.2 Data collection

a) At the end of 72 h on float, read and record all individual cell voltages, electrolyte temperatures, specific gravities, and levels (see clause 7). Refer to annex A of IEEE Std 450-1995.

b) Any cell that shows a specific gravity or voltage outside the manufacturer's specified limits requires corrective action in accordance with the manufacturer's instructions.

c) As necessary, use approved water, (or electrolyte if approved by the manufacturer) to adjust the electrolyte level of all cells to a level specified by the manufacturer.

d) Record new electrolyte levels.

6.3.2.1 Optional measurements

Measurement techniques have been developed to obtain data related to battery condition. While standardized techniques may not exist, the results often provide valuable information to the informed user. Annex B has been provided for the user who may want to collect additional baseline data.

6.3.3 Acceptance test

When required, an acceptance test shall be conducted in accordance with IEEE Std 450-1995.

6.4 Connection to dc system

If not already connected to the dc system, connect the battery to the dc system at this time.

7. Records

Data obtained from receiving, storage, assembly, and freshening charge are pertinent to the maintenance and operational life of the battery. The recommended records should be in accordance with cell identification [see 6.2.2 item k)]. The data that should be dated, recorded, and maintained in a suitable permanent file for record purposes and future reference includes:

a) Receiving inspection data and conditions of charge [see 6.1.3 item c)]

b) Initial resistance values of the intercell connections [see 6.2.2 item l)]

c) Individual cell specific gravities (corrected for temperature), voltage measurements, and electrolyte levels [see 6.3.2 item a)]

d) Acceptance test data (see 6.3.3)

8. Bibliography

[B1] *Illuminating Engineering Society of North America Lighting Handbook, Reference and Application*, 1993.

Annex A

(informative)

Example methods

NOTE—This annex was taken from annex F of IEEE Std 450-1995.

The following are examples of how to take intercell detail connection resistance measurements for a variety of available battery designs. Other battery designs and methods of taking resistance readings are also used but are not specified in this annex. It is important to select a method for a particular battery design and use the same method consistently for trending purposes.

A.1 Recommended method for performing detail connection resistance readings using a micro-ohmmeter

a) When taking micro-ohmmeter readings, the probes should be held perpendicular to the battery post.

b) Set the micro-ohmmeter scale to the lowest resistance scale.

c) **DO NOT TAKE A READING ACROSS THE CELL.** This reading could damage the meter.

d) When performing micro-ohmmeter readings, it is recommended that these readings be taken from the battery post to the battery post of connected cells, or from the battery post to the terminal lug.

NOTE—It is not acceptable to record the micro-ohm readings in milliohms. All readings must be converted into micro-ohms.

The proper and improper methods of performing detailed connection resistance readings are shown in figures A.1a) and A.1b), respectively.

a) Proper method

b) Improper method

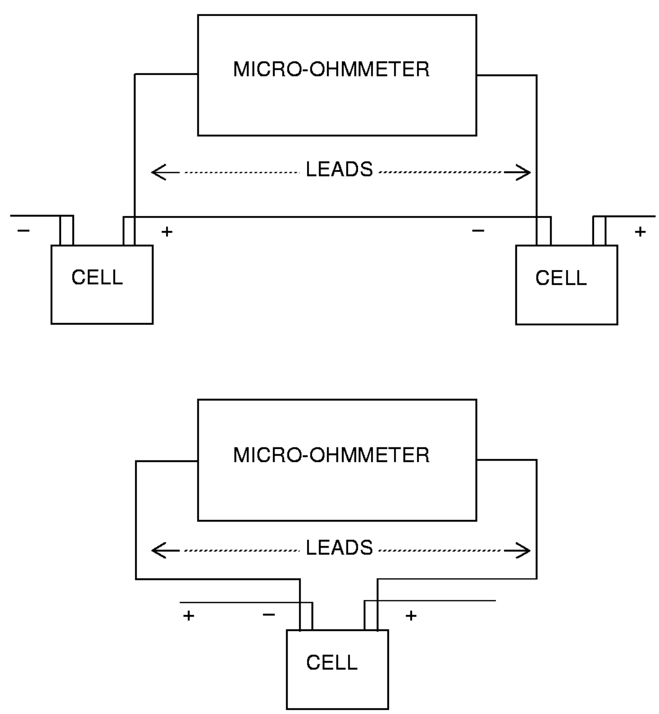


Figure A.1—Detailed connection resistance measurement

A.2 Recommended method for single intercell connections and parallel-post intercell connections

a) Measure the intercell connection resistance of each intercell connection by measuring from the positive terminal post to the negative terminal post of the adjacent cell.

b) Record the measurements.

NOTE—Single intercell connections and parallel-post intercell connections detail connection resistance measurements are treated in the same manner.

Figure A.2 shows a typical single intercell connection. Figure A.3 shows a typical parallel-post intercell connection.

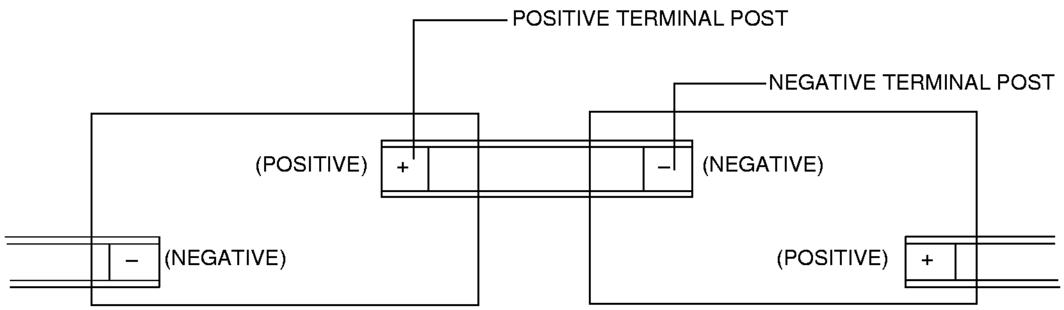


Figure A.2—Single intercell connection (typical)

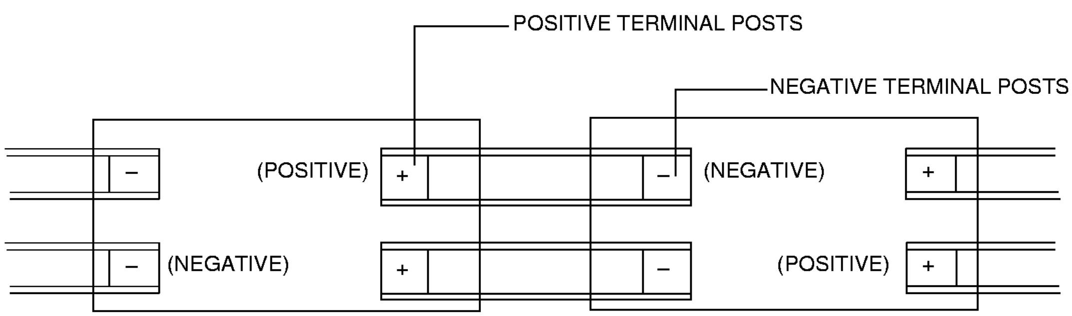


Figure A.3—Parallel-post intercell connection (typical)

A.3 Recommended method for double-post intercell connections

a) Measure the intercell connection resistance of each intercell connection by measuring from
   1) Terminal post A to terminal post C
   2) Terminal post B to terminal post D
b) Record the measurements.

NOTE—The resistance of intertier and interrack connections, with or without connection plates, can be performed using steps a) and b) above.

Figure A.4 shows a typical double-post intercell connection.

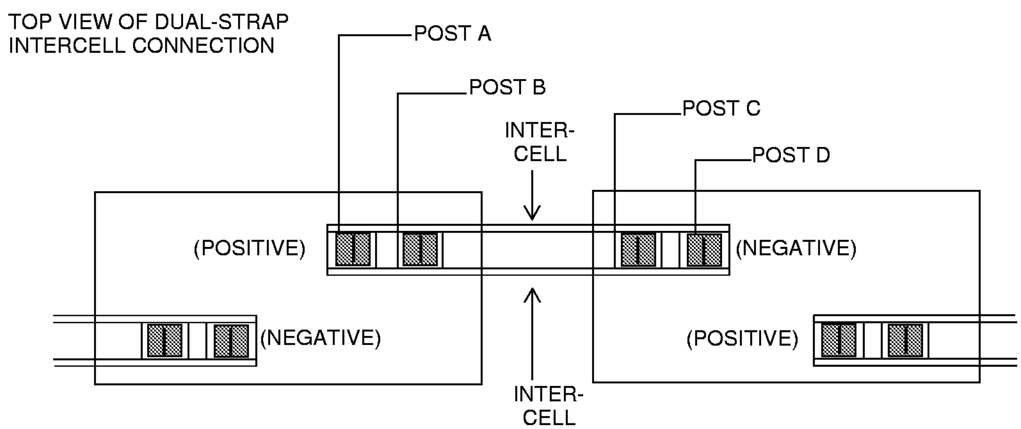


Figure A.4—Double-post intercell connection (typical)

A.4 Recommended method for triple-post intercell connections

a) Measure the intercell connection resistance of each intercell connection by measuring from
   1) Terminal post A to terminal post D
   2) Terminal post B to terminal post E
   3) Terminal post C to terminal post F
b) Record the measurements.

NOTE—The resistance of intertier and interrack connections, with or without connection plates, can be performed using steps a) and b) above.

Figure A.5 shows a typical triple-post intercell connection.

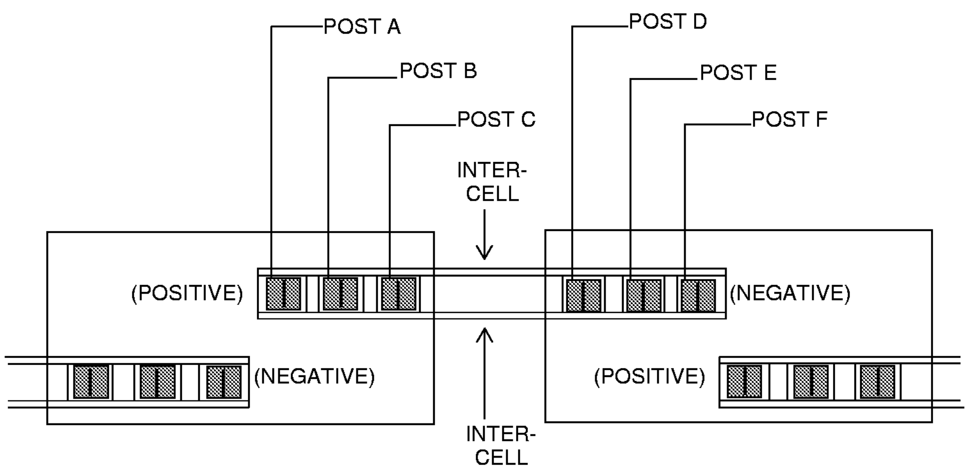


Figure A.5—Triple-post intercell connection (typical)

A.5 Recommended method for flag-post intercell connections

a) Measure the connection resistance of the intercell connections from terminal post A to terminal post B.

b) Measure the connection resistance of the intertier and interrack connections from terminal post A to terminal post B and/or from terminal post A to terminal lug A and terminal post B to terminal lug B.

c) Measure the connection resistance of the terminal connections from terminal post C to terminal lug D on the connecting cable.

d) Record the measurements.

Figure A.6 shows typical flag-post terminal connections.

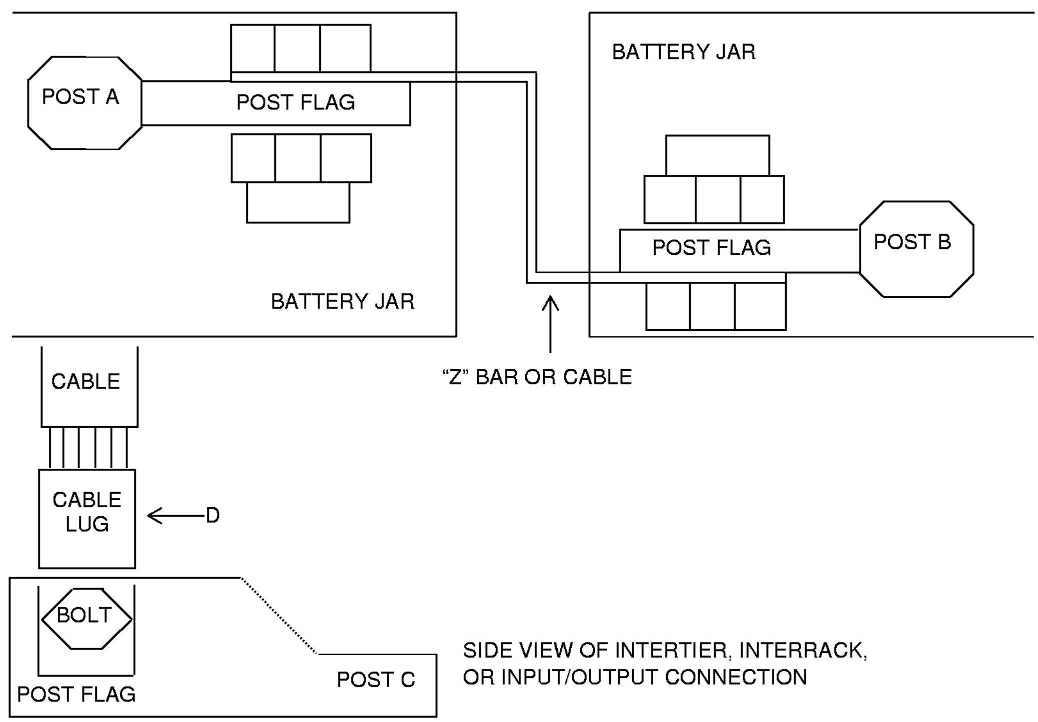


Figure A.6—Flag-post terminal connections (typical)

A.6 Recommended method for single connections

a) Measure the connection resistance of single terminal connections by measuring from terminal lug to terminal post.

b) Record the measurements.

Figure A.7 shows a typical single terminal connection.

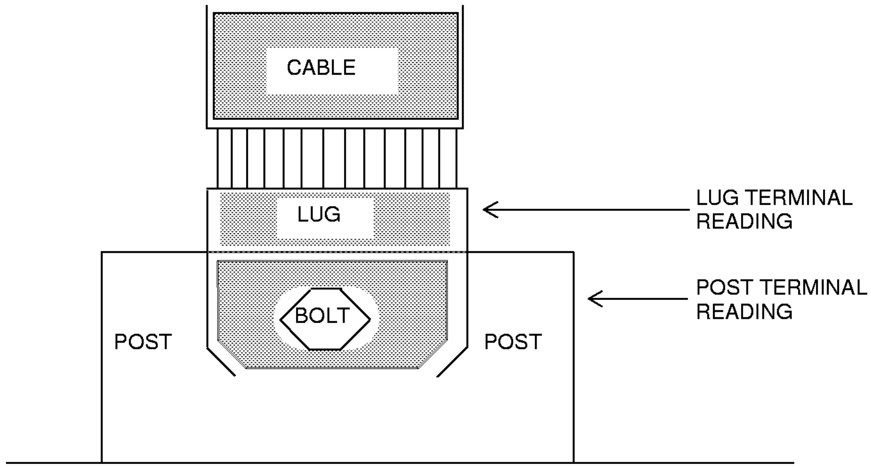


Figure A.7—Single terminal connection (typical)

A.7 Recommended method for multiple terminal connections

a) Measure the connection resistance of each terminal connection by measuring from

   1) Terminal lug A to terminal post A

   2) Terminal lug B to terminal post B

b) Record the measurements.

Figure A.8 shows a typical multiple terminal connection.

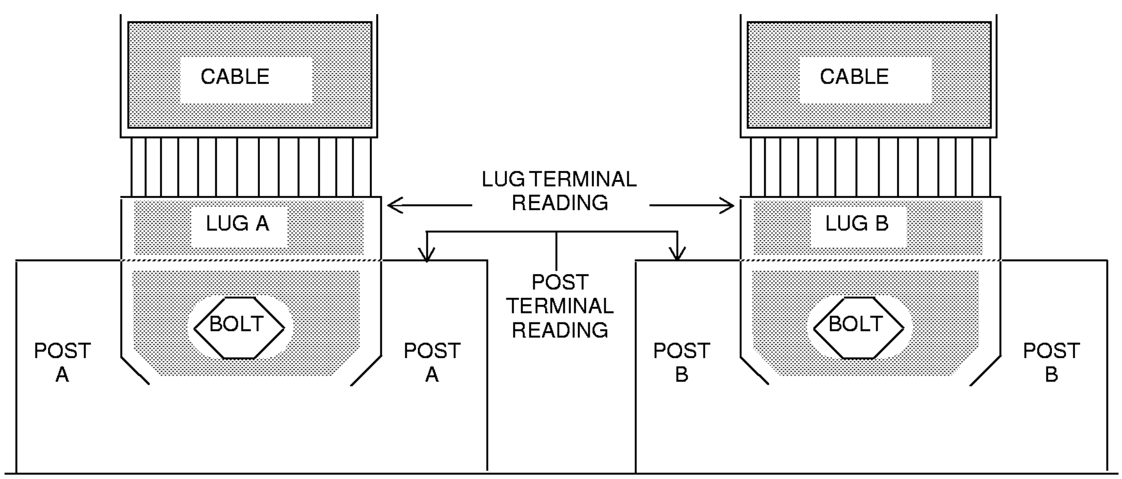


Figure A.8—Multiple terminal connection (typical)

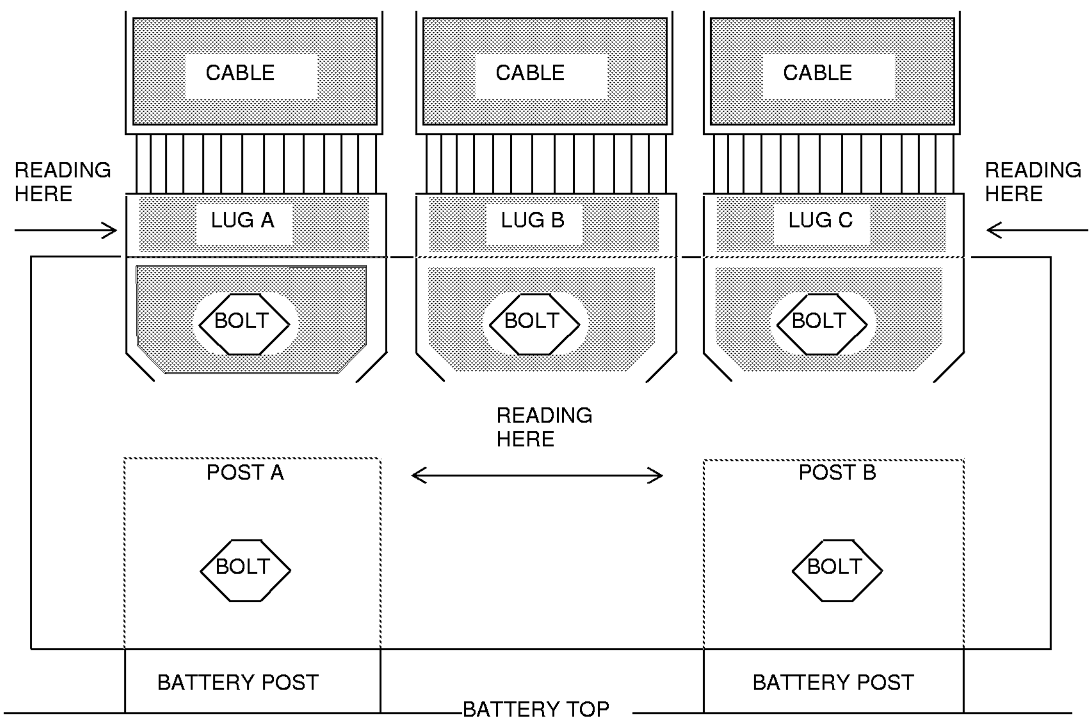
A.8 Recommended method for cable, plate, and post connections

a) Measure the terminal connection resistance of each terminal connection by measuring from
   1) Terminal lug A to terminal post A
   2) Terminal lug B to terminal post A
   3) Terminal lug C to terminal post B
   4) Terminal lug D to terminal post A
   5) Terminal lug E to terminal post B
   6) Terminal lug F to terminal post B

b) Record the measurements.

NOTE—The resistance of interrack connections and terminal connections will be performed using steps a) and b) above.

Figure A.9 shows cable, plate, and post connections.



NOTE—Lug on the other side of plate from Lug A is marked as Lug D, Lug B as Lug E, and Lug C as Lug F.

Figure A.9—Cable, plate, and post connections

Annex B

(informative)

Cell/unit internal ohmic measurements

These measurements provide information about circuit continuity and can be used for comparison between cells and for future reference.

The internal impedance of a cell consists of a number of factors, including: the physical connection resistances, the ionic conductivity of the electrolyte, and the activity of electrochemical processes occurring at the plate surfaces. With multicell units, there are additional contributions due to intercell connections. The resultant lumped impedance element can be quantified using techniques such as the following:

a) Impedance measurements can be performed by passing a current of known frequency and amplitude through the battery and measuring the resultant ac voltage drop across each cell/unit. The ac voltage measurement is taken between the positive and negative terminal posts of individual cells or the smallest group of cells possible. Compute the resultant impedance using Ohm's law.

b) Conductance measurements can be performed by applying a voltage of known frequency and amplitude across a cell/unit and observing the ac current that flows in response to it. The conductance is the ratio of the ac current component that is in phase with the ac voltage, to the amplitude of the ac voltage producing it.

c) Resistance measurements can be performed by applying a load across the cell/unit and measuring the step change in voltage and current. The ohmic value is calculated by dividing the change in voltage by the change in current.

After making initial measurements using the particular technique, the observed values should be recorded as baseline values. The type of test equipment used, the test points selected, cell/unit voltages, and electrolyte temperatures should be recorded for future reference.