



APTA BTS-BS-RP-007-26

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Bus Safety Working Group

Out-of-Service Storage of Vehicles with High-Voltage Lithium-Ion Energy Storage Systems

Abstract: This recommended practice provides guidance to bus transit agencies for storing transit vehicles equipped with high-voltage lithium-ion batteries—including battery electric, hybrid electric and fuel cell electric vehicles—when not in normal service operation. It outlines procedures for short-term, long-term and decommissioned storage to maintain safety, extend battery life and minimize risks. This recommended practice does not apply to routine daily parking or to vehicles in the active service pool.

Keywords: battery bus fire, battery electric bus, electric bus, fuel cell electric bus, hybrid bus, hybrid electric bus, fuel cell bus, high-voltage battery, lithium-ion, safety, storage procedure, thermal event

Summary: This recommended practice establishes guidance for the safe out-of-service storage of vehicles equipped with high-voltage lithium-ion batteries. It addresses three key storage phases: short-term storage (less than approximately one month), long-term storage (one month to approximately 12 months) and decommissioning (more than approximately 12 months). This document emphasizes the importance of correct state of charge, environmental conditions and safety practices to minimize degradation and reduce fire risk. Agencies are encouraged to adapt this recommended practice to their unique fleets, facilities and regulatory environments while integrating OEM-specific requirements. This document should be used in conjunction with appropriate procedures for handling damaged or malfunctioning high-voltage lithium-ion batteries and vehicles.



Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the [manual for the APTA Standards Program](#). This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the APTA Zero Emission Bus Safety Technical Advisory Group, as directed by the APTA Bus Safety Working Group and the Bus Systems Standards Policy and Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any recommended practices or guidelines contained herein is voluntary. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit agency's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This is a new document.



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Participants

The American Public Transportation Association greatly appreciates the contributions of the **APTA Zero Emission Bus Safety Technical Advisory Group** and the **APTA Bus Safety Standards Working Group**, which provided the primary effort in the drafting of this document.

At the time this standard was completed, the technical advisory group included the following members:

Mike Finnern, *WSP*, Chair Zero Emission Bus Safety Technical Advisory Group

Michael Smith, Chair Bus Safety Standards Working Group

Lynn McFadden, Vice Chair Bus Safety Standards Working Group

Rahmane Camara, *Connecticut DOT*
Eric Belmont, *GFT*
Falco Benfield, *Maryland MTA*
Christopher Brewster, *Birmingham-Jefferson County Transit Authority*
Marla Blagg, *AC Transit*
Mohammed Boukhriss, *Houston Metro*
Louis Brown, *HNTB*
Sean Cagan, *San Antonio VIA*
Jewels Carter, *AECOM*
Brian Clem, *IndyGo*
John Curley, *Foothill Transit*
Jonathan Farhat, *AC Transit*
Michael Flocchini, *AC Transit*
Brian Funk, *Metro Transit*
Charlie Gamble, *ADS Safety*
Jared Garcia, *San Diego MTS*
Chris Geraci, *JTA*
Jamaine Gibson, *ATU*
Jodi Godfrey, *CUTR*
Thomas Greufe
Forrest Jones, *STV, Inc.*
Patrick Kaufman, *Gillig*
James Keane, *NJ Transit*

Bhavin Khatri, *SFMTA*
William Korth, *NY RTS*
Alex Kumnik, *PRT*
Daniel Lang, *Hatch*
Bryan Lee, *CALSTART*
Brian Lim, *Stantec*
Mike Macas, *Toronto Transit Commission*
Michael Marks, *King County Metro*
Janice Mayo, *HNTB*
Michael McDonald, *New Flyer*
James Oliver, *City of Galveston*
Carly Rask, *King County Metro*
John Ryall, *Polyvantis*
Akshi Sharma, *Trapeze*
Marcia Siler, *WMATA*
Sean Slyman, *OnCommand Connection*
Schneider St.Preux, *Miami-Dade Transit*
Henry Staten Sr., *CATS*
Jennifer Sweten, *King County Metro*
Bryan Valenzuela, *Sunline Transit*
Aaron Vogel, *AC Transit*
Stephanie Walker, *Birmingham-Jefferson County Transit Authority*
Janee Weaver, *North County Transit*

Project team

Lisa Jerram, *American Public Transportation Association*
Brian Alberts, *American Public Transportation Association*
Brian Heanue, *American Public Transportation Association*
Annabelle Swift, *American Public Transportation Association*
Tdisho Pendelton, *American Public Transportation Association*



Introduction

This introduction is not part of APTA BT-BS-RP-007-26, “Out-of-Service Storage of Vehicles with High-Voltage Lithium-Ion Energy Storage Systems.”

Transit agencies are increasingly deploying vehicles powered by high-voltage (HV) energy storage systems, including battery electric buses (BEBs), hybrid electric buses, medium-duty electric shuttles, fuel cell electric buses (FCEBs), and electric and hybrid automobiles or other equipment. While these propulsion technologies differ, all rely on HV batteries that require careful management during storage to preserve system health, minimize degradation, and reduce the risk of fire or other hazards.

This recommended practice provides guidance for short-term storage, long-term storage and decommissioning of vehicles with HV lithium-ion batteries when not in normal service operation. This document should be used in conjunction with appropriate procedures for handling damaged or malfunctioning HV lithium-ion batteries and vehicles. Agencies operating FCEBs should refer to original equipment manufacturer (OEM) guidance and hydrogen safety codes for complementary requirements related to hydrogen storage and fuel cells.

Scope and purpose

The purpose of this recommended practice is to establish standardized practices for storing and managing HV lithium-ion batteries in transit vehicles when not in everyday, normal operational use. Specifically, this document seeks to do the following:

- Support agencies in safely storing HV batteries used in BEBs, FCEBs, hybrid electric buses and medium-duty electric vehicles (EVs).
- Provide clear procedures for short-term storage, long-term storage and decommissioning of HV batteries.
- Extend the service life and performance of HV batteries.
- Reduce risk of thermal events, electrical hazards or mechanical failures associated with HV battery storage.

The values and ranges specified in this document are for lithium-ion based battery chemistries. Other types of batteries (nickel-metal hydride, lead acid, etc.) may require different values.

Out-of-Service Storage of Vehicles with High-Voltage Lithium-Ion Energy Storage Systems

1. Overview of HV battery storage needs

1.1 Risks of HV batteries in transit vehicles

Vehicles equipped with HV batteries face specific risks when stored for extended periods. Improper storage may lead to the following:

- Increased battery degradation from extreme environmental conditions, overly deep discharging or prolonged inactivity.
- Thermal events (including thermal runaway) if packs experience internal failures or are damaged. Internal failures that can cause damage include coolant leakage or internal cell failures such as separator layer failures.

1.2 Scope clarification

This recommended practice is focused solely on the out-of-service storage of vehicles that contain HV batteries. While applicable to BEBs, EVs, hybrids and FCEBs, it does not prescribe procedures for non-battery systems such as hydrogen storage tanks or fuel cell stacks. Agencies should implement additional complementary standard operating procedures (SOPs) to address storage of those systems.

1.3 Operational readiness vs. preservation

Use the following storage stages as guidelines:

- **Short-term storage** emphasizes keeping vehicles ready for a rapid return to service. This is defined as less than approximately one month of storage, but that can be more if required.
- **Long-term storage** prioritizes preserving HV battery health and preventing degradation. This is defined as more than one month but less than one year of storage, but that can be greater if required.
- **Decommissioning** is recommended to ensure safety if storage exceeds, or is expected to exceed, approximately 12 months and the vehicle is not planned for future use.

1.4 Choosing a storage procedure

The time frames noted in these procedures are meant to be directional indications. Judgment should be used to determine which storage method is most appropriate. Take care to establish a realistic time frame for how long a vehicle is expected to be stored. A conservative approach is recommended when there is uncertainty over the return-to-service time frame. The date the vehicle was placed in storage and estimated return-to-service time frame should be posted on a temporary sign on the vehicle. Should the time frame be extended, the next phase of storage procedure should be followed.

1.5 Transit agency responsibility

Agencies should use this document as a framework for creating a customized SOP for their particular operation and equipment. It is recommended that each agency also develop an SOP for handling damaged or malfunctioning HV batteries or vehicles, as well as coordinate with—and provide vehicle-specific training to—local first responders.

2. Short-term storage (up to approximately one month)

Applies to: A vehicle kept out of service for up to approximately one month and expected to be returned to service quickly. A typical example of when short-term storage procedures apply is if the vehicle is awaiting a minor repair.

Goal: Keep vehicles in ready-to-deploy condition while minimizing battery degradation. Maximize the use of the onboard battery management system (BMS) and thermal controls to ensure that vehicles remain operationally prepared. During short-term storage, it is expected that the 12/24 V systems on the vehicle will remain connected and charged. The agency should charge the low-voltage batteries according to manufacturer recommendations.

2.1 Parking location

1. Vehicles with no suspicion of battery damage that are awaiting repairs to non-battery-related systems may park in their normal designated areas.
2. Vehicles with accident damage, suspicion of problems with the HV battery systems or diagnostic warnings related to the battery system should be parked outside in a quarantine area and separated from other vehicles or infrastructure by 50 ft if feasible. A minimum spacing of 20 ft is highly recommended. Monitor for a potential thermal issue (per appropriate damaged battery SOP) and consult with the OEM for further action. Parking on the top, outdoor floor of a parking structure is not recommended.
3. Protect from flooding.
4. Do not store beneath heaters or near high radiant heat sources.

2.2 Battery state of charge

1. Maintain state of charge (SOC) between 20% and 60% for optimal performance and safety.
 - a. Activating the vehicle's HVAC system is an effective way of reducing the SOC without driving.
2. Avoid leaving vehicles at greater than 90% SOC or at less than 5%.
3. Charge the 12/24 V batteries, as needed, to ensure that they maintain sufficient energy to power onboard systems.

2.3 Thermal management

1. Keep the battery thermal management system (BTMS) or equivalent cooling/heating connected and ready to operate whenever the vehicle is turned on. Do not drain any liquid cooling system.
2. To minimize degradation due to extreme temperatures, it is recommended to keep the battery between -4°F (-20°C) and 95°F (35°C). Care should be taken to never let battery temperature fall below -40°F (-40°C) or exceed 140°F (60°C).

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3. If ambient temperatures are expected to fall outside the recommended range, it is recommended to move the vehicle to a climate-controlled location or to allow the vehicle to remain powered on so the BTMS will remain powered and can maintain battery temperature for the duration of the extreme temperature event. This may require periodic recharging to maintain SOC in the recommended range. However, vehicles with suspected battery damage should remain outside; moving the vehicle to an indoor climate-controlled location should be done only if the vehicle has no suspected battery issue.

2.4 Safety and monitoring

1. Vehicles with suspected HV battery system damage must be parked in isolation, clearly marked, and have the HV system locked and tagged out.
2. Vehicles with suspected HV battery system damage should be monitored for escalating battery issues, as needed. Checking for increasing battery pack temperature with a thermal camera at least once per day is suggested. A measured temperature at greater than 5 °F above ambient could indicate that a battery thermal event is underway. Recheck hourly; if temperature continues to rise, a thermal event may be underway.
3. Follow agency SOP for handling damaged or malfunctioning HV batteries or vehicles.

2.5 Weekly activation

1. Each stored vehicle should be powered on at least once per week for two to four hours. The vehicle need not be monitored directly during this time.
 - a. This allows the low-voltage (LV) system to recharge, the BMS to balance battery packs, and onboard diagnostics to identify issues.
2. Any fault codes or warnings generated must be logged and reported to maintenance. Battery-related faults should be addressed appropriately.
3. Verify HV battery SOC, if required.

2.6 Return to service

1. Visually inspect the packs for issues such as damage to wiring, damage to coolant lines and connections, open vents, swelling, or leaks.
2. Ensure that any BTMS fluid levels are full.
3. Power on the vehicle and monitor for battery-related diagnostic codes.
4. Perform any other vehicle maintenance or return to service activity as prescribed by the OEM.
5. Charge the battery to full (100% or highest possible).
6. Complete a 2- to 5-mile test drive, verifying that there are no battery-related faults or issues.
7. Release to service.

3. Long-term storage (over approximately one month)

Applies to: A vehicle kept out of service for over one month, and perhaps a year or longer, that is planned for an eventual return to service.

Goal: Preserve HV battery health and extend service life by maintaining stable environmental conditions and safe SOC levels while the vehicle is not in regular service. This procedure is similar to short-term storage but with longer intervals between regular checks and a more thorough return-to-service procedure.

3.1 Parking location

1. Vehicles in long-term storage should be parked outside and at least 10 ft away from other vehicles or critical infrastructure.

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2. Vehicles with accident damage, suspicion of problems with the HV battery systems or diagnostic warnings related to the battery system should be parked outside in a quarantine area and separated from other vehicles or infrastructure by 50 ft if feasible. A minimum spacing of 20 ft is highly recommended. Monitor for a potential thermal issue and consult with the OEM for further action. Parking on the top, outdoor floor of a parking structure is not recommended.
3. Protect from flooding.
4. Do not store beneath heaters or near high radiant heat sources.

3.2 Battery state of charge

1. Adjust SOC to 20% to 40%
 - a. Activating the vehicle's HVAC system is an effective way of reducing the SOC without driving.

Check SOC monthly; recharge to 30% if below 5%. If the battery SOC indicates 1% or lower, it may be overdischarged. *Do not charge*; consult the OEM for next steps.

3.3 Thermal management

1. Keep the battery thermal management system (BTMS) or equivalent cooling/heating connected and ready to operate whenever the vehicle is turned on. Do not drain any liquid cooling system.
2. To minimize degradation due to extreme temperatures, it is recommended to keep the battery between -4°F (-20°C) and 95°F (35°C). Care should be taken to never let battery temperature fall below -40°F (-40°C) or to exceed 140°F (60°C).
3. If ambient temperatures are expected to fall outside the recommended range, it is recommended to move the vehicle to a climate-controlled location or leave the vehicle turned on so the BTMS can maintain battery temperature for the duration of the extreme-temperature event. This may require periodic recharging to maintain SOC in the recommended range. This should be done only if the vehicle has no suspected battery issue.

3.4 Safety and monitoring

1. Vehicles with suspected HV battery system damage must be parked in isolation, clearly marked, and locked/tagged out.
2. Vehicle with suspected HV battery system damage should be monitored for escalating battery issues as needed. Checking for increasing battery pack temperature with a thermal camera at least once per day is suggested. A measured temperature greater than 5°F above ambient could indicate that a battery thermal event is underway. Recheck hourly; if the temperature continues to rise, a thermal event may be underway.
3. Follow agency procedure for handling damaged or malfunctioning HV batteries or vehicles.

3.5 Monthly activation and check

1. Prior to turning the vehicle on, visually inspect the packs for issues such as damage to wiring, damage to coolant lines and connections, open vents, swelling, or leaks.
2. Ensure that the BTMS fluid levels are full.
3. If disconnected, reconnect and charge LV batteries.
4. Power on the vehicle and monitor for battery-related diagnostic codes for four to eight hours before any driving or charging of the vehicle occurs.
 - a. This allows the LV system to recharge, the BMS to balance battery packs and onboard diagnostics to identify issues.
5. Any fault codes or warnings generated must be logged and reported to maintenance. Battery-related faults should be addressed appropriately.

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6. Verify SOC, and charge if required.
 - a. Log SOC of each pack so it can be monitored over time.
 - b. If the rate of self-discharge is greater than 2% to 3% per month for a pack, the vehicle should be moved to a quarantine parking location and checked by the OEM.
7. Confirm BTMS operation by verifying that battery temperatures are within OEM-specified range (typically within 5 °F of ambient, if not in direct sunlight) and similar across packs.

3.6 Return to service

1. Visually inspect the packs for issues such as damage to wiring, damage to coolant lines and connections, open vents, swelling, or leaks.
2. Ensure that the BTMS fluid levels are full.
3. Power on the vehicle and monitor for battery-related diagnostic codes.
4. Follow OEM HV battery preventive maintenance recommendation for yearly activity if the vehicle has been sitting for longer than six months. At a minimum this should include changing moisture prevention systems (desiccants) and inspecting or changing battery pack vents and drains.
5. Charge the battery to full (100% or highest possible).
6. Leave the vehicle on for eight hours or until packs are balanced to within 3 percentage points of each other. This may take more than eight hours.
7. Perform any other vehicle maintenance or return to service activity as prescribed by the OEM.
8. Complete a 5- to 10-mile test drive, verifying that there are no battery-related faults or issues.
9. Release for service.

4. Decommissioning and end-of-life vehicle and battery storage

Applies to: Permanent removal of a vehicle from service (will not be used again).

Goal: Safely transition vehicles and their HV batteries out of service by mitigating risks, ensuring regulatory compliance and supporting recycling/reuse where possible.

4.1 Assessment

1. Have a qualified technician conduct final inspection of the HV battery and vehicle systems.
 - a. Visually inspect the packs for issues such as damage to wiring, damage to coolant lines and connections, open vents, swelling, or leaks.
 - b. Review vehicle diagnostic system for any battery-related faults.
 - c. Any vehicles with damage or suspected of having battery issues should be moved to a quarantine area and separated from other vehicles or infrastructure by 50 ft if feasible. A minimum spacing of 20 ft is highly recommended. Monitor for a potential thermal issue, and consult with the OEM for further action.
2. Identify whether HV batteries will be reused, recycled or disposed of per regulatory requirements.
 - a. Batteries in good health should first be considered for use as spare parts or for second-life applications outside the vehicle.

4.2 Battery and vehicle preparation

1. If HV batteries are planned for return to service or reuse (spares or second life), follow the recommendations in Section 5 of this document.
2. If vehicles and batteries are permanently decommissioned, take one of the following steps:
 - a. Ideally, remove battery packs and send them to a certified recycling facility. Contact the vehicle OEM for suggested recycling locations.

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- b. If not possible to remove and recycle batteries:
 - discharge batteries to less than 10%;
 - leave HV and LV electrical connectors connected to maintain pack environmental sealing protection; and
 - drain all coolant from HV thermal management circuits per OEM procedures.

4.3 Decommissioned battery storage

1. Store decommissioned batteries outside.
2. Stacking of battery packs may be done if OEM-approved and racking is appropriately weight-rated.
3. Maintain a minimum 3 ft clearance between packs or pack stacks (or per OEM/NFPA 855 guidance).
4. Maintain a minimum of 10 ft clearance to other items or flammable goods.
5. Packs should be stored on appropriate racking and raised off the ground.
6. Clearly label packs as “High-Voltage Battery – Do Not Move Without Authorization.”
7. Protect from flooding.

4.4 Vehicle parking location

1. Vehicles with batteries removed may be parked in any location.
2. Vehicles with decommissioned batteries still installed should be parked outside and at least 5 ft from other vehicles and 20 ft from any critical infrastructure. This recommendation is based on the HV batteries being brought to a safer, low-energy state, thus allowing for higher-density parking. Parking on the top, outdoor floor of a parking structure is not recommended.
3. Protect from flooding.

4.5 Documentation

1. Maintain records of decommissioning procedures and dates, including the following:
 - a. chain of custody for batteries
 - b. coolant drainage confirmation
 - c. certification of recycling or repurposing
2. Clearly mark vehicles with their condition and status of battery packs (removed or still installed, for example).

5. Storage of battery packs planned for reuse or spares

Applies to: HV battery packs stored either as spare parts or awaiting return or reuse.

Goal: Ensure safe storage of HV battery packs that are not installed in vehicles, while preserving state of health and minimizing fire risk. Battery packs with damage or that are suspected of malfunctioning should be kept outside in a quarantine area.

5.1 Storage facility and environmental conditions

The following storage parameters are recommendations and will work in most cases. Always verify the specific recommendations with the OEM.

1. Optimal life will be achieved by storing in a climate-controlled facility between 32 °F (0 °C) and 77 °F (25 °C), with 20% to 70% relative humidity.
2. Do not exceed 113 °F (45 °C).
3. Keep away from direct sunlight, water intrusion, condensation and flammable materials.
4. Stacking of battery packs may be done if OEM-approved and if racking is appropriately weight-rated.
5. Maintain a minimum 3 ft clearance between packs or pack stacks (or per OEM/NFPA 855 guidance).

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6. Maintain a minimum of 10 ft clearance to other stored items or flammable goods.
7. Packs should be stored on appropriate racking and raised off the floor.
8. Clearly label packs as “High-Voltage Battery – Do Not Move Without Authorization.”

5.2 State of charge and monitoring

The following SOC values are recommendations and will work in most cases. Always verify the specific recommended ranges with the OEM.

1. Adjust SOC to 20% to 40% \pm 10 percentage points before storage.
2. Verify SOC every six months; recharge to 30% if below 10%.
 - a. Connect to the pack, enable the BMS and gather the required data.
 - b. Coordination with the OEM for test equipment may be required to wake up the pack for checks and charging, if needed. This equipment may consist of a stand-alone “test box” that can be connected to a battery pack, power the BMS and report appropriate data from the pack.

5.3 Handling and movement

1. Move packs only with proper lifting equipment and approved carriers/crates.
2. Personnel must be HV battery trained and equipped with the appropriate personal protective equipment when handling HV battery packs.
3. If a pack is dropped, punctured or otherwise damaged, immediately move the pack outside to a designated quarantine zone. Checking for increasing battery pack temperature with a thermal camera at least once per day is suggested for packs with suspected damage. A measured temperature greater than 5 °F above ambient could indicate that a battery thermal event is underway. Recheck hourly; if temperature continues to rise, a thermal event may be underway.
4. Multiple damaged packs should be placed at least 10 ft from each other in the quarantine area.

5.4 Return to service

1. Follow OEM preventive maintenance recommendations for yearly activity if packs have been sitting for longer than six months. At a minimum this should include changing moisture prevention systems (desiccants) and inspecting or changing battery pack vents and drains.
2. Pack charges should be within 3 percentage points of each other when being reinstalled in a vehicle.
3. Turn on the vehicle and monitor the packs for four to eight hours for any signs of issues or fault codes.
4. Complete a 5- to 10-mile test drive, verifying that there are no battery-related faults or issues.

6. Customization guidance for agencies

This recommended practice provides a foundational framework. Each agency should customize the following:

- storage locations (indoor vs. outdoor, spacing and facility design)
- emergency procedures, including integration with local fire department protocols
- staff roles, identifying who is responsible for SOC monitoring, inspections, and reporting
- OEM-specific requirements, as each manufacturer may prescribe additional steps
- training frequency, ensuring that staff receive refresher training on HV battery storage and safety

7. Other Considerations:**7.1 Safety Risk Mitigation**

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- 1) Agencies developing processes for the long-term storage of vehicles should apply their established Safety Risk Management and Management of Change processes, as required under the Public Transportation Agency Safety Plan, to systematically identify hazards, assess and evaluate safety risk, and implement and document appropriate mitigations. Identified risks and mitigations should be tracked in accordance with the agency’s hazard management and risk acceptance procedures. Where long-term storage introduces new or modified system elements, agencies should conduct a formal safety analysis to determine whether those elements warrant inclusion in the Safety and Security Certification (SSC) process in accordance with the agency SSC plan or APTA SS-ISS-RP-008-24..

7.2 Security

- 1) Stored vehicles are valuable assets to a transit agency that may create risks that can be evaluated using the *Security Risk Assessment Methodology for Public Transit APTA SS-SIS-S-017-2* and require appropriate security measures described in: *Security Program Considerations for Public Transit APTA SS-SIS-S-010-13, Rev. 1*.
- 2) Access to stored vehicles may need to be subject to the restrictions described in *Approaching Access Management, APTA SS-ECS-RP-005-25*.

7.3 Emergency Preparedness

- 1) Stored vehicles may also contain materials and technologies unfamiliar to first responders, and agencies should consider involving their local first responders in targeted training and assisting them in creating appropriate scenarios for drills and exercises to ensure they are prepared to meet the agency's needs. See *First Responder Familiarization of Transit Systems APTA SS-SEM-RP-002-08* and *Transit Exercises APTA-SS-SEM-S-004-09*

7.4 Cybersecurity

- 1) Any changes to the operating technology necessary to store vehicles should be evaluated to mitigate any new cybersecurity vulnerabilities. See *Operational Technology Cybersecurity Maturity Framework (OT-CMF) Overview APTA SS-CCS-RP-006-23*

7.5 Risk and Liability

- 1) Agencies should engage their risk management and insurance partners in evaluating risks associated with the long-term storage of rolling stock and impacts to adjacent infrastructure. This assessment should identify emerging exposures, define appropriate mitigation strategies, and ensure adequate insurance coverage is in place to address new or evolving risks.

References

National Fire Protection Association standards:

- NFPA 13, Automatic Sprinkler Systems Handbook
- NFPA 70E, Safety-Related Maintenance and Special Equipment Online Training
- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems

Definitions

cell: The basic electrochemical unit that stores and releases energy.

decommission: Permanent removal of a vehicle from service.

high voltage: Typically greater than 60 Vdc or greater than 30 Vac.

long term storage: Keeping a vehicle out of service for more than approximately one month but less than approximately one year. This is done when the vehicle is expected to be out of service for a longer period of time than for short-term storage but is planned for return to service at some point.

module (sub-pack): A group of cells that are electrically connected and mechanically packaged together for protection, monitoring and thermal management. Some battery OEMs call a module a sub-pack.

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overdischarged: A battery discharged to below its minimum internal voltage limit (less than 1% state of charge). An overdischarged battery may develop internal faults, resulting in a loss of performance or failure.

pack: An assembly of one or more modules combined with structural housing, electrical connections, sensors, cooling and control systems to form a complete, ready-to-use energy storage unit. This document addresses battery handling only at the pack level.

self-discharge: The gradual loss of charge in a high-voltage battery over time when it is not connected to a load or in active use, caused by internal chemical reactions within the cells.

short term storage: Keeping a vehicle out of service for up to approximately one month. This is done when the vehicle is expected to be returned to service quickly.

string: A series of battery modules or packs connected in series to achieve the desired system voltage.

Abbreviations and acronyms

- BEB** battery electric bus
- BMS** battery management system
- BTMS** battery thermal management system
- EV** electric vehicle
- FCEB** fuel cell electric bus
- HV** high voltage
- HVAC** heating, ventilation and air conditioning
- LV** low voltage
- NFPA** National Fire Protection Association
- OEM** original equipment manufacturer
- OSHA** Occupational Safety and Health Administration
- SOC** state of charge
- SOP** standard operating procedure
- V** volts
- Vac** volts alternating current
- Vdc** volts direct current

Document history

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