NEMA US 80027-2023

Safe Handling of Hazardous Voltage Battery Storage Systems

Published by

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209

www.nema.org

NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

NEMA Standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus Standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. While NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the document and it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its Standards and guideline publications. NEMA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document.

NEMA disclaims and makes no guaranty or warranty, express or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your particular purposes or needs. NEMA does not undertake to guarantee the performance of any individual manufacturer or seller's products or services by virtue of this Standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other Standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health or safety–related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.

Table of Contents

Foreword 4

Glossary 6

1. Background 7

1.2 Qualified/Unqualified Person 7

1.3 Personal Protective Equipment 8

1.4 Arc Flash 9

1.5 Approach Boundaries 9

2. Safe and Environmentally Conscious Processing and Dismantling 11

2.1 Before Vehicle Collection 11

2.2 During Vehicle Collection 12

2.3 Vehicle on Site and Initial Check In 12

2.4 Inventory, Dismantling and Hazardous Voltage Battery Storage 13

2.5 Safe Transportation of EV/HEV batteries 14

2.6 Selling and disposal 14

3. Other Resources 15

Foreword

NEMA's Energy Storage Council developed this document to identify safety issues such as arc flash when handling hazardous voltage battery packs. It also identifies electrical safety categories that are important to understand before proceeding with energized electrical work associated with automotive batteries and other hazardous voltage systems. It covers direct and indirect hazards, shock and arc boundaries, hazard risk categories, and personal protective equipment (PPE); ensuring proper storage/isolation in battery packs; checking the current status of the battery. Also covered are best practices for testing the state of health of battery systems and procedures for obtaining a permit to work on HV vehicles. This document is not intended to be a comprehensive step by step process to eliminate all risks from dismantling energy storage systems.

About the National Electrical Manufacturers Association (NEMA)

Founded in 1926 and headquartered near Washington, D.C., NEMA represents 325 member companies that manufacture products used in the generation, transmission and distribution, control, and end use of electricity. These products are used in utility, industrial, commercial, institutional, and residential applications. The association's Medical Imaging & Technology Alliance (MITA) Division represents manufacturers of cutting-edge medical diagnostic imaging equipment, including MRI, CT, x ray, and ultrasound products. Worldwide sales of NEMA-scope products exceed $140 billion.

About the NEMA Energy Storage Council

The NEMA Energy Storage Council is established to coordinate activity between NEMA members and non-members to:

- Develop and promote standards, white papers, other technical documents and educational materials to facilitate the production, integration, re-use and recycling of energy storage devices;
- Gather market data and perform other industry research related to energy storage;
- Advocate for policies that benefit stakeholders across the energy storage value chain; and
- Educate electrical distributors, installers, consumers, and Authorities Having Jurisdiction on related code requirements and best practices.

At the time it was approved, the Energy Storage Council was composed of the following members:

Argonne National Laboratory
Automotive Recyclers Association
Battery Resourcers
Call2Recycle
EPRI
Generac Power Systems, Inc.

Kulr Technologies
Tesla Inc.
UL Solutions

Glossary

Arc Flash Hazard	A source of possible injury or damage to health associated with the release of energy caused by an electric arc.
Automotive Dismantler/Recycler	An entity that is lawfully authorized to engage in the acquisition and dismantling of motor vehicles for processing and selling recycled original equipment components, high voltage batteries, cores, and recyclable materials.
Automotive Recycling	The safe and environmentally responsible processing of motor vehicles for the sale of ***ROE-Recycled Original Equipment®*** automotive parts and recyclable materials.
Deenergized	Free from any electrical connection to a source of a potential difference and from electrical charge; not having a potential different from that of the earth
Depollution	The minimum technical requirements for the treatment of end-of-life vehicles such as discharge of battery pack and removal of explosive devices such as air bags and seat belt tensioners
Electric Vehicle (EV)	A vehicle propelled by an electrified system that is powered by high voltage batteries and/or capacitors. The high voltage batteries and/or capacitors are capable of being recharged by an external energy source.
Hazardous Voltage	OSHA considers all voltages of 50 volts or above to be hazardous
High Voltage Battery Recycler	An entity that is engaged in the collection and recycling of high voltage batteries for the purpose of reuse, repurposing, and the recycling of recyclable materials.
Internal Combustion Engine (ICE) Vehicle	A motor vehicle exclusively powered by hydrocarbon-based fuel products.
Scrap Metal Processor	One who, from a fixed location, utilizes machinery and equipment for processing and manufacturing iron, steel, or nonferrous metallic scrap into prepared grades and whose principal product is scrap iron, scrap steel, or nonferrous metallic scrap to sell for remelting purposes.
Qualified Person	One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.
Shock Hazard	A source of possible injury or damage to health associated with current through the body caused by contact or approach to exposed energized electrical conductors or circuit parts
State of Charge	The level of charge of an electric battery relative to its capacity. The units of SoC are percentage points (0% = empty; 100% = full).
High Voltage Vehicle (HVV)	Any *Electric Vehicle* or *Hybrid Electric Vehicle* that has an onboard high voltage (DC voltage over 60 volts) battery power source.
Hybrid Electric Vehicle (HEV)	A motor vehicle powered by both an internal combustion engine and an electric motor powered by a high voltage battery.

1. Background

Life-after-first-use industries such as Automotive Dismantlers/Recyclers are realizing the need to process hazardous voltage electric vehicle batteries as the mobility market electrifies and batteries become one of the largest end-of-life products. Batteries are used extensively in hybrid and all electric vehicles. These vehicles typically use 12 V battery to operate the airbags, windows, door locks, and interior and exterior lights. Modern electric vehicles can also contain battery systems in the 400-800 V range. All hazardous voltage batteries pose a risk if not properly prepared, trained and using all necessary standard operating procedures. This danger can be higher if the battery systems in the vehicles have been compromised from an accident. Lithium-ion batteries contain high-energy and present electrical, chemical and thermal hazards. It is imperative that these vehicles are only dismantled and processed at end of life by a certified facility. Improper handling of the vehicles can lead to serious injury or death from electric shock.

Hazardous voltage battery systems can also be used in non-transportation applications such as residential, commercial or industrial facilities.

1.2 Qualified/Unqualified Person

Those who work on or near electrical equipment must be qualified to do so, as authorized by the institution authority having jurisdiction. A qualified person is one who “has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved”.[1] An additional precaution is needed for work on energized electrical systems. Live work, i.e., work on energized conductors, should be avoided whenever possible. However, automotive battery systems are always energized, unless they have been completely discharged, and do not provide any circuit protection or interruption such as circuit breakers in alternating current (AC) systems that stop the flow of electricity.

Whether someone is considered to be a "qualified person" will depend upon various circumstances in the workplace. For example, it is possible and, in fact, likely for an individual to be considered "qualified" with regard to certain equipment in the workplace, but "unqualified" as to other equipment. (See OSHA 29 CFR 1910.332(b)(3) for training requirements that specifically apply to qualified persons.) An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person is considered to be a qualified person for the performance of those duties. Note that this program does NOT meet the requirements for becoming a Qualified Person.[2] For more information, see NFPA 70E Article 110.6 and OSHA 29 CFR 1910.332 “Training.”

Requirements of a qualified person:

- Completion of required training on the hazards of electrical equipment and operations.

[1] OSHA 29 CFR 1910.399
[2] Prevention Strategies for Electrical Currents, National Safety Council

- Training and experience in working with electricity. Knowledge of electrical hazards (such as shock and flash) and how to avoid them.
- Ability to distinguish exposed energized parts from other parts of electrical equipment. Ability to read and interpret a facility's electrical one-line diagram.
- Ability to determine nominal voltage of exposed live parts.
- Ability to determine approach distances when working on electricity.
- Knowledge of proper Personal Protective Equipment (PPE). Knowledge of lockout/tagout procedures.
- Knowledge of a facility's electrical safety plan.

Only a qualified person can perform the following:

- Work on energized parts over 50V
- Test exposed circuits

Unqualified Person

- Has some electrical knowledge/experience, but must limit work to de-energized parts.
- Has little or no training on identifying and preventing the electrical hazards associated with working on or near exposed energized parts.

1.3 Personal Protective Equipment

Personal protective equipment (PPE) refers to items typically worn by a worker to provide protection from recognized hazards. Depending on the job task to be performed, PPE for the electric power industry generally includes safety glasses, face shields, hard hats, safety shoes, insulating (rubber) gloves with leather protectors, insulating sleeves, and flame-resistant (FR) clothing. Additional PPE, such as fall protection equipment, respirators, chemical-resistant or cut-resistant gloves, and chaps, may be required, depending on the results of the hazard assessment required under OHSA 1910.132.[3] Electrical PPE is specifically for protecting the person from electrical hazards.

Listed below are categories of PPE and recommendations

- Hand protection
- Foot protection
- Arm protection
- Body protection
- Head and hearing protection

[3] OSHA, "Personal Protective Equipment (PPE)." Electric Power ETool: Personal Protective Equipment (PPE), www.osha.gov/SLTC/etools/electric_power/personal_protective_equipment.html.

1.4 Arc Flash

An arc flash is the light and heat produced from an electric arc supplied with sufficient electrical energy to cause substantial damage, harm, fire or injury. Note that welding arcs can turn steel into a liquid with an average of only 24V DC. When an uncontrolled arc forms at very high voltages, arc flashes can produce deafening noises, supersonic concussive-forces, super-heated shrapnel, temperatures far greater than the Sun's surface, and intense, high-energy radiation capable of vaporizing nearby materials.

Examples that could initiate an arc flash:

- Connecting cables into battery fed systems
- Changing components
- Handling and moving batteries
- Repairing batteries
- Working on associated battery systems
- Testing and fault-finding
- Working with batteries post-accident

NFPA 70E is the Standard for Electrical Safety in the Workplace and helps companies and employees avoid workplace injuries and fatalities due to shock, electrocution, arc flash, and arc blast, and assists in complying with OSHA 1910 Subpart S and OSHA 1926 Subpart K. More information about requirements for safe work practices to protect personnel by reducing exposure to major electrical hazards can be found in NFPA 70E.

1.5 Approach Boundaries

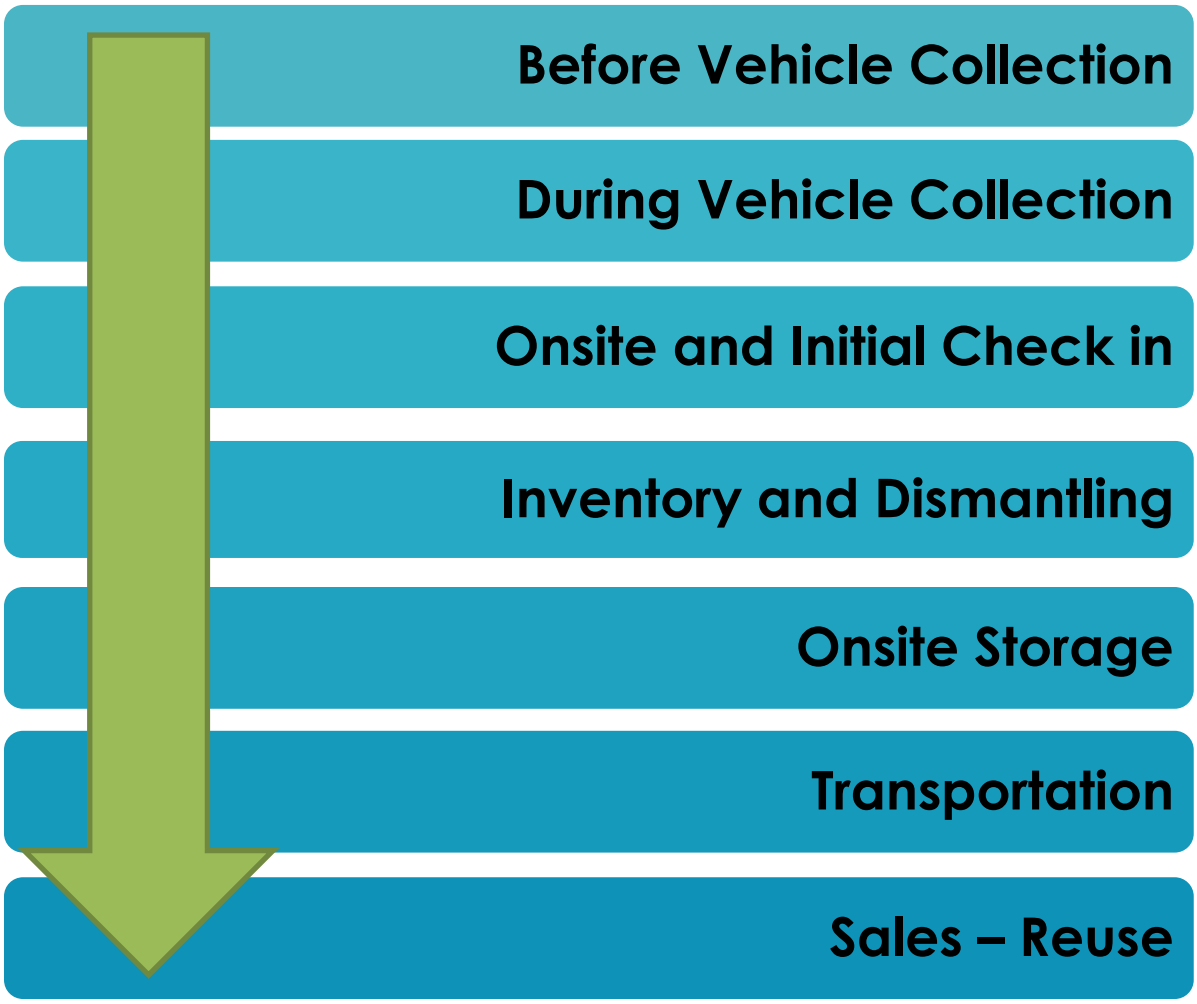
Under NFPA 70E, there are three boundaries—limited approach, restricted approach, and arc flash boundary. These boundaries trigger multiple requirements in 70E such as determining the type and level of PPE and qualifications required to cross into each level. As part of a larger training and safety program, these boundaries are put in place to minimize risk through avoidance or the use of PPE.

Limited and restricted approach boundaries deal with shock and are determined by NFPA 70E Tables 130.4(C)(a) for AC systems and 130.4(C)(b) for DC systems, while Arc Flash boundaries are determined through an Arc Flash Analysis or through the use of the use of the Arc Flash PPE Categories in 130.7(C)(15)(a). A example of an arc flash warning is shown in the image below.


WARNING
Qualified Persons Only
Arc Flash and Shock Hazards
Appropriate PPE Required
REVIEW SAFE WORK PRACTICES PRIOR TO WORK
3.10
cal/cm^2
Arc Flash Protection Boundary: 2 ft 8 in
Incident Energy @ Working Distance: 1 ft 6 in
Recommended (minimum) PPE:
Arc-rated(AR) clothing >= estimated Incident Energy; Long-sleeve shirt and pants/coverall/arc flash suit; AR face shield & balaclava or arc flash suit hood; AR outerwear as needed (e.g., jacket, parka, rainwear, hard hat liner); Heavy-duty leather gloves, AR gloves, or rubber insulating gloves w/Leather protectors; Hard hat. Safety glasses/goggles; Hearing protection. Leather footwear.
480 VAC Shock Hazard
00 Glove Class
3 ft 6 in Limited Approach
1 ft Restricted Approach
ESS
ELECTRICAL SAFETY SPECIALISTS
Job# ESS-2018-05-03-02
Prepared 04/02/19
Location: EXT 12

2. Safe and Environmentally Conscious Processing and Dismantling

The Automotive Recyclers Association has developed a high voltage vehicle dismantling protocol for a certified auto recycler.[4] All areas of handling the vehicle from acquisition to final disposition is covered in the protocol. This includes before and during vehicle collection, onsite and initial check-in, inventory and dismantling, storage, transportation, sales and recycling for recovery. This section is a summary of the protocol.



2.1 Before Vehicle Collection

As soon as a recycler is aware they are acquiring a hybrid electric or electric vehicle (HEV/EV), the vehicle record should be noted as a "HAZARDOUS VOLTAGE" if possible. The goal of this step is to alert the transportation drivers and the initial vehicle intake and inventory team of the potential danger the HEV/EV may have. Transportation drivers and loader operators should be trained of the potential dangers and exercise HEV/EV safety steps while transporting these types of vehicles. HEV/EV specific personal protective equipment (PPE) should be available to all involved in the collection and intake of the vehicle. These staff members should also be

[4] Automotive Recyclers Association's High Voltage Vehicle Dismantling Protocol for a Certified Auto Recycler

trained in how to use the PPE, and which hazards to watch for. The personnel involved in acquiring the vehicles should assess the type of damage the vehicle has and identify any vehicle at high risk of having a compromised battery compartment. If there are concerns, they should alert the transportation staff and the initial staff involved in unloading the vehicle at the dismantling facility.

2.2 During Vehicle Collection

During the vehicle retrieval process, when an HEV/EV is identified, the vehicle must be clearly marked, so the vehicle is easily identifiable as “Hazardous Voltage”. The ARA has examples of warning signage that must be applied to multiple sides of the vehicle. Whenever possible, and depending on the transportation arrangements, proper PPE, and qualified personnel, must be present. The qualified personnel must be trained whenever possible to assess possible damage to the hazardous voltage batteries prior to loading the vehicle. The transportation team should look for physical damage to the hazardous voltage battery and symptoms such as a thermal incident which could be indicated by fire or discoloration of the hazardous voltage cables. If the transportation personnel are unsure, they should call and consult with other experts for advice. If still uncertain, the vehicle should be left alone until a specialist can be consulted. Flooded vehicles should also have special attention paid to them.

2.3 Vehicle on Site and Initial Check In

Once the HEV/EV arrives at the Automotive Dismantler/Recycler’s location, if it has not been done already, the “hazardous voltage” signage must be added to multiple sides of the vehicle. PPE necessary for hazardous voltage safety must be readily available, and properly maintained at the facility. This PPE includes insulated hazardous voltage lineman’s gloves, approved face shield, insulated footwear, insulated tools and a safety pull-away hook. A voltage meter should also be available for checking circuits. It is also important to recognize that each vehicle can be different, and you must also follow the manufacturers processes to make the vehicle safe. Some manufacturers have different processes and research of each new make and model will be required along with the normal safety awareness.

Workflow decisions must be made and consider what systems will need the factory power, for proper inventory and removal of certain parts. Once those decisions have been made, the order of events should be determined. Once the proper information has been recovered from the vehicle and inventory and workflow decisions have been made, qualified personnel utilizing the proper PPE, can now remove the hazardous voltage battery master disconnect service plug and zip tie it to the steering wheel.

With the vehicle properly safeguarded and displaying a hazardous voltage warning, the HEV/EV should be placed in a segregated area if possible, awaiting final dismantling. A newly acquiried HEV/EV must first have its high voltage batteries identified and safely removed. Once the high voltage battery is removed, the battery must be safely stored to prevent risks associated with thermal events.

2.4 Inventory, Dismantling and Hazardous Voltage Battery Storage

If it had not already been done during the initial vehicle check-in and inventory, and after the dismantler has recovered the data they need from the vehicle, qualified personnel utilizing the proper PPE will first remove the hazardous voltage battery master disconnect. The dismantler should zip tie the master disconnect service plug on vehicle's the steering wheel.

Resistive discharging of lithium-ion battery packs, for example, is not a time-based activity. The target state would be a percentile of the State of Charge (SOC%) and the size and capacity and the discharger would determine how long it would take for a pack to be discharged to an appropriate level for further handling/dismantling. That appropriate SOC% level is not only determined by HV safe handling guidance but also by follow-on recycling activities. Not all recycling technologies are created equal; some physical processing techniques may not be able to handle high SOC% modules and may result in physical deflagration/environmental release. While this will be the process for most of the HEV/EV, always research with the manufacturer of that vehicle to find the exact process to make the vehicle safe for hazardous voltage battery removal. It is also important to consider if the vehicle systems are needed for any of the dismantling and part removal process.

After the proper time has passed for the hazardous voltage system to discharge, qualified personnel utilizing the proper PPE and tools will remove the hazardous voltage battery assembly. These batteries can be very heavy. It is important to confirm the facility has the proper lifting device or cooperation of a protected teammate to be able to remove the battery following the manufacturers recommended processes. Once the battery is safely removed and secured to a nonconductive pallet, it is recommended to zip tie the master disconnect plug to the opposite side of the plug on the battery case. (Hybrid batteries should never have their cases opened by anyone other than a trained professional in hazardous voltage batteries.) The qualified personnel will wrap any exposed/disconnected individual hazardous voltage wire ends in electrical tape to insulate them properly for safety.

All hazardous voltage warning signage, should now be replaced with signage that indicates the hazardous voltage battery has been removed, which marks the vehicle as safe for further dismantling and processing.

The hazardous voltage battery assembly will then be properly stored for future sale as a recycled original equipment component or for proper recycling. It is recommended that quantities of batteries be stored in a separate area, if possible segregated in a separate building or protected outdoor structure, that is easily identifiable and accessible in the event of an emergency. Store away from other combustible materials whenever possible.

Batteries must be properly stored, away from moisture, away from direct sunlight and in a clearly marked and controlled area. Nickel-metal hydride (NiMH) and Lithium-ion (Li-ion) batteries must be separated in the storage area. Batteries can be stacked no more than two high and must be separated by a non-conductive layer such as wood or rubber sheeting. Follow the specific storage instructions for each type of battery (see Automotive Recyclers Association

University and reference the Electric and Hybrid Vehicle Technology Guide). The storage must also be done in accordance with the local fire code.

The vehicle (absent its high voltage battery(s)) is now ready for dismantling, storage, and end of life processing once the other normal depollution of the vehicle has taken place. Following this protocol, and the normal processes that are inherent to a Certified Auto Recycler, will lead to a safe process that is good for the environment, and the circular economy of the vehicle and its components. Every vehicle is an opportunity to find great parts for reuse and if not sold for reuse, recycling.

When transporting with forklifts or dismantling the vehicle, please be aware of all specially colored hazardous voltage wiring (usually orange) and components. Orange cabling means that it contains hazardous voltage. As an additional reminder, inverters and other hazardous voltage components that have been damaged in an accident or flood should be treated with caution, pending inspection by a trained specialist. The electric motor can produce energy if the drive wheels are rotated, so be mindful if moving vehicles in a manner that could result in wheel turn. Once the battery has been removed, the hazardous voltage energy is in the battery, and not with the vehicle, but caution must always be observed.

2.5 Safe Transportation of EV/HEV batteries

HEV/EV batteries must be transported as “dangerous goods” when shipped on ground transportation or shipping carriers. If the proper procedures have been followed, the complete battery assembly, sealed in its factory housing, with the safety interlock plug removed, can be transported safely. Safe Transportation of High Voltage batteries or cells include being packed in such a manner as to prevent short circuits, including movement which could lead to short circuits. Once the connectors or leads are protected to prevent short circuit, the battery or cell should be wrapped with adequate dunnage to prevent movement or damage and secured or strapped to a non-conductive shipping container such as a wooden pallet or crate or other strong outer packaging conforming to general packaging requirements. Batteries must be secured to prevent inadvertent movement, and the terminals may not support the weight of other superimposed elements. Batteries that are damaged in an accident, causing the leaking of fluids or exposure of the conductors, must be handled in a very specific manor and will require special best management practices and requirements.

2.6 Selling and disposal

Every vehicle is full of opportunities to harvest good parts for reuse, saving consumers budgets and contributing to the sustainability goals for our planet. Along with reuse, recycling of the non-useable parts is paramount, with so many precious commodities used in the manufacturing of these vehicles. The high voltage battery and the special high voltage components are of particular focus. The most effective use of electric vehicle batteries is reuse. Reuse is the purest form of recycling saving money and precious resources. High voltage batteries and other hazardous voltage components can be safely reused if the HVVDP protocols are followed. Another use for these components will be repurposing for other solutions. There are developing markets for people to use the hazardous voltage components in other environmentally sustainable solutions, outside of automotive use. There are also developing markets for

remanufacturers that need the hazardous voltage batteries as components, or the reusable resources found within them. The markets to properly dispose of the unneeded and damaged batteries are rapidly developing and a certified HVV dismantler must assure that all batteries sold or processed for recycling are delivered through proper shipping channels to be processed by an EPA R2 certified facility that will provide a traceable end of life use of the battery and or its components in a documented environmentally correct method.

3. Other Resources

Automotive Recyclers Association's High Voltage Vehicle Dismantling Protocol for a Certified Auto Recycler. This protocol contains information on High Voltage awareness and protocols for safe and environmentally conscious Electric and Hybrid Vehicle processing and dismantling.

Hybrid and electric vehicle emergency field guide. This one-stop guide covers the vital aspects of electric, hybrid, fuel cell, and gaseous fuel hazard awareness and procedures -- including information from related NFPA codes, OEMs and new consistent Moditech Rescue Solutions® vehicle diagrams. https://catalog.nfpa.org/Emergency-Field-Guide-P13872.aspx

SAE International (2012) Surface vehicle recommended practice J2990, Hybrid and EV first and second responder recommended practice, Society of Automotive Engineers. Aims to describe the potential consequences associated with hazards from EVs and suggest common procedures to help protect emergency responders, tow and/or recovery, storage, repair, and salvage personnel after an incident has occurred with an electrified vehicle. Industry design standards and tools were studied and where appropriate, suggested for responsible organizations to implement. https://www.sae.org/standards/content/j2990_201907

NFPA Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results, July 2013. The overall goal of this project is to conduct a research program to develop the technical basis for best practices for emergency response procedures for electric drive vehicle battery incidents, with consideration for certain details including: suppression methods and agents; personal protective equipment (PPE); and clean-up/overhaul operations. https://www.nfpa.org/News-and-Research/Data-research-and-tools/Electrical/Emergency-Response-to-Incident-Involving-Electric-Vehicle-Battery-Hazards

Electrical Safety Practices Developed for Automotive Lithium-Ion Battery Dismantlement, ORNL/TM-2019/1366. ORNL is developing electrical safety practices for handling and disassembling automotive lithium-ion batteries in a research environment. Online literature searches did not reveal any standard electrical safety practices for disassembling lithium ion battery stacks from automobiles. https://info.ornl.gov/sites/publications/Files/Pub133363.pdf