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NATIONAL STANDARD

STANDARD FOR SAFETY

ANSI/CAN/UL 1974, Evaluation for Repurposing Batteries

ANSI/UL 1974-2018

Standards Council of Canada
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SCC FOREWORD

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UL Standard for Safety for Evaluation for Repurposing Batteries, UL 1974

First Edition, Dated October 25, 2018

Summary of Topics

The First Edition of UL 1974 has been issued to reflect the latest ANSI and SCC approval dates, and to incorporate the proposals dated March 30, 2018 and August 17, 2018.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated March 30, 2018 and August 17, 2018.

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Approved American National Standard

ANSI

ANSI/UL 1974-2018

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OCTOBER 25, 2018

UL 1974

Standard for Evaluation for Repurposing Batteries

First Edition

October 25, 2018

This ANSI/CAN/UL Safety Standard consists of the First Edition.

The most recent designation of ANSI/UL 1974 as an American National Standard (ANSI) occurred on October 25, 2018. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on October 25, 2018.

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Preface (UL)

This is the First Edition of the ANSI/CAN/UL 1974 Standard for Safety for Evaluation for Repurposing Batteries.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 1974 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

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This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Repurposing Batteries, STP 1974.

This list represents the STP 1974 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE.

INTRODUCTION

1 Scope

1.1 This standard covers the sorting and grading process of battery packs, modules and cells and electrochemical capacitors that were originally configured and used for other purposes, such as electric vehicle propulsion, and that are intended for a repurposed use application, such as for use in energy storage systems and other applications for battery packs, modules, cells and electrochemical capacitors.

1.2 This standard also covers application specific requirements for repurposed battery packs/systems and battery packs/systems utilizing repurposed modules, cells and other components.

1.3 This standard does not cover the process for remanufactured batteries, which are also referred to as refurbished or rebuilt batteries.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this Standard shall comply with the requirements for that component. Section 5 includes CSA, UL, and ULC components standards that may be used in the products covered by this Standard.

2.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this Standard; or

b) Is superseded by a requirement in this Standard.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Undated References

4.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance with this standard. It is intended that the application and use of repurposed batteries covered by this standard in an end product shall conform to the applicable installation codes and standards as appropriate for the country or countries where the repurposed battery is to be used.

CSA Standards

C22.1, *Canadian Electrical Code, Part I Safety Standard for Electrical Installations*

CAN/CSA C22.2 No. 0, *General Requirements – Canadian Electrical Code, Part II*

CAN/CSA-E62133, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications*

IEC Standards

IEC 61982-4, *Secondary Batteries (Except Lithium) for the Propulsion of Electric Road Vehicles – Part 4: Safety Requirements of Nickel-Metal Hydride Cells and Modules*

IEC 62133-1, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made from Them, for Use in Portable Applications – Part 1: Nickel Systems*

IEC 62133-2, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made from Them, for Use in Portable Applications – Part 2: Lithium Systems*

IEC 62619, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Secondary Lithium Cells and Batteries, for Use in Industrial Applications*

IEC 62660-3, *Secondary Lithium-Ion Cells for the Propulsion of Electric Road Vehicles – Part 3: Safety Requirements*

IEEE Standards

IEEE 1625, *Rechargeable Batteries for Multi-Cell Mobile Computing Devices*

IEEE 1725, *Rechargeable Batteries for Cellular Telephones*

SAE Standards

SAE J2464, *Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing*

SAE J2950, *Recommended Practices (RP) for Shipping Transport and Handling of Automotive-Type Battery System – Lithium Ion*

UL Standards

UL 810A, *Electrochemical Capacitors*

UL 1642, *Lithium Batteries*

UL 1973, *Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications*

UL 2054, *Household and Commercial Batteries*

UL 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications*

UL 2580, *Batteries for Use in Electric Vehicles*

UL 62133, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications*

ULC Standards

CAN/ULC 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications*

CAN/ULC-S2580, *Batteries for Use in Electric Vehicles*

6 Glossary

6.1 For the purpose of this standard the following definitions apply.

6.2 BATTERY – A general term for either a single cell or a group of cells connected together either in a series and/or parallel configuration.

6.3 BATTERY MANAGEMENT SYSTEM (BMS) – The electrical, electronic and software monitoring and control system of a battery that is often relied upon to maintain the battery and its component cells within their specified operating region for charge and discharge, and may be source of memory of the battery operation throughout its life.

6.4 BATTERY PACK – Assemblies of batteries that contain one or more cells/modules that are ready for use, contained in a protective enclosure, which may or may not contain protective devices, cooling systems and monitoring circuitry.

6.5 BATTERY SYSTEM – An assembly that is ready for use and consists of the battery pack and BMS and other monitoring circuitry and controls and that provides electric energy for applications such as an electric vehicle. This assembly can include thermal management and safety systems. Some battery systems may include electrochemical capacitors.

6.6 CALENDAR EXPIRATION DATE – Years or months designated by the original manufacturer to guarantee the performance of the cell, module, and/or battery pack/system. This may also be known as expiration date for usage. Sometimes referred to a ″duration of life″.

6.7 CELL – The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, separators, container, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

6.8 DUT – Device under test.

6.9 ELECTROCHEMICAL CAPACITOR – An electric energy storage device where electrical charge is typically stored as a result of non-Faradaic reactions at the electrodes. The unique porous surface of the electrodes increases the surface area for holding charge resulting in much larger capacitance and energy density. Some other common names for an electrochemical capacitor are ″double layer capacitor″, ″ultra capacitor″, ″electrochemical double layer capacitor″ and ″super capacitor″.

6.10 GRADING – A process performed by the repurposing manufacturer of evaluating battery packs, modules and cells against metrics to determine if they may be directly reused or can be sorted into respective groups for repurposing based upon determined state of health and remaining usable energy as determined in the process associated with the repurposing of the subject items.

6.11 HIGH (HAZARDOUS) VOLTAGE –

In the United States, voltage exceeding 30 Vrms/42.4 Vac peak or 60 Vdc is considered hazardous.

In Canada (per C22.1 and CAN/CSA-C22.2 No. 0) voltage exceeding 30 Vrms/42.4 Vac peak or 42.4 Vdc is considered hazardous unless indicated otherwise in the intended end use application standard noted in Table 7.1.

6.12 INSULATION, ELECTRICAL – Materials or other means including distances through air (i.e. clearances) or over surfaces (i.e. creepage distances) used to prevent electrical conduction.

6.13 INSULATION LEVELS – The following are levels of electrical insulation:

a) BASIC INSULATION – Insulation to provide basic protection against electric shock.

b) DOUBLE INSULATION – Insulation comprising both basic insulation and supplementary insulation.

c) FUNCTIONAL INSULATION – Insulation that is necessary only for the correct functioning of the equipment. Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

d) REINFORCED INSULATION – Single insulation system that provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard. The term ″insulation system″ does not imply that the insulation has to be in one homogeneous piece. It may comprise several layers that cannot be tested as basic insulation and supplementary insulation.

e) SUPPLEMENTARY INSULATION – Independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

6.14 MANUFACTURER – The organization responsible for the original manufacturing of the battery or the specified components such as the component cells and BMS, sometimes referred to as the original equipment manufacturer (OEM).

6.15 MANUFACTURER, REPURPOSING – The organization responsible for the used battery repurposing process.

6.16 MODULE – A subassembly consisting of a group of cells or electrochemical capacitors connected together either in a series and/or parallel configuration (sometimes referred to as a block) with or without battery monitoring unit.

6.17 RECYCLE – The recapture of materials for reuse from a product that has reached its end of life and has been disposed of.

6.18 REMANUFACTURED BATTERY – A battery pack/system that was used in the field and returned for repair and/or replacement of parts for use in the same intended application. Other terms used for a remanufactured battery are ″refurbished battery″ or ″rebuilt battery″.

6.19 REPURPOSED BATTERY – A battery pack/system that was used in one application in the field that is subject to some level of analysis and reconfiguration for use in a different application. An example of a repurposed battery is a stationary energy storage battery that has been built using used electric vehicle batteries, modules or cells. Another term for a repurposed battery is ″second life battery″.

6.20 ROOM AMBIENT – The room ambient temperature controlled by the repurposing manufacturer for the battery sorting and grading process, typically T_R ±2°C (±3.6°F), where T_R is a value between 20°C and 25°C.

6.21 SAMPLE, FRESH – The new sample produced by the OEM, typically not more than 6 months old.

6.22 SORTING AND GRADING PROCESS – A determination of the state of health and other parameters of the subject to identify continued viability and the rating mechanisms the repurposing manufacturer may use for those that are determined suitable for continued use.

6.23 STATE OF CHARGE (SOC) – The available capacity in a battery system, battery pack, module or cell expressed as a percentage of rated capacity in terms of both coulombic capacity (Ah) and/or energy capacity (Wh).

6.24 STATE OF HEALTH (SOH) – A quantification of condition of the battery and the level of expected performance for reuse, and the amount of usable energy capacity in a battery and its anticipated useful cycle life determined through various diagnostic measurements, which can include usable energy decay, increase in internal resistance, etc.

CONSTRUCTION

7 General

7.1 The used components of the battery systems should not to be considered for repurposing if they have already been used longer than the calendar expiration date specified by the original manufacturer. The repurposing manufacturer should confirm the designated calendar expiration date of the components for repurposing.

7.2 The construction of a battery for the purpose of sorting and grading associated with its repurposing shall be based on its suitability for its intended end use application. Guidance on required battery construction can be found in the standards referenced in Table 7.1.

Table 7.1
Applicable standard requirements

End Use application	Standard
Batteries For Use In Light Electric Vehicle (LEV) Applications	UL 2271 / CAN/ULC 2271
Batteries For Use In Electric Vehicles	UL 2580 / CAN/ULC-S2580
Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications (The scope of UL 1973 includes batteries for use as auxiliary power in recreational vehicles and for temporary energy storage system applications that are mobile, but used as stationary energy storage.)	UL 1973

7.3 The repurposing manufacturer shall set up the requirement documents for the key construction and materials related to safety in order to comply with the end application standard. During the redesign and reassembly of the repurposed batteries, these requirement documents shall be followed.

8 Materials

8.1 Materials employed in the battery shall be suitable for the intended application. Non-metallic materials utilized as enclosures, casings and electrical or thermal insulation shall have temperature, flammability, and electrical or other material properties sufficient for their utilization in the battery and the battery's intended use. Metallic materials shall be corrosion resistant and if used for current carrying parts, consist of metals acceptable for that purpose.

8.2 Guidance on suitable material choices for the intended battery application may be found in the standards outlined in Table 7.1.

9 Enclosures

9.1 The suitability of a battery enclosure is dependent upon the end use design and application. The enclosure may serve as a protective casing of a component battery intended to be installed into equipment, where it will be protected by the equipment enclosure or it may serve as all or part of the equipment enclosure. If the battery enclosure serves as all or part of an end use application enclosure, the type of application (e.g. whether the product is a portable, a vehicle or a stationary application, etc.) will also determine the requirements for that enclosure.

9.2 When evaluating the enclosure construction, consideration shall be given to the materials employed as outlined in Section 8, the robustness of the enclosure to prevent mechanical abuse to the contents of the enclosure, the methods of securement of the enclosure parts, and the size and location of openings in the enclosure to ensure the ventilation or thermal management of the battery and to prevent access to hazardous parts of the battery and to prevent ingress of debris and moisture into the enclosure.

9.3 Guidance of requirement and evaluation of the battery enclosure for the intended application may be found in the standards outlined in Table 7.1.

10 Wiring and Connections

10.1 Wiring shall be reliably secured to prevent inadvertent shorting and reduction of spacings. The wiring shall be provided with insulation sufficient for the voltage levels and environmental exposure. Refer to the battery standards of Table 7.1 for wiring criteria for specific end use applications.

11 Electrical Spacings and Insulation Levels

11.1 There are several different levels of insulation that may be provided in a battery depending upon the voltage. These levels include functional insulation, basic insulation, double insulation (consisting of basic and supplementary insulation) and reinforced insulation. See 6.13 for definitions of the insulation levels.

11.2 Batteries with hazardous voltage circuits shall be provided with at least two levels of protection between hazardous voltage circuits and accessible conductive parts consisting of one of the following:

a) Basic insulation plus protective grounding;

b) Double insulation; or

c) A single layer of reinforced insulation determined equivalent to double insulation.

11.3 Electrical spacings through air, referred to in some standards as clearances, and over surface, referred to in some standards as creepage distances, shall comply with the requirements outlined in the applicable battery standards of Table 7.1.

12 Controls

12.1 BMS and other protection controls that are intended to be used in the repurposed battery shall be evaluated to ascertain their ability to serve their intended purpose. Any reliability analysis of the BMS and other battery control system relied upon for safety, shall comply with the requirements of the applicable battery standards of Table 7.1. A check of the BMS functionality shall be part of the repurposing production testing on all production battery systems with the BMS included for repurposing, in accordance with 19.6.

13 Coolant and Other Critical Systems

13.1 Other systems of the battery such as thermal management systems shall be evaluated to determine that they are functioning and can remain if intended to be used in a repurposed battery. Systems relied upon for the safe operation of the repurposed battery shall meet the criteria of the intended end use application standard. Refer to the battery standards of Table 7.1.

14 Cells and Electrochemical Capacitors

14.1 Cells and electrochemical capacitors intended for repurposing shall have been determined to comply with appropriate safety test requirements outlined in Table 14.1, or other cell or capacitor safety evaluation if determined to provide an equivalent level of safety, as required in its end application standards.

Table 14.1
Cell safety criteria

Chemistry	Safety Test Requirements[a)]
Lithium ion	UL 2580/CAN/ULC-S2580, UL 2271/CAN/ULC 2271, UL 1973, UL 1642, UL 62133/CAN/CSA-E62133, IEC 62133-2, IEC 62619, IEC 62660-3
Chemistries other than lithium ion	UL 2580/CAN/ULC-S2580, UL 2271/CAN/ULC 2271, UL 1973, UL 2054, UL 62133/CAN/CSA-E62133, IEC 61982-4, IEC 62133-1
Electrochemical capacitors	UL 2580/CAN/ULC-S2580, UL 2271/CAN/ULC 2271, UL 1973, UL 810A

[a)] Other safety test requirements may be applied if determined equivalent.

14.2 Compliance is determined through review of documentation that the cell or capacitor design had complied with a safety testing program suitable for the technology when initially manufactured. If proof of compliance is not available then compliance shall be determined through the tests outlined in one of the appropriate referenced standards in Table 14.1. Testing may be conducted at the module level for repurposed uses, if the cells or capacitors cannot be easily disassembled from the module.

14.3 Cells assembled into repurposed batteries shall be of same model from a same manufacturer.

QUALITY CONTROL AND SAFETY OF FACILITIES FOR REPURPOSING

15 Quality Control

15.1 The repurposing manufacturer shall have sufficient knowledge of the characteristics and handling of cells, modules, battery packs/systems and/or BMS to perform sorting and grading for repurposing, and shall have documented production process controls in place. These controls shall continually monitor and record the following key elements of the repurposing manufacturing process that can affect safety, and shall include measured parametric limits enabling corrective/preventative action to address defects (out of limit parameters) found affecting these key elements:

a) Control of incoming parts including used batteries;

b) Control of repurposing processes and data gathering; and

c) Control of rejected parts.

15.2 The facilities used for repurposing shall provide a controlled environment for storage, handling and testing the batteries, in accordance with the repurposing manufacturer's specifications. Test equipment used for evaluation of the batteries shall be:

a) Suitable for the testing;

b) Maintained in accordance with the test equipment specifications; and

c) Calibrated on a routine basis, in accordance with the repurposing manufacturer's quality control procedures.

16 Safety of Facilities for Repurposing

16.1 Batteries such as lithium ion batteries are considered hazardous materials and handling and testing of batteries shall be done with care. Repurposing manufacturers shall have operating procedures in place for the safe handling, storage, testing, shipping and disposal of batteries and parts associated with repurposing.

16.2 Facilities utilized for the repurposing of batteries including their storage, processing and testing, shall be in accordance with local fire and building codes.

EXAMINATION OF INCOMING SAMPLES

17 General

17.1 As part of the repurposing sorting procedure, a visual examination shall be made of the battery and an assessment of the manner in which it was tested as part of the manufacturing process shall be conducted. If available a review of the battery's previous use shall also be conducted.

17.2 Care when handling and storing batteries, especially large battery samples such as EV batteries, should be practiced at all times. Storage of batteries shall be in accordance with repurposing manufacturer's procedures and also in accordance with local fire and building codes with regard to hazardous materials storage. When transporting batteries, including used EV batteries, transport regulations should be followed. Guidance on the safe handling and transport of EV batteries can be found in SAE J2950.

18 Procedures for Examination and Sorting of Used Batteries and Their Components

18.1 General

18.1.1 Documentation and information related to the battery pack/system to be repurposed such as markings, instructions, history of previous use including electronic data stored, and involvement in any incidents that would affect its safety or performance, and other information shall be reviewed by the repurposing manufacturer to assist in understanding the overall construction of the battery, how the battery was intended to be used, information on components that are critical to the safe operation and use of the battery and to assist in establishing the overall state of health of the battery.

18.2 Information gathering and review as part of the initial sorting procedures

18.2.1 Battery

18.2.1.1 Information (such as labels, specifications, maintenance history, records of any safety related incidents) available on the battery shall be gathered and reviewed by the repurposing manufacturer for an understanding of the battery to be used for repurposing. Documentation useful for determining the state of health and for a better understanding of the overall battery design and history includes the following:

a) Battery markings: Battery nameplate for ratings, and other markings, including date of manufacturer, warning labels, symbols and instructions;

b) Battery schematics;

c) Battery specifications, instructions including information on the battery chemistry, and other available literature on the battery including commissioning, recommissioning, charging, discharging, storage, service/handling/ operational procedure manuals, electric vehicle first responder manuals, etc.;

d) Battery construction and configuration, weight, dimensions, contents of battery, schematics and configuration of modules and other parts in battery;

e) Information on the battery system components such as cooling system (including coolant if applicable), isolation monitoring system, high voltage bus, insulation and support materials, etc.;

f) Reason for the battery being taken out of service, date of removal from service and information on storage and handling history before repurposing procedures;

g) If available, information on the BMS should be gathered including BMS specifications, algorithms for charging and discharging, BMS manufacturer, part number, date of manufacturer, etc.;

h) If available, the storage condition after the battery has been taken from the previous end application and the latest operational data available from the BMS before the battery was taken from the previous end application; and

i) If available, the records of the battery fault/breakdown/abnormal conditions and maintenance in the previous end application.

18.2.2 Modules

18.2.2.1 Information available on the battery modules shall be gathered for review by the repurposing manufacturer for a better understanding of the design of the battery. The following information shall be gathered:

a) Module markings, ratings, manufacturer and part number as well as date of manufacturer and any other markings on the modules;

b) Module specifications, instructions and other available literature including installation information of module, charging and discharging parameters; and

c) Module configuration and construction, including contents of module, schematics and configuration of cells, weight, and dimensions.

18.2.3 Cells

18.2.3.1 Information available on the cells used in the battery shall be gathered and reviewed by the repurposing manufacturer for a better understanding of the battery design, and state of health of the cells. This information shall include:

a) Date of manufacture of the cells;

b) Chemistry of the cells, weight, dimensions, and overall design of the cells if available, etc.;

c) Manufacturer and part number of the cells, along with other markings on cells;

d) The cell specification sheet indicating ratings for nominal voltage and capacity of cells at start of life, discharging, charging, storage and other specifications of the cells shall be provided;

e) If available, the safety test data/information on safety tests conducted on the cells gathered for review; and

f) Calendar expiration date.

18.2.3.2 The cell construction shall be reviewed according to the repurposing manufacturer's procedure for an understanding of the internal construction of the cells. If drawings and information from the cell manufacturer are not available, a disassembly of a representative discharged cell(s) from a battery intended for repurposing, shall be conducted to review the internal construction including electrode assembly, placement of insulation, separator coverage, center tube (if present in the battery design), vent or other means to relieve pressure, internal protective devices, tab construction and placement, etc. See IEEE 1625 or IEEE 1725 for guidance on cell construction items to review. The construction information shall be gathered and can assist with the cell data analysis of 19.9.

18.2.4 BMS and auxiliary systems

18.2.4.1 Information on the BMS and other auxiliary systems, such as the cooling system used in the battery that are intended to be repurposed, shall be gathered and reviewed for a better understanding of the battery design, state of health, and suitability for repurposing. The information to be gathered and reviewed may include:

a) For BMS:

1) Date of manufacture, part number and manufacturer and BMS specifications with regard to current, voltage and temperature protections and correlated trip delay time;

2) Communication protocols, CANBUS message schemes, variables, etc.;

3) BMS software version update related to battery safety during service; and

4) Schematics, board layout, algorithms, markings and any literature pertaining to use, installation, operation, programming and maintenance of the BMS.

b) For cooling systems:

1) Manufacturer, part number and specifications with regard to temperature and controls, system flow rate, and incoming and outgoing temperatures;

2) Coolant material/fluid and parts list of cooling system; and

3) Information on installation, trouble shooting, operating, maintenance, etc.

c) For other systems:

1) Manufacturer, part number and specifications (e.g. electrical ratings, physical dimensions, use parameters, etc.); and

2) Information on installation, trouble shooting, operating, maintenance, etc.

18.3 Initial and subsequent rejection procedures

18.3.1 A review of available information on the battery use, safety related incidents or repairs shall be conducted to determine the reason(s) for the battery to be taken out of service from its first use application. Batteries taken out of service due to certain known exposure circumstances that could affect their safe operation and use shall not be considered for repurposing in accordance with the repurposing manufacturer's procedures. These circumstances may include, but are not limited to, severe environmental exposures and abuses such as vehicle crash which is likely to have affected the battery, vehicle flooding, and exposure to fire. The repurposing manufacturer shall identify for their processes, those exposure situations where a battery may not be considered for repurposing.

18.3.2 In addition to exposure criteria for rejection, the repurposing manufacturer shall identify performance issues, physical, and other signs of damage to or problems with the batteries or other parts to be repurposed that would be cause for rejection during the initial and subsequent sorting and grading process for repurposing.

18.3.3 Batteries and other parts intended to be rejected for re-use, shall be disposed of according to repurposing manufacturer's procedures as identified in Section 21. Batteries and parts identified as not suitable for repurposing shall not be reintroduced into the sorting and grading process.

18.3.4 The samples that are not rejected shall be assigned tracking numbers and shall then be subjected to subsequent sorting and grading procedures.

18.4 Visual inspection of incoming samples

18.4.1 A visual inspection of the incoming sample such as the overall battery and its auxiliary systems shall be conducted before disassembly. Visible signs of damage such as cracks, swelling, notable odor, discoloration, or burn marks, shall be noted and documented. Visible damage that is identified shall be reviewed with the repurposing manufacturer's procedures for rejection to determine if it is necessary to reject all or some portions of the assembly as a result of visible signs of damage.

18.5 Gathering and analysis of BMS data

18.5.1 An important means for obtaining information on the state of health of the battery, modules and cells is through accessing the stored data from the battery BMS. See Appendix A for information that may be gathered from the BMS that would be useful in determining the health of the battery for repurposing. Minimally, the level of information that should be retrieved from the BMS for sorting and grading of the battery, modules, cells and other components monitored by the BMS that are intended for repurposing shall include:

a) The average and extreme values of voltage, current, temperature, and SOC;

b) The out of specification values for voltage, current and temperature;

c) The total times or numbers at extreme values and out of specification values for voltage, current and temperature;

d) The total charge and discharge throughput over the lifetime;

e) The total times or numbers under charge and under discharge over the lifetime;

f) The number or type of error messages; and

g) The number of times contactor operated.

Exception: In some cases, BMS data may not be available for analysis. For this situation, a process for conducting an in-depth analysis of the incoming samples is required including a procedure for determining the health of the cells and other parts of the system without the aid of BMS data through testing of samples and documentation provided on the cells and comparison with data from fresh samples or specifications for the cells.

18.5.2 If any out of specification limits for voltage, current and temperature are not a signal for immediate rejection of the battery for repurposing, the maximum value of the parameter and length of exposure time to these out of specification limits shall be retrieved from the BMS if available. A determination must then be made as to effect on the cells for repurposing. If the length of exposure to out of specification limits is not available from the BMS, the battery and/or the damaged module or cell, shall be rejected for repurposing unless it can be established through testing that the cells have sufficient health for repurposing.

18.5.3 If the number of error messages from the BMS or number of times the contactor operates is outside of specified limits, this shall be an indication for rejection of the battery for repurposing due to faulty BMS information and/or potential battery exposure to hazardous conditions unless it can be established through testing that the cells have sufficient health for repurposing.

18.6 Disassembly and examination

18.6.1 The procedure for evaluating batteries for repurposing shall include a visual examination of the battery pack/system and its components and parts to determine that there is no visible evidence of damage. Any signs of visible damage determined during this examination shall be considered sufficient reason for rejection of the damaged component, unless the damage is minor and it can be determined through testing that the damage does not impact the safety of the batteries and parts for repurposing. Examples of signs of damage that can be considered grounds for rejection can include, but are not limited to the following:

a) Swelling of cells or modules, vented cells, electrolyte leakage, bent/damaged casings and terminals, traces of burning or other damage;

b) Frayed, damaged wiring, damaged/discolored insulation, damaged HV bus, isolation system damage, examination of PCBs for damage;

c) Bent or damaged casings and enclosure or support structures, loose connections and parts; or

d) Damage of thermal management systems such as leaking coolant systems, blockage of fans or other locking or overloading of rotating parts.

18.6.2 After overall nondestructive examination of the battery packs/systems and its parts and any testing in accordance with Section 19 that needs to be conducted on the assembled battery pack/system prior to disassembly, the pack shall be disassembled into its anticipated smallest usable part for repurposing. This can be minor disassembly of auxiliary or other parts with the pack remaining in its original configuration, to disassembly into modules or even individual cells.

18.6.3 The procedures for safely disassembling the battery pack including the need for any initial discharging shall be conducted according to the repurposing manufacturer procedures. Individual separated parts taken from the battery pack shall be tagged with a tracking number and documented in a process log. Discarded parts shall be removed from further processing and disposed of in accordance with 18.3 and Section 21.

18.7 Storage condition tracking

18.7.1 Batteries that are intended for repurposing in accordance with this standard shall have the ambient temperature and humidity conditions associated with their storage before repurposing monitored and recorded on minimum a daily basis by the repurposing manufacturer.

18.7.2 Any charging or discharging conducted as part of the storage procedures shall be measured and recorded by the repurposing manufacturer.

18.7.3 The open circuit voltage (OCV) of the part(s) under storage after the sorting and grading procedure shall be documented at the initial and final stage of storage of the processed parts by the repurposing manufacturer. Any sorted parts that are found to have a self-discharge rate outside of the repurposing manufacturer's established acceptable limits, shall be discarded according to procedures outlined in Section 21.

18.8 Grading of batteries for repurposing

18.8.1 The repurposing manufacturer shall have a system for grading cells, modules and battery packs/systems for repurposing. This is to ensure that assemblies using repurposed cells and modules disassembled from previously used battery packs employ a combination of used cells, modules and battery packs that are balanced and appropriately matched to prevent performance and safety problems in the final assembly.

18.8.2 Cells and modules that have been disassembled from a battery pack and battery packs that have been found suitable for repurposing through evaluation and testing shall be graded in a manner to ensure they are assembled with cells, modules and battery packs that are equivalent with regard to remaining usable energy and state of health.

18.8.3 The repurposing manufacturer shall have a defined criterion for the grading of the batteries. It is recommended that the repurposing manufacturer use a 6 sigma limit or narrower from the new battery specification values as a criterion for properties, such as OCV, capacity, internal resistance, mass, dimensions, etc. For example, batteries that fall within a 6 specified sigma range for each property can be placed in a particular grade associated with that sigma limit.

18.8.4 As part of the grading system, batteries shall be identified and documented by the repurposing manufacturer with regard to their assigned grade upon completion of the evaluation including testing, and sorted into their specified grades prior to being re-assembled into a module or battery assembly.

PERFORMANCE

19 Testing for the Sorting and Grading Process

19.1 General

19.1.1 In addition to the inspection for damage outlined in 18.4, the following test procedures shall be conducted by the repurposing manufacturer as part of the routine analysis of the incoming battery assembly:

a) Incoming open circuit voltage (OCV) measurements (19.2);

b) Incoming high voltage isolation check (19.3);

c) Capacity check (19.4);

d) Internal resistance check (19.5);

e) Check of BMS controls and protection components (19.6);

f) Discharge/charge cycle test (monitoring of temperature, voltage and current of cells and modules) (19.7); and

g) Self-discharge (19.8).

19.1.2 In conducting these tests, when the original specification is referenced, it applies to the specification of the batteries as reported by the original manufacturer of the item.

19.1.3 The test procedures in 19.4, 19.5, 19.7, and 19.8 shall be conducted on the whole battery pack/system and also on its smallest intended disassembled unit for repurposing. For example if the smallest disassembled unit is a module, the testing is done on the whole battery pack/system and also on the modules intended for repurposing. If the smallest disassembled unit is a cell, the testing is done on the whole battery pack/system and also on the cells intended for repurposing.

19.1.4 If the repurposing manufacturer only intends to repurpose a module or cell, the only testing required on the battery pack/system is the incoming OCV (19.2) and the incoming high voltage isolation check (19.3) tests. The tests of 19.4 through 19.8 can be waived on the battery pack/system if the battery pack/system will not be repurposed and only the disassembled modules and cells are being repurposed.

19.1.5 All data obtained during the testing noted above is to be documented and compared with specified values to determine if they fall within the acceptable levels for the parameters. DUTs that fall within the acceptable levels are further grouped according to tolerance range per 18.8.

19.1.6 Batteries and/or parts falling outside of specific limits for testing shall be rejected in accordance with repurposing procedures of 18.3 and Section 21.

19.1.7 The parts measured (i.e. battery pack/system, modules and cells) shall be assigned tracking numbers for tracking purposes during the process.

19.2 Incoming open circuit voltage (OCV) measurements

19.2.1 The following OCV measurements shall be made on the battery and its components for determining its state of charge as needed for the various tests of this standard:

a) Battery Pack/System high voltage system OCV;

b) Module OCVs; and

c) Cell OCVs.

19.2.2 The sum of cell OCV voltage in the module shall be compared to the module OCV, the sum of module OCV voltage in the battery pack/system shall be compared to the battery pack/system OCV. The reason for any variation shall be determined and recorded. The misused cells should be identified for further determination through subsequent testing.

19.2.3 The measured OCVs shall be compared to the minimum voltage limit acceptable for the DUT specified by the repurposing manufacturer. Those cells and modules and battery packs/systems that have been found larger than or equal to the specified minimum voltage limit shall be subjected to other processing tests as required in this standard to determine acceptance. Those DUTs with OCV below the minimum voltage limit specified by the repurposing manufacturer shall be rejected and discarded in accordance with 18.3 and Section 21. All OCV measurements shall be documented with parts measured identified.

19.3 Incoming high voltage isolation check

19.3.1 The isolation of the battery high voltage system shall be checked to determine that there is no insulation breakdown in the battery. The insulation shall be checked as outlined in 19.3.2 – 19.3.4.

19.3.2 A battery with accessible parts shall be subjected to an insulation resistance test first between the positive terminal and accessible dead metal parts of the battery and second between the negative terminal and the accessible dead metal parts of the battery. If the accessible parts of the battery are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts.

19.3.3 The insulation resistance shall be measured after a minimum 60-s application with an insulation resistance measurement device using a 500 Vdc potential applied to the locations under test.

19.3.4 The measured insulation resistance between the positive/negative terminals and the accessible dead parts of the battery shall be at least 100 Ω/V for dc circuit and at least 500 Ω/V for ac and ac combined circuit or 50,000 Ω. If the modules and cells are intended to be repurposed even in a battery pack with low isolation resistance, special care shall be taken during disassembly of those battery packs/systems to identify the circuits with breakdown isolation. Batteries or battery circuits with values below these limits shall be rejected and discarded in accordance with 18.3 and Section 21. The repurposing manufacturer may be able to use individual cells or modules from a battery that has low insulation resistance if their process can demonstrate that these components have not been damaged and are suitable for repurposing.

19.3.5 All high voltage isolation check measures shall be documented and the battery identified.

19.4 Capacity check

19.4.1 The capacity check of the battery (cell, module or battery pack/system) shall be conducted according to the standard capacity test as specified by the repurposing manufacturer. If the standard capacity test method is not available, the capacity check test shall be conducted as follows in 19.4.2 – 19.4.4.

19.4.2 The cell, module or battery pack/system shall be charged in accordance with the repurposing manufacturer's specifications at room ambient temperature until it is fully charged. The DUT shall remain at rest in room ambient conditions at full state of charge for a period of 1 to 4 h.

19.4.3 At the conclusion of the rest period, the DUT shall be subjected to a constant current or constant power discharge at the repurposing manufacturer's standard discharge rate until it reaches the end of discharge condition. The delivered coulombic capacity and/or energy capacity to specified end of discharge condition shall be recorded.

19.4.4 The capacity of the aged DUT shall be calculated using the measured values for current and time and documented. This measured value obtained for capacity shall be compared with the repurposing manufacturer's ratings or as-received data on the DUT's capacity. DUTs whose measured capacities show a drop greater than the repurposing manufactures specified limits for capacity shall be rejected and discarded in accordance with 18.3 and Section 21.

19.4.5 All capacity measurements shall be recorded with measured DUTs identified. Cells and modules that are not rejected shall be sorted according to available capacity into groups per 18.8.

19.5 Internal resistance check

19.5.1 An internal resistance check of the battery (battery pack, module or cells) shall be conducted. This test shall follow the capacity check test of 19.4. The test shall be conducted in accordance to the standard resistance test as specified by the repurposing manufacturer. If the standard resistance test is not available, the test shall be conducted as follows in 19.5.2 – 19.5.7. If a complete battery pack is intended for repurposing, there shall be additional resistance checks at the module level (or cell level if the battery does not contain modules) at locations where cells may be subjected to the most severe thermal conditions during use due to their location within the battery pack.

19.5.2 The DUT shall be charged per the repurposing manufacturer's specifications in room ambient conditions until the DUT is in the fully charged condition. The sample shall then sit at fully charged condition at room ambient between 30 min to 4 h.

19.5.3 The DUT shall be discharged at a constant current rate I_1, specified by the repurposing manufacturer in room ambient temperatures for a duration of T_1 specified by repurposing manufacturer (typically a discharge time to reach capacity between 80% to 90% SOC), the discharge voltage V_1 under load shall be measured and recorded. The DUT is then immediately subjected to an additional constant current discharge at a rate of $I_2 = 5I_1$ for a duration of T_2 specified by repurposing manufacturer (in seconds, typically a discharge time between 1 s to 10 s). The corresponding discharge voltage V_2 of the DUT is measured under load and recorded at the end of pulse discharge. Voltage and current during the discharge should be recorded at a rate not less than $10/T_2$ sample per second.

19.5.4 The resistance shall be calculated using the following formula and compared with the specified value:

$$R = (V_1 - V_2)/(I_2 - I_1)\ (\Omega)$$

Where:

R is the dc resistance in ohms (Ω).

V_1 is the first voltage measurement in volts (V).

I_1 is the first discharge current rate in amps (A).

V_2 is the second voltage measurement in volts (V).

I_2 is the second discharge current rate in amps (A).

19.5.5 The internal resistance of the DUTs shall be determined using the method outlined in 19.5.4. DUTs with a measured internal DC resistance greater than the specified value by the repurposing manufacturer based on its intended repurposing application shall be rejected and discarded in accordance with 18.3 and Section 21.

19.5.6 All internal DC resistance measurements shall be recorded with measured DUTs identified. All internal resistances shall also be cataloged based on remaining capacity, previous duty cycle, and previous climate, if known, and historic data used for comparison against similar specimens.

19.5.7 The DUT shall be continuously discharged to 20% SOC in accordance with the method specified by the repurposing manufacturer and then allowed to rest at room ambient temperature between 30 min to 4 h. The internal resistance measurement shall then be repeated on samples that are at 20% SOC in accordance with 19.5.3 through 19.5.4.

19.5.8 DUTs that have not been rejected shall be subjected to further repurposing processes.

19.6 Check of BMS controls and protection components

19.6.1 If the BMS and any other protection components are to be utilized for repurposing, a check to ensure that they are functioning as anticipated shall be conducted on the battery.

19.6.2 A functionality check of the BMS and other protection components shall be conducted to determine that they are suitable for repurposing, the functionality check shall include both performance and safety parameters to ensure functionality of these parts.

19.6.3 When evaluating the BMS for functionality, a review of its data including error messages shall be obtained and reviewed to determine if the BMS can be utilized for repurposing. See Appendix A.

19.6.4 Components including the BMS that are located in high voltage circuits shall be evaluated for damage to insulation through inspection and if necessary dielectric withstand voltage testing. The voltage test value and method of testing shall be in accordance with the applicable end use application battery standard outlined in Table 7.1.

19.6.5 If the BMS or other controls are determined to be unsuitable for repurposing, they shall be rejected and discarded in accordance with 18.3 and Section 21.

19.7 Discharge/charge cycle test (monitoring of temperature, voltage and current of cells and modules)

19.7.1 The battery (battery pack/system, module or cells) shall be subjected to discharge/charge cycles while monitoring for temperature, voltage and current to ensure that component cells or modules are operating within the repurposing manufacturer's specifications.

19.7.2 The samples shall be discharged and charged for at least 1 cycle at room ambient temperature. If the minimum operating ambient temperature as specified by the repurposing manufacturer for the repurposed application is equal or lower than 0°C (32°F), the sample shall also be discharged and charged for at least 1 cycle at that minimum operating ambient temperature ±2°C (±3.6°F).

19.7.3 With the battery connected to a source of supply, it shall be charged in accordance with specifications, while monitoring temperatures, voltage and current on the individual cells or modules during charging, until the battery reaches its fully charged state. At the conclusion of the charge, the battery shall be discharged under maximum, normal loading conditions specified by the repurposing manufacturer based on the repurposed application while monitoring temperatures, voltage and current on the cells and modules.

19.7.4 Temperatures, voltages and current on the cells and modules measured shall be compared with specifications to determine if they fall within the specified limits. DUTs that have cells and modules outside of the limits for temperature, voltage and current specified by the repurposing manufacturer, shall be rejected and discarded in accordance with 18.3 and Section 21.

19.8 Self discharge

19.8.1 The modules and cells shall be evaluated for self-discharge in accordance with 19.8.2 as part of the determination of its state of health. Depending upon the level of disassembly for repurposing (i.e. cell, module or battery pack), the self-discharge shall be checked at the cell level and at the module level. For repurposing complete battery packs, all modules shall be checked and cells chosen for checking levels of self-discharge, shall be those cells in locations considered to be subject to worst case thermal conditions during their use.

19.8.2 The DUTs shall be charged to a fully charged state and then be stored in a controlled environment at room ambient for at least 1 day. The OCV of the fully charged DUT shall be recorded at 5 min, 1 h, and 24 h after charging and at the end of the storage period if longer than 24 h or a higher sampling rate specified by the repurposing manufacturer during the storage period. The OCV measured at each storage stage shall be compared with the acceptable limit for self-discharge as specified by the repurposing manufacturer.

19.8.3 Self discharge measurements shall be recorded with measured DUTs identified.

19.8.4 DUTs with self-discharge level greater than the specified value by the repurposing manufacturer should be rejected and discarded in accordance with 18.3 and Section 21. DUTs that have not been rejected shall be further processed.

19.9 Cell performance and safety characterization

19.9.1 The repurposing manufacturer shall have a program for long term data gathering on aged cell samples representative of samples for repurposing. For those module designs where the cells cannot be separated out to gather this data, this testing can be done at the module level. This data shall be used to better characterize used cells' performance and safety to inform the repurposing manufacturer's process improvements. Refer to Appendix C for additional guidance.

20 Testing of Assembled Repurposed Batteries

20.1 Assemblies using repurposed batteries shall comply with the application specific tests for those batteries. See Table 7.1 for a list of application specific battery standards that shall be used for test requirements.

20.2 Assemblies using repurposed batteries shall comply with the applicable tests in the transportation regulations before shipping.

20.3 Samples used for testing shall be representative of design intent with the worst case representative state of health for a given test (e.g. samples with highest level of energy may be worst case for certain tests), using actual repurposed cells/modules that have completed the repurposing process in accordance with Sections 17 – 19.

21 Disposal of Damaged and Rejected Parts Procedures

21.1 Any parts that are identified for rejection for repurposing including parts identified for disposal including rejected cells, modules and complete batteries shall be documented and then disposed in accordance with the repurposing manufacturer's process for disposal and local regulations. The process shall identify those parts intended for recycling as well.

21.2 The method for documentation and disposal of rejected parts is to prevent re-introduction of any parts back into the re-use process.

PACKING AND SHIPMENT

22 General

22.1 Batteries, module and cells evaluated for repurposing shall be provided with packaging for shipment in accordance with transport regulations and shall be secured within the packaging to prevent short circuiting or damage from anticipated shipping conditions.