SURFACE VEHICLE INFORMATION REPORT	J2974	APR2015
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Technical Information Report on Automotive Battery Recycling

RATIONALE

Battery Recycling is an integral part of the lifecycle management of vehicles. Currently there is a lack of recommended practices and standards for automotive battery recycling. Materials contained within batteries may be regulated as hazardous. Proper recycling will minimize/eliminate the need for disposal of spent batteries. Recycling can provide market stabilization by returning critical materials back into the manufacturing process and reducing dependence on primary sources.

This SAE Technical Information Report on Automotive Battery Recycling will provide a compilation of recycling methodologies and current practices for the automotive, battery and recycling industry. This will aide in determining recycling routes and methods available for new battery technologies.

1. SCOPE

This SAE Technical Information Report provides information on Automotive Battery Recycling. This document provides a compilation of current recycling definitions, technologies and flow sheets and their application to different battery chemistries.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

European Union Battery Directive 2006/66/EC of the European Parliament and of the Council of the 6 September 2006 on batteries and accumulators and repealing Directive 91/157/EEC

US EPA (2014) Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles (Report # EPA 744-R-12-001). Retrieved from http://www.epa.gov/dfe/pubs/projects/lbnp/final-li-ion-battery-lca-report.pdf

Sullivan, J.L. Gaines, L. (2010) A Review of Battery Life-Cycle Analysis: State of Knowledge and Critical Needs (ANL/ESD/10-7). Retrieved from http://www.transportation.anl.gov/pdfs/B/644.PDF

U.S. Life Cycle Inventory Database." (2012). National Renewable Energy Laboratory, 2012. Retrieved from https://www.lcacommons.gov/nrel/search

ECAR - Hybrid Vehicle Dismantling Guide v3, 2012. Retrieved from http://www.ecarcenter.org/

USABC - 2014 Recommended Practice for Recycling of xEV Electrochemical Energy Storage Systems (2014) Town Center Drive Suite 300, Southfield, MI 48075 Accessed June 24th, 2014: http://www.uscar.org/guest/teams/68/USABC-Battery-Recycling-Group

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

J2984 Identification of Transportation Battery Systems for Recycling Recommended Practice

J2950 Recommended Practices for shipping transport and handling of automotive type battery systems – Lithium Ion

J2936 SAE Electrical Energy Storage Device Labeling Recommended Practice

J2344 Guidelines for Electric Vehicle Safety

J1766 Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing

3. SAE J1715/2 - BATTERY TERMINOLOGY DEFINITIONS

3.1 TERMS

3.1.1 Rechargeable Energy Storage System (RESS) - Any energy storage system that has the capability to be charged and discharged. (Examples: batteries, capacitors, and electro-mechanical flywheels). SAE J1715/2

3.1.2 Hazardous Waste Disposal - Disposal of a battery at end of life in a regulated facility

3.1.3 Energy Recovery - Recovery of energy from materials contained within a product i.e. Waste to Energy

3.1.4 Recycling - Recovery of materials contained in the battery

3.1.5 Direct Recycling - Recycling of materials contained in the battery for functional reuse with minimal processing

3.1.6 Salvage - Removal and recovery of a battery(s) from vehicle

3.1.7 Collection - Gathering of batteries in a central location prior to shipment to a recycling facility

3.1.8 High Voltage - Above 60 DCV (SAE Doc. J2344) when high voltage PPE becomes required (ISO6469)

4. DOCUMENT CONTENT

4.1 Initial & Intermediate Transportation

For initial and intermediate transportation recommendations refer to SAE J2950 – Recommended Practices for shipping transport and handling of automotive type battery - Lithium Ion.

4.2 Salvage

The ECAR – Hybrid Vehicle Dismantling Guide has an extensive amount of information covering the safe removal and proper handling of the battery pack and parts from hybrid vehicles.

4.3 Disassembly and Discharge

With the complexity of new battery / energy storage systems a large amount of information will have to be available for the safe handling removal disassembly and processing, see Table 1.

Table 1 - Information sources relevant to energy storage systems handling and recycling

Information	Example source
Battery design	
Design for recycle	USCAR -2014 Recommended Practice for Recycling of xEV Electrochemical Energy Storage Systems
Life cycle assessment	ANL/ESD10-7 - A Review of Battery Life Cycle Analysis
Removal and storage	
Battery removal from vehicle	Service Manual, ECAR Hybrid Vehicle Dismantlers Guide
Storage requirements for removed batteries	NFPA Electric Vehicle Safety Training Universal Waste Rules - i.e. US 40 CFR 273 US 40 CFR 266 subpart G - Lead Acid Batteries Local Building Codes
Firefighting recommendations	NFPA Electric Vehicle Safety Training
Liquid coolant for battery	Universal Waste Rules - i.e. US 40 CFR 273
Transporation of batteries	
Transporation of bulk battteries and defective batteries	SAE J2950, DOT HAZMAT table (Title 49 CFR 172.101)
Discharge and disassemvly	
Electrical safety: handling instructions	SAE J2344, SAE J1766, ISO 6469-3:2011, ISO 6469-4.2
Battery chemistry/type	Service Manual, MSDS, SDS, SAE J2984, SAE J2936
Disassembly	Section 4.3, Service Manual
Dischage procedure	
Minimum state of charge (SOC)	Service Manual
Discharge procedure	Service Manual
Internal battery components and wiring diagram	Service Manual
Damaged batteries	
Rendering vehicle/battery safe	NFPA Electric Vehicle Safety Training
External signs of battery failure/danger	SAE J2950, ISO 6469-4.2

4.3.1 Example Disassembly Document for a generic Lithium Ion Battery Pack as pertinent to the design. For safety concerns, the battery pack should be disassembled in accordance with the guidance specified by the manufacturer (if any). This example is meant to be explanatory not instructional.

1. Prior to disassembling a Battery Pack:

   a. Remove ring(s) and jewelry.

   b. Wear personal protective equipment suitable for disassembly of high voltage battery packs in a plant environment.

   c. Wear personal protective equipment for possible hazardous material exposure <u>and</u> high voltage exposure when disassembling damaged / abused battery systems.

   d. Understand Safety and Warning labels attached to the battery pack.

   e. Have a place to store large format batteries before disassembly and battery components after disassembly.

   f. Maintain safe working distance between modules being disassembled and other modules.

2. Identify the Battery using: Shipping paperwork, shape, size, configuration, labels, embedded logos.

3. Inspect for any damages including: dents or holes in case and/or leaking. Note any electrolyte smell when the battery is unpacked. Refer to SAE J2950 Section 6 for handling / packaging of damaged battery systems.

4. Place battery system on a flat, non-conductive surface. Additional safety equipment to consider for teardown area could include: fire extinguishers, fire blankets, electrical blankets, AED, and a means of exhausting noxious fumes.

5. Confirm absence of high voltage at the system's output terminals. Confirm the electrical isolation of the batteries from the case.

6. Discharge battery according to manufacturer's recommendations if possible and safe to do so.

7. Remove / open the high voltage interlock switch / plug. It will be labeled and may be colored bright orange. Note that high voltage is still present in the battery but the highest measurable voltage is reduced.

8. Remove any components that may be attached to the outer surface of the system:

    a. Fan and ductwork.

    b. Controller

9. If applicable drain coolant.

10. Remove external cover(s) of battery system. Doing this will likely expose cables, contactors, bus-bars, and terminals that will have high voltage present. These components should be identified with "High Voltage" labels and / or a bright orange color.

11. Trace one of the bright orange cables / bus-bars from the pack's output terminal until you find were it is connected on the modules or internal array of cells.

12. Carefully disconnect this cable from the end module or cell of the battery pack and then insulate its terminal, and the battery pack terminal, with electrical tape or other non-conductive material. Where ever practical, electrically insulated tools should be used.

13. There may be another cable or bus-bar that is attached to the other end of the battery pack module or cell array. Carefully disconnect this cable and insulate its terminal and the battery pack terminal with electrical tape or another non-conducting material.

14. There may be sets of thinner wires that connect the battery pack controller to individual cells or modules. They are used to monitor the individual cell or module voltages. There may be high voltages between the pins or wires in the harness. Start at one end of the array and carefully disconnect the wire harnesses from the cells until the final wire / harness is removed at the other end of the array. Avoid starting the disconnection process in the middle of the array, especially if the controller is still attached at the other end.

15. Depending on the pack design, the next step will either be removing the cells or modules from the pack housing <u>or</u> the next step will be removing the remaining "non-cell" components like contactors, current sensors, and miscellaneous low voltage cables.

16. Within the module or cell array there may be intermediate cables or bus bars that connect modules or smaller groups of cells together to form the full array. Carefully remove these cables or bus bars, one at a time, and insulate the exposed cell terminal. It is possible that the cells or modules may be welded together instead of using a removable fastener. In this case, the welds will have to be cut, or the module/array will be removed as a complete unit.

17. Upon successful removal of the cells/modules from the battery pack housing, they should be protected from shorting and packaged per company safety procedure and regulatory requirements.

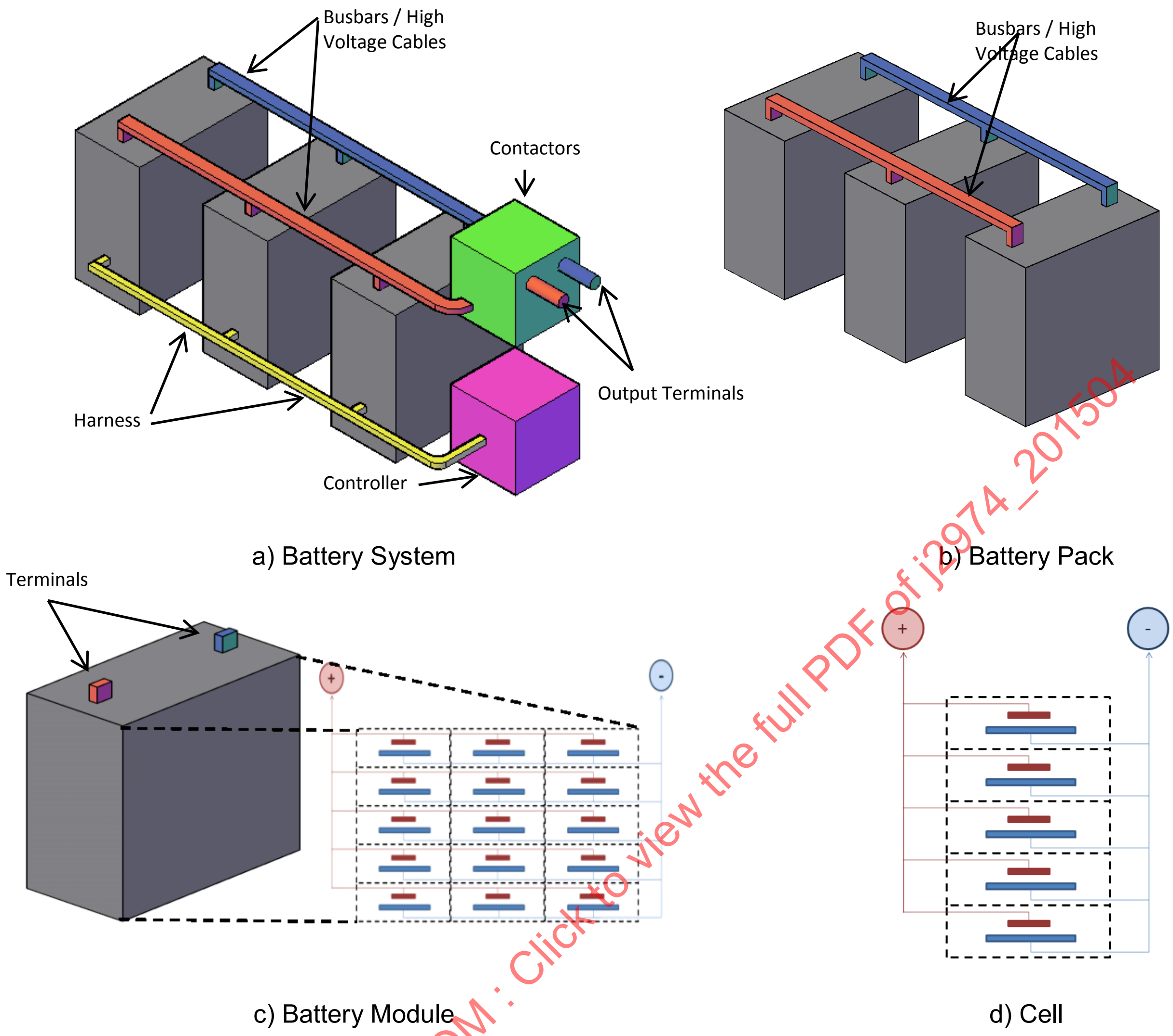

Figure 1 - Typical energy storage system

4.4 Chemistry Identification / Labeling

To better aid in sorting and separation of battery components a recommended practice for battery labeling has been developed. This system provides information on cathode, anode and any miscellaneous properties. For information refer to SAE J2936 and SAE J2984.

4.5 Collection and Sorting of Feedstock

Recycling processes are enhanced by segregating batteries into separate fractions based on chemistry. This can greatly reduce the cost of recycling, unwanted emissions and safety concerns. Presently hand sorting by chemistries is common prior to shipment to recyclers.

4.6 Compilation of recycling methodologies

There are three general routes for recycling of batteries at end of life; pyrometallurgy, hydrometallurgy and physical separation. Additional processing or mixing of the flow sheets is common as the main focus on battery recycling has traditionally been metals recovery. With advances in technology additional materials in batteries have been recycled including electrolyte and casing materials. Specifics of process and chemistry will vary on a case by case basis but this is to outline some of the general process streams and by products.

4.6.1 Pyrometallurgical Processing

Pyrometallurgical processing involves a thermal or high temperature process in which metals are reduced back to a base metallic state. The oxidation potential of the metals typically determine which metals report to the melt and which report to the slag, this can be controlled through the atmosphere present in the smelter. Any remaining organic components are burned for energy recovery. Waste and byproducts can include: drosses, slags, soot and other emissions, as well as high quality heat. These facilities benefit greatly from economies of scale. Capital cost and permitting burden are high. This type of process has been applied to lead acid, NiCd, NiMH and Li-Ion.

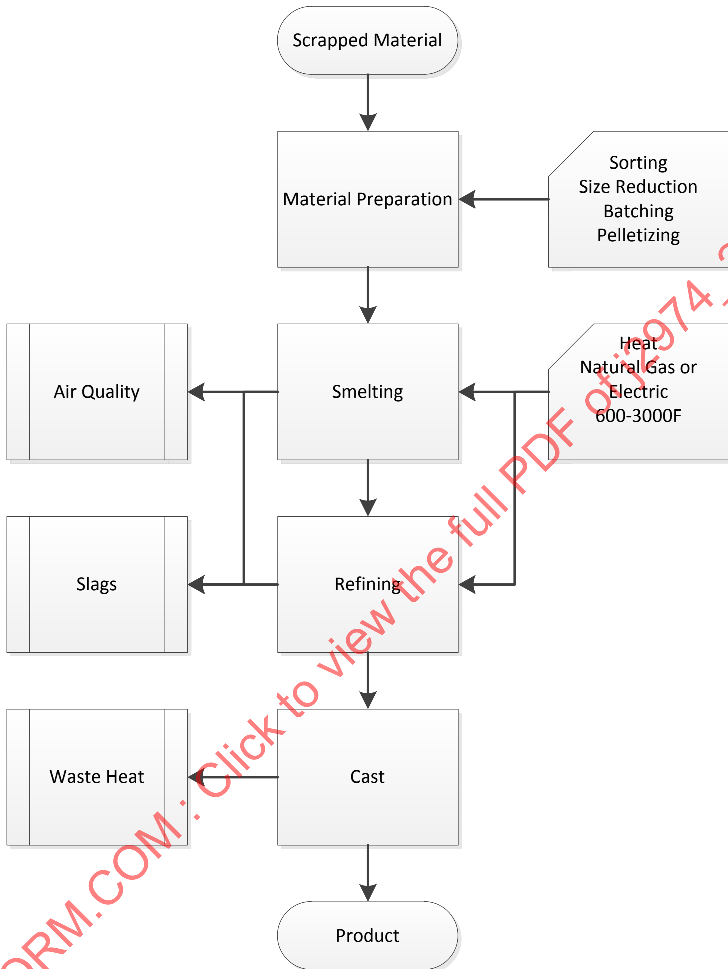

Figure 2 - Pyrometallurgical processing

4.6.2 Hydrometallurgical Processing

Hydrometallurgical Processing uses aqueous chemicals, acids, bases or other lixiviant's to leach the material. This is usually followed by species separation and purification processes. The materials are then precipitated as hydroxides / salts or electrorefined for reuse as metal. Byproducts include: leach residue, waste water that requires further treatment, and sludge's from waste water treatment. Hydroxide and salts are often reprocessed in pyrometallurgical facilities to produce metals. Capital cost is comparable to pyrometallurgy, and permitting burden is reagent specific. This type of process has been applied to lead acid, NiCd, NiMH and Li-Ion.

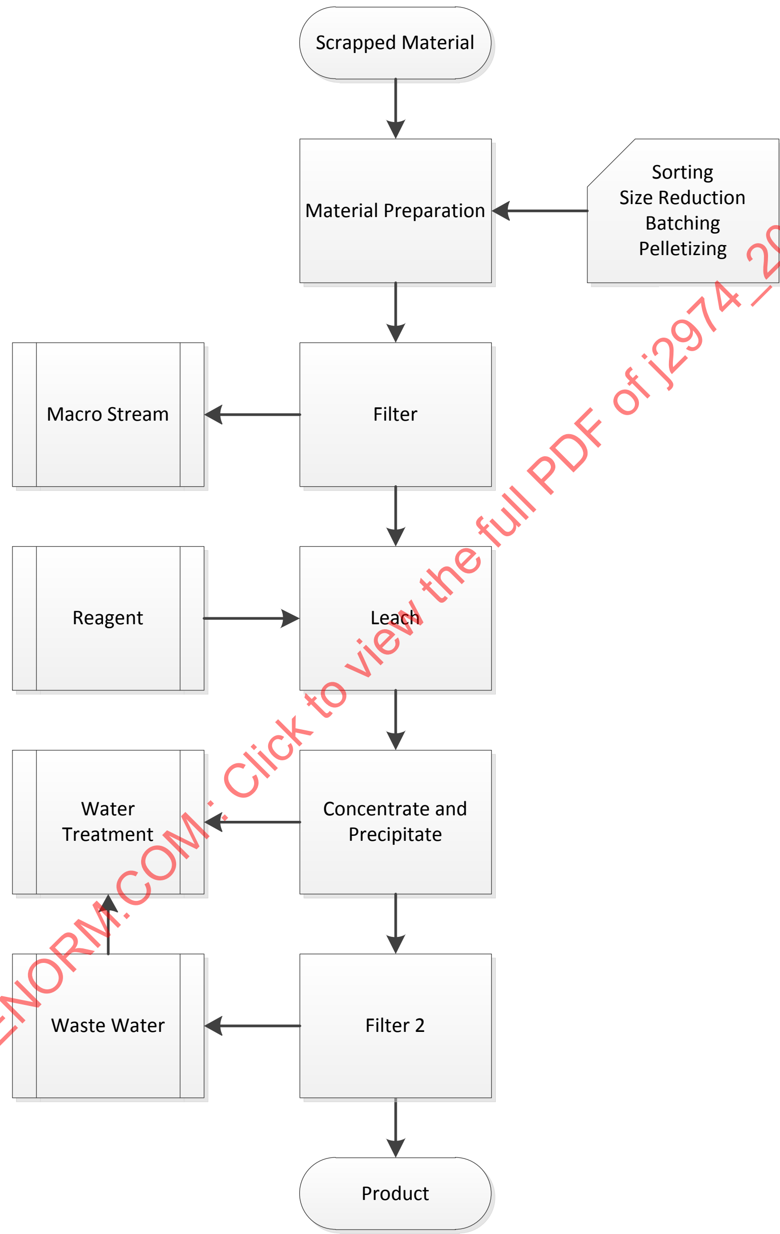

Figure 3 - Hydrometallurgical processing