SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Recommended Practices for Shipping Transport and Handling of Automotive-Type Battery System - Lithium Ion

RATIONALE

These recommendations are being updated to reconcile regulatory changes that have occurred since the original publication. Additionally, the inspection process for determining a damaged/defective battery has been updated to reflect further guidance and packaging instructions provided by regulators. For completeness of the transportation guidance, regulatory references were added for lithium metal batteries and cells.

1. SCOPE

This SAE Recommended Practice (RP) aids in the identification, handling, and shipping of lithium batteries to and from specified locations. It is the specific intent of this RP to identify, utilize, and reference existing U.S. and international hazardous materials (dangerous goods) transportation regulations, which are the only methodologies to be used to establish transportability. It is also the intent of this RP to provide recommendations to be used by service and shipping personnel for the purpose of determining a possibly damaged/defective battery's transportability. In support of the service and shipping personnel, these recommendations seek to use standard tools of the trade and avoid laboratory type equipment.

1.1 PURPOSE

This SAE RP provides a basis from which to determine the relevant regulations to consult when preparing a battery for shipment. It also provides recommendations that can be implemented during the development of the battery to be used by qualified users to determine the transportability of a battery. The determination of whether the battery is transportable or not with regard to current regulations is shared by the battery original equipment manufacturers (OEM) and the shipper.

The generic term "battery" shall be used to identify automotive-type lithium ion "traction" batteries when used as intended by the vehicle and battery original equipment manufacturers OEMs for ground vehicles.

While the recommendations provided in this document are intended for the automotive industry, nothing in this document precludes other industries from referencing this material for use in their specific industry.

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For more information on this standard, visit
https://www.sae.org/standards/content/J2950_202006

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

NOTE: Users should ensure that the latest revisions and legislative updates of these documents are being referenced.

2.1.1 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 6469-1:2019 Electrically Propelled Road Vehicles - Safety Specifications - Part 1: On-Board Rechargeable Energy Storage System (RESS)

2.1.2 United Nations Publications

Available from UN Economic Commission for Europe, Information Service, Palais des Nations, CH-1211 Geneva 10, Switzerland, Tel: +41 0 22 917 44 44, www.unece.org.

Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, 7th Revised Edition, 2019. ST/SG/AC.10/11/Rev.7.

Recommendations on the Transport of Dangerous Goods, Model Regulations, 21st Revised Edition, 2019. ST/SG/AC.10/1/Rev. 21 (Vol. 1 and 2).

2.1.3 United States Department of Transportation, Pipeline and Hazardous Materials Safety Administration

U.S. Code of Federal Regulations, 49 CFR, Subchapter C - Hazardous Materials Regulations (available online at https://ecfr.io/Title-49/).

2.2 Related Publications

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

2.2.1 ICAO Publications

Available from International Civil Aviation Organization, 999 University Street, Montreal, Quebec H3C 5H7, Canada, Tel: +1 514-954-8219, http://www.icao.int/.

Technical Instructions for the Safe Transportation of Dangerous Goods by Air, 2019-2020 Edition.

2.2.2 IATA Publications

Available from International Air Transport Association, Publications Assistant, 800 Place Victoria, P.O. Box 113, Montreal, Quebec H4Z 1M1, Canada, Tel: 1-514-874-0202, www.iata.org.

International Air Transport Association (IATA) Dangerous Goods Regulations 61st Edition, 2020.

2.2.3 Other Publications

International Maritime Dangerous Goods Regulations (IMDG), 2018 Edition, Amendment 39-18; International Maritime Organization (IMO).

3. DEFINITIONS

All definitions are in accordance with SAE J1715 or SAE J1715/2 or taken from the regulatory references.

Additional definitions:

3.1 BATTERY

Two or more cells which are electrically connected together and fitted with devices necessary for use; for example, case, terminals, marking, and protective devices.

3.2 BATTERY SYSTEM

Completely functional energy storage system consisting of the pack(s) and necessary ancillary subsystems for physical support, thermal management, and electronic control.

3.3 BATTERY PACK

A single assembly with batteries that is part of a battery system. In some cases, a single pack may comprise the complete battery system.

3.4 CELL

An electrochemical cell is a device that converts chemical energy into electrical energy or vice versa when a chemical reaction is occurring in the cell. Typically, it consists of two electrodes immersed into a solution (electrolyte) with electrode reactions occurring at the electrode-solution surfaces. (From SAE J1715/2, “Electrochemical Cell”.)

3.5 COMPETENT AUTHORITY (CA)

Any authority designated or otherwise recognized by a state (country) to perform specific functions related to international standards.

3.6 COMPETENT AUTHORITY APPROVAL

An approval by the competent authority that is required under an international standard (for example, the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air and the International Maritime Dangerous Goods Code).

3.7 DISASSEMBLY

A vent or rupture where solid matter from any part of a battery system has been physically detached.

3.8 EXPLOSION

Very fast release of energy sufficient to cause pressure waves and/or projectiles that may cause considerable structural and/or bodily damage.

3.9 FIRE

The emission of flames from a battery (approximately more than 1 second). Sparks are not flames.

3.10 LEAKAGE

The visible escape of electrolyte or other material from a cell or battery or the loss of material (except battery casing, handling devices, or labels) from a cell or battery.

3.11 PACK

See battery pack.

3.12 RESPONSIBLE ORGANIZATION

The organization which is responsible for overseeing the required tests and assuring the propriety of the tests and results. Examples are vehicle or battery system manufacturers or independent test authorities.

3.13 RUPTURE

The mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage, but not ejection of solid materials.

3.14 SERVICEABLE

A device or component that can be quickly, safely, and easily removed and replaced by the user without having to send the entire product or system to a repair facility. The defective device or component is found by standard troubleshooting procedures and is removed and replaced using standard non-specialized tools.

3.15 TRACTION BATTERY

A battery designed to provide electrical energy to motors which directly, or in combination with another energy source, propel a vehicle.

3.16 VENTING

The release of excessive internal pressure from a battery cell, module, or pack in a manner intended by design to preclude rupture or explosion.

4. TRANSPORTATION REGULATIONS

4.1 Responsibilities

In addition to any other battery design, performance, or fit requirements, both the requirements generator (the battery “customer”) and/or battery design/manufacturer must provide sufficient guidance to enable the safe shipment and/or transport of each battery in full compliance with the applicable transportation regulations regardless of type, construction, size, or application. This responsibility includes the elimination, or mitigation to an acceptable safety level, of occupational and environmental hazards associated with the transport, packaging, and handling of same. In addition, the need for all special tools, adapters, and kits must be identified, and appropriate actions taken, to allow access to same for qualified users. These responsibilities are equally applicable to battery OEM-approved secondary (subsequent use) applications, intended and approved non-vehicle applications, rebuild/recondition operations, and recyclers.

As a minimum, the requirements generator (the battery “customer”) and/or battery design/manufacturer must develop, proof, publish, and disseminate in the English language all datum required to enable the capability to identify, classify, move (handling), and safely ship and/or transport each type of battery within the legal/regulatory requirements of the U.S./national or international transportation regulations.

4.2 Regulatory Flow Diagram

NOTE: The material presented here is not all inclusive of the regulations that are required to ship a product but is meant to educate the reader on the complexity involved in doing so. The reader is encouraged to review the regulations cited here so that they follow proper regulatory requirements. The chart below outlines a process that can be followed to ensure that cells and batteries are shipped per the required regulations. It is a regulatory requirement that anyone involved in the handling of dangerous goods (hazardous material) be trained to do so.

The transport of rechargeable lithium ion batteries in the various forms (batteries by themselves, contained in equipment, packed with equipment or in a battery powered vehicle) is allowed for transport if certain regulatory requirements are met. This document is formatted in such a manner as to aid the reader in determining those requirements. The flowchart below provides a map of how these requirements are presented. The first section aids in the determination of what kind of battery is being considered for transportation. Once this determination is made, applicable packaging instructions and regulations can be followed to properly offer the shipment for transport.

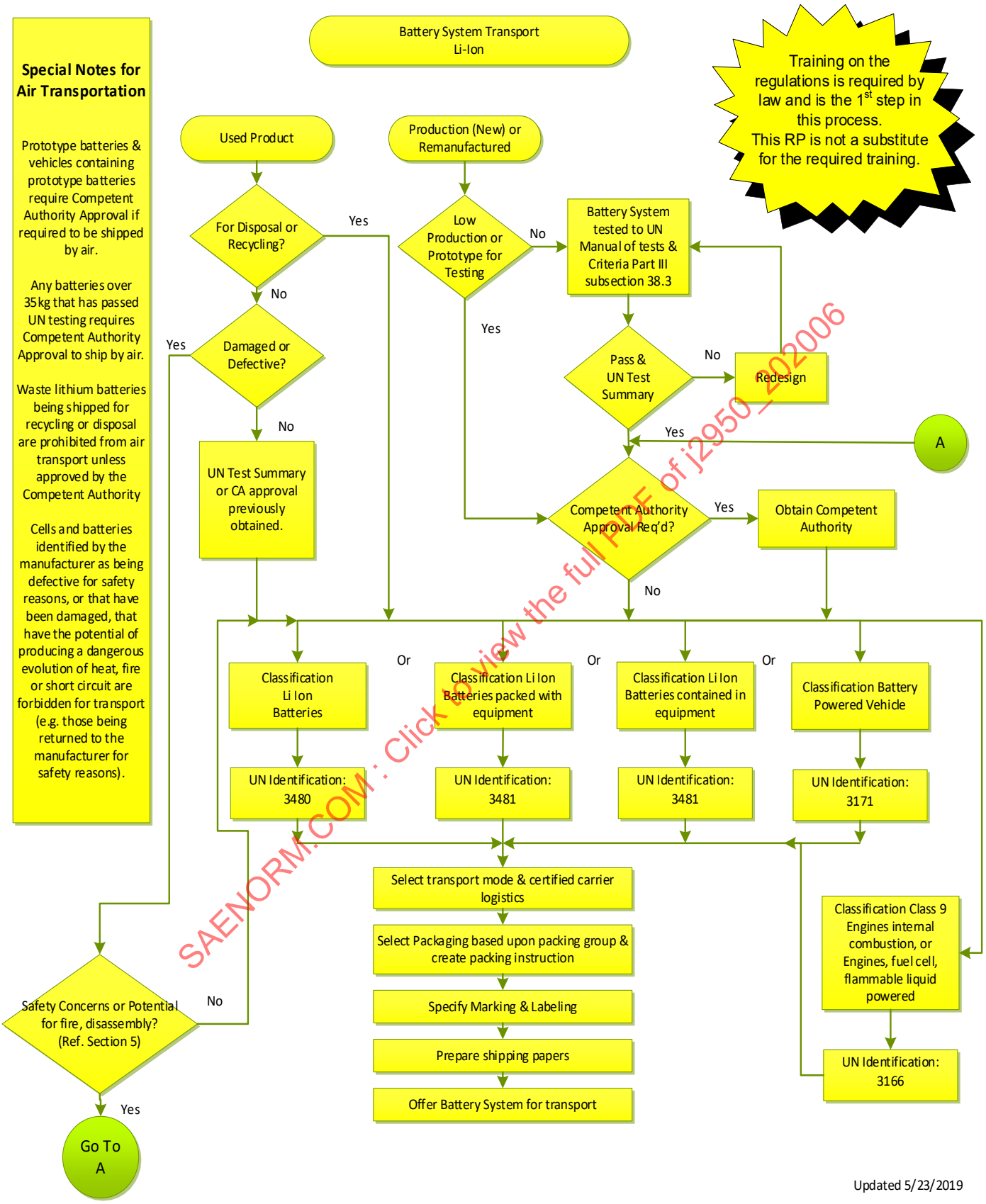

Figure 1 - Battery type determination

4.2.1 Regulations

The regulations that govern the transport of rechargeable lithium ion (including lithium ion polymer) cells and batteries, classified dangerous goods, are based on the UN Recommendations on the Transport of Dangerous Goods Model Regulations. Transport of dangerous goods is regulated internationally by the International Civil Aviation Organization (ICAO) Technical Instructions and corresponding International Air Transport Association (IATA) Dangerous Goods Regulations, and the International Maritime Dangerous Goods (IMDG) Code. In the United States, transportation of these batteries is regulated by the Hazardous Materials Regulations (HMR), which is found at Title 49 of the Code of Federal Regulations, Sections 100 through 185. Shipping requirements for lithium cells and batteries can be found in Section 173.185. Applicable special provisions are found in Section 172.102. These sections provide detailed information on packaging and exceptions for cells and batteries, while further information on packaging and specifications for packaging can be found in Sections 172.101 and 178. The Office of Pipeline and Hazardous Materials Safety Administration (PHMSA), which is within the U.S. Department of Transportation (DOT), is responsible for drafting and writing the U.S. HMR that govern the transportation of hazardous materials (also known as dangerous goods) by air, rail, highway, and water.

Lithium ion cells and batteries are identified as Class 9 hazardous materials, which is one of nine classes of hazardous materials or dangerous goods defined in the UN, U.S., and other transportation regulations. As Class 9 hazardous materials, cells and batteries must meet UN 38.3 requirements, make available a UN38.3 Test Summary Report, and use proper packaging, marking, labeling, and shipping paper requirements.

UN 38.3 requirements are documented in the UN Manual of Tests and Criteria, Sub-Section 38.3. The UN tests require the battery or cell to not exhibit: leakage, venting, disassembly, rupture, fire, and to maintain open circuit voltage. UN 38.3 consists of the following T1-T8 tests:

Test T.1: Altitude Simulation
Test T.2: Thermal Test
Test T.3: Vibration
Test T.4: Shock
Test T.5: External Short Circuit
Test T.6: Impact (Cell Only)
Test T.7: Overcharge
Test T.8: Forced Discharge (Cell Only)

For large batteries and assemblies, some exceptions exist for UN 38.3 tests. These exceptions are described in 38.3.3 (f) and 38.3.3 (g).

Table 1 provides a summary of the proper shipping names and ID numbers for lithium batteries, cells, and applications. Table 2 (lithium-ion) and Table 3 (lithium metal) provide a synopsis of the regulations currently in effect for both the U.S. and internationally.

Table 1 - Lithium cell and battery UN ID numbers

Proper Shipping Name	UN Number
Lithium metal batteries	UN 3090
Lithium metal batteries packed with equipment	UN 3091
Lithium metal batteries contained in equipment	UN 3091
Lithium ion batteries	UN 3480
Lithium ion batteries packed with equipment	UN 3481
Lithium ion batteries contained in equipment	UN 3481
Engines, internal combustion, flammable gas powered or engines, internal combustion, flammable liquid powered or vehicle, flammable gas powered or vehicle, flammable liquid powered	UN 3166
Battery powered vehicle	UN 3171

Table 2 - Lithium-ion regulatory requirements overview

Regulation	Lithium-Ion Type*	Watt Hour (Wh) Rating	Mode	Testing	Classification	Quantity	Packaging	Labeling
49CFR IATA	Cells or Batteries	≤2.7 Wh	Air	UN38.3	Excepted	NA	≤ 2.5 kg net, rigid packaging, 1.2m drop ≤30% SOC	Lithium Battery Mark CAO Label
49CFR IATA	Cell	> 2.7 Wh ≤ 20 Wh	Air	UN38.3	Excepted	≤ 8 cells^	Rigid packaging 1.2m drop, ≤30% SOC	Lithium Battery Mark CAO Label
49CFR IATA	Cell	≤ 20 Wh	Air	UN38.3	Class 9	> 8 cells	< 10 kg net, rigid packaging 1.2m drop, ≤30% SOC	Lithium Battery Mark, Li Class 9 Label CAO Label
IMDG	Cell	≤20 Wh	Vessel	UN38.3	Excepted	NA	≤ 30 kg gross, rigid packaging 1.2m drop	Lithium Battery Mark[1]
49 CFR	Cell	≤ 20 Wh	Ground	UN38.3	Excepted	NA	≤ 30 kg gross, rigid packaging 1.2m drop	Lithium Battery Mark, FBTPAX Mark or CAO Label
49CFR IATA	Cell	> 20 Wh	Air	UN38.3	Class 9	NA	> 5 kg but ≤ 35 kg net, UN Spec Packaging PGII ≤30% SOC	CAO Label, Li Class 9 Label
49CFR	Cell	> 20 Wh ≤ 60 Wh	Ground	UN38.3	Excepted	NA	≤ 30kg gross, rigid packaging 1.2m drop	Lithium Battery Mark, FBT Mark
49CFR IATA	Battery	>2.7 Wh ≤100 Wh	Air	UN38.3	Excepted	≤ 2 batteries total^	rigid packaging 1.2m drop, ≤30% SOC	Lithium Battery Mark CAO Label
49CFR IATA	Battery	≤ 100 Wh	Air	UN38.3	Class 9	> 2 batteries	≤ 10 kg, rigid packaging 1.2m drop, ≤30% SOC	Lithium Battery Mark, Li Class 9 Label CAO Label
49 CFR	Battery	≤ 100 Wh	Ground	UN38.3	Excepted	NA	≤ 30 kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark, FBTPAX Mark or CAO Label
IMDG	Battery	≤100 Wh	Vessel	UN38.3	Excepted	NA	≤ 30 kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark[1]
49CFR	Battery	>100 Wh ≤300 Wh	Ground	UN38.3	Excepted	NA	≤ 30kg, rigid packaging 1.2m drop	Lithium Battery Mark, FBT Mark
49CFR IATA	Battery	>100 Wh	Air	UN38.3	Class 9	NA	≤ 35 kg, UN PGII <30% SOC	Lithium Battery Mark, Li Class 9 Label CAO Label
49CFR	Cells or	All other*	Ground /	UN38.3	Class 9	NA	UN Spec Packaging PGII	Li Class 9 Label

FBTPAX "Lithium Ion Batteries - Forbidden for Transport Aboard Passenger Aircraft."
FBT "Lithium Batteries - Forbidden for Transport Aboard Aircraft and Vessel."
CAO Cargo aircraft only.
* When not identified as damaged, defective, or recalled, for disposal or recycling, low production run, or prototype.
^ No more than one package per consignment.
1 U.S. DOT may require the CAO label or FBTPAX mark when shipping into or from the U.S.

Table 3 - Lithium metal regulatory requirements overview

Regulation	Lithium-Metal Type*	Lithium (g) Rating	Mode	Testing	Classification	Quantity	Packaging	Labeling
49CFR IATA	Cells or Batteries	≤0.3 g	Air	UN38.3	UN 3090	NA	≤ 2.5 kg net, rigid packaging, 1.2m drop	Lithium Battery Mark CAO Label
49CFR IATA	Cell	> 0.3 g ≤ 1 g	Air	UN38.3	UN 3090	≤ 8 cells^	Rigid packaging 1.2m drop,	Lithium Battery Mark CAO Label
49 CFR	Cell	≤ 1 g	Ground	UN38.3	Excepted	NA	≤ 30 kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark, FBTPAX Mark or CAO Label
49CFR IATA	Cell	≤ 1 g	Air	UN38.3	UN 3090	> 8 cells	≤ 2.5 kg net, rigid packaging 1.2m drop,	Lithium Battery Mark, Li Class 9 Label CAO Label
IMDG	Cell	≤1 g	Vessel	UN38.3	UN 3090	NA	≤ 30kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark[1]
49CFR IATA	Cell	>1 g	Air	UN38.3	UN 3090	NA	≤ 35 kg net, UN Spec Packaging PGII	CAO Label, Li Class 9 Label
49CFR	Cell	≤5 g	Ground	UN38.3	UN 3090	NA	≤ 30kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark, FBT Mark
49CFR IATA	Battery	>0.3 g ≤2 g	Air	UN38.3	UN 3090	≤ 2 batteries total^	rigid packaging 1.2m drop,	Lithium Battery Mark CAO Label
49CFR IATA	Battery	≤ 2 g	Air	UN38.3	UN 3090	> 2 batteries	< 2.5 kg net, rigid packaging 1.2m drop,	Lithium Battery Mark, Li Class 9 Label IATA requires CAO Label
49 CFR	Battery	≤ 2 g	Ground	UN38.3	Excepted	NA	≤ 30 kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark, FBTPAX Mark or CAO label
IMDG	Battery	≤2 g	Vessel	UN38.3	UN 3090	NA	≤ 30kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark[1]
49CFR	Battery	>2g ≤25 g	Ground	UN38.3	UN 3090	NA	≤ 30kg gross, rigid packaging, 1.2m drop	Lithium Battery Mark, FBT Mark
49CFR IATA	Battery	>2 g	Air	UN38.3	UN 3090	NA	≤ 35 kg net, UN PGII	Li Class 9 Label CAO Label
49CFR IMDG	Cells or Batteries	All other*	Ground / Vessel	UN38.3	UN 3090	NA	UN PGII	Li Class 9 Label

FBTPAX "Lithium Ion Batteries - Forbidden for Transport Aboard Passenger Aircraft".
FBT "Lithium Batteries - Forbidden for Transport Aboard Aircraft and Vessel."
CAO Cargo aircraft only.
* When not Identified as damaged, defective, or recalled, for disposal or recycling, low production run, or prototype.
^ No more than one package per consignment.
1 U.S. DOT may require the CAO label or FBTPAX Mark when shipping into or from the U.S.

5. DAMAGED OR DEFECTIVE DETERMINATION

For lithium-ion cells and batteries, the UN tests are considered the internationally recognized criteria for determining the classification of the cells and batteries and are utilized by governments worldwide to authorize the transport of the cells and batteries. The twenty first revised edition of the Recommendations on the Transport of Dangerous Goods Model Regulations was published in 2019 by the United Nations and introduced a new packing instruction for damaged and defective batteries. Additionally, the UN Model regulations, special provision 376 provided the following guidance which may identify cells or batteries which are damaged or defective:

1. Cells or batteries identified as being defective for safety reasons;

2. Cells or batteries that have leaked or vented;

3. Cells or batteries that cannot be diagnosed prior to transport; or

4. Cells or batteries that have sustained a physical or mechanical damage.

NOTE: In assessing a cell or battery as damaged or defective, an assessment or evaluation shall be performed based on safety criteria from the cell, battery, or product manufacturer or by a technical expert with knowledge of the cell's or battery's safety features. An assessment or evaluation may include, but is not limited to, the following criteria:

a. Acute hazard, such as gas, fire, or electrolyte leaking;

b. The use or misuse of the cell or battery;

c. Signs of physical damage, such as deformation to cell or battery casing, or colours on the casing;

d. External or internal short circuit protection, such as voltage or isolation measures;

e. The condition of the cell or battery safety features; or

f. Damage to any internal safety components, such as the battery management system.

To further assist the battery and transport industry in diagnosing the damaged or defective status of a suspect cell or battery which has not been identified as being defective for safety reasons, the following inspection steps have been developed as a high-level screening process to identify a battery that might be damaged or defective and warrant further inspection by more trained personnel. The intent of these inspections is that anyone familiar with cells or batteries may be able to inspect them for indications of damage/defects without special skills, tools and expertise. For those with special tools and skills, additional techiques are provided for further inspection to demonstrate the battery or cell is not damaged or defective. If all these inspection steps are satisfactorily met, the battery can be presumed to be shippable as a Class 9 regulated battery.

5.1 Battery Damaged or Defective Determination Flow Diagram

The flowchart below provides a visual step-by-step flow of the process used in this section for determining the transportability of a battery.

NOTE: Not every battery shipment requires an inspection. The inspection steps listed below are provided for when there is a reason to suspect a battery/cell may be damaged; e.g., after a vehicle accident, manufacturer recall, or abnormal handling of battery/cell (dropped package, fork truck mishandling).

NOTE: The inspection flow provided is a suggested sequence; however, certain situational circumstances may require the alteration of the inspection sequence. Provided the required inspection steps are completed, the order of inspections steps are not critical.

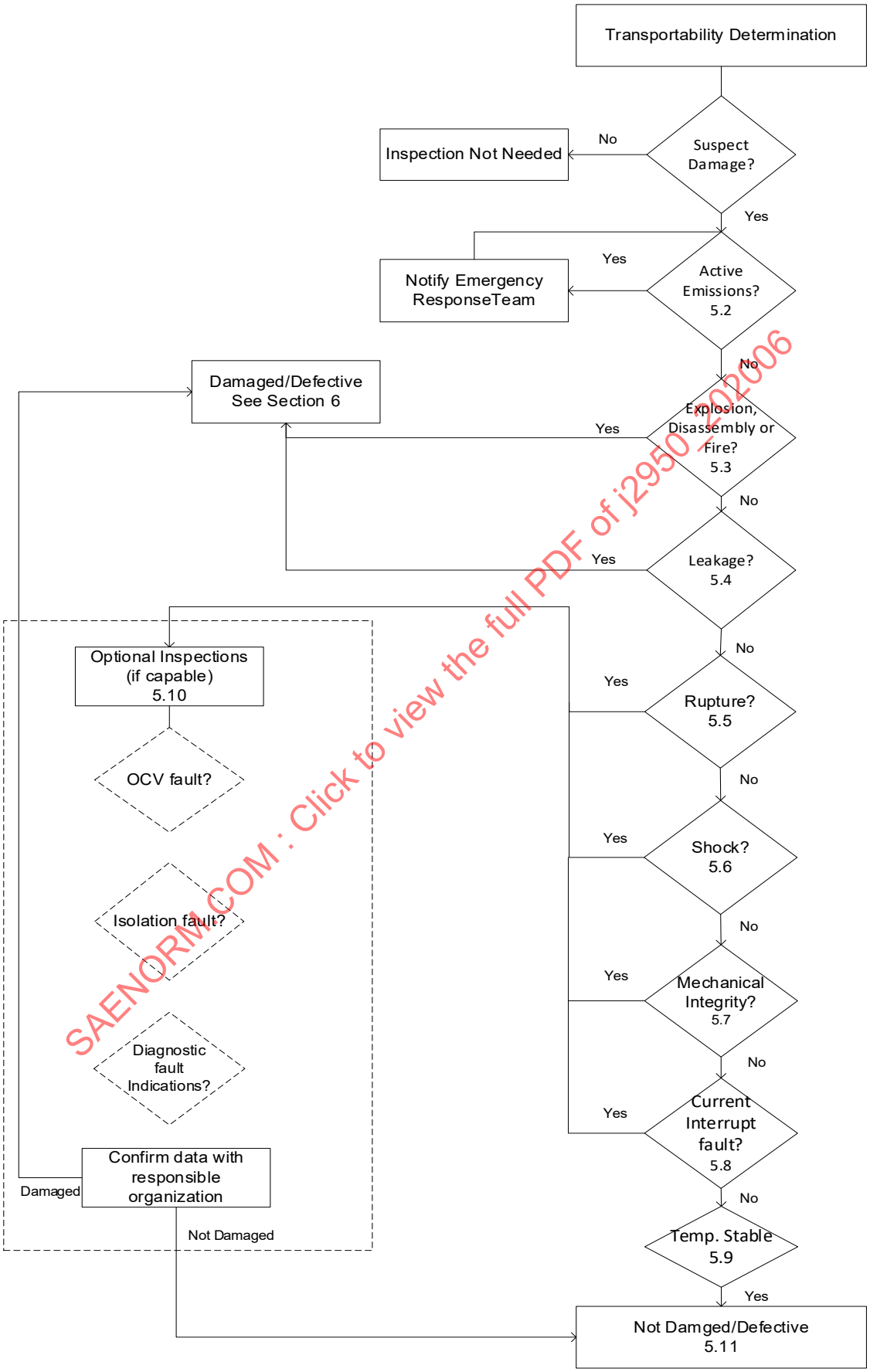

Figure 2 - Battery damaged or defective determination flow diagram

5.2 Immediate Safety Assessment of Battery Stability

Visible evidence of active emissions (e.g., smoke, venting, flames, sparks, electrical arcs; or abnormal odor(s) different than electrolyte which has a sweet odor, or audible popping sounds). If yes, notify appropriate Emergency Response Teams; otherwise, proceed to 5.3.

5.3 Explosion, Disassembly, or Fire

Examine battery for evidence of explosion, disassembly, or fire. Look for burned or charred components, deformed or warped plastic cases; peeling, blistering, or discoloration of paint; evidence of battery disassembly; grey or black residue; melted seals; metallic splatter, such as copper or aluminum; and/or an abnormal odor such as a burnt odor but different than electrolyte which has a sweet odor. If evidence of explosion, disassembly, or fire is identified, proceed to Section 6; otherwise, proceed to 5.4.

5.4 Leakage

Examine battery for leakage. If electrolyte is leaking, it usually emits a sweet, ether-type odor which is typically very detectible by those with a normal sense of smell. Inhalation of vapors emanating from an RESS may be hazardous and appropriate precautions should be taken. Other evidence of leakage includes wet areas or puddles; salt crystal residue from leaked electrolyte which has evaporated, signs of discoloration, or gelatinous residue. The battery may contain multiple sources of liquids that could indicate other leaks such as coolant used for an internal cooling system. Additional sources of contamination, external to the battery are not relevant to leakage (e.g., transmission oil, washer fluid, etc.). Effort should be made to determine if the leak is coming from an internal source. For external non-electrolyte leaks, material should be absorbed and disposed of in a legal and proper manner. For internal leakage (e.g., coolant leakage or electrolyte leakage), which may create the potential for short circuits, precaution should be taken and proceed to Section 6; otherwise, proceed to 5.5.

5.5 Rupture

Examine battery for evidence of rupture, where case is opened such that internal components are exposed (e.g., can you see into the battery (cells and internal components) or is there a visible opening internal to the battery sufficient for a liquid to enter). If rupture is detected, proceed to 5.10; otherwise, proceed to 5.5.

5.6 Shock

Determine if the battery has experienced any damaging shock levels during shipping or use. If shock sensors are used in the battery or in the shipping crate, utilize these sensors to determine if the battery has experienced levels that exceed the UN38.3 T4 test levels proceed to 5.10; otherwise, proceed to 5.6.

5.7 Mechanical Integrity

Examine battery for loss of mechanical integrity, by identifying abnormal movement of internal components (e.g., an abnormal rattle or noise while moving the battery); external wiring and/or electrical connections damaged such as dents, crush, scratches, punctures, tears or corrosion; physical evidence that the battery has been modified externally by the removal of covers and/or external parts without authorization; or signs of physical damage, such as deformation to cell or battery casing (e.g., bulging or cracked case). If integrity is suspect, proceed to 5.10; otherwise, proceed to 5.7.

NOTE: The intent of this step is not to physically shake the battery to test for abnormal movement of components.

5.8 Current Interrupt Devices

Inspect for activated current interrupt devices such as fuses. Inspect serviceable current interrupt devices for evidence of activation. If current interrupt devices are functional and unactivated, proceed to 5.9. If the current interrupt devices are activated, such as a blown fuse, this may indicate the potential for a short circuit inside the battery. Consult the responsible organization for disposition of faulted current interrupt devices; otherwise, do not replace or repair the current interrupt devices if activated. Proceed to 5.10.