BLUE WHALE
ENERGY & INNOVATION

Best Practices for Discharging DDR Batteries

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AGENDA

1. Criticality of DDR Battery Management
2. Challenges
3. Landscape
4. Defining DDR
5. Physics of Failure
6. Ins & Outs of DDR Management
7. Future
8. Q & A

The Critical Imperative of DDR Battery Management

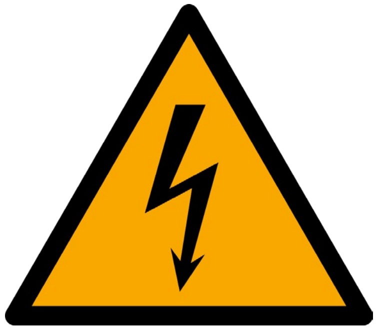
Images Courtesy of Call2Recycle Canada

The Challenge & Why It Matters

- Damaged, Defective, or Recalled (DDR) batteries are highly volatile and pose unique safety risks due to their unstable condition and high energy content.
- Why Best Practices Matter - Proper handling and discharge are critical to prevent:

Fires & Explosions

Toxic Gas Exposure



Electrical Accidents

Core Goals: Ensure worker safety, protect assets, and maintain regulatory compliance.

Understanding DDR Batteries

- A DDR battery is a lithium-ion battery that is unsafe for normal use.
  - Damaged: Physically compromised by an external force (e.g., dropped, crushed, penetrated, water-immersed).
  - Defective: Has an inherent flaw from its design or manufacturing (e.g., internal contamination, separator tears, BMS failure). The defect may not be visible.
  - Recalled: Officially identified by a manufacturer or regulatory body (e.g., CPSC) as a safety risk. Verify at www.recalls.gov.

- Hazards & Regulatory Landscape

THE PHYSICS OF BATTERY FAILURE

The Physics of Failure: Thermal Runaway

- Thermal Runaway is a rapid, self-sustaining exothermic chain reaction.
- Process:
  1. Heat breaks down internal components (SEI layer).
  2. The separator melts, causing an internal short circuit.
  3. The cathode decomposes, releasing oxygen.
  4. The electrolyte vaporizes into flammable and toxic gases (H2, CO, HF).

- Result: The cell ruptures or explodes, ejecting flaming material. This does not require external oxygen.

Image Courtesy of Latent Heat Solutions

The Physics of Failure: Stranded Energy

- Stranded Energy is the significant electrical charge that can remain in a battery even after a fire or if it appears inert.
- This poses a persistent risk of electric shock or reignition hours or even days later.
- **NEVER assume a damaged battery is "dead".**

The Regulatory Matrix

DDR battery management involves a complex, overlapping framework.

DOT / PHMSA	Regulates DDR batteries as Class 9 Miscellaneous Hazardous Materials. T his mandates stringent packaging, labeling, and training. Air transport is strictly forbidden.
EPA / RCRA:	Classifies most discarded lithium-ion batteries as hazardous waste. Batteries with a breached casing are fully regulated hazardous waste.
NFPA:	Develops critical fire safety codes. NFPA 855: Stationary Energy Storage Systems. NFPA 70E: Electrical Safety in the Workplace.
OSHA:	Ensures worker safety through rules on Hazard Communication, PPE, and battery handling/charging areas.

PRE-DISCHARGE PROTOCOLS

Incoming Process & Initial Communication

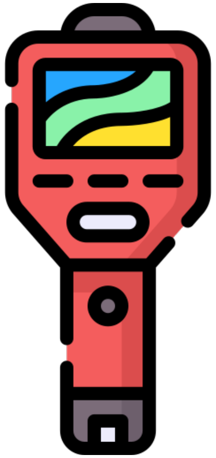
- The first opportunity to contain risk is before and upon arrival.
- Pre-Arrival Communication:
  - Gather details from the shipper: battery type, voltage, state-of-charge (SOC), nature of defect.
  - Request the sender reduce charge to <30% SOC before shipment.
- Verify Shipping Compliance:
  - Ensure the package meets DOT/Transport Canada rules for UN Class 9 hazardous materials.
- On-Arrival Check:
  - Look for leakage, odor, heat, or packaging damage.
  - Immediately isolate the shipment if any red flags are present.

Identification and Condition Assessment (Triage)

- A systematic triage process is essential upon arrival.

Expert Evaluation: Involve a battery engineer or technical specialist to assess the battery and consult any available BMS data.

Visual & Sensory Inspection: Carefully check for bulging, cracks, leakage, corrosion, burnt plastic odors, or hissing sounds. When in doubt, classify as DDR.



Thermal Diagnostics: Use a non-contact thermal imaging camera to detect hot spots that indicate internal shorts.

Defect Categorization & Quarantine

Use a tiered system to classify risk and prioritize handling

Level 1 (Low Risk)	Recalled/defective, but no visible damage.
Level 2 (Moderate Risk)	Visible deformation, casing intact, thermally stable.
Level 3 (High Risk)	Casing breached, active leaking/venting, elevated temperature.
Level 4 (Critical Risk)	Actively smoking, hissing, flaming, or rapidly heating. This is an active emergency.

Quarantine Storage & Monitoring

- Storage Setup:
  - Designate a cool, dry, well-ventilated quarantine area away from main workspaces.
  - Use fire-resistant containers (e.g., steel bins).
  - Fill containers with an inert filler (sand, vermiculite) to stabilize and suppress flames.
  - Cover all exposed terminals.
- Spacing & Monitoring:
  - Keep containers separated by at least 3 feet; do not stack.
  - Mark the area with clear signage.
  - Monitor regularly with thermal cameras and have fire detection systems in place.
  - Do not store DDR batteries long-term. Process them ASAP.

Qualified Personnel & PPE

- Personnel: Only qualified personnel with high-voltage safety training should perform discharge procedures. Always have at least two people present.
- Personal Protective Equipment (PPE) is mandatory:
  - Electrical PPE: Voltage-rated insulated gloves, face shield, arc-flash clothing, insulated tools.
  - Chemical/Fire PPE: Nitrile/neoprene gloves, fire-resistant apron, full-face respirator with appropriate cartridges.

DISCHARGE PROTOCOLS

The Disassembly Decision

This is a critical, risk-based analysis. The default is to avoid disassembly.

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Disassembly Before Discharge:

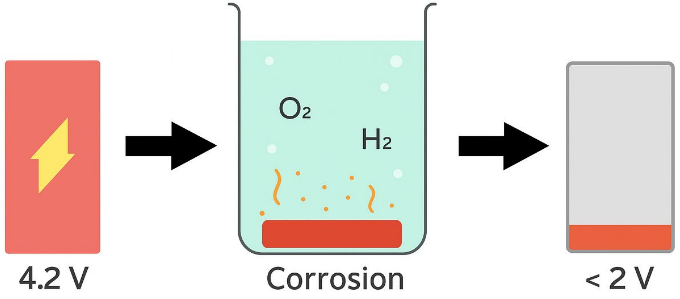
- May be considered for stable batteries (Level 1-2).
- To address known cell imbalances or for component salvaging.
- Must be done in a controlled environment following OEM protocols.

NO Disassembly (Discharge Intact):

- Preferred for high-risk batteries (Level 3-4).
- When OEM schematics are unavailable.
- When the design is inaccessible.

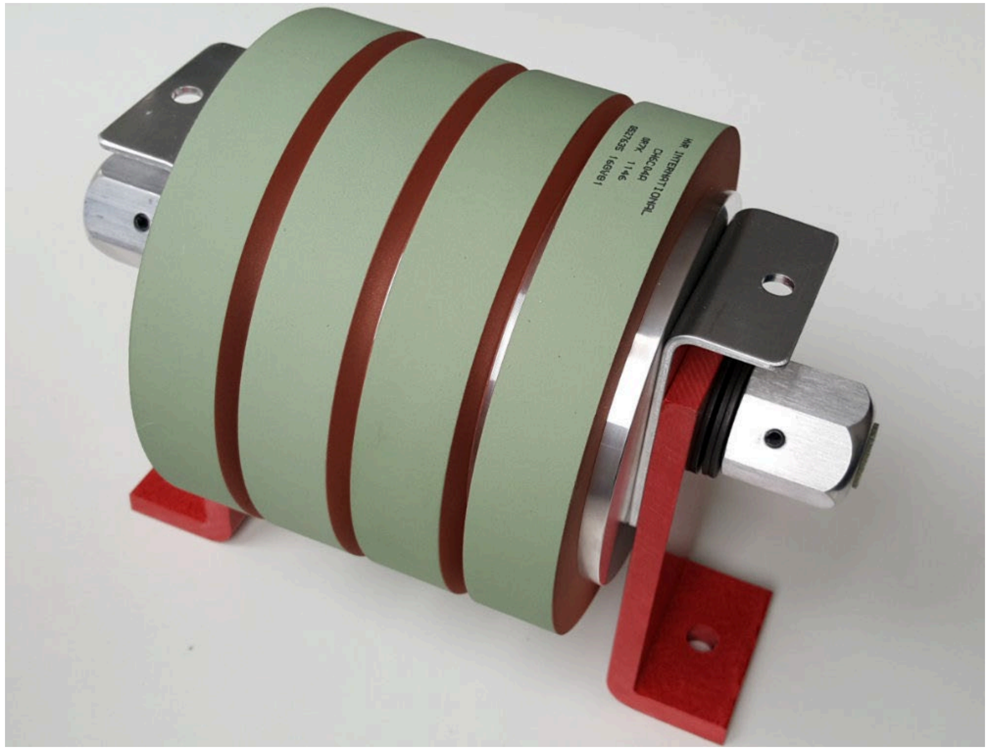
Discharge Method 1: Saltwater (Brine) Bath

- **Process:** Submerging the battery in a saltwater solution to create a slow short circuit.
- **Pros:** Simple, low capital cost.
- **Cons (Significant Risks):**
  - Poor Safety: Uncontrolled reaction generates flammable hydrogen and toxic chlorine gas.
  - Incomplete Discharge: Corrosion often prevents full discharge, leaving a hazardous, partially charged battery.
  - Severe Environmental Contamination: Creates toxic hazardous wastewater.
  - Not a recommended best practice due to safety and environmental risks.



Discharge Method 2: Resistive Load Bank

- **Process:** Connecting the battery to high-wattage resistors, which dissipate the energy as heat.
- **Pros:** Straightforward, does not produce chemical waste.
- **Cons:**
  - Moderate Safety: High risk of overheating resistors or the battery itself.
  - Requires continuous supervision by qualified personnel to monitor temperature and voltage.
  - Risk of over-discharging cells if not controlled.



Discharge Method 2: Battery Cycler/Electronic Discharger

- **Process:** Uses programmable electronic equipment for precise, software-driven control over the discharge process.
- **Pros:**
  - Excellent Safety: Fully automated with programmable safety limits and auto-shutdown.
  - High Efficiency & Control: Provides detailed data logging for compliance and can be highly automated.
  - Energy Recovery: Advanced models can feed energy back to the grid (regenerative).
  - This is the industry best practice for safety and control.
- **Cons:** Very high capital cost.

Monitoring During Discharge

- Continuous monitoring is essential, regardless of the method.
- Voltage: Track the voltage drop; sudden changes indicate problems.
- Temperature: Use an IR thermal camera. Keep the battery below ~60°C. A rapid temperature rise is a key indicator of impending thermal runaway.
- Environment: Ensure adequate ventilation and use gas detectors (CO, HCl, HF) if possible.
- NEVER leave a DDR battery unattended during discharge.

Controlled Environment & Safety Measures

- Location: Use a non-combustible area (concrete floors) with an exhaust hood/vent system.
- Fire Suppression: Have appropriate means ready.
    - Large amounts of water are effective for cooling.
    - Class D extinguishers for burning metals.
    - Keep dry sand, ABC, and D extinguishers nearby.
- Containment & Shielding: Work over a spill tray and use blast shields (polycarbonate barriers).
- Supervision: At least one qualified person must monitor the process at all times.

Completion Check & Post-Discharge Handling

- Verification: After discharge, verify the battery is at or near 0V.
- Rest & Re-Check: Let the battery rest for at least 24 hours and re-check for voltage "rebound" from stranded energy.
- Handling:
  - Label the battery as "Discharged/Deactivated" with the date and method.
  - The battery is now safer for transport/recycling but should still be handled with caution.

TRAINING & COMPLIANCE

Personnel Training & Qualifications

- A tiered training structure is essential.
- General Awareness: For all employees on basic hazards and emergency actions.
- Hazmat Training: For workers handling or packaging DDR batteries (DOT, EPA, OSHA).
- Specialized High-Voltage Qualification: For personnel performing disassembly or discharge. This includes electrical safety (NFPA 70E), LOTO, and emergency response.
- Regular refresher courses are critical.
- Build a culture of safety.

Regulatory Compliance & AHJ Collaboration

- Integrated Compliance:
  - Follow all DOT, EPA, NFPA, and OSHA requirements for storage, handling, labeling, and shipping.
  - Treat all byproducts (brine, electrolyte, etc.) as hazardous waste unless proven otherwise.
- Collaboration with Authorities (AHJs):
  - Proactively engage with your local fire department.
  - Share site plans and your Emergency Response Plan (ERP).
  - Conduct joint training drills.

Emergency Response Planning (ERP)

- A robust, site-specific ERP is non-negotiable.
- Fire Emergency Plan: Define clear steps: Alarm -> Evacuate -> Call 911 (specify Li-ion fire).
- Response Tactics:
  - Prioritize life safety and evacuation.
  - Firefighters will likely use a defensive strategy (protect exposures, let it burn).
  - If an offensive attack is safe, the goal is COOLING with large, sustained volumes of water.
- Post-Incident:
  - A fire watch is needed for 24+ hours due to reignition risk.
  - Conduct a root-cause analysis and update safety plans.

Documentation & Chain of Custody

- Meticulous record-keeping is crucial for compliance and liability.
- Maintain a complete log for every DDR battery from receipt to final disposition.
- Record:
    - Intake information and photos.
    - Triage and risk assessment results.
    - Discharge data (method, duration, final voltage).
    - Shipping papers for final disposition.

FUTURE OF DDR

Emerging Technologies & Continuous Improvement

- Emerging Diagnostics:
  - AI and Physics-Informed Neural Networks (PINN) to predict internal battery state.
  - Advanced Imaging (X-ray CT) to visualize internal damage non-destructively.
- Continuous Improvement:
  - Stay current by participating in industry groups (NAATBatt, SAE).
  - Subscribe to safety advisories from PHMSA, CPSC, etc.
  - Analyze lessons learned from real-world incidents to refine your own practices.

Key Pillars & Forward Vision

- Safe DDR management rests on four key pillars:
  1. Proactive Risk Assessment: Triage and quarantine.
  2. Engineered Safety: Using the right tools, like electronic dischargers.
  3. Rigorous Training: Investing in qualified personnel.
  4. Emergency Preparedness: Planning and collaborating with first responders.
- Outcome: Adhering to these practices protects workers, prevents catastrophic losses, and builds the public and regulatory confidence needed for a sustainable, circular battery economy.

Q&A