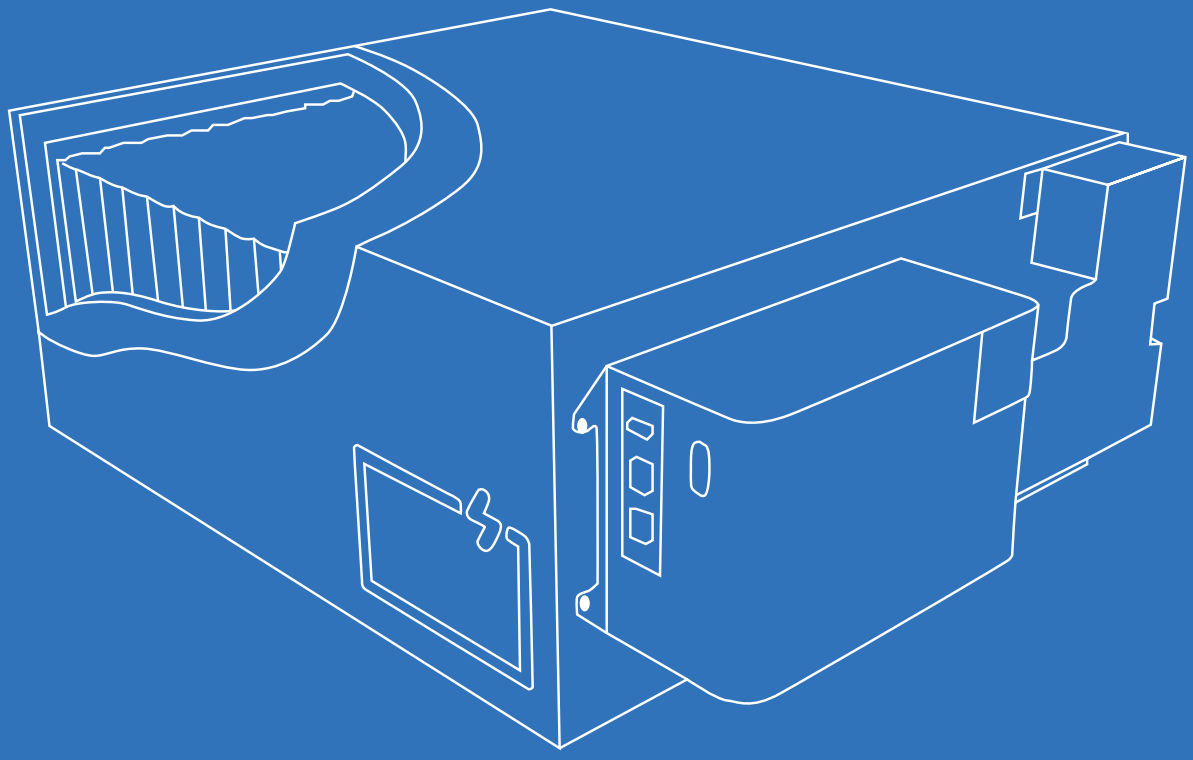
GE Transportation

Energy Storage

Durathon* Battery

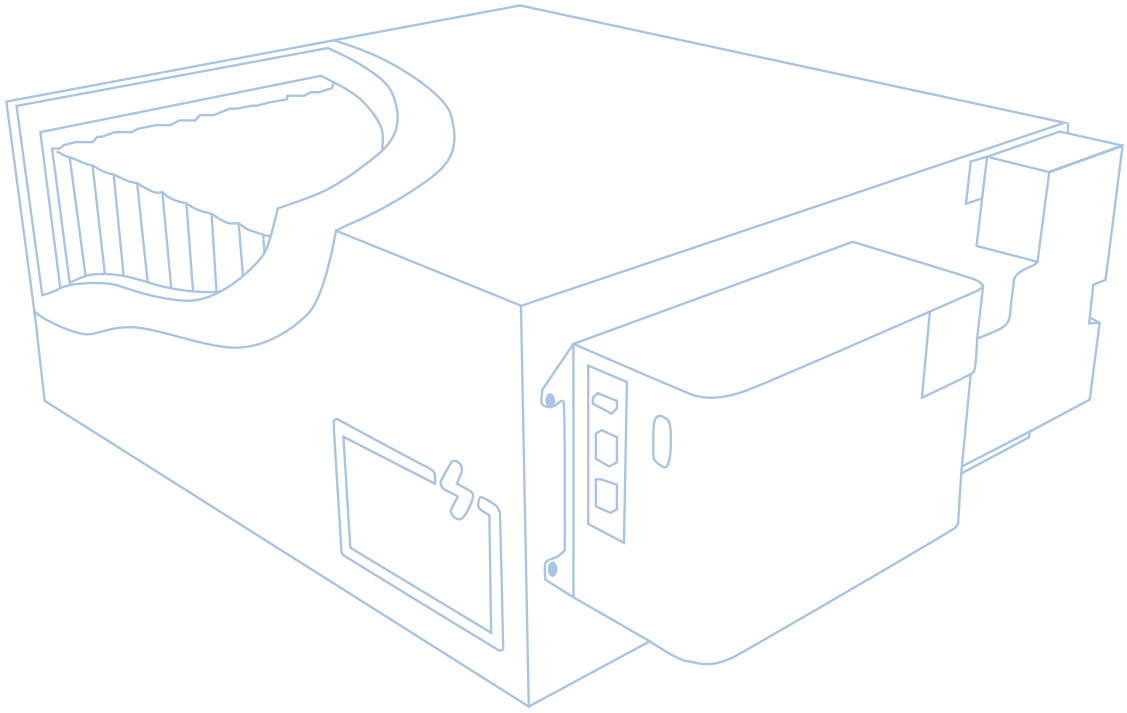
SAFETY BRIEF



imagination at work

GE's Durathon Battery

is a high-temperature industrial battery engineered to meet a growing need for safe, high-performance energy storage in both stationary and mobile applications.



Summary

Durathon Battery technology features a non-toxic, temperature-stable, hermetically sealed nickel salt chemistry. This brief explains how the Durathon Battery's inherent safety features significantly reduce the impact of or avoid failure modes common to high-temperature industrial batteries and how its control system strategy increases reliability and ensures high operational availability.

Industrial Battery Failure Modes

Failures can occur in even the best-engineered batteries due to abuse, damage and other external factors. GE chose a nickel salt electrochemistry for the Durathon Battery because of its inherent safe response to known battery failure modes, including:

- Toxicity
- Electrolyte breakage
- Overcharge
- Overtemperature
- Mechanical damage

Toxicity

Durathon Batteries contain sodium, sodium chloride (common salt), nickel, nickel chloride, ceramic and trace amounts of other metal halides. It contains no toxic substances and is >99% recyclable.

Electrolyte Breakage

All batteries need an ion-conducting, electrically insulating barrier called an electrolyte to store and discharge electrical energy. In industrial batteries the electrolyte may be solid, for example a polymer or a ceramic, or it may be an aqueous solution contained by separating diaphragms. If this barrier breaks due to operating stresses or physical abuse, a hazardous energy release can occur. In many of today's industrial batteries a hole in the barrier may create a short circuit, generating heat and igniting flammable elements in the battery such as lithium or sulfur. A battery fire can be a catastrophic event, destroying not only the battery but surrounding equipment as well.

Durathon Batteries are different. They are not susceptible to fires because the sodium, nickel salts and other electrode components are not flammable.

In the event of a break in the ceramic electrolyte, the cell is specially engineered to contain the cell content within a welded, hermetically sealed steel cell case. The main risk for a nickel salt battery following an electrolyte break is that corrosive materials from inside the ceramic tube may, at high enough temperatures, corrode through the metal cell case. This could damage neighboring cells in the battery and potentially breach the battery skin. The Durathon Battery's cell design developed at GE's Global Research Center avoids the case corrosion problem by incorporating internal features that dissipate heat and electrical energy. As a result, the material exiting the broken ceramic tube reacts and becomes inert without damaging the cell case. Sodium in the broken cell then becomes an electrical short — permitting the battery to continue to function with its remaining cells, at reduced capacity.

Overcharge

Batteries store energy by moving ions across an electrolyte in response to an electrical charging potential. If the charging potential continues to be applied after all the available ions have been moved, additional reactions may take place which overcharge the battery.

Different battery technologies respond to overcharge in different ways. Liquid electrolyte cells such as lead-acid batteries produce flammable hydrogen by electrolysis. Other batteries can experience a thermal runaway as unwanted oxidation reactions generate heat and pressure within the cells.

The Durathon Battery's chemistry is inherently overcharge-resistant. As it charges, the cathode chemistry acidifies, raising the open-circuit voltage of the battery until it matches the charging potential. Once these two voltages are balanced, current can no longer flow into the battery and charging stops automatically. The battery will stabilize at full charge when the correct charging voltage is applied; the only way to overcharge a Durathon Battery is to apply a charging voltage in excess of the design maximum.

The Durathon Battery's cell is designed to tolerate an overcharge beyond rated capacity. Its design includes features to minimize internal gas pressures and prevent a breach in the welded steel cell case. If a Durathon Battery cell is overcharged to failure the ceramic electrolyte will experience a condition as described in the "Electrolyte Breakage" section.

Overtemperature

While internal battery temperatures can reach up to 350°C, the outer skin of the Durathon Battery stays at no more than 10°C above ambient temperature thanks to a double-walled, vacuum-insulated enclosure. In the event of a vacuum loss, for example due to a puncture in the outer case, the skin temperature will rise. In most ambient conditions the remaining insulation will keep the maximum outer temperature below 60°C, preventing it from becoming a touch hazard. Potential hot surfaces on the battery are clearly marked.

Excessive temperatures, whether because of a battery fault or external conditions, can cause serious problems for industrial batteries. Some batteries contain substances that boil at less than 100°C above the battery's normal operating temperature range. In these systems an electrical fault or physical damage can cause enough of a temperature rise to boil the cell materials, resulting in pressures that can breach cell containment.

The Durathon Battery's nickel salt chemistry does not develop significant vapor pressure until approximately 800°C, 450°C above the maximum normal battery operating temperature. Durathon Batteries have passed fire immersion tests to confirm safe overtemperature performance even in a catastrophic situation.

Physical Abuse

The Durathon Battery has many layers of protection which resist physical abuse. The outer case is a double-walled, welded steel enclosure. Inside, the cells are packed in double-thick mica insulation which supports the cells and prevents electrical shorting. Each cell case is drawn from a single piece of steel, eliminating fabrication welds. The cells rest on a corrugated steel sump designed to contain spilled reactants within the battery enclosure in the unlikely event of a cell breach.

If all three physical layers of protection are breached, metallic sodium could be exposed. Sodium is highly reactive and if exposed to water it may burn violently. A sodium fire can be extinguished with a dry compound such as soda ash, salt, sand or a class "D" fire extinguisher.

Preventing Failures: The Battery Management System

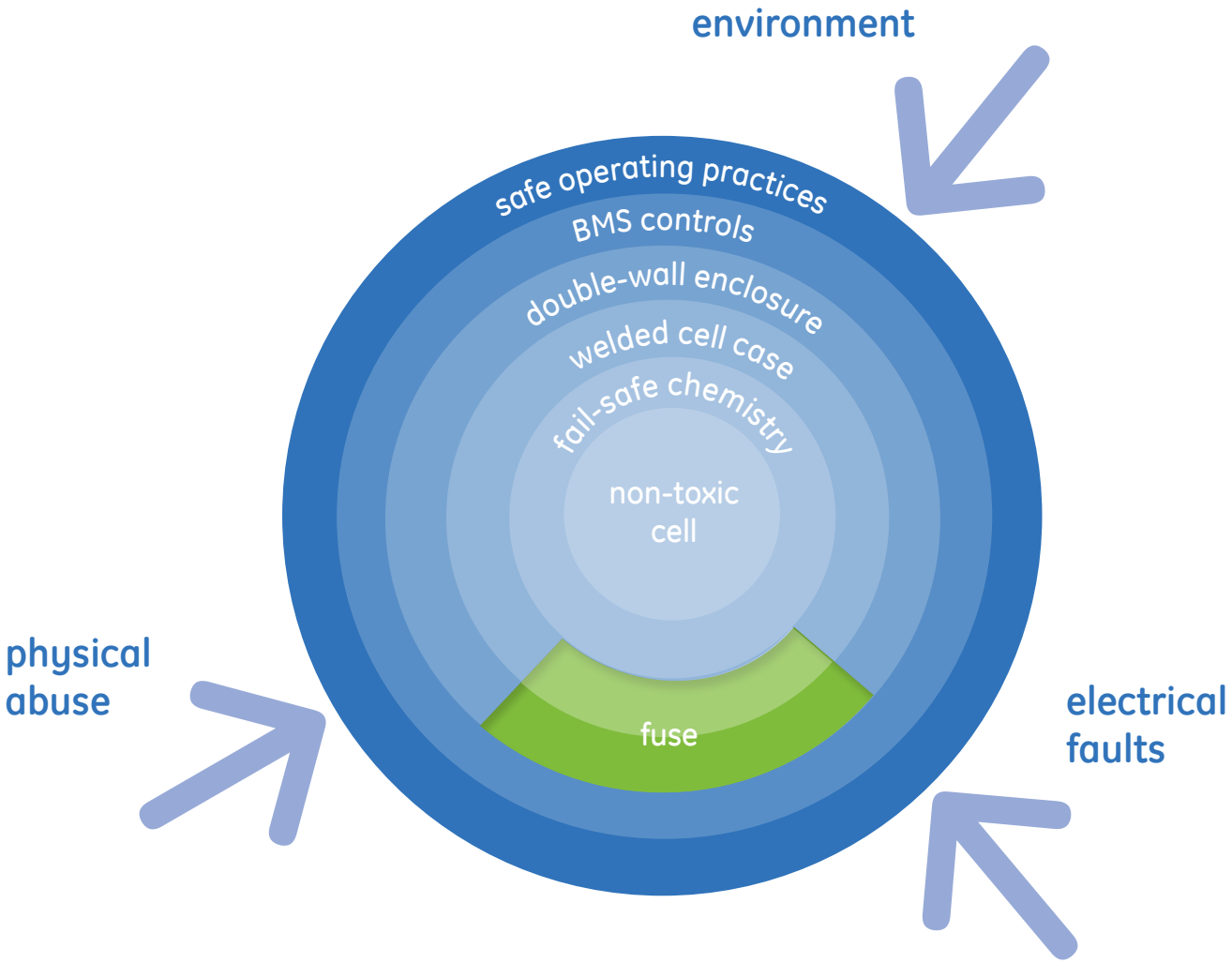
A battery management system (BMS) mounted on each Durathon Battery module protects the battery from conditions that could cause a failure, opening contactors to electrically isolate that battery — and that battery only — for as long as the problem persists. When conditions return to normal the battery reconnects automatically.

Protective Event	Response
Over Current	Disconnect, then reclose when current is within safe operating range
Over/Under Voltage	Disconnect, then reclose when voltage is back within range
Over/Under Temperature	Disconnect, then reclose when battery temperature is within range
Over Maximum State of Charge	Disconnect, then reclose on discharge command
Below Minimum State of Charge	Disconnect, then reclose on recharge command
Heater Stuck "On"	Log fault, disconnect, no reclosure until fault cleared
Cell Failures	Log fault, disconnect if failures exceed safe limits

The BMS can operate in ambient temperatures from -40°C to +65°C (-40F to +149F) and elevations up to 3,000 meters (9,840 ft). It is IP-20 rated (similar to NEMA-1). It features an isolated communications port and a battery fuse to protect the battery system in case of a contactor failure.

Shipping and Storage

Sodium solidifies at 95°C. Below this temperature the Durathon Battery is completely inert and can be moved or shipped. It can be stored in this state for several years, with no maintenance, without losing its charge or any increase in internal resistance.



Durathon Battery Safety Strategy: Multilayered Protection

The protective controls and inherent safety of the Durathon Battery work together to protect against common industrial battery failure modes.

The first line of defense for any battery is safe operating practices. Batteries should be housed in suitable racks or enclosures using recommended safe handling methods. Charging equipment must operate at the correct voltage and include overcurrent protection.

If safe operating limits are exceeded, each battery module's BMS will open its contactors to electrically isolate that module from the rest of the system. The BMS continues to sense operating conditions and will return the battery to service when conditions warrant.

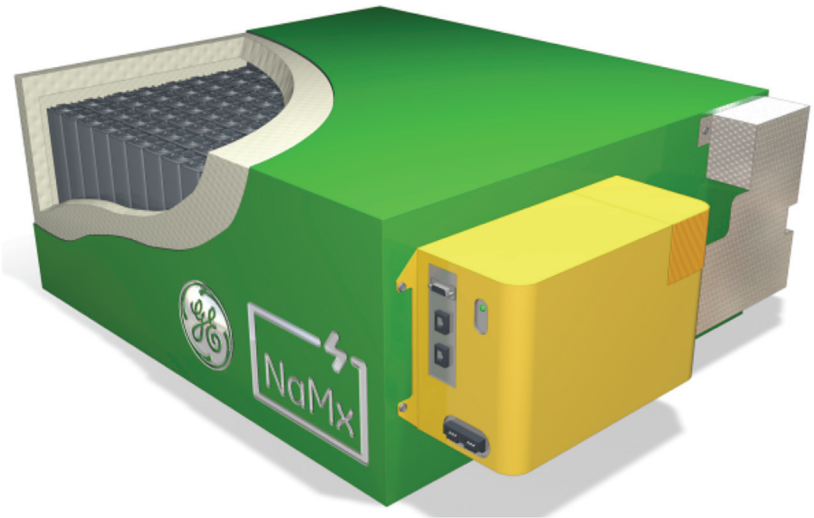
In the event of a controls failure the contactors open safely. If excessive current welds the contactors closed, a battery module fuse (either internally mounted in the BMS or incorporated in the module disconnect switch) protects the cells from overcurrent.

Even if a failure mode bypasses all of these controls, the Durathon Battery's chemistry limits hazardous conditions. Multiple layers of physical protection — a double-walled steel case and hermetically welded cells — shield the active cell components from damage and contain cell failures within the battery module. Finally, all cell materials are non-toxic and can be recycled at the end of the battery's service life.

Appendix: Compliance to Industrial Standards and Regulations

The Durathon Battery is designed to meet or exceed all required industrial and regulatory criteria. For additional details, please refer to each respective organization's publications.

- Underwriters Laboratory (UL) - standard 1973
- IEEE - Guide 1679.2
- NEC - comply to article 480 for storage batteries
- Selective insurance company compliance requirements
- Telcordia - NEBS certified to level 3(NEBS) certified to level 3
- CE Marking – low voltage, EMC, and pressure equipment directives
- FCC, CISPR, NEBS EMC – comply to each criteria
- ISTA – 2B certified
- GE Internal Ecomagination – corporate criteria



Physical Tests Conducted

The following tests have been completed to meet the Industrial Standards and Regulations as documented in each organization's criteria.

NEBS Level 3

- Temperature, humidity and altitude
- Fire resistance
- Handling shock
- Earthquake, office vibration and transportation vibration
- Airborne contaminants
- Acoustic noise and illumination
- Electrostatic discharge and EFT (electrical fast transients)
- Electromagnetic Interference
- Lightning and AC power fault
- Electrical safety
- Bonding and grounding

ISTA

- Atmospheric conditioning
- Compression to 4x shipping weight (about 900 kg)
- Vibration to 25mm peak
- Drop shipping package flat from 6 inches (~152 mm)
- Rotational edge drop from 8 inches (~203 mm)
- Vibration to 25mm peak

UL -1973

- Overcharge
- Short circuit
- Forced discharge
- Temperature
- Dielectric
- Insulation resistance
- Abnormal operation
- Crush
- Impact
- Rod Static
- Resistance to moisture
- 10 Newton force
- Fire exposure
- IEC 61000-6-2 (Immunity)
- IEC 61000-6-4 (Emissions)
- Short circuit
- Abnormal charge
- Shock
- Vibration
- Heating
- Temperature cycling

GE Packaging and Shipping Criteria

- Side impact on 10% incline at 5.75 ft/second (1.75m/sec)
- Bottom impact from 8 inches (~203 mm)
- Rotational edge drop from 10 inches (~254 mm)
- Bottom impact from 1.2 meters (results in no hazards)
- 72 hours at -29°C, 72 hours at 38°C/85% RH, 6 hours at 60°C/30% RH
- Negative pressure (15,250 meters altitude) for 24 hours
- 24 hours vibration for each mode of transportation, Truck, Rail, Air, ISTA2B
- Compression of 3 meter stack for 28 days at ≥40°C

EMC Criteria

- FCC Class A
- CISPR 11 Class B
- NEBS Level 3
- IEC 61000-4-2 – ESD to 15kV (Air), 8kV (Contact)
- IEC 61000-4-3 – radiated Immunity (3v/m)
- IEC 61000-4-4 – EFT
- IEC 61000-4-5 – surge Immunity to 4kV
- IEC 61000-4-6 – conducted Immunity
- IEEE C62.41 – surge Immunity to 4kV, 100kHz ring wave and combination wave

For more information,
visit our website at geenergystorage.com.

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