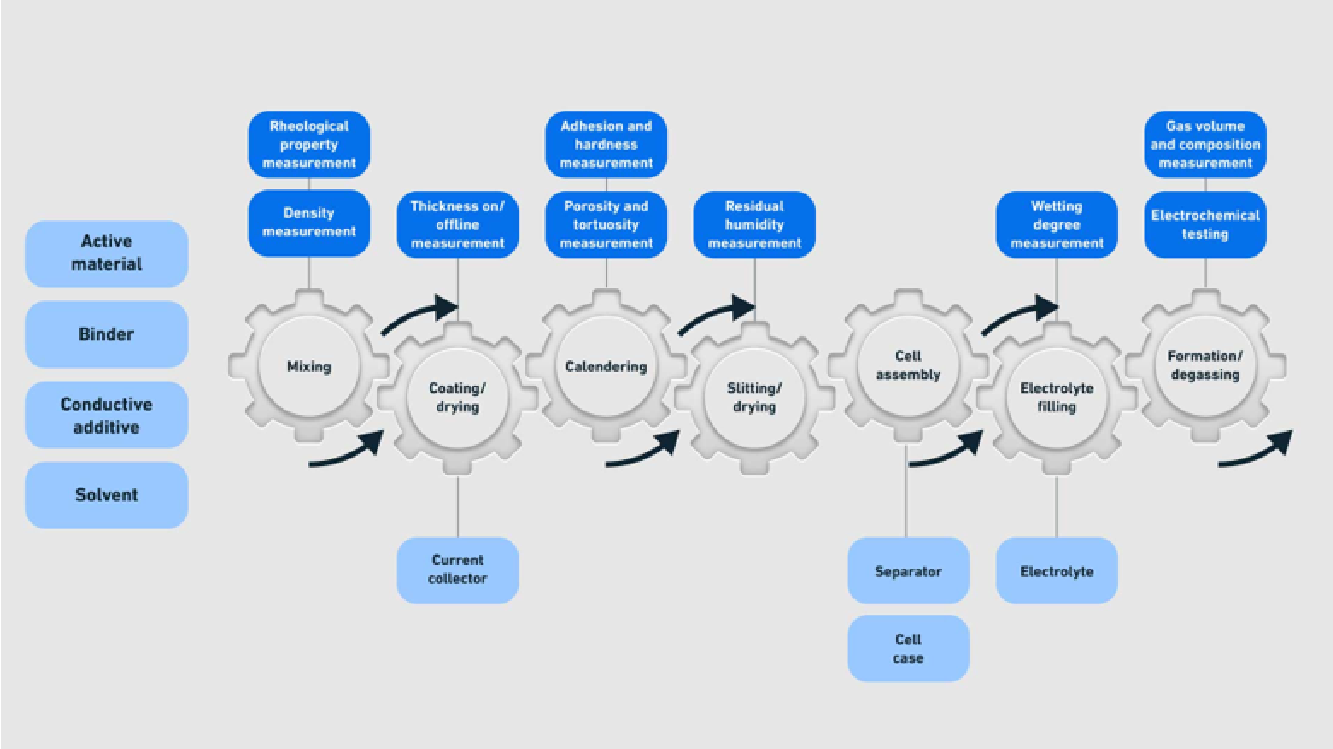
Safety Bulletin
Battery Safety

NEBULA SAFETY & ENVIRONMENTAL

Battery Manufacturing Safety Considerations

Battery manufacturing involves the handling of flammable solvents, reactive materials, fine powders, corrosive electrolytes, and high stored electrical energy. Many battery technologies rely on manufacturing steps such as anode and cathode slurry preparation, coating, drying, electrolyte handling, and formation that closely resemble traditional chemical processing operations. While not all battery manufacturing facilities are formally covered under OSHA's Process Safety Management (PSM) standard (29 CFR 1910.119), the hazards present are consistent with those the standard was designed to address.

Figure 1: Representative Battery Manufacturing Process Overview



Industry experience has shown that battery manufacturing incidents can result in fires, explosions, toxic gas/dust releases, and significant facility damage. These events are frequently driven by abnormal but credible conditions rather than routine operation, highlighting the importance of systematic hazard identification and evaluation.

In This Issue

This Safety Bulletin provides an overview of battery safety and the importance of conducting a safety review to evaluate hazards and mitigate risk.

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Battery Manufacturing Process Hazards
Battery manufacturing hazards are present throughout multiple stages of production. During electrode manufacturing, solvent-based anode and cathode slurries are mixed, transferred, coated, and dried, often at elevated temperatures. Subsequent assembly and formation steps introduce electrical energy and heat generation, increasing both the likelihood and severity of failure.

Failures in upstream manufacturing steps may not immediately manifest but can propagate into downstream operations, where the presence of electrical energy, confinement, and dense cell arrangements can significantly escalate consequences.

Anode and Cathode Slurry Manufacturing Hazards

Anode and cathode slurries typically consist of active material powders, binders, conductive additives, and liquid solvents. Slurry preparation systems include agitated vessels, pumps, transfer piping, coating equipment, drying ovens, and exhaust ventilation systems. These operations introduce several credible hazards that are well suited for evaluation using Process Hazard Analysis (PHA) techniques.

Potential PHA-identified hazards include:
- Accumulation of flammable/toxic solvent vapors due to ventilation or exhaust failure
- Static discharge during slurry transfer or coating operations
- Ignition of solvent vapors in coating or drying equipment
- Combustible dust hazards from dried electrode materials
- Loss of temperature control in drying ovens
- Loss of containment of toxic additive solids

Formation, Testing, and Electrical Hazards

Formation and testing steps introduce electrical energy to newly assembled cells. In certain battery technologies, including lithium-ion systems, abnormal charging or testing conditions can result in overheating, gas generation, internal short circuits, or cell failure.

Potential PHA-identified hazards include:
- Cell overheating and initiation of thermal runaway
- Propagation of failure to adjacent cells or equipment
- Generation of flammable or toxic gases under abnormal conditions
- Inadequate ventilation in formation or testing areas
- Electrical faults, unintended current paths, or equipment failures

Multiple industry incidents have involved fires during formation or early testing, where a single cell failure escalated rapidly due to close spacing, insufficient thermal isolation, or delayed detection.

Thermal Runaway and Escalation Potential

Thermal runaway represents one of the most severe hazards in battery manufacturing, particularly for high-energy battery chemistries. Once initiated, thermal runaway can produce intense heat, flammable gases, and toxic decomposition products, potentially overwhelming ventilation, fire detection, and suppression systems.

Recent manufacturing incidents, including large-loss fires at battery production facilities, have demonstrated how rapidly thermal events can escalate when cells are densely packed or when failures propagate between process stages.

PHAs are particularly effective at identifying:

- Credible initiating events for thermal runaway
- Escalation pathways between cells, racks, and process equipment
- Dependencies on ventilation, cooling, power, and control systems
- Limitations of passive and active safeguards during abnormal conditions

Figure 2: Thermal Runaway and Propagation

Manufacturing Quality and Latent Defect Risks

Many battery manufacturing incidents are ultimately traced back to latent defects introduced earlier in the process. Contamination, inconsistent bonding or welding, mechanical damage, or process variability may not be detected immediately but can contribute to failure during formation or later stages.

Potential PHA-identified risks include:

- Introduction of defective cells into high-energy processes
- Limited inspection capability for critical defects
- Single-point failures in quality or control systems
- Poor traceability of materials or process conditions

Evaluating how quality-related failures interact with thermal and electrical hazards is a key strength of structured PHA methodologies.

The Role of PHAs in Battery Manufacturing

While PHAs are not explicitly required by regulation for many battery manufacturing operations, they provide a structured framework for identifying and evaluating high-consequence hazards that may not be fully addressed by prescriptive codes or equipment standards alone.

PHAs add value by:

• Evaluating abnormal but foreseeable operating conditions and associated hazards
• Identifying interactions between chemical, thermal, mechanical, and electrical systems
• Assessing loss-of-utility scenarios such as ventilation, cooling, or power failures
• Identifying escalation pathways and safeguard dependencies
• Supporting defensible, risk-based decision making
• Demonstrating alignment with recognized and generally accepted good engineering practices (RAGAGEP)

Applicable Codes, Standards, and Guidance

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Occupational Safety and Process Safety

• OSHA 29 CFR 1910.119 – Process Safety Management of Highly Hazardous Chemicals
• OSHA 29 CFR 1910 Subpart H – Hazardous Materials
• OSHA 29 CFR 1910 Subpart S – Electrical Safety
• OSHA 29 CFR 1910 Subpart Z – Toxic and Hazardous Substances

Fire and Explosion Protection

• NFPA 30 – Flammable and Combustible Liquids Code
• NFPA 68 – Explosion Protection by Deflagration Venting
• NFPA 69 – Explosion Prevention Systems

E**lectrical and Equipment Safety**

• NFPA 70 (NEC) – National Electrical Code
• UL 1642 – Lithium Cell Safety
• UL 1973 – Battery Systems Safety
• UL 9540 / UL 9540A – Battery System Safety and Thermal Runaway Testing

Ventilation and Industrial Hygiene

• ACGIH Industrial Ventilation Manual

P**rocess Safety Guidance**

• CCPS Guidelines for Hazard Evaluation Procedures
• CCPS Guidelines for Risk Based Process Safety

While these standards provide important requirements and guidance, they do not replace the need for facility-specific hazard evaluation.

Why PHAs Should Be Strongly Considered

The absence of a legal requirement does not eliminate risk. Battery manufacturing has demonstrated the potential for high-severity incidents driven by abnormal but foreseeable conditions, including thermal runaway, fire propagation, and toxic gas release.

For battery manufacturing facilities—particularly those involving solvent-based slurry systems, coating and drying operations, and high-energy formation steps—PHAs should be strongly considered as part of a comprehensive approach to process safety. Applying PHA rigor helps organizations proactively identify vulnerabilities, evaluate safeguards, and reduce the likelihood of fires, explosions, and production-impacting events.

References:

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Nebula Safety and Environmental is experienced facilitating and supporting PHAs. Please reach-out to the Nebula Safety and Environmental Team at NebulaSafety.com for additional information.