In Partnership between

BELAY ENERGY SOLUTIONS, LLC & DEFEND THE ZERO, LLC

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Hidden BESS Exceptions: Know the Differences and Earn Trust

BESS Fire Testing, Systems Engineering, and Whole-System Quality Assurance and Managing the Strategic Exceptions

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Authors: Beth Schroeder (Belay Energy Solutions, LLC), John Schoeb (Defend the Zero, LLC)

Support from: Andy Laib, Carter Wilding-White

Executive Summary

Reading time is about 20 minutes. Much of this document contains reference materials and appendices.

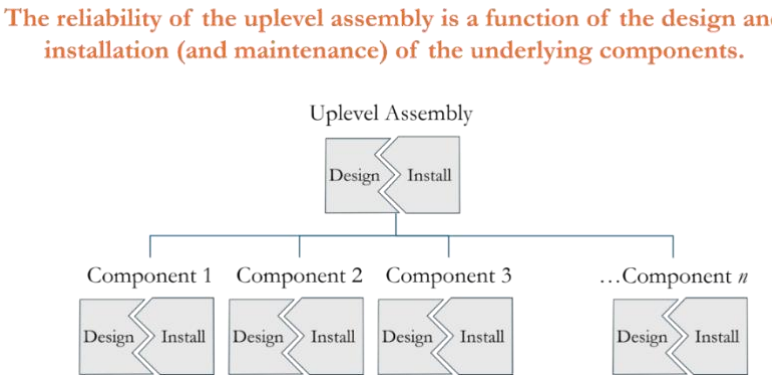
Ask an owner, an EPC, or a code official what it means to "inspect a BESS," and most will picture someone opening an enclosure door and looking at the battery racks. Merely opening the door tells an incomplete story and is costing our industry dearly in delayed schedules, broken insurance contracts, and safety-margin failures. Many assume the battery enclosure is the one component on a site that arrives already engineered, factory-tested, and certified. The BESS is not certified. It is not a listed appliance. UL 9540 is a system-level listing, and some of the system isn't even in the enclosure. Often, the UL 9540 listing does not cover all aspects of the enclosure; examples are seismic or environmental ratings, and depending on the country of origin, there may be an issue with NEC code. Many of the serious problems we are finding in the field are in the enclosure. To compound this, the remainder of the site - the civil work, the AC electrical system, the torque on every mechanical and electrical connection, the metering, and the protection and life-safety systems - is built by hand in the field, under schedule pressure. This haste often leads to defects.

This white paper states that good designs, installation, and maintenance directly affect the most dangerous system-level hazards. Defend The Zero, LLC has created extensive tools to actively find hidden issues and fix defects before they become problems. In a world of moratoriums, complex codes, and tight schedules, it's more important than ever to accelerate our industry's focus on design quality, craft, and execution excellence.

Part One — Strategic Exceptions. We use Fire Testing as an example to explain why a report exception, while never ideal, could be warranted in our rapidly growing battery industry. Full compliance with standards is always best. However, new technology may occasionally outpace our standards. Compliance to an existing standard should not make a new technology less safe. We explore how UL 1973 and UL 9540A answer two different questions about module thermal propagation. UL 1973 tests what happens when one cell goes into thermal runaway. UL 9540A tests what happens when a cell within a module propagates to an adjacent cell. Both tests are critical and cannot be skipped as they teach us how systems respond to some of the most common failure modes. UL 9540A module test procedure can make module designs *less* resistant to thermal runaway. This happens when an OEM removes insulating materials per the heating-initiating procedures/notes. The UL 9540A module testing should not be skipped as it is a critical input to understanding Large Scale Fire Test (LSFT) behavior when a module is overwhelmed. Instead, we explore an exception: altering the UL 9540A module test ignition method to match the LSFT initiation method, rather than making the module and system inherently less safe and adding erroneous data collection to satisfy a checkbox.

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Part Two — Hidden Exceptions. An exception is never ideal and pure compliance and certification must be the goal. Sometimes during a permitting process, things can get missed, skipped or become regionally nuanced. We make the case that teams must actively uncover and address any hidden exceptions as early as possible. We walk through what a whole-system BESS quality assurance program actually covers: five field best-practice disciplines and a comprehensive thirty-page field inspection library. Only three of thirty worksheets touch the battery or inverter unit itself. We focus on the importance of factory testing being right. Factory testing must find and detect meaningful hazards before equipment ever reaches site, the jurisdictional handoff at close-out, and the documentation gaps that make an insurer decline, refuse to renew, or attach unfavorable terms.



Attached are five supporting appendices, developed and used by our teams on active BESS projects:

- **Appendix A — RASIC (RACI) Matrix by Role. We map out a cross-functional plan for high-quality, on-time delivery. No finger-pointing.** *Turns "whose job was this?" into a documented answer before it becomes a dispute.*
- **Appendix B — BESS Insurance Submission Readiness Checklist** with code referenced. *Catches the missing documentation that stalls underwriting before it costs you weeks.*
- **Appendix C — NFPA 855 Permitting Detail Sheet to eliminate some of the most common surprises.** *Flags the code details AHJs actually stop on, before they stop your permit.*
- **Appendix D — ZDP Program Overview & Field Inspection Worksheets. A comprehensive collection of planning activities to ensure your site finds hidden issues.** *Structures the walk-through so hidden issues surface on your schedule, not the AHJ's.*
- **Appendix E — ZDP Field Inspection Worksheets.** The worksheets themselves — dual sign-off, Yes/No/N-A format. *Forces a documented, shared decision on every line item — no ambiguity, no single point of accountability.*

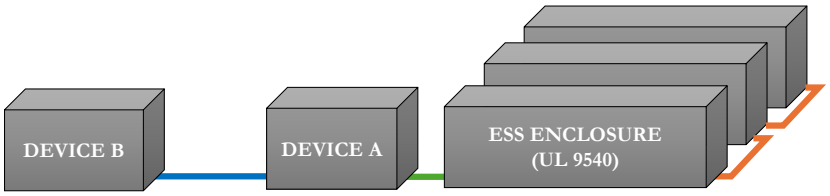
> **The Zero Defect Program (ZDP)**
> ZDP is Defend the Zero's quality assurance framework for battery energy storage system (BESS) construction. It is built around a simple philosophy: Zero Harm, Zero Defects, Zero Failures, and is designed to catch and correct installation issues while work is in progress, rather than relying on a punch list at the end of the project.

The thought-line across every section and every appendix is the same: A project does not lose an insurer, a schedule, or a court case because of a defect. Because of the sheer volume of parts, every large, hand-built system will have some defects. Operators and AHJs lose because, when asked, they cannot prove exactly what was built, tested, verified, and fixed. Conversely, when you execute a comprehensive quality assurance/quality control plan from day one, you can answer these questions with incredible accuracy. In the end, putting a multi-functional accountable plan in place helps

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everyone win. Scared communities feel more reassured, AHJs and insurers see risks being mitigated, and OEMs and operators realize revenue faster.

Site Electrical Systems Require Extra Thought and Attention



Who makes sure these connections were designed correctly?
Installed correctly? Maintained correctly? Who is responsible for a failure?

WARNING: The design experts who understand Device A cables ■ , Device B cables ■ and ESS integration ■ are all different. Also note that an ESS design team may not have considered all local electrical codes and licensing laws (example: fire alarms) in their designs.

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Part One: Exceptions Can Be Strategic and Appropriate

Small Failures and Big Fires: Why BESS Safety Requires Both Tests

Standard fire-safety testing for battery energy storage systems tests individual component failures. What has been identified in the field is multiple components or systems have compounding failures resulting in fires beyond what testing predicted. The LSFT was designed and adopted by the industry to better understand the most catastrophic events and the surrounding environment.

Testing every combination of individual component failures is close to impossible. The math explodes quickly. Engineers often multiply small probabilities together — 1-in-1,000 times 1-in-1,000 equals 1-in-1,000,000 — and round the result down to "ignore." That is a mistake, because the math only holds if the two failures are truly unrelated. In real fires, they usually share a root cause: a badly assembled part, a bad update, poor maintenance. And so they happen together far more often than the math predicts. This is a multi-cause failure, and single-failure testing is not built to test this scenario.

So how do we replicate an event that has so many possible starting failures? We create an extreme event (LSFT) and purposely overwhelm the modules. In doing so, we make sure the extreme event will not cause injury or site propagation. But that alone is not enough. We must ensure known single-failures are statistically unlikely. Why? Because by making the single failures statistically unlikely we also make the top level severe event less likely. Think of a fault tree. The probability of the parent event is based on the probability of the single-failure (child) events below**. A balanced system ensures the 1. single-failure events are statistically unlikely in the design, 2. the top level failure is as benign as possible, and 3. top-level failures are statistically unlikely to occur. *It must be all three*.**

What Avalanche Forecasting Teaches Us About Battery Testing

Avalanche forecasters don't wait for a real avalanche; they trigger a small, controlled slide to learn how the whole slope would behave. Battery testing works the same way: the Large-Scale Fire Test (LSFT) is the deliberate worst-case trigger, and it only means something if the inputs and the component-level characterization were accurate to begin with.

The U.S. Army plans for two scenarios: the Most Likely Course of Action and the Most Dangerous Course of Action. Battery testing works the same way. UL 1973 covers the Most Likely: expected failure modes, including single-cell internal shorts. The 2026 -edition UL 9540A (with section 10 -an intentionally ignited LSFT, in accordance with NFPA 855 and IFC Section 1207) covers the Most Dangerous: true worst-case behavior, carried into a deliberately catastrophic large-scale fire test. UL 1973 confirms the expected hazards are unlikely to cause an issue on their own. UL 9540A ensures the “avalanche” worst case isn’t catastrophic. Both must be verified with behaviors vetted, and an exception skipping testing is ill advised.

Let’s imagine a module designed to limit single-cell propagation. The team has run UL 1973 fire testing at least three times, and no propagation has happened. The module assembly line has a 100% installation check, making assembly errors virtually impossible. With the statistically significant UL 1973 testing and the quality inspection report, it is possible to conclude that single-cell internal shorts are unlikely to propagate inside a module -- a very good thing. But fast-forward to UL 9540A module testing. The same module design now cannot obtain certification. Why? The UL 9540A 8.2.5 (2026) procedure requires multi-cell propagation for compliance. There is a note suggesting the need to remove thermal barrier protection, making the module less likely to stop a thermal runaway event.

Adding to the confusion is UL 9540 Annex B2.10 which recommends insulating cells to prevent cell-to-cell runaway. This is the reality module teams worldwide are facing: do we make the module less safe to pass UL 9540A, or do we stand by our insulated module and UL 1973 results? This is the rare case when an exception might be applied, allowing an alternate initiation method that mimics LSFT behavior and retains module insulation.

We want to reiterate the none of these tests should be overtly skipped. The hazards and statistical probability of single-failure, sub-system (e.g. module) events tie directly to the probability and severity of the uplevel system (e.g. enclosure). Attention must be focused on minimizing the probability and hazards of sub-component and system level responses.

The UL9540a module level test should be rewritten and changed to a pretest for LSFT preparation. If a module has already pass UL1973 then repeating the UL9540a module level test after changing the design to be less safe is a waste of time. Unless an OEM wants to use the results as a marketing tool, the data collected during the 1973 tests and the UL9540a Cell level tests are enough to show nonpropagation and to determine that a LSFT is needed. Therefore, reworking the module level test to conduct a practice test on the module initiation method for the LSFT collects different data and gives testing labs and companies more information to continue forward with confidence. Rarely it may make sense to run research and development tests in the same manner as the currently UL9540a module level test (forcing cell to cell propagation) but the module level test in its current state is a waste of time and money for the majority of the industry.

> ***Happening now:*** *The new version of UL 9540A is being drafted as of this writing and many proposals are being considered. One of which is a new way to account for battery module designs that protect against single-cell thermal runaway. In this proposal, superior module designs that demonstrate protection from single-cell internal short propagation would be permitted to show compliance with CSA C22.2 Number 350. The designs would not be forced to eliminate thermal barriers.*

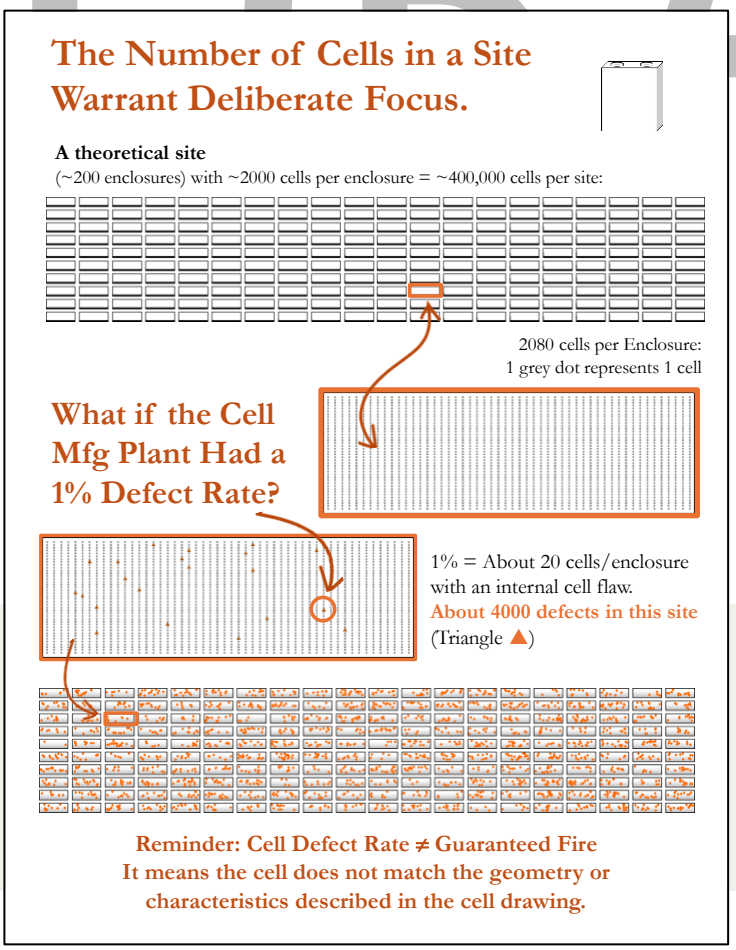
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Focus on High-Hazard, High-Count Parts First

NFPA 855 and the International Fire Code both call out hazards that must be evaluated for reliability and survivability: explosion control, fire (thermal runaway, detection, suppression), and BMS failure. Counting how many of each component sits on a real site makes the risk concrete:

Hazard	General Number per ESS Enclosure	General Number per Site (200 enclosures)
Cell internal shorts and associated vented gases	> 1,000	>> 100,000
Arc flash / electrical connections	> 50	> 10,000
Hose connections / leaks	> 50	> 10,000
BMS / controls failures	~ 5	~ 1,000

Key takeaway: A permitting package is thick and data-heavy. Don't let the volume distract you, instead focus first on the hazards that are both high-risk and high-volume*. Even at a disciplined 1% manufacturing defect rate, a 200-enclosure site with roughly 400,000 cells contains about 4,000 flawed cells. This does not mean the cell flaws are all bad enough to lead to an internal short, but the defect does mean that an internal short is more likely. This is why UL 1973 single-cell internal short propagation testing is critical and cannot rely on a single sample. We must have statistical confidence that a cell short will be limited to one cell and will propagate.*



Note that the 1% figure is a conservative planning assumption for FAT/QA sampling design, not a measured defect rate for any named OEM. Published research on cell-level production reject rates documents pre-shipment reject rates of 5–10%, depending on manufacturer maturity (Ank, Stock, Wassiliadis, et al., "Influence Analysis of Production Defects of Lithium-Ion Cells Using Single-Cell and Multi-Cell Characterization," Journal of Energy Storage, Vol. 62, 2023). Post-QC field-failure rates for internal-short thermal events at large-volume manufacturers have separately been reported in the 1–5 ppm range. The 1% figure falls within that documented range, and the underlying argument — that a single-sample UL 1973 test cannot represent a 100,000+ cell population — holds at any rate above roughly 0.01%.



A Message to the Authorities Having Jurisdiction

Exceptions in battery energy storage only hold up if the technical rigor behind them does. That rigor lives in details our industry too often treats as boilerplate: creepage and clearance distances, cell internal shorts and their ability to propagate. The geotechnical assessment must account for the site's actual earth chemistry rather than a generic soil report, and seismic loading report must be tied to the site's real seismic risk profile rather than a standard assumption. None of that gets waived on faith.

Here's the truth: a documented exception isn't the dangerous part. The exceptions written into a permitting package, backed by data, are the ones doing their job. Strategic, well-supported exceptions that keep communities safe should be celebrated, not treated with suspicion. What causes mayhem in a permitting process are the unwritten exceptions: the ones nobody flagged, nobody justified, and nobody asked you about. Do not let a UL 9540 certificate give you a false sense of security. Actively find the exceptions and missing holes. Ensure every exception to, every exception from and all alternatives to the code as prescribed is explicitly included in submitted documentation and sufficiently justified. Demand exceptions up-front, in full, every time. We believe AHJs should demand nothing less.

In a battery industry still building its safety culture, there's zero room for opinion.

Every claim, every exception, every design decision needs objective, verifiable data behind it. Flag "safer", "better", "worse" as opinions and demand comparable data. That's the only currency that holds up when something goes wrong.

How we get there

The only way to know which exceptions are legitimate, and which are liabilities waiting to surface, is for our battery experts to sit down directly with you. We need to hear what worries you and your community. We need to know the questions your experience has taught you the hard way. That skepticism, earned by veteran fire officials, investigators, and inspectors who have seen what happens when corners get cut, is exactly what keeps this industry honest. So we're asking for a conversation. No slide deck, no sales pitch; just time in your office to talk through the project, the community it sits in, and what about BESS keeps you up at night.

We also know that not every AHJ comes to this with the same runway. Some of you are permitting your first ESS project with no prior playbook to lean on. When that's the case, our job is to show up with facts and clarity so you can make a timely and confident decision for your community; not to make you feel like you're catching up. The goal is not to wind up in extensive litigation and town hall meetings.

Where we land

Some exclusions are strategic and make projects safer. Others are ambiguous, and when they are, we owe you clarification. Our land, our communities, our people, our design, our industry, and our reputation are all on the line. Our goal is simple: design systems that communities and AHJs feel confident deploying. Full stop.

When a permitting package looks intimidating on paper, permitting needs to become a team sport. Let's get together and talk through the facts; the products, the installation, the standards, before assumptions run rampant and incorrect conclusions are formed.

This is our industry and our responsibility. We win through deep, candid collaboration: making energy more available while keeping your community safe.

Part Two: Beyond the Enclosure

Why Whole-System Quality Assurance Is the Real Zero Defect Standard for Battery Energy Storage

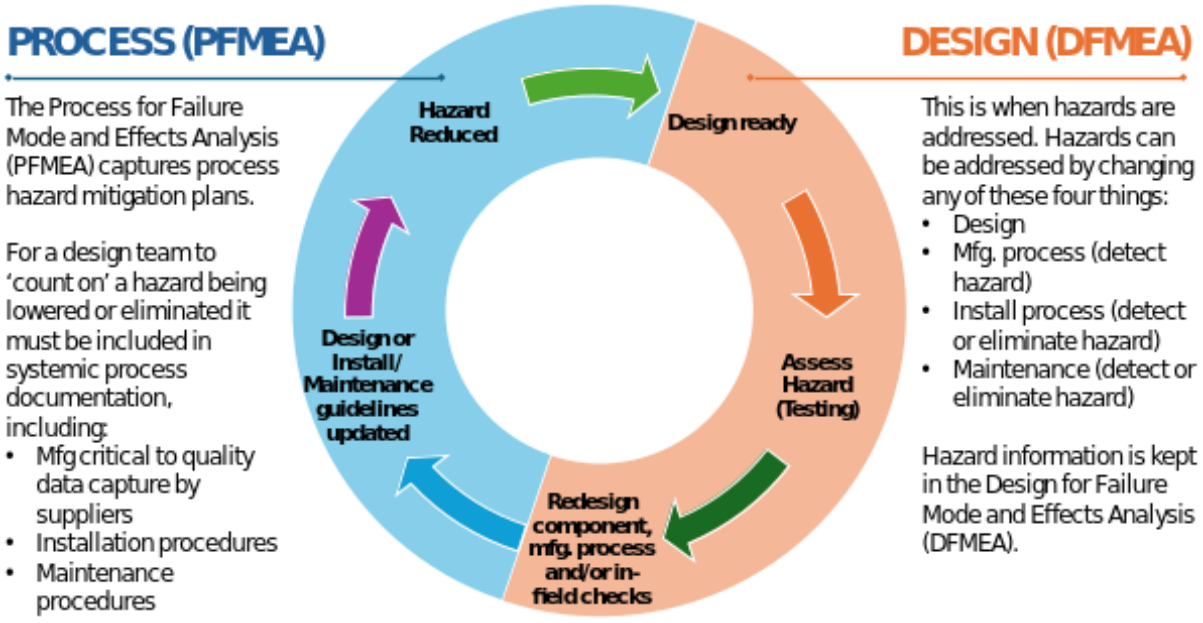
Overview

WHY is this part important? When the fire marshal comes to the site, they look at the BESS enclosure (Or appliance) and whether the documentation aligns with the requirements. They are not looking from the enclosure to the interconnect. Meanwhile, the electrical inspector arrives on site and checks electrical infrastructure and that the BESS (appliance in their mind) is connected. Neither is inspecting the key components that lead to the site's largest risk of electrical failure. EPRI failure-incident data shows that most BESS failures with a known system age occur during construction, commissioning, or within the system's first two years of operation (Srinivasan, Shaw, Billaut, et al., "Insights from EPRI's Battery Energy Storage Systems (BESS) Failure Incident Database: Analysis of Failure Root Cause," EPRI/TWAICE/PNNL, May 2024). At commissioning, assumptions are made. The manufacturer's site technician is assuming that the correct wire and components were installed upstream to the interconnect. Additional assumptions are made that the engineer of record specified the correct wire. The procurement team purchased and sent the correct wire to the site. The electricians installed the wires correctly. All come to find out that the wire size was correct, but the wire was aluminum vs. copper. To the inspector, it all "looks" correct but can yield catastrophic problems. In this section, we'll educate you on a process that catches issues long before the AHJ's come to site. This process mitigates harm, defects, and failure by identifying items that can halt a project downstream, reducing or eliminating the cost of rework, repair, and replacement.

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A design team engineers a product and identifies hazards. They then must change the design or ensure that the design arriving on site cannot have these failures. But what if that message doesn't make it to the factory or the folks installing the site? What if the critical component they were concerned about is never checked on or maintained?

Systems engineering is one of the hardest things to get right, especially across disciplines. A designer builds in clearance to prevent arcing — but does the installer know a wire routed too close could cause arcing later? **To lower a hazard, the fix must go into the design documents (DFMEA) or process documents (PFMEA). If it isn't written down, it doesn't count.**



Safety is a team sport, and it only takes one player to make an honest mistake. The projects that get this right are the ones where the testing lab, the AHJ, installers, equipment makers, and technical experts all work together. The ones that don't, end up with an incident, code violations, voided insurance, and a community with nobody to hold accountable.

A checklist that assigns a named, responsible party to every gap—adjusted to the specifics of a given system—is a strong starting point, but the Hazard Mitigation Analysis, DFMEA/PFMEA, and fault tree analysis matter most. Periodically re-checking a random sample of ESS containers against the original design and code intentions- not every unit, but the top 20 to 30 items across the site- catches problems long before they become real ones.

> **See Appendix A — RASIC Matrix by Role:** *the role-by-role Responsible / Accountable / Supporting / Consulted / Informed matrix that puts a named party against every gap referenced above.*

A BESS arrives on site as an engineered, factory-tested product. What is built by hand in the field, under time pressure, by a rotating crew of subcontractors is everything around the enclosure: the civil work it sits on, the AC electrical system, the torque on every connection, the metering, and the and life-safety systems. That is where most installation defects happen.

> *UL 9540 certification verifies that the design did not demonstrate hazards in lab testing during the brief time it was tested. This certification can create a false sense of security, as quality control, installation, and local electrical code design issues can quietly build up and lead to real site failures.*

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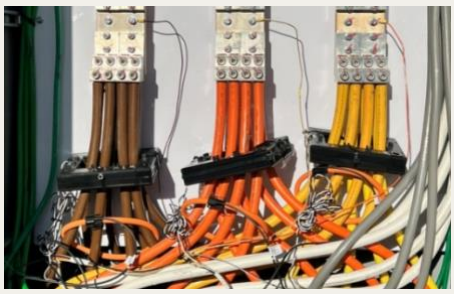
This section walks through a real-world, whole-system BESS QA/QC program—five best-practice disciplines and a 30-worksheet field inspection library—reflecting the diligence needed to find and mitigate potential hazards, including a staged, gate-by-gate review process and a three-layer assurance approach: technical, regulatory, and social.The Enclosure Myth

The enclosure is the most visible, most marketed, most heavily engineered single component on the site. But a BESS often doesn't fail because of the factory-built. It fails because of what happens after it lands on site: an unverified torque value, a conduit clearance conflict, an undersized or untested grounding conductor, a **current transformer (CT)** wired out of phase, a fire-detection system commissioned on paper but never tested. Each of these is a balance-of-plant item, installed by hand by a crew that did not build the battery.

A **CT stands for Current Transformer**. It is an electrical device used to measure alternating current (AC). It works by wrapping around a primary high-current conductor (such as a heavy battery cable or busbar) and producing a proportional, much lower current in its secondary wiring. This smaller current can then be safely monitored by meters, protection relays, and control systems.

In a Battery Energy Storage System (BESS), CTs are critical for accurately tracking how much power is flowing into or out of the batteries.

If a CT happens to be wired out of phase (meaning its polarities or phases are swapped during site installation), the control system receives incorrect data. It might think the battery is discharging when it is actually charging, leading to critical system errors, improper balancing, or catastrophic electrical faults.



Example of CT's in an electrical enclosure

These defects also surface on a delay — a bad bus connection does not fail the day it is torqued down; it fails after months of thermal cycling; a grounding deficiency shows up as a nuisance trip during the first heavy rain. And then the crew that installed it is gone. By the time an enclosure-only inspection would notice most of these problems, the schedule room to fix them inexpensively is gone too.

> *The battery enclosure is the one thing on a BESS site that arrives already inspected. Everything else is inspected on-site and has not had an annual follow-up operations and maintenance inspection. And in some cases, the new electrical design (possible hidden exceptions), specific to that region, has never been tested – not once.*

How a Program Prioritizes: Assume It's a Problem Until Proven Otherwise

A **mature engineering program** starts with a tougher assumption: any component that is both high-hazard and present in large numbers must be presumed a problem until the project proves otherwise through actual lab and site testing, not a data sheet. Three categories, more than any other, have had multiple industry failures and are highlighted in many of the real-world failures that have occurred:

- **Cells and thermal propagation**
- **Hose connections**
- **Electrical connections**

> *The question is not whether a connection, a hose, or a cell might fail. It is whether the project can prove, in writing, through a documented inspection process, that it won't.*

> A **mature engineering program** operates on the principle that high-hazard components present in large numbers must be presumed problematic until proven safe through actual laboratory and site testing rather than relying on manufacturer data sheets. The framework mandates assigning a single, named owner with specific written deliverables, such as hazard mitigation, permitting, and electrical integration checklists, for high-risk categories, including cells and thermal propagation, hose connections, and electrical connections.

Each of these work streams needs a single, named owner. Do this before schedule and budget pressure make the assignment political. Back the assignment with a specific deliverable, not a verbal commitment: a hazard-mitigation and permitting checklist, an electrical integration checklist scaled to the actual joint count, and a change-management process to track design or installation decisions that change mid-project. If the parts showing up at the site don’t match the numbers on the test reports, which can happen more frequently than one would expect, there needs to be scrutiny and action.

> **See Appendix A — RASIC Matrix by Role:** *the named-owner assignments behind each work stream, including FAT protocol development, NCR escalation, and engineering review of ambiguous field conditions.*

Where the Codes Actually Apply

Confusion starts with which certification answers which question:

- **UL 9540A** — large-scale fire test (LSFT); characterizes thermal runaway propagation in an extreme event and off-gas hazard; informs separation distances and explosion protection. This is also where we learn about cell and module behaviors (off-gassing, temperatures and heat release rates)
- **UL 1973** — the stationary battery system standard; governs cell- and module-level construction and propagation mitigation from a single-cell internal short, the most common battery failure
- **UL 9540** — overall safety standard for the assembled system, distinct from UL 9540A despite the same number.
- **NFPA 855** — the fire code: siting, separation, detection, suppression, and emergency response information. Not an electrical code.
- **NFPA 70 / 70E** — often referred to as the "National Electrical Code (NEC)" — covers electrical installation and the arc-flash and shock protection required to work on it safely.
- **IEEE 1547** — utility interconnection, ride-through, and protection behavior.

Six standards, six different questions. In practice, a single project binder is expected to answer all of them with one certificate. A rigorous program requires three separate things matched to three separate questions: a UL 9540 listing, a UL 9540A large-scale test report, and a UL 1973 certificate. Sorted out before energization, not during an investigation.

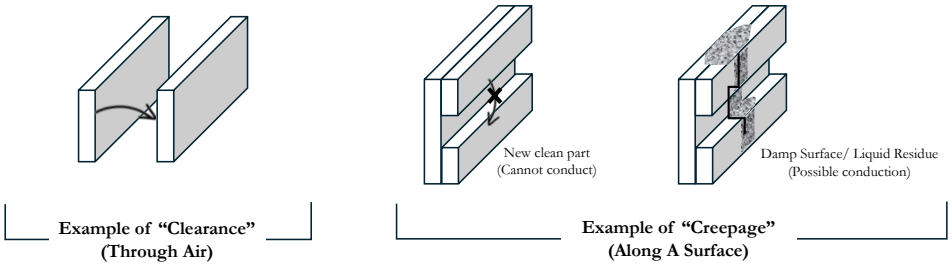
> **See Appendix B — BESS Insurance Submission Readiness Checklist, Section 2:** *a quick-reference map of which code governs which question. Appendix C — NFPA 855 Permitting Detail Sheet is the field-ready form for tracking exactly these UL 9540/9540A distinctions, project by project.*

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Clearance and creepage distances have the same problem. ANSI/UL 840 and its international counterpart IEC 60664-1 are general-purpose insulation-coordination standards; IEC 62477-1 is the standard scoped to BESS power-conversion equipment, with its own clearance and creepage tables and altitude correction factors — the defensible citation for an AHJ submittal, not the general-purpose base standard underneath it.

To make the distinction crystal clear for a broader audience who might not understand the difference between creepage and clearance, we can break it down simply:

- **Clearance** is the shortest distance between two conductive parts through air (like the risk of a spark jumping across a gap).
- **Creepage** is the shortest distance between two conductive parts along the surface of the insulating material (think of it as the risk of a current "crawling" across a dirty or damp circuit board).



Here is a direct comparison of how the general standards differ from specific standards required for a BESS system:

Feature / Metric	General Standards (ANSI/UL 840 / IEC 60664-1)	BESS Specific Standard (IEC 62477-1)
Primary Scope	General-purpose insulation coordination for generic electrical equipment.	Safety requirements for power electronic converter systems and **BESS equipment**.
Altitude Correction	Standard barometric adjustments, often requiring manual calculation or generic multiplier tables.	**Dedicated altitude correction factors** specific to the high-voltage, high-density environments of power converters.
AHJ Submittal Status	**Weak.** Functions as a base reference, but lacks the specific environmental and application context for energy storage.	**Strong & Defensible.** Provides the exact clearance and creepage tables required to prove compliance for energy storage conversion.

Five Disciplines, One Standard

A whole-system program organizes field best practices into five discipline sections, spanning the full project lifecycle and applied alongside engineered drawings, manufacturer manuals, and applicable codes:

- **AC Electrical** — the largest category in the field library: equipment placement, conductor sizing, terminations, and the clearance/creepage distances that decide whether a live component arcs to its neighbor. A connection that tests clean on inspection day can still fail a year later because of residue nobody wiped away or because it went uninspected for a year.
- **Torquing** — the variable most often assumed versus verified. The correct value from the manufacturer's torque table, applied with a calibrated tool, logged by connection ID, not a paint mark that can rub off or be copied.
- **Ground Mount / Civil** — site work, trenching, grading, stormwater control, and the foundation the rest of the system stands on. Grounding conductors must be continuity-tested before backfill, because a deficiency found after the trench is closed requires excavation, not a quick fix.
- **BESS Installation** — adherence to the OEM's installation requirements for the battery and inverter units. The smallest discipline by inspection count, as it is the part of the system that arrives most thoroughly engineered.
- **Metering** — meter and CT installation, phasing verification, and the cabling that the owner, utility, and market operator all depend on. A CT installed with the wrong polarity will not stop the system from running—it will just make every downstream number wrong, silently, for months, which can lead to larger problems.

Many a field engineer has scratched their head in front of a BESS System, trying to figure out why it isn't working, only to find the electrician didn't check the CT's polarity markings to confirm the direction of energy flow and installed it backward. It is an easy fix, but something a robust QA/QC program could have caught long before the cost of rework.

Each discipline closes with a field self-check checklist and explains the underlying code or engineering reason, not just the rule, so a crew can apply the same reasoning to a condition the checklist did not anticipate.

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> **See Appendix D — ZDP Program Overview:** *the full description of each discipline and how it maps to the field inspection worksheet library.*

The QA/QC Inspection Architecture: What Actually Gets Inspected

A representative program uses thirty standardized, discipline-specific worksheets — Yes/No/N-A format, dual sign-off from the subcontractor and an independent field inspector, creating a shared, dated record. Inspection expectations are set before the contract is even priced. A worksheet is never certified against partially completed work, and a second failure on the same item escalates past the field level to a formal corrective action request.

Sorted by category, the 30-worksheet library shows where BESS installation risk is inherently hidden

Category	# Worksheets	Representative Worksheets
Civil, Foundations & Grading	4	Trenching; Equipment Foundation/Pad; Underground Duct Bank/Manhole/Handhole; Grading/Retention Basin
AC Electrical & Switchgear	11	AC Wiring & Conduit; Fused/Non-Fused Disconnects; Main Breakers; Circuit Breaker Panels; Transformers; Switchgear; Mini Power Zone; Recloser Cabinet
Protection, Controls & Instrumentation	5	DAS/Site Controller Cabinets; SEL Relay Cabinet; Transformer Protection Relay; Weather Station Cabinet
Metering	4	Utility Meter Socket; CT Cabinet; Meter Cabinet; PT Cabinet
Site Security & Life Safety	3	Permanent Fencing; FLIR/Standard Camera Systems; Fire Detection/Alarm System
The Battery Unit Itself	3	BESS; BESS with Inverter; BESS Inverter

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> **3 of 30 worksheets inspect the battery or inverter unit itself.**
>
> *Note: Worksheet count reflects inspection scope, not a measured risk weighting on its own; it is corroborated here by root-cause incident data. Of the 26 incidents in EPRI's BESS Failure Incident Database with a determined root cause, only 3 (11%) were attributed directly to the cell/module. At the same time, balance-of-system and controls accounted for the large majority of failed elements (Srinivasan, Shaw, Billaut, et al., "Insights from EPRI's Battery Energy Storage Systems (BESS) Failure Incident Database: Analysis of Failure Root Cause," EPRI/TWAICE/PNNL, May 2024, EPRI Product ID 3002030360).*

Ten percent of the library covers the equipment most people picture when they hear "BESS inspection." The other ninety percent — civil, AC electrical, protection and controls, metering, and life safety — is where a whole-system

program earns its value. AC electrical and switchgear alone account for 11 of the 30 worksheets, more than the battery, metering, and life-safety categories combined.

> **See Appendix D — ZDP Program Overview and Appendix E — ZDP Field Inspection Worksheets** *for the complete, categorized worksheet list and the discipline-specific worksheets themselves.*

The Safety Story Starts Before Mobilization

Every discipline above assumes the equipment that shows up on site is the equipment that was designed, built, and qualified — an assumption only as good as the Factory Acceptance Test (FAT) behind it. It is common to see a production lot represented by a FAT sample size of one, with a bare pass/fail checkbox instead of a traceable record.

The automotive industry solved this decades ago: Advanced Product Quality Planning pairs DFMEA/PFMEA with formal control plans and statistically derived sample sizes. Applied to BESS FAT, that means sizing the sample to the lot — torque and crimp verification warrant 10 to 20% of the lot — documenting which crimp tool and die were used, and retaining the full measurement record rather than a bare pass/fail mark.

FAT and Site Acceptance Testing (SAT) are complementary, not interchangeable — FAT catches what left the factory wrong; SAT catches what happened in transit and installation. A complete record links them, so you can check a field anomaly against what the same unit measured on the factory floor months earlier.

> **See Appendix A — RASIC Matrix by Role:** *the QA Field Inspector and Project Manager are Responsible/Accountable for FAT protocol development and execution.*

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From Inspection to Assurance

Worksheets alone do not make a quality program; the process around them does:

- Inspection expectations are priced into the bid and reviewed at kickoff, before work begins.
- Work is inspected periodically and once a full discipline, or an agreed section of it, is complete.
- A "No" on any worksheet is a logged non-conformance; systemic or safety issues escalate to a formal Non-Conformance Report.
- A field condition that does not clearly pass or fail gets engineering review, not a forced guess.
- Commissioning — functional testing, BMS/EMS/SCADA verification, torque and megger record review, life-safety walkdown — is expected to surface few new issues, because the QA/QC process already caught them. This often yields few to zero punch list items, saving project cost and avoiding delays.
- We retain completed worksheets, photos, and test reports for the life of the asset. We review these records during annual O&M inspections and use them as a benchmark.

This is the same discipline that shows up at the program level as a staged, gate-based review process across three layers of assurance — technical, regulatory, and social. The field worksheets are where that framework meets the ground.

Who's Actually Signing Off

The fire marshal holds authority under NFPA 855; the electrical inspector holds authority under NEC Article 705. In practice, each often defers to the other on anything that straddles the line — clearances, protective device coordination, signage — leaving a project stuck for weeks over whose decision it is, not a genuine disagreement about the work itself.

A commissioning agent and an insurer's loss-control surveyor are effectively asking the same underlying question as an AHJ: was this built the way it was represented? When each party reconstructs that answer independently, the project pays for the same verification multiple times — in schedule, in premium, in staff time.

One fix gaining traction: bring in a qualified, independent third-party inspector early—not a substitute for the AHJ's authority, but a technical resource that walks both offices through the same body of evidence. A small number of states have begun requiring this on BESS projects. The same worksheet and photo record built for a future warranty claim is the evidence an AHJ or insurer needs to sign off with confidence—a program built once that serves every audience that ever needs to ask whether this was built right.

> ***See Appendix A — RASIC Matrix by Role:*** *the Note on Final Sign-Off and the Fire Marshal / Electrical Inspector role sections spell out exactly this split.*

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9. What Makes an Insurer Walk Away — and What Makes a Mistake Expensive

Both questions share the same answer: documentation. Not whether a defect exists — some level of defect is inevitable — but whether the project can prove, on demand, exactly what was built, tested, and verified. The gaps that most often cause a carrier to decline, non-renew, or attach unfavorable terms:

- Certification offered as evidence for the wrong question or hazard
- No factory-to-field chain of custody — a FAT record that cannot be tied to the units installed.
- Missing functional test records for life-safety systems.
- An unresolved prior incident or near-miss with no documented root cause.
- No independent verification behind the installation record.
- A history of moisture-related alarms without documented remediation.

> ***An insurer does not walk away because a project has defects. Every project has defects. An insurer walks away because a project cannot prove which ones were found — and fixed.***

The same gaps turn a small field problem into an expensive one: a systemic error caught on unit three hundred instead of unit three; unverified work covered up before inspection; jurisdictional stalemates at closeout carrying real cost every week; a warranty dispute with no contemporaneous record; and, worst of all, the cost of insuring the next asset in the portfolio once a carrier has seen one claim it could not get a straight answer about.

> **See Appendix B — BESS Insurance Submission Readiness Checklist:** *every gap above maps directly to a checklist item and its governing citation.*

Why the Full Scope Matters

For owners: fewer punch-list items and a complete record to defend a warranty claim years into the asset's life. **For EPCs:** a documented process is protection as much as oversight; a crew inspecting discipline by discipline spends far less on rework than one that finds a repeated problem at final walkthrough. **For AHJs:** a documented, repeatable basis for acceptance. **For insurers:** increasingly, documented evidence of installation quality is becoming underwriting collateral, not just a construction-phase nicety. **For O&M teams:** the as-built record is the baseline every future inspection, retrofit, or permit renewal gets measured against.

Conclusion

Part One and Part Two are the same argument at two different scales. Part One showed why single-failure, pass/fail testing cannot catch the combinations of small problems that cause real BESS fires, and why the industry needs two different tests answering two different questions: UL 1973 for the failures everyone expects, UL 9540A's large-scale fire test for the one nobody thought possible. It highlights that some exceptions may appear intimidating but may be highlighting a superior technology that our standards have not caught up to yet. It also highlights that many exceptions are hidden or missing and a deep focus on high hazard and high volume components and sub-systems is always appropriate.

Part Two showed the same blind spot on the construction site: an enclosure-only inspection catches the one component that already arrived tested and certified, while missing the combination of small field errors — an unverified torque value, a grounding deficiency, a CT wired out of phase — that only shows up months later, after the crew that installed it is gone. A cell test that checks failure modes one at a time and a punch-list walkthrough that checks the finished enclosure are making the same mistake at different points in a project's life: both mistake "this one thing passed" for "the system is safe."

The fix, in both cases, is the same: proof, matched to the right question, carried through in writing. A DFMEA or PFMEA that was never written down does not count, no matter how well the engineer understood the hazard in the moment. A torque value that was never logged by connection ID did not happen, as far as an AHJ, an insurer, or a future O&M team is concerned. The field program described in Part Two — five disciplines, a 30-worksheet inspection library, a documented FAT-to-SAT chain of custody, dual sign-off on every item — is the practical answer to the testing gap identified in Part One: it is what a characterization-based, common-cause-aware standard looks like once it is applied to the ninety percent of a BESS site the factory never touched.

As the asset class matures, the industry's standard for both "tested" and "inspected" is likely to keep moving in the same direction: toward documented, statistically grounded, whole-system records rather than a single certificate, a single large-scale test, or a single walkthrough. Projects that adopt that standard now — in the test lab and in the field — are building the evidentiary track record the entire asset class needs to keep earning the trust of AHJs, insurers, and the communities these systems are sited in.

The best-practice guidance and 30-worksheet inspection library referenced throughout this paper reflect the kind of whole-system program Defend The Zero builds and runs for its clients. For a walkthrough of how a program like this integrates with a specific project's schedule, contact Defend The Zero, LLC.

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A note from the Authors

Safety knows no competition. As battery and energy veterans with over forty years of experience, we care about this industry deeply. We have developed safe and reliable systems during our tenure and know it's possible. We want the AHJs and the public to also know how safe and reliable these battery systems can be. Right now, there are too many black eyes on energy storage and too many scared communities. Far too often our friends and neighbors ask: well would you ever let one of these things in your neighborhood? And the answer is always yes. We know what when these batteries are designed, installed and maintained correctly, they are extremely safe and reliable. Unfortunately, that answer usually earns us a skeptical look.

We need to change that.

…We would love to hear from you! Your passions. Your wins. Your visions for this industry. What does our industry do well? What could we do better? Your topic could become our next white paper. We'll do the research, take on the tough subjects, and share what we find with this group. We welcome the tough conversations and passion. We know that what we wrote here likely is not the perfect answer. But we felt the need to start the conversation. And no matter how uncomfortable, the passion still ultimately leads to great ideas, safer batteries and confident communities.

Thank you for reading,

John Schoeb

Beth Schroeder

About the Organizations and Authors

Belay Energy Solutions

Belay Energy Solutions helps battery companies strengthen their engineering evidence and product safety before problems become costly, guiding teams through the "valley of death" between development and commercialization where weak documentation, delayed permitting, or product recalls can stall momentum. Co-founded by Andy Laib and Beth Schroeder, the firm draws on deep experience in large-scale battery fire testing, hazard analysis, and battery system design across ESS, EV, micro-mobility, tools, and consumer battery applications. Belay is active in industry standards work through NFPA and SAE, speaks regularly at battery safety and testing conferences, and delivers technical training for manufacturers, engineering teams, and first responders, helping companies bring stronger, better-tested products to market with greater confidence and reduced risk.

www.belayenergysolutions.com
beth.schroeder@belayenergysolutions.com
andy.laib@belayenergysolutions.com

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Defend The Zero, LLC

Defend The Zero, LLC is an owner's representative and energy infrastructure consulting firm co-founded by John Schoeb and Carter Wilding-White. The firm provides battery energy storage system (BESS) safety oversight, balance-of-plant electrical inspections, hazard mitigation analysis (HMA) and emergency response plan (ERP) development, factory acceptance testing (FAT), and safety and quality management system support (ISO 45001/14001/9001). Built around a core philosophy of Zero Harm, Zero Defects, Zero Failures, Defend The Zero applies a three-layer assurance model: Technical, Regulatory, and Social, to help energy infrastructure clients de-risk projects from design through long-term operation.

www.defendthezero.com
john@defendthezero.com
carter@defendthezero.com

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APPENDICES

Appendix A

RASIC Obligations by Role

What each party is Responsible for, Accountable for, Supporting, consulted on, and Informed of — across pre-construction, field QA, commissioning, close-out, and insurance readiness.

Phase	Activity / Deliverable	Owner	EPC/ GC	Sub	DTZ QA Insp.	DTZ PM	Comm. Agent	AHJ– Fire	AHJ– Elec.	IE	Insurer	O&M
Pre-Construction	Establish QA/QC inspection expectations & incorporate into contractor bid documents	A	C	I	S	R	I	I	I	I	I	I
Pre-Construction	Project kick-off meeting — align on documentation standard, photo standard, records format	I	S	C	R	A	I					
Pre-Construction	Certification scope-matching verification (UL 9540 / 9540A / UL 1973 matched to the right question)	I	S		R	A	C	C	C	I		
Pre-Construction	FAT protocol development — sample size, DFMEA/PFMEA-informed, Gauge R&R	I	C		R	A	C			I		
Pre-Construction	FAT execution — torque/crimp-die documentation and factory-to-field chain of custody	I	S		R	A	I			C	I	I
Field Construction QA	Apply discipline-specific best practices (AC Electrical, Torquing, Civil, BESS Install, Metering)	I	S	R	A	I						
Field Construction QA	Complete discipline-specific field inspection worksheets (30-worksheet library, dual sign-off)	I	S	R	A	S				I		I
Field Construction QA	Torque verification & connection-ID documentation (calibrated tool, logged by connection)		S	R	A	I				I		I
Field Construction QA	Grounding electrode / bonding continuity testing prior to backfill		S	R	A	I						
Field Construction QA	Non-conformance identification, correction, and re-inspection (field level)		S	R	A	I						

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Phase	Activity / Deliverable	Owner	EPC/ GC	Sub	DTZ QA Insp.	DTZ PM	Comm. Agent	AHJ– Fire	AHJ– Elec.	IE	Insurer	O&M
Field Construction QA	NCR escalation to formal Non-Conformance Report (systemic, safety, or code issues)	I	C		I	R	A			I	I	
Field Construction QA	Engineering review of field conditions that are not clearly Yes/No on a worksheet		I		I	I				R	A	C
Commissioning	Site Acceptance Testing (SAT) execution & records	I	S	S	A	R	C			I		
Commissioning	Functional testing of protection & control devices		S		A	R	I			C		
Commissioning	BMS / EMS / SCADA communications verification	I			A	R	C					
Commissioning	NFPA 855 life-safety systems walkdown (detection, suppression, signage functional test)		S		A	R	C			I		
Commissioning	Review of torque and megger test records generated during installation		S		A	R						
Close-Out & Sign-Off	Final code-compliance acceptance / sign-off*	I	S	I	R	S		S	A/A	I	I	
Close-Out & Sign-Off	Emergency Response Plan (ERP) development & fire dept./EMS coordination	A	I		R	C		S				
Close-Out & Sign-Off	Life-of-asset record retention — worksheets, photos, test reports, NCRs	I			R	A				I	I	I
Insurance & Risk	Insurance submission package assembly (SOV, codes & standards documentation)	A	S		R	C					I	
Insurance & Risk	Risk-engineering survey / site visit coordination	A	S		S	S					R	
Insurance & Risk	Root cause analysis of incidents or near-misses	I	S		I	R				A	C	I

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** Final sign-off authority splits by jurisdiction — the Fire Marshal holds authority under NFPA 855 and the Electrical Inspector under NEC Article 705/706. A shared, independently verified record (built from the field worksheet library) is what lets both offices sign off against the same evidence instead of negotiating jurisdiction in the field.*

Legend & Notes

RASIC Legend

Code	Term	Definition
R	Responsible	Does the work. May be more than one party on an activity performed jointly (e.g., dual sign-off on a field worksheet).
A	Accountable	Owns the outcome and is the final decision-maker / sign-off authority. Kept to one party per row wherever the source material supports a single owner; split-jurisdiction items are footnoted.
S	Support	Provides resources, labor, or assistance to the Responsible party but does not own the result.
C	Consulted	Two-way input sought before or during the activity (subject-matter expertise, code interpretation, risk appetite).
I	Informed	Kept informed of progress or outcome after the fact; one-way communication.

Role Definitions

Role	Definition
Owner	Asset owner / developer commissioning the BESS project; ultimate holder of the risk and the insurance policy.
EPC / GC	Engineering, procurement & construction contractor or general contractor of record; prices and manages the installing subcontractors.
Installing Subcontractor	Field crew performing the discipline-specific work (civil, AC electrical, BESS setting, metering, etc.) and co-signing field worksheets.
DTZ QA Field Inspector	Defend The Zero's independent, on-site QA/QC representative; performs discipline-by-discipline field inspection and co-signs worksheets.
DTZ Project Manager	Defend The Zero's program lead; owns the QA/QC program structure, NCR escalation, and the overall documented record.
Commissioning Agent	Performs functional testing of protection/controls, BMS/EMS/SCADA verification, and the NFPA 855 life-safety walkdown at commissioning.
AHJ – Fire Marshal	Authority having jurisdiction under NFPA 855 for fire/life-safety sign-off.
AHJ – Electrical Inspector	Authority having jurisdiction under NEC Article 705/706 for the electrical interconnection.
Independent Engineer (IE)	Third-party engineer of record, typically engaged on financed / tax-equity deals to review the technical record.
Insurer / Loss-Control Surveyor	Underwriter or risk-engineering surveyor evaluating the asset before binding or renewing coverage.
O&M / Asset Management	Owner's operations & maintenance / long-term asset management team; primary consumer of the as-built record after commissioning.

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Source & Notes

Role assignments reflect the process described in this program's source documents (kickoff-meeting agreement, dual sign-off, NCR escalation to the Project Manager, the discussion of who signs off, and the insurance-readiness checklist's sections). Where a document did not name a specific accountable party, the most consistent reading of the narrative was used — confirm against your actual project org chart and contracts before treating this as final.

Rows are organized by phase (Pre-Construction, Field Construction QA, Commissioning, Close-Out & Sign-Off, Insurance & Risk) rather than by the 30 individual worksheets, since the worksheets share the same Sub / QA Inspector pattern within each discipline.

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Appendix B

BESS Insurance Submission Readiness Checklist

Code-referenced edition — NFPA 855, NEC Article 706, IEEE 1547 family · Defend The Zero, LLC

What this is: individual carriers do not publish their underwriting checklists — those stay proprietary until a formal submission or risk engineering survey. This edition ties each readiness item to the specific code or standard section that a risk engineer, AHJ, or independent engineer would actually cite: NFPA 855 (2023) for fire/life-safety, NEC Article 706 for the electrical installation, the IEEE 1547 family for grid interconnection, and a set of site-specific engineering items that are easy to underestimate on a first pass — foundation/geotechnical design, seismic qualification (IEEE 693), altitude-corrected creepage/clearance (IEC 60664-1), corrosion exposure (ISO 9223 / NEMA 250), and oil containment (NEC §450) — plus FM Global 5-33 and UL 9540/9540A where they set the practical benchmark.

How to use it: Section 2 is a quick-reference map of the codes and standards in play. Sections 3–13 are the working checklist, each item tagged with its governing citation in brackets. Section 14 flags where carrier posture is known to diverge.

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1. Project & Asset Information

The baseline Statement of Values (SOV) data every underwriter needs before technical review even begins.

☐ Site address, coordinates, and jurisdiction (AHJ)

☐ Commercial operation date (COD) — actual or projected

☐ Nameplate capacity (MW / MWh) and duration

☐ Battery chemistry and cell/module/rack/container OEM

☐ System integrator and EPC contractor of record

☐ Total insured value / replacement cost basis

☐ Interconnection voltage, point of interconnection, and utility/ISO

☐ Offtake structure — PPA, tolling agreement, merchant

☐ Ownership structure and named insured entities

☐ O&M provider and contract term

2. Codes & Standards Framework — Quick Reference

What governs what, and why it matters to an underwriter, before the item-by-item checklist below.

Document	Governs	Why an Underwriter Cares
NFPA 855 (2023)	Siting, spacing, fire detection/suppression, explosion control, gas detection, HMA, ERP, ESS in dwellings (Ch. 15), and electrochemical ESS specifics (Ch. 9, consolidated 2023).	The code baseline nearly every carrier's risk engineer will check the design against, even carriers that also apply their own internal loss-prevention standard.
NEC Article 706 (NFPA 70)	ESS listing/marking, disconnecting means (706.15), wiring and conductor sizing (706.30), overcurrent protection (706.31), charge control (706.33), qualified-persons-only servicing.	Electrical installation defects and inadequate disconnect/labeling are recurring root causes in BESS loss investigations — underwriters want to see 706 compliance documented, not assumed.
FM Global Data Sheet 5-33	Prescriptive spacing, enclosure, and detection requirements; FM Approved equipment.	The most detailed publicly available carrier loss-prevention standard; referenced even by non-FM markets as a benchmark.
UL 9540 / UL 9540A	System listing (9540) and large-scale/unit-level fire test method (9540A) used to establish or reduce required spacing.	Underwriters and AHJs use 9540A results to validate any spacing reduction from NFPA 855 defaults.
IEEE 1547-2018 / 1547.1-2020	DER interconnection and interoperability with distribution systems; 1547.1 provides the conformance test procedures.	Confirms the BESS won't destabilize the grid it's tied to — a factor in both liability exposure and interconnection agreement compliance.
IEEE 1547.9-2022	Guide for applying IEEE 1547 specifically to energy storage DER (distinct considerations from generation-only DER).	Shows the interconnection design accounted for storage-specific behavior (bidirectional flow, state-of-charge dependent response), not a generic solar DER template.
IEEE 2800-2022	Interconnection and interoperability of inverter-based resources at transmission/sub-transmission level.	Applicable on utility-scale projects tied at transmission voltage — relevant for larger BESS assets like utility-interactive storage plants.
UL 1741 (SB)	Inverter/PCS testing aligned with IEEE 1547-2018 grid-support functions.	Confirms the power conversion system is certified to actually deliver the ride-through/voltage-support behavior IEEE 1547 requires.

Reviewer notes on this framework

• The NFPA 855 separation and setback values referenced above are minimums only, and they were originally written for units or groupings of units of no more than 50 kWh each. As individual units now regularly exceed 4,000 kWh — and may be grouped at separation distances smaller than those required between even 50-kWh groupings — all proposed setback and separation distances need to be validated against the hazard potential of the specific BESS being proposed, not assumed from the code table alone.

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• Fire Code language takes precedence over NFPA 855 language in states that have adopted a fire code based on the International Fire Code (IFC) — which is the vast majority of states. Confirm which document controls for the project's specific jurisdiction.

• The large-scale fire test (LSFT) referenced in the UL 9540/9540A row is only finally incorporated in the 2026 (6th) edition of UL 9540A. Further modeling and analysis is usually necessary, and close coordination with the equipment manufacturer is key to ensuring testing is conducted accurately and that equipment-specific details and structural tolerances are correctly input into any modeling.

3. Siting, Spacing & Fire Separation

NFPA 855 sets the baseline separation; FM 5-33 is more prescriptive; UL 9540A testing is the mechanism for justifying anything tighter.

☐ Minimum 3 ft (914 mm) separation between individual ESS units [NFPA 855 §15.3.1 (dwellings); analogous separation required for non-dwelling installations under Ch. 9]

☐ Reduced spacing substantiated by large-scale fire and explosion testing rather than assumed [NFPA 855 §9.1.5 / Annex G; UL 9540A unit- and installation-level test data]

☐ Setback distances from property lines, exposures, and occupied buildings documented against code table, not just site plan intent [NFPA 855 Ch. 9 separation tables; FM Global 5-33 §2.3]

☐ Fire-rated separation walls or barriers specified where minimum spacing cannot be achieved [NFPA 855 Ch. 9; FM Global 5-33 §2.3.3–2.3.4]

☐ Rooftop installations (if applicable): stairway/roof access, 5 ft service walkway, standpipe outlet, radiant-energy fire detection [NFPA 855 §9.5.3.1.1 / TIA 23-2]

☐ Fire apparatus access roads and staging area adequacy confirmed with local fire authority [NFPA 855 Ch. 4 general requirements; local fire code]

☐ Topographic, flood, and wildfire exposure assessment

☐ Documented equivalency approval where design departs from prescriptive spacing [NFPA 855 §1.5 Equivalency]

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4. Geotechnical, Foundation & Environmental Containment

Two categories that rarely make it into a submission on their own initiative — one because it's treated as a structural afterthought, the other because most people, including many underwriters, don't realize it's a code requirement at all.

4a. Geotechnical & Foundation

☐ Geotechnical investigation/report completed for the site — soil bearing capacity, groundwater table, seismic site class [IBC Ch. 18 (Soils and Foundations); referenced by the project's adopted building code]

☐ Foundation design (slab, pier, screw pile, ballasted, etc.) engineered from the geotech report and the equipment manufacturer's loading and leveling tolerances — not a generic pad detail applied across all soil conditions

☐ Differential settlement analysis addressing cumulative equipment weight over time, not just initial static load

☐ Settlement tolerance cross-checked against enclosure/container manufacturer requirements — misalignment from settling can compromise door seals, fire-rated separation, and conduit/cable entries that were sized and sealed at install

☐ Seismic design category and frost depth incorporated into the foundation design [ASCE 7 (referenced by IBC Ch. 18); local frost-depth requirements]

☐ Foundation design stamped by a licensed PE

☐ Post-installation settlement monitoring plan — survey benchmarks and a periodic re-leveling/inspection interval, not a one-time as-built survey

4b. Oil Containment

☐ Secondary containment provided for all oil-filled equipment (transformers, oil-filled switchgear, etc.) — a code requirement independent of any environmental permitting [NEC §450.23–450.27 confinement of liquid safeguards for liquid-filled transformers]

☐ Containment volume sized to hold the full oil volume of the largest piece of equipment plus a precipitation/freeboard allowance — not just a nominal curb [Common design basis of 100% of largest unit's oil volume; commonly cited alongside NFPA 850 guidance]

☐ Containment structure verified watertight and chemically resistant to the oil in service, with a compliant drainage or oil-water separator provision

☐ Spill Prevention, Control, and Countermeasure (SPCC) Plan in place if aggregate aboveground oil storage across the site exceeds 1,320 gallons [40 CFR Part 112 (EPA SPCC Rule); secondary containment or documented alternative measures under §112.7(c) / §112.12(c)]

☐ Aggregation check performed across all oil-filled devices on site (transformers, oil-filled switchgear, hydraulic/lubricating oil reservoirs) — the SPCC threshold is additive across the whole facility [40 CFR §112.1]

☐ Containment and SPCC status called out explicitly in the insurance submission

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4c. Site-Specific Environmental & Electrical Design Data (design team deliverables)

Four items that routinely get treated as generic or assumed-compliant when they should be calculated for the actual site — each has shown up as a real gap in the field, not a theoretical one.

☐ Site-specific seismic hazard analysis / ground motion parameters obtained for the actual site — not a regional assumption carried over from a similar project [ASCE 7 site-specific ground motion procedures]

☐ Seismic qualification of major equipment — battery racks, transformers, switchgear, PCS — performed by analysis or shake-table test at the seismic level applicable to the site, with anchorage design matching the equipment's actual qualified level [IEEE 693-2018]

☐ Site elevation confirmed and creepage/clearance distances recalculated where the site sits above the reference altitude built into the equipment's factory insulation coordination [IEC 60664-1; cross-check against NEC §110.4 and the equipment's UL listing basis]

☐ Equipment voltage withstand and current-carrying de-rating confirmed for altitude against actual OEM datasheets — not assumed from sea-level nameplate ratings

☐ Site corrosivity assessed against a recognized classification rather than assumed benign based on distance from the coast — inland sites with heavy winter road-salt use can see chloride exposure comparable to coastal sites [ISO 9223 atmospheric corrosivity categories]

☐ Enclosure, hardware, and coating specification matched to the assessed corrosivity category — a code-compliant NEMA/UL Type 4X rating does not guarantee marine-grade 316 stainless performance where conditions warrant it [NEMA 250; ASTM B117; NEC §300.6 and Table 110.28]

☐ Water table depth measured and documented for the actual site rather than estimated from regional geologic data

☐ Site drainage and stormwater runoff design sized for a high-water/heavy-precipitation event, not just typical rainfall

☐ Groundwater intrusion risk into below-grade conduit, vaults, or foundations addressed where the water table is shallow

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5. Fire Detection, Suppression & Explosion Control

The most heavily weighted category in underwriter risk engineering reviews — thermal runaway is the dominant BESS loss driver.

☐ Smoke and fire detection system design [NFPA 855 §4.8]

☐ Fire control and suppression system design, or documented detect-isolate-"let burn" strategy with AHJ concurrence [NFPA 855 §4.9; Annex G]

☐ Certified off-gas / early-warning detection (make, model, certification basis) tied into the fire control sequence [NFPA 855 §4.8; UL 9540A off-gas test methodology]

☐ Explosion control and deflagration venting design basis where the enclosure requires it [NFPA 855 Ch. 4 / Ch. 9; FM Global 5-33]

☐ Exhaust ventilation design for off-gas mitigation [NFPA 855 Ch. 9]

☐ Smoke/heat detection interlocked to BMS/EMS automatic shutdown

☐ Fire watch, notification, and mutual-aid protocol with local fire department

6. Hazard Mitigation Analysis (HMA) & Technical Documentation

The HMA is the document an underwriter is most likely to ask for by name — treat it as a submission centerpiece, not a compliance afterthought.

☐ Hazard Mitigation Analysis completed and current for the as-built configuration [NFPA 855 §4.4 — mandatory for most ESS installations]

☐ Failure modes addressed: thermal runaway propagation, stranded energy, re-ignition risk, gas accumulation

☐ UL 9540 system listing on file

☐ UL 9540A test data at cell, module, and unit/array level — including large-scale fire test results if performed

☐ Battery Management System (BMS) architecture and safety interlocks documented

☐ Energy Management System (EMS) integration and remote monitoring/shutdown capability documented

☐ OEM warranty terms, augmentation plan, and degradation curve

☐ Combustible storage restrictions within the ESS area addressed [NFPA 855 §4.5]

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7. Electrical Installation — NEC Article 706

Electrical installation defects and inadequate disconnect/labeling are recurring findings in BESS loss investigations; this is where a risk engineer's site walk often starts.

☐ ESS product listing and nameplate marking complete and legible [NEC 706 Part II and marking requirements referenced throughout Art. 706]

☐ Disconnecting means provided to isolate the ESS from other power sources, utilization equipment, and premises wiring [NEC §706.15(A)]

☐ Disconnect readily accessible — within the ESS or within sight and 10 ft of it, or lockable-open if not within sight [NEC §706.15(B); §110.25]

☐ Disconnect marking includes source identification/location per §110.22, durable for the installation environment

☐ Battery-specific disconnecting means addressed where batteries are separate from ESS electronics and field-serviceable [NEC §706.15(E)]

☐ Conductor sizing per Article 706 requirements [NEC §706.30]

☐ Overcurrent protective devices listed for DC application with correct voltage/current/interrupting rating [NEC §706.31(A) and (C)]

☐ Charge control provisions in place, adjustable controls restricted to qualified personnel [NEC §706.33(A)]

☐ Point of interconnection (supply side vs. load side) documented against Article 705 requirements [NEC §705.12(A)/(B)]

☐ Qualified-persons-only servicing restriction posted and enforced

☐ Emergency shutdown function and exterior-accessible initiation device, where applicable [NEC §706.15]

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8. Grid Interconnection & Controls — IEEE 1547 Family

Interconnection compliance is both a utility contractual requirement and a liability/reliability factor underwriters increasingly ask about on larger assets.

☐ DER interconnection design compliant with distribution-level requirements [IEEE 1547-2018]

☐ Conformance testing performed per the applicable test standard [IEEE 1547.1-2020]

☐ Storage-specific interconnection behavior addressed (bidirectional flow, state-of-charge dependent response) — not a generic generation-only DER design [IEEE 1547.9-2022]

☐ Transmission/sub-transmission-level interconnection compliance confirmed for utility-scale assets tied above distribution voltage [IEEE 2800-2022]

☐ Inverter/PCS certified for the grid-support functions the interconnection agreement requires [UL 1741 SB]

☐ Utility interconnection agreement executed and consistent with the as-built control settings

9. Codes, Permits & Third-Party Certifications

☐ AHJ building and fire permit approvals on file

☐ NFPA 855 compliance documentation / code analysis package

☐ Commissioning reports — functional and performance testing

☐ Independent Engineer (IE) report, where applicable (common on financed/tax-equity deals)

10. Operations, Maintenance & Emergency Response

☐ O&M plan and on-site/remote staffing model

☐ Preventive maintenance schedule and inspection frequency

☐ Emergency Response Plan (ERP) coordinated with local fire/EMS [NFPA 855 §4.3]

☐ Training records — site personnel and first-responder familiarization [NFPA 855 §4.3]

☐ Incident and near-miss reporting protocol

11. Loss History & Risk Management

☐ Prior loss runs — project-specific and, where available, OEM/integrator fleet-wide history

☐ Root cause analyses of any prior incidents or near-misses

☐ Physical security plan for the site

☐ Cybersecurity posture for SCADA/EMS control systems

12. Transit, Cargo & Construction Phase

Applicable when placement includes marine cargo, delay in start-up, or builder's risk exposure.

☐ Packaging and shipping standards for cells/modules in transit

☐ Laydown and construction-phase fire protection plan

☐ Builder's risk to operational-policy transition plan and gap coverage

13. Liability & Financial Structure

☐ General liability and pollution/environmental liability scope

☐ Business interruption / delay-in-start-up exposure and values

☐ Named insured and additional insured schedule

☐ Waiver of subrogation and lender/financing-party requirements

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14. Carrier Posture — Where the Market Diverges

Not a rule set — a directional guide based on publicly documented carrier behavior. Confirm current appetite and requirements with your broker for any live placement.

Carrier / Underwriter	Known Posture	What That Means for a Submission
FM Global	Prescriptive — publishes Data Sheet 5-33 with defined spacing, enclosure, and detection requirements; strong preference for FM Approved equipment.	Design to 5-33 spacing/separation tables up front; FM Approval status of BMS/detection gear should be documented in the submission.
GCube (Tokio Marine HCC)	Specialist, data-driven — publishes its own BESS loss research; explicitly prioritizes module spacing, OEM involvement, and root-cause culture over blanket exclusions.	Come with loss-history transparency and a clear root-cause process; GCube's public reporting signals they reward demonstrated risk maturity over pure prescriptive compliance.
Zurich / AIG / Chubb / AXA XL / Munich Re	Performance-based — apply NFPA 855 as the code baseline, then run a project-specific risk engineering survey rather than a fixed public checklist.	Expect a site visit or virtual risk engineering call; have the full technical package ready, including geotechnical/foundation and oil containment documentation, rather than assuming a document dump substitutes for it.
Lloyd's syndicates / London market facilities	Capacity-stacking — multiple syndicates follow a lead underwriter's terms on a single risk.	One strong, complete submission to the lead can carry the whole placement; inconsistent or partial answers slow every follower market at once.

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Sources: NFPA 855 (2023) Standard for the Installation of Stationary Energy Storage Systems, including TIA 23-1 and TIA 23-2; NFPA 70 (NEC) Article 706, Article 705, §300.6, Table 110.28, and §450.23–450.27; International Building Code (IBC) Chapter 18; ASCE 7; 40 CFR Part 112 (EPA SPCC Rule); IEEE 1547-2018, 1547.1-2020, 1547.9-2022, 2800-2022, 693-2018; IEC 60664-1; ISO 9223; NEMA 250; ASTM B117; UL 9540 / UL 9540A; UL 1741 SB; FM Global Data Sheet 5-33; GCube "Batteries Not Excluded: Getting the Insurance Market on Board with BESS" (2024). Code citations reflect the 2023 edition of NFPA 855 and current NEC structure as of this document's preparation — verify against the edition adopted by the project's AHJ, which may lag the latest published edition, and confirm SPCC applicability against actual site oil inventory. This checklist is a readiness tool, not a substitute for a code official's determination, a broker's formal submission requirements, or legal/insurance/engineering advice.

Appendix C

NFPA 855 Permitting Detail Sheet

Field	Entry
Site Location	
Fire Marshal	
Date of Report	

UL 9540 Details (General)

Field	Entry
Date testing completed	DD-MONTH-YY
NRTL Name, Location	Name, Location
Do part numbers from test reports and maintenance reports match received parts?*	Y / N
OEM Name	
ESS Product Name and Part Number tested	

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UL 9540A Details

Field	Entry
Cell Testing Date	DD-MONTH-YY
Cell Test NRTL, Location	Name, Location
LSFT Test Date	DD-MONTH-YY
LSFT NRTL, Location	Name, Location
Cell UL 9540A gas reports match deflagration/plume analysis?*	Y / N

** If part numbers do not match, please include a separate statement showing design changes and rationale, or provide updated test reports from the NRTL reflecting the correct part numbers.*

Critical Equipment Planning and Maintenance

Per NFPA 855 §4.4.5, construction, equipment, and systems having hazards listed in the HMA must be installed, tested, and maintained according to the manufacturer's recommendations. List the critical equipment and where details can be found regarding maintenance, installation, etc. Control plans and PFMEAs should be checked.

Component / Sub-system	MII	O	S	T
Component or sub-system 1				
Component or sub-system 2				
Component or sub-system … n				

MII = Manufacturer Installation Instructions · O = Operating Manual · S = Service/Maintenance Plan · T = Test

Regionally Specific Design Considerations (NFPA 855, Section 5.4)

Installation building codes vary regionally, especially electrical and alarm codes and regulations. The regionally specific design needs to be verified — and in some cases, it may need to be created. This checklist assigns responsibility for confirming that a design was created, installed, and is being maintained in accordance with local laws.

Item	Y/N	Comment
Plumbing: Is the design, installation, and maintenance in accordance with nationally recognized standards for the installed region?		
Fire Alarm: Is the design, installation, and maintenance in accordance with nationally recognized standards for the installed region?		
General Hazard Detection Systems and Control Circuits: Is the design, installation, and maintenance in accordance with nationally recognized standards for the installed region?		
Ventilation Systems: Is the design, installation, and maintenance in accordance with nationally recognized standards for the installed region?		
General Electrical Connections/Altitude: High altitudes result in thinner air, which can make arcing ‘easier.’ At high altitudes it is important to check and adjust wiring distances. Was the design verified against the installed altitude?		

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Conditions of Acceptability (Exclusions)

Occasionally a required task or test is not performed as part of the larger testing, and the stamp/certification is granted with "conditions." It is critical to understand the excluded tasks/tests to understand implications for a specific site.

Exclusions	List
List all exclusions in UL 9540 (example: seismic, corrosion testing)	
List all exclusions in UL 9540A	
List all exclusions in UL 1973	
List all exclusions in UL 1741	
List all exclusions in NFPA 855	
List all exclusions in NFPA 70 or NEC	
List other exclusions	

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Appendix D

Zero Defect Program (ZDP) — BESS Quality Assurance Program Overview

Defend The Zero, LLC

> *REDACTED OVERVIEW VERSION — this is a condensed, redacted overview of the Zero Defect Program (ZDP) for BESS construction quality assurance. Detailed inspection criteria, code-reference line items, acceptance thresholds, non-conformance forms, and sign-off records have been removed from this version. The complete field-ready program — including all 30 discipline-specific inspection worksheets — is available to engaged clients and partners under NDA.*

Program Overview

The Zero Defect Program (ZDP) is Defend The Zero's quality assurance framework for battery energy storage system (BESS) construction. It is built around a simple philosophy — Zero Harm, Zero Defects, Zero Failures — and is designed to catch and correct installation issues while work is in progress, rather than relying on a punch list at the end of the project.

The program combines discipline-specific best-practice guidance with a structured, proactive field inspection process. Each discipline of work is reviewed against the project's engineered drawings, manufacturer instructions, and the applicable codes and standards, with both the installing subcontractor and an independent Defend The Zero QA representative signing off on completed work.

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Best Practices Disciplines

The program's best-practice guidance is organized into five core disciplines covering the full BESS construction scope:

- **AC Electrical —** Covers equipment placement, conductor and termination practices, splicing, and junction box requirements for the AC portion of a BESS installation, from the BESS/PCS interconnection through the site's point of utility interconnection. Practices are based on the National Electrical Code and related low-voltage equipment standards.
- **Torquing —** Establishes requirements for making and verifying torque on mechanical and electrical connections, including tooling calibration, documentation, and visual verification marking, consistent with manufacturer specifications and electrical safety work practices.
- **Ground Mount / Civil —** Covers site housekeeping, trenching, underground conduit and duct bank installation, concrete pad and foundation work, and outdoor AC equipment and switchgear installation, consistent with excavation safety and underground installation requirements.
- **BESS Installation —** Covers pad and foundation readiness, safe lifting and rigging, anchoring and torque requirements, conduit sealing, and signage/emergency response plan coordination for battery energy storage system units, consistent with the applicable stationary energy storage system installation standard.
- **Metering —** Covers meter and current transformer installation, phase rotation and CT orientation verification, reference voltage wiring, and metering data cable practices, including guidance for interpreting phase/vector diagrams during commissioning.

QA/QC Inspection Program

Field inspections are performed discipline-by-discipline using standardized worksheets, so that deficiencies are identified and corrected while the crew and equipment access are still in place. Any item that does not fully conform is logged, corrected, and re-inspected before it is accepted.

Completed worksheets, along with supporting photographs and test records, become part of the permanent project quality record and are referenced during commissioning, warranty service, and any future root-cause investigation. The worksheets are cross-referenced to the National Electrical Code, NFPA 70E/72/855, applicable OSHA construction and general industry provisions, IEEE 1547, and relevant UL, IEC, and NETA product and testing standards.

Field Inspection Worksheet Library

The ZDP field inspection program includes 30 discipline-specific worksheets covering the full BESS construction scope, organized into six categories. Worksheet titles are listed below; the detailed inspection criteria, acceptance thresholds, and non-conformance tracking forms are not included in this overview.

Civil, Underground & Structural

- #1 Trenching
- #23 Equipment Foundation / Pad
- #24 Underground Duct Bank / Manhole / Handhole
- #25 Grading / Retention Basin
- #26 Permanent Fencing

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AC Electrical & Switchgear

- #2 AC Wiring and Conduit
- #3 AC Gear, Fused Disconnect
- #4 AC Gear, Non-Fused Disconnect
- #5 AC Gear, Main Breaker
- #6 AC Gear, Main Breaker with Enclosure
- #7 AC Gear, Circuit Breaker Panel
- #8 AC Gear, Utility Meter Socket
- #10 AC Gear, Transformer
- #19 AC Gear, Mini Power Zone
- #22 AC Gear, Switchgear

BESS Equipment

- #13 BESS Site Controller Cabinet
- #14 BESS with Inverter
- #15 BESS
- #16 BESS Inverter

- #17 AC Gear, BESS Transformer

Metering & Protection

- #9 AC Gear, CT Cabinet
- #12 Meter Cabinet
- #18 PT Cabinet
- #20 SEL Relay Cabinet
- #21 Recloser Cabinet
- #27 Transformer Protection, SEL Relay

Monitoring & Controls

- #11 DAS / Controller Cabinet
- #28 Weather Station Cabinet & Components

Life Safety & Security

- #29 Fire Detection / Alarm System
- #30 Standard/Security Camera Systems

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For access to the complete Zero Defect Program — including full inspection worksheets, acceptance criteria, and QA/QC forms — please contact Defend The Zero, LLC at info@defendthezero.com.

Appendix E

ZDP Field Inspection Worksheets

Defend The Zero, LLC and its subcontractors use the following 30 field inspection worksheets to verify contract-compliant installation of the BESS scope of work, from civil/underground work through life-safety and security systems. The installing EPC and an independent Defend The Zero representative complete each worksheet together, and it becomes a permanent quality record for the project. Any item marked “No” must be logged in that worksheet's Non-Conformance / Punch-List Log, corrected, and re-inspected before the item is marked “Yes.”

- #1 — Trenching Inspection Worksheet
- #2 — AC Wiring and Conduit Inspection Worksheet
- #3 — AC Gear – Fused Disconnect Inspection Worksheet
- #4 — AC Gear – Non-Fused Disconnect Inspection Worksheet
- #5 — AC Gear – Main Breaker Inspection Worksheet
- #6 — AC Gear – Main Breaker with Enclosure Inspection Worksheet
- #7 — AC Gear – Circuit Breaker Panel Inspection Worksheet
- #8 — AC Gear – Utility Meter Socket Inspection Worksheet
- #9 — AC Gear – CT Cabinet Inspection Worksheet
- #10 — AC Gear – Transformer Inspection Worksheet
- #11 — Controller Cabinet Inspection Worksheet
- #12 — Meter Cabinet Inspection Worksheet
- #13 — BESS Site Controller Cabinet Inspection Worksheet
- #14 — BESS with Inverter Inspection Worksheet
- #15 — BESS Inspection Worksheet
- #16 — BESS Inverter Inspection Worksheet
- #17 — AC Gear – BESS Transformer Inspection Worksheet
- #18 — PT Cabinet Inspection Worksheet
- #19 — Weather Station Cabinet & Components Inspection Worksheet
- #20 — AC Gear – Mini Power Zone Inspection Worksheet
- #21 — SEL Relay Cabinet Inspection Worksheet
- #22 — Recloser Cabinet Inspection Worksheet
- #23 — AC Gear – Switchgear Inspection Worksheet
- #24 — Equipment Foundation/Pad Inspection Worksheet
- #25 — Underground Duct Bank / Manhole / Handhole Inspection Worksheet

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- #26 — Grading / Retention Basin Worksheet
- #27 — Permanent Fencing Worksheet
- #28 — Transformer Protection – SEL Relay Worksheet
- #29 — Fire Detection / Alarm System Worksheet
- #30 — Standard/Security Camera Systems Worksheet

The complete, field-ready worksheets — dual sign-off blocks, Yes/No/N-A criteria, and non-conformance tracking — are available to engaged clients and partners under NDA. Contact Defend The Zero, LLC at info@defendthezero.com to request access.

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Worksheet #10 — AC Gear – Transformer Inspection Worksheet

AC Gear / Transformers

Project Name	
Date & Time	
Item / Location Inspected	
Transformer ID / kVA Rating	
Inspector Name(s) & Company	

"Compliant" — The term "compliant" means the item, material, or installation conforms 100% with the contract documents, issued-for-construction (IFC) drawings, project specifications, applicable manufacturer installation/O&M instructions, and all governing codes and standards in effect for the project (including but not limited to the National Electrical Code (NEC), NFPA 70E, applicable OSHA 29 CFR 1926 provisions, IEEE 1547, and product listing standards). Any deviation, however minor, is a non-conformance and must be logged in the Non-Conformance / Punch-List Log on this worksheet, dispositioned, corrected, and re-inspected before the item is marked "Yes."

#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
1	Concrete support pad construction, dimensions, and reinforcement are compliant with the IFC structural drawings.						
2	[redacted]						
3	Sealing of underground conduits at the transformer entrance (duct seal, mudplugs) is compliant to prevent oil migration and pest/rodent entry.						
4	[redacted]						
5	Equipment is listed/labeled as required (UL, FM, CSA, CE, TUV) and the listing mark is legible and undamaged.						
6	[redacted]						
7	No shipping or handling damage is present (dents, cracked bushings, broken hinges, water intrusion evidence); any damage is documented, photographed, and reported to the PM before installation.						
8	[redacted]						

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#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
	[redacted]						
9	Gear support structure (unistrut, pad, stand) construction, leveling, and anchorage are compliant; cut ends of unistrut/strut channel are treated with cold-galvanizing ("galvi") compound.						
10	[redacted]						
11	Working clearances comply with NEC 110.26; door(s) open ≥ 90° with the code-minimum depth and width of clear space maintained in front of and beside the gear.						
12	[redacted]						
13	Conduits penetrating buildings, pads, or gear are sealed around the exterior and duct-sealed inside at the point of penetration into conditioned or environmentally rated spaces; unused knockouts/conduit openings are closed with listed plugs.						
14	[redacted]						
15	Conduit sizes, fill, and connections/bushings are compliant with NEC Chapter 9 and the IFC drawings.						
16	[redacted]						
17	Conductor phase/polarity is verified by conductor color and/or phase tape marking at every termination and is consistent throughout the circuit.						
18	[redacted]						
19	Conductor bending radii meet the cable manufacturer's minimum bend radius and NEC requirements.						

EXAMPLE

#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
20	[redacted]						
21	Zip ties used for wire management are cinched snugly (not tight enough to deform insulation), spaced to prevent sagging between ties, and excess tie strap is trimmed flush with no sharp edge remaining.						
22	[redacted]						
23	Enclosure exterior and interior are free of damage and defects; scratches are touched up, and any corrosion/rust is removed and treated per the coating manufacturer's repair procedure.						
24	[redacted]						
25	Door and panel locking/latching mechanisms, including provisions for lockout/tagout, operate correctly and are compliant with the specified hardware.						
26	[redacted]						
27	All punch-list items identified during this inspection are logged, tracked to closure, and re-verified before the worksheet is signed as complete.						
28	[redacted]						
29	Tap changer is set to the position specified by the engineer of record, and the setting is recorded and photographed.						
30	[redacted]						
31	Dissolved gas analysis (DGA) oil sample, where required for the unit size/voltage class, has been taken and submitted, with baseline results on file.						

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#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
32	[redacted]						
33	Radiator fins/cooling equipment (if applicable) are undamaged and unobstructed.						
34	[redacted]						

Non-Conformance / Punch-List Log

NCR #	Item #	Description of Non-Conformance	Corrective Action Taken	Verified By / Date

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Subcontractor Inspection Completed By: *By signing this document, the Subcontractor represents that all information documented above is correct and that all listed items are complete and contract-compliant, or that non-conformances have been fully documented in the NCR log below.*

Print Name:	Signature:	Date:

Defend the Zero, LLC Inspection Completed By: *By signing this document, the Defend the Zero, LLC Quality Assurance agent represents that this inspection was performed in the field, that all information documented above was independently verified, and that any noted non-conformances have been logged and are being tracked to closure.*

Print Name:	Signature:	Date:

Worksheet #14 — BESS with Inverter Inspection Worksheet

BESS

Project Name	
Date & Time	
Item / Location Inspected	
BESS Unit ID	
Inspector Name(s) & Company	

"Compliant" — The term "compliant" means the item, material, or installation conforms 100% with the contract documents, issued-for-construction (IFC) drawings, project specifications, applicable manufacturer installation/O&M instructions, and all governing codes and standards in effect for the project (including but not limited to the National Electrical Code (NEC), NFPA 70E, applicable OSHA 29 CFR 1926 provisions, IEEE 1547, and product listing standards). Any deviation, however minor, is a non-conformance and must be logged in the Non-Conformance / Punch-List Log on this worksheet, dispositioned, corrected, and re-inspected before the item is marked "Yes."

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#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
1	Equipment is compliant upon delivery, confirmed by nameplate — UL 9540/9540A, FM, CE, TUV, where applicable.						
2	[redacted]						
3	The PCS-controlled current setting label is placed on conductors or in proximity to the bus bars per the manufacturer's install manual (e.g., Tesla Install Manual or equivalent OEM guide).						
4	[redacted]						
5	Gear support structure construction is compliant, including the minimum 2% downward slope away from adjacent units for back-to-back installations to manage drainage.						
6	[redacted]						
7	Labels are installed, suitable for the environment, and compliant, including current arc-flash calculations.						
8	[redacted]						
9	Grounding is compliant with the design and NEC 250/NFPA 855 requirements for BESS installations.						

#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
10	[redacted]						
11	AC conductors are compliant with respect to color, gauge, type, and voltage rating.						
12	[redacted]						
13	Conductor bending radii are compliant.						
14	[redacted]						
15	Zip ties within the cabinet are installed to prevent sagging between ties; ties are cinched snugly but not tight, and excess tie strap is trimmed.						
16	[redacted]						
17	The floor panel is reinstalled and conduits are sealed around it, or the concrete/foundation-to-BESS gap is sealed, to exclude moisture and pests.						
18	[redacted]						
19	Phase rotation is tested, verified, and noted on the commissioning record.						
20	[redacted]						
21	All Ethernet cables were tested end-to-end (certified) and marked as tested.						
22	[redacted]						
23	The enclosure is free from damage and defects; scratches are touched up, and rust is removed and touched up.						
24	[redacted]						
25	The chassis locking mechanism is compliant, and any required intrusion/tamper alarm contacts are installed and functional.						

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#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
26	[redacted]						
27	HVAC/thermal management system for the enclosure is operational and free of installation debris in intake/exhaust paths.						
28	[redacted]						

Non-Conformance / Punch-List Log

NCR #	Item #	Description of Non-Conformance	Corrective Action Taken	Verified By / Date

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Subcontractor Inspection Completed By: *By signing this document, the Subcontractor represents that all information documented above is correct and that all listed items are complete and contract-compliant, or that non-conformances have been fully documented in the NCR log below.*

Print Name:	Signature:	Date:

Defend the Zero, LLC Inspection Completed By: *By signing this document, the Defend the Zero, LLC Quality Assurance agent represents that this inspection was performed in the field, that all information documented above was independently verified, and that any noted non-conformances have been logged and are being tracked to closure.*

Print Name:	Signature:	Date:

Worksheet #24 — Equipment Foundation/Pad Inspection Worksheet

Civil / Structural

Project Name	
Date & Time	
Item / Location Inspected	
Foundation / Pad ID	
Inspector Name(s) & Company	

"Compliant" — The term "compliant" means the item, material, or installation conforms 100% with the contract documents, issued-for-construction (IFC) drawings, project specifications, applicable manufacturer installation/O&M instructions, and all governing codes and standards in effect for the project (including but not limited to the National Electrical Code (NEC), NFPA 70E, applicable OSHA 29 CFR 1926 provisions, IEEE 1547, and product listing standards). Any deviation, however minor, is a non-conformance and must be logged in the Non-Conformance / Punch-List Log on this worksheet, dispositioned, corrected, and re-inspected before the item is marked "Yes."

#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
1	Excavated materials are placed neatly, set back per OSHA 1926.651(j), so as not to interfere with or endanger ongoing work.						
2	[redacted]						
3	The base/sub-base material is contract-compliant (gradation, thickness, compaction).						
4	[redacted]						
5	Foundation location(s), width, length, and depth are compliant with the IFC drawings.						
6	[redacted]						
7	If any foundation locations deviated from the IFC Plans, the PM was notified in writing of the details of the change.						
8	[redacted]						
9	Trench boxes/shields, if required, are compliant and rated for the excavation depth and soil conditions.						

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#	Inspection Item — "Compliant" = 100% conformance with contract documents, IFC drawings, and applicable codes/standards	Yes	No	N/A	Sub. Init.	QA Init.	Notes
10	[redacted]						
11	Conduit stub-up window/pattern (location, size, projection height) is compliant with the equipment manufacturer's foundation template.						
12	[redacted]						
13	Conduit openings are temporarily sealed (capped) to prevent the ingress of debris and concrete during pour.						
14	[redacted]						
15	Anchor bolt template, embedment depth, projection, and bolt pattern match the equipment manufacturer's foundation drawing; template is braced and verified level/square immediately before pour.						
16	[redacted]						
17	Concrete mix design, type, and specifications (compressive strength, air entrainment) are compliant with the structural drawings.						
18	[redacted]						
19	Concrete cylinder/cube samples are taken per the testing plan, and break results meet the specified compressive strength at the required age.						
20	[redacted]						
21	Foundation dimensions and elevation are verified by as-built survey after form removal and compared to the design tolerance.						
22	[redacted]						
23	Disposition of excess backfill material is compliant with the site's spoil management plan.						
24	[redacted]						

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Non-Conformance / Punch-List Log

NCR #	Item #	Description of Non-Conformance	Corrective Action Taken	Verified By / Date

Subcontractor Inspection Completed By: *By signing this document, the Subcontractor represents that all information documented above is correct and that all listed items are complete and contract-compliant, or that non-conformances have been fully documented in the NCR log below.*

Print Name:	Signature:	Date:

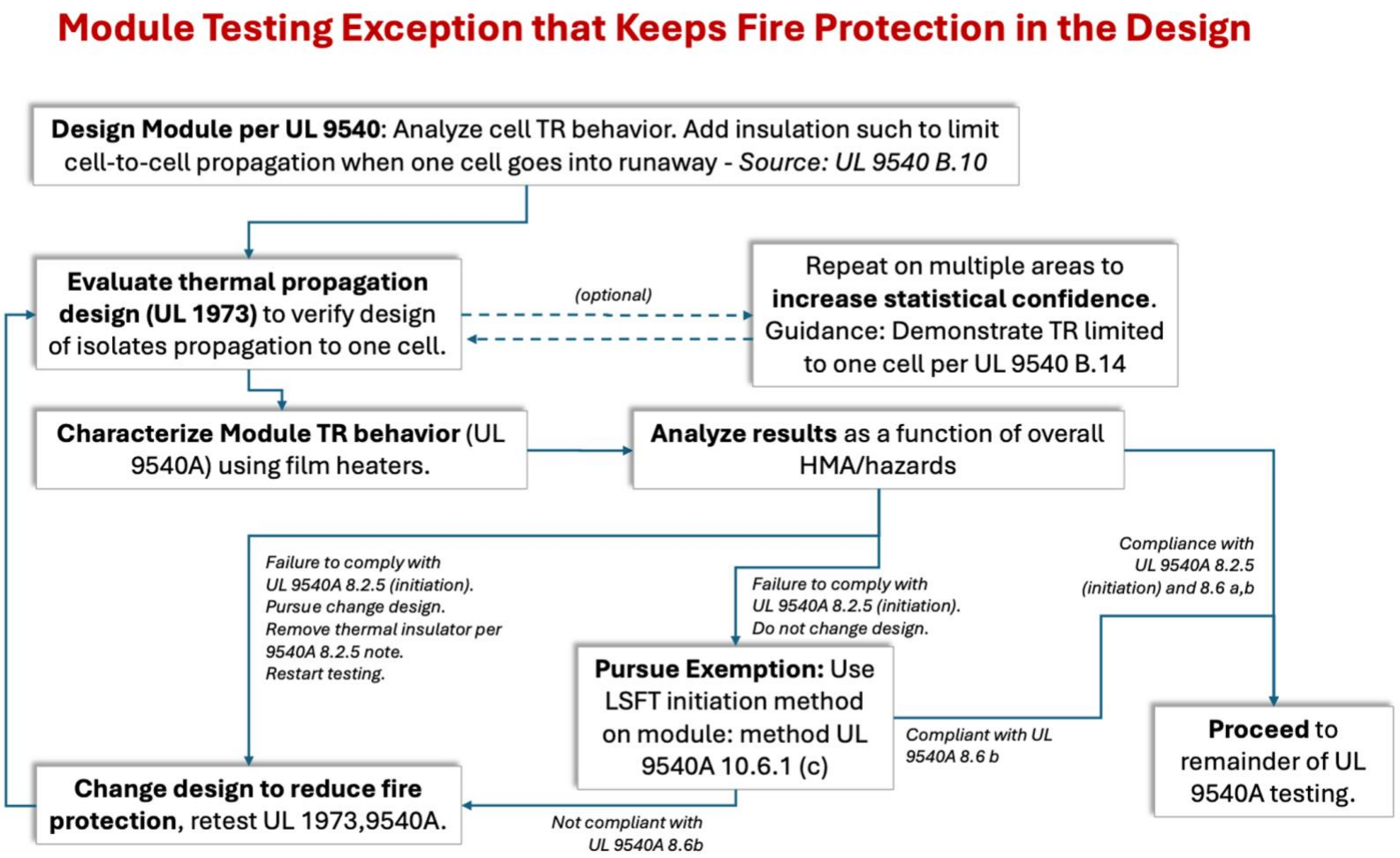
Defend the Zero, LLC Inspection Completed By: *By signing this document, the Defend the Zero, LLC Quality Assurance agent represents that this inspection was performed in the field, that all information documented above was independently verified, and that any noted non-conformances have been logged and are being tracked to closure.*

Print Name:	Signature:	Date:

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Appendix E: Alternate Test Path for Modules that Refuse to Propagate

This test path may be suitable for new technologies that are highly resistant to cell internal short thermal runaway propagation. This method prioritizes the best practice in UL 9540 to use insulation in the design rather than following the UL 9540A note that the protective insulation may need to be ripped out to be compliant with the procedure. Note that with the pending update of UL 9540, an alternative is being proposed that would allow insulation materials to remain and have insulation properties verified via CSA 22.2 Section 350. This conflicting information between standards will hopefully be addressed and eliminated.



Alternate Test Path for Modules That Refuse to Propagate

This test path may be suitable for new technologies that are highly resistant to cell internal-short thermal-runaway propagation. This method prioritizes the UL 9540 best practice of keeping insulation in the design, rather than following the UL 9540A note that it may need to be removed to be compliant with the procedure. With the pending update of UL 9540A, this conflicting information between standards will hopefully be addressed and eliminated.

Module Testing Exception That Keeps Fire Protection in the Design

- 1. Design module per UL 9540: analyze cell thermal-runaway (TR) behavior. Add insulation to limit cell-to-cell propagation when one cell goes into runaway (source: UL 9540 B.10).
- 2. Evaluate thermal propagation design (UL 1973) to verify the design isolates propagation to one cell — optionally repeated across multiple areas to increase statistical confidence (guidance: demonstrate TR limited to one cell per UL 9540 B.14).
- 3. Characterize module TR behavior (UL 9540A) using film heaters, then analyze results as a function of overall HMA/hazards.
- 4a. Result — "No thermal propagation demonstrated": change the design, remove the thermal insulator per 9540A §8.2.5 note, and restart testing.
- 4b. Result — "No thermal propagation demonstrated," insulation retained: do not remove fire protection and do not change the design. Instead, pursue an exemption using the LSFT initiation method on the module (UL 9540A §10.6.2).
- 4c. Desired result — "TR established with multiple cells into runaway": proceed to the remainder of UL 9540A testing.

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