ASSOCIATED ENVIRONMENTAL SYSTEMS

INCREASING SUCCESS: AES'S LEAN APPROACH TO BATTERY TESTING

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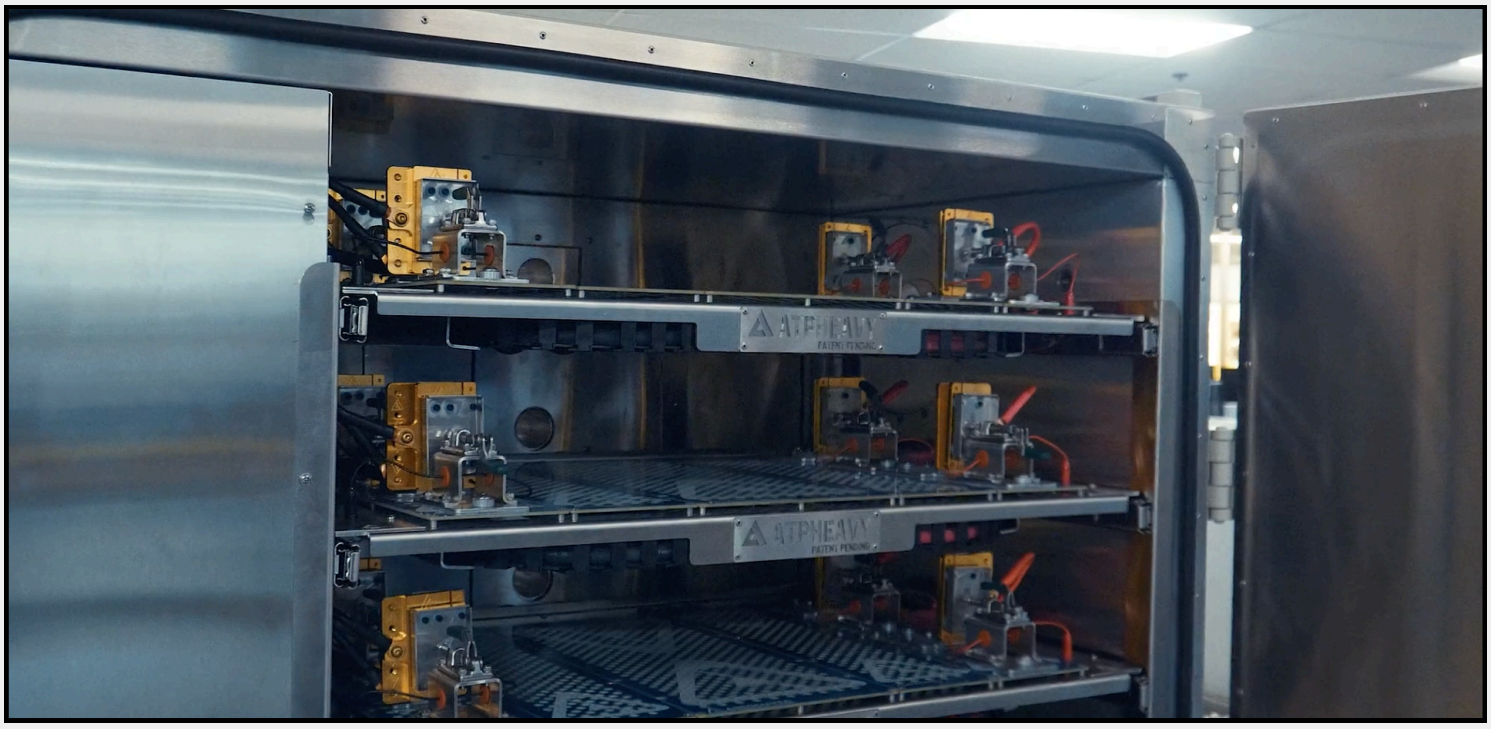

ABSTRACT

As consumers demand more sustainable, long-lasting, and effective products, industries must create products that exceed expectations and bring them to market quickly. As a result, companies turn to battery testing to analyze new technologies and verify that a product is safe and reliable. Without proper testing strategies in place, businesses can develop a poor workflow process, increasing waste, safety risk, and non-value add work time. With AES, reduce the potential for hazardous and inefficient battery testing with lean manufacturing. At Associated Environmental Systems (AES), we have incorporated lean methodologies, 5S principles, and safety protocols to ensure progress. Learn more about the benefits of AES's approach to battery testing and how lean methodologies increase success.

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INTRODUCTION

Technologies, including AI, are advancing battery capabilities, helping to decipher test data that leads to understanding battery physics that current testing tools cannot solve. Battery developments are revealed faster than before, giving researchers insight into performance and various types of batteries, including solid-state or cobalt-free lithium-ion batteries that may fuel future innovation.

As battery technology continues to explode, battery testing is growing alongside it at an exponential rate. Within the EV industry alone, its testing market is going through a significant transformation. It's estimated to expand impressively at a Compound Annual Growth Rate (CAGR) of 16.59%, potentially reaching $6.46 billion by 2032. Fueling the rapid growth in the U.S. are new companion bills regulating lithium-ion batteries, including one passed in August 2024 that mandates the Consumer Product Safety Commission (CPSC) to implement new safety standards to reduce the risk of fires, explosions, and other hazards associated with lithium-ion batteries. Additionally, the consumer electronics testing market continues to rise, pushing companies to produce more devices that can withstand temperature, moisture, and humidity. Consumers are becoming ever-dependent on batteries that can improve their quality of life and provide them top-notch performance.

AES is a full-service expert provider that knows what testing equipment is needed to bring a battery to market and how to improve a company's testing process. Knowing that inefficient use of the chamber wastes time and money, AES aims to set up its customers for success with lean manufacturing, thus minimizing mistakes, optimizing value-add work, and reducing waste. The world relies on your products to stimulate change—we'll help you achieve that and more.

WHAT IS LEAN MANUFACTURING

Understanding lean manufacturing principles and their value is critical to improving operations. Lean methodologies can significantly boost productivity and efficiency in your lab when properly implemented. Lean manufacturing aims to maximize resources by eliminating waste—factors that slow down processes and reduce competitiveness. Waste typically falls into seven key categories:

- Overproduction (stocking too much product)
- Motion (bodily movement of workers or machines)
- Inventory (unprocessed products or excess stock)
- Defects (products deviating from design standards)
- Overprocessing (manufacturing unnecessary components)
- Waiting (wasted time, slowed or halted processes)
- Transportation (moving materials from one position to another)

Once waste is determined and identified, a business must operate by principles that guide its manufacturing and how its team works together and interacts with customers. These five principles include:

1. Value
Value is always determined by the customer's need for a specific product. Understand the timeline for manufacturing and delivery, the price point, and important requirements or expectations that must be met.

2. Value Stream Mapping
Once the value is identified, map out the value stream. This covers all the steps involved from beginning to end. Value stream mapping helps determine every step that does not create value and then finds ways to eliminate wasteful steps.

3. Create Flow
After removing waste, it's important to ensure no interruptions. Teams come together to brainstorm new ways to be more efficient during production.

4. Pull System
An effective pull system improves your time to market. Products become much easier to deliver, ensuring they don't have to be stockpiled or built in advance. Overall, this saves time and money for the manufacturer.

5. Continuous Movement
Implementing lean principles in one project is not enough—they should be carried out across all projects. Teams must be vigilant to ensure that these principles are not compromised and use the proper tools to reduce waste continually.

LEAN MANUFACTURING PROCESS: 5S AND 6S FOR SAFETY

To apply lean manufacturing, following the 5S and the 6S for safety is the best practice. 5S helps make workplaces safer, and organized and maximize productivity. This methodology is centered around the following activities:

- Sort (remove that which isn't needed)
- Set in Order (organize what remains)
- Shine (inspect and clean the work area)
- Standardize (record standards for 5S)
- Sustain (consistently apply 5S standards)

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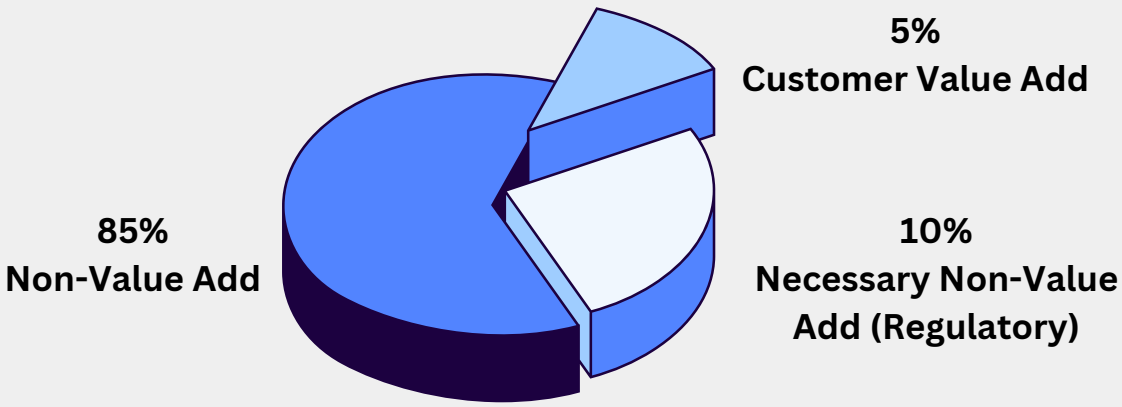
VALUE AND NON-VALUE ADD TO BATTERY TESTING

What Is Identified As Value and Non-Value Add for Battery Testing?
Every lab has an activity that is value add or non-value add work. Value add is the essential work a customer is willing to pay for, and non-value add is the waste that prevents the business from progressing. Within battery testing, non-value-added work, also known as non-lean work, is work that comprises idle time, excess movements, and handling.

Non-Value Add for Battery Testing
This could look several ways in the lab, including:

- Spending time connecting each channel from your battery testing equipment to your cells, modules, or packs inside a chamber.
- This could also include untangling messy wires and having an unorganized test set-up.
- Establishing communication between your battery testing equipment and environmental test chambers without proper technology.
- Physically moving and tracking batteries.
- Building test profiles and configurations to match your battery tester.
- Attempting to collect useful data and analyze it.

Although harmless from the outside, these activities can be potentially harmful for battery testing. Ideally, for testing success, you want to aim for:



By following a lean approach, you can save non-value add time, which maximizes battery **production.**

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WHAT IS AES'S APPROACH TO BATTERY TESTING

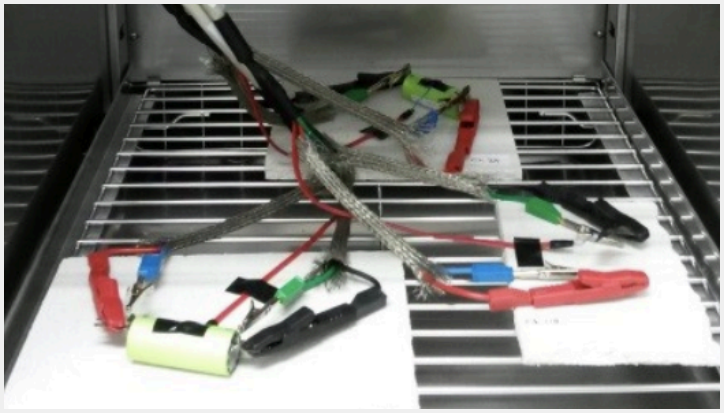
Redefining Battery Chamber Design
Our decades of experience have provided insight into customer pain points and what's missing. We set out to improve the customer experience within all forms of testing, including battery testing, to help customers achieve success. Over the years, we've seen many companies not using a lean approach to battery testing and the effects it has had on their production. Their chambers often included:

- **Wasted space**: Messy and unorganized wiring leads to poor utilization of space.
- **Conductive surfaces:** An improper layout could create conductive surfaces that potentially shorten cells, starting a battery thermal event (BTE).
- **Poor labeling:** Not labeling channels that correspond to the cycler creates inefficiency.

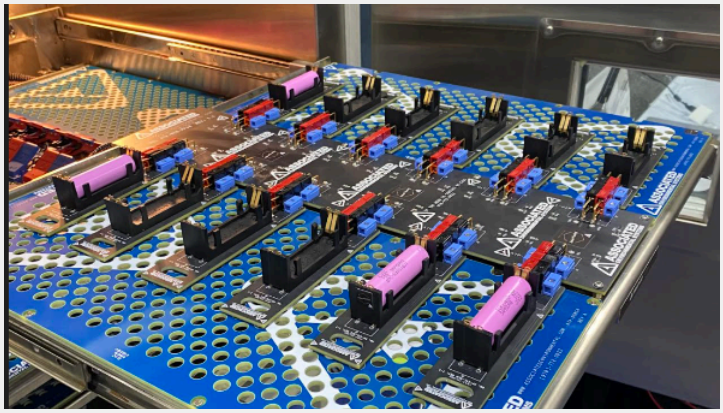
To combat unproductive battery testing provisions, AES created mistake-proofing and lean designs for battery testing:

- Labeling channels and cables that correspond with the cycler.
- Color-coding for positive and negative
- Pre-wired systems so cells easily connect (Known as our All Test Platform (ATP) system)
- Mounted, gold-plated kelvin clips with plastic dividers to prevent shorts
- Igus track and sliding shelves to organize cables
- Perforated, non-conductive Fr4 testing surface prevents shorts

We built our ATP battery fixtures on AES's lean designs. These battery solutions account for various battery cell sizes, formats, and chemistries. The ATP® series consists of ATPPRIME, ATPHEAVY, ATP Adaptable, and ATPFLEX, providing flexibility, convenience, and compatibility with battery test chambers.



Not Lean



Lean

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BATTERY TESTING SAFETY FEATURES

Customers need to be able to rely on the chamber they have purchased. Each environmental chamber for battery testing and the supplies AES creates come with reliable battery testing features that protect teams and ensure success:

PREVENTATIVE SAFETY FEATURES	PREVENTATIVE ACTION
Set Point Temperature Limit	Prevents the chamber from being set to a temperature outside the desired range.
High Low Temperature Limit	High low limit control(FM approved) is independent from primary chamber controller. This is a back-up safety to the set point temperature limit safety feature.
Product Sensors	Measures the cell temp. If cell temperature gets too high, testing will be stopped.
Rapid Rise	Measures cell and air temperature. If the chamber is heating or cooling too fast, this feature shuts down testing prior to a BTE.
Temperature Limited Sheath Heaters	Keeps surface temperature of the heater far below the auto-ignition temperature of any gas present in the chamber, preventing ignition.
Alarm Input/Output	I/O designed to communicate alarm status between chamber and cycler, hardwired.
Gas Sensor/s *Optional*	Monitor gas levels inside the chamber for abnormal conditions. Puts chamber in alarm state with abnormal levels.

MITIGATION SAFETY FEATURES	MITIGATION ACTION
Emergency Stop Button	Stops all temperature conditioning and put the chamber in an alarm state.
Reinforcement	Reinforced chamber inner structure and enhanced door structure hinging and latching. Designed to handle pressure increase during BTE.
Safety Purge	Removes oxygen from chamber and replaces with inert gas (fire suppression).
Audible and Visual Alarm	Alerts chamber user/s to alarm status and evacuate area.
Burst Disk/Low Flow Vent	Graphite burst disk and rupture sensor relieve pressure in case of BTE.
Door Lock	Prevents access to the chamber when running or in alarm condition. Intergrated door position sensor (open/close).
Alarm Input/Output	Communicates alarm status between chamber and cycler and triggers audible and visual alarms. Halts temperature conditioning and charging/discharging.

SEVERITY LEVEL	DESCRIPTION	EFFECTS
0	No effect	No effect. No loss of functionality
1	Reversible Loss of Function	No defect; no leakage; no venting, fire, or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell reversibly damaged. Repair of protection device needed.
2	Irreversible Defect/Damage	No leakage; no venting, fire, or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell irreversibly damaged. Repair needed.
3	Leakage Δ mass <50%	No venting, fire, or flame; no rupture; no explosion. Weight loss <50% of electrolyte weight (electrolyte = solvent + salt).
4	Venting Δ mass >=50%	No fire or flame; no rupture; no explosion. Weight loss ≥50% of electrolyte weight (electrolyte = solvent + salt).
5	Fire or Flame	No rupture; no explosion (i.e., no flying parts).
6	Rupture	No explosion, but flying parts of the active mass.
7	Explosion	Explosion (i.e., disintegration of the cell).

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OPTIMIZE TESTING WITH BENCHTOP CHAMBERS

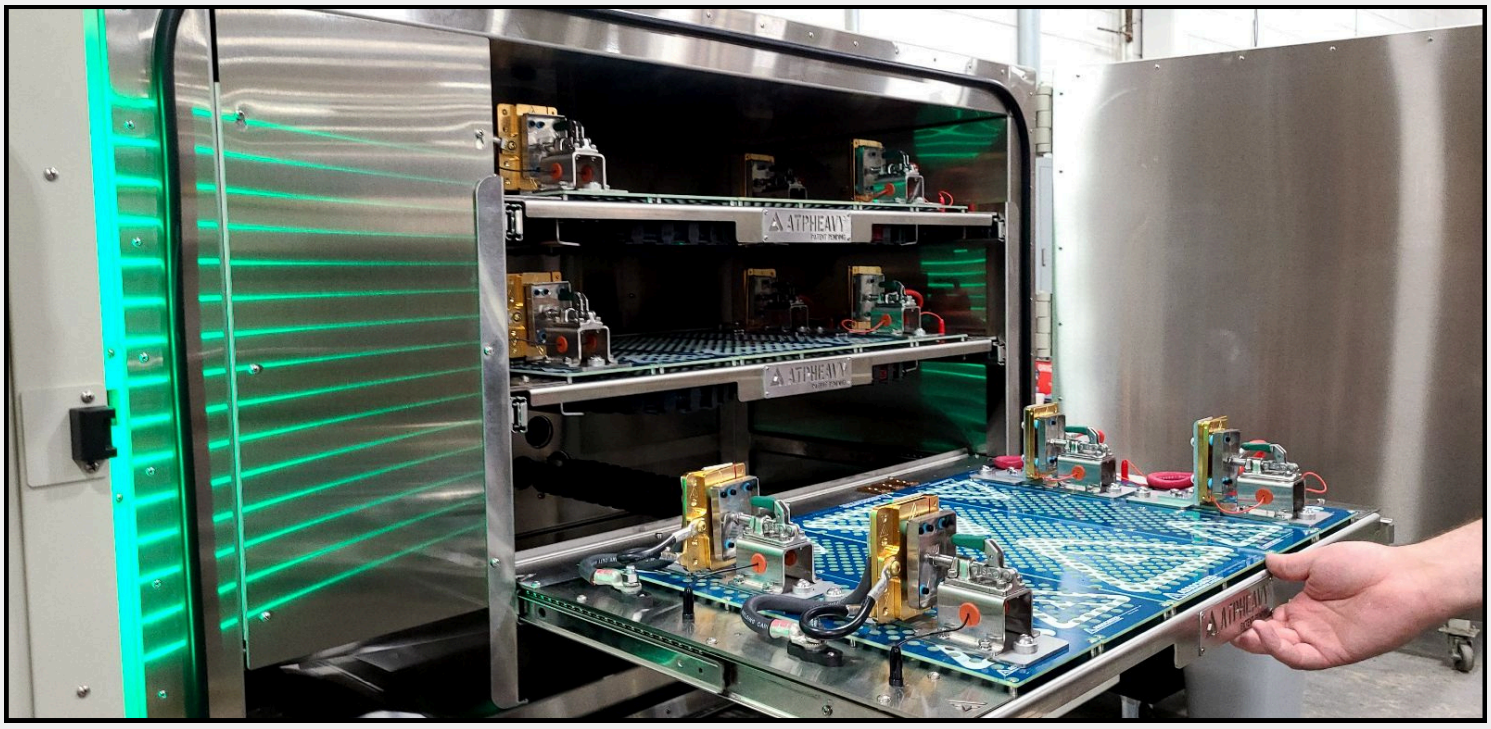
When it comes to battery testing chambers, AES enforces lean principles by encouraging its customers to go with smaller chambers. Even though labs can have different purposes and testing needs, labs can reduce waste and optimize their resources by opting for smaller chambers and stacking chambers.

Benefits of Using Small Testing Chambers
Testing in smaller battery test chambers provides:

- Faster results
- Redundancy in case the chamber or tester fails
- Safety, in case of a BTE (Battery Thermal Event)
- Better temperature uniformity and less impact on other cells in case of a BTE
- Maximized lab footprint
- Greater price-per channel

To understand what type of battery test chamber is right for you, whether you're conducting EV battery testing or consumer electronics battery testing, AES recommends that customers identify several factors. A critical piece of the equation is cell geometry. To understand your testing set-up needs, first, you will need to let your manufacturer know your cell format, the physical dimensions of your cell, and contact points. Once those items are clearly distinguished, you can better understand which how many channels we can support in your custom-tailored fixture that will go inside your battery test chamber.

Our solutions focus on taking a lean approach by optimizing floor space while maintaining safety, ergonomics, and testing requirements. We often discourage customers from thinking they need a large chamber to maximize channel count and point them towards a lean solution that factors in the ideal density that the chamber can contain if there is a BTE. Our team provides a density portion calculation, helping them understand which of our chambers can handle both the ideal channel count and density. Determining the ideal density gives you insight into whether or not your testing needs to be completed in multiple chambers instead of one larger chamber.



CONCLUSION

AES's battery testing solutions are designed to help you reduce waste and optimize non-value add work. Avoid the clutter and distractions that force your battery testing off track and pivot your attention to what matters most: bringing innovative products to market. With AES, you can rely on our expert guidance and products to adapt to ongoing changes and maximize your lab space.

Stay lean to move your testing forward. Get in touch with an AES sales engineer today to learn more about our approach to lean manufacturing in battery testing across multiple industries.

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