UL XPLORLABS

PORTABLE ELECTRICAL POWER

STUDENT

THERMAL TEST

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

YOUR NAME

QUESTIONS TO XPLORE

HOW CAN WE PROTECT PEOPLE AND COMPONENTS FROM THAT HEAT?

WHAT IS THERMAL RUNAWAY AND WHAT DOES HEAT HAVE TO DO WITH IT?

As we learned in Investigation 1, safety scientists ask why a phenomenon happens. Safety engineers ask how they can solve the problem and keep people safe. Both ask how they can design and communicate solutions.

We know that the development of any technology can lead to unintended consequences and new safety risks, particularly when these advances are fully integrated into everyday life, and battery technology is no different. Safety science research and testing is a crucial way manufacturers can develop and build batteries safely for use in emerging applications. Because lithium-ion batteries are the leading rechargeable battery for consumer electronics and electric vehicles, and are a rapidly growing source for energy storage, it is important that safety standards continue to evolve. This evolution drives safer commercial use as lithium-ion batteries power more products and are more widely used in daily devices.

THE CHALLENGE

Now that your team has done the tensile testing and constructed the enclosure, can it pass the final safety test for thermal performance?

XPLORATION

Safety Engineers follow a set of standards when evaluating products and components for safety. Standards are rigorous requirements that determine the performance of the product and may establish size or shape or capacity of a product, process, or system. As examples, standards help ensure that the same size screw can be purchased anywhere in the world, that a light bulb bought at any store fits a socket in anyone's home, and plugs for electrical appliances fit outlets. With standards, our homes, workplaces, and public buildings are safer from collapse, fire, and explosion.

This Investigation will test the thermal performance of your hoverboard enclosure design using a bundle of 4 handwarmers to represent the battery pack.

The final design must protect the battery, support the weight of 1 pound (Investigation 2), and pass thermal performance test. The Safety Standards for hoverboard sets the guidelines for determining whether or not the battery pack maintains normal operating temperatures and/or exceeds maximum temperature rise.

When you put the battery pack (bundle of 4 handwarmers) inside your enclosure, does the surface of the enclosure stay within the 7⁰F range set by the standard? Does the internal temperature of the battery pack stay within a 5⁰F limit? If your design passes these final requirements, your product will pass the test!

If your enclosure does not pass these final requirements for safety, it is up to your group to predict why the enclosure did not pass and to make adjustments to your design that will keep the temperature from increasing beyond the safety standard requirements. Once you make the adjustments, run the tests again. This is the process of safety engineering!

TEMPERATURE TEST FOR HOVERBOARDS

Hoverboard Part	Maximum Temperature Rise Allowed
Enclosure	May not exceed 7⁰F
Battery Pack Interior	May not exceed 5⁰F

XPLORATION

MATERIALS

- ◯ **From Investigation 2 — hoverboard enclosure designed/built/tested by group**
- ◯ **Bundle of 4 handwarmers* — use a rubber band to bundle the handwarmers****
- ◯ **Meat thermometer**
- ◯ **Infrared thermometer or other surface thermometer that reads over 140°F**
- ◯ **One can of soup weighing 16-18 oz*****
- ◯ **Student lab notebooks or student XplorLabs pages**

NOTES

*For battery placement phase within the hoverboard enclosure, the handwarmers can be handled in the packaging without activating them. Once handwarmers are activated (taken out of packaging) limit handling because the more the handwarmer is handled, the faster the heat dissipates.

**When bundling the battery pack (handwarmers) with the rubber band, be sure not to wrap them too tightly.

***The soup is meant to represent the shape and weight distribution of a person relative to the size of your hoverboard enclosure.

Engineers do a series of tests, make models and prototypes, test, and redesign. It is not often, if ever, that an engineer gets the perfect design on the first try. Engineering is about gathering information, making a plan, testing, and redesigning. Remember that as you test the placement of the battery packs. Can you make it better by making modifications? Remember to record any changes that you make!

PROCEDURE

- ◯ Use the thermometer to RECORD the temperature (ºF) of the enclosure surface over the location of where the battery pack will be. Hint: place a mark on the surface for ease in identifying location.
- ◯ Use the meat thermometer to RECORD the internal temperature (ºF) of the battery pack. For the best results, make sure to insert the thermometer in between, the middle of, the bundled handwarmers (do not bundle too tight).
- ◯ Arrange the activated (hot) battery pack in the enclosure. Place the soup can on the enclosure (representing the person standing on the hoverboard).
- ◯ Set the timer for 5 minutes. (Good time to check your data tables and make sure your observations are complete!)
- ◯ After 5 minutes, use the thermometer to RECORD the external temperature (ºF) of the enclosure surface over the location of the battery pack, use the spot you marked.
- ◯ Take the battery pack out and immediately measure the internal temperature (^{0}F) of the battery pack using the meat thermometer. RECORD the internal temperature of the battery pack.
- ◯ Did the external temperature of the enclosure increase by more than 7ºF? If yes, redesign the placement of the battery pack inside your enclosure and repeat the test.
- ◯ Did the internal temperature of the battery pack increase by more than 5ºF? If yes, redesign the placement of the battery pack inside your enclosure and repeat the test.
- ◯ If the answers to both questions in steps 7 and 8 are no, your design has passed the thermal performance test as required in the safety standard.

ROLES

THE STUFF SUPERVISOR
Gathers and cleans up materials

THE EXPERIMENT EXEC
Runs the experiment

THE DIRECTOR OF DOCUMENTS
Reads the procedure to the group and helps the group members with data collection

THE PRINCIPAL PRESENTER
Shares the group's work with the rest of the class

DRAW THE SET-UP OF THE THERMAL TEST HERE

THERMAL TEST DATA

Trial	**EXTERNAL TEMP(°F)** Enclosure without battery pack	**EXTERNAL TEMP(°F)** Enclosure with battery pack (after 2 min)	**TEMP(°F) Difference**
	A	**B**	=B-A >7°F, fail <7°F, pass
1			
2 Data from redesign 1 (if needed)			
3 Data from redesign 2 (if needed)			

Trial	**INTERNAL TEMP(°F)** Battery pack	**INTERNAL TEMP(ªF)** Battery pack inside the enclosure (after 2 min)	**TEMP(°F) Difference**
	C	**D**	=D-C >5°F, fail <5°F, pass
1			
2 Data from redesign 1 (if needed)			
3 Data from redesign 2 (if needed)			

XPLANATION

Draw/write/discuss the successful design features that passed the thermal performance test. What were the unsuccessful features?

XPLANATION

What was a common factor that caused heat to be trapped inside the enclosure? How can you mitigate (lessen) for that factor in your design? Did the materials you used in your enclosure design contribute to heat generation? How?

XPLANATION

What surprised you? What did you predict correctly?

ELABORATION

RESEARCH OTHER PRODUCTS ON THE MARKET THAT USE LITHIUM-ION BATTERIES

- **Pick out your favorite product and think about the design of the product.**
- **Why is it important in the design phase to determine where the placement of the battery pack is and what might cause heat generation within that product?**

**An example might be a smart phone or an electric vehicle, or think even bigger like a solar storage system*

BOEING 787 INVESTIGATION

On January 7, 2013, at 10:21 Eastern Standard Time, smoke was discovered by cleaning personnel in the aft (rear) cabin of a Boeing 787, which was parked at General Edward Lawrence Logan International Airport in Boston, Massachusetts.

About the same time, a maintenance manager in the cockpit observed that the auxiliary power unit (APU) had automatically shut down. Shortly afterward, a mechanic opened the aft electronic equipment bay and found heavy smoke coming from the lid of the APU battery case and a fire with two distinct flames at the electrical connector on the front of the case.

None of the 183 passengers and 11 crewmembers was aboard the airplane at the time, and none of the maintenance or cleaning personnel aboard the airplane was injured. Aircraft rescue and firefighting personnel responded, and one firefighter received minor injuries.

This led the National Transportation Safety Board (NTSB) to ground 50 Dreamliner airplanes — a dramatic step. When a plane is grounded it means they are not allowed to fly. The NTSB chose UL to conduct a comprehensive investigation led by UL's safety scientists and engineers. Many other safety scientists and engineers worked with UL to complete a comprehensive forensic analysis on the Boeing 787's battery and cells. Their findings were:

"The NTSB determines that the probable cause of this incident was an internal short circuit within a cell of the APU [Auxiliary Power Unit] lithium-ion battery, which led to thermal runaway that cascaded to adjacent cells, resulting in the release of smoke and fire. The incident resulted from Boeing's failure to incorporate design requirements to mitigate the most severe effects of an internal short circuit within an APU battery cell and the Federal Aviation Administration's failure to identify this design deficiency during the type design certification process" (NTSB's Incident Report, (2013) Probable Cause).

Source: Boston Herald

READ

http://www.ul.com/inside-ul/powering-up-from-dreamliners-to-hoverboards-ul-researcher-alvin-wu-leads-efforts-to-make-batteries-safer-2/

CHALLENGE

If you were asked to help with the Boeing 787 Investigation, which role would you rather be in – a safety scientist who asks why a phenomenon happens or a safety engineer who asks how to solve the problem? Why?