FIRE SUPPRESSION FOR LITHIUM ION BATTERIES

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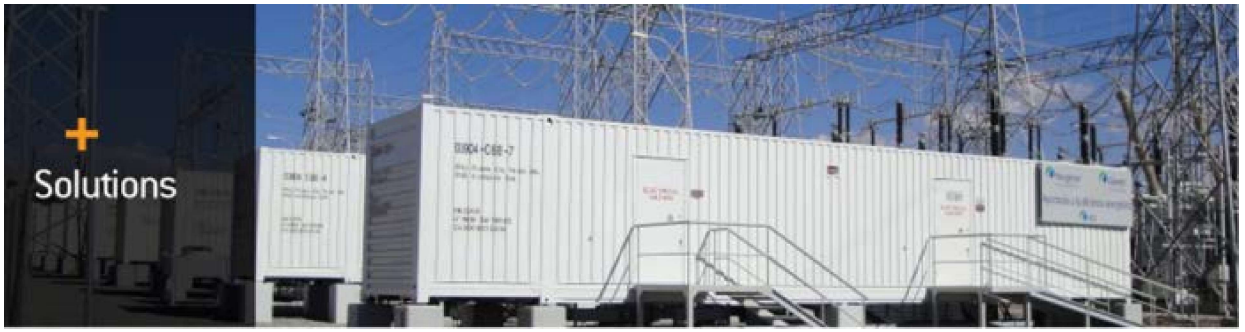
WHAT WE WILL COVER

- What are Lithium-ion (Li-ion) batteries?
- Where are they used?



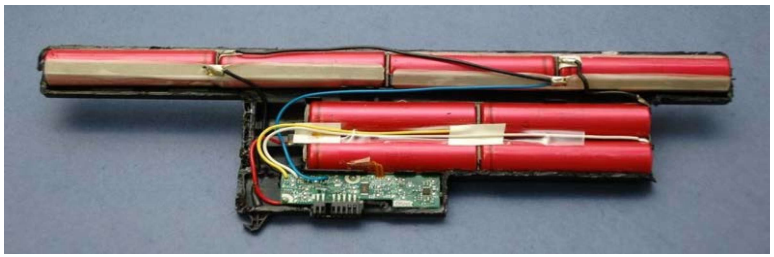
WHAT WE WILL COVER

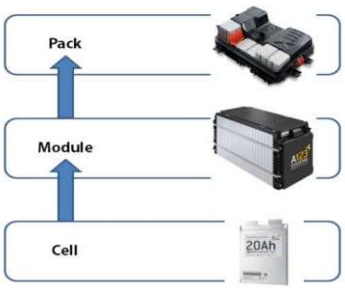
- What do you need to know about them?
  - Difference between Li-ion and Lithium (Li)
  - Different types of Li-ion batteries
  - What is an electrolyte?
  - Thermal runaway
  - Fire protection standards??

- What information is required to be collected by you?
- Q&A

WHAT ARE LI-ION BATTERIES?

- A **lithium-ion battery** or **Li-ion battery** is a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging
- Contain Anode, Cathode, Electrolyte and Separator





WHERE ARE THEY USED?

- Consumer electronics
- Power tools

- Energy storage systems (grid & distributed)
  - Wind farms
  - Power plants & substations (grid stabilization)
  - Distributed/shared residential (photovoltaic systems)
  - Data centers
    (future prediction to power infrastructure)

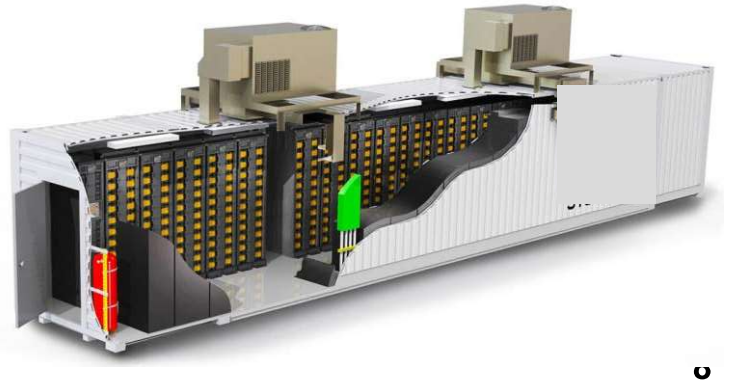
KEY THINGS TO KNOW

- Different types (Cathode Material): Lithium Iron Phosphate(LFP), Lithium Ion Maganese Oxide(MO) and Nickel Maganese Cobalt Oxide (NMC)
  - These are considered the most stable (LFP being the most stable)
  - Lower energy density and longer life
- Lithium Cobalt Oxide
  - High energy density but more unstable when damaged
- They **do not** contain metallic lithium
- **Does not** present a Class D fire hazard
  - Combustible/self-oxidizing metals

KEY THINGS TO KNOW

- Electrolytes
  - Complex formulations of lithium salts ($LiPF_6$, $LiBF_4$, $LiClO_4$)
  - Organic solvent (ethylene carbonate (EC), dimethyl carbonate(DMC), diethyl carbonate(DEC), ethyl acetate(EA)
  - Class B Materials, not Class D

- Manufacturers of electrolytes constantly are tweaking formulas
  - Formulation variances affect design concentration requirements



KEY THINGS – WHY DO THEY FAIL?

- Mechanical abuse
  - Crush/penetration
- Thermal abuse
  - High storage temps (non-climate controlled area)
  - Stored next to heater
  - Exposure to flame
  - Direct discharge of hot vent gas into adjacent cell
- Electrical abuse
  - Overcharging

KEY THINGS – WHY DO THEY FAIL?

- Cell manufacturing defects
  - Internal shorting
  - Defective materials
- One or multiple of these potentially result in:
  - Internal heating and electrical shorting
  - Thermal runaway, cell rupture and discharge of the flammable electrolyte
  - Gases from vented electrolyte coming into contact with hot surface or ignition source

KEY THINGS – WHAT IS THERMAL RUNAWAY?

- Cell thermal runaway refers to internal rapid self-heating of a cell derived from the exothermic chemical reaction
- In a thermal runaway reaction, a cell rapidly releases its stored energy
- The more energy a cell has stored, the more energetic a thermal runaway reaction will be

KEY THINGS – WHAT IS THERMAL RUNAWAY?

- Internal temperature can reach 1,112 degrees F (600 degrees C)
- This reaction will result in the breach of the Li-Ion pressure relief vent and release of the flammable electrolyte material

Note: Once the flammable electrolyte vent gas comes in contact with an ignition source (hot case, spark, etc.) the gas will ignite

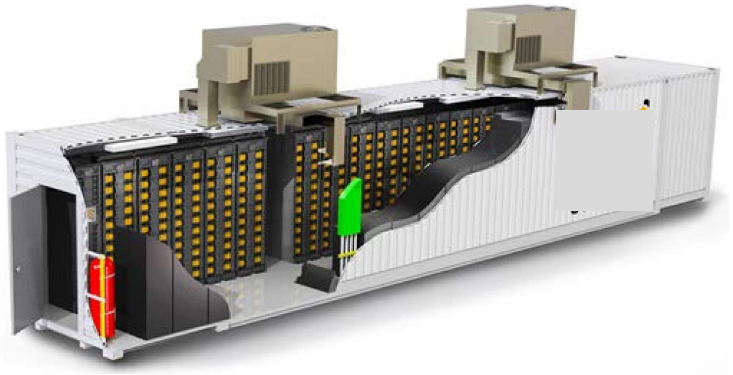
Note: Thermal Runaway is an **internal failure** of the battery and cannot be controlled by any suppression system

KEY THINGS – FIRE PROTECTION STANDARDS & TEST METHODS

- NFPA 855 (Developmental Draft Only) Installation of Stationary Energy Storage Systems (ESS)
- UL9540A – Safety Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

WHAT IS KIDDE FIRE SYSTEMS DOING?

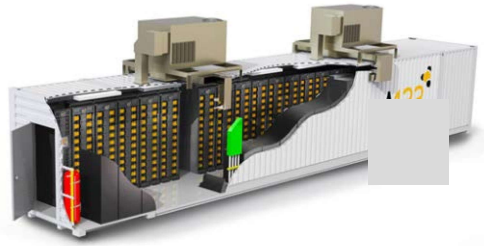
- Involved with protecting Li-ion energy storage systems since 2009
- Provide guidance and consultation to distribution



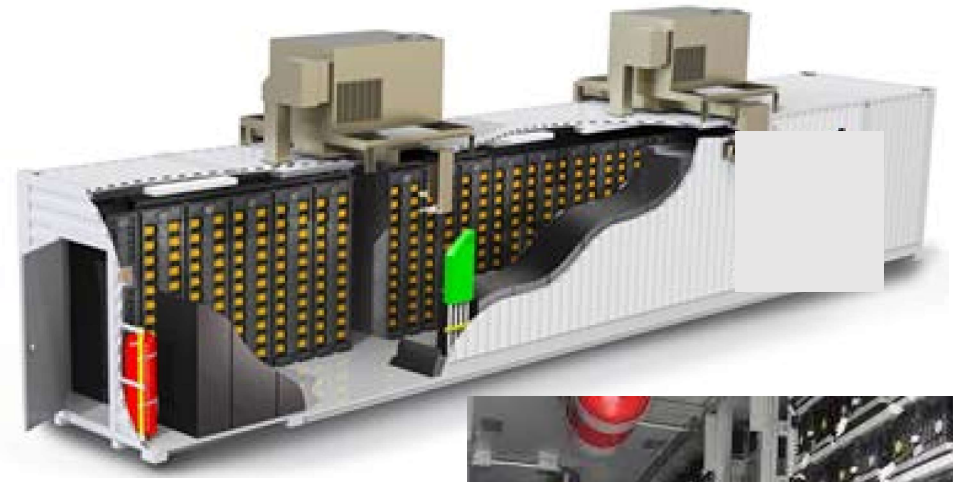
WHAT IS KIDDE FIRE SYSTEMS DOING?

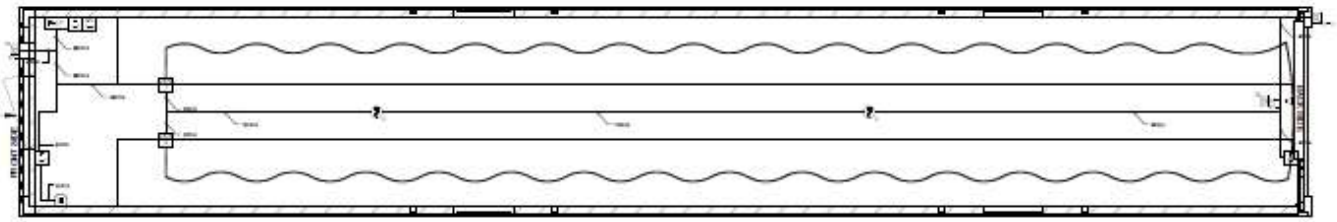
- Working with OEM partners (LG Chem, NECES, Demand Energy, Samsung, etc) to:
  - Test electrolyte(s) to determine cup burner value
  - Define design concentration off of cup burner per NFPA 2001
    - FM200™ design concentration range: 9.0-9.5%/v*
    - NOVEC™ 1230 design concentration range: 6.2%-7.2%/v*

*Note: these range values are for tested electrolytes

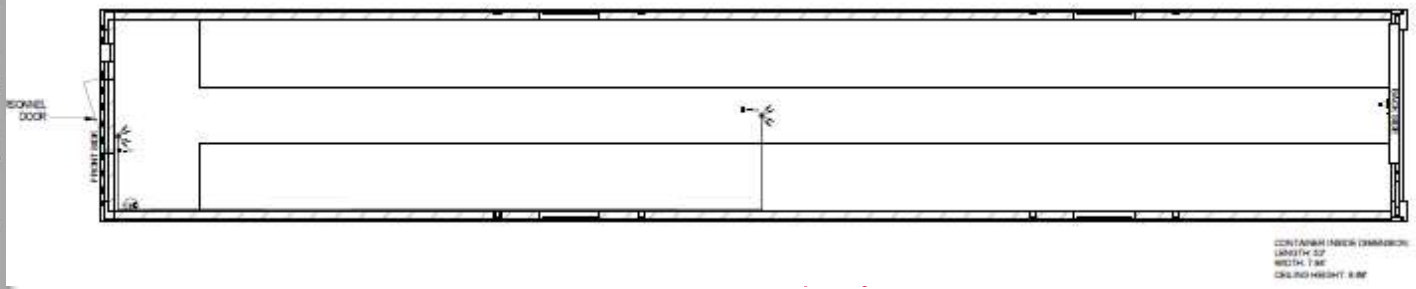


DESIGN LAYOUT





ELECTRICAL LAYOUT PLAN VIEW



WHAT IS KIDDE FIRE SYSTEMS DOING?

- Initial guidance in 2013

Materials	Novec 1230 Fire Protection Fluid (FK-5-1-12)	FM-200 (HFC-227ea)	Argonite (IG-55)
Ethyl Acetate	6.2% / V	8.9% / V	52.9% / V
Diethyl Carbonate	6.4% / V	8.5% / V	52.9% / V
Dimethyl Carbonate	6.3% / V	8.8% / V	52.9% / V
Ethyl Methyl Carbonate	6.6% / V	Data unavailable	52.9% / V
Propylene Carbonate	6.7% / V	Data unavailable	52.9% / V
% / V = percentage by volume			

WHAT IS KIDDE FIRE SYSTEMS DOING?

- White paper published in 2013 (Jonathan Ingram)
  - "Lithium Ion Batteries: A Fire Potential in Waiting"

http://www.datacenterjournal.com/lithium-ion-li-ion-batteries-a-fire-potential-in-waiting

Electrolytes are Class B materials (flammable liquid), and the design concentration should be determined by test for the particular composition present.

The DATACENTER Journal
Where IT, Facilities and Design Meet

Lithium Ion (Li-Ion) Batteries: A Fire Potential in Waiting

by Jonathan Ingram, Director of Product Marketing at Kidde Fire Systems

a single space. The uses of Li-ion cells in these applications need to be reviewed for potential fire hazards, and fire protection strategies must be applied and implemented to reduce the risk.

Potential fire protection strategies include using gaseous fire-suppression agents, such as FM-200, 3M Novec 1230 fire protection fluid and/or Argonite to protect large arrays of Li-ion cells.

What You Should Know About Lithium-Ion Batteries

Li-ion batteries do not contain Lithium in its metallic form. Therefore, these batteries do not pose a Class D fire risk as compared with batteries that do contain metallic lithium.

Electrolytes used in Li-ion batteries are complex formulations composed of lithium salts such as $LiPF_6$, $LiBF_4$ or $LiClO_4$ in an organic solvent such as ethylene carbonate (EC), dimethyl carbonate (DMC), diethyl carbonate (DEC) or ethyl acetate (EA). A liquid

The proliferation of battery technologies in modern industry is presenting fire professionals with new sets of challenges. Confusion exists as to the correct approach for protecting industrial batteries from fire, including battery manufacturing, battery storage and battery-powered applications.

Lithium-ion (Li-ion) cells are distinctly different from lithium (primary) cells and are used in large numbers in power-grid stabilization systems, containerized battery systems and other large-scale applications. These types of systems have thousands to tens of thousands of these Li-ion cells integrated into

OTHER SUPPRESSION OPTIONS

- Inert Gas
  - Not tested as much as NOVEC™ & FM-200™ in U.S.
  - Design concentrations may exceed LOAEL
  - Venting requirements (reduced by KFS new inert gas platform)
- CO_2 – 50% concentration
- High Pressure Water Mist
  - Preliminary testing done by Marioff® for specific battery manufacturer
  - Looking to explore additional testing with well known 3rd party testing lab

WHAT INFO DO YOU NEED TO COLLECT?

- Determine what battery technology is present
  - Li-ion, Lithium, Lead Acid, other
  - If Lead Acid, protect using standard Class C design
- Manufacturer of the battery module
- Name of the electrolyte

WHAT INFO DO YOU NEED TO COLLECT?

- MSDS of specific electrolyte **(not the battery)**

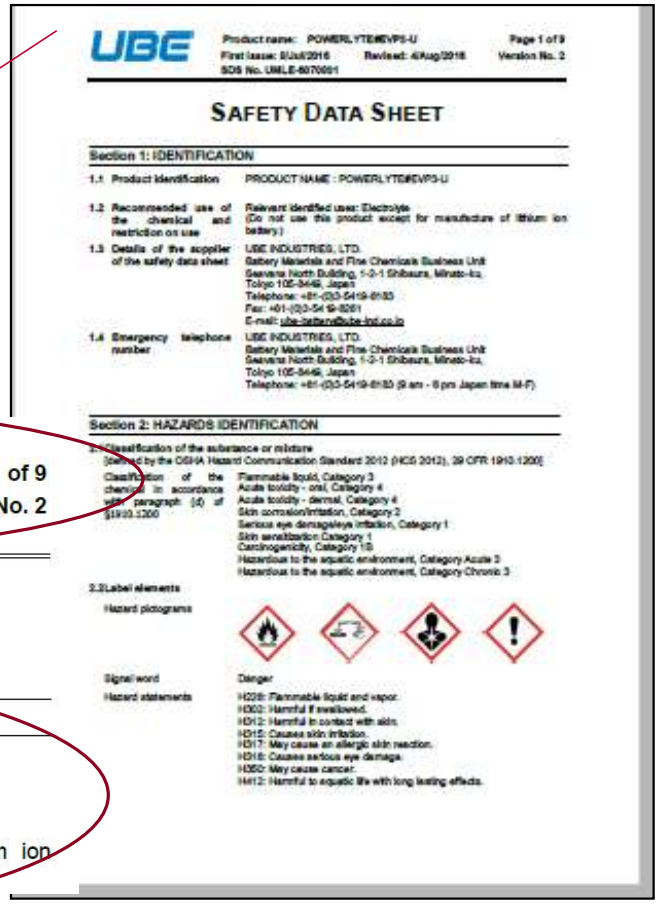
UBE

Product name: POWERLYTE#EVP3-U **Page 1 of 9**
First issue: 8/Jul/2016 **Revised: 4/Aug/2016** **Version No. 2**
SDS No. UMLE-6070801

SAFETY DATA SHEET

Section 1: IDENTIFICATION

1.1	**Product identification**	PRODUCT NAME : POWERLYTE#EVP3-U
1.2	**Recommended use of the chemical and restriction on use**	Relevant identified uses: Electrolyte (Do not use this product except for manufacture of lithium ion battery.)



WHAT INFO DO YOU NEED TO COLLECT?

- Is OEM or battery manufacturer willing to submit sample of raw electrolyte?
  - If not previously tested by KFS
  - Need 1 quart sample for each agent (FM200™ or NOVEC™) to be tested
  - KFS will supply shipping address to send sample to
  - Testing will take 3-4 weeks from receipt of electrolyte at lab

OTHER CONSIDERATIONS

- Check with the AHJ to determine any additional requirements (NYC/FDNY, etc.)
- Treat area as empty when doing design for containers, pre-fab enclosures, etc.
- Manufacturers of Energy Storage Systems (ESS) battery modules are doing the following precautions:
  - Isolating battery cells from one another
  - Monitoring and trending battery behavior and characteristics to isolate affected cells and head off thermal runaway
- Keep informed about new changes happening in the ESS industry

OTHER CONSIDERATIONS

- If you are not sure about the specific battery technology or design concentrations ask KFS. If we are not sure we will require cup burner testing.
- Preliminary Guidance* – if no info is available:
  - Quote NOVEC™ between 8% to 8.5%/v until sample can be tested
  - Quote FM200™ between 9.8% to 10%/v until sample can be tested

* KFS prefers to determine exact design concentration by testing. The above guidance can be used only if customer looking for budgetary number.

CONCLUSIONS

- Lithium-ion and Lithium batteries are not the same. Know the difference.
  - **Lithium Ion** represents **Class B** fire hazard
  - Lithium represents a Class D fire hazard
- Clean Agents can be used to protect areas containing Li-ion batteries
  - Need to know electrolyte used in the battery and if it has been tested
  - New KFS inert gas platform (Argon, Nitrogen, Argonite, and IG-541) will provide additional options

CONCLUSIONS

- Collect all relevant information about the Li-ion battery
  - Manufacturer
  - Electrolyte name
  - MSDS
  - Are they willing to provide samples for testing?
  - Are there any local requirements you need to be aware of?
- Keep up-to-date on developments with NFPA 855 (Draft Standard progress), local requirements, changes to electrolytes by manufacturers
- Call Kidde Fire Systems with any questions