COLUMBUS
INTERNATIONAL CODE COUNCIL 2017

Energy Storage Systems – Fire Safety Concepts in the 2018 International Fire and Residential Codes

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Tuesday, September 12, 2017

8:00 AM - 9:30 AM

ICC INTERNATIONAL CODE COUNCIL®

Energy Storage Systems
Fire Safety Concepts in the 2018 IFC & IRC

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Legacy Stationary Battery Systems

Primary use

- Emergency and standby power for buildings
- UPS
- Telecommunication system backup power

Legacy Stationary Battery Systems

Location

- Telecom central offices (dedicated use)
- Internet data centers
- Incidental use areas in occupied buildings

Legacy Stationary Battery Systems

Lead acid system hazards:

- Hydrogen gas produced during charging
- Corrosive liquid spills
- Large quantities of electrical energy

Energy Storage Systems (ESS)

Expanding energy storage infrastructure

- Grid balancing and resiliency
- Mitigating renewable energy intermittency
- UPS

Utility, commercial and residential applications

Modern Battery Technologies

Stationary battery technologies include

- Flow batteries
- Sodium-sulfur batteries
- Lithium-ion batteries
- Others technologies on the way

Energy density and cost drive new battery technologies

6

Modern Battery Installation Scenarios

Mixed Occupancy Building

Dedicated ESS Building

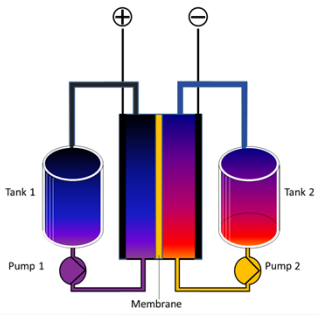
Rooftop Installations

Outdoors Near Building

Outdoors Remote

Flow Batteries

- Two tanks of liquids, pumped past a membrane between electrodes
- Electric current produced while both liquids circulate in their own respective space
- System includes pumps, sensors, control units, secondary containment



Flow Batteries

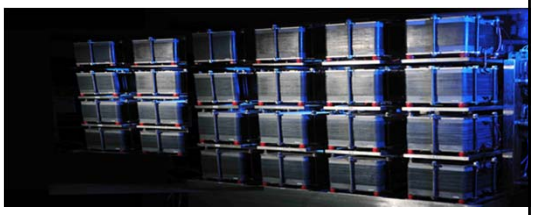
Redox - Electro-chemical components dissolved in electrolyte

Vanadium flow batteries use the same chemical in both tanks

Advantages - Flexible layout, long cycle life, quick response times, no harmful emissions

Disadvantages - Relatively low energy density

Wide range of chemistries have been tried



9

Sodium–Sulfur Batteries

Molten-salt construction with liquid sodium and sulfur

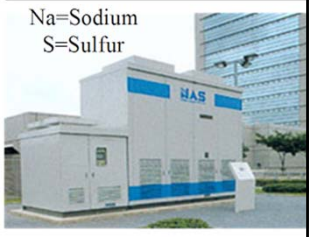
High energy density, and long cycle life

Operating temperatures of 600+ °F

Highly corrosive sodium polysulfides

Vacuum insulated boxes protect sodium from water and oxidizing atmospheres

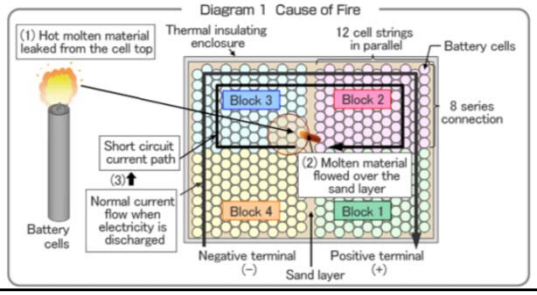
NAS Batteries



Pure sodium spontaneously burns in contact with air and moisture

Sodium–Sulfur Batteries - 2011 Tsukuba Fire

- 40 battery modules, one faulty cell breached
- Hot molten material created a short circuit/fire in adjoining cells
- Module released flames and hot molten material that melted battery cell casings inside battery modules installed above and below, causing the fire to spread further
- Fuses and fire barriers between modules subsequently added



11

Lithium-ion Batteries

- Excellent energy density
- The current battery of choice
- Batteries and systems are readily available

Lithium-ion Batteries

- Lithium technologies differ and are continually evolving
- Lithium NCA – Higher energy density, operating temperatures
- Lithium LFP – Lower energy density, cost, operating temperatures

Risks and potential fire hazards vary between technologies

Li-ion Battery Incidents

EXPLODING E-CIGARETTE BATTERIES SENDING MORE BURN VICTIMS TO SEATTLE HOSPITAL

Li-ion Battery Cell Reactions

Overheating and cell rupture is possible from:

- Overcharging
- Short circuits
- Manufacturing defects

Overheated cell can vent flammable gas

Ignition source creates fire/explosion

Thermal runaway in one battery will readily spread to adjacent cells

15

Li-ion Batteries Abnormal Charging

16

Overheated Hoverboard Batteries

17

Re-ignition Hazards

18

2015 IFC Battery Systems Requirements

Since 1997 (lead-acid) battery systems allowed in incidental use areas

1 or 2 hour fire-rated separations

Hazmat requirements exempted

Spill control, ventilation, smoke detection

Battery quantities unlimited

Location in building not regulated

Standby & emergency power, UPS use

Current codes do not adequately protect newer battery technologies

Addressing New Potential Hazards

How to address hazards with new batteries being deployed?

Large quantities of Lithium-ion batteries will be present

Proven effective protection methods not yet available

Need to cover new/future battery and other ESS technologies

What do emergency responders need to know to respond?

20

New Battery System Requirements

Proposals F95-16 and RB171-16 were adopted for the 2018 IFC, IBC and IRC

2018 NFPA 1 adopted similar requirements

Intent - Both 2018 fire codes will include similar requirements

NFPA 855 ESS standard under development

2018 IFC requirements already proposed for adoption by the CSFM

FCAC ESS Working Group Strategy

Have something in the 2018 fire codes to address hazards

Conservative requirements due to lack of field experience, fire testing and research

Allow modifications based on a HRA and full scale fire and fault condition testing

Six month deadline to prepare proposals for the 2018 fire codes

2018 Fire Codes

Initial attempt to address new technologies and applications

Hazard mitigation analysis

Size/spacing/MAQ limits

UL 9540 Listing

Outdoor installation

BMS

Location in building

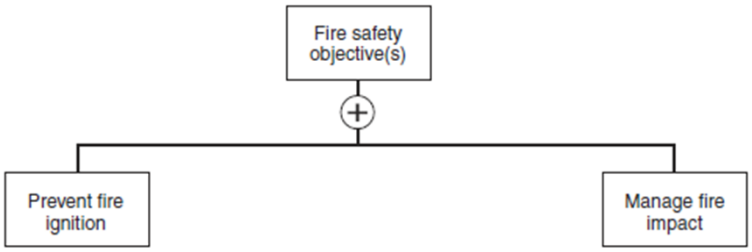
Technology specific protection

Exceptions for large scale fire/fault condition testing

23

Concepts for Protecting Energy Systems

NFPA 550: Guide to the Fire Safety Concepts Tree



Listed ESS
BMS and compatible equipment
Proper installation
Ventilation, as needed

Fire-resistive separation
Suppression and control
Array spacing and MAQs
Location in building or on property
Signage

24

IFC Threshold Limits

2015 threshold
50 gallons electrolyte for lead-acid, Ni-Cad, VRLA
1,000 pounds for lithium-ion and lithium metal polymer
Other technologies not covered
Use - Standby and emergency power or UPS

2018 threshold
Lead acid, Ni-Cad - 70 KWh
Lithium, sodium all types - 20 KWh
Flow batteries - 20 KWh
Other battery technologies 10 KWh
Use - No limitations

25

2018 IFC General

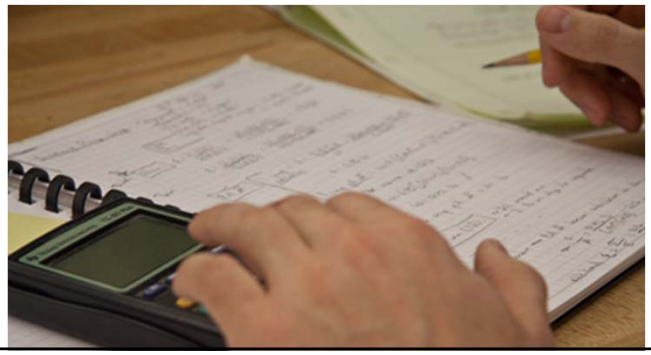
Installation and operation permits
Seismic and structural design per IBC Chapter 16
Vehicle impact protection
Combustible storage not allowed in battery rooms, cabinets
Testing, maintenance and repairs per the manufacturer's instructions

26

2018 IFC Hazard Mitigation Analysis

Hazard mitigation analysis (HMA) shall be provided for:

1. Battery technologies not specifically covered
2. Multiple battery technologies in a room with a potential for adverse interactions
3. When allowed as a basis for increasing MAQs



27

2018 IFC Hazard Mitigation Analysis

The HMA will evaluate the consequences of failure modes

- Thermal runaway in a single battery array
- Failure of the energy management system
- Failure of ventilation system
- Voltage surges on the primary
- Short circuits on the load side of the batteries
- Failure of the smoke or gas detection, fire suppression

The fire code official is authorized to approve the hazardous mitigation analysis based on the HMA.

The HMA is a tool to address unknowns with new technologies

28

Location of Battery Rooms in Buildings

2015 IFC
No restrictions on location in a building or on the property

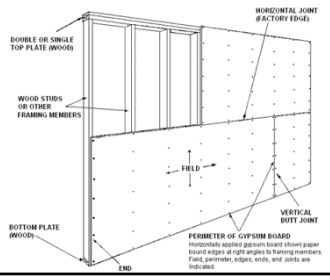
2018 IFC
Battery room floor < 75 feet above the lowest level of fire department vehicle access, and < 30 feet below the lowest level of exit discharge
Exception: Installations on noncombustible rooftops > 75 feet that do not obstruct fire department rooftop operations when approved by the fire code official.

29

Fire-Resistive Separations

2015 IFC
Battery room must be separated from other areas of the building in accordance with Section 509.1 of the International Building (1 or 2 hours depending on adjacent occupancy)

2018 IFC
No changes, still allowed in incidental use areas



30

New Stationary Storage Battery Concepts

Prepackaged stationary storage battery system
Pre-engineered stationary storage battery system

31

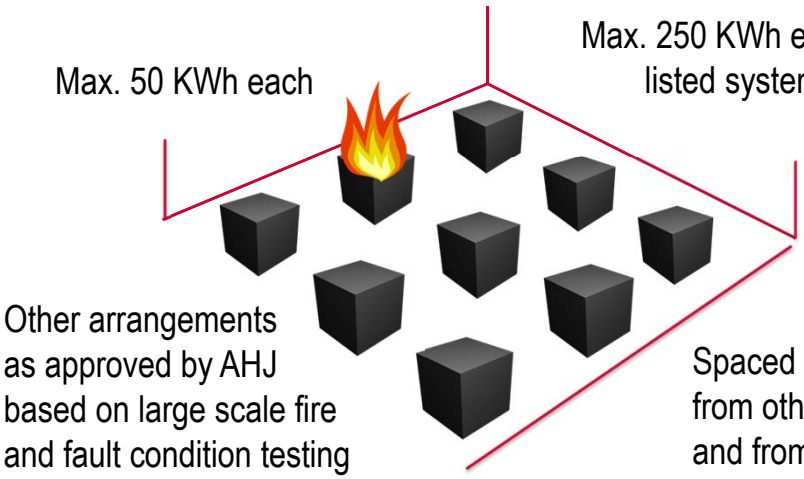
Battery Arrays (Size and Spacing)

2015 IFC
No restrictions on battery arrangements within the room

2018 IFC
- Storage batteries, prepackaged , pre-engineered battery systems segregated into arrays not exceeding 50 KWh each
- Battery arrays must be spaced three feet from other battery arrays and from walls in the storage room
  - Exceptions:
  - 1.Lead acid batteries arrays
  - 2. Listed pre-engineered and prepackaged battery systems can be 250 KWh

32

New Battery Array Concepts



33

Maximum Allowable Quantities

2015 IFC
No restrictions on the quantity of batteries in an incidental use area

2018 IFC
MAQ for an incidental use area within buildings is 600 KWh
- 100 KWh for technologies not covered by the code
- No limit for lead acid battery systems

Fire areas containing battery systems above the MAQ shall comply with Group H requirements
Exception: When approved, larger quantities allowed based on HMA and large scale fire and fault condition testing by an approved testing laboratory.

34

2018 IFC Outdoor Installations

Installations in outdoor enclosures or containers which can be occupied are treated as battery storage rooms

Exception: Battery arrays in noncombustible containers are not required to be spaced three feet from the container walls.

Outdoor battery systems must be separated 5 feet from lot lines, public ways, buildings and other exposure hazards

2018 IFC Batteries and Equipment

Storage batteries (except lead-acid) must be UL 1973 listed

Prepackaged/pre-engineered systems must be UL 9540 listed

Battery chargers must be listed and compatible with the battery chemistry and the manufacturer's charging specifications

Inverters must be listed and suitable for utility interactive system use if operating in parallel with the electrical grid

Vented batteries must include flame-arresting safety caps

2018 IFC Battery Management Systems

A BMS must be provided to monitor and balance cell voltages, currents and temperatures within manufacturer's specs

The BMS must transmit an alarm to an approved location if hazardous temperatures or other conditions are detected

37

2018 IFC - Battery Management Systems

A BMS must be provided to monitor and balance cell voltages, currents and temperatures within manufacturer's specs

~~The BMS must transmit an alarm to an approved location if hazardous temperatures or other conditions are detected~~

The BMS should shut down equipment and notify staff if hazardous temperatures or other conditions are detected

Fire detection and/or smoke alarms should notify responders of a fire

2018 IFC Battery Room Protection

Automatic smoke detection system per Section 907.2.

Signage on or near battery room doors:

- Cautionary markings to identify hazards with specific batteries (corrosives, water reactive, hydrogen gas, Li-ion batteries, etc.)

39

2018 IFC Battery Specific Protection

Systems that release toxic/highly toxic gases during charging, discharging and normal use must comply with Chapter 60

Exhaust ventilation is required for system that produce combustible gases during normal use

Spill control and neutralization required for systems with liquid electrolytes

40

Fire Suppression Systems

2015 IFC
Not required

2018 IFC
Battery rooms need a NFPA 13 system
Commodity classifications per Chapter 5 of NFPA 13.
If the storage batteries are not addressed in Chapter 5 of NFPA 13, the fire official can approve the system based on full scale fire and fault condition testing

41

Hilden Germany Recycling Plant Fire

32 tons of cylindrical Li-ion batteries were reportedly involved

600 KWh of Li-ion batteries (MAQ) in an incidental use area ~ 7 tons

2018 IFC Chapter 12 Energy Systems

Consolidates new and existing energy related requirements

1201-02 General and definitions

1203 Emergency and standby power systems

1204 Solar photovoltaic power systems

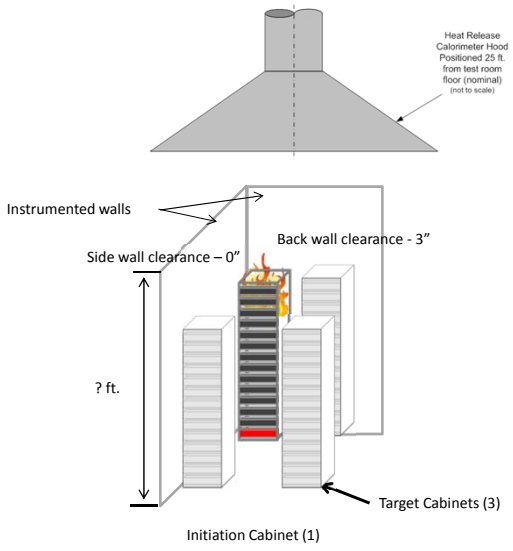
1205 Fuel cell energy systems (New)

1206 Electrical energy storage systems

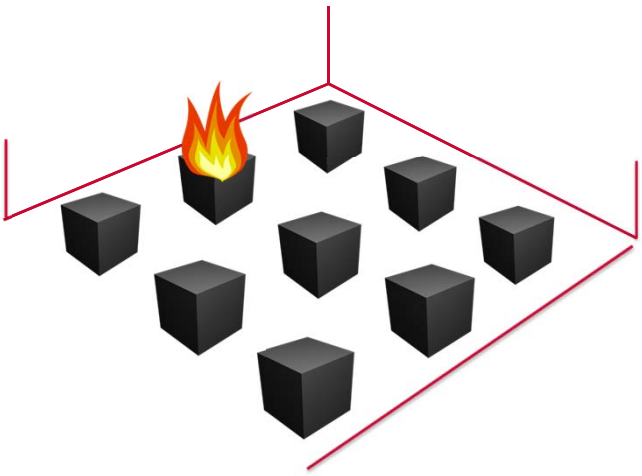
- 1206.1 Scope
- 1206.2 Stationary storage battery systems
- 1206.3 Electrical capacitor energy systems (New)

43

Fire Propagation From Array Test

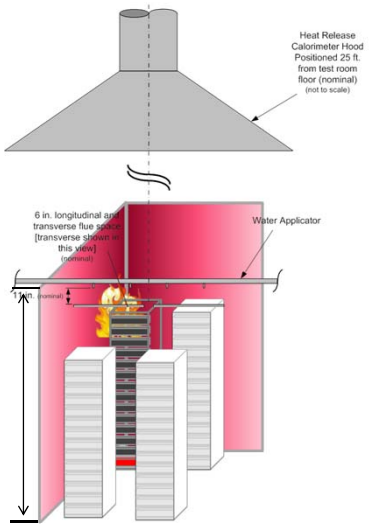


Fire Propagation From Array Test



45

Effect of Sprinkler Test



Consumer Considerations

The “Smart grid” enables consumers to enhance their electric utilization with consumer storage systems

Residential ESS

Li-ion Battery System

Electric Vehicle

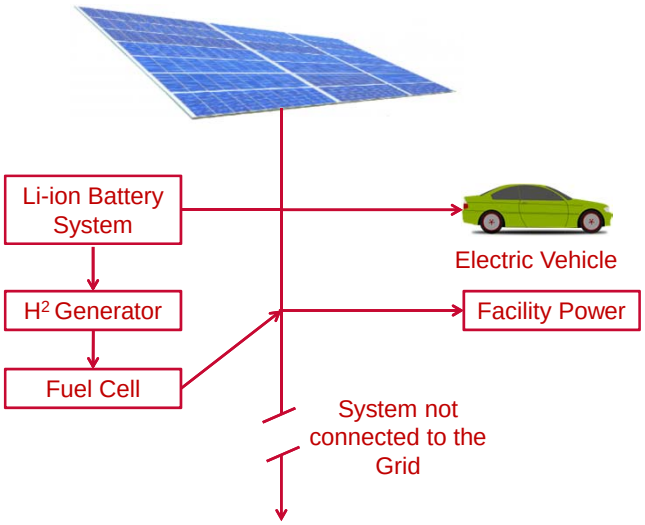
Solar or off-peak demand utility power charges the battery system

Utility Interactive Inverter

Electrical Panel

48

Off Grid ESS Application



49

Residential Storage Battery Systems

Lithium-ion with BMS

One manufacturer has 6.4 KWh unit ~$3000

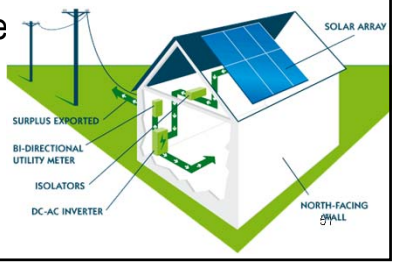
Will provide power for a typical home overnight, but probably not A/C

Multiple systems can be provided to increase capacity

50

2018 IRC Battery Systems

Applies to battery systems > 1KWh
Battery systems must be listed to UL 9540
Installed per the manufacturer's instructions
Cannot be installed within habitable space of a dwelling unit
Electrical installation same as residential PV systems
Ventilation required if charging produces hydrogen gas
Vehicle impact protection, if applicable



Repurposing EV Battery Systems

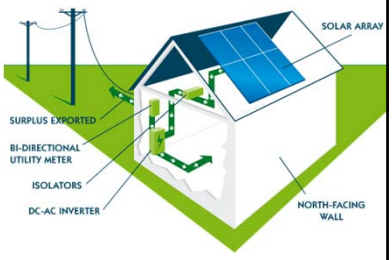
Used Li-ion EV battery systems that no longer provide a sufficient driving range will be replaced in the vehicle, but still retain significant capacity that may be used in non-EV applications

These batteries can be used to capture surplus renewable energy during times of low demand for use during higher demand time periods.

UL 1974 being developed to verify safety methodology

2018 IRC Repurposed Batteries

Where approved, repurposed unlisted battery systems from electric vehicles are allowed to be installed outdoors or in detached sheds ≥ five feet from exterior walls, property lines and public ways.



53

Take Aways

What do code authorities need to know?

Resiliency/cost savings are driving demand for new energy solutions

Installations may be coming to your jurisdiction soon

Hazards associated with various energy technologies

Prudent to share information with emergency responders and other stakeholders

New code requirements cover traditional, new and future technologies

Future ESS code changes are still needed

54

Future Code Change Focus Areas

Being explored by the FCAC ESS work group

Installation scenarios

Review size/spacing/MAQs

Commissioning/ Decommissioning

Exhaust/deflagration venting

Fire propagation tests

BMS performance

Evaluate sprinkler effectiveness

Better categorize batteries

55

Introduce Installation Scenario Criteria

Mixed Occupancy Building

Dedicated ESS Building

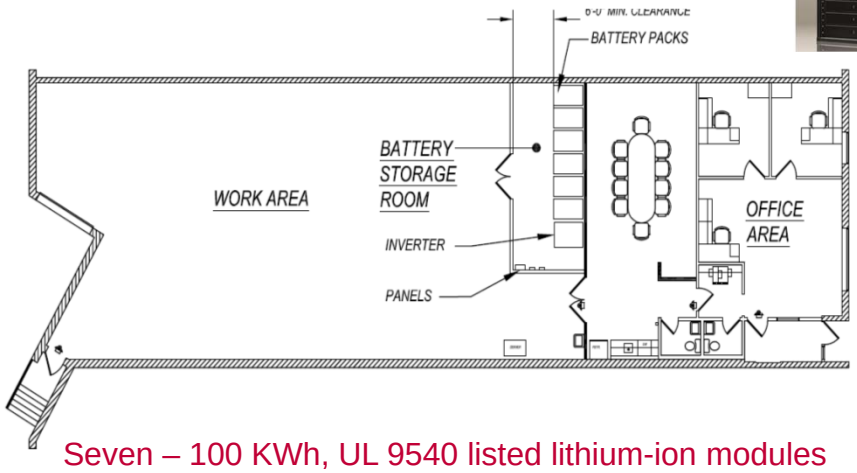
Rooftop Installations

Outdoors Near Building

Outdoors Remote

Exercises Applying the 2018 IFC ESS Requirements

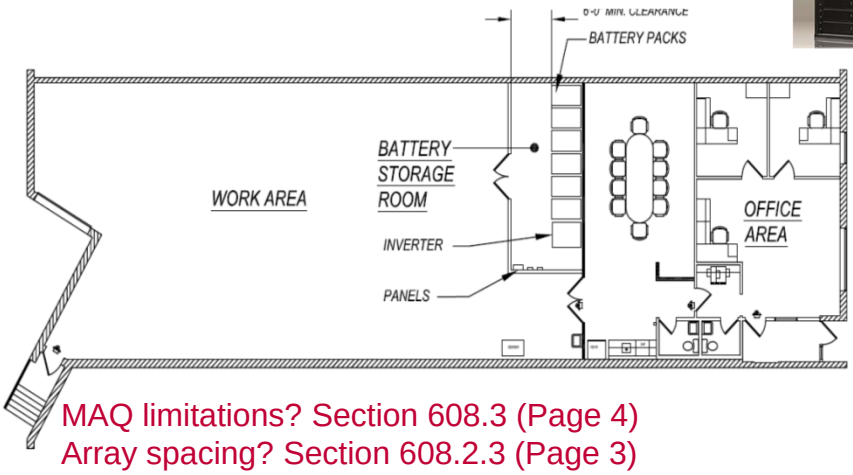
ESS Battery Exercise 1



Seven – 100 KWh, UL 9540 listed lithium-ion modules
Spaced six inches from walls and from each other
Meeting room is an A occupancy
How can you approve this installation?

58

ESS Battery Exercise 1



MAQ limitations? Section 608.3 (Page 4)
Array spacing? Section 608.2.3 (Page 3)
Is ventilation required? Section 608.5.3 (Page 6)
Spill control/neutralization? Section 608.5.5 (Page7)
Signage Section 608.2.6 (Page 3)

59

MAQ Increase and Array Spacing Justification

What is acceptable?

A reputable FPE firm's fire modeling data, supported by cone calorimeter testing from FM showing flashover does not occur.

The modules' UL 9540 listing card and copy of the UL listing mark

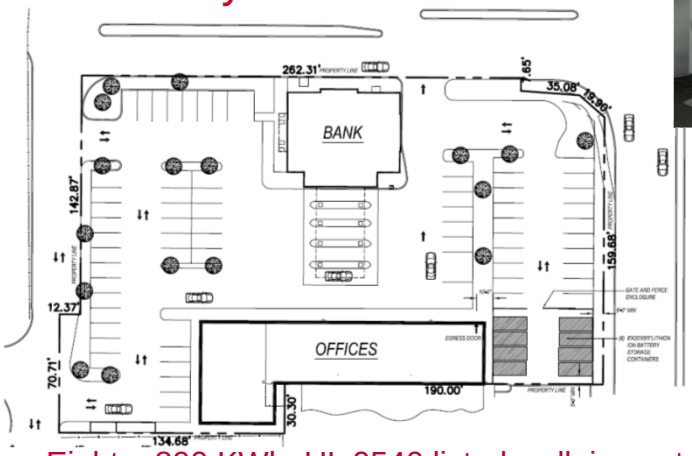
An FPRF test report, with video footage, documenting how units subjected to an external fire outdoors did not explode or release significant energy.

A large scale UL or FM fire test report of an indoor burn of the manufacturers modules with six inch spacings, along with an applicable sprinkler test report.

The same report from a competitor's module with identical KWh rating and enclosure dimensions.

60

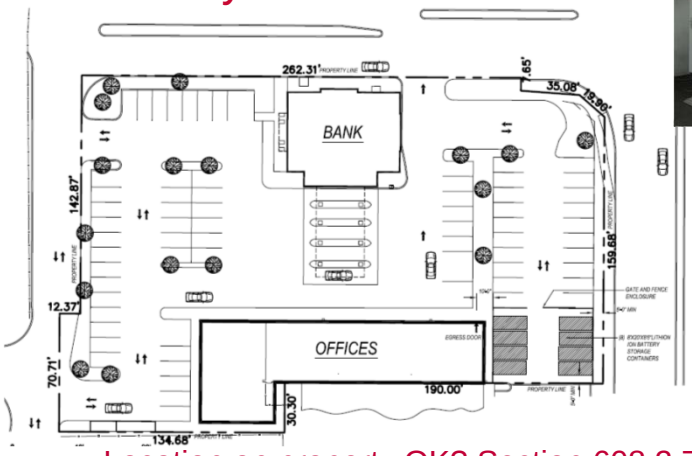
ESS Battery Exercise 2



Eight – 800 KWh, UL 9540 listed walk in containers with Li-ion
Six foot setbacks, adjacent Group B occupancy
How can you approve this installation?

61

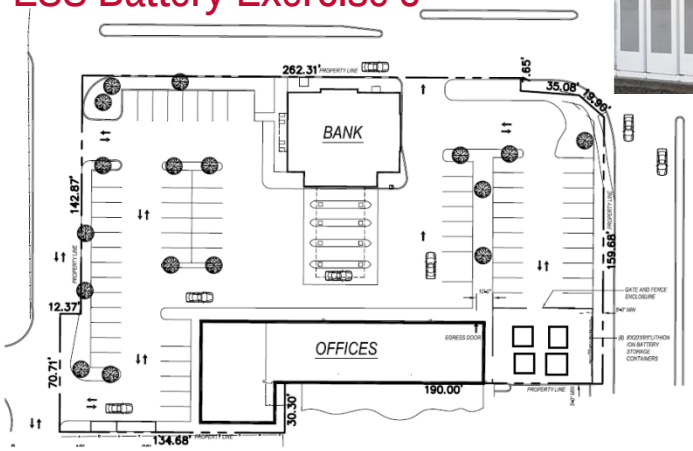
ESS Battery Exercise 2



Location on property OK? Section 608.2.7 (Page 4)
Smoke detection required? Section 608.5.2 (Page 6)
Sprinklers required? Section 608.5.1 (Page 6)
Array spacings and MAQs? Sections 608.2.3 and 608.3

62

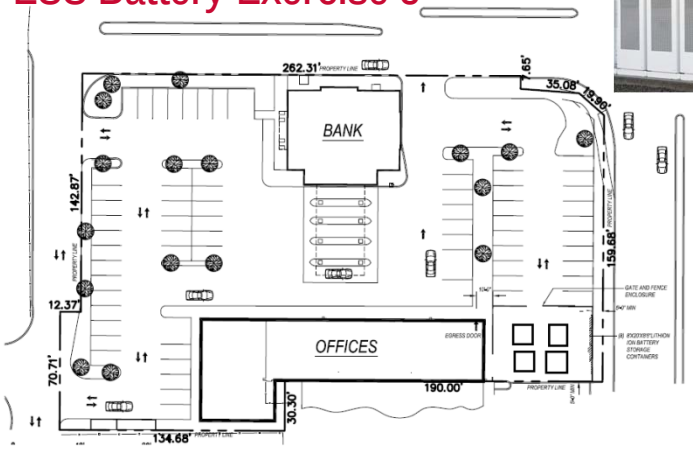
ESS Battery Exercise 3



Four – 1.2 MWh, UL 9540 listed units with Li-ion
Six foot setbacks, adjacent Group B occupancy
How can you approve this installation?

63

ESS Battery Exercise 3



Site security? Section 608.2.7.3 (Page 4)
Smoke detection & sprinklers required? Section 608.5 (Page 6)
Array spacings and MAQs? Sections 608.2.3 and 608.3
Large scale fire testing required?

64

Discussion