

ATTACHMENT 13
HAZARD MITIGATION ANALYSIS

MANCHESTER PUBLIC LIBRARY BATTERY ENERGY STORAGE SYSTEM

1041 MAIN STREET, MANCHESTER, CT 06040

Prescriptive Code Review + Hazard Mitigation Analysis

Confidential

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Executive Summary

This report serves as the prescriptive code review and hazard mitigation analysis (HMA) related to the Eaton xStorage 250-1000 kW lithium-ion battery energy storage system (BESS) to be installed outdoors as part of the Manchester Public Library project. The BESS consists of a 1118.1 kWh lithium-ion BESS unit to be located outdoors at 1041 Main Street, Manchester, Connecticut 06040. This lithium-ion BESS will support the new Manchester Public Library building being constructed on the same project site.

The state of Connecticut currently adopts the 2022 *Connecticut State Fire Safety Code* (CSFSC), based on the 2021 *International Fire Code* (IFC), and the 2022 *Connecticut State Fire Prevention Code* (CSFPC), based on the 2021 edition of the National Fire Protection Association (NFPA) *Fire Code* (NFPA 1).

Chapter 12 §1207.1.4 of the CSFSC provides requirements for BESS installations. Chapter 52 of CSFPC also provides requirements for BESS installations and references NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020 edition. In the context of these codes and standards, the outdoor installation of a lithium-ion BESS shall not exceed the prescriptive maximum stored energy value of 600 kWh unless an engineering hazard mitigation analysis (HMA) is provided in accordance with CSFSC §1207.1.4 and NFPA 855 §4.8.2.

Jensen Hughes prepared the HMA for the Manchester Public Library project based on the design failure modes identified in CSFSC §1207.1.4.1 and NFPA 855 §4.1.4.2. A consequences-based analysis was conducted to identify plausible failure modes, evaluate preventive and mitigative barriers in place, assess potential consequences, and propose site-specific recommendations. The HMA also outlines how the current measures and proposed recommendations satisfy the compliance approval criteria specified in CSFSC §1207.1.4.2 and NFPA 855 §4.1.4.3.

Based on a review of the prescriptive code requirements, the project documentation, the BESS product documentation, and the HMA, the site-specific fire safety recommendations outlined in Section 5.1 have been proposed for the project. Implementation of these measures is required to meet the approval criteria detailed in Section 5.2.

This report was based solely upon and limited to the available information provided by the Town of Manchester. Information not provided by the Town of Manchester was not considered part of this analysis.

Note: Certain items, as noted throughout this report, are based on information that was not available or could not be confirmed at the time of this review. These items are subject to verification as additional information becomes available. Where specific details have not yet been confirmed, assumptions were made based on available product listings, industry best practices and features generally provided with commercially available listed BESS products.

List of Acronyms and Abbreviations

<i>Acronym / Abbreviation</i>	<i>Full Term</i>
AHJ	Authority Having Jurisdiction
BESS	Battery Energy Storage System
BMS	Battery Management System
EMS / ESMS	Energy Management System / Energy Storage Management System
EOP / ERP	Emergency Operation Plan / Emergency Response Plan
FMEA	Failure Mode and Effect Analysis
HMA	Hazard Mitigation Analysis
HVAC	Heating, Ventilation, and Air Conditioning
IDLH	Immediately Dangerous to Life or Health
IEEE C2	National Electrical Safety Code (NESC)
ITM	Inspection, Testing, and Maintenance
kWh	Kilowatt-hours (unit of energy)
kW	Kilowatts (unit of power)
LFL	Lower Flammability Limit
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
O&M	Operations and Maintenance
PCS	Power Conversion System
UL	Underwriters Laboratory

1.0 Introduction

Jensen Hughes, Inc. (consultant) has been retained by the Town of Manchester (client) to provide a third-party technical review in the form of a prescriptive code review and hazard mitigation analysis (HMA) related to the Eaton xStorage 250-1000 kW lithium-ion battery energy storage system (BESS) to be installed outdoors as part of the Manchester Public Library project. The BESS consists of a 1118.1 kWh lithium-ion BESS unit and auxiliary equipment to be located outdoors at 1041 Main Street, Manchester, Connecticut 06040. This lithium-ion BESS will support the new Manchester Public Library building being constructed on the same project site.

This HMA report provides an overview of the proposed installation site and the BESS product, reviews the prescriptive code requirements applicable to the BESS, identifies reasonably foreseeable hazards, assesses the anticipated effectiveness of protective measures in place to mitigate these hazards, and develops site-specific hazard mitigation and fire and life safety recommendations.

The main sections of the report and a description of the content are provided in Table 1-1.

Table 1-1: Report Organization

<i>Section</i>	<i>Description</i>
1.0 – Introduction	Presents the purpose, scope, and outline of the report.
	Lists the primary applicable codes and standards for the BESS installation.
	Lists the HMA requirements and approval criteria.
2.0 – General Information	Provides an overview of the project and site details.
	Describes the BESS installation, its components, and safety features, and related safety testing data.
3.0 – Prescriptive Code Analysis	Provides an evaluation of compliance with the code requirements for BESS installations in CSFSC, CSFPC, and NFPA 855.
4.0 – Hazard Mitigation Analysis	Provides the required HMA per CSFSC §1207.1.4 and NFPA 855 §4.8.2, including an evaluation of the consequences of BESS failure modes, an assessment of existing barriers against these failure modes, and recommendations for additional protection measures.
5.0 – Conclusions	Summarizes the HMA recommendations and evaluates the HMA approval criteria.
6.0 – References	Lists the references used in developing this report.

1.1 PURPOSE + SCOPE

The purpose of the HMA is to provide sufficient evidence that the BESS installation for the Manchester Public Library project will meet the approval criteria specified in CSFSC §1207.1.4.2 and NFPA 855 §4.1.4.3 based on the anticipated failures.

This HMA supplements the large-scale or full-scale fire testing required by CSFSC §1207.1.5 and NFPA 855 §4.1.5, conducted by UL (Changzhou) Quality Technical Service Co., LTD on a representative unit of the BESS in accordance with UL 9540A (4th edition 2019).^[8]

The scope of this HMA includes the following steps:

- + **Determination of failure modes and approval requirements:** Failure modes identify the scenarios required to be evaluated in the HMA. Approval requirements establish the criteria by which the HMA must be compared to constitute an acceptable BESS installation.
- + **Review of product and site-specific information:** Available product-specific and site-specific information, including UL 9540A testing results, is reviewed to provide a baseline for the HMA.
- + **Prescriptive code review:** Specific requirements from the applicable codes and standards for the project that necessitate further support through the HMA are identified.
- + **Hazard mitigation analysis:** Failure Mode and Effects Analysis (FMEA) is provided to analyze the required failure mode scenarios and determine the associated consequences and mitigation strategies.
- + **Recommendations:** The consequences of the HMA are compared to the approval requirements for each failure mode scenario to evaluate the BESS installation for compliance. Recommendations are provided where gaps exist between the consequences of failure modes and approval requirements.

1.2 APPLICABLE CODES AND STANDARDS

The BESS installation of the Manchester Public Library project is subject to the following codes and standards:

- + *2022 Connecticut State Building Code (CSBC)*, based on the 2021 International Building Code (IBC).
- + *2022 Connecticut State Fire Safety Code (CSFSC)*, based on the 2021 International Fire Code (IFC).
- + *2022 Connecticut State Fire Prevention Code (CSFPC)*, based on the 2021 edition of the National Fire Protection Association (NFPA) Fire Code (NFPA 1).
- + NFPA 70, *National Electrical Code*, 2020 edition, as adopted by the CSBC.
- + NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020 edition, as referenced by the CSFPC.
- + UL 9540, *Standard for Energy Storage Systems and Equipment*, 1st edition, 2016.
- + UL 9540A, *Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 3rd edition, 2018.
- + UL 1973, *Standard for Batteries for Use in Light Electric Rail Applications and Stationary Applications*, 2016.

- + UL 1741, *Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*, 2016.
- + NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.
- + NFPA 69, *Standard on Explosion Prevention Systems*, 2019 edition.
- + NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2019 edition.
- + NFPA 72, *National Fire Alarm and Signaling Code*, 2019 edition.
- + NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2019 edition.
- + NFPA 1142, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, 2017 edition.
- + ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 2016.
- + UL 263, *Standard for Fire Tests of Building Construction and Materials*, 2018.

The following includes a list of standards corresponding to the testing and certifications provided for the Eaton xStorage 250-1000 kW BESS and its components, as referenced throughout this report:

- + UL 1741, *Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*, 2021.
- + UL 1973, *Standard for Batteries for Use in Light Electric Rail Applications and Stationary Applications*, 2018.
- + UL 9540, *Standard for Energy Storage Systems and Equipment*, 3rd edition, 2023.
- + UL 9540A, *Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 4th edition, 2019.
- + UL 864, *Standard for Control Units and Accessories for Fire Alarm Systems*.
- + UL 521, *Standard for Heat Detectors for Fire Protective Signaling Systems*.
- + UL 268, *Standard for Smoke Detectors for Fire Alarm Systems*.
- + UL 2775, *Standard for Fixed Condensed Aerosol Extinguishing System Units*.
- + UL 464, *Standard for Audible Signal Appliances*.
- + IEC 61010, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use*
- + EN 60326-1, *Printed Boards – Generic Specification*.

1.3 HMA REQUIREMENTS AND APPROVAL CRITERIA

The HMA evaluates the following failure modes or fault conditions related to the BESS installation as required by CSFSC §1207.1.4.1 and NFPA 855 §4.1.4.2:

1. Thermal runaway condition in a single module, rack, or BESS unit, addressed in Section 4.1.
2. Failure of an energy storage management system addressed in Section 4.2.
3. Failure of a required ventilation or exhaust system addressed in Section 4.3.
4. Failure of a required smoke detection, fire detection, fire suppression, or gas detection system, addressed in Section 4.4.

5. Voltage surges on the primary electrical supply, addressed in Section 4.5.
6. Short circuits on the load side of the BESS, addressed in Section 4.6.
7. Required spill neutralization not being provided or failure of a required secondary containment system. *This failure mode is not applicable to lithium-ion BESS, as lithium-ion batteries are sealed; there is no spill component associated with them. In addition, spill control and neutralization are not required for lithium-ion BESS per CSFSC Table 1207.6.*

Only a single failure mode is evaluated in each scenario as required by CSFSC §1207.1.4.1 and NFPA 855 §4.1.4.2.1. The evaluation includes a written description of the failure mode, the barriers in place to prevent and/or mitigate the failure, and the consequences of the failure. Where existing barriers do not adequately prevent or mitigate consequences, recommendations were made. This written evaluation is analogous to a generic bowtie evaluation. It should be noted that this is a consequence-based analysis, meaning that the likelihood of the event is not considered.

The HMA demonstrates compliance of the BESS installation by evaluating it against the following approval criteria required by CSFSC §1207.1.4.2 and NFPA 855 §4.1.4.3:

1. Fires will be contained within unoccupied BESS rooms for the minimum duration of the fire resistance rating specified in CSFSC §1207.7.4 and NFPA 855 §4.3.6 (i.e., 2 hour fire-resistance rated separations).
2. Suitable deflagration protection is provided where required.
3. BESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.
4. Toxic and highly toxic gases released during normal charging, discharging, and operation will not exceed the Permissible Exposure Limit (PEL) in the area where the BESS is contained.
5. Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of immediately dangerous to life or health (IDLH) level in the building or adjacent means of egress routes during the time deemed necessary to evacuate occupants from any affected area.
6. Flammable gases released during charging, discharging, and normal operation will not exceed 25 percent of their lower flammability limit (LFL).
7. Flammable gases released from the BESS during fire, overcharging, and other abnormal conditions will be controlled through the use of ventilation of the gases, preventing accumulation, or by deflagration venting.

Compliance with the above approval criteria is evaluated in Section 0.

2.0 General Information

This section provides general information on the project, including the installation site and surrounding area, details about the BESS and its safety features, and available testing data supporting the HMA. The information presented below is based on the client-provided documentation as referenced in Section 6.0 of this report.

2.1 PROJECT OVERVIEW

General project information is provided in Table 2-1.

Table 2-1: Project Information

<i>Facility Name</i>	Manchester Public Library
<i>Facility Owner</i>	Town of Manchester
<i>Facility Address</i>	1041 Main Street, Manchester, Connecticut 06040
<i>BESS Manufacturer</i>	Eaton
<i>BESS Model</i>	Eaton xStorage 250-1000 kWh BESS: Model B0253010000001 <ul style="list-style-type: none"> + Three (3) CATL EnerOne lithium-ion battery cabinets + One (1) EPC Power CAB1000/AC-3.2L inverter/power conversion system (PCS) cabinet + One (1) control cabinet
<i>Design Basis BESS Output</i>	1118.1 kWh / 250 kW
<i>BESS Function</i>	Support the new Manchester Public Library building being constructed on the same project site.
<i>BESS Installation</i>	Outdoor ground-mounted, non-residential use, near-exposure installation. Refer to Section 3.1 of this report for details on installation classification.

2.2 SITE DETAILS

The Manchester Public Library BESS installation is an outdoor, ground-mounted, non-residential use installation to be located on a pad at the Manchester Public Library site in Manchester, Connecticut.

The BESS will be located outdoors and separated from the adjacent parking area by a curb, and fence. The BESS will be located on a raised concrete pad next to the newly constructed library building, parking area, parking canopy structures, residential structures, and commercial buildings.

Unenclosed surface-level parking, two unenclosed parking canopy structures with solar panels, and an adjacent residential garage are located within 100 feet of the BESS pad. Additionally, an underground geothermal vault is

located within 100 feet of the BESS pad.^[19] Other exposures are located more than 100 feet from the BESS pad.^[2] The nearest existing fire hydrant is located on Maple Street, north of the BESS, approximately 124 feet from the BESS / equipment pad.^{[4][19]}

The BESS cabinets and associated electrical equipment are enclosed within a locked security fence. Access to the BESS and associated equipment is restricted to authorized personnel.

The adjacent grade-level parking lot is located approximately 1 foot 6 inches from the BESS installation pad and 3 feet from the nearest BESS cabinets.

Figure 2-1 shows an aerial view of the BESS installation, fire hydrant location, and adjacent exposure hazards within 100 feet of the BESS.

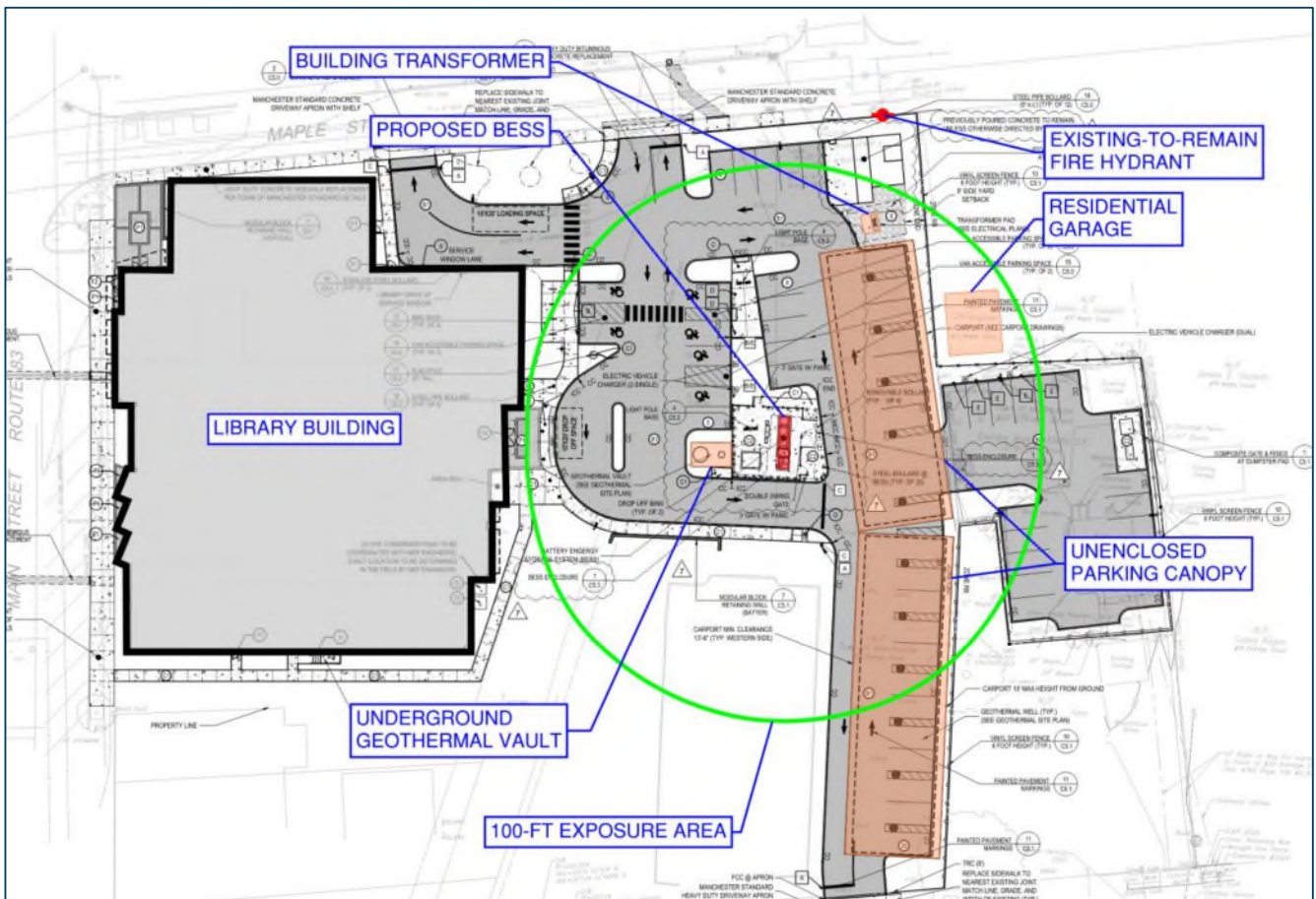


Figure 2-1: Aerial View and Adjacent Exposures of the Library Project Site.

Figure 2-2 illustrates the BESS equipment pad plan.

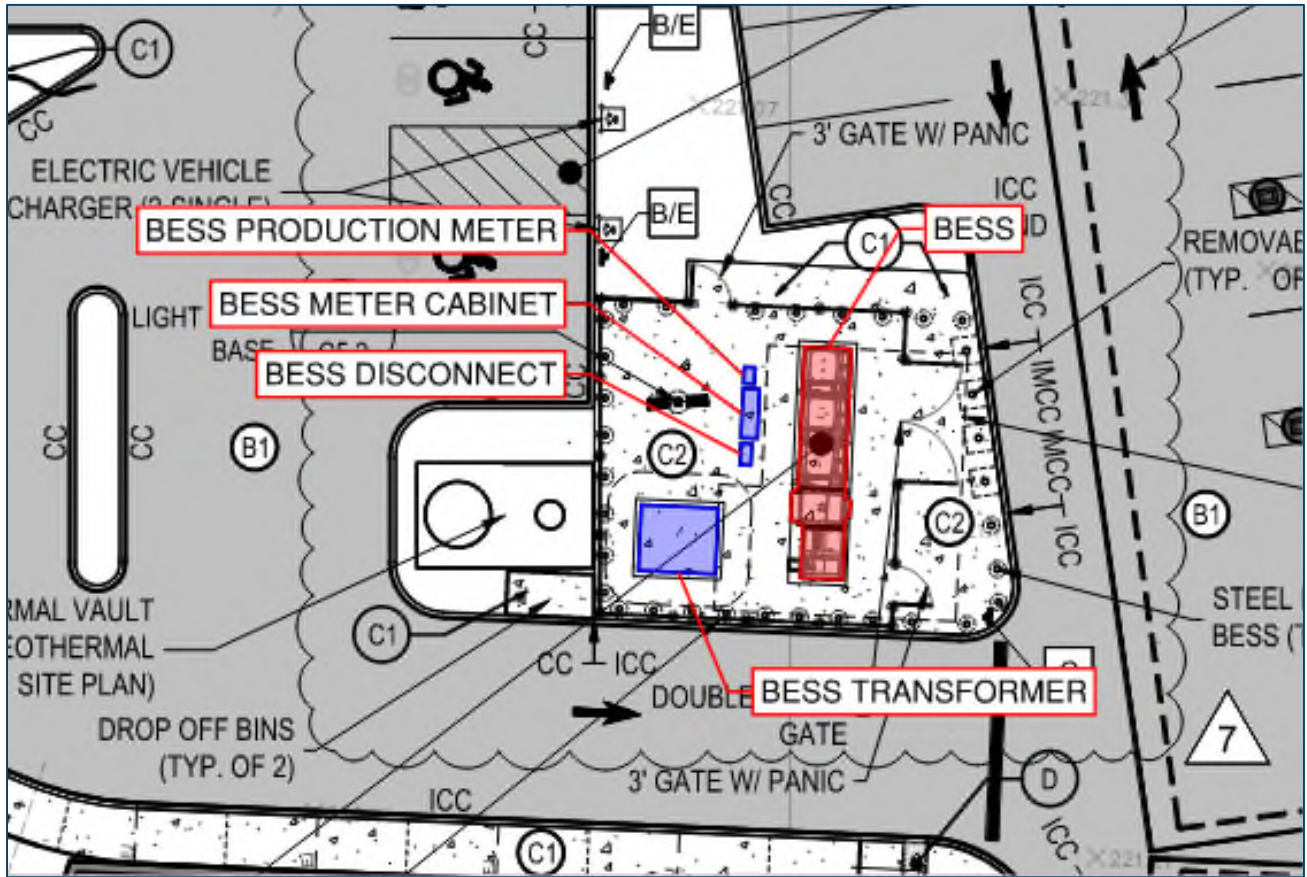


Figure 2-2: Proposed BESS Location and Adjacent Exposure Hazards (equipment pad plan).

Table 2-2 indicates the adjacent exposure hazards and their distance from the BESS pad. Exposure hazards located more than 100 feet from the BESS constitute a code compliant standoff distance and are not included in this analysis.

Table 2-2: Adjacent Exposure Hazards to the BESS Installation

<i>Exposure Hazard</i>	<i>Distance to BESS Pad</i>
BESS Production Meter	4 ft 4 in
BESS Meter Cabinet	3 ft 10 in
BESS Disconnect Switch	4 ft 4 in
BESS Transformer	6 ft 7 in
Underground Geothermal Vault	17 ft 8 in
Adjacent Grade-Level Parking	11 ft 4 in
Adjacent Solar Parking Canopy	20 ft 10 in
Residential Garage Structure	68 ft 0 in
Library Building Transformer	78 ft 7 in

2.3 BESS DETAILS

The Eaton xStorage 250-1000 kWh BESS Model B02530100000001 consists of three (3) CATL EnerOne battery cabinets, one (1) EPC Power CAB1000/AC-3.2L inverter/PCS cabinet, and one (1) control cabinet.^{[18][6]}

Each CATL EnerOne battery cabinet includes a battery unit (or rack) Model Ox52280-E or Ox52280-P with 8 lithium-ion battery modules. Each battery module Model M52280-E or M52280-P consists of 52 battery cells connected in series. The battery cells Model CB310 or CB2W0 are 280 Ah prismatic lithium iron phosphate (LFP) cells.^[8] Each battery cabinet also includes a self-contained, liquid cooling unit, gas detection, smoke detection, heat detection, an aerosol fire extinguishing system, a deflagration vent, communication and power cables, rack connections, and the battery management system (BMS).

The PCS cabinet is EPC Power CAB1000/AC-3.2L Model 50-100181 with an output power of 1500 kW. The control cabinet includes an auxiliary transformer, self-contained air cooling, two internal heaters, auxiliary components, Global Stored Energy Controls (GSEC) / energy management system (EMS), network switch, battery cabinet communication modules, uninterruptible power supply (UPS) for critical control power, surge protection devices (SPDs), and fire control panel.

Illustrations of the BESS and its components are shown below in Figure 2-3, and Figure 2-4.



Figure 2-3: BESS Cabinet, Interior of BESS Cabinet, Battery Module, and Battery Cell (left to right)



Figure 2-4: Rendering of Eaton xStorage 250-1000 kWh BESS Model B0253010000001.

Additional information regarding the cell, module, unit, and BESS is provided in Table 2-3.

Table 2-3: Additional Eaton B02530100000001 BESS Specifications

<i>Cell</i>	Model	CB310, CB2W0
	Manufacturer	Contemporary Amperex Technology Co., Limited (CATL)
	Format Factor	Prismatic
	Chemistry	Lithium Iron Phosphate (LFP)
	Electrical Ratings	280 Ah / 3.2 V / 896 Wh
	Dimensions / Weight	207.2 mm x 173.9 mm x 71.7 mm / 5450±300 g
	Listing / Certification	UL 1973 (No. MH62898 issued by UL) ^[10]
<i>Module</i>	Model	M52280-E, M52280-P
	Manufacturer	Contemporary Amperex Technology Co., Limited (CATL)
	Configuration	52S/1P (52 cells in series)
	Electrical Ratings	280 Ah / 166.4 V / 46.592 kWh
	Dimensions / Weight	810±5 mm x 1155±5 mm x 243.4±5 mm / 320±10 kg
	Listing / Certification	None
<i>Unit or Rack</i>	Model	Ox52280-E, Ox52280-P
	Manufacturer	Contemporary Amperex Technology Co., Limited (CATL)
	Configuration	8S/1P (8 modules in series, 416 cells in series)
	Electrical Ratings	280 Ah / 1331.2 V / 372.74 kWh
	Dimensions / Weight	1300 mm x 1300 mm x 2280 mm / 3650 kgs
	Listing / Certification	UL 1973 (No. U14 004951 0008 Rev.01 issued by TUV SUD) ^[8]
<i>BESS</i>	Model	B02530100000001
	Manufacturer	Eaton Corporation
	Components	<ul style="list-style-type: none"> + Three (3) battery cabinets with one unit/rack each + One (1) inverter/PCS cabinet Model No. 50-100181 + One (1) control cabinet
	Electrical Ratings	1,118.1 kWh / 250 kW
	Dimensions / Weight	251.5" W x 64.6" D x 89.8" H / 23,148 lbs
	Operating Conditions	-20°C to 50°C (-4°F to 122°F); 0~95% RH
	Listing / Certification	<ul style="list-style-type: none"> + UL 1973 for unit (No. U14 004951 0008 Rev.01 by TUV SUD)^[8] + UL 1741 for PCS (No. CU 72302284 01 by TÜV Rheinland)^[14] + UL 9540 for BESS (No. CU 72301943 0001 by TÜV Rheinland)^[11]

2.4 BESS SAFETY FEATURES

The Eaton xStorage 250-1000 kWh BESS Model B02530100000001 design has numerous safety features that should prevent failure of the lithium-ion cells or, if failure occurs, should prevent further escalation of the hazard.

The safety features related to the cell, module, unit/rack, and BESS are summarized below in Table 2-4.

Table 2-4: BESS Safety Features.

<i>Component</i>	<i>Safety Features</i>
<i>Cell</i>	<ul style="list-style-type: none"> + UL 1973 (No. MH62898 issued by UL)^[10]
<i>Module</i>	<ul style="list-style-type: none"> + Mica sheet between the cell assembly and the top enclosure to inhibit propagation.
<i>Unit/ Rack</i>	<ul style="list-style-type: none"> + UL 1973 (No. U14 004951 0008 Rev.00 & Rev.01 issued by TUV SUD)^[8] + One (1) gas detector (Nexceris Model 241029) located at the top of the unit, IEC 61010 and EN 60326-1 listed (Intertek 5016770). Detailed product information was not provided for Jensen Hughes review. + One (1) heat detector (Apollo Fire Detectors Ltd. Model 55000-142), located at the top of the unit, UL 521 listed (UL File S5053), with a fixed temperature activation at 76.7 °C and an operating temperature range of 0 °C to 60 °C. Detailed product information was not provided for Jensen Hughes review. + One (1) smoke detector (Apollo Fire Detectors Ltd., Model 55000-326) located at the top of the unit, UL 268 listed (UL File S5022), with an operating temperature range of 0 °C to 60 °C. Detailed product information was not provided for Jensen Hughes review. + Aerosol fire suppression system located at the top of the unit. See details below. + Integrated liquid cooling unit.
<i>BESS</i>	<ul style="list-style-type: none"> + UL 1973, UL 1741, and UL 9540 listed <ul style="list-style-type: none"> - UL 1973 for unit (No. U14 004951 0008 Rev. 00 & Rev.01 issued by TUV SUD) ^[8] - UL 1741 for PCS (No. CU 72302284 01 issued by TÜV Rheinland)^[14] - UL 9540 for BESS (No. CU 72301943 0001 issued by TÜV Rheinland)^[11] + The battery unit/rack is housed in a NEMA Type 3R (IP54) rated enclosure/cabinet equipped with: <ul style="list-style-type: none"> - Air International (Shanghai) Co., Ltd. Model BTMS-80-ES liquid cooling unit located within the unit with R134a refrigerant.^{[15][7]} - Stat-X Model 100E aerosol fire extinguishing system that discharges aerosol throughout BESS units. - Deflagration vent provided by the front door to the cabinet. The design has been evaluated by TÜV Rheinland against the deflagration venting principles in Chapter 6 of NFPA 68 (2023) using CFD analysis.^[12]

Component *Safety Features*

BESS
(Continued)

- + The control cabinet is comprised of an IP66 outdoor enclosure integrated with a NEMA Type 3R outdoor-rated auxiliary transformer. The control cabinet is equipped with:
 - External Warning Communication System (EWCS) to automatically notify the system owner, local personnel, and predefined local emergency response personnel in the event of a critical battery failure, smoke, gas, or extreme temperature detection.^[6]
 - Audible and visual alarm system (fire alarm horn and strobe) installed on the exterior of the control cabinet.^[6]
 - Door-mounted Heating, Ventilation, and Air Conditioning (HVAC) unit and two internal heaters used to maintain all component temperatures within their respective operating limits.^[6]
 - CATL main battery management unit (MBMU) and secondary battery management unit (SBMU) to monitor and control the batteries.^[6] Detailed information on BMS features was not provided.
 - Global Stored Energy Controls (GSEC) or energy management system (EMS) for communication between the battery cabinets and PCS through Modbus communication.^[6]
 - + The PCS is housed in an IP54 and NEMA Type 3R outdoor-rated enclosure and equipped with:
 - "Emergency Power Off" (EPO) button installed on inverter (PCS). Pressing the button faults the inverter, ceasing power commands, and opening the internal contactors. The inverter fault will immediately trigger the Global Stored Energy Controls (GSEC) or energy management system (EMS) shutdown sequence, opening all battery rack HV relays and disconnecting the system from the point of common coupling (PCC). This will cut all power to and from the BESS, inclusive of control and cooling power to components, but voltages may still be present upstream of the system and on the UPS backup.^[6]
 - Air International (Shanghai) Co., Ltd. Model BTMS-80-ES 8kW liquid cooling unit located within the PCS with R134a refrigerant 50/50 water glycol mix.^{[15][7]}
-

2.5 BESS SAFETY TESTING

UL 9540A testing has been performed by UL (Changzhou) Quality Technical Service Co., Ltd and UL-CCIC Company Limited, Guangzhou Branch, in accordance with the UL 9540A standard (4th edition, 2019) on representative samples of the cell, module, and unit (rack) levels of the Eaton xStorage 250-1000 kWh BESS Model B02530100000001.

The different test levels provide essential information on the thermal runaway behavior and propagation, heat release rate, gas generation, composition, and flammability, and flaming, deflagration, flying debris, and re-ignition hazards. This information should be used to assess the battery system's thermal runaway hazard and design explosion control systems. In addition, this information should be considered when evaluating the potential LFL and IDLH concentrations for occupants and fire responders.

Cell-Level Testing

Cell-level testing was conducted on samples of the CB310 and CB2W0 cell. The cell-level UL 9540A test results are summarized in summarized in Table 2-5 of this report. Since thermal runaway was induced in the cell and the cell vent gas was found to be flammable, the performance criteria of the cell-level test UL 9540A (4th edition, 2019) have not been met, and module-level testing is required.

Module-Level Testing

Module-level testing was conducted on samples of the M52280-E and M52280-P modules. The module-level UL 9540A test results are summarized in Table 2-5 of this report. Since module (and cell) vent gas is flammable, the performance criteria of the module-level test UL 9540A (4th edition, 2019) have not been met, and unit-level testing is required.

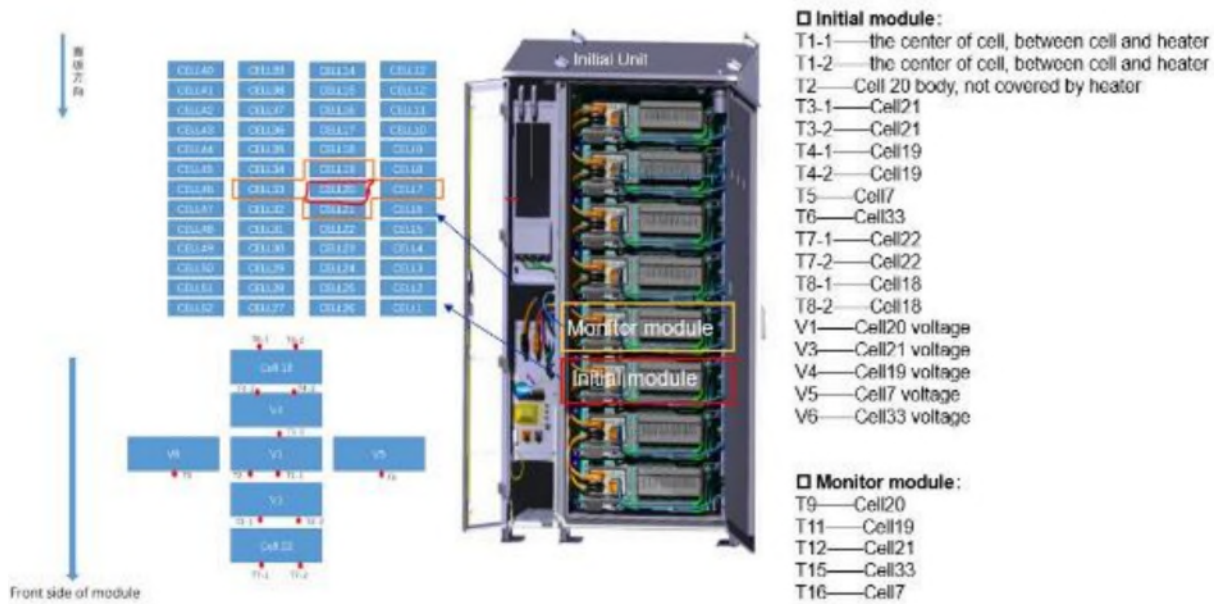
Unit-Level Testing

Unit-level testing was conducted on the Ox52280-E and Ox52280-P units according to the non-residential outdoor ground-mounted BESS installation type. The unit tested contains a total of 8 modules and 416 cells (52 cells per module). The unit was tested without the liquid coolant and aerosol systems. The pipes for the coolant were empty, and the aerosol system was not powered during the test. The Initiating Unit was positioned 10 mm from the Target Units, 100 mm from the instrumented front wall, and 160 mm from the instrumented side wall. The Initiating Unit and Target Units contained 8 modules to check for propagation from unit to unit. The initiating module was located in the Initiating Unit. One cell (Cell 20) was forced into thermal runaway by an external thin-film heater with a thermal ramp.

Per the unit-level test results, off-gassing and thermal runaway were induced in the initiating cell (Cell 20) and propagated to an adjacent cell (Cell 19) within the module. No indication of module-to-module propagation was observed. No external flaming, flying debris, or explosion hazards occurred from the initiating unit. No sparks, electrical arcs, or other electrical events were observed during the test. No re-ignition was observed after the test. The unit-level UL 9540A test results are summarized in Table 2-5 of this report.

The unit-level UL 9540A (4th edition) test criteria were met. The separation distances to exposures were farther than the greatest flame extension observed during the test (the initiating unit did not exhibit external flaming); the surface temperature of modules within target units did not exceed the cell venting temperature; the surface temperature on instrumented walls did not exceed a 97°C (175°F) rise above ambient; venting of gases did not create an explosion hazard; heat flux on the egress path did not exceed 1.3 kW/m².

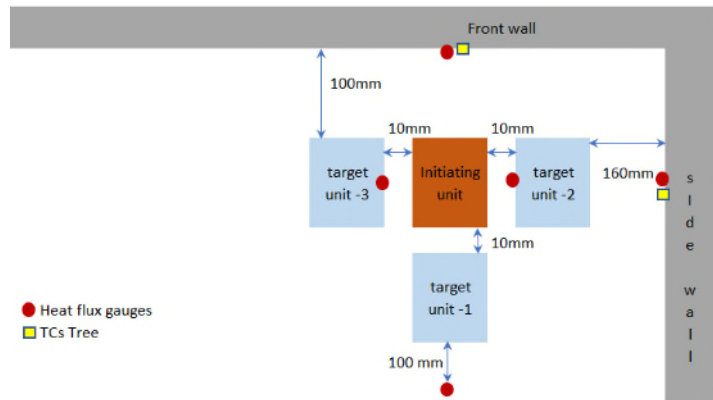
Unit-level test setup and pre-test photo are shown in Figure 2-5.



Location of Initiating Module and Monitor Module within the Initiating Unit/Rack, Including Heater and Thermocouple Locations



Pre-Test Photo of the Test Area



Unit Test Configuration (view from top)

Figure 2-5: : UL 9540A Unit Level Test Layout and Results

Unit-level post-test photos are shown in Figure 2-5.



Initiating Unit Post-Test Photo



Initiating Module Post-Test Photo

Figure 2-6: : UL 9540A Unit Level Test Layout and Results.

Table 2-5: Summary of UL 9540A Test Results

<i>Level</i>	<i>Test Element</i>	<i>Results</i>																																										
Cell Level	Cell Surface Temperature at Gas Venting	168.2°C																																										
	Cell Surface Temperature at Thermal Runaway	239.6°C																																										
	Gas Volume	221.3 L																																										
	Gas Composition	<table border="0"> <tr><td>Carbon Monoxide</td><td>11.086%</td></tr> <tr><td>Carbon Dioxide</td><td>33.290%</td></tr> <tr><td>Hydrogen</td><td>35.698%</td></tr> <tr><td>Methane</td><td>10.075%</td></tr> <tr><td>Acetylene</td><td>0.164%</td></tr> <tr><td>Ethylene</td><td>5.259%</td></tr> <tr><td>Ethane</td><td>1.089%</td></tr> <tr><td>Propadiene (Allene)</td><td>0.000%</td></tr> <tr><td>Propyne</td><td>0.000%</td></tr> <tr><td>Propene</td><td>0.571%</td></tr> <tr><td>Propane</td><td>0.232%</td></tr> <tr><td>C4</td><td>0.382%</td></tr> <tr><td>C5</td><td>0.091%</td></tr> <tr><td>C6</td><td>0.060%</td></tr> <tr><td>C7</td><td>0.005%</td></tr> <tr><td>C8</td><td>0.000%</td></tr> <tr><td>Benzene</td><td>0.023%</td></tr> <tr><td>Toluene</td><td>0.002%</td></tr> <tr><td>Dimethyl Carbonate</td><td>1.879%</td></tr> <tr><td>Ethyl Methyl Carbonate</td><td>0.091%</td></tr> <tr><td>Diethyl Carbonate</td><td>0.000%</td></tr> </table>	Carbon Monoxide	11.086%	Carbon Dioxide	33.290%	Hydrogen	35.698%	Methane	10.075%	Acetylene	0.164%	Ethylene	5.259%	Ethane	1.089%	Propadiene (Allene)	0.000%	Propyne	0.000%	Propene	0.571%	Propane	0.232%	C4	0.382%	C5	0.091%	C6	0.060%	C7	0.005%	C8	0.000%	Benzene	0.023%	Toluene	0.002%	Dimethyl Carbonate	1.879%	Ethyl Methyl Carbonate	0.091%	Diethyl Carbonate	0.000%
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	Lower Flammability Limit	7.85% volume at ambient temperature 6.47% volume at 168.2 °C																																										
	Vent Gas Burning Velocity	64 cm/s																																										
	Vent Gas Max. Explosion Pressure	103 psig																																										

<i>Level</i>	<i>Test Element</i>	<i>Results</i>		
Module Level	Pre-Flaming Gas Composition	Total Hydrocarbons (Propane Equivalent)	147 L (34.1%)	
		Carbon Monoxide	37 L (8.6%)	
		Carbon Dioxide	111 L (25.8%)	
		Hydrogen	136 L (31.6%)	
	Flaming Gas Composition	No flaming occurred		
	Peak Smoke Release Rate (SRR)	9.0 m ² /s		
	Total Smoke Released (TSR)	513 m ²		
	Peak Chemical Heat Release Rate (PHRR)	No flaming occurred		
	Unit (Rack) Level	Maximum Target Unit Temperature	30°C	
		Maximum Wall Surface Temperature	29°C	
Pre-Flaming Gas Composition		Total Hydrocarbons (Propane Equivalent)	284 L (68.7%)	
		Carbon Monoxide	0.23 L (0.1%)	
		Carbon Dioxide	7.51 L (1.8%)	
		Hydrogen	121.8 L (29.5%)	
Flaming Gas Composition		No flaming occurred		
Peak Smoke Release Rate (SRR)		0.23 m ² /s		
Peak Heat Release Rate (PHRR)		No flaming observed		
Total Heat Release (THR)		No flaming observed		
Maximum Heat Flux on Target Modules		0 kW/m ²		
Maximum Heat Flux on Target Wall		0 kW/m ²		
Maximum Heat Flux of Egress Path		0 kW/m ²		

3.0 Prescriptive Code Analysis

The prescriptive requirements for the project are based on the various applicable codes and standards outlined in Section 1.2 to support the HMA in Section 4.0 of this report. Where requirements conflict, the most stringent set of requirements is recommended for use.

3.1 INSTALLATION CLASSIFICATION

Based on the information provided in Section 2.0, the BESS installation will be located less than 100 feet from exposure hazards and does not exceed the maximum dimensions for an outdoor BESS enclosure (i.e., 53 ft x 8 ft x 9.5 ft). Thus, the BESS installation will be classified as an "Outdoor Location Near Exposures" per CSFSC §1207.8.2 and NFPA 855 §4.4.3.1(2).

Figure 3-1 below demonstrates the classification process of the BESS installation.

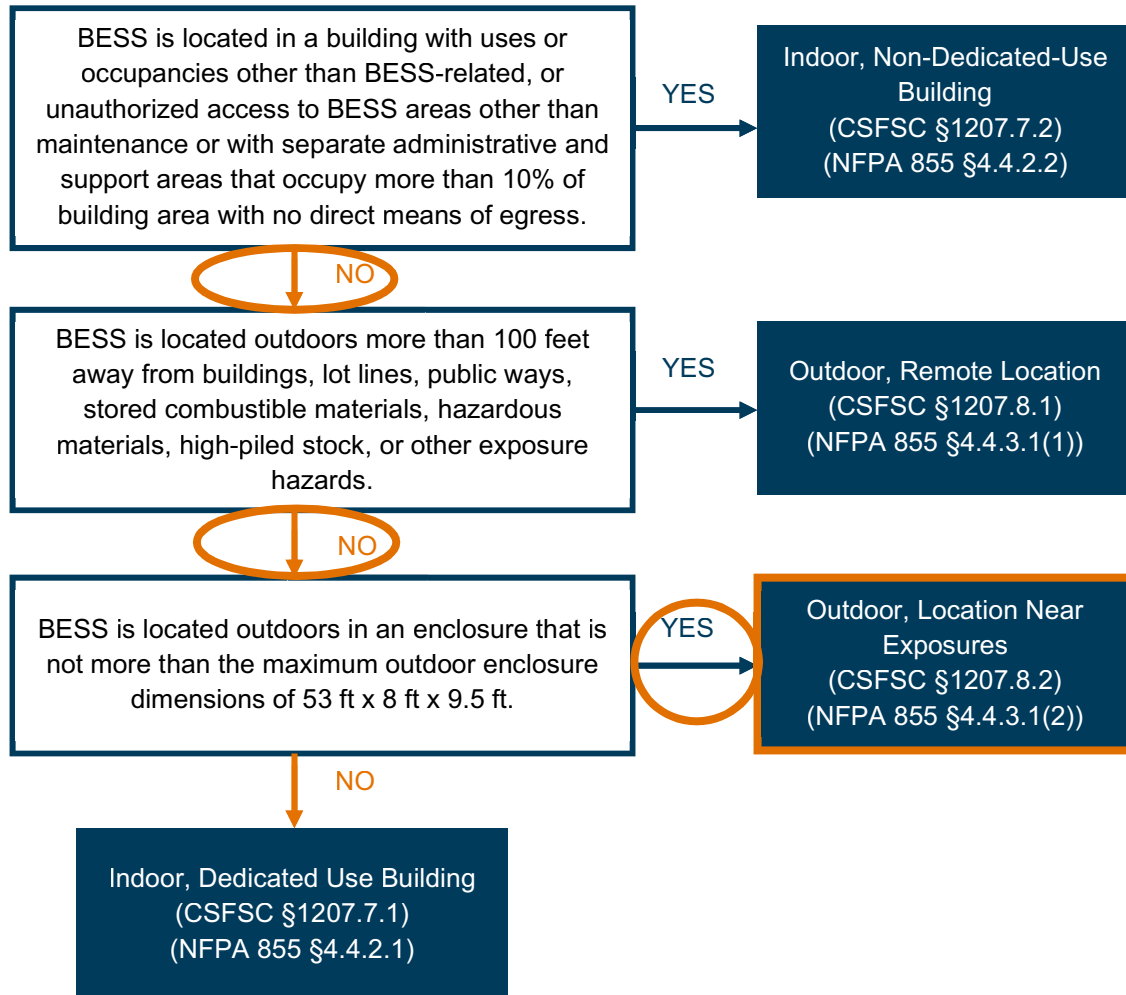


Figure 3-1: BESS Classification Flowchart.

3.2 CODE REQUIREMENTS

Table 3-1 identifies compliance applicable code requirements from CSFSC §1207 and CSFPC Chapter 52 specifically relevant to the subject BESS installation classified as an "Outdoor Location Near-Exposures". The table also evaluates the applicability of each requirement based on the current project information and whether compliance is achieved, outside the scope of this report, or requires further evaluation. Requirements that are not fully addressed through prescriptive means, or that depend on site-specific conditions or pending additional documentation, are carried forward for evaluation as part of the HMA in Section 4.0.

Table 3-1: CSFSC & CSFPC Compliance Review.

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Applicability	CSFSC §1207.1.1 CSFPC §52.1.1	<ul style="list-style-type: none"> + BESS having an aggregate capacity exceeding the threshold quantities established in CSFSC Table 1207.1.1 shall comply with CSFSC §1207 (20 kWh for lithium-ion BESS). + BESS having an aggregate capacity exceeding the threshold quantities established in NFPA 855 Table 1.3 (20 kWh for lithium-ion BESS) shall comply with CSFPC Chapter 52. 	<p>Applicable –</p> <p>The BESS installation exceeds the 20-kWh limit.</p>
Permits	CSFSC §1207.1.2 CSFPC §52.1.2	<ul style="list-style-type: none"> + Permits shall be obtained for BESS as follows: <ul style="list-style-type: none"> - Construction permits shall be obtained for stationary BESS installations. Permits shall be obtained in accordance with CSFSC §105.6.5. - Operational permits shall be obtained for stationary BESS installations. Permits shall be obtained in accordance with CSFSC §105.5.14. + Permits, where required, shall comply with CSFPC §1.12. 	<p>System owner responsibility –</p> <p>Permits are beyond the scope of this HMA.</p>
Emergency Operation Plan (EOP)	CSFPC §52.1.4	<ul style="list-style-type: none"> + An EOP shall be readily available for use by facility operations and maintenance personnel. [NFPA 855 §4.1.3.2.1] + The EOP shall be readily available to emergency responders. + Emergency contact numbers for the owner representative and O&M staff shall be accessible to emergency responders. 	<p>System owner responsibility –</p> <p>The details of the EOP are beyond the scope of this HMA. An EOP was provided that is specific to this installation.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Construction Documents	CSFSC §1207.1.3 CSFPC §52.1.2.3	<p>+ The following information shall be provided with the permit application for AHJ approval:</p> <ol style="list-style-type: none"> 1. Location and layout diagram of the room or area in which the BESS is installed. 2. Details on the hourly fire-resistance ratings of assemblies enclosing the BESS, or relied upon in relation to BESS 3. The quantities and types of BESS units to be installed. 4. Manufacturer’s specifications, ratings, and listing of each BESS. 5. Description of energy (battery) management systems and their operation. 6. Location and content of required signage. 7. Details on fire suppression, smoke or fire detection, thermal management, ventilation, exhaust, and deflagration systems, if provided. 8. Support arrangement associated with the installation, including any required seismic restraint. 9. A commissioning plan complying with CSFSC §1207.2.1. 10. A decommissioning plan complying with CSFSC §1207.2.3. <p>+ Construction documentation shall include the documents required in NFPA 855 §4.1.2.1.</p> <p>+ [NFPA 855 §4.1.2.1.2] The following test data, evaluation information, and calculations shall be provided in addition to the plans and specifications in §4.1.2.1.1 where required:</p> <ul style="list-style-type: none"> - Large-scale fire test data per §4.1.5. - HMA per §4.1.4. - Calculations or modeling data to determine compliance with NFPA 68/69 per §4.12. - Other test data, evaluation information, or calculations as required. <p>+ [NFPA 855 §4.1.2.1.4] If modeling data is provided, validation of the modeling results shall also be included.</p>	<p>System owner responsibility –</p> <p>Construction documents are beyond the scope of this HMA.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
HMA	CSFSC §1207.1.4	<p>+ An FMEA or other approved HMA shall be provided in accordance with CSFSC §104.8.2 under any of the following conditions:</p> <ol style="list-style-type: none"> 1. Where BESS technologies not specifically identified in Table 1207.1 are provided. 2. More than one BESS technology is provided in a room or enclosed area where there is a potential for adverse interaction between technologies. 3. Where allowed as a basis for increasing maximum allowable quantities (600 kWh for lithium-ion BESS). See CSFSC §1207.5.2. <p>+ The hazard mitigation analysis shall evaluate the consequences of the failure modes outlined in CSFSC §1207.1.4.1. Only single failure modes shall be considered.</p> <p>+ The fire code official is authorized to approve the hazard mitigation analysis, provided the consequences of the hazard mitigation analysis demonstrate the conditions outlined in CSFSC §1207.1.4.2.</p> <p>+ Construction, equipment, and systems that are required for the BESS to comply with the hazard mitigation analysis shall be installed, maintained, and tested in accordance with nationally recognized standards and specified design parameters.</p>	<p>Pending approval –</p> <p>The BESS installation exceeds 600 kWh. This document constitutes the HMA required to allow the BESS to exceed the maximum allowable quantity of 600 kWh. See Section 4.0 for details on the HMA.</p>
Large-Scale Fire Test	CSFSC §1207.1.5	<p>+ Where required elsewhere in CSFSC §1207, large-scale fire testing shall be conducted on a representative BESS in accordance with UL 9540A. The testing shall be conducted or witnessed and reported by an approved testing laboratory and show that a fire involving one BESS will not propagate to an adjacent BESS. The test report shall be provided to the fire code official for review and approval.</p>	<p>Compliant –</p> <p>Unit-level UL 9540A testing has been conducted for the BESS.</p> <p>See Section 2.5 for test data and information.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Fire Remediation	CSFSC §1207.1.6	<ul style="list-style-type: none"> + Where a fire or other event has damaged the BESS and ignition or re-ignition of the BESS is possible, the system owner, agent, or lessee shall take actions outlined in CSFSC §1207.1.6, at their expense, to mitigate the hazard or remove damaged equipment from the premises to a safe location. + Remediation measures shall be provided in accordance with NFPA 855 §4.16. 	<p>System owner responsibility –</p> <p>Fire remediation is beyond the scope of this HMA.</p>
	CSFPC §52.2		
Commissioning	CSFSC §1207.2.1	<ul style="list-style-type: none"> + Commissioning of newly installed BESS shall be conducted prior to the BESS being placed in service in accordance with a commissioning plan that has been approved prior to initiating commissioning. The commissioning plan shall include the criteria prescribed in CSFSC §1207.2.1. + During the commissioning process, BESS shall be evaluated for proper operation in accordance with the manufacturer’s instructions and the commissioning plan prior to final approval. + A report describing the results of the system commissioning, including the results of the initial acceptance testing required in CSFSC §1207.2.1.1, shall be provided to the fire code official prior to final inspection and approval and maintained at an approved on-site location. + BESS commissioning shall be performed in accordance with NFPA 855 Chapter 6 and approved prior to putting the system into service. + A commissioning plan meeting the provisions of NFPA 855 Chapter 6 shall be provided to the building owner or their authorized agent and the AHJ. [NFPA 855 §4.1.2.4] 	<p>System owner responsibility –</p> <p>The details of the commissioning plan are beyond the scope of this HMA. A commissioning plan specific to this installation was provided.</p>
	CSFPC §52.1.5		

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
O&M	CSFSC §1207.2.2 CSFPC §52.1.3, §52.1.6, §52.4	<ul style="list-style-type: none"> + An O&M manual shall be provided to both the BESS owner or their authorized agent and the BESS operator before the BESS is put into operation. The manual shall include the information outlined in CSFSC §1207.2.2. + The BESS shall be operated and maintained in accordance with the manual, and a copy of the manual shall be retained at an approved on-site location. + Systems that monitor and protect the BESS installation shall be inspected and tested in accordance with the manufacturer’s instructions and the operation and maintenance manual. Inspection and testing records shall be maintained in the operation and maintenance manual. + A copy of the operations and maintenance manual shall be placed in an approved location to be accessible to AHJs and emergency responders. [NFPA 855 §4.1.2.3.2] + O&M, and testing of BESS shall be in accordance with NFPA 855 Chapter 7. 	<p>System owner responsibility –</p> <p>O&M is beyond the scope of this report.</p>
De-commissioning	CSFSC §1207.2.3 CSFPC §52.1.5	<ul style="list-style-type: none"> + The code official shall be notified prior to the decommissioning of a BESS. Decommissioning shall be performed in accordance with the decommissioning plan that includes the following. <ul style="list-style-type: none"> - A narrative description of the activities to be accomplished for removing the BESS from service and from the facility in which it is located. - A listing of any contingencies for removing an intact operational BESS from service, and for removing a BESS from service that has been damaged by a fire or other event. + A decommissioning plan shall be prepared in accordance with NFPA 855 Chapter 8 and approved prior to putting the system in service. 	<p>System owner responsibility –</p> <p>The details of the decommissioning plan are beyond the scope of this HMA. A decommissioning plan specific to this installation was provided.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Equipment Listings and Requirements	CSFSC §1207.3 CSFPC §52.1.7	<ul style="list-style-type: none"> + BESS shall be listed in accordance with UL 9540. + Chargers, inverters, and energy storage management systems shall be covered as part of the UL 9540 listing or shall be listed separately. + Inverters shall be listed and labeled in accordance with UL 1741. Only inverters listed and labeled for utility interactive system use and identified as interactive shall be allowed to operate in parallel with the electric utility power system to supply power to common loads. + Where required by the BESS listing, an approved energy storage management system that monitors and balances cell voltages, currents, and temperatures within the manufacturer’s specifications shall be provided. The system shall disconnect electrical connections to the BESS or otherwise place it in a safe condition if potentially hazardous temperatures or other conditions, such as short circuits, overvoltage, or undervoltage, are detected. + Enclosures of BESS shall be of noncombustible construction. + BESS electrical circuitry shall be within weatherproof enclosures marked with the environmental rating suitable for the type of exposure required by NFPA 70. [NFPA 855 §4.4.3.7.1] 	<p>Compliant –</p> <p>The Eaton xStorage 250-1000 system is listed per UL 9540, 2023 edition, including all its components.</p> <p>The PCS is listed per UL 1741, 2021 edition.</p> <p>The BESS enclosure is noncombustible.</p> <p>The BESS enclosures are provided with IP54, IP66, and NEMA Type 3R environmental ratings, which are suitable for the intended outdoor exposure and consistent with the intent of NFPA 70 requirements for equipment installed in outdoor locations.</p>

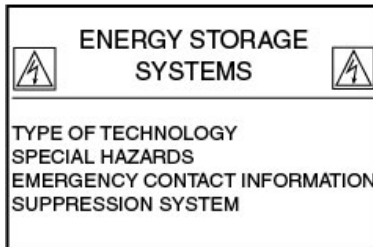
<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Repairs, Retrofits, Reused, and Repurposed Equipment	CSFSC §1207.3.6 through §1207.3.9 CSFPC §52.1.11, §52.1.17	<ul style="list-style-type: none"> + Repairs of BESS shall only be done by qualified personnel. Repairs with other than identical parts shall be considered retrofitting. Repairs shall be documented in the service record log. [NFPA 855 §4.2.2.1] + Retrofitting of an existing BESS shall comply with CSFSC §1207.3.7 and NFPA 855 §4.2.3.1 + Reused and repurposed equipment shall comply with CSFSC §1207.3.9 and NFPA 855 §4.2.10.1. 	<p>Not applicable –</p> <p>BESS uses new storage batteries intended for BESS applications.</p> <p>Repairs are beyond the scope of this report.</p>
Installation	CSFPC §52.1.7	<ul style="list-style-type: none"> + The installation of BESS and related systems shall be in accordance with NFPA 855. + [NFPA 855 §4.3.1] BESS shall be installed in accordance with their listing, the manufacturer's installation instructions, and this standard. + [NFPA 855 §4.3.4] The weight of the BESS and all associated equipment, components, and enclosure elements and their impact on the dead and live loads of the building or system foundation shall be per the local building code. 	<p>Compliant –</p> <p>BESS is located outdoors with other auxiliary equipment on a pad.</p>
System Interconnections	CSFPC §52.1.9, §52.3	<ul style="list-style-type: none"> + All electrical connections and wiring to and from a BESS or the components of a BESS, and connections to fuel gas, liquid fuel, or water shall be in accordance with Chapter 5 of NFPA 855. + [NFPA 855 §5.1] All electrical connections and wiring to and from a BESS or the components of a BESS shall be in accordance with NFPA 70 or IEEE C2 based on the location of the BESS in relation to and its interaction with the electrical grid. 	<p>System owner responsibility –</p> <p>Electrical connections and wiring to and from the BESS shall be installed in accordance with NFPA 70. Verification of field-installed electrical interconnections and wiring is the responsibility of the system owner and installing electrical contractor and is subject to AHJ review and approval.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Disconnecting Means	CSFSC §1207.4.1	<ul style="list-style-type: none"> + Where the BESS disconnecting means is not within sight of the main electrical service disconnecting means, placards or directories shall be installed at the location of the main electrical service disconnecting means indicating the location of BESS disconnecting means in accordance with NFPA 70. + [NFPA 855 §5.2] A readily accessible disconnecting means for the BESS shall be provided within sight of the BESS in accordance with NFPA 70. + [NFPA 855 §4.3.5.3] A permanent plaque or directory denoting the location of all electric power source disconnecting means on or in the premises shall be installed at each service equipment location and at the location(s) of the system disconnect(s) for all energy sources capable of being interconnected. 	<p>Compliant –</p> <p>A readily accessible BESS disconnecting means and associated signage are required to be provided in accordance with NFPA 70.</p> <p>Per meeting with the design team on 3/11/2026, a disconnect button is provided with signage in a location approved by the Fire Marshal.</p>
Communication Systems	NFPA 855 §5.4	<ul style="list-style-type: none"> + [NFPA 855 §5.4] BESS shall have communication interconnections between the BESS components and site-located systems necessary for safe operation of the system and in accordance with product listing, manufacturer installation instructions, and this document. 	<p>System owner responsibility –</p> <p>Communication systems are beyond the scope of this HMA.</p>
Support Systems	NFPA 855 §5.5	<ul style="list-style-type: none"> + [NFPA 855 §5.5] All connections to and from a BESS or the components of a BESS to required plumbing, fire alarm, detection, or control circuits or to ventilation systems shall be in accordance with nationally recognized standards applicable to those systems, manufacturer’s instructions, listings, and the applicable provisions of NFPA 855 Chapters 4 and 5. 	<p>System owner responsibility –</p> <p>Support systems connections are beyond the scope of this HMA.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Working Clearances	CSFSC §1207.4.2	+ Access and working space shall be provided and maintained about all electrical equipment to permit ready and safe operation and maintenance of such equipment in accordance with NFPA 70 and the manufacturer’s instructions.	System owner responsibility – Access and required working clearances around BESS electrical equipment shall be provided and maintained in accordance with NFPA 70 and the manufacturer’s installation instructions. Verification of field-installed clearances is the responsibility of the system owner and is subject to AHJ review and approval.
	CSFPC §52.1.14		
Seismic and Structural Design	CSFSC §1207.4.4	+ Stationary BESS shall comply with the seismic design requirements in CSBC Chapter 16, and shall not exceed the floor loading limitation of the building.	System owner responsibility – Structural design is beyond the scope of this report.
		+ [NFPA 855 §4.3.3] BESS shall be seismically braced per the local building code.	
Vehicle Impact Protection	CSFSC §1207.4.5	+ Where BESS are subject to impact by a motor vehicle, including forklifts, vehicle impact protection shall be provided in accordance with CSFSC §312 and NFPA 855 §4.3.7.3.	Compliant – Vehicle impact protection is provided via bollards.
	CSFPC §52.1.19		
	NFPA 855 §4.3.7.3		

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Combustible Storage	CSFSC §1207.4.6 CSFPC §52.1.10	<ul style="list-style-type: none"> + Combustible materials shall not be stored in BESS rooms, areas, or walk-in units. Combustible materials in occupied work centers covered by CSFSC §1207.4.10 shall be stored at least 3 feet from BESS cabinets. + Combustible materials not related to the BESS shall not be stored in rooms, cabinets, or enclosures containing BESS equipment. [2020 NFPA 855 §4.1.6.1] + Combustible materials related to the BESS shall not be stored within 3 ft (914 mm) of BESS equipment. [2020 NFPA 855 §4.1.6.2] 	<p>Compliant –</p> <p>Combustible storage is not located within 3 feet of the BESS.</p>
Environment	CSFPC §52.1.13	<ul style="list-style-type: none"> + The temperature, humidity, and other environmental conditions in which a BESS is located shall be maintained in accordance with the listing (if listed) and the manufacturer’s specifications. [2020 NFPA 855 §4.2.6] 	<p>Compliant –</p> <p>BESS cabinets are provided with HVAC units and IP ratings.</p>
Fire Command Centers	CSFPC §52.1.16	<ul style="list-style-type: none"> + In buildings containing BESS and equipped with a fire command center, the command center shall include signage or readily available documentation that describes the location and type of BESS, operating voltages, and location of electrical disconnects as required by NFPA 70. [NFPA 855 §4.3.12] 	<p>Not applicable –</p> <p>The BESS is an outdoor, cabinet-style (non-walk-in) installation and is not located within a building.</p>
Toxic and Highly Toxic Gases	CSFSC §1207.4.7	<ul style="list-style-type: none"> + BESS that have the potential to release toxic and highly toxic gas during charging, discharging, and normal use conditions shall be provided with a hazardous exhaust system. 	<p>Not applicable –</p> <p>The BESS uses lithium-ion batteries, which do not release toxic gases during normal charging, discharging, and operation.</p>

Requirement	Section	Description	Compliance
Signage	CSFSC §1207.4.8 CSFPC §52.1.18	<ul style="list-style-type: none"> + Approved signs shall be provided on or adjacent to all entry doors for BESS rooms or areas and on enclosures of BESS cabinets and walk-in units located outdoors, on rooftops or in open parking garages. Signs designed to meet both the requirements of this section and NFPA 70 shall be permitted. The signage shall include the following or equivalent: + “ENERGY STORAGE SYSTEM,” “BATTERY STORAGE SYSTEM,” or the equivalent. + The identification of the electrochemical ESS technology present. + “ENERGIZED ELECTRICAL CIRCUITS.” + Where water-reactive electrochemical ESS are present, the signage shall include “APPLY NO WATER.” + Current contact information, including phone number, for personnel authorized to service the equipment and for fire mitigation personnel required by CSFSC §1207.1.6.1. + Approved signage shall be provided in the following locations: [NFPA 855 §4.3.5.1] <ul style="list-style-type: none"> - On the front doors to rooms or areas containing BESS or in approved locations near the entrance to BESS rooms. - On the front doors to outdoor occupiable BESS containers. - In approved locations on outdoor BESS that are not enclosed in occupiable containers or otherwise enclosed. + The signage required shall be in compliance with ANSI Z535 and include the following information: [2020 NFPA 855 §4.3.5.2] 	<p>Compliant –</p> <p>Per meeting with the design team on 3/11/2026, a disconnect button is provided with signage in a location approved by the Fire Marshal.</p>



<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Security of Installations	CSFSC §1207.4.9 CSFPC §52.1.15	+ Rooms, areas and walk-in units in which electrochemical BESS are located shall be secured against unauthorized entry and safe-guarded in an approved manner. Security barriers, fences, landscaping and other enclosures shall not inhibit the required air flow to or exhaust from the electrochemical BESS and its components.	Compliant – A secure fence is provided around the BESS equipment.
Fire Department Access	CSFPC §52.1.7 2020 NFPA 855 §4.4.3.8	+ Fire department access roads shall be provided to outdoor BESS installations in accordance with the local fire code.	Compliant – Fire department access roads are provided adjacent to the BESS.
Size and Separation	CSFSC §1207.5.1 NFPA 855 §4.6	+ Electrochemical BESS shall be segregated into groups not exceeding 50 kWh. Each group shall be separated by a minimum of 3 feet from other groups and from walls in the storage room or area. + The fire code official/ AHJ is authorized to approve larger capacities or smaller separation distances based on large-scale fire testing complying with CSFSC §1207.1.5 and NFPA 855 §4.1.5.	Compliant – The BESS comprises three battery cabinets installed side by side. Each cabinet has a battery unit/rack with a nominal energy capacity of 372.74 kWh, exceeding the prescriptive 50 kWh and 3 feet limits. Unit-level UL 9540A testing has been conducted for the BESS are considered to justify grouping and separations exceeding prescriptive limits. See Section 2.5 for UL 9540A test details.

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Maximum Allowable Quantities	CSFSC §1207.5.2	<ul style="list-style-type: none"> + Fire areas within rooms, areas, and walk-in units containing electrochemical BESS shall not exceed the maximum allowable quantities in CSFSC Table 1207.5 (600 kWh for lithium-ion BESS). + Where approved by the fire code official, rooms, areas and walk-in units containing electrochemical BESS that exceed the amounts in CSFSC Table 1207.5 shall be permitted based on an HMA in accordance with CSFSC §1207.1.4 and large-scale fire testing complying with CSFSC §1207.1.5. 	<p>Compliant –</p> <p>The BESS has a nominal energy capacity of 1,118.22 kWh, which exceeds the prescriptive 600-kWh limit.</p> <p>The HMA in this report and the UL 9540A testing for the BESS are considered to justify an allowance beyond the 600 kWh prescriptive limit.</p> <p>See Section 2.5 for UL 9540A test details.</p>
Elevation	CSFSC §1207.5.3	<ul style="list-style-type: none"> + Electrochemical BESS shall not be located in the following areas: <ul style="list-style-type: none"> - Where the floor is located more than 75 feet above the lowest level of fire department vehicle access. - Where the floor is located below the lowest level of exit discharge. + [2020 NFPA 855 §4.3.9] BESS shall be located only on floors that can be accessed by external fire department laddering capabilities unless a higher location is approved by the AHJ. 	<p>Not applicable –</p> <p>The BESS is located outdoors at grade.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Fire Detection	CSFSC §1207.5.4 CSFPC §52.1.24	<p>+ An approved automatic smoke detection system or radiant energy-sensing fire detection system complying with CSFSC §907.2 shall be installed in rooms, indoor areas, and walk-in units containing electro-chemical BESS. An approved radiant energy-sensing fire detection system shall be installed to protect open parking garage and rooftop installations. Alarm signals from detection systems shall be transmitted to a central station, proprietary or remote station service in accordance with NFPA 72, or where approved to a constantly attended location.</p> <p>+ Where required by the fire code official, visible annunciation shall be provided on cabinet exteriors or in other approved locations to indicate that potentially hazardous conditions associated with the BESS exist.</p> <p>+ Where smoke and fire detection is provided, it shall be in accordance with NFPA 855 §4.10.</p>	<p>Compliant –</p> <p>The BESS is an outdoor cabinet-style installation, not located in rooms, indoor areas, or walk-in units.</p> <p>The BESS cabinets are equipped with smoke and heat detection with a horn and a strobe on the exterior of the cabinets.</p> <p>The BESS fire alarm system is tied to the library fire alarm system and reports directly to a central monitoring station.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Fire Suppression	CSFSC §1207.5.5 CSFPC §52.1.22	<ul style="list-style-type: none"> + Rooms and areas within buildings, and walk-in units containing electrochemical BESS shall be protected by an automatic fire suppression system designed and installed in accordance with CSFSC §1207.5.5. + Where fire suppression and control is provided, it shall be in accordance with NFPA 855 §4.4.4.3. + [NFPA 855 §4.4.4.3] BESS located in walk-in enclosures on rooftops or in open parking garages shall be provided with automatic fire control and suppression systems within the enclosure in accordance with NFPA 855 §4.11. + [NFPA 855 §4.11.2] Where required by NFPA 855, sprinkler systems shall be installed in accordance with NFPA 13 or equivalent. + [NFPA 855 §4.11.3] Other automatic fire control and suppression systems shall be permitted based on reports issued as a result of large-scale fire testing in accordance with NFPA 855 §4.1.5. The automatic fire control and suppression systems shall comply with the applicable NFPA standard or equivalent (e.g. NFPA 2010 for aerosol extinguishing systems) 	<p>Not applicable –</p> <p>The BESS is an outdoor installation and does not include a walk-in unit. Fire suppression is not prescriptively required.</p> <p>An aerosol fire extinguishing system is installed within the BESS enclosure as an additional protective feature; however, the system was not actuated during unit-level UL 9540A testing and is not credited for fire suppression or control performance.</p> <p>The aerosol system and deflagration vent were not evaluated in conjunction as part of installation-level testing. Control logic / sequencing are not implemented for these two systems. Per email correspondence on 05/26/2026, the aerosol discharge pressure is significantly below the deflagration vent activation threshold.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Water Supply	CSFPC §52.1.25 NFPA 855 §4.13	<ul style="list-style-type: none"> + Where water supplies are provided, they shall be in accordance with NFPA 855 §4.13. + Where required elsewhere in this standard, sites where nonmechanical BESS are installed shall be provided with a permanent source of water for fire protection. [NFPA 855 §4.13.1] + Where no permanent, adequate, and reliable water supply exists for fire-fighting purposes, the requirements of NFPA 1142 shall apply. [2020 NFPA 855 §4.13.2] + Accessible fire hydrants shall be provided for site BESS installations where a public or private water supply is available. [2020 NFPA 855 §4.13.3] + Fire hydrants installed on private fire service mains shall be installed in accordance with NFPA 24. [2020 NFPA 855 §4.13.4] 	<p>Compliant –</p> <p>A fire hydrant supplied from the public water supply system is provided adjacent to the BESS.</p>
Maximum Enclosure Size	CSFSC §1207.5.6	<ul style="list-style-type: none"> + Outdoor walk-in units housing BESS shall not exceed 53 feet by 8 feet by 9.5 feet high, not including bolt-on HVAC and related equipment, as approved. Outdoor walk-in units exceeding these limitations shall be considered indoor installations. 	<p>Not applicable –</p> <p>The BESS does not include a walk-in unit.</p>
Vegetation Control	CSFSC §1207.5.7 CSFPC §52.1.7 NFPA 855 §4.4.3.6	<ul style="list-style-type: none"> + Areas within 10 feet on each side of outdoor BESS shall be cleared of combustible vegetation and other combustible growth. Single specimens of trees, shrubbery, or cultivated ground cover, such as green grass, ivy, succulents, or similar plants used as ground cover, shall be permitted to be exempt, provided that they do not form a means of readily transmitting fire. 	<p>Compliant –</p> <p>The BESS site plans show a clearance of at least 10-ft to vegetation.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>		
Means of Egress Separation	CSFSC §1207.5.8	<ul style="list-style-type: none"> + BESS located outdoors and in open parking garages shall be separated from any means of egress as required by the fire code official to ensure safe egress under fire conditions, but in no case less than 10 feet. + The fire code official is authorized to approve a reduced separation distance (3 ft minimum) if large-scale fire testing complying with CSFSC §1207.1.5 is provided that shows that a fire involving the BESS will not adversely impact occupant egress. 	<p>Compliant –</p> <p>The BESS is located more than 10 feet from any required means of egress.</p>		
	CSFPC §52.1.20			Exhaust Ventilation	CSFSC §1207.6.1
Exhaust Ventilation	CSFSC §1207.6.1	<ul style="list-style-type: none"> + Where required by CSFSC Table 1207.6, or elsewhere in CSFSC, exhaust ventilation of rooms, areas, and walk-in units containing electrochemical BESS shall be provided in accordance with CSFSC §1207.6.1. + Per CSFSC Table 1207.6, exhaust ventilation is not prescriptively required for BESS using lithium-ion battery technology under normal conditions; however, CSFSC Table 1207.6(f) specifies that exhaust ventilation is required when flammable gases are released under abnormal conditions. + Where ventilation is provided, it shall be in accordance with NFPA 855 §4.9. 	<p>Not applicable –</p> <p>The BESS enclosure is a cabinet-style (non-walk-in) unit and is installed outdoors, not within enclosed rooms or indoor areas. Exhaust ventilation is not prescriptively required for lithium-ion BESS under normal operating conditions.</p> <p>Under abnormal conditions involving flammable gas release, the enclosure does not rely on exhaust ventilation. Gas and pressure relief are addressed through deflagration venting in accordance with NFPA 68.</p>		
	CSFPC §52.1.23				

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Spill Control and Neutralization	CSFSC §1207.6.2	<ul style="list-style-type: none"> + Where required by CSFSC Table 1207.6, or elsewhere in CSFSC, areas containing free-flowing liquid electrolyte or hazardous materials shall be provided with spill control and neutralization in accordance with this section. + Per CSFSC Table 1207.6, spill control and neutralization are not required for BESS using lithium-ion battery technology. 	<p>Not applicable –</p> <p>The BESS utilizes sealed lithium-ion battery cells and does not contain free-flowing liquid electrolyte or other hazardous liquids requiring spill control or neutralization. Accordingly, the spill control and neutralization requirements do not apply.</p>
Classified Area Location	<p>CSFPC §52.1.7</p> <p>NFPA 855 §4.4.3.9</p>	<ul style="list-style-type: none"> + The BESS shall not be located in a classified area as defined in NFPA 70 or IEEE C2 unless listed and approved for the specific installation. 	<p>Not Applicable –</p> <p>The BESS is not located within a classified (hazardous) area, as defined by NFPA 70 or IEEE C2. Accordingly, the requirement for listing and approval for installation in classified areas does not apply.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Explosion Control	CSFSC §1207.6.3 NFPA 855 §4.12	<ul style="list-style-type: none"> + Explosion control complying with CSFSC §911 shall be provided for rooms, areas, or walk-in units containing electrochemical BESS technologies. + Lithium-ion BESS installed within a room, building, cabinet, or walk-in unit shall be provided with one of the following: [NFPA 855 §4.12.1] <ul style="list-style-type: none"> - Explosion prevention systems designed, installed, operated, maintained, and tested in accordance with NFPA 69. - Deflagration venting installed and maintained in accordance with NFPA 68. + Explosion prevention and deflagration venting shall not be required where approved by the AHJ based on large-scale testing in accordance with NFPA 855 §4.1.5 and a deflagration hazard study that demonstrates that flammable gas concentrations in the room, building, BESS cabinet, or BESS walk-in unit cannot exceed 25 percent of the LFL. [NFPA 855 §4.12.1.2] + Where approved, BESS cabinets that have been designed to ensure no hazardous pressure waves, debris, shrapnel, or enclosure pieces are ejected, as validated by installation-level large-scale testing and engineering evaluation complying with NFPA 855 §4.1.5 that includes the cabinet, shall be permitted in lieu of providing explosion control complying with NFPA 68 or NFPA 69. [2020 NFPA 855 §4.12.1.2] 	<p>Compliant –</p> <p>Explosion control is provided for the BESS via a cabinet-level deflagration venting system as found in Chapter 6 of NFPA 68 (2023).</p> <p>Per the BESS manufacturer the front door of the cabinet is designed to function as the deflagration vent panel, for controlled pressure relief under deflagration conditions.</p> <p>The manufacturer’s NFPA 68 report ^[12] included a CFD analysis that predicts a maximum average internal pressure of approximately 0.48 bar-g, which is below the enclosure design pressure of 0.50 bar-g specified by the manufacturer’s mechanical analysis. The CFD analysis report and findings were not reviewed or verified as part of this HMA.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Safety Caps	CSFSC §1207.6.4	<ul style="list-style-type: none"> + Where required by CSFSC Table 1207.6, or elsewhere in CSFSC, vented batteries and other BESS shall be provided with flame-arresting safety caps. + Per CSFSC Table 1207.6, safety caps are not required for BESS using lithium-ion battery technology. 	<p>Not applicable –</p> <p>The BESS utilizes sealed lithium-ion battery cells installed within factory-assembled cabinets and does not include vented batteries with free vent openings requiring flame-arresting safety caps. Accordingly, the safety cap requirements do not apply.</p>
Electrochemical Energy Storage Systems	<p>CSFPC §52.5</p> <p>NFPA 855 §9.2</p>	<ul style="list-style-type: none"> + Where electrochemical energy storage systems are provided, they shall be in accordance with NFPA 855 Chapter 9. + Lithium-ion BESS shall be provided with all the following: [NFPA 855 §9.2, Table 9.2] <ul style="list-style-type: none"> - Thermal runaway protection in accordance with NFPA 855 §9.3. Per NFPA 855 Table 9.2(f), thermal runaway protection is permitted to be part of a BMS that has been evaluated with the battery as part of the evaluation to UL 1973 or UL 9540. - Explosion control in NFPA 855 §4.12 - Size and separation in NFPA 855 §4.6. 	<p>Compliant –</p> <p>Thermal runaway protection in the BESS is provided via the BMS, which is evaluated as part of the BESS that is UL 9540 listed, with battery cabinets that are UL 1973 listed.</p> <p>Explosion control is provided via an NFPA 68 deflagration venting system.</p> <p>Size and separation exceeding prescriptive limits are supported by UL 9540A test data.</p>

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Thermal Runaway Protection	CSFSC §1207.6.5 NFPA 855 §9.3	+ Batteries and other BESS shall be provided with a listed device or other approved method to prevent, detect, and minimize the impact of thermal runaway.	Compliant – Thermal runaway protection in the BESS is provided via the BMS, which is evaluated as part of the BESS that is UL 9540 listed, with battery cabinets that are UL 1973 listed.

<i>Requirement</i>	<i>Section</i>	<i>Description</i>	<i>Compliance</i>
Clearance to Exposures	CSFSC §1207.8.3 NFPA 855 §4.4.3.3	<ul style="list-style-type: none"> + BESS located outdoors shall be separated by a minimum of 10 feet from the following exposures: <ul style="list-style-type: none"> - Lot lines. - Public ways. - Buildings. - Stored combustible materials. - Hazardous materials. - High-piled stock. - Other exposure hazards. + Clearances are permitted to be reduced to 3 feet where a 1-hour free-standing fire barrier suitable for exterior use and extending 5 feet above and 5 feet beyond the physical boundary of the BESS installation is provided to protect the exposure. + Clearances to buildings are permitted to be reduced to 3 feet where noncombustible exterior walls with no openings or combustible overhangs are provided on the wall adjacent to the BESS and the fire-resistance rating of the exterior wall is a minimum of 2 hours. + Clearances to buildings are permitted to be reduced to 3 feet where a weather-proof enclosure constructed of noncombustible materials is provided over the BESS, and it has been demonstrated that a fire within the enclosure will not ignite combustible materials outside the enclosure based on large-scale fire testing complying with CSFSC §1207.1.5 and NFPA 855 §4.1.5. + [NFPA 855 §4.4.3.3.6] Exhaust outlets from a BESS that exhaust other than ventilation air shall be located at least 15 ft from HVAC air intakes, windows, doors, loading docks, ignition sources, and other openings into buildings and facilities. + [NFPA 855 §4.4.3.3.7] Exhaust outlet(s) from a BESS shall not be directed onto means of egress, walkways, or pedestrian or vehicular travel paths. 	<p>Compliant –</p> <p>Distances from the BESS to adjacent exposure hazards meet or exceed the minimum 10-ft requirement. Refer to Section 2.2 for site separation distances. Clearances of electrical equipment associated with the BESS are provided in accordance with the manufacturer’s guidance and are not considered exposure hazards.</p> <p>Under normal operation, the BESS exhausts only ventilation air; under abnormal conditions, gases or particulate matter may be discharged through the front-facing deflagration vent. Adjacent buildings and residential structures are located more than 15 ft from the BESS, The BESS is not located adjacent to designated means of egress, pedestrian walkways, or vehicular travel paths. Final confirmation of exhaust orientation is recommended.</p>

4.0 Hazard Mitigation Analysis

This section of the report outlines the HMA for the Manchester Public Library project. An FMEA was performed on the failure modes that the CSFSC and NFPA 855 require to be addressed, as discussed in Section 1.3 of this report. Each failure mode is described in detail, along with its potential consequences, provided preventive and mitigative barriers, and site-specific recommendations to mitigate the resulting consequences.

4.1 THERMAL RUNAWAY CONDITION IN A SINGLE MODULE, ARRAY, OR UNIT

4.1.1 Description

The failure mode where a single cell has entered thermal runaway, resulting in flames/ combustion or production of flammable or explosive gases, was investigated.

Thermal runaway is a condition in which a battery cell increases its temperature through self-heating in an uncontrollable fashion. This phenomenon typically progresses to a point at which the cell's heat generation is higher than the rate at which heat can dissipate, potentially leading to the release of flammable gas, fire, or explosion. Once thermal runaway has started in a cell, it cannot be stopped. Thermal runaway can produce a significant amount of volatile gas that causes increased pressure within the cell housing and eventually leads to forceful venting. If there is sufficient oxygen and a competent ignition source, these cell vent gases may ignite.

Thermal runaway can be caused by physical damage (puncture, crushing), electrical issues (deep discharge, overcharging), exposure to elevated ambient temperatures, and manufacturer defects (imperfections, contaminants).

For BESS installations such as this, common causes of single-cell thermal runaway include malfunctioning of electrical equipment, manufacturing defects, and aging of the cells that leads to internal short-circuiting (dendrite growth, core collapse, etc.). Impact from vehicles or heat from fires caused by external exposures and electrical equipment may also lead to internal cell failures.

Cells in thermal runaway can cause adjacent cells to also undergo thermal runaway in a phenomenon known as thermal runaway propagation. A cell may cause thermal runaway in adjacent cells through one of several heat transfer mechanisms: 1) conductive heat transfer via direct contact between cells, 2) overcurrent caused by damaged circuitry, and 3) impingement of hot or flaming vent gases. Cells may also cause thermal runaway in adjacent cells due to the effects of the cell depressurization (thermally from the fireball or mechanically from the force) or due to the original cell swelling into the adjoining cell and causing physical damage.

Sustained cell-to-cell thermal propagation can lead to three primary hazardous scenarios:

- + Rapid ignition of flammable gases, sustained propagation, and resultant full-scale fire.
- + Multiple cells venting flammable gases without sufficient temperature for ignition.
- + Multiple cells venting flammable gases but delayed ignition, leading to a deflagration (i.e., explosion).

4.1.2 Barriers

Mitigation strategies are put in place to help prevent batteries from entering thermal runaway, cope with the byproducts of thermal runaway, and provide cooling to slow the cascading effects of propagation to other cells within a module and/or unit or rack. These barriers include:

- + Cell abuse tolerance is the ability of the cells to withstand thermal and electrical abuse without going into failure themselves. The cells are listed to UL 1973 to withstand some degree of thermal and electrical abuse (e.g., high temperature, overcharge).
- + Unit or rack thermal abuse tolerance is the ability of the cells to withstand thermal and electrical abuse without going into failure themselves. The rack/unit is listed to UL 1973 to withstand some degree of thermal and electrical abuse (e.g., high temperature, overcharge).
- + Passive battery module protection via a mica sheet between the cell assembly and the top enclosure and a metal bottom enclosure that resists thermal runaway and its propagation outside the module, as shown in the UL 9540A module-level test in Section 2.5 of this report.
- + System electrical abuse tolerance via UL 9540 certification, demonstrating its ability to withstand adverse electrical abuse such as overcharge or dead shorts without failure
- + Unit or rack overcurrent protection, is incorporated through integrated protection features (e.g., current interrupt devices, breakers, fuses, contactors, or other passive surge-arresting elements) that may open the circuit in the case of failure. The unit is listed to UL 1973, which includes evaluation of protection against overcurrent and fault conditions.
- + MBMU and SBMU to monitor and control the batteries. BMS protection that disconnects the affected cell, modules, and racks in the event of abnormal conditions that may be a precursor to thermal runaway.
- + Multi-detection system via gas, smoke, and heat detectors.
- + Deflagration venting in accordance with NFPA 68 for pressure relief that opens upon excessive internal pressure buildup, mitigating explosion hazards.

4.1.3 Consequences

While numerous safeguards and barriers will be provided, single-cell failures are possible due to manufacturing defects or simply due to aging, which could lead to the consequences evaluated below:

Fire and Radiant Heat Exposures

Per the UL 9540A testing of the Eaton xStorage 250-1000 kWh BESS, referenced in Section 2.5 of this report, no indication of module-to-module propagation was observed. No external flaming, flying debris, or explosion hazards occurred from the initiating unit. No sparks, electrical arcs, or other electrical events were observed during testing. No re-ignition was observed after the test. Heat flux measured on the target modules and the egress path was less than 4.5 kW/m². These conditions are not expected to pose an excessively hazardous environment for the nearby service personnel or the responding fire department providing manual fire suppression, if necessary.

In addition to internal failure modes, there is also a possibility for a fire originating from adjacent equipment on the BESS pad (i.e., PCS, generators, transformers) to propagate to the BESS. Based on the provided plans, multiple pieces of equipment are located in close proximity to the BESS (less than 10 feet) and could be involved or damaged in a potential fire event

Based on the current conditions on-site, the parking areas, adjacent equipment, and some vegetation located more than 10 feet away from the BESS may still experience elevated radiative heat fluxes. It is important to note that radiant heat damage and possible ignition can extend beyond the visible flame extent. If the fire department

response is significantly delayed or manual suppression is not activated, equipment or vehicles adjacent to the installation may be damaged or become involved in the event. Failure of the detection, suppression, and manual firefighting response was evaluated in more detail in Section [4.4](#) of this report.

Deflagration and Explosion

Thermal runaway of a single cell may propagate to adjacent cells, modules, units/racks, and equipment and generate substantial volumes of flammable gases. Multiple cells or modules releasing flammable gas can lead to a scenario where an explosion could occur.

Based on the UL 9540A unit-level test described in Section 2.5 of this report, no flying debris or explosion hazards were observed during the test.

The deflagration vent system is certified to comply with NFPA 68. Due to the passive nature of the deflagration vent system, its failure is considered a less plausible scenario for the purpose of this analysis, assuming that the deflagration vent is designed in accordance with NFPA 68 and that inspection, testing, and maintenance are provided in accordance with NFPA 68, which is the responsibility of the system owner. The failure of the deflagration vent system was evaluated in more detail in Section [4.3](#) of this report.

Toxic Smoke and Gas Exposure

A toxic gas dispersion calculation was not performed; however, toxic smoke and gases resulting from a full-scale fire event will be at an elevated temperature, causing the gases to rise and dissipate into the atmosphere. While people, service personnel, and first responders in the vicinity, such as the adjacent parking area or residential building, could potentially experience some exposure to released gases, they should be able to evacuate away from the source of the smoke and toxic gases during the incipient stages of the event, given a proper alarm and notification system.

4.1.4 Recommendations

It is recommended to revise and update the installation level Emergency Operation Plan (EOP) at regular intervals, as necessary. The local fire department and emergency response personnel should review this EOP and train as necessary to maintain familiarity with the installation, its hazards, and its integrated safety features.

Additionally, it is recommended that all fire protection systems associated with the BESS be inspected, tested, and maintained in accordance with manufacturer requirements and applicable NFPA standards to confirm continued functionality. System fault, supervisory, and alarm signals should be verified during commissioning and periodically thereafter to confirm that system impairments are promptly identified.

4.2 FAILURE OF THE ENERGY STORAGE MANAGEMENT SYSTEM

4.2.1 Description

The Energy Storage Management System (ESMS) is defined as an electronic system that protects the BESS from operating outside its safe operating parameters and disconnects electrical power to the BESS or places it in a potentially safe condition if potentially hazardous temperatures or other conditions are detected [CSFSC §202]. The ESMS is also defined as a system that monitors and controls one or more individual management systems, such as battery management systems (BMS), and optimizes the

performance of a BESS and has the ability to control the disconnection of the BESS in the event of abnormal conditions [NFPA 855 §3.3.8].

This definition implies that, at a minimum, the ESMS encompasses the performance of the BMS for the BESS cabinets. The ESMS for the BESS is a site-level controller, while the BMS is part of the product-level control system within the BESS cabinets. The BMS is defined as a system that monitors, controls, and optimizes the performance of an individual or multiple battery modules in BESS and has the ability to control the disconnection of the module(s) from the BESS in the event of abnormal conditions. This system can be completely independent of the ESMS. [NFPA 855 §3.3.3].

The failure mode where the multi-level BMS (MBMU + SBMU) or the system controller (GSEC) fail was investigated. These systems are responsible for battery monitoring, safety functions, and communication with the PCS, HVAC, and fire protection systems. If either system fails, there is an increased risk of battery overheating, electrical faults, or loss of emergency response coordination.

Potential causes of multi-level BMS and system controller failure include:

- + Loss of communication between the system controller, multi-level BMS, and PCS, leading to uncontrolled charging/discharging.
- + Software or firmware malfunction preventing normal battery monitoring and protection.
- + Power supply failure affecting the multi-level BMS and system controller.
- + Electrical faults such as fuse failure, surge protection failure, or contactor adhesion failure leading to the inability to disconnect faulty battery cell/modules/racks.

4.2.2 Barriers

The barriers intended to prevent the multi-level BMS or the system controller failure from escalating include:

- + Cell abuse tolerance is the ability of the cells to withstand thermal and electrical abuse without going into failure themselves. The cells are listed to UL 1973 to withstand some degree of thermal abuse (e.g., high temperature, overcharge).
- + Unit or rack thermal abuse tolerance is the ability of the cells to withstand thermal and electrical abuse without going into failure themselves. The unit/rack is listed to UL 1973 to withstand some degree of thermal abuse (e.g., high temperature, overcharge).
- + System electrical abuse tolerance via UL 9540 certification demonstrating its ability to withstand adverse electrical abuse, such as overcharge or dead shorts, without failure.
- + Unit or rack overcurrent protection is incorporated through integrated protection features (e.g., current interrupt devices, breakers, fuses, contactors, or other passive surge-arresting elements) that may open the circuit in the case of failure. The unit is listed to UL 1973, which includes evaluation of protection against overcurrent and fault conditions.
- + Manual E-STOP buttons on the PCS allow operators to immediately shut down the system in case of control failure.

4.2.3 Consequences

The failure of the multi-level BMS or the system controller can result in the following:

- + If the multi-level BMS fails, battery modules may overcharge, overheat, or over-discharge, leading to thermal runaway. The consequences of a thermal runaway event are described in Section 4.1.3.
- + If the system controller is unresponsive, it may fail to activate safety shutdowns, fire protection systems, or HVAC controls, leading to escalating risks.
- + If the connection between the multi-level BMS and the system controller fails, the PCS may continue charging/discharging batteries with energy imbalances or overcurrent issues, which can lead to thermal runaway. The consequences of a thermal runaway event are described in Section 4.1.3.

4.2.4 Recommendations

It is recommended to perform periodic inspection, testing, and maintenance (ITM) of the multi-level BMS and system controller in accordance with manufacturer recommendations and industry-standard practices.

If a multi-level BMS or system controller failure occurs, the worst-case consequence is thermal runaway. Hence, the same recommendations as provided in Section 4.1.4 apply.

4.3 FAILURE OF A REQUIRED VENTILATION OR EXHAUST SYSTEM

4.3.1 Description

The Eaton xStorage 250-1000 kWh BESS is an outdoor, cabinet-style (non-walk-in) enclosure that uses lithium-ion batteries. Thus, mechanical ventilation or exhaust systems are not prescriptively required as described in Section [3.2](#) of this report, unless it is used as a means for explosion control in accordance with NFPA 69.

However, the BESS is provided with deflagration venting in accordance with NFPA 68 as a means of explosion control to mitigate pressure buildup in the event of a thermal runaway. Failure of the deflagration vent system provided for the BESS cabinets is considered for this scenario.

A failure of the deflagration vent system could result in excessive pressure buildup within the BESS cabinets, increasing the risk of structural deformation, component damage, or uncontrolled gas release in case of an incident. A highly plausible cause of such failure is the accumulation of snow or ice on cabinet door-mounted deflagration vent panels, which could obstruct the venting process. In addition, a potential interaction between the aerosol extinguishing system and the deflagration vent system could occur if not properly coordinated. Refer to more details in Section 4.4 of this report.

4.3.2 Barriers

Routine inspection, testing, and maintenance of the deflagration vent system in accordance with NFPA 68 and the manufacturer's O&M manuals.

4.3.3 Consequences

The failure of the deflagration vent system can result in the following:

- + Without a functioning vent, gases generated during a thermal runaway event could increase internal pressure, leading to potential cabinet deformation or structural failure.
- + If flammable gases accumulate within the cabinet and the deflagration vent fails, the risk of an uncontrolled deflagration (i.e., explosion) increases.
- + If electrical arcing or high heat ignites the gases, an explosive event could occur, causing fragmentation hazards and damage to surrounding vehicles, occupants, or first responders.
- + Without proper venting, hot gases and flames could remain trapped inside the cabinet, causing increased heat exposure to adjacent battery modules and equipment. This could lead to a chain reaction that escalates beyond the affected cabinet.
- + If gas release is restricted, the aerosol suppression system may be less effective in dispersing suppressant throughout the cabinet.

4.3.4 Recommendations

Ensure the deflagration vent system is appropriately inspected, tested, and maintained.

4.4 FAILURE OF A REQUIRED SMOKE DETECTION, FIRE DETECTION, FIRE SUPPRESSION, OR GAS DETECTION SYSTEM

4.4.1 Description

The Eaton xStorage 250-1000 kWh BESS is an outdoor, cabinet-style (non-walk-in) unit equipped with gas detection, smoke detection, heat detection, and an aerosol fire extinguisher system.

A failure of any of these may occur due to component malfunction, loss of power or communication, improper installation, environmental exposure, lack of maintenance, or control system faults. If detection or suppression systems do not activate as designed, abnormal battery conditions such as overheating, gas generation, or fire may go undetected or unmitigated, increasing the potential for escalation of the event.

In addition, a potential interaction between the aerosol extinguishing system and the deflagration vent system could occur if not properly coordinated. While the pressure generated by the aerosol system's discharge is expected to remain below the activation threshold for the deflagration vent, this should be verified by reviewing pressure sensor data to ensure there is no conflict between the two systems during an event.

Failure of manual firefighting response due to an impaired fire hydrant is also considered for this scenario.

4.4.2 Barriers

The barriers intended to prevent failure of detection or suppression systems from escalating include:

- + Multi-layered fire detection system via gas, smoke, and heat detectors that operate independently, ensuring that failure of one system does not disable the entire detection function. The fire detection/alarm systems are assumed to be provided with emergency power backup. This information is assumed and needs to be confirmed, as no fire alarm sequence of operations is currently available.

- + Gas detection intended to identify off-gassing conditions associated with battery failure prior to fire development, enabling alarms and protective actions. Details of gas detection thresholds and response logic have not been provided and require confirmation.
- + BMS detection via redundant temperature thresholds in the BMS trigger alarms and shutdown sequences before reaching critical failure conditions. This information needs to be confirmed, as no BMS information is currently available.
- + Manufacturer testing, evaluation, and listing of detection and suppression components as part of the UL 9540-listed BESS. Spec sheets and listing certificates for the detection systems are not currently provided.

4.4.3 Consequences

- + If gas detection fails, flammable gas release associated with cell venting or early thermal runaway may go undetected, allowing gas accumulation within the cabinet and increasing the potential for deflagration or overpressure prior to vent activation.
- + If smoke or heat detection fails, fire development may progress before alarms are initiated, leading to delayed emergency response. In addition, the aerosol fire extinguishing system will not activate if communication with smoke/heat detectors is lost. Without activation, thermal runaway could escalate beyond the affected battery cabinet, increasing radiant heat exposure to adjacent equipment.
- + A potential conflict between the aerosol fire extinguisher system discharge and deflagration vent activation could result in unintended vent operation if pressure thresholds are exceeded. This interaction should be evaluated through a review of the pressure sensor data to confirm compatibility between the systems. This ensures that the pressure generated during aerosol discharge remains below the threshold that could inadvertently activate the deflagration vent.
- + If the manual firefighting response is impaired due to a non-functional fire hydrant, a more severe fire event and increased damage to nearby equipment and exposures could occur. In the event of an impairment of the closest hydrant, additional water supply could be accessed from the next adjacent hydrant or by local fire department water tankers. A manual hose stream could potentially be used to cool the BESS cabinets and adjacent exposures to limit fire propagation. Lack of adequate emergency response planning, training, and familiarity with the site may result in an ineffective response or harm to emergency responders.

4.4.4 Recommendations

It is recommended that all fire protection systems associated with the BESS be inspected, tested, and maintained in accordance with manufacturer requirements and applicable NFPA standards to confirm continued functionality. System fault, supervisory, and alarm signals should be verified during commissioning and periodically thereafter to confirm that system impairments are promptly identified.

4.5 VOLTAGE SURGES ON THE PRIMARY ELECTRICAL SUPPLY

4.5.1 Description

Voltage surges on the primary electrical supply serving the BESS represent transient overvoltage events originating from the utility grid or on-site electrical systems, such as generators and upstream distribution equipment, as applicable.

Voltage surges may be introduced during switching operations, lightning events, grid disturbances, equipment energization or de-energization, faults within associated power electronics, load changes, or abnormal operating conditions. Voltage surges may propagate through the electrical supply to the inverter/PCS and associated components, potentially subjecting the BESS to abnormal electrical stress.

4.5.2 Barriers

The barriers intended to prevent the voltage surge failure mode from escalating include:

- + BMS current, voltage, and temperature monitoring, which has been evaluated as part of the UL 1973 listing for the unit and the UL 9540 listing. Details on the BMS features are not currently provided.
- + Inverter/PCS protective functions, including overvoltage detection, voltage limits, and automatic shutdown under abnormal voltage conditions, which have been evaluated as part of the UL 1741 listing for the PCS.
- + Passive circuit protection and electrical abuse tolerance incorporated into the battery system, which has been evaluated as part of the UL 1973 listing for cell and unit.

4.5.3 Consequences

Voltage surges on the primary electrical supply may result in abnormal voltage conditions at the inverter/PCS and associated electrical components, potentially causing equipment damage, control system malfunction, or improper charging or discharging of the battery system. Repeated or severe voltage surges may increase electrical and thermal stress on battery cells and power electronics and may degrade protective functions over time. If such conditions are not adequately detected and controlled, they may contribute to battery failure and escalation to thermal runaway. The consequences of a thermal runaway event are described in Section 4.1.3.

4.5.4 Recommendations

It is recommended to perform periodic inspection, testing, and maintenance (ITM) of all electrical equipment tied to the BESS in accordance with manufacturer recommendations and industry-standard practices.

In case of voltage surges on the primary electrical supply, the worst-case consequence is thermal runaway. Hence, the same recommendations as provided in Section 4.1.4 apply.

4.6 SHORT CIRCUITS ON THE LOAD SIDE OF THE BESS

4.6.1 Description

A short circuit on the load side of the BESS represents an electrical fault occurring in downstream equipment or wiring supplied by the BESS, such as connected loads, inverter/PCS equipment, or associated cabling.

A short circuit on the load side of the BESS may be caused by failures in downstream electrical components or wiring, including insulation breakdown, cable damage, loose or improper connections, equipment faults within inverters/PCS or switchgear, or damage resulting from mechanical impact, moisture intrusion, or aging.

4.6.2 Barriers

The barriers intended to prevent the short circuit failure mode from escalating include:

- + Electrical protection measures such as overcurrent protection devices (e.g., fuses, circuit breakers), which has been evaluated as part of the UL 1973 listing for unit.
- + BMS current, voltage, and temperature monitoring, which has been evaluated as part of the UL 1973 listing for unit and UL 9540 listing. Details on the BMS features are not currently provided.
- + Passive circuit protection and electrical abuse tolerance incorporated into the battery system, which has been evaluated as part of the UL 1973 listing for cell and unit.
- + Inverter/ PCS protective functions, including hazardous current detection and automatic shutdown upon short-circuit conditions, which have been evaluated as part of the UL 1741 listing.

4.6.3 Consequences

A load-side short circuit creates a low-resistance path that can result in a sudden and excessive current demand from the BESS. This may lead to rapid battery discharge, elevated internal temperatures, and increased electrical and thermal stress on the battery system and associated power electronics. If protective devices or control systems do not isolate the fault in a timely manner, these conditions may contribute to battery failure and escalation to thermal runaway. The consequences of a thermal runaway event are described in Section 4.1.3.

4.6.4 Recommendations

It is recommended to perform periodic inspection, testing, and maintenance (ITM) of all electrical equipment tied to the BESS in accordance with manufacturer recommendations and industry-standard practices.

In case of a short circuit on the load side of the BESS, the worst-case consequence is thermal runaway. Hence, the same recommendations in Section 4.1.4 apply.

5.0 Conclusions

Based on a review of available project documentation, the applicable prescriptive requirements of CSFSC §1207 and CSFPC Chapter 52, and NFPA 855 (as referenced by CSFPC Chapter 52), as well as HMA, it is concluded that the Manchester Public Library BESS should demonstrate compliance with the pending compliance items in Section 3.2 and the recommendations identified through the HMA in Section 4.0.

5.1 HMA RECOMMENDATIONS

Table 5-1 lists the fire and life safety recommendations (not in any priority order) that were identified during the prescriptive code review in Section 3.0 and the HMA in Section 4.0. Note that all previous recommendations have been cleared based on updated documentation provided by the design team and manufacturer.

Table 5-1: HMA Recommendations

<i>No.</i>	<i>Category</i>	<i>Description</i>
1	-	Reserved (cleared from prior revision)
2	-	Reserved (cleared from prior revision)
3	-	Reserved (cleared from prior revision)
4	-	Reserved (cleared from prior revision)
5	-	Reserved (cleared from prior revision)
6	-	Reserved (cleared from prior revision)
7	-	Reserved (cleared from prior revision)
8	-	Reserved (cleared from prior revision)
9	-	Reserved (cleared from prior revision)
10	-	Reserved (cleared from prior revision)
11	-	Reserved (cleared from prior revision)
12	-	Reserved (cleared from prior revision)

5.2 HMA APPROVAL

Table 5-2 summarizes how the Manchester Public Library BESS satisfies each HMA approval criterion discussed in Section 1.3 of this report. Where a criterion is not directly applicable, this is noted.

Table 5-2: Approval of HMA

<i>Approval Criteria</i>	<i>Criteria Satisfied?</i>	<i>Comment</i>
1. Fires will be contained within unoccupied BESS rooms for the minimum duration of the fire resistance rating specified in CSFSC §1207.7.4 and NFPA 855 §4.3.6 (i.e., 2-hours).	N/A	The BESS enclosure is a cabinet-style (non-walk-in) unit and is installed outdoors, not within unoccupied BESS rooms or indoor areas. Thus, the BESS enclosure does not require a fire-resistance rating. Clearances from exposures should be maintained on-site in accordance with the applicable codes and standards as summarized in Section 3.0.
2. Suitable deflagration protection is provided where required.	Y	Deflagration protection is provided via a deflagration vent on the door of each BESS cabinet. The vent system appears to be compliant with NFPA 68 Chapter 9.
3. BESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.	N/A	The BESS enclosure is a cabinet-style (non-walk-in) unit and is installed outdoors, not in occupied work centers or indoor areas. Site fire detection and alarm measures can help initiate a fire department response and inform people nearby of a hazardous event occurring at the BESS.
4. Toxic and highly toxic gases released during normal charging, discharging, and operation will not exceed the Permissible Exposure Limit (PEL) in the area where the BESS is contained.	N/A	The BESS uses lithium-ion batteries, which do not release toxic gases during normal charging, discharging, and operation. Gases are only vented from the batteries during abnormal conditions.

<i>Approval Criteria</i>	<i>Criteria Satisfied?</i>	<i>Comment</i>
<p>5. Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of immediately dangerous to life or health (IDLH) level in the building or adjacent means of egress routes during the time deemed necessary to evacuate occupants from any affected area.</p>	<p>Y</p>	<p>The BESS enclosure is a cabinet style that is not a walk-in unit and is installed outdoors.</p> <p>A toxic gas dispersion or toxic plume analysis was not performed. However, toxic smoke and gases would be expected to rise and dissipate into the surrounding atmosphere. While people in nearby areas, such as the adjacent buildings, could potentially experience some exposure to released gases, they should be able to evacuate away from the source of smoke and toxic gases during the incipient stages of the event.</p>
<p>6. Flammable gases released during charging, discharging, and normal operation will not exceed 25 percent of their lower flammability limit (LFL).</p>	<p>N/A</p>	<p>The BESS uses lithium-ion batteries, which do not release flammable gases during normal charging, discharging, and operation. Gases are only vented from the batteries during abnormal conditions.</p>
<p>7. Flammable gases released from the BESS during fire, overcharging, and other abnormal conditions will be controlled through the use of ventilation of the gases, preventing accumulation, or by deflagration venting.</p>	<p>Y</p>	<p>Deflagration protection is provided via a deflagration vent on the door of each BESS cabinet. The BESS manufacture conducted computational fluid dynamics modeling to analyze the required deflagration vent area. This analysis concluded that the vented pressure is less than the enclosure strength. The actual findings of the CFD venting report were not verified as part of this HMA.</p>

6.0 References

The following references were used in the development of this report:

- [1]. Drawing C2.1, Layout Plan, prepared by Benesch, 09/23/2024 (including revisions through 11/24/2025). File: "2025-12-23 - Eversource Transformer Alteration"
- [2]. Drawing C2.2, BESS System Radius Plan, prepared by Benesch, 09/23/2024 (including revisions through 11/24/2025). File: "C2.2 - BESS Radius"
- [3]. Drawing C3.2, Utility Area Enlargement, prepared by Benesch, 09/23/2024 (including revisions through 11/24/2025). File: "2025-12-23 - Eversource Transformer Alteration"
- [4]. Drawing C4.0, Site Utility Plan, prepared by Benesch, 09/23/2024 (including revisions through 11/24/2025). File: "2025-12-23 - Eversource Transformer Alteration"
- [5]. Electrical Drawings, prepared by Consulting Engineering Services, Inc., 10/01/2024 (including revisions through 12/24/2025). File: "MPL Electrical DG Application Dwgs"
- [6]. Eaton xStorage 250-1000 kW Battery Energy Storage System Installation and Operation Manual, P-164001236-Rev 02, Copyright 2025. File: "eaton-xstorage-250-1000kw-io-manual-p-164001236"
- [7]. Air International (Shanghai) Co., Ltd., 8kw Energy Storage Liquid Cooling Unit User Manual, Model BTMS-80-ES, 17/03/2021. File: "User Manual-8kw Energy storage liquid cooling unit-20210319"
- [8]. UL 9540A Unit Test Report, Contemporary Amperex Technology Co., Limited Models CB310 and CB2W0. Issued by UL (Changzhou) Quality Technical Service Co., LTD, 2022/09/05. File: "4790294261-Final report"
- [9]. UL 9540A Module Test Report, Contemporary Amperex Technology Co., Limited Models CB310 and CB2W0. Issued by UL (Changzhou) Quality Technical Service Co., LTD, 2022/01/27. File: "UL9540A_Module_0.5P-1P"
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- [12]. TÜVRheinland NFPA 68 Test Report, Report Number CN24TT8A 001, 2024/11/09. File: "CN24TT8A 001_NFPA 68_TR_extsigned"
- [13]. EPC Power Corp., PCS Specification, Models 50-100100 and 50-100-181, February 2022. File: "CAB1000 Spec Sheet 483795"
- [14]. TÜVRheinland PCS UL 1741 Certificate, Certificate Number CU 72302284, 21/09/2023. File: "CAB1000 3L2 690V cert CU72302284.01"
- [15]. Contemporary Amperex Technology Co., Limited (CATL), EnerOne+ Brochure, 2023/08/25. File: "datasheet-catl-enerone-407-3-kwh-0-5-c"
- [16]. Stat-X Aerosol Fire Suppression Fixed System: Electrical Units for Ordinary Locations Specifications. Website: "<https://www.statx.com/product/stat-x-fixed-system-electrical-units/>"
- [17]. TÜVRheinland Battery Rack UL 1973 Certificate, Certificate Number CU 50601445 0001, 12/08/2023. File: "EnerOne-UL1973-CU 50601445 01_Cert"

- [18]. Custom Electric, Inc., Manchester Public Library Submittal, Battery Energy Storage System (Resubmittal for Record), 07/02/25. File: "263317-226-001 Battery Storage Resubmittal FOR RECORD rs"
- [19]. Drawing C2.0, Materials Plan, prepared by Benesch, 09/23/2024 (including revisions through 11/24/2025) provided via email on 04/14/2026. File: "C2.0 - Materials Plan Radius"