The Commonwealth of Massachusetts
Energy Facilities Siting Board

EFSB 21-02

DIRECT PREFILED TESTIMONY OF

MILOSH T. PUCHOVSKY

ON BEHALF OF INTERVENOR SAVE THE PINE BARRENS

EXHIBIT STPB-MTP-1

September 29, 2022

TABLE OF CONTENTS

I. Introduction

Q. Please state your name and business address.

A. My name is Milosh T. Puchovsky. My business address is 100 Institute Road, Worcester, MA, 01609.

Q. Please state your occupation and current place of employment.

A. I am Associate Department Head and Professor of Practice in the Department of Fire Protection Engineering at Worcester Polytechnic Institute ("WPI").

Q. Please describe your educational background and relevant work experiences.

A. I hold both a B.S. and M.S. from WPI in Mechanical Engineering and Fire Protection Engineering. I possess 34 years of experience with evaluating fire hazards, the selection and design of fire and life safety systems, and the application and revision of associated regulations. I am a member of numerous industry committees including those of the National Fire Protection Association (NFPA), the Society of Fire Protection Engineers ("SFPE") and Underwriters Laboratories (UL). I teach graduate level courses and industry seminars on a range of technical fire safety subjects. I am Past President and a Fellow of SFPE, served as Secretary to NFPA's Standards Council, overseeing the development of all NFPA's codes and standards, and led the development of NFPA's performance-based codes initiative facilitating the greater application of calculation methods and computer fire models in fire safety design. I am registered professional fire protection engineer in the state of Massachusetts. Specific to Energy Storage Systems ("ESS") I have lead projects at WPI, observed ESS fire tests and worked as a subject matter expert ("SME") with UL in the development of UL 9540A, *Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems* and with the City of New York in the development of protocols for ESS installations. I have provided expertise to the NFPA technical committee responseible for NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems* and presented at NFPA, SFPE and the International Association of Arson Investigators – Massachusetts Chapter conferences and seminars. A copy of my curriculum vitae is attached to my testimony as Exhibit A.

Q. Have your previously testified in any formal hearing before regulatory bodies?

A. I have testified in court three times on fire safety systems. I have been deposed numerous times on matters concerning fire safety.

II. Purpose of Testimony

Q. Are you aware of Cranberry Point Energy Storage LLC's ("Cranberry Point"), pending petition before the Energy Facilities Siting Board ("Siting Board") to construct a battery energy storage system ("BESS") facility in the Town of Carver Massachusetts (the "Project")?

A. Yes.

Q. What is the purpose of your testimony?

A. I am providing this testimony to the Siting Board in support of Save the Pine Barrens ("STPB") presentation of evidence concerning the Project. Specifically, in my testimony, I present my analysis and expert opinions concerning certain matters related to the safety and potential for future emergency incidents at the Project and related to emergency planning for such incidents.

Q. How is your testimony organized?

A. In **Part III**, I provide some foundational background for my testimony by describing the design and operation of lithium-ion battery energy storage systems such as the one proposed by Cranberry Point, including key design features from a fire safety perspective.

In **Part IV**, I describe the risks associated with such energy storage systems, including those associated with the Facility proposed for Carver.

In **Part V**, I describe relevant fire safety regulations and how they pertain to Cranberry Point's proposed project, the deficiencies in the Cranberry Point project's compliance with these regulations, and the potential consequences of the failure to comply with these regulations and emergency events at the proposed facility.

Q. Are you presenting any exhibits in addition to your testimony and the curriculum vitae you previously identified?

A. No.

III. Overview of Battery Energy Storage Systems

Q. What is a lithium-ion battery energy storage system?

A. A lithium-ion battery energy storage system—abbreviated "BESS"—is an electrochemical energy storage system utilizing lithium-ion battery chemistry to store electrical energy for later use. Manufacturers continue developing batteries with higher energy densities, allowing for greater energy capacity of BESS.

Q. Please elaborate on the term "lithium ion."

A. The term "lithium-ion" does not represent a specific battery, but rather a family of batteries with a wide array of differing chemistries. However, this group of batteries are all characterized by the transfer of lithium ions between the electrodes during the charge and discharge cycles.

A lithium-ion battery contains three fundamental components: (1) electrodes; (2) the separator; and (3) the electrolyte. Electrodes are conductors through which electricity enters or exits the battery. Between the positive electrode (called the "cathode") and negative electrode (called the "anode") lies a separator which can be composed of a micro-perforated plastic. During the charging process, lithium-ions move between the anode and the cathode. The liquid electrolyte, commonly composed of a lithium salt and a flammable organic solvent, allows the lithium-ions to move through the separator from the cathode to the anode. There are two tabs per lithium-ion cell, one per electrode – cathode and anode. These tabs allow an electrical connection to be made during the transfer of lithium-ions. During the charge/discharge process, the electrons flow through the external electrical circuit, while lithium-ions move between the cathode and the anode.

Q. What distinguishes lithium-ion batteries from other types of batteries?

A. Lithium-ion batteries are often used in BESS applications because of their improved ability to retain charge. As batteries age, their capacity fades, meaning that as those batteries get older, they can no longer reach a full charge. This is true of all batteries, including lithium-ion batteries. Lithium-ion batteries, however, only lose ¼ the amount of charge typically lost per month in other standard batteries such as lead-acid or nickel-cadmium. Additionally, lithium-ion batteries possess a greater energy storage capacity and density as compared to other battery types.

Q. What are the design features of a typical BESS?

A. Variation exists in the designs of energy storage systems based on manufacturer specifications and proprietary technology with systems continuing to evolve. For this reason, and as I will testify later, this injects several unknown variables when quantifying risks and planning for emergencies associated with BESS facilities. Put simply, at this point there is not really a "typical" BESS installation.

That said, the basic components and their orientation can be described in at least a generic manner. The individual components of a BESS installation consist of cells, modules, racks, and storage container units. Cells are the basic building blocks of the system and are connected to comprise a module (sometimes installed on a tray) of batteries. Multiple modules are electrically interconnected to form a rack (sometimes referred to as a unit). An array of racks can be arranged within a storage unit or container to form a large-scale BESS installation. Differing terminology can occur amongst battery manufacturers and testing protocols.

Q. What is a "cell"?

A. A cell is essentially a single lithium-ion battery. Manufacturers produce different cell sizes and formats such as cylindrical, prismatic, or pouch. The cells can have vents to prevent internal over-pressurization. Each cell format is available in various sizes corresponding to variation in the cell mass, energy density, amperage, etc.

Q. What is a "module"?

A. A module is a series of cells electrically interconnected in series and/or parallel to provide higher voltages and capacities. Modules can be equipped with electrical protection (fuses) and sensors for monitoring of voltages and (sometimes) temperatures, and either passive or active ventilation provisions. Modules are placed and electrically interconnected with a Battery Management System (BMS) and Junction Box (JB) in vertical racks. Modules can also be equipped with a Thermal Management System (TMS) to maintain suitable operating temperatures.

Q. What is a "rack"?

A. A rack within an energy storage system consists of a series of modules electrically interconnected to provide a larger energy output at a required voltage. A rack typically has multiple drawers/trays. Within each tray there will be single or multiple modules depending on the size and formats of the cells utilized. Each rack can have a rack-level battery management system that communicates with the module sensors, and one or more DC connectors and fuses.

Q. What other components are associated with a BESS installation?

A. A containerized ESS storage unit consists of arrays of lithium-ion battery racks arranged to obtain a desired energy/power output. Within this system will be a device, often referred to as an inverter, to convert the energy from DC to AC and vice versa to allow the stored energy to be utilized on an electrical grid or other electrical distribution network. The container can be equipped with a system level Battery Management System (BMS) for electrical control, a Heating Ventilation Air Conditioning (HVAC) system, and a fire detection and suppression system. Interactions with power supply and discharge systems occur via an external Power Conversion System and Energy Management System. The units have doors for operating and maintenance personnel and for installation and replacement of equipment. There can also be vents on the units to facilitate cooling and the release of toxic and ignitable gases during abnormal conditions.

Utility scale containerized ESSs can be contained within standard ISO-Containers. However, some manufactures use custom designed containers. The container is typically rectangular, made of steel, and intended for the transport and storage of materials without unloading the cargo. In large ESS facilities, there are often multiple containers placed adjacent to each other. The number of ESS containers is usually dependent on the power/energy demand of the facility. The greater the number of containers and the closer their proximity to each other on an given site, the greater the overall likelihood of a thermal runaway and fire event and resulting consequences.

IV. Risk of Potential Emergency Events at Battery Energy Storage Systems

A. Risks and Hazards Associated with BESS Installations.

Q. You've described for us the general components to a BESS installation. Are there hazards associated with lithium-ion BESS installations?

A. Yes.

Q. Please elaborate on those hazards.

A. Lithium-ion batteries' primary hazard is that there is a potential risk of thermal runaway resulting in fire or explosion. Once started, lithium-ion battery fires have proven difficult to extinguish and are known to produce dangerous gases. The National Fire Protection Association ("NFPA") ESS Safety Fact Sheet identifies thermal runaway, stranded energy, toxic and flammable gas generation and deep-seated fires as key hazards associated with ESS installations.

Q. Before we talk more about those risks, please tell us about the NFPA.

A. The NFPA is a non-profit organization that, among other activities, creates and publishes codes and standards for fire, electrical, and related hazards. Regulatory authorities, experts and emergency responders among others typically use NFPA standards with respect to such hazards.

Q. What NFPA standard is relevant to this Facility?

A. NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2023 Edition, identifies the following hazards with respect to ESS installations: fire and explosion, chemical (hazardous materials), electrical including stranded or stored energy, and physical (burn, ruptured lines, projectiles). The hazards can vary by battery technology and can also vary under normal operating conditions compared with emergency and abnormal conditions.

Q. What is "thermal runaway"?

A. Thermal runaway is a term used for the rapid uncontrolled release of heat energy from a battery cell. It is a condition when a battery creates more heat than it can effectively dissipate. Thermal runaway in a single cell can result in a chain reaction that heats up neighboring cells. As this process continues, it can result in a battery fire or explosion. This thermal runaway can be the ignition source for larger battery fires.

Q. Is thermal runaway of concern with this Facility?

A. Yes.

Q. Are there other unique hazards associated with BESS thermal runaway events?

A. Yes. The hazard concerns "stranded" or stored electrical energy. Stranded energy is energy that can be accumulated and reserved for future use. As with most electrical equipment, stranded energy in a BESS presents a shock hazard. But what is more interesting and unique about BESS is that often, even after a thermal runaway event and fire or explosion, there is still energy retained or stranded within the BESS.

That stranded energy presents both a significant challenge and hazard. Because the BESS equipment including terminals are often damaged by a thermal runaway, fire, or explosion, discharging that stranded energy can be difficult. That difficulty in turn creates a number of hazards. First, it is hazardous to first responders and others who perform firefighting and related emergency response services at such a BESS installation. Second, the lingering, stranded energy can also cause reignition of the fire hours or even days after an initial fire or explosion. In other words, even when a BESS fire is contained and extinguished, it can unexpectedly reignite at a later time because of that stranded energy.

Q. Are these stranded energy hazards a concern with this Facility?

A. Yes.

Q. Are fire and explosions a concern with BESS installations?

A. Yes. Fire and explosion hazards associated with lithium-ion BESS installations are centered on the lithium-ion battery's flammable organic electrolyte and its highly reactive electrodes. The high performance of lithium-ion batteries is attributed to the unique combination of materials used, which under normal operating conditions does not pose a problem. However, when lithium-ion batteries undergo a failure, the separation layer is breached allowing the electrodes to react with the electrolyte, producing high temperatures, pressures, and eventually resulting in a fire or explosion. The heat released from lithium-ion battery fires can be significant, posing fire propagation hazards which accumulate with subsequent failures.

Any one of several fault conditions, including electrical faults, overcharging, and particulate/moisture contamination, can lead to an escalated temperature in one lithium-ion cell, causing deterioration and eventual failure of the cell separator, with subsequent electrolyte decomposition and elevated vapor pressure. This leads to a thermal runaway venting in the cell that can then propagate to many other cells in an energy storage battery module. The vented thermal runaway causes flammable gas to be emitted into the battery enclosure, where the resulting flammable mixture can be ignited by hot module casings, electrical connectors, or ejected sparks from the involved module.

Q. What conditions can cause deterioration of the cell, leading to thermal runaway?

A. A lithium-ion battery can result in a fire due to electrical, mechanical or thermal failures. Electrical failures consist of overcharge or over-discharge of the battery cells. Mechanical failures consist of manufacturing defects, internal short circuit of the battery system, or physical damage to the battery due to puncture, dent or tear. Other conditions such as low ambient pressure, vibration, shock, corrosion, or impact can also initiate a mechanical failure event within a lithium-ion battery. A lithium-ion battery can also encounter a mechanical failure if a particle is inadvertently lodged into the cell during the manufacturing process. A dendrite or "particle" in the cell can cause localized resistance heating around the particle, which causes an internal short-circuit, and an increase in internal temperature and pressure within the cell. Thermal failures include overheating or internal localized heating. The batteries can become overheated by an external fire/heat source or from ambient temperatures that exceed the battery's thermal stability limits. Both electrical and mechanical failures develop internal localized heating within a lithium-ion battery which contributes to a thermal degradation of the cell as described above.

All failure modes within lithium-ion batteries generate heat and stimulate further thermally-driven chemical reactions within the cell until an ultimate failure point known as thermal runaway is reached resulting in fire.

Q. How do failure conditions cause thermal runaway?

A. Fire can erupt in a lithium-ion battery once it undergoes one of the failure modes. A thermal, electrical, or mechanical failure, or combination thereof, can lead to thermal runaway. A lithium-ion battery goes into thermal runaway when the cell temperature reaches a threshold that causes an uncontrollable rapid release of energy and corresponding temperature rise resulting in a thermal event, such as a fire. The stability of a lithium-ion cell is primarily dependent on temperature. The temperature of the cell is determined based on the heat generation/dissipation rates. If the heat cannot be dissipated linearly at an equivalent rate of generation, then the internal chemical reactions become stimulated by the increasing temperature and induce the cells into thermal runaway.

Thermal runaway results in increased temperatures that can cause a rapid increase in pressure within the battery. Under these conditions, the pressure initiates a violent ejection of the flammable volatiles, resulting in a self-sustaining fire or explosion. As combustion endures, the cells continue to swell and release bursts of flames. More flames continue to be produced from the batteries with greater intensity and magnitude, while gaseous products from the lithium-ion combustion reaction are emitted. Once a lithium-ion battery within a BESS ignites, the other cells have the potential to overheat and initiate propagating thermal runaway reactions between adjacent batteries, modules, and racks within the BESS. During a propagating thermal runaway event, the energy release is extremely hazardous and difficult to control, signifying the ultimate failure point of a Li-ion BESS.

Q. How do explosions result from failure conditions?

A. There have been two types of explosions associated with BESS: flammable gas explosions due to gases generated in battery thermal runaway events, and electrical arc explosions, both of which can lead to structural failure of battery electrical enclosures and significant injury. The thermal runaway gas explosion scenarios, which can be initiated by various electrical faults, can be either prompt ignitions soon after a large flammable gas mixture is formed, or delayed ignitions associated with late entry of air such as when a door to a BESS enclosure is opened by first responders and/or loss of gaseous fire suppression agent in the BESS enclosure if so equipped. The electrical explosions have resulted from limited electrical protection to prevent high energy arcs within electrical boxes associated with the BESS enclosure that are vulnerable to arc induced high magnitude pressures and thermal loads.

Q. Are there other hazards associated with BESS thermal runaway events?

A. Yes. There are two other hazards I would like to address: (1) those associated with toxic and flammable gases, and (2) those associated with "deep-seated" fires.

Q. Please elaborate on the hazards associated with toxic and flammable gases.

A. Toxic and flammable gases are generated and released when batteries undergo thermal runaway and combustion. If the gases do not ignite before the lower explosive limit is reached, an explosive atmosphere inside of the BESS room or container can be created. Toxic and corrosive gases can also be produced and released as can oxidizing gases which accelerate the combustion process.

During failure conditions such as thermal runaway, fire, and abnormal faults, some BESS, in particular electrochemical lithium-ion batteries and capacitors, begin off-gassing flammable and toxic gases, which can include mixtures of CO, H_2, ethylene, methane, benzene, HF, HCl, and HCN. Among other things, these gases present an explosion hazard that needs to be mitigated. Explosion control or venting can be provided to mitigate this hazard.

Q. What are the dangers and difficulties associated with deep-seated fires?

A. A deep-seated fire can be described as a fire that is difficult to reach from a firefighting perspective. BESS installations usually comprise of batteries that are housed in a protective metal or plastic casing within larger cabinets. These layers of protection help prevent damage to the batteries. But the same protection that can prevent damage may also prevent water or other fire-fighting agents from reaching the seat of the fire. Often, emergency responders will use water as a fire-fighting agent to dissipate the heat associated with a BESS fire. The protective casing and structures associated with BESS, however, means that it takes greater effort and larger amounts of water to effectively reach the fire source and dissipate the heat generated from BESS fires. Cooling the hottest part of the fire is often difficult because it is shielded from water discharge. That difficulty can prolong the duration of a BESS fire. Furthermore, delayed thermal runaways and reignition can occur hours or days after an initial event.

Q. Are these toxic and flammable gas and deep-seated fire hazards potential hazards that are associated with BESS installations?

A. Yes.

Q. How do emergency and abnormal conditions differ from normal operating conditions?

A. Hazards associated with BESS can vary by technology, but can also vary under normal operating conditions, e.g. routine charging and discharging operations, compared with emergency and abnormal conditions, e.g. thermal runaway. Under normal operating conditions, fire and explosion hazards can be due to heat sources such as live parts that can be in contact with combustible materials during service or maintenance, or to ignition of combustible concentrations or ignitable fluids and solids that can occur as part of the normal operation of ESS, such as hydrogen off-gassing from batteries with aqueous electrolytes that are open to the atmosphere.

Under abnormal operating conditions, fires or explosions can be the direct result of (i) the development of an ignitable atmosphere due to overheating and venting of flammable gases in the presence of hot surfaces, live electrical equipment, or other sources of ignition, (ii) short circuits and thermal runaway causing overheating of electrical parts or ignitable plastic casings. As noted above thermal runaway can lead to a cascade failure of several modules or racks, and extensive fire damage, and (iii) the production of an oxidizing gas from a thermal runaway or other event which increases the intensity of a fire.

Q. Could you please comment on fire and explosion hazards during these emergency or abnormal operating conditions that you just explained?

A. Fire and explosion hazards differ during emergency or abnormal conditions due to the overheating and venting of flammable gases from battery cells. If that venting occurs near an overheated component—which serves as an ignition source—or another form of ignition source, then there is the risk of a fire or explosion. A fire or explosion may occur if concentrations of flammable gases—for example, hydrogen—are sufficient to create combustible or flammable mixtures in the presence of those overheated BESS components or other ignition sources.

Q. Is this type of hazard of concern with this Facility?

A. Yes.

B. Examples of BESS Installation Risks and Hazards Resulting in Actual Emergency Events.

Q. Are these hazards just theoretical or are you aware of actual incidents involving these hazards and BESS installations?

A. These hazards are not just theoretical. I am aware of a number of BESS installations that have experienced incidents involving fires and explosions.

Victoria Australia: A fire of a Tesla Megapack BESS installation in Victoria, Australia on July 30, 2021 spread to an adjacent BESS unit and required 150 fire fighters, 30 vehicles and 3-days to fully extinguish. Since the fire could not be truly extinguished, the firefighters were limited to cooling the outside of the containers to stop the spread/damage to adjacent containers.

Surprise, Arizona: Another BESS installation fire occurred on April 19, 2019 in Surprise, Arizona, 28 miles northwest of Phoenix, AZ. This incident required the aid of a HAZMAT team due to the presence of toxic gases emanating from the unit. An explosion ensued when firefighters opened the unit door to extinguish the fire. The blast wave pressures and velocities propelled the firefighters causing significant injuries. The emerging jet flame from the energy storage unit ("ESU"), which was observed to be at least 23 m in length and 6 m high, produced severe burn injuries. Four HAZMAT firefighters were hospitalized, and several other firefighters needed HCN decontamination and overnight monitoring in a hospital.

Monterey, California: More recently on Tuesday, September 20th, 2022 a Tesla battery ESU at a utility site in Monterey County, California caught fire, triggering the shutdown of the state's scenic coastal highway and shelter-in-place warnings for local residents. It's not clear how the utility's 182.5-megawatt Tesla battery ESU caught fire, but the site had to be disconnected from the grid. The utility's facility is located adjacent to another 400-megawatt battery storage site, which has experienced two overheating incidents in the past year that forced part of the system to shut down. A warning by Monterey County officials asked residents to "Please shut your windows and turn off your ventilation systems." In a tweet from the Public Information for Monterey County account, officials reported on the Megapack battery fire at the Elkhorn facility, saying, "While the fire is considered fully controlled, smoke may still occur in the area for several days."

As these prior incidents demonstrate, fires at BESS installations can be extremely difficult to extinguish. That is largely because of the battery chemistry and arrangement of the installations, and the exothermic process involved. Indeed, in many cases, emergency responders are simply unable to extinguish the fires, and, instead, must allow each fire need to burn itself out. Significant amounts of water are often needed for fire suppression operations and to cool adjacent structures so those additional structures do not also ignite.

Q. Could any or all of the above failure conditions be present at the proposed Cranberry Point facility?

A. Cranberry Point's proposed facility comprises at least 82 Tesla Megapack 2 XL enclosures, each potentially containing up to 24 AC battery modules, with potential for addition of more enclosures up to 150 MW. See Cranberry Point Response to STPB Information Request 1-47 and Exhibit STPB 2-1. Note that the number of proposed enclosures and battery modules is inconsistent amongst the documents submitted.

As described in Part V below, the materials submitted lack sufficient and necessary detail to properly assess the relevant hazards and proposed means of mitigation. What can be determined is that in the unlikely event of a fire, explosion, or thermal runaway event, the consequences could mirror those seen in Victoria, Phoenix and Monterey County, and it is unclear if first responders will be properly equipped with the resources and knowledge necessary to effectively and safely suppress such a fire and control its related effects.

V. Deficiencies in Emergency Response Planning to Address and Mitigate Hazards

Q. Could you please briefly explain what you wish to accomplish in this Section of your testimony?

A. In the prior two Sections of my testimony, I explained the basics of how BESS installations work and the potential hazards and risks associated with BESS installations. In this Section, and with that background and foundation, I provide my opinions about Cranberry Point's proposed emergency response planning for this Facility.

Q. How does one address the risk of fire at BESS installations?

A. Fire is generally a rare event. But as we all know, fires do occur. When a fire does occur, its impact can be devastating from a life safety, property protection, mission continuity, community livelihood and environmental perspective.

We must therefore design facilities to account for that risk of fire and we must plan for it. Numerous regulations are adopted to address unwanted fire and its effects on our society that address both fire prevention (minimize likelihood of ignition) and fire protection (manage impact of fire once ignition has occurred). Fire prevention and fire protection measures address design features built into an installation and operational aspects such as pre-incident planning, emergency response and training. To account for uncertainty in operational effectiveness and potential safety system failure, fire regulations include a certain level of redundancy in their provisions and the use of specially evaluated equipment and systems.

As I have already testified, BESS installations introduce a risk of fire with real world examples of that risk resulting in an actual fire. With respect to BESS, more robust measures are necessary based on our real-world experience that these fires can and do occur, and when they happen they can be significant, sustained events. In particular, in my opinion, robust design and emergency planning and training are necessary for any BESS installation. Such design, planning and training is informed by a hazard mitigation analysis ("HMA").

Q. What is an HMA?

A. An HMA is an evaluation of potential BESS failure modes and the safety-related consequences attributed to the failures. An HMA is a tool to inform more robust designs, equipment, and emergency operations plans, or "EOP". An HMA would characterize the potential hazards and their likelihood of occurring in an explicit and quantifiable manner.

Q. What is an EOP?

A. A document that identifies and sufficiently characterizes potential emergency events at a facility or location, and provides detailed information (strategies, tactics, procedures, equipment, etc.) to be employed by responding personnel. The EOP along with an associated comprehensive training program is a key resource used by responding personnel in effectively managing incidents and events for the protection of occupants, first responders, property, the environment, and other assets at risk.

Q. What is an Emergency Response Plan ("ERP")?

A. Depending upon its contents and intent for a given project an ERP can serve to satisfy a portion of or the entirety of an EOP. NFPA 855 identifies details of an ERP and calls for the following contents: introduction (purpose, limitations, facility description, plan review and revision), emergency response management (overall organization, roles and responsibilities, preparation and planning for emergencies, communications, operator safety and equipment, safety training), emergency response (discovery, initial response/notification procedures, sustained actions, post-emergency reporting procedures), fire incidents (conditions associated with ESS, response to a fire incident, employee training and education, site maintenance and housekeeping), medical emergency, security incidents, severe weather, and cybersecurity.

C. NFPA 855's Requirements for This Facility.

Q. Is there a specific standard that governs these aspects of planning and mitigating the risks of fire at BESS installations?

A. Yes. NFPA 855 is a key regulatory document addressing the design, construction, installation, commissioning, operation, maintenance, and decommissioning of stationary energy storage systems, and the storage of lithium metal or lithium-ion batteries. The most current version of NFPA 855 is the 2023 edition.

Q. How does NFPA 855 apply to this Facility?

A. For the Facility at Cranberry Point, NFPA 855 requires a HMA, emergency planning and training, and an EOP. The HMA is to be provided to the Authority Having Jurisdiction (AHJ) for review and approval. Details on emergency planning and training are to be provided by the owner of the BESS or their authorized representative so that BESS facility operations and maintenance personnel and emergency responders can address foreseeable hazards associated with the on-site systems. NFPA 855 provides specific details on the information to be addressed and included by an HMA and ERP.

Q. What does NFPA 855 specifically require for an EOP for this Facility?

A. As required by NFPA 855, the EOP must include the following:

1. Procedures for safe shutdown, de-energizing, or isolation of equipment and systems under emergency conditions to reduce the risk of fire, electric shock, and personal injuries, and for safe start-up following cessation of emergency conditions;

2. Procedures for inspection and testing of associated alarms, interlocks, and controls;
3. Procedures to be followed in response to notifications of system alarms or out-of-range conditions that could signify potentially dangerous conditions, including shutting down equipment, summoning service or repair personnel, and providing agreed-upon notification to fire department personnel, if required;
4. Emergency procedures to be followed in case of fire, explosion, release of liquids or vapors, damage to critical moving parts, or other potentially dangerous conditions;
5. Response considerations similar to a safety data sheet (SDS) that will address response safety concerns and extinguishment when an SDS is not required;
6. Procedures for dealing with ESS equipment damaged in a fire or other emergency event, including contact information for personnel qualified to safely remove damaged ESS equipment from the facility;
7. Other procedures as determined necessary by the AHJ to provide for the safety of occupants and emergency responders; and
8. Procedures and schedules for conducting drills of these procedures.

Q. Does NFPA 855 require anything else with respect to this Facility?

A. NFPA 855 additionally requires fire and explosion testing to be conducted on a representative BESS in accordance with UL 9540A or equivalent test standard. UL9540A determines the capability of a battery to go into a thermal runaway condition and then evaluates the fire and explosion hazard characteristics. This is not a pass-fail test. It is an evaluation that should be used to determine criteria such as spacing between the systems, fire protection, ventilation, etc. The report is to be provided to a qualified person, such as a fire protection engineer, to provide such criteria. As noted on the UL website: "As a test method, UL 9540A testing does not provide a certification, UL Mark, or pass/fail results," said Maurice Johnson, business development engineer with UL's Energy Systems and e-Mobility group." The information from UL 9540A testing supports important safety decisions about how the BESS will be installed and used. The best way for manufacturers to share that their energy storage battery products have been tested for thermal runaway is to list them in the UL 9540A test database."

D. <u>Cranberry Point's Draft ERP and Other Submissions Do Not Satisfy NFPA 855 Requirements And Are Otherwise Inadequate to Address and Mitigate the Facility's Potential Risks and Hazards.</u>

Q. Have you reviewed Cranberry Point's submissions for this Facility in relation to NFPA 855?

A. Yes.

Q. In your opinion, do those submissions satisfy NFPA 855's requirements?

A. No.

Q. Why not?

A. To date, only a draft ERP dated 3 August 2021 ("CP ERP") has been submitted to address fire safety related concerns. In my review, I did not see that Cranberry Point has submitted an HMA. Moreover, in my opinion, the CP ERP does not contain the required content or detail necessary to satisfy NFPA 855's requirements.

Q. In your opinion, what are the deficiencies with the CP ERP?

A. The CP ERP speaks to some of the information to be addressed as required by NFPA 855, as listed above, but it is incomplete and lacks sufficient detail to effectively assess the related hazards and means of effective mitigation. Additionally, the CP ERP lacks details on necessary procedures, resources and training for Fire Department and other emergency responder personnel.

Q. Can you elaborate on those deficiencies?

A. Yes. I believe the easiest way to address them is to progress through the document in the order I see them.

Section 4 (System Specific Fire Protection & Safety Controls):

Section 4.1 (Condition Monitoring & Alarming): Statements in the CP ERP are made that "...risk of fire or explosion exists." (See section 4.1.) These risks are not identified or quantified. The completion of an HMA would identify and quantify these risks. As I testified, an HMA is required for exactly that reason. The absence of an HMA from Cranberry Point's submission is therefore problematic.

Section 4.2 (Considerations for Incidents and Emergencies)

Section 4.2.2.1 (Thermal Runaway/Fire): Statements in the CP ERP indicate that testing for the Tesla Megapack has shown that a propagating thermal runaway event due to internal causes is very unlikely. But no specific test reference is provided. A unit level UL 9540A test report has been submitted on September 22, 2022. It is unclear if this is the test report on which the CP ERP relies, or if the test report addresses the specific Tesla Megapack's proposed for installation in Carver.

In any event, this report addresses one scenario of a thermal runaway event and does not include cell level and module level testing. Accordingly, the following necessary details are absent: (1) the methodology required to initiate thermal runaway for testing; (2) gas composition, volume and explosibility parameters; (3) number of initiating cells required for propagation of thermal runaway; and (4) heat, smoke and flammable gas release rates and total release quantity.

The UL 9540A report that Cranberry Point submitted also only addresses one failure mode of a thermal runaway event. An HMA—which should have been prepared but has not been submitted in this proceeding—would address other possible failure modes and how they are to be mitigated. There can be no doubt that other failure modes are possible because the CP ERP acknowledges other failure modes: "External factors, including a large impact that damages many cells at once or a pro-longed exposure to an intense external fire, could create a propagating thermal runaway event that may spread throughout the entire enclosure." However, only a vague reference to a means of mitigation is provided with the following statement: "In such a case, it is likely that all battery modules will consume themselves. In the event of a fire, the design approach is for the Megapack contents to be fully consumed based upon data from UL 9540A installation level tests." No test reports supporting this statement have been provided.

Beyond those deficiencies, the ERP also states that if a propagating thermal runaway occurs "all faults are monitored passively by the Tesla computer system which then will be relayed to the Network Operations Center (NOC) that will review and act accordingly." The ERP is silent, however, with respect to any meaningful details and procedures about how this will happen. Cranberry Point provides no details with respect to what it means to operate accordingly or the location of the NOC.

Additionally, the ERP places the decision on application of manual firefighting operations on the incident commander. But the ERP does not provide sufficient guidance to the incident commander on the need for the application of external suppression, in what manner and in what quantity. ("[T]he decision to apply external suppression to the troubled enclosure and adjacent units is ultimately at the discretion of the incident commander.") An HMA would identify these specific hazards and the means of mitigation including necessary procedures, equipment and quantity and delivery of water. Training of fire department personnel would also be expected. None of this detail, however, is provided in the ERP or elsewhere.

Section 4.2.2.2 (Explosion/Deflagration Control): The CP ERP refers to explosion and deflagration hazards and the use of over-pressure vents and a proprietary sparker system to prevent a dangerous buildup of gases within the enclosure of combusting flammable off-gases during a runaway event. Where explosion hazards exist, NFPA 855 requires an explosion prevention system designed, installed, operated, maintained, and tested in accordance with NFPA 69, or deflagration venting installed and maintained in accordance with NFPA 68. Explosion prevention and deflagration venting are not required where approved by the AHJ based on fire and explosion testing, and a deflagration hazard study demonstrating that flammable gas concentrations cannot exceed 25 percent of the lower flammable limit ("LFL"). Such approval and documentation of a study documenting data on gas composition and release rates has not been submitted. Additionally, no information or test reports are referenced validating the effective and long-term performance of the vents and proprietary sparker system including its activation (such as use of gas detection) and maintenance.

The CP ERP also states that "Emergency responders and others may observe a continual sparking within cabinets at certain locations. This is a normal operational feature of the unit, *i.e.*, the 'sparker system', which is part of the automatic safety system to prevent a dangerous build-up of gases within the enclosure." No details on fire department training and operational tactics on this proprietary system are provided.

Section 5 (Potential Hazards):

Section 5 of the CP ERP addresses risks posed by lithium-ion battery failures. Electric shock, arc flash, fire, explosion, and the by-product from off-gassing are noted. The ERP specifically states that "During failure, a lithium-ion battery may emit tens to hundreds of liters of off gas, and larger failures may emit thousands of liters of gas." While these risks are noted in a generic manner, no details specific to the Facility installation are provided and quantified. An HMA would identify and quantify the specific risks for the installation under consideration.[1] I have already testified to the absence of an HMA from the materials I have reviewed.

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[1] The CP ERP does acknowledge specific hazards through the following statements. BESS electrical equipment: "There are disconnects that will de-energize select parts of the system, but the batteries themselves will remain energized." BESS battery fire: "Battery fires present unique hazards, including stranded energy and re-ignition risk." BESS off-gassing: "Lithium-ion batteries release flammable and toxic chemicals when subjected to electrical or physical damage, including fire. Chemicals released can also pose an inhalation hazard."

With certain hazards, the CP ERP requires action by first responders. But the CP ERP does not provide guidance about what action is required. For example, for BESS explosion/deflagration hazards, the CP ERP states that "responders should be aware that unexpected situations may arise and a safe standoff distance from the troubled enclosure is recommended." This statement provides no actual guidance about what the actual "safe standoff distance" would be in the event of an "unexpected situation."

With respect to water run-off the CP ERP states that "Water run-off could be considered contaminated, and all efforts should be taken to minimize unnecessary firefighting water contamination of the surrounding environment. Robust drainage and water run-off features are included in the design of the facility to capture credible worst case water discharge." The CP ERP refers to water quality treatment and control of peak discharge from 2-year and 10-year storms, but no correlation to necessary water flows for firefighting purposes has been submitted. In fact, there is no discussion as to the quantity and flow rate of firefighting water needed. An HMA would be address this.

Section 6 (Potential Site-Specific Hazards):

Section 6 of the CP ERP addresses potential site-specific hazards. These include residential exposures; electrical substation; adjacent buildings and structures; wetland and cranberry bogs; and surrounding wooded area. For these hazards, statements are made to the effect that the risks are "minimal" or "are not expected to pose a risk". No justification is made for these statements and no detail or analysis is provided to support those statements.

Other statements refer to "requisite protective measures, including standoff distances", "other precautions", and "should be monitored and cooled should it be necessary" without providing sufficient guidance or other qualifying information. Specific detail is to be provided considering the uniqueness of BESS risks as noted in section 5 of the CP ERP.

Section 7 (Required Personal Protective Equipment):

Section 7 of the CP ERP addresses required personal protective equipment. The statement "if no fire or explosion risk is present" is made. No detail is provided as to how such risks in this context are to be identified and assessed by first responders, in relation to developing their own policies and procedures with respect to personal protective equipment.

Section 8 (Emergency Response Recommendations):

Section 8 of the CP ERP addresses emergency response recommendations which call for an initial scene assessment to be conducted and conveyed to incoming responders. No details are provided as to how the assessment is to be conducted with respect to site specific ESS hazards and by whom. A HMA would address this.

Section 9 (Specific Recommendations by Type of Emergency):

Section 9 of the CP ERP addresses specific recommendations by type of emergency. These emergencies include fire, deflagration/explosion, electric shock, arc flash, chemical release and drainage and water run-off.

Overall, the hazards are described in a generic fashion lacking detailed assessment and quantification. Specific countermeasures to adequately address the hazards are also presented in a generic fashion without sufficient justification supporting their effectiveness provided. Various warnings about the hazards are presented but without detailed strategies, procedures and tactics for mitigating them.

Statements such as "a safe stand-off distance", "extinguish the fire only if imminent threat to life safety exists", "allow the BESS to burn in a controlled fashion", " protect exposures as needed and let the unit burn itself out", "utilizing water to cool and protect adjacent exposures and mitigate the spread of fire", and "considerable stored energy in the batteries that poses a potential electric shock hazard" are made. However, no detail is provided as to how fire responders are to effectively plan, prepare and act on these statements and warnings.

The CP ERP states that "Chemicals released during a fire or explosion will be in a gaseous form and primarily pose an inhalation hazard. A fog pattern from a handline or monitor nozzle may be an effective way to control the off-gassing event on the exterior of the battery container from migrating to unwanted areas. However, if water is used in extinguishing flames, these gases can become acids which may cause skin irritation. Water curtains or hose streams may be applied to adjacent exposures for cooling purposes. If any indicators are present of damage or heat to an adjacent system, the BMS data shall be closely monitored for the adjacent system and relayed to the appropriate individual within the Incident Command System. Following partial or complete consumption of the system by fire, batteries may continue to emit low levels of flammable gases and dangerous levels of toxic gases for an extended period of time. The risk of battery re-ignition and/or secondary ignition remains present for hours or even days after the smoke/flame was initially detected. Even if a lithium-ion battery fire has been extinguished, there is still a risk of re-ignition." No detail is provided as to how fire responders are to effectively plan, prepare and act on these statements and warnings.

Section 10 (System Specific Fire Protection & Safety Controls):

Section 10 of the CP ERP addresses system specific fire protection and safety controls. Much of this section remains a work in progress with many details to be determined as noted in the ERP.

Appendix A:

Appendix A of the CP ERP addresses Safety Data Sheets. None have been provided.

Appendix D:

Appendix D of the CP ERP addresses subject matter expert (SME) incident response. The term "qualified SME" is used but no details are provided as to how such qualifications are determined and verified. The term "certain thresholds" is used with respect to remote monitoring and notification. No details are provided as what the thresholds are and what is specifically being monitored. Upon notification, the SME is to respond to the scene "within time frames acceptable to the local fire department." Information is lacking as to how the fire department is to establish this time frame. The SME is to "provide guidance based on available data and expertise on how to contain the fire or event." The guidance referred to needs to be established for various scenarios as determined through the HVA and coordinated with the fire department prior to any actual events. Additionally, a training program on any response and tactics should be completed and routinely drilled. Procedures for scene coordination and system restoration need to be established, documented and approved by the fire department.

E. Cranberry Point's ERP and Related Submissions Are Insufficient to Show that Cranberry Point Has Engaged in Sufficient Emergency Management and Other Planning for this Facility.

Q. What are the risks to emergency response personnel posed by the failure of Cranberry Point to meet the requirements of NFPA 855 described above?

A. Without a HMA and comprehensive emergency and training planning completed as required by NFPA 855, the risks to fire fighters along with any mitigating measures cannot be properly assessed.

As previously described, a key concern with lithium-ion chemistries is significant generation of heat and venting of flammable gases that typically include a high concentration of CO and CO2. As the flammable gases vent, they may ignite and cause jetting flames. If the gases do not ignite during venting, then an explosion hazard can develop if the gases accumulate in an enclosed space like a BESS enclosure. These potential fire, explosion, and toxicity hazards seriously jeopardize firefighter safety unless a detailed EOP and training program based on an HMA is developed and approved by the fire department.

When batteries are in thermal runaway, the electrical discharge from short circuiting can cause localized Joule heating which may develop temperatures exceeding flaming combustion. Flammable lithium-ion battery vent gases consist of hydrogen, carbon monoxide, and hydrocarbons. Other battery materials such as plastics are also involved. What complicates the fire response is that flaming fires are not needed to perpetuate thermal runaways. The thermal runaways can continue independent of burning and continue to produce flammable gases which can pose respiratory and explosion hazards. A specific fire service concern which is not the case for typical structure fires is that some lithium-ion batteries may release hydrogen fluoride in a gaseous form due to the breakdown of fluoride compounds in the electrolyte. Exposure to hydrogen fluoride is a respiratory hazard and there is also concern about its effects on firefighter personal protective equipment.

Unlike a typical electrical or gas utility, a BESS installation does not have a single point of disconnect. There are disconnects that will deenergize select parts of the system, but batteries will typically remain energized. As previously discussed, stranded energy within the batteries poses an electrical shock hazard to firefighters. When any battery fire is extinguished, there is still stranded energy within the unaffected cells that will need to be properly handled to reduce the risk of an additional fire or electrical shock hazard.

Firefighters need to be trained to understand and properly respond to the associated BESS hazards of thermal runaway, thermal runaway propagation, fire/explosion, toxic gas release and stranded energy. Otherwise, firefighters are placed at great personal risk when responding to BESS incidents.

VI. Conclusion

Q. Does this conclude your direct testimony?

A. Yes, but I reserve the right to supplement this testimony if any additional information becomes available due to later-filed discovery responses or other materials

Affidavit of Milosh T. Puchovsky

I, Milosh T. Puchovsky, affirm under the pains and penalties of perjury that:

1. I am testifying on behalf of the Intervenor, Save the Pine Barrens, in the Energy Facilities Siting Board's proceeding docketed as number EFSB21-02;

2. This prefiled testimony was prepared by me or at my direction, under my supervision and control; and

3. The information contained in this prefiled testimony is true and accurate to the best of my knowledge and belief at the time I signed this affidavit.

4. My analysis and conclusions are stated with a reasonable degree of scientific and engineering certainty.

____
Milosh T. Puchovsky

EXHIBIT A

Milosh T. Puchovsky, PE, FSFPE

Professor: Fire Protection Engineer

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508-498-3154
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Professional Experience Summary

As WPI's only Professor of Practice in Fire Protection Engineering, Milosh is engaged in a wide range of industry activities bringing his unique experience and perspective to the modern-day classroom. He leads and advises research projects, develops and instructs numerous educational programs, and consults on a variety of fire safety subjects. He chairs and serves on numerous technical committees and panels responsible for the development and revision of fire safety regulations, design methods and industry standards.

Milosh is a registered professional engineer possessing over 30 years of experience with (a) fire protection, suppression and detection systems including sprinklers, standpipes, fire pumps, water supplies, clean and gaseous agents and foam; (b) design, installation and inspection standards such as NFPA 13, 14, 20, 25, 72 and 101, (c) means of egress & occupant response; and (d) building codes, fire regulations and testing procedures; and (e) fire hazard analysis including that of lithium ion battery Energy Storage Systema and (f) the application of computer fire models and third party reviews.

Through his professional practice, Milosh provides analysis and litigation support specific to fire and life safety system design, installation, and performance. He authors and reviews technical publications, speaks at industry conferences, and serves prominent roles with the National Fire Protection Association (NFPA), Society of Fire Protection Engineers (SFPE), Fire Protection Research Foundation (FPRF) and Underwriter's Laboratories (UL).

As Standards Council Secretary and Assistant Vice President at NFPA, Milosh oversaw the technical and procedural development of all NFPA codes and standards. He also led NFPA's performance-based codes initiative facilitating the greater application of engineering methods in fire safety design. Milosh worked in the insurance industry evaluating fire risks and protection systems, and as an engineering consultant designing systems, specifying products, and developing fire safety strategies.

Milosh is Past President and Fellow of SFPE, a member of the Society's Engineering Licensing Committee and technical editor for Systems Chapters of the Handbook of Fire Protection Engineering. He is also a principal member of the UL Fire Council that advises UL on its product test standards and fire safety initiatives. Milosh holds two engineering degrees, and an engineering license in Fire Protection.

Skills and Qualifications Highlights

- Full-time professor and subject matter expert teaching, researching, and advising
- Litigation support providing expert analysis and testimony for fire loss, system malfunction and patent dispute
- Fire protection system design and performance evaluation
- Building and fire code development and consultation
- Calculation of fire behavior and effects using computer models and numerical techniques
- Occupant egress analysis including timed egress studies
- 3rd party design and code compliance reviews
- Standardized fire testing protocols and procedures
- Insurance loss control services and inspections
- Technical program development and delivery in traditional and virtual formats
- Engineering project management for domestic and international projects
- Business development including engaging prospective clients, writing proposals and marketing services
- Professional society leadership & strategic planning
- Author, editor and technical reviewer for key industry publications

Employment History

Worcester Polytechnic Institute, Department of Fire Protection Engineering, Worcester, MA
2017 – Present Associate Department Head, and Principal Industry Liaison
2008 – Present Professor of Practice, and Director of Corporate & Professional Education
2003 – 2007 Adjunct Associate Professor

Milosh Puchovsky & Associates, LLC, Mendon, MA
2008 - Present, Principal

National Fire Protection Association, Quincy, MA
2007- 2008 Assistant Vice President – Codes & Standards Administration; Standards Council Secretary
2003 – 2007 Principal Fire Protection Engineer – Building and Life Safety Codes
1993 – Present Principal Instructor – NFPA Technical Fire Safety Seminars

Arup, (Ove Arup & Partners Massachusetts Inc.) Cambridge, MA
2001 – 2003 Senior Consulting Fire Engineer

National Fire Protection Association, Quincy, MA
2000-2001 Director, Codes and Standards Development – Standard Administration
1996-2000 Senior Fire Protection Engineer - Systems and Applications Engineering
1993-1996 Fire Protection Engineer – Systems and Applications Engineering

Chubb Group of Insurance Companies, Boston, MA
1992-1993 Risk Engineer

Foehl Sherman, Inc. Burlington, Ma
1991 Consulting Fire Protection Engineer and Building Code Consultant

Rolf Jensen and Associates, Inc. Concord, CA (Fire Protection Engineering Consulting Firm)
1988-1989 Fire Protection Engineer & Building Code Consultant

Education

- M.S. (Fire Protection Engineering) Worcester Polytechnic Institute, Worcester, MA, 1991
- B.S. (Mechanical Engineering) Worcester Polytechnic Institute, Worcester, MA, 1988

Registration

Registered Professional Engineer (Fire Protection), Massachusetts (License number 38530)

Professional Affiliations

National Fire Protection Association
Society of Fire Protection Engineers
Underwriters Laboratories

Honors

Fellow – SFPE (2008); Hats Off Award – SFPE (2015); Faculty Achievement Award – WPI (2016, 2020)

Teaching, Training and Course Development Responsibilities

WPI Department of Fire Protection Engineering - Graduate Engineering Courses (responsible for development and delivery; traditional face-to-face, virtual and blended delivery methods)

- FP 553 – Fire Protection Systems – Students who complete FP 553 will have developed a practical technical understanding of design principles for automatically activated fire protection systems including sprinkler, standpipe, fire pump and water supply. Relevant physical phenomena, functionality and purpose of these systems are introduced, as are associated calculation and assessment techniques, regulations, equipment requirements, and product approval evaluations. (Co-instructed prior to full time appointment at WPI in 2008)
- FP 554 – Advanced Fire Suppression – Students who complete FP 554 will have developed a practical technical understanding of the purpose and design principles for water spray, water mist, residential sprinkler, clean agent, halon, carbon dioxide, foam, and wet chemical fire suppression systems and devices. Structural support and bracing of fire suppression systems are also introduced.
- FP 555 – Detection, Alarm and Smoke Control - Students who complete FP 555 will have developed a practical technical understanding of design principles for: (a) fire detection systems using flame, heat and smoke detector technology, (b) fire alarm, occupant notification and control systems, and (c) smoke control systems based on buoyancy and pressure differences across barriers for the purpose of occupant survivability.
- FP 570 – Building Fire Safety – Students who complete FPE 570 will have developed a practical technical understanding of the building design process and the roles of project stakeholders in addressing fire and life safety concerns principally through the application of building regulations, standards of practice, construction features, passive and active systems, means of egress, fire test methods, and the use of interior finish materials.
- FP 571 – Performance Based Design – Students who complete FPE 571 will have developed a practical technical understanding of the differences between applying traditional code mandated prescribed fire protection, and the need for implementing computer models and other calculation techniques in developing and assessing solutions for specific fire safety concerns. (Co-instructed prior to full time appointment at WPI in 2008)
- FP 580B – Business Practices in Fire Protection Engineering – This course introduces and strengthens business concepts, skills and services associated with fire protection engineering. Students learn how technical and engineering skills need to be blended into a professional business practice environment. Students develop an understanding of financial considerations, managerial responsibilities and the soft skills necessary for successful engineering and research operations. Students monetize services and products, prepare business plans, identify customers, and develop technical and cost proposals, workflow timelines, project budgets, invoice and cash flow models, and professional quality technical reports. Written and oral communication skills are advanced. Executives from the FPE industry will provide guest lectures and insight on key topics.

WPI Department of Fire Protection Engineering - Undergraduate Engineering Courses

- FP 3070 – Fundamentals of Fire Safety – Guest lecturer
- FP 3080 – Introduction to Building Fire Safety System Design – Content development and lead instructor

Northeastern University - Industry Related Seminars (traditional face-to-face program, 1995 - 2002)

- Professional Engineering Exam Preparation Course for Fire Protection Engineering

NFPA – Industry Related Seminars (traditional face-to-face programs, 1993 – present)

- Installation of Sprinkler Systems (NFPA 13)
- Inspection, Maintenance and Testing of Water-Based Fire Protection Systems (NFPA 25)
- Fire Pumps (NFPA 20)
- Sprinkler System Hydraulics
- Automatic Sprinkler Systems & Fire Alarm Systems Plans Review
- Life Safety Code Essentials, Life Safety Code for Health Care, Plans Review (NFPA 101)
- Health Care Facilities (NFPA 99)
- National Fire Alarm & Signaling Code (NFPA 72)
- Special Suppression Systems (NFPA 11, NFPA 12, NFPA 15, NFPA 17, NFPA 17A, NFPA 750, NFPA 2001, and NFPA 2010)
- Code Requirements for Maintaining Fire & Life Safety Systems
- Smoke Control Systems (NFPA 92)
- Fixed Guideway Transit & Passenger Rail Systems (NFPA 130)

Technical Committees, Panels and Boards

NFPA TC on Fire Pumps (NFPA 20) – Chair, 2018 – Present; Member 2001-2003, 2009-2018; Staff Liaison, 1996-2001

NFPA TC on Sprinkler System Discharge Criteria (NFPA 13) – Member, 2001-2003, 2014 – Present; Staff Liaison, 1996-2000

NFPA TC on Safety to Life Fundamentals (NFPA 101, NFPA 5000) – Member, 2001-2003, 2009 - Present

NFPA TC on Residential Sprinkler Systems (NFPA 13D & 13R) - Member, 2010 – Present; Staff Liaison, 1996 -2000;

SFPE: President 2016; Board of Directors 2017-2007; Strategic Planning Committee Chair, 2014

Underwriters Laboratories Fire Council – Member, 2010 – Present

UL Standards Technical Panel 199 – Sprinkler Equipment for Fire Protection – Member, 2015 - Present

SFPE Professional Engineering Exam Licensing Committee – Member, 2003 - Present

FPRF Technical Panel on Fire Risk Terminology – Member, 2019

FPRF Technical Panel on Oxygen Reduction Systems for Warehouse Storage Applications – Member, 2018

SFPE Executive Director Search Committee – Member, 2008 – 2009

NFPA TC on Commissioning & Integrated Testing (NFPA 3 & NFPA 4), Member 2011 - Present

NFPA Technical Committee on Water Mist Systems (NFPA 750) - Member 2009 – Present; Staff Liaison, 1994 - 1997

NFPA TC on Cultural Resources (NFPA 909, 914) - Member 2009 – present; Staff Liaison, 2003 - 2007

NFPA TC on Contents & Furnishings (NFPA 101 & NFPA 5000) -Member 2010 – Present; Staff Liaison, 2003 – 2007

NFPA TC on Health Care Facilities – Fundamentals (NFPA 99) – Member 2014 - Present

FPRF Technical Advisory Panel on Residential Sprinkler Systems – 2008 - 2009

NFPA Standards Council – Secretary, 2007 - 2008

FPRF Research Advisory Panel – Member, 2007 – 2008

ANSI Executive Standards Council – Member, 2007 - 2008

FPRF Technical Advisory Panel on Risk Methods – Member, 2006 – 2007

FPRF Technical Advisory Panel on Evacuation of High-Rise Occupants – Member, 2006 - 2007

NFPA High-Rise Building Safety Advisory Committee – Secretary, 2004 – 2007

NFPA TC on Fire Risk Assessment Methods (NFPA 550, NFPA 551) Staff Liaison, 1999-2001, 2003-2007

NFPA TC on Industrial and Storage Occupancies (NFPA 101 and NFPA 5000) Staff Liaison, 2003 – 2007

NFPA TC on Fire Safety Features (NFPA 101 and NFPA 5000) - Staff Liaison, 2003 – 2007

NFPA TC on Mercantile and Business Occupancies (NFPA 101 and NFPA 5000) - Staff Liaison, 2003 – 2007

NFPA TC on Smoke Control Systems (NFPA 92, NFPA 204) - Staff Liaison, 2003 – 2007

NFPA TC on Fire Doors (NFPA 80, NFPA 105) - Staff Liaison, 2003 – 2007

NFPA In-house Task Group on Performance-Based Codes – Chair, 1993 – 2001, 2003 – 2007

NFPA In-house Resource Team on Homeland Security and Critical Infrastructure – Member, 2005 - 2008

SFPE Task Group on Performance-Based Design and Analysis – Member 2003 – Present

TC on Hazards and Risk of Contents and Furnishings (NFPA 555, NFPA 556, NFPA 557) - Staff Liaison, 2003 – 2007

Inter-jurisdictional Regulatory Collaboration Committee (International Performance-Based Building Codes) - Member, 2003 – 2007

NFPA TC on Fire Tests (30 fire test standards) - Staff Liaison, 2003 – 2005

NFPA TC on Manufactured Housing (NFPA 225, NFPA 501, NFPA 501A) – Staff Liaison, 2003 - 2005

NFPA TC on Automatic Sprinkler Systems (NFPA 13, NFPA 13D, NFPA 13R) Staff Liaison, 1996 -2000, Principle Member, 2001-2003

SFPE Design Team Liaison Task Group – Member, 1999 - 2003

NFPA TC on General Storage (NFPA 231, 231, NFPA 231D, NFPA 231E, NFPA 231F, NFPA 46) Staff Liaison, 1993-2000

ISO TC 21/SC5 – Sprinkler and Water Spray Extinguishing Systems – Secretary, 1996 – 2001

NFPA TC on Standpipe Systems (NFPA 14) Staff Liaison, 1993-1997

NFPA TC on Private Water Supply Piping (NFPA 24, NFPA 291) Staff Liaison, 1993 – 1997

NFPA TC on Water Spray Systems (NFPA 15) Staff Liaison, 1993-1997

NFPA TC on Foam Water Sprinkler Systems (NFPA 16, NFPA 16A) Staff Liaison, 1993-1997

NFPA TC on Record Protection (NFPA 232, NFPA 232A) Staff Liaison, 1993-1997

Selected Engineering Design Experience

OMMA Concert Hall, Athens, Greece
Project leader responsible for conducting an NFPA 101 fire and life safety analysis for Greece's premier concert hall expansion. Served as primary contact for this Athens based architectural and construction firm. The project, most of which was underground, included two new concert halls (one of which was 13 stories in height), parking facilities, banquet facilities, exhibition center and numerous vertical openings. A combination of prescriptive and performance-based design methods was employed.

High Museum, Atlanta, GA
Conducted fire engineering analysis involving computational fluid dynamics computer program to form the basis of a code variance for a sprinkler system installation. Fire development and sprinkler response were assessed to identify options for preserving the unique ceiling structure proposed by the architect. Successfully negotiated the approach and solution with the building official.

Downtown Transit Center, New York City, NY
Conducted fire, life safety and risk assessments for the redevelopment of the former World Trade Center site. Included analysis of potential extreme events including those associated with fire, blast and biochemical threats.

Massachusetts Institute of Technology, Main Group Master Plan, Cambridge, MA
Conducted fire protection and life safety master plan for the renovation of MIT's main group buildings. Identified options for preserving the historic character and functionality of this cluster of historic buildings that function as a single structure.

King Abdulaziz Airport, Jeddah, Saudi Arabia
Project included a major airport expansion project including airport terminal building and parking facilities. Client was an architect based in the Hague, Netherlands. Conducted an NFPA 101 analysis and developed alternate means of protection.

Dulles Airport Expansion, Sterling, Virginia
Code analysis, fire safety strategy development, computational fire and smoke management study for the construction of a new midfield concourse and APM station. Included CFD computer modeling, egress analysis and assessment of fire size and growth for APM vehicles.

Unified Science Center, Hamilton College, Clinton, New York
Smoke management study for the renovation of a 1920's era building. Included strategy development and smoke movement calculations for a complex new atrium.

Honolulu International Airport, Honolulu, HI
Development and expansion of new international airport terminal. Prepared overall fire protection strategy, conducted code analysis, and identified and resolved code issues.

Harvard University, Cambridge, MA
Master plan survey and evaluation of various university buildings including hospitals, dormitories and academic buildings to identify deficiencies with regard to code compliance and fire protection systems.

Leeds School of Business, Boulder, CO
Smoke management system and life safety analysis for a new atrium building.

Ritz Carlton Hotel, San Francisco, CA
Renovation of a historic college building to a new luxury hotel. Prepared overall fire protection program, conducted egress analysis, and developed and negotiated alternative means of fire protection and life safety to preserve historic character of the building.

Downtown Plaza, Sacramento, CA
Development of six city blocks into a new covered shopping mall and entertainment complex. Prepared overall fire and life safety program, conducted egress analysis, and identified and developed alternative means of protection where strict compliance with building and fire code requirements was not possible.

FuelCell Energy, Torrington, CT
Fire hazard analysis of process equipment used in the production of fuel cells. Developed plan to mitigate associated fire and explosion hazards.

ABC Studios, New York, NY
Development of specifications for maintenance and testing of building fire protection systems. Sprinkler system design for storage areas.

Baker Library, Dartmouth College, Hanover, NH
Retrofit of automatic sprinkler system into historic library. Designed sprinkler and fire pump systems to achieve overall fire protection goals while maintaining the unique character of the building.

Publications and Technical Programs

Texts

SFPE Handbook of Fire Protection Engineering, 6th edition, SFPE, Technical Editor, Chapters on Design Calculations for Fire Protection Systems – Sprinklers, Hydraulics & Water Supplies, Detection & Alarm, Smoke Control, Hydraulics, Halon, Clean Agents, Carbon Dioxide, Water Mist, Foam) – In Preparation

"Automatic Sprinkler System Calculations," SFPE Handbook of Fire Protection Engineering, 6th edition, SFPE (In Preparation)

"Engineering Considerations for Fire Protection System Selection," SFPE Handbook of Fire Protection Engineering, 6th edition, SFPE, (In Preparation)

"The Role of Performance-Based Codes and Standards in Fire Safety Design," Section 4, Chapter 13, Fire Protection Handbook, 20th ed, NFPA, (In Preparation)

NFPA 20 Stationary Fire Pump Handbook, 2019 Edition, NFPA (Contributing Author)

"Interrelationship of NFPA Standards Pertaining to a Fire Pump Installation" Supplement 2, Stationary Fire Pumps Handbook, 5th Edition, NFPA, 2016.

Automatic Sprinkler Systems for Residential Occupancies Handbook, 2016 Edition, NFPA (Contributing Author)

SFPE Handbook of Fire Protection Engineering, 5th edition, SFPE, 2015 (Section Technical Editor for chapters on Design Calculations for Fire Protection Systems)

"Engineering Considerations for Fire Protection System Selection," SFPE Handbook of Fire Protection Engineering, 5th edition, SFPE, 2015

Automatic Sprinkler Systems for Residential Occupancies Handbook, 2013 Edition, NFPA (Contributing Author)

Stationary Fire Pumps Handbook, 2013 Edition, NFPA (Contributing Author)

"Section 12, Structural Fire Protection", Fire Protection Handbook, 20th edition, NFPA, 2008 (Section Technical Editor)

"Performance-Based Fire Codes and Standards," Section 4, Chapter 13, Fire Protection Handbook, 19th ed, NFPA, 2003

"The Application of Performance-Based Design Concepts for Fire and Life Safety", Supplement 7, Life Safety Code Handbook, 9th and 10th editions, NFPA, 2003, 2006

"Section 10, Water Based Fire Protection Systems", Fire Protection Handbook, 19th edition, NFPA, 2003 (Section Technical Editor)

"Fire Pump Controllers and Electric Power Supplies for Fire Pumps", Section10, Chapter 8, Fire Protection Handbook, 19th edition, NFPA, 2003 (with James Nasby)

"Automatic Sprinkler Systems", Section 10, Chapter 11, Fire Protection Handbook, 19th edition, NFPA, 2003

"Pumps for Fire Protection," 1st edition, NFPA, 2002 (with Ken Isman)

"A Brief Introduction to Sprinkler Systems for Life Safety Code Users," Supplement 3, Life Safety Code Handbook, 8th edition, NFPA, 2000

"Automatic Sprinkler Systems Handbook" 8th edition, NFPA 1999

"Fire Pump Handbook," 1st edition, NFPA, 1998 (with Ken Isman)

"Automatic Sprinkler Systems Handbook" 7th edition, NFPA 1996

"Performance-Based Fire Codes and Standards," Section 11, Chapter 9, Fire Protection Handbook, 18th ed, NFPA, 1997

"General Indoor Storage," Section 9, Chapter 18, Fire Protection Handbook, 18th edition, NFPA, 1997

"Outdoor Storage Practices," Section 9, Chapter 19, Fire Protection Handbook, 18th edition, NFPA 1997

Reports & Periodicals

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"The Development and Deployment of Water Mist Fire Suppression Technology," DiNenno Prize Nomination, Subject Matter Expert Peer Review, (http://www.nfpa.org/dinenno), January 2020.

"Ensuring Fire Safety of Closed Warehouses by Optimizing the Number of Fire-Fighting Devices," Safety & Fire Technology, Ms. Ref. SFT-00037-2019-01, December 2019.

"Reliability of Automatic Sprinkler Systems for Fire Protection: How to Collect, Analyze, and Present Reliability Data," (pre-publication proposal review), CRC Press, December 2018.

"An Efficacy Evaluation of Water Mist Protection of Solid Combustible Fires in an Open Environment," Fire Technology, Ms. Ref. FIRE-D-18-00095

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“Fire Alarm Systems - An Analysis of Addressable Fire Alarm Notification Appliances” (with C. Cyr & D. Parrow), *NFPA Conference and Exposition*, Boston, MA, June 2022.

“Fire Pumps and the 2022 Edition of NFPA 20,” SFPE Greater Atlanta Chapter Annual Seminar (Virtual), Atlanta, GA, March 16-17, 2021.

“The Feasibility of Protecting Residential Structures from Wildfires using a Fixed Exterior Fire Fighting System,” (with A. Simeoni, E. Han, D. Parrow and A. Rozen, SFPE New England Chapter Meeting, Norwood, MA, Feb 3, 2020.

“A Case Study in Utilizing an Existing High-Rise Building’s Fire Protection System Infrastructure for Fighting Exterior Façade Fires,” (with Zachary Magnone), Suppression, Detection and Signaling Research and Applications Conference (SUPDET), Denver, CO, September 17-20, 2019

“Case Studies in the Application of Electronic Sprinkler Technology for Warehouse Operations”, NFPA Conference and Expo, San Antonio, TX, June 17-20, 2019

2nd Annual Center for Global Public Safety Industry Stakeholders’ Forum – *Energy Initiatives & Their Impact on Public Safety*, Organizer and Moderator, Worcester Polytechnic Institute, March 27, 2019.

“Heroic Science: What is Fire Protection Engineering,” (with E. Brecher, V. Hutchison and V. Kimmerly), 2018 Annual National Collegiate Honors Council, Boston, MA, November 9, 2018.

“Large-Scale Fire Testing to Determine Fire Protection Requirements for Battery Energy Storage Systems,” (with Adam Barowy), SFPE Conference and Expo, Nashville, TN, October 29, 2018

2nd Annual Global Public Safety Symposium - *New Frontiers in Global Public Safety,* Organizer and Moderator, Worcester Polytechnic Institute, September 17, 2018.

“Introductory Overview on Using UL 9540A Data for Fire Safety Design Applications,” Sustainable CUNY / SERTA Stakeholder Workshop, New York, NY, August 27, 2018

Center for Global Public Safety Industry Stakeholder’s Forum – *Focus on Fire Protection, Water Security, Food Safety and Emergency Response*, Organizer and Moderator, Worcester Polytechnic Institute, April 30, 2018.

“Addressing Excess Fire Pump Pressures,” 2018 Fire Protection Symposium - New England Association of Fire Protection System Designers, Bartlett, New Hampshire, March 2018

“A Radiation Heat Transfer Analysis of Lithium-Ion Battery Energy Storage Systems (ESS)” SFPE Conference and Expo, Montreal, Quebec, Canada, October 10, 2017

"Lithium-Ion Battery Energy Storage Systems: Characterizing Fire Incidents and Effective Protection Schemes," (with V. Hutchison), NFPA Conference and Expo, Boston, MA, June 6, 2017

"Fire Safety Engineering Practice – Graduate and Undergraduate Education and Research," (with T. El-Korchi), *First Workshop on Fire Safety Engineering,* University of Campinas, Campinas, Brazil, March 23, 2017

"Advanced Design Concepts and Calculations for Fire Alarm Systems," *Seminario: Bombas Contra Incendio Basado en NFPA 72*, Fire Prevention Institute, Mexico City, Mexico, February 28-29, 2017

"An Overview of the Fire Hazards Associated with Lithium Ion Batteries," (with V. Hutchison), *International Association of Arson Investigators – Massachusetts Chapter Technical Seminar,* Auburn, MA, November 17, 2016

"Advanced Topics on the Application and Use of Fire Pumps," *Seminario: Bombas Contra Incendio Basado en NFPA 20*, Fire Prevention Institute, Mexico City, Mexico, November 14-15, 2016

"Careers in Fire Protection," *Massachusetts STEM Summit 2016*, (with A. Kimball, K. Bigda, J.C. Harrington) Worcester, MA, November 1, 2016

"Using FDS for Fire Scene Analysis," *SFPE Conference and Expo*, (with B. Rabidou, D. Savva, F. Kang, R. Kennedy, C. Wood) Denver, CO, September 2016

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"Computer Fire Modeling & Sprinkler System Design," *SFPE New York Metro Chapter Technical Seminar*, New York, NY, March 2016.

"New Design Options for Fire Pump Installations," 2016 NEAFPSD 25th Chapter Anniversary & Fire Protection Symposium, Bartlett, New Hampshire, March 2016

"The Proper Use of Fire Pumps & the 2016 Edition of NFPA 20," *Fire Sprinkler Americas Conference*, International Fire Sprinkler Association, Medellin, Columbia, February 2016

"SFPE's Strategic Plan", *Technical Committee Meeting of the Fire Suppression Systems Association,* Fajardo, Puerto Rico, February 2016

"The Critical Impact of Fire Protection System Maintenance", *SFPE United Arab Emirates Chapter Meeting*, Dubai, UAE, November 2015

"Designing for Inspection, Testing and Maintenance of Fire Protection Systems", *NFPA Conference and Exposition*, Chicago, IL, June 2015

"Using Fire Modeling to Establish Sprinkler System Design Criteria", *SFPE Minnesota Chapter Meeting*, Roseville, MN, May 2015

"New Means of Egress Provisions for NFPA 101", *SFPE United Arab Emirates Chapter Meeting*, Dubai, UAE, February 2015.

"SFPE's New Strategic Plan", *SFPE Conference and Expo*, Long Beach, CA, October 2014

"Fire Pumps, NFPA 20 and Tall Buildings", *SFPE United Arab Emirates Chapter Meeting*, Abu Dhabi, UAE, September 2014

"Fire Pump Installations for Tall Buildings", *NFPA Conference and Exposition*, Las Vegas, NV, June 2014.

"Explosion Hazard Classification and the Use of Electrical Equipment", *Technical Workshop for Riley Power, Inc.,* Worcester, MA, February 2014.

"Fire Pumps: What You Need to Know", *Fire Sprinkler America's Conference*, Panama City, Panama, February 2014.

"Setting Sprinkler System Performance Criteria when NFPA 13 Won't Cut It", *SFPE Rocky Mountain Chapter 1st Annual Fire Protection Symposium*, Boulder, CO, April 2013.

"Update on SFPE Activities," *SFPE New York Metro Chapter Meeting*, New York, NY, March 2013.

"New Design Considerations for Fire Pump Installations," *SFPE Engineering Technology Conference*, Savannah, GA October 2012

"Sprinklers in Fire Engineered Solutions," *9th International Fire Sprinkler Conference*, Paris, France, June 28-29, 2012

"Appropriateness of Current Occupant Load Factors for Business Occupancies," *NFPA Conference and Exposition*, Las Vegas, NV, June 2012

"New Options for Fire Pump Installations," *SFPE New York Metro Chapter Annual Seminar*, Brooklyn, NY, February 2012.

"Systems Selection for Fire Protection – Factors that Should Influence a FPE's Decision Making Process," *SFPE Engineering Technology Conference*, Portland, OR, October 2011

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"Fire Protection System Selection for Special Hazards," *SFPE Greater Atlanta Chapter 7th Annual Fire Safety Conference*, Duluth, GA, March 2011.

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"Training Future Fire Protection Engineers," *NFPA Conference and Exposition*, Las Vegas, NV, June 2010.

"Advocating Sprinklers – A Report on Research, Code Changes and Other Initiatives at NFPA," *New England Fire Protection Symposium,* West Dover, VT, March 2008.

"Predicting Detector Actuation," *Fire Protection Research Foundation Suppression and Detection Symposium,* Orlando, FL, March 2008 (session moderator)

"NFPA and Fire Safety in High Rise Buildings: A Status Report," *NFPA World Safety Conference and Exposition,* Boston, MA, June 2007.

"Using Risk Concepts in Codes and Standards Development," *NFPA World Safety Conference and Exposition,* Boston, MA, June 2007.

"An Approach for Applying Risk Concepts in the Development of Codes and Standards," *NFPA World Safety Conference and Exposition,* Boston, MA, June 2007.

"NFPA Regulations – Notices of Intent to Make a Motion for the National Electrical Code", *NFPA Electrical Inspectors Forum*, Quincy, MA, May 2007.

"NFPA High-Rise Building Safety Advisory Committee and the NIST/WTC Recommendations" *Fire Safety Directors Association of Greater New York – Spring Seminar*, New York, NY, May 2007.

"Fire Detection, Alarm Systems and Human Behavior," *Fire Protection Research Foundation Suppression and Detection Symposium*, Orlando, FL, March 2007 (session moderator)

"Code Options for Rehabilitating Historic Buildings," *Traditional Buildings Exhibition and Conference*, Boston, MA, March 2007

"High Rise Buildings – Where Are the Codes Heading?" *Society of Fire Protection Engineers – New England Chapter,* Norwood, MA, November 2006 (with B. Tubbs)

"NFPA 914 – Code for Fire Protection of Historic Structures and Building Rehabilitation," *Protection Heritage International Conference,* Ljubljana, Slovenia, May 2006

"Property and Life Safety in Health Care Facilities" *NFPA Niagara Frontier Chapter 2006 Spring Seminar*, Buffalo, NY, May 2006

"Status Report on NFPA's Response to the NIST WTC Recommendations," *National Institute for Building Sciences – Multi-hazard Mitigation Council,* Washington, D.C., May 2006

"The Concept of Fire Risk and Its Potential Impact on the Role of Sprinkler Systems," *NFSA 2006 Annual Seminar*, South Hampton, Bermuda, April 2006

"New Code Provisions for Building Rehabilitation," *Traditional Buildings Exhibition and Conference,* Chicago, IL, April, 2006

"NFPA's Perspectives on High Rise Safety," *National Council of Structural Engineering Associations*, Kansas City, MO, October 2005

"NFPA's Comments on Building and Fire Codes & Practices", *Technical Conference on the Federal Building and Fire Safety Investigation of the World Trade Center Disaster,* National Institute of Standards and Technology, Gaithersburg, MD, September 2005

"NFPA Comments to NIST's Federal Building and Fire Safety Investigation of the World Trade Center Disaster" National Fire Protection Association, August, 2005 (with R. Solomon, R. Fahy, *et al*.)

"Rehabilitating Tall Buildings in a Post 9/11 World," *Traditional Building Exhibition and Conference,* Philadelphia, PA, April 2005

"NFPA Comments to NIST's Report of the Technical Investigation of the Station Nightclub Fire," National Fire Protection Association, March 2005 (with R. Solomon, R. Cote, R.Fahy, *et al*.)

"Balancing Life Safety with the Historic Preservation of Tall Buildings," *Council on Tall Buildings & Urban Habitat International Conference on Tall Buildings in Historical Cities - Culture & Technology for Sustainable Cities* ,Seoul, South Korea, October 2004

"A Bottom-Up Analysis for Performance Designs" *5th International Conference on Performance-Based Codes and Fire Safety Design Methods*, Luxembourg, October 2004

"Making Old Buildings Work: Building Rehab Code Provisions for Safety" *Restoration & Renovation Conference*, Boston, MA, April 2004 (with Marilyn Kaplan)

"Sprinkler Systems as a Design Option for Historic Buildings", *New England Fire Protection Symposium*, West Dover, VT, March 2004

Global Policy Summit on the Role of Performance-Based Building Regulations in Addressing Societal Expectations, International Policy, and Local Needs, Washington, D.C., November 2003 (Session Chair and member of organizing committee)

NIST Workshop on Fire Safety Design and Retrofit of Structures, Baltimore, MD, September 2003 (Work Group Facilitator)

"NFPA's Comments to the American Society for Healthcare Engineering of the American Hospital Association Alcohol-Based Hand Rub Solution Fire Modeling Analysis Report", NFPA, July 2003 (w/ R. Solomon)

"An Overview of Hanging and Bracing Requirements for Sprinkler Systems", *Fire Prevention Association of Massachusetts - 17th Annual Educational Seminar*, Amherst, MA, April 2003

"Sprinkler Systems – Which System for What Hazard?" *Massachusetts Building Commissioners and Inspectors Association – Monthly Meeting*, Sturbridge, MA, November 2002

"Design Vision, Building Codes and Fire Engineering", *Build Boston - Boston Society of Architects*, Boston, MA, November 2002 (with Jeff Tubbs)

"Consideration of Extreme Events in Building Management and Design", *Build Boston - Boston Society of Architects*, Boston, MA, November 2002 (with Brian Meacham and Jeff Tubbs)

"Sprinklers as A Code Solution," *4th International Fire Sprinkler Conference*, Prague, Czech Republic, July 2002

"Sprinkler Systems for Storage and Bulk Retail," *Fire Prevention Association of Massachusetts – 16th Annual Educational Seminar*, Amherst, MA, April 2002

Performance-Based Design Requirements for the First Edition of the NFPA Building Code, *4th International Conference on Performance-Based Codes and Fire Safety Design Methods*, Melbourne, Australia, March 2002 (with Greg Harrington)

"Using Fire Models to Demonstrate Sprinkler System Effectiveness, "*New England Fire Protection Symposium*, Bartlett, NH, March 2002

"An Overview of NFPA's New Project on Fire Risk Assessment Methods," *The International Conference on Engineered Fire Protection Design*, San Francisco, CA, June 2001 (with Ken Richardson)

"Electric Power Supply Requirements for Fire Pumps," *Society of Fire Protection Engineers - New England Chapter Annual Technical Seminar*, Randolph, MA, March 2001. (with Larry Wenzel)

"An Overview of Organizational and Technical Changes for the 1999 edition of NFPA 13," *NFPA Fall Meeting*, Orlando, FL, November 2000

"Future Considerations for NFPA 13" *New England Fire Protection Symposium*, Bartlett, NH, March 2000.

"Electrical Power Supply Requirements of NFPA 20", *New England Fire Protection Symposium*, Bartlett, NH, March 2000

"Automatic Sprinkler Systems" *Wisconsin Code Enforcement Officials Special Seminar*, Madison and Wausau, WI, February 2000

"NFPA Overview and Technical Changes ½ Day Program," *Wisconsin Building Code Refresher Program*, University of Wisconsin, Madison, WI, February 2000

"Implementing Performance-Based Design through the Application of Fire Safety Regulations," *2nd Conference on Fire Safety Design in the 21st Century*, Worcester, MA, June 1999

"NFPA 13 – Major Changes for the 1999 edition," *SFPE Southern Ontario Chapter Meeting*, Toronto, Canada, January 2000

"Technical and Organizational Changes for the 1999 Edition of NFPA 13," *SFPE New England Chapter Meeting*, Norwood, MA, December 1999

"An Introduction to NFPA 13," *NFPA Regional Conference*, Kuala Lumpur, Malaysia and Hong Kong, China, November, 1999

"NFPA 13 Plans Review Seminar," *Rhode Island Fire Marshall's Association*, Providence, RI, October 1999

"NFPA 13 Changes ½ Day Program," *American Fire Sprinkler Association*, New Orleans, LO, September 1999. (with R. Huggins and B. Caputo)

"NFPA 13 – The Next Century" *Fire Marshall's Association of North America - Delaware Valley Chapter Meeting*, Philadelphia, PA, September 1999

"Electric Power Supply for Motor Driven Fire Pumps," *National Fire Sprinkler Association Annual Seminar*, Chicago, IL, September, 1999

"NFPA 13 / NFPA 25 Surveyor Training Course," *National Health Care Finance Administration*, Denver, CO, June 1999.

"Major Proposed Changes and Additions to the Next Edition of NFPA 13," *American Society of Plumbing Engineers - Boston Chapter Meeting*, Randolph, MA, January 1999

"The Reorganization and Expansion of NFPA 13," *3rd International Fire Sprinkler Conference*, Glasgow, Scotland, July 1998

"Seminar on Fire Protection Systems – Sprinklers and Fire Pumps," *NFPA Special Meeting*, Bangkok, Thailand, July 1998. (with D. Hague)

"An Overview of NFPA 13, NFPA 231 and NFPA 20," *NFPA Special Meeting and Workshop*, Kuala Lumpur, Malaysia, July 1998.

"An Introduction to Performance-Based Codes and Design Approaches," *South Carolina Fire Inspectors Association Spring Seminar*, Myrtle Beach, SC, June 1998.

"Technical Differences Between the 1991 and the 1996 editions of NFPA 13," *Montana Fire Marshall's Association – Monthly Meeting*, Helena, MT, June 1998

"Domestic Fire Protection Using Residential Sprinklers and Inspection, Testing and Maintenance Procedures for Water Based Fire Protection Systems," *Fire-X '98*, Birmingham, England, May 1998

"Sprinkler Technology and the Application of NFPA's Sprinkler Standards," *NFPA Regional Conference*, Mexico City, Mexico, April 1998

"Reorganization of NFPA's Sprinkler Project," *NEAFPSD New England Fire Sprinkler Technical Seminar*, Bethel, ME, March 1998

"NFPA 13 – Major Changes," *American Society of Plumbing Engineers – Miami Chapter*, Miami, FL, February 1998

"Proposed Changes to NFPA 231 and NFPA 231C," *American Fire Sprinkler Association's 16th Annual Convention*, Albuquerque, New Mexico, October 1997

"Performance Codes and the Role of NFPA," *Performance Codes: How Will They Happen*, American Institute for Architects, San Francisco, CA, October 1997

"Supervision of Automatic Sprinkler Systems," *Pennsylvania Tri-State Fire Alarm Seminar*, Philadelphia, PA, September 1997

"Performance-Based Regulations - What Role Will They Play," *Proceedings of the Fire Risk and Hazard Assessment Symposium*, National Fire Protection Research Foundation, San Francisco, CA, June 1997

"Performance-Based Language in Existing NFPA Codes," *SFPE Design Workshop – Introduction to Performance-Based Design for AHJ's*, Los Angeles, CA, May 1997

"Current Issues Facing Water-Based Fire Protection Systems," *NFPA Annual Meeting*, Los Angeles, CA, May 1997.
"New Orleans Warehouse Fire," *NFPA Annual Meeting*, Los Angeles, CA, May 1997

"Pumps for Fire Protection, and Fire Protection Technology Update" Fire-X '97, Birmingham, England, May 1997 (with K. Isman and M. Riffey)

"NFPA's Future in Performance-Based Codes and Standards," *Building Performance: What Is It?,* American Institute for Architects, Washington, D.C., April 1997

"Fire Sprinklers – NFPA 13 and 13D Update," *NFPA Western Regional Meeting*, Sacramento, CA, April 1997

"An Introduction to Performance-Based Codes and Design Approaches," *Connecticut Fire Marshall's Annual Seminar*, New Haven, CT, March 1997

"NFPA 101 and Sprinkler Protection," *New England Fire Sprinkler Technical Seminar*, Bethel, ME, March 1997

"NFPA 13 – An Overview of Major Changes," *New England Association of Fire Protection System Designers Monthly Meeting*, Westborough, MA, March 1997

"Review of NFPA 13 Code Changes," *American Society of Plumbing Engineers/Society of Fire Protection Engineers – Empire Chapter Joint Meeting*, Syracuse, NY, December 1996

"An Introduction to Fire Pumps," *NFPA Fall Meeting*, Nashville, TN, November 1996

"Recent NFPA Fire Investigations," *NFPA Fall Meeting*, Nashville, TN, November 1996 (with R. Bielen and Ed Comeau)

"Performance-Based Language in Existing NFPA Codes," *SFPE Design Workshop – Introduction to Performance-Based Design for AHJ's*, Nashville, TN, November 1996

"NFPA 13 Update," *New England Association of Fire Protection System Designers 3rd Biennial Fire Protection Product Show and Seminar*, Randolph, MA, October 1996

"Performance-Based Codes and Standards and Their Effect on Building Design," *International Performance Codes: The Coming Impact on Your Practice*, American Institute for Architects, Vancouver, Canada, October 1996

"A Dual Track Performance / Prescriptive Based Approach for Fire Safety Codes and Standards," *Proceedings - Fire Safety Conference on Performance Based Concepts*, Federal Institute of Technology, Zurich, Switzerland, October, 1996

"Sprinkler and Fire Suppression System Plan Review," *Connecticut Fire Marshall's Association Technical Seminar*, Fairfield, CT, August 1996

"NFPA 750 – NFPA's New Standard on Water Mist Systems, and Changes to the 1996 edition of NFPA 13" *National Fire Sprinkler Association Area 1 Seminar*, Saratoga Springs, NY, July 1996

"Update on Residential Sprinkler Systems," *Fire Marshall's Association of Colorado Annual Conference*, Vail, CO, July 1996

"Creating Performance-Based Documents at the NFPA," *Proceedings of the Fire Risk and Hazard Assessment Symposium*, National Fire Protection Research Foundation, San Francisco, CA, June 1996

"Perspectives on the Transition to Performance-Based Codes – Panel Discussion," *NFPA Annual Meeting*, Boston, MA, May 1996.

"Keeping Pace with Water-Based Technology," *NFPA Annual Meeting*, Boston, MA, May 1996

"NFPA's Perspective on Performance-Based Codes and Standards," *International Meeting of the Confederation of Fire Protection Associations*, Boston, MA, May 1996

"Fire Investigation Report - Warehouse Fire, New Orleans, Louisiana", National Fire Protection Association, March 1996 (with Edward Comeau)

"Supplementing NFPA's Codes and Standards with Performance-Based Provisions," *Proceedings for Interflam '96*, Cambridge, England, March 1996

"NFPA's Objectives in Pursuing Performance-Based Codes and Standards," *Proceedings of the International Conference on Performance-Based Codes and Fire Safety Design Methods*, Society of Fire Protection Engineers, Ottawa, Canada, 1996

"Implementing Emerging Technologies Through Fire Safety Codes and Standards," *Demonstration of Limited Water Supply Fire Suppression Technologies*, National Institute of Standards and Technology, Gaithersburg, MD, March 1996

"An Overview of the 1996 edition of NFPA 13," *American Society of Plumbing Engineers – NYC Chapter Meeting*, New York, NY, February 1996

"NFPA's Future in Performance-Based Codes and Standards", *NFPA Fall Meeting*, Chicago, IL, November 1995

"Performance Based Design in the United States," *Proceedings of the International Conference on Fire Research and Engineering*, Society of Fire Protection Engineers, Orlando, FL, September 1995

"Performance-Based Standards from the NFPA Perspective," *Urban Fire Marshall's Forum*, Quincy, MA, August, 1995

"NFPA Standards Adopted by the Uniform Fire Code," *Western Fire Chiefs / International Fire Code Institute Annual Meeting*, Las Vegas, NV, July 1995

"Performance Based Design in United States," *Pacific Rim Conference of Building Officials,* Darwin, Australia, May 1995

"Fire Case Studies – The Builders Square Fire – Panel Discussion," *NFPA Annual Meeting*, San Francisco, CA, May 1994

"Water Mist Systems for Fire Protection," *Video Fuego Technical Conference*, Badajoz, Spain, May 1994

"Fire Protection Standards for Records, Record Centers and Archives Facilities," *ARMA – Boston Chapter Meeting*, Boston, MA, April 1994 (with R. Ortisi-Best)

"Technical Changes to NFPA's Storage Standards," *NFPA Fall Meeting*, Phoenix, AZ, November 1993