Fire Suppression for Battery Energy Storage Systems on Rolling Stock

WHITE PAPER

Stat-X® Aerosol Fire Suppression

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In the U.S., electric vehicles (EVs) are on track to sell one million units in 2023. And in other sectors in the transportation industry, that success certainly is being recognized. As the world seeks to mitigate the effects of global warming, all users of carbon-based fuels are essentially on notice that they too need to do their part in reducing carbon emissions.

The other sectors in the transportation industry are listening and responding. Lithium-ion battery energy storage systems (BESS) are being deployed in most all forms of transportation. Just about every type of road transport vehicle now has a battery-powered version. BESS- and hybrid-powered vessels are already among us, and the world's first battery-powered passenger aircraft is soon to take off.

Therefore, it only stands to reason that BESS-equipped rolling stock should be included in this transition. And they are. As we will describe below, BESS are currently being widely used in the rolling stock industry. As virtually all trains are ultimately electric powered, it was not a hard jump for the industry to integrate BESS into their propulsion drivers.

BESS on Rolling Stock

BESS are incorporated into rolling stock in a few different ways. Modern rail conveyances are electrically propelled by either drawing electricity directly from overhead lines or the third rail, or, using diesel generators in the locomotive to produce electricity that drives the traction motors. So, adding a BESS was a natural evolution.

Like automobiles, some trains use a hybrid approach. This involves a diesel generator delivering power while the train is fully underway, but relying on battery power when making short moves or traveling at low speed on flat terrain. Commonly referred to as Zero Emission Booster Locomotives (ZEBL), rail authorities are finding this hybrid approach increases performance while reducing carbon emissions and improving fuel efficiency.

BESS are also commonly used for "switcher" locomotives—those used in train yards to move rail cars when assembling or disassembling a trainset. Because they only move rail cars short distances at intermittent intervals, there is less concern about range because the switcher locomotives have time to recharge throughout the shift.

As rolling stock continues to seek more power efficiency, BESS are used to store energy produced by regenerative braking. These systems allow the train's electric traction motors to be used as a generator converting the train's kinetic energy into electricity which is stored in an onboard BESS. That energy can then be used to help power the train during acceleration or on uphill grades.

Incorporating BESS into rolling stock's power mix is good news for the environment, as well as for the bottom lines of rail operators. But, as it is with every form of energy, there is a downside risk associated with BESS.

How BESS Work (and Fail)

Before describing the risks and mitigation solution, it is important to understand how a lithium-ion BESS both works and fails. There are a number of battery options for BESS such as lead acid batteries, but about 90% of the BESS market is comprised of lithium-ion batteries.

Lithium-ion batteries are a Nobel Peace Prize-winning development. Not surprisingly, they are the number one choice for BESS, packing tremendous energy into a relatively compact package.

Lithium-ion batteries contain a positive cathode and a negative anode. During discharge, lithium ions move from the negative anode to the positive cathode, and then back when charging. This mechanism is immersed in an ion-conducting electrolyte (a low-viscosity flammable liquid solvent).

Taken together in a housing or container, the lithium-ion batteries are called "cells." A BESS can contain dozens, hundreds, or even

thousands of cells to store energy. The cells are typically packed in modules held in racks, and the racks are stored in various types and sizes of containers.

When there is a problem with or damage to a lithium-ion BESS, it can fail in a dramatic, fiery fashion. BESS most often fail during charging but are also known to fail while in use. A lithium-ion battery fails in stages which can take place both with astonishing speed or slowly over time. Either way, the end result is typically a deep-seated, hard-to-extinguish fire.

Stage One: The battery is compromised in some way, e.g., manufacturing defect, mechanical damage, electrical fault, etc.

Stage Two: The battery heats up and begins off gassing vaporized electrolyte which is flammable.

Stage Three: Visible smoke is produced signaling the start of a thermal runaway. In a thermal runaway, one heated cell heats up an adjacent cell, which heats up yet another adjacent cell in a chain-reaction fashion.

Stage Four: The smoke and flammable vapors explode into fire which continues to involve additional cells and is very difficult to extinguish.

BESS Fire Hazards

With lithium-ion BESS becoming more prolific by the day, the incidents involving BESS are multiplying as well. Any cursory internet search yields scores of stories and videos involving fires and explosions related to BESS failure. While fire statistics indicate that EVs have a lower fire incident rate than internal combustion engine vehicles, they do happen with increasing frequency, and they often make the news because of their dramatic nature.

Fire departments and regulatory bodies, by necessity, are taking notice. As of June 2023, the Fire Department of New York (FDNY) reports that fires involving lithium-ion batteries have killed more people, year to date, than all of 2021 and 2022 combined. Nine persons have died and 64 have been injured in 92 fires related to lithium-ion batteries.

According to FDNY, E-bikes are the major offender in most of these fires. Currently, the City of New York is introducing additional legislation to curb this ongoing and increasingly deadly trend.

Ask any firefighter who has responded to a lithium-ion battery fire, and they will tell you they do not want to respond to another. Fire departments are rapidly finding out that BESS fires are deep-seated and hard to extinguish. With EVs in particular, firefighters have discovered that it can take thousands of gallons of water to successfully extinguish the fire—compared to a few hundred gallons with vehicles having an internal combustion engine.

In addition to being difficult to distinguish, BESS fires are also inherently dangerous. When the battery cell fails, it produces flammable vapors in large quantities. Since BESS are housed in enclosures, when the enclosure is opened and the vapors mix with air, an explosive mixture can rapidly develop. This exact scenario injured four firefighters in Arizona in 2019 when they were called to a smoking BESS at a local utility.

If you did not watch the short videos earlier, take a moment to do so now. The dramatic videos illustrate just how fast a BESS can fail and create life-threatening circumstances. With the video of the bus fire, it is easy to imagine if the BESS was on a crowded train instead. The people were literally fleeing for their lives, which would have been far more difficult on a moving train—as set out in more detail below. Attempts to extinguish the fire with portable fire extinguishers were futile and the bus was a total loss.

Fires on trains involving batteries are already occurring. Recently, fires involving train batteries have occurred in Chicago[1] and Boston[2]. In another incident, a container full of lithium-ion batteries exploded and burned on a train in downtown Houston[3].

A BESS fire anywhere is a serious incident. But when it takes place aboard a moving train which may be filled with passengers, it is a recipe for disaster. The fire could easily go unnoticed for a period of time, the train could be in a tunnel, or, trains often traverse rural areas far away from assistance. Any of these scenarios, or combinations thereof, could lead to a significant loss of life at worst, or at best, considerable property losses. There are just too many factors working against the train and the subsequent responders.

The only chance for a positive outcome when a train experiences a BESS fire is an onboard fire suppression system that can quickly intervene when the BESS fire is in its initial stages. The problem with this is that fire suppression systems on trains can be problematic to design and install.

Because trains obviously must be mobile, they cannot be connected to a water supply. They also consist of individual cars that may not remain connected for

long. This rules out a centralized system that is piped or otherwise connected to all cars. Plus, they operate in harsh environments. And lastly, not all agents are effective on lithium-ion BESS fires.

What is needed is a self-contained fire suppression system that can stand up to the rigors of rail service while being effective at disrupting a BESS fire. Additionally, the system's agent must be safe. It must not be harmful to humans, the environment, or equipment. These requirements eliminate almost every typical fire suppression agent/system.

The Rolling Stock Fire Suppression Solution

While the list of viable options for rolling stock fire suppression is severely curtailed when considering the requirements listed above, there is one agent and delivery system that positively thrives under these conditions: Stat-X®. If we explore the requirements one by one, it quickly becomes clear that Stat-X is the obvious choice when the requirement is protecting a rolling stock BESS.

Self-Contained Fire Suppression System

Stat-X is supplied in compact, self-contained units. The units can be used individually or connected as a system. The units can be activated by a fire detection system, or the units themselves can function as a heat detector to discharge at a predetermined temperature. There is no piping and no centralized components. Further, the compact units can easily be retrofitted, require minimal space, and are simple to install.

Withstand the Rigors of Rail Service

Stat-X units are especially designed to be installed in hot, dusty, remote areas. They are supplied in a sturdy housing and are not adversely affected by vibration and movement. Once installed, they are virtually maintenance-free and have a long service life. There is no requirement to weigh the cylinders and they do not have the onerous testing and verification requirements found with many of the legacy fire suppression systems.

Effective at Disrupting a BESS Fire

Stat-X has been third-party tested on a lithium-ion BESS fire by the world-renowned testing agencies, DNV and PVEL. The tests demonstrated that Stat-X is effective at suppressing lithium-ion BESS fires, disrupting thermal runaway, and preventing the explosion that so often accompanies these events. The quick action of Stat-X—combined with its ability to remain suspended after discharge—make it the ideal agent for battery fire protection.

Agent Must be Safe

In addition to being so effective, one of the best attributes of Stat-X is the certainty of its safety. The proprietary, potassium-based agent is perfectly safe to use in normally occupied areas. It has zero global-warming potential, zero ozone-depletion potential, and zero atmospheric life. Users can be certain that they will not later be faced with the costly prospect of replacing their fire suppression agent in the future because it has been found to be harmful in some fashion.

Lithium-ion BESS are coming en masse to rolling stock conveyances. With this development comes an entirely new set of fire suppression requirements. While sourcing an effective response to protecting trains from BESS fires may seem like a daunting challenge to some, it need not be. Stat-X is an agent that is proven effective at mitigating BESS fires while not possessing any of the downside health and environmental risks common to many other agents on the market.

SOURCES

[1]https://www.trains.com/trn/news-reviews/news-wire/16-siemens-battery-fire/?utm_source=Mfg.

[2]https://www.cbsnews.com/boston/news/mbta-releases-video-showing-battery-exploding-on-new-orange-line-train/?utm_source=Mfg.

[3]https://www.trains.com/trn/news-reviews/news-wire/28-lithium-ion-batteries-cause-fire-and-explosion-aboard-up-train/?utm_source=Mfg.

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