AIG

Insight

Balanced Risk Engineering Solutions

Managing Lithium-Ion Battery Exposures

The inherent hazards associated with Lithium-Ion batteries and steps to consider in mitigating the risk

Background

Lithium Ion (Li-Ion) batteries have been around since the 1990's. They provide significant energy in a compact footprint (i.e. high energy density) and as such, they have grown in popularity in recent years. Typical uses include the following:

For Commercial Applications

- Consumer electrical/electronic devices such as mobile phones, laptop computers, cameras, etc.
- Consumer sport/recreation devices such as scooters hover boards (self-balancing scooters), electric bicycles, etc.
- Medical devices such as patient monitors, surgical tools, etc.
- Industrial equipment such as cordless power tools, security systems, fire protection systems, etc.
- Automotive applications such as all-electric and hybrid vehicles
- Aircraft Direct Current (DC) systems

For Large Energy Applications

- Multi Mega-Watt (MW) stand-alone Battery Energy Storage Systems (BESS) for Grid support
- High-Rise building battery storage for Energy management
- Wind Turbine Generator (WTG) control systems

Note that this Insight Bulletin applies to Li-Ion batteries. Li-Ion batteries are rechargeable batteries, sometimes referred to as secondary batteries. Li-Ion batteries do not contain free lithium metal and as such, **do not** represent a Class D fire exposure. This bulletin is **not** applicable to Lithium batteries, sometimes called primary batteries, which are non-rechargeable and contain lithium metal presenting a Class D fire exposure.

High density battery energy storage is inherently dangerous whether in large energy or commercial applications. There have been a number of high profile fires and losses associated with Li-Ion batteries such as a large commercial aircraft fire; a Battery Energy Storage System (BESS) warehouse fire; electric vehicle fires; hover board fires; and numerous small consumer application device fires (i.e. computer and cell phones).

The aim of this document is to describe the risks associated with Li-Ion battery technology and provide guidance on how to manage this technology effectively. This bulletin addresses both commercial and large energy installations.

Risk Characteristics

Li-Ion battery risk can be categorized as a chemical, electrical, mechanical or operational issue as defined below:

- Chemical and mechanical risks result from a battery sustaining mechanical damage which causes internal shorting of the battery and can liberate corrosive and flammable electrolyte from the battery. This occurs when the battery is dented, crushed or penetrated. When these batteries are exposed to internal heating from shorts, the closed packaging can cause the battery to fail explosively and burst into pieces ejecting hot ignitable liquid to the surrounding area. This event is similar to a small Boiling Liquid Expanding Vapor Explosion (BLEVE) type event which can result in personnel exposures and fires.
- Electrical risks include issues associated with current flow in the battery, such as short circuits, overcharging, rapid-discharge, battery cell shorting, etc. Battery current flow results in heat which is controlled by a battery thermal management system. Proper battery charging needs to be controlled. Improper over-charging, rapid-discharge, and short circuit events generate unwanted chemical reactions which are more exothermic than normal. In cases where battery cooling is challenged, thermal run-away can occur as organic solvent is expelled from the battery vent resulting in fire, toxic or harmful gas emissions, and ejection of battery internals. Once one battery goes into thermal run-away, it has the potential to produce enough heat to trigger thermal run-aways in adjacent cells. This produces an escalating fire that may prove very difficult to control.

- Operational risks include those that result from the loss of a critical battery function. Examples include loss of emergency systems, failure of high asset value systems and failure of equipment to shutdown properly.

In addition to Li-Ion battery installations, organizations that manufacture, ship, and store Li-Ion batteries are not immune to risk concerns. Thermal run-away events have contributed to a number of large scale fires in facilities that store Li-Ion batteries.

As an emerging technology, Li-Ion batteries are being utilized in advance of the development of relevant product and safety standards. As these standards are clarified, it is possible that new issues will arise governing their operation that may impact users.

Fire risk is a major concern for Li-Ion batteries. These batteries use ignitable liquids as electrolyte within sealed packaging. As an evolving industry, where rigid manufacturing and purity standards are being developed, sometimes foreign matter accidently enters the battery during manufacture which can induce internal battery failure and initiate fire. **Sourcing batteries from reliable manufacturers following rigid quality protocols becomes a significant preventative measure.**

With very high energy density, these batteries are susceptible to externally induced failure by mechanical abuse (crushing or penetrating the battery); electrical abuse (overcharging, rapid discharge, improper charge rate, internal or external short circuit) or by thermal abuse (overheating/fire exposure).

When Li-Ion batteries fail from any of these adverse conditions, the tightly packed batteries also exhibit the characteristic of thermal run-away. The extreme, sudden rates of heat release spread the fault throughout the battery package. This liberates significant heat. Successful control of this condition requires what is described as “copious quantities” of water to absorb the evolved heat and stop the reaction. **The quantity of water required to control thermal runaway exceeds the capability of most typical building sprinkler systems.**

Currently, research is underway into the effectiveness of different fire extinguishing media that can control a fire caused by the ignitable liquid electrolyte, and, also provide sufficient heat absorbing capacity to cool batteries to prevent thermal run-away events. Caution should be exercised regarding claims attributable to particular extinguishing agents targeted at Li-Ion battery hazards. Data from full scale testing should be sought from recognized authorities to substantiate specific product claims.

There is little standardization between differing battery chemistries because the research and development of Li-Ion batteries is moving quickly. This creates an environment where operational safety dictates that a detailed understanding of the operating parameters of the battery being used must be understood. The mixing of battery types, battery manufacturers, Battery Management System (BMS) systems, and charging equipment should be avoided.

Full scale fire testing of Li-Ion batteries has revealed that these batteries contain significant amounts of stored energy. Following a fault, residual energy remains in the battery which can contribute to delayed re-ignition of the batteries after apparent extinguishment. Reliable observation has revealed that re-ignition following initial extinguishment can occur from a few hours to several weeks after an initial fire event. It is for this reason that suspect batteries must be promptly removed and stored remotely following any kind of damage, fault, or failure of batteries, chargers, or BMS.

The issue of stored energy also presents safety challenges and concerns to fire fighters. Sufficient stored electrical energy remains in battery arrays, which presents serious electrical shock exposure to fire fighters restricting the ability of fire fighters to safely use tools and hose streams. Where batteries are used, fire departments should be consulted so that they can create pre-incident plans to address emergencies.

Stranded energy within batteries following a fault or fire presents added issues to manage. First responders cannot leave the equipment in an unsafe condition following an incident. Qualified staff must disconnect the battery from charging and discharging wiring. The battery must be promptly removed to a safe location so a potential re-ignition does not cause any added damage. This must be done with consideration to the hazardous materials and stranded energy which the battery contains. This could require special transport and disposal considerations.

As with most alternative energy equipment, batteries are installed on the owner’s side of the utility meter. Because of this the local power utility will typically not be able to intervene and assist during faults or emergencies. Users of Li-Ion equipment should consider this and make arrangements for access to qualified technical assistance.

Managing the Risk

Li-Ion battery risks can be managed effectively providing personnel understand the battery technology and concerns, have proper electrical protection, control, and alarm systems, have proper fire protection/detection systems, and have proper plans and response protocols. The following list highlights critical issues to consider:

- Battery procurement purchase requirements need to specify that batteries are procured to applicable industry standards and tests. It is important to source batteries from proven, reputable manufacturers with rigid quality programs.
- Electrical design needs to address proper charging, including rate of charge and discharge. BMS design, fuse protection, and local/remote alarms need to be included in the system design.
- All batteries shall be of the same type (i.e.- no mixing and matching of batteries)
- Manufacturer safety instructions and warnings need to be incorporated.
- Batteries and chargers should be installed in non-combustible rooms and combustible material should not be located inside the room.
- Fire detection and protection systems including type of agent, flow rate should be considered in the design.
- Room design should consider adequate ventilation and removal of products of combustion as well as suppression agent runoff/drainage.

- Isolation and segregation of batteries to limit damage in the event of a thermal run-away event should be considered. Consider the need for observation enclosures (i.e. lab-hoods, etc.)
- Installation instructions need to specify and ensure proper storage and transport details to prevent any mechanical damage to the battery. If batteries are misused, mistreated, or defective, batteries shall be removed from service and quarantined remotely.
- Clients should consider the use of a consultant that specializes in Li-Ion battery fire management and suppression
- As Li-Ion batteries have unique considerations, awareness training needs to be conducted regarding the unique hazards associated with these batteries. Operations, maintenance and fire-fighting organizations need to be aware of how to fight a fire associated with thermal run-away of Li-Ion batteries. Training should include issues such as battery fire behavior, emergency response procedures, fire-fighting strategies, personnel protection, etc. Training should identify that Li-Ion battery fires can start at any time, in partial charge states, with or without charger operation. Training should identify any hazards associated with Li-Ion battery fire fumes for personnel and fire-fighter safety.
- Standard Operating Procedures (SOP's) need to be developed to provide guidance for shipping, receiving, handling, daily inspection and use of batteries.
- Emergency response procedures need to be developed to address issues such as toxic by-products during fire, first-responder protocol, Safety Data Sheet (SDS) considerations, type of extinguishing agent, etc.
- Routine Inspection, maintenance, and test intervals should be specified and documented in procedures. This should include batteries, chargers, electrical alarm and fire detection systems. Test and maintenance intervals should be based upon appropriate industry standards and manufacturer instruction manual guidance.
- Thermography should be conducted periodically to verify batteries, battery connections, chargers.
- Legacy maintenance staff may not be familiar with operational and maintenance requirements of Li-Ion batteries. Qualifications and testing procedures should therefore be established for maintenance staff working with Li-Ion batteries.
- Proper chargers designed for the specific battery system should always be used and should not be considered 'interchangeable'.
- Batteries should not be charged when buildings are un-occupied, particularly if protection/detection/alarm systems are not robust and 24 hour/7 day monitoring of alarms is not included in the design.

Conclusion

Li-Ion batteries are being used extensively in both commercial and large energy risks. There are risk-related challenges associated with Li-Ion batteries and solutions are being developed through new standards development, testing procedures, training, etc. As such, careful attention to risk mitigation recommendations is critical to safe use of this technology.

For more Information

For further information, contact your local AIG Global Property insurance engineer. Questions can also be directed to Paul F. Hesler at paul.hesler@aig.com or Walter Groden at walter.groden@aig.com

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