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CHAPTER 555 - VOLUME 1

SURFACE SHIP FIREFIGHTING

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555-8.14 LITHIUM BATTERY FIREFIGHTING PROCEDURE

NOTE

Catastrophic failure of a lithium battery will be referred to as a cook-off in this discussion. Note that the term cook-off is not used in general lithium battery safety literature, but better reflects worst case shipboard casualty conditions.

555-8.14.1 GENERAL. Lithium batteries are being introduced aboard ships to provide high-density energy storage for permanent shipboard equipment such as Uninterrupted Power Supplies (UPS) and mission related equipment such as radios and other portable equipment for embarked forces, onboard weapons and propulsion components for deployed vehicles. Lithium battery designs vary significantly in chemistry, core design and safety features. Common chemistries include but are not limited to: lithium/thionyl chloride, lithium/sulfur dioxide, lithium/vanadium oxide, lithium/carbon monofluoride, lithium ion/cobalt oxide, and lithium/manganese dioxide. A cell is a single independent container and a battery is one or more cells combined to provide power to a designated application. A cell designed to be used only once is called a primary cell and one designed to be recharged and used more than once is called a secondary cell. Charging a primary cell is not authorized and would be very hazardous. Many lithium battery applications consist of a small single cell the size of a coin (or button or pellet) which is integral to larger equipment or weapons systems and pose only a minor hazard if they cook-off. However, the use of much larger lithium batteries consisting of many cells is increasing, such as for primary propulsion energy sources for small vehicles. Cook-off of these larger lithium batteries can pose a serious hazard to personnel and to the ship.

a. Lithium batteries designed specifically for U.S. Naval use are tested and safety certified in accordance with NAVSEAINST 9310.1(series) “NAVAL LITHIUM BATTERY SAFETY PROGRAM” and are described in further detail in NAVSEA Technical Manual S9310-AQ-SAF¬010 “TECHNICAL MANUAL FOR BATTERIES, NAVY LITHIUM SAFETY PROGRAM RESPONSIBILITIES AND PROCEDURES”.

555-8.14.2 Lithium Battery Cook-off.

a. This discussion does not cover non-catastrophic battery leaks and other failures.

b. A lithium battery cook-off poses a much greater hazard than the casualty involving a comparable non-lithium lead-acid or alkaline battery of equal power capacity. Catastrophic failure of a traditional lead-acid or alkaline battery failure is principally an uncontrolled discharge (e.g., short) of its stored electrical energy which generates heat and flames and may release hydrogen gas if cell reversal occurs. A typical lithium battery cook-off not only discharges its stored electrical energy, but as each cell fails it can forcefully eject a pressurized

mist of combustible or flammable electrolyte which can ignite as a large fireball and trigger the cascading cook-off of remaining cells. So the total energy released is much greater that the power rating of the cell.

c. Many lithium battery cells have a pressure-actuated vent to reduce the severity of a cook-off by reducing the throw distance of electrolyte and reducing or eliminating production of lethal fragments. Cook-off of a lithium cell can be initiated by improper charging or overcharging, internal shorting due to penetration or shock (such as dropping), external heating, or internal component failure due to a manufacturing flaw. If internal safety features are ineffective and the temperature increases in the lithium cell, it transitions into a thermal runaway and the resulting internal pressure forcefully vents cell contents into the local atmosphere. Depending on the specific battery chemistry, the venting materials could include a mist or spray of combustible or flammable electrolyte. This electrolyte mist can mix with the surrounding air and ignite into an external fireball, producing a high radiant flux with large quantities of hot, dense, acrid smoke. Cell cook-off can also produce hazardous fragment projectiles.

WARNING

During cook-off of a large lithium cell or battery, the resulting fireball and dense, acidic and toxic smoke can be Immediately Dangerous to Life and Health (IDLH) for unprotected personnel. Depending on the battery chemistry, gaseous and liquid by-products can be caustic to eyes, skin and respiratory track. Breathing protection is required for all personnel within the affected compartment when a lithium battery creates noticeably acrid or visible smoke until the atmosphere is determined to be safe. If very high acid gas concentrations form, they can pose a hazard to protected personnel by skin absorption and damage to protective breathing equipment.

d. Cook-off of a single cell in a multi-cell lithium battery typically results in a quick venting, lasting only a few seconds, of heated electrolyte which ignites and forms a fireball. This cook-off can initiate a violent cascading cook-off of the remaining cells over a period of seconds to minutes. Each cell cook-off typically generates a loud bang or explosion sound. If the battery container is breached, individual cells or fragments may be thrown across the space.

e. Cook-off of lithium batteries generally does not release or expose significant amounts of pure lithium metal because the lithium is bonded or reacted with other materials within the battery.

WARNING

The fireball and heat can pose an immediate threat to adjoining exposed weapons, other lithium battery containers and vital equipment. Large lithium batteries should not be stowed under or adjacent to weapons containing energetic material, other large lithium batteries or vital equipment. Figure 555-8-11 shows the results of a 40-cell lithium ion (Li Ion) battery failure consisting of a cook-off of multiple cells, test battery approximately 30 inches long and 18 inches in diameter, each cell rated for 225 W•h.

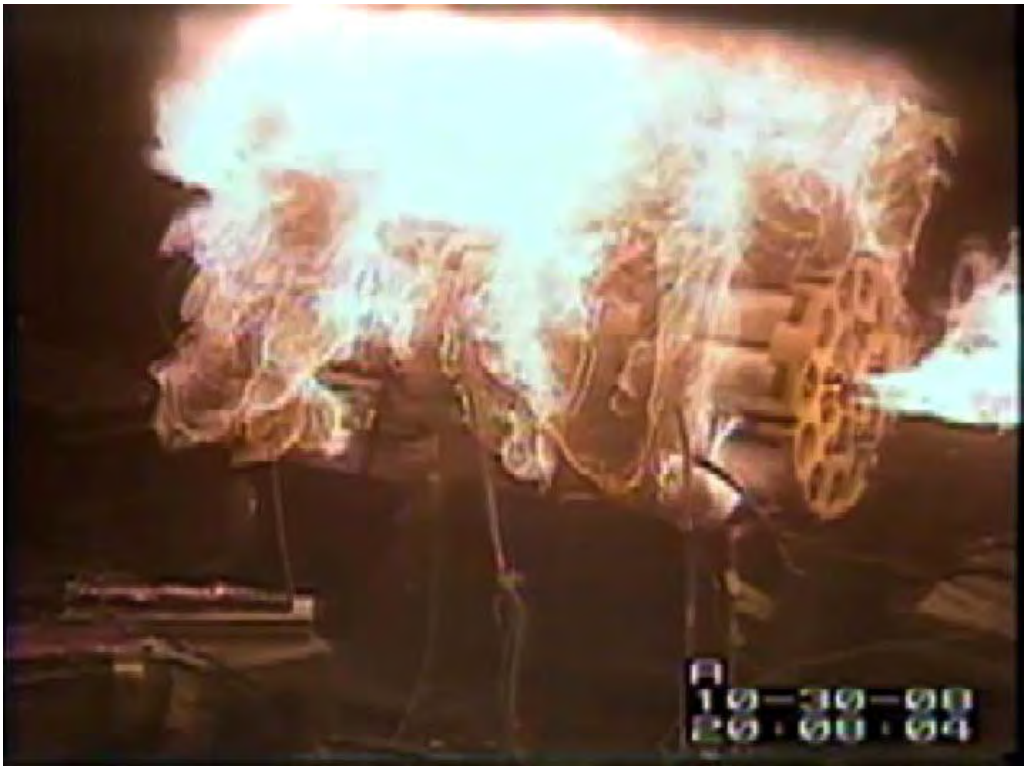

Figure 555-8-11 Example of a Lithium Ion Battery Failure.

WARNING

In addition to fireballs of combustible or flammable electrolyte common to many lithium batteries, Lithium Manganese Dioxide (Li/MnO2) batteries can violently eject molten metal and incandescent ejecta which pose an additional hazard to exposed personnel, see figure 555-8-12 (test battery consisted of three D-cells, total size approx 8.5 inches long and 1.45 inches in diameter, contained in a 3” diameter x 36” long stow).

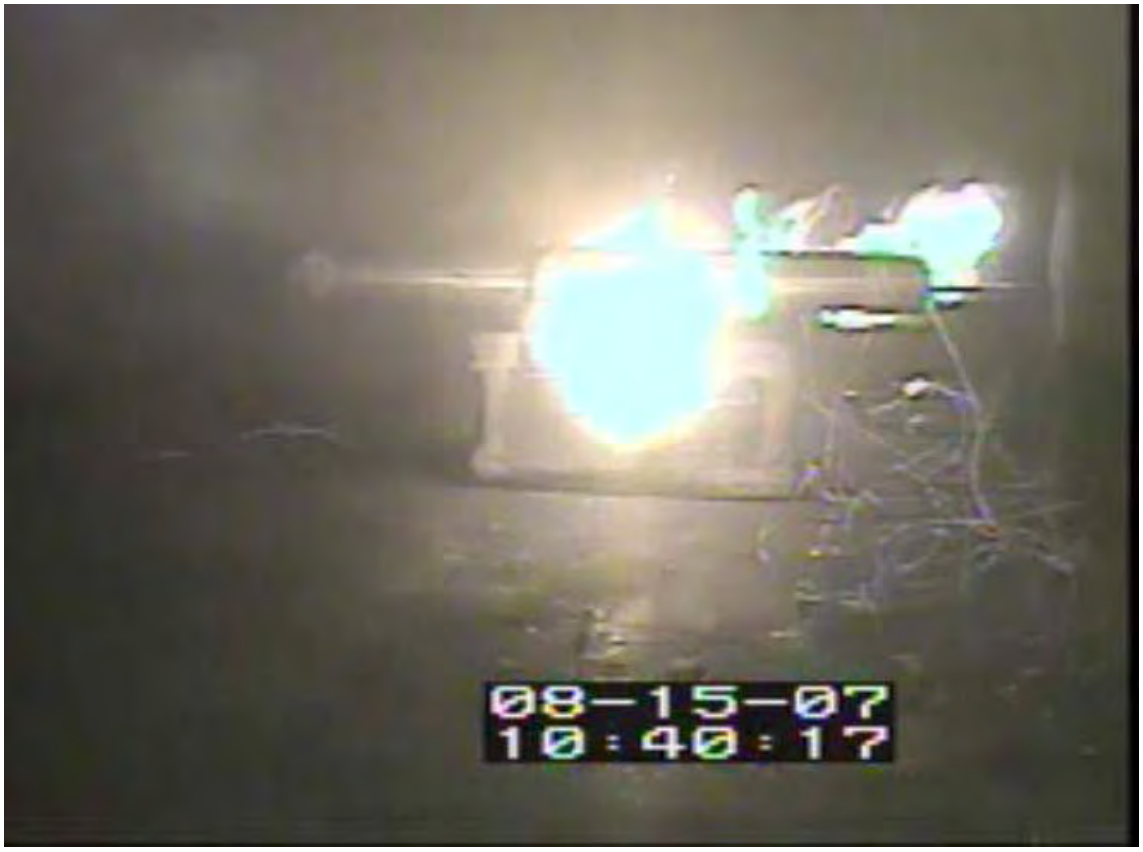

Figure 555-8-12 Example of a Lithium/Manganese Dioxide Battery Failure.

555-8.14.3 Lithium Battery Firefighting Procedure.

555-8.14.3.1 Cook-off of a Single Lithium Cell. Cook-off of a single cell is a short-term event which is principally a toxic gas hazard. Breathing protection is required until the compartment is gas-freed. Insure that the single cell cook-off does not initiate a secondary fire in adjoining material. There is no foolproof universal indicator that a cell is about to cook-off. Rapid changes in voltage or increase in temperature are good indicators of a failing cell, but one may not be able to see/feel those in every battery configuration. A Navy Firefighters' Thermal Imager should be used to look for temperature increases.

555-8.14.3.2 Cook-off of a large Multi-cell Lithium Battery.

1) Cook-off of a single cell in a multi-cell lithium battery results in a few seconds of electrolyte venting, which commonly ignites as a fireball and can begin a violent cascading cook-off of the remaining cells over a period of seconds to minutes, each cell venting its own fireball of electrolyte. A lithium battery cook-off involving more than a few hundred watt-hours (W•h) can produce significant thick, toxic smoke which will fill a compartment in seconds. Breathing equipment and a NFTI will be needed immediately by responding personnel to function in the space.
2) Dry chemical and carbon dioxide extinguishers are generally ineffective and are not recommended. Portable AFFF fire extinguishers may provide some limited cooling, but should not be used if hose reels or hose lines are available, as a significant volume of extinguishing media is usually needed to combat a lithium battery fire and portable AFFF fire extinguishers will only provide limited amounts of media. Commercial Class D fire extinguishers, which are listed on some lithium battery Material Safety Data Sheets (MSDS), are ineffective and are not recommended.
3) Limited testing demonstrates that application of a narrow-angle fog of water or AFFF is the preferred method

to cool the battery, suppress fireballs as they occur, and reduce likelihood cook-off of remaining cells. Water or AFFF is also used to cool exposed hazardous materials or equipment, such as ammunition and explosives (A & E), other batteries and pressurized hydraulic piping and prevent fire spread to nearby combustible material. Maintain an adequate distance for personnel safety from exposure to fireballs and from projected fragments. Utilize personnel wearing SCBAs and FFEs as soon as they are available.

NOTE

There is little free lithium in Navy-approved lithium batteries, so there is no hazard of significant volumes of hydrogen formation due to water reaction with free lithium or risk of a violent lithium-water reaction or fire.

4) Continue to cool the battery for several minutes after the last cell cook-off. Follow-on cell cook-off may occur without warning while the battery is hot. Do not approach until there is confidence that all reactions have stopped.

5) Initiate active desmoking of the affected compartment as soon as practicable during the casualty to remove heat, smoke and toxic gases. Active desmoking can be initiated simultaneously with other actions.

555-8.14.3.3 Protection from an Exposure Fire. A lithium battery can cook-off when heated by an external fire. Apply water or AFFF to keep the battery cool.

555-8.14.3.4 Post-Casualty Clean-Up. The discharge products from lithium battery cook-off vary with the different chemistries. Typical products can include acid gases, oxidizers and other toxic and irritating materials. Appropriate ventilation and personal protective equipment is needed for post-casualty clean-up. Firefighting agent run-off may be caustic. Sensitive electrical and electronic equipment which has been exposed to acidic smoke should be quickly washed and cleaned to halt progressive corrosion damage.

555-8.14.4 Post-casualty clean-up.

1) Battery components and individual cells may be thrown some distance from their original location. Utilize the NFTI to locate remaining cells and determine if they are hot, which indicates they are undergoing an internal short. A remaining cell may undergo internal discharge of many hours after the initial casualty, as indicated by being hot, and could potentially transition to cook-off. Hot cells should be left undisturbed until they cool. If clean up is necessary before remaining cells are cool, hot or damaged cells should be placed in an open metal container by personnel wearing a firefighters' ensemble and SCBA and disposed of overboard or placed in a safe topside location. A closed container could pose a greater shrapnel hazard if the battery cooks off.

2) The discharge products from lithium battery cook-off vary with the different chemistries. Typical products can include acid gases, oxidizers and other toxic and irritating materials. Appropriate ventilation and personal protective equipment is needed for post-casualty clean-up. Firefighting agent run-off may be caustic. Sensitive electrical and electronic equipment which has been exposed to acidic smoke should be quickly washed and cleaned to halt progressive corrosion damage.