Recommendation 18-5:
Guidance on Fighting High-Energy Fires

I. Submission

The recommendations below were submitted by the High-Energy Fire Training Enhancement Workgroup (HEFTE WG) for consideration by the Air Carrier Training Aviation Rulemaking Committee (ACT ARC) at F2F-18. The ACT ARC Steering Committee adopted the recommendations, and they are submitted to the Federal Aviation Administration as ACT ARC Recommendation 18-5.

II. Statement of the Issue

Title 14 of the Code of Federal Regulations (14 CFR) part 121 requires that each certificate holder's training program provide crewmember emergency training that covers a variety of emergency situations. The portions of the regulation relevant to the HEFTE WG are those related to training for emergency situations that may involve fire. Section 121.417 (Crewmember Emergency Training) references the use of portable fire extinguishers, knowledge of different classes of fires, and instruction in responding to in-flight fires in multiple locations and smoke control procedures.

Firefighting training for cabin crewmembers has evolved over the years to address the latest identified hazards. For example, early firefighting training focused on fires started accidentally by passengers extinguishing cigarettes in lavatory trash receptacles. Firefighting training has also focused on responding to electrical fires resulting from malfunctions of galley equipment. Firefighting training later focused on the appropriate response to hidden fires, which may require application of fire extinguishing agents behind interior panels.

More recently, battery fires and the carriage of large quantities of lithium batteries as cargo on flights have become significant concerns across the aviation industry. The risks associated with the carriage of lithium batteries as cargo can be attributed, in part, to non-compliant shippers and/or shipments of batteries. In the cabin, the focus is related to passengers carrying Personal Electronic Devices (PED) powered by lithium batteries. Media coverage has highlighted numerous instances of PED fires, such as laptop batteries exploding and burning. Fire risks associated with PEDs were further highlighted when a major cellular phone manufacturer recalled one of its products due to serious fire and burn hazards.

According to the Federal Aviation Administration (FAA) Air Traffic Organization, part 121 air carriers transport approximately 2.5 million passengers per day in the national airspace system (NAS). Assuming each passenger carries two to three lithium battery-powered PEDs1, this translates to the potential for approximately 2.3 billion lithium battery-powered devices carried in aircraft passenger cabins each year in the NAS. As passenger volumes and the number of PEDs per passenger continue to increase, the probability of encountering an overheat or high-energy fire (HEF) event increases as well.

The FAA has attempted to address emerging fire hazards, such as the transportation of lithium ion (rechargeable) and lithium metal (non-rechargeable) batteries and has provided guidance including firefighting procedures applicable to those products. The FAA has issued multiple publications on the subject of fighting fires to assist certificate holders in minimizing the risks of

[1] For calculation purposes, the HEFTE WG used 2.5 PEDs per person.

in-flight fires. These documents, which include Advisory Circulars (AC), Safety Alerts for Operators (SAFO), and Information for Operators (InFO) (see Attachment 6: Reference Documents) reflect the best information available on the subject at the time of publication. As more devices are brought on board the aircraft, either in the cargo area or the cabin, updates to guidance and training material are needed to keep pace with the changing hazards and risks associated with these devices and products.

Recognizing that enhancing safety requires a proactive approach, the HEFTE WG was formed to recommend updates and/or improvements to current training and guidance associated with the response to HEFs that can occur in the occupied areas of an aircraft. These recommendations primarily address issues related to training for cabin or flightdeck crewmembers in terms of immediate response to HEFs in the cabin or flightdeck. A HEF, especially involving lithium batteries, may appear to be extinguished, but testing has shown that it may re-ignite. Flight deck and cabin crews should work together to continually assess any device(s) that were involved in the HEF, even after extinguishment and containment, to determine if deviations in the flight are warranted.

III. Background

Although there are inherent differences between HEFs and other types of on-board fires in the way they initiate and propagate and the best ways to extinguish them, the general philosophy of firefighting is the same – immediate and aggressive actions are necessary. The general approach to dealing with all types of fires continues to be:

- Locate the source of the fire;
- Fight the fire using the appropriate equipment and methods;
- Move passengers away and/or mitigate their potential negative reactions/interference;
- Coordinate actions with all crewmembers, as applicable;
- Continue to monitor the area of the fire to ensure no re-ignition occurs; and
- Report the event to appropriate management or authorities.

Current FAA Advisory Circular (AC) 120-80A, In-flight Fires, dated December 22, 2014, contains information related to the hazards of lithium battery fires. The AC notes that "rechargeable lithium ion batteries are capable of overheating, leading to a process called thermal runaway, which can cause the sudden release of the contents of the battery as a flaming jet, heavy smoke, unburned hydrocarbons, or in some cases the battery can explode or rocket. Once one cell in a battery pack goes into thermal runaway, it produces enough heat to cause adjacent cells to go into thermal runaway. The resulting fire can flare repeatedly as each cell ruptures and releases its contents."2

The current suggested HEF firefighting strategy is to extinguish any active fire, and then cool the device by dousing it with an appropriate type of liquid.3 The purpose of cooling the device is to prevent additional battery cells from going into thermal runaway. AC 120-80A cautions that injury could result if the device is picked up or moved if it is smoking or burning. The AC further warns that ice should not be used to cool the device.

The issue of containment after an event has generally been left to the discretion of the air carrier. Most air carriers have drafted procedures directing crewmembers to submerge the device in a liquid at some point. With the increase in the incidence of HEF events on board aircraft, and the publicity and safety concerns surrounding HEFs escalating, some air carriers

[2] AC 120-80A, 8.f. Lithium Ion Batteries, p.5.
[3] AC 120-80A, 13.h. What are the Recommended Procedures for Fighting a Lithium Battery Fire?, p.10.

have chosen to equip their aircraft with fire containment kits or bags to facilitate containment. In December 2017, the FAA published Notice 8900.430, which provides specific guidance on responding to HEFs using commercially available containment products. That Notice states there are currently no FAA test standards for containment products, nor an approval process for these products. The recommendations in this document, in part, address containment products. As noted above, the products and procedures used to combat HEFs differ from those used to fight other fires. The HEFTE WG reviewed regulatory requirements and guidance material related to crew training and procedures related to fighting HEFs to help formulate the information in these recommendations. A list of those documents can be found in Attachment 6.

In addition to the document review, the HEFTE WG observed and participated in demonstrations of procedures typically used to fight lithium battery fires in an air carrier aircraft passenger cabin at the FAA William J. Hughes Technical Center ("FAA Tech Center") in Egg Harbor Township, New Jersey on February 21, 2018.[4]

The document review and the demonstrations revealed that since the 2014 issuance of AC 120-80A, the industry has gained significant additional knowledge about fighting HEFs as technologies continue to evolve. To incorporate this new information and to ensure continued safe and effective response to HEFs, the FAA should revise its guidance materials and air carriers should revise their training programs. Specifically, the recommendations detailed in the sections below support updating guidance and training materials to include the following topics:

- Identification of early warning signs of the potential overheat of PEDs and necessary actions to reduce the likelihood of the device going into thermal runaway and causing a fire.
- Methods to extinguish an HEF related to a device that is designed to be waterproof.
- Enhanced crewmember training to provide information on the volatility of HEFs, including the need for additional caution when approaching or opening compartments when it is suspected that a device is in thermal runaway. This includes emphasis on the need to wear appropriate personal protective equipment (PPE) when approaching a potential HEF.
- Information related to the smoke/fumes created by burning HEFs, including volume and toxicity of smoke/fumes and discussion related to appropriate containment or control methods for smoke/fumes.
- Guidance to flightcrews specific to installed or portable Electronic Flight Bags (EFB). Updated guidance is imperative considering that some flightdeck EFBs are mounted, making them difficult to remove or resulting in a unique firefighting challenge for HEFs involving them. Training for this scenario is needed.
- Enhanced crewmember training to include more hands-on training on fighting HEFs.
- Appropriate guidance related to the possible movement of a PED before, during, or after an HEF, including appropriate disposal of the device.
- New performance standards for HEF containment and/or control equipment.

[4] See Attachment 2 for additional details.

IV. and V. Recommendations and Rationale
The ACT ARC recommends the following for FAA consideration:

> ***Recommendation 18-5(a):*** The ACT ARC recommends the FAA update advisory guidance for industry stakeholders related to HEFs, by encouraging and supporting certificate holders to update their firefighting training and procedures related to HEFs.

The HEFTE WG's review of multiple industry documents highlighted the fact that FAA guidance does not contain some information included in the other documents reviewed and is inadequate and outdated.

As an example, there is conflicting guidance on whether to move a PED that is emitting smoke. AC 20-42D and the Supplement to Safety Alert for Operators (SAFO) 09013 advise not to use fire resistant burn bags to isolate burning lithium batteries, and both state "Transferring a burning appliance into a burn bag may be extremely hazardous." FAA Notice 8900.430, addressing "Containment Products Used for Fire Extinguishing", notes the FAA has no objection to the use of the various commercially manufactured containment products, provided the procedures recommended in FAA guidance are followed. Researchers from the FAA Fire Safety Branch (ANG-E21) and aerospace engineers from the Transport Airplane Directorate (TAD) were presented with a series of questions on the use of fire containment products and concluded that containment devices should not be used in an attempt to extinguish a PED fire due to the dangers associated with picking up the PED while the device is in an unstable condition (that is, while the fire is still actively burning or the device appears to be expanding or popping from heat). The rationale for not moving such a device is that a fire in one cell of a battery may not have propagated to other cells. If the device is hot, a continuing potential for propagation exists; therefore, the device should not be moved until thoroughly cooled.

This inconsistency between the guidance from regulatory authorities and product vendors on whether or not to move a device is one example of why the guidance related to training for HEFs should be updated. The ACT ARC recommends updating FAA guidance related to fighting HEFs as a means to improve safety, and in particular, recommends the specific changes to AC 120-80A noted in Attachment 5. Once FAA guidance is updated, air carriers should also update their procedures and training to incorporate the latest information on how HEFs start and propagate, and how best to extinguish them.

While there can be differences in the way an HEF in the flightdeck is observed, approached, and extinguished when compared with an HEF in the cabin, there are some similar basic characteristics that all crewmembers should understand with respect to HEF. The following are factors the FAA and air carriers should consider when developing guidance and policy.

Recognizing the Early Warning Signs of Battery Overheating
Although the focus of most guidance is on fighting HEFs already underway, prevention of initiation of thermal runaway is another key mitigation of HEF risk. If crewmembers are made aware of a possible overheat of a PED, they may be able to prevent a potential/imminent thermal runaway from starting an HEF. HEFs are unique and may not present or progress in the same manner as other fires; therefore, crewmembers should be trained that early intervention can make a difference. In some situations, an HEF can start quickly, while in others, the buildup to an HEF can take longer.

As an example, a device may exhibit signs of overheating prior to thermal runaway. Such overheating can manifest itself in different ways, depending on the device. It is the understanding of the HEFTE WG that many handheld devices are designed to display a heat warning at a specific temperature, as determined by the manufacturer of the device. Other manufacturers have stated that their devices are designed to expand, swell or pop open to vent the inside of the device. This expansion is usually associated with extreme heat prior to thermal runaway.

In addition to the device being hot to the touch, other signs might be present. Signs that a thermal runaway is imminent or that thermal runaway is underway include the following:

- Display alert that device is overheated and must cool down;
- Excessive heat (device feels hot to the touch);
- Discoloration or deformation of display, including rainbow effect;
- Smell of burning plastic;
- Smoke emitting from device;
- Sizzling or hissing sounds;
- Sparks; and
- Loud popping sounds or explosions like fire crackers.

The objective of recognizing early warning signs is to take action to stop the device from overheating, thereby preventing the introduction of smoke, flames, or fire in the aircraft. HEFs can be the result of a variety of initiating factors, including battery malfunction, physical device damage, internal short circuit, improper stowage, improper charging (including use of aftermarket charging hardware) and/or overcharging. Crewmember situational awareness and vigilance is necessary throughout the flight to ensure preparedness for an early intervention if necessary. Passengers may not notify the cabin crew or be aware of a potential problem, so cabin crewmembers need to be prepared to deal with any number of scenarios during any stage of a possible HEF.

In addition, an air carrier that provides EFBs powered by lithium batteries to crewmembers should work with the EFB manufacturer to understand the particular device's design warning features and relay that information as part of the training on the required EFB.

<u>Cooling of Batteries Experiencing Thermal Runaway</u>
Cooling battery cells in an electronic device to limit thermal propagation to adjacent cells is critical, whether prior to thermal runaway or after flames from a runaway have been extinguished. Current training programs recommend cooling the cells by dousing the device with water or other non-alcoholic liquid. Dousing with liquid is intended to ensure that the device is saturated internally, which cools the battery cells. However, as more waterproof and water-resistant devices enter the consumer market, particularly devices without keyboards, such as smartphones and tablets, ensuring that cooling liquids infiltrate the burning device becomes more challenging.

Crewmembers should be aware of potential impediments to cooling battery cells, especially when they are sealed in waterproof or water-resistant devices. During the FAA's field testing of firefighting methods, a chemistry wash bottle with a small nozzle was used to direct water into some of the openings, gaps, or ports on devices undergoing thermal runaway (for example, the headphone jacks and charging ports). The use of such a bottle was found to be effective in allowing firefighting personnel the ability to introduce liquid into the device, such that the battery experiencing runaway could be wetted. While an interesting technique, it is noted the use of a chemistry wash bottle required individual firefighters to be within a potentially unsafe distance of the burning device.

At this time, the ACT ARC is not proposing any changes to emergency firefighting guidance that would recommend use of such small nozzle type devices. The purpose of this information is to share lessons learned regarding impediments to mitigating thermal runaway. As noted above, once thermal runaway begins, the burning device, regardless of whether it is waterproof or water resistant, should swell or pop open, creating gaps. A directed flow of liquid into these gaps may be necessary to ensure that battery cells are wetted sufficiently to halt thermal runaway.

Emphasis on Use of PPE & Volatility of HEF

Given the nature of an HEF, it is important that guidance and air carrier training emphasize the need for crewmembers to exercise caution when approaching an HEF and the importance of using appropriate PPE. During one of the demonstration exercises at the FAA Tech Center, the "flight attendant" firefighter experienced difficulties with respect to some of her firefighting equipment, specifically the proper donning of protective breathing equipment (PBE) and use of firefighting gloves. Because of these difficulties, she attempted to approach the HEF without full protective gear but was stopped by the safety personnel in the demonstration.

After the demonstration, the flight attendant volunteer noted that she had been trained to take immediate and aggressive action when fighting fires. When she experienced difficulty donning her PBE, her primary impression was that she was not fighting the HEF fast enough, especially when she could hear the device "exploding" in the overhead bin. That prevailing thought drove her to attempt to fight the fire without fully considering the hazards of doing so without the protection offered by PPE. The importance of PPE cannot be overemphasized. Upon opening the overhead bin, fire debris was expelled toward her head.[5]

While an unselfish nature and desire to quickly and aggressively attack a fire can be appreciated, it is also concerning because of the volatile and unpredictable nature of HEFs. It is not proposed that crewmembers unnecessarily delay their response to an active fire, but they should be well trained on the hazards associated with HEFs and the need for using PPE.

Since the last revision of AC 120-80 and other FAA guidance material were published, there have been gains in research and knowledge related to battery fires. As the need for more powerful batteries grows, battery technology advances. For example, older nickel-cadmium battery technology is being supplanted by lithium batteries. Lithium batteries can be single or multi-cell batteries and are usually divided into two categories:

- Lithium-metal (non-rechargeable) – often used in calculators and cameras; and
- Lithium-ion/Lithium-polymer (rechargeable) – often used in cell phones, tablets, laptops, electric/hybrid cars, and power banks.

These batteries are considered dangerous goods and can result in a chemical fire, that is, an HEF. In a thermal runaway event, when the energy of a battery cell is released, it can generate large quantities of smoke, flammable gas, heat (in excess of 600°C), fire, explosion, or a spray of flammable electrolytes. The nature of these powerful explosions at the time of thermal runaway needs more focus in FAA guidance and in air carrier training.

As batteries become more powerful, so too can the nature of HEFs, potentially resulting in aircraft structural damage. During one of the FAA Tech Center demonstration exercises, a laptop with a charged six-cell lithium-ion battery was placed in an overhead bin and thermal

[5] See Attachment 2 for additional information on the HEF extinguishment demonstration exercises.

runaway was initiated. As a result of the HEF, the flight attendant volunteer was unable to open the overhead bin door normally and had to force it open with the help of others. This bin opening failure was not expected.

Attachment 3 recounts an actual personal experience of one of the HEFTE WG members involving an on-board fire. In that emergency situation, a fire behind a panel caused the metal screws normally used to open the panel to malfunction. Eventually, the flight attendant had to use a butter knife to pry open the panel to access the fire area. FAA guidance and air carrier training should highlight the possibility of aircraft structural damage and how it may inhibit firefighting.

Smoke and Fume Concerns
The aircraft environment creates unique challenges in both the flightdeck and the cabin related to smoke, fumes, and noxious gases. Differing designs in ventilation systems and distribution of airflow should be considered when addressing the hazards of the build-up of possibly large quantities of smoke and toxic and flammable gases. The presence of smoke, fumes, or gases in either the flightdeck or the cabin can be hazardous, but for different reasons, and both locations need to be evaluated for an effective response.

From an HEF risk perspective, the primary threat on the flightdeck is an EFB experiencing overheat and/or thermal runaway releasing dense smoke or gases. The HEFTE WG notes the use of EFBs has proliferated, but FAA guidance on managing EFB fire events has not kept pace. Current design standards for the flightdeck require that in the event of a detonation of an explosive or incendiary device, means must be provided to limit the entry of smoke, fumes and noxious gases into the flightdeck. (See 14 CFR § 25.795(b)(1).) This regulation, which was intended to ensure flightdeck security, assumes the explosive or incendiary event has occurred in another location on the airplane, as opposed to occurring in the flightdeck, as could happen if a pilot EFB goes into thermal runaway. Lack of visibility and the possibility of being overcome by smoke and fumes are immediate challenges to be addressed by pilots facing a HEF event in the flightdeck. See Recommendation 18-5(c) below for additional concerns related to smoke in the flightdeck.

The prospect of an HEF in the cabin also presents challenges. Smoke and fumes emissions can and should be mitigated by the use of a PBE, but this does not address the flammable nature of such gases. The February 2018 demonstrations at the FAA Tech Center made it evident that a device in thermal runaway can quickly generate sufficient flammable gas in the small space inside an overhead bin to cause an explosion. At an earlier date, the FAA Tech Center performed a test on a galley cart filled with portable in-flight entertainment units in thermal runaway. That test yielded a video of an explosion inside the cart which blew the cart door open with substantial force and flames. It is important that air carrier training programs ensure that crews have the knowledge and skills necessary to cope with dense smoke or explosive aspects of HEFs.

Flightdeck/Cabin Procedures & Safety Management Systems (SMS)
Teamwork is necessary to a successful result when fighting an on-board fire. Differing aircraft configurations demand that individual air carriers develop and implement well-considered procedures based on their specific needs. This is of particular importance if a carrier chooses to include flight attendants in procedures for removal of an EFB or personal PED from the flightdeck due to a battery overheat or thermal runaway event. For example, advising flight attendants as soon as possible about a hot device that needs to be removed from the flightdeck will allow the flight attendants time to retrieve appropriate equipment and be better prepared to

deal with the HEF. Procedures should be transparent, properly interfaced, and trained so that all flightdeck and cabin crewmembers know what to expect from each other.

Recommendations for effective crew communication are addressed in Recommendation 18-5(d). Air Carriers can use their SMS to develop mitigations related to HEFs, including individual and/or team procedures, training, communications, and use of commercially available products. At a minimum, safety risk assessments and mitigations should include potential risks to passengers, crewmembers, and the safety of the flight. Mitigations should be specific and standardized, including education of crewmembers to improve the use of their professional judgment when considering moving an overheating PED.

Training Environment

The environment used to conduct training is an important component in the effectiveness of the instruction provided. Air carriers are encouraged to utilize the most realistic training environment possible within their operations. As an example, the use of a simulator or cabin mockup would generally be preferred to conducting HEF training only in a classroom or in a fire pit. In addition, training equipment that accurately reflects the installed emergency equipment type should also be used whenever possible.

When presenting instruction, carriers should attempt to create a realistic environment. In a simulator or cabin mock-up, this generally can include providing a cabin environment that replicates the confines of an aircraft and location of installed emergency equipment and allows realistic communications and coordination with crewmembers and passengers. Introduction of simulated smoke and/or fire during practical training is also encouraged, if the simulator or cabin mockup has the capability.

Static aircraft can also be effectively utilized in training. Air carriers can develop programs using training equipment as part of practical training on the aircraft, similar to a cabin mockup. When air carriers use static aircraft for training, they should document any temporary removal of live equipment during practical training and ensure required equipment is re-installed and checked before the aircraft is returned to service. Training personnel should have a similar process to document the removal and return of training equipment.

In the absence of simulators, mock-ups, or static devices, air carriers should develop realistic classroom practice. The classroom should be arranged to accurately reflect the air carrier's particular aircraft environment and configuration. The purpose is to attempt to replicate the actual confines of the aircraft environment, which can have an effect on the designated procedure for a particular training event. This can include the utilization of specific aircraft components, such as aircraft seats, overhead bins, and installed equipment where available. In addition, typical items found in the cabin may also be utilized, such as carry-on luggage, service carts, and catering supplies. The classroom should be arranged to simulate the aisle width, seat pitch and any unique features of the aircraft that could affect response to an emergency event. If possible, replicating an overhead bin structure is suggested.

Air carriers may find preliminary training and practice in a classroom environment enhances additional training completed using a cabin mock-up or static device, especially if the physical characteristics of the mock-up or static device prevent trainees from observing other trainees' actions.

Training Techniques

Regardless of the environment used, hands-on exercises and simulated exercises offer a practical experience close to what can be expected in actual occurrences. Therefore, hands-on exercises and simulated exercises should be integrated into HEF training. The training equipment utilized during training should also mimic the safety and emergency equipment used on the operator's aircraft. This will allow the trainee to utilize the actions and forces necessary to operate each item.

If the specific equipment utilized does not have an appropriate "training" device available and/or the air carrier is unable to utilize actual items due to cost or other factors, an air carrier may need to be creative in developing alternatives to mimic these devices. For example, to replicate a vacuum sealed bag, the development of a permanent bag with alternate closing options, such as Velcro, would be preferential to eliminating the action of opening the bag altogether from the simulation. In addition to utilizing realistic training equipment, the equipment should also be mounted or stowed in a manner similar to that found on the aircraft. When not utilizing mock-up or static devices, this can be accomplished by mounting the correct brackets or holder to a suitable surface for attachment and use.

Scenario Training

During the HEFTE WG review of guidance and air carrier training programs, it became evident that there was a need for more extensive HEF training. It is recommended that air carriers provide training on combatting HEFs utilizing simulated exercises representing full context scenarios, where crewmembers apply the operator's procedures and associated crew responsibilities for dealing with the HEF. This best practice recommendation is based on the HEFTE WG observations of and discussion following the February 2018 demonstrations at the FAA Tech Center.[6]

Each of the four demonstrations provided insight into how a flight attendant may need to assess, fight, and mitigate different types and locations of HEF. Therefore, it is recommended that air carriers train on a variety of different events. The specific events or scenarios trained can be derived from recent HEF incidents experienced by the air carrier or other air carriers. If no specific event is noted, it is recommended that, at a minimum, air carriers attempt the following three scenarios:

1. HEF on a tray table;
2. HEF in a seat back pocket; and
3. HEF in an overhead bin.

It is further recommended that the air carrier not utilize the most easily accessible placement for extinguishment or mitigation of the HEF. An air carrier may want to place the device on the tray table of the window seat, as opposed to the aisle seat tray table, or inside a carry-on item. This allows for the simulated exercise to replicate the need to manage passengers and coordinate crew communications during the training event.

On the flightdeck, there are three EFB battery fire-training scenarios that should be addressed, including:

1. High EFB temperature (for example, the EFB shuts down, produces an electrical burning smell, or gets hotter than normal), with no visible smoke;
2. Thermal runaway of the EFB battery with light visible smoke; and
3. Thermal runaway of the EFB battery with visible smoke and flames.

For both the cabin and flightdeck training scenarios, hands-on use of any applicable emergency equipment for fighting the HEF (for example, PBE or smoke goggles) should be used.

[6] See Attachment 2 for additional details.

> ***Recommendation 18-5(b):*** The ACT ARC recommends the FAA publish guidance advising air carriers electing to equip aircraft with HEF containment products to develop procedures for and hands-on training on the use of such equipment.

As noted above, the proliferation of lithium battery powered devices has resulted in an increased risk of thermal runaway. As a result, many air carriers have opted to provision aircraft with non-required items of equipment for fighting and/or containing HEFs. However, there are no specific requirements with respect to training for use of such non-required equipment.

Absent effective training, there is a risk of wasting valuable time that is needed to successfully extinguish and/or contain HEFs due to lack of practical familiarity with equipment intended to assist crews in the firefighting process. Additionally, as there are no regulatory standards for these non-required pieces of equipment,[7] there is uncertainty as to their ability to enhance the firefighting effort. Proper care and due diligence must be utilized in the selection and use of any non-required equipment to ensure it is capable of adequately mitigating the hazard and does not create a hindrance or further hazard to the crew during the firefighting process.

Recognizing the risks of an ineffective response to HEFs, the HEFTE WG reviewed a variety of products that could be used in fighting such fires on aircraft. This discussion included commonly used types of fire extinguishers and smoke hoods and additional items of equipment some air carriers have voluntarily installed on their aircraft. The HEFTE WG collected general information from air carriers regarding their firefighting training, and asked air carriers if they supplied any equipment not required by applicable regulations for their firefighting procedures or as part of their procedures relating to combating or containing HEFs. Multiple air carriers noted that they had begun installing specific HEF containment devices on their aircraft. Others noted that they were in the process of reviewing options from different vendors with the ultimate goal of purchasing some type of containment device for their fleet.

The most common non-required firefighting equipment includes, but is not limited to, the following items:

- Fire Gloves
- Eye Goggles
- Fire Blankets
- Various types of Fire Containment Devices

The HEFTE WG also reviewed information on training provided by air carriers that voluntarily equip their fleets with HEF containment products and found that training for the use of such products varied widely between air carriers. It was specifically noted that many air carriers had trained their crewmembers on use of containment products by issuing bulletins on the product and associated procedures, or by providing a computer-based training (CBT) on the product, rather than conducting hands-on training on the use of the products.

There is a concern that inadequate training may result in a significant disruption of the firefighting process. This concern was validated after witnessing problems with the donning and activation of required equipment during the firefighting demonstration exercises conducted at

[7] This recommendation is limited to issues surrounding air carriers' voluntary installation of containment products or other non-required equipment on aircraft. Recommendations regarding the possible design certification and approval of items of non-required firefighting equipment are contained in Recommendation 18-5(e).

the FAA Tech Center in February 2018. If these problems can occur with mandatory equipment that currently require hands-on drills training, then the same problems can occur with equipment for which hands-on drills training is not required or provided. The same issue exists with respect to non-required items of PPE such as fire gloves, which some air carriers have elected to install in their fleets to assist crew efforts to fight HEFs. The result can be a delay in fighting or properly containing an HEF or overheating device due to a lack of familiarity and practice with use and donning of on-board equipment.

<u>WG Consensus</u>
The elevated risk associated with an HEF in a contained environment and the potential hazard of unexpected disruptions, such as the failure of equipment or structural impediments can factor into any HEF event. Hands-on drills incorporated into scenario-based training (in addition to bulletins, revisions, and CBT) are recommended to increase awareness and recognition of situations that warrant the use of such equipment and problem-solving during such situations.

Training is not "one-size fits all" for air carriers, as they will need to take into consideration differing company policies, equipment, and procedures. Some aspects of training, such as the general steps of fighting a fire, will not vary. As with any emergency response, hands-on training is important for a successful outcome and should include all pieces of non-required and required equipment installed in the air carrier's fleet that could potentially be used to fight and contain HEFs.

<u>Time Factor</u>
Realistic scenario-based training is recommended, including the addition of a realistic time element to reflect the immediate, imminent, or potentially catastrophic nature of the event. Realistic training must also include a variety of training scenarios based on the likelihood of potential HEF scenarios and the applicable air carrier operations.

Factors for individual air carriers to consider when establishing time elements for scenarios include but are not limited to:

- Location of the event (for example, flightdeck or cabin, hidden or in plain sight);
- Type of available installed equipment (for example, some PBEs take longer to don and activate than others, containment products);
- Problem-solving scenarios (for example, malfunction of equipment, devices housed in waterproof cases, or passenger panic will require more time to contain and control the fire); and
- Overheat versus thermal runaway situation.

Current FAA guidance suggests a 15-minute waiting period[8] after extinguishment of flames and smoke before moving a device experiencing thermal runaway or an HEF. Per the guidance, 15 minutes is a pre-determined period after which it is considered reasonable to assume that the fire is "contained" enough that the device may be safely moved to a place where it can be properly "controlled".[9] This presents a unique challenge when determining a "timeline" to be included in training scenarios.

This concept notwithstanding, 15 minutes may <u>not</u> be a suitable timeframe for events which take place in the flightdeck, where unobstructed visibility of the instrument panel and protection from

[8] InFO 17021 and IATA COSBPG, Appendix B.
[9] The terms "control" and "contain" are often used interchangeably because no proper definition for either exists in AC 120-80 (See "Definitions" Section 1.g).

noxious fumes are imperative and of immediate concern for positive control of the aircraft. There is also the concern of the limited space in the flightdeck to deal with an HEF event and the proximity of the device to other electronic systems. Retention of the device in the flight crew compartment could be a greater risk than transfer of the device to the passenger compartment, where flight attendants can more appropriately deal with the hazard. Therefore, pilot training should emphasize the utilization of a common sense approach if a 15-minute waiting period is not appropriate for the situation. Training programs should include a scenario such as this so that the instructor can observe crewmembers exercising good judgment and crew resource management skills, taking reasonable actions, and using PPE.

A 15-minute waiting period may not be practical to incorporate into individual HEF hands-on drills during on-site training; therefore, air carriers may use an alternate method for scenarios. As an example, an instructor may artificially accelerate the timeline for training purposes; i.e., the instructor states 15 minutes has elapsed, when in reality only a short time has passed.

Considerations for Non-Required Fire Gloves

If an air carrier chooses to provide fire gloves, care should be taken in selecting an appropriate product. Fire gloves require dexterity to pick up small, thin devices. Thick firefighter type gloves could prove clumsy for this purpose. The length of the glove should also be no longer than mid-forearm length. It is noted, however, that gloves that go to the elbow on a large person may extend to the shoulder on smaller individuals. The gloves should have a rubber coating on the palm side to enable the wearer to grip devices or objects. The gloves should also meet a National Fire Protection Association (NFPA) or equivalent rating such as European Standard EN407:2004 for flame resistance and/or EN659 for abrasion/resistance and contact heat. As high a temperature resistance as possible is ideal, but at a minimum a temperature resistance of 400ºC is desired.

Regardless of whether an air carrier elects to provision its aircraft with non-required equipment specifically intended to control or contain an HEF, the aircraft should be appropriately equipped to allow crewmembers to safely move a device undergoing an imminent or active thermal runaway. Appropriate equipment could include long-handled tongs or other grabbing devices, or fire gloves.

Recommendation 18-5(c): The ACT ARC recommends the FAA update its advisory guidance for industry stakeholders to include more specific information for flightdeck crewmembers responding to HEFs to maintain aircraft control, including the handling of toxic and flammable fumes emitted by HEFs.

Fire and smoke are immediate safety concerns anywhere in an aircraft but are even greater concerns in the flightdeck where they could cripple vital systems or, in the case of smoke, impede the flightcrew members’ ability to see flight instruments, and, as a result, negatively affect the flightcrew’s ability to maintain aircraft control. In addition, concerns exist with respect to the toxicity and potential irritant properties associated with smoke. Flightcrew members need adequate procedures to maintain aircraft control and effectively clear smoke from the cockpit, including smoke continuously emitting from a device undergoing thermal runaway.

Electronic Flight Bags (EFBs) represent possible sources of HEFs and resultant smoke and fumes in the flightdeck. EFBs have proven to be a valuable part of the modern flightdeck and have reduced pilot workload and enhanced the safety of flight operations. Despite some of the acknowledged concerns of EFBs related to HEFs, it is important to note that this recommendation does not suggest that company-required EFBs should be removed from the flightdeck or that their work-related use in the flightdeck should be stopped.

Testing conducted by the FAA Tech Center has demonstrated that in rare instances, the lithium battery(ies) in EFB's may experience thermal runaway. Testing has also shown that a considerable amount of smoke may be produced during thermal runaway events. These demonstration tests were conducted in a large, well-ventilated test facility. Although the HEFTE WG's area of focus is related to training, the WG members expressed concerns about the quantity of smoke produced especially when contemplating the differences in size of the test facility when compared to an actual flightdeck.

FAA regulations and guidance (for example, AC 25-9A, Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures) set standards for testing the ability to detect smoke, demonstrating that smoke will not penetrate occupied compartments, and demonstrating that smoke in the flightdeck can be readily evacuated. Specific to smoke evacuation in the flightdeck, AC 25-9A indicates that the smoke should be reduced within 3 minutes to ensure no interference with flight operations. AC 25-9A has not been revised since January 1994 and may not adequately reflect current concerns with respect to HEFs and their associated smoke conditions. If too much smoke is generated or if the smoke cannot be adequately removed from the flightdeck, the pilots may be unable to see their flight instruments, inhibiting their ability to safely fly and land the aircraft.

In addition to previously referenced training regarding recognition of potential thermal runaways and dealing with HEFs, flightdeck crewmembers' training should be enhanced to include the critical importance of maintaining aircraft control during smoke, fire, and fume events. In the event the flightdeck cannot be cleared of smoke, additional research into technologies that allow the pilot to maintain adequate visual reference to critical fight instruments and the exterior environment is essential. Proper training for any installed equipment incorporating such a technology (i.e., a Vision Enhancement System) should be developed, along with other best practices for safe operation in a continuous flightdeck smoke environment.

Flightdeck crewmembers fighting HEFs require adequate protection from injuries caused by fire, fragments discharging (shrapnel), or toxic smoke being produced. While private industry has developed fire containment devices, some may still allow for the release of unacceptable amounts of hazardous vapor gas. Safety Data Sheets[10] explain the toxicity of vapor emitted during a PED thermal runaway. Crewmember training and incorporation of safety devices to protect a crewmember/firefighter are needed. Furthermore, once the overheated PED is extinguished or secured in a container, that container should prevent vapor escaping the containment vessel while pressure pulses are safely vented.

With this in mind, the ACT ARC recommends the following to inform and support the FAA's guidance development:

1. The FAA Tech Center should conduct further lithium battery thermal runaway testing in one of its test aircraft or flightdeck mock ups with air-conditioning packs "on" and the manufacturer's procedures followed to determine if a thermal runaway could generate enough smoke to prevent the pilots from safely flying and landing the aircraft. This

[10] Occupational Safety and Health Standards (29 CFR 1910.1200(g)) require that the chemical manufacturer, distributor, or importer provide Safety Data Sheets (SDSs) (formerly MSDSs or Material Safety Data Sheets) for each hazardous chemical to downstream users to communicate information on these hazards.

testing should either be conducted by forcing lithium battery devices to thermal runaway while in the flightdeck or simulating a thermal runaway event through some other means.

2. If this testing determines that there is the potential for sufficient smoke generation, such that the pilot's ability to fly the aircraft is impacted, the FAA should demonstrate/validate that the aircraft flightdeck could be cleared of smoke produced by a lithium battery thermal runaway event in 3 minutes, per AC 25-9A, 12.e.(2).

If the flightdeck cannot be sufficiently cleared of smoke in 3 minutes, vision assurance technology should be implemented to improve pilot visibility. AC 25-9A 12.e.(3) addresses continuous smoke and optional vision enhancement devices. Pilot vision on the flightdeck is critical to safely operating an aircraft. Any mitigation or technology should allow flightcrew members to see the attitude indicator or other primary flight displays and to see outside the airplane for landing.

Recommendation 18-5(d): The ACT ARC recommends the FAA develop advisory guidance for air carrier crewmember training with respect to effective communications related to HEFs.

AC 120-80A, In-Flight Fires, provides guidance on flight attendant actions in the event of an in-flight fire. In particular, it recommends the cabin crew quickly evaluate the situation, gain access to the fire, and attack the fire using all available resources. These efforts require immediate communication and coordination skills, particularly from the cabin to the flightdeck. The HEFTE WG believes greater knowledge and skill-based training curricula should be developed to address this critical component to safety.

Guidance and training should emphasize communication skills among cabin and flight crewmembers and/or able-bodied passengers (ABP). According to research conducted by the FAA Civil Aerospace Medical Institute (CAMI),[11] flight attendants surveyed overwhelmingly felt that the communication and coordination procedures taught during the ground school portion of flight attendant training were generally adequate, but practice of these procedures during training was either inadequate or non-existent. Many persons surveyed stated that more emphasis should be placed on crew communication and coordination with passengers during the skill-based curriculum. Furthermore, CAMI's research indicates that almost 50 percent of problems encountered during in-flight firefighting are directly due to communication and coordination issues. This research highlights a systemic safety problem related to communication.

Communication is a multi-faceted process, the effectiveness of which depends entirely on the crew's training, assertiveness and proficiency. The ACT ARC recommends that the emphasis items suggested in Attachment 4 be included in air carrier training programs, including the ground school classroom curriculum, practice scenarios, and hands-on drills evaluations. Ideally, air carriers will use a combination of the three methods best suited to them to provide cabin crewmembers with the knowledge needed and the opportunity to practice the skills necessary to successfully fight an actual in-flight HEF or to prevent one from occurring. Applying best practices training methods to ensure crewmembers use effective communication and coordination techniques is a key to that success.

[11] FAA Civil Aviation Medical Institute (CAMI) Report AM-17/11, Cabin Crew Fire Training Needs Analysis, June 2017.

As recommended in a report by a previous ACT ARC workgroup, the benefits of a joint CRM type training cannot be understated.[12] FAA Order 8900.1 also "recognizes the value of all activities that encourage communication and coordination between crewmembers. This would include joint CRM training, joint evacuation training…"[13] The ACT ARC recommends improvements to emergency training to include a combined emergency drill scenario, with both pilots and flight attendants, focused on the issue of HEF. As an example, the scenario could reflect a flightdeck EFB HEF event that would require effective communication and immediate action steps, including transitioning the HEF event from the flightdeck to the cabin.

Recommendation 18-5(e): The ACT ARC recommends the FAA undertake future initiatives relating to mitigation of HEF risk, to include developing applicable technical performance standards for HEF containment and/or extinguishing products; review the need for a centralized reporting repository; updating advisory guidance for industry stakeholders on HEF training; and updating testing with respect to smoke concerns.

The HEFTE WG acknowledges that its scope and that of the ACT ARC are limited to developing recommendations to the FAA regarding air carrier training. These limits notwithstanding, the HEFTE WG believes that a comprehensive approach to reducing risks associated with HEF requires actions outside of the training domain. The ACT ARC therefore submits the following recommendations regarding non-training-related FAA actions. Recommendation 18-5(e). also serves the purpose of creating a type of check-list in relation to the multiple recommended tasks applicable to the FAA.

HEF Containment Devices

Multiple air carriers have equipped their aircraft with containment devices for use by crewmembers to store PEDs after thermal runaway or during HEF events. These are non-required pieces of equipment that currently lack any developed standards regarding their manufacture, performance-based testing, or use during an HEF event. As such, air carriers rely largely on product manufacturers' claims of performance and depend on manufacturers for guidance and recommendations regarding training and use of the products. Research is necessary to develop a definitive performance standard for such containment devices to ensure adequate protection. This performance standard should clarify the intent of the usage of these products, as well as the characteristics required for adequate HEF containment, including handling of any toxic or flammable gases that may be emitted from a device.

Therefore, the ACT ARC recommends the FAA take steps toward development of comprehensive performance standards for PED battery fire containment systems. Performance standards should address not only fire containment, but also the potential for release of toxic vapors and the ability to safely protect firefighting crewmembers while using such systems.

Updated Advisory Material

Throughout the document review process it was noted that there was some conflicting guidance on whether to move a PED that is emitting smoke. AC 20-42D and the Supplement to Safety Alert for Operators (SAFO) 09013 advise not to use fire resistant burn bags to isolate burning lithium batteries, and both state "Transferring a burning appliance into a burn bag may be extremely hazardous."

Conflicting guidance is found in FAA Notice 8900.430, addressing "Containment Products Used

[12] ACT ARC Recommendation 16-6, Delivery of Cross-Functional CRM Training, August 3, 2016.

[13] FAA Order 8900.1, Flight Standards Information Management System (FSIMS), Vol. 3, Ch. 23, Para. 3-1792.

for Fire Extinguishing," which notes that the FAA has no objection to the use of the various commercially manufactured containment products, provided the procedures recommended in FAA guidance are followed. Yet some vendors are purporting that their products can be used on burning devices.

Recommendation 18-5(a). provides updated theories about fighting and extinguishing HEFs and provides suggestions related to training environments, techniques and scenarios. To assist the FAA, the training concepts from Recommendation 18-5(a). are reflected in Attachment 5, which includes suggested language for an update to AC 120-80A to include HEF training scenarios, additional equipment, unique characteristics of lithium fires, and recommendations as to best practices for crewmembers and suggested changes for air carriers to incorporate into their training programs. The ACT ARC recommends that the FAA update the other applicable guidance on this topic to reflect the information in Attachment 5.

Handheld Fire Extinguishers

Current FAA guidance on fighting HEFs reference only Halon fire extinguishers, instructing crewmembers to extinguish any open flames with Halon followed by dousing the device with water or any other available non-alcoholic liquid to adequately cool the battery and ensure that no further thermal runaway occurs. Research is needed to provide guidance for the use of other extinguishers (such as water extinguishers) that may be available to the crewmember. If multiple extinguisher types are available to the crewmember, guidance should be provided regarding what the primary or preferred agent for handling an HEF should be under the circumstances. As Halon alternatives are implemented, it is important that research be conducted to ensure that these agents are at least as effective as Halon against HEFs. Additionally, some manufacturers have suggested that their containment products can also extinguish a HEF. While researching Halon alternatives, the FAA should determine whether an assessment of the fire extinguishing capabilities of such products is applicable or necessary. Consideration should include whether use of a containment product for fire extinguishment would require crewmembers to physically move an active HEF into the product. If it is determined that assessment of the extinguishment capability of such products is necessary, the FAA should take the steps necessary to develop performance standards for these products or containers similar to the recommendation above for Halon alternatives.

Training Videos

The ACT ARC recommends the FAA create more up-to-date videos for air carrier training. These training videos should be developed with the objectives of providing trainees a realistic portrayal of the volatility and intensity of HEFs and their associated hazards. These videos should provide crewmembers information as to difficulties that may be encountered during application of firefighting measures during realistic line operations. These scenario-based videos should include at minimum possible locations of HEFs, difficulties in accessing the HEF, and specific guidance on how to approach each of the individual scenarios.

Centralized Repository for HEF Incidents

The HEFTE WG sees a need for a centralized repository for HEF incidents, as incident details could drive future research and training. The FAA should review its internal and external reporting requirements to ensure this information is compiled and shared for use by all aviation stakeholders. The ability to identify trends and analyze data within this centralized repository is critical to ensure its effective implementation.

Smoke Testing and Mitigation in the Flightdeck

A number of questions and concerns remain unresolved with respect to the effects of smoke and fire on the flightdeck and how best to mitigate them. For example, testing at the FAA Tech

Center has demonstrated battery fire smoke is capable of entering the flightdeck even with current certification standards in place. Questions also exist as to whether smoke generated inside the flightdeck can be removed to ensure that the pilot's visualization of controls is not obstructed. Additional research as noted in Recommendation 18-5(c) should be conducted.

Defining Containment and Control

Recommendation 18-5(g). suggests definitions for inclusion in FAA guidance material. While the term "containment" is widely used by vendors (for example, representing that their equipment is intended to "contain" lithium battery fires), the equipment offered by these vendors encompasses a wide variety of products with differing capabilities and levels of effectiveness. While this is helpful guidance, one problem identified by the HEFTE WG is that there appears to be no generally accepted definition of the term "containment" when applied to fighting HEFs on board an aircraft. Fortunately, "containment" and a related term, "control", are well-defined concepts in other contexts, including firefighting in forests and buildings. In the forest fire scenario, there is a clear distinction between contained and controlled:[14]

> "Containment means a line is constructed, mopup is ongoing, and the spread is stopped, at least for now. Control means mopup near the lines is complete and the line is expected to hold."

In addition, with most fires, there are two separate physical properties requiring containment or control: smoke and flames. Many of the available products labeled as "containment" products may in fact actually "control" smoke, flames, or both; what is lacking are standards to test and verify the specific capabilities and levels of effectiveness of these products.

Therefore, the ACT ARC recommends that the FAA develop comprehensive definitions or terminology for "containing" or "controlling" lithium battery HEFs. Additionally, the FAA should develop standards for HEF "containment" equipment that will allow the industry to validate effectiveness in the following four categories, separately or in combination:

- Containment of smoke;
- Containment of flames;
- Control of smoke; and
- Control of flames.

Recommendation 18-5(f): The ACT ARC recommends the FAA issue guidance providing information on identifying items most likely to be involved in HEFs and potential hazard scenarios based on item attributes such as chemical content, size, and form factor.

Cell phones and laptop computers were some of the first lithium ion battery-powered devices to receive wide acceptance by consumers. Concurrently, thermal runaways of laptop batteries began to occur and recalls of batteries began. The problem of thermal runaways and recalls of cell phone and laptop batteries persists today. Many new products have come to market, including digital cameras, "smart" cell phones, tablet computers, mobility aids, e-cigarettes, unmanned aircraft systems (drones), powerbanks, baby strollers, various types of self-balancing personal movement devices (hoverboards, balance wheels), fitness trackers, fidget spinners, smart bags including self-propelled bags that follow the traveler, rideable baggage, heated jackets, e-bikes, e-vehicles, wireless headsets and earbuds, Bluetooth and smart speakers, and

[14] Bill Gabbert, *Contained or Controlled*?, Wildfire Today, April 29, 2009. <https://wildfiretoday.com/2009/04/29/contained-or-controlled/>.

children's sneakers, among other devices. Practically all types of devices have experienced at least one thermal runaway; some of these events have been headline grabbing news.

The chemistry behind the batteries is as varied as the products. Some lithium ion chemistries or form factors may be safer than others, but none are guaranteed not to go in to thermal runaway. As technologies continue to evolve, similar form factors store increasingly larger amounts of potential energy, which increases the potential risk of more dangerous fires. Continued evaluation is critical to keep pace as new technologies become available. For lithium metal and lithium ion thermal runaways, the standard mitigation continues to be to cool the device with non-alcoholic liquids, after first addressing the fire with halon to extinguish flames. Following these initial steps to cool the batteries out of thermal runaway, methods for containment can be applied.

Other energy technologies exist, from fuel cell products to technologies on the horizon such as lithium-sulphur graphene batteries, capacitors, and super capacitors, which will present new challenges to crewmembers in dealing with potential fires. As such, guidance to deal with these threats will continue to evolve.

In addition to identifying HEF risks associated with portable electronic devices, the updated guidance should note that some aircraft designs include permanently-installed batteries in varying locations. While these installations should be subject to strict design, manufacturing, maintenance, and inspection standards, there is still an inherent risk that both old and new generations of these high-energy batteries could cause an HEF on board. While crewmembers and other firefighters should be aware of the locations of these devices, they should also be aware that identifying the source of some of these hidden fires may be more difficult than originally anticipated when AC 120-80 was amended to include the concept of hidden fires. One example of the difficulty in finding an installed battery fire is the July 12, 2013, Ethiopian Airlines Boeing 787 accident in which the five lithium-metal battery cells in the emergency locator transmitter (ELT) went into thermal runaway. The accident occurred on the ground at London Heathrow Airport. Airport Rescue and Fire Fighting Service (RFFS) firefighters had difficulty finding the fire as the ELT was installed in the attic area above the passenger cabin ceiling, mounted on a bracket between two fuselage frames, surrounded by insulation blankets. Extinguishing the flames required the removal of ceiling panels.

Recommendation 18-5gf): The ACT ARC recommends the FAA take steps to standardize terms and definitions related to HEFs used in FAA guidance material and air carrier manuals.

The ACT ARC recommends the FAA adopt standardized terminology for items, actions, and conditions relating to HEFs, potential HEFs, and related mitigations, to facilitate meaningful discussion and development of best practices and guidance. The ACT ARC suggests the following definitions as initial steps toward development of an HEF glossary:

<u>High Energy Fire (HEF)</u>
High Energy Fire involves combustion of dangerous goods containing chemicals with a high energy density, such as is available in lithium batteries. HEFs may occur when such batteries experience thermal runaway. An HEF can be explosive, exceedingly hot, and can result in large volumes of toxic or flammable gases. After extinguishment, the device may require a period of time to cool prior to containment to minimize the possibility of re-ignition.

Portable Electronic Device (PED)
Portable Electronic Device means any piece of lightweight, battery-powered equipment. PEDs are typically consumer-owned and operated, and are capable of communications, data processing, and/or utility. Examples range from handheld, lightweight devices such as tablets, e-readers, and smartphones, to small devices such as MP3 players and electronic toys.

Thermal Runaway
Thermal Runaway refers to a situation where the chemical condition and the temperature within the battery cell are such that heat is generated faster than it can be dissipated, resulting in a chain reaction where the rising cell temperature accelerates the chemical reaction in the battery and destroys it. The thermal runaway event is often associated with the release of significant quantities of smoke, gases, and heat (in excess of 600^{0}C), as well as the potential for resulting fire, explosion, and/or the release of flammable electrolyte material as well as miscellaneous shrapnel from the device.

Containment
The term "containment" is widely used by vendors that market equipment intended to "contain" lithium battery fires. This equipment encompasses a wide variety of products with differing capabilities and levels of effectiveness. A number of vendors market fire "containment" kits/bags that may consist of a bag, sleeve, or box, sold with or without additional tools such as fire gloves, pry bars, and face protection/shields. These containment products are generally for use after the fire has been extinguished. Vendors may state in their advertising and marketing videos that their products are "FAA certified", "successfully tested by the FAA" or "meet FAA standards". However, the Fire Safety Branch of the FAA Tech Center and the Aircraft Certification Service emphasize that there are currently no FAA test standards for these products, nor is there a mechanism in place for the approval of these products. The FAA provides no stated objection to the use of the various commercially manufactured products provided the procedures recommended in FAA guidance, such as InFO 17021, are followed.

VI. Scope of Work and Background

ACT ARC Recommendation 18-5 addresses item 1 in the HEFTE WG Scope of Work, which responds to ACT ARC Initiative #30:

HEFTE WG Scope of Work:

1. Recommend updates/improvements to current training and guidance around response to high-energy (HEF) fires that can occur in the occupied areas of the aircraft.
    a. Update the FAA guidance related to HEFs. Support operators updating their firefighting training and procedures related to HEFs,
    b. Recommendations for training for air carriers electing to equip with HEF containment products and procedures,
    c. Recommendations specific to flightcrew response to HEF to maintain aircraft control while responding to HEF, including the handling of toxic and flammable fumes emitted by HEF,
    d. Recommendations for applying effective communications related to HEFs,
    e. Recommendations for updating FAA guidance (Training, products, combine/consolidate documents, development of testing procedures)
    f. Recommendations on providing information on identifying items most likely to be involved in HEFs and potential hazard scenarios based on item attributes such as chemical content, size, and form factor,
    g. Recommendations for standardizing terms and definitions in FAA guidance material and air carrier manuals.

ACT ARC Initiatives:

- Initiative #30: Assess the need for comprehensive revisions and reorganization of flight attendant qualification and training requirements and standards.

Attachment 1: Suggested HEF Firefighting Practices and Procedures

Based on its document review the ACT ARC recommends the following as best practices to enhance crewmember firefighting training, subject to continuous review and improvement through an established Safety Management System (SMS) or equivalent process. Air carriers should compare these best practices to current training relating to HEFs. If sections are missing, it is recommended that the air carrier adopt these best practices in its training. The basic firefighting principles are:

- FIND AND IDENTIFY type and source of fire or smoke.
- EXTINGUISH fire immediately and aggressively utilizing PPE.
- COMMUNICATE with the flight crew.
- OBTAIN additional firefighting supplies.
- WATCH for re-ignition. (Add: containment and isolation for suspected lithium battery fires).
- PASSENGER MANAGEMENT - Relocate away from fire/heat, instruct to protect nose and mouth with tissues, utilize as ABP.

1. Assess the Situation

- Failing or failed device location (specific procedures may vary somewhat by location)
    - Cabin: aisle, under the seat, tray table, bin, seatback pocket, lavatory, in a bag, in a seat, etc.
    - Flightdeck: mounted, stowed, etc.
- Type of device (laptop, tablet, smartphone, powerbank, EFB, etc.)
- Device status (hot, smoking, burning, charging, etc.)
- Device orientation (vertical, horizontal)
- How passengers, other crew, and ABP are responding

2. Fight the Fire

- Clear occupants from the area around the device and reseat as necessary; recognize the potential for an emergency landing.
- Don PPE (gloves, PBE, etc.).
- Obtain appropriate firefighting equipment (halon or water extinguisher, or other acceptable extinguishing product).
- Approach device with appropriate caution and only as closely as necessary to effectively extinguish flames and mitigate smoke generation.
- After extinguishing the device, douse the device with water or other non-alcoholic liquid. Note: Liquid could turn to steam when dousing a hot battery with water; multiple applications of liquid may be necessary.
- Ensure, as far as possible, that water used to cool the batteries is entering the interior of the device.

Move the device into water bath (or equivalent) only if deemed necessary to ensure no re-ignition of fire, observing the following considerations.

- The device should only be moved once it has cooled down and there is no evidence of smoke, heat, debris, or shards of material separating from the device, or there is a reduction in the crackling or hissing sound.
- The waiting period for a device to cool enough to handle (while wearing appropriate PPE) may vary based on the device and its size and the situation.
- Most guidance suggests letting the device rest and cool for approximately 15 minutes before moving the device.
- Cooling or movement times could vary, especially for a device in the flightdeck. Retention of the device in the flight crew compartment for a full 15 minutes could present

a greater risk than moving the device to the passenger compartment where flight attendants may more readily be able to deal with the situation.
- The phase of flight should be considered when determining when or if to move the device.
- MANDATORY: Use protective equipment (gloves, PBE).

3. Precautions – Maintain a safe distance from the device while monitoring cool down.
- A safe distance would be the same as fighting other on-board fires.
- Continue to use PBE to minimize risk of injury from unexpected thermal runaway/explosion.

4. Location of the PED fire onboard – Where to move it?
- Is the device easily accessible in the cabin – overhead bin, under passenger seat, electrically adjustable seats, or is the passenger using the device?
- Is the device visible or "inside" a bag, etc.? What is the suggested response when the item is not visible?

a) Overhead bin: Smoke coming from an overhead bin and device not visible or easily accessible
- Exercise caution/conduct a tactile search of the closed bin area to determine the temperature and presence of fire (possible flashfire).
- If possible, remove other baggage from the bin to identify and access the affected baggage/item.
- It is NOT recommended to open the affected baggage when there is any indication of smoke or flames.
- Fight the fire using lithium battery procedures.
- Move the device as appropriate after a safe time has elapsed.
- Isolate the device.
- Monitor the device and the surrounding area for the remainder of the flight.

b) Under passenger seat or in an electronically adjustable seat: Smoke or fire visible indications
- Fight the fire using lithium battery procedures.
- Move the device as appropriate after a safe time has elapsed.
- Isolate the device.
- Monitor the device and the surrounding area for the remainder of the flight.

5. Flightdeck event – May be critical to move the device into the cabin immediately.
- Follow Assess steps above.
- Is smoke generation affecting visibility?
- If the device is on fire – pilot to fight the fire with the use of firefighting equipment in the flightdeck.
- If the device is not on fire or the fire is extinguished – remove the device from the flightdeck, using protective equipment and following communication protocols to alert flight attendants
- Flight attendant to:
  - Fight the fire using lithium battery procedures.
  - Move the device as appropriate after a safe time has elapsed.
  - Isolate the device.
  - Monitor the device and the surrounding area for the remainder of the flight.

- *If the device is mounted, are there specific steps to remove from mounting stowage?*
    - Consideration for what protective equipment is available for the pilots.

- *Are there any security considerations relevant to opening the flightdeck door?*
    - Air operator security procedures would need to be considered based on the threat of a fire in the flightdeck (Captain's authority overrides).

a) Specific firefighting steps like dousing the device with liquids should be done in conjunction with aircraft manufacturer's suggestions for liquid dousing relative to flightdeck instrumentation.

- Dousing the device is better than an unchecked flightdeck fire. Are there different responses depending on the fire type, location, intensity?
- Air operators would need to determine if it is safer to douse the device in the flightdeck and put out the fire

b) Procedures/responsibilities after landing for removal of the device and documentation of the incident response.

- Apply air operator's post-incident process.
- Report to regulatory authorities to ensure industry-wide continuous improvement of procedures, practices, and equipment.

NOTE: Recommend that targeted crew training programs encompass all possible PED fire location scenarios, as noted above.

Attachment 2: Overview Lithium Battery Firefighting Demonstration

On February 21, 2018, the High-Energy Fire Training Enhancement Workgroup (HEFTE WG) observed and participated in demonstrations of procedures typically used to fight lithium battery fires in a simulated air carrier aircraft passenger cabin at the William J. Hughes Technical Center ("FAA Tech Center") in Egg Harbor Township, New Jersey.

In the first three demonstrations, FAA Tech Center personnel induced a thermal runaway of a lithium ion battery installed in a laptop computer by use of a heating film. The laptop batteries each contained six fully charged Li-ion cells. HEFTE WG subject matter expert D.K. Deaderick, FAA Flight Standards Service, Air Carrier Operations Branch, performed firefighting procedures consisting of deployment of a halon fire extinguisher to extinguish any flames, followed by dousing the device with drinking water contained in 0.5-liter plastic bottles.

Although not all air carriers supply protective gloves, they were provided for this demonstration for safety reasons. Also, FAA and International Civil Aviation Organization procedures suggest that any containment technique, in this case the bucket of water, should be utilized after cooling the device with water, nonflammable liquid or an aqueous extinguishing agent for at least 15 minutes. In the demonstrations, the devices were moved immediately after dousing with water, not waiting the suggested 15 minutes.

In the fourth demonstration, FAA Tech Center personnel induced a thermal runaway of lithium polymer battery cells grouped together, and used the same procedures as above (halon extinguisher followed by dousing with water). That grouping contained 10 polymer cells of 2500 mAh each.

<u>Demonstration 1 – Laptop on Tray Table</u>

In this demonstration, the laptop was placed on a passenger tray table. Upon thermal runaway, the laptop burst into flames. Ms. Deaderick donned her PBE and extinguished the flames using a halon extinguisher. She then doused the laptop with six bottles of water (0.5 liters each), and after donning protective gloves, picked up the laptop and submerged it in a bucket of water.

Notes/unanticipated complications:

- Ms. Deaderick experienced some difficulty in deploying the PBE. Specifically, she found it difficult to pull the two oxygen cylinders apart to start oxygen flow.
- Protective gloves were not used during the pouring of water on the device even though Ms. Deaderick's hand was in close proximity to the device, but were used when moving the device to the bucket of water.

Demonstration 2 – Laptop in Overhead Bin

In this demonstration, the laptop was placed in an overhead bin and the door was closed. No other items were in the overhead bin with the laptop. Once thermal runaway became apparent, Ms. Deaderick donned her PBE and protective gloves, deployed the halon extinguisher, doused the laptop with six bottles of water, removed it from the overhead bin, and submerged it in a bucket of water.

Notes/unanticipated complications:

- Ms. Deaderick again experienced difficulty deploying the PBE. She attempted to approach the bin to fight the fire without the smoke hood on but was held back by the safety personnel. This is a concern because upon opening the overhead bin fire debris was expelled toward her head.
- The thermal runaway and/or the resulting fire damaged the overhead bin, such that Ms. Deaderick was unable to open it to gain access to the laptop. FAA Tech Center personnel attempted to assist Ms. Deaderick, and, ultimately, broke the door off the overhead bin at the hinge points.
- Ms. Deaderick was unable to remove the pin from the halon extinguisher while wearing protective gloves, and removed one to do so. She subsequently redonned the glove to continue the procedure.
- Ms. Deaderick reported some difficulty opening the bottles of water while wearing protective gloves.
- Due to the height of the overhead bin, Ms. Deaderick's ability to see into the bin was limited.

Demonstration 3 – Laptop in Seatback Pocket

In this demonstration, the laptop was placed in a seatback pocket. Upon thermal runaway, the laptop caught fire. The force of the runaway also projected flaming matter onto the passenger dummy in the seat immediately aft of the laptop, igniting its clothing. Ms. Deaderick donned her PBE and extinguished the flames on the laptop and the dummy. She then doused the laptop with six bottles of water, donned protective gloves, removed the laptop from the seatback pocket, and placed it in a bucket of water.

Notes/unanticipated complications:

- Ms. Deaderick again experienced some difficulty deploying the PBE, but had greater success than in previous attempts.
- Ms. Deaderick did not wear gloves to deploy the halon extinguisher or douse the laptop with water.

Demonstration 4 – Lithium Polymer Cells in Overhead Bin

In this demonstration, ten lithium polymer battery cells (2500 mAh each) bound together were placed in the overhead bin, and thermal runaway was induced using a heating film. Upon thermal runaway, FAA Tech Center personnel wearing protective firefighting gear, including gloves and portable oxygen, extinguished the flames using a halon extinguisher, and doused the battery cells with six bottles of water. These actions failed to completely halt the thermal runaway. The FAA Tech Center personnel then removed the battery cells from the overhead bin and submerged them in a bucket of water.

Notes/unanticipated complications:

- Due to the earlier damage to the overhead bin (see Demonstration 2), the bin door was not closed during the demonstration.
- The battery cells continued to produce significant amounts of smoke even after the flames were extinguished. Additionally, pouring water on the cells created clouds of water vapor. The combined effect of the smoke and water vapor impeded the ability of the FAA Tech Center personnel to see into the overhead bin.
- Thermal runaway continued to propagate to additional battery cells even after the flames had been extinguished and the cells had been doused with water.

Attachment 3: Actual Situation Resulting in Delay of Access to Fire

Aircraft: DC8-62 Combi
Occurrence Time & Location: Central Indian Ocean 2 hours into flight
Location on Aircraft: Aft right-side galley above service/entry door
Type fire: Class C involving relay and circuit breaker panel

Situation: About two hours into the flight, a loud electrical-type explosion occurred behind two removable interior panels housing relay bundle and galley/lavatory circuit breakers. The explosion was accompanied by bright blue light that came out through the seams of the panel door, followed immediately by an orange flame that could be seen through the normal seam opening between the two panel doors. The panel doors were secured by thumb screws. Company SOPs included pre-flight checks to ensure proper operation and opening of the panel door over the circuit breakers in case a circuit breaker needed to be pulled for something like an oven fire, for example.

After the explosion, the metal screws became very hot, and the initial attempt to open the panel was unsuccessful. What may have delayed the process was the expansion of material in the panel and metal screw due to the heat from the initial explosion and brief flames afterward. This made it very challenging to open using the normal push-and-twist method, so the panel had to be forced open with the aid of a butter knife.

For comparison sake, although it was loud and bright enough to light up a dimly lit cabin, it was brief, and did not seem to have as much force behind it as the ones witnessed during the overhead bin tests in Atlantic City.

Disclaimer: This is a HEFTE WG member's personal recollection of the event, which happened close to two decades ago.

Attachment 4: Training Considerations for Effective Communication

Communication/Coordination training should emphasize clear, concise exchange of information and updates between the flightdeck crew and flight attendants. It is important to exchange all essential information to ensure that all crewmembers make well-informed decisions. Air carrier training should consider and address the following:

A. Logistics

Familiarity with aircraft configuration, and numbers and locations of personnel and firefighting and communications equipment for each aircraft in a carrier's fleet

- Appropriate communication methods may differ for wide-bodied, narrow-bodied and Combi aircraft.

Consider the number of flight attendants available

- Multiple Flight Attendant (FA) Operations
- Single FA Operations

Passenger count and flight demographics

- Communication/coordination may be more challenging with a full passenger count
- Clear language and assertive instructions are essential.
- Improvised communication techniques, such as use of Public Address (PA) system for management of situation, may be necessary.
- Situational awareness regarding passengers during all phases of flight. An overnight flight versus a day flight may result in less or more use of PEDs and/or charging during a flight.

B. Location

Flightdeck Event

- Appropriate communication methods may differ for wide-bodied, narrow-bodied and Combi aircraft.
- Communication/coordination with cabin for removal of device utilizing standard operating procedures (requires synergy in flightdeck/cabin procedure interface for safe "hand-off" of device to the cabin crew)
- Device overheat/thermal runaway procedures will differ.

Cabin Compartment Event

- Delegation of duties (fire-fighter, communicator, and runner)
- Communication with flightdeck, passengers, able-bodied helpers and other flight attendants
- Concise event details relayed (location, source, size, crew actions, passenger actions). An HEF source can be aircraft installed equipment or passenger PED.
- Importance of communication throughout event and post-event procedures, including the condition of the cabin, and the condition of crew and passengers

Aircraft Equipment Event

- Aircraft-specific, knowledge-based training on where hidden fires are more likely to occur, and mandatory use of standard verbiage for identification of these areas (cheek area, tunnel area, overhead area, etc.)
- Expectations of cabin crew faced with hidden HEF event

- Location of accessible installed aircraft equipment powered by lithium batteries (for example, automated external defibrillator, ELT)
- Communication may originate from flightdeck or cabin

C. Overcoming Challenges to Communication

Different situations may result in different communication challenges including, but not limited to, degraded communication for crewmembers wearing PPE, time constraints, and multi-tasking in a limited crew environment. These challenges should be mitigated to ensure effective and timely communication.

Best communication method

- May depend on size of cabin, location of device and/or availability of crew and helpers
- Communication equipment varies among carriers
- Interphone, Satcom, PA, Verbal
- Alternate communications in the event of system failure addressed in pre-flight briefing
- The importance of procedural interface between flightdeck and cabin, and the use of standard terminology to reduce confusion and misunderstanding

Assertive passenger management techniques

- Congestion in the aisle or area of the fire
- Negative panic situation
- Utilizing passengers willing and able to assist (ABPs)
- Choosing and briefing ABPs prior to departure in single-FA operations

Communicating effectively while using Protective Breathing Equipment (PBE)

Flight attendants should train on communicating over the interphone to the flightdeck or on the PA system to the passengers while wearing PBE or other PPE

Overheated device versus thermal runaway

- Communication with passenger as to type of device, composition of battery, immediate removal of power if applicable
- Turning device off and remaining off for flight duration, and directing passenger to keep device visible and monitor if overheat situation.
- Communicating all information gathered about device to flightdeck

D. Post-Event Communication/Coordination

During Flight

- Preparation for emergency or normal landing
- Keep the flightdeck informed on device monitoring, state of cabin and passengers.

On the Ground

- Follow Operator procedures for coordination of device (hazardous materials) removal upon arrival
- Follow Operator procedures for reporting of in-flight or on-the-ground HEF

E. Pre-Departure Communication

On the Ground

- Announcements in the terminal or in the cabin prior to flight should be expanded to educate and raise awareness of passengers around PED fires
- Communication with passengers via PA announcement for overheated device awareness and procedure to contact cabin crew immediately
- Other applicable PA announcements regarding crushed PEDs
- Pre-Flight Safety Briefings to include review of procedure for device removal from flightdeck

Attachment 5: Recommendations for FAA Guidance Update

The ACT ARC recommends the FAA update advisory guidance for industry stakeholders related to HEFs (Advisory Circular (AC) 120-80A, *In-Flight Fires*) to include the creation of a new, standalone Section 14 containing the following information:

14. Procedures for Fighting a High-Energy Fire (HEF)

The use of PEDs powered by lithium batteries by the public is increasing. According to the Federal Aviation Administration (FAA) Air Traffic Organization, part 121 air carriers transport approximately 2.5 million passengers per day in the national airspace system (NAS). Assuming that each passenger carries two to three lithium battery-powered PEDs, potentially 2.3 billion lithium ion battery-powered devices can enter aircraft passenger cabins every year in the NAS. As passenger volumes and PEDS per passenger continue to increase, the probability of encountering an overheat or HEF event increases as well.

Crewmembers should exercise extreme caution when approaching a lithium battery-powered PED that is overheating, smoking, deforming, or is on fire. The following procedures are recommended for mitigating the risks of HEFs on board an aircraft. There are three basic concepts that should be included in an air carrier's policy and training.

- **Recognizing** overheat indicators and actions necessary to prevent a device from starting an HEF or thermal runaway;
- **Extinguishing** the HEF, with the appropriate extinguisher; and
- **Cooling** and **containing** procedures to prevent re-ignition, spread of flames, and ongoing generation of smoke.

a. Recognizing the Early Warning Signs of PED Overheating

Passenger or crewmember early recognition of a possible PED battery overheat situation may prevent a potential/imminent thermal runaway from starting an HEF. The objective is to stop the device from overheating, thereby preventing the build-up of smoke and open flames. HEFs are unique and may not present or progress in the same manner as other fires. In some situations, an HEF can start quickly; in other situations, the buildup to an HEF can be gradual.

Devices prior to thermal runaway may show signs of overheating. These signs, depending on the device, may include preprogrammed alerts, discoloration of screens, smoking, expanding or swelling, or simply being hot to the touch. Some air carrier procedures may suggest that an overheating device be contained and monitored to mitigate the start of a HEF.

It may not be possible to visually identify the item (the source of the fire) right away, especially if the fire has started in a seat pocket or inside a carry-on bag, or is generally not readily accessible. There have also been reported incidents of inadvertent crushing or damage of PEDs. Small PEDs (for example, smartphones, tablets, e-readers or MP3 players) can inadvertently slip or drop between the mechanical parts of an electrically adjustable seat and be crushed or damaged, resulting in potential HEF.

In all of these cases, firefighting procedures should be applied as a first step.

b. Extinguishing the HEF

The steps to extinguish an HEF are similar to fighting other fires in the aircraft cabin; any differences relate to the potential for excessive heat and volatility from an HEF. Quick and aggressive action is necessary to determine the source of hot spots, smoke, and/or flames. The crew should quickly evaluate the situation, gain access to the fire, and attack the fire using all available equipment and resources, which may include deadheading crewmembers or able-bodied persons (ABP).

- Clear occupants from the area around the device. The perimeter, which should be discussed in advance during training, may be based on several factors including but not limited to the apparent size and energy of the battery in the device that is overheating, the specific location and available area in the airplane, and experience gained from a study of past, industry-wide incident reports.
- Don PPE (gloves, PBE, etc.) using appropriate, trained procedures.
- Obtain appropriate firefighting tools (halon or water extinguisher, or other acceptable extinguishing product)
- Approach the device with appropriate caution and only as close as necessary to effectively extinguish flames and mitigate smoke generation while avoiding possible exposure to shrapnel ejected from the device were the battery to explode.
- Extinguish the fire to prevent its spread to other battery cells or to additional flammable materials.
- If the device involved in the HEF is connected to a power supply, it should be disconnected if deemed safe to do so. If applicable, aircraft in-seat power supplies may need to be turned off.

c. Cooling and Containing

Some air carriers may have purchased a specific product that would cause some of these steps to vary slightly due to the recommended procedures of the specific product's manufacturer. Air carriers should compare their product procedures with the suggested steps below to ensure that the device involved in a HEF is cooled to prevent thermal runaway, and adequately contained to prevent re-ignition.

1. Cool a smoking, overheating, or deforming device with water, non-alcoholic beverages, a water extinguisher, or an aqueous extinguisher. The most effective cooling is achieved by ensuring the liquid gets inside the device. This may require discharging liquid into any openings within the unit or any openings formed as a result of a PED failure. PBE should be worn to protect the crewmember from fumes;[15]
2. Liquid may turn to steam when applied to the hot battery.
3. Continue to cool the device and let it rest without touching it for at least ten to fifteen (10 to 15) minutes[16] and monitor for re-ignition. The waiting period for a device to cool may vary based on situational awareness or the phase of flight (cruise, approach) and should be addressed in the operator's training program.

4. Using appropriate protective gloves, place the device in an empty container. Examples include a trash bin, galley compartment bin, a product developed specifically for lithium battery fire containment, or other available container that is capable of safely containing the device and the non-flammable liquid in which it is submerged.
5. Fill the container with water or non-alcoholic liquid to completely submerge the device. Smoke may still come out of an open-topped container.
6. Place the container in a secured area that is accessible to the cabin crew yet removed

[15] WEAR OXYGEN MASKS WITH REGULATOR SET TO 100% OXYGEN.
[16] ICAO Dangerous Goods and IATA Appendix B Checklists.

from passengers and prevents spillage in the event of turbulence or other upset.

7. Monitor the device and surrounding area for the remainder of the flight and provide status updates to the pilot in command (PIC).
8. After landing, apply air carrier post-incident procedures. These may include identifying to ground personnel where the item is stowed.

WARNING: Do not attempt to pick up and move a smoking or burning device! You may be injured.

WARNING: Do not cover the device or use ice to cool the device. Ice or other materials insulate the device, increasing the likelihood that additional battery cells will reach thermal runaway.

d. Flightcrew Actions in the Event of an HEF

OVERHEATING DEVICE ON THE FLIGHTDECK

- PED overheat warning signs are not different than warning signs of PEDs in the passenger cabin, with the exception that they may be easier to detect because of the close proximity of the devices to the pilots.
- If overheat is detected, one pilot must establish control of the aircraft and consider immediate descent and landing at the nearest suitable airport.
- Disconnect the device from power or attempt to power off the device.
- Douse the device with water or other liquids to cool the device; if the device is mounted in the aircraft, dousing may need to occur when in the mounts.
- When the device can be safely moved it should be placed in a container filled with enough liquid to submerge the device (liquids may need to be provided by cabin crew).
- Signal and coordinate with the cabin crew related to moving the device out of the flightdeck into a secure location in the cabin.

HEF ON THE FLIGHTDECK (flames present) –Similar to other fires, flightcrews should take the following immediate actions:

- One pilot must establish control of the aircraft (pilot flying (PF)) and consider immediate descent and landing at the nearest suitable airport.
- Don PPE (crew oxygen masks (PF) or PBE (pilot monitoring (PM)).
- Don fire gloves if provided.
- Obtain appropriate firefighting tools (halon or water extinguisher, or other acceptable extinguishing product).
- Immediately use fire extinguisher to extinguish the fire.
- Utilize smoke mitigation procedures as necessary.
- Once the device is extinguished or no flames are present, the device should be placed in a container filled with liquid to submerge the device.
- If the device cannot be removed from the flightdeck, liquids should be poured on the device and monitored for re-ignition.
- Signal and coordinate with the cabin crew related to the need for a containment device or moving the device out of the flightdeck into a secure location in the cabin.

Warning: Do not attempt to pick up and move a smoking or burning device!

Flightcrew members must don smoke goggles and oxygen masks at the first indication of smoke or fumes and before accomplishing any abnormal or emergency procedures associated with smoke or fume elimination.

Guidance suggests that devices should be allowed to cool for 10 – 15 minutes before moving the device; however, that suggested time may not be suitable for a flightdeck HEF event. Retention of the device in the flightdeck could be a greater risk than transferring the device to the passenger cabin where flight attendants can more readily monitor the situation.

NOTE: Sections subsequent to Section 14 could be renumbered. The information in current Section 14, FLIGHTCREW ACTIONS IN THE EVENT OF A CABIN FIRE, could be renumbered to become Section 15 but content would not change.

Attachment 6: Reference Documents

The HEFTE WG referenced the following documents or information while developing this recommendation.

Regulations:

- 14 CFR §121.417 – Crewmember Emergency Training
- 14 CFR §25.795 – Security Considerations
- 29 CFR §1910.1200 – Hazard Communication

Guidance Documents:

- AC 25-9A, Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures, January 6, 1994
- AC 25.795-3, Flightdeck Protection (Smoke and Fumes), October 24, 2008
- AC 120-80A, In-Flight Fires, December 22, 2014
- Information for Operators (InFO) 17021, Risk Associated with the Use of Fire Containment Products by Title 14 of the Code of Federal Regulations (14 CFR) Part 91 subpart K (91K), 121, 125 and 135 Operators, December 26, 2017
- Safety Alerts for Operators (SAFO) 09013, Fighting Fires Caused By Lithium Type Batteries in Portable Electronic Devices, June 23, 2009
- AC 20-42D, Hand Fire Extinguishers for use in Aircraft, January 14, 2011
- FAA Order 8900.1, Flight Standards Information Management System (FSIMS)

Reports/Articles:

- International Air Transport Association (IATA) Cabin Operations Safety Best Practices Guide, 3rd Edition, 2017 (COSBPG), Appendix B – Amplified Cabin Crew Checklist for Fires Involving Batteries and Portable Electronic Devices (PEDs)
- IATA COSBPG, Appendix C – Lithium Battery Fire Prevention – PEDs inadvertently crushed or damaged in electrically adjustable seats;
- IATA Lithium Batteries Risk Mitigation Guidance for Operators, 2nd Edition, 2016;
- Lithium Batteries: Safe to Fly?, Safety First #21, January 2016;
- Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods (International Civil Aviation Organization (ICAO) Doc 9481);
- Aviation Cargo and Passenger Baggage Events Involving Smoke, Fire, Extreme Heat or Explosion Involving Lithium Batteries or Unknown Battery Types, FAA Office of Security and Hazardous Materials Safety, May 22, 2017;
- FAA Civil Aviation Medical Institute (CAMI) Report AM-17/11, Cabin Crew Fire Training Needs Analysis; and
- Various air carrier training and risk assessment documents.