

**COMMANDER DIRECTED  
INVESTIGATION FINDINGS AND CONCLUSIONS**

**PREPARED BY**

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**CONCERNING**

**EGLIN AFB ACCIDENTAL HIGH EXPANSION FOAM DISCHARGE AND FATALITY**

**8 JANUARY 2014**

**Authority and Scope.** Commanders have the inherent authority to conduct a Command Directed Investigation (CDI) to investigate matters under their command, unless preempted by higher authority. Pursuant to this authority, Maj Gen Arnold W. Bunch Jr., Commander, Air Force Test Center, appointed Col Robert F. Weaver, II on 10 Jan14, to conduct the Investigation into all aspects of the facts and circumstances regarding the accidental activation of the fire suppression system in building 130 and the subsequent death of an Air Force contractor. The CDI was conducted from 13 Jan14, to 31 Jan 14 at Building 2, 96th Test Wing, Office of the Staff Judge Advocate, Eglin Air Force Base, Florida.

Based on my investigation, I made the following findings:

**Finding 1.** Several factors combined to cause the unintended activation of the fire suppression system. The unusually cold temperatures caused part of the Inspector Test Station to freeze, which led to a pressure build up, which in turn caused a full-port ball valve (FBV) to crack, leading to the separation of the line. This created water flow within the lines which caused the HEF system to activate. Finally, the relatively short time between audible alarm and system activation combined with a lack of awareness of the operation of the abort functionality of the HEF system contributed to two separate failed attempts to abort the HEF activation.

**Finding 2.** Several factors combined to cause the death of CONTRACTOR 1. These included the decision by him and others to enter Hangar 130 contrary to instructions from on-scene emergency personnel, the four contractors taking the elevator to the floor of the hangar and the ensuing disorientation that resulted when they became engulfed in the foam. While the precise mechanism of CONTRACTOR 1's death cannot be stated without access to the autopsy results, it is apparent that his entry into the foam-immersed environment brought about his death.

**Finding 3:** There are mitigation measures which can greatly reduce the potential for similar incidents in the future. Potential mitigation measures can be divided into three areas: changes to HEF suppression system configuration, incident and rescue operations and HEF equipped hangar worker training.

## **Background.**

The High Expansion Foam (HEF) fire suppression systems in the hangar bay of Hangar 130, commonly referred to as “King Hangar,” unintentionally activated on 8 Jan 14 at 1124 hours. The hangar and adjoining building were successfully evacuated and emergency crews responded. The entire hangar floor was covered with approximately 17’ of HEF engulfing all but the very top of the vertical fins of the A-10, F-16 and three F-15 aircraft in the hangar. With personnel safe and accounted for, emergency responders focused on foam containment to minimize environmental impact. Four civilian contractors who worked in Building 129 re-entered Hangar 130 through a third floor catwalk between the hangar and Building 129. After observing the foam-filled hangar, they then took an elevator to the first floor and into an area under the foam’s surface, at which point they were engulfed. Two of the contractors escaped the hangar within a few minutes and alerted on-scene emergency crews that two personnel were trapped in the hangar. Rescue operations were begun immediately, ultimately resulting in the rescue of one of the two remaining maintainers. The final maintainer was pulled from the foam approximately 1 hour and 19 minutes after being submerged. He was in a state of cardiac arrest and was non-responsive to CPR. He was transported to the Eglin AFB Hospital with CPR administered en route, but was pronounced dead at 1412 hours.

Hangar 130 is Eglin’s largest aircraft maintenance hangar. It is skewed relative to true north, but local practice at Eglin is to treat the hangar doors as north- and south-facing, with Building 129 directly east of Hangar 130. The hangar bay is 90,600 square feet with three-story “lean-tos” on the west and east sides of the hangar bay. It was constructed in 1954 with water-only deluge fire suppression in the hangar bay and no fire suppression in the lean-tos. In 2009, wet-pipe sprinkler protection was retrofitted throughout the building and HEF was added to the hangar bay. The hangar is capable of holding over a dozen small aircraft or 2-4 large bomber or cargo aircraft. It is used primarily for intermediate-level maintenance and has many secondary functions such as weapons load training, aircraft modification and occasional special functions. Although it sits at the edge of a controlled area, it is readily accessible from the street and from the flight line. It is adjacent to a large maintenance and administration building, Building 129, which houses backshop maintenance activities such as fabrication and sheet metal, as well as Wing Safety Offices on the third floor. Building 129 and Hangar 130 are connected by numerous passageways on the ground floor as well as a catwalk at the third floor. Hangar 130 suffered major hurricane damage in 2004, rendering second and third floor offices on the southeast side unusable. Hangar 130 has offices that permanently house the 96 MXG Weapons System Standardization section as well as offices currently occupied by the Aircraft Modification Branch of the 896th Test Support Squadron “Range Group.” At any given time, depending on the aircraft and projects working out of Hangar 130, occupants can include Lockheed-Martin and Defense Support Services (DS2) contractors as well as a large variety of military and civilian test support personnel.

The primary risk in Hangar 130 is the potential of a fuel spill fire, which requires a foam-based fire suppression system. Since 1998, the AF has mandated the use of HEF for all new or retrofitted aircraft hangars. The original fire suppression system in Hangar 130 was a water-only deluge system. In the 2007 timeframe, the base decided to upgrade the hangar to the new AF standard – HEF activated by water flow in a roof-level wet-pipe sprinkler system. Hangar 130 has two HEF systems (“North” and “South”), each supplying 8 roof-mounted foam generators. To provide rapid foam coverage under aircraft, the HEF system must produce foam at a discharge rate sufficient to cover the entire hangar floor to a depth of 1 meter (39 inches) within 4 minutes; the discharge rate is then tripled to compensate for the possibility of the hangar doors being open. The system contains enough foam concentrate to generate HEF for 15 minutes. Both HEF systems are simultaneously activated when water flow is detected in either of the two roof-level wet-pipe water-only sprinkler systems in the hangar bay. The vane-type water flow detector in each sprinkler system is a circular paddle in the sprinkler piping; when water flows through the piping, the paddle is deflected, causing a switch to register the water flow. By AF standards, the water flow detector must have an adjustable time delay having a range of 0-90 seconds. At lower delay settings, the detector is vulnerable to pressure surges causing false activations; at longer delays, an actual fire could cause extensive aircraft damage before the foam system is activated. Typical practice is to set the delay at approximately the mid-point of the range; test records for 2013 indicate the water flow detectors in the Hangar 130 were set at delays of 54 and 59 seconds. The original installation of the HEF system in 2008 included a subset of foam system controls on the floor of the hangar bay. There is a “foam control station” near each corner of the bay. Each station has a Foam Activation Button which activates both HEF systems after a 30-second pre-discharge warning period; filling the system piping takes about 40-60 seconds before HEF begins falling. Each foam control station also has a deadman-type Foam Abort Button. Depressing-and-holding the Foam Abort Button before the HEF system activates will preclude the HEF systems’ activation for as long as the button is depressed. If the HEF systems’ flow control valves (FCVs) have already activated, depressing-and-holding the Foam Abort Button will initiate a shut-down process that takes approximately 90 seconds for these particular HEF flow control valves as they come from the factory. After the FCVs close, the foam generators continue to produce HEF for approximately another 100 seconds before the foam noticeably stops. The system in Hangar 130 includes a module in the Foam System Control Panel that automatically closes the hangar’s aircraft doors when the HEF systems are activated.

Both the sprinkler systems and the HEF systems are supplied by three fire pumps in Building 132, approximately 500 feet east of Hangar 130. A 25 gpm jockey pump maintains normal pressure of 145 psi on the fire suppression systems. If there is water flow exceeding the jockey pump’s capacity, the water pressure falls to a point at which the first fire pump is activated. The other fire pumps activate sequentially (10 second intervals) when the operating fire pump(s) cannot maintain adequate pressure.

Hangar 130 experienced another unintentional HEF release on 12 Apr 12 which filled the hangar bay with foam to approximately 15 feet high. Earlier in that day, a contractor was welding on the sprinkler system in the hangar bay in an effort to stop leaks from the roof-level wet-pipe sprinkler system they had installed three years earlier. A few hours after the sprinkler system was refilled, the system resumed leaking and soon thereafter the fire pumps started and then the HEF systems activated. Local CE craftsmen and Senior Fire Protection Engineer (FPE) at AF Civil Engineer Center (AFCEC) concluded there was an excessive amount of air trapped in the sprinkler system, and the pressure surge from the fire pumps starting compressed that large volume of air, resulting in an extended flow of water past the water flow detector that exceeded the time delay setting of the water flow detectors. When the HEF system activated, the hangar doors were partially open, allowing some HEF to spill onto the ramp south of the hangar. There were concerns that a quantity of the HEF foam runoff would enter the storm drains which discharge into a local stream. Efforts to break down the HEF (including using blowers, fans, turret-nozzle streams from an ARFF truck using ultra-high pressure water, and street sweepers) were ineffective in capturing/destroying the escaped HEF. No one was injured in this discharge, but three of the eight aircraft in the hangar were damaged and the event was categorized as a Class C ground event. As a result of this HEF release, the Senior FPE at AFCEC recommended a new Inspector's Test Connection, for the purpose of releasing trapped air, at the remote end of each wet-pipe sprinkler system in the hangar bay. This work was accomplished by a contracted company, ICFP Inc. The Senior FPE also recommended (1) surge suppression tanks be installed (in lieu of inappropriate expansion tanks installed in 2008), (2) all system valves be properly labeled and supervised, (3) the HEF flow control valves be modified to close in a much shorter time than the manufacturer's setting of 90 seconds, and (4) the sprinkler contractor develop a short CD for training hangar occupants on how their particular HEF system operated. All of these were accomplished following the 2012 HEF release except for modification of the HEF flow control valves.

The base issued a contract to install the two new Inspector's Test Connections, install the proper surge suppression tanks on every sprinkler and HEF system, add a second waterflow detector on each hangar bay sprinkler system, and develop a PowerPoint slideshow on a CD. This work was accomplished by the installer of the original fire protection systems in 2008, ICFP, Inc. The contractor provided CE with the training materials in the form of a CD containing a PowerPoint slideshow. This slideshow was tailored for hangar occupants and explained how the HEF system functioned, how the Foam Control Stations worked and what the local audio-visual alarms meant. The PowerPoint slideshow was provided to some 96 MXG personnel in January 2013 but was not incorporated into a formal training requirement for Hangar 130 occupants and was not seen by any of the personnel currently working in Hangar 130 who were interviewed.

HEF system training is performed on an informal basis at Eglin AFB. There is no regulation or directive that specifically requires HEF system training, although general statements involving

fire suppression training are cited in AFI 91 series directives. There are no entries in surveyed Eglin personnel Job Safety Training Outlines or Guides for Hangar 130 that provide any HEF system information. The current Facility Manager of Hangar 130 testified that he had never received specific training regarding the fire suppression system.

Eglin experienced extraordinarily cold temperatures between 6 and 8 Jan 14. The temperature went below freezing on 6 Jan 14 around 1900 hours reaching lows near 17 degrees Fahrenheit. For the next 18 hours, the temperature remained below 32 degrees Fahrenheit, warming for two hours to 33.6 degrees, and then back below freezing for another 16 hours. By 1100 hours local on 8 Jan, the temperature had climbed to 39 degrees. This combination of extended freezing temperatures followed by a rapid thaw frequently results in burst pipes and leaks.

Early in the week of 6 Jan 14, the Facility Manager for Hangar 130 (FM) received a call from Civil Engineering that freezing temperatures could pose a threat to the fire suppression system in Hangar 130, and they requested he keep the hangar doors closed. FM did so to the best of his ability, but maintenance activity necessitated the doors be partially opened. Around 1105 hours on 8 Jan 14, multiple personnel discovered that the wet-pipe sprinkler system Inspector Test Station at the northwest corner of Hangar 130 had apparently broken and the pipe had separated resulting in a 3" icicle and slow leak. This was called in to the Maintenance Operations Center (MOC) at 1110 hours who in turn called Civil Engineering (CE). As the flow increased, another call was placed from MOC to CE at 1115 and a separate call was placed to the Fire Department at approximately 1122. Fearing a HEF discharge, maintenance personnel began covering canopies and sensitive electronic equipment just in case. At 1123, the flow had reached a volume such that the wet-pipe sprinkler system flow meter initiated the HEF discharge sequence. CE reported problems with their electronic log system and reported being inundated with calls regarding leak and pipe issues. The first CE log entry for reported foam discharge was made at 1133 hours.

At 1124 hours, the Eglin Fire & Emergency Service Department received an alarm notification that there was water flow in the north sprinkler system and that the HEF systems had activated. The dispatcher confirmed the foam activation and dispatched the Assistant Chief of Operations (A/C of Ops), A/C of Fire Prevention, Battalion Chief 1 (Batt-1) and Truck-85 (TR-85). The A/C of Ops served as the Incident Commander (IC). The A/C of Training and the Training Specialist responded three minutes later, and the A/C of Training was designated Safety Officer. When the fire alarm in Hangar 130 was activated, all personnel from both Building 129 and Hangar 130 were evacuated due to the proximity of those buildings. The IC confirmed there was no fire and directed TR-84 to shut down the fire pumps in the pump house (Building 132). The IC began confirmation of complete occupant evacuation and accountability. This was complicated by the diverse population of the hangar. After a short search for a couple individuals who had departed for lunch, supervisors from the 96 MXG, DS2, 896 TSS and Lockheed Martin all reported 100% accountability. At this point, the operation transitioned from

an emergency to a foam-containment operation. The IC released all trucks and personnel except Batt-1 and TR-85, who doffed unnecessary personal protective equipment and continued diking outside ramp drains to minimize foam entering the storm drainage system.

Fire Department personnel, accompanied by CONTRACTOR 1--the FATALITY--checked passages between Hangar 130 and Building 129 to make sure that foam was not escaping toward Building 129. Doors were secured between the two, and it was determined that personnel could return to work in Building 129. Fire Department personnel also determined that Hangar 130 was off-limits and communicated this to CONTRACTOR 1 as well as via radio and word of mouth among on-scene personnel. Some Weapons Standardization personnel requested permission to retrieve personal items from the outside offices of Hangar 130--an area behind walls which kept the foam out and with ready outside access--and were given permission to do so.

Three DS2 contract maintainers, CONTRACTOR 2, CONTRACTOR 3 and CONTRACTOR 4, entered Building 129 and used the catwalk to view the foam-filled hangar. At some point on this trip, they were joined by CONTRACTOR 1. Unbeknownst to fire department personnel securing the scene, an estimated 10-12 personnel used the catwalk from Building 129 to access the third floor balcony of Hangar 130 and observe/photograph the foam covering the hangar floor. After observing the foam for approximately 10 minutes, CONTRACTOR 1, CONTRACTOR 2, CONTRACTOR 3 and CONTRACTOR 4 decided to exit by using the Hangar 130 elevator. The elevator opened on the ground floor in an area under the foam blanket. The four maintainers were immediately engulfed. They unsuccessfully attempted to escape through the roof of the elevator and then left into the foam via the main doors of the elevator to find an exit. The individuals started off together, but were immediately separated. CONTRACTOR 2 and CONTRACTOR 3 made it out of the hangar via separate exit paths within a few minutes of being engulfed. They alerted remaining Fire Department personnel who immediately began rescue operations to locate and rescue CONTRACTOR 4 and CONTRACTOR 1, who were still in the foam.

When they escaped from the building, CONTRACTOR 2 and CONTRACTOR 3 advised the fire fighters that visibility would be zero in the hangar bay and even verbal communications were totally muffled by the foam. Emergency responders formed two-person teams who entered the hangar bay from Building 129 through a set of doors about 25 feet south of the elevator. Rescuers worked in teams of two, tethered by ropes to the two-person Rapid Intervention Team (RIT) required to remain outside of the hazardous environment by OSHA regulations. The first entry team, operating under Battalion Chief 1 (BC-1) searched to the right and within approximately five minutes found CONTRACTOR 4 back at the elevator. The rescuer shared his SCBA air with CONTRACTOR 4, while being guided by the rope back into Building 129.

The second entry team entered through the same doorway and searched left as far as their rope allowed. A third entry team, operating under BC-2, entered Hangar 130 through a door further

south of the first entry door but was unsuccessful finding CONTRACTOR 1. The fourth entry team, under BC-1, entered the hangar through the original door and searched several feet deeper into the hangar, going both left and right, but were also unsuccessful in finding CONTRACTOR 1. About that time, a person ran up to BC-2 and said he thought he had heard someone banging on hangar's wall further south. BC-2 and entry team five relocated to a doorway further south and searched left. They found CONTRACTOR 1, lying on his back and non-responsive. The team lifted CONTRACTOR 1 by his shoulders and dragged him back into Building 129, where the medics started CPR. CONTRACTOR 1 was taken by ambulance to the Eglin Hospital Emergency Room, where he was pronounced dead.

The autopsy report was not available as of the finalization of this CDI report (7 Feb 14). It is presumed that CONTRACTOR died as a result of being rendered unconscious, either from a blow to the back of the head or as a result of panic or asphyxiation. He ended up on his back, unconscious, under 17' of HEF, and apparently "drowned" or "suffocated" as a direct result.

During the CDI investigation, weather conditions similar to those Eglin experienced 6-8 Jan 14 were repeated 28-30 Jan 14. As happened on 8 Jan 14, as temperatures rose on 30 Jan 14, more pipe leaks resulted. The Inspector's Test Station on the southeast corner began leaking from the UL-certified globe valve. Although not exactly the same, the construction of this line is similar to the one which failed on 8 Jan 2014.

Safety Investigation Board (SIB) members and CDI officer both arrived Monday, 13 Jan 14. The SIB President and I met Monday evening to discuss ground rules, and agreed to daily contact to exchange information and protect safety privilege. An OSHA team was already on Eglin AFB. I met with the OSHA team lead on Tuesday, 14 Jan 14, to discuss the roles of their teams and compare notes. The CDI team worked on Eglin from 13 to 31 Jan 14, at which time members had all returned to their home stations to complete report writing.

## **Findings, Analysis and Conclusions.**

**Finding 1.** Several factors combined to cause the unintended activation of the fire suppression system. The unusually cold temperatures caused part of the Inspector Test Station to freeze, which led to a pressure build up, which in turn caused a full-port ball valve (FBV) to crack, leading to the separation of the line. This created water flow within the lines which caused the HEF system to activate. Finally, the relatively short time between audible alarm and system activation combined with a lack of awareness of the operation of the abort functionality of the HEF system contributed to two separate failed attempts to abort the HEF activation.

### **Facts.**

The extraordinarily cold temperatures between 6 and 8 Jan 14 were responsible for a number of burst water lines. The cold snap was extraordinary more for its duration than for its lows. According to the 96th Weather Flight at Eglin, the last time Eglin experienced a freeze of that duration was 18 years ago in 1996. The average low temperature for January (the coldest month of the year in Florida) is 42 degrees. Although it has dipped below 20 degrees three times since 2000, the duration of the freeze combined with the low temperatures was very unusual (although it did happen again 28-30 Jan 14, toward the end of the CDI). These were clearly the coldest temperatures that Eglin has seen since the HEF and wet-pipe sprinkler systems were installed. The conditions were perfect for causing wet pipe systems to break and leak as they thawed, as they did in significant numbers on the morning of 8 Jan 14.

Two wet-pipe sprinkler system lines were added in 2012 to allow air venting of the sprinkler banks. These additional Inspectors Test Stations also allow the system to be tested by replicating sprinkler flow. This modification was installed based on conclusions from the 2012 accidental HEF discharge to fix one of the suspected causes. These lines run parallel to the hangar wall near the hangar doors, and vent outside. The modification was contracted to ICFP Inc., whose as-built drawings included a note that says draining sections of pipe that could have trapped water during freezing conditions is a responsibility of the owner or occupant. Following this recommendation would require deactivation of the system and draining the lines during freezing conditions. Witness testimony indicates that one of the pipes on the Inspector Test Stations began leaking minutes before the foam released. A cracked full port ball valve (FBV) on one of these wet-pipe lines was discovered.

The certification status of the FBV could not be confirmed. It did not have Underwriters Laboratory (UL) or FM Global (FM) markings, the manufacturer's literature does not indicate UL-listing or FM-approval and queries to the manufacturer were not answered. Analysis of the valve and fracture revealed that it suffered from effects of corrosion on the fracture surface as, "The wall thickness varies significantly, suggesting core shift during casting or inadequate centering when machining the interior details." The thickness at the fracture point was .04" minimum thickness whereas directly opposite the crack, the minimum thickness was .115".

Civil Engineering actively anticipated and responded to the results of the extended freeze. It is noteworthy that they made a call to Hangar 130 maintainers requesting the doors stay shut, but this approach was of limited value in an unheated hangar. From the time the leaking Inspector Test Station valve was reported to CE to the time the HEF activation sequence initiated was approximately 13 minutes. CE records show over 70 cold weather related calls between 0645 hours and 1124 hours when the HEF system discharged, with over 25 of these being for burst, broken or leaking pipes. It should be noted that the CE call log and work order system was experiencing problems, and not all calls were being logged at the point of the discharge. Although a call regarding the HEF system should have received a very high priority, there were numerous safety-related issues that CE was working, and a response within 13 minutes, even in the best of circumstances would be remarkable.

Weapon Standardization section personnel mentioned to CDI interviewer that the building had experienced power fluctuations earlier in the day of the mishap, believed to be the regular testing of the ability to switch from grid to generator power and back again. Both visible flashing lights and loud, audible warnings worked as designed and triggered once the wet-pipe flow meter initiated the HEF discharge sequence.

Two individuals did attempt to utilize the HEF System Abort switch. MX1 hit the abort button at the southeast corner of the hangar just as foam began falling from the foam generators. He held the button in for an estimated 20-40 seconds before the foam reached his location and a supervisor recommended that he evacuate. On the opposite corner of the hangar, MX2 also pressed the abort button after foam had begun discharging, and held it an estimated 55-60 seconds. When MX2 did not see change in the foam flow after 60 seconds, he released the button to evacuate and the foam discharge continued unabated.

### **Analysis.**

The correlation of the cracked FBV, temperature data and reported sequence of events supports the theory that part of the Inspector Test Station line froze, causing a pressure build-up and resulting crack of the FBV and separation of the Inspector Test Station line at that point. The valve's structural failure resulted in water flow in the wet-pipe sprinkler system which eventually activated the HEF systems.

National Fire Protection Association (NFPA) Standard 13, Standard for the Installation of Sprinkler Systems, is the internationally-recognized consensus standard covering the design and installation of fire sprinkler systems. NFPA 13 (para 6.1.1.2) requires all materials and devices essential to successful system operation to be "listed" or "approved." NFPA 13 makes a differentiation between components critical for successful operation and test/drain valves which are typically not critical for successful operation of a sprinkler system. Components required for successful operation of the wet-pipe sprinkler system are required to be "listed," commonly

accepted as UL-listed or FM-approved. Test valves and drain valves are only required to be “approved” by the authority having jurisdiction. NFPA does NOT take into account the fact that wet-pipe systems may be tied into the HEF activation sequence. The Statement Of Work (SOW) for the Inspector’s Test Station modification stated;

“4.2.1 Modify automatic wet pipe fire suppression sprinkler system currently installed in Hangar 130. For bidding purposes use Ordinary Hazard Group 2 IAW UFC 3-600-01 and NFPA 13.” ...”All sprinkler pipes, braces and hangers, etc., shall be designed and installed to meet seismic zone 3. All fire sprinkler components shall be UL-listed or FM-approved.”

It becomes a matter of interpretation whether the 96 CEG should have accepted the modified wet-pipe Inspector’s Test Station drain valve without an UL or FM certified part. Although “sprinkler components” would reasonably include the test/drain valve, NFPA does differentiate between drain/test valves and other sprinkler components critical for operation of a wet sprinkler system. Under ordinary conditions, if the Inspector’s Test Station valve is broken (won’t open, leaking, etc.), the wet-pipe sprinkler system will still function as intended. It is only by virtue of the wet-pipe system being tied to HEF activation that this valve becomes critical. Based on the wording of the SOW, it is unclear that the intention was to exceed the requirements of NFPA 13 by requiring a listed FBV.

The inspection and acceptance process at Eglin is accomplished through CE and includes the approval of material submittals and acceptance of the percentage of work completed in order for the contractor to bill/invoice. The contractor cannot use material on any project without prior CE approval. Quality and progress monitoring, as well as inspection and acceptance processes, are done on a daily basis by the project manager and project inspector.

The dramatic variance in FBV wall thickness indicates that the installed valve was of less-than-acceptable quality. Mandating a UL or FM certified part may have resulted in a higher quality FBV with more uniform wall thickness. However, it should be noted that a sister valve with more uniform wall thickness was also unable to withstand the pressures imposed by a freezing line in an Air Force Research Laboratory test. The impact of a non-certified FBV is unclear, but certainly a noteworthy finding.

Personnel were slow to respond to the alarm sounds and lights, initially wondering if they were a by-product of the power fluctuations experienced during generator-to-power-grid tests conducted on Hangar 130 earlier that morning. Once realizing that HEF discharge was a possibility, personnel at both northwest and southeast corners of the Hangar quickly made their way to and depressed the Foam Abort Buttons in those corners. However, data and witness observations make it clear that these buttons were pushed outside the 30-second pre-discharge warning phase.

Foam Abort Button functionality is complicated, with the system having different termination times in different phases of foam discharge. These timings are not well known, are not part of formal training, and are not included on any of the system signage. Had maintenance personnel been more familiar with the system, they may have elected to post someone at the Foam Abort Button when they discovered the Inspector's Test Station leaking as opposed to (or in addition to) covering aircraft in case of a foam release. If the Foam Abort Button is depressed during the 30-second pre-discharge phase, the HEF FCVs will not open and foam discharge is avoided. On 8 Jan 14, the HEF system had passed the 30-second pre-discharge warning phase, and the FCVs had actually opened before MX1 or MX2 hit a Foam Abort Button. Neither individual could have realistically waited the 90 seconds required for the factory-set FCVs to close plus the additional 100 seconds for the foam to cease discharging.

The SOW for the 2012 fire protection modification project in Hangar 130 did not address modifying the rate of closure of the FCVs. During this SIB and CDI, a number of functional tests of the FCVs were conducted, and neither FCV performed as a factory-set FCV would be expected to perform. The south FCV closed consistently in approximately 24 seconds. The north FCV, however, consistently took approximately 100+ seconds to close, which is slightly slower than even the factory setting. This demonstrates the wide variance in the FCV closing times. The net result is that the current configuration of the HEF FCVs requires the Foam Abort Button to be held in for over 3 minutes before the foam will consistently stop discharging. If MX1 or MX2 had depressed the Foam Abort Button immediately after the HEF FCVs opened, by the time the foam stopped flowing the foam in Hangar 130 would likely have been over 10 feet deep. There was also an anomaly in the activation of the signal from the vane-type water flow detectors on the wet-pipe sprinkler systems. ETL 02-15 requires those water flow detectors to have an adjustable delay of 0-90 seconds so their sensitivity to pressure surges can be controlled. CE inspection reports for 2013 indicated the delays were set at 54 seconds on the north sprinkler system and 59 seconds on the south sprinkler system. When tested during the SIB and CDI, for some reason neither water flow switch sent a water flow signal until 1 minute 37 seconds after the water began discharging at the Inspector's Test Connection.

There were also two noteworthy anomalies associated with the functioning of the Foam Abort function, although neither of these anomalies had any impact on the mishap.

- (1) It was expected that, once the 30-second pre-discharge phase had begun, depressing the Foam Abort Button would stop the 30-second countdown for as long as the button was depressed, but when the button was released the countdown would continue from the point at which it was interrupted. In fact, depressing-and-releasing the Foam Abort Button during the pre-discharge phase reset the countdown clock back to the full 30 seconds.
- (2) It was also expected that, once the Foam Abort Button had successfully terminated the foam discharge, releasing that button would immediately start the foam flow again.

The logic is that if someone aborted the foam flow because they thought a fire had been suppressed, and they then realized that the fire was not successfully controlled, releasing the dead-man button should immediately start the foam flowing again. However, during the SIB/CDI testing, it was discovered that, after successfully stopping the foam discharge via the Foam Abort Button, the Foam System Control Panel restarted the 30-second pre-discharge delay phase before the HEF FCVs re-opened.

Two aspects of the HEF system as installed at Eglin are worth analyzing. The first is the 30-second delay between alarm and HEF discharge. Although equipped with four Foam Abort Buttons, Hangar 130 is a large complex with many shops, offices and less accessible areas that are sometimes thinly manned. It is not a given (as witnessed in this incident) that occupants will be able to assess the situation, determine that an HEF abort is appropriate, travel to the switch and depress it before the HEF discharge sequence begins. If this time were doubled, it would dramatically increase the chances that inadvertent releases would be aborted before foam started falling. This would naturally come with additional risk to life and property for an actual fire.

Specific to the HEF systems in Hangar 130, after the FCVs close, the foam continues to flow unabated for a period of approximately 100 seconds. If the FCV is modified to a 20-second shut-down, the amount of foam generated from the moment the Foam Abort Button is depressed to the cessation of foam being discharged is still 120 seconds. In Hangar 130 that would result in the foam being approximately 5.5 feet deep, assuming there was no foam on the floor when the Foam Abort Button was depressed. This makes use of the Abort Button impractical after the pre-foam discharge phase has ended without further modification.

Once the FCV is closed, there is no longer any pressure on the base of the foam system riser, indicating that any foam solution that is being converted into foam after the FCV is closed is likely flowing by gravity into the foam generators. To eliminate the generation of foam after the FCV has closed, there are two possibilities. One would be to eliminate any foam solution piping above the foam generators. A second option would be to install automatic-closing valves in the foam solution piping at each foam generator, with those valves being closed electrically immediately after the FCV has closed. (Closing the valves at the foam generators before closing the FCV could generate a water hammer.) Since adding additional valves to the system has some impact on system reliability, the more desirable option would be to change the foam solution piping.

The following factors were considered, but were determined to not play a significant role in the mishap: The mental state and relationship between DS2 contractors appeared to be normal--there was no evidence of drug/alcohol impairment or any type of malicious intent. Although there was a leak at the Building 132 pump house, the pumps that feed the HEF and wet-pipe system all appeared to function normally. Emergency response was complicated by an In Flight Emergency that called some firefighters away following the initial foam discharge, but adequate

numbers of rescue personnel were on hand to conduct required operations at each phase. There were no known significant pre-existing medical conditions for CONTRACTOR 1, although the autopsy report is not yet available to confirm this. Fire system controls for Hangar 130 are outside the manufacturer's humidity operating limits for their equipment, although there is no evidence that this adversely impacted system performance. The absence of illuminated exit signs on the nearby stairwell door is also noteworthy, but would not have been effective in the HEF environment as all HEF immersed individuals reported a complete white-out, with no visibility except in the very small areas cleared directly in front of their faces.

**Conclusion:** The primary cause of the inadvertent HEF discharge was a combination of historically low temperatures for a sustained period, a system design that allows autonomous HEF release with very limited opportunities for personnel to terminate the sequence and an added wet-pipe Inspector Test Station with a faulty valve.

**Finding 2.** Several factors combined to cause the death of CONTRACTOR 1. These included the decision by him and others to enter Hangar 130 contrary to instructions from on-scene emergency personnel, the four contractors taking the elevator to the floor of the hangar and the ensuing disorientation that resulted when they became engulfed in the foam.

**Facts.**

The four DS2 contractors, CONTRACTOR 1, CONTRACTOR 2 and CONTRACTOR 3 and CONTRACTOR 4, were fabrication maintainers whose primary duties were in the machine shops in Building 129. The DS2 lead at Eglin stated that these DS2 contractors entered an area that they were not familiar with and had no reason to be on the day of the mishap. DS2 contract maintainers testified that they were “curious” to see the foam. They also testified that they lost situational awareness and made a mistake by taking the elevator from the third floor of Hangar 130 to the ground floor. The elevator was marked with a “Do Not Use in Case of Fire” sign, but was fully operational at the time of the mishap. The third floor elevator entrance was separated from the third floor balcony by a wall with door frame but no door. The second floor had a wall with door in place. The ground floor, however, had no wall between the hangar and the elevator, was in a recessed area that was open to the main hangar and was filled with foam when the elevator opened.

There are 19 entrances to Hangar 130 to include passageways between Building 129 and Hangar 130, exterior personnel doors, hangar doors, roll-up garage-style doors, the third floor catwalk and corner stairwells. The IC had personnel posted at both hangar doors, but did not physically control access via the other entrances to the hangar. Exits were inspected during a Fire Prevention Inspection in 2012, and found to be in compliance with IAW NFPA 101 Chapter 40.6 Special Provision for Aircraft Servicing Hangars with the exception of illuminated exit signs on hangar stairwell doors, to include the stairwell nearest the elevator.

After the initial response and accountability, the IC and assembled leadership maintained control of the scene through radio communications and word of mouth. Focus was on “keeping the foam in” as opposed to “keeping the people out.” Restrictions on entering Hangar 130 were communicated--but not universally received and/or obeyed. Eglin’s Fire Department largely relied on the physical improbability of entering foam-immersed areas to prevent access to Hangar 130, and did not put up signs or post guards at every hangar entrance. There was unanticipated and unauthorized traffic between Building 129 and Hangar 130 via the catwalk that was invisible to fire department personnel on the ground. Unbeknownst to fire department personnel securing the scene, an estimated 10-12 personnel used the catwalk from Building 129 to access the third floor balcony of Hangar 130 and observe/photograph the foam covering the hangar floor.

The DS2 personnel as well as other hangar workers interviewed all stated they had never considered the possibility of complete foam immersion or what they would do if they found themselves in this situation. All three DS2 personnel who survived the foam immersion stated that they were “surprised” and “panicked.” The few seconds they had before being submerged--with no subsequent ability to communicate--were used trying to escape through the elevator roof and then agreeing to

hold hands and stick together. Unfortunately, the plan to stay together quickly fell apart when the maintainers let go of each other to clear foam from their mouths and eyes. CONTRACTOR 2 and CONTRACTOR 3 were able to evacuate quickly but described a very limited ability to breathe and no ability to communicate or see. CONTRACTOR 2 went west and made his way to the glass door leading to a storage area and Building 129, smashed through the glass, unlatched the door and immediately ran for help. CONTRACTOR 3 covered his mouth with his shirt and felt his way along the wall, backtracking east to the nearby stairwell door and made his way out. CONTRACTOR 4 started in the same direction as CONTRACTOR 2, but was separated. CONTRACTOR 4 made his way back to the elevator and discovered that if he kept his head facing the ground, didn't move, and swept the foam continuously away from his face, that he could breathe. He calmed down and focused on clearing a breathing space and moving very slowly. CONTRACTOR 4 realized that he had his cell phone, and decided to try to make a call for help. At that point, roughly 30 minutes after taking the elevator to the ground floor, CONTRACTOR 4 heard rescue personnel.

### **Analysis.**

The elevator maintenance records were reviewed and its functionality was tested. It functioned as designed on the day of the mishap. The line-of-sight sensor just above the floor-level at the elevator door also worked as designed. Unfortunately, this prevented the door of the elevator from closing as soon as foam had crossed the elevator threshold on the ground floor--essentially immediately. Escape through the top of the elevator was not possible from the rear of the elevator, where the DS2 personnel removed ceiling tiles in an attempt to escape. It was possible to use fire controls to lock the elevator to a certain floor, but these were not tied to the HEF activation sequence and were not set manually during the mishap period.

One comment heard repeatedly when discussing both this and the previous incident is the difficulty in viewing foam as dangerous, even a foam-filled hangar. There is something inherently benign about soap bubbles and foam. Its use in baths and parties combined with its harmless qualities when used in small quantities create an image that is hard to overcome. An air of excitement surrounds test and accidental HEF releases by all witness reports during this mishap. The DS2 maintainers were stunned when the foam became a life-threatening and panic-inducing substance. This difficulty in recognizing a large quantity of HEF as a potentially deadly environment certainly contributed to the desire to observe the foam from the third floor balcony. This might also have contributed to the DS2 maintainers not more carefully considering elevator use.

Strong control of HEF immersed areas can be difficult. The two HEF discharges at Eglin demonstrate this. Discharges ordinarily fill multi-story hangars with many entrances/exits that have many areas where workers can become confined. Large hangar doors can result in a significant volume of foam outside the hangar, posing an even greater challenge for scene control. High Expansion Foam has a quality that attracts bystanders. Until now, HEF was not seriously viewed as a life-threatening hazard, and the HEF itself was seen as deterrent enough to keep onlookers from getting close enough to actually become immersed.

Leadership at AFCEC and at Eglin discussed the 2012 discharge and actions that were taken during the course of this investigation, but the “lessons learned” appeared to be based on their functional assessment of the event. The most common input was that environmental impact from the Apr 2012 discharge was too great, and attempts were made to reduce the amount of HEF runoff that made it into the storm drains and thereby into a local stream. Likewise, AFCEC lessons learned focused on work that was done on the HEF and wet-pipe system, and the need to bleed air to reduce fluid fluctuations in the line. To this end, they proposed and approved the modifications as previously described.

Discussion with the DS2 maintainers provided insight into the best way to survive foam immersion. If personnel find themselves immersed and do not have a clear path to freedom, the techniques used by CONTRACTOR 3 and CONTRACTOR 4 provide insight into the best way to survive by focusing on breathing and slowly making your way to freedom. Facing the ground, using your hands to create a breathing space in the foam and pulling your shirt over your mouth if possible appears to be a viable way to stay conscious and continue to function. Moving slowly, finding a wall and following it to a door or exit is clearly the best recommendation that we can give our folks for surviving foam immersion. However, they all stated that if you can see a clear path out of the foam, move in that direction as quickly as safely possible without hitting obstructions or slipping. It is not believed that functional illuminated exit signs on the stairwell door would have been visible at all through the foam.

The fire fighters who entered the hangar confirmed that visibility was zero; helmet-mounted flashlights did not help. Verbal communication was also nearly impossible beyond a few inches. Fire fighters regularly train in low-light and even no-light conditions, but several fire fighters commented that being engulfed by the foam, with no visibility and no sound, was scary even for a trained professional. One of the entry teams also lost radio contact, and the base is investigating whether that was due to foam infiltrating their radios.

On-scene maintainers assisted rescue operations by using a piece of AGE (a Hobart -86) with attached air exhaust hose to clear a path in the foam and find the hangar door attachment point. They were then able to use a Coleman tug to pull the door open, facilitating rescue operations. Although effective at clearing areas at the edge of the foam, the -86 was not successful at clearing a space inside the hangar, as the created bubble quickly collapsed around the user. However, this was a noteworthy technique that might have broader applications when considering rescue operations and foam dispersal. They also briefly considered positioning a jet aircraft so that it could create exhaust airflow through the hangar, an option ruled out for many reasons.

It is highly unlikely that taking an elevator into a HEF immersed area will result in additional injuries or fatalities. However, there are many other possible and much more likely ways that maintainers and hangar personnel could find themselves trapped in HEF foam following a discharge. Hangar 130 has a few of these hazards. There are bathrooms and showers that only open into the main hangar area. A person in the shower may very well find himself in a situation where exit is blocked by foam following a discharge. Many operations on aircraft in Hangar 130 require fall protection or are in

areas where a rapid egress is not possible. Even the best trained maintainer could find himself unable to exit the hangar until the HEF has reached an area over their heads. Other hazards include possible slipping or tripping, running into hangar equipment that results in an injury and lack of mobility, being in a confined space like a tool cage or engine exhaust.

There is surprisingly little knowledge on HEF: specifically in the areas of conducting rescue operations, environmental impacts and suffocation/respiratory/contact hazard. HEF is being installed in more aircraft hangars every day. Discussion with professionals at Eglin, Edwards, Wright-Patterson and Tyndall revealed significant knowledge gaps. On-line searches exploring HEF manufacturer sites and fire suppression installers--even Google internet searches--turn up little useful information.

### **Conclusion.**

The main reason for the fatality and injuries suffered as a result of the mishap was the entering of Hangar 130, a building known to be off limits following the release of HEF, by CONTRACTOR 1 and the accompanying contractors. Their unfamiliarity with the facility led to a loss of situational awareness, and they made the extremely poor decision to take the elevator from the third floor to the first floor of Hangar 130. The mishap chain had many links that, if broken, may have prevented the accidental release of foam and immersion of maintainers. Recommendations and possible mitigations focus on these links.

**Finding 3:** Potential mitigation measures can be divided into three areas: changes to HEF suppression system configuration, incident and rescue operations and HEF equipped hangar worker training.

### **Analysis.**

Tying the HEF activation sequence to wet-pipe sprinkler flow resulted in a system prone to inadvertent activations. There are a number of short-term and long-term courses of action (COAs) that will potentially mitigate this risk and warrant consideration. Foremost among these are the following: 1) Disconnect automatic activation based on wet-pipe flow, 2) Tie HEF activation to wet-pipe flow plus another fire indicator such as a heat detection device, 3) Improve training and understanding of the HEF sequence abort function to reduce the number of inadvertent HEF discharges, 4) Improve wet-pipe sprinkler systems in HEF equipped hangars to decrease their failure rates. One additional HEF system change that should be considered is the timing of the 30-second delay between alarm and HEF discharge initiation.

One measure considered was disabling autonomous release of HEF completely. The risks associated with this COA need to be seriously analyzed. It appears that this COA would violate Air Force Environmental Technical Letter (ETL) 02-15. Based on limited information with regard to DoD and commercial aviation-wide statistics and a thorough risk analysis, we do not recommend disabling automatic HEF release at this time. Instead, we recommend other mitigating actions be taken to reduce the chances of inadvertent HEF release.

It should be possible to incorporate additional sensors to the HEF activation sequence, eliminating wet-pipe flow as the sole fire indicator. This would be hangar-dependent, and would likely come at a significant cost. An example of this would be electronic flame detection. Adding a positive flame detection sensor response to the wet-pipe sprinkler flow would greatly reduce accidental HEF activations. This possibility merits further study.

A better understanding of the HEF system will increase the chances that inadvertent system activations will be stopped before foam discharge or that foam discharges can be paused and terminated before the HEF presents a great threat to personnel. HEF system training was performed on an informal basis at Eglin AFB. There is no regulation or directive that specifically requires HEF system training. There are no entries in surveyed Eglin personnel Job Safety Training Outlines or Guides that provide any HEF system details. The contractor that installed the HEF system provided training materials and CD-ROMs with recommended training. In addition, a short Microsoft PowerPoint slideshow was created and had limited and informal circulation, although it was not seen by any of the personnel in Hangar 130 that were interviewed.

Although it did not play a significant role in this mishap, it was discovered that hangar doors are triggered to automatically close should HEF be discharged. Personnel leaving the hangar noted the hangar doors closing. This feature of the HEF discharge sequence is intended to maximize the height of the HEF on any fire within the hangar by keeping the foam in. No personnel were trapped or hit

by the moving doors, although this did influence the decision of one of the abort button holders to evacuate.

**Prioritized List of Recommendations:**

1. Create and integrate HEF fire suppression system training into formal training and hazard identification processes. Recommend development of a formal HEF Hazard Awareness Computer Based Training (CBT) course delivered via the Automated Distributed Learning System (ADLS) with an annual interval. The CBT should require participants to select accurate responses to scenario-based situations and provide an automated completion certificate upon successfully meeting course objectives. Additionally, it is recommended that formal familiarization training specific to each hangar equipped with a HEF fire suppression system be created, delivered and documented locally. Include (at a minimum) automatic and manual system activation sequences, alarm sounds and lights, sequence timing, abort switch/button availability and location, specific risks to hangar users (enclosed locations, elevators, stairwells, tool cages, etc.), dangers of HEF (suffocation and contact risks), evacuation, survival methods, and accountability. Finally, recommend that workplace job safety training include the above details for each HEF-equipped hangar fire suppression system(s) in which personnel routinely work. Document annually via AF Form 55 with supervisor and employee signatures required.
2. I recommend that some details of this investigation be disseminated among commanders who have HEF equipped hangars. A better understanding of the potential hazards associated with HEF should underscore the need for incident scene control in the event of future activations.
3. CE should inspect wet-pipe sprinkler systems to ensure proper certification of parts and condition, specifically looking for non-certified parts and excessive corrosion.
4. Commanders in charge of HEF equipped hangars should inspect them to identify areas that could trap or injure occupants in the event of a foam release and/or rapid evacuation (tool cribs, metal stairs, etc.) Mitigation measures should be taken!
5. HEF equipped hangars should be evaluated to determine the correct length for the pre-discharge warning phase following automatic HEF initiation. Specific to King Hangar--30 seconds is too short. Recommend King Hangar's warning phase be extended to 1 minute.
6. Policy should mandate use of UL listed or FM certified parts in test and drain lines for wet-pipe systems that tie into HEF activation. This will decrease the chances that a lower-quality valve will be in a position to cause a HEF discharge.
7. Rescue Personnel should incorporate HEF specific rescue techniques into personnel training. Recommend that planned HEF releases could also serve as in-foam training opportunities.
8. Evaluate redesign of the HEF systems to enable faster closing of the FCV and termination of foam flow after the discharge sequence has begun, as suggested by the AF FPE. Specifically to Eglin's

Hangar 130 system, the trim on the HEF FCVs should be modified to close the FCV within 20 seconds of when a Foam Abort Button is depressed.

9. The Hangar 130 elevator should be programmed to stay at the third floor in the event of HEF foam activation.

10. HEF system signs at abort buttons must be clarified. We recommend that the signs be modified to provide a better description of foam termination times after the system has been activated. I recommend something as simple as, “Depress button until fire department arrives or it becomes unsafe due to foam cutting escape routes or covering head. Pressing during [30 second] alarm phase will stop foam from discharging. Once foam is discharging, it may take up to 2 minutes before foam stops.” Note that in some cases this should be augmented by more precise spoken alarm messages, if hangars are equipped with voice instruction alarms.

11. AFTC installations should review cold-weather contingency plans and include HEF disabling or protection steps in the event of predicted freezing temperatures.

12. Accountability following a HEF discharge is paramount. It was well executed in this instance, but not without difficulty and not without being a source of concern for senior leadership. HEF equipped hangars must emphasize strict accountability following a discharge and maintenance of a sharp situational awareness so that personnel can be located quickly in the event of a discharge.

13. HEF discharge sites should be treated as a significant health risk until the foam disperses to a level where all areas are readily accessible. We recommend that emergency action checklists be reviewed and that HEF discharge specific items be added. These can cover post-emergency actions-- balance of safety, environmental and mission (equipment/resource protection) with the new understanding that HEF can be a deadly environment. Emphasis must be placed on strict access control, cordoning and restriction of non-essential personnel into HEF discharge sites.

14. Disable the automatic hangar door operation that closes hangar doors automatically with HEF activation. Recognition that the HEF is a dangerous environment combined with the sensory-deprivation qualities of the foam make automatic door closure a particularly dangerous action. If a real fire exists and in some situations, responding Fire Department personnel may be able to close the doors if warranted. Note that if unoccupied, hangar doors are ordinarily closed.

15. 96 TW leadership should address the requirement for a temperature management system for the wet-pipe sprinkler system in Hangar 130.