TEXAS
STATE FIRE MARSHAL'S OFFICE

Firefighter Fatality Investigation

Investigation Number FY 11-05

Caleb Nathanael Hamm

Bureau of Land Management
Bonneville Interagency Hotshot Crew
July 7, 2011

Texas Department of Insurance
Austin, Texas

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ACKNOWLEDGEMENTS

The Texas State Fire Marshal wishes to thank the following entities for their cooperation and assistance in the investigation of this incident and the preparation of this report:

Bureau of Land Management

Texas Forest Service

Mineral Wells Emergency Management Services

Palo Pinto County Sheriff's Department

Southwestern Institute of Forensic Sciences

National Institute for Occupational Safety and Health

And the many emergency responders to this incident

Executive Summary

On July 7, 2011, Bureau of Land Management (BLM) firefighter (FF) Caleb Nathanael Hamm collapsed and died during wildland firefighting operations in a remote area of Palo Pinto County, Texas. Hamm, beginning his sixth year as a firefighter of the BLM, was in his first year with the Bonneville Interagency Hotshot Crew (IHC) based in Salt Lake City, Utah. The IHC responds nationally to assist local, state, and federal agencies and arrived in Texas on July 1, 2011, after fighting fire in Georgia for four days. Three days of rest and three days of staging preceded the IHC assignment to the County Road (CR) 337 fire northwest of Mineral Wells, Texas.

Beginning July 6, 2011, the IHC was assigned fireline construction, cold trailing, and mop up operations during a coordinated response to the CR 337 fire. July 6, 2011, ended without incident and July 7 began with the morning safety briefing at the staging area. Weather conditions were hot and dry on July 7, 2011, with afternoon temperatures reaching above 105°F. The afternoon assignments were a continuation of the fireline construction, cold trailing, and mop up. Caleb Hamm was assigned to Squad C, which later split into pairs to continue cold trailing operations.

At approximately 1545 hours after stumbling along the trail, Caleb Hamm reportedly advised the Squad C team leader that he was hot and had a little headache. The team leader told Hamm to take a break if he needed and then left Hamm to assist another squad. When the team leader returned approximately 5 minutes later, he saw that Caleb Hamm had collapsed onto some rocks along the trail. Hamm was unresponsive. Emergency Medical Technicians (EMTs) assigned to the IHC initiated basic life support measures for heat related illness and possible trauma. Extraction from the remote area took 45 minutes during which time Hamm went into cardiac arrest. It was another 15 minutes after the arrest before Hamm was aboard an advanced life support ambulance. Hamm arrived at the hospital emergency room with a core temperature of 108°F. At 1703 hours, the emergency room physician pronounced Hamm dead.

An autopsy conducted by the Southwestern Institute of Forensic Sciences in Dallas concluded that the death was a result of hyperthermia.

The Texas State Fire Marshal's Office recognizes that heat related illness and exertion related heatstroke is preventable. Fire departments should incorporate the following preventative recommendations into department policies and procedures. (Portions reprinted with permission of the National Institute of Occupational Safety and Health)

- *Always work in pairs and/or be in direct communication with crewmembers.*

- *Instruct fire fighters and command staff that hydration alone will not prevent HRI;*
- *Develop re-acclimatization schedules for wildland fire fighters not working for more than 4 days;*
- *Measure environmental heat conditions using a Wet Bulb Globe Thermometer (WBGT);*
- *When heat stress criteria are exceeded, discontinue physically demanding training according to the guidelines developed independently by the United States (U.S.) Army/Air Force and American College of Sports Medicine (ACSM);*
- *When heat stress criteria are exceeded, require hourly work/recovery cycles according to NIOSH and ACGIH guidelines, particularly when the operation does not involve rescue operations;*
- *When heat stress screening criteria are exceeded, consider monitoring fire fighters for signs of heat strain;*
- *When heat stress screening criteria are exceeded, consider a bimodal shift or two shifts;*
- *Consider incorporating a screening checklist for heatstroke risk factors into the Agency's medical screening and medical examination program;*
- *Promptly alert local EMS units of a medical emergency per Incident Command protocols.*
- *When exertional heatstroke is suspected, inform responding EMS units of the potential need for cold/ice water immersion therapy.*
- *Seek input from crewmembers and frontline supervisors about removing barriers, real or perceived, to reporting or seeking medical attention for heat strain or HRI.*
- *Consider cases of HRI, particularly severe cases such as heatstroke or rhabdomyolysis that result in death or hospitalization, as a sign that the current heat stress program is inadequate.*
- *Consider incorporating members of the Department's Safety Office into the Operations Management Team.*

This report is to honor Caleb Nathanael Hamm by taking the lessons learned from this tragic incident so others may not perish.

Caleb Hamm, 23 years old, was beginning his sixth year as a member of the Bureau of Land Management. He was qualified as a Firefighter Type 2 (FFT2) and Faller Class A (FALA).

Introduction

On Friday, July 8, 2011, the Texas State Fire Marshal's Office was notified by the Texas Forest Service that Bureau of Land Management firefighter Caleb Hamm died while performing firefighting operations on the scene of a wildland fire in Palo Pinto County on July 7, 2011.

The State Fire Marshal's Office commenced the firefighter fatality investigation under the authority of Texas Government Code Section 417.0075.

(a) *In this section, the term "firefighter" includes an individual who performs fire suppression duties for a governmental entity or volunteer fire department.*

(b) *If a firefighter dies in the line of duty or if the firefighter's death occurs in connection with an on-duty incident in this state, the state fire marshal shall investigate the circumstances surrounding the death of the firefighter, including any factors that may have contributed to the death of the firefighter.*

(c) *In conducting an investigation under this section, the state fire marshal has the same powers as those granted to the state fire marshal under Section 417.007. The state fire marshal will coordinate the investigative efforts of local government officials and may enlist established fire service organizations and private entities to assist in the investigation.*

(d) *The state fire marshal will release a report concerning an investigation conducted under this section on completion of the investigation.*

(e) *Not later than October 31 of each year, the state fire marshal will deliver to the commissioner a detailed report about the findings of each investigation conducted under this section in the preceding year.*

(f) *Information gathered in an investigation conducted under this section is subject to Section 552.108.*

(g) *The authority granted to the state fire marshal under this section will not limit in any way the authority of the county or municipal fire marshal to conduct the county or municipal fire marshal's own investigation into the death of a firefighter within the county or municipal fire marshal's jurisdiction.*

Texas State Fire Marshal Paul Maldonado assigned Deputy State Fire Marshal Clint Williams to investigate the firefighter fatality.

The Bureau of Land Management Serious Accident Investigation Team responded to conduct an investigation.

The National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program conducted an independent investigation.

Wildland Fire Conditions

There were no structures involved in the origin of the fire. Forecast conditions and Actual Observed conditions are reported by the Texas Forest Service.

The State of Texas' 2011 wildfire season began in mid-November 2010 and by July 2011, millions of dollars in property and thousands of acres were destroyed. Thick grasses and vegetation that grew because of the rains during 2010 dried up during the drought, leaving substantial fuels for fast moving fires. The 2011 fire season was to become the most devastating and costly fire season period in Texas history and in July there was no end to the drought in sight. The extremely dry fuels resulted in extreme fire conditions, fire behavior, and flame lengths.

The CR 337 fire involved areas of rugged terrain with native stands of Texas oak, cedar elm, ashe juniper, sumac, hackberry, and prickly pear along with grasses such as Texas wintergrass, bluestem, and ragweed. Non-native trees include salt cedar, juniper, and mesquite.

Weather conditions in the Palo Pinto County area on July 7, 2011, were hot and dry with winds 5-10 mph from the SSE and relative humidity 20%-40%. A high temperature of 106°F was recorded in Mineral Wells between 3:00 and 4:00 PM.

Fire Behavior forecast by the Texas Forest Service for July 7, 2011.

FIRE BEHAVIOR FORECAST

FORECAST NUMBER: #3	**TYPE OF FIRE: Wildland**
FIRE NAME: CR 337	**OPERATIONAL PERIOD: 07/08/2011 0800-2000**
DATE ISSUED: 07/07/2011	**TIME ISSUED: 1800**
UNIT: Texas Forest Service	**SIGNED: /s/ Mike Beasley FBAN**

INPUTS

FUEL ASSUMPTIONS:
The fuel types found in the area are Fuel Model **GS2** (Moderate Load, Dry Climate Grass-Shrub);and Fuel Model **4** (dense cedar-juniper-oak). Fuel model 4 is capable of supporting high intensity, fast spreading, surface and crown fire. This fuel model is the principle timber/tall shrub fuel found throughout the fire area in lowlands and on slopes. There is more live oak mixed in on north slopes. The grass-shrub fuel is found on the uplands and other areas w/o the cedar-juniper-oak fuel.

WEATHER SUMMARY: ***See spot weather forecast for detailed information.***

Mostly sunny, isolated showers and thunderstorms during the afternoon. 10% chance of precipitation

Highs:104°, RH: 19% , Winds S 10 mph, Haines Index 6

FIRE BEHAVIOR OUTPUTS

General: MODERATE to VERY HIGH rates of spread. Torching and crown fire runs with spotting are possible in the presence of tightly spaced brush or timber canopies.
Watch for *erratic winds associated with outflows and/or frontal passage, as well as dry lightning* in the afternoon.

Critical fire behavior thresholds for the fire area, any combination of these factors greatly increase fire behavior **(temp > 90°, RH < 25%, winds > 20 mph, and 100 HR fuel moisture less than 11%).** Three of these four thresholds will be exceeded during the operational period.

SPECIFIC: The following fire parameters can be expected:

Very active fire behavior with rapid ROS, torching and crowning likely in continuous canopy fuels.

Fuel Model GS2 (Moderate Load, Dry Climate Grass-Shrub): ROS 0.4 - 0.5 mph, Flame Length 6-8 feet.

Fuel Model 4 (dense shrub/cedar); ROS 1.2 -1.7 mph, Flame Length 25 - 28 feet. Direct attack at the head is not possible with even the lowest forecasted wind speeds. Transition from surface to crown fire probable with the forecasted winds. Torching and crown fire behavior is a certainty in those areas with larger dead & down fuels.

Probability of Ignition: 100%
Max. spotting distance: 0.6 mile

With no intel from the fire today, we cannot speak to specific sites on the fire posing additional or unusual safety risks to firefighters.

AIR OPERATIONS: Generally good flying conditions except for erratic winds near any thunderstorms in the afternoon.

SAFETY

Base all actions on current and expected fire behavior. Beware of shifting erratic winds coming from thunderstorms and building cumulus. **Always establish LCES.**

A MOMENT FOR SAFETY CAN LAST A LIFETIME.

Origin and Cause Investigation

The CR 337 fire started by lightning on July 4, 2011, five miles northwest of Mineral Wells, in Palo Pinto County. The fire burned 1204 acres and destroyed four structures.

Fire Ground Operations and Tactics

Note: The following sequence of events is based on dispatch log and firefighter witness statements. Those events with known times are identified. Events without known times are approximated in the sequence of events based on firefighter statements regarding their actions and observations.

The following is excerpted, in part, from the National Institute of Occupational Safety and Health (NIOSH) investigation report F2011-17-UT. http://www.cdc.gov/niosh/fire/reports/face201117.html

On July 7, the Bonneville IHC attended briefings from 0800 to 0830 hours during which safety and fire behavior were emphasized. They were told to expect hot conditions with temperatures above 100°F with relative humidity between 18%-26%. After the morning briefing they were taken to Drop Point (DP) 20 where they received their work assignments and another safety briefing covering hazards and fire behavior. Hydration and work pacing were emphasized.

- *Work pacing is the process by which firefighters set their own work pace. It allows firefighters to take rest pauses (seconds) and rest breaks (minutes) whenever needed (e.g., when they feel short of breath, overheated, or exhausted).*

For hydration, each crewmember was required to carry 6 quarts of water. In addition, each crewmember (except the sawyers who carried chainsaws) carried an extra 1-gallon canteen of water and 2 bottles of Gatorade®.

Crewmembers were wearing/carrying their typical wildland gear (green Nomex® pants, cotton tee-shirt, long sleeve Nomex® shirt, boots, hardhat, gloves, and a 35-40 pound pack.)

The Bonneville IHC's assignment was to construct a fireline (handline) and cold trail along a ridge until they tied-in with the Big Bear IHC. Hamm was initially assigned "swamper" duties (clearing limbs after tree-cutting), assisting the sawyer on a saw team. In addition to the typical gear listed above, the swamper and sawyer wear leather chaps for leg protection from scratches while clearing trees and shrubs. Hamm performed the swamper task from about 0900 to 1130 hours, when he requested transfer because of fatigue. He was reassigned to work the cold trail with a hand tool.

As they moved along the ridge, the crew wanted to reach the tie-in location before the other IHC, a goal described as a friendly competition. *As a result, crewmembers along the line stated they were working faster and with fewer breaks/pauses than normal.* In addition, some crewmembers reported feeling that if they took a break, crew leaders would see this as a sign that they were not up to IHC standards and reputation. Some crewmembers believed that taking “extra” rest breaks/pauses might jeopardize future IHC employment/assignments.

At 1230 hours, the crew tied-in with the Big Bear IHC, and began cold trailing and mop up along the line until 1330 hours when they broke for lunch. They ate and drank as a group in the general area. All crewmembers were hot, sweaty, and tired but none reported signs or symptoms of Heat Related Illness (HRI) to their supervisor. After lunch, a supervisor noted that most of the water in the canteens had been consumed. The crew refilled and topped-off their water bottles and canteens for the afternoon.

At 1410 hours, the crew broke into three squads (six men per squad). Each squad continued to secure the line and mop up back toward DP 20. At about 1530 hours, Squad C split into three pairs.

At about 1545 hours, Caleb Hamm, working with the Squad C crew leader, stumbled on a rocky slope while hiking down a drainage area. When asked whether he was okay by the lead crewmember, Hamm responded “he was hot and had a little headache.” Hamm was told to take a break if needed. The Squad C crew leader told Hamm he was going to tie in with crewmembers from Squad B and he would be right back. When he returned at 1550 hours, Hamm had collapsed and was unresponsive in some rocks along the trail.

Location of Collapse (Courtesy of BLM)

The Squad C crew leader radioed the assistant superintendent that a FF was down. One of the IHC's emergency medical technicians (EMT No. 1) heard the radio traffic and headed toward the downed FF. Arriving about 2 minutes later, EMT No. 1 found the FF wedged between some rocks with his feet dangling. Initial assessment found the FF with labored breathing and unresponsive to commands, but responsive to pain (sternal rub). Thinking of both heat stress and the possibility of trauma due to a fall, EMT No. 1 ordered a backboard, oxygen, and the trauma kit from the crew's truck and requested the crew's other EMT (EMT No. 2) for assistance. The crew superintendent notified Air Attack of the medical emergency and requested advanced life support (ALS) to DP 20.

About 1556 hours, EMT No. 2 reached Hamm. Hamm's skin was very hot to the touch, and the crew attempted to cool the FF by removing his pack, shirt, and boots and pouring water on him. His pulse was 120 beats per minute (normal 60 to 100) and his respiratory rate was 12 breaths per minute (normal 8-12). Hamm was loaded onto the backboard and a tarp was held over him for shade while the IHC cut an extraction line to the nearest dirt road (about 300 feet).

Photo of a Section of the Extraction Line (Courtesy of BLM)

At about 1610 hours, Hamm's condition deteriorated. He stopped breathing and an oral pharyngeal airway was placed. EMTs administered breaths using a CPR pocket mask. Because the Air Attack helicopter did not have the cab space needed to transport a patient on a backboard, the operations chief requested an ambulance from the local fire department (1614 hours) and a MedEvac helicopter from the local hospital (1616 hours).

At 1620, while the extraction line was being cut, Hamm went into cardiac arrest and CPR was initiated. Hamm was passed along the extraction route by crewmembers using a conveyor belt method and for 2 to 3 minutes CPR could not be administered. CPR resumed at the dirt road as the crew loaded and secured Hamm onto a waiting Texas Forest Service Regional Fire Coordinator's truck.

The MedEvac helicopter and the local ambulance arrived at DP 20 at 1631 and 1635 hours, respectively. Both medic crews traveled up the dirt road in a four-wheel drive vehicle to meet the Texas Forest Service truck and then caravanned down the hill to DP 20.

Photo of Drop Point 20 (Courtesy of BLM)

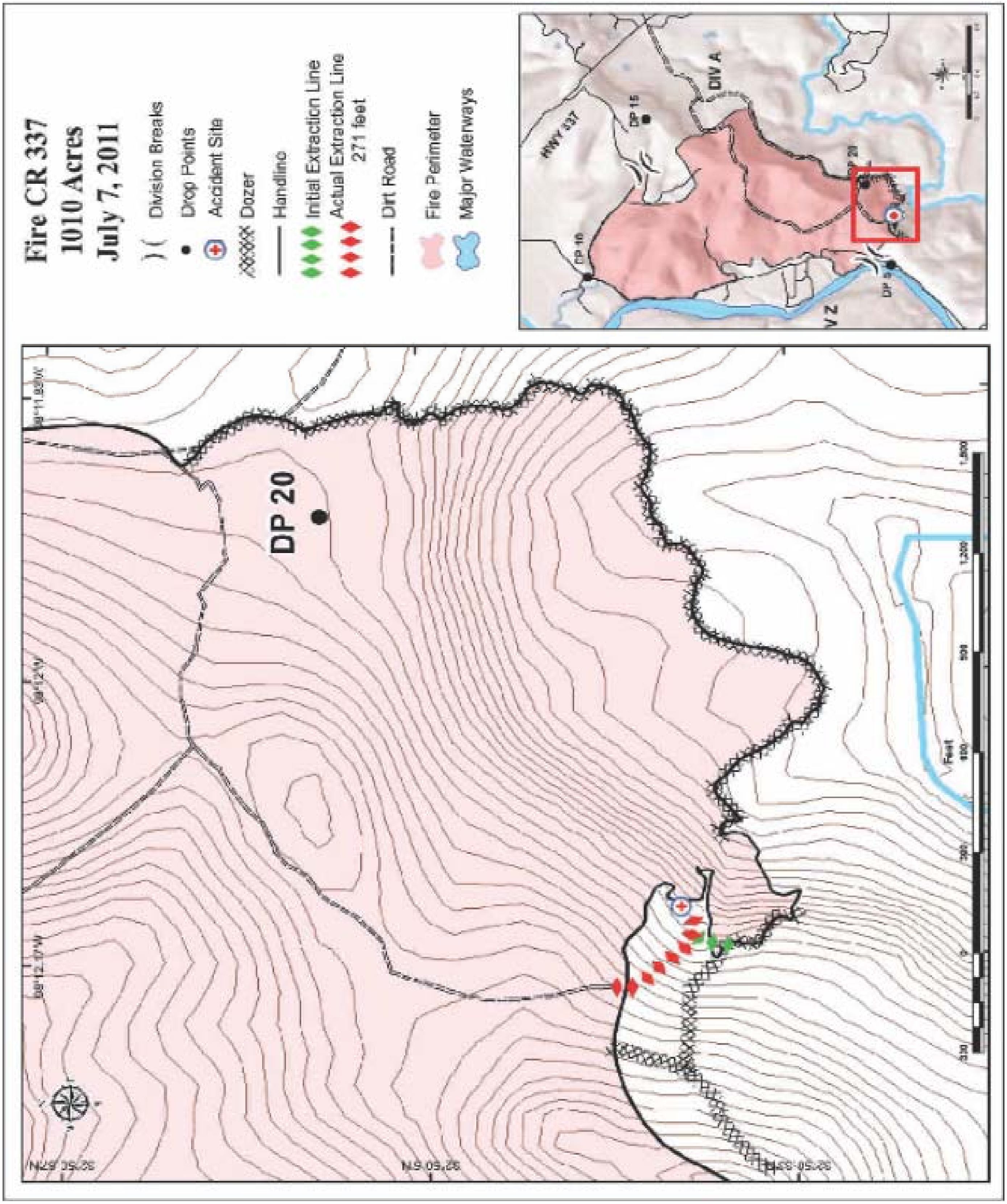
On arrival at DP 20, the medic crews began advanced life support (ALS) measures, delivering oxygen by bag valve mask and medications by an intravenous line. At 1645 hours, the ambulance departed DP 20 for the hospital. While enroute, Hamm's heart rhythm changed to ventricular fibrillation and a shock (defibrillation) was administered on two separate occasions. Both times Hamm's heart rhythm reverted to a systole.

The ambulance arrived at the local hospital's emergency room at 1658 hours. The ER staff continued CPR and ALS. A rectal temperature showed 108°F. Despite these efforts, Hamm's condition did not improve.

At 1703 hours, the attending physician pronounced Caleb Hamm dead and resuscitation efforts were stopped.

An autopsy conducted by the Southwestern Forensics Science Institute on July 8, 2011, concluded Caleb Hamm died as a result of hyperthermia. It is noted that toxicology screens are negative for alcohols or medications and that electrolyte levels indicate "no dehydration."

Courtesy of BLM



Personal Protective Equipment

Firefighter Hamm was wearing wildland firefighting apparel including Nomex® shirt and trousers. All BLM crewmembers were wearing/carrying their wildland gear (green Nomex® pants, cotton tee-shirt, long sleeve Nomex® shirt, boots, hardhat, gloves, and a 35-40 pound pack).

Findings and Recommendations

Recommendations are based upon nationally recognized consensus standards and safety practices for the fire service. Firefighting personnel should know and understand nationally recognized consensus standards. Fire departments should create and maintain SOGs and SOPs to ensure effective, efficient, and safe firefighting operations.

Heat Related Illness and exertional heatstroke are considered preventable occurrences with recognizable warning signs/symptoms that may include" headache" and "feeling hot."

The following recommendations are adopted from NIOSH report F2011-17-UT. The full NIOSH report can be viewed at *http://www.cdc.gov/niosh/fire/reports/face201117.html*

- Always work in pairs and/or be in direct communication with crewmembers.

It is not clear what role, if any, the FF being left alone for several minutes prior to his collapse played in his death. However, firefighters should always have a buddy system to provide help during work or training [Sharkey and Gaskill 2009]. It is unclear how often being left alone occurs during wildland fire fighting, but this episode was not the only one in which a wildland fire fighter collapsed while separated from his or her crew [USFA 2012].

- Instruct firefighters and command staff that hydration alone will not prevent HRI;

This case, as well as others from the wildland fire service, demonstrates that heatstroke and heat exhaustion can occur despite adequate hydration.

- Develop re-acclimatization schedules for wildland fire fighters not working for more than 4 days;

If wildland fire fighters are not working for more than 4 days during the fire season, and are not exposed to hot environments, a program of re-acclimatization should be instituted. The duration of the re-acclimatization period should be directly related to the length of time without heat exposure.

- Measure environmental heat conditions using a Wet Bulb Globe Temperature;

The WBGT is a validated, simple, quick, inexpensive, and widely used index that accounts for all four components of environmental heat: air temperature, humidity, air movement, and radiant heat. Use of the commonly reported heat index does not account for the cooling effect of the wind or the radiant heat of the sun or fire. Thus, it does not provide a valid estimate of the heat stress experienced by the wildland fire fighter.

- When heat stress criteria are exceeded, discontinue physically demanding training according to the guidelines developed independently by the U.S. Army/Air Force and the American College of Sports Medicine (ACSM);

To be consistent with these organizations, investigators recommend cancelling all physically demanding training for acclimatized individuals performing moderate to heavy tasks when the WBGT is above 32.0.

- When heat stress criteria are exceeded, require hourly work/recovery cycles according to NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH) guidelines, particularly when the operation does not involve rescue operations;

This case and the unknown number of unreported cases show that heat stress and HRI occur among wildland firefighters. The evidence also suggests that wildland firefighters are not able to appropriately self-pace their work to prevent HRI. Mandatory work-recovery cycles, like those developed for the United States military and general industry, should be implemented during severe environmental conditions. These work-recovery cycles should be based on WBGT, metabolic work requirements, and acclimatization.

- When heat stress screening criteria are exceeded, consider monitoring firefighters for signs of heat strain;

ACGIH recommends monitoring for signs of heat strain when its screening criteria are exceeded. According to ACGIH, an individual’s heat stress exposure should be discontinued when **any** of the following signs of heat strain occur:

- Sustained (over several minutes) heart rate in excess of 180 beats per minute (bpm) minus the individual’s age in years for those with normal cardiac performance;
- Core body temperature above 38°C (100.4°F) in unacclimatized personnel and above 38.5°C (101.3°F) in heat-acclimatized personnel;

- Recovery heart rate above 100 bpm at 1 minute after peak work effort;
- Symptoms of sudden and severe fatigue, nausea, dizziness, or lightheadedness.

Consider the use of heart rate as a non-specific indicator of heat strain. Therefore, when heat stress screening criteria are exceeded, we recommend stopping work when either: 1) symptoms appear (sudden and severe: fatigue, nausea, dizziness, or lightheadedness) or 2) there is an oral temperature above 38.5°C (101.3°F).

- When heat stress screening criteria are exceeded, consider a bimodal work shift or two shifts;
Another IHC, operating in similar environmental conditions in the same State, reported most of their crew suffered mild heat illness at least once during their 14-day assignment and two members experienced moderate heat illness. To address this hazardous condition, the acting superintendent of this IHC had his crew monitor and patrol fire from air-conditioned vehicles during the hottest periods of the day (e.g., 1400-1800 hours). He called this a “bimodal” work shift. During severe environmental conditions this acting superintendent would initiate a bimodal work shift unless life or property was threatened. An alternative to a bimodal work shift would be to deploy two crews; the first crew working from 0600 to 1400 hours and the second crew working from 1400 to 2200 hours.

- Consider incorporating a screening checklist for heatstroke risk factors into the agency’s medical screening and medical examination program;
The agency currently requires candidates to pass pre-placement and periodic medical evaluations. As part of this evaluation, all candidates and members (or their physician) complete a checklist for individual heatstroke risk factors. Individual risk factors include the following:

- previous history of exertional heatstroke
- lack of heat acclimatization
- poor physical fitness
- obesity
- sleep deprivation
- various medical conditions (e.g., heart disease, renal disease, diabetes mellitus, skin conditions, sunburn, sweat gland dysfunction, viral illness, diarrhea, etc.)
- sunburn
- medications that reduce sweating (e.g., Benadryl®)
- medications that can cause dehydration (e.g., over-the-counter medications containing ephedrine or synephrine, diuretics)

- medications that can inhibit central thermoregulation (e.g., neuroleptics and tricyclic antidepressants)
- drugs that reduce cutaneous blood flow (e.g., stimulants such as cocaine, amphetamines, ephedrine, pseudoephedrine, caffeine, theophylline)

If one of these conditions is present, the examining health care provider should provide an opinion regarding a work restriction in hot environments. The agency would determine whether that restriction could be accommodated.

- When exertional heatstroke is suspected, inform responding EMS units of the potential need for cold/ice water immersion therapy.

Rapid core temperature reduction is the most effective treatment for exertional heatstroke. Other treatments (e.g., ice packs applied to the neck and groin, IV fluids, and oxygen administration) are less effective. Although treatment protocols vary and are the responsibility of the EMS provider, the wildland fire service can raise awareness of this issue among those responsible for establishing protocols and provide the guidance developed by professional organizations.

- Seek input from crewmembers and frontline supervisors about removing barriers, real or perceived, to reporting or seeking medical attention for heat strain or HRI.

Investigators found no evidence of barriers to reporting HRI. In fact, the fire safety office is interested in increasing the ability of its reporting systems to capture all injuries and illnesses. In this regard, additional support for the ISUITE and SafeNet reporting systems is needed. During the interviews, NIOSH learned that fear of not being rehired the next fire season concerned crewmembers. Operations Management and Human Resource staff are encouraged to explore this issue further and develop strategies to address job insecurity.

- Consider cases of HRI, particularly severe cases such as heatstroke or rhabdomyolysis that result in death or hospitalization, as a sign that the current heat stress program is inadequate.

Cases of HRI should be considered a ***"sentinel health event."*** Each case of HRI should be investigated to provide a better understanding of what aspect of the program is not working.

- Consider incorporating members of the department's Safety Office into the Operations Management Team.

Occupational safety and health professionals from the department's Safety Office can add a useful perspective to complement that of safety officers on the Operations Management Team. Both groups working together may identify creative solutions to the issues raised by this investigation.

Appendix

Definitions

Cold Trailing: A method of controlling a partly dead fire edge by carefully inspecting and feeling with the hand for heat to detect any fire, digging out every live spot, and trenching any live edge.

FALA - Faller A: An individual being trained or evaluated in introductory level, noncomplex chain saw operations. Work of a Class A Faller must be under the supervision of a qualified Faller B or Faller C.

Handline: Fireline constructed with hand tools.

Sawyer: A person who is qualified to cut down trees or snags, perhaps while the tree or snag is burning.

Swamper: A worker who assists sawyers by clearing away brush, limbs, and small trees. Carries fuel, oil, and tools and watches for dangerous situations.

NIOSH Discussion (see NIOSH report F2011-17-UT)

http://www.cdc.gov/niosh/fire/reports/face201117.html

Hyperthermia is characterized by an uncontrolled increase in body temperature that exceeds the body's ability to lose heat [CDC 2006]. Exertional hyperthermia is defined as a core body temperature above 104°F during activity [Armstrong et al. 2007]. Caleb Hamm had a core body (rectal) temperature of 108°F approximately 70 minutes after his collapse. His core body temperature probably was higher than 108°F at the time of his collapse.

Hyperthermia was listed as a cause of death on the autopsy report. Heat sources for hyperthermia are external to the body (environmental) and internal to the body (metabolic heat produced during physical exertion). *Heat stress* is the sum of the heat generated from the body plus heat gained from the environment minus heat lost due to evaporation [NIOSH 1986; ACGIH 2011]. Mild to moderate heat stress may cause discomfort, but is not harmful to health. As heat stress increases, it causes *heat strain*, which is a physiologic response of the body. Heat strain manifests as increases in heart rate and core body temperature. As heat strain approaches human tolerance limits and core body temperature rises, the risk of HRI increases.

Environmental Heat Load. Four factors determine environmental heat: air temperature, humidity, air movement, and radiant heat. Heat indices have been developed to incorporate these factors into a single measure of heat load. While the “Heat Index” commonly reported by the U.S. National Weather Service accounts for air temperature and humidity, it does not account for air velocity (a major factor in removing heat) or radiant heat (solar or fire). In the 1950s, the Wet Bulb Globe Temperature (WBGT) was proposed as a simple, quick, and inexpensive index that could account for radiant heat. It was initially adopted by the U.S. Marines to monitor training conditions, and it has since been adopted as the most practical index of environmental heat load [Minard 1961; NIOSH 1986; Parsons 2006; Armstrong et al. 2007; ACGIH 2011].

In this incident, incident command measured three of the four environmental factors on an hourly basis. At 1500 hours, shortly before the FF collapsed, the dry bulb temperature was 105°F, the wet bulb temperature was 75°F, the humidity was 24%, and the wind was 1-3 mph with 0% cloud cover. Radiant heat (e.g., solar or burning embers) was not measured. Under certain conditions, the WBGT can be estimated from temperature and humidity [ACSM 1984; Bureau of Meteorology 2010]. Because there were light winds with no cloud cover and the firefighters were only cold trailing (no embers), conditions were appropriate for using the estimating formula. The estimated WBGT was 34°C-35°C (93.2°F-95°F) (Appendix B).

Metabolic Heat Generated During Wildland Fire Fighting. For those engaged in moderate to heavy physical work, metabolic heat is the primary driver of heat stress. The metabolic heat generated by wildland fire fighting, including IHC, has been estimated by a variety of methods (indirect calorimetry, double labeled water, and physical activity monitors), by task, by physical activity, and by daily expenditure. Tasks such as extensive hiking, fireline construction, chain-saw work, and brush removal require approximately 7.5 kilocalories per minute (kcal/min) or 450 kcal/hour [Budd et al. 1997; Ruby et al. 2002; Sharkey and Gaskill 2009]. Physical activity energy expenditures were estimated at 360 kcals/hour and were affected by work assignment, self-selected work intensity and fire location [Heil 2002; Ruby et al. 2002]. Total daily energy expenditure was estimated to average 4,664 [Heil 2002] and 4,878 [Ruby et al. 2002] kcal/day. These latter studies, however, reported the average energy expenditures over multiple days and would miss bursts of work activity that put firefighters at increased risk for HRI and heatstroke. These daily energy expenditures are similar to those reported for military combat training and mountain climbing [Forbes-Ewan et al. 1989; Hoyt et al. 1991; Pulfrey and Jones 1996].

The metabolic heat requirements of wildland firefighters can also be estimated by task analysis. The NIOSH investigators’ estimates, derived from IHC tasks performed on July 7 described to NIOSH during interviews, are approximately 520 kcal/hour (Appendix C). These estimates are roughly consistent with those of other researchers using a variety of measurement techniques.

Evaporation and Clothing. Heat is removed from the body primarily by evaporation of sweat from the skin. With the exception of the chaps worn by the sawyer and the swamper, the clothes worn by IHC are well suited to remove heat by evaporation and convection [NIOSH 1986; ACGIH 2011].

Heat-related Illness (HRI) and Heatstroke.

When individuals with hyperthermia become symptomatic, the condition is known as HRI. HRI represents a wide spectrum of conditions typically ranging in severity from skin rashes and heat cramps, to heat exhaustion, heat syncope, and heatstroke. The milder HRI conditions (rash and cramps) do not necessarily precede the more severe conditions and, as this case suggests, heatstroke can be the presenting illness. Heatstroke, the most severe form of HRI, is a life-threatening condition. It is defined as a core body temperature greater than 104°F with central nervous system disturbances and multiple organ system failure [Donoghue et al. 1997; Armstrong et al. 2007]. In the general population, heatstroke has a mortality rate ranging from 33%-80% [Vicario et al. 1986; Seraj 1992]. However, when immediate cold/ice water immersion is administered for exertional heatstroke, studies suggest a dramatic reduction in mortality [Bouchama et al. 2007]. Caleb Hamm had heatstroke.

Like hyperthermia, heatstroke is grouped according to the primary source of the heat: internal (exertional) and environmental (classic). Exertional and classic heatstroke differ both clinically and epidemiologically. Exertional heatstroke tends to occur in younger, healthier persons (e.g., military recruits and athletes) who present with sweat-soaked and pale skin at the time of collapse. Classic heatstroke tends to occur in elderly patients with chronic medical conditions who present with dry, hot, and flushed skin [Lugo-Amador et al. 2004]. Hamm's presentation and clinical course was typical of exertional heatstroke while working in severe environmental conditions.

Magnitude of the Problem: Heatstroke Fatalities.

Among wildland firefighters and structural firefighters assigned to wildland/grass/brush fires, the National Fire Protection Association (NFPA) reported seven heatstroke deaths for the 33-year period from 1979 to 2011 [Fahy 2011]. The National Wildland Coordinating Group (NWCG) reported five heatstroke fatalities (three of which were included in the NFPA database) among wildland firefighters spanning the 85-year period, 1910 to 1996 [NWCG 1997]. Of these five heatstroke fatalities, only two were federal wildland firefighters and this was the first heatstroke death in the agency’s history. Heatstroke fatalities are extremely rare among federal wildland firefighters.

Magnitude of the Problem: HRI.

The agency maintains a Safety Management Information System (SMIS) database of wildland firefighter injuries and illnesses reported from workers compensation claims (Form CA-1) or examination/treatment authorizations (Form CA-16). At the request of NIOSH, the agency searched this database for cases attributed to "heat" or "dehydration" during the 12-year period from 2000 to 2011; 255 cases were identified (Table 2). NIOSH considers cases of HRI to be "sentinel health events" indicating heat stress control measures may be inadequate [NIOSH 1986]. Sentinel health events are preventable diseases, disabilities, or deaths whose occurrence is a warning signal of possible inadequate preventive or therapeutic care [Rutstein et al. 1983].

***Magnitude of the Problem: Unreported HRI*.**

During the NIOSH interviews, many IHC members reported symptoms consistent with mild to moderate HRI, not only at this incident, but throughout their careers. These symptoms included feeling hot, exhausted, and nauseated, and having headaches. None, however, reported a heat-related injury/illness to their supervisors or into a reporting system. When asked why they had not reported the incident, crewmembers responded that they considered it "part of the job" and feared a negative influence on being rehired the next fire season.

A 1996 survey of over 1,000 wildland firefighters found that many firefighters "do not report safety-related incidents 1) out of fear of discipline or reprisal, 2) because the reporting system is inconvenient, 3) because they believe that the report will not be acted upon, or 4) they fear losing hard earned credibility" [TriData 1996, 1998]. To address this problem, wildland fire service agencies have empowered every firefighter, regardless of rank, to embrace and promote a reporting culture. Efforts to improve reporting were aided by several new reporting systems introduced between 1999 and 2004: 1) SafeNet, an anonymous reporting system, 2) the SMIS database mentioned above that allows either the employee or the supervisor to report incidents into a department-wide database, 3) a "Lessons Learned" website, and 4) an injury/illness module added to the software/database used by medical units to input cases (ISUITE). Although these measures have helped improve the safety culture and the reporting of injuries and illnesses among wildland firefighters, more can be done.

***Personal Risk Factors for HRI and Exertional Heatstroke*.**

Personal risk factors for exertional heatstroke include increased age, obesity, poor physical fitness, a previous history of exertional heatstroke, various medical conditions (e.g., heart disease, renal disease, diabetes mellitus, skin conditions, sunburn, sweat gland dysfunction, viral illness, diarrhea, etc.), and some medications (e.g., drugs that reduce sweating such as antihistamines, such as Benadryl®), drugs that reduce cutaneous blood flow (e.g., stimulants such as cocaine, amphetamines, ephedrine, pseudoephedrine, caffeine, energy drinks, dietary supplements, theophylline), drugs that can cause dehydration (e.g., diuretics), and drugs that can inhibit central thermoregulation (e.g., neuroleptics and tricyclic antidepressants) [Armstrong et al. 2007]. The FF was not known to have had any of these risk factors.

Environmental Risk Factors for HRI and Exertional Heatstroke.

A variety of organizations have developed guidelines for stopping or restricting physical activities based on the WBGT, metabolic work requirements, and acclimatization (discussed in the next section). For moderate (300 kcal/hour) to heavy (415 kcal/hour) work among acclimatized individuals, the U.S. Army and Air Force cancel all scheduled physical training when WGBT is above 32.0 [Pennington et al. 1980; Nunneley and Reardon 2009]. The military waives these restrictions for "essential operational commitments […] where the risk of heat casualties may be warranted" [Pennington 1980]. The American College of Sports Medicine (ACSM) recommends cancelling all scheduled events when WBGT is above 32.3 [Armstrong et al. 2007]. For WBGT above 35, NIOSH recommends discontinuing heat exposure (work) for acclimatized workers on moderately physically demanding jobs (300 kcal/hour) [NIOSH 1986]. For WBGT above 31.5, ACGIH recommends discontinuing heat exposure (work) [ACGIH 2011]. These guidelines are based on an 8-hour workday and a 40-hour workweek. It is unclear if these guidelines are adequate for the work schedules of wildland firefighters that typically involve 2-week deployments working 12-16 hours per day.

NIOSH investigators estimated that the WBGT was 34°C-35°C (93.2°F-95°F) and the metabolic requirements of the IHC members were at least 300 kcals/hour at the time of this incident [Sharkey and Gaskill 2009]. ACGIH guidance would recommend ceasing work. The NIOSH guidance would recommend either precluding work or resting for at least 45 minutes for every 15 minutes of work.

Wildland firefighters are at risk of HRI due to metabolic work requirements, environmental conditions, and long work hours. However, compared with many other occupations, wildland firefighters have the advantage of being able to regulate their work pace (self-pacing). Self-pacing would allow wildland firefighters to control the most important heat stress factor, metabolic heat production. However, it is unclear whether wildland firefighters, particularly IHC, appropriately self-pace their work. Heil reported the rate of energy expenditure tended to vary between 240 and 360 kcal/hour, and commented that wildland firefighters paced themselves for a 10-16 hour workday [Heil 2002]. Yet the Heil study showed the highest energy expenditures in the afternoon when environmental temperatures were highest. Even if wildland firefighters self-pace to "light" work (180 kcal/hour), the recommendations of ACGIH and NIOSH would not change at a WBGT of 34°C-35°C (93.2°F-95°F) (Appendices D, E-1, and E-2).

IHC are an elite workforce, selected for their superior physical fitness, motivation, dedication, and esprit de corps. Although significant efforts have been made to improve the safety culture of the wildland fire service, interviews conducted by NIOSH suggest that at least some wildland firefighters fear being labeled as weak, not having "the right stuff," or not being rehired the following spring.

These concerns could push crewmembers to work without breaks, even when symptoms are present, thereby increasing their heat stress, risk of heat strain, and risk of a subsequent HRI.

Other Risk Factors for HRI and Exertional Heatstroke*.*

Additional risk factors for HRI and heatstroke include dehydration, lack of heat acclimatization, sleep deprivation and fatigue, and rhabdomyolysis [Armstrong et al. 2007]. The following discussion provides background on these issues and addresses whether they may have been a factor in this incident.

Dehydration. Dehydration occurs during prolonged exertion when fluid losses from sweating and rapid breathing are greater than fluid intake. The reduced intravascular volume associated with dehydration results in reduced blood flow to the skin (convection heat loss) and reduced sweating (evaporative heat loss), two of the body's most important cooling mechanisms [Lugo-Amador et al. 2004]. Impaired cooling increases the body's core temperature, which increases the risk of exertional heatstroke. Throughout Hamm's deployment, debriefing sessions emphasized heat stress and the importance of drinking water and sports drinks to prevent dehydration. Although two crewmembers reported restricted access to water during previous deployments, water access during this incident was not reported as a problem. Crewmember reports that the FF drank adequate amounts of water (at least 2 gallons during the morning shift), the finding of normal urea nitrogen levels, and the autopsy finding of 300 cc of non-concentrated urine in Hamm's bladder, indicate that the FF was not dehydrated [Collins 2011].

Acclimatization.

Lack of heat acclimatization is another heatstroke risk factor. With heat acclimatization, physiological changes (sweating at a lower temperature, more sweating, less electrolyte loss, etc.) make the body more efficient in dealing with heat stress. Any exercise program that builds and maintains a high level of aerobic fitness partially adapts the body to heat stress [Nunneley and Reardon 2009]. To fully acclimatize, the body needs to experience the actual work conditions in consecutively increasing 1½- to 2-hour increments. Adaptive physiological changes occur within 4 days, but complete acclimatization can take up to 3 weeks [Voltaire et al. 2002]. Once heat stress exposure stops, the body's adaptive mechanisms regress; clinically significant reductions are seen within 4 days [ACGIH 2011]. With 1 to 2 weeks without exposure, re-acclimatization requires 4 to 7 days (Figure 1) [Bass 1963; ACGIH 2011].

The FF in this incident was very fit and was acclimatized throughout his summer IHC deployment. However, with 3 days of travel and 3 days of staging between June 29 and July 4, he probably lost some acclimatization benefits. His work shifts of 11 hours on July 4 and 16 hours on July 7 allowed some re-acclimatization, but the benefits of acclimatization may have been blunted by sleep deprivation and fatigue [Nunneley and Reardon 2009; Sharkey and Gaskill 2009].

Sleep Deprivation and Fatigue.

Although sleep deprivation and fatigue have been associated with exertional heatstroke [Armstrong et al. 1990], the relationship is not well established. One study has shown that with increasing fatigue, the work rate slows, thereby reducing the metabolic production of heat [Heil 2002]. Most, if not all, IHC crewmembers reported some sleep deprivation and fatigue on July 6 and 7.

Rhabdomyolysis. As core body temperature increases, muscle cells begin to break down, releasing myoglobin into the blood stream. This process, known as rhabdomyolysis, has been observed in firefighters, particularly during physical fitness testing or training [CDC 1990; NIOSH 2012]. Rhabdomyolysis is one type of HRI or can be a complication of a HRI [Huerta-Alardin et al. 2005]. With reduced intravascular volume and reduced kidney blood flow from dehydration, the circulating myoglobin can “clog” the kidneys, resulting in acute tubular necrosis and acute kidney failure [Brown 2004; Sawka et al. 2007]. The histology findings from the autopsy did not indicate acute tubular necrosis.

Treatment. Rapid core body temperature reduction is the most important treatment for exertional heatstroke. Its use has resulted in lower exertional heatstroke mortality rates [Castrani 1990; Bouchama et al. 2007; McDermott et al. 2009]. Cold/ice water immersion is the best method, and is endorsed by the ACSM and the National Athletic Trainers’ Association [Binkley et al. 2002; Armstrong et al. 2007]. In this incident, it was impractical for the agency to provide ice along the fireline (e.g., at DP 20), and responding EMS unit protocols did not include cold/ice water immersion as a treatment modality for exertional heatstroke.

It took crewmembers about 45 minutes to extract Hamm to DP 20, the last 15 minutes of which the FF was in cardiac arrest. There was a 20-minute delay in notifying the local EMS units; however, those units still arrived at DP 20 about 5 minutes before Hamm's arrival. The notification delay, therefore, did not result in treatment delays. The ALS measures taken in the field and hospital (i.e., IV fluids, cardiac monitoring, and oxygen administration) would not have rapidly lowered Hamm's core body temperature.

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