



Wildland Fire Fighter Dies from Hyperthermia and Exertional Heatstroke While Conducting Mop-Up Operations - Texas

Executive Summary

On June 23, 2011, a 23-year-old male seasonal wildland fire fighter (FF) on an interagency hot shot crew (IHC) deployed from his duty station in Utah to fight wildland fires in Georgia and Texas. After fighting fires in Georgia for 4 days, the crew was dispatched to Texas. After travelling for 3 days, then staging for 3 days, the crew began fire fighting on July 4, 2011.

On the morning of July 7, 2011, the FF was assigned swamper duties (clearing limbs after tree-cutting) to construct a fireline followed by cold trail operations (a component of mop-up) with a hand tool. After lunch, the FF refilled his water supply and continued securing the fireline and mopping up for about 1.5 hours. After being left alone for a short period of time, the FF was found unconscious at approximately 1550 hours. The weather was sunny and hot: a temperature of 105 degrees Fahrenheit (°F), relative humidity of 24% with minimal wind (1 to 3 miles per hour).

Initial assessment by the crew's emergency medical technician (EMT) suggested the FF suffered from heat-related illness (HRI). Air Attack was notified as the crew EMTs provided basic HRI care at this remote location (the FF's pack and shirt were removed, he was doused with water, and a tarp was held up for shade). Local emergency medical service (EMS) units (ambulance and Air Evacuation helicopter) were not notified of the incident for about 20 minutes due to uncertain drop point coordinates. This delay, however, did not delay advanced life support (ALS) treatment because it

took 45 minutes to extract the FF to the drop point where the local EMS units were waiting.

Approximately 30 minutes after his collapse, the FF's condition deteriorated; respiratory arrest was followed by cardiac arrest, and cardiopulmonary resuscitation (CPR) was begun.

Approximately 15 minutes after his cardiac arrest the FF arrived at the drop point and the local, ambulance and Air Evacuation units initiated advanced life support (ALS) but their treatment protocols for exertional heatstroke did not include cold/ice water immersion therapy. When the FF arrived at the hospital ED a core temperature of 108° F was documented and ALS continued for an additional 5 minutes. At 1703 hours the attending physician pronounced the FF dead and resuscitation efforts were stopped.

The autopsy report listed the cause of death as "hyperthermia." NIOSH investigators agree with the Medical Examiner's assessment. NIOSH investigators conclude that the FF's hyperthermia was precipitated by moderate to heavy physical exertion in severe weather conditions. These factors led to exertional heatstroke.

All of the IHC members were exposed to heat stress (hot environmental conditions). Most IHC members interviewed by NIOSH reported symptoms consistent with HRI (feeling hot, feeling tired/fatigued/exhausted, weakness, headache, or nausea). Although indicators of heat strain were not

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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH “Fire Fighter Fatality Investigation and Prevention Program” which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency’s reports do not name the victim, the fire department or those interviewed. The NIOSH report’s summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency’s recommendations and is not intended to be definitive for purposes of determining any claim or benefit. For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Executive Summary (cont.)

measured (core body temperature, heart rates), on the basis of the environmental conditions and the reported symptoms, NIOSH investigators concluded that many of the IHC crewmembers had mild to moderate HRI.

Fatal exertional heatstroke is extremely rare among wildland fire fighters; this was the first reported case in the Agency's 65-year history and only the second reported federal wildland fire fighter to die from heatstroke according to wildland fire service records. Agency records, however, show that less severe cases of HRIs and dehydration are more common; 255 cases occurred over the past 12 years. NIOSH considers cases of HRI to be "sentinel health events" [NIOSH 1986]. Sentinel health events are preventable diseases, disabilities, or deaths whose occurrence serves as a warning signal that preventive or therapeutic care may be inadequate [Rutstein et al. 1983].

To prevent HRI and heatstroke, a number of organizations have developed guidelines for determining when environmental conditions are too hot to continue training, sporting, or work activities. The environmental conditions during this incident exceeded these guidelines. NIOSH investigators offer the following safety and health recommendations to reduce heat stress, heat strain, and prevent future cases of HRI and exertional heatstroke among wildland fire fighters. Implementing these recommendations will demonstrate a continuing commitment to improve the safety culture of the wildland fire service.

- **Strengthen the Agency's current heat stress program with the following components:**
 - 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;
- ***Always work in pairs and/or be in direct communication with crewmembers.***
- ***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.***

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Executive Summary (cont.)

- *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.*

Introduction & Methods

On July 7, 2011, a 23-year-old male wildland fire fighter (a member of an IHC) suffered fatal exertional heatstroke during mop-up operations. NIOSH was notified of this fatality on July 12, 2011 by the United States Fire Administration. On July 12, 2011, NIOSH contacted the employing Agency to gather additional information and initiate the investigation. On September 26, 2011, a Safety and Occupational Health Specialist and a Medical Officer from the NIOSH Fire Fighter Fatality Investigation Team traveled to Utah (Safety and Occupational Health Specialist) and Idaho (Medical Officer) to conduct an investigation of the incident. In addition, NIOSH met with Agency officials on April 9-10, 2012, to review and discuss the draft report. NIOSH investigators acknowledge the cooperation and assistance of Agency managers and crewmembers during the investigation.

During the investigation, NIOSH personnel interviewed the following people by phone or in person:

- State Fire Management Officer
- District Fire Management Officer
- Agency Human Resources Personnel
- Agency Fire Safety Manager
- Agency Fire Director
- Agency Program Specialist with the Medical Standards Program
- Incident Management Team Liaison
- IHC supervisor
- IHC members (of the 22 members of the crew: 13 were interviewed, 9 either refused or did not respond)
- Former IHC members

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Introduction & Methods (cont.)

- FF's parents
- FF's girlfriend
- Pathologist from the Office of the Medical Examiner who conducted the autopsy

NIOSH personnel reviewed the following documents:

- FF's personnel folder
- FF's time and attendance records for June 5 to July 7, 2011
- Agency policies and operating guidelines (i.e., Red book)
- Agency training records
- Agency "Serious Accident Investigation Factual Report"
- EMS/ambulance incident report
- Hospital ED record
- Autopsy report
- Agency medical records
- Agency chart of the number of wildland fire fighter injuries and illnesses due to heat or dehydration

Results of Investigation

Days Prior to the Incident. The FF was beginning his fifth season as a wildland fire fighter and his first season with the IHC. The crew was deployed from their Utah home base on June 23 to a fire in Georgia. After 2 days of travel from Utah to Georgia, the crew fought the fire for 4 days in hot and humid conditions [95°F – 99°F and 35% - 44% humidity].

On June 29 the crew was deployed to fires in Texas. After 3 days of driving, the crew staged in Sweetwater, Texas beginning on July 2 where they spent two nights in motels. On July 4, the crew was assigned an 11-hour shift of fire suppression (1330 hours to 2400 hours). On July 5 the crew was dispatched to another fire, but the request was cancelled and the crew returned to staging.

On July 6 the crew was dispatched to the CR 337 fire, a fire that started on July 4 from a lightning strike and had burned over 1,000 acres and four structures. The crew met for breakfast (0500 hours) and then traveled 120 miles to attend the CR 337 briefing session at the local high school (about 0800 hours). After about a 5-mile transport to the drop point (DP 20), they worked handlines and cold trailing for about 8 hours, ate dinner at DP 20, and returned to a hotel near the briefing center at 2200 hours. During that shift, it was hot, a high temperature of 103°F, and the crew took short breaks to eat lunch, snack, and drink fluids, but no formal lunch break occurred. Several fire fighters reported to NIOSH investigators that during and after this shift they were hot, tired, nauseated, dizzy, and had headaches; one fire fighter had vomited. These are all symptoms consistent with mild to moderate HRI. After spending the night in their motel, the crew returned to the CR 337 fire on July 7.

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Results of Investigation (cont.)

Incident. On July 7, the crew began their day at 0600 hours and drove from their motel to the CR 337 briefing area at the local high school. The crew attended briefings from 0800 to 0830 hours; safety and fire behavior were emphasized. They were told to expect hot conditions (temperatures above 100°F with relative humidity between 18%-26%). The crew then drove the 5 miles to DP 20 and unloaded; at 0900 hours they were briefed on work assignments, hazards, and fire behavior (Photograph 1). At this briefing hydration and work pacing were emphasized. Work pacing is the process by which fire fighters set their own work pace. It allows fire fighters 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 two bottles of Gatorade®. Crewmembers were wearing/carrying their typi-

cal wildland gear (green Nomex® pants, cotton tee-shirt, long sleeve Nomex shirt, boots, hardhat, gloves, and a 35-40 pound pack.)

The crew's assignment was constructing a fireline (handline) and cold trailing along a ridge until they met ("tied-in") with another IHC. The FF was initially assigned "swamper" duties (assisting the sawyer) on a saw team. The swamper and sawyer duties are considered very strenuous. 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. The FF 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 other IHC. They 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 HRI to their supervisor. After lunch, a supervisor noted that most of the water in the canteens had been



Photograph 1: Drop Point (DP) 20
Courtesy of the Agency's safety office

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Results of Investigation (cont.)

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, the FF, working with the Squad C crew leader, stumbled on a rocky slope while hiking down a drainage area. When asked if he was okay by the lead crewmember, the FF responded that “he was hot and had a little headache.” He was told to take a break if needed. The Squad C lead crewmember left the FF for a few minutes while he assisted another squad. When he returned at 1550 hours, he found the FF unresponsive in some rocks along the trail (Photograph 2). Although WBGT measurements were not available, weather conditions at 1500 hours were: dry bulb temperature of 105°F (40.6° Celsius(C)), wet bulb temperature of 75°F, 24% relative humidity, wind speed of 1-3 miles per hour (mph), and 0%

cloud cover. Dry bulb temperature is a measure of ambient air temperature and wet bulb temperature is a measure of ambient air temperature cooled by the evaporation of water from the wet temperature sensing element [NIOSH 1986].

The Squad C lead crewmember radioed the Assistant Superintendent that a FF was down. One of the crew’s emergency medical technicians (EMT#1) heard the radio traffic and headed toward the downed FF. Arriving about 2 minutes later, EMT#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#1 ordered a backboard, oxygen, and the trauma kit from the crew’s truck and requested the crew’s other EMT (EMT#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 #2 reached the FF. The FF’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). The FF was loaded onto the backboard. A tarp was held over him for shade while the IHC cut an extraction line from the FF’s location to the nearest dirt road (about 300 feet) (Diagram 1).

At about 1610 hours the FF’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



Photograph #2: Trail where FF was found unconscious
Courtesy of the Agency’s safety office

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Results of Investigation (cont.)

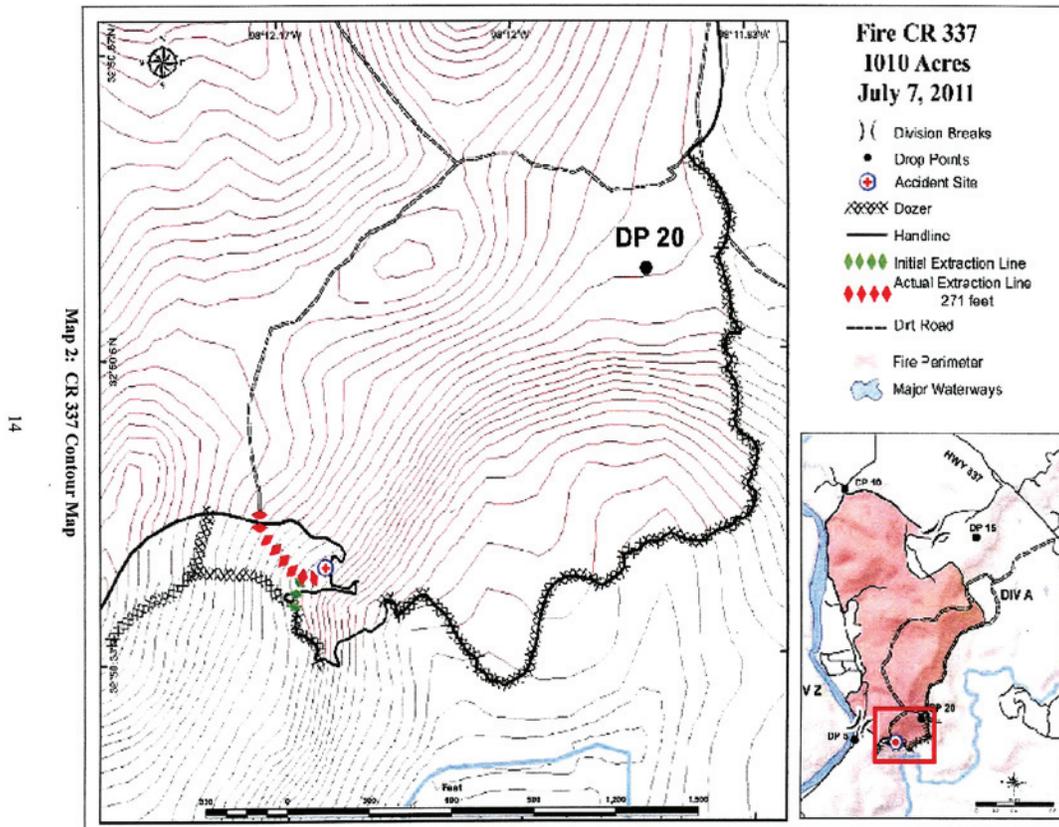


Diagram #1: Map of the Extraction Line; Courtesy of the Agency's Safety Office

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).

While the extraction line was being cut, the FF went into cardiac arrest (1620 hours) and CPR was initiated. Some crewmembers reported that the FF vomited during the resuscitation effort. Shortly thereafter, the FF was passed along the extraction route by crewmembers using a conveyor belt method (Photograph 3 and 4). This took about 2 to 3 minutes during which time CPR could not be administered. On arrival at the dirt road (Photograph 5), CPR resumed as the crew loaded and

secured the FF onto the waiting Regional Fire Coordinator's truck. The truck began traveling down the dirt road about 2100 feet to DP 20. Meanwhile, 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 Regional Fire Coordinator's truck. They all caravanned down the hill to DP 20.

On arrival at DP 20, the medic crews delivered oxygen to the FF by bag valve mask. At 1637 hours the FF was successfully intubated and had a pulse oximeter reading of 98% SaO₂ (normal), suggesting he was getting adequate oxygen into his blood. A cardiac monitor showed asystole (no

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Results of Investigation (cont.)



Photograph 3: Extraction line
Courtesy of the Agency's safety office



Photograph 5: Photograph where Extraction Line ended onto Dirt Road
Courtesy of the Agency's safety office



Photograph 4: Extraction line continued
Courtesy of the Agency's safety office

heart beat). An intravenous (IV) line was started and ALS medications, including IV fluid, were administered. The MedEvac and local ambulance crews discussed the best mode of transportation to the local hospital. They concluded that better medical care could be provided in the ambulance,

so at 1645 hours the ambulance departed DP 20 for the hospital. While enroute the FF's heart rhythm changed to ventricular fibrillation and a shock (defibrillation) was administered on two separate occasions. Both times the FF's heart rhythm reverted to asystole.

The ambulance arrived at the local hospital's ED at 1658 hours. The ED staff checked the endotracheal tube's placement and continued CPR and ALS. A rectal temperature showed 108°F. Despite these efforts, the FF's clinical condition remained unchanged. At 1703 hours the attending physician pronounced the FF dead and resuscitation efforts were stopped.

Medical Findings. The autopsy report, completed by the pathologist with the Medical Examiner's Office, listed the cause of death as "hyperthermia." Pertinent findings from the autopsy included no evidence of significant heart problems [normal sized heart (370 grams), normal heart valves,

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Results of Investigation (cont.)

no evidence of left ventricular hypertrophy, no conduction system abnormalities, and no coronary artery disease or thrombus] (Appendix A). The pathologist noted that the FF had a non-atheromatous 50% narrowing of his left anterior descending coronary artery not felt to be clinically significant. Other pertinent negative findings included no evidence of a pulmonary embolus (blood clot in the lung arteries); negative blood tests for drugs, alcohol, or medications known to exacerbate heat stress; 300 cubic centimeters (cc) of normal colored urine in the bladder; no evidence of acute tubular necrosis of the kidney on histology; and normal vitreous (eye fluid) electrolytes [134 milliequivalents (mEq/L) sodium per liter, 10.8 mEq/L potassium, 117 mEq/L chloride, 37 mEq/L glucose, and 13 mEq/L urea nitrogen]. These findings confirm the FF was not dehydrated and did not suffer from significant hyponatremia.

The FF had no previous medical problems, was taking no medications, and had no history of HRI while growing up or during his previous seasons as a wildland fire fighter. He was 69" tall and weighed 151 pounds, giving him a body mass index (BMI) of 22.3. A BMI of 18.5–24.9 is considered "normal" [CDC 2011]. He was physically fit and active on a daily basis. The FF passed his most recent pack test (see description in the following section) in May 2011.

Agency's Wildland Fire Fighter Program

Employment and Training. The Agency requires all new wildland fire fighter I or II applicants to complete an application and possess wildland fire-fighting certification otherwise known as the "Red Card." The red card is acquired by the following:

- 1) completing four courses: Introduction to ICS (I-100), Firefighter Training (S-130), Introduction to Wildland Fire Behavior (S-190), and Human Factors on the Fireline (L-180)
- 2) completing a health screening questionnaire (HSQ), and
- 3) passing a work capacity test (for the fire fighter position this requires the "arduous pack test"). The pack test requires the applicant to hike 3 miles with a 45-pound pack in 45 minutes or less.

The applicant is then referred for a preplacement medical evaluation (discussed below), a drug test, and a background check before receiving a job offer from the Agency. The FF was red card certified on May 7, 2011 and certified as a fire fighter type II (FFT2), a helicopter crewmember, and a tree faller class A.

The Agency has listed the essential job functions and work conditions for arduous duty wildland fire fighters (Appendix B). Once certified, wildland fire fighters can work on a variety of fire units. For his first three seasons (2007-2009), the FF worked on a "hand crew." Hand crews consist of 18-20 crewmembers who operate on wildland and prescribed fires, typically constructing fire lines with hand tools and chainsaws, burning out areas using drip torches and other firing devices, and performing mop-up and rehabilitation of burned areas. During his fourth season (2010), the FF worked on a "helitack crew." Helitack crews are delivered to fires via helicopter and suppress wildfires using hand tools and chainsaws.

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Agency's Wildland Fire Fighter Program (cont.)

During the FF's fifth season, he was accepted into an IHC. Hotshot crews are typically comprised of 20 crewmembers used for wildfire suppression and fuel reduction. While they perform the same duties as hand crews, they are generally placed in the most rugged terrain on the most active and difficult fire areas [NIFC 2011]. According to this IHC website, "hotshots typically carry packs that weigh up to 45 pounds and sometimes find themselves hiking rough terrain for several miles before reaching the work site. Shifts normally last up to 16 hours, but during initial attack can go much longer. The work can be exhausting at times, pushing some to their physical and mental limits. Temperatures during the work period can range from the low 30's to above 110° F." The FF was working on an IHC for 3 months prior to his death.

Preplacement Medical Evaluation. The Agency requires a preplacement (baseline) medical evaluation for all permanent positions. Components of this evaluation include the following:

- 1) Complete medical history (self-reported)
- 2) Physical examination (including vital signs – height, weight, blood pressure, pulse, and respirations)
- 3) Vision test (acuity, color, peripheral fields, and depth perception)
- 4) Audiogram
- 5) Spirometry
- 6) Blood tests: chemistries, complete blood count, and lipids
- 7) Urinalysis
- 8) Tuberculosis skin test (Mantoux)
- 9) Resting electrocardiogram for applicants aged 40 years or older

These medical evaluations can be performed by a Nurse Practitioner, Physician Assistant, or Physician licensed under a State Board of Medicine. Once this evaluation is complete, the clinician makes a determination regarding medical clearance for fire fighting duties and the candidate forwards the packet to the Fire Management Officer or the Servicing Human Resources Officer. The FF passed his baseline medical evaluation in 2007. At that time, the components of the medical evaluation included only items 1-4.

Periodic Medical Evaluations. The Agency requires all wildland fire fighters to undergo an abbreviated annual medical evaluation. This evaluation consists of a self-completed medical history (HSQ – Health Screening Questionnaire) and screening tests (vital signs, vision, and hearing). More extensive medical evaluations are triggered by the age of the fire fighter. For permanent fire fighters under the age of 45, medical evaluations are conducted every 5 years. For permanent fire fighters 45 years and older, medical evaluations are conducted every 3 years. The components of these periodic medical evaluations are the same as the baseline medical evaluation. They are performed by health care providers at no cost to the fire fighter.

Exit Medical Evaluations. All permanent wildland fire fighters receive a medical evaluation when they terminate service. The components are the same as the baseline evaluation (minus the Mantoux test). The evaluations are performed by health care providers at no cost to the fire fighter.

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Agency's Wildland Fire Fighter Program (cont.) Discussion (cont.)

Fitness Programs. The Agency supports fitness activities for all its employees by encouraging participation in a fire operations fitness challenge. The fitness challenge tests participants in four basic exercises: push-ups, pull-ups, sit-ups, and a 1.5- or 3-mile timed run. One hour of work time is authorized for this voluntary program that measures current fitness, establishes fitness goals, tracks fitness improvement, and provides recognition for participation and high achievers.

Discussion

Hyperthermia.

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]. The FF 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. Environmental heat is determined by four factors: 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 commonly reported "Heat Index" 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 fire fighters 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 C).

Metabolic Heat Generated During Wildland Fire Fighting. For those engaged in moderate to heavy physical work, metabolic heat is the primary

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Discussion (cont.)

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, fire-line 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 kcal/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 fire fighters 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 fire fighters 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 D). 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]. The FF 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]. The FF's presentation and clinical course was typical of exertional heatstroke while working in severe environmental conditions.

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Discussion (cont.)

Magnitude of the Problem: Heatstroke Fatalities.

Among wildland fire fighters and structural fire fighters 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 fire fighters spanning the 85-year period, 1910 to 1996 [NWCG 1997]. Of these five heatstroke fatalities, only two were federal wildland fire fighters and this was the first heatstroke death in the Agency's history. Heatstroke fatalities are extremely rare among federal wildland fire fighters.

Magnitude of the Problem: HRI. The Agency maintains a Safety Management Information System (SMIS) database of wildland fire fighter 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 1). 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,

Table 1. Reported cases of "Heat" or "Dehydration" by activity from 2000 to 2011

Categories	Wildland Fire	Pre-scribed Fire	Training	WCT	Yearly Totals
Year					
2000	11	0	0	0	11
2001	8	0	0	0	8
2002	9	0	1	0	10
2003	25	2	2	1	30
2004	8	0	2	1	11
2005	9	2	2	1	14
2006	25	0	4	1	30
2007	25	2	5	1	33
2008	26	2	4	0	32
2009	18	2	4	0	24
2010	16	3	5	0	24
2011	22	3	3	0	28
Total	202	16	32	5	255

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 fire fighters found that many fire fighters "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 fire fighter, 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

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system, 2) the SMIS database mentioned above which 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 fire fighters, 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 (e.g., 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 cancels all scheduled physical training when WBGT is above 32.0 [Pennington et al. 1980; Sawka et al. 2003; Nunneley and Reardon 2001]. The military waives these restrictions for “essential operational commitments....where the risk of heat casualties may be warranted” [Pennington et al. 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 fire fighters which 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 requirement of the IHC members were at least 300 kcal/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 fire fighters are at risk of HRI due to metabolic work requirements, environmental conditions, and long work hours. However, compared to many other occupations, wildland fire fighters have the advantage of being able to regulate their work pace (self-pacing). Self-pacing would allow wildland fire fighters to control the most

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important heat stress factor, metabolic heat production. However, it is unclear if wildland fire fighters, 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 fire fighters 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 fire fighters 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 E, F-1, and F-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 fire fighters 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 the FF’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 the FF’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 2001]. To fully acclimatize, however, 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].

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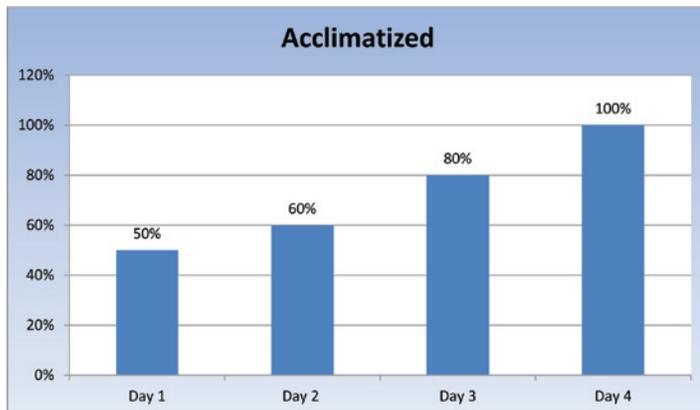


Figure 1: Work Schedule for Heat Acclimatized Employees* (Based on a 10-hour work shift)

*Adapted from NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

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 2001; 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 fire fighters, 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 FF’s 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 [Costrini 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 fire line (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 the FF 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 the FF’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 the FF’s core body temperature.

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Recommendations

NIOSH investigators offer the following safety and health recommendations to reduce heat stress and heat strain, and prevent future cases of HRI and exertional heatstroke among wildland fire fighters. Implementing these recommendations will demonstrate a continuing commitment to improve the safety culture of the wildland fire service.

Recommendation #1: Strengthen the agency's heat stress program with the following components:

- **instruct fire fighters 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 [Alexander 2011; Cuddy and Ruby 2011]. Although they can occur together, only 20% of hospitalized heatstroke cases show signs of dehydration [Epstein et al. 1999; Carter et al. 2005]. The Agency's educational materials and training programs focus on maintaining and increasing the body's cooling mechanisms via hydration, physical fitness, and acclimatization [Sharkey and Gaskill 2009; Domitrovich 2011]. Giving equal attention to controlling the primary source of heat generation (metabolic heat produced during work requiring heavy physical exertion) would strengthen these materials and programs, and enhance HRI prevention.

- **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. These missed work days could be vacation days, days off due to injury or illness, travel days, or staging days. The duration of the re-acclimatization period should be directly related to the length of time without heat exposure. For example, 6 days with no heat exposure would require 3 days of re-acclimatization. Figure 1 provides a re-acclimatization schedule for someone missing 6 days of work.

- **measure environmental heat conditions using a WBGT;**

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 [Parsons 2006]. 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 ACSM;**

To be consistent with these organizations, the NIOSH investigators recommend cancelling all physically demanding training for acclimatized individuals performing moderate to heavy when the WBGT is above 32.0 [Pennington et al. 1980; Armstrong et al. 2007; Nunneley and Reardon 2001].

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Recommendations (cont.)

- **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;**

This case, the other case reports in the scientific literature, the 255 cases in the Agency's SMIS database, and the unknown number of unreported cases show that heat stress and HRI occur among wildland fire fighters. The evidence also suggests that wildland fire fighters are not able to appropriately self-pace their work to prevent HRI [Cuddy and Ruby 2011]. Mandatory work-recovery cycles, like those developed for the United States military and general industry, should be implemented during severe environmental conditions [Pennington et al. 1980; NIOSH 1986; Nunneley and Reardon 2001; Sawka et al. 2003; ACGIH 2009]. These work-recovery cycles should be based on WBGT, metabolic work requirements, and acclimatization (Appendices E, F-1, F-2).

- **when heat stress screening criteria are exceeded, consider monitoring fire fighters for signs of heat strain;**

ACGIH recommends monitoring for signs of heat strain when its screening criteria are exceeded (Appendix E). 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.

NIOSH investigators 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) 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 [Alexander 2011]. 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 Supervision would initiate a "bimodal work shift unless life or property was threatened [Alexander 2011]. 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.

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Recommendations (cont.)

- **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 preplacement and periodic medical evaluations. As part of this evaluation, NIOSH investigators recommend that 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.

Recommendation #2: 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, fire fighters 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].

Recommendation #3: Promptly alert local EMS units of a medical emergency per Incident Command protocols.

NIOSH investigators do not believe the 20-minute delay in notifying local EMS units in this incident resulted in any treatment delays. Nonetheless, timely reporting could be a factor in other instances and following Incident Command policy is essential.

Recommendation #4: 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 [Costriani 1990; Bouchama et al. 2007; McDermott et al.

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Recommendations (cont.)

2009]. 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 [Binkley et al. 2004; Armstrong et al. 2007].

Recommendation #5: Seek input from crewmembers and frontline supervisors about removing barriers, real or perceived, to reporting or seeking medical attention for heat strain or HRI.

NIOSH investigators found no evidence that the Agency erected 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 are 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.

Recommendation #6: 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.

NIOSH considers cases of HRI to be 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 [NIOSH 1986; Nunneley and Reardon 2001].

Recommendation #7: Consider incorporating members of the Department’s Safety Office into the Operations Management Team.

Occupational safety and health professionals from the Department 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.

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Investigator Information

This incident was co-investigated by the two members of the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Tommy Baldwin, MS, is a safety and occupational health specialist, a National Association of Fire Investigators (NAFI) certified fire and explosion investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former fire chief and emergency medical technician. Thomas Hales, MD, MPH, is board certified in Occupational and Environmental Medicine, and Internal Medicine as is a member of the NFPA Technical Committee on Occupational Safety and Health, and vice chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

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Appendix A

Autopsy Findings

- Hyperthermia - rectal temperature of 108°F upon arrival in the emergency department
- No evidence of significant dehydration or rhabdomyolysis
 - 300 cc of normal colored urine in the bladder
 - No evidence of acute tubular necrosis of the kidney on histology
- Cardiac:
 - Normal sized heart (370 grams) [Silver and Silver 2001]
 - No evidence of left ventricular hypertrophy
 - No evidence of conduction system abnormalities,
 - No evidence of heart valve problems
 - Minimal or no atherosclerosis in any of the coronary arteries
 - No evidence of recent thrombus (blood clot in the coronary arteries), although a 50% narrowing (not plaque) in the left anterior descending coronary artery was noted,
 - No abnormalities seen on microscopic examination of the heart muscle
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs, alcohol, stimulants, or controlled substances were negative

References:

Silver MM, Silver MD [2001]. Examination of the heart and of cardiovascular specimens in surgical pathology. In: Silver MD, Gotlieb AI, Schoen FJ, eds. Cardiovascular pathology. 3rd ed. Philadelphia, PA: Churchill Livingstone, pp. 8–9.

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Appendix B

12

ESSENTIAL FUNCTIONS AND WORK CONDITIONS OF AN ARDUOUS DUTY WILDLAND FIREFIGHTER

Time/Work Volume	Physical Requirements	Environment	Physical Exposures
<i>May include:</i>			
<ul style="list-style-type: none"> • long hours (minimum of 12 hour shifts) • irregular hours • shift work • time zone changes • multiple and consecutive assignments • pace of work typically set by emergency situations • ability to meet “arduous” level performance testing (the “Pack Test”), which includes carrying a 45 pound pack for 3 miles in 45 minutes, approximating an oxygen consumption (VO₂ max) of 45 mL/kg-minute • typically 14-day assignments But may extend up to 21-day assignments • for smokejumpers - ability to meet the minimum Smokejumper Fitness Test, which includes 1 ½ mile run in 11:00 minutes or less, 25 pushups, 7 pullups, 45 situps; and carry 110 lbs for 3 miles in 90 minutes or less. 	<ul style="list-style-type: none"> • use shovel, Pulaski, and other hand tools to construct fire lines • lift and carry more than 50# • lifting or loading boxes and equipment • drive or ride for many hours • fly in helicopters and fixed wing airplanes • work independently, and on small and large teams • use PPE (includes hard hat, boots, eyewear, and other equipment) • arduous exertion • extensive walking, climbing • kneeling • stooping • pulling hoses • running • jumping • twisting • bending • rapid pull-out to safety zones • provide rescue or evacuation assistance • use of a fire shelter • for smokejumpers - lift and carry more than 100 lbs; perform parachute jumps, and perform parachute landings on uneven terrain 	<ul style="list-style-type: none"> • very steep terrain • rocky, loose, or muddy ground surfaces • thick vegetation • down/standing trees • wet leaves/grasses • varied climates (cold/hot/wet/dry/humid/snow/rain) • varied light conditions, including dim light or darkness • high altitudes • heights • holes and drop offs • very rough roads • open bodies of water • isolated/remote sites • no ready access to medical help 	<ul style="list-style-type: none"> • light (bright sunshine, UV) • burning materials • extreme heat • airborne particulates • fumes, gases • falling rocks and trees • allergens • loud noises • snakes • insects/ticks • poisonous plants • trucks and other large equipment • close quarters, large numbers of other workers • limited/disrupted sleep • hunger/irregular meals • dehydration
Exam_20111024			

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Appendix C

Estimating Wet Globe Bulb Temperature (WBGT)
From Temperature and Relative Humidity.*

		Wet Bulb Globe Temperature (WBGT) from Temperature and Relative Humidity																														
		Temperature (°C)																														
Relative Humidity (%)	0	15	16	16	17	18	18	19	19	20	20	21	22	22	23	23	24	24	25	25	26	27	27	28	28	29	29	30	31	31	32	32
	5	16	16	17	18	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	27	28	29	29	30	31	31	32	33	33	34	35
	10	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29	30	30	31	32	32	33	34	35	36	36	37
	15	17	17	18	19	19	20	21	21	22	23	23	24	25	26	26	27	28	29	29	30	31	32	33	33	34	35	36	37	38	39	
	20	17	18	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	31	32	32	33	34	35	36	37	38	39			
	25	18	18	19	20	20	21	22	23	24	24	25	26	27	28	28	29	30	31	32	33	34	35	36	37	38	39					
	30	18	19	20	20	21	22	23	23	24	25	26	27	28	29	29	30	31	32	33	34	35	36	37	39							
	35	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39								
	40	19	20	21	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39									
	45	19	20	21	22	23	24	25	26	27	27	28	29	30	32	33	34	35	36	37	38											
	50	20	21	22	23	23	24	25	26	27	28	29	30	31	33	34	35	36	37	39												
	55	20	21	22	23	24	25	26	27	28	29	30	31	32	34	35	36	37	38													
60	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38															
65	21	22	23	24	25	26	27	28	29	31	32	33	34	36	37	38																
70	22	23	24	25	26	27	28	29	30	31	33	34	35	36	38	39	WBGT > 40															
75	22	23	24	25	26	27	29	30	31	32	33	35	36	37	39																	
80	23	24	25	26	27	28	29	30	32	33	34	36	37	38																		
85	23	24	25	26	28	29	30	31	32	34	35	37	38	39																		
90	24	25	26	27	28	29	31	32	33	35	36	37	39																			
95	24	25	26	27	29	30	31	33	34	35	37	38																				
100	24	26	27	28	29	31	32	33	35	36	38	39																				

Note: This table is compiled from an approximate formula which only depends on temperature and humidity. The formula is valid for full sunshine and a light wind

*Source: Bureau of Meteorology [2010]. Thermal comfort observations - Web Bulb Globe Temperature (WBGT). Australian Government. [http://www.bom.gov.au/info/thermal_stress/#wbgt]. Date accessed: April 2012.

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Appendix D

Estimated Metabolic Heat Production (in kilocalories per minute) Rate for Interagency Hotshot Crew (IHC) Positions [ACGIH 2011, ISO 1989, NIOSH 1986]

<u>Various IHC Positions</u>	<u>kcal/min*</u>
A. Body Position and Movement	
Standing	0.6 kcal/min
Intermittent walking up and down	1.0 kcal/min
B. 'Type of Work –	
Whole Body – Moderate	5.0 kcal/min
C. Basal metabolism	<u>1.0 kcal/min</u>
Metabolic Rate Total	7.6 kcal/min x 60 min/hr = 456 kcal/hr
D. Multiply by the weight correction factor** -	456 kcal/hour x 1.14 = 520 kcal/hr

Total estimated metabolic rate = 520 kcal/hour

*For a standard male worker of 70 kg (154 pounds) body weight and 1.8 m² (19.4 feet²) body surface.

**The weight correction factor (WCF) is used when an employee weight plus his/her pack or load weigh other than 154 pounds (lbs). The factor is calculated by dividing the sum of the employee's current body weight (BW) and the pack weight as an average during the shift (PW) by 154 lbs [WCF = (BW + PW) ÷ 154 lbs]. The FF's correction factor on July 7, 2011 was estimated to be: (151 lbs + 25 lbs) ÷ 154 lbs = 1.14.

ACGIH [2011]. Heat stress and strain: documentation of TLVs and BEIs. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

International Organization for Standardization (ISO) [2004]. Ergonomics of the thermal environment – Determination of metabolic rate. Geneva, Switzerland.

NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

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Appendix E

TABLE 2. Screening Criteria for TLV[®] and Action Limit for Heat Stress Exposure

Allocation of Work in a Cycle of Work and Recovery	TLV [®] (WBGT values in °C)				Action Limit (WBGT values in °C)			
	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
75 to 100%	31.0	28.0	–	–	28.0	25.0	–	–
50 to 75%	31.0	29.0	27.5	–	28.5	26.0	24.0	–
25 to 50%	32.0	30.0	29.0	28.0	29.5	27.0	25.5	24.5
0 to 25%	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

Notes:

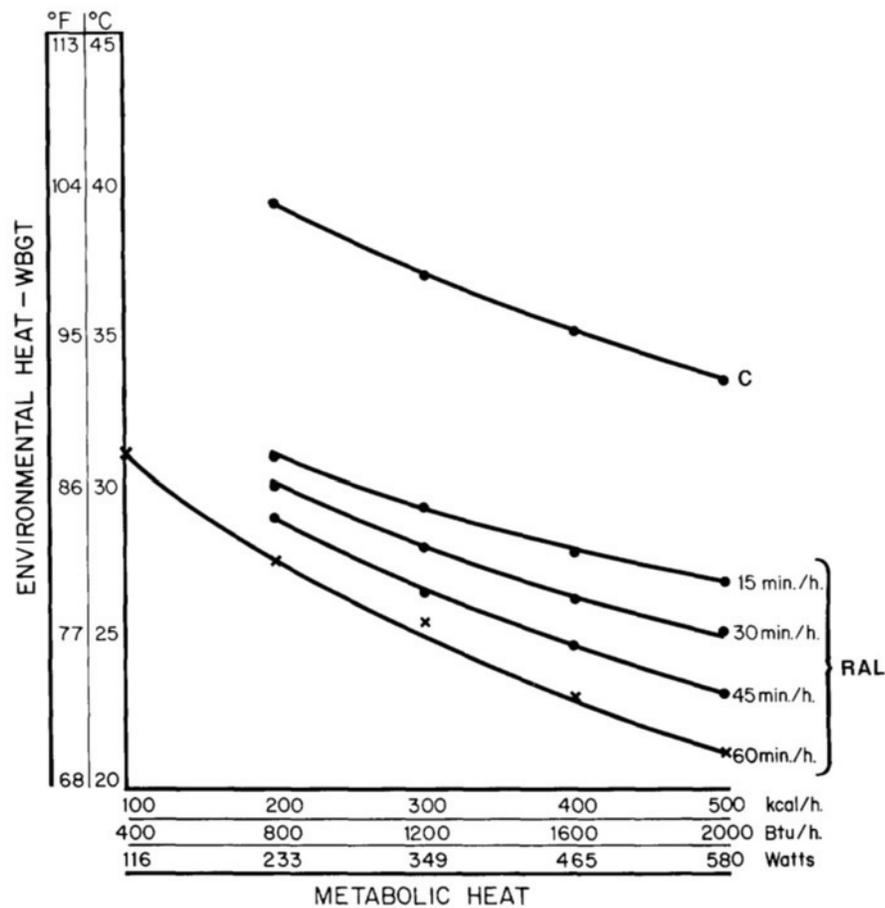
- See Table 3 and the *Documentation* for work demand categories.
- WBGT values are expressed to the nearest 0.5 °C.
- The thresholds are computed as a TWA-Metabolic Rate where the metabolic rate for rest is taken as 115 W and work is the representative (mid-range) value of Table 3. The time base is taken as the proportion of work at the upper limit of the percent work range (e.g., 50% for the range of 25 to 50%).
- If work and rest environments are different, hourly time-weighted averages (TWA) WBGT should be calculated and used. TWAs for work rates should also be used when the work demands vary within the hour, but note that the metabolic rate for rest is already factored into the screening limit.
- Values in the table are applied by reference to the “Work-Rest Regimen” section of the *Documentation* and assume 8-hour workdays in a 5-day workweek with conventional breaks as discussed in the *Documentation*. When workdays are extended, consult the “Application of the TLV[®]” section of the *Documentation*.
- Because of the physiological strain associated with Heavy and Very Heavy work among less fit workers regardless of WBGT, criteria values are not provided for continuous work and for up to 25% rest in an hour for Very Heavy. The screening criteria are not recommended, and a detailed analysis and/or physiological monitoring should be used.
- Table 2 is intended as an initial screening tool to evaluate whether a heat stress situation may exist (according to Figure 1) and thus, the table is more protective than the TLV[®] or Action Limit (Figure 2). Because the values are more protective, they are not intended to prescribe work and recovery periods.

Source: ACGIH [2011]. Heat stress and strain: documentation of TLVs and BEIs. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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Appendix F-1

NIOSH Recommended Heat Stress Alert and Heat-Stress Exposure Limits
Heat-Unacclimatized Individuals.*

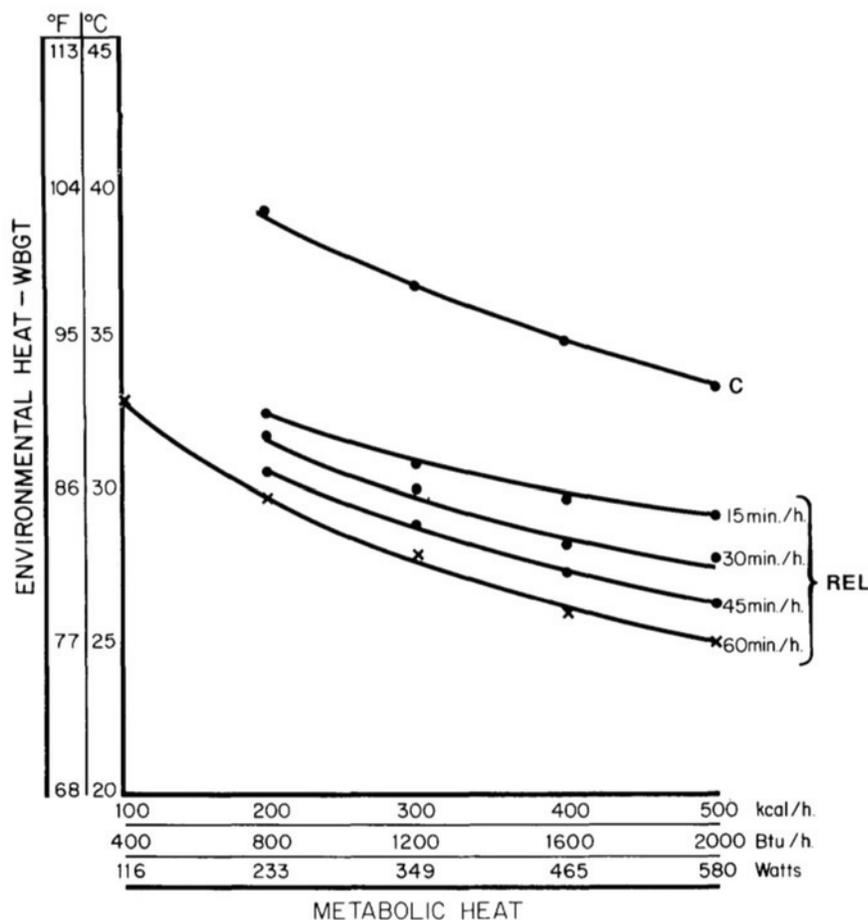


Source: NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

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Appendix F-2

NIOSH Recommended Heat Stress Alert and Heat-Stress Exposure Limits
Heat-Acclimatized Individuals.*



Source: NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.