



Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation
and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

May 2012

Engineer Dies from Heart Attack and Cardiac Arrest – Indiana

Executive Summary

On July 9, 2011, a 50-year-old male volunteer fire department (FD) engineer (the Engineer) began a 40-hour technical rescue and structural collapse training program. The training occurred on three consecutive weekends for 8 hours each day. The training occurred when the weather was hot and humid; daily heat indexes ranged from 84.5 degrees Fahrenheit (°F) to 103°F. In addition, the Engineer had a number of medical conditions that should have restricted his work as a structural fire fighter according to the National Fire Protection Association (NFPA).

After the first weekend of training, the Engineer expressed no cardiac or respiratory symptoms, but according to others at the training program, he did not appear well. During the second and third weekends of training, July 16–17, 2011, and July 23–24, 2011, the Engineer reduced his level of participation because of nausea. After the training, he missed 2½ days of work (as a commercial truck driver) because he was not feeling well. On July 30, 2011, 6 days after the last training session, the Engineer was hospitalized for respiratory distress. After 6 days of treatment in the hospital, the Engineer suffered a heart attack and subsequent cardiac arrest on August 5, 2011. Cardiac resuscitation efforts were unsuccessful, and the Engineer died.

The death certificate listed “cardiopulmonary arrest due to hypercapneic/hypoxic respiratory failure due to obesity-induced hypoventilation” as the cause of death. No autopsy was performed. Given

the Engineer’s underlying pulmonary problems, NIOSH investigators concluded that the physical stress of the training in elevated environmental temperatures may have contributed to the respiratory decline that preceded his heart attack and death.

NIOSH investigators offer the following recommendations to address general safety and health issues. If in place before this incident, these recommendations may have prevented the Engineer’s death.

Provide annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Incorporate exercise stress tests following standard medical guidelines into an FD medical evaluation program.

Recommendations for the Regional Training Academy:

Strengthen the Training Academy’s heat stress program with the following components: Measure environmental heat conditions with a wet bulb globe temperature (WBGT).

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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.)

Discontinue physically demanding training when heat stress criteria are exceeded according to the guidelines developed independently by the U.S. Army/Air Force and the American College of Sports Medicine.

Require hourly work/recovery cycles when heat stress criteria are exceeded according to NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH) guidelines.

Monitor fire fighters' vital signs in rehab.

The following recommendations address general safety and health issues for the FD. These recommendations would not have prevented the Engineer's death but are good health and safety measures to follow.

Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Perform an annual physical performance (physical ability) evaluation for all members.

Perform an autopsy on all on-duty fire fighter fatalities.

Introduction and Methods

Six days after completing training, a 50-year-old male volunteer Engineer was hospitalized for difficulty breathing. He remained in the hospital and 6 days later suffered a cardiac arrest; he died on August 5, 2011. NIOSH contacted the affected FD on August 12, 2011, to gather additional information, and again on November 22, 2011, to initiate the investigation. On November 30, 2011, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire chief
- Regional training academy instructor
- Engineer's spouse

NIOSH personnel reviewed the following documents:

- FD incident report
- FD standard operating procedures
- FD annual report for 2010
- Emergency medical service (ambulance) report
- Hospital ED records
- Hospital in-patient records
- Death certificate
- Primary care physician records

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Investigative Results

Incident. On July 9, 2011, the Engineer reported to the regional training center for a 40-hour technical rescue/structural collapse training program. The training was scheduled for three weekends from 0800 hours to 1700 hours each day. Trainees wore station uniforms with hard hat, gloves, leather boots, and safety glasses. The first day of training consisted of morning classroom instruction; the afternoon consisted of constructing shoring and wooden stabilization structures outside. Weather conditions included a daily high temperature of 87°F with a relative humidity of 46%, giving a heat index of 88.2°F and an estimated wet bulb globe temperature (WBGT) of 83.3°F (Appendices A and B) [NOAA 2011]. The second day of training, July 10, 2011, consisted of the same outdoor training. Weather conditions included a daily high temperature of 88°F with a relative humidity level of 52%, giving a heat index of 91.8°F and an estimated WBGT of 86.0°F (Appendices A and B) [NOAA 2011]. According to witnesses, during the day, the Engineer appeared ill, but did not report cardiac or respiratory symptoms.

The following weekend was also hot and humid. The heat index was 88.8°F on July 16, 2011, and 96.5°F on July 17, 2011; the estimated WBGT was 85.1°F on July 16, 2011, and 91.4°F on July 17, 2011 (Appendices A and B) [NOAA 2011]. The Engineer appeared pale and was seen leaning on stationary items. Although he participated in the training activities, the Engineer had difficulty lifting and cutting the lumber. Instructors asked several times if he was okay. The Engineer insisted that he was okay and wanted to continue the training. After going home, he rehydrated, took a nap, and reported feeling better.

During the third weekend of training, it was again hot and humid. The heat index was 103°F on July 23, 2011, and 84.5°F on July 24, 2011; the estimated WBGTs were 95.0°F on July 23, 2011, and 84.2°F on July 24, 2011 (Appendices A and B) [NOAA 2011]. The instructors noted that the Engineer was barely able to complete the training tasks. The instructors expressed their concern, but the Engineer said he would notify someone if he was “not okay.” The class ended, and the Engineer drove home. Concerned about his health, the instructors telephoned the Engineer’s fire chief. The fire chief drove to the Engineer’s home, but the Engineer was in the shower and did not hear the doorbell. Later in the evening, the chief telephoned the Engineer to discuss the day’s training and the instructor’s concerns. The Engineer replied that the weather was hot and that he would be okay.

The Engineer did not go to work July 25, 2011, and July 26, 2011. He went to work July 27, 2011, but came home early complaining to his wife that he felt “worn out and ached all over.” The Engineer worked July 28, 2011, and July 29, 2011, but complained of fatigue and shortness of breath. On July 30, 2011, the Engineer asked his spouse to drive him to the hospital.

Arriving at the hospital’s ED, the Engineer’s complaints included respiratory distress, coughing, congestion, and wheezing. He had an elevated blood pressure of 179/100 millimeters of mercury (mmHg), a pulse rate of 96 beats per minute (normal is 60–100 beats per minute), a respiratory rate of 24 breaths per minute (normal is 6–12 breaths per minute), and an oxygen saturation level of 88% (normal is 97%–99%). He complained of bilateral leg pain. Given his history of obstructive

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Investigative Results (cont.)

sleep apnea, pulmonary embolism, and deep vein thrombosis, a treatment regimen for respiratory distress was initiated. His primary admission diagnosis was acute respiratory failure due to obstructive chronic bronchitis with acute exacerbation, obesity hypoventilation syndrome, atrial fibrillation, and hypoglycemia. A chest x-ray revealed cardiomegaly but no obvious infiltrates or evidence of heart failure. An electrocardiogram (EKG) revealed normal sinus rhythm. Laboratory blood tests did not reveal evidence of cardiac damage (normal troponin T and creatine kinase-myocardial bands). He was initially started on a bi-level positive airway pressure machine but shortly thereafter required mechanical ventilation (intubation).

Over the next 5 days, the Engineer was weaned off mechanical ventilation and placed on the bi-level positive airway pressure machine again. On August 5, 2011, blood tests revealed cardiac damage (elevated levels of troponin T and creatine kinase-myocardial bands). At 1601 hours, the Engineer suddenly became very short of breath and then unresponsive. The cardiac monitor revealed pulseless electrical activity. Cardiac resuscitation efforts began and continued until 1645 hours, when the attending physician pronounced him dead, and resuscitation efforts were stopped.

Medical Findings. The death certificate, completed by the medical examiner, listed “cardiopulmonary arrest due to hypercapneic/hypoxic respiratory failure due to obesity induced hypoventilation” as the cause of death. No autopsy was performed.

The Engineer had multiple medical problems that, according to NFPA 1582, could have precluded work as a fire fighter. These included the following:

- Hypertension, diagnosed in 1991 with treatment initiated in 2006
- Obesity, treated with gastric bypass surgery in 2006 resulting in a weight drop from 430 pounds to 288 pounds in 2007. At the time of his death he weighed 328 pounds. His body mass index (BMI) was 38.9 kilograms per meter squared (kg/m²). A BMI of >30.0 kg/m² is considered obese [CDC 2011]. Since 2006, the Engineer developed a complication of the gastric bypass operation, episodic hypoglycemia [Patti and Goldfine 2010].
- Sleep apnea diagnosed in 2000 treated with continuous positive airway pressure machine, which was used intermittently
- Recurrent pulmonary embolisms due to deep vein thrombosis treated with an inferior vena cava filter. Most recent pulmonary embolism was diagnosed in 2010.
- Atrial fibrillation, treated with a blood thinner (coumadin) and defibrillation in 2010
- Cardiac conduction disorder (incomplete left bundle branch block) diagnosed in 2010
- Concentric left ventricular hypertrophy due to long-standing hypertension diagnosed by echocardiogram in 2006
- Diabetes mellitus diagnosed prior to 2006 and treated with diet (most recent HbA1c was 6.1% in 2010 [normal])
- Hypercholesterolemia diagnosed prior to 2006 and treated with diet (most recent cholesterol blood level was normal [131 milligrams per deciliter] in 2010)
- Smoking

In December 2010 the Engineer was hospitalized for chest pain. After heart attack was ruled out, he had a stress echocardiogram. He exercised for 6 minutes 50 seconds on the Bruce protocol (Stage

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Investigative Results (cont.)

II) achieving 7 metabolic equivalents (METs). It is unclear why the test was stopped at this point. He reported no symptoms, had a normal blood pressure response, no wall motion abnormalities, and no arrhythmias or changes of ischemia on EKG. These results were essentially unchanged from an exercise stress test performed in 2006 except the 2006 test was stopped due to shortness of breath and light-headedness after he achieved 93% of his maximal heart rate. After either test, no mention was made of clearing the Engineer for fire fighting duties.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 7 career and 25 volunteer uniformed personnel serving 20,000 residents in a geographic area of 60 square miles. In 2011, the FD responded to 1,064 incidents: 65 fire calls, 694 medical calls, and 305 other calls.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, complete an interview with the fire chief, be recommended to the fire board, and pass the fire board interview. The new member is placed on 2-year probation and must pass (1) a preplacement medical evaluation (discussed below), (2) a physical ability test, (3) Fire Fighter 1 training, (4) Fire Fighter 2 training, and (5) a background check. Career fire fighters work a 24-hour shift, followed by 48 hours off-duty. Volunteer members must attend regular monthly meetings and training. The Engineer, a volunteer, was certified as a Fire Officer, Fire Fighter 2, Apparatus Operator, Emergency Medical Technician, Fire Instructor, Wildland Fire Fighter, Technical Rescue, and Hazardous Materials to the technician level. He had 20 years of fire fighting experience.

Description of the FD (cont.)

Preplacement Medical Evaluations. The FD requires preplacement medical evaluations for all applicants. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Complete blood count
- Urinalysis
- Urine illicit drug screen
- Spirometry
- Resting EKG
- Chest x-ray (baseline)
- Hearing (audiometric) test
- Vision screen
- Tuberculin (PPD) skin test
- Respiratory protection questionnaire

The evaluations are performed by a city-contracted physician. Once this evaluation is complete, the contract physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. No medical evaluation was performed when the Engineer joined the FD 20 years ago.

Periodic Medical Evaluations. Beginning in 2011, the FD required periodic medical evaluations every other year for all members. The components are the same as the preplacement medical evaluation. These are performed by a city-contracted physician who makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. The Engineer had not been scheduled for this evaluation.

Members injured on duty must be evaluated by the city-contracted physician who forwards a return to duty decision to the FD. Members injured off duty must be evaluated by their primary care physician,

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Description of the FD (cont.)

who forwards an opinion to the city-contracted physician who makes a final medical clearance decision. Career members who are ill and off work for two or more shifts, or volunteers who miss training and responses for 2 months or more must be evaluated by their primary care physician to return to work. An annual self-contained breathing apparatus facepiece fit test is required.

Health and Wellness Programs. The FD requires a preplacement physical ability test for all candidates. However, no annual physical ability test is required. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire station. The FD pays for local gym memberships for members. The Engineer participated in an exercise program that included walking 1–2 miles four times weekly.

Dicussion

The Engineer suffered respiratory failure upon hospital admission. His respiratory failure was due to a combination of previous pulmonary embolism, sleep apnea, and obesity. While in the hospital, the Engineer suffered a heart attack and subsequent cardiac arrest.

To reduce the risk of incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Engineer had eight conditions relevant to medical clearance: pulmonary embolism, sleep apnea, atrial fibrillation, anticoagulation therapy, atrioventricular block, hypertension, beta blocker therapy, and diabetes mellitus.

Dicussion (cont.)

Pulmonary Embolism. In December 2010, the Engineer was hospitalized for a pulmonary embolism. NFPA 1582 states that an acute, recent, or chronic pulmonary embolism interferes with a member's ability to safely wear a self-contained breathing apparatus, climb ladders, operate from heights, walk or crawl in the dark along narrow and uneven surfaces, and operate in proximity to electrical power lines or other hazards [NFPA 2007a].

Sleep Apnea. In 2000 the Engineer was found to have obstructive sleep apnea and was prescribed a continuous positive airway pressure unit; his use of the unit was intermittent. NFPA 1582 identifies sleep apnea as a “disorder of respiratory regulation that can result in gas exchange abnormalities (hypoxemia [decrease in oxygen saturation] or hypercapnic disorder [elevated carbon dioxide with serum PCO₂ ≥ 45 mmHg]) that prevent the safe performance” of fire fighting tasks, wearing a self-contained breathing apparatus, climbing six or more flights of stairs while wearing turnout gear, advancing charged hoselines, and prolonged extreme physical exertion [NFPA 2007a]. It is unclear if the Engineer's sleep apnea was serious enough to result in job restrictions per NFPA 1582.

The U.S. Department of Transportation will not grant a commercial driver's license if a person has a clinical diagnosis of a respiratory dysfunction likely to interfere with his/her ability to control and drive a commercial motor vehicle safely [49 CFR 391.41]. A medical expert panel has recommended that the Federal Motor Carrier Safety Administration's current guidelines pertaining to individuals who have obstructive sleep apnea be replaced with the following statement: “A diagnosis of obstructive sleep apnea precludes an individual from obtaining unconditional certification to drive a commercial motor vehicle for

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Discussion (cont.)

the purposes of interstate commerce” [Ancoli-Israel et al. 2008].

Obesity. The Engineer’s weight was 495 pounds in 2006 and 288 pounds in 2007; his BMI was 58.7 in 2006 and 34.1 in 2007. Obesity can interfere with a fire fighter’s ability to safely perform the essential job tasks of fire fighting. These tasks require upper body strength and aerobic capacity of at least 12 METs [Glenhill and Jamnik 1992]. The Engineer’s upper body strength was not measured and an exercise stress test showed an aerobic capacity of approximately 7 METs.

Hypertension. The Engineer was diagnosed with high blood pressure in 1991. NFPA 1582 considers severe uncontrolled high blood pressure (systolic pressure > 180 mmHg, diastolic pressure > 100 mmHg, or mean systolic blood pressure > 120 mmHg or malignant hypertension to compromise a member’s ability to safely perform essential job functions [NFPA 2007a]. Although the Engineer had concentric left ventricular hypertrophy due to long-standing hypertension, his most recent blood pressure measurements (January 2011) did not meet the above criteria for restricted duty.

Atrial Fibrillation and Anticoagulation Therapy.

The Engineer was diagnosed with atrial fibrillation in June 2010 when he was hospitalized for high blood pressure. NFPA 1582 considers that atrial fibrillation and full-dose anticoagulation compromise a member’s ability to safely perform climbing ladders, operate from heights, walk or crawl in the dark along narrow and uneven surfaces, operate in proximity to electrical power lines or other hazards, and perform as an integral component of a team, where sudden incapacitation of a member can result in mission failure or in risk of injury or death to civilians or other

team members [NFPA 2007a]. The Engineer was prescribed coumadin for atrial fibrillation. Therefore, he should have been restricted from fire fighting duties. Even though the Engineer’s primary duty was as a driver/operator of fire apparatus, he actively participated in strenuous activities in training and during emergency responses.

Atrioventricular Block. NFPA 1582 considers left bundle branch block and right bundle branch block to potentially compromise a member’s ability to safely perform as an integral component of a team, where sudden incapacitation of a member can result in mission failure or in risk of injury or death to civilians or other team members [NFPA 2007a]. The Engineer was diagnosed with incomplete right bundle branch block in 2006 and incomplete left bundle branch block in 2010.

Diabetes Mellitus. NFPA 1582 provides guidance for fire department physicians to follow when treating diabetic fire fighters. The standard states that fire fighters with diabetes mellitus that is controlled by diet, exercise, or oral hypoglycemic agents should be restricted from duty unless the member meets all of the following criteria:

- If on oral hypoglycemic agents, has had no episodes of severe hypoglycemia (defined as requiring assistance of another in the preceding year)
- Has achieved a stable blood glucose as evidenced by HA1C level less than 8 during the prior 3-month period
- Has a dilated retinal exam by a qualified ophthalmologist or optometrist that shows no higher grade of diabetic retinopathy than microaneurysms
- Has normal renal function on the basis of a calculated creatinine clearance greater than 60 milliliters per minute and absence of proteinuria

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Discussion (cont.)

- Has no autonomic or peripheral neuropathy
- Has normal cardiac function without evidence of myocardial ischemia on cardiac stress testing (to at least 12 METs) by EKG and cardiac imaging [NFPA 2007a].

The Engineer was not prescribed diabetic medications or insulin, but had complications of asymptomatic hypoglycemia due to his gastric bypass operation. Hypoglycemia can cause sudden incapacitation, and NFPA recommends restricting the job duties of fire fighters with this condition [NFPA 2007a]

Beta Blocker Therapy. In 1991 the Engineer was found to have hypertension. In 2007, he was prescribed an antihypertensive beta blocker. The NFPA considers use of beta blockers to potentially preclude safely wearing the fire protective ensemble and safely climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces, and operating near electrical power lines or other hazards because of the risk for dehydration, electrolyte disorders, lethargy, and disequilibrium [NFPA 2007a].

Given the Engineer's atrial fibrillation, pulmonary embolism, full-dose anticoagulation treatment, atrioventricular block, beta blocker medication, and hypoglycemia, he should have been restricted from full fire suppression duties.

Coronary Heart Disease and Exercise Stress Tests. The Engineer had multiple risk factors for coronary heart disease and despite being asymptomatic, should have had additional exercise stress tests to screen for coronary heart disease. Recommendations for conducting exercise stress tests on asymptomatic individuals without known heart disease are varied. The following paragraphs sum-

marize the positions of widely recognized organizations on this topic.

National Fire Protection Association (NFPA) 1582, a voluntary industry standard, recommends an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (i.e., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease (CAD)
- two or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter), hypertension (diastolic blood pressure greater than 90 mm of mercury), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology/American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states that the evidence to conduct stress tests in asymptomatic individuals with diabetes mellitus is "Class IIa," which is defined as "conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/opinion is in favor." The ACC/AHA guideline states the evidence is "less well established"

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Discussion (cont.)

(Class IIb) for the following groups:

- persons with multiple risk factors (defined similarly to those listed by the NFPA)
- asymptomatic men older than 45 years and women older than 55 years:
 - who are sedentary and plan to start vigorous exercise
 - who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters)
 - who are at high risk for CAD due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation provides guidance for those seeking medical certification for a commercial driver's license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic "high risk" drivers [Blumenthal et al. 2007]. The panel defines high risk drivers as those with any of the following:

- diabetes mellitus
- peripheral vascular disease
- age 45 and above with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, the USPSTF found "insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning..." Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004].

The USPSTF does note that "For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

Given the Engineer's age and CAD risk profile, the NFPA, the ACC/AHA, and the Department of Transportation would have recommended a symptom limiting exercise stress test.

Heat Stress and Heat Related Illness. Heat stress is the sum of the heat generated from the body plus heat gained from the environment minus heat lost from 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 heat related illness (HRI) increases. HRI represents a wide spectrum of conditions typically ranging from skin rashes and heat cramps, to heat exhaustion, heat syncope, and heatstroke. The Engineer reported nausea during the training, which could have represented the early stages of a HRI.

Heat Indices. The technical rescue and structural collapse training occurred during hot and humid weather conditions. The heat index ranged from 84.5°F to 103°F. The heat index reported by the U.S. National Weather Service accounts for air temperature and humidity, but it does not account for wind (a major factor in removing heat) or radiant heat from the sun. In the 1950s wet bulb globe temperature

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(WBGT) was proposed as a simple, quick, and inexpensive index that could account for wind and 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].

A variety of organizations have developed guidelines for stopping or restricting physical activities based on the WBGT, metabolic work requirements, and acclimatization (described below). For moderate (300 kcal/hour) to heavy (415 kcal/hour) work among acclimatized individuals, the U.S. Army and Air Force cancel scheduled physical training when WBGT is above 89.6°F [Pennington et al. 1980; Nunneley and Reardon 2009]. The American College of Sports Medicine recommends cancelling all scheduled events when WBGT is above 90.1°F [Armstrong et al. 2007]. NIOSH and ACGIH have developed work-rest recommendations based on WBGT, metabolic work requirements, and acclimatization (Appendices C–E)

Acclimatization. Acclimatization is a series of physiological changes (sweating at a lower temperature, more sweating, less electrolyte loss, etc.) that make the body more efficient in reducing 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, 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]. Given the Engineer's occupation, limited exposure to hot environments, and poor physical condition, he was probably not acclimatized. Lack of heat acclimatization is a risk factor for HRI.

Rehabilitation. Rehabilitation (rehab) units allow fire fighters to rest, remove personal protective gear, drink fluids, and have their health status monitored. The training center's rehab unit provided a place to rest, drink cold liquids, and remove PPE (station uniforms worn by the trainees are well suited to remove heat by evaporation and convection). However, health monitoring did not appear to be provided. Finally, the Engineer had many personal risk factors for HRI. These include increasing age, obesity, poor physical fitness, various medical conditions (e.g., heart disease, diabetes mellitus).

The NFPA recommends developing a standard operating guideline for rehab at incidents and training exercises [NFPA 2008a]. A lesson plan was written for the training, but it did not include a medical component.

Rehab operations should consider hot weather conditions, including temperature, relative humidity, and direct sunlight [NFPA 2008a]. Humans can easily exceed a sweat rate of 64 ounces per hour in hot and humid conditions. Encapsulating fire fighting gear interferes with heat dissipation and traps moisture next to the skin. Hence, sweating begins and continues, even after work is stopped and the fire fighter enters rehab [NFPA 2008a].

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Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. If in place before this incident, these recommendations may have prevented the Engineer's death.

Recommendation #1: Provide annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2007a]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. To ensure improved health and safety of candidates and members, and to ensure continuity of medical evaluations, it is recommended the FD comply with this recommendation, particularly the section devoted to stress tests to screen for coronary heart disease. However, the FD is not legally required to follow the NFPA standard. Applying this recommendation involves economic repercussions and may be particularly difficult for smaller fire departments to implement.

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and EMTs from the local ambulance service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation,

if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. According to these guidelines, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. In certain instances, the FD currently utilizes the member's personal physician to clear fire fighters for return to duty.

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Recommendations (cont.)

In this case, given the Engineer's medical conditions and risk factors for CAD, the FD physician following NFPA 1582 guidelines would have restricted him from fire fighting duties, from tasks such as physically demanding training, and from working in hot environments.

Recommendation #3: Incorporate exercise stress tests following standard medical guidelines into a fire department medical evaluation program.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with two or more CAD risk factors [IAFF, IAFC 2008; Gibbons et al. 2002; NFPA 2007a]. The Engineer was over the age of 45 and had four of the risk factors for CAD (high blood lipids, high blood pressure, smoking, and diabetes mellitus) listed by these organizations. Seven months prior to his death, the Engineer had a negative sub-maximal exercise stress test. A symptom-limiting exercise stress test could have identified his underlying CAD.

Recommendations for the Regional Training Academy:

Recommendation #4: Strengthen the agency's heat stress program with the following components:

Measure environmental heat conditions with 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].

Discontinue physically demanding training when heat stress criteria are exceeded according to the guidelines developed independently by the U.S. Army/Air Force and the American College of Sports Medicine.

To be consistent with these organizations, the NIOSH investigators recommend cancelling all physically demanding training for acclimatized individuals performing moderate to heavy work when the WBGT is above 89.6°F [Pennington et al. 1980; Armstrong et al. 2007; Nunneley and Reardon 2009].

Require hourly work/recovery cycles when heat stress criteria are exceeded according to NIOSH and ACGIH guidelines.

Mandatory work-rest cycles should be based on WBGT, metabolic work requirements, and acclimatization (Appendices C–E).

Monitor fire fighter's vital signs in rehab when heat stress screening criteria are exceeded.

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 100.4°F in unacclimatized personnel and above 101.3°F in heat-acclimatized personnel

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Recommendations (cont.)

- 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 symptoms appear (sudden and severe: fatigue, nausea, dizziness, or lightheadedness) or if the individual has an oral temperature above 101.3°F.

The following recommendations address general safety and health issues for the FD.

Recommendation #5: Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; NFPA 2008b; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing

the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than \$1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007]. The FD currently has a voluntary wellness/fitness program which incorporates both career and volunteer personnel. Given the FD's structure, the NVFC program would be very helpful [USFA 2004]. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program. During exercise time, employees should be taken out of service to ensure uninterrupted participation.

Recommendation #6: Perform an annual physical performance (physical ability) evaluation for all members.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b]. This could be incorporated into the annual task-level training program.

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Recommendations (cont.)

Recommendation #7: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008, the USFA published the Firefighter Autopsy Protocol [USFA 2008]. With this publication, the USFA hoped to provide “a more thorough documentation of the causes of firefighter deaths for three purposes:

1. to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;
2. to help determine eligibility for death benefits under the Federal government’s Public Safety Officer Benefits Program, as well as state and local programs; and
3. to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired.”

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin 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. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales 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

Daily Temperature, Humidity, and Heat Index Highs During Training

Date	Temp °F (°C)	Humidity (%)	Heat Index*	Estimated WGBT °F (°C)*
July 9, 2011	87 (30.6)	46	88.2°F	83.3 (28.5)
July 10, 2011	88 (31.1)	52	91.8°F	86.0 (30.0)
July 16, 2011	87 (30.6)	48	88.8°F	85.1 (29.5)
July 17, 2011	91 (32.8)	50	96.5°F	91.4 (33.0)
July 23, 2011	89 (31.7)	70	103.0°F	95.0 (35.0)
July 24, 2011	81 (27.2)	69	84.5°F	84.2 (29.0)

*Estimates using Bureau of Meteorology [2010]. Thermal comfort observations – Wet Bulb Globe Temperature (WBGT). Australian Government. [http://www.bom.gov.au/info/thermal_stress/#wbgt]. Date accessed: February 2012.

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Appendix B

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

Wet Bulb Globe Temperature (WBGT) from Temperature and Relative Humidity	
Relative Humidity (%)	Temperature (°C)
	20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
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
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 C

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:

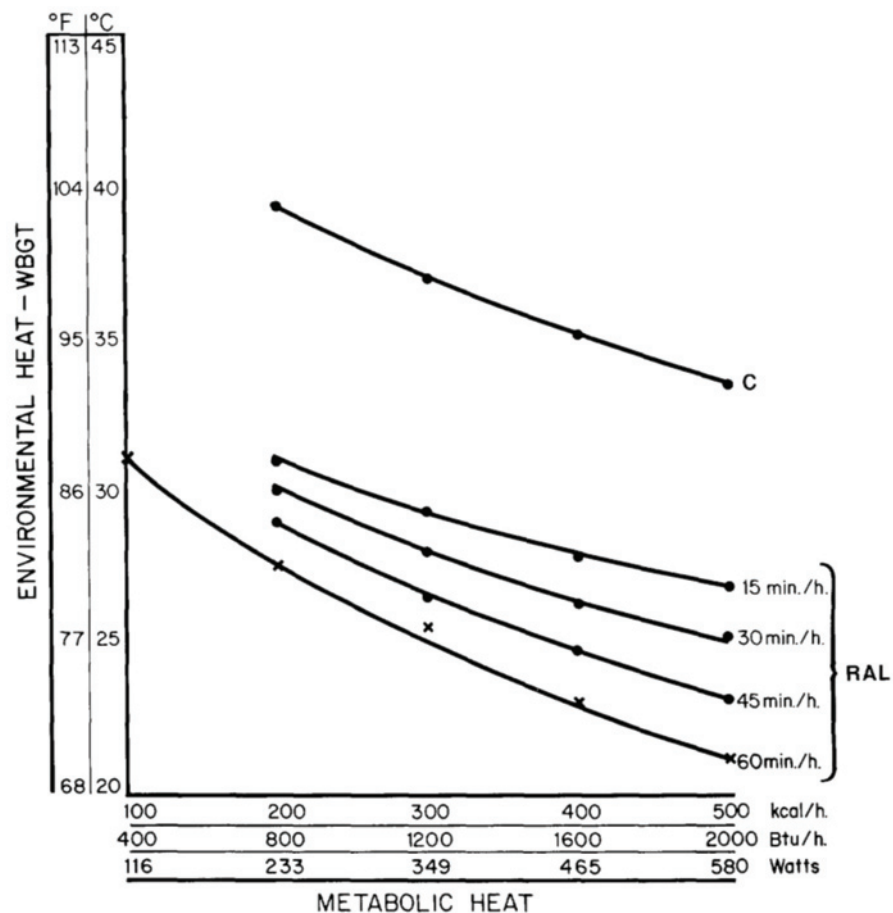
- See Table 3 and the *Documentation* for work demand categories.
- WBGT values are expressed to the nearest 0.5 °C.
- The thresholds are computed as a TWA-Metabolic Rate where the metabolic rate for rest is taken as 115 W and work is the representative (mid-range) value of Table 3. The time base is 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.

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Appendix D

NIOSH Recommended Heat Stress Alert and Heat Stress Exposure Limits for Heat-unacclimatized Individuals*

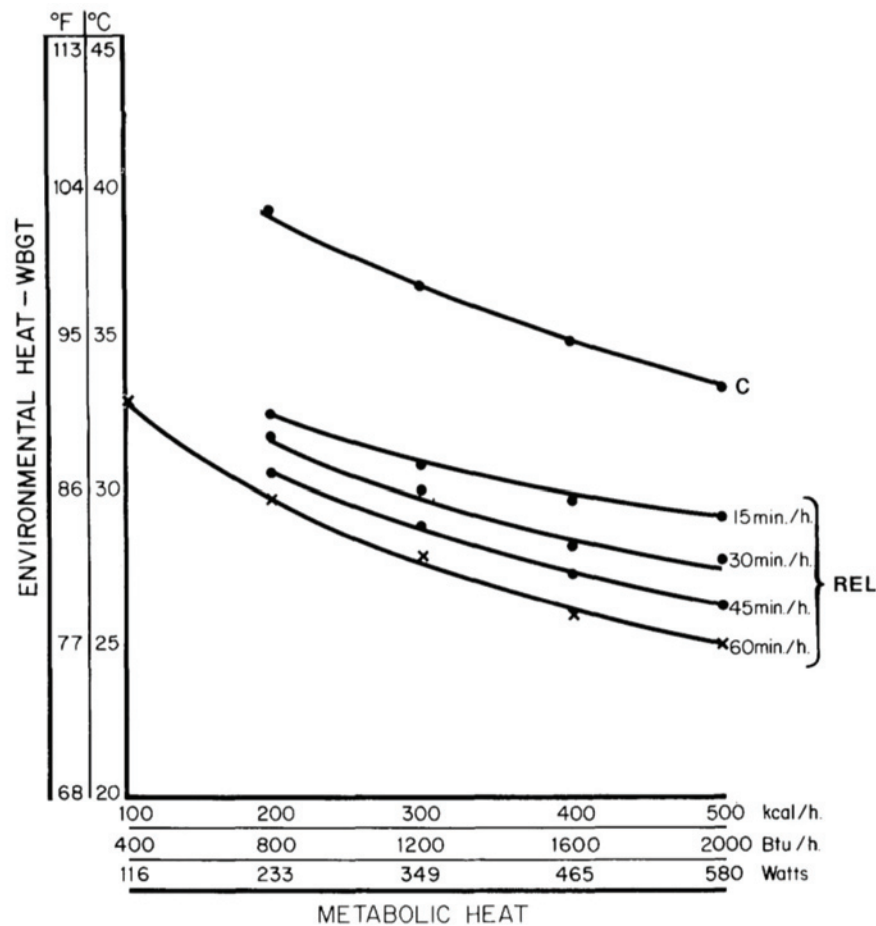


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Appendix E

NIOSH-recommended Heat Stress Alert and Heat-Stress Exposure Limits for Heat-acclimatized Individuals



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