TO: Director, National Institute for Occupational Safety and Health

FROM: California Fatality Assessment and Control Evaluation (FACE) Program

SUBJECT: Fire fighter dies of heat stroke while making a fire line during a wildland fire in California

SUMMARY
California FACE Report # 97CA010

A 21-year old fire fighter (decedent) died, another fire fighter was overcome by heat stroke, and two others by heat exhaustion during the construction of a fire line during a small, wildland fire which occurred in an area of steep slopes. The group to which these fire fighters belonged underwent 1 to 1 1/2 hours of physical training on the morning of the fire. Thereafter, they practiced cutting a fire line for 1 hour just prior to being called to the fire scene. Fire fighters were wearing standard gear including work pants under Nomex pants and a Nomex shirt with no lining worn over a white T-shirt. Of the crew interviewed by the employer, 80% had symptoms of heat illness. The decedent had been ill the day prior to the incident. The ambient temperature at the time of the incident was 98 degrees F and the relative humidity was approximately 30%. The CA/FACE investigator concluded, that in order to prevent future occurrences, fire agencies should:

- Require supervisors to regularly monitor firefighters, using generally accepted methods, during periods of high heat stress.
- Assure firefighters workloads are appropriate for their level of acclimatization.
- Assure firefighters workloads are appropriate for ambient weather conditions and clothing.

INTRODUCTION

On May 29, 1997 at 2:35 p.m. a 21-year old male fire fighter was overcome with heat stroke and died eleven hours later. One other fire fighter was overcome by heat stroke and two by heat exhaustion. The fire fighters were constructing a fire line during a 20-acre brush fire. Approximately 2 to 2 1/2 hours into the line construction crew members began to fall ill. The CA/FACE investigator learned of the incident on May 29, 1997 when paged by the International Association of Fire Fighters (IAFF) in Sacramento. The CA/FACE investigator traveled to the employer's local headquarters on June 3, 1997 An IAFF health and safety staff member from Sacramento was also present. They met with the fire agency's investigation team and interviewed its members. The CA/FACE investigator also contacted the local Cal/OSHA district office, obtained a form 36, and obtained a preliminary report and copies of operating procedures

from the fire service having jurisdiction.

The fire service for whom the decedent worked has been an organized agency for twenty-one years. The total number employed by the fire service is approximately 2,400. There were 37 fire service members at the scene of the incident. In addition, a local fire department was also present. The decedent had been a contracted worker for the fire service since February 18, 1997, but this was his first opportunity to fight a real fire. Each member of the fire service undergoes 64 hours of training, including a section on heat illness. The crew leader (a fire captain) is the person assigned to safety duties and devotes 100% of his time to these duties. Employer stated that "tailgate" sessions are held on a regular basis.

INVESTIGATION

The scene of the fire was a 20-acre area covered by dry grass and scattered brush in a rocky area. The area was gently to steeply sloped with the average slope being moderately steep. No shade existed in the area which was dotted with boulders and exposed rock formations. The weather conditions in the incident area at 12:35 PM were a dry bulb temperature of 98 degrees F, relative humidity of 30%, calm, with clear skies and slight haze. Witnesses indicated that the site where the decedent was working had a noticeable increase in air temperature. This was possibly due to the reflection and/or radiation of heat from a large rock face and the area being sheltered from air currents.

The decedent had been ill with a suspected viral or bacterial infection. It was unknown at the time if he was taking any medication. Other crew members reported that there was an illness, with symptoms similar to those of the decedent, among the crew. The decedent had just come back from his days off, was officially sick for one day, but did not bring a doctor's return to duty note. On the morning prior to the incident, the crew of which the decedent was a member exercised for 1 to 1 1/2 hours as part of their physical training regimen. Thereafter, the crew practiced constructing a fire line for approximately 1 hour. At approximately 1030 a.m. the fire was reported and crews from the local and state fire departments responded. The crew of which the decedent was a member was part of the callout and arrived at 11:45 a.m. They were given their assignment to construct a fire line on the right flank of the fire from its origin to the base of a large rock face. There was no fire along this line. It was constructed as a precaution. The forward progress of the fire had been contained by aircraft drops and hose line.

The crew began to construct the fire line as assigned, beginning at approximately noon. When they reached the rock face they were given instructions to continue by constructing a fire line in an eastward direction below the rock face. The crew members carried canteens and would drink whenever desired. Just prior to 2:00 p.m. the crew took a 15 minute rest break at which time they rehydrated with water or Gatorade. At approximately 2:00 p.m. the crew resumed cutting the fire line below the rock face. At about 2:15 p.m., a member of the crew fell and broke his shoulder. He was later diagnosed with heat exhaustion. He received first aid on site and was subsequently transported to the hospital. Prior to this, however, a member of another crew suffered heat exhaustion, was treated by paramedics and was returned to his base of operation.

At approximately 2:30 p.m. the decedent moved off the fire line. It was thought that he

was going to relieve himself. However, about five minutes later he was seen on the ground, thrashing in the bushes. The crew leader, a fire captain, went to his location. The decedent was found to be semi-consciousness and suffering from severe heat stress. The fire line construction was stopped. A paramedic captain on the rock above the decedent immediately went to the decedent's location. Personnel on the scene treated the decedent for shock and heat illness including clothing removal, dumping canteens of water on his skin, and applying chemical cold packs to the body.

The crew captain called for medical assistance and informed the incident commander (IC) that he had a fire fighter down. The paramedics arrived at approximately 2:50 p.m. at which time they applied additional cold packs, administered oxygen and started an IV saline solution. At 2:57 an additional paramedic unit arrived at the scene. At 3:00 p.m. another member of the crew went down with heat illness symptoms. He was subsequently diagnosed with heat stroke. At 3:15 the decedent was carried by stretcher off the hillside to a waiting ambulance which departed at 3:20 for the hospital. The decedent died at the hospital at 1:06 a.m. on May 30, 1997. The second fire fighter affected with heat stroke was removed from the hillside at 3:25 p.m.

CAUSE OF DEATH

The Office of the Medical Examiner stated the cause of death to be hypoxic encephalopathy secondary to hyperthermia.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Fire agencies should require supervisors to regularly medically monitor firefighters, using generally accepted techniques, during periods of high heat stress.

Discussion: The American Conference of Governmental Industrial Hygienists (ACGIH), the National Institute of Occupational Safety and Health (NIOSH), and the Federal Occupational Safety and Health Administration (OSHA) recommend medical monitoring of workers during periods of high heat stress. According to the decedent's employer, the medical condition of members of the decedent's crew was monitored by the crew captain. The captain performed the evaluation while supervising the firefighters work. The captain would observe and question each firefighter. There was no set schedule for how frequently each worker was visited. While observation and questioning can provide valuable information regarding a person's level of heat stress, they have not been found to be as reliable a predictor of future heat illness as oral temperature, heart rate, recovery heart rate, and extent of water loss. Although oral temperature and extent of water loss would probably have been difficult to obtain in conditions existing at the time of the incident, obtaining the heart rate and recovery heart rate would have been simple. The most frequently used protocol for obtaining the heart rate (P1) is to measure the individuals pulse during the interval from 30 seconds to 60 seconds after rest begins and then to multiply by two. The recovery heart rate (P3) is obtained by measuring the pulse during the interval from 2 1/2 minutes until 3 minutes after rest begins and then to multiply by two. If P3 is greater than 90 beats/min or P1-P3 is less than 10 beats/min, the individual is probably exceeding his/her

capacity for tolerating heat stress. When this occurs, the individual may develop some form of heat illness; heat cramps, heat exhaustion, heat stroke, etc. The different forms of heat illness are points along a continuum of severity. Heat stroke is simply the most extreme form of heat illness. If an individual shows signs of one form of heat illness, it implies they will develop a more severe form if no intervention/relief occurs. The presence of any form of heat illness is an indicator that exposure controls are inadequate. If information on heart rate and recovery heart rate had been available during the incident it may have influenced decisions regarding rest, rehydration, and medical intervention.

Recommendation #2:
Fire agencies should assure firefighter workloads are appropriate for their level of acclimatization.
Discussion: The decedent and his fellow crew members lived and trained at a mountain camp approximately 40 miles from the incident site. The average maximum daily temperature at this camp was 81.5 degrees F during the ten workdays prior to the incident. The maximum measured temperature during the incident was 98 degrees F. The difference in the ambient temperature between the period of their training and the period of the incident suggests the fire crew would not have been fully acclimated to the conditions at the incident site. The decedent was probably even less acclimated than the rest of the crew due to his days off with illness. Acclimatization is one of the major factors in determining how well an individual is able to respond to heat stress. It generally takes five days of working at least 1 1/2 hours/day in a particular environment before the body becomes acclimated. Some acclimatization can be lost in as little as 3-4 days if the individual is exposed to a substantially different environment. To protect workers while developing acclimatization, NIOSH recommends new workers should be exposed to work in heat 20% on day 1 with a 20% increase each subsequent day. For workers who have had recent previous experience with the job, NIOSH recommends 50% exposure on day 1, 60% exposure on day 2, 80% on day 3 and 100% on day 4. The firefighters in this incident had performed 2 hours of activity at their camp before being called to the fire, and then worked for two hours at the incident site only stopping sporadically to drink water. According to NIOSH recommendations for partially acclimated workers, the firefighters should have then stopped work in that environment for the day or at least taken a much longer break. By continuing to work in a substantially hotter environment than that in which they had trained, the decedent and crew members were put at higher risk for all types of heat illness.

Recommendation #3: Fire agencies should assure firefighters workloads are appropriate for ambient weather conditions and clothing.
Discussion: The weather conditions in the incident area at 12:35 PM were a dry bulb temperature of 98 degrees F, relative humidity of 30%, calm, with clear skies and slight haze. Various organizations/agencies have made recommendations on workloads and schedules for high temperature environments; e.g. ACGIH, NIOSH, OSHA, and the United States Forest Service (USFS). The USFS does not make recommendations about the amount of time which should be spent at work and rest for specific temperature-humidity combinations, nor do they give an

absolute temperature (environmental or individual body core) above which work should be stopped. The USFS does state that at a temperature of 98 degrees F and 30% relative humidity, the conditions existing at the time of the incident, that "only heat acclimated individuals can work safely for extended periods." They recommend work-rest cycles be adjusted on the basis of heart rate monitoring.

The ACGIH, NIOSH, and OSHA recommendations for work schedule are determined by metabolic work rate, clothing, and the Wet Bulb Globe Temperature Index (WBGT) with provisions for adjustments on an individual basis through medical monitoring. The WBGT is an empirical index that uses a formula combining natural wet bulb temperature, globe temperature, and dry bulb temperature to provide an assessment of environmental heat stress. Although the natural wet bulb temperature and globe temperature were not measured at the site, their lowest possible values can be determined using the weather data that was collected. Using these calculated values for the natural wet bulb temperature and globe temperature, the WBGT could have been no lower than 80.1 degrees F at the time of the incident. The metabolic work rate for the work the firefighters were performing can be calculated, using formulas from NIOSH and ACGIH, as 400-500 kcal/hour. This calculated value is consistent with a study of Australian firefighters fighting brush fires who were found to have average measured metabolic rates of 432 kcal/hour.

The firefighters at this incident were wearing two layers of clothing; undershirt and dungarees under NOMEX shirt and pants. For a workload of 450 kcal/hour, two layers of clothing, and a WBGT of 80.1 degrees F, ACGIH, NIOSH, and OSHA all recommend that workers spend 30 minutes resting for every 30 minutes working. In this incident the firefighters worked two hours stopping sporadically to drink from canteens, then rested 15 minutes, then resumed work. The length of the work period and briefness of the break were inadequate to allow many of the firefighters effective recovery from heat stress. This was demonstrated not only by the death of the decedent, but also by the second case of heat stroke and high proportion of co-workers reporting symptoms of heat illness. Some firefighters are able to work on a continuous basis in similar severe conditions without developing heat illness. ACGIH states that workers who are more tolerant to work in the heat than average and who are under medical supervision may exceed the recommendations. However, this ability is highly individual, cannot be predicted, and can change rapidly over time. The factor that is usually predominant in determining a particular worker’s heat tolerance is that worker’s aerobic fitness (work capacity). Tests of aerobic fitness should play a major ongoing role in determining individual firefighter’s workloads.

By implementing and strictly following ACGIH, NIOSH, and OSHA recommendations on heat stress limits, fire agencies would provide a greater margin of safety in protecting all firefighters from heat illness. Implementation could be rapidly completed. The only equipment required would be the portable monitors for immediate determination of the WBGT, and these are readily available. Firefighters already undergo training in avoiding heat stress, therefore only a change of material and perhaps some slight additional training time would be required.

References:

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FATALITY ASSESSMENT AND CONTROL EVALUATION PROGRAM

The California Department of Health Services, in cooperation with the California Public Health Foundation, and the National Institute for Occupational Safety and Health (NIOSH), conducts investigations on work-related fatalities. The goal of this program, known as the California Fatality Assessment and Control Evaluation (CA/FACE), is to prevent fatal work injuries in the future. CA/FACE aims to achieve this goal by studying the work environment, the worker, the task the worker was performing, the tools the worker was using, the energy exchange resulting in fatal injury, and the role of management in controlling how these factors interact.

NIOSH funded state-based FACE programs include: Alaska, California, Colorado, Georgia, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, New Jersey, Wisconsin, and Wyoming.

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Additional information regarding the CA/FACE program is available from:

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