Volpentest HAMMER Training and Education Center
Managed by Mission Support Alliance, LLC

4-Hour Heat Stress Training

Student Manual

Prepared by Mizula, LLC 2011

2890 Horn Rapids Road, Richland, WA 99354

This training program was developed for the Volpentest Hammer Training and Education Center by

Mizula, LLC
21 Fletcher Lane
Hollis, NH 03049
603-689-4225
MizulaLLC@charter.net

Acknowlegdements

Mizula LLC would like to thank the following individuals and organizations for their contribution to this work:

- Bernard Mizula: Curriculum development
- Mark Jackson: Grammar review
- Darrell VanWagner: Graphics development and manual design/layout

Table of Contents

Introduction 1

1. Case Studies, Statistics and Regulations 2
    Case studies 2
    Causal factors that affect heat stress 3

Statistics on Heat Stress and HRI 4
    Large scale heat-related health incidents 4
    West coast studies concerning heat stress 4

Agencies and organizations that protect workers from heat stress 5
    Occupational Health and Safety Administration (OSHA) 5
    Department of Energy (DOE) 6
    The Center for Disease Control (CDC) and the National Institute of Occupational Safety and Health (NIOSH) 6
    The state of Washington has a few regulatory requirements for heat stress! 6
    American Conference of Governmental Industrial Hygienists (ACGIH) 8

2. Physiology of Heat Stress Illnesses and Treatment 8
    Heat Balance 8
    Heat Stress, Heat Strain and HRI 9
    Heat stress can lead to an increase in other safety, health and job-related issues 15

3. Work Environment Evaluation 17
    Wet Bulb Globe Temperature 17
    Heat Index 19
    Humidex 19
    ACGIH approach for heat stress evaluation 20

4. Work Environment Controls 20
Engineering controls 21
Administrative controls and work practices 23
Issues with work clothing and hot environments 29
Personal Protective Equipment (PPE) 31
5. HAMMER 4-hour heat stress course final activity 33
Summary 34
Resources 34

Introduction

This course was prepared for DOE Hanford workers, worker-trainers and health and safety professionals. This course deals with the topics of heat stress, heat strain and heat-related illness (HRI), their measurement and control and pertinent regulations. It is designed as a thermal stress refresher course but may also be used as an introductory course. If you are a worker taking this course, your instructor will most likely add materials to the course relating to your company's heat stress program and any Hanford SOPs concerning working in hot environments.

This course is divided into five main sections that follow the PowerPoint presentation as follows:

1. Case studies, statistics and regulations
2. Physiology, heat stress illnesses and treatment
3. Work environment evaluation
4. Work environment controls
5. Final group activity

After completing this course, you will be able to:

- Define heat stress, heat strain and heat-related illness (HRI)
- List five HRIs, identify their symptoms and state first aid measures for each
- List other issues heat stress can cause
- List two ways workers are protected from heat stress through regulations
- List five heat stress control methods
- Measure environmental conditions and develop a work plan to reduce heat stress for a given job

1. Case Studies, Statistics and Regulations

Being too warm while working is not just uncomfortable, it can be dangerous. Too much heat can cause serious health effects, and even death. In addition, excessive heat makes workers less productive and more likely to make mistakes, including errors that can cause injuries and fatalities. This section of the course will briefly cover some heat stress case studies and important statistics concerning heat stress and work. This section also covers regulations and guidance that protect workers from harm.

Case studies

Case study # 1

On June 15, 2006, at the DOE Central Training Academy, a participant in the DOE Security Protection Officer Training Competition suffered a heat injury during a strenuous team competition. The ambient temperature was 90 °F with 21 % humidity. The participant was hospitalized for 8 days before being released. (ORPS Report SO--CTAW-CTA-2006-0001).

Case study # 2

An employee of a non-governmental subcontractor (local small business) was standing on a ladder preparing a mobile office for transport when he apparently fell about 6 feet from the ladder and sustained severe trauma to his head and neck. He was pronounced dead on arrival at a local hospital.

On July 12, 2004, the subcontractor's employee underwent outpatient surgery with general anesthesia. On July 13, 2004, the subcontract company owner and employee worked for approximately four hours. Later that day at home, the subcontractor's employee was observed vomiting and collapsing twice. He stopped taking his medication. On July 14, 2004, the subcontract company owner and employee again worked for approximately four hours.

On the morning of July 15, 2004, the subcontractor's employee, while refilling a water bottle, remarked to another worker about the heat, saying he felt dizzy twice while working that morning, and that he had had surgery 3 days before. Later that day, the subcontractor's employee, while refilling his water bottle at the other mobile office, again remarked to building occupants about the heat. He expressed his desire to remain in the air-conditioned trailer. After returning to the job site about 5 minutes later, the subcontract company owner instructed the employee to remove the trim from the south side of the mobile office. When

the subcontract company owner went outside to check on the employee, when he no longer heard the power drill the employee was using, he found the employee lying motionless at the bottom of the ladder. A subsequent medical examination determined the employee had sustained a basal skull fracture and a laceration on the back of his head.

Upon review of the incident, it was determined that the employee's medical conditions may have contributed to his fall. In addition, high temperatures on the day of the accident (up to 98°F), and the employee's difficulty in acclimatizing to the heat may have aggravated his medical conditions.

Case Study #3

On June 26, 2006, a construction laborer suffered heat stroke while laying pipe. The 27-year old victim was newly hired and had not acclimated to working in hot weather. His current employer, a construction company, performs various types of outdoor construction. On the day of the incident a four-member work crew, including the victim, were laying an underground water line along a public road. The job was to lay sections of 12-inch PVC pipe in a 4-foot trench. The victim was carrying, laying, and connecting pipe and then leveling the trench. The crew began work at 8:30 a.m. and continued through the day. It was a hot day, with temperatures ranging from 82 to 105 degrees Fahrenheit and the humidity from 46 to 56%. The worksite was mostly exposed to direct sun. The employer had provided drinking water for the workers. It was reported that the victim consumed nearly five bottles of water during the day. At about 3 p.m. he became ill and his employer suggested that he rest in the shade. About 15 minutes later, his co-workers noticed he was slumped over and unconscious. Paramedics transported the victim to a hospital, where he died six days later from complications related to heat stroke.

Causal factors that affect heat stress

How can you tell who will be affected by heat stress and suffer HRIs? The question is difficult to answer because there are many contributing factors, such as the person's age, weight, degree of physical fitness, degree of acclimatization, metabolism, use of alcohol or drugs, and a variety of medical conditions, such as hypertension. All of these factors affect a person's sensitivity to heat. However, even the type of clothing the worker wears must be considered. Prior heat injury predisposes an individual to additional injury.

It is difficult to predict just who will be affected and when, because individual susceptibility varies. In addition, environmental factors include more than the ambient air temperature. Radiant heat, air movement, conduction, and relative humidity all affect an individual's response to heat.

With this said, you may be surprised to know that well-conditioned athletes are affected by heat stress and suffer HRI, including heat stroke! Even if you have a low susceptibility to heat stress, if you push your limits, you will EVENTUALLY succumb and perhaps experience a HRI.

Statistics on Heat Stress and HRI

Large scale heat-related health incidents

According to the Center for Disease Control (CDC), 3,443 deaths occurred in the U.S. from exposure to extreme heat between 1999 and 2003. Perhaps one of the most horrifying tolls a heat wave has incurred was in Europe (France in particular) where nearly 40,000 deaths were reported throughout European nations in 2003. Of these deaths, 14,802 occurred in France alone, according to the French National Institute of Health.

West coast studies concerning heat stress

In 2006, the State of California's Division of Occupational Safety and Health (Cal/OSHA) performed a detailed analysis of 25 investigations on heat-related illnesses that occurred in 2005 and that resulted in emergency room visits, hospital stays, or deaths. The results were to be used, in part, to develop a statewide heat illness prevention standard. Their findings may be of interest to DOE and its contractors. The findings are summarized below:

- Death resulted in 54% of the cases
- 38% of victims required 24+ hours of hospitalization
- 84% of cases involved outdoor work exclusively
- 92% of cases involved moderate or strenuous work
- Average temperature in cases was 96 °F
- Average humidity was 29%
- Work was in direct sunlight 76% of the time
- Shade was available in 77% of the cases
- Potable water was present in 100% of cases
- 78% of cases showed inadequate fluid consumption by workers

The state of Washington's Safety and Health Assessment & Research for Prevention (SHARP) department has reviewed the workers' compensation claims involving HRIs

among Washington state workers. The study analyzed ten years of workers' compensation data from 1995 to 2004. The SHARP study found that industry sectors accounting for the most number of claims were:

- Construction with 150 claims (34%)
- Public Administration with 71 claims (16%)
- Manufacturing with 43 claims (10%)
- Agriculture, Forestry, Fishing and Hunting with 31 claims (7%)

Workers in Eastern Washington were at higher risk of HRIs. Only 22% of Washington residents live in Eastern Washington. However, 47% of the HRI workers' compensation claims occurred there. Individual case files indicated several risk factors known to contribute to HRI. These included medical conditions and medication use known to affect the body's ability to cope with high heat.

SHARP also reviewed the literature regarding HRI. An executive summary of SHARP's report: Heat-related Illness in Washington State, State Fund Workers' Compensation Claims, 1995-2004 is available online (http://www.lni.wa.gov/) or by calling the SHARP program at 1-888-667-4277.

Agencies and organizations that protect workers from heat stress

Now that we know a little about how widespread the problem of heat stress is, let's review government agencies and professional organizations that put forth regulations (laws that must be followed) and recommendations or guidance that is meant to protect workers from heat stress.

Occupational Health and Safety Administration (OSHA)

OSHA does not have any regulations covering heat stress in the work environment. If heat stress is a workplace issue, the organization will cite employers under the General Duty clause. In addition, it is expected that OSHA inspectors will evaluate heat stress and as such, a chapter dedicated to heat stress investigation is found in Section III: Chapter 4 of the OSHA Technical Manual.

In addition, it is important to note here that some states have agencies that operate occupational safety and health programs, under an agreement with OSHA, in accordance with Section 18 of the Occupational Safety and Health Act of 1970. If you work at DOE Hanford, then you are working in an OSHA environment. However, on DOE sites, under the DOE

851 health and safety regulation, Federal OSHA regulations are used to cover many health and safety hazards.

Even though there is no official OSHA heat stress regulation, in 2011, OSHA started a heat stress campaign to Prevent Heat Illness in Outdoor Workers. The campaign information and resources can be accessed at http://www.osha.gov/SLTC/heatillness/index.html

Department of Energy (DOE)

Section 534 of DOE-STD-1098-99, Radiological Control, discusses heat stress as it applies to radiological work. The Standard recommends addressing heat stress when planning work in hot environments, setting appropriate work time limits, using clothing that wicks perspiration away from the body, using body cooling devices, and relaxing protective clothing requirements. It also points out that heat stress has occurred at ambient temperatures less than 70 °F when multiple sets of anti-contamination clothing (anti-C's) or plastic suits were worn or when strenuous work was required.

The Center for Disease Control (CDC) and the National Institute of Occupational Safety and Health (NIOSH)

NIOSH and the CDC create recommended procedures and guidance for activities conducted in hot weather. NIOSH also developed the "Criteria for a Recommended Standard: Occupational Exposure to Hot Environments" with the last revision being in 1986. As we will learn in sections 2, 3 and 4, NIOSH has created heat stress evaluation tools and first aid guidance for those who suffer an HRI.

The state of Washington has a few regulatory requirements for heat stress!

The state of Washington is one of the few states (California is another) that have regulations concerning heat stress. Below is a brief presentation describing what those regula-

tions cover and their identification so that you may investigate them further.

WAC 296-62-09013 Temperature, radiant heat, or temperature-humidity combinations

1) Workmen subjected to temperature extremes, radiant heat, humidity, or air velocity combinations which, over a period of time, are likely to produce physiological responses which are harmful shall be afforded protection by use of adequate controls, methods or procedures, or protective clothing. This shall not be construed to apply to normal occupations under atmospheric conditions that may be expected in the area except that special provisions which are required by other regulations for certain areas or occupations shall prevail. [Order 73-3, § 296-62-09013, filed 5/7/73.]

WAC 296-62-095 Outdoor heat exposure

The regulation covers:

- Outdoor temperature action levels
- Employer and employee responsibility
- Drinking water
- Responding to signs and symptoms of heat-related illness
- Information and training

1) WAC 296-62-095 through 296-62-09560 applies to all employers with employees performing work in an outdoor environment.

First aid for wildland fire fighters [WAC 296-305-07017]

(1) At all wildland fires, members shall be provided with a minimum of one quart per two-hour time period of electrolyte drinks or potable water.

(2) Officers at wildland fires shall be trained in the symptoms of heat-related disorders and shall observe their crews for such behavior. Appropriate action shall be taken in the event a crew member displays such symptoms.

Control heat stress hazards created by PPE [WAC 296-824-60015]

Control hazards created by the use of PPE, including:

- Heat stress due to extremely high temperatures
- Any other employee health hazard and consideration

American Conference of Governmental Industrial Hygienists (ACGIH)

ACGIH recommends removal from heat exposure if:

- Sustained (several minutes) heart rate > (180 bpm – accounting for age)
- Body core temp > 38.5°C for medically selected & acclimatized
- Body core temp > 38°C in medically unselected & un-acclimatized
- Recovery heart rate after 1 minute peak effort > 120 bpm
- Symptoms of sudden & severe fatigue, nausea, dizziness or lightheadedness

ACGIH states individuals may be at greater risk if the following occurs:

- Profuse sweating is sustained over hours
- Weight loss over shift > 1.5% body weight
- 24-hour urinary sodium excretion is < 50 mmoles

ACGIH also as many heat stress evaluation tools which will be reviewed in section 3 and 4 of this course.

2. Physiology of Heat Stress Illnesses and Treatment

Heat Balance

An essential requirement for continued normal body function is that the deep body core temperature be maintained within the acceptable range of about 98.6oF (37oC) ±1.8oF (1oC). To achieve this body temperature equilibrium, a constant exchange of heat between the body and the environment takes place. The fundamental laws of thermodynamics of heat exchange between objects govern the rate and amount of heat exchange in a worker. The amount of heat the body must exchange to maintain equilibrium is a function of the total heat produced by the body (metabolic heat) and the heat gained and lost to the environment. The environmental exchanges depend on air temperature, humidity, skin temperature, air velocity, evaporation of sweat, radiant temperature and clothing worn. Respira-

tory heat loss is rarely used in the heat balance equation because it is generally very small except during hard work in dry environments. With that said, the main factors in maintaining heat balance are metabolic rate, radiant heat, convection and evaporation rate. The simple form of the heat balance equation is shown below:

$$S=M+R+C+E$$

Where:

S = heat storage rate
M = metabolic rate
R = radiant heat exchange rate
C = Convective heat exchange rate
E = Evaporation rate of heat

If S is negative, heat is being removed from the body into the environment. In hot work environments, this is a good thing because if it is done fast enough, it will reduce the likelihood of heat strain. If S is positive, heat is loaded on the body. As the heat load increases, the body will attempt to cool itself to maintain its ideal core temperature. If the bodies cooling mechanism is not sufficient, a HRI can develop. Heat stress, heat strain and HRIs are discussed in depth in the next section.

Heat Stress, Heat Strain and HRI

To have a complete understanding of how workers are affected by heat during their work, we need to understand the differences between heat stress, heat strain and the various heat-related illnesses they will lead to if heat stress goes unchecked. It is also helpful to understand the basic physiological process that occurs when the body undergoes heat strain.

The ACGIH's definition of heat stress is the "net heat load to which a worker may be exposed from the combined contributions of metabolic cost of work, environmental factors and cooling requirements." Health and safety professionals and workers are able to evaluate the environmental factors and job tasks which can lead to increased heat stress on a worker and then institute control methods before the next phase of the thermal stress chain occurs. Heat stress can be like a volcano, at the base are many

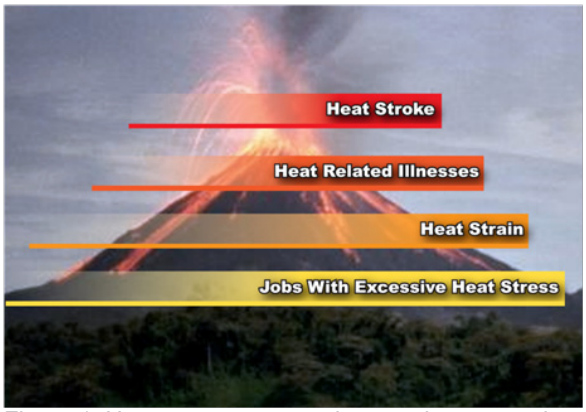

Figure 1. Heat stress presented as a volcano erupting.

opportunities for excessive heat stress related jobs, as the heat stress builds on the body it turns to heat strain. The hotter it gets and/or the longer a worker is exposed, the greater the chance of heat strain developing into an HRI. If heat strain is not controlled–BOOM–an eruption of HRIs are there to affect workers; including heat stroke, which is deadly or causes brain damage in 50% of those afflicted by it.

Heat strain is the next progression in the thermal stress chain. It is the overall physiological response resulting from heat stress, including how the body tries to cool itself, what happens to the body's temperatures and consequently, what types of health ailments the body will display if the heat strain is not brought under control. During heat strain, a worker may be experiencing different physiological symptoms, which could lead to an HRI. It is important to note, a worker in a heat strain condition may not be aware of what is happening until an HRI is displayed. It is important to watch your co-workers during heat stress work situations to ensure heat strain does not develop and warn them, supervisors or health and safety staff if it does. Under DOE 851, workers have the right to stop work in certain situations; an extreme heat stress work situation, which could lead to one of the more harmful HRIs, is a justifiable work stoppage situation!

Heat-related illnesses are the health effects seen on the body if heat strain is not brought under control. You may become dizzy, experience nausea, loose motor skills or be unable to remove heat from your body. Some severe outcomes include fainting and death. The following sections detail the six different HRIs, their signs and symptoms and standard first aid measures that can be conducted until EMS arrives. It is important to know that basic first aid measures, such as removing a worker from an extreme heat stress situation and cooling them off with ice or water until EMS arrives could be LIFE SAVING measures. The following set of five graphics show thermal imaging along with a description of what happens to the body undergoing various stages of heat strain.

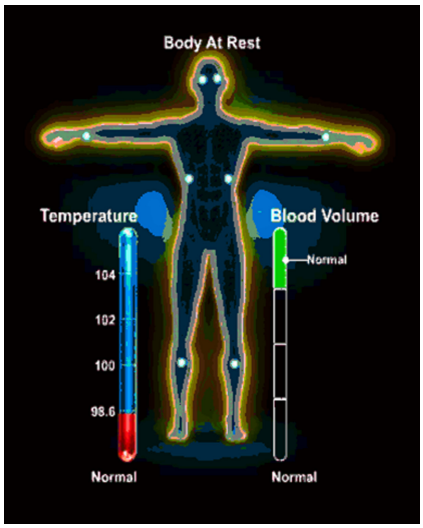

Figure 2. Physiology of heat stress #1.

During both rest and activity, the human body tries to maintain an internakl temperature of 98.6 F.

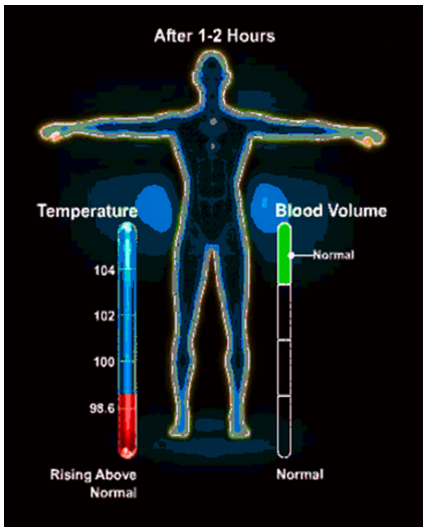

Figure 3. Physiology of heat stress #2.

- Hot weather, heat sources, and hard work raise the body's core temperature.
- Heated blood is pumped to the skin's surface, where body heat transfers to the environment, if cooler.
- If heat has to be shed faster, sweat carries it outside skin and evaporates to aid cooling.

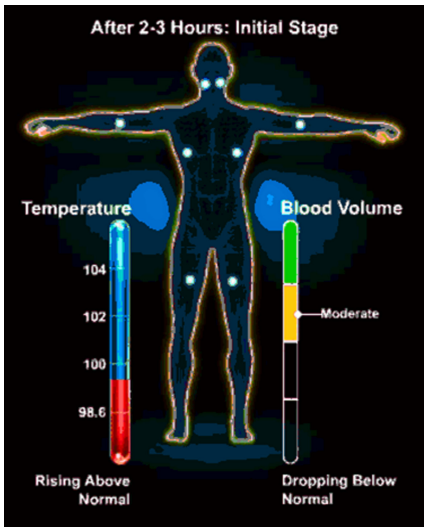

Figure 4. Physiology of heat stress #3.

- During heavy work, a body can lose 1-2 liters of water per hour.
- After 2-3 hours of fluid loss, a person is likely to:
  - Lose endurance
  - Become uncomfortable
  - Feel hot
  - Become thirsty

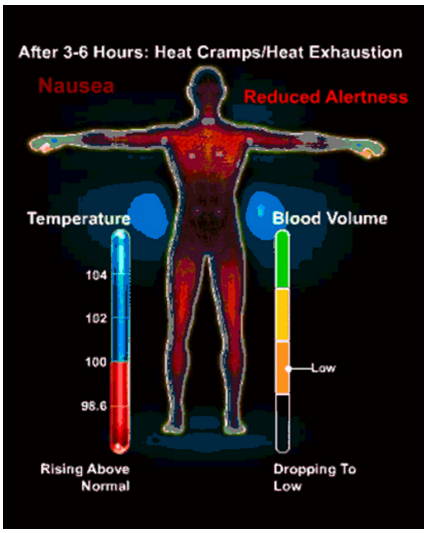

Figure 5. Physiology of heat stress #4.

- Water is key to cooling body and combatting heat stress.
- Without fluid replacement during an extended period of work, the body is at risk of exhaustion.
- Untreated heat exhaustion may lead to heat stroke.

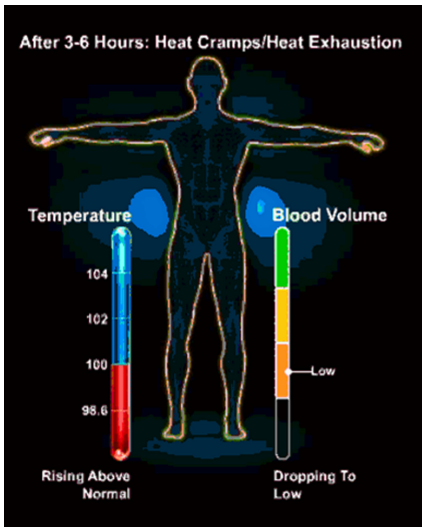

Figure 6. Physiology of heat stress #5.

- The longer the body sweats, the less blood there is to carry excess heat to skin or oxygen and nutrients to muscles.
- After 3 hours, a dehydrated worker may experience:
- Headaches
- Muscle fatigue
- Loss of strength
- Loss of accuracy and dexterity
- Heat cramps
- Reduced alertness
- Nausea

Now that we understand how the body generally reacts to heat stress, let's look at the health effects that can develop if heat strain is not controlled. Uncontrolled exposure to heat can cause a number of adverse health effects as outlined below:

Heat Fatigue

Heat fatigue refers to the temporary state of discomfort and mental or psychological strain arising from prolonged heat exposure. Workers unaccustomed to the heat are particularly susceptible and can suffer, to varying degrees, a decline in task performance, coordination, alertness, and vigilance. The severity of transient heat fatigue will be lessened by a period of gradual adjustment to the hot environment (heat acclimatization).

Heat rash

Heat rash, also known as prickly heat, is likely to occur in hot, humid environments where sweat is not easily removed from the surface of the skin by evaporation and the skin remains wet most of the time. The sweat ducts become plugged, and a skin rash soon appears. When the rash is extensive or when it is complicated by infection, prickly heat can be very uncomfortable and may reduce a worker's performance. The worker can prevent this condition by resting in a cool place part of each day and by regularly bathing and drying the skin.

Workers experiencing heat rash should:

- Try to work in a cooler, less humid environment when possible
- Keep the affected area dry
- Dust powder on the skin to decrease discomfort

Figure 7. Example of heat rash.

Heat cramps

Heat cramps are painful spasms of the muscles that occur among those who sweat profusely in heat, drink large quantities of water, but do not adequately replace the body's salt loss. The drinking of large quantities of water tends to dilute the body's fluids, while the body continues to lose salt. Shortly thereafter, the low salt level in the muscles causes painful cramps. The affected muscles may be part of the arms, legs, or abdomen, but tired muscles (those used in performing the work) are usually the ones most susceptible to cramps. Cramps may occur during or after work hours and may be relieved by drinking salted liquids by mouth.

Workers with heat cramps should:

- Stop all activity and sit in a cool place
- Drink clear juice or a sports beverage
- Do not return to strenuous work for a few hours after the cramps subside because further exertion may lead to heat exhaustion or heat stroke
- Seek medical attention if any of the following apply:
  - The worker has heart problems
  - The worker is on a low-sodium diet
  - The cramps do not subside within one hour

Heat exhaustion

Heat exhaustion includes several clinical disorders having symptoms which may resemble the early symptoms of heat stroke. Heat exhaustion is caused by the loss of large amounts of fluid by sweating, sometimes with excessive loss of salt. A worker suffering from heat exhaustion still sweats but experiences extreme weakness or fatigue, giddiness, nausea, or headache. In more serious cases, the victim may vomit or lose consciousness. The skin is

clammy and moist, the complexion is pale or flushed, and the body temperature is normal or only slightly elevated.

In most cases, treatment involves having the victim rest in a cool place and drink plenty of liquids. Victims with mild cases of heat exhaustion usually recover spontaneously with this treatment. Those with severe cases may require extended care for several days. There are no known permanent effects.

Treat a worker suffering from heat exhaustion with the following:

- Have them rest in a cool, shaded or air conditioned area
- Have them drink plenty of water or other cool, nonalcoholic beverages
- Have them take a cool shower, bath, or sponge bath

Heat Syncope (fainting)

A worker who is not accustomed to hot environments and who stands erect and immobile in the heat may faint. With enlarged blood vessels in the skin and in the lower part of the body due to the body's attempts to control internal temperature, blood may pool there rather than return to the heart to be pumped to the brain. Upon lying down, the worker should soon recover. By moving around, and thereby preventing blood from pooling, the patient can prevent further fainting.

Workers with heat syncope should:

- Sit or lie down in a cool place when they begin to feel symptoms
- Slowly drink water, clear juice, or a sports beverage

Heat stroke

Heat stroke is the most serious of health problems associated with working in hot environments. It occurs when the body's temperature regulatory system fails and sweating becomes inadequate. The body's only effective means of removing excess heat is compromised with little warning to the victim that a crisis stage has been reached.

A heat stroke victim's skin is hot, usually dry, red or spotted. Body temperature is usually 105o F or higher, and the victim is mentally confused, delirious, perhaps in convulsions, or unconscious. Unless the victim receives quick and appropriate treatment, death can occur.

Heat stroke is a 911 EMERGENCY! Any person with signs or symptoms of heat stroke requires immediate hospitalization. **However, first aid should be administered immediately.** This includes removing the victim to a cool area, thoroughly soaking the clothing with water or ice, and vigorously fanning the body to increase cooling. Further treatment at a medical facility should be directed to the continuation of the cooling process and the monitoring of complications which often accompany the heat stroke. Early recognition and treatment of heat stroke are the only means of preventing permanent brain damage or death, which occurs in 50% of heat stroke victims.

Take the following steps to treat a worker with heat stroke:

- Call 911 and notify their supervisor
- Move the sick worker to a cool shaded area
- Cool the worker using methods such as:
  - Soaking their clothes with water
  - Spraying, sponging, or showering them with water
  - Fanning their body

Heat stress can lead to an increase in other safety, health and job-related issues

Certain safety problems are common to hot environments. Heat tends to promote accidents due to the slipperiness of sweaty palms, dizziness, or the fogging of safety glasses, etc. Wherever there exists molten metal surfaces, steam, etc., the possibility of burns from accidental contact also exists. Aside from these obvious dangers, the frequency of accidents, in general, appears to be higher in hot environments compared to more moderate environments. One reason for the increase frequency is that working in a hot environment

Figure 8. Workers are more at risk to falls if suffering a HRI.

lowers the mental alertness and physical performance of an individual. Increased body temperature and physical discomfort promote irritability, anger, and other emotional states which sometimes cause workers to overlook safety procedures or to divert attention from hazardous tasks.

NIOSH advises that workers suffering from heat stress are also more prone to suffer other injuries as well, including:

- Reduced work performance
- Increased accidents
- Reproductive problems
- Heart/lung strain

Case Study:

Heat stress affects helicopter pilots' job skills

- Workers aren't as alert or productive in the heat
- A 1993 study of Israeli helicopter pilot errors (n=500) found dose-response relationship with ambient temp (Froom)
- Work/rest scheduling can greatly reduce the amount of productive work time.

NASA conducted a study, CR-1205-1, "A Compendium of Human Responses to the Aerospace Environment" and they found a surprising correlation between the effective temperature and human productivity. See Table 1 below for the study's findings:

Table 1. NASA CR-1205-1

Temperature in ºF	75	80	85	90	95	100	105
% Loss in work output	3	8	18	29	45	62	79
% Loss in accuracy		5	40	300	700		

3. Work Environment Evaluation

Environmental heat measurements should be made at, or as close as possible to, the specific work area where the worker is exposed. When a worker is not continuously exposed in a single hot area, but moves between two or more areas having different levels of environmental heat, or when the environmental heat varies substantially at a single hot area, environmental heat exposures should be measured for each area and for each level of environmental heat to which employees are exposed.

Wet Bulb Globe Temperature

Figure 9. A WBGT meter.

The **Wet Bulb Globe Temperature** (WBGT) is a combined measurement of temperature, humidity, wind speed and solar radiation. It is the preferred instrument and method for determining actual heat load that a worker may be experiencing. It is calculated using the formula:

$$WGBT=0.7Tw + 0.2Tg + 0.1Td$$

- Tw = Natural wet-bulb temperature (humidity indicator)
- Tg = Globe thermometer temperature (measured with a globe thermometer, also known as a black globe thermometer, to measure solar radiation)
- Td = Dry-bulb temperature (normal air temperature)

Temperatures may be in either Celsius or Fahrenheit.

The following formula is used indoors or when solar radiation is negligible:

$$WBGT = 0.7Tw + 0.3Tg$$

- With direct exposure to sunlight:

$$WBGTout = 0.7Tnwb + 0.2Tg + 0.1\ Tdb$$

- Without direct exposure to the sun:

$$WBGTin = 0.7Tnwb + 0.3Tg$$

ACGIH evaluation tools are based on WBGT for workers in a basic, summer work uniform. Table 2 shows the WBGT additions (in oF) for various types of work clothing.

Table 2. ACGHI WBGT for different work clothing

Type of clothing	WBGT addition oF
Summer work uniform	0
Cloth (woven material) overalls	3.5
Double-cloth overalls	5.0

Once the WBGT is determined, the calculated value(s) may be applied to various tables to determine heat stress work plans, work/rest schedules, etc., as we will see in Section 4.

Heat Index

The National Weather Service (NWS) uses a heat index temperature that combines temperature and humidity to gauge how warm it feels.

Temperature (F) versus Relative Humidity (%)

°F	90%	80%	70%	60%	50%	40%
80	85	84	82	81	80	79
85	101	96	92	90	86	84
90	121	113	105	99	94	90
95		133	122	113	105	98
100			142	129	118	109
105				148	133	121
110						135

HI	Possible Heat Disorder:
80°F - 90°F	Fatigue possible with prolonged exposure and physical activity.
90°F - 105°F	Sunstroke, heat cramps and heat exhaustion possible.
105°F - 130°F	Sunstroke, heat cramps, and heat exhaustion likely, and heat stroke possible.
130°F or greater	Heat stroke highly likely with continued exposure.

Figure 10. Heat Index chart.

Humidex

The Humidex developed by the Canadian government is another method to determine heat exposure based on temperature and humidity.

Humidex from Temperature and Relative Humidity Readings

Relative Humidity (%)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
100	29	31	33	35	37	39	41	43	45	48	50	53	55	58									
95	28	30	32	34	36	38	40	42	44	47	49	51	54	56	59								
90	28	30	31	33	35	37	39	41	43	45	48	50	52	55	57	60							
85	27	29	31	32	34	36	38	40	42	44	46	49	51	53	56	58							
80	26	28	30	32	33	35	37	39	41	43	45	47	50	52	54	57	59						
75	26	27	29	31	33	34	36	38	40	42	44	46	48	50	53	55	57						
70	25	27	28	30	32	33	35	37	39	41	43	45	47	49	51	53	56	58					
65	24	26	27	29	31	32	34	36	38	40	42	43	45	47	50	52	54	56					
60	24	25	27	28	30	32	33	35	37	38	40	42	44	46	48	50	52	54	57				
55	23	24	26	27	29	31	32	34	36	37	39	41	43	45	46	48	50	52	55	57			
50	22	24	25	27	28	30	31	33	34	36	38	40	41	43	45	47	49	51	53	55	57		
45	22	23	24	26	27	28	30	32	33	35	37	38	40	42	43	45	47	49	51	53	55	57	
40			24	25	26	28	29	31	32	34	35	37	39	40	42	44	45	47	49	51	53	54	56
35				24	26	27	28	30	31	33	34	36	37	39	40	42	43	45	47	49	50	52	54
30							27	28	30	31	33	34	36	37	39	40	42	43	45	47	48	50	52
25										30	32	33	34	36	37	39	40	42	43	45	46	48	49
20																		40	41	43	44	45	47

Temperature (C)

LEGEND	HUMIDEX RANGE	DEGREE OF COMFORT
	Less than 29	No discomfort
	30 - 39	Some discomfort
	40 - 45	Great discomfort; avoid exertion
	Above 45	Dangerous
	Above 54	Heat Stroke imminent

Figure 11. Humidex heat exposure chart.

ACGIH approach for heat stress evaluation

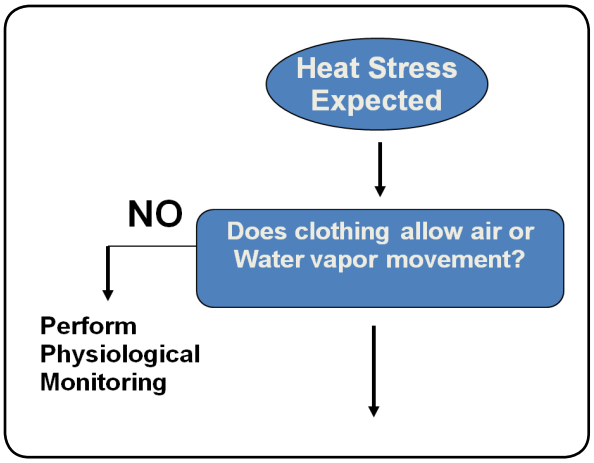

Figure 12. Excerpt from ACGIH heat stress evaluation flow chart.

4. Work Environment Controls

One of the best ways to reduce heat stress on workers is to minimize heat in the workplace. However, there are some work environments where heat production is difficult to control, such as when furnaces or sources of steam or water are present in the work area or when the workplace itself is outdoors and exposed to varying warm weather conditions. We will now look at different methods for controlling heat stress; some may work with all jobs in all work environments while others can only be applied to specific jobs and work environments.

It is always best to work from the Hierarchy of Controls to reduce workplace hazards. For heat stress, we will review common engineering controls, administrative controls and PPE controls for reducing heat stress hazards.

Engineering controls

We will now look at five major types of engineering controls to reduce heat stress as shown below:

- Ventilation
- Air cooling
- Fans
- Insulation
- Shielding

Ventilation

General ventilation is used to dilute hot air with cooler air (generally cooler air that is brought in from the outside). This technique clearly works better in cooler climates than in hot ones. A permanently installed ventilation system usually handles large areas or entire buildings. Portable or local exhaust systems may be more effective or practical in smaller areas.

Figure 13. General ventilation system, courtesy Roda.

Air cooling

Air treatment/air cooling (HVAC) differs from ventilation because it reduces the temperature of the air by removing heat (and sometimes humidity) from the air.
Air conditioning is a method of air cooling, but it is expensive to install and operate. An alternative to air conditioning is the use of chillers to circulate cool water through heat exchangers over which air from the ventilation system is then passed; chillers are more efficient in cooler climates or in dry climates where evaporative cooling can be used.

Figure 14. HAVAC system at NREL.

Fans

Another way to reduce heat stress is to increase the airflow or convection using fans in the work area (as long as the air temperature is less than the worker's skin temperature). Changes in air speed can help workers stay cooler by increasing both the convective heat exchange (the exchange between the skin surface and the surrounding air) and the rate of evaporation. Because this method does not actually cool the air, any increases in air speed must affect the worker directly to be effective.

Figure 15. Fan used at brake tent during Gulf Coast oil clean up 2010.

NOTE: If the dry bulb temperature is higher than 35° C (95° F), the hot air passing over the skin can actually make the worker hotter. When the temperature is more than 35° C and the air is dry, evaporative cooling may be improved by air movement, although this improvement will be offset by the convective heat. When the temperature exceeds 35° C and the relative humidity is 100%, air movement will make the worker hotter. Increases in air speed have no effect on the body temperature of workers wearing vapor-barrier clothing.

Insulation

It may be possible to prevent heat conduction by insulating the process or hot item. For instance, improving the insulation on a furnace wall can reduce its surface temperature and the temperature of the surrounding area.

Shielding

Shields can be used to reduce radiant heat, i.e. heat coming from hot surfaces within the worker's line of sight. Surfaces that exceed 35° C (95° F) are sources of infrared radiation that can add to the worker's heat load. Flat black surfaces absorb heat more than smooth, polished ones. Having cooler surfaces surrounding the worker assists in cooling because the worker's body radiates heat toward the surfaces.

Figure 16. This proximity PPE uses a combination of insulation and shielding.

With some sources of radiation, such as heating pipes, it is possible to use both insulation and surface modifications to achieve a substantial reduction in radiant heat. Instead of reducing radiation from the source, shielding can be used to interrupt the path

between the source and the worker. Polished surfaces make the best barriers, although special glass or metal mesh surfaces can be used if visibility is a problem.

Shields should be located so that they do not interfere with airflow, unless they are also being used to reduce convective heating. The reflective surface of the shield should be kept clean to maintain its effectiveness.

Administrative controls and work practices

Worker acclimatization

Figure 17. Rad workers at DOE Hanford conduct work in anti-Cs.

Humans are largely capable of adjusting to the heat. This adjustment to heat, under normal circumstances, usually takes about 5 to 7 days, during which time the body will undergo a series of changes that will make continued exposure to heat more endurable.

On the first day of work in a hot environment, the body temperature, pulse rate, and general discomfort will be higher. With each succeeding daily exposure, all of these responses will gradually decrease, while the sweat rate will increase. Once acclimatized to the heat, the worker will find it possible to perform work with less strain and distress.

Gradual exposure to heat gives the body time to become accustomed to higher environmental temperatures. Heat disorders in general are more likely to occur among workers who have not been given time to adjust to working in the heat or among workers who have been away from hot environments and who have gotten accustomed to lower temperatures. Hot weather conditions of the summer are likely to affect the worker who is not acclimatized to heat. Likewise, workers who return to work after a leisurely vacation or extended illness may be affected by the heat in the work environment. Whenever such circumstances occur, the worker should be gradually reacclimatized to the hot environment.

An acclimatization study conducted by Cal/OSHA showed that most HRI incidents occurred during a new worker's first 4 days of work in a hot work environment. **This shows the importance of gradual acclimatization of workers** into hot work environments to which they may not be accustomed.

Case Study

Cal/OSHA acclimatization findings shed light on its importance-2005

- 80%HRI incidents in the first 4 days
- 46% HRI incidents in the first day
- 34% HRI incidents on days 2 - 4
- 4%HRI incidents during 5 days - 2 weeks period
- 16% HRI incidents in weeks 3 - 52

NIOSH suggests the following heat exposures during acclimatization. See Table 3 below:

Table 3.NIOSH suggested heat exposure during acclimatization

Day Number	Experienced heat worker	New heat worker
1	50%	20%
2	60%	42%
3	80%	60%
4	100%	80%
5	100%	100%

Speak with your supervisor or occupational medical staff if you are having trouble adjusting to the heat or if you have questions about how heat may affect a medical condition you have!

With Acclimatized Workers:

- Blood flow to the skin is reduced; more blood is available for the muscles
- Heart rate is more stable, heart stroke volume increases and blood volume increases

HAMMER

Acclimatization does not decrease your body's need for hydration!

HAMMER

Training Workers

Training is the key to good work practices. Unless all employees understand the reasons for using new, or changing old, work practices, the chances of such a program succeeding are greatly reduced.

Figure 18. Laborers finishing a group activity during HAZWOPER training.

NIOSH states that a good heat stress training program should include at least the following components:

- Knowledge of the hazards of heat stress
- Recognition of predisposing factors, danger signs, and symptoms
- Awareness of first aid procedures for, and the potential health effects of, heat stroke
- Employee responsibilities in avoiding heat stress
- Dangers of using drugs, including therapeutic ones, and alcohol in hot work environments
- Use of protective clothing and equipment

- Purpose and coverage of environmental and medical surveillance programs and the advantages of worker participation in such programs

Schedule work in cooler parts of the day or a cooler season

Hot jobs should be scheduled during cooler parts of the day and routine maintenance and repair work in hot areas should be scheduled during the cooler seasons of the year.

Rest/Break Areas

Providing cool rest areas in hot work environments considerably reduces the stress of working in those environments. There is no conclusive information available on the ideal temperature for a rest area. However, a rest area with a temperature near 76° F appears to be adequate and may even feel chilly to hot, sweating workers, until they are acclimatized to the cooler environment. The rest area should be as close to the workplace as possible. Individual work periods should not be lengthened in favor of prolonged rest periods. Shorter but frequent work/rest cycles are the greatest benefit to the worker.

Figure 19. Air conditioned, portable office can be a great brake area.

Work/rest schedules

Employers should develop and institute a work/rest schedule for workers based on their measured heat load and work demand (see ACGIH work rest schedule TLV, Table 4). However, the work/rest schedule should not be used exclusively. The work/rest schedule should be used in conjunction with a work heat strain monitoring program. The ACGIH TLV work/rest schedule is for workes wearing light clothing only.

Table 4. ACGIH work/rest schedule for acclimatized workers (WBGT in degrees Fahrenheit)

Work demand	Light	Moderate	Heavy	Very Heavy
100% work	85.1	81.5	78.8	
75% work; 25% rest	86.9	83.3	81.5	
50-50	88.7	85.1	83.3	81.5
25% work; 75% rest	90.5	87.8	86	85.1

Worker monitoring programs

Every worker who works in extraordinary conditions that increase the risk of heat stress should be personally monitored. These conditions include wearing semi-permeable or permeable clothing when the temperature exceeds 21° C (69.8° F), working at extreme metabolic loads (greater than 500 kcal/hour), etc.

Figure 20. A physicians assistant monitors a 33rd CST member before allowing him to suit up.

Personal monitoring can be done by checking the heart rate, recovery heart rate, oral temperature, or extent of body water loss.

To check the heart rate, count the radial pulse for 30 seconds at the beginning of the rest period. If the heart rate exceeds 110 beats per minute, shorten the next work period by one third and maintain the same rest period.

To check the recovery heart rate, compare the pulse rate taken at 30 seconds (P1) with the pulse rate taken at 2.5 minutes (P3) after the rest break starts. The two pulse rates can be interpreted using Table 5.

Table 5.Heart rate recovery criteria-OSHA Technical Manual Section III, Chapter 4		
Heart rate recovery pattern	P3	Difference between P1 and P3
Satisfactory recovery	<90	-
High recovery (Conditions may require further study)	90	10
No recovery (May indicate too much stress)	90	<10

Oral temperature can be checked with a clinical thermometer after work before the employee drinks water. If the oral temperature taken under the tongue exceeds 37.6° C, shorten the next work cycle by one third.

Body water loss can be measured by weighing the worker on a scale at the beginning and end of each work day. The worker's weight loss should not exceed 1.5% of total body weight in a work day. If a weight loss exceeding this amount is observed, fluid intake should increase.

What ACGIH recommends

Table 6 lists the ACGIH recommendations for worker monitoring based on temperature and type of clothing worn.

Table 6.ACGIH suggested frequency of physiological monitoring (minutes)		
Adjusted temperature (oF)	**Normal work clothing**	**Impermeable clothing**
90 or above	Every 45	Every 15
87.5 - 90	Every 60	Every 30
82.5 - 87.5	Every 90	Every 60
77.5 - 82.5	Every 120	Every 90
72.5 - 77.5	Every 150	Every 120

Drinking Water

Figure 21. A drinking water cooler.

In the course of a day's work in the heat, a worker may produce as much as 2 to 3 gallons of sweat. Because so many heat disorders involve excessive dehydration of the body, it is essential that water intake during the workday be about equal to the amount of sweat produced. Most workers exposed to hot conditions drink less fluids than needed because of an insufficient thirst drive. A worker, therefore, should not depend on thirst to signal when and how much to drink. Instead, the worker should drink 5 to 7 ounces (about a cup) of fluids every 15 to 20 minutes to replenish the necessary fluids in the body. There is no optimum temperature of drinking water, but most people tend not to drink warm or very cold fluids as readily as they will cool ones. Whatever the temperature of the water, it must be palatable and readily available to the worker. Individual drinking cups should be provided–never use a common drinking cup.

Heat-acclimatized workers lose much less salt in their sweat than do workers who are not adjusted to the heat. The average American diet contains sufficient salt for acclimatized workers even when sweat production is high. If, for some reason, salt replacement is required, the best way to compensate for the loss is to add a little extra salt to food. Salt tablets **should not** be used.

Issues with work clothing and hot environments

Clothing inhibits the transfer of heat between the body and the surrounding environment. Therefore, in hot jobs where the air temperature is lower than the skin's temperature, wearing clothing reduces the body's ability to lose heat into the air.
When the air temperature is higher than the skin's temperature, clothing helps to prevent the transfer of heat from the air to the body. However, this advantage may be negated if the clothes interfere with the evaporation of sweat.

Figure 22. A Navy survey team member is decontaminated during a WMD drill.

In dry climates, adequate evaporation of sweat is seldom a problem. In a dry work environment with very high air temperatures, protective clothing could be an advantage to the worker. The proper type of clothing depends on the specific circumstance. Certain work in hot environments may require insulated gloves, insulated suits, reflective clothing, or infrared reflecting face shields for protection against radiant and conductive heat.

Wearing an impermeable suit greatly increases the risk of heat stress illnesses!

Water, including sweat, cannot evaporate when a worker wears a hazmat suit. The moisture is trapped and causes the humidity inside the suit to rise, making it feel warmer than the actual temperature.

Figure 19 shows that at 70° F, the temperature in the suit feels like 72° F, an insignificant increase. However, at 85° F, the temperature in the suit feels like 108° F. If at 85° F you work in direct sun, the added radiant heat would cause the temperature in the suit to feel like 121° F!

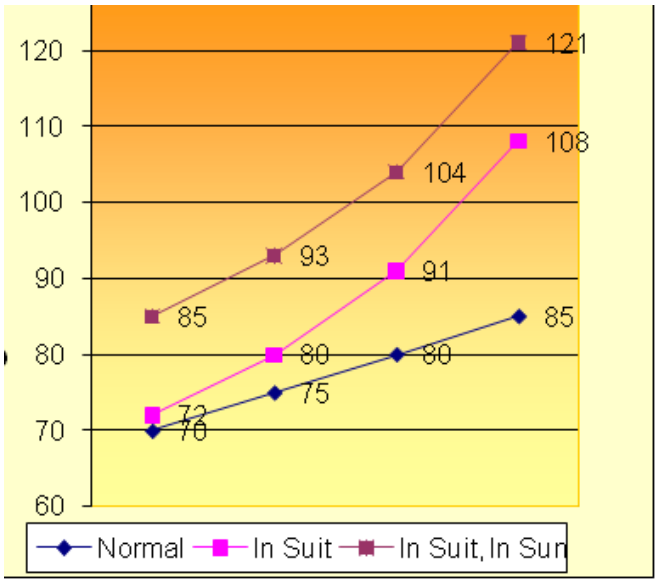

Figure 23. Temperatures seen as a result of workers wearing hazmat suits.

Respirator usage

The weight of a self-contained breathing apparatus (SCBA) increases stress on a worker, and this stress contributes to overall heat stress. Chemical protective clothing such as totally encapsulating chemical protection suits will also add to the heat stress problem.

Protective clothing and heat can increase radiological exposure!

Reichelt, Clay, and Eichorst analyzed 68 cases in ORPS database of radiological contamination through protective clothing. Of the cases, 79% of cases involved perspiration-soaked clothing. Of the cases, 84% identified hot, humid, or damp conditions. Most of the cases involved strenuous work with perspiration. Cloth or water-resistant clothing often fails to protect during demanding work. The study found that multiple layers do not provide multiple protections. Many incidents of contamination included multiple layers of clothing (4 layers in one case). The study also found that multiple layers of protection greatly increases heat stress risks (1995 ORNL heat stress case).

Personal Protective Equipment (PPE)

For general work concerning environmentally hot environments, workers should wear light-colored, loose-fitting clothing made from breathable fabric.

Reflective clothing

Reflective clothing, which can vary from aprons and jackets to suits that completely enclose the worker from neck to feet, can stop the skin from absorbing radiant heat. However, since most reflective clothing does not allow air exchange through the garment, the reduction of radiant heat must more than offset the corresponding loss in evaporative cooling. For this reason, reflective clothing should be worn as loosely as possible. In situations where radiant heat is high, auxiliary cooling systems can be used under the reflective clothing.

Ice vests

Commercially available ice vests, though heavy, may accommodate as many as 72 ice packets, which are usually filled with water. Carbon dioxide (dry ice) can also be used as a coolant. The cooling offered by ice packets lasts only 2 to 4 hours at moderate to heavy heat loads, and frequent replacement is necessary. However, ice vests do not encumber the worker and thus permit maximum mobility. Cooling with ice is also relatively inexpensive.

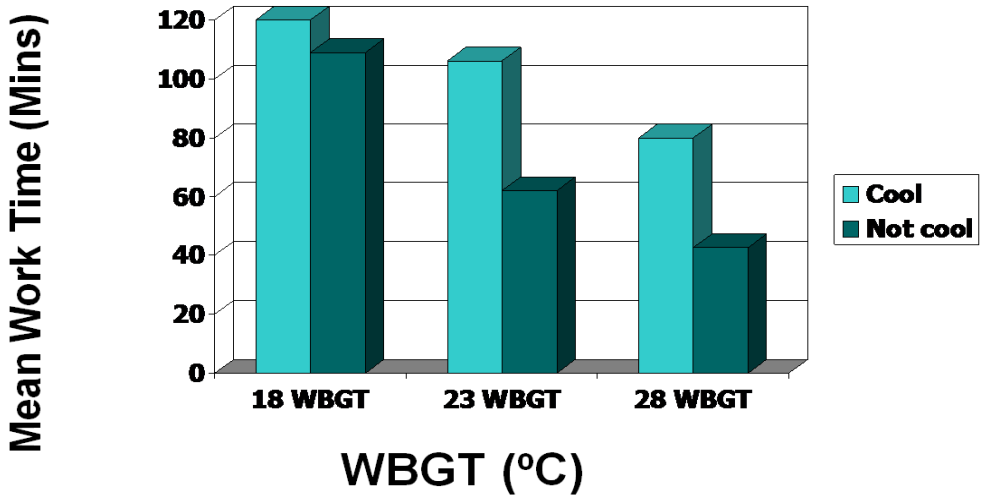

Figure 20. Effects of ice-cooling on work in PPE, Muir, Bishop, and Ray, 199.9

Wetted clothing

Wetted clothing is another simple and inexpensive personal cooling technique. It is effective when reflective or other impermeable protective clothing is worn. The clothing may be wetted terry cloth coveralls or wetted two-piece, whole-body cotton suits. This approach to auxiliary cooling can be quite effective under conditions of high temperature and low humidity, where evaporation from the wetted garment is not restricted.

Water-cooled garments

Water-cooled garments range from a hood, which cools only the head, to vests and “long johns,” which offer partial or complete body cooling. Use of this equipment requires a battery-driven circulating pump, liquid-ice coolant, and a container. Although this system has the advantage of allowing wearer mobility, the weight of the components limits the amount of ice that can be carried and thus reduces the effective use time. The heat transfer rate in liquid cooling systems may limit their use to low-activity jobs; even in such jobs, their service time is only about 20 minutes per pound of cooling ice. To keep outside heat from melting the ice, an outer insulating jacket should be an integral part of these systems.

Circulating air

Circulating air is the most highly effective, as well as the most complicated, personal cooling system. By directing compressed air around the body from a supplied air system, both evaporative and convective cooling are improved. The greatest advantage occurs when circulating air is used with impermeable garments or double cotton overalls.

5. HAMMER 4-hour heat stress course final activity

Time for activity: 1.5 hours (50 minutes for instructions and work and 40 minutes for report back.)

Objective: This activity will allow participants to bring together all of the concepts they reviewed in the heat stress class. The final product of the activity is a work plan. To create the plan, participants will evaluate a work area's environmental conditions for heat stress and then evaluate the job being conducted and apply controls to reduce heat stress. Participants will also get a chance to practice using heat stress evaluation tools.

Task: This final activity will be conducted in a group, table top and hands-on fashion. Each group will be assigned a job and work area to evaluate for heat stress. You may use any heat stress evaluation tools you brought with you (WBGT, etc.) or you may use the ones provided by your instructor(s). Once you have returned from the evaluation, you will discuss your measurement results and job evaluations with the group. Create an agreed upon work plan that will reduce heat stress for the workers conducting the work in the environment. You can assume that the environmental conditions will be the same for four days (in case the job may take more than one day.) Since this is your work site, include details about the job in your plan that are relevant to heat stress.

Job 1: Outside: heavy equipment operator will be grading for three days. The dozer has an open cab.

Job2: Outside: carpenter is replacing windows in a structure. She has one assistant working with her throughout the day, when needed. The rest of the time the assistant is working indoors cleaning up the shop. This work task will take four days to complete.

Job 3: Outside: radiological workers are opening waste containers for characterization. Work crew is wearing PPE required for this work. You found out one of the crew is new to this area; he previously worked indoors at a DOE site on the east coast. This characterization work will take 6 days to complete.

Job 4: Outside: Roofers are fixing a membrane on roof tops where several leaks have been identified. This task will take approximately two days.

Job 5: Inside: Electricians are conducting maintenance on electrical and mechanical systems in a boiler room for one day.

Job 6: Outside: two workers are entering a confined space to conduct work that will last two days. One entrant is new to confined space work but has worked outdoors at Hanford for one year.

Summary

Now that you have completed the thermal stress review course, you should have a clear understanding of current heat stress issues and what regulatory organizations you can draw on for assistance. You should also now have a good understanding of how to identify the common HRIs, ensure workers recover from them and how to prevent them from happening!

Resources

ACGIH. (2008). TLVs and BEIs. ACGIH. Cincinnati, OH.

Hanford Hills/OPEX. (2011). http://msa.hanford.gov/hills/.

Muir, Bishop, and Ray. (1999). Effects of a novel ice-cooling technique on work in protective clothing at 28 degrees C, 23 degrees C, and 18 degrees C WBGTs. Am Ind Hyg Assoc J. Jan-Feb;60(1):96-104.

NIOSH. (1986). Criteria for a Recommended Standard: Occupational Exposure to Hot Environments. http://www.cdc.gov/niosh/86-113.html.

NIOSH. (2011). Workplace Safety and Health Topics: Heat Stress. http://www.cdc.gov/niosh/topics/heatstress/.

OSHA. (1999). Technical Manual. Section III, Chapter 4 Heat Stress. http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.

Plog, Barbara A. (2002). Fundamentals of Industrial Hygiene. National Safety Council.

Reichelt RA, Clay ME, Eichorst AJ. (1998). Radioactive contamination incidents involving protective clothing. Health Phys. Jan;74(1):99-107.

U.S. Navy (2007). Prevention and Treatment of Heat and Cold Stress Injuries. Navy Environmental Health Center. Portsmouth, Virginia.

Washington State Department of Labor and Industries. (2011). Outdoor Heat Exposure (OHE, Heat Stress). http://www.lni.wa.gov/safety/topics/atoz/heatstress/.

Volpentest

HAMMER

Training and Education Center

Managed by Mission Support Alliance, LLC

Volpentest HAMMER. Hanford, WA 2011