Industry Guide 35

A Guide to

Preventing Heat Stress and Cold Stress

NCDOL

N.C. Department of Labor

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This guide is intended to be consistent with all existing OSHA standards; therefore, if an area is considered by the reader to be inconsistent with a standard, then the OSHA standard should be followed.

To obtain additional copies of this guide, or if you have questions about North Carolina occupational safety and health standards or rules, please contact:

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Additional sources of information are listed on the inside back cover of this guide.

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Foreword

Heat and cold pose a special threat to North Carolina's workers. Many manufacturing workers must deal with hot temperatures in their factories throughout the year. Thousand of outdoor workers face the threat of cramps, exhaustion, heat stroke and worse every summer. During the winter months, these workers must prepare for cold temperatures.

A Guide to Preventing Heat Stress and Cold Stress explains what thermal stress can do to working people and discusses ways to avoid the many health problems it can cause.

In North Carolina, the N.C. Department of Labor enforces the federal Occupational Safety and Health Act through a state plan approved by the U.S. Department of Labor. NCDOL offers many educational programs to the public and produces publications to help inform people about their rights and responsibilities regarding occupational safety and health.

When reading this guide, please remember the mission of the N.C. Department of Labor is greater than just regulatory enforcement. An equally important goal is to help citizens find ways to create safe workplaces. Everyone profits when managers and employees work together for safety. This booklet, like the other educational materials produced by the N.C. Department of Labor, can help.

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Commissioner of Labor

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Understanding How the Body Regulates Heat

Introduction

The human body, being warm blooded, maintains a fairly constant internal temperature, even though it is being exposed to varying environmental temperatures. To keep internal body temperatures within safe limits, the body must get rid of its excess heat, primarily through varying the rate and amount of blood circulation through the skin and the release of fluid onto the skin by the sweat glands. These automatic responses usually occur when the temperature of the blood exceeds 98.6°F and are kept in balance and controlled by the brain.

Sweating does not cool the body unless the moisture is removed from the skin by evaporation. Under conditions of high humidity, the evaporation of sweat from the skin is decreased and the body's efforts to maintain an acceptable body temperature may be significantly impaired. These conditions adversely affect an individual's ability to work in the hot environment. With so much blood going to the external surface of the body, relatively less goes to the active muscles, the brain and other internal organs; strength declines; and fatigue occurs sooner than it would otherwise. Alertness and mental capacity may also be affected. Workers who must perform delicate or detailed work may find their accuracy suffering, and others may find their comprehension and retention of information lowered.

In spite of our proven ability to deal with a wide range of external temperatures, it is also a proven fact that we can die of heat stroke at ambient temperatures below 90°F. The secret to our survival in the heat lies in our ability to maintain our core temperature at a constant level. Any physiological or environmental factor that tends to increase that core temperature is a potential cause of heat stress. When we experience an adverse health effect because of heat stress, we experience heat strain.

Heat stress and heat strain can sneak up on us. They can happen while we work at the jobsite or around the house or while we participate in physical activities such as sports or hiking. It is easy to get caught up in what we are doing and ignore the initial signs of heat strain. If we are not aware of these signs and do not consciously watch for them, we can wind up in serious trouble before we realize a problem exists. To prevent heat stress from causing effects ranging from reduced productivity to life threatening emergencies, we need to know more about how we function in the heat.

Successfully avoiding problems related to working in the heat requires cooperation between workers and management. Each individual worker is best able to determine whether he or she is experiencing adverse effects of heat strain. Management must make sure that employees understand the symptoms of heat related illnesses and watch for them among themselves and their fellow workers. Management must also make sure that appropriate control programs are put in place to prevent heat stress problems.

This guide is valuable both to the reader who wants more than a working knowledge of heat stress and to the reader who desires the lifesaving essentials of the subject. The information is straight-forward and easily understood. At the same time, the guide is sufficiently technical so as to be considered a resource for health professionals.

How Metabolism and Physical Activity Heat the Body

Unlike cold-blooded animals such as reptiles, whose body temperatures rise and fall with the temperature of their surrounding environment, we humans are functional only when our body temperature is maintained within a very narrow range. The complex reactions that convert food, water and oxygen into the chemical and electrical energies that power and sustain life are extremely temperature dependent. If the core temperature goes up or down by just a few degrees, those reactions no longer occur in a normal manner and we can find ourselves in a life-threatening situation.

A portion of the heat that is given off as a by-product of biochemical reactions is used to maintain a nearly constant body core temperature. If that temperature starts to fall by a couple of degrees, mechanisms such as shivering are used to generate additional heat to help maintain the core temperature. The process of work generates more heat than is normally needed to maintain the core temperature. If we generate more excess heat than we can get rid of, our core temperature will start to rise and we have the stage set for heat stress.

For purposes of understanding heat stress, the body can be divided into two parts: a central core and a surrounding shell. The central core is made up of organ systems such as the brain, heart, lungs and digestive tract. To remain functional, temperatures throughout the core must remain within an extremely narrow range of 99–100°F. A rise of only one degree in core temperature is enough to signal the onset of heat stress. Although rectal monitors provide more accurate estimates of core temperatures, oral temperatures are most often used for core estimates. Oral temperatures generally run about one degree lower than core temperatures.

The peripheral shell of the body is made up of layers of muscle, fat and skin. This shell surrounds and protects the core and provides a means for exchanging body heat with the surrounding environment. Shell or skin temperatures are normally cooler by 5–6°F than the core temperature and can range up or down depending upon work rate and environmental conditions.

The amount of body heat that is generated in the core is strongly dependent on the level of physical activity involved. At rest, a male person of 154 pounds (referred to as a standard male) generates approximately 90 kilocalories per hour of heat as a by-product of metabolic energy production. Heavy physical activity can produce more than 600 Kcal/hr of excess heat. (See Table 1 for estimates of heat production for a variety of work tasks.) All of the heat generated by work must be eliminated from the body in order to maintain a constant core temperature.

How the Body Responds to Excess Heat

Elimination of excess heat from the body's core is basically a two-step process. The heat must first be transferred from the body's core to its shell. It is then eliminated from the shell to the surrounding environment. If the rate of heat production is too high, or something interferes with or limits heat transfer from the core to the skin to the environment, heat stress and strain are definite possibilities.

Blood is the primary vehicle used by the body to transfer heat from the core to the skin. When the brain's heat regulation system senses that excess heat is building up in the core, the heart rate accelerates to speed up the flow of blood from the core to the skin. Blood vessels in the skin are dilated or opened to receive the increased flow of blood and heat.

As the rate of work increases, the body's demand for oxygen also increases. The heart has to beat faster to supply the additional oxygen throughout the body. As the oxygen is burned in muscles and other tissues, the excess heat generated has to be transferred from the core to the skin. In a way, a paradox is created because the blood has to serve two different functions, both of which put increased demands on the heart as the work rate increases. The muscles need more oxygen, which they get from the blood. The temperature regulation system in the brain tries to direct the blood out to the skin where it can pool and get rid of its load of excess heat. At high work rates, the heart has trouble meeting all the demands placed on it. The result is an increasing heart rate and core temperature coupled with a decreasing ability of the muscles to maintain the high work rate without fatiguing. Table 2 offers an idea of what happens as the heart tries to cope with work rates ranging from rest up to a maximum work rate.

Table 1

Metabolic Work Rates as a Function of Task*

Body Position and Movement	Work Rate Kcal/minute**
Sitting	0.3
Standing	0.6
Walking	2.0–3.0
Walking uphill	add 0.8/meter rise

Type of Work	Average Kcal/minute	Range Kcal/minute
Hand work		0.2–1.2
light	0.4	
heavy	0.9	
Work with one arm		0.7–2.5
light	1.0	
heavy	1.8	
Work with both arms		1.0–3.5
light	1.5	
heavy	2.5	
Work with whole body		2.5–9.0
light	3.5	
moderate	5.0	
heavy	7.0	
very heavy	9.0	
Basal Metabolism	1.0	

Sample Calculation

Activity	Average Kcal/minute
Assembly work with heavy hand tools	
Standing	0.6
Heavy work with both arms	2.5
Basal metabolism	1.0
Total Kcal/minute	4.1

*Adapted from reference source 3. (See References within this publication.)

**For standard worker of 154 pounds and 19.4 square feet of body surface.

Table 2

Heart Rate, Core Temperature and Endurance Time Corresponding to Relative Maximum Work Rate*

	Percent Maximum Work Rate					
	Rest	**25%**	**33%**	**50%**	**75%**	**100%**
Heart rate/minute	60–80	90–100	105–110	120–130	150–160	180–190
Core temperature at equilibrium (°F)	98.6	99.3	100.0	100.8	101.8 unstable	continuous rise
Endurance time for continuous work	—	>8 hours	8 hours	1 hour	15–20 minutes	4–6 minutes

*Adapted from reference source 4. (See References within this publication.)

Excess Body Heat Should Dissipate to the Environment

When heat is transferred from the core to the skin, several mechanisms are employed to lose the heat to the environment. The most important of these mechanisms are evaporation, convection and radiation.

Evaporation

Sweating is the body's most effective mechanism for losing heat in a hot and/or heavy work environment. Heat loss at a rate of 0.58 Kcal per gram of evaporated sweat occurs as heat from the skin is used to evaporate the sweat. Most of the body's skin surface contains sweat glands, which are activated in stages as needed by the brain.

The maximum sweat rate that can be maintained by a healthy, well-acclimatized young male is about one quart per hour. To be effective in cooling the body, the sweat must actually evaporate from the skin instead of dripping off or being wiped off. The evaporation of one quart of sweat from the skin will remove approximately 600 Kcal of heat from the body. The actual evaporation rate depends upon a number of environmental factors, including temperature, relative humidity and wind speed.

Convection

The process of convection involves the transfer of heat from the skin to the surrounding air. The rate of heat loss by convection depends upon factors such as air temperature, wind speed and type of clothing. If the air is actually hotter than the skin, a reverse transfer of heat from the air to the body will occur.

Radiation

Heat transfer by infrared or "heat" radiation involves the flow of heat energy from warmer surfaces to surrounding cooler surfaces. Skin that has been warmed by blood flow from the core radiates heat to the surrounding environment. If the environment includes surfaces or systems such as furnaces or boilers that are significantly hotter than the skin, the flow of heat by radiation may also reverse and go from the environment to the body, thereby adding to the total heat load of the body. The rate of heat transfer by radiation is a function of the types of surfaces involved and the temperature difference between them. The direction of radiant heat flow is always from a warmer surface to a cooler surface.

The ability of a surface to absorb and radiate heat is primarily a function of the color and texture of the surface. As you have probably noticed while standing in an asphalt parking lot on a hot summer day, smooth dark-colored surfaces can absorb a great deal of heat energy. In doing so, they get much hotter than the surrounding environment and consequently become very efficient heat radiators as well. The use of light colored clothing is one means of blocking or reducing the effects of radiant heat.

Health, Age and Work Practices Affect Heat Regulation

Now that we have looked at the primary means used by the body to dissipate excess core heat, we need to consider some physiological factors that can limit its ability to do so. These factors mainly involve work rate, age, body size and shape, degree of acclimatization, condition of the heart and skin, and the availability of fluids and salt to replace sweat losses.

Work Rate

Work rate is the single most important factor that determines how much heat is generated in the core. It is obvious that the more vigorously we use our muscles, the more heat we generate. When we stop to rest, the rate of heat production can drop dramatically. However, removal of the heat already produced and stored in the core depends on a number of factors and may take quite a while. It is important to remember that the fastest way to decrease the rate of heat production is to decrease the work rate. As we will see later, regulation of work-rest periods is an important strategy in controlling potential heat stress.

Age

Generally speaking, older workers (over 40 years old) are at a disadvantage relative to younger workers when doing sustained work in the heat. The maximum possible output of the heart decreases with age, which limits the body's ability to transfer heat from the core to the skin. The efficiency of the sweating mechanism, which normally accounts for the greatest amount of heat removal from the skin during high work rates, also decreases with age. Older workers generally start sweating later, and actually sweat at a lower rate, than younger workers. Consequently, older workers tend to build up more core heat during hot work and require longer rest periods to recover to normal levels.

Body Size

Heat production in the core is related to body weight or mass. Heat dissipation from the skin is a function of the area of skin available for heat elimination. Stocky or obese workers, therefore, may be at a greater risk for heat disorders than workers with higher skin area-to-weight ratios. Workers with heart disease or skin disorders are also at greater risk.

Even extremely healthy, well-conditioned workers will experience symptoms of heat strain when initially subjected to conditions of heat stress. Symptoms may include light-headedness, a pounding heart and dehydration. If the worker continues on successive days to work under heat stress conditions, the symptoms of heat strain will decrease. The increased tolerance to heat that comes from working in a hot environment for a period of one or two weeks is called heat acclimatization. The process involves building up increased blood volume, increasing the rate and efficiency of sweating, and reducing the amount of salts lost during the process of sweating.

The process of acclimatizing to a hot environment requires successive heat exposures of at least one hour per day. Acclimatization does not occur unless work is done at a rate that will elevate body temperature. A good schedule to follow for new workers gaining an initial acclimatization to heat is a 20 percent schedule of exposure for the first day, followed by a 20 percent per day increase in exposure over the next four days.

Some degree of heat acclimatization can be lost over a period of a weekend. Most of a worker's heat acclimatization can be lost during a two-week vacation. Managers should be aware of this fact and allow workers returning from vacations or long absences to gradually reacclimatize. Reacclimating workers should start with a 50 percent exposure schedule on their first day back, followed by 20 percent per day increases in exposure thereafter.

Fluids and Salt

Since sweating accounts for much of the heat dissipated during hot work, there is a constant need to replace the fluids lost as sweat. A fully acclimatized worker can maintain a sweat rate of about one quart per hour throughout a work day. If the fluids and salts that are lost as sweat are not replaced, severe dehydration can occur. Thirst alone cannot be relied upon to keep up with the fluid losses that are associated with sustained work in hot environments as it is a poor indicator of one's level of hydration.

A plentiful supply of cool, fresh water must be kept readily available to workers engaged in hot work. They should be encouraged to drink at regular intervals rather than only when they feel thirsty. Drinking a cup of water every 15 to 20 minutes is a good way to maintain fluid balance under heat stress conditions.

Well acclimatized workers lose less salts when they sweat. The average American diet probably contains enough salt to replace the salts lost during sweating. Any worker on a salt restricted diet should consult a physician before increasing salt intake as a preventive measure against heat stress.

The Environment May Limit Heat Dissipation

As previously discussed, the body uses several mechanisms including evaporation, convection and radiation to eliminate excess heat from the skin. The effectiveness of these mechanisms is strongly affected by the surrounding environment, as well as by the type of clothing worn.

Heat removal by evaporation depends primarily on air temperature, moisture content and wind speed. One of the main parameters to consider is moisture content or humidity. Relative humidity is a measure of how much moisture or water vapor the air can hold at a given temperature. When the relative humidity reaches 100 percent, the air is saturated with water vapor. If we tried to put more water vapor into such air, it would condense out of the air in the form of rain or dew.

Warm air can hold more water vapor than cold air. For example, air that is fully saturated (100 percent relative humidity) at 60°F has a relative humidity of only 35 percent at a temperature of 90°F. Evaporation would not be effective for heat removal in the first case but could be very effective in removing heat in the second case.

The type and amount of work clothing also affect the rate of heat removal. Fabrics that do not freely "breathe" will tend to trap evaporated water vapor next to the skin. This has the same effect as raising the humidity and will greatly decrease the cooling we would otherwise get from sweating. Non-breathing or "vapor-barrier" clothing also restricts the removal of body heat by air convection.

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Learning About the Hazards of Heat Stress

A number of physiological problems are related to the buildup of excessive heat in the body. They range from annoying skin rashes to potentially fatal heat stroke. This section looks at the causes and symptoms associated with the most common heat disorders.

Heat Rash

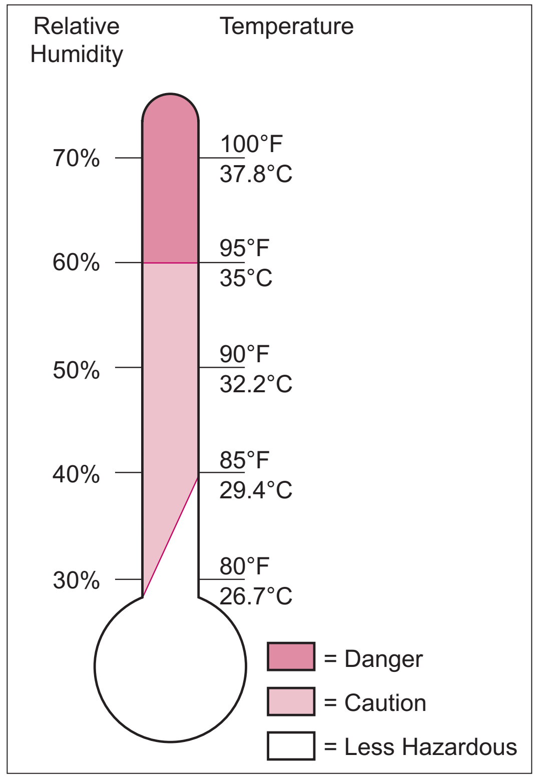
Heat rash, also known as prickly heat, is often associated with hot, humid environments. It is caused when sweat cannot freely evaporate from the skin and sweat ducts become plugged. Inflammation of the plugged sweat ducts causes a rash of tiny red blister-like eruptions to develop. Heat rash can cause a prickling sensation during heat exposure. If the plugged sweat ducts become infected, a case of heat rash may become so uncomfortable that it can be disabling.

Heat rash can be prevented by wearing work clothes that allow the sweat to evaporate as much as possible. Providing a cooler break area can also aid in allowing the skin to dry during work breaks. Thorough cleansing of the skin following the work shift will help prevent infection. The use of mild drying lotions may also be effective in reducing heat rash.

THE HEAT EQUATION

HIGH TEMPERATURE + HIGH HUMIDITY + PHYSICAL WORK = HEAT ILLNESS

When the body is unable to cool itself through sweating, **serious** heat illnesses may occur. The most severe heat-induced illnesses are **heat exhaustion** and **heat stroke**. If actions are not taken to treat heat exhaustion, the illness could progress to heat stroke and possible **death**.



Heat Cramps

The process of sweating results in the loss of body fluids and salts. The loss of about 1 percent body water through sweating can be tolerated without serious effect. When sweat losses exceed this amount, serious consequences of dehydration can begin to be seen. Blood volume is reduced by dehydration, which makes further effects of heat stress more likely. Work performance can also be impaired. If the dehydration contin-ues and becomes severe, symptoms such as shriveled skin, dry mouth and tongue, and sunken eyes appear. Dehydration is caused by the inadequate replacement of fluids and salt and can cause heat cramps and/or heat exhaustion.

If the fluids lost through sweating are replenished without sufficient salt replacement, heat cramps can occur. Heat cramps are painful spasms of large muscles primarily used during work, such as the arm, leg, back and abdominal muscles. Heat cramps are caused in part by the excessive loss of salt during heavy sweating. This decrease in salts causes body fluids to migrate into muscle fibers, which causes them to go into spasm.

Firm pressure or a gentle massage may provide some immediate relief for a cramping muscle. The best way to prevent heat cramps is to ensure that salts are replaced during and after periods of heavy sweating. This can be accomplished by making sure that an adequate supply of drinking water is kept available in the immediate work area. Workers exposed to heat stress should be encouraged to drink on a frequent and regular basis.

Fainting

Fainting is a loss of consciousness caused by inadequate blood supply to the brain. When fainting occurs, assist the person in lying down in a cool place and consult a physician. To prevent fainting in high temperatures, move about and stretch to improve circulation.

Heat Exhaustion

Heat exhaustion occurs when the body's blood supply is not large enough to accomplish its major tasks of supplying oxygen throughout the body and removing heat from the core. The heat removal task causes blood to pool in the skin, which leaves less blood available to carry oxygen to the brain. Sweat-induced dehydration, which reduces blood volume, increases the potential for heat exhaustion.

Early symptoms of heat exhaustion can include fatigue, headache and dizziness when you stand up. Profuse sweating, a rapid pulse rate, loss of appetite, nausea and vomiting may also be present. The victim of heat exhaustion may become disoriented or actually faint, which poses a risk of physical injury from falling.

What Should Be Done:

- Move the person to a cool shaded area to rest. Don't leave the person alone. If the person is dizzy or light headed, lay him or her face up with legs raised 6 to 8 inches. If the person feels nauseated, lay him or her sideways.
- Loosen and remove any heavy clothing.
- Have the person drink some cool water (a small cup every 15 minutes) if not feeling nauseated.
- Try to cool the person by fanning. Cool the skin with a cool spray mist of water or wet cloth.
- If the person does not feel better in a few minutes, call for emergency help (ambulance or call 911).

If heat exhaustion is not treated, the illness may advance to heat stroke.

In the absence of any injury, recovery from heat exhaustion is generally quite rapid if the victim is allowed to lie down and rest in a cool area. Elevating the feet 8 to 12 inches above the head may be helpful. Replacement of water and electrolytes should be included in the recovery period. Preventive measures include preventing dehydration by ensuring adequate replacement of water and salt, and allowing workers to acclimatize to hot working conditions.

Heat Stroke—A Medical Emergency

The most serious heat-related problem is heat stroke, which is life threatening. Heat stroke occurs when the core temperature rises so high that the body's normal cooling mechanism ceases to function. In effect, the brain gives up and stops doing the things it normally does to maintain body temperature at a constant level.

As the core temperature rises above 105°F, sweating ceases. Since sweating is normally the body's most effective means of dissipating excessive heat, the body is placed in a condition of serious risk when it stops. Without the cooling power of sweat, the core temperature can rapidly rise to critical levels. Adverse effects such as protein denaturation, enzyme degradation, and changes in the structure and function of cells can cause tissue damage and death. The brain is especially sensitive to such effects.

The skin of a heat stroke victim is usually very hot and dry. The victim normally appears flushed and has a rapid pulse, and may be confused and nauseated. Symptoms of heat stroke may also include convulsions or unconsciousness.

Heat stroke must be treated as a medical emergency. Trained medical personnel should be summoned as soon as possible. In addition, the first aid actions described below should be taken on the spot since they may make the difference between recovery, irreversible brain damage or death for the victim.

The immediate steps to follow for a heat stroke victim while waiting for medical personnel to arrive include:

1. Move the victim to a cooler location.
2. Remove any outer clothing that would interfere with the free circulation of air around the victim's body.
3. Apply cool water to the entire body surface of the victim. Use ice if necessary.
4. Vigorously fan the victim to increase the cooling effect of the water.

The key to preventing heat stroke is the ability to recognize the kinds of physical activity and environmental conditions that can cause it. Warning signs such as heat cramps or exhaustion are not always precursors of heat stroke. Unless unusual medical conditions preexist, vigorous physical activity is usually required to generate high levels of core heat and induce heat stroke. Victims often get so involved in what they are doing that they ignore the symptoms until they are in an emergency situation from which they cannot recover without aid. *Therefore, it is extremely important that employees are not assigned to do vigorous work alone in hot locations.*

Table 3 provides a synopsis of symptoms and immediate treatment for heat disorders.

Table 3

Signs, Symptoms and Treatment for Major Health Effects Caused by Heat Stress*

Effect	Clinical Features	Predisposing Factors	Treatment
Heat rash	Profuse tiny red blisters on affected area; prickling sensation during heat exposure	Long exposure to humid heat with skin wet with unevaporated sweat	Mild drying lotions; clean skin to prevent infection
Heat cramps	Painful spasms of muscles used at work (arms, legs or abdominal); onset during or after work hours	Heavy sweating during hot work; drinking large volumes of water without replacing salt loss	Give electrolyte solution
Heat exhaustion	Fatigue, headache, nausea, giddiness; clammy, moist skin; may faint on standing; rapid, thready (weak or faint) pulse	Lack of acclimatization; failure to replace water and/or salt lost during sweating	Remove to cooler environment; keep at rest until water and electrolyte balance has been restored
Heat stroke	Hot, dry skin; core temperature >105°F; confusion, convulsions, loss of consciousness	Lack of acclimatization; lack of physical fitness; recent alcohol consumption; dehydration; chronic heart disease	Immediate and rapid cooling of body; treat shockif necessary; treat as life-threatening emergency

*Adapted from reference source 4. (See References within this publication.)

How to Protect Workers

- Learn the signs and symptoms of heat-induced illnesses and what to do to help the worker.
- Train the workforce about heat-induced illnesses.
- Perform the heaviest work in the coolest part of the day.
- Slowly build up tolerance to the heat and the work activity (usually takes up to two weeks).
- Use the buddy system (work in pairs).
- Drink plenty of cool water (one small cup every 15–20 minutes).
- Wear light, loose fitting, breathable (like cotton) clothing.
- Take frequent short breaks in cool shaded areas. (Allow your body to cool down.)
- Avoid eating large meals before working in hot environments.
- Avoid caffeine and alcoholic beverages. (These beverages make the body lose water and increase the risk for heat illnesses.)

Workers Are at Increased Risk When

- They take certain medication. (Check with your doctor, nurse or pharmacy and ask if any medicines you are taking affect you when working in hot environments.)
- They have had a heat-induced illness in the past.
- They wear personal protective equipment (like respirators or suits).

3

Preventing and Controlling Heat Stress

The Occupational Safety and Health Act of North Carolina says that: "Each employer shall furnish to each of his employees conditions of employment and a place of employment free from recognized hazards that are causing or are likely to cause death or serious injury or serious physical harm to his employees." This section discusses how the dangers of heat stress can be removed from the work environment.

The techniques that can be applied to preventing heat stress fall into three general categories. The first category includes engineering controls designed to limit the environmental heat load and to enhance the rate at which heat can be eliminated from the body. The second category includes training for employees and providing personal protective equipment that can also be used in specific cases to limit heat stress potential. The third category involves work practices designed to reduce the level of metabolic heat that is generated by each worker.

Engineering Controls

Engineering controls can be used to modify the rate of convective, radiative and evaporative heat exchange between workers and their surrounding environment. Some general guidelines can be applied to the selection of appropriate types of engineering controls.

Air temperature and velocity are the main factors that affect the body's heat loss or gain by convection. Heat loss occurs when the ambient air temperature is less than skin temperature (approximately 95°F). Under these conditions, increasing air velocity through the use of fans and reducing the amount of clothing can increase the rate of heat loss by convection. The opposite applies if the ambient temperature is greater than 95°F. In that case, the body will gain heat by convection so air velocity should be minimized. Covering the body with increased clothing can help reduce the rate of heat gain by convection. When feasible, reducing the air temperature by air conditioning is very effective.

The effects of radiative heat gain can be reduced by placing a reflective screen between the radiant heat source and the worker. The screen can range in complexity from insulated furnace jackets to reflective metal shields to reflective clothing of the type firefighters often wear. Covering the body with normal clothing can also provide some protection from radiant heat sources.

Engineering controls that can enhance body heat loss through evaporation include measures that increase air velocities and methods that decrease ambient humidity levels. Reducing the amount of clothing, especially if it limits the free flow of air around the body, will also enhance cooling by evaporation.

Work Practices

Work practices can be used to reduce the chances of workers' suffering from heat stress. Usually, this generally involves reducing or controlling the rate at which heat is generated by the body. Scheduling hot or strenuous work during the cooler part of the day can be a very effective technique. Particular attention should be paid to whether workers have had an opportunity to acclimatize to the hot conditions that are anticipated.

Frequent alternation between work and rest breaks also helps limit core heat buildup and allows the body time to dissipate excess heat. It may be necessary to use a larger number of workers for especially hot jobs so that the work-rest schedule can be maintained. Scheduling periodic maintenance functions such as re-roofing buildings during nonsummer months is another example of an effective work practice.

Training and Personal Protective Equipment

Worker training is an extremely important aspect of a heat stress prevention program. Program objectives should include:

1. Training supervisors and workers to watch for and detect the major signs and symptoms of heat strain and to take immediate first aid steps when they are detected.
2. Training supervisors to understand the importance of allowing workers to acclimatize to hot conditions and to self-pace their work rate during periods of high heat exposure.
3. A general appreciation of the importance of keeping a supply of drinking water readily available for workers involved in hot work. The training must also emphasize the importance of drinking on a regular basis, rather than relying on thirst.

Medical screening of workers who may be exposed to hot work environments will help identify those employees whose ability to handle heat may be compromised by existing health problems such as heart disease. Other measures such as reflective clothing or personal ice vests can be used to limit heat buildup and extend the period of time a person can work in a hot environment without incurring undue risk of heat stress.

4

Heat Stress Summary

Heat Stress in the Workplace

North Carolina employees work in a wide variety of high temperature environments. Being uncomfortable is not the major problem with working in high temperatures and humidities. Employees who are suddenly required to work in a hot environment face additional, and generally avoidable, hazards to their individual safety and health. Employers should provide appropriate training to employees on preventive measures and adequate protection necessary to prevent heat stress.

Workers who perform hazardous jobs while exposed to temperatures greater than 79°F are known to have high accident rates and suffer from heat stress. Intensive physical activity in high temperature environments results in higher perspiration and heart rates. Long-term exposure of non-acclimatized people to heat stress is unhealthy and counterproductive. Acclimatizing and educating employees to work in high temperatures, together with effective engineering control of heat sources, will provide a safe and healthy work environment for North Carolina's workforce.

Heat Stress Disorders

To maintain internal body temperatures within safe limits, the body must get rid of its excess heat, primarily by varying the rate and amount of blood flow through the skin and the release of fluid onto the skin by the sweat glands for evaporative cooling. Under conditions of high heat and humidity, the evaporation of perspiration from the skin is decreased, and the body's efforts to maintain a normal temperature may be impaired. With so much blood going to the external surface of the body, relatively less goes to the brain, the active muscles and other internal organs. The results are that strength declines and fatigue occurs sooner. Alertness and mental capacity may also be affected. Employees who perform delicate or detailed work may find their accuracy suffering. Other workers may suffer lowered comprehension and retention of information.

One of the most basic but effective ways to stop heat stress disorders is to practice "preventive behavior" on the job. The following are some practices that can be implemented in most hot work environments.

- Drink water. Increase water/fluid intake to replace body fluid lost through perspiration. Caution: in extreme heat, thirst is not a reliable guide to the body's need for water.
- Eat lightly. Avoid heavy meals and foods that are hard to digest.
- Avoid alcohol. Alcohol causes dehydration.
- Rest often. Give the body a chance to cool off.
- Plan ahead. Perform work activities during cooler periods of the day.
- Minimize activity in hot areas. Slow down the work pace.
- Reduce the number and duration of exposures.
- Wear proper clothing. Heat reflective or light colored clothes, material that "breathes," and even certain personal protective equipment, such as ice vests, can help workers combat heat stress.

5

Cold Stress

Understanding the Dangers of Cold Stress

Workers who are exposed to extreme cold or work in cold environments may be at risk of cold stress. Extremely cold or wet weather is a dangerous situation that can cause occupational illness and injuries such as hypothermia, frostbite and trench foot. When the body is unable to warm itself, serious cold-related illnesses and injuries my occur, and permanent tissue damage and death may result.

Workers in such industries as construction, commercial fishing and agriculture need to be especially mindful of the weather, its effects on the body, proper prevention techniques and treatment of cold-related disorders.

An individual gains body heat from food and muscular activity and loses it through convection, conduction, radiation and sweating to maintain a constant body temperature. When a person's body temperature drops even a few degrees below its normal temperature of 98.6°F, the blood vessels constrict, decreasing peripheral blood flow to reduce heat loss from the surface of the skin. Shivering generates heat by increasing the body's metabolic rate.

The four environmental conditions that cause cold-related stress are low temperatures, high/cool winds, dampness and cold water. One of the gravest dangers of winter weather is wind chill. The wind chill is based on the rate of heat loss from exposed skin by combined effects of wind and cold. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature. Figure 1 shows a wind chill chart from the National Weather Service.

Figure 1

Wind Chill Chart

Temperature (°F)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times — 30 minutes — 10 minutes — 5 minutes

$$\text{Wind Chill } (°F) = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T = Air Temperature (°F) V = Wind Speed (mph)

Source: National Weather Service, National Oceanic and Atmospheric Administration.

Hypothermia (Medical Emergency)

Hypothermia is a medical emergency that occurs when the body loses heat faster than it can produce heat, causing a dangerously low body temperature. It is a condition in which the body uses up its stored energy and can no longer produce heat. It often occurs after prolonged exposure to cold temperature. Hypothermia can occur when you are exposed to cold air, water, wind or rain. It can occur when land temperatures are above freezing or water temperatures are below 98.6°F. Cold-related illnesses can slowly overcome a person who has been chilled by low temperatures, brisk winds or wet clothing.

What Happens to the Body

Normal body temperature (98.6°F) drops to or below 95°F; fatigue or drowsiness; uncontrolled shivering; cool bluish skin; slurred speech; clumsy movements; irritable, irrational or confused behavior.

Early symptoms

- Shivering
- Fatigue
- Loss of coordination
- Confusion and disorientation

Late symptoms

- No shivering
- Blue skin
- Dilated pupils
- Slowed pulse and breathing
- Loss of consciousness

What Should Be Done—First Aid: Land Temperatures

- Call for emergency help (ambulance or call 911).
- Move the person to a warm, dry area. Don't leave the person alone. Remove any wet clothing and replace with warm, dry clothing or wrap the person in blankets.
- Have the person drink warm, sweet drinks (sugar water or sports-type drinks) if they are alert. **Avoid drinks with caffeine** (coffee, tea or hot chocolate) or **alcohol**.
- Have the person move their arms and legs to create muscle heat. If they are unable to do this, place warm bottles or hot packs in the arm pits, groin, neck and head areas. **DO NOT** rub the person's body or place them in warm water bath. This may stop their heart.

What Should Be Done—First Aid: Water Temperatures

- Call for emergency help (ambulance or call 911). Body heat is lost up to 25 times faster in water.
- **DO NOT** remove any clothing. Button, buckle, zip and tighten any collars, cuffs, shoes and hoods because the layer of trapped water closest to the body provides a layer of insulation that slows the loss of heat. Keep the head out of the water and put on a hat or hood.
- Get out of the water as quickly as possible or climb on anything floating. **DO NOT** attempt to swim unless a floating object or another person can be reached because swimming or other physical activity uses the body's heat and reduces survival time by about 50 percent.
- If getting out of the water is not possible, wait quietly and conserve body heat by folding arms across the chest, keeping thighs together, bending knees and crossing ankles. If another person is in the water, huddle together with chests held closely.

Frostbite

Frostbite is an injury to the body that is caused by freezing, which most often affects the nose, ears, cheeks, chin, fingers or toes.

Symptoms

- Reduced blood flow to hands and feet
- Numbness
- Aching
- Tingling or stinging
- Bluish or pale, waxy skin

What Should Be Done—First Aid: Land Temperatures

- Move the person to a warm dry area. Don't leave the person alone.
- Remove any wet or tight clothing that may cut off blood flow to the affected area.
- **DO NOT** rub the affected area, because rubbing causes damage to the skin and tissue.
- **Gently** place the affected area in a warm (105°F) water bath and monitor the water temperature to **slowly** warm the tissue. Don't pour warm water directly on the affected area because it will warm the tissue too fast causing tissue damage. Warming takes about 25-40 minutes.
- After the affected area has been warmed, it may become puffy and blister. The affected area may have a burning feeling or numbness. When normal feeling, movement and skin color have returned, the affected area should be dried and wrapped to keep it warm. **Note:** If there is a chance the affected area may get cold again, do not warm the skin. If the skin is warmed and then becomes cold again, it will cause severe tissue damage.
- Seek medical attention as soon as possible.

Trench Foot

Trench foot is an injury of the feet resulting from prolonged exposure to wet and cold conditions that can occur at temperatures as high as 60°F if the feet are constantly wet.

Symptoms

- Reddening of the skin
- Numbness
- Leg cramps
- Swelling
- Tingling pain
- Blisters or ulcers
- Bleeding under the skin
- Gangrene (foot may turn dark purple, blue or gray)

First Aid

- Remove shoes/boots and wet socks.
- Dry feet.
- Avoid walking on feet, as this may cause tissue damage.

Chilblains

Chilblains are ulcers formed by damaged small blood vessels in the skin, caused by the repeated exposure of skin to temperatures just above freezing to as high as 60°F.

Symptoms

- Redness
- Itching
- Possible blistering
- Inflammation
- Possible ulceration in severe cases

First Aid

- Avoid scratching.
- Slowly warm the skin.
- Use corticosteroid creams to relieve itching and swelling.
- Keep blisters and ulcers clean and covered.

How to Protect Workers From Cold Stress

- Recognize the environmental and workplace conditions that lead to potential cold-induced illnesses and injuries.
- Learn the signs and symptoms of cold-induced illnesses/injuries and what to do to help the worker.
- Train the workforce about cold-induced illnesses and injuries.
- Select proper clothing for cold, wet and windy conditions. Layer clothing to adjust to changing environmental temperatures. (Tight clothing, however, can reduce blood circulation to the extremities.) Wear a hat and gloves, in addition to underwear that will keep water away from the skin (polypropylene). Be aware that some clothing may restrict movement resulting in a hazardous situation.

- Protect the ears, face, hands and feet in extremely cold or wet weather. Boots should be waterproof and insulated. Wear a hat to reduce the loss of body heat from your head.
- Carry extra socks, gloves, hats, jacket, blankets, a change of clothes and a thermos of hot liquid.
- Include chemical hot packs in your first aid kit.
- Avoid touching cold metal surfaces with bare skin.
- Take frequent short breaks in warm dry shelters to allow the body to warm up.
- Perform work during the warmest part of the day.
- Avoid exhaustion or fatigue because energy is needed to keep muscles warm.
- Use the buddy system (work in pairs).
- Drink warm, sweet beverages (sugar water, sports-type drinks). Avoid drinks with caffeine (coffee, tea or hot chocolate) or alcohol.
- Eat warm, high-calorie foods like hot pasta dishes.

Workers Are at Increased Risk When...

- They have predisposing health conditions such as cardiovascular disease, diabetes and hypertension.
- They take certain medication (ask your doctor, nurse or pharmacist if any medicines you are taking can affect you while working in cold environments).
- They are in poor physical condition, have a poor diet or are older.

Appendix

Measuring Heat Stress Potential

The primary factors that determine the potential for heat stress are (1) the level of work that controls the amount of heat that is generated and (2) the environmental conditions that control the rate at which excess body heat can be dissipated. Assessing the potential for heat stress is generally a two-step process. First, an estimate of the heat load to be dissipated is made based upon the type and level of work activity. The second step involves determining through environmental measurements the rate at which heat can be lost from the body into the environment.

A number of tables (such as Table 1) have been developed to estimate heat load as a function of work activity. This estimate becomes the metabolic heat load portion of equations and models used to assess heat stress potential. Work rate values are often expressed either as BTU/hr or as Kcal/hr. A conversion factor of 3.98 Kcal per BTU can be used to translate between the units.

The environmental parameters that are normally used to assess the rate at which heat can be transferred from the skin to the environment include wet bulb temperature, dry bulb temperature, globe temperature and air velocity. Some or all of these parameters are combined to form the part of the equation regarding rate of heat loss. Although a national heat stress standard does not currently exist, exposure guidelines based on the Wet Bulb Globe Temperature Index are widely used to assess heat stress potential.

Wet Bulb Globe Temperature Index

The WBGT Index uses a combination of wet bulb (humidity), globe (radiant) and dry bulb (ambient) temperature readings to assess heat stress potential. Depending upon whether the work is conducted indoors or outdoors, the following equations are used to calculate the WBGT index.

Indoors WBGT = 0.7 Twb + 0.3 Tg

Outdoors WBGT = 0.7 Twb + 0.2 Tg + 0.1 Ta

where: WBGT = wet bulb globe temperature index
Twb = non-aspirated wet bulb temperature
Tg = black globe temperature
Ta = dry bulb temperature

The calculated WBGT index value is used along with the estimated metabolic work load for a job or task to evaluate the potential for heat stress. Locating the intersection of these values on the WBGT graphs in Figures 2 and 3 provides an estimate of the heat exposure limit that should be applied to prevent heat strain in either non-acclimatized or acclimatized workers. The following example illustrates how the WBGT index is used to evaluate heat stress potential:

Given:

Task requiring a worker to perform moderate whole body work outdoors while standing on a black asphalt surface

Twb = 75°F
Tg = 120°F
Ta = 95°F

Determine:

Recommended exposure limit

Solution:

Estimation of metabolic heat load from Table 1

0.6 Kcal/min for standing body position
5.0 Kcal/min for whole body work
1.0 Kcal/min for basal metabolism
6.6 Kcal/min x 60 min/hr = 396 Kcal/hr

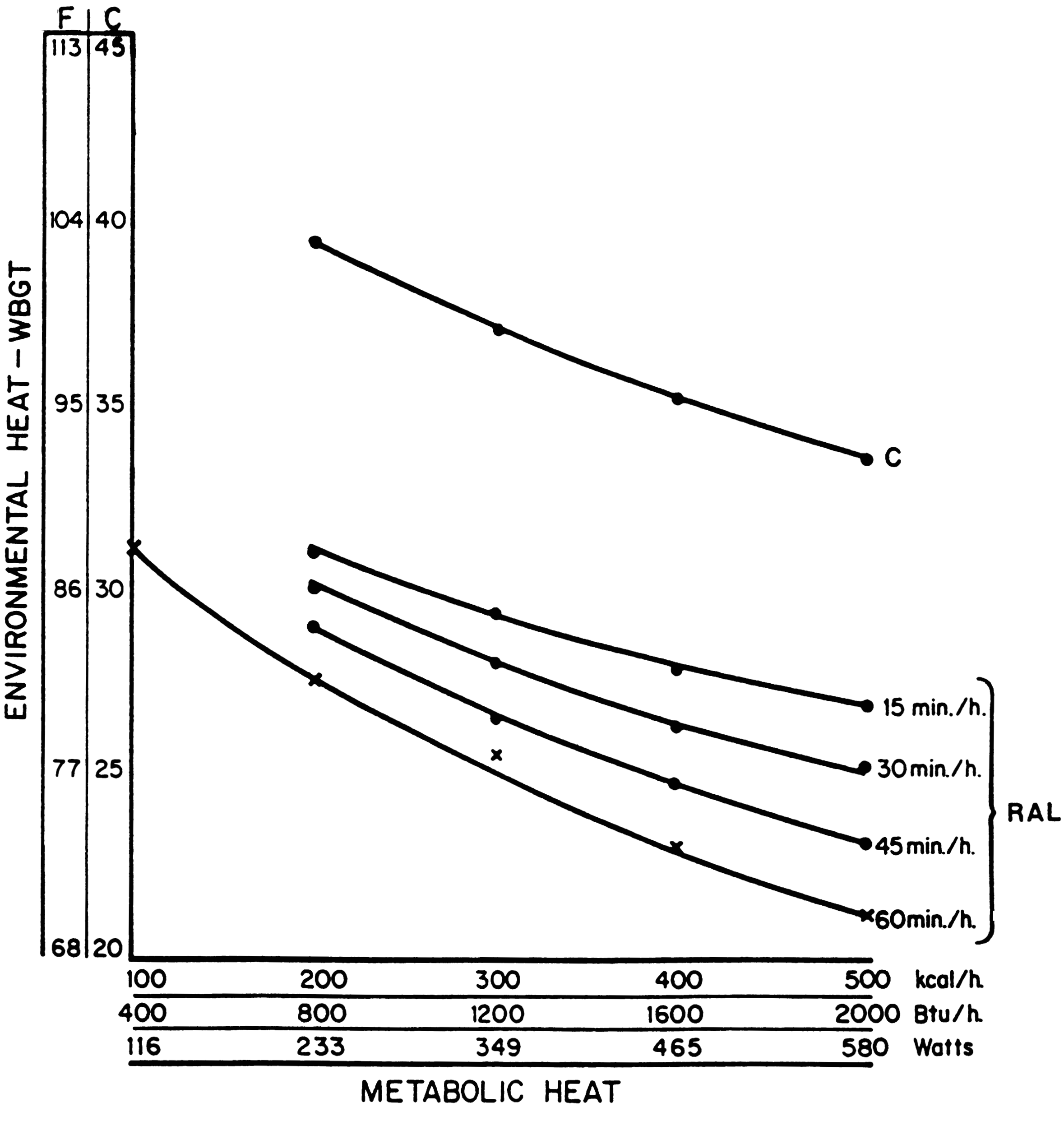
Calculation of WBGT index value:

(0.7 x 75) + (0.2 x 120) + (0.1 x 95) = 86°F

Recommended exposure limit from Figure 3 = 15 min/hr

Figure 2

Recommended Heat Stress Limits for Non-acclimatized Workers*

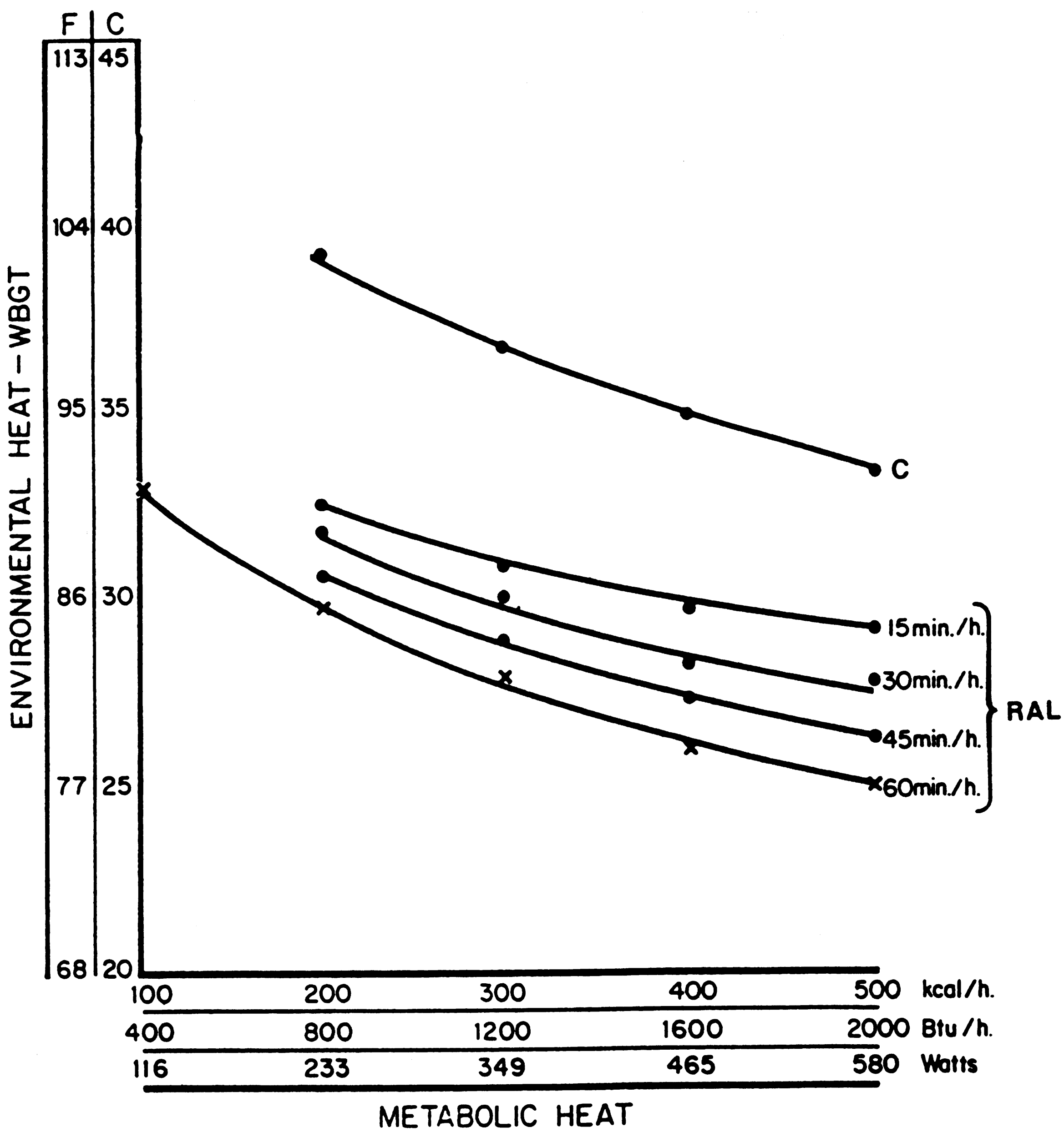


C = ceiling limit
RAL = recommended alert limit for standard worker

*Adapted from reference source 1. (See References within this publication.)

Figure 3

Recommended Heat Stress Limits for Acclimatized Workers*



C = ceiling limit
RAL = recommended alert limit for standard worker

*Adapted from reference source 1. (See References within this publication.)

References

1. American Industrial Hygiene Association. Heating and Cooling for Man in Industry, 2nd ed. Akron, Ohio. 1975.
2. National Safety Council. *Fundamentals of Industrial Hygiene.* 5th ed. Edited by Barbara A. Plog. Chicago. 2002.
3. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. *Criteria for a Recommended Standard: Occupational Exposure to Hot Environments.* Publication No. 86-113. www.cdc.gov/niosh/86-113.html (June 7, 2011).
4. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. *The Industrial Environment—Its Evaluation and Control.* Washington, D.C. 1973. www.cdc.gov/niosh/pdfs/74-177.pdf (June 7, 2011).
5. U.S. Department of Labor, Occupational Safety and Health Administration. *Protecting Workers From Heat Stress.* OSHA 3154-08-10R v2. www.osha.gov/Publications/osha3154.pdf (June 7, 2011).
6. U.S. Department of Labor, Occupational Safety and Health Administration. *Protecting Workers in Cold Environments.* Fact Sheet No. OSHA 98-55. www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FACT_SHEETS&p_id=186 (April 29, 2011).
7. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. *Winter Weather.* www.noaawatch.gov/themes/winter.php (May 3, 2011).

Additional Resources on Hot and Cold Work Environments

NCDOL publications

http://www.nclabor.com/osha/etta/A_to_Z_Topics/heat_stress.htm

OSHA's Campaign to Prevent Heat Illness

http://www.osha.gov/SLTC/heatillness/index.html

OSHA's Educational Resources

http://www.osha.gov/SLTC/heatillness/edresources.html

OSHA's Training Resources

http://www.osha.gov/SLTC/heatillness/trainingresources.html

OSHA's Cold Stress card in English

http://www.osha.gov/Publications/osha3156.pdf

OSHA's Cold Stress card in Spanish

http://www.osha.gov/Publications/osha3158.pdf

NIOSH Heat Stress page

http://www.cdc.gov/niosh/topics/heatstress/

NIOSH Cold Stress page

http://www.cdc.gov/niosh/topics/coldstress/

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Occupational Safety and Health (OSH)

Sources of Information

You may call 1-800-NC-LABOR (1-800-625-2267) to reach any division of the N.C. Department of Labor; or visit the NCDOL home page on the World Wide Web: http://www.nclabor.com.

Occupational Safety and Health Division

Mailing Address:
1101 Mail Service Center
Raleigh, NC 27699-1101
Local Telephone: 919-807-2900 Fax: 919-807-2856

Physical Location:
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For information concerning education, training, interpretations of occupational safety and health standards, and OSH recognition programs contact:

Education, Training and Technical Assistance Bureau

Mailing Address:
1101 Mail Service Center
Raleigh, NC 27699-1101
Telephone: 919-807-2875 Fax: 919-807-2876

Physical Location:
111 Hillsborough St.
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For information concerning occupational safety and health consultative services contact:

Consultative Services Bureau

Mailing Address:
1101 Mail Service Center
Raleigh, NC 27699-1101
Telephone: 919-807-2899 Fax: 919-807-2902

Physical Location:
111 Hillsborough St.
(Old Revenue Building, 3rd Floor)

For information concerning migrant housing inspections and other related activities contact:

Agricultural Safety and Health Bureau

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1101 Mail Service Center
Raleigh, NC 27699-1101
Telephone: 919-807-2923 Fax: 919-807-2924

Physical Location:
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(Old Revenue Building, 2nd Floor)

For information concerning occupational safety and health compliance contact:

Safety and Health Compliance District Offices

Raleigh District Office (3801 Lake Boone Trail, Suite 300, Raleigh, NC 27607)
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Asheville District Office (204 Charlotte Highway, Suite B, Asheville, NC 28803-8681)
Telephone: 828-299-8232 Fax: 828-299-8266

Charlotte District Office (901 Blairhill Road, Suite 200, Charlotte, NC 28217-1578)
Telephone: 704-665-4341 Fax: 704-665-4342

Winston-Salem District Office (4964 University Parkway, Suite 202, Winston-Salem, NC 27106-2800)
Telephone: 336-776-4420 Fax: 336-767-3989

Wilmington District Office (1200 N. 23rd St., Suite 205, Wilmington, NC 28405-1824)
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N.C. Department of Labor (Other than OSH)

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