Establishing a Foundry Heat Stress Management Program

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Contents

List of Tables

List of Figures

Section 1
Protection Strategy for Hot Work Activity

1.1 Challenges of Heat Stress Management

Experience has shown that safe and healthy work environments are an essential element in the success and viability of foundries and can have a positive impact on casting quality. The purpose of foundry health and safety programs is to assure a workplace free of substantial risk of injury or health impairment. Among the risk factors in metalcasting is worker exposure to heat associated with foundry processes.

Working strenuously in a hot environment (termed hot work activity) can tax the body's limited capability to control its own internal temperature. The heat load to which the body may be subjected due to environmental and metabolic heat is termed "heat stress." The body's physiological response to heat stress is termed, "heat strain." If precautions are not taken, heat strain can become excessive, leading to heat disorders. Section 2 describes how the body accommodates hot work activity and what happens when the capacity of the temperature control system of the body is exceeded. Heat related disorders range from heat irritation and cramps to death from heat stroke. When human performance suffers as a consequence of excessive heat strain, the worker and those around the worker are at greater risk of injury.

The potential hazard from heat stress on foundry workers varies substantially with the particular assignment. The hottest work is usually associated with the melting and pouring of metal and handling of castings soon after they are removed from their molds. Of equal concern are the highly variable maintenance activities, which may involve substantial exertion in unusual body postures, sometimes conducted in close proximity to hot sources and in relatively confined situations. The thermal environment needs to be considered in the hazard evaluation associated with work in confined spaces.

The capability of workers to sustain performance during hot work activity varies dramatically among workers, which definitely complicates heat strain management. Some major individual differences include age, current health state, degree of physical fitness, experience working or exercising in the heat (acclimatization), type and quantity of medications taken, and personal habits, such as receiving a proper sleep period.

1.2 Fundamental Premise: Heat Disorders are Preventable

Heat disorders are preceded by early warning signs. Workers who are properly prepared for hot work activity can be trained to recognize these physical signs and to immediately take appropriate actions that will prevent heat strain from becoming excessive. In its *Industrial Ventilation Manual of Recommended Practice,* the American Conference of Governmental Industrial Hygienists (ACGIH) affirms that, "The incidence and severity of heat strain will vary greatly among people, even though all are exposed to the same level of heat stress. Paying attention to the early signs and symptoms of heat strain is the best first line of defense against debilitating heat-induced discomfort and injuries."[1]

The heat stress management program described here is based on a strategy of recognition of early warning signs and of immediate response to these signs. This strategy will succeed in preventing heat disorders if workers:

- Maintain physical preparedness for hot work activities.
- Manage work activity and personal habits to control heat buildup in the body.
- Recognize and heed early warning signs of advancing heat strain by interrupting hot work activity to allow recovery, assessment, and follow-up.

There is an upper limit, however, to what personal preparations and self-monitoring can achieve. If for any reason a prepared worker either misinterprets the warning signs or is slow to heed them, heat strain could progress rapidly under certain conditions. One of the manifestations of advancing heat disorders is mental confusion. At this point, a worker cannot be expected to respond appropriately and may be in need of intervention by co-workers and supervisors. To address this possibility, an effective heat stress management program should foster a teamwork approach in which self-monitoring is backed up by workers looking out for one another, by making observations and actively inquiring so that they may form their own opinion, and respond to the heat strain status of their co-workers.

Workers will not be able to fully satisfy these requirements without training, support, and follow-up. A heat stress management program involves active involvement of management, workers, supervisors, and co-workers. The interrelationship of functional activities to be performed by these participants is embedded in the logic sequence presented and described in Section 3. This sequence constitutes one of two principle focuses of the preventative heat strain management program described here.

The second focus of an effective heat stress management program follows from the inherent limitations of the first. The higher the heat stress, the greater the risk of excessive heat strain causing a heat disability. Assurance of program success can be gained through a continuing, proactive approach to evaluating and reducing heat stress sources. A strategy for controlling heat stress sources is presented in Section 4.

Section 2
Effect of Hot Work Activity on the Body

2.1 Introduction

The body has its own temperature monitoring and control systems. For a human being to function properly, chemical and biological processes within the body require close control of body temperature around a set point. When a person is healthy, his or her temperature control system closely controls deep body temperature (core temperature) at approximately [98.6 degrees Fahrenheit (°F) and 37 degrees Celsius, (°C)]. During hot work activity, the body must release heat in order to maintain core temperature control. The body has a system to automatically achieve this heat release. There is an upper limit, however, to the extent of hot work activity which can be sustained without exceeding the capability of this temperature control system to limit heat strain.

Causes of heat buildup in the body capable of generating excessive heat strain during hot work activities, referred to as sources of heat stress, emanate from both inside and outside the body and include:

1. Excess heat generated by the process, termed metabolism, which the body uses to convert food into the energy needed to contract muscles and perform useful activities.
2. Restrictions which clothing and personal protective equipment (PPE) place on release of excess body heat.
3. Heat transmitted to the body by a hot work environment.

2.2 Temperature Control in the Body

The body fuels its muscular system through metabolism primarily of carbohydrates and fats. Carbohydrates are converted by the body into glucose, which in turn is broken down to produce energy for cells, including the contractile energy of muscle fibers. Skeletal muscle metabolism generates substantial amounts of internal body heat as a by-product, the amount of that heat being proportional to the level of activity.

The cardiovascular system participates in the metabolism process by supplying food nutrients to the active muscles and carrying away waste products from them. The cardiovascular system also redirects blood flow as required to transport heat generated by muscle metabolism from deep inside the body (core area) to the skin area where the process of removal of heat from the body takes place. This redirection of blood flow pumped by the heart is accomplished by expanding blood vessels in the skin area (vasodilation) and contracting blood vessels in the core area (vasoconstriction).

2.3 Heat Release from the Body

There are four different mechanisms by which heat is transferred either to or from the skin area of the body: conduction, convection, thermal radiation, and evaporation of perspiration. Each of these mechanisms of heat transfer is described below.

Conduction heat transfer to or from the skin occurs when the skin temperature is different than the temperature of clothing and other objects in direct contact with the skin. **Convective heat transfer** occurs when the skin temperature is different than the temperature of the moving air environment surrounding the skin. **Thermal radiation** occurs when skin temperature is different than the temperature of objects that surround but do not contact the body and are in direct line of sight with the body. Radiant heat is thereby transmitted from the body to those objects or vice versa without heating up the air environment in between. For heat to be released from the skin by convection, conduction, and thermal radiation, the environment surrounding the body must be lower in temperature than the skin. **Evaporation of perspiration** does not have this temperature limitation and becomes the sole method of heat release from the body as the surrounding environment exceeds skin temperature.

Heat loss by evaporation begins with the body secreting perspiration from sweat glands in the skin, which in turn wets the skin's surface. As the perspiration absorbs heat from the skin and from the environment, the liquid evaporates and the heat of vaporization is carried away with the vapor produced. What results is a very noticeable cooling sensation on the skin as the perspiration evaporates. As heat generated by the body increases with greater exertion, perspiration rate is increased through the body's automatic activation of a greater number of sweat glands.

At higher temperatures of the environment surrounding the body, the rate of heat loss through evaporation increases. Unfortunately, the percentage of the heat of vaporization, which is drawn from the skin, decreases under this condition while at the same time, the percentage of heat of vaporization drawn from the environment increases. Thus, the capability of the perspiration evaporation process to remove heat from the body decreases as environmental temperature rises.

If due to a hot environment, the vaporization rate matches the perspiration rate and the skin dries out, the skin becomes subject to substantial convective heating from the air in contact with the skin when the air temperature exceeds skin temperature (*i.e.*, above about 95°F (35°C). At the other extreme, if perspiration rate greatly exceeds sweat vaporization rate, due to high work activity and/or to a humid environment, the body produces beads of perspiration which roll off the body or soak into the clothing, providing little heat relief. Heat relief from perspiring occurs primarily by vaporization of perspiration off of the skin.

2.4 Effects on the Cardiovascular System

The cardiovascular system works hard to relieve the body of heat during hot work activity. This system can become strained as muscle metabolism increases, generating more heat to be transported to the skin for removal. The heart responds by pumping more blood at an increased heart rate. Vasodilatation of blood vessels reduces restriction to blood flow and maximizes blood flow rate. However, at some point, return of venous blood to the heart cannot keep up, resulting in diminished blood volume pumped with each heart beat and a drop in blood pressure. Blood flow to the brain is thereby reduced and with it the effectiveness of brain functions. Blood can also pool in the body at reduced blood pressure. The cardiovascular system tries to compensate for this limiting condition through an even faster heart beat and by constricting blood flow to the abdominal organs, causing abdominal cramping.

Unless body fluids lost from sweating are continuously replenished, profuse sweating can cause the body to be dehydrated to an extent that reduces blood flow and throws off the body's electrolyte balance.

2.5 Progression of Heat Strain

A worker can sense the onset of excessive heat strain caused by the rise in body core temperature by means of very specific signs and symptoms (see Table 1). These signs and symptoms indicate that the body is beyond the point where it can adequately compensate for the heat load. Unless corrective action is taken at this stage of progression of heat strain, the heat disorders summarized in Table 2 are likely to occur.

Table 1. Early Warning Signs and Symptoms of Excessive Heat Strain Levels that Could Result in Heat Disorders

Profuse Sweating – copious amounts of perspiration or persons dripping with sweat and soaking their clothing. Skin cool to the touch.

Increased Heart Rate - a pounding pulse which does not diminish, even with rest.

Abnormal Physical Sensations - reduced blood flow to the brain, as blood pressure falls to accommodate blood flow to the skin area and muscles.

- Dizziness
- Nausea
- Blurred vision
- Loss of peripheral /tunnel vision
- Postural instability
- Ringing in the ears
- "Unusual" taste in the mouth
- Hand tremors
- Flu-like symptoms
- Muscle cramps

Diminished Work Performance - fatigue which evidences itself in:

- Decline in task performance
- Loss of coordination
- Decline in alertness and vigilance
- Altered mental status
- Unconsciousness

Table 2. Heat Disorders

Heat Disorder	Signs and Symptoms	First Aid/Medical Procedures
Heat rash (prickly heat) from plugged sweat ducts	Skin rash appears; infections can develop.	■ Rest in the respite room; regular bathing and drying of the skin.
Heat cramps	Painful spasms of the muscles from profuse sweating and replenishment of fluids but not salt; symptoms may extend beyond work shift.	■ Replenish water and electrolytes; rest in respite room until cramps go away.
Fainting from blood pooling	Collapsing.	■ Lying down and resting in respite room; replenishing water and electrolytes; subsequently moving around to resist blood pooling.
Heat exhaustion	Skin clammy and moist from excessive perspiration; complexion pale or flushed, body temperature only slightly elevated, experiencing extreme fatigue, giddiness, dizziness, nausea, and headache; may vomit or lose consciousness.	■ Rest in respite room; replenish water and electrolytes. ■ Medical surveillance before return to work.
Heat stroke (Medical Emergency)	Hot, dry, red, blotched, or spotted skin; worker is mentally confused, delirious, perhaps in convulsions or unconscious, deep breathing followed by periods of shallow breathing, rapid strong bounding irregular pulse, dilated pupils.	■ Quick and appropriate treatment demanded or death or permanent disability could occur. ■ Get emergency medical attention. ■ Remove to respite room. ■ Cool the body. ■ Hospitalization. ■ Medical surveillance before return to work.

Section 3
Program to Prevent Heat Disorders During Hot Work Activity

3.1 Basic Protection Model

A logic chart which summarizes key elements to be included in a program to manage hot work activities is presented in Fig. 1. The logic sequence proceeds from prerequisites for engaging in hot work activity, to performance criteria for conducting hot work activity, to actions which should follow the recognition by workers of early warning signs of excessive heat strain. Each of the items on the logic chart is expanded in the following subsections.

3.2 Personal Preparations

All staff either performing or supervising hot work activity should be prepared at all times for the physiological challenge which this work imposes. Due to their health state and physical condition, not all workers are capable of performing hot work activities in a safe and healthy manner. Health clearance and ongoing health surveillance is a prerequisite for hot work activity to assure that no one is placed at unacceptable risk of developing a heat disorder. Hot work activity on a continuous basis should not commence until a medically cleared person is trained and acclimatized for hot work activity.

3.2.1 Assigned Responsibilities

Prevention of heat disorders requires dedication and cooperation at all levels of the company, including management, workers, and supervisors. Responsibilities for each of these groups are listed in Table 3. This group may need outside medical and industrial hygiene support to implement a proactive program of worker protection.

3.2.2 Health Clearance

There are physicians and nurses who specialize in industrial environments. These trained professionals can be called upon to provide the type of medical surveillance needed for a program to prevent heat disorders. That service should include:

1. Monitoring the ongoing health status of all new and existing foundry workers in terms of their past history of work in hot environments and their present capability for such work. The impact of pregnancy, illness, and medications on this capacity needs to be assessed. For example, the method for maintaining electrolyte balance by ingesting electrolyte drinks would need to be reviewed in the case of a person on a low sodium diet (Section 3.3.2).

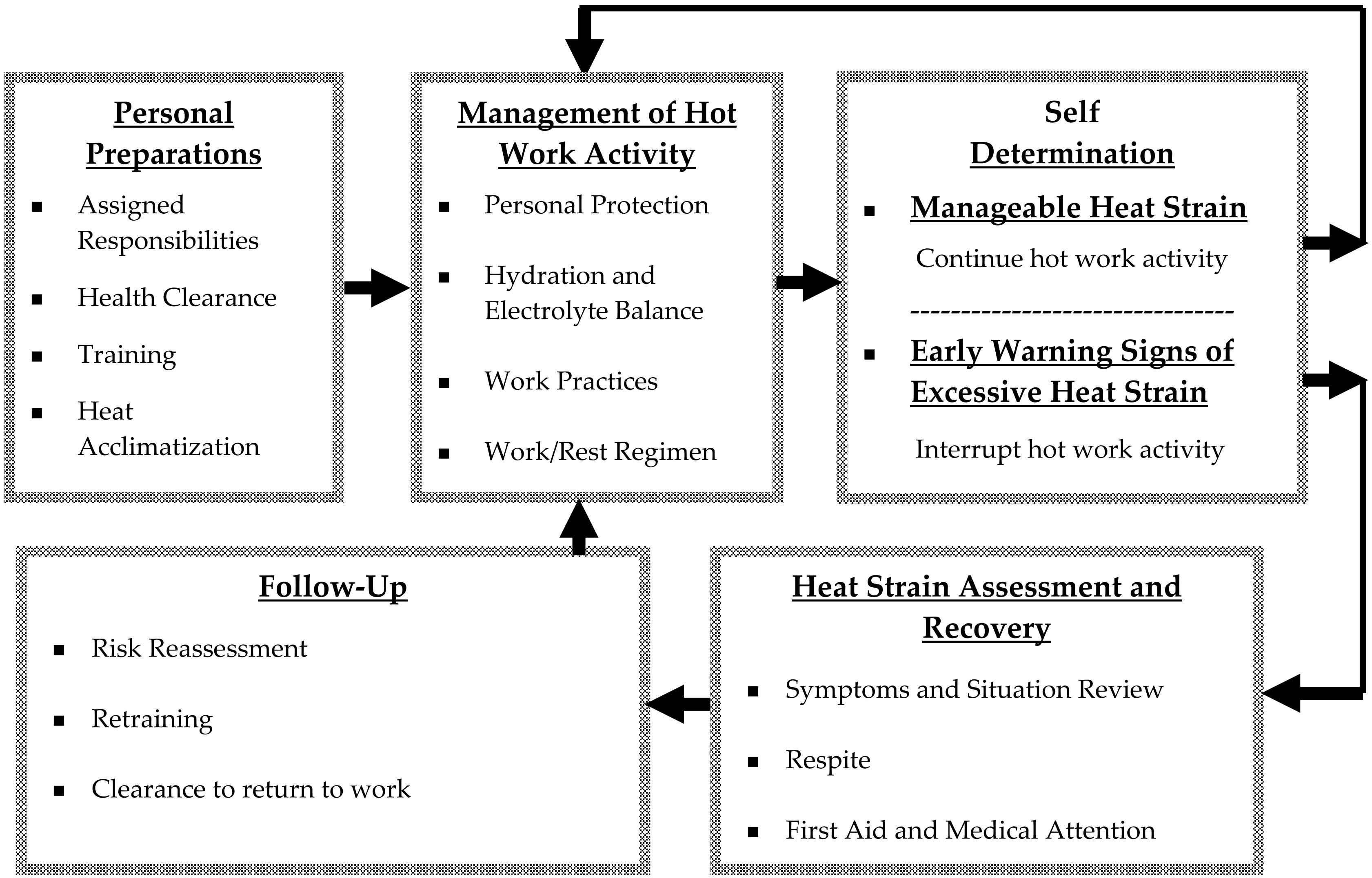

Fig. 1. Basic protection model for managing hot work activity.

Table 3. Organizational Responsibilities of a Heat Stress Management Program

Management Responsibilities:

- Establish responsibilities for determining and monitoring the risks of heat stress during metalcasting.
- Establish job requirements and provide conditions that can be performed in a safe and healthy manner.
- Limit hot work assignments to workers physically and medically fit to complete them safely.
- Be responsive to feedback from workers concerning all safety and health issues, including heat stress.
- Educate and train workers and supervisors on a regular basis, especially prior to hot weather.
- Provide the means for workers to become gradually acclimated to hot work assignments, to conveniently replenish body fluids and electrolytes lost in sweating, and to seek heat stress relief, such as in a cooled break room.
- Provide an isolated setting within the workplace (respite room) with provisions and support for heat strain monitoring, for recovery from heat stress as well as for application of first aid.
- Establish procedures for heat related emergency situations.
- Utilize medical support and oversight of the Heat Stress Program.
- Follow up to prevent recurrence of any reported heat disorders.
- Work with foundry operational, maintenance, and engineering staff to identify and pursue opportunities to improve heat controls.

Worker Responsibilities:

- Lead a healthy lifestyle that will assure preparedness for assuming work in a hot foundry environment.
- Perform assignments in ways that minimize heat stress.
- Learn how to recognize and respond to the early warning signs of heat strain and heat disorders.
- Promptly report all changes in health status and early warning signs of heat strain.
- Follow company industrial hygiene procedures with respect to heat acclimatization, hydration, electrolyte replacement, work/rest regimens, use of personal protective equipment, and heat strain recovery.
- Watch for and report heat strain symptoms in fellow workers.
- Cooperate with monitoring requirements for heat stress and strain.
- Suggest ways to improve heat stress controls.

Supervisor Responsibilities:

- Understand the effects of heat stress on worker safety, health, and productivity.
- Learn to recognize early warning signs of excessive heat strain in workers.
- Assure that workers respond to early warning signs of excessive heat strain.
- Monitor adherence to company-established work/rest regimens for hot environments.
- Communicate heat safety concerns to management.
- Follow through on monitoring requirements for heat stress and strain for supervised job functions and departments for which responsible.
- Develop, communicate, and assist in implementing controls for heat stress.

2. Guiding the creation of onsite heat strain monitoring and respite, including satisfying privacy concerns associated with heat strain and health information.
3. Responding to calls for assistance during incidents of heat disorders.
4. Overseeing the training of foundry staff or contracted nurses who assess heat strain and oversee recovery and follow up activities.
5. Sharing this medical responsibility within the organization of the medical provider to assure continuous access by the foundry to prepared medical staff.

3.2.3 Training

In a work environment, training becomes warranted when people understand and are committed to achieving objectives, but lack knowledge and skill to achieve those objectives. Training is also necessary to assure that the worker accepts the need to conform to enhanced safety and health measures while striving to be productive. To be successful, a heat stress management program must function on the knowledge, skill, and motivational levels.

The knowledge basis includes understanding how the body controls its temperature during hot work activity, what active role the worker must take to maximize the body's capabilities, and what signs to look for in oneself and in fellow workers that signal that heat strain has risen to a level that can produce dangerous heat disorders.

Skill and motivation both enter the picture with regard to personal habits and work practices that minimize heat stress and strain:

- Keeping fit and rested for work activity
- Maintaining an effective level of hydration and electrolytes in the body
- Reducing metabolic and environmental heat stress in performance of the work
- Properly wearing and maintaining PPE

The effectiveness of training and program implementation can be enhanced by incorporating a "buddy system" approach. Having employees teamed up and looking out for one another can reduce the possibility that heat-induced mental confusion could delay responding to early warning signs of excessive heat strain.

In heat stress program development and training of workers, emphasis should be placed on the special needs of maintenance workers. In maintenance, it is possible for hazardous work conditions to occur which have never before been encountered in the foundry. Management systems need to establish that the safety of maintenance workers is a priority over production. In addition, necessary PPE, proper tools, and safe access provisions should all be made readily available. The training of maintenance staff on prevention of heat disorders should be specific and directed toward their special needs.

Worker training to assure compliance with administrative heat stress control procedures should intensify just prior to the onset of hot weather. Foundry heat stress originates from the hot environment within the metalcasting facility, but it is also weather dependent. In all foundries, the indoor thermal environment is significantly affected by hot and humid weather, which can be predicted through weather reports. The need for control of heat stress will definitely be weather-driven.

Key worker training objectives are listed in Table 4.

Table 4. Personal Preparations: Training Objectives

- Understanding the potential that heat stress has for creating heat disorders.
- Learning procedures for adaptation to the environment, for the wearing of personal protective equipment, as well as for staying hydrated and electrolyte-balanced.
- Recognizing the early warning signs of excessive heat strain in one's body and responding to these signs as well as communicating to co-workers and supervisors (self-determination).
- Recognizing the same warning signs in co-workers and communicating those observations to other co-workers and supervisors.
- Knowing the correct procedures to follow in heat stress emergency situations.
- Utilizing heat stress controls: engineering, administrative, and work practices.

3.2.4 Heat Acclimatization

Working safely in a hot environment requires adaptation which is termed heat acclimatization. As the body adjusts to hot work activity, perspiration output and the capability of the body to cool itself more effectively increases. Perspiration composition is also affected, becoming more dilute and expelling less of its electrolytes. As acclimatization proceeds, heat strain is reduced and the hot work activity becomes more tolerable. Heat disorders occur most frequently in un-acclimated workers.

The worker must be active in a hot environment for acclimatization to occur. Spending inactive time in a hot environment is not sufficient to confer heat acclimatization, nor does physical conditioning alone eliminate the need to undergo the heat acclimatization process. Physical conditioning does improve cardiovascular function, which allows the worker to better cope with the strain that hot work activity places on the circulatory system.

Similar to other forms of physical conditioning, heat acclimatization should be undertaken as a gradual process of increasing the body's tolerance to heat stress. For a healthy worker, the process may require a week or more during which time hot work activity should be limited based on the individual's capability to adjust to the hot work environment. In the book *Industrial Health*, the author, Jack E. Peterson states that a person in good physical shape can achieve 80 percent acclimatization to a specific job and level of heat stress by working hard two hours per day for four to five days.[2].

If the job for which the worker is being acclimatized involves significant heat stress, acclimatization should probably proceed in steps, starting with moderate work activity in a hot environment and proceeding to more strenuous activity. It is critical that the worker remain hydrated and electrolyte-balanced throughout the acclimatization process.

Acclimatization is not lost to a significant extent over a weekend away from hot work activity. On the other hand, loss of acclimatization over a two week interval away from hot activity may be substantial, warranting several days to become reacclimatized.

Abrupt weather changes involving temperature swings can complicate the acclimatization process, especially when environmental conditions surrounding hot work activity become suddenly and markedly hotter due to the weather.

The same response measures following early warning signs of excessive heat strain during hot work activity also apply during the acclimatization process. The heat acclimatization process should be monitored, using heat strain measurements as appropriate (*e.g.,* oral temperature and heart rate).

3.3 Managing Hot Work Activity

Preventing heat disorders involves more than personal preparations for hot work activity. The activity itself must be managed to assure that heat strain can be controlled. The need for PPE, the need to stay continuously hydrated and electrolyte-balanced, the need to utilize systems in place and work practices that minimize heat stress, and the need for properly-timed cool down periods pose challenges which must be managed.

3.3.1 Personal Protective Equipment (PPE)

A guideline is available from the American Foundry Society 10Q Health and Safety Committee which presents a recommended approach to selecting proper PPE for potentially hazardous work situations in foundries. The guideline is called, "Guide for Selection and Use of Personal Protective Equipment and Special Clothing for Foundry Operations."[3] In this document, special emphasis is placed on defining needed protection from exposure to molten metal sparks, splashes, and explosions in melting and casting operations as well as protection from exposure to radiant heat from close proximity to melting equipment and to molten metal. PPE which can provide the needed protection unfortunately also reduces heat release from the body, thus increasing heat stress. The proper strategy in this case is not to compromise personal protection against hot process sources by eliminating any portion of the recommended PPE. Rather, the proper approach is to fully apply personal protective measures and to recognize and manage the heat stress associated with this PPE regimen.

Some heat stress-limiting measures to prevent excessive heat strain while wearing impermeable PPE include:

- Limit the duration of activities which require donning this type of PPE and follow these periods of use of this PPE with a period of cooling (see Work/Rest Regimen, Section 3.3.4).
- Reduce both the physical work requirements and the duration of activities with exposure to high process and environmental heat.
- As needed, employ cooling vests and air supplied PPE to cool the skin without compromising the impermeability of the PPE.

3.3.2 Hydration and Electrolyte Balance

There are three principal issues surrounding workers staying hydrated:

1. Dedication to remaining hydrated.
2. Easy access to water and to drink containing electrolytes.
3. Natural (or enforced) breaks in the work sequence that permit a pause to take a drink and to urinate.

The first of these is the most difficult to confront. Some of the difficulties are bound up in human physiology itself. A person does not feel thirsty until dehydration is already well-advanced. Thus, thirsty sensation does not provide a reminder to the worker to replenish water lost in sweating. Consequently, a worker must set a drinking pattern for himself or herself to prevent periods of time from passing without drinking any water. One suggestion that a healthy worker can use as a check is whether urination rate slows down and urine color darkens. A dehydrated person urinates very infrequently and the urine is more darkly colored. Only a hydration rate which matches sweating rate could achieve an unchanged urination pattern.

3.3.3 Work Practices

Workers can help reduce job-related heat stress in terms of controlling both metabolic rate and heat stress from process and environmental heat situations. The greater the energy level of the work, the higher the metabolic rate and the higher the excess heat which the body must discharge. The energy required by the body to perform work is dependent on the type of task being undertaken and the body posture necessary to perform it. The impact of inefficient tasks and awkward postures is discussed in Section 4.2. Some work stress-limiting work practices are listed in Table 5.

Table 5. Hot Work Activity: Work Practices to Limit Heat Stress

- Utilizing proper ergonomics, limiting individual exertion level, and setting a job pace.
- Managing time spent in close proximity to hot processes.
- Employing available mechanical assistance devices.
- Keeping hot processes enclosed whenever possible.
- Allowing time to drink water.
- Removing oneself or others from hot locations whenever possible.
- Taking break times in cooler environments without radiant heat sources.
- Scheduling of hot maintenance tasks.

3.3.4 Work/Rest Regimen

Due to limited endurance of the body, interruptions in physical work activities are needed whether or not the job can be classified as hot work activity. This basic human need stems from the cycle of fatigue/recovery of the muscles and the cardiovascular system which supports both muscle metabolism and temperature control in the body. Not only does the body need to slow down the heart rate and reduce lactic acid associated with muscle fatigue, body core temperature also needs to return to normal.

Controlling the duration of heat stress is important in a program to prevent heat disorders. This control is typically achieved in various ways:

- Organizing the work so that natural (or enforced) breaks occur in the action, allowing retreat from the hot conditions;
- Rotating jobs;
- Assigning relief workers for regular breaks or for designated rest times;
- Making accommodations in hot work assignments to allow acclimatization to properly proceed at reduced levels of heat stress.

The above heat stress controls are categorized as administrative, and they need to be applied in a very consistent manner, following mandated procedures.

The establishment of administrative procedures should follow detailed evaluations of hot jobs, including heat stress and heat strain assessments and scrutiny of heat controls (see Section 4).

3.4 Self-Determination

A cooperative atmosphere should be created in which workers choose to report the early warning signs of excessive heat strain. Unless they do so, a proactive program to prevent heat disorders is impossible. The training process must acknowledge and work beyond a series of barriers that may exist in the minds of workers that stand in the way of choosing to report. Some of these barriers include:

1. Reluctance to report early warning signs when one’s co-workers are not reporting (Human reaction to heat stress is very individualistic, and norms for what is tolerable are not valid).
2. Putting completion of the task ahead of personal needs. (A heat disorder will detract far more from productivity than the time spent in assuring that heat strain limits are not exceeded).

3. Perception that one's performance rating will suffer because of the report. (Management and supervisor support are prerequisite to allay the anxieties of workers on the issue of job security).

3.5 Heat Strain Assessment and Recovery

The planning, installation, and staffing for this provision of the Program should rest in the hands of a single function, preferably the Safety and Health Director.

The response to a worker report of heat strain symptoms or to a heat disorder should be immediate by a person on staff who is trained and available to perform these duties:

- Meet the heat stress-affected person at the respite room and guide their activities while in the room.
- Listen to their reported symptoms and assess the seriousness of the situation.
- Take heat strain measurements (*e.g.*, core temperature and heart rate).
- Apply first aid as needed, including cooling of the body and replenishment of water and electrolytes.
- Get medical assistance, including assistance in transporting the person to a hospital, if necessary.
- Keep records of services provided by the respite room and initiate follow-up activities.
- There is a medical component to heat strain monitoring and recovery, necessitating a close working relationship between the responsible function and the person(s) providing medical surveillance. Responses to reports of heat strain symptoms and subsequent recovery steps should be reviewed medically as these cases occur to provide medical guidance on a timely basis.

3.5.1 Respite Room Design Criteria

Gathering heat strain measurements and responding to the range of situations from early warning symptoms through heat disorders requires an isolated, dedicated, and environmentally controlled space which will need to be constructed. Some guidelines for that construction are as follows:

- Locate the respite room to facilitate easy access by workers.
- Control the environment in the room to provide clean, cool, dry air and minimal radiant heat load. Circulate the air throughout the respite room.
- Only allow drinking for hydration and electrolyte replacement, using provisions supplied in the room.
- Install a telephone for emergency communication

- Consider installing a bed for recovery from blood pooling (see Table 2).
- It should be noted that cooled break areas stocked with provisions for fluid and electrolyte replacement are also important to maximize recovery from heat stress exposure. The respite room is a separate room and should not be utilized for this ongoing function of the foundry heat management program.

3.6 Follow-Up

The follow-up items include risk assessment, retraining, and clearance to return to work. Some risk assessment and retraining is warranted prior to sending a worker back to a situation that has already demonstrated that it can produce early warning signs of excessive heat strain. In particular, situations where there is equipment or process malfunctions, shortage of staff, or other extenuating circumstances could delay clearance or necessitate altered practices.

3.6.1 Risk Assessment

Risk assessment is an ongoing activity with the objective of proactively addressing issues which could put workers at risk of excessive heat strain. People vary widely with regard to their capability to endure hot work activity. For this reason, risk assessment must be individualized and job specific.

There are a number of inputs which comprise the information needed for assessing and managing the risk of excessive heat strain for specific workers in specific work activities:

1. Past history of the worker in hot work environments (Section 3.2.2).
2. Current health and fitness state of the worker, including consideration of medications taken (Section 3.2.2).
3. Feedback by the worker and by response personnel following personal recognition of signs and symptoms of excessive heat strain when performing this job (Section 3.6).
4. Degree of heat acclimatization (Section 3.2.4).
5. Maintenance of a hydrated and electrolyte-balanced state (Section 3.3.2).
6. Metabolic energy requirements associated with the work (Section 3.3.3).
7. Nature of personal protective equipment which should be worn (Section 3.3.1).
8. Task and environmental conditions affecting heat release from the body.

The risk assessment component of follow-up has broad implications for a heat stress and strain control program. Feedback associated with specific events of recorded excessive heat strain can be utilized in establishing priorities for control. These event assessments should be incorporated into a broader annual comprehensive assessment of heat stress issues and the effectiveness of the response program.

3.6.2 Retraining

This retraining may be done to re-emphasize established work practices, but it should also incorporate the findings of both the situation review which follows the worker's report of the occurrence of early warning signs of excessive heat strain and the risk assessment.

3.6.3 Clearance to Return to Work

Direct medical input to this decision is definitely warranted in cases when the symptoms review indicates that a heat disorder was already underway. Medical review of the assessment and recovery protocol should always be done as a check on the process of reviewing situations and symptoms (Section 3.5).

Section 4
Strategy for Control of Heat Stress Sources

4.1 Introduction

The primary goal in controlling heat stress sources is to assure that the capability of the body to control core temperature is maintained. As was discussed in Section 2, the body transfers excess metabolic heat from the core area to the skin area for discharge to the environment. The efficiency of heat removal from the skin is affected by environmental factors, especially body coverings. The focus for heat exposure control consists of limiting metabolic heat and addressing environmental factors which inhibit heat loss from the skin or transfer environmental heat to the skin.

This section separately explores the heat stress control issues which exist inside and outside the body. The section ends with identification of some available methods for assessing environmental parameters of heat stress.

4.2 Human Work Efficiency

The metabolic energy required by the body to perform work depends on the type and intensity of tasks being undertaken and the body postures which must be assumed in the process. Muscle contraction allows the body to apply force by causing rotation of bones around their joint pivots. Each of the many independent rotational movements of joints has a mechanical advantage associated with it. When work tasks are performed at poor mechanical advantage, metabolic energy requirements are high.

Certain classes of tasks are generally mechanically inefficient for the body to perform. These include:

- Shoveling
- Using heavy hammers
- Lifting heavy objects from the floor (especially large objects which are difficult to grasp)
- Carrying loads up stairs
- Throwing heavy objects
- Pulling or pushing heavy loads

Included in the forces which muscles must apply to do work are the forces to support the body in the posture which must be assumed. Certain postures are classified as "awkward," because they require large efforts to maintain, sometimes from muscle groups that work at poor mechanical advantage:

- Continuously bending from the waist
- Lifting without the back being straight
- Working with arms raised above the shoulders

The American Foundry Society (AFS) has published a manual for assessing the ergonomics of work, *Metalcasting Ergonomics*, 2nd Edition.[4] Following the recommendations of that manual will help to improve work efficiency, and in that way to reduce metabolic requirements and the heat generation that goes with it.

4.3 Necessity of Air Movement

The body is almost entirely covered during foundry work. The arms, legs, and trunk are usually fully covered. The head is often covered by a hard hat and the face is sometimes covered by a shield. This subsection discusses the essential role that air movement of proper temperature has in removing body heat of a worker whose body is substantially covered with clothing and PPE.

Body coverings reduce heat discharge from the body in these ways:

- Evaporation of sweat is hampered by the rise in humidity in the air gaps between the skin and body coverings.
- Body coverings reduce air motion across the skin, a prerequisite for convective heat transfer.
- Clothing absorbs sweat, thus reducing evaporation directly from the skin, which is the primary mechanism of heat removal from the body. Evaporation off of wet clothing cools the skin far less than evaporation directly off of the skin.
- Radiant heat is shielded to some extent by regular work clothes, and is shielded almost entirely by impermeable, reflective coverings. All body coverings, even reflective ones, in turn heat up and transfer that heat to the body by conduction.

Depending upon the temperature and humidity of the work environment, air movement across the body can reduce to some extent the limitations to heat transfer from the body that body coverings pose. However, as explained in Section 2.3, the hotter the environment into which sweat evaporates, the larger the portion of the heat of vaporization which is drawn from the environment and the smaller the amount drawn from the skin. In addition, the driving force for convective heat transfer from the skin is the temperature differential between the skin (higher temperature) and the environment (lower temperature). When the environmental temperature reaches skin temperature at around 95 °F (35 °C), the environment begins to heat the skin. At this point, air movement against the skin begins to pose a safety risk. If evaporation rate surpasses sweating rate at these higher temperatures and the skin dries out, convective heat gain by the skin will place the worker at a very elevated and possibly very dangerous heat stress risk.

Radiant heat load on the body only exacerbates this situation. If the skin temperature approaches the body core temperature, the body is prevented from transferring heat from its core area to the skin which is a prerequisite for removing excess heat from muscle metabolism. At this point, body core temperature will rise out of control and heat disorders will result.

In summary, air movement is essential to heat stress control in foundries, but the temperature of that moving air must be limited.

4.4 Foundry Heat Sources

A program to limit environmental heat stress should focus on containment and control of waste process heat. The term waste heat as applied here denotes all modes by which thermal energy from foundry processes escapes into the plant environment. Some of the ways that this escape occurs are the following:

- Thermal convection off of exposed molten metal surfaces and off of hot foundry equipment such as furnaces and ovens;
- Unventilated combustion sources such as gas-fired ladle preheaters;
- Open room cooling of castings and return sand.

The heat transfer mechanisms of radiation, conduction, and convection work together to spread waste heat throughout the foundry. For example, an uncovered ladle of molten metal moving from a melting furnace to a pouring line heats up all building and equipment surfaces that have line-of-sight contact with this traveling heat source. Air movement within the foundry subsequently transfers the heat from these heated building and equipment surfaces by convection to the background air, heating it up.

Another example involves exposed hot castings moving by vibratory conveyor following their exit from shakeout. By conduction, the castings heat the metal conveyor along which the castings are moving and with which they are in contact. The hot conveyor and its castings in turn efficiently transfer the heat to the air by virtue of the vibratory agitation of the air, which enhances convective heat transfer.

4.5 Heat Strain Predictive Method

The effectiveness of a program to assure that foundry workers are not exposed to hot work conditions to the extent that they are subjected to excessive heat strain would be enhanced by the availability of measurement data linking heat strain to heat stress indicators in foundries. The heat stress management method described in this document affords an opportunity to establish such a predictive heat stress/heat strain relationship.

A heat strain reference point is created if and when workers report early warning signs of excessive heat strain. The proper response to these incidents is for the worker to remove himself or herself from that hot work activity. Follow-up steps which are recommended prior to return to work include a risk assessment (Section 3.6.1). That risk assessment could include measurement of heat stress indicators which could be employed to develop a heat strain/heat stress predictive relationship for that particular hot work activity.

4.6 Thermal Environmental Indicators

Thermal data gathered in the foundry can serve a valuable predictive role in a heat stress management program. The previous three subsections discussed heat stress concerns which require additional information in the form of measurements before program improvements can be effectively implemented.

The needs for thermal environmental data in a foundry heat stress management program generally fall into two classes:

1. Measurements which define thermal environmental conditions to which workers are exposed at their work stations, and
2. Measurements which focus attention on significant fugitive heat sources and on the manner in which this heat accumulates in the foundry.

The remainder of this subsection addresses each of these classes of needs for environmental measurement data separately. Table 6 lists some available methods for taking the measurements.

Table 6. Thermal Environmental Assessment Methods Using Commercially Available Instrumentation

Parameter	Measurement Methods[1]	Notes	Reference
1. Dry Bulb Temperature	Thermometer; two methods (forced air and natural)	▪ Should be shielded against hot radiant sources	1
2. Wet Bulb Temperature	Employs wetted cotton wick on thermometer; two methods (forced air and natural)	▪ Typically used with dry bulb temperature to allow determination of humidity	1
3. Globe Temperature	Dry bulb thermometer inside of a copper sphere painted matte black	▪ Used to assess radiant heat level and to identify radiant heat sources	1
4. Wet Bulb Globe Temperature at Work Locations (WBGT)	Use of natural wet bulb and globe thermometers to produce a heat stress index	▪ Useful for heat stress screening	1, 5
5. Air Velocity	Requires low velocity measurement method, typically swing vane anemometer or thermo anemometer	▪ Used with dry bulb temperature and humidity to indicate convective heat transfer and sweat evaporation potential	1
6. Airspace Temperature Profiling (grid sampling)	Typically done with forced air dry bulb and wet bulb (Parameters 1 and 2)	▪ Useful for assessing ventilation effectiveness throughout the occupied foundry airspace	6[2]
7. Surface Temperature Sensing and Profiling	Contact and non-contact infrared sensing and infrared thermal imaging	▪ Assessing insulation of hot processes and assessing impact of radiant heat on elevated temperatures of building structures and equipment	
8. Indoor/Outdoor Differential Temperature	Thermometer, on-site meteorological station or local meteorological information service	▪ Indicator of extent to which waste heat is building up in the foundry ▪ Useful in combination with measurements of all other parameters	

Notes:

1. Mercury thermometers shall not be employed in any of the instruments used for heat stress assessment.
2. The example used in Section 8.5 of Reference 3 describes grid sampling of air contaminants to produce air quality profiles. The same technique can be used to produce temperature profiles.

4.6.1 Heat Stress Conditions at Work Stations

As discussed in Section 4.3, the effectiveness of excess heat removal from the body is dependent in large measure on the thermal environment which exists in the air gap between body coverings and the skin. This is an extremely difficult environment to measure and assess. It is possible, however, to assess the thermal environment at each work location, external to the body coverings. The first five parameters in Table 6 help to characterize that environment.

Parameters 1 through 4 involve temperature measurements which address the various modes of environmental heat transfer, both airborne and radiant. Parameter 5 addresses air movement, whose critical need at proper temperature was stressed in Section 4.3. Additionally, it is always advisable when undertaking work location assessments to document outdoor thermal environmental conditions (Parameter 8, Table 6).

4.6.2 Heat Sources and their Impacts

Parameter 6 involves a relatively new technique of temperature contour mapping throughout the foundry. This technique focuses on the occupied workspace at all levels of the foundry. As such, it is able to define the extent of heat stratification that may occur in, for example, a sand tower. Thermal contour mapping is capable of identifying foundry "hot spots," which are created by ventilation defects, in particular, stagnation.

Parameter 7 is not a new technique and is employed in industry as much to assess process insulation for energy conservation as it is to assess waste heat sources. Section 4.4 discussed how hot sources in the foundry can warm the total foundry environment, comprised of air and solid objects, through conduction, convection, and radiant heat transfer.

It is always advisable when undertaking a heat source assessment to document outdoor thermal environmental conditions (Parameter 8).

Section 5
References

1. *Industrial Ventilation, A Manual of Recommended Practice*, ACGIH, 26th Edition, pp. 4-12 (2007).

   Order from:
   American Conference of Governmental Industrial Hygienists
   1330 Kemper Meadow Drive
   Cincinnati, Ohio 45240-1634
   Telephone: (513) 742-2020 www.acgih.org

2. *Industrial Health,* Peterson, Jack E., Prentice Hall, Inc., Englewood Cliffs, New Jersey, 07632, pp. 224-225 (1977).

3. *Guide for Selection and Use of Personal Protective Equipment and Special Clothing for Foundry Operations,* AFS Environmental Health & Safety Committee-10Q (September 2005)

   Order free-of-charge online at www.afsinc.org or toll-free at 800-537-4237

4. *Metalcasting Ergonomics,* Second Edition, AFS Ergonomics Task Force, AFS Environmental Health & Safety Committee-10Q (2004).

   Order on-line at www.afsinc.org or toll-free at 800-537-4237

5. *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, ACGIH,* (The companion document has an extensive bibliography: *Documentation of the Threshold Limit Values for Physical Agents, 7th Edition*.)

   Order from:
   American Conference of Governmental Industrial Hygienists
   1330 Kemper Meadow Drive
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6. *Managing the Foundry Indoor Air Environment,* R. Scholz, P.E., CIH, Principal Author, AFS Environmental Health & Safety Committee-10Q (2003).

   AFS publications can be ordered on-line at www.afsinc.org or toll-free at 800-537-4237

Related Reading

Criteria for a Recommended Standard: Occupational Exposure to Hot Environments, Revised Criteria (1986).

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