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LIMITING INJURY/ILLNESS AT THE HOT WORKPLACE

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INTRODUCTION

This paper reviews the current status of research as it is reflected in acceptable guidelines and limits for work in hot occupational environments. The worker engaged in job activities while in an uncomfortably hot or dangerously hot environment has two avenues leading to potential injury and illness. First the physiological responses can produce heat illness such as heat cramps, syncope, exhaustion or stroke. Secondly, the effects of heat on the worker's perceptual motor and cognitive task performance can negatively affect the operations of controls, attention to warning signals and reaction-response times. Reduced performance in these types of tasks can lead to mishaps and injuries to the worker and/or other co-workers.

Thermal Measurements

Evaluating the thermal environment requires appropriate methods and instruments. Accurate measurement of the basic thermal components (i.e., air temperature, wet bulb temperature, air velocity and radiant heat) can be affected by a large number of variables. Thermometers for measuring temperature may be liquid in glass, bimetallic, resistance, thermocouples, or electronic instruments utilizing these principles. Depending on the methods and set-up for taking the measurements, the same type thermometer may be used to measure dry bulb, psychometric wet bulb, natural wet bulb, and/or globe temperature. In order to obtain accurate measurements it is important to allow adequate stabilization time, shield the instrument from radiation effects (unless it is a radiation measurement), and to be sure that the sensing element is located so as to be representative of the area of thermal interest. The velocity of air can be determined through the use of vane anemometers or thermal anemometers such as hot-wire or heated thermocouple anemometers. Accurate determination and air velocity contour maps in a work area are difficult, or often impossible, due to the variability of air movement, both with time and in space. A variety of radiometers have been used to measure radiant flux. In the occupational environment the Vernon globe thermometer, or a miniature-sized correlate globe thermometer, represents the most commonly used device for estimating radiant heat (Ramsey and Beshir, 1997).

Measurement Variability

Variability in the measurement of thermal instruments is a function of many things including; the instrument itself, the parallax or other visual and placement differences, the individual differences in perception and interpretation between and within an individual observer, the fluctuations of the environment due to changes in air movement, moving cloud cover outdoors, and thermostat cycles of the heating or cooling units indoors.

A group of observers, if asked to independently determine a temperature using the same instrument, will typically produce a distribution of temperature values, not a single value. The estimates of temperature are typically represented by a population of values with some central tendency and some dispersion, or variance. For example, the measurement of air temperature using a sling psychrometer and compared with those obtained from an electronic instrument should have the same central tendency unless there is calibration error. The electronic instrument, however, would likely generate a distribution with smaller variance since decimal numbers are directly available without the human round-off that occurs in reading most thermometers.

In comparing a natural wet bulb which is shielded versus one that is unshielded a substantially higher value can result if the instrument is unshielded in a radiant field. However, it is important when shielding the natural wet bulb from the radiant source that the flow of air not be blocked. Measurements of globe temperature using a standard 6 inch diameter globe generally require a stabilization time of 15 to 20 minutes. If readings are obtained after only a few minutes, errors are possible since the estimate of radiant heat will be made prior to equalization of the thermal system.

A review of the specific sources of measurement variation is presented in Ramsey (1987).

Human Thermoregulation

There are several factors which have direct and major contributory influence on the degree of heat storage within the human. The basic thermodynamic process of heat exchange between the individual and the environment can be represented as follows:

$$S = M \pm C \pm R \pm K - E$$

where
S = body heat storage
M = energy metabolism or body heat production
C = convective heat exchange
R = radiative heat exchange
K = conductive heat exchange, and
E = evaporative heat exchange.

Thermal equilibrium occurs when heat storage (S) is zero, and indeed the thermoregulation process in humans attempts to maintain this as a goal. The metabolic heat production (M) is always a positive factor, even under basal or resting conditions, since the body oxidizes fuel (food) and is generating heat in the metabolic process. The convective heat exchange (C) represents thermal exchange between the body and the fluid/air which surrounds it, and may be either positive or negative depending upon whether the temperature is above or below the temperature of the human skin. Radiative heat exchange (R) may also be either positive or negative depending upon whether the human body represents the hot or cold radiative body in the environment. Conductive heat exchange (K) is normally considered to be negligible in thermal balance considerations since humans sensory receptors do not normally allow contact between extremely hot or extremely cold bodies for a duration long enough to transfer much heat conductively. Evaporative heat exchange (E), which is always a negative factor in this equation, represents the major mechanism for dissipation of stored body heat.

Exposure Limits

Levels associated with threshold limits of exposure at the hot workplace are based on the above thermoregulation principles. In a laboratory very sophisticated thermal and metabolic heat production measurements can be made. Field measurements of occupational heat on the other hand, are commonly taken using the Wet Bulb Globe Temperature (WBGT) as specified in the threshold limit values of ACGIH (1992) and of ISO 7243 (1989). Figure 1 shows the recommended heat stress threshold and ceiling limits for acclimatized workers (NIOSH, 1986). The WBGT in this chart is expressed as a one-hour time weighted average where WBGT is a function of natural wet bulb temperature and radiant heat. The workload or metabolic heat can be determined indirectly through oxygen consumption measurements or estimated by means of tables (Ramsey and Beshir, 1997). Other WBGT limits have been developed for stay-times in the heat and for situations where personal protective clothing which restricts evaporation is a factor. A summary of these limits can be found in Ramsey (1978) or Ramsey (1994).

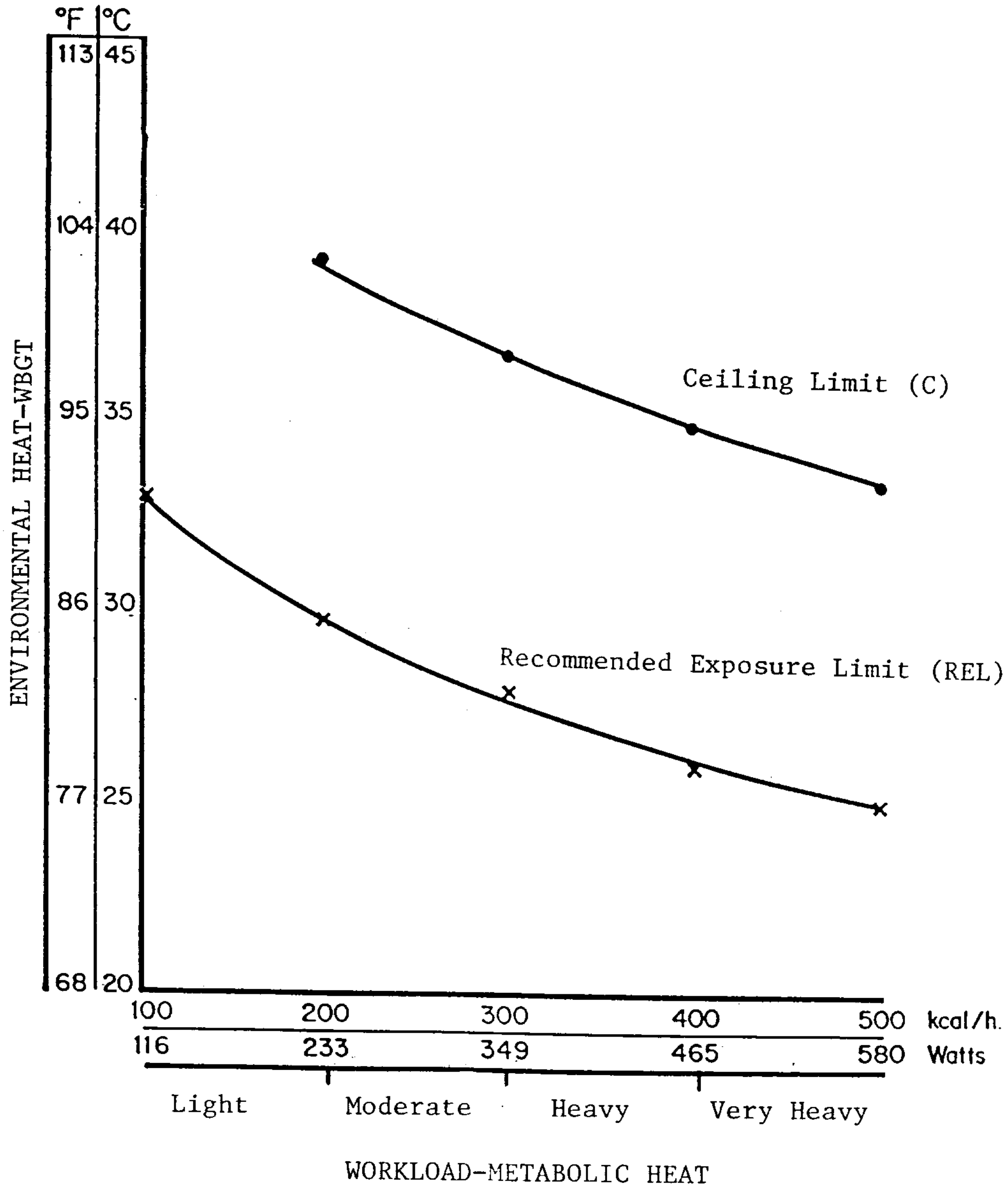

Figure 1. Recommended Heat-Stress Exposure Limits for Acclimatized Workers

Adapted from: NIOSH, Occupational exposure to hot environments DHHS (NIOSH) #86-113, 1986.

Safety and Performance

Worker exposure to heat can also lead to performance decrement, which in turn has implications to worker safety (Ramsey, et al., 1983). The literature in this area is contradictory primarily because of the many variables that can affect human performance. There are however guidelines that have resulted from compilation of many individual studies which can provide guidance to the designer or operator of work task in the heat. A summary of approximately 160 individual studies of perceptual motor performance reported in the literature yielded some interesting results. For very simple mental tasks and for cognitive tasks a very minimal effect due to duration of exposure or thermal level was found. For perceptual motor task other than very simple or mental tasks the onset of performance decrement was noted in the 30-33°C WBGT range of temperature. This temperature is consistent with the recommended exposure limits for work in the heat at low levels of metabolic heat (Ramsey, 1995).

Managing Environmental Heat Exposure

The actions available for protecting the heat exposed worker consists of an array of activities relating to the design of the job, the work and the environment. These actions or practices group logically into three major areas; personal, engineering, and administrative (Ramsey, et al., 1994). Personal controls would include:

(1) Portable water: An adequate supply of cooled water should be available near the worksite and workers should be informed of the necessity of frequent water intake.

(2) Acclimatization: Newly assigned employees and those recently returning from serious illness or long vacations should be especially cautious about their level of work pace in the heat until they have had an opportunity to become acclimatized.

(3) Self-determination: Based on signs and symptoms of heat strain the worker who has been trained to recognize heat problems should be allowed to limit the exposure by stretching the work over a longer period of time or by taking more frequent breaks.

(4) General lifestyle items: A healthy lifestyle is important to lowering the risk of heat related disorder. This includes a well-balanced diet with adequate salt intake (not salt tablets), adequate rest, and recognition that some diseases and illnesses, especially those generating fever, place a worker at a much higher risk.

Engineering control of heat exposure and heat stress will include:

(1) General ventilation: Increased general ventilation or spot cooling can be used to reduce temperature at the workplace.

(2) Exhaust ventilation: Local exhaust ventilation at points of high heat production will help remove heat from the work area.

(3) Local cooling: Local or spot cooling of the worker may be an effective and energy efficient means of providing relief from heat exposure.

(4) General cooling or refrigeration: Evaporative cooling or mechanical refrigeration can be used to reduce the temperatures of supply air and general worksite temperatures.

(5) Fans: Personal cooling fans increase air velocity and evaporative heat loss as long as the air temperatures are below 35°C.

(6) Radiant shielding: Shielding by means of reflective screens, barriers, aprons or clothing will interrupt line of sight radiant thermal exchange.

(7) Isolation or change: Isolation, re-location, redesign or substitution of equipment, and/or processes should be considered as means to reduce the thermal stress at the worksite.

(8) Excessive moisture reduction: The relative humidity levels can be reduced by repairing steam leaks, avoiding water on the floor, or minimizing splashing or spraying from processes.

(9) Cooling devices and personal clothing: Personal cooling devices and/or protective clothing (e.g., circulating air systems, liquid cooling systems, ice cooling garments, evaporative cooling or reflective clothing) may help reduce heat stress in applications where other controls are limited.

Administrative practices would include:

(1) Training in heat stress and its control: Each workplace where heat stress may occur should have all workers and supervisors trained in the recognition and first-aid of heat strain and heat related disorders, heat stress, hygiene practices and countermeasures for controlling heat stress.

(2) Metabolic heat reduction: Internally generated heat can be reduced by providing relief workers or other adjustments in the duration of the work period, the frequency and length of rest pauses, the pace and tempo of the work, as well as increased use of work saving devices or mechanization.

(3) Scheduled peaks: When feasible heavy work should be scheduled during the cooler parts of the work shift or on cooler days.

(4) Rest areas: The use of air conditioned or cooler areas for rest and recovery will reduce heat storage in the worker, hasten recovery and increase heat tolerance.

(5) Buddy rule: The risk of excessive heat exposure will be reduced if the worker is under observation by a trained supervisor or fellow worker who can detect early signs of heat strain and also respond to emergencies.

(6) Medical: Those exposed to extreme heat exposure should be medically evaluated before placement in this type of work and medically examined periodically thereafter.

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