HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT
HETA 90-224-L2089
TUCSON ROCK & SAND COMPANY
TUCSON, ARIZONA
DECEMBER 1990

Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226

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I. INTRODUCTION

On April 9, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request from workers employed at the Tucson Rock and Sand Company to investigate a potential heat stress problem. The requestors described a problem of high temperatures inside the cabs of cement mixers in the summer time. The request mentioned that employees had experienced symptoms of light-headedness, nausea, and fatigue during different times during the summer of 1989. During August 6-9, 1990, NIOSH conducted a site survey which consisted of collecting background information on the nature of the request, conducting a walk-through survey of the facilities, and collecting environmental samples in the cabs of various cement mixers over three days.

II. BACKGROUND

The Tucson Rock and Sand (TRS) Company supplies gravel and ready-mix cement to companies throughout the Tucson area. TRS employed 135-140 personnel in 1989 and had a current personnel roster of 115 at the time of the survey. The current hourly workforce included 10 mechanics, 3 laborers, 35 drivers, and 15 operations personnel. The hours worked by the drivers was dependent on the cement orders received and was based on the number of orders and the time of delivery requested. Usually, the drivers started between 4:00 am and 7:00 am. Work continued until there were no more orders, or until it was projected that there would be no more orders. A few of the later starting drivers were kept at the plant into the afternoon to cover any last minute orders. Drivers would call a dispatch number after 5:00 pm to find out the schedule for the following day which included when they started or if they were off. The company operated 6 days a week.

The HHE request mentioned that drivers had experienced occasional problems with heat stress noting symptoms of lightheadedness, dizziness, nausea, and disorientation. The drivers also mentioned that the effect of the heat was dependent on the weather conditions of the day and the type of pour they had to do. If they could get out of the cab and unload from the rear of the truck, then the heat was usually not too bad. The worst kind of unloading was a stemwall or detail pour where they had to stay in the cab for a long time, continually moving the truck along the cement form. Curb pours were typical of this type of work. The drivers had to be continually alert, using both hands and feet, shifting to get a good view out the various mirrors, and had no control over positioning their truck out of the direct sun so as to reduce the radiant heat load.

Another factor that the drivers mentioned that effected them was the long hours they had to work some days and the cumulative effect of several such days in a row. This was generally not the case at the time of the survey since the building market was down and the competition in the cement business was high. However, 10-14 hour days were not unusual.

The company had been providing limited heat-stress awareness training to a number of workers. Due to the drivers' early and erratic schedules, only a handful had received the training. A heat stress awareness poster had been put on the bulletin board in the drivers' break room. This break room was air conditioned and had a water fountain and soft drink machine in it. Likewise, the batch office where workers waited for their orders or during truck loading, was air conditioned. A water fountain and bathroom were located in this building.

III. MATERIALS AND METHODS

The NIOSH evaluation consisted of assessing heat exposure using the Wet Bulb Globe Thermometer (WBGT) method[1], estimating metabolic heat loads by keeping a detailed account of the job tasks, and interviewing drivers and company management personnel regarding heat stress experiences and company policy. The WBGT measurements were made with instruments that were carried by a survey team member and accompanied the drivers where ever they went for the full shift of the drivers. WBGT measurements were made using a variety of instruments including two older, manually operated Reuter-Stokes WiBGet models, a Metrosonics model hs-371 Portable Heat Stress Monitor, a manual Metrosonic model hs-360 Portable Heat Stress Monitor, and four Reuter-Stokes model RSS-214 portable heat stress monitoring systems. The first day of the survey there were four instrument failures including the two older WiBGet models, the Metrosonics hs-371, and one of the model RSS-214 Reuter-Stokes instruments. The four model RSS-214s were being used by a company-hired contractor, EnviroMED, to conduct side-by-side WBGT measurements with the NIOSH instrumentation (the 2 WiBGets, the Metrosonics hs-371, and the Metrosonics hs-340). After the failure of three of the NIOSH instruments and one of the contractor instruments on the first day, the instrumentation was pooled in order to complete the survey without a repeat visit.

Originally, two NIOSH personnel and two company-provided personnel were to carry two instruments each around with one driver each day while the contactor personnel would follow in another vehicle. Only 6 of the 49 cement trucks had seats which could hold more than one person, so we were limited to these vehicles. The scheduling of the vehicles was open to NIOSH suggestions. After the instrument failures, only four instruments were available and it was decided that only one instrument per vehicle would be used to optimize the number of individual drivers that could be monitored in one day. The "survey team" then consisted of the two NIOSH personnel, one company management person, and one contractor person. One other contract person accompanied one of the trucks. Detailed notes were kept regarding the age, weight and sex of the driver, and the times and tasks performed by each of the drivers. These notes were then used to estimate the metabolic heat load of the driver during the performance of different tasks so as to be able to compare the WBGT measurements against the recommended levels.

IV. EVALUATION CRITERIA

The primary sources of air contamination criteria generally consulted include: (1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs); (2) the American Conference of Governmental Industrial Hygienist's (ACGIH) Threshold Limit Values (TLVs); and (3) the U.S. Department of Labor (OSHA) federal occupational health standards. These sources provide environmental limits based on airborne concentrations of substances to which workers may be occupationally exposed in the workplace environment for 8 to 10 hours per day, 40 hours per week for a working lifetime without adverse health effects. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational diseases. In evaluating the exposure levels and recommendations for reducing these levels found in these reports, it should be noted that industry is legally required to meet those levels specified by an OSHA standard. However, at present, there is limited information from OSHA on exposure criteria for workers exposed to physical agents. Criteria for physical agents not covered by OSHA come from either ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI).

A. Hot Work Environments[1-3]

NIOSH originally defined hot environmental conditions as any combination of air temperature, humidity, IR radiation, and wind speed that exceeds a WBGT value of 79° Fahrenheit (F) or 26° Celsius (C). NIOSH, in its revised criteria for occupational exposure to hot environments, presents maximum recommended heat stress levels on a sliding scale of WBGT values for various metabolic heat levels (work effort). The recommended heat stress limits are presented as a series of five curves on a graph. Four curves represent different work-rest regimens, while the fifth curve is a ceiling limit which is not to be exceeded at any time for any work level without the workers being equipped and properly using appropriate and adequate heat-protective clothing and equipment. In order to use the criteria one must compute 1-hour time-weighted average WBGT values for the work area and estimate the work effort (metabolic heat) produced by the tasks performed by the worker in the hot environment. Figures 3 (recommended Heat-Stress Alert Limits (RALs) for heat-unacclimatized workers) and 4 (recommended Heat-Stress Exposure Limits [RELs] for heat-acclimatized workers), shown in reference 1, present this information.

These criteria assume the worker is clothed in the customary one-layer work clothing ensemble, is physically and medically fit, has good nutrition, and has adequate salt and water intake. Additionally, the worker should not have any preexisting medical conditions which might impair the body's thermoregulatory mechanisms. Alcohol use and certain therapeutic or over-the-counter medications can also impair the body's heat tolerance and may increase the risk for heat injury or illness. The NIOSH evaluation criteria may not be applicable if the worker or conditions do not meet the above requirements. There is no applicable OSHA permissible exposure limit for heat stress.

B. Heat Stress[1-3]

Heat stress is defined as the total net heat load on the body, which is comprised of contributions from exposure to external environmental sources and from metabolic heat production.

Four factors influence the interchange of heat between the human body and the environment. These are: (1) air temperature, (2) air velocity, (3) moisture content of the air, and (4) radiant heat sources. Industrial heat problems involve a combination of these factors which produce a working environment that may be uncomfortable or even hazardous because of an imbalance of metabolic heat production and heat loss.

The fundamental thermodynamic processes involved in heat exchange between the body and its environment may be described by the basic equation of heat balance:

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

where S = change in body heat content (heat gain or loss); M = rate of metabolism (associated with body function and physical work); E = heat loss through evaporation of perspiration); R = heat loss or gain by radiation (infrared radiation emanating from warmer surfaces to cooler surfaces); and C = heat loss or gain through convection (passage of a fluid [air] over a surface with the resulting gain or loss of heat). Under conditions of thermal equilibrium (essentially no heat stress) heat generated within the body by metabolism is completely dissipated to the environment and deep body (core) temperature remains constant at about 98.6°F (37°C).

When heat loss fails to keep pace with the heat gain, the core temperature begins to rise. At this point certain physiologic mechanisms begin to function in an attempt to increase heat loss from the body. First there is dilation of the blood vessels of the skin and sugcutaneous tissues with diversion of a large part of the body's blood supply to the body surface and extremities. An increase in circulating blood volume also occurs through the withdrawal of fluids from body tissues. These circulatory adjustments enhance the heat transport from the body core to the surface. Simultaneously, the sweat glands become active, spreading fluid over the skin, which removes heat from the skin surface by evaporation. Evaporative cooling must balance the combined effects of metabolic and environmental heat load to maintain thermal equilibrium. If this fails, heat storage begins with the resultant strain of increase body temperature.

Prolonged exposure to excessive heat may cause increased irritability, lassitude (weariness), increased anxiety, and inability to concentrate. The results are mirrored by a general decrease in the efficiency of production and the quality of the finished product.

The acute physical disabilities cause by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke.

Chronic heat illnesses are those occurring as after-effects of acute heat illnesses; those brought on by working in excessive hot jobs for a few weeks, months, or years but without the occurrence of acute heat illness; and those associated with living in climatically hot regions of the world. Chronic after effects associated with acute heat illnesses can include reduced heat tolerance, dysfunction of sweat glands, reduced sweating capacity, muscle soreness, stiffness, reduced mobility, chronic heat exhaustion, and cellular damage in different organs, particularly in the central nervous system, heart, kidneys, and liver.

Chronic heat illnesses not associated with an acute incident of heat illness can fall into one of two categories based upon the duration of exposure. After several months of exposure to a hot working environment chronic heat exhaustion may be experienced. Symptoms which may develop include headache, gastric pain, sleep disturbance, irritability, vertigo, and nausea. After many years in a hot job, cumulative effects of long-term exposure which may develop are hypertension, reduced libido, sexual impotence, myocardial damage, and nonmalignant diseases of the digestive organs.

V. RESULTS

The weather conditions encountered during the survey are summarized in Table I. Early August was chosen for the survey even though the daytime high temperatures are lower than in June or July, because the humidity was generally higher and the daytime temperatures are still relatively high. The first day of the survey was below normal in temperatures due to rain. The second day temperatures were the same as the normal temperatures for that time of year, and the third day was warmer than normal. The area had experienced an all-time high temperature in late June that hit 118°F, so these survey temperatures, even though normal, seemed low.

A summary of the hourly WBGT readings from ten different trucks over three days is given in Table II. Since the WBGT readings need to be hourly averages for comparison to the NIOSH RELs, hourly averages were developed starting with when the person reported to work and averaging every hour thereafter. The table also includes information on the specific truck and driver plus the results of any side-by-side monitoring data. The data in parenthesis are those collected by the contractor for parallel sampling. None of the readings were very high on August 7 due to the overcast and rainy conditions. The highest readings on August 8, WBGT of 85.5 and 86.4 °F, were in the late afternoon. The daytime high temperatures were 6°F warmer on August 9, and the WBGT readings were only slightly higher, on average, than those of the previous day.

In order to determine the recommended heat exposure limits, an estimate of the metabolic heat load for each of the drivers had to be made. Using Table V-3 in reference #1 and notes on the major tasks of the drivers, Table III was assembled. This table summarizes the major job tasks and the resulting body position, type of work and the estimated energy cost determined for each tasks. Once the highest WBGT readings were established for each driver, an analysis of the metabolic heat output was determined for each driver for the time period corresponding to the highest WBGT reading. This was done by determining the amount of time each driver spent at the tasks described in Table III and time-weighting the energy cost per task over the hour. The resulting metabolic output was then adjusted for the drivers weight by multiplying by the factor: weight (in kilograms [Kg]) divided by 70 Kg (Wt/70 Kg). Since the WBGT readings were so low on August 7 and no heat stress conditions were encountered, the estimated metabolic heat load for those four drivers is an estimate of their daily output, not just the output for the one-hour of highest heat exposure. In general, the daily output was comparable to the various hourly outputs.

The adjusted metabolic output is summarized in Table IV along with the corresponding highest WBGT measurement and the recommended heat-stress exposure limits for a heat-acclimatized worker. The recommended limits are given as the maximum time allowed (15, 30, 45, or 60 minutes) per hour, for exposure to the heat-stress condition as measured by the WBGT[1]. Only two of the driver's conditions exceeded the NIOSH REL; the driver in truck #302 on August 8 and on August 9. This is a result of the fairly high WBGT reading, the moderate level of activity during that period, and the large adjustment for the worker's weight (a 1.59 upward adjustment factor). According to these findings for August 8, this driver should not have been exposed to the heat-stress condition longer than 15 minutes during that one-hour period. If you average the WBGT readings over the highest hour period, not just arbitrarily every hour from when work was started, the driver in truck #302 on 8-8-90 had a peak one-hour exposure of 90.9°F. Estimating a similar metabolic output, then this exposure is above even the NIOSH REL for 15-minutes per hour. The data from August 9 indicate that this driver should not have been exposed to these conditions for longer than 45 minutes during the one-hour period.

VI. DISCUSSION AND CONCLUSION

In general, the potential for heat stress does exist for any workers in the southwest who have to be out in the sun. Most workers who are from the area, learn at an early age how to cope with living, working and playing in the heat. Therefore, worker awareness of heat stress condition and the warning signs of heat stress, stroke or exhaustion are usually known. Sometimes, this is a disadvantage because local people feel that they know about heat and how to deal with it and, thus, can become a victim of conditions which are beyond their ability to cope. If a worker is not from the area, they might be likely to suffer from problems due to lack of acclimatization, awareness of the problem, and the potential for exposure to heat stress conditions. Therefore, a good heat stress education program is warranted.

Several of the drivers related incidents where they had felt light-headed, dizzy or nauseous after a prolonged heat exposure. In all cases, the drivers said they pulled over to the side of the road, if they were driving, until the ill feeling passed or, if they were not driving, they sat down for awhile. The accident reports were reviewed for the past 5 years and there have been very few accidents or injuries reported. For example, there had been only one preventable accident in the last 2-1/2 years and only 2 accidents total in 1989. Considering the number of vehicles on the road, this is an excellent safety record. If the drivers were being adversely effected by the heat, one would expect to see the number of accidents increase. This was not the case.

The workers have a chance to get out of the heat and get a drink of water whenever they return to the plant. When they leave for a job, they are not allowed to stop anywhere to get a drink and they must bring their own drinking water. If they are stuck at a job for a long time, there is no opportunity to get out of the heat or there may not be any water to drink if their own runs out. Some of the construction sites have water available.

The environmental conditions measured reflect only conditions at the time of the survey. Conditions during other times in the summer, such as the record high temperature of 118°F illustrates, are probably worse. The heat stress conditions need to be monitored more often and during the worst days of the summer.

VII. RECOMMENDATIONS

Similar to chemical exposures, control of heat stress conditions can be accomplished in a variety of ways. This includes the use of engineering controls, administrative controls, and personal protective equipment. The most effective engineering control would be to air condition the truck cabs. Administrative controls would include adjusting work schedules to insure workers get some time each hour to cool down, especially during the hottest time of day. Personal protective equipment would not, in this case, be very effective. Any of these control measures, or some combination thereof, would have to take into account the feasibility of use given the type of work being conducted.

1. The plant needs to develop a heat stress program which includes a program of worker training, medical surveillance, periodic medical exams, posting of heat stress conditions, and periodic measurements of heat stress conditions. The recommendations for a thorough heat stress program are outlined in reference #1. The applicable pages from the NIOSH criteria document are attached in Appendix 1.

2. The plant should provide cooled drinking water (50 to 59°F) to the workers to take with them to the job sites. This could be in the form of a water cooler which is picked up each day when they get their trucks.

3. The plant needs to have monitoring equipment available to take WBGT measurements so as to know when heat stress conditions exist. A contingency plan should be developed to handle high heat days such as those encountered in June 1990. The contingency plan should consider ways to increase breaks in a cool area, e.g. in the break room, encourage water consumption, and consider shorter working periods.

IX. REFERENCES

1. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to hot environments revised criteria 1986. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1986. (DHHS [NIOSH] publication no. 86-113).

2. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values (TLVs) and Biological Exposure Indices for 1989-90. ACGIH, 6500 Glenway Avenue, Cincinnati, Ohio 45211-4438.

3. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to hot environments. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1972. (DHEW publication no. (NIOSH) 72-10269).

TABLE I

WEATHER CONDITIONS DURING SURVEY
HETA 90-224
TUCSON ROCK & SAND COMPANY
TUCSON, ARIZONA

Date	Survey Conditions High Temp.	Low Temp.	High RH (time)	Low RH (time)	Comments	Normal Conditions High Temp.	Low Temp.	Average RH
8-7-90	89	68	90% (6 am)	42% (3 pm)	Overcast, light rain	96	73	30%
8-8-90	96	71	71% (7 am)	28% (4 pm)	Mostly sunny	96	73	30%
8-9-90	102	73	71% (6 am)	24% (3 pm)	Sunny	96	73	30%

TABLE II

SUMMARY OF WBGT RESULTS
HETA 90-224
TUCSON ROCK & SAND COMPANY
TUCSON, ARIZONA
AUGUST 7-9, 1990

Date	Time	Truck #	Worker Age	Worker Wt.	Worker Sex	Hourly WBGT (°F) 1	2	3	4	5	6	7	8	9	10
8-7	5:15-7:51	307	52	220	M	70.0	70.6	70.8							
8-7	4:59-8:05	306	43	230	M	* (71.1)	* (67.2)	* (69.9)							
8-7	4:50-7:07	303	32	155	M	70.4 (70.1)	69.5 (69.9)	69.7 (68.8)							
8-7	5:45-8:07	302	48	245	M	69.2	73.0	72.7							
8-8	5:15-15:26	306	50	145	M	74.4	74.3	77.4	73.7	76.5	82.6	79.8	81.8	80.2	80.6
8-8	5:20-14:50	302	48	245	M	71.3	75.6	73.7	78.8	81.8	79.0	70.0	85.5	86.4	81.1
8-8	5:25-14:49	304	32	110	F	70.3	74.6	76.8	77.5	80.6	79.0	74.0	81.5	80.4	
8-8	4:00-16:00	307	52	220	M	71.0	70.6	72.3	76.0	79.8	78.9	80.0	79.9	81.8	80.7
8-9	5:43-12:50	306	50	145	M	72.0 (71.3)	74.6 (75.9)	77.3 (77.5)	78.3 (78.1)	76.1 (76.2)	81.5 (84.4)	84.1 (85.9)			
8-9	10:45-	302	48	245	M	84.0	78.4	88.1	83.8	75.8					

*Instrument failed to function. Numbers in parenthesis are from duplicate monitoring.

TABLE III
SUMMARY OF ESTIMATED ENERGY COST BY TASK
HETA 90-224
TUCSON ROCK & SAND COMPANY
TUCSON, ARIZONA
AUGUST 7-9, 1990

TASK	BODY POSITION	TYPE OF WORK	ESTIMATED ENERGY COST (kcal/minute)
Driving	Sitting	2 arm, light work	1.8
Washing truck	Standing	2 arm, light work	2.1
Adding/dropping chutes*	Walking	Whole body, heavy work	8
In batch office	Standing	Hand, light work**	1.0
In drivers break room	Sitting	Hand, light work**	0.7
Unloading:			
in truck	Sitting	2 arm, light work	1.8
back of truck	Standing	2 arm, light work	2.1
		or 1 arm, light work	1.6
Wash rack	Standing	2 arm, light work	2.1
Loading truck	Standing	1 arm, light work	1.6

*This is estimated to take 2 minutes to add or drop chutes.
**Represents minimum energy expenditure.

NOTE: See reference #1, Table V-3, page 62 for details.

TABLE IV
SUMMARY OF HIGHEST WBGT READINGS AND ESTIMATED METABOLIC HEAT LOAD, ADJUSTED FOR WEIGHT, VERSUS RECOMMENDED WBGT READINGS

HETA 90-224
TUCSON ROCK & SAND COMPANY
TUCSON, ARIZONA
AUGUST 7-9, 1990

Date	Truck #	Worker Wt. Kg (lbs)	Weight Adjust (Wt/70Kg)	Highest Hourly WBGT(°F)	Estimated* Metabolic Load (kcal/min)	Adjusted** Metabolic Load (kcal/hr)	Recommended Exposure Limits,WBGT 15 (m/hr)	30 (m/hr)	45 (m/hr)	60 (m/hr)
8-7	307	100 (220)	1.43	70.8	2.62	225	89.5	87.8	86.2	84.2
8-7	306	105 (230)	1.49	71.1	2.80	252	89	87	85	83
8-7	303	70 (155)	1.0	70.4	3.39	204	90	88.7	86.8	85
8-7	302	111 (245)	1.59	73	2,85	257	88.8	86.8	84.8	82.8
8-8	306	66 (145)	0.94	82.6	2.60	145	92.6	91.5	89.7	88
8-8	302	111 (245)	1.59	86.4	3.01	294	87.5	85.5	83.5	81.5
8-8	304	50 (110)	0.71	81.5	3.26	139	93	91.8	90	88.5
8-8	307	100 (220)	1.43	81.8	3.37	280	88	86	84	82
8-9	306	66 (145)	0.94	84.1	2.72	153	92.5	91.0	89.2	87.7
8-9	302	111 (245)	1.59	83.1	2.80	267	88.2	86.2	84.2	82.3

NOTE: Estimates done according to "Occupational Exposure to Hot Environments. NIOSH, Cincinnati, Ohio, 1986. (DHHS [NIOSH] publication No. 86-113).
*See Table III for list of energy output by task.
**Calculated by the Estimated Metabolic Heat Load (kcal/min) by 60 min/hr and by the Weight Adjustment Factor

APPENDIX 1

NIOSH RECOMMENDATIONS FOR AN OCCUPATIONAL STANDARD FOR WORKERS EXPOSED TO HOT ENVIRONMENTS

I. RECOMMENDATIONS FOR AN OCCUPATIONAL STANDARD FOR WORKERS EXPOSED TO HOT ENVIRONMENTS

The National Institute for Occupational Safety and Health (NIOSH) recommends that worker exposure to heat stress in the workplace be controlled by complying with all sections of the recommended standard found in this document. This recommended standard should prevent or greatly reduce the risk of adverse health effects to exposed workers and will be subject to review and revision as necessary.

Heat-induced occupational illnesses, injuries, and reduced productivity occur in situations in which the total heat load (environmental plus metabolic) exceeds the capacities of the body to maintain normal body functions without excessive strain. The reduction of adverse health effects can be accomplished by the proper application of engineering and work practice controls, worker training and acclimatization, measurements and assessment of heat stress, medical supervision, and proper use of heat-protective clothing and equipment.

In this criteria document, total heat stress is considered to be the sum of heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body to the environment. The bodily response to total heat stress is called the heat strain. Many of the bodily responses to heat exposure are desirable and beneficial. However, at some level of heat stress, the worker's compensatory mechanisms will no longer be capable of maintaining body temperature at the level required for normal body functions. As a result, the risk of heat-induced illnesses, disorders, and accidents substantially increases. The level of heat stress at which excessive heat strain will result depends on the heat-tolerance capabilities of the worker. However, even though there is a wide range of heat tolerance between workers, each worker has an upper limit for heat stress beyond which the resulting heat strain can cause the worker to become a heat casualty. In most workers, appropriate repeated exposure to elevated heat stress causes a series of physiologic adaptations called acclimatization, whereby the body becomes more efficient in coping with the heat stress. Such an acclimatized worker can tolerate a greater heat stress before a harmful level of heat strain occurs.

The occurrence of heat-induced illnesses and unsafe acts among a group of workers in a hot environment, or the recurrence of such problems in, individual workers, represents "sentinel health events" (SHE's) which indicate that heat control measures, medical screening, or environmental monitoring measures may not be adequate [1]. One or more occurrences of heat-induced illness in a particular worker indicates the need for medical inquiry about the possibility of temporary or permanent loss of the worker's ability to tolerate heat stress. The recommended requirements in the following sections are intended to establish the permissible limits of total heat stress so that the risk of incurring heat-induced illnesses and disorders in workers is reduced.

Almost all healthy workers, who are not acclimatized to working in hot environments and who are exposed to combinations of environmental and metabolic heat less than the appropriate NIOSH Recommended Alert Limits (RAL's) given in Figure 1, should be able to tolerate total heat without substantially increasing their risk of incurring acute adverse health effects. Almost all healthy workers, who are heat-acclimatized to working in hot environments and who are exposed to combinations of environmental and metabolic heat less than the appropriate NIOSH Recommended Exposure Limits (REL's) given in Figure 2, should be capable of tolerating the total heat without incurring adverse effects. The estimates of both environmental and metabolic heat are expressed as 1-hour time-weighted averages (TWAs) as described in reference [2].

At combinations of environmental and metabolic heat exceeding the Ceiling Limits (C) in Figures 1 and 2, no worker shall be exposed without adequate heat-protective clothing and equipment. To determine total heat loads where a worker could not achieve thermal balance, but might sustain up to a 1 degree Celsius (1°C) rise in body temperature in less than 15 minutes, the Ceiling Limits were calculated using the heat balance equation given in Chapter III, Section A.

In this criteria document, healthy workers are defined as those who are not excluded from placement in hot environment jobs by the explicit criteria given in Chapters I, IV, VI, and VII. These exclusionary criteria are qualitative in that the epidemiologic parameters of sensitivity, specificity, and predictive power of the evaluation methods are not fully documented. However, the recommended exclusionary criteria represent the best judgment of NIOSH based on the best available data and comments of peer reviewers. This may include both absolute and relative exclusionary indicators related to age, stature, gender, percent body fat, medical and occupational history, specific chronic diseases or therapeutic regimens, and the results of such tests as the maximum aerobic capacity ($\dot{V}O_2max$), electrocardiogram (EKG), pulmonary function tests (PFTs), and chest x rays (CXRs).

The medical surveillance program shall be designed and implemented in such a way as to minimize the risk of the workers' health and safety being jeopardized by any heat hazards that may be present in the workplace (see Chapters IV, VI, and VII). The medical program shall provide for both preplacement medical examinations for those persons who are candidates for a hot job and periodic medical examinations for those workers who are currently working in hot jobs.

Section 1 - <u>Workplace Limits and Surveillance</u>

(a) Recommended Limits

(1) Unacclimatized workers: Total heat exposure to workers shall be controlled so that unprotected healthy workers who are not acclimatized to working in hot environments are not exposed to combinations of metabolic and environmental heat greater than the applicable RAL's given in Figure 1.

(2) Acclimatized workers: Total heat exposure to workers shall be controlled so that unprotected healthy workers who are acclimatized to working in hot environments are not exposed to combinations of metabolic and environmental heat greater than the applicable REL's given in Figure 2.

(3) Effect of Clothing: The recommended limits given in Figures 1 and 2 are for healthy workers who are physically and medically fit for the level of activity required by their job and who are wearing the customary one layer work clothing ensemble consisting of not more than long-sleeved work shirts and trousers (or equivalent). The REL and RAL values given in Figures 1 and 2 may not provide adequate protection if workers wear clothing with lower air and vapor permeability or insulation values greater than those for the customary one layer work clothing ensemble discussed above. A discussion of these modifications to the REL and RAL is given in Chapter III, Section C.

(4) Ceiling Limits: No worker shall be exposed to combinations of metabolic and environmental heat exceeding the applicable Ceiling Limits (C) of Figures 1 or 2 without being provided with and properly using appropriate and adequate heat-protective clothing and equipment.

(b) Determination of Environmental Heat

(1) Measurement methods: Environmental heat exposures shall be assessed by the Wet Bulb Globe Thermometer (WBGT) method or equivalent techniques, such as Effective Temperature (ET), Corrected Effective Temperature (CET), or Wet Globe Temperature (WGT), that can be converted to WBGT values (as described in Chapters V and IX). The WBGT shall be accepted as the standard method and its readings the standard against which all others are compared. When air- and vapor-impermeable protective clothing is worn, the dry bulb temperature (t_a) or the adjusted dry bulb temperature (t_{adb}) is a more appropriate measurement.

(2) Measurement requirements: Environmental heat measurements shall be made at or as close as feasible to the work area where the worker is exposed. When a worker is not continuously exposed in a single hot area, but moves between two or more areas with differing levels of environmental heat or when the environmental heat substantially varies at the single hot area, the environmental heat exposures shall be measured at each area and during each period of constant heat levels where employees are exposed. Hourly TWA WBGTs shall be calculated for the combination of jobs (tasks), including all scheduled and unscheduled rest periods.

(3) Modifications of work conditions: Environmental heat measurements shall be made at least hourly during the hottest portion of each workshift, during the hottest months of the year, and when a heat wave occurs or is predicted. If two such sequential measurements exceed the applicable RAL or REL, then work

conditions shall be modified by use of appropriate engineering controls, work practices, or other measures until two sequential measures are in compliance with the exposure limits of this recommended standard.

(4) Initiation of measurements: A WBGT or an individual environmental factors profile shall be established for each hot work area for both winter and summer seasons as a guide for determining when engineering controls and/or work practices or other control methods shall be instituted. After the environmental profiles have been established, measurements shall be made as described in (b)(1), (2), and (3) of this section during the time of year and days when the profile indicates that total heat exposures above the applicable RAL's or REL's may be reasonably anticipated or when a heat wave has been forecast by the nearest National Weather Service station or other competent weather forecasting service.

(c) Determination of Metabolic Heat

(1) Metabolic heat screening estimates: For initial screening purposes, metabolic heat rates for each worker shall either be measured as required in (c)(2) of this section or shall be estimated from Table V-3 to determine whether the total heat exposure exceeds the applicable RAL or REL. For determination of metabolic heat, Table V-3 shall be used only for screening purposes unless other reliable and valid baseline data have been developed and confirmed by the indirect open-circuit method specified in (c)(2) of this Section. When computing metabolic heat estimates using Table V-3 for screening purposes, the metabolic heat production in kilocalories per minute shall be calculated using the upper value of the range given in Table V-3 for each body position and type of work for each specific task(s) of each worker's job.

EXAMPLE:

As shown in Table V-3 (D, Sample calculation), for a task that requires the worker to stand and use both arms, the values to be added would be 0.6 kilocalories per minute (kcal/min) for standing, 3.5 kcal/min for working with both arms, and 1.0 kcal/min for basal metabolism, for a total metabolic heat of 5.1 kcal/min for a worker who weighs 70 kilograms (kg)(154 lb). For a worker that has other than a 70-kg weight, the metabolic heat shall be corrected by the factor (actual worker weight in kg/70 kg). Thus for an 85-kg worker the factor would be (85/70) = 1.21 and the appropriate estimate for metabolic heat would be (1.21)(5.1) = 6.2 kcal/min for the duration of the task.

(2) Metabolic heat measurements - Whenever the combination of measured environmental heat (WBGT) and screening estimate of metabolic heat exceeds the applicable RAL or REL (Figures 1 and 2), the metabolic heat production shall be measured using the indirect open-circuit procedure (see Chapter V) or an equivalent method.

Metabolic heat rates shall be expressed as kilocalories per hour (kcal/h), British thermal units (Btu) per hour, or watts (W) for a 1-hour TWA task basis that includes all activities engaged in during each period of analysis and all scheduled and nonscheduled rest periods (1 kcal/h = 3.97 Btu/h = 1.16 W).

EXAMPLE:

For the example in (c)(1), if the task was performed by an acclimatized 70-kg worker for the entire 60 minutes of each hour, the screening estimate for the 1-hour TWA metabolic heat would be (5.1 kcal/min)(60 min) = about 300 kcal/h. Using the applicable Figure 2, a vertical line at 300 kcal/h would intersect the 60 min/h REL curve at a WBGT of 27.8°C (82°F). Then, if the measured WBGT exceeds 27.8°C, proceed to measure the worker's metabolic heat with the indirect open-circuit method or equivalent procedure.

If the 70-kg worker was unacclimatized, use of Figure 1 indicates that metabolic heat measurement of the worker would be required above a WBGT of 25°C (77°F).

(d) Physiologic Monitoring

Physiologic monitoring may be used as an adjunct monitoring procedure to those estimates and measurements required in the preceding Parts (a), (b), and (c) of this section. The total heat stress shall be considered to exceed the applicable RAL or REL when the physiologic functions (e.g., core or oral body temperature, work and recovery pulse rate) exceed the values given in Chapter IX, Section D.

Section 2 - Medical Surveillance

(a) General

(1) The employer shall institute a medical surveillance program for all workers who are or may be exposed to heat stress above the RAL, whether they are acclimatized or not.

(2) The employer shall assure that all medical examinations and procedures are performed by or under the direction of a licensed physician.

(3) The employer shall provide the required medical surveillance without cost to the workers, without loss of pay, and at a reasonable time and place.

(b) Preplacement Medical Examinations

For the purposes of the preplacement medical examination, all workers shall be considered to be unacclimatized to hot environments. At a minimum, the preplacement medical examination of each prospective worker for a hot job shall include:

(1) A comprehensive work and medical history, with special emphasis on any medical records or information concerning any known or suspected previous heat illnesses or heat intolerance. The medical history shall contain relevant information on the cardiovascular system, skin, liver, kidney, and the nervous and respiratory systems;

(2) A comprehensive physical examination that gives special attention to the cardiovascular system, skin, liver, kidney, and the nervous and respiratory systems;

(3) An assessment of the use of therapeutic drugs, over-the-counter medications, or social drugs (including alcohol), that may increase the risk of heat injury or illness (see Chapter VII);

(4) An assessment of obesity (body fatness), that is defined as exceeding 25% of normal weight for males and exceeding 30% of normal weight for females, as based on age and body build;

(5) An assessment of the worker's ability to wear and use any protective clothing and equipment, especially respirators, that is or may be required to be worn or used; and

(6) Other factors and examination details included in Chapter VII, Section B-1.

(c) Periodic Medical Examinations

Periodic medical examinations shall be made available at least annually to all workers who may be exposed at the worksite to heat stress exceeding the RAL. The employer shall provide the examinations specified in Part (b) above including any other items the examining physician considers relevant. If circumstances warrant (e.g., increase in job-related heat stress, changes in health status), the medical examination shall be offered at shorter intervals at the discretion of the responsible physician.

(d) Emergency Medical Care

If the worker for any reason develops signs or symptoms of heat illness, the employer shall provide appropriate emergency medical treatment.

(e) Information to be Provided to the Physician

The employer shall provide the following information to the examining physician performing or responsible for the medical surveillance program:

(1) A copy of this recommended standard;

(2) A description of the affected worker's duties and activities as they relate to the worker's environmental and metabolic heat exposure;

(3) An estimate of the worker's potential exposure to workplace heat (both environmental and metabolic), including any available workplace measurements or estimates;

(4) A description of any protective equipment or clothing the worker uses or may be required to use; and

(5) Relevant information from previous medical examinations of the affected worker which is not readily available to the examining physician.

(f) Physician's Written Opinion

The employer shall obtain a written opinion from the responsible physician which shall include:

(1) The results of the medical examination and the tests performed;

(2) The physician's opinion as to whether the worker has any detected medical conditions which would increase the risk of material impairment of health from exposure to anticipated heat stress in the work environment;

(3) An estimate of the individual's tolerance to withstand hot working conditions;

(4) An opinion as to whether the worker can perform the work required by the job (i.e., physical fitness for the job);

(5) Any recommended limitations upon the worker's exposure to heat stress or upon the use of protective clothing or equipment; and

(6) A statement that the worker has been informed by the physician of the results of the medical examination and any medical conditions which require further explanation or treatment.

The employer shall provide a copy of the physician's written opinion to the affected worker.

Section 3 - <u>Surveillance of Heat-Induced Sentinel Health Events</u>

(a) Definition

Surveillance of heat-induced Sentinel Health Events (SHE's) is defined as the systematic collection and analysis of data concerning the occurrence and distribution of adverse health effects in defined populations at risk to heat injury or illness.

(b) Requirements

In order to evaluate and improve prevention and control measures for heat-induced effects, which includes the identification of highly susceptible workers, data on the occurrence or recurrence in the same worker, and distribution in time, place, and person of heat-induced adverse effects shall be obtained and analyzed for each workplace.

Section 4 - Posting of Hazardous Areas

(a) Dangerous Heat-Stress Areas

In work areas and at entrances to work areas or building enclosures where there is a reasonable likelihood of the combination(s) of environmental and metabolic heat exceeding the Ceiling Limit, there shall be posted readily visible warning signs containing information on the required protective clothing or equipment, hazardous effects of heat stress on human health, and information on emergency measures for heat injury or illness. This information shall be arranged as follows:

DANGEROUS HEAT-STRESS AREA
HEAT-STRESS PROTECTIVE CLOTHING OR EQUIPMENT REQUIRED
HARMFUL IF EXCESSIVE HEAT EXPOSURE OR WORK LOAD OCCUR
HEAT-INDUCED FAINTING, HEAT EXHAUSTION, HEAT CRAMP,
HEAT RASH OR HEAT STROKE MAY OCCUR

(b) Emergency Situations

In any area where there is a likelihood of heat stress emergency situations occurring, the warning signs required in (a) of this section shall be supplemented with signs giving emergency and first aid instructions.

(c) Additional Requirements for Warning Signs

All hazard warning signs shall be printed in English and where appropriate in the predominant language of workers unable to read English. Workers unable to read the signs shall be informed of the warning printed on the signs and the extent of the hazardous area(s). All warning signs shall be kept clean and legible at all times.

Section 5 - Protective Clothing and Equipment

Engineering controls and safe work practices shall be used to maintain worker exposure to heat stress at or below the applicable RAL or REL specified in Section 1. In addition, protective clothing and equipment (e.g., water-cooled garments, air-cooled garments, ice-packet vests, wetted-overgarments, heat-reflective aprons or suits) shall be provided by the employer to the workers when the total heat stress exceeds the Ceiling Limit.

Section 6 - Worker Information and Training

(a) Information Requirements

All new and current workers, who are unacclimatized to heat and work in areas where there is reasonable likelihood of heat injury or illness, shall be kept informed, through continuing education programs, of:

(1) Heat stress hazards,

(2) Predisposing factors and relevant signs and symptoms of heat injury and illness,

(3) Potential health effects of excessive heat stress and first aid procedures,

(4) Proper precautions for work in heat stress areas,

(5) Worker responsibilities for following proper work practices and control procedures to help protect the health and provide for the safety of themselves and their fellow workers, including instructions to immediately report to the employer the development of signs or symptoms of heat stress overexposure,

(6) The effects of therapeutic drugs, over-the-counter medications, or social drugs (including alcohol), that may increase the risk of heat injury or illness by reducing heat tolerance (see Chapter VII),

(7) The purposes for and descriptions of the environmental and medical surveillance programs and of the advantages to the worker of participating in these surveillance programs, and

(8) If necessary, proper use of protective clothing and equipment.

(b) Continuing Education Programs

(1) The employer shall institute a continuing education program, conducted by persons qualified by experience or training in occupational safety and health, to ensure that all workers potentially exposed to heat stress have current knowledge of at least the information specified in (a) of this section. For each affected worker, the instructional program shall include adequate verbal and/or written communication of the specified information. The employer shall develop a written plan of the training program that includes a record of all instructional materials.

(2) The employer shall inform all affected workers of the location of written training materials and shall make these materials readily available, without cost to the affected workers.

(c) Heat-Stress Safety Data Sheet

(1) The information specified in (a) of this section shall be recorded on a heat-stress safety data sheet or on a form specified by the Occupational Safety and Health Administration (OSHA).

(2) In addition, the safety data sheet shall contain:

(i) Emergency and first aid procedures, and

(ii) Notes to physician regarding classification, medical aspects, and prevention of heat injury and illness. These notes shall include information on the category and clinical features of each injury and illness, predisposing factors, underlying physiologic disturbance, treatment, and prevention procedures (see Table IV-1).

Section 7 - Control of Heat Stress

(a) General Requirements

(1) Where engineering and work practice controls are not sufficient to reduce exposures to or below the applicable RAL or REL, they shall, nonetheless, be used to reduce exposures to the lowest level achievable by these controls and shall be supplemented by the use of heat-protective clothing or equipment, and a heat-alert program shall be implemented as specified in (d) of this section.

(2) The employer shall establish and implement a written program to reduce exposures to or below the applicable RAL or REL by means of engineering and work practice controls.

(b) Engineering Controls

(1) The type and extent of engineering controls required to bring the environmental heat below the applicable RAL or REL can be calculated using the basic heat exchange formulae (e.g., Chapters III and VI). When the environmental heat exceeds the applicable RAL or REL, the following control requirements shall be used.

(a) When the air temperature exceeds the skin temperature, convective heat gain shall be reduced by decreasing air temperature and/or decreasing the air velocity if it exceeds 1.5 meters per second (m/sec) (300 ft/min). When air temperature is lower than skin temperature, convective heat loss shall be increased by increasing air velocity. The type, amount, and characteristics of clothing will influence heat exchange between the body and the environment.

(b) When the temperature of the surrounding solid objects exceeds skin temperature, radiative heat gain shall be reduced by: placing shielding or barriers, that are radiant-reflecting or heat-absorbing, between the heat source and the worker; by isolating the source of radiant heat; or by modifying the hot process or operation.

(c) When necessary, evaporative heat loss shall be increased by increasing air movement over the worker, by reducing the influx of moisture from steam leaks or from water on the workplace floors, or by reducing the water vapor content (humidity) of the air. The air and water vapor permeability of the clothing worn by the worker will influence the rate of heat exchange by evaporation.

(c) Work and Hygienic Practices

(1) Work modifications and hygienic practices shall be introduced to reduce both environmental and metabolic heat when engineering controls are not adequate or are not feasible. The most effective preventive work and hygienic practices for reducing heat stress include, but are not limited to the following parts of this section:

(a) Limiting the time the worker spends each day in the hot environment by decreasing exposure time in the hot environment and/or increasing recovery time spent in a cool environment;

(b) Reducing the metabolic demands of the job by such procedures as mechanization, use of special tools, or increase in the number of workers per task;

(c) Increasing heat tolerance by a heat acclimatization program and by increasing physical fitness;

(d) Training supervisors and workers to recognize early signs and symptoms of heat illnesses and to administer relevant first aid procedures;

(e) Implementing a buddy system in which workers are responsible for observing fellow workers for early signs and symptoms of heat intolerance such as weakness, unsteady gait, irritability, disorientation, changes in skin color, or general malaise; and

(f) Providing adequate amounts of cool, i.e., 10° to 15°C (50° to 59°F) potable water near the work area and encouraging all workers to drink a cup of water (about 150 to 200 mL (5 to 7 ounces) every 15 to 20 minutes. Individual, not communal, drinking cups shall be provided.

(d) Heat-Alert Program

A written Heat-Alert Program shall be developed and implemented whenever the National Weather Service or other competent weather forecast service forecasts that a heat wave is likely to occur the following day or days. A heat wave is indicated when daily maximum temperature exceeds 35°C (95°F) or when the daily maximum temperature exceeds 32°C (90°F) and is 5°C (9°F) or more above the maximum reached on the preceding days. The details for a Heat-Alert Program are described in Chapter VI, Section C.

Section 8 - Recordkeeping

(a) Environmental Surveillance

(1) The employer shall establish and maintain an accurate record of all measurements made to determine environmental and metabolic

heat exposures to workers as required in Section 1 of this recommended standard.

(2) Where the employer has determined that no metabolic heat measurements are required as specified in Section 1, Part (c)(2) of this recommended standard, the employer shall maintain a record of the screening estimates relied upon to reach the determination.

(b) Medical Surveillance

The employer shall establish and maintain an accurate record for each worker subject to medical surveillance as specified in Section 2 of this recommended standard.

(c) Surveillance of Heat-Induced Sentinel Health Events

The employer shall establish and maintain an accurate record of the data and analyses specified in Section 3 of this recommended standard.

(d) Heat-Induced Illness Surveillance

The employer shall establish and maintain an accurate record of any heat-induced illness or injury and the environmental and work conditions at the time of the illness or injury.

(e) Heat Stress Tolerance Augmentation

The employer shall establish and maintain an accurate record of all heat stress tolerance augmentation for workers by heat acclimatization procedures and/or physical fitness enhancement.

(f) Record Retention

In accordance with the requirements of 29 CFR 1910.20(d), the employer shall retain records described by this recommended standard for at least the following periods:

(1) Thirty years for environmental monitoring records,

(2) Duration of employment plus 30 years for medical surveillance records,

(3) Thirty years for surveillance records for heat-induced SHE's, and

(4) Thirty years for records of heat stress tolerance augmentation

(g) Availability of Records

(1) The employer shall make worker environmental surveillance records available upon request for examination and copying to the subject worker or former worker or to anyone having the specific

written consent of the subject worker or former worker in accordance with 29 CFR 1910.20.

(2) Any worker's medical surveillance records, surveillance records for heat-induced SHE's, or records of heat stress tolerance augmentation that are required by this recommended standard shall be provided upon request for examination and copying to the subject worker or former worker or to anyone having the specific written consent of the subject worker or former worker.

(h) Transfer of Records

(1) The employer shall comply with the requirements on the transfer of records set forth in the standard, Access to Medical Records, 29 CFR 1910.20(h).

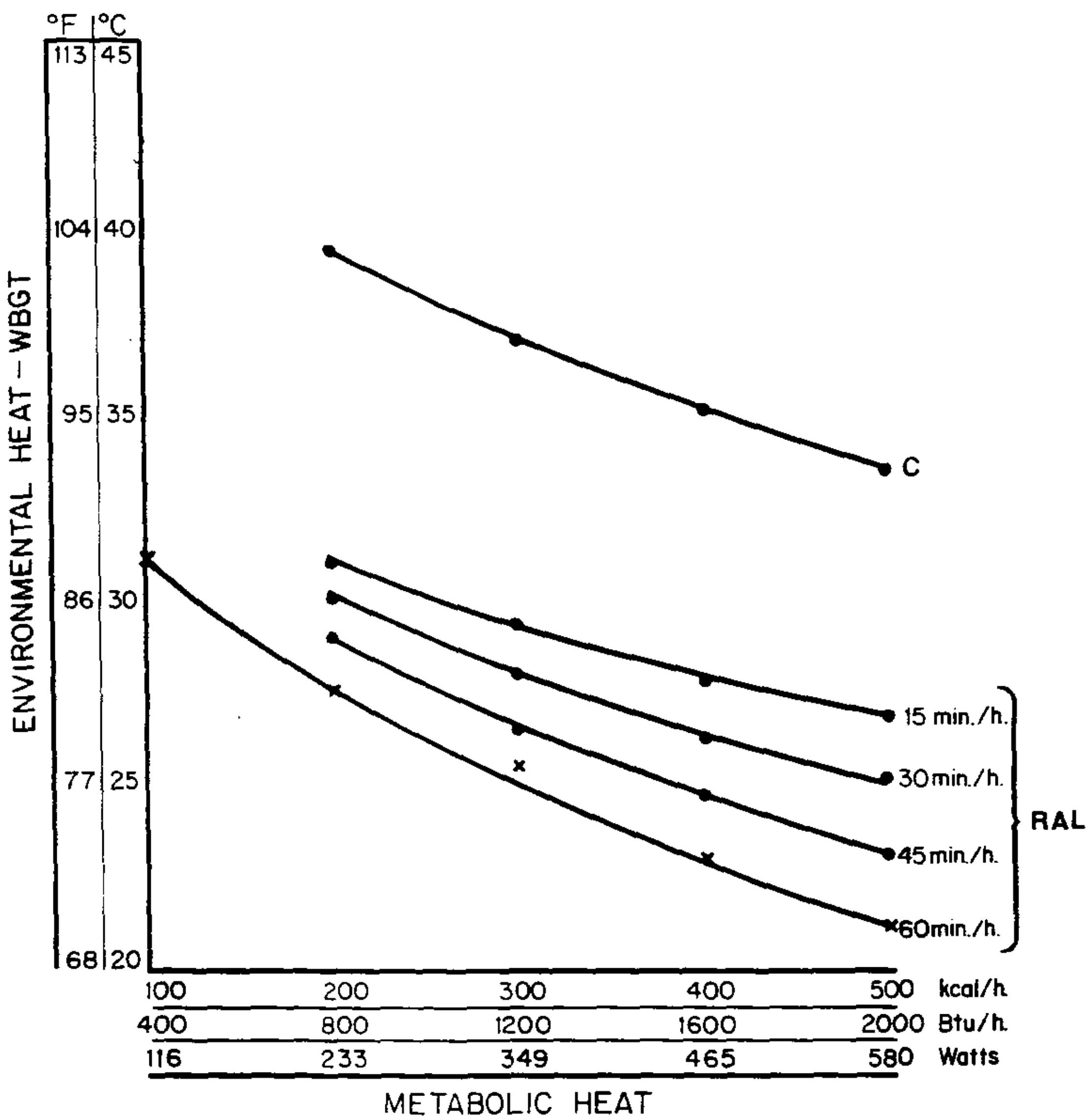

Figure 1. Recommended Heat-Stress Alert Limits
Heat-Unacclimatized Workers

C = Ceiling Limit
RAL = Recommended Alert Limit
*For "standard worker" of 70 kg (154 lbs) body weight and
1.8 m^2 (19.4 ft^2) body surface.
Based on References 2,3,4,5,6,7,8.

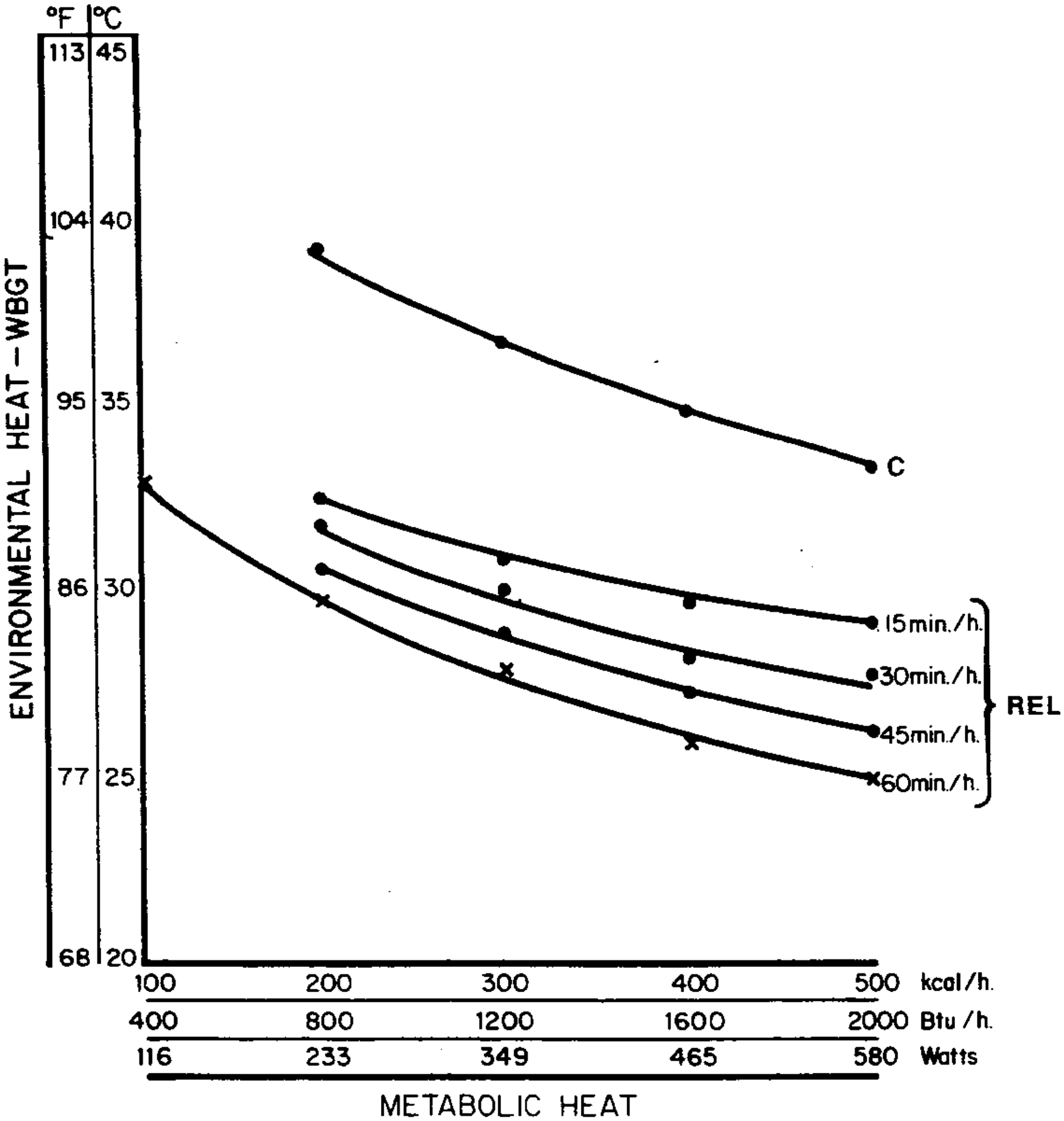

Figure 2. Recommended Heat-Stress Exposure Limits
Heat-Acclimatized Workers

C = Ceiling Limit
REL = Recommended Exposure Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.
Based on References 2,3,4,5,6,7,8.