V. DEVELOPMENT OF STANDARD

Basis for Previous Standards

There are a great number of recommendations for permissible exposure limits to work in hot environments. The recommended limits were expressed in terms of different indices, most of which were designed to consolidate into a single value the four climatic factors, air temperature, humidity, radiant heat, and wind velocity, and often the work load as well. Some other indices expressed the recommended exposure limits in values on a scale which was the result of a ratio with an upper limit value of 100.[77,81] Again other indices expressed the limits in terms of magnitude of one or more physiological responses. All these indices were recently evaluated.[72,73,74] Also, the World Health Organization (WHO) convened a panel of experts to review the heat stress indices.[46] They found shortcomings in all the existing indices as well as in the proposed upper limits set forth in each of these indices.

A. Validity of Indices

Most of the indices are derived from laboratory experiments, thus their relevance to industrial conditions is questionable. Furthermore, the subjects observed in these laboratory studies were mainly young university students or military personnel or, as in Wyndham's[76] studies, Bantu miners. The responses of such a subject group may not be identical to responses of an industrial worker population. An important problem is whether the severity of physiological strain correlates with the scale of different indices. Peterson[74] showed in his study that while some indices correlate well with some physiological responses, none of them correlates well with all physiological responses. He recommends the use of at least three indices simultaneously to evaluate adequately the heat strain of an exposed man.

Another problem plaguing some indices is that in order to make them simple enough for use in industry, certain assumptions had to be made which were by no means proven and equations had to be simplified which further reduced the accuracy of the index.[16]

B. Validity of Proposed Limits

A number of limits, such as recommended by Yaglou and Minard,[75] Brief,[60] and Wyndham[76] in terms of the WBGT or ET indices are empirical and are intended to reduce the frequency of heat casualties. Such criteria are not applicable to industrial workers because they do not give a satisfactory margin of safety.

Another common objection which has been raised against almost all earlier proposed limits is that they are not based on observations of industrial worker populations. Those limits mentioned in the foregoing paragraph are based on data obtained on marine recruits[75] and Bantu miners,[76] who are young, physically fit people and are exposed only for 1 - 2 years to hot working conditions. In addition most of the limits are based on the averages of the observations; thus the limits are theoretically safe only for 50% of the observed population.

The only index[77] which recommends specific allowances for individual differences in age, sex, fitness, body build, acclimatization, hydration, and other conditions which may reduce tolerance to work in heat without causing apparent diseases is the Relative Strain Index. Unfortunately, these recommendations are too vague to be used as bases for an industrial standard. They were originally prepared for use in Civil Defense Shelters.

The first U. S. standard[78] for work in hot environments dates back to 1941, when a Committee on Atmospheric Comfort published their report entitled Thermal Standards in Industry. The criteria of this standard are not spelled out clearly and the permissible exposure limits are intended only as a guide. The Committee recommended that each indusry must develop its own standard because of the complexity of industrial work and the individual differences between workers. As general criteria the Committee quoted comfort and health of individuals, their work output, and their physiological and psychological reaction to work. They applied the Effective Temperature (ET) as the index with which to express their proposed limits. However, since the ET does not include the work load factor, they limited themselves to exposure limits for only two levels of work. The higher level is given at 432 Kcal/hr and the lower is given only in qualitative terms as "light sedentary activities." As far as women are concerned, there is only a comment stating that females are less fit than males. However, since the criteria by which they arrived at these limits are not described, this recommended standard could not be used as a basis for a NIOSH recommendation. Brouha[66] and later Fuller[79] recommended limits based on the concept of accumulation of cardiovascular strain. Their limits are based on the concept that the first minute post exercise recovery heart rate (P_1) should not exceed 110 beats per minute, and that within 3 minutes recovery time the pulse rate should decrease at least by 10 beats per minute. The recovery heart rate is estimated by counting the pulse rate during the second thirty seconds of any given minute during recovery and multiplying this count by two. The validity of this principle seemed to be upheld in recent studies in industry.[29]

The WHO panel of experts[46] recommended that a deep body temperature of 38°C should be considered as the limit of permissible exposure to work in heat. This is also in agreement with several observations which showed that above a body temperature of 38°C the probability of suffering a heat disorder or illness gradually increased.[79a] This is also in agreement with Lind's studies on the prescriptive zone.[80]

<u>Considerations for a Recommended Standard</u>

The principal criteria for a heat stress index for industrial use are:

1. Applicability should be proven in industrial use.
2. All important factors should be included.
3. The measurements and calculations required should be simple.
4. The included factors should have a valid weight in relation to total physiologic strain.

5. Applicable and feasible for setting regulatory limits.

There are four indices which satisfy the first criterion: the Effective Temperature (ET), WBGT index,[75] the HSI of Belding and Hatch,[81] and the Predicted Four Hour Sweat Rate (P4SR).[82] All of these indices include the four climatic factors: air temperature, humidity, radiant heat, and wind velocity. However, the work load is not included in the ET and WBGT. This fact weighs in favor of HSI and P4SR. On the other hand, the calculation of these latter two indices is much more complicated than that of ET and WGBT, even when the available monograms are used. Between ET and WBGT, the latter one wins out in simplicity of calculation. Another aspect which makes WBGT more desirable is that while wind velocity must be measured for the other three indices, for WBGT this is not required. This is a very important consideration in view of the difficulty NIOSH has experienced in field studies[1] in establishing an hourly time-weighted average value for this factor. One important reason for this is that as man moves around while performing his job, he is exposed to wind velocities which vary considerably and often suddenly.

As far as the fourth criterion is concerned, all four indices have some shortcomings, as pointed out in the previous section. Thus, from this point of view, none of the four indices has an advantage over the other.

The HSI has many advantages from the point of view of the fifth criterion, the greatest one being that it makes it possible to calculate the allowable exposure time as well as the minimum recovery time for a given heat stress condition.[83]

The studies performed by Lind[80] on the prescriptive zone (PZ) were used as a basis for the determination of the environmental conditions (including different combinations of climatic and work load), which can be tolerated by 95% of the worker population with body temperatures not in excess of 38°C.

The essence of this principle is shown in Figure 5. Each point on the graph represents the result of an experiment lasting until the rectal temperature of the observed subject reached a steady state. This took about 30-to-60 minutes depending on the intensity of the combined heat-work exposure. It becomes apparent from the graph that up to a certain level of effective temperature (ET) the equilibrium rectal temperatures follow a straight horizontal line, i.e., they do not increase, no matter how much the ET is increased in the heat chamber. However, the rectal temperature is higher when the work rate is higher. Thus, in this range of environmental heat the rectal temperature is determined only by the work intensity. This range is called the prescriptive zone (PZ).

Over a certain level of environmental heat each of the three curves in the graph show a sudden turn upward, indicating that over this level the equilibrium rectal temperatures increased each time the climatic conditions became hotter. Thus, in this range of environmental heat the deep body temperature becomes sensitive to changes in climatic conditions and man can easily lose his ability to maintain an equilibrium temperature, thus leading to heat disorders. This range of climatic conditions is called the environment driven zone (EDZ). The environmental temperatures at the border between the PZ and EDZ are called the upper limit of prescriptive zone (ULPZ).

The value of the ULPZ varies for different individuals. It is higher for men who are acclimatized to heat, by approximately 4.0°F ET, and is lower the more clothing an individual wears.

To make sure that 95% of a heat acclimatized population wearing worker uniforms will not have a rectal temperature in excess of 38°C, it must be established at what level of environmental heat will the 5 percentile man reach his ULPZ, and this value has to be corrected for the level of acclimatization and clothing. This ULPZ was found in a paper of Lind and Liddell[84] in which they tested the ULPZ of a group of 128 men of average physical fitness. Figure 6 shows that about 95% of the men could reach an equilibrium deep body temperature in the 3-hour exercise test if the climatic conditions did not exceed 80.5°F. Thus, at a work load of 300 Kcal/hr the 5 percentile man's ULPZ lies about 1.0°C lower than that of the subjects' observed by Lind in his first study of the PZ.[80] This result was adopted as a guideline to correct the ULPZ values orginally recommended by Lind as shown in Figure 7. As can be seen, it was assumed that a larger correction is required at higher levels of work load when the rectal temperature in the PZ is already very close to 38°C and no correction was applied at the lowest level of work load where the rectal temperature in the PZ is much lower than 38°C. Another justification for applying this upward adjustment for heavy work and downward adjustment for light work comes from the study of Kraning et al.[85] In this study evidence was presented that the heat generated by work metabolism causes about twice as much strain on the cardiovascular system as the same amount of heat taken up from the environment. Studies performed by NIOSH have confirmed these findings.

Corrections would also be needed for clothing because Lind's subjects were tested wearing shorts and sneakers only whereas the workers in hot industries wear underwear and work uniforms as well as boots. This would require a lowering of the ULPZ value. However, an increase would be permitted because it is assumed that the workers in hot jobs will be acclimatized. These two factors then cancel out each other. The ULPZ values read from the abscissa in Figure 7 are expressed in terms of basic ET. They were converted by using Minard's[86] graph showing the correlation between ET and WBGT. In this graph, however, the normal ET is stated for semi-nude men. Thus the ULPZ values read from Figure 7 were first converted to normal ET values, then to WBGT values.

Justification for using time-weighted average hourly work-load values for intermittent work comes from another study by Lind.[87] The results showed that from the point of view of the ULPZ it does not matter whether a certain hourly amount of work is performed at a lower rate continuously or at a higher rate but interrupted with rest periods.

The permissible exposure limits for heat stress cannot be based on 8-hour average values because if excessive exposure persists for longer than 1 hour, the worker may accumulate enough heat in his body to cause him to suffer an acute heat disorder or heat illness; thus in continuous heat exposure, hourly averages are necessary. However, if the exposure is intermittent the accumulation of heat will be slowed down; thus, it is permissible to average the exposure every 2 hours.

The ULPZ was found to be the same for men of different ages, thus no correction for age is required according to Lind et al.[88] However, when older men are exposed to strenuous heat load an increased caution is advisable because of their lowered physiological capacities and increased susceptibility to diseases.

A sex difference in the pattern and magnitude of physiological responses to work in heat has been demonstrated. Whether the observed differences in the responses reflect real differences in heat tolerance or in work performance is not fully proven (see references 33, 43, and 89 thru 96).

In resting-in-heat studies the young female subjects had a higher body temperature and a lower sweat production than did the young males for the same heat exposure.[89] The onset of sweating occurred at a higher body temperature in the females, which resulted in a time delay in the onset of sweating during both severe and mild heat stress. Actual tolerance time in the severe heat was shorter in the females even though the maximum endurable body temperature was the same in both sexes. The symptoms present when an individual collasped from the heat stress were comparable even though the females found the stress intolerable sooner with work-in-stress. Women started to sweat at a higher skin temperature and had a lower sweat production for any specific heat load. Calculated skin temperatures at the onset of sweating were about 4°F higher in female than male subjects and for equal sweat rates the skin temperature was 1.8°F lower in the males.

In spite of the greater strain in women, they are capable of effective heat acclimatization. However, even after acclimatization the sweat rate is lower in the females, and they may have more subjective distress. Resistance to naturally occurring heat waves seems to be lower in women. Apparently there is no real difference in the degree of acclimatization that can be reached in men and women, but they may achieve equal acclimatization in different ways using different configurations of components of the regulating process.

The question arises whether the lower sweat production in females may be due to fewer active sweat glands during the heat exposure. Both the total number of sweat glands and the number per unit area of skin surface are greater in females. In lean females one hundred sweat glands per square centimeter of skin were counted while fifty-nine per square centimeter were found in males. In obese females there were seventy-five per square centimeter and in obese males, forty-seven per square centimeter. A recent WHO report questions this difference in sweat rates after acclimatization.[96a]

Differences in pulse rate responses to a standard work-in-heat test between both young and old men and women have been found.[46] At the lower levels of work the women had pulse rates ten to twelve beats per minute higher than the men. For the high levels of work the differences were twenty to thirty beats per minute higher in the females. The higher pulse rates in the women reflect both the heat stress and the physical work and are higher in the women mainly because the work is relatively harder for them. Oxygen consumption expressed as milliliters per kilogram of body weight was about 15 to 20% higher in women than in men. The highest level of physical work used in the test required about 43% of the predicted maximum aerobic capacity for the older men, 30% for the young men, 66% for the older women, and 44% for the younger women.

Wing[97] reviewed the results of 15 studies performed in different laboratories on the effect thermal stress has on mental performance. It is quite apparent from these studies that thermal stress is an important factor where the worker has to make critical decisions, make fine discriminations, or has to perform fast and skillful actions because safety will depend on constant alertness. The number of errors made will increase if the worker is exposed to heat even before body temperature or pulse rate reaches critical levels.

Figure I-1 in the recommended standard is adapted from Wing's[97] review paper. Although Wing recommended these limits only as tentative upper performance limits, they are considered to be the best presently available. Since Wing's values were expressed in ET, they were converted by using Walters'[98] graph on correlation between ET and WBGT.

As shown in Figure I-1 of the recommended standard, unimpaired mental performance can be maintained below 86°F WBGT for 4 hours and probably even longer, although this needs experimental confirmation. Since environmental conditions above 86°F WBGT are permissible only for jobs with a work load below 200 Kcal/hr for men and below 150 Kcal/hr for women, Figure I-1 of the recommended standard has to be taken into consideration only in sedentary jobs.

It is impossible that for unimpaired mental performance as work loads above 200 Kcal/hr, the 86°F WBGT may be too high. However, there are no data available either supporting or contradicting this assumption.

Since then this problem was investigated in several studies and discussed at two Workshop sessions at the University of Pittsburgh. At these workshops the leading experts in problems of industrial heat stress agreed that the Brouha method should be used as a means of monitoring cardiovascular strain in industry.

Figure 8 shows data obtained in PHS field studies on the dehydration of workers exposed to hot environments. There is a correlation between daily sweat loss and dehydration: the higher the sweat loss the more dehydrated the worker will be at the end of the work shift. However, this correlation was quite different in the four plants. The heavy equipment operators sweated the least, but dehydrated most. At about the same level of daily sweat loss, the foundry men and chemical plant workers dehydrated significantly less. Finally, the aluminum reduction workers whose daily sweat loss was the highest did not dehydrate more than workers of the chemical plant.

When analyzing for causes of the differences in the extent of dehydration, it was discovered that aluminum reduction plant workers were supplied from their drinking fountains a 0.1% salt solution. Thus, it was made sure that the salt they lost by sweating was replaced each work day. For the chemical plant workers and the foundry men salt tablets were available at the drinking fountains. The heavy equipment operators were not supplied with any additional salt, except that salt ingested with their midday lunch.

These results suggest that salt supplementation may play an important role in preventing dehydration.

Another difference between the working condition of the heavy equipment operators and the workers of the other three plants was in the availability of drinking water. Whereas the heavy equipment operators had to go out of their regular path and disembark from their vehicles to have a drink of water, all the workers in the rest of the plants had to do was to go a few steps to the nearest drinking fountain. This circumstance may have also contributed to the higher level of dehydration of the heavy equipment operators. Indeed, it was observed that the workers were not drinking as often as necessary to replace their water loss if they had to make some effort to reach the source of water. These results indicate the importance of making drinking water available close to the job site and recovery places where the workers' daily sweat loss exceeds 2 liters.

In Figure 8 a horizontal broken line is drawn at the 1.5% dehydration level. This is done because the results of earlier NIOSH studies suggested that if the level of dehydration exceeds 1.5% of body weight the physiological responses, such as the body temperature and heart rate, start to increase, indicating an increase of strain. In this respect it may be worth mentioning that among the heavy equipment operators the accident frequency was double that observed at other locations where the same operations were performed, but in comfortable climatic conditions.

It may be assumed that the dehydrated heavy equipment operators, unaware of their diminished performance capacity, may have been unable to react fast enough and correctly in situations where sudden action would have been necessary to prevent an accident. This again may be interpreted as a warning as to the importance of proper fluid and salt replacement in hot jobs.

<u>Summary of the Basis for the Work Practices Standard</u>

The work of Linde,[80,84] in the development of the prescriptive zone (PZ) is undoubtedly the basis for the best approach for the development of an environmental standard for heat stress because it combines both the climatic and work load conditions that are imposed upon the worker in hot industries. There are, however, a number of practical shortcomings and unresolved questions related to this approach.

These unresolved questions which will require additional research to validate the hypotheses presently proposed as the best technique for evaluation of heat stress conditions dictates the necessity for the development of the work practices standard as outlined in this document as opposed to an environmental standard. The additional research is such that it would be impossible to utilize an environmental standard at this time without stringent limitations being placed upon both the worker and management. Such an approach would be unrealistic.

The validation of the Upper Limit of Prescriptive Zone (ULPZ) concept is essential. It is necessary that this approach be validated with additional data from a normal industrial work force. More data is needed on age and sex distribution of the work force. Another shortcoming that must be clarified is effect of the process of natural selection that normally occurs in the industrial situation where the worker himself determines his ability to endure high heat stresses. This particular consideration is one which may have resulted in heat stress standards in the past that were unrealistic for an industrial population. The intermittent exposures that are normal in the industrial population represent another significant factor which was not thoroughly considered in the previous recommendation. The lack of data regarding intermittent exposures to heat is one of the major unresolved questions of the effect of heat stress on the work force. Differences in sweat loss under a wide variety of industrial conditions still has also not been thoroughly studied. In addition, the wide variety of work loads and the intermittency of work loads that are normal in industrial operations have a major effect upon heat stress. This also must be studied prior to the development of a practical environmental heat stress level. The previous studies have been conducted with soldiers,[75] usually stripped to the waist, or have been under conditions where the subjects are stripped to the waist or are wearing minimal amounts of clothing.[76] This must also be considered in relationship to the normal work clothes of the industrial worker, as well as any other protective clothing that such a worker may be wearing.

All of the above factors can have a significant impact upon the level of heat stress to which a worker might be permitted to be exposed without adverse affects. At this time, such factors without sufficient validation would result in severe limitations on any environmental levels that might be proposed. The information does exist, however, to allow for environmental measurements that can be utilized to initiate work practices that will protect the industrial worker. Additional research is being conducted with regard to how the questions, indicated above, might be resolved.

Environmental Measurements

The climatic conditions are expressed in wet-bulb globe temperature (WBGT) on both the Fahrenheit and Centigrade scales.

Assessment of the WBGT Index

The numerical value of the WBGT Index is calculated by the following equations:

1. Indoors or outdoors with no solar load

   WBGT = 0.7 WB + 0.3 GT

2. Outdoors with solar load

   WBGT = 0.7 WB + 0.2 GT + 0.1 DB

   Where WB = natural wet-bulb temperature obtained with a wetted sensor exposed to the natural air movement (unaspirated)

   GT = globe thermometer temperature

   DB = dry-bulb temperature

The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(WBGT_1) \times (t_1) + (WBGT_2) \times (t_2) + \ldots.(WBGT_n) \times (t_n)}{(t_1) + (t_2) + \ldots.(t_n)}$$

where

$WBGT_1$, $WBGT_2$, ... $WBGT_n$ are calculated values of WBGT for the various work or rest areas occupied during the total time period. t_1, t_2,... t_n are the elapsed times in minutes spent in the corresponding area. This same equation shall be used to calculate the average WBGT for a workman who toils at various work stations at various work rates and/or under different environmental conditions.

Time-weighted average WBGT values should be calculated on an hourly basis in continuous heat exposure and on a two-hourly basis in intermittent heat exposure.

Instrumentation

The instruments required for determining the WBGT Index are a natural wet-bulb thermometer, a globe thermometer, and when outdoors in sunshine, a dry-bulb thermometer.

A satisfactory wet-bulb thermometer may be constructed using a mercury-in-glass thermometer having a range of 30 to 120°F with 0.5°F graduations, and guaranteed to be accurate within $\pm$ 0.5°F throughout its range. A centigrade thermometer of comparable accuracy may also be used. A highly absorbent woven cotton wick shall cover the thermometer bulb and at least 1-1/4 inches of the thermometer stem above the bulb. The lower end of the wick shall be immersed in a reservoir of distilled water. There shall be one inch of wetted wick exposed to the air between the top of the reservoir and the bottom of the bulb. The wick should be wet to the top at all times. Under unusually hot or dry conditions this may be difficult to achieve, and special provisions may be necessary, such as an auxiliary water supply or manual wetting.

The globe thermometer should consist of a 6-inch diameter thin copper sphere, the outside of which is painted a matte black. Either Krylon No. 1602 Ultra Flat Black Enamel or 3 M No. 101-C10 Nextel Black Velvet coating is available in spray cans and will provide an satisfactory surface. A mercury-in-glass thermometer, having a range of 30 to 220°F with 1°F graduations and guaranteed to be accurate to ± 1°F, should be inserted through the shell with the thermometer bulb located at the center of the globe. The thermometer mounting and the globe support may be arranged in several ways. One convenient method is to use a globe having a spud with a 1/4 inch pipe tapping. The thermometer can be inserted through a hole drilled through the spud and supported at the proper height by a ring of rubber tubing, and the complete assembly can be supported by a clamp around a 1/4 inch nipple screwed into the spud. Another satisfactory method is to insert the thermometer through a rubber stopper in a hole in the top of the globe. The globe is then supported from the bottom by a 3/16 inch rod threaded into a matching spud. The globe thermometer should be allowed 20 minutes to reach equilibrium.

When a dry-bulb temperature is necessary it may be obtained with a mercury-in-glass thermometer as specified above for the wet-bulb thermometer. The dry-bulb thermometer should be shielded from solar radiation, but shielding must be applied in such a manner that air circulation over the thermometer bulb is not restricted.

Mercury-in-glass thermometers have been indicated as the sensing elements in the above described instruments. Thermocouples, thermistors, or any other sensors which will provide the same accuracy are equally acceptable. In some cases these may have an advantage over the ordinary thermometer in that the signals from such sensors may be readily recorded.

A suggested arrangement of the instruments is given in Figure 9. Further instrument details and techniques for their use may be found in references.[99,100,101]

In addition to the above described instrumentation which requires the calculation of the WBGT index value, there are instruments described in the literature[98,102,103] or available on the market which sense the required temperatures and automatically integrate them to give a readout in WBGT. Another such instrument is currently (March, 1972) being developed by NIOSH.

Instrumentation for the determination of the WBGT Index should always be located so that the readings obtained will be truly representative of the environmental conditions to which the workman is exposed. Sensors should be at about the mean height of the worker, and due consideration should be given to the location of radiation sources and the direction of air movement. A record shall be maintained of the WBGT Index observed at each of the various hot work sites.

Medical

The purpose of the pre-placement examination of persons applying for hot jobs is the same as for evaluating the health status of a prospective employee for any job, namely, to determine his mental, physical and emotional qualifications to perform his job assignment with reasonable efficiency and without risk to his own health and safety or to that of his fellow employees.[104]

The examining physician, however, will recognize the particular requirements for persons whose jobs involve significant heat exposure. He should be probing in taking the employees' history, both medical and occupational, in order to discern possible evidence of intolerance to heat either occupational or off the job.

By the same token, a history of successful adaptation to heat exposure on previous jobs is perhaps the best criterion on which to predict effectiveness of a worker's future performance under heat stress, assuming that levels of work demands and heat exposure are equivalent and that no significant alteration has occurred in his health status since his previous employment.

For new employees without previous occupational exposure to heat, they should not be assigned to hot jobs where the environmental conditions exceed 79°F WBGT for men and 76°F WBGT for women until they are acclimatized. It has been established that both heat tolerance and also physical work capacity decline with age.[105,106]

During both the history taking and the physical examination, the examiner should direct careful attention particularly to detect evidence of chronic functional or organic impairments not only of the cardiovascular system but also of the kidneys, liver, endocrines, lungs, and skin. Significant disease of any of these systems should be disqualifying for new employement on jobs involving severe heat exposure, or for those previously employed on such jobs if the disease is progressive despite treatment.

Careful inquiry should be made on use of drugs, particularly hypotensive agents, diuretics, antispasmodics, sedatives, tranquilizers, and anti-depressants as well as the abuse of drugs, particularly amphetamines, hard narcotics, and alcohol. Many of these drugs impair normal responses to heat stress and others alter behaviour, thus, exposing the employee or fellow workers to health and safety hazards. Evidence of therapeutic use of one or more of these categories of drugs or personal abuse of alcohol and other drugs should be disqualifying.

Other qualifications depend on the job demands independently from heat exposure, for example, statutory requirements to qualify as a vehicle operator, craneman, locomotive engineer, etc., would obviously need to be met as well as nonstatutory requirements for jobs in a particular industry. A glucose tolerance test, renal clearance studies, X-ray examination of the renal pelvis and biliary system with contrast media, pulmonary function tests and other special tests are recommended when indicated in addition to routine 12-lead ECG 14" x 17" chest X-ray, and the usual blood and urine analyses.

Workers employed on jobs which regularly expose them to levels of heat stress which have been determined to approach or equal permissible limits prescribed by the heat standard should be examined periodically on an annual basis or more frequently if indicated. The examination should be conducted during the summer season. In employees after the age of forty-five, physical and laboratory examinations should be designed to detect conset of chronic impairments of the cardiocirculatory and cardio-respiratory systems and also to detect metabolic, skin, and renal disease. In cases of older employees who had not undergone the pre-placement examination, and whose health records indicated pre-existing chronic diseases of the systems referred to in the section on pre-employment examination, the examination should determine the extent to which such impairments have progressed. For all employees on hot jobs undergoing periodic examination, any history of acute illness or injury, either occupational or nonoccupational, during the interval between examinations, should be carefully evaluated. Repeated accidental injuries on the job or frequent sick absence should alert the physician to possible heat intolerance of the employee or the possibility of an aggravating stress with heat in combination, such as CO. Nutritional status should be noted and advice offered to correct overweight.

In industrial establishments in which heat stress approaches or equals permissible limits only during the summer season, periodic examinations should be administered during the summer. In establishments in which heat stress at the permissible level occurs throughout the year, the periodic examination can be administered at any time regardless of season. The first periodic examination of workers already employed on hot jobs who had not undergone the pre-placement examination required for new employees should be conducted within a year. Guidelines for qualifications should be the same as for new employees but with due allowance made for successful performance on the job, which as indicated earlier is perhaps the most important criterion in evaluating a worker's capacity to adapt to heat stress on the job.

In cases of those previously employed but with a record of health impairment or significant impairments found first on periodic examinations, the examiner should determine whether pre-existing impairments had been effectively controlled by treatment. If progressive, despite treatment, these findings should disqualify the employee from continuing on the same job. In case of impairments detected for the first time, the examiner should evaluate these in light of possible aggravation by heat stress. If such a likelihood exists, the employee should be reevaluated periodically at intervals shorter than those recommended for routine periodic examinations.

For a new employee undergoing his first periodic examination, the examiner should note evidence of heat intolerance, including a history of repeated accidental injury on the job, episodes of heat disorder, or frequent sick absence. In such cases, the examiner should assess the employees capacity to continue on the same job and consider recommending his transfer if indicated.

The supervisor and selected personnel should be trained in recognizing the signs and symptoms of heat disorder and in administering first aid. As described earlier, the most serious emergency is heat stroke signaled by the signs of dry, hot, red, or mottled skin, mental confusion, delirium, convulsions, or coma, and a high and rising rectal temperature, usually 106°F and above but occasionally lower, between 104 and 106°F.

First aid treatment requires immediate removal to a cooler area, soaking the clothing in cold water, and fanning vigorously. The final treatment is conducted in a medical facility but first aid must not be delayed.

In severe heat exhaustion, the victim may faint on standing, but unlike heat stroke the skin is wet and cool. He should be given water by mouth if conscious, and transported to the medical facility without delay.

Medical facilities to treat heat disorders should be as close as possible to work areas. Qualified personnel as appropriate must be available. In treating heat stroke an air conditioned room should be available, and provided with a tub and ice for immersion and massage treatment or a suitable table on which the patient may be placed, wrapped in wet sheets, and exposed to vigorous fanning. A special table is described by Leithead and Lind, 1964.[16]

Chlorpromazine, as an adjuvant to cooling treatment, may be administered in dosages of 25 to 50 mg I.V. This tends to reduce shivering and increases rate of heat dissipation.

Body temperature should be measured every 3 to 5 minutes and cooling interrupted when the rectal temperature reaches a level of 100 to 101°F. Monitoring is then continued to detect recurrence of hyperthermia or continued drop in temperature to hypothermic levels. This is avoided by reducing heat loss with blankets.

Shock may be present on admission to the medical facility. This is often corrected by the cooling treatment. If shock persists after adequate cooling, treatment should include oxygen inhalation, with careful administration of I.V. fluids, and use of pressor agents. With prompt first aid and emergency treatment by cooling, shock will rarely be a complication.

Heat exhaustion is treated by oral administration of salted liquids or by I.V. infusion of normal saline if the patient is unconscious or vomiting.

In heat cramps, treatment is by I.V. infusion of normal saline, with rapid administration of 250 ml within 5 to 10 minutes. The patient then continues to replace body salt by ingesting salted foods and liquids. In moderate to severe cases bed rest for 24 hours is indicated.

Apprisal of Employees of Health and Safety Practices in Hot Environments

Exposure to hot environmental conditions can lead to primary heat illnesses, to unsafe acts, or to increased susceptibility to toxic chemicals and physical substances. Through the application of basic health and safety procedures, the individual may by proper precautions reduce the likelihood of ill effects from a hot work environment. Each employee who may be exposed to heat and each supervisor should through a safety training and indoctrination program be made aware, as a minimum, of the points discussed below:

It is essential that water intake during the workday should about equal the amount of sweat produced. Work in a hot environment may result in sweat productions of 1 to 3 gallons a day. If this water lost in the sweat is not replaced, dehydration with its debiliating effects will result. Thirst is an inadequate drive to stimulate one to drink that much more water. An ample supply of cool water readily available to the workers is required and the worker should be encouraged to take a drink of water each 15 to 20 minutes preferably using disposable paper cups rather than drinking directly from the fountain.

Large amounts of salt may be lost in the sweat particularly by the individual not acclimatized to heat. The salt must be replaced daily to prevent heat induced salt deficiency heat illness.

The acclimatized individual looses much less salt in his sweat. Salt can be replaced by liberally salting ones food or by using a 0.1% salt solution drinking water. About 1 level tablespoon of table salt to fifteen quarts of water will make a 0.1% salt solution. Enteric coated salt tablets may also be used; however, they must be taken with ample water to prevent gastric irritation. It is particularly important that salt depletion is prevented by supplemental salt intake during the first few days of heat exposure when the worker is not yet acclimatized.

Each employee exposed to heat should weigh himself at the beginning and end of the workday to insure that fluid intake has been sufficient to prevent serious dehydration. Weight loss at the end of the workday should not exceed 1.5% of the worker's body weight.

Each employee should be instructed on how to recognize the symptoms of heat disorders and illnesses including dehydration exhaustion, heat syncope, heat cramps, salt deficiency exhaustion, prickly heat and heat stroke. Recognition of early warning signs so that corrective or evasive action can be taken is one of the best means of preventing health damage. The major heat disorders are shown in Figure 3 and have been discussed in the section on Medical Considerations.

The most prevalent of the heat disorders is undoubtedly heat syncope (possibly along with heat edema) which is seldom a debilitating disorder. Fainting may follow prolonged standing, sudden postural changes, unaccustomed exercise, particularly if the exercise involves stooping or heavy lifting or standing upright after exercise. Fainting of this nature is not unusual in hot surroundings and in heat unacclimatized individuals. It is seldom reported among those who are accustomed to and experienced in living in hot climates, a fact that can be related partly to the development of acclimatization and partly to "learning to live with hot climates".

Heat syncope is usually self-limiting, since recovery follows assumption of the recumbent position; but if an individual faints in a confined area and is unable to fall down, death can and does result. Fainting at the job site can also have serious safety consequences. Treatment of the patient involves removal to cool surroundings where he or she is allowed to rest. The disorder is readily prevented by education of the unacclimatized as to the causes of the disorder, by careful introduction of the uninitiated to the problems associated with lack of acclimatization, and by grading the amount of work until acclimatization is achieved.

It is not possible to assign specific levels of heat stress in which heat syncope may be expected; the reasons for this lies in the wide degree of individual variation on exposure to heat and the relatively different response of individuals to work in the heat depending on 1) their physical condition and 2) their state of acclimatization. Hence, heat syncope is an unpredictable disorder, but is preventable by proper indoctrination and education in sensible "hot-weather hygiene".

Other important problems are disorders of water and electrolyte balance. The principle disorders in this category are water-depletion heat exhaustion and salt-depletion heat exhaustion. Neither need occur in industry. Both disorders occur following continued heavy sweating. It is not uncommon for industrial workers to lose 10-12 liters (20-25 pints) of sweat each day[107] and if that much water is not replaced, water depletion occurs. Irrespective of whether water depletion occurs rapidly (e.g., in a day) or progressively (over many days), the end result is the same. In extreme examples, as for men lost in a desert with no water to drink to replace sweat losses, death can occur in 12 hours and is usually inevitable within 48 hours.[16] Even for individuals in a temperate climate, such as castaways at sea, water deprivation will usually result in death in 7-10 days. Death from water depletion will occur if 9-10 liters (18-20 pints) is lost from the body, and loss of 4 liters (8 pints) without replacement leads to intense thirst, a rapid heart rate, and a high body temperature. Water intake must equal the water loss by sweat if this disorder is to be avoided; workers exposed to hot climates must be encouraged to drink an ample supply of water or flavored drinks which must be readily available to them. Again, there is no specific environmental condition above which this disorder occurs, since it depends simply on the replacement of the fluid loss which occurs even in comfortable conditions; however, the hotter the environment is, the greater is the fluid loss by sweating and the worker will thereby come closer to water depletion.

Salt is also lost in the sweat. The concentration of salt in the sweat is higher in unacclimatized men than in acclimatized men, but the concentration also depends on the dietary salt intake, which is usually in excess of the body's needs.[107] If salt lost in the sweat exceeds the dietary intake, a salt depletion occurs. If this is not corrected, a vicious cycle can occur, since salt depletion can lead to loss of appetite and nausea, leading in turn to a further salt depletion; moderately severe salt depletion results in vomiting and diarrhea, with further loss of salt. If this cycle is not interrupted, death inevitably follows. Those who suffer salt depletion complain of weariness and weakness and may suffer muscle cramps; headaches, giddiness, and other symptoms are common. While those who are not acclimatized are at greatest risk, the disorder can occur in any individual who sweats a lot and whose dietary salt intake is low. Supplementary salt of 5 to 15g daily may be required by unacclimatized men to avoid salt depletion. though this may be reduced by half or more after 10 days of work in the heat. While at least some of this supplementary salt can be obtained by the additional salting of food, it may be necessary to supply salted drinks or salt tablets to be taken with drinking water.

The most severe heat disorder is heatstroke, the mortality rate for which has been found to be between 25% and 75%.[16] The variability in mortality depends on the length of time elapsing between the onset of the disorder and the start of treatment and the highest body temperature attained during the episode. Heatstroke always constitutes an urgent medical emergency, in which the basic requirement is to cool the patient rapidly.

Heatstroke is a state of thermoregulatory failure usually of sudden onset, following exposure to hot environments, and is characterized by a disturbance of the central nervous system (often expressed as convulsions), by a failure of sweating (so that the skin is hot and dry), and by a high deep body temperature. The body temperature at the time of onset of the disorder is usually in excess of 40.5°C (105°F) although cases have been reported at 39.5°C (103°F). The treatment of heatstroke must be vigorous and immediate, under the careful control of a physician.

The environmental conditions in which heatstroke has been reported have been plotted on a psychrometric chart (Figure 10) and are surprisingly low.

But the values reported do not include the degree of radiant heat load, nor do they disclose the rate of work of the victims prior to the onset of the disorder; both of these contributions to the total heat load were probably high in many cases. Nevertheless, heatstroke has been known to occur in environmental conditions that are not particularly severe. Additional contributory causes can be of many origins - heavy clothing, water depletion, age, cardiovascular, or other concurrent disease, obesity, hard physical work, etc. It is not uncommon for heat disorders to co-exist and for one to predispose the individual to another. But heat syncope and heatstroke are mutually exclusive - syncope will in this event protect the individual from the more severe disorder.

This brief summary of heat disorders outlines the origins of and the methods of prevention of the commoner disorders; further and detailed information is available in the extensive review by Leithead.[16]