TB MED 507
NAVMED P-5052-5
AFP 160-1

DEPARTMENT OF THE ARMY TECHNICAL BULLETIN
DEPARTMENT OF THE NAVY PUBLICATION
DEPARTMENT OF THE AIR FORCE PUBLICATION

OCCUPATIONAL AND ENVIRONMENTAL HEALTH

PREVENTION, TREATMENT AND CONTROL OF HEAT INJURY

HEADQUARTERS, DEPARTMENTS OF THE ARMY, NAVY AND AIR FORCE
JULY 1980

TECHNICAL BULLETIN
MED No. 57
NAVY PUBLICATION
No. P-5052-5
AIR FORCE PUBLICATION
No. 160-1

DEPARTMENTS OF THE ARMY, THE NAVY
AND THE AIR FORCE
WASHINGTON, DC, *25 July 1980*

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* This bulletin supersedes TB MED 175/NAVMED P-5052-5/AFP 160-1, 25 April 1969.

SECTION I

INTRODUCTION

1. Purpose. The purpose of this bulletin is two-fold—

a. To provide military physicians and other Medical Department personnel with information essential to a preventive program to control the adverse effects of high temperatures on Armed Forces personnel.

b. To provide a guide to the diagnosis and treatment of the three clinical syndromes resulting from overexposure to heat; namely, heat cramps, heat exhaustion, and heat stroke.

SECTION II

ETIOLOGIC CONSIDERATIONS

(Also refer to Section IV)

2. Environmental and Physiologic Relationships.

a. Exposure to high environmental temperature produces stress on the body. As the body attempts to compensate, physiological strain results. This strain, usually in combination with other strains caused by work, dehydration, and fatigue, may lead to manifestations of heat disorders and disability. Environmental conditions which influence the heat equilibrium of the body and its physiologic adjustments are air temperature, the temperature of surrounding objects, vapor pressure of water in the air (humidity), and air movement. The impact of these conditions is influenced by the type and amount of clothing worn and by the integrity of the body's physiologic mechanisms. The body loses heat by conduction and convection, by radiation and by evaporation. Conduction of heat to or from solid objects can usually be ignored in considering body heat stress since so little contact surface is involved, although of course any contact with hot liquids or surfaces above 114°F (46°C) can produce pain; slightly higher temperatures can produce burns. Heat loss by conduction to air occurs where the air in contact with the skin is below body temperature; conversely, heat gain by conduction from air occurs when this air temperature exceeds that of the body. Then convection, induced by thermal currents, by body motion or by natural air movement (wind), exchanges the air next to the body and the process of conduction-convection continues. The body loses heat by radiation when the surrounding objects have surface temperatures lower than the temperature of the body surface and gains heat by radiation when the temperature of surrounding surfaces is above that of the body surface. Accordingly, temperature combinations of the air and the surrounding objects may exist which result in heat gain by the body due to radiation, even though the air temperature is below that of the body. Radiation heat exchange is independent of air motion and, in fact, occurs in a vacuum, for example in space. Among the normal physiologic responses to heat stress are vasodilatation in the skin and a corresponding increase in the heart rate. Both of these adjustments increase the amount of heat transferred by circulating blood from the center of the body to the skin, thus increasing transfer of body heat to the skin and therefore increasing heat loss (or reducing heat gain) by conduction-convection and radiation. However, these adjustments place a strain on the circulatory system and play an important role in the production of heat illnesses.

b. The body at rest eliminates about 25% of its basal heat production by evaporation of water from the lungs and through the skin. When the body cannot lose sufficient heat by conduction-convection and radiation and the skin temperature rises to a significant level (approximately 95°F; 35°C), the activity of the sweat glands increases. Then heat loss by evaporation of sweat becomes

the most important and sometimes the only means of maintaining normal body temperature. However, as the vapor pressure (humidity) of the air increases, the capacity of the air to evaporate the sweat produced by the body decreases, thus reducing cooling, since it is the evaporation of sweat which produces cooling (approximately 0.58 kilocalories of heat removed per gram of sweat evaporated). Inadequate cooling increases sweating and excessive sweating may lead to a marked loss of body water and salt. The body water is lost, at least initially, almost entirely from the circulating blood volume and, if the water is not replaced, the resulting dehydration adds to the strain on the circulatory system. This is usually an important factor in the cause of heat exhaustion. Hyperventilation, i.e. panting, while perhaps increasing the heat loss via the lungs, can result in a lowered blood carbon dioxide (pCO_2) level and this respiratory alkalosis may also contribute to the heat exhaustion syndrome, occasionally being severe enough in a resting individual to produce tingling, numbness, tetany and fainting.

c. Heat cramps and heatstroke are other manifestations of heat stress. In the etiology of the former, a disproportionate loss of sodium chloride relative to water loss due to excessive sweating is a primary factor. While the physiologic basis for heatstroke is not fully understood, it is associated with high internal body temperatures (usually with rectal temperatures greater than 106° F (41°C)). Although sweat rates have been documented to exceed 2 liters per hour for short time intervals, sustained sweat rates are usually 1 liter per hour or less. Inability to eliminate sufficient body heat as a result of either high ambient vapor pressure (humidity) or physiologically limited sweat production results in high internal body temperatures that may damage central nervous system centers concerned with vasomotor and sweating control. The resulting cessation of sweating, onset of shivering and/or vasoconstriction leads to an uncontrolled and explosive rise in body temperature. The central nervous system damage is frequently irreversible if temperatures are markedly elevated for sufficient lengths of time and may be accompanied by acute renal failure, pulmonary edema, and hepatic damage. Heat stroke is thus a true medical emergency.

d. Air motion (convection) is a significant factor in the relationships described above as it usually replaces the layer of air next to the skin with cooler or drier air, thereby facilitating heat loss due to conduction, and accelerating evaporation of sweat. These beneficial effects diminish progressively as humidity and air temperature increase. When air temperature is higher than skin temperature, heat transfer by conduction tends to transfer air heat to the skin.

e. Other major factors influencing physiologic responses incident to high temperature exposures relate to the physical work performed prior to and during the exposure, and the physical condition of the individual. The body is constantly producing heat, but during physical work the production of heat is increased in proportion to the type, intensity, and duration of the work; for example, for marching, an increased heat production results from any increase in the load carried or in the rate of marching or in the grade or difficulty of the terrain being traversed. Thus, physical work accentuates the effects of high temperature. Lack of acclimatization, obesity (which increases the load carried and generally indicates a poor physical condition), dehydration, excessive consumption of alcohol, lack of sleep, old age and poor health, and cumulative "fatigue" and accumulated body heat storage (due to lack of adequate recovery periods) are examples of conditions which decrease a person's ability to withstand high temperatures.

3. Evaluating the Environment.

a. Four basic factors that determine the degree of heat stress exerted by the environment are air temperature, vapor pressure or humidity, air movement, and heat radiation. The air temperature is read from the ordinary dry bulb thermometer. This reading is affected primarily by the air temperature but can be affected by heat radiation; a strong current of air passing over the unshielded thermometer bulb may be sufficient to cancel the error from absorbed radiant heat. The aspirated wet bulb temperature is the reading of the thermometer when the bulb is covered with a wet wick and a sufficient current of air is passed over the wick. The amount of heat lost by the bulb under these conditions, and thus the reading of the thermometer, is affected by both temperature and vapor pressure (humidity). The wet bulb temperature is always below the dry bulb temperature except when the relative humidity is 100 percent, at which point both temperatures are equal. The air movement is usually determined by an anemometer. The naturally-convected (i.e. unventilated) wet bulb temperature will be higher than the aspirated wet bulb temperature, particularly in still air situations; convergence of

the two measurements begins at low air movements, with the two becoming nearly the same at air velocity of about 7 miles per hour (3.1 m/sec). Radiant heat can be most easily assessed by using a "black" globe thermometer that integrates the cooling or heating effects of air movement with the radiant heat gain or loss. The globe thermometer consists of a 6-inch hollow copper sphere, with a wall about 0.022 inches thick, painted matte (flat) black on the outside, and containing a thermometer bulb or other temperature sensor at the center of the sphere. A globe should be left in position about 20 minutes to achieve needed equilibrium. Smaller globe thermometers have been devised from 1.64 to 4.0 inches outside diameter to reduce equilibrium times; not all have provided data equivalent to the standard globe.

b. The shielded dry bulb temperature is, in general, a poor indication of thermal stress because it is not affected by humidity, air movement or radiation. The shielded wet bulb temperature is a better index since it includes the humidity factor as well as the air temperature. For example, work which is relatively easy at a dry bulb temperature of 96°F (36°C) with an 80°F (27°C) wet bulb (humidity of 50 percent) becomes impossible at the same dry bulb temperature as the wet bulb approaches 96°F (36°C) (100 percent humidity). At a given wet bulb temperature, the dry bulb temperature can vary over a wide range without much physiologic or psychologic effect on an individual. However, the wet bulb temperature is not a good index of the heat stress imposed upon individuals exposed to radiant heat. Air movement also is not taken into account in these measurements. Many attempts have been made to devise a single index combining all four of these factors which is simple and can be used without elaborate equipment or training of personnel; use of the naturally convected (unaspirated) wet bulb has proven to be of signigficant help in projecting the stress of an environment.

c. The WBGT index, utilized in Appendixes A and B, is the most practical heat stress index for characterizing the effect of a heat stress environment on the individual. For use of the WBGT index in assessing heat stress situations, research and years of experience have shown that the most practical WBGT index is obtained by adding 70 percent of the naturally convected wet-bulb temperature, 20 percent of the black globe temperature, and 10 percent of the dry-bulb temperature.

d. Generally, a person in the field has only conventional thermometers available to obtain unshielded dry bulb and unshielded, unaspirated wet bulb temperatures. With some ingenuity, he can achieve a first order approximation of the WBGT, as shown in Appendix A. The Army has developed another method in which a portable, hand-held mechanical wet-bulb-globe-temperature (WBGT) kit (NSN 6665-00-159-2218) is utilized; a modest but tolerable sacrifice in accuracy was made to permit easy mobility of the equipment when used to obtain information of local heat stress conditions with troops. Dry bulb, wet bulb, and approximate globe temperatures are read from thermometers and a special slide rule is used to obtain the WBGT index. The Navy has developed a third generation electronic heat stress monitor (NSN-2H-6685-01-055-5298) that is also portable and hand-held. It is extremely accurate for both single and multiple site monitoring in shipboard spaces, inside vehicles, and in field conditions. Shielded dry bulb, shielded wet bulb (aspirated and unaspirated), and fast-response globe temperatures, air movement and WBGT index values are readily displayed for local or remote sites and for electronic or manual recording.

SECTION III

PREVENTION

4. **General.** Successful prevention of adverse effects of heat depends largely on education of personnel, including the personnel exposed to heat, and especially those charged with the supervision of such personnel. Specifically, prevention of heat injury involves development of procedures to alert individuals to the existence of dangerous heat stress levels, the application of any practicable measures to reduce both the severity and duration of the exposure and adoption of techniques to increase the resistance of exposed persons. Procedures for estimating the heat stress level are

explained above and detailed in Appendix A. The severity of the effects of a given environmental heat load is decreased by reducing the work load, increasing the frequency and/or duration of rest or relief periods and by introducing any measure which will protect the individual from the hot environment. Resistance is increased by gradual acclimatization of individuals to hot environments, or at least graduated introduction of the required work level in a hot environment, by replenishing water and salt losses from the body as they occur and by the maintenance of the optimum physical condition of personnel. Each of these measures is discussed briefly in paragraphs 5 through 10, followed by mention of special considerations relating to the prevention of heat injury among recruits.

5. Water.

a. The human body is highly dependent on water to cool itself in a hot environment. An individual subjected to high heat stress may, by sweating, lose water in excess of one quart per hour. These losses must be replaced or rapid rise in body temperature and heart rate, decrease in the ability and motivation to work, and deterioration in morale will occur, followed eventually by heat exhaustion. Water loss must be replaced, preferably by periodic intake of small amounts of water throughout the work period. Table 1 may be used as a guide to estimate the drinking water requirements for personnel exposed to heat. During the period of moderate activity, with moderate environmental conditions prevailing, water requirement will be one pint or more per hour per man. This is best taken at 20 to 30 minute intervals. As activities or conditions become more severe the intake should be increased accordingly. Thirst is not an adequate stimulus for water intake; men with ample water supplies will frequently dehydrate by one or two quarts unless drinking is encouraged or required by command control. In fact, some overhydration is strongly recommended. The optimum drinking water temperature is between 50°F and 60°F (10°C and 16°C), and flavoring the water lightly with citrus fruit flavors (or extracts) enhances its palatability.

b. The myth that men can be taught to adjust to decreased water intake has been disproven many times.

Table 1. Water Requirements

Activity	Illustrative Duties	Quarts per man per day for drinking purposes (a guide for planning only) WBGT or WD Index*	
		Less than 80°	Greater than 80°
Light	Desk work	5	6
Moderate	Route march	7	9
Heavy	Forced marches; stevedoring; entrenching; or route marches with heavy loads or in CBR protective clothing.	9	13

* 80° WBGT or WD index is approximately equivalent to a dry bulb temperature of 85° in a jungle or 105° in a desert environment. (WD= 0.85WB + 0.15DB)

When water is in short supply, significant water economy can be achieved only by reducing physical activity, or limiting it to the early morning, evening, and night hours when the heat load is less and thus sweating is reduced. Any attempt at water economy by restricting water intake must be paid for in reduced work capability, reduced efficiency and increased risk of a heat injury.

6. Salt.

a. In addition to water, sodium chloride also is lost in the sweat. While the diet ordinarily contains an adequate amount of salt, additional salt may be provided cautiously during the first few days of exposure to heat, especially in the case of unacclimatized individuals in whom salt losses are greater than after acclimatization. However, additional salt intake can delay the rate at which the full sweat production, appropriate to a given heat/work load, occurs; this can result in greater heat accumulation and higher body temperature if salt is given in excess. Among acclimatized individuals the need for added salt varies. Persons in the older age groups tend to retain excess salt in the body, their need for additional salt after acclimatization thus being less than those in the younger age groups. However, under heavy heat stress when sweating is excessive, intake of some additional salt by the acclimatized individual may be indicated with caution. Excess intake of salt should be avoided since it may cause increased thirst and incapacitating nausea. Unless men are sweating continuously or repeatedly, they do not require saline fluids or salt tablets. Extra salt in the cooking, in the bread and on the plate, coupled with sound training will meet most requirements. When water supplies are restricted, salt in excess

of that normally present in food is contraindicated. When food intake is restricted, or voluntarily limited, as it may be during the first few days of heat exposure, salt must be provided by other means in conjunction with a balanced water intake.

b. A convenient way to provide adequate salt to large numbers of personnel is to salt all drinking water to a concentration of 0.1 percent. This can be done as follows (See also Appendix C):

(1) 1 pound table salt to 100 gallons of water.

(2) 0.3 pound table salt to the Lyster bag, (36 gallons).

(3) One-fourth teaspoonful table salt (or if available, two 10-gram salt tablets) to each quart of water.

NOTE: Plain salt tablets contain cornstarch as a disintegrating agent. The plain salt tablet should not be ingested directly since it disintegrates within 2 minutes and salt in concentrated form is not readily absorbed and may cause gastrointestinal disturbance.

c. If, salt tablets are used instead of the above 0.1 percent saline solution, their use must be under medical control. Impregnated salt tablets have a membranous structure which prolongs disintegration so that about half the tablet is dissolved after 45 minutes and the rest over a total period of three hours. Accordingly, one impregnated salt tablet provides a more or less even availability of 10 grains of absorbable salt over a three hour period. Excess intake of salt in the form of salt tablets should be particularly avoided since it may cause increased thirst and intestinal disturbances.

d. Due to the very high salt concentration in field rations, caution must be taken to maintain a high water intake and to avoid excessive salt intake among personnel on field rations.

7. Acclimatization.

a. Training programs for personnel who are climatically and/or physically unseasoned to heat should be limited in intensity and time. A period of approximately two weeks with progressive degrees of heat exposure and physical exertion should be allowed for substantial acclimatization (about 78%). If men are required to perform heavy physical work before being properly acclimatized, the work is poorly performed, development of the capacity to work effectively is retarded, and the risk of heat injury and disability is high. A period of acclimatization is necessary regardless of the individual's physical condition, although the better the physical condition the quicker acclimatization is completed.

b. Acclimatization to heat begins with the first exposure, and is usually developed to about 45–52% by the end of the first week. Individuals who are unusually susceptible to heat will require additional time for acclimatization. Full acclimatization (the ability to perform a maximum amount of strenuous work in the heat) is attained most quickly by graded, progressively increasing work in the heat. Full heat acclimatization can be achieved by as little as two 50-minute periods of work in the heat each day. The work task should require cardiovascular endurance work, e.g., running in place, rather than muscle work such as pushups. Resting for three or four days in the heat, with activity limited to that required for existence, results in only partial acclimatization; physical work in the heat must be accomplished for development of full acclimatization to that work level in a given hot environment. A day or two intervening cool weather will not interfere significantly with acclimatization to a hot climate.

c. If it is necessary that work be accomplished during the period of acclimatization, advantage should be taken of the cooler hours in accomplishing the work. A schedule should be established which provides for increasingly longer work periods alternating with rest periods. The following plan is suggested for troops other than basic trainees, since for the latter it is not advisable that work be accomplished in the heat during the basic training period when risk of heat injury is high. The schedule shown in Table 2 should be modified, consistent with local conditions:

Table 2. Schedules of Work, if Necessary During Acclimatizing Period

Moderate conditions WBGT or WD less than 80°; hours of work*			Severe conditions, WBGT or WD greater than 80°; hours of work		
	Morning	Afternoon		Morning	Afternoon
First day	1	1	First day	1	1
Second day	1½	1½	Second day	1½	1½
Third day	2	2	Third day	2	2
Fourth day	3	3	Fourth day	2½	2½
Fifth day	Regular duty		Fifth day	3	3
			Sixth day	Regular duty	

* Recommended for men in fair or worse physical condition; with some care, very fit individuals should do double this schedule and be able to perform regular duty on 3rd or 4th day.

The work period should be divided so that a man works and rests in alternating periods. When necessary for the accomplishment of a given task,

two details can be arranged to work in sequence. The above schedule is based on work equal to that of marching with a 20 pound pack at the rate of 2.5 miles per hour. Lighter work may be carried out for longer, and heavier work for shorter periods of time. During the midday period the men should rest and keep in the shade as much as possible. Peak WBGT conditions usually occur between 1200 and 1400 hours. Local and regional variations may warrant modifications of the above schedule. Acclimatization schedules for unseasoned individuals, including recruits, should be scaled down to their tolerance.

d. Adequate water must be provided during the acclimatization period as well as other times (para 5).

e. Once acclimatized, personnel will retain most of their adaptation for about one week after leaving the hot environment, but if not exposed to work at high temperatures, the acclimatization will then decrease at a variable rate, the major portion usually being lost within one month.

f. Acclimatization to a hot, dry (desert) environment increases markedly the ability of men to work in hot, moist (jungle) environments; however, for proper acclimatization to the latter, residence with regulated physical activity is required. While carefully and fully developed acclimatization to a hot, dry environment increases resistance, it does not confer complete protection against ill effects of heat, particularly moist heat.

g. Under conditions of heat stress, meals should be cool rather than hot. The heaviest meal should be served in the evening rather than at noon. An hour of rest following the noon meal is beneficial.

8. **Physical Condition.** The general physical condition of the individual has a significant bearing on the reaction to heat stress. Individual susceptibility to heat may be enhanced by a large number and variety of conditions including:

- Acute and chronic infections including the convalescent state
- Febrile conditions
- Reactions to immunizations
- Vascular diseases
- Diarrhea
- Conditions affecting sweat secretion
- Skin trauma, such as heat rash or acute sunburn
- Previous occurrence of heat stroke
- Recent use of alcohol (24-hours)
- Chronic use of diuretics
- Dehydration
- Lack of sleep
- Fatigue
- Obesity
- Poor physical condition
- Older age
- Drugs which inhibit sweating as atropine, scopolamine, antihistamines, some tranquilizers, cold medicines, and some antidiarrheal medications.

The risk of heat injury is very much higher in overweight, unfit, persons than in those of normal weight, and special care should be exercised when such persons are exposed to high temperatures. One attack of either heat stroke or severe heat exhaustion may predispose to a second. An individual once affected should therefore be exposed to subsequent heat stress with caution. Predisposition is not developed in the case of heat cramps.

9. **Work Schedules.** Work schedules must be tailored to fit the climate, the physical condition of personnel, and the military situation. Close supervision by medical officers, responsible commanders, and experienced para-medical personnel is essential in achieving maximum work output with minimum hazard. Certain general principles must be considered.

a. The amount of heat produced by the body increases directly with increasing work. Therefore, reduction of workload markedly decreases the total heat stress.

b. Workloads and/or duration of physical exertion should be less during the first days of exposure to heat and should be gradually increased to allow acclimatization (para 7).

c. While decisions to modify work schedules must be governed by the particular local situation, heavy work should be scheduled for the cooler hours of the day such as early morning or late evening.

d. Alternate work and rest periods may prove desirable. Under moderately hot conditions, 5-minute rest periods in the shade alternating with 25 minutes of work in the sun may be desirable. Under severe conditions the duration of rest periods should be increased.

e. Exposure to high temperature at night as well as in the daytime will decrease the amount of work men can perform effectively.

f. Work loads must be reduced at high temperatures when dehydration resulting from excess sweating and lack of water replacement occurs (para 5). When water is in short supply, working in the early morning and evenings will allow much more work to be accomplished for the expenditure of a given amount of water than working during the hottest hours of the day.

g. Work in the direct sun should be avoided as far as possible on hot days.

h. Unnecessary standing at attention in the heat should be avoided because continued standing places an added burden on the circulation.

i. When the temperature is excessively high, physical work should be curtailed or, under extremely severe conditions, even suspended. The temperature at which work should be curtailed or suspended depends on the humidity, radiant heat, air movement, character of the work, degree of acclimatization of personnel, and other factors. Specific guidance is given in Appendix A. Heat casualties have been observed at WBGT temperatures of 75°F (24°C) and lower. Overexertion can cause heat injury at even lower temperatures, especially if body armor or vapor impermeable protective clothing is worn.

10. Protection From the Environment.

a. Sunburn is caused by overexposure of skin to the ultraviolet radiation of the sun. Severe cases are disabling and can predispose to other forms of heat illness. The disorder is prevented through use of shelter, clothing, sun screen lotions containing para-amino benzoic acid, or its derivatives and limited sequential exposure. Fair-skinned individuals should be particularly careful although dark-skinned individuals can be similarly affected.

b. Except when exposed to the sun's rays, an individual in a hot environment is better off wearing the least allowable amount of clothing. Clothing reduces the exposure of the body surface to solar radiation, but at the same time decreases the movement of air over the skin. To take full advantage of its benefits and minimize its disadvantages, clothing should be loose fitting especially at neck, wrists and lower legs to allow circulation of air. Protection from the environment also includes such simple but frequently overlooked things as marching troops over grass rather than concrete and operating in such shade as is available.

11. Special Considerations in Recruit Training.

a. Basic trainees comprise a special group of the unseasoned personnel identified in para 7*a* that requires particular attention because of the unusual physical stresses involved in basic training in summer heat. Adjustment to this stress is difficult and must be taken into account in planning training schedules. Curtailment of work and scheduling of strenuous training activities for the coolest parts of the days will yield greater efficiency and less disruption of training than will insistence upon routine completion of a heavy schedule. Heat casualties occur most frequently during the first two weeks of basic training and during the bivouac week. They are associated especially with firing on the rifle range, squad tactical training, and retreat parades. Particular attention should be paid to decreasing the heat strain accompanying these activities.

b. Recruit heat casualties tend to occur in groups within particular units. Responsible commanders and medical officers should therefore promptly investigate each case to determine the unsafe practice or condition responsible and institute measures to prevent additional cases.

12. Special Considerations in Troop Transportation to Tropical Combat Zones.

a. Transportation of troops by ship to tropical combat zones requires two 50 minute periods of vigorous exercise daily to maintain physical fitness and to begin acclimatization to heat. The type of exercise selected should stress the cardiovascular system rather than development of muscle power, e.g., running (in place) rather than weight lifting (pushups).

b. Transportation of troops by air to tropical combat zones creates the possibility of unacclimatized troops being injected into combat situations in hot environments. All possible steps to induce heat acclimatization prior to deployment should be attempted.

13. Special Consideration in Armed Forces Industrial-Type Settings Ashore. Prevention of adverse effects of heat has been discussed relative to general military situations and the control of physical activity in military training. In addition, however, WBGT threshold values for instituting proper preventive measuring during hot weather in Armed Forces industrial-type settings ashore are given in Appendix B. The health practices described in paragraphs 4 through 10 of this

Section become particularly necessary when WBGT values are reached for the hottest two-hour period of the industrial work shift. These threshold values must not be confused with the physiological heat exposure limits (PHEL), which deal with maximum time-weighted-mean limitations on an individual's work capacity in hot environmnets.

14. Special Consideration in Hot Environments Afloat. In certain environments afloat, heat frequently exceeds man's ability to adapt. Therefore, exposure limits for high heat stress areas afloat have been established through use of the PHEL, described in detail in Navy Medical Department publication NAVMED P-5010-3, Manual of Naval Preventive Medicine. The PHEL's are maximum allowable conditions of work and WBGT levels; the PHEL concept should be applied only in cases of short-term work exposures of up to eight hours' duration. The limits presume that no prior heat injury is present and that no cumulative fatigue exists prior to reexposure. The physiologic impact of repetitive exposures to heat stress over the span of several days is the subject of scientific investigations. The PHEL concept is based upon a comprehensive set of physiologic criteria of heat tolerance that is reversible without evidence of persistant injury.

15. USAF Flying Operations.

a. USAF major heat stress problems involve personnel such as maintenance crews, air policemen, and flight crews who are routinely exposed to hot climates outdoors. Factors such as length and type of work, energy produced, and complexity of the tasks performed must be considered. Maintenance crews are more likely to work harder for a longer period of time than flight crews or air policemen; however, they will generally achieve a higher level of acclimatization. Also, the consequence of errors by aircrews makes it essential that their efficiency and alertness not be compromised.

b. An "unimpaired mental performance standard" for our flight crews (See Figure 1) must be maintained. Heat stress encountered by flying personnel occurs during preflight, engine start, taxi out, and standby for takeoff. Total ground time can be considerable even in fighter aircraft and result in a significant heat load. Additionally, the heat load experienced by the aircrew in the cockpit is more severe than on the ramp because of the reduced air velocity and the personal equipment worn. The WBGT in the cockpit may be as much as 20 degrees F (11°C) higher because of the reduction in the convective and evaporative heat loss mechanisms. Exposures such as this are usually not significant, providing takeoff is followed by a high altitude mission where the aircrew can recover in a cool environment. However, if a significant heat load is experienced during the ground time and followed by a prolonged low-level mission where the flight level ambient temperature is high, then tolerance limits should be closely calculated and monitored by the flight surgeon and flying supervisors.

c. The Fighter Index of Thermal Stress (FITS) developed at the USAF School of Aerospace Medicine by Stribley and Nunneley [SAM TR-78-6, USAFSAM (VNT)] provides a realistic guideline for insuring safe fighter operations in hot weather. The FITS chart is based in part on data (RAF and others) which relate cockpit conditions to ambient WBGT. It is assumed that aircrew metabolism is 2 to 3 times resting levels and T_{bg} exceeds T_{db} by 18 degrees F (at 10°C). WBGT is estimated from air temperature (T_{db}) and relative humidity (or dew point). The FITS is primarily designed to provide operational supervisors an easily used guide to predict when cockpit environmental conditions during low-level missions may jeopardize aircrew performance.

d. The assumptions involved in developing the FITS limit its use to men wearing the light weight flight suit in fighter type aircraft with bubble canopies. It should not be used with large multi-engine aircraft because the radiant heat loads are different than those used in this index. The index is not valid for determining exposure limits for maintenance crews and other personnel working on the flight line or outdoors (See paragraph 13).

16. Education. As noted in para. 4, prevention of heat casualties depends largely on the education of personnel exposed and especially upon supervision by informed responsible commanders. Every individual exposed to unaccustomed high temperatures should be informed of the potentially serious results of heat injury, the general nature of these conditions, and how they can be prevented. Supervisors and responsible officers must, in addition, be able to identify environmental conditions under which adverse effects of heat are likely to occur. They should recognize the earliest signs of heat injury and take appropriate action to prevent its occurrence. All personnel should be able to apply effective first aid.

Mental confusion and overactivity commonly preceds collapse from heatstroke. Supervisors must be alert to detect this condition, enforce rest, and obtain medical assistance promptly. Responsible medical officers should assist commanders in the development of local programs for heat injury prevention and continuously observe and advise in its application.

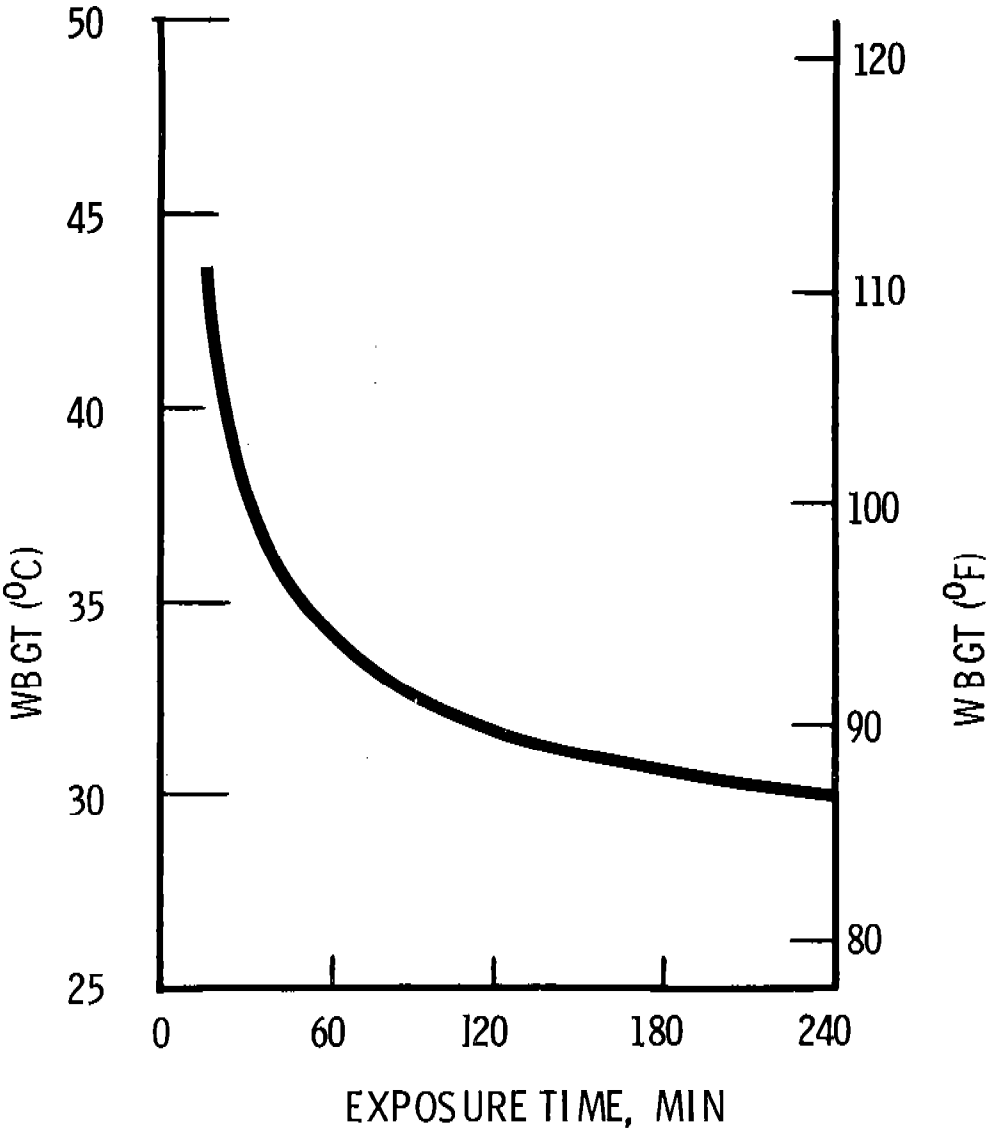


FIGURE 1. UPPER LIMITS OF EXPOSURE FOR UNIMPAIRED MENTAL PERFORMANCE

(Ref: Occupational Exposures to Hot Environments, US Department of HEW, HSM 72-10269, 1972, Page 188)

SECTION IV

DIAGNOSIS AND TREATMENT OF ADVERSE EFFECTS OF HEAT

17. General. The temperature of the human body is regulated within extremely narrow limits, although there may be marked variations in the environmental heat. The mechanisms which dissipate the major portion of body heat are discussed in Section II. As noted, three fairly distinct clinical syndromes may occur, depending upon the manner of breakdown of the individual's heat adjustment. These syndromes are heat cramps, heat exhaustion, and heat stroke. The three conditions produce distinctive signs and symptoms which should be recognized at once, not only by the medical officer but also by the line officer and other personnel, if the patient is to receive proper care and attention. All military personnel in the field should be familiar with the first-aid treatment of these conditions. Table 3 can be used to distinguish between salt and water depletion, and upon differentiation should be used as a guide for subsequent patient treatment.

Table 3. Symptoms of Salt Depletion versus Water Depletion

Item	Salt Depletion	Water Depletion
1. Duration of symptoms	3–5 days	1 day
2. Thirst	Seldom	Prominent
3. Fatigue	Prominent	Seldom
4. Cramps	Prominent	None
5. Vomiting	Prominent	Seldom
6. Weakness	Progressive	Acute

18. Heat Cramps.

a. Symptoms. Painful cramps of the voluntary muscles may occur following exposure to heat. Heat cramps result primarily from excessive loss of salt from the body. The muscles of the extremities and of the abdominal wall are usually involved and the cramps may be of great severity. Heat cramps can occur alone or in the presence of heat exhaustion. Body temperature is normal unless heat cramps are accompanied by heat exhaustion.

b. Treatment. Heat cramps are promptly relieved by replacing the salt lost from the body. Saline solution (0.1 percent) by mouth or intravenous physiological saline solution should be administered; care should be taken not to give excessive amounts of saline solution. Thus, once it is ascertained that the cramps are not transitory and minor in nature, and after small amounts of saline have been ingested, if feasible serum sodium levels should be determined to confirm the patient's electrolyte status.

19. Heat Exhaustion.

a. Symptoms and Clinical Picture. Heat exhaustion occurs as the result of peripheral vascular collapse due to excessive salt depletion and dehydration. The syndrome is characterized by profuse sweating, headache, tingling sensations in the extremities, pallor, dyspnea, palpitations associated with gastrointestinal symptoms of anorexia, and, occasionally, nausea and vomiting. Neuromuscular disturbances with trembling, weakness, and incoordination coupled with cerebral signs ranging from slight clouding of the sensorium to momentary loss of consciousness complete the classical picture. Heat cramps may be present. Physical examination reveals a mild to severe peripheral circulatory collapse with a pale, moist, cool skin and a rapid (120–200 beats/minute at rest), thready pulse. Systolic blood pressure will generally have been quite elevated (180 mm Hg or higher during work) prior to onset of the illness, followed by a rapid drop while work continued, usually reaching normal range by the time of examination. However, pulse pressure will usually remain decreased and is a clue at the time of physical examination. The oral temperature may be subnormal (as in cases where hyperventilation is present) or slightly elevated, but the rectal temperature is usually elevated. It is not uncommon to find rectal temperatures in heat exhaustion patients in the range of 99–104°F (37–40°C), depending on the type and duration of physical activity prior to overt illness. From the standpoint of pathogenesis, heat exhaustion is not one but several entities; *it can occur from physical work alone, even in the absence of dehydration or salt deficiency.* Nevertheless, in some cases, more frequently in unacclimatized personnel, water or salt deficiency is present to some degree and may be primarily responsible for the clinical picture. Unless salt deficiency has been clearly demonstrated by laboratory analysis of serum or urine, one should be suspicious of *salt loading,* if a reasonably normal diet has been maintained and supplementary salt has been taken indiscriminately.

b. Treatment. Any physical factor that promotes the return of blood to the heart will help to relieve this condition. Elevation of the patient's legs, and instituting cooling measures are indicated. This should be done in a cool place, if possible, with adequate water intake. As in the case of heat cramps, saline solutions should be administered when salt depletion is indicated from the assessed symptomatology (see Table 3), and/or has been documented by quantitation of serum electrolytes. When physical exertion preceded the onset of heat exhaustion, and a salt deficiency exists, the judicious intravenous administration of physiologic saline or 5 percent glucose and saline may accelerate recovery. Recovery is usually prompt, but immediate return to duty is inadvisable except in the mildest cases. All patients suffering an episode of severe heat exhaustion should be assigned light duty for 24–48 hours following their recovery. Should a patient experience additional bouts of severe heat exhaustion, a careful review of the medical history and working situation should be undertaken and corrective action instituted. Documentation of the heat illness should be accomplished at the earliest possible date and entered into the individual's medical record.

20. Heat Stroke (Heat Pyrexia, Sun Stroke). HEAT STROKE IS A MEDICAL EMERGENCY, with a high mortality rate.

a. Symptoms and Clinical Picture. Whereas *heat exhaustion* may be regarded as the end result of overactive heat-balance mechanisms that are still functioning, *heat stroke* results when thermoregulatory mechanisms are *not* functional, and the main avenue of heat loss (cooling by evaporation of sweat) is blocked. There may be prodromal symptoms of headache, malaise, and excessive warmth, or a general picture of heat exhaustion. The onset is usually abrupt with sudden loss of consciousness, convulsions, or delirium. Sweating may or may not be absent in the typical case. During the early stages of this condition, the temperature has become elevated, and the skin is hot, flushed, and perhaps dry; in severe cases, petechiae may be present. Deep body temperature is high, frequently in excess of 106°F (41°C). A rectal temperature exceeding 108°F (42°C) is not uncommon and indicates a poor prognosis. The pulse is full and rapid, while the systolic blood pressure may be normal or elevated and the diastolic pressure may be markedly depressed (60 mmHg or lower). Respirations are rapid and deep and simulate Kussmaul breathing. As the patient's condition worsens, cyanosis is usually noted together with a peripheral vascular collapse manifested by a rapid pulse and hypotension. The breathing becomes shallow and irregular. Pulmonary edema, incontinence, vomiting, hemorrhagic tendencies, disturbance of muscle tone, myocardial necrosis, meningismus, opisthotonos, jaundice, albuminuria, thrombocytopenia, and prolongation of the prothrombin time may occur. Renal failure with rapidly developing hyperkalemia and azotemia is not uncommon. Death may ensue very rapidly, but if the patient survives until the second day, recovery usually occurs. Rectal temperatures of 102°–103°F (39°–40°C) may persist for several days during which time mental disturbances, excitement, and delirium may continue or recur. Headache may persist for several weeks after the attack. In the first few days after the temperature has been reduced from a critical level severe relapses may occur. The patient should, therefore, be observed carefully during this period and rectal temperatures should be recorded frequently. Treatment, as outlined below, should be started again at the first indication of relapse. It is also important to emphasize that the heat regulating centers may be extremely labile for many weeks after an attack. One attack of heat stroke predisposes to a second attack, and care should be taken by the individual to avoid a second exposure to the precipitating condition. An alternative view is that the individual is a member of a susceptible population and remains susceptible.

b. Treatment.

(1) Lowering of body temperature. The lowering of the patient's body temperature as rapidly as possible is the most important objective in the treatment of heat stroke. The longer hyperpyrexia continues, the greater is the threat to life. Measures to lower the individual's body temperature should be initiated at the earliest possible moment. In the field, the patient's clothes should be removed. If there is any source of cool water or ice nearby, the patient should be immersed in cold water, otherwise water should be sprinkled over the patient and its evaporation hastened by fanning. An excellent field expedient is the use of an Indian pump to spray water on the patient while fanning with a shirt or sheet. In addition to these cooling measures, attendants should elevate the patient's legs. Arrangements should be made for the immediate removal of the individual to a hospital or properly equipped treat-

ment facility. Cooling measures should be continued during the transfer; the passage or air currents through the opened door of an ambulance will aid cooling. Upon reaching the medical facility, the patient should be placed in a tub of water and ice. After the rectal temperature reaches 100°F (about 38°C), the patient should be removed to a bed and the temperature taken every ten minutes. If the temperature tends to rise, a wet sheet should be wrapped around the body and fanning started. Cooling should be stopped if the patient starts to shiver or shows any sign of convulsions. Normal saline should be administered cautiously intravenously and the pulse, blood pressure and central venous pressure checked for evidence of circulatory collapse or overload. It is undesirable and dangerous to lower the patient's temperature initially below 100°F (38°C) (rectal), since if this is done there may be a rapid fall of body temperature to critical levels. Rectal temperature should, therefore, be checked every ten minutes during this phase of treatment. If the rectal temperature continues to fall, the patient should be warmed cautiously until his temperature is restored to normal.

(2) Drugs.

(a) Sedative Drugs. Sedative drugs act to disturb the heat regulating center and should be avoided as much as possible. Restlessness can usually be controlled with restraint of the patient. Sedatives are indicated in the treatment of convulsions. If a longer acting drug is needed, pentobarbital should be administered intramuscularly. Sodium amytal and morphine are contraindicated.

(b) Other Drugs. Atropine or other drugs which may interfere with sweating are contraindicated. Epinephrine and other adrenergic drugs should not be used. However, when hypotension occurs accompained by low cardiac output (elevated central venous pressure, congestive heart failure) isoproterenol (or dopamine) can be effective in improving cardiovascular dynamics. Intravenous administration of mannitol to induce osmotic diuresis may be useful where renal tubular necrosis is suspected. The use of aspirin is not indicated, since there is no evidence that it will lower body temperature in the noninfectious state.

(3) Fluids. Parenteral administration of physiological saline solution in moderate amounts (1,000–1,500 cc.), is indicated. However, extreme caution must be exercised if a hyperthermic state exists. Subsequent fluid administration is determined by hourly urinary output and serum electrolyte determinations. Care should be taken in the administration of parenteral fluids if there are signs of pulmonary congestion or rising central venous pressure. Close observation of the patient for renal failure is necessary. Rapidly developing hyperkalemia and azotemia necessitates hemodialysis or peritoneal dialysis.

(4) Plasma Volume Expanders. Plasma volume expanders should be administered if there is evidence of shock, especially if the patient is reasonably normothermic. A rapid pulse, of small volume, is an indication for their use. Care should be taken in the administration of plasma volume expanders if there is evidence of pulmonary congestion or rising central venous pressure.

(5) Venesection. Venesection is ineffective in treating the pulmonary edema which occurs with heat stroke.

(6) Oxygen. Oxygen should be administered by face mask or nasal catheter if cyanosis or pulmonary congestion is present. The use of a nasal catheter rather than a face mask is recommended if the patient has been vomiting, because of the danger of aspiration from the face mask.

APPENDIX A

WET BULB GLOBE TEMPERATURE (WBGT) INDEX

1. Method and Equipment.

a. The WBGT Index is computed from readings of (1) a stationary wet bulb thermometer exposed to the sun and to the prevailing wind, (2) a six inch black globe thermometer similarly exposed, and (3) a dry bulb thermometer shielded from the direct rays of the sun. All readings are taken at a location representative of the conditions to which men are exposed. The wet bulb and globe thermometers are suspended in the sun at a height of four feet above ground, as shown in Figure 1. A period of at least 20 minutes should elapse before readings are taken.

b. The wet bulb thermometer is a standard laboratory glass thermometer with its bulb covered with a wick (heavy white shoe-string). The wick dips into a flask of clean, preferably distilled, water. The mouth of the flask should be about three-fourths of an inch below the tip of the thermometer bulb. The water level in the flask should be high enough to insure thorough wetting of the wick. The water should be changed daily after rinsing out the flask and washing the wick with soap and water. To avoid erroneous readings, the water and wick must be free of salt and soap.

c. The conventional globe-thermometer apparatus consists of a six inch hollow copper sphere painted flat black on the outside and containing a thermometer with its bulb at the center of the sphere. The thermometer stem protrudes to the outside through a stopper tightly fitting into a brass tube soldered to the sphere (Fig. 2). The sphere has two small holes near the top used for suspending the sphere with wire or strong cords. The globe must be kept dull black at all times, free of dust or rain streaks, by dusting, washing, or repainting if necessary.

d. Shaded dry bulb.

e. The WBGT Index is computed as follows:

WBGT = 0.7 wet bulb temperature
+ 0.2 black globe temperature
+ 0.1 shaded dry bulb temperature

2. Use of the WBGT Index in Control of Physical Activity. The proponents of the WBGT index have proposed the following as a standard for application of the index. IT SHOULD BE EMPHASIZED that the measurements must be taken in a location which is the same as, or closely approximates, the environment to which personnel are exposed.

a. When the WBGT index reaches 78°F (26°C), extremely intense physical exertion may precipitate heat exhaustion or heat stroke; therefore, caution should be taken.

b. When the WBGT index reaches 82°F (28°C), discretion should be used in planning heavy exercise for unseasoned personnel.

c. When the WBGT index reaches 85°F (29°C), strenuous exercise such as marching at standard cadence should be suspended in unseasoned personnel during their first three weeks of training. At this temperature training activities may be continued on a reduced scale after the second week of training.

d. Outdoor classes in the sun should be avoided when the WBGT exceeds 85° (29°C).

e. When the WBGT reaches 88°F (31°C), strenuous exercise should be curtailed for all recruits and other trainees with less than 12 weeks training in hot weather. Hardened personnel, after having been acclimatized each season, can carry on limited activity at WBGT of 88°F to 90°F (31°C–32°C) for periods not exceeding six hours a day.

f. When the WBGT index is 90°F (32°C) and above, physical training and strenuous exercise should be suspended *for all personnel* (excluding essential operational commitments not for training purposes, where the risk of heat casualties may be warrented).

g. Wearing of body armor or NBC warfare protective uniforms in effect adds 10°F (6°C) to the measured WBGT. Limits should be adjusted appropriately.

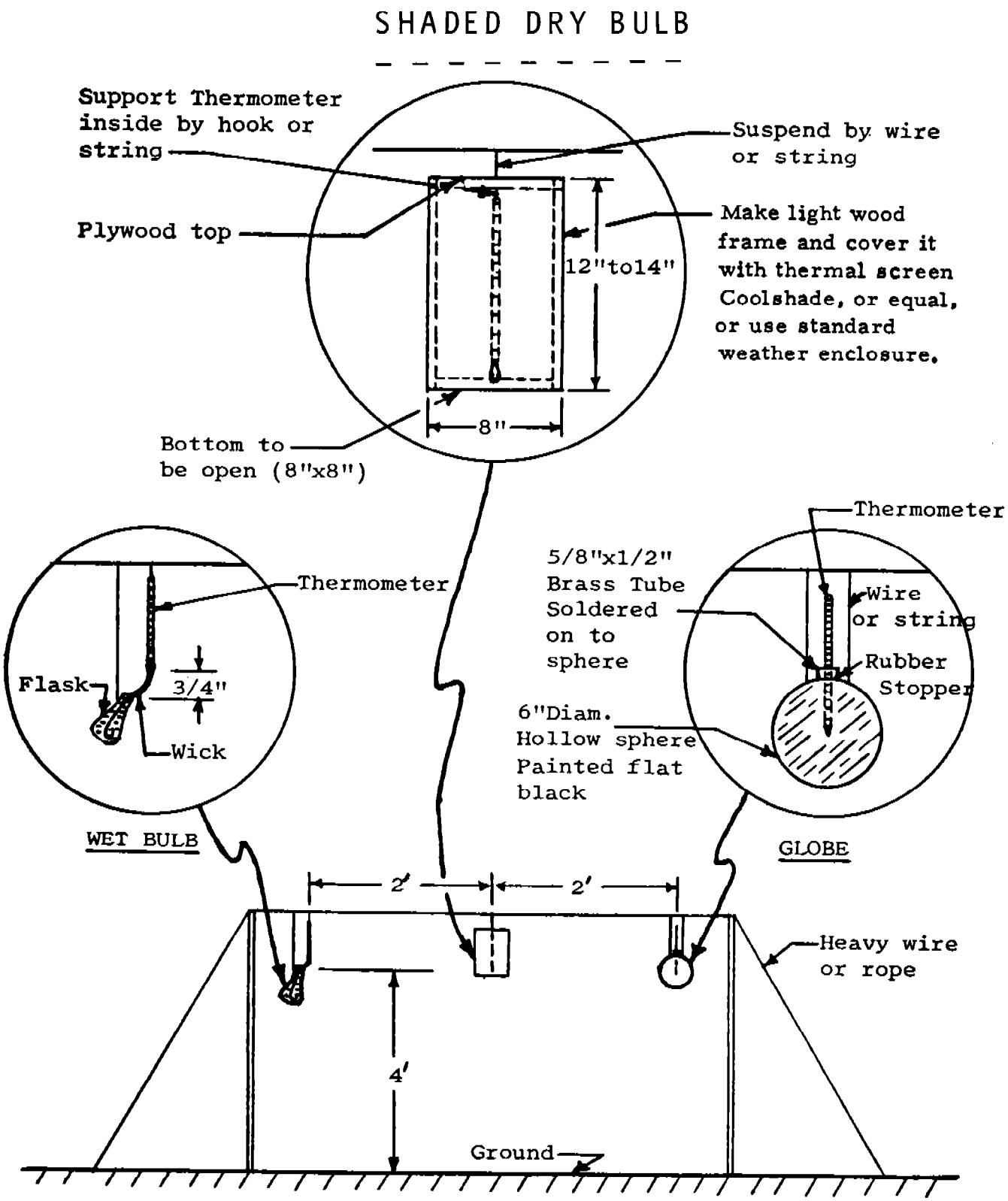


Figure 1. WBGT index field apparatus.

APPENDIX B

WBGT THRESHOLD VALUES FOR INSTITUTING PROPER PREVENTIVE MEASURES

1. *Method and Equipment.*

a. The WBGT Index is computed as given in Appendix A, using the measurements described therein. The metabolic rate of the work performed is determined from Table I. In view of personnel varying the type of work it is necessary to determine various work rates and the lengths of times for each.

Table I. Estimates of Metabolic Heart Production of Various Types of Activities (for a 154 pound; 70 kg. man). (Rest Pauses Not Included).

		Metabolic Heat Production (kcal/hr)	(Watts)
	Sleeping	63	73
	Sitting quietly	101	117
	Sitting, moderate arm and trunk movements (e.g., desk work, typing)	113–139	131–162
Light Work	Sitting, moderate arm and leg movements (e.g., playing organ, driving car in traffic)	139–164	162–191
	Standing, light work at machine or bench, mostly arms	139–164	162–191
	Sitting, heavy arm and leg movements	164–202	191–235
	Standing, light work at machine or bench, some walking about	164–189	191–220
Moderate Work	Standing, moderate work at machine or bench, some walking about	189–353	220–411
	Walking about with moderate lifting or pushing	252–353	293–411
Heavy Work	Intermittent heavy lifting, pushing, or pulling (e.g., pick and shovel work)	378–504	440–586
	Hardest sustained work	504–605	586–704

b. Time-weighted-mean metabolic rates are calculated by use of the following equation:

$$t_{wm}\ MR = \frac{(MR_1 \times t_1 + (MR_2 \times t_2) + \cdots + (MR_n \times t_n)}{t_1 + t_2 + \cdots + t_n}$$

where: t_{wm} = time-weighted-mean

MR = metabolic rate

t = time (in minutes)

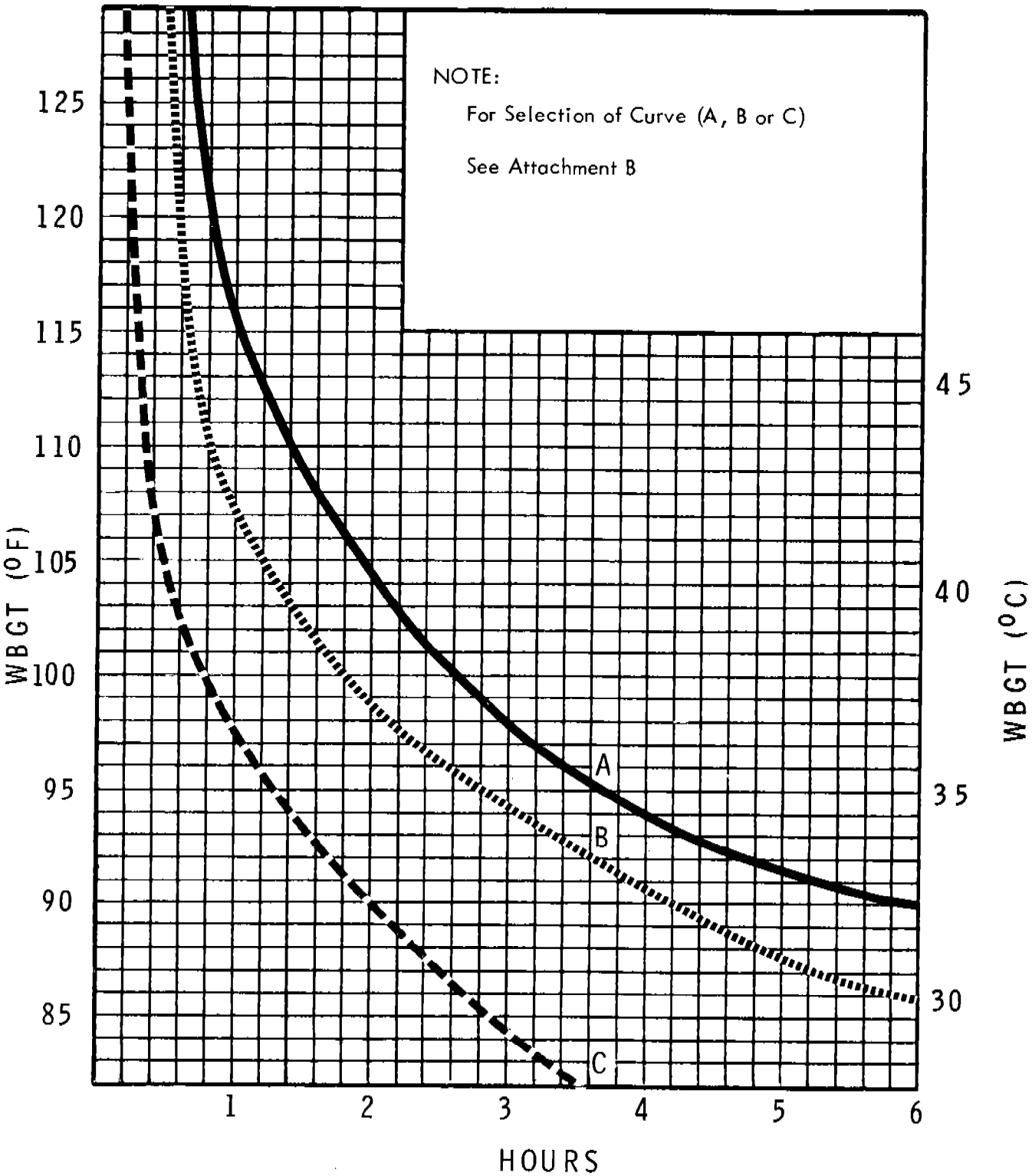
Subscripts related to the specific metabolic

c. The recommended threshold WBGT values for instituting sound hot weather practices in industrial-type settings are given below:

Work Load	Threshold 2-Hour Exposure WBGT Values	
	(°F)	(°C)
Light Work (t_{wm} MR = 152 kcal/hr *or* 177 Watts)	86	30
Moderate Work (t_{wm} MR = 192 kcal/hr *or* 223 Watts)	82	28
Heavy Work (t_{wm} MR = 232 kcal/hr *or* 270 Watts)	77	25

d. The above threshold values apply to the hottest two-hour period of the industrial work shift. When these WBGT values are reached, it is essential to have sound health practices noted in Section III in effect.

Appendix C (Attachment A) PHEL Chart



APPENDIX C (ATTACHMENT B)

PHEL CURVE GENERAL APPLICABILITY

PHEL CURVES	NON-NUCLEAR STEAM PROPELLED SHIPS	NUCLEAR POWERED SHIPS	GAS TURBINE/DIESEL PROPELLED SHIPS
A	Fireroom boiler water level checkman and engine room watches during other than heavy repair or casualty control activity.	Non-roving watches during other than heavy repair or casualty control activity.	Engineering operating watch stations during other than heavy repair or casualty control activity.
B	Fire room and engine room watch supervisors during roving inspection of space.	Roving watches.	Lower and upper level watch standers during other than heavy repair or casualty control functions.
		Personnel performing maintenance or repairs requiring moderate exertion.	
	Fire room burnerman during other than casualty control functions.	Laundry personnel.	Messenger during other than full power conditions or continuous mobility.
	Fire room and engine room messengers during other than full power conditions or when continuous mobility is not required.		Laundry personnel.
	Laundry personnel.		
C	Any personnel involved in heavy repair work or casualty control functions.	Any personnel involved in heavy repair work or casualty control functions.	Any personnel involved in heavy repair work or casualty control functions.
	Fire room and engine room messengers during full power operation or other activities requiring continuous mobility.		Messengers during full power operation or activities requiring continuous mobility.

Note: Use PHEL Curve "V" from Fig. 3-5 of NAVMED P-5010-3 for all scullery personnel.

APPENDIX D

PREPARATION OF 0.1 PERCENT SALT SOLUTION

A solution of 0.1 percent table salt in drinking water may be prepared by one of the following general methods:

a. Adding table salt directly to the drinking water (Table I).

Table I

Table Salt	Diluting Water
2 ten-grain salt tablets*—dissolved in	1 quart canteen
4 ten-grain salt tablets*—dissolved in	2 quart canteen
1½ level mess kit spoons—dissolved in	5-gallon can
9 level mess kit spoons—dissolved in	Lyster bag
1 level canteen cup—dissolved in	250-gallon water trailer

* Salt tablets should be crushed before attempting to dissolve them.

b. Preparing a saturated salt solution (approximately 26 percent) and adding specific quantities of the saturated solution to the drinking water (Table II).

Table II

Saturated Salt Solution*	Diluting Water
⅛ canteen cap (1 qt size) added to	1 quart canteen
¼ canteen cap (2 qt size) added to	2 quart canteen
1 mess kit spoon added to	Gallon
5 mess kit spoons added to	5-gallon can
½ canteen cup added to	Lyster bag
4 canteen cups added to	250-gallon water trailer

* To prepare a saturated salt solution, dissolve nine level mess kit spoons of table salt in ⅔ of a canteen cup of water.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1988-554-030/85039