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This document provides background information on the physiological effects of extreme cold on the human body. A brief overview of some of the physiological problems of operation in a cold environment and the procedures used to overcome these problems are provided along with the detailed techniques and requirements for tests involving the effects of a cold environment on personnel.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-100
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AD No.

ARCTIC PERSONNEL EFFECTS

1. PURPOSE AND SCOPE. This document provides background information on the physiological effects of extreme cold on the human body. A brief overview of some of the physiological problems of operation in a cold environment and the procedures used to overcome these problems are provided along with the detailed techniques and requirements for tests involving the effects of a cold environment on personnel. The word "man", "men", and "he" when used in this document, represents both men and women unless otherwise stated.

2. BASIC INFORMATION. Test personnel must be aware of the effects of extreme cold on personnel to safely and completely test military equipment in the arctic. This document discusses the problems normally encountered by personnel in extreme cold. The information test personnel need concerning the symptoms, methods of prevention, and treatment of various types of cold injury is provided at paragraphs 4.2b and 4.2c. Detailed information on the physiological processes and accommodations required to solve these problems, and the techniques by which they can be evaluated under field conditions are discussed at paragraphs 5 and 6.

3. TECHNICAL PRESENTATION

3.1 General. Accommodation to the environment is required of all men. This requires psychological adjustments, and not all men are equally suited to the requirement. Men with medical histories of upper respiratory tract disease, emotional disturbances, rheumatoid disease, and defective vision are more likely to become casualties to rigorous exposure. However, it is not essential that man be warm to be effective, as the absence of complete comfort can induce increased effort. Neither is it essential that man have a certain number of hot meals each day. The normal human body will remain effective as long as the caloric and fluid intake and dissipation are reasonably matched, nitrogen balance is maintained, and the body is not subjected to destructive influence.

4. COLD EFFECTS

4.1 General. In intense cold a man may become intellectually numb, neglecting essential tasks. In addition, the essential tasks require more time and effort to achieve. Under some conditions (particularly cold water immersion) a man in excellent physical condition may die in a matter of minutes.

4.2 Hypothermia. Hypothermia is a term used to describe general lowering of body temperature due to loss of heat at a rate faster than it can be produced. Frostbite may occur without hypothermia when extremities do not receive sufficient heat from central body stores due to inadequate circulation and/or inadequate insulation. However, both conditions, hypothermia and frostbite, may occur in the same case if exposure is to below freezing temperatures as in the case of an avalanche accident. Hypothermia may also occur from exposure to temperatures above freezing, especially from immersion in cold water or from the effect of wind. Physical exhaustion and insufficient food may raise the risk of hypothermia, as has occurred when inexperienced and ill-equipped hikers have been caught in mountain storms. Exposure to wet-cold conditions has also led to hypothermia in cave explorers. Aviators downed in cold water, and boating accidents in northern waters are other examples of situations in which hypothermia is a risk. Intemperate use of alcohol leading to unconsciousness in a cold environment is still another condition which can result in hypothermia.

a. Dangers of hypothermia. As central body temperature falls from the normal level of 37°C (98.6°F), various body processes are slowed. Circulation of blood is retarded, movements become sluggish, coordination is reduced, and judgment becomes impaired. With further cooling unconsciousness results. At a deep body temperature below 29°C (85°F), there is increased risk of disorganized heart action or heart standstill which results in sudden death.

b. Prevention. Prevention of hypothermia consists of all actions which will avoid rapid and uncontrolled loss of body heat. Divers, boaters, and aviators operating in cold regions must be equipped with protective gear such as immersion suits and liferafts with spray covers. Ice thickness must be tested before river or lake crossings. Anyone departing a fixed base by aircraft, ground vehicle, or on foot must carry sufficient protective clothing and food reserves to allow survival during unexpected weather changes or other unforeseen emergencies. Traveling alone is never safe. Expected itinerary and arrival time should be left with responsible parties before any departure of base in severe weather. All persons living in cold regions should become skilled in the construction of expedient shelters from available materials. The excellent heat insulating qualities of snow should be emphasized.

c. Treatment.

(1) The objective of treatment is to rewarm the body evenly and without delay, but not so rapidly as to further disorganize body functions such as circulation. A person suspected of hypothermia should be immediately moved to a warm enclosure. A useful procedure in case of accidental breakthrough into ice water, or other hypothermia accident, is to immediately strip the victim of wet clothing and bundle him into a sleeping bag with a warm companion whose body heat will aid in rewarming. Mouth-to-mouth resuscitation should be started at once if the victim's breathing has stopped or is not regular and of normal depth. Warm liquids may be given gradually to a conscious patient, but must not be forced on an unconscious or stuporous person for fear of strangulation.

(2) If movement is necessary, the hypothermia patient should be handled on a litter since the exertion of walking may aggravate circulation problems.

(3) Be alert for the onset of rewarming shock. A medical officer is needed without delay to attend any serious hypothermia patient, since this condition is life-threatening until normal body temperature has been restored. Immersion of a hypothermia patient in a warm water bath is a rapid means of restoring body temperature, but since this rapid rewarming may aggravate heart and circulation problems temporarily, this procedure should only be done with medical officer in attendance.

4.3 Windchill. Frostbite can occur even in relatively warm temperatures if the wind penetrates the layer of insulating warm air to expose body tissue. As an example, with the wind calm and a temperature of -29°C (-20°F), there is little danger from windchill. However, if the temperature is -29°C (-20°F), there is a wind of 10 m/s (20 kts), the equivalent chill temperature is -59°C (-75°F). Under these conditions there is great danger and exposed flesh may freeze within 30 seconds.

ESTIMATED WIND SPEED	ACTUAL THERMOMETER READINGING (F°)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	EQUIVALENT CHILL TEMPERATURE (F°)											
CALM	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-24	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-21	-35	-51	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
WIND SPEED GREATER THAN 40MPH HAVE LITTLE ADDITIONAL EFFECT	LITTLE DANGER Under 5 hours with dry skin Maximum danger of false sense of security				INCREASE DANGER Flesh may freeze within 1 min.			GREAT DANGER Flesh may freeze within 30 seconds				
	DANGER FROM FREEZING OF EXPOSED SKIN											
IMERSION FOOT (TRENCHFOOT) MAY OCCUR AT ANY POINT ON THIS CHART												

WIND CHILL CHART

4.4 Frostbite is the freezing of some part of the body by exposure to temperatures below freezing. It is a constant hazard in operations performed at freezing temperatures, especially when the wind is strong. Usually, there is an uncomfortable sensation of coldness followed by numbness. There may be a tingling, stinging, or aching sensation, even a cramping pain. The skin initially turns red. Later it becomes pale gray or waxy white. For all practical purposes frostbite may be classified as superficial or deep. Treatment and management are based solely upon this classification.

a. It is easier to prevent frostbite, or stop it in its very early stages, than to thaw and take care of badly frozen flesh. Clothing and equipment must be fitted and worn so as to avoid interference with circulation. To prevent severe frostbite:

(1) Sufficient clothing must be worn for protection against cold and wind. The face must be protected in high wind, and when exposed to aircraft prop blast.

(2) Every effort must be made to keep clothing and body as dry as possible. This includes avoidance of perspiring. For heavy work in the cold, remove outer layers as needed, and replace as soon as work is stopped. Socks should be changed as needed whenever the feet become moist, either from perspiration or other sources.

(3) Any interference with the circulation of the blood reduces the amount of heat delivered to the extremities. All clothing and equipment must be properly fitted and worn to avoid interference with the circulation. Tight fitting socks, shoes, and handwear are especially dangerous in very cold climates.

(4) Cold metal should not be touched with the bare skin in extreme low temperatures. To do so could mean loss of skin.

(5) Adequate clothing and shelter must be provided during periods of inactivity.

(6) The face, fingers, and toes should be exercised from time to time to keep them warm and to detect any numb or hard areas. The ears should be massaged from time to time with the hands for the same purpose.

(7) The buddy system should always be used. Men should pair off and watch each other closely for signs of frostbite and for mutual aid if frostbite occurs. Any small frozen spots should be thawed immediately, using bare hands or other sources of body heat.

b. Some cases of frostbite may be superficial, involving the skin. But if freezing extends to a depth below the skin it constitutes a much more serious situation, demanding radically different treatment to avoid or minimize the loss of the part (fingers, toes, hand, feet). If a part of the body becomes frostbitten it appears yellowish or whitish gray. Frequently there is no pain, so keep watching one another's face and hands for signs. The face, hands, and feet are the parts most frequently frostbitten. The problem is to distinguish between superficial and deep frostbite. This can usually be told with respect to the face. The hands and feet are a different matter. A person may be able to judge by remembering how long the part has been without sensation. If the time was very short, the frostbite is probably superficial. Otherwise assume the injury to be deep and therefore serious.

c. For treatment of superficial frostbite in the field:

(1) Cover the cheeks with warm hands until pain returns.

(2) Place uncovered superficially frostbitten fingers under the opposing armpits, next to the skin.

(3) Place bared, superficially frostbitten feet under the clothing against the belly of a companion.

(4) Do not rewarm by such measures as massage, exposure to open fires, cold water soaks, rubbing with snow.

(5) Be prepared for pain when thawing occurs.

d. In treatment of deep frostbite (freezing injury) the following measures must be taken: If freezing is believed to be deep, do not attempt to treat it in the field. Get to a hospital or aid station by the fastest means possible. If transportation is available, avoid walking. Protect the frozen part from additional injury but do not attempt to thaw it out by rubbing, bending, or massage. Do not rub with snow; do not place in either cold or warm water; do not expose to hot air or open fires; do not use ointment or poultices. Thawing in the field increases pain and invites infection, greater damage, and gangrene. There is less danger of walking on feet while frozen than after thawing. Thawing may occur spontaneously, however, during transportation to a medical facility. This can not readily be avoided since the body in general must be kept warm. In many cases, thawing under supervision of doctors experienced in cold regions treatment will preclude amputation of frostbitten member.

4.5 Snow Blindness. Snow blindness occurs when the sun is shining brightly on an expanse of snow, and is due to the reflection of ultraviolet rays. It is particularly likely to occur after a fall of new snow, even when the rays of the sun are partially obscured by a light mist or fog. The risk is also increased at high altitudes. In most cases, snow blindness is due to negligence or failure on the part of the soldier to use his sunglasses. Waiting for discomfort to develop before putting on glasses is folly. A deep burn of the eyes may already have occurred by the time any pain is felt. Putting on the glasses then is essential to prevent further injury but the damage has already been done. Symptoms of snow blindness are a sensation of grit in the eyes with pain in and over the eyes made worse by eyeball movement, watering, redness, headache, and increased pain on exposure to light. First aid measures consist of blindfolding, which stops the painful eye movement, or covering the eyes with a damp cloth, which accomplishes the same thing. Rest is desirable. If further exposure to light is unavoidable, the eyes should be protected with dark bandages or the darkest available glasses. The condition heals in a few days without permanent damage once unprotected exposure to sunlight is stopped.

5. HUMAN EFFECTS

5.1 Human performance and survival in the cold ultimately depends on the maintenance of thermal balance. Men exposed to cold can lose heat from the body at a greater rate than they can produce it, whether at rest or at work. The heat content of any physical body, including the human body, can be calculated using such simple physical considerations as the mass (M in kilograms) and the specific heat of the tissue (c_p in kcal/kg°C, where a specific heat of one is the number of calories required to raise a mass kilogram of water 1°C). Thus, for an average man of 70 kg (154 lbs) the heat content can be calculated by multiplying this mass times 0.83, the specific heat for average human tissue, yielding a value of 58 kcal/°C of mean mass temperature. Taking 0°C (32°F) as an arbitrary reference level, then one can calculate the mean body temperature for the mass of the body by considering the body as divided into two compartments, a core and a shell with the core representing roughly one-third of the mass in a comfortable condition. With a typical core temperature of 37°C (98.6°F rectal temperature) and a shell or skin temperature of about 34°C (93°F) in a comfortable condition the calculated average temperature (T_A) for the total mass of body is 35°C. The heat content (H_C) can be calculated as outlined above by the following equation:

$$H_C = 0.83 \times M \times T_A \qquad (1)$$

Thus, the body has a heat content of approximately 2100 kcal and a change of 58 kilocalories for this average 70 kg soldier, represents a change in mean body temperature of about 1°C.

5.2 Subject discomfort is reported by such a standard 70 kg individual when a heat debt of 140 kcal is incurred; this represents about 7 percent of his total heat content and can occur for a resting subject after about 3 hours at -18°C (0°F), wearing the full arctic uniform, or in about 2 hours at 4°C (40°F) wearing ordinary winter clothing. A sleeping individual will awake after losing about 75 kcal, typically distributed as a fall in mean skin temperature (T_s) of about 3.1C° (5.5F°) and a fall in deep body temperature (T_{re}) of about 0.5C° (0.9F°).

5.3 A fall in deep body temperature below 35°C (95°F) threatens loss of control of body temperature regulation, while a temperature of 28°C (82°F) is considered critical for survival, despite recorded survival from a deep body temperature of 18°C (65°F). Rates of fall or core temperature of 3C° (5.5F°) per hour have been observed in subjects immersed in 10°C (50°F) water without residual ill effects.

5.4 In the cold, skin temperatures vary widely over the body with the temperatures on the central torso being considerably warmer than those further out on the extremities. In order to calculate a truly average mean skin temperature for the surface of the body, the temperatures of the various sections are multiplied by weighting coefficients representative of the percentage of the total body surface area a given temperature represents. Thus, for example, a forehead temperature is taken as 10 percent (i.e., T forehead x 0.10) to signify that the forehead temperature is taken as an average temperature for 10 percent of the total body surface area. The mean temperature so arrived at for the total body is called "mean weighted skin temperature" or "mean skin temperature." When calculating mean skin temperature, a good rule to follow is forehead 10 percent, torso 70 percent, and thigh 20 percent.

5.5 A mean skin temperature of 33°C (92°F) is "comfortable", 31°C (88°F) is "uncomfortably cold", 30°C (86°F) is "shivering cold", and 29°C (84°F) is "extremely cold"; the critical subjective skin temperature tolerance limit appears to be about 25°C (77°F). While mean skin temperature can thus be important, it is more frequently the temperature of the extremities that is critical in the cold since one of the first responses to cold exposure is a reduction of blood flow to the skin (vasoconstriction) which drastically reduces circulatory heat input to the hands and feet. A skin temperature of 20°C (69°F) for the hand is reported as "uncomfortably cold", 15°C (59°F) as "extremely cold", and 4°C (40°F) as "painful", with identical reports for the foot occuring at 3C° (5F°) warmer temperatures for each response. Subjective comfort aside, from a practical standpoint -34°C to -46°C (-30°F to -50°F) is probably the lower limit for efficient outdoor operations. At -51°C (-60°F) many kinds of outdoor activities become exceedingly difficult, although with appropriate equipment and good training and leadership, reasonable periods of exposure are possible; however, the risk of freezing and loss of toes, fingers, and even life itself is high if anything goes wrong. Nevertheless, exposures outdoors at -100°F have occurred in the Antarctic without injury.

5.6 When, during rest, vasoconstriction per se is insufficient to reduce heat loss from the body to about the same level as the body's heat production, a second automatic body defense is shivering, triggered by either a low deep body temperature, a low skin temperature, a rapid change of skin temperature, or by some combination of these three. Perhaps preceded by an inperceptible increase in muscle tension and by the noticeable "goose flesh" produced by the constriction and small muscles which erect the hair (thus increasing the insulation effectively in more heavily furred mammals) shivering begins slowly and locally, resulting initially in a heat production 1½ to 2 times resting levels. Additional body areas are recruited until violent, whole body shivering, resulting in a maximum shivering heat production approaching 425 kcal/hr, renders the individual totally ineffective.

5.7 Man may "accustomize", i.e., learn how to survive, in cold environments. Given sufficient cold exposure, man also undergoes changes in his body indicating "acclimatization." Among these changes are a higher comfort sensation as a result of maintenance of greater skin blood flow in general, a reduction in risk of cold injury associated with improved circulatory regulation of heat input (blood flow) to the extremities, and physiologic mechanisms involving endocrine changes (notably sensitivity to norepinephrine) which allow "non-shivering," (metabolic increased) heat production; however, these physiological changes in man are generally small and require repeated, uncomfortably cold exposures to induce them. Thus, such factors as accustomization, training, experience, and provision of adequate protective clothing are much more useful and important.

5.8 The nutritional requirements of adequately clothed men in extreme cold are not appreciably different from that of men living in a comfortable climate. The difference observed is accounted for by the added work caused by these factors: (1) Carrying the weight of the heavy clothing, since energy cost is a linear function of total weight (particularly the heavy protective footwear). (2) The inefficiency of walking in the snow which increases energy costs by 15 percent. Note, however, that these two requirements for increased calories only apply to men working outdoors. On the other hand, nude or inadequately clothed men exposed to cold at rest cannot tolerate caloric deficits as well as men with adequate protection, and appear to be particularly susceptible even to mild cold injury (e.g., chillblains of the feet) when protein deficiency accompanies overall caloric inadequacy.

5.9 The solution to exposures to low temperature is either maintaining a high heat production by activity, or reducing heat loss by clothing. Note that clothing only reduces the rate of heat loss and thus merely extends "stay time." No conventional clothing can provide enough insulation for indefinite exposure at rest at even -4°C (25°F). There is no magic insulating material; insulation is primarily a function of clothing thickness and indeed, the thickness of the trapped or bulkier and lighter the clothing, the better. Spot radiant heating or "showers" of hot air if the individual is at a fixed worksite, or by provision of auxiliary heated clothing is the only way to ensure warmth.

5.10 The usual problem in the cold is not protecting the torso, but the extremities which as thin cylinders, are particularly susceptible to heat loss and are difficult to insulate without a dramatic increase in the surface area available for heat loss; the extremities are also particularly prone to vasoconstriction which reduces their circulatory heat input by more than 90 percent. Protection for the respiratory tract appears to be unnecessary in healthy individuals even at -46°C (-50°F), although asthmatics or individuals with even mild cardiovascular problems may benefit from a rewarming respiratory mask. Face masks are generally unnecessary since circulatory heat to the face is not reduced by vasoconstriction; however, if there is a high wind (windchill level above 1400) there is a risk of freezing cold injury to exposed skin. With good torso clothing, a parka with a fur lined hood to minimize penetration to the face and 10 watts of auxiliary heat to each hand and foot, inactive men have remained, without difficulty, at -54°C (-65°F) with a 10mph wind for more than 6 hours. As long as their finger skin temperature was maintained above 16°C (60°F) to maintain manual dexterity, such men could perform work without difficulty except from the loss of mobility and manual dexterity from wearing the protective clothing *per se*.

6. TEMPERATURE MEASUREMENT.

6.1 Aside from the conventional mercury or alcohol-in-glass thermometer, temperatures in the laboratory or field are usually measured using thermocouples or thermistor sensors. The preferred sensor for a given application depends on a number of factors, among which are cost, the accuracy and range of measurement that are required, the number of variables to be measured and the desired simplicity of the measuring system.

6.2 Thermocouples are voltage generating devices produced by joining the ends of two wires, metals or alloys. Several standard combinations of metals are in general usage, each with a specific curve of voltage output versus temperature, and each designed for a specified temperature range.

Millivolt versus temperature tables for each type of thermocouple are available from the wire and instrument manufacturers. The copper-constantan thermocouple, designated as type T, is most commonly used for measurements in the normal environmental range and for physiological temperature. Its change in voltage per degree is relatively high (about 40 microvolts per degree C), the wire is inexpensive and easily formed into a thermocouple, and its calibration is quite stable in normal or mildly corrosive atmospheres. Accuracy of type T thermocouples is within ± 0.3°C. The limit of error does not include errors introduced by measuring instruments or calibration shifts due to faulty interconnecting wiring between the thermocouple and measuring device. A measuring system accuracy better than 0.2°C can generally not be expected unless the entire system is calibrated onsite using a controlled water bath and precision thermometer. Properly constructed thermocouples show little drift with time and require only infrequent calibration to insure maximum accuracy.

a. Thermocouples for physiological use are generally constructed of no. 30 AWG or finer wire to permit intimate contact with the skin and to obtain rapid response to change. If larger wire is used for surface measurements, the thermocouple may extend into and be influenced by the microclimate overlying the measurement site. This restriction usually does not apply where the thermocouple is used in an internal body cavity, as in the rectum. A no. 30 AWG couple also reduces the likelihood that heat will be conducted toward or away from the junction if the leads are not the same temperature; nevertheless, it is good practice to avoid large temperature changes along the wires for several inches from the junction. Ideally, the thermocouple should be formed by butt welding the wires together; however, satisfactory results can be obtained by twisting the ends of the wires together, or by overlapping the ends of the two wires and soldering them. The latter method is recommended for making skin thermocouples. After soldering the junction, the leads are twisted together for 3 to 4 inches except for a 1-inch diameter loop at the junction. These leads are then connected to larger extension wires of no. 22 AWG copper and constantan. This type of couple can be held in close contact with the skin using elastic threads tied on either side of the junction. The threads are simply passed around any body section of limb like a belt, pulled taut, and tied with a bow.

b. Measuring instruments for thermocouples include precision manually balanced potentiometers reading in microvolts; small battery operated indicators which, when balanced, read either the thermocouple voltage or the actual temperature; automatic direct reading meters; and finally, self-balancing electronic single and multipoint temperature indicators and recorders. The choice depends largely on the accuracy required and whether or not power is available. The smaller battery operated portables are most useful in the field but their accuracy is limited to about 1°C (2°F); these devices have recently been improved by using transistor amplification in the unbalanced detector (formerly a galvanometer) needed for adjusting the instrument. These portable instruments all contain a standard reference cell which must be protected against freezing. If power is available, an electronic indicator or recorder is preferable; the precision of balancing is far better than if done manually, the reference cell has been replaced with an electronic circuit, and high gain amplifiers permit use of much narrower ranges than in an indicator. The limit of error for a recorder is usually about 0.3 percent of span (0.1°C for a 25-degree span). These recorders, and some portables, provide automatic temperature compensation, i.e., electrically correct for the effect of the second thermocouple formed where the constantan wire from the sensor joins the copper wire in the instrument. If such compensation is not provided, the constantan wire must be joined with a copper wire from the instrument in a bath of melting ice at 0°C or an electrical icepoint reference system to eliminate the junction EMF. Either method is more accurate than electronic compensation and is used with all high precision potentiometers.

c. Direct reading sensitive microammeters which respond to the thermocouple output are also available for temperature measurement. These are more frequently used for commercial applications than in research. They are simple to install but are usually limited in accuracy. These meters are calibrated to correct for the voltage drop caused by current flowing through the thermocouple leads, and must be used with a specified external (thermocouple plus extension wire) resistance. Potentiometric type instruments of the types described earlier do not impose this limitation since there is no current flow in the thermocouple circuit when the instrument is balanced; the potentiometer then produces an output voltage which is equal and opposite to that generated by the thermocouple.

6.3 Thermistors.

a. Thermistors are temperature sensitive resistors with a high (4 to 5 percent per degree C) temperature coefficient of resistance. They are available in many shapes (washers, disks, rods, beads) and also as complete probes (tubular, banjo, rectal, hypodermic needle). Several manufacturers make and market interchangeable probes with precise resistance temperature characteristics and excellent long term stability. Many of these are relatively inexpensive. Various types of lightweight, battery powered temperature indicators are available. Most are quite simple to operate. The better units are quite accurate and have sensitivities of 0.1 percent of range or better. Indicators with spans of 10°C (18°F) or less as well as wide range and multiple range instruments are available. System accuracies (including probe) of 2 percent of range can be obtained routinely; much better accuracy is possible with calibrated probes and careful indicator adjustment. Thermistor systems are therefore the measuring devices of choice for accurate field measurements (such as in the measurement of rectal temperature).

b. Other than indicators with manually switched probe inputs, multipoint indicators and recorders for thermistors are not available, although many special measuring systems have been designed. Long term stability of thermistors has only recently become a reality and recorder manufacturers have therefore been slow to market standard recorders with the required circuits for thermistors (although units for wire-type resistance units have long been available); however, a system for recording temperatures from thermistors is simple to design if an indicator is available; the recorder output of the indicator is simply connected into a standard millivolt recorder, and probe temperature determined using either a conversion chart or a special recorder scale and chart based on the temperature range and output voltage characteristics of the indicator. Details of such applications are given later.

c. Since thermistors have high temperature coefficients, the scale on the conventional temperature indicator is usually somewhat nonlinear. This normally is not a disadvantage unless temperature is being measured at the compressed end of the scale. One manufacturer, using an array of thermistors and resistors, has developed extremely linear measuring system for the research laboratory market; however, these systems and probes are thermistor systems and their use should be considered only for a special applications where extreme precision is required.

6.4 Since neither type of sensor is ideal for all applications, an intelligent choice requires knowledge of the basic features of each type. The thermocouple is inexpensive compared with the thermistor and is usually the logical choice where a large number of elements is required, such as in measuring multiple skin temperatures on a number of subjects. Thermocouples are, in addition, much smaller than thermistor elements except for bead types which are expensive, fragile, and generally not interchangeable. As noted earlier, small size is a definite requirement for surface temperature measurements, particularly where air motion is high and the temperature difference between the surface and air is large. Skin temperatures under clothing have been measured with thermistors at some laboratories but the practice is not recommended unless some margin for error is acceptable. Thermocouples are also relatively stable with little tendency to change calibration under normal use; with correctly manufactured and calibrated wire, their voltage-temperature relationships are quite consistent, thus insuring reasonable accuracy insofar as the sensor is concerned. This does not guarantee accurate temperature measurement even with a correctly calibrated instrument. Several possibilities for error are introduced because of the low voltage signal of a thermocouple which must be recognized and avoided; errors as large as 2 to 3 degrees C. have been seen where proper precautions were not taken. Spurious error producing EMF's can be introduced in the measuring circuit by (1) thermal gradient switches, (2) foreign metals in the thermocouple circuit, particularly where temperature changes occur along the wire, and (3) by corroded connections produced by use of acid fluxes in soldering. The use of foreign metals is not likely to cause errors but the chance can be minimized by (1) avoiding the use of connectors in the extension leads, or using special types made of the same metal as the wires, (2) using no soldered joints, and (3) insuring that no connector or splice is within 3 meters (10 feet) of a sharp thermal gradient in the wire (such as would occur in passing a cable through a wall from a heated building to a cold outside environment). Stray electrical fields around thermocouple leads usually do not affect calibration since the wires form a low-resistance path for any induced error signals; there are a-c signals, which do not, in themselves, affect the balance point of the potentiometers; however, they are occasionally strong enough to bypass the filters in the measuring circuits of electronic recorders, and overload the amplifier causing insensitivity, motor stall, and generally erratic behavior. These problems may usually be overcome by proper instrument or thermocouple ground, or by adding special filters suggested by the instrument manufacturer. The remaining disadvantage of thermocouples is that portable temperature indicators appropriate for field use are usually wide range (over 50°C) instruments which cannot be read with a precision of much better than 0.5°C even if a sensitive detector and extreme care in balancing the instrument is employed. The larger portables are more satisfactory, especially those calibrated in millivolts, but these are heavy and require adjustment of several dials to obtain a reading. Those with transistorized detectors are far more satisfactory than those employing light beam galvanometers or d'arsonval type meter movements, which have marginal sensitivity.

a. Thermistor sensors have many features which make them preferable to thermocouples despite their higher cost and larger size. Most of these advantages arise because the voltages in thermistor circuits and the change in output per degree are 1000 or more times as great as with a thermocouple. As a result, extreme sensitivity is not required of the detector and small contact potentials caused by dissimilar metals, heating of switches, etc. are relatively unimportant. Only copper wire is used in the circuit, hence there is no need for compensation for thermocouple effects where the leads enter the instrument. Of course, since the thermistor is a resistance element, spurious resistance introduced in the leads and at connectors must be kept within acceptable limits or accounted for by adjusting the calibration of the indicator. As an example, the resistance of a popular type of interchangeable thermistor changes by about 70 ohms per degree at skin temperature. If the error from spurious resistance is to be limited to 0.05 degrees C, the resistance of leads, etc. must not exceed 3 to 4 ohms. With tight connections, this means that 150 meters of no. 16 AWG wire or 30 meters of no. 22 AWG wire could be used. A further advantage of thermistors, particularly in field work, is the extreme simplicity of the temperature indicator. Small, lightweight, automatically indicating indicators are available which require no adjustment except for occasional checks of the supply voltage using the meter on the device; these units can be designed to cover any specified range, with spans as small as 5°C and accuracies of better than 1 percent of span. Most of these indicators have an output for recording with a potentiometeric type millivoltmeter. Procedures for utilizing this output are described later.

b. Thermistors lack the flexibility of application that thermocouples possess, although this limitation may not be a disadvantage for most users. Several thermocouples may be wired in series to measure temperature difference. These techniques cannot be employed with thermistors (although temperature difference can be measured with a special, rather complex instrument).

6.5 Specialized Thermocouple and Thermistor Circuits

Many modifications of standard thermocouple and thermistors circuits have been made locally to meet special temperature measuring requirements. These will be described in detail where possible; exact values of added circuit components, where required, will of course depend on the characteristics of the instrument being modified.

a. Simplified Wiring for Multiple Thermocouple Applications

In cases where temperature readings are taken at several adjacent sites, it is convenient to common all of the constantan leads from the couples and use one lead to the indicator or recorder, in addition to a separate copper wire for each thermocouple. This is done to: (a) reduce the weight and bulk of the wiring, as in the measurement of multiple skin bites on a human subject; (b) allow use of commercial multiconductor cable plus a single constantan rather than special single twin-lead thermocouple wire; and (c) avoid switching constantan wires at the instrument; the common is brought directly to the negative input of the measuring circuit, thus eliminating the possibility of thermal EMF's at switch contacts, and possible errors introduced by connecting the constantan circuits to the (-) terminal through copper wires or busbars, switches with plated contacts, and then more copper wires. Similar problems do not arise in switching the individual copper leads at the recorder, since there is practically no thermocouple effect (EMF) at copper to brass junctions. The only restriction to use of common constantan is that each thermocouple must be insulated from the others; if they are not, the common places all thermocouples in parallel, and each will indicate an average temperature of all couples. Slight leakage paths such as would exist between thermocouples placed on human skin, especially when wet, can be tolerated since these paths have much higher resistance than the thermocouple circuits and thus cause little interaction of readings.

b. Measuring the Average Temperature of Two or More Thermocouples

In certain cases, it is desirable to measure an average temperature rather than individual values. This can be accomplished automatically by connecting all the copper leads to one common return and all the constantan leads to another. The average will be an arithmetic mean of all temperatures if all the thermocouple circuits have the same resistance between one common and the other. The common connections may be made near the junctions or at the measuring instrument. If a weighted mean average is desired (for example, a weighted mean from temperatures at several skin sites) the required weighting can be obtained by adjusting the resistance of each circuit so that it is inversely proportional to the weighting the couple is to have. This is conveniently done by inserting resistors between the thermojunctions and the copper common. To illustrate, if two thermocouples are to be weighted 75 percent and 25 percent, respectively, the resistance includes the resistance of the wire between the two commons, but this can be neglected in calculating the value of the resistors provided relatively high values are used. For example, a no. 30 AWG thermocouple 30 cm long would have a resistance of about 4 ohms. The smallest resistor in series with this thermocouple should be about 100 ohms to keep the weighting error to a minimum. The weighting error in this example would not be 4 percent as might appear, but somewhat less since all the couples would add 4 ohms to their respective circuit resistance.

c. Measuring Temperature Differences with Thermocouples

(1) The difference in temperature between two sites, as between skin and ambient air, can be measured directly using two thermocouples joined in opposition (constantan to constantan) so that a difference in voltage between thermocouple output appears at the copper leads. It is preferable to join the constantan wires (by twisting or crimping) rather than the coppers since the copper connections at the recorder will need no compensation. The temperature difference must be recorded in millivolts, then converted to temperature using conversion tables. The millivoltage for a given temperature difference is somewhat dependent on the level of the two temperatures (less output at low temperatures); however, in the human environmental range, an error of only about 0.1°C will be introduced if the actual level is neglected and temperature difference read directly from the tables, i.e., taken at the value corresponding to the measured millivoltage. This procedure simply implies that one temperature was 0°C (32°F), in which case the actual temperature read from the tables and the temperature difference would be the same.

(2) The average temperature difference between two surfaces or between a surface and a single site can be similarly measured. All the thermocouples on each surface may be connected to produce the desired average output, then the two outputs may be wired in opposition in the same manner as two single thermocouples; however, for measuring temperature differences between two surfaces, a better arrangement is the alternate connection of the thermocouples on the two surfaces to form a thermopile. Less wire is required and the output voltage to the recorder is higher (the sum of the difference outputs of all thermocouple pairs). In this arrangement, copper is connected to copper and constantan to constantan. The wires from the thermopile are both copper, thus requiring the same number of couples on each surface. The average output voltage per pair is found by dividing the total output by the number of pairs.

d. Recording Temperature from Thermistor Sensors

(1) Most of the laboratory grade temperature indicators for thermistors sensors have built-in output terminals for connecting a recorder. These terminals provide a d-c output proportional to meter deflection; in most instruments, zero output corresponds to one scale limit (either high or low) and maximal output to the other limit. This maximum may vary, depending on circuit design from 10 to over 100 millivolts, and may be adjustable. If only one sensor is involved, recording the output is simply a matter of connecting a recorder of the required range and a high input imepdance. The recording will be in millivolts and not linearly related to temperature. Either a conversion chart of millivolts versus temperature must be drawn up or a special chart and scale obtained for the recorder to obtain direct temperature measurement. For narrow spans (10 degrees C or less) the indicator output is sufficiently linear to allow the use of a linear chart without introducing errors of more than 0.1°C. In these instances, a recorder may be made direct reading by matching the recorder span to the output of the indicator and selecting a chart with the same number of divisions (or a multiple) as the degrees of indicator span. For example, a 100-division chart might be used to give 0.1 degree resolution from an indicator with a 10-degree span.

(2) Where the recorder output cannot be matched to the span of an existing recorder, two options are available; (1) if the span is greater than full scale indicator output may be recorded over only part of the chart; (2) if the span is too small to accommodate the output, the signal may be reduced so that it matches the recorder. Option (2) is preferable, especially where a bad mismatch of output and recorder occurs. Where the desired indicator output is a small fraction of the available voltage, the reduced level can be obtained simply by adding a low-value adjustable resistor in series with the meter. This is conveniently done by disconnecting the one meter lead and inserting the resistor between the open lead and the meter terminal. Wires to the recorder are then brought out from either end of the resistor. The resistor is adjusted to produce a full-scale chart reading when the indicator is also reading full-scale. Selection of the correct size resistor requires knowing the current range of the meter; the minimum value which can be used is given by the equation:

$$\text{Resistance} = \frac{\text{desired output at full scale}}{\text{full scale meter current}} \qquad (2)$$

For example, if the full-scale output is to be 10 millivolts, then, with a 50 microampere meter movement the resistor must have a value of at least 10×10^{-3} volts divided by 50×10^{-6} amperes, or 200 ohms. In this instance, a 1-watt, 10-turn rheostat with a total resistance of 250 ohms would probably be chosen to allow for minor variations in the meter characteristics. This could easily be adjusted so that the indicator and recorder full-scale readings coincided within 1 percent or less. The addition of this resistor will have practically no effect on the indicator calibration if its value is small compared to the meter resistance, i.e., only a small fraction of the total output is used. This may not be true if the desired output is more than 25 percent of the total, since this requires increasing the resistance of the meter circuit by 25 percent; this change may seriously alter the calibration of the indicator, especially one with a wide temperature range (span greater than 20°C). Methods for obtaining a reduced output should be obtained from the manufacturer in these cases. No serious error would be caused by the modification described above since the indicator had a full-scale output of 150 millivolts before modification; the increase in resistance of the meter circuit was accordingly only 6.7 percent.

e. Multiple Point Recording from Thermistor Sensors

Numerous systems have been designed for multiplexing signals from several thermistors. Usually, each sensor is connected into its own signal conditioner, and records may be printed in digital form, transferred to tape, or permanently stored on cards. When none of these systems are available, multiple recording can still be accomplished using only a single temperature indicator and a standard multipoint millivolt recorder. In this system, the thermistors are sequentially switched into the indicator by the recorder switching mechanism, and the indicator in turn provides the driving signal for the recorder. The recorder printing is thus synchronized with the switching operations on the thermistors. This system is set up by disconnecting the common lead from one of the instrument switches or switching relay banks from the measuring circuit in the recorder and reconnecting this common to the input jack in the indicator. One lead from each sensor is connected to an input terminal on the disconnected switch. The other lead is commoned with those of other sensors and connected to the other terminal on the indicator input jack.

f. Intermixed Recording from Thermistor and Thermocouple Sensors

(1) The ideal way to record from both thermocouples and thermistors is to use two recorders or a dual-range recorder capable of being programmed for automatic intermixing of thermocouple and millivolt signals. These are somewhat more expensive than conventional recorders designed for one type of input and not usually available in the average laboratory. As a field expedient, a thermocouple recorder can be used, although a separate temperature indicator is required for each thermistor, since the switches in the recorder are needed for thermocouples. These are connected to the recorder in the usual way and read out directly in temperature. The thermistors are connected to their respective indicators and the outputs in turn connected to recorder inputs; however, copper wire may not be connected to the (-) terminals which are intended for constantan leads. One wire from the indicator must therefore be changed from copper to constantan in an ice bath or 0°C reference before it is connected to the recorder. By observing indicator output polarity, one such interconnection will suffice for all indicators; this "common" can then be connected to all points which are to switch thermistor output voltages. The other lead from each indicator is connected separately to a point on the other recorder switch bank.

(2) Since the indicator output for a given temperature will be different than for a thermocouple, the recorder will not be direct reading for thermistors. Instead, it will indicate a temperature which produces a thermocouple voltage equal to indicator output. Zero output will record at 0°C (32°F), 1 millivolt at about 25.3°C (77.5°F), and 2 millivolts at 49.2°C (120.5°F). If the recorder range were -32 to 52°C (-25°F to 125°F) the indicator might therefore be set to produce full-scale output of 2 millivolts. One end of the indicator scale would then record as 0°C and the other as 49.2°C. Alternatively, the meter resistor might be adjusted to produce the 2 millivolt output with the meter only partially deflected, thus reducing the range of indicator temperature which could be recorded. For example, if the indicator range were 38°C to 43°C, and hence the recorded range would be from 38°C to 43°C. This might be done to increase resolution when temperatures lower than 38°C were not expected.

7. PERSONNEL CLOTHING AND LIFE SUPPORT EQUIPMENT

7.1 Introduction. Clothing has been designed to a much greater extent by fashion and by technological developments in industry than by any scientific analysis of the heat exchange allowed by clothing between the wearer and his environment. Requirements to maximize survival time, extend performance time and improve the general comfort of soldiers, exposed to extremes of arctic, desert, or tropic environments have required the development of a multidisciplinary, multilevel program.

a. These scientific analyses, essential to deal with environmental extremes, can also be applied to suggest clothing designs for less extreme environments and to evaluate the relative contribution of various factors to thermal aspects of clothing comfort.

b. A multidisciplinary approach has been evolved at the Research Institute of Environmental Medicine in Natick, Massachusetts to assess the thermal interactions between the environment, the uniform worn, and man and his job. Studies are conducted at five different levels of analysis with each level providing information which can be related to the others as follows: (a) the physical heat transfer characteristics of the uniform materials are measured using classical heated flat plate theory and also a unique "sweating" flat plate; (b) complete clothing ensembles, with and without such additional items as gloves, headgear, or backpacks, etc, are evaluated on a "sweating" copper manikin for the heat transfer characteristics of the clothing ensemble; the values obtained are used in biophysical calculations in a programmed computer model to predict the wearer's tolerance limits; (c) carefully controlled physiological trials are carried out in climatic chambers with volunteer subjects dressed in the clothing systems, to validate or refine the computer predicted tolerance limits; (d) controlled, small scale studies are conducted in the field or at the worksite with groups of men wearing specified clothing systems and carrying out specified tasks under conditions of environment, terrain, and work rate where physiological problems are anticipated based upon experience in climatic chamber trials; (e) studies with these clothing systems are carried out collaboratively during actual field operations scheduled. Specific details of the methodology that is used in part of the laboratory studies are presented but the methods for field evaluation must be determined on an individual basis; however, the information given should give sufficient background to plan and conduct a field evaluation.

7.2 <u>The "Clo" Unit</u>

Some years ago physiologists working in the field of clothing and the associated heat transfer from a man, developed a technique to determine how much heat would pass through a garment by thermal radiation and convection from the skin[1]. The difference between a man's skin temperature and the ambient temperature was taken as a gradient across which, to avoid change in body temperature, he had to eliminate the difference between his metabolic heat production and the heat he could lose by evaporation of sweat from his skin or of water from his lungs. The nonevaporative component was assumed to go through the clothing by normal radiation and convection heat transfer. They then defined the insulation of a clothing system, plus the overlying still air layer, in terms of a "clo" unit and derived a system of units such that the dry heat transfer (i.e., convective plus radiant) per unit gradient from skin to ambient temperature (0°C) would be 5½ kilocalories per meter square of surface per hour, per clo; that is:

$$H_{Dry} = \frac{5.55 \text{ Kcal m}^2\text{hr}}{\text{clo}} \quad \text{per } ^\circ\text{C} \qquad (3)$$

This physical equation states that heat flow equals the driving force, in this case a temperature gradient, divided by the resistance, expressed here in "clo." This basic approach for radiation-convection heat loss yields a quantitative assessment of how good a given uniform is for a resting man in cold weather since radiation and convection are major avenues of heat loss in the cold; however, for a working man in the cold, evaporation of sweat becomes an important avenue of heat loss. Furthermore, radiation and convection heat loss decrease with increasing ambient temperature while evaporative cooling rises. Thus, the "clo" value alone is insufficient in the heat.

7.3 <u>The Permeability Index, "i_m":</u>

A similar form of equation can be used to predict evaporative heat transfer:

$$H_{Evap.} = \frac{5.55 \text{ S } (P_s - P_a)}{\text{clo}} \qquad (4)$$

Equation 4 is a form of the psychrometric (i.e., slung) wet bulb thermometer equation where the "clo" value is the insulation of the air layer around the

[1]Footnote matches reference number in appendix A.

thermometer. The gradient for evaporative transfer is the difference between the vapor pressure at the surface (P_s) and the ambient vapor pressure (P_a) in millimeters of mercury (mm Hg). Using the slope (S) of the wet bulb lines on a psychrometric chart, which is about 2°C per mm Hg, a vapor pressure difference can be converted to an equivalent temperature gradient. One can then determine the evaporative heat loss from a square meter of surface with a given water vapor pressure; e.g., at 35°C (the skin temperature of a sweating man) there would be a vapor pressure of 42mm Hg at the skin end the gradient will thus be 42 mm minus the ambient air vapor pressure. It has been proposed that the evaporative heat transfer for a nude man, or for any clothing system, could be expressed as the ratio of the actual evaporative heat loss, as hindered by the clothing, to that of a wet bulb with equivalent "clo" insulation[2]. The proposal suggested expanding Equation 4 to include this "permeability" ration index (i_m) so that:

$$H_{Evap.} = \frac{5.55\ i_m\ S\ (P_s - P_a)}{Clo} \qquad (5)$$

The index of evaporative loss (i_m) could range from 0, for a system with no evaporative heat transfer, to 1 for a system which had no more impendance to evaporative heat transfer than the usual wet-bulb thermometer. The conventional wet-bulb, of course, is a sling (i.e., rapidly moving) wet-bulb where the still air barrier is greatly reduced. Since a soldier is surrounded by a relatively undisturbed air layer, i_m seldom approaches 1.0 for a man, but tends to be limited in still air to about 0.5.

7.4 Determination of "Clo" abd "i_m"

The flat plate apparatus is used in the measurement of the "clo" insulation value. The apparatus consists of a test section surrounded on all four sides by a guard section with another guard section beneath the entire upper plate. All three sections are instrumented with plate temperature sensors, heating elements, and thermostats. The sample to be tested is placed on the surface and the entire assembly is placed in a constant temperature cabinet. In operation, power to the guard sections is controlled so that their surface temperature is identical to that of the test section. Thus, there is no gradient for heat loss from the bottom or edges of the test section. After equilibrium is established, the power required by the test section equals the heat lost through the insulation and can be expressed as kcal/m^2 - hr degree of gradient from plate to surface to ambient air temperature. This can be converted to the corresponding "clo" insulating value for the sample plus the adhering air layer, using equation 3. If a thin cotton "skin" is placed on the plate surface and a water level is maintained at the surface of some small holes drilled in sections A and B, then the "skin" sucks out enough water to maintain a constant saturated surface pressure. A constant ambient vapor pressure is maintained in the measuring

[2]Footnote number matches reference number in appendix A.

chamber and power requirements measured just as for the dry plate. The permeability index value (i_m) can be determined for a given sample plus its adhering air layer by means of equation 5. The flat plate determinations of "clo" and "i_m" are primarily of use in selection of the fabrics to be used in a clothing system. The effects on heat transfers of different weaves, perforations, different finishes or treatments, the effects and best arrangement of multiple layers, etc., all can be established using the sweating flat plate[3]. Heated, dry and "sweating" cylinders have been developed to mimic the cylindrical shape of the body. These are useful in studying wind penetration through clothing, and effects of spacer materials, but there are factors of drape, fit, and shape which are difficult to stimulate even on a cylinder. Also, a complete uniform is made up of a number of different components, protecting various parts of the body, so that evaluation of a complete clothing system requires a more sophisticated model than a cylinder[4].

7.5 The Copper Man

a. The solution has been the development of life sized, heated copper manikins. The manikin also has a "sweating" copper skin. The heat provided to the manikin to maintain a constant skin temperature can be measured and the ambient temperature and vapor pressure of the test chamber can be controlled; skin and air temperature and vapor pressure are measured. Thus, the radiant-convective heat loss and the evaporative heat loss caused by a given gradient of temperature and vapor pressure can be calculated for any clothing system worn. This technique has been in use for the last 5 years. Using the insulation and evaporative transfer indices, "clo" and "i_m," with some physiological knowledge, tolerance times can be predicted, for a given task, for men in the chambers and in the field. One solves the equation that heat stored by the body must be the difference between the heat produced at work, and that lost by evaporation and by radiation and/or convection through the clothing system. Since the average soldier has $1.8 m^2$ of surface area, by estimating his skin temperature (T_s), total nonevaporative heat transfer can be calculated for any given ambient dry bulb temperature Ta in °C as:

$$H_{Dry} = 10 (T_s - T_a)/clo \qquad (Kcal\text{-}man\text{-}hr) \qquad (6)$$

Where a 36°C skin temperature has been assumed for the clothed sweating ... If heat production is known, after allowing for respiratory heat loss and any solar heat load gain, one can calculate whether the man can eliminate all the heat he is producing or whether some of it will be stored in his body. Indeed, using this specific heat of human tissue (0.83 kcal/kg - °C), it can be calculated that the body temperature of a 70 kg (154 lb) soldier will increase by 1°C (1.8°F) for each 58 kcal that must be stored (i.e., 0.83 x 70). This allows prediction of tolerance as the time to reach a given body temperature. A computer program has been devised which incorporates many of the significant physiological, physical, and environmental

[3], [4]Footnote numbers match reference numbers in appendix A.

factors involved in human heat transfer. If the appropriate values for clothing, environment and metabolic heat production are supplied, the model will predict the body temperature response of an individual under the chosen conditions; however, these predicted responses must be checked by actual environmental exposures of men.

b. In summary, the combined use of clo and i_m/clo as measured on heated, sweating copper manikins is a valuable tool for predicting a rank order of thermal stress effects for clothing ensembles worn in the cold or heat. Care must be taken if air permeabilities differ widely or if clothing design allows unusual air exchange during subject motion. More recent studies have suggested the necessary modifications to the static manikin measurement for air motion and for subject generated air motion. This newer approach allows precision prediction of the thermal responses of a man (T_s - T_a) as a function of his clothing, his heat production and the ambient environment. Thus assessment of the insulation (clo) value and evaporative impedence (i_m/clo) value of a clothing system can provide an accurate estimate of the relative advantages of one garment or fabric over another with respect to the thermal protection and/or strain associated with wearing the clothing. There are effects of cut, drape, and fit which must receive special consideration. The techniques presented are a valuable tool in clothing design and such evaluations are desirable in studies of the man-clothing-job-environment-system for ordinary clothing as well as for such advanced concepts as clothing systems with intrinsic environmental conditioning sources.

c. The advantages of carrying out the detailed evaluations of the thermal protection, and problems associated with any arctic (or any other) protective clothing systems in the laboratory and climatic chamber should be obvious. Precision measurement, assessment of minor differences, and prediction for any combination of clothing, work level, wind and temperature can be carried out. Similarly precise techniques are being developed for protection afforded the extremities (hands, feet, face) by gloves, boots, face masks, hoods, etc. Thus, field evaluations of the thermal protective aspects of arctic gear should never be carried out until the "homework" in the laboratory has been completed and then only as a validation of the laboratory findings under field conditions. On the other hand, the laboratory cannot provide the wear testing, the blowing snow, and realism of the field environment.

d. Personnel involved in planning, carrying out, or evaluating the results of such field evaluations should insist on having the results of the laboratory and/or climatic chamber evaluations on the specific items to be tested <u>before</u> planning the details of the field evaluation.

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