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REFERENCE SOURCES IN THE PHYSIOLOGY OF EXTREME ENVIRONMENTAL TEMPERATURES

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FOREWORD

The bibliography list reported here was compiled by engineering personnel and part-time student employees at the Aircraft Propulsion Laboratory. The literature survey resulting in this list was conducted as a preliminary to achieving the main objectives of a project dealing with the evaluation of various possible methods of heating, cooling, and ventilating combat tanks under extreme environmental conditions.

This project is sponsored by the Detroit Ordnance District under Contract No. DA-20-018-ORD-13146. At the Detroit Arsenal the project is designated as No. TT1-696, and Mr. John Gallombardo of that organization is the Project Engineer. The Engineering Research Institute designation of the project is No. 2167, and joint local supervisors are Dr. Richard Morrison of the Aeronautical Engineering Department and Dr. Frank L. Schwartz of the Mechanical Engineering Department, University of Michigan.

ABSTRACT

A short discussion and conclusions are presented concerning articles and reports on which the recommendations of physiological criteria for evaluating systems for heating, cooling, and ventilating combat tanks are based. The reports found to be most pertinent are listed, together with short abstracts of their content. Two sets of recommendations are made. The first set, specific to the present project, suggests the following objectives in designing a system:

1. Maximum operational efficiency of the crew should be the primary overall objective,

2. No attempt should be made to control relative humidity,

3. Air-ventilation rate should be as recommended by the Office of the Surgeon General; 250 cubic feet per minute per man,

4. An attempt should be made to keep air velocities below 100 feet per minute,

5. In the high extreme ambient range the compartment should be cooled to a minimum of 85°F with a maximum of 90°F,

6. In the low extreme ambient range, the compartment should be heated to a minimum of 20°F with a maximum of 25°F.

The second set of recommendations, pertaining to future physiological research, suggests the following projects to be conducted by qualified people:

1. Experimentally determined ventilation requirements in the tank crew compartment,

2. Determination of the effects of radiation between the human body and the vehicle walls,

3. Determination of the extent of mutual aggravation of all the annoyances in tank operation, and the conduction of a more extensive literature search, with emphasis on foreign sources and discussions.

DISCUSSION

The evaluation of possible methods of heating, cooling and ventilating combat tanks requires the establishment of suitable basic standards. It was with this necessity in mind that a literature survey was conducted with the objective of determining the effects of extreme ambient temperatures on the activities of human beings. More specifically, the types of environment which are of particular interest are (1) warm environments as experienced in the desert with ambient temperatures up to 120°F and (2) cold environments as experienced in arctic lands with ambient temperatures down to -30°F. These specifications place the survey within relatively narrow limits. For example, interest in a desert environment implies interest in a hot, dry climate as opposed to the hot, humid atmosphere normally expected in tropical jungles.

The period of years of primary interest covered in this list are those from about 1938 to the present, although the survey itself was not limited as to time of publication. The number of reports that were studied totaled about five hundred and the abstracts which follow represent those reports published since 1938 that contained information thought to be useful to the project. It must be emphasized that there was no attempt to make the survey all-inclusive, since such an objective could well be made the goal for a separate project. The point here was merely to obtain information in an amount to form a basis for reasonable conclusions. In somes cases, answers to requests for reports and information have not yet been received. In other cases, where investigations are currently in progress, information was given for use on this project only; that is, the stipulation was made that the investigators be neither quoted nor referenced at the present time. Finally, some reports have been omitted because they did not come to the attention of the authors or were not deemed to have sufficient bearing on the project. It should be additionally noted that all reports and articles listed here are of an unclassified nature.

During recent years there has been an increasing intensity of research concerned with the physiological and psychological reactions of human beings to extreme environments of temperature and humidity. The impetus for these studies has derived in large measure from the recognition, on the one hand by industry, of the desire for maintaining top health and efficiency standards in human beings in order to realize maximum production. On the other hand, modern architectural design has placed a premium on proper air conditioning (heating, cooling, ventilation, and humidity control) in home living. More recently the methods of physiological research have been applied to problems of the military, naval, and air services, especially in regard to fighting aircraft, submarines, and the foot soldier. In the latter instances, however, the work thus far completed seems relatively limited in quantity, although excellent in quality.

The literature survey under discussion here has resulted in the finding of reports concerning two projects which were done directly relative to situations to be encountered by tank crewmen under extreme environmental conditions. One of these was done for the Australian Government and the other was sponsored by the German Government, both during World War II. These reports are mentioned later.

In addition to these reports there is a wealth of data concerning research in the generalized physiological sense and also concerning research inspired by specific problems. Much of this data can be interpolated in terms of tank compartment requirements, but there are numerous gaps in the available information which must be filled and, barring actual experimentation, the process would be almost intuitive in some cases. In considering the effect of extreme temperatures it must be remembered that even the normal occupational existence of a tank crewman is made up of conditions which would be considered extreme on the basis of a temperate environment. He is subject to extremes of space restriction and must often spend prolonged periods in positions for which the body is not adjusted. There is a constant chorus of noises of many frequencies and volume levels. There are vibrations caused by the running of the engine and the slapping of individual track blocks on the ground as the tank moves. The frequency and amplitude of these noises and vibrations can vary over wide ranges according to the operating conditions and are superimposed on the rolling and swerving motions of the tank as it maneuvers over combat terrain. Psychologically, there is the uncomfortable feeling that the size of the vehicle makes it clearly visible to all enemy gun crews, while the visibility of of the tank crew members is limited to the very narrow field presented by the viewing-periscopes. These are all normal tribulations of a tank crew in combat in any environmental situation. Now add to these conditions a temperature environment which is either in a hot or cold extreme. At this point it is wondered whether the effects of temperature can be regarded in an isolated sense, or whether these effects and those mentioned above mutually aggravate the situation and, if so, to what extent.

Concerning the studies done by the Australians, three reports have been acquired. The work was done under the direction of Dr. Douglas H. K. Lee when he was associated with the University of Queensland. Of the three reports, FLSR No. 3 is entitled "Psycho-Motor Efficiency (As Measured by Time for Accurate Gun-Laying) under Hot Condtions"; AFV No. 39 is entitled "Trial Tank Air Conditioning Equipment. Hot Room Tests"; and AFV No. 48 is entitled "Field Trials of Methods of Tank Personnel Cooling Carried Out in New Guinea, November, 1943". These reports are considered pertinent enough to the present project so that reprints are being made, with the permission of Dr. Lee who is now associated with the Johns Hopkins University in the capacity of Professor of Physiological Climatology. The reports, when reprinted, will be forwarded to the interested agencies.

Reports concerning the German work are somewhat more difficult to obtain since they were written during World War II and were disposed of in various ways near the end of the war. Two have been located and these seemingly cover only a small part of the overall picture. Translations have been made in the present project, but no reprints are planned. Copies of the translations are to be forwarded to the Detroit Arsenal. According to E. T. Simonson*, the Germans had expended a total of thirty man-years on the project, the object of which was to increase the fighting efficiency of combat tank crews operating in the North African Theater by air-conditioning the vehicle during periods of hot temperature extremes. They had developed a cooling hood arrangement which was to envelop the head and shoulders of the subject. The system seemingly was based on some previous findings that about seventy-five percent of the heat to be removed from the subject could be removed via the head. Nothing has been found thus far by this project concerning any of the work which resulted in these conclusions. It has been stated that all the physiological research on the project was done at Heidelberg University under the direction of Professor Achelis. The present Director of the Physiological Institute of Heidelberg University, Dr. H. Schaefer, has stated that the Institute could not provide additional information or reports; these were all either submitted to appropriate German Army agencies, destroyed, or turned over to the United States Military on the latter's entry into Heidelberg.

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* E. T. Simonson "German Refrigeration Industry", Combined Intelligence Objectives Sub-Committee, Item No. 22, File No. XXIV-30. Available from ASTIA Document Service Center; Knott Building, Dayton, Ohio, as report No. ATI-59620.

Combat operations in which the situation of the combatants might seem to bear at least a partial analogy to that of tank-crew members might include submarine warfare, surface naval warfare, and aerial warfare. Reports have been found concerning work done along these lines by the Americans, British, and Germans. Probably the majority of the work that has been found dealing with the physiology of extreme temperatures relative to aircraft has been done in the United States. The need for such studies has become more urgent in view of the great increase in altitude and speed at which aircraft operate. Problems are presented by the heat resulting from high speeds, by solar radiation, and by the heat given off from the large amount of electrical equipment in the pilot compartment. In many respects the problems of cooling aircraft are similar to those of cooling combat tanks. However, the solution to the comfort cooling problem seems more readily available in aircraft, due to the availability of large amounts of compressed air bled off either from the engine turbine or engine supercharger, as the case may be. No such copious supplies of air are presently available in a combat tank.

It is not permissible to make reference to most current physiological research projects. Interested persons can obtain "Notices of Research Projects" from the BioSciences Information Exchange of the National Research Council, Division of Medical Sciences. This is done by writing to that organization at 1113 Du Pont Circle Building, Washington 6, D. C. and stating the inquirer's interest.

Probably the primary source for obtaining reports pertaining to government sponsored projects is the Armed Services Technical Information Agency (ASTIA), Document Service Center, Knott Building, Dayton 2, Ohio. It would undoubtedly be fruitful for an investigator to contact this agency before considering any literature search completed. In fact, it would be worthwhile to visit their offices and inspect the files of classified and unclassified documents. Before making such a trip, however, it is imperative to inquire of the agency what steps should be taken for obtaining necessary clearances and providing evidence of a "need to know". Generally reports are immediately available for inspection and can be obtained on thirty-day loan. Also, it is possible to arrange for obtaining permanent copies of specific reports.

CONCLUSIONS

As a result of the literature search, it would seem reasonable that the following conclusions pertinent to the present project can be made:

(1) In the matter of ventilation the tank crew compartment presents a unique situation in that the volumetric space allotment per man is quite a bit smaller than that considered in the reports studied. This is complicated by the fact of high concentrations of gun fumes being generated within the tank and also by the possibility at all times of high concentrations of dust being drawn into the compartment. Nothing was found in the literature which could be extended in terms of this situation with any degree of confidence. The Office of the Surgeon General has recommended a ventilation requirement in tanks of 250 cubic feet per minute per man, but no information has been found concerning research to back up this figure.

(2) At temperatures which are warm, but below about 95°F and with humidities in the ordinary or high ranges, an increase in air velocity serves to widen the zone of evaporative regulation, thus increasing a sense of comfort. At temperatures of about 95°F and higher, with low humidities, the increase in evaporative heat loss is offset by an increase in convective heat gain so that the limits of tolerance to heat are decreased with increasing air velocity.

(3) It is estimated that within ordinary temperature ranges humidity does not have much influence on the effect of air velocity on feelings of comfort. In the warm ranges, velocities up to 100 feet per minute may result in a cool, comfortable feeling, but in the cool ranges of teperature an air velocity of over 30 feet per minute might be uncomfortable. Also bearing on the feelings of comfort is the fact that some parts of the body are more sensitive to air currents than others. It is agreed that velocities which are much above the threshold value of air current perceptibility will cause discomfort. It is obvious that in a limited space, such as a tank crew compartment, difficulties may be expected in reconciling air-volume rate with air velocities for reasonable comfort.

(4) In environments where humidity is extremely low the lack of moisture may result in drying of the mucous membranes of the skin and of the fluid on the surface of the eyes. The results of work reported regarding these characteristics indicate that no permanent damage to the tissue results from exposure to these conditions, but on the other hand

irritation and temporary discomfort may be experienced, such as smarting of the eyes, sore throat, and so forth.

(5) Variations in relative humidity do not have much effect on skin and body temperatures, except in the extreme ambient temperature ranges.

(6) In the zone of evaporative regulation, the rate of sweat secretion is governed by skin and rectal temperatures and not by relative humidity of the ambient air. However, the relative humidity does affect the amount of evaporation which can take place from the skin and if the rate of secretion exceeds the ability of the air to absorb the moisture through evaporation, then the excess sweat is seen on the skin in liquid form. It is also probable that insensible perspiration, which is normally present even under cool circumstances, ceases.

(7) At mean skin temperatures of about 90°F and above, evaporative heat loss becomes the chief means of maintaining the body-heat balance. At this temperature the upper limits of evaporative regulation for a clothed person lie at a relative humidity of about 90%. For 95°F the upper limit is at a relative humidity of about 70% and at 100°F the figure is about 50%.

(8) In hot, humid atmospheres the limiting factor to evaporative heat regulation is the capacity of the air for absorbing water, but in hot, dry atmospheres the limiting factor is the ability to produce enough sweat to keep up with the evaporative requirement for regulating body temperature. Failure of the evaporative heat regulation may be caused by fatigue of the sweating mechanism, as this fatigue occurs at a faster rate in humid, rather than dry atmospheres.

(9) In air temperatures up to about 93°F variation in relative humidity has no appreciable effect on the magnitude of evaporative heat loss of resting men.

(10) Work efficiency is quite sensitive to temperature and relative humidity. For example, one paper reports a fifty percent decrease in work efficiency when the temperature is raised from 90 to 110°F at a relative humidity of 60%. At temperatures which are lower, but still warm, it is reasonable to suppose that there will be a significant lowering of work efficiency with an increase in temperature or relative humidity. At these lower ranges the amount of changes required to produce a given decrement in efficiency would be greater.

(11) Mental efficiency, accuracy, and alertness are also largely dependent on temperature and relative humidity. A paper reporting research done along these lines concludes that the optimum conditions for accurate work under conditions of the experiment were those where the wet-bulb temperature was 75°F and the dry-bulb temperature was 85°F (relative humidity about 60%) with an air velocity of 100 ft per minute. The figure of 100 ft per minute was not shown to be an optimum air velocity, but was one of the conditions imposed on the experiment. Raising the wet and dry-bulb temperatures to 85 and 95°F, respectively, resulted in an error increase of about 30% (air velocity was again 100 ft per minute). It was stated by the author that, based on normal atmospheric conditions as applied in previous research, the increase in decrement is equivalent to about 50%.

(12) It has been shown in one study that the ideal situation of comfort exists when the skin temperature remains at about 91°F, when there is a minimum of heat change in the body tissues, and when there is a minimum evaporative rate. This situation was attained for a clothed, resting subject at an air temperature of 79°F with a minimum air movement and the assumption of one cold wall. For moderate indoor activity the desirable air temperature is estimated at 75°F.

(13) When the skin temperature of the fingers drops below about 60°F there is considerable decrement in manual dexterity. Gloves cannot be adequate to maintain this skin temperature at ambient temperatures below 30°F; mittens of fur and leather material can be used down to about 20°F to maintain the finger skin temperature at 60°F.

(14) Body insulation requirements for a human doing light work, such as driving a car or standing with light movement, in terms of the Clo unit are approximately doubled when amibient temperature is dropped from 60 to 20°F and are doubled again in dropping from an ambient temperature of 20 to -20°F.

(15) If sweating occurs in men clothed in cold weather garments, this sweat may freeze at some layer of the garment between the skin and the atmosphere. Such frozen moisture has the effect of filling in the voids which had contained insulating air, thus cutting down on the effective insulation of the clothing. Additionally, where such sweating is the result of working, some of the moisture may collect on the inner layers and continue to evaporate after work has ceased, thus removing additional heat from the body.

(16) If the temperature of the solid surroundings is substantially different from the dry-bulb temperature, radiation will have a large effect on body-heat loss or body-heat gain, as the case may be.

RECOMMENDATIONS

The conclusions arrived at in this study of the literature lead to two sets of recommendations, one of which is specific to this project and the other of which is concerned with future physiological research. It should be remembered that the literature survey is interested in setting up heating, cooling, and ventilation standards toward which an attempt should be made to meet. The feasibility of meeting such standards is not within the scope of this report and, therefore, will not be discussed here.

A. Recommendations Specific to the Present Project

(1) In order to obtain an optimum design for the best results at the least cost, the criteria of a good system should be such that the stress is on improvement in operational efficiency rather than crew comfort in the primarily humane sense. For example, by cooling the compartment to 75°F perhaps an ideal atmosphere can be obtained. But on the other hand it may be that the greatest relative gain in crew efficiency lies in cooling only to some higher temperature below which the increased cost in money and space yields only diminishing returns.

(2) No attempt should be made to control the relative humidity in the compartment. The interest of the present project is concerned with hot desert atmospheres and cold arctic atmospheres, both of which are typically low in humidity. As stated in the "Discussion and Conclusions" section above, the main difficulties to be anticipated, at the temperature ranges that it is hoped to maintain, consist in drying of the skin, mucous membranes, and eye fluids. These effects have been shown to be temporary in nature and not a serious detriment to efficient operation.

(3) As regards the rate of ventilation that should be required, there seems to be no alternative but to accept the recommendation of the Office of the Surgeon General. It should be remembered here that nothing could be found to support the figure cited. The suggested air ventilation rate is 250 cubic feet per minute.

(4) Reconciliation of air velocities with the relatively large ventilation rate seems almost certain to provide a difficult problem in the actual design of the system. It is recommeded that attempts be made to keep air velocities below 100 feet per minute with the definite specification that air currents in excess of this velocity be directed away from sensitive portions of the body.

(5) In the high-extreme amibient ranges, the objective should be to cool the compartment to a range of 85°F minimum and 90°F maximum temperature. The minimum is concerned with economy of money and space, while the maximum results from consideration of the physiological conclusions reached above. More specifically, 85°F should be the goal with 90°F as an allowable maximum.

(6) In the low-extreme ambient ranges the objective should be to heat the compartment to a range of 20°F minimum and 25°F maximum temperature. Here the minimum figure results from the desirability of maintaining warmth with as little bulkiness of clothing as possible. Also, at temperatures below this figure it is almost impossible to maintain the fingers at a temperature conducive to manual dexterity. At this ambient temperature range, mittens can be used to maintain finger warmth, and exit air flow from the heating vents can be aimed over small-levered controls to provide warmth when mittens are removed to operate them (in order to maintain the compartment temperature at 20°F, the air at the heating-vent exits will have to be at a considerably higher temperature). The maximum temperature of 25°F is specified, in this instance, not only from an economy standpoint, but also in view of the fact that higher temperatures might result in overheating of the body in its heavy clothing. Lighter clothing for the men might not be feasible, since in many situations they will have occasion to dismount frequently from the vehicle.

B. Recommendations for Additional Physiological Research by Qualified Personnel

(1) If, indeed, there doesn't exist any experimental data on which the recommendation for ventilation rate by the Office of the Surgeon General is based, then it would seem highly desirable to conduct some research in an effort to establish ventilation standards. These standards should be based on the need for removing noxious gun-smoke fumes as a primary criterion. In heating or cooling the tank it is desirable from an economic standpoint to use at least partial recirculation of the compartment air, but for purposes of finding ventilation requirements this need not be considered initially. The effect of ventilation on the concentrations of dust to be expected in the compartment should also be considered.

(2) The men in the crew compartment are surrounded on all sides by steel walls which are uninsulated and in direct contact with the outside atmosphere. The temperature on the interior face of these walls will be substantially similar to that on the exterior face and this temperature will lie somewhere between the outside air and inside air temperatures, probably being somewhat different from both. The search of the literature has shown that if the temperature of the solid surroundings of a subject is much different from that of the intervening air, then the conditions for feeling of comfort in the subject might be greatly altered by radiation effects. In view of these facts, it is recommended that a project be initiated for determining the effects of radiation between the human body and the vehicle walls on the body-heat balance and feeling of comfort.

(3) As mentioned in the discussion above, it can be wondered whether the effects of extreme heat and cold aggravate the other annoyances of tank operation or vice versa and, if so, to what extent. The recommendation here is that a project be initiated to determine the mutual effects of extreme temperature and such things as vibrations, noise, cramped space, and the psychological effects of limited vision. A worthwhile reminder at this point is the fact that there is one other factor which is extremely important to consider, but almost impossible to measure. This factor is the effect of realization by the crewman engaged in battle that he is involved in a life-death struggle. One army man made the statement that if a man knows that he is going to live or die on the basis of what he does extreme temperature will have no effect whatever on his efficiency. It seems pretty well agreed among physiologists and psychologists that this assumption is a false one. But it would seem that conclusive proof of the truth or falsity is desirable and the project which presents such proof, one way or the other, will be performing a great service in the general sense as well as in the narrow sense of tank-atmosphere adjustment.

(4) A more complete search of the literature should be made, with emphasis of foreign publications and reports. The Germans spent a total of thirty man-years on research devoted to the feasibility of cooling tank crew compartments in desert environments. Efforts should be made to track down all information on this project, whether in the form of reports or as a result of discussion with personnel who were engaged in the work.

BIBLIOGRAPHY

1. "Abnormal Air Conditions in Industry; Their Effects on Workers and Methods of Control", C. P. Yaglou, J. Ind. Hygiene, 19, 12-43 (January, 1937).

This report considers temperature effects on humans. Cold, chilling drafts, and great temperature changes increase susceptibility to some diseases. Workers in hot trades lean toward diseases of the upper respiratory tract and acute heat disease in common. Hot and humid conditions make subjects particularly susceptible. Many mortality tables and graphs are recorded in this article.

2. "Acclimatization to Extreme Cold", S. M. Horvath, et al., Am. J. Physiol., 149, 99-108 (July, 1947).

Metabolic observations were made on five subjects who resided continuously for three days in a 77°F environment, eight days in a cold environment (22°F), then three more days at 77°F at 50 percent relative humidity. There were no changes in basal values in heart rate or body temperature. The deviation of the exposure did not markedly affect the energy output of the subjects who were breathing cold air while sitting. One subject breathing 68°F air decreased caloric output with increased exposure time. On returning to 77°F environment this subject did not show an increased metabolic rate, were increased during low-temperature exposure. This damped out with continued exposure.

3. "Acclimatization to Extreme Heat and Its Effect on Ability to Work In Less Severe Environments", S. M. Horvath and W. B. Shelly, Am. J. Physiol., 146, 336-43 (June, 1946).

Sixteen soldiers were required to walk one hour a day in 120°F dry-bulb and about 91°F wet-bulb conditions to determine the degreee of acclimatization as shown by ability to work in less severe environments. The authors found that acclimatization to short periods or work in a hot environment not only enables men to perform work for a longer period of time in that environment, but ensures them the ability to work for at least four times as long in less severe heat.

4. "Acclimatization to Heat and Cold", E. M. Glaser, J. Physiol., 110, 330-7, (December, 1949).

An attempt was made to determine whether acclimatization to cold exists, how the movement of blood between the inside of the body and the extremities are affected by continued exposure to heat and cold, and whether or not acclimatization to heat and cold is modified by frequent changes in environmental temperature. The experimenters found that in the period between the first and third day there was a significant increase in the skin and rectal temperature and in feeling of comfort of the six subjects. This was taken as a sign of acclimatization to cold. Acclimatization to heat and cold was accompanied by changes in the rate of superficial blood flow and total blood volume, but there was no change in blood distribution. Frequent changes in temperature may be beneficial to those who must adapt to extreme climatic conditions.

5. "The Addition of Salt to Drinking Water", Report of Council of Pharmacy and Chemistry, J.A.M.A., 129, 131 (1945)

This practice is recommended; about one gram of sodium chloride in each quart of water.

6. "Adrenal Cortex and Work in the Heat", M. Moneirn, et al., Am. J. Physiol., 143, 169 (1945).

This investigation showed that large doses of extract of adrenal cortex had no effect on the subjects' performance in the heat.

7. "Air Conditioning in Industry - Physiological Reactions of Individual Workers to High Effective Temperatures", W. L. Fleischer, et al., A.S.H.V.E. Transactions, 45, 59 (1939).

Tests were made on seven college students and two older men doing light work in atmospheres ranging from 77.5 to 92.5°F Effective Temperature and for relative humidities of 60, 75 and 90%. The work entailed slight muscular activity and required alertness to the task. Relations are given between length of exposure in hot atmospheric conditions and changes in various physiological reactions, such as body temperature, pulse rate, vital capacity, lencocyte count, weight loss, forehead and body perspiration, and feeling of warmth. The first two are indicated as being most significant.

8. "Arctic Research at Point Barrow, Alaska", L. Irving, Science, 1071, 284-6 (March, 1948).

This article describes the general conditions and possibilities of research at Point Barrow. Higher metabolic rates for arctic organisms are mentioned.

9. "Atmospheric Conditions Encountered During Survey of RAAF Ground Crew on Tropical Service and Their Relationship to Both Sweat Loss and Results Obtained With Harvard Pack Test (Ninth Report of Field Investigation Into Incidence of Tropical Fatigue)", R. K. MacPherson, et al., Trop. Dis. Bull. 44, 934-5 (October, 1947).

This is an abstract of the referred to Ninth Report.

10. "The Autonomic Mechanism of Heat Conservation and Dissipation", O. R. Hyndman and J. Wolkin, Am. Heart J., 22, 289 (1941).

Investigations into the nature of skin reactions to heat were made by isolating parts of the body, locally heating or failing to heat these parts, and recording skin temperatures. Three different systems regulate protective mechanisms such as sweating: (1) the sweating gland itself, (2) reflex through the spinal cord, and (3) the central, or hypothalamic, control. The article concludes: (1) fingers and toes exhibit greatest rise in temperature when the body is heated, (2) body temperature is maintained mostly by surface reactions, but when extreme temperatures occur a central controller manifests itself. For the condition where only one part of the body is heated, the entire skin surface is integrated for purposes of heat dispersion.

11. "Basic Procedure in Calculation of Heat Exchange of Clothed Human Body", L. P. Herrington, Yale J. Biol. and Med., 19, 735-55 (March, 1947).

A summary of findings during the war years on the effectiveness of different types of clothes. Many tables and formulas are given. The upper and lower range of survival, clo units, and desirability of heat for extremities in relation to trunk are discussed. The Dachau experiments are quoted to show death time on immersion in cold water (67 minutes in 4.6°C water).

12. "The Blood Circulation in the Human Limb; Observations On the Differences Between the Parts; Remarks On Regulation of Body Temperatures", R. T. Grant and R. S. B. Person, Clin. Sc., 3, 119 (1938).

The determination was made that direct conduction from acting muscles to the skin takes place. The arms and legs do not show vasoconstriction when the feet and hands do.

13. "Blood Volume Changes In Men Exposed To Hot Environmental Temperatures For a Few Hours", N. Glickman et al., Am. J. Physiol., 134,165 (1941).

Experiments were made on healthy males 20 to 27 years old. All measurements were taken under basal conditions. Determinations were made of blood count, blood volume by the dye method, serum protein, and albumin. Pulse rate and rectal temperatures were used for correlation. Conclusions: (1) at dry bulb 37.2 and 44.7 °C with wet bulb from 20.1 to 27.5 °C and during exposure of from 59 to 160 minutes, there was an increase in blood volume; (2) in four experiments under similar conditions there were decreases in blood volume; (3) in fourteen experiments no change occurred; (4) increase in pulse rate correlates well with rectal temperature, but rectal temperature rises less when blood volume doesn't increase; and (5) a considerable quantity of fluid can be requisitioned from tissues and evaporated from the blood without affecting blood volume. The authors also state that individual inability to withstand heat may lie in failure of blood plasma to increase.

14. "Body Temperatures: Effects of Climatic Extremes", M. Critchley, Brit. J. Ind. Med., 4, 164-90 (July, 1947).

A summary of the work done on the effects of heat and cold on the human body. The author states that efficiency drops in both heat and cold. The drop in efficiency starts at about 87.5°F in the hot range. Nothing has been done in the cold range. He lists physiological responses to heat as (1) elevated body and skin temperatures, (2) increased pulmonary ventilation, and (3) sweating. His discussion of cold is mainly concerned with being immersed in cold water. The author also states that acclimatization to heat can be induced artificially, but not much is known about acclimatization to cold.

15. "Cardiac Output In Rest and Work In Humid Heat", E. Amussen, Am. J. Physiol., 131, 54 (1940).

Acclimatization to humid heat was found to involve keeping circulation at normal level, both at rest and at work.

16. "Cardiac Output, Peripheral Blood Flow, And Blood Volume Changes In Normal Individuals Subjected To Varying Environmental Temperatures", F. K. Hick, et al., Heat. Pip. and Air Cond., 11, 50-3 (January, 1939).

This report gives results of the measurement or cardiac output, quantity of peripheral blood flow, and circulating blood volume on two subjects, one male and one female. Observations were made for a comfortable condition, a hot dry condition, and hot wet condition. The results seem to show that rate of blood flow through the skin governs its temperature and that skin temperature controls the loss of heat to meet the needs of the individual. It was found that (1) cardiac output does not rise until metabolism rises on exposure to heat, (2) peripheral blood flow becomes great as mean skin temperature approaches rectal temperature, (3) blood volume rises after exposure to hot wet conditions, and (4) cardiac output is governed by heat production.

17. "Cardiovascular Adjustments Of Man In Rest and Work During Exposure To Dry Heat", H. L. Taylor, et al., Am. J. Physiol., 139, 583 (1943).

The following questions are posed: (1) How fast do men acclimatize to heat? (2) How great a variation exists between men? (3) Can man's response to heat be predicted? (4) What is the sequence of adjustments in acclimatization? Seven thousand observations were made. Predictions of a man's resistance to heat could not be based on any standard measurement. Great individual differences in heat adaption were found. The questions posed are rather vaguely answered.

18. "Cerebellar Syndrome Following Heat Stroke", W. Freeman and S. E. Dumoff, Arch. Neurol. Psych., 51, 67 (1940).

An enumeration of the permanent effects which can occur after a severe heat stroke. The statement is made that internal temperature may rise to 111°F with rapid and permanent recovery occuring later.

19. "A Characteristic of Human Temperature Regulation", C. R. Spealman, Proc. Soc. Exper. Biol. Med., 60, 11 (1943).

Results of experiments consisting of immersing subjects in cold water and recording their rectal temperatures against time show an immediate drop of body temperature and then a stabilization. Gastric temperatures also were taken toward the end of the experiment and were found to be from 0.4 to 1.2°C higher than rectal temperatures. No correlation of shivering between subjects was noted.

20. "Climatic Effects On Cardiac Output and the Circulation of Man", J. C. Scott, et al., Am. J. Physiol., 129, 102 (1940).

Pulse rates, blood pressures, pulse wave velocities, and cardiac output were measured on subjects exposed to warm and cool environments. Relationships of the various factors are shown by table and graph.

21. "Climatic Effect On the Volume and Composition Of Blood In Man", H. C. Bazett, et al., Am. J. Physiol., 129, 69 (1940).

This article concludes that the acclimatization which occurs within several days is accompanied by significant blood volume change. The change is an increase with warmth and a decrease with cold.

22. "Clinical Trial of Vitamin B_1 and C in The Prevention of Heat Disease", L. A. Shoudy and G. H. Collins, Ind. Med., 14, 573 (1945).

Giving salt or salt and vitamin tablets to men who work in the heat diminished the number of cases of heat cramps, but vitamin tablets alone had no effects.

23. "Cold-physiologic Effects (With Special Reference To Dachau Experiments)". A. P. Gagge and L. P. Herrington, Am. Rev. Physiol., 9, 409-28, (1947).

24. "Cold Weather Effects on Circulation", A. Samuelson, Hygeia, 24, 896 (December, 1946).

25. "Comfort Requirements For Low Humidity Air Conditioning", F. C. Houghten, et al., Heat., Pip. and Air Cond., 13, 57-63 (January, 1941).

This report deals with comfort reactions in entering and setting in a room conditioned in the range of 64 to 74°F. Pulse rate, degree of perspiration, feeling of warmth, body temperature, and skin temperature of the index finger, chest, and forehead were observed. Results: (1) extremities (index finger) are lower in temperature when subject reports "cool feeling", and (2) optimum comfort is at 70 to 73°F with 30 percent relative humidity. The report contains many graphs correlating different observations.

26. "Comparison of Physiological Adjustments of Human Beings During Summer and Winter", N. Glickman, et al., A.S.H.V.E. Trans., 54, 307 (1948).

Three experiments were made on each of four healthy male students during the summer and three similar experiments were made on the same students during the winter. The subjects all entered a "comfortable" room for one hour, entered a hot room for one hour, and then returned to the comfortable room for one hour. The comfortable room was maintained at a dry-bulb temperature of 76°F for all experiments and the relative humidity was placed at three different values: 30, 60, and 80 percent. Observations were made of rectal and skin temperatures, evaporative weight loss, pulse rate, and comfort vote while the subjects remained seated in Troemner balances. There was little evidence that seasonal adaptations were of any importance in determing a subject's responses.

27. "Composition of Sweat During Acclimatization to Heat", D. B. Dill, et al., Am. J. Physiol., 123, 412 (1938).

This article reports experiments in which the chemical content of the sweat is measured. Lack of salt, reducing ability of sweat glands, may cause heat cramps.

28. "Conditons For Comfort", C. S. Leopold, A.S.H.V.E. Trans., 53, 295 (1947).

A discussion is presented of comfort charts and the concept of a comfort zone. The definition of comfort for purposes of this discussion is "the absence of discomfort or annoyances due to temperature and atmospheric effects indoors". Specification of an effective temperature band of theoretical tolerance is given on the basis of a census of several thousand thermostat settings in several office buildings in various parts of the United States. This band extends over the range of Effective Temperatures from 74.5 to 77.0. For a lightly-clothed, semi-reclining subject the point of no heat storage occurs at 77.5 degrees Effective Temperature. The outlined conditions for the comfort zone are not considered detrimental to good health on the basis of absence of evidence to the contrary.

29. "Control of Body Heat Loss Through Radiant Means", C. S. Mills and C. Olge, Heat. Pip., and Air Cond., 9, 697-9 (November, 1937).

In this experiment four rooms were used with differing types of heat and reflective walls. It was found that practically all body-heat loss could be absorbed through radiation. One room was lined with aluminum foil and contained six cold plates. Even at 89 to 92°F room temperature and 60 to 70% relative humidity body chilling was evident. Results showed that: (1) comfort can be regulated through radiant means alone, (2) feasibility of such control lies in differences exhibited by various substances, and (3) foil wall surfaces act as efficient passive reflectors of radiant heat.

30. "Control of Excessive Heat and Humidity in Industry; Putting Theory Into Practice", J. B. Skinner and W. M. Pierce, J. Ind. Hyg and Toxicol. 27, 31-5 (January, 1945).

A report of conditions in hot industries relating them to maximum "effective" temperature (86°F). The following methods of combating high temperatures are suggested: (1) use of salt, (2) air motion, (3) exhaust ventilation, (4) supplied air, (5) reduction of radiant heat, (6) insulation, and (7) cooling of interior.

31. "Decline In Rates Of Sweating Of Men Working In Severe Heat", S. D. Gerking and S. Robinson, Am. J. Physiol., 147, 370-8 (October, 1946).

Six subjects were exposed to the following environments: dry heat (40-50°C, 18-38% relative humidity) and moist heat (31.9-38°C, 51-95% relative humidity). Results showed that the rates of sweating declined steadily as the experiment progressed. The decline in sweating rates was greater in humid than in dry heat and greater in army tropical uniforms than in shorts. There was a greater decline in sweating rate as initial rate was increased. The author concludes that, since the decline was not associated with dehydration nor decreased strength of the stimulus, the sweating mechanism was fatigued.

32. "Definition of The Upper Limit of Environmental Warmth by Psychological Tests of Human Performance", N. H. Mackworth, The Royal Society, Empire Scientific Conference Report, I, (1948).

Four different experiments were made to determine the effects of heat on human efficiency. The first was a test requiring heavy muscular work plus accurate muscular control. The second consisted of wireless telegraphy reception to determine the effects on high speed semi-automatic work. The third consisted of coding and decoding messages in order to determine the effect on intellectual activity. The fourth was a visual attention test. It was found that the more skilled the operator in wireless telegraphy, the fewer were his mistakes, the higher the temperature to which his percentage of mistakes was not affected by temperature. Also measured was the ability to sleep without restlessness. Accurate work decreased and restless sleep increased sharply between 90/80 and 95/85 (DB/WB)°F. It was also found that there was no direct relationship between rectal temperature and incidence of mistakes, both being dependent on room temperature.

33. "Dehydration Produces Intolerance to Heat", E. F. Adolph, Fed. Proc. 4, (1945).

This abstract refers to dehydration experiments on seven species of mammals, including man. After water equal to about 10 percent of body weight is lost, deep temperature climbed explosively. Each specie had a temperature level above which they succumbed (except that there was no determination on men). Man tolerated dry atmosphere above 53°C for eight hours without water.

34. "Desert Climate; Physiological and Clinical Observations", W. S. S. Ladell, Lancet, 2, 491 (1944).

Observations were made on the British Wartime Army in Iraq where temperatures went up to a range between 100 and 115°F with relative humidity of approximately 15 per cent. Many tables and graphs are given on body weight, urine volume, sweat analysis, blood analysis and pressure, pulse rate, and types and frequencies of heat disease. Two types of heat disease symptoms are described.

35. "Desert Climate; Physiologic and Clinical Observations", W. S. S. Ladell, et al., J. Ind. Hyg., 27, Suppl. 70 (Abstract), (April, 1945).

This is an abstract of reports of observations on British Army personnel in Southern Iraq. Sweat, urine, and various types of heat exhaustion were analyzed. Heat exhaustion type 1 (vomiting, cramps, paleness, collapsing and sweating) appeared to be due more to salt depletion than type 2 (defective sweating, polyuria, and prickly heat). Incidence of type 2 could probably be diminished with a few days in cooler climate after 8 weeks of continued heat exposure.

36. "Dietary Protein and Physical Fitness in Temperate and Hot Environments", G. Pitts, et al., J. Nutrition 27, 497 (1944).

Three healthy young males were required to do physical work in temperate and tropic conditions (95°F, 85 percent relative humidity, 15 mph wind). Under different diet conditions measurements were taken on metabolism, blood pressure, pulse rate, and rectal temperatures. Results showed that there was no change in work output or physical fitness due to eating large quantities of meat, indicating that a wide range of protein intake is tolerated.

37. "Disturbances of Temperature Regulation in Man", C. Davison, Assoc. Res. Nerv. Ment. Dis. Proc., 20, 774 (1940).

Clinical investigation and autopsy reveal that the hypothalamus was damaged in cases of lack of proper temperature regulation. Those with high temperatures had lesions on the rostral part, and those with low temperatures had lesions on the caudal part of the hypothalamus. In one case where the entire hypothalamus had lesions, the subject had both high and low temperatures.

38. "Draft Temperatures and Velocities in Relation to Skin Temperature and Feeling of Warmth", F. C. Houghten, et al., Heat. Pip. and Air. Cond., 10, 145-52, (February, 1938).

Experiments are reported on fifteen males, eighteen to thirty years old. Thermocouples on skin surfaces of neck and ankles were used and drafts were directed on these two areas. A discussion is made on the difficulty of measuring skin temperature, due to interference from natural evaporation, etc. The study shows that there is a definite relation between skin temperature and the velocity and temperature of air. For the same change in air temperature and velocity, a greater change in skin temperature is indicated for the neck as compared to the ankle. Higher draft velocity and lower draft temperature is permissible for the ankle than for the neck. Indices are set for minimum temperatures and maximum velocities on neck and ankle beyond which drafts are intolerable.

39. "Effect of Ambient Air Temperature and of Hand Temperature on Blood Flow in Hands", C. R. Spealman, Am. J. Physiol., 145, 218 (1945).

Measurements of blood flow were made under cold, moderate, and hot conditions. Blood flow was greater both at cold and warmer temperatures than at moderate hand temperatures. At any given hand temperature the blood flow was greater the warmer the body.

40. "The Effect of Body Size Upon Energy Exchange in Work", S. Robinson, Am. J. Physiol., 136, 363 (1942).

A small man was able to maintain heat balance under severe heat while working, where a large man could not. One large man and one small man, both athletes, were used in the experiment. The author concludes that comparatively larger skin surface for given weight enabled the small man to survive more easily than the larger man.

41. "The Effect of Climate Upon the Volume of Blood and of Tissue Fluid In Man", W. H. Forbes, et al., Am. J. Physiol., 130, 739 (1940).

Experiments in Mississippi in the summer time indicate an average of 5 percent greater blood volume in laboratory workers who had formerly resided in Massachusetts.

42. "Effect of Clothing on Ability of Men to Work in Intense Heat", W. B. Shelley, et al., J. Clin. Invest., 25, 437-46 (May, 1946).

Experiments at the Armored Medical Research Center showed that clothing (single layer herringbone twill) reduces the limiting wet-bulb temperature for effective work by 2°F from 94 to 92°F wet bulb at 93-95°F dry bulb and from 92 to 90°F wet bulb at 120°F dry bulb. The men in these experiments were walking three miles per hour for four hours. The article contains a graph showing upper limits for nude and for clothed men in terms of humidity and temperature.

43. "Effects of Cold Air On Air Passages and Lungs; Experimental Investigation", A. R. Moritz and J. R. Weisiger, Arch. Int. Med., 75, 233-40 (April, 1945).

Dogs were made to breathe extremely cold air (-50 to -28°C) for periods ranging from 20 to 133 minutes. The results warrant the following conclusions: it is unlikely that the air passages of man would be injured by cold encountered in nonexperimental conditions so long as the air is inhaled through the nostrils or partially closed lips and even though extemely cold air was inhaled through a widely opened mouth, it would be warmed to a point well above freezing before it encountered any vital organ in the air passage.

44. "Effects of Cold on Efficiency of Man", S. M. Horvath and A. Freedman, J. Avia. Med., 18, 158-64 (April, 1947).

Twenty-two men lived in a cold chamber at -20°F from 8 to 14 days. They were given a series of tests to measure responses and performance. Seventy other men were exposed for three hours to temperatures from -10 to -14°F. These men were given tests that measured the strength of their grip. The experimenters found that reaction time to visual stimulation was not altered during exposure, but that digital dexterity and hand strength were markedly reduced.

45. "The Effects of Cooling and Warming on the Vital Capacity, Forearm and Hand Volume and Skin Temperature", E. M. Glaser, J. Physiol, 109, 421 (1949).

Five men were place in a hot room (105°F dry bulb and 95°F wet bulb) where vital capacity increased and in a cold room (1°C with 300 ft per minute air movement) where vital capacity decreased. The same type of reaction was found when lower limbs were immersed in hot and cold water. The author concludes that cooling results in movement of blood from extremities to lungs and warming results in movement from lungs to extremities.

46. "Effect of Experimental Fever Upon the Circulation in the Human", J. W. Moore and J. M. Kinsman, T. A. Am. Physicians, 51, 260 (1936).

Blood flow is measured under conditions of experimental fever, but no consistency is found that can relate the body temperature to blood flow.

47. "Effects of Heat and High Humidity on Prolonged Visual Search as Measured by the Clock Test", N. H. Mackworth, Report prepared for the Habitability Sub-Committee of the R.N.P.R.C., (February, 1946).

Eighty-nine men were tested at various dry-bulb and wet-bulb temperature readings. Twenty men were tested at 75/65°F, twenty-three others at 85/75°F, twenty-four at 95/85°F, and twenty-two at 105/95°F. The main findings were:

(1) Hot, moist atmospheres impair the accuracy with which faint visual signals are detected in a relatively monotonous situation.

(2) Responses tend to become sluggish, but not so markedly as the decline in accuracy of work.

(3) Optimum dry-bulb and wet-bulb temperatures for accurate visual search is 85/75°F. Performance deterioration becomes statistically definite at 95/85°F.

(4) There is no statistically reliable relationship between final rectal temperature and incidence of missed signals.

48. "Effects of Heat on Wireless Telegraphy Operators Hearing and Recording Morse Messages". N. W. Mackworth, Brit. J. Ind. Med., 3, 143-58 (July, 1946).

This is a study of the effect of temperature on the performance of monotonous tasks. It was found that hot and moist atmospheres impaired the accuracy with which the subjects could receive messages. It was also found that this atmosphere raised the rectal temperature , but that this in no way gave an idea of the accuracy of the reception.

49. "Effect of Low Temperature on the Human Body; Freezing to Induce Hibernation", L. K. Wright, Refrig. Eng. 38, 143-4 (September, 1939).

A report on the work of Drs. Fay and Smith of Philadelphia on the inducement of sleep in humans by bringing the body temperature down to below 90 to 82° in one case, with no ill effects. Memory becomes vague during the process. Bowels, kidneys, and digestive organs cease functioning.

50. "The Effect of Salt on the Work Performance of Man During Dry Heat and Experimental Heat Exhaustion", H. L. A. Taylor, et al., Am. J. Physiol., 140, 439 (1943).

Groups of men given high (30 gm) moderate (15 gm), and low (6 gm) amounts of salt per day were placed in three different temperature environments and observations and measurements were made of their work capacity. No more than 13-17 gm of salt per day is ever needed.

51. "Effects of Temperature Change on the Water Balance in Men", C. L. Corley and J. L. Mickerson, Am. J. Physiol., 143, 373 (1945).

Results show that in hotter environments increased sweating takes place, resulting in less urination. The converse is true for cooler environments.

52. "The Effect of Temperature on Blood Flow and Deep Temperature in the Human Forearm", H. Barcroft and O. G. Edholm, J. Physiol., 102, 5 (1943).

Approximately seventy experiments were carried out on five normal men 25 to 40 years of age. Blood flow and deep muscle temperature were measured in one immersed foreman with the bath kept at varying temperatures from 13 to 45°C for 2 hours. The blood flow increases and decreases with temperature changes and this is correlated with deep muscle temperature. Body-temperature changes about 1°C when the forearm is immersed in 13°C water, as compared with when it is immersed in 45°C water.

53. "Effect of Wet Garments on Body Weight Loss at High Environmental Temperatures", N. Lifson and M. B. Sisscher, J. Ind. Hyg. Toxicol., 25, 434 (1943).

Subjects tested for weight loss were found to have lost much less weight in wet clothes when resting and working at a temperature of 110°F with 25 percent relative humidity. At 97°F with 67 percent relative humidity at rest there was substantial weight conservation, but under working conditions more body weight was lost. In general, the subjective preference was expressed for the condition in which less body weight was lost, thus, the vote was for wet clothes for all, but work in hot humid environments.

54. "Effects on Lungs and Air Passages of Extremely Hot and Extremely Cold Air", A. R. Moritz, Bull. New Eng. Med. Center, 7, 222-3 (October 1945).

Experiments were performed to determine the effects of cold air (-28 to -50°C) on lungs and air passages. The experimenters came to the conclusion that even though extremely cold air was inhaled rapidly through a widely opened mouth, it would be warmed enough before reaching the lungs to prevent damage.

55. "Environmental Conditions Which Indicate Sweating in Resting Man", G. E. Burch, Proc. Soc. Exper. Biol. and Med., 67, 521-3 (April, 1948).

Observations were made on eleven subjects of varying ages to discover the environmental conditions necessary to induce sweating. These studies indicate that an environmental temperature of 34.4°C and a relative humidity of 50 percent are essentially the threshold for sweating in normal man. Exercise and increased rate of heat production lower the threshold.

56. "Environmental Temperatures and B-vitamin Requirements", C. A. Mills, Arch. Biochem., 1, 73 (1942).

In rats, B-vitamin requirements are twice as high for thiamine and pyridoxin and five times as high for choline at 91°F than at 68°F.

57. "Environmental Temperatures and Resistance to Infection", C. A. Mills and L. H. Schmidt, Am. J. Trop. Med., 22, 655 (1942).

This experiment concerns the innoculation of acclimated mice with Type I pneumoccus. Those kept at 90°F died in a little more than half the time as those kept at 67°F.

58. "Environmental Temperatures and Thiamine Requirements", C. A. Mills, Am. J. Physiol., 133, 525 (1941).

An investigation on rats shows that thiamine requirements were twice as high at 90°F as at 65°F.

59. "Environmental Temperature and Vitamin K Deficiency", C. A. Mills, et al., Am. J. Physiol., 141, 359 (1944).

Results show that rats placed in tropical heat suffer from severe and highly fatal vitamin K deficiency, but that moderate temperatures cause a lower demand for this vitamin.

60. "Evaporation From Human Skin With Sweat Glands Inactivated", E. A. Pinson, Am. J. Physiol., 137, 492 (1942).

Insensible sweat occurs on skin surfaces in which the sweat glands have been rendered inactive, although increase in sweat due to increase in heat has been stopped. The author concludes that there is insensible sweat at least down to 10°C and this might not come through the sweat glands.

61. "Exchanges of Heat and Tolerances to Cold in Men Exposed to Outdoor Weather". E. F. Adolph and G. W. Molnar, Am. J. Physiol., 146, 507-37. (July, 1946).

Nearly nude men were exposed outdoors to environments ranging from 32 to 88°F and wind velocities from 5 to 15 mph. Their responses over 1 to 4 hour periods were measured in terms of pulse rates, arterial pressure, deep and skin temperatures, ventilation rate, urinary flow, blood concentration, and heat exchanges (production, storage, sensible exchange, and evaporative loss). It was found that skin temperatures were proportional to air temperatures, and rectal temperatures never fell below 96°F. Oxygen consumption while shivering was five times that while not shivering. Shivering produced muscular fatigue. Due to the shivering and the intense superficial vasoconstriction of cold, the arterial pressure increased and the blood became concentrated. The pulse rate accelerated linearly with oxygen consumption. The inability of men to produce sufficient heat to compensate for severe heat loss was demonstrated. Sunshine is helpful in saving heat while wind is detrimental.

62. "Experimental Investigation of the Effect of Change in Atmospheric Conditions and Noise Upon Performance; Investigation on Desirability of Air Conditioning Naval Vessels", M. S. Viteles and K. R. Smith, Heat. Pip. and Air Cond., 18, 107-12 (March, 1946).

This report involves an analysis of changes in work output, feeling, and physiological state of males doing selected tests in different temperature and humidity levels. Tests indicate that (1) there is no need to maintain temperature below 80°F so far as work output is concerned, and (2) there is no need to keep noise level below 90 decibels to maintain output. Temperature increase adversely affects work output much more than does noise increase.

63. "An Experimental Study of Heat Collapse", J. S. Weiner, J. Ind. Hyg. and Toxicol., 20, 389 (1938).

Mine workers in South Africa were subjected to work in a room at 94 to 95°F wet-bulb and 96 to 98°F dry-bulb temperature. Six of thirty-six subjects were affected by the heat and collapsed. This heat collapse can be induced in certain individuals by keeping them erect in humid heat. The collapse is due to over-vasodilatation near skin surfaces and "pooling" of the blood away from the head, which brings on slowing of the heart and an extreme fall in blood pressure. In those who did not collapse compensatory actions took place which sped up the heart, maintaining adequate circulation. Air movement not only promotes heat loss through evaporation, but it is thought that air stimulation of the skin reflexly influenced muscle tone, which acts as a stimulant to peripheral blood flow.

64. "Factors Influencing Salt Concentration in Sweat", R. E. Johnson, et al., Am. J. Physiol., 141, 575 (1944).

Experiments showed that sweat chloride (a) increases as work is prolonged, (b) varies between individuals, (c)varies inversely to the amount of drinking water, (d) increases with rate of sweating, and (e) increases with body and skin temperature.

65. "Failure of the Sweat Mechanism in the Desert", J. Wolkin, et al., J.A.M.A., 124, 478 (1944).

This appears to be a separate syndrome which does not fall into the accepted categories of heat stroke, heat exhaustion, or heat cramps. Immediate removal from heat is advised and the authors would not advise returning to hot conditions even after the sweat glands have resumed working. This is a very rare disease.

66. "Field Trials of Methods of Tank Personnel Cooling Carried Out in New Guinea, November 1943.. Douglas H. K. Lee, AFV 48, December 3, 1943.

Attempts were made to determine the magnitude of the climatic problem insofar as it effects tank crews (British "Matilda" tanks) and also to determine what method of cooling would produce the necessary improvement. Tank crews were subjected to seven hour test periods during which conditioned and unconditioned air was passed over their body surfaces by means of jets or air distribution harnesses. Air was delivered in quantities of 8 CFM per man and 16 CFM per man. Measurements were made with reference to the effect of cooling methods on the air in the crew compartment, on physiological reactions of the crew, and on the individual crew members' subjective reactions as expressed in conference. The following conclusions were reached: (1) some form of personnel cooling is essential for efficient operation of tank crews in the tropics; (2) of the cooling methods tested the best was to supply each man with 8 CFM of air, dehumidified to a dewpoint of 50°F, by harness; (3) the next best method was to supply 16 CFM per man of untreated air by harness; and (4) a jet of untreated air may not prevent breakdown.

67. "Heat Effects in British Service Personnel in Iraq", T. C. Morton, Trans. Roy. Soc. Trop. Med. Hyg., 37, 347 (1944).

The effects of desert heat up to 125°F in Iraq are discussed. Mention is made of the three conventional types of heat disease and treatments for them. A discussion on the article by several doctors is also presented.

68. "Heat and Cold (Regulation)", D. H. K. Lee, Ann. Rev. Physiol., 10, 365-86 (1948).

69. "Heat Effects - Long Term Acclimatization", W. R. Christensen, Am. J. Physiol., 148, 86-90 (January, 1947).

A presentation of data relating to the physiological responses of seven healthy soldiers to daily exposures to high temperatures (90°F) and relative humidity (85%). The subjects, after being acclimatized for one month, were exposed to these conditions for six months. The results do not indicate any trend either in pulse rate or rectal temperature. However, five of the seven subjects exhibited a decline in sweat rate.

70. "Heat: Effect of Acclimatization on Circulatory Responses to High Environmental Temperatures", C. H. Wyndham, J. Applied Physiol., 4, 383-95. (November, 1951).

Heart rate, blood pressure, rectal temperature, weight, sweat rate, and blood flow measurements on the arms and hands were made on subjects when entering and leaving a controlled room on successive days. Results show a progressive decrease in heart rate, pulse pressure, and in blood flow. In summary it is stated that (1) acclimatization to heat shows increase in peripheral resistance, and reduction in peripheral blood flow, and (2) peripheral blood flow and heart rate are roughly linear with sweat-rate index. Many graphs and tables showing the various measurements are presented.

71. "Heat Effects - Physiologic Effects", A. P. Gagge and L. P. Herrington, Ann. Re. Physiol., 9, 409-28 (1947).

72. "Heat Exchanges During Recovery From Experimental Deficit of Body Heat", E. A. Pinson and E. F. Adolph, Am. J. Physiol., 136,105-14 (1942).

Four unclothed men were seated in an atmosphere at 31°C and 25 percent relative humidity. On drinking 1.5 liters of ice water each body became cooler to the extent of 0.72 calories per kilogram. In 200 minutes 85 percent of the heat debt was paid off, half by reduction in vaporization and half by reduction in convection due to lower skin temperatures. Metabolism was not increased.

73. "Heat Exhaustion", A. W. Wallace, Mil. Surgeon, 93, 140 (1943).

A report of heat exhaustion cases at Keesler Field during summer months. Steps taken to reduce heat disease cases were: more water intake, more salt intake, greater rest periods, and sparser use of clothing. Heat disease is classified as to body temperature levels.

74. "Heat Regulation During Acclimatization in Hot, Dry (Desert Type) Environment", L. W. Eichna, et al., Am. J. Physiol., 163, 585-97 (December, 1950).

This test was carried out on three men who worked for 1 hour in a temperature of 123°F and relative humidity of 15 percent as they became acclimated to this hot environment. The acclimatization process returned body temperature to normal level (i.e., normal in reference to a cool environment) and set skin temperatures at a level which permitted thermal equilibrium with the environment and at the same time permitted the transfer of body heat to the skin without overtaxing the circulation. The principle adaptive mechanism of acclimatization which produced these changes was an increase in evaporative cooling, which lowered the skin temperature and accounted for 75 to 90 percent of the reduction in body temperature and heat content. A small decrease in metabolic heat production accounted for 5 to 20 percent reduction in body-heat content.

75. "Heat Regulation Effects on Man of High Temperatures, With Special Reference to Work of Heat Physiology Team at National Hospital", W. S. S. Ladell, Brit. M. Bull., 5, 5-8 (1947).

Tests were conducted to determine (1) the value of acclimatization, (2) how men react to continued raised body temperatures, and (3) how long a man will continue to sweat at a high rate. It was found that (1) when a man first tries to work in heat he is inefficient, but as he becomes acclimatized he becomes more efficient; (2) there is a considerable variation in tolerance to continued raised body temperature; and (3) that sweat glands fatigue rapidly at high rates of secretion. The latter is not important, however, because in actual situations the conditions that lead to high sweat rates seldom last long enough to fatigue the sweat glands.

76. "Heat Regulation - Man's Exchanges and Physiologic Responses", W. Machle and T. H. Hatch, Physiol. Rev., 27, 200-27 (April, 1947).

The stated purpose of this article is to summarize the heat-transfer laws with respect to man and his environment, to review recent work, and to emphasize war studies. A section on mathematical considerations is given which deals with the heat balance equation, coefficients of heat exhange, equilibrium state, equivalent environments, and physical instruments for measuring equivalence. A section on the physiological effects of heat deals with body temperature, blood flow circulation, sweating, salt depletion, metabolism and nutrition, the gastro-entric tract, thermal regulation, acclimatization, work in hot environments, upper limits of tolerance, and heat disease. An extensive bibliography is given.

77. "The Heat Regulation of Small Laboratory Animals at Various Environmental Temperatures", L. P. Herrington, Am. J. Physiol., 129, 123 (1940).

Several small animals were studied at temperature ranges from 13 to 35°C. Metabolism, rectal temperature, and conductance values are computed at each temperature level. Body-heat level does not correspond well with metabolism changes.

78. "Heat Regulation - Physiology of Heat and Cold", J. R. Brobech, Ann. Rev. Physiol., 8, 65-88 (1946).

79. "Heat Regulation - Thermal Balance of Men Working in Severe Heat", Robinson and Gerking, Am. J. Physiol., 149, 476-88 (May, 1947).

In dry heat (temperature 122°F dry bulb, 83°F wet bulb) a man dressed in shorts assumed thermal equilibrium with the atmosphere in the second hour of exposure (skin and rectal temperatures, 100 and 96°F respectively). A man dressed in a tropical suit, doing the same work in the same environment, attained thermal equilibrium in the third and fourth hours. This was followed by a pronounced secondary rise in both skin and rectal temperatures in the fifth and sixth hours. This rise was always associated with a decline in sweating and a rise in metabolic rate over the equilibrium period. The decrease in sweating occurred gradually over the last four or five hours. It was found that the accumulation of sweat by the clothing increased the men's heat gain by convection and radiation. The fatigue of the sweating mechanism occurred when the skin temperature was maintained at high levels (95 to 98.6°F) for long periods and when initial rates of sweating were high.

80. "Heat Sickness", V. C. Baird and H. T. Engelhardt, M. Rec. and Ann., 40, 1591-3 (October, 1946).

A classification of heat sickness is presented: (1) heat cramps, exhaustion, and stroke; (2) prickly heat and loss of ability to sweat.

81. "Heat Transfer in Man", D. K. C. MacDonald and C. H. Wyndham, J. Appl. Physiol., 3, 342-64 (December, 1950).

There were four different tests run in this experiment of which the present project was interested in only two.

(I) Two subjects were required to work for 2 hours in a 115°F dry-bulb, 85°F wet-bulb environment. On the second, third, and fourth days, the temperatures were 130°F dry bulb and 90°F wet bulb and the subjects were required to do varying amounts of work. Rectal and skin temperatures were measured at regular intervals along with sweat rate. It was found that rectal temperatures fell, then rose while the men were resting after entering the hot room, rising further on commencement of work. Skin temperature rose sharply on entering the chamber, but stopped rising with the onset of sweating. On the commencement of work the skin temperature rose again in one subject, but didn't in the second subject who had some acclimatization from an earlier experiment.

(II) A subject wearing cold weather clothing was subjected to temperatures of 22 to 32°F. Rectal and skin temperatures were measured. The subject was required to rest for 2 hours then work for 1 hour. It was found that skin temperatures dropped sharply the first hour and less sharply the second hour. For the first half hour of work the temperature continued to fall, but less sharply. During the second half hour the temperature rose sharply and at the end of the hour of work had reached the value observed at the beginning of the test. Rectal temperatures fell sharply at first and then leveled off to a new equilibrium in the two rest hours. At the commencement of exercise the temperature rose immediately and then leveled off to equilibrium in 1 hour.

82. "Hot Humid Environment; Effect on Performance of Motor Coordination Test", J. S. Weiner and J. C. D. Hutchinson, Brit. J. Ind. Med., 2, 154-7 (July, 1945).

Three groups of subjects were used in this test: (1) resting nude subjects were given a short exposure (2 hours) to an Effective Temperature of 91°F (95°F dry bulb, 90°F wet bulb); (2) clothed subjects, after working in an environment of 88°F Effective Temperature, were exposed to the same conditions as in (1); and (3) nude subjects were exposed for long periods to Effective Temperatures of 82 to 96°F. All showed a measurable impairment of manual dexterity and coordination.

83. "Human Efficiency and Comfort in Indoor Climates", L. P. Herrington, Heat. Vent. and Air Cond., 47, 53-60 (July, 1950).

This article deals with (a) the biophysical heat balance of the human body, (b) comfort significance of the heating and air conditioning situation, and (c) human efficiency in relation to thermal environments. Reference is made to many different investigations and a summary is made of the current state of knowledge in each subject.

84. "Human Tolerance Limits for Extreme Heat", W. V. Blockley and C. L. Taylor, A.S.H.V.E. Trans., 55, 399 (1949).

Experimental work was done on two student volunteers in order to determine physiological effects on human beings under extreme conditions such as might be experienced with air flight speed of 800 mph in an unconditioned pilot compartment. Ambient temperatures imposed on the subjects ranged from 140 to 240°F. Measurements taken included rectal temperature, mean skin temperature, exhaled air temperature, heart rate, respiration volume, and blood pressure. Approximate tolerance times are also noted. A correlation is derived for an "Index of Physiological Strain" as a function of exposure time, with air temperature parameters.

85. "Human Tolerance to Heat", W. Machle, Heat. Pip. and Air Cond., 19, 109-10 (February, 1947).

A review of some recent work in man's reaction to high temperature, mentioning the concept of thermal equilibrium and stating the lack of knowledge and investigation on this subject. Reference is also made to investigations of 1942-45 at the Armored Medical Research Laboratory. Formulas concerning human heat input and output are given. The statement is made that, with hard work, rectal temperatures can go to 103°F with no ill effects; on the other hand disabling heat exhaustion may occur with no rise in rectal temperature.

86. "The Hypothalamus as a Thermostat Regulating Body Temperature", S. W. Ranson, Psychosomatic Medicine, 1, 486 (1939).

Experiments on cats indicate that a region of the hypothalamus controls the heat regulation of the body. Damage to this section causes rectal temperatures to fluctuate with environmental temperatures. In the case of a human whose temperature fell to 92.4°F for a month, the the hypothalamus nucleus was found on autopsy to have been destroyed.

87. "The Importance of Clothing in Air Conditioning", C. P. Yaglon and Anne Messer, J.A.M.A. 117, 1261 (1941).

This article is concerned only with conventional clothes in moderate temperature.

88. "The Influence of Clothing on the Physiological Reactions of the Human Body to Varying Environmental Temperature", A. P. Gagge, et al., Am. J. Physiol., 124, 30 (1938).

A comparison of reactions between clothed (business suit with vest) and nude subjects. The relationship of skin temperature to sensations of unpleasantness is very close, in both heat and cold. Many tables and charts are included in this article. Among the conclusions reached are (1) that a normally clothed person can tolerate an 8°C difference between skin temperature and environmental temperature before body cooling starts, compared with 4°C for a nude subject; and (2) that heat loss by evaporation takes place on the skin surface and not in the folds of clothes.

89. "Influence of Clothing, Work and Air Movement on Thermal Exchanges of Acclimatized Men in Various Hot Environments", N. A. Nelson, et al., J. Clin. Invest., 27, 209-16 (March, 1948).

Four acclimatized males were placed in various hot environments and wind velocities wearing different types of clothing and undergoing different motions. The environment varied from 90°F dry bulb and 70°F wet bulb to 120°F dry bulb and 88°F wet bulb, with wind velocities from 30 ft per minute to 600 ft per minute. The environmental data gathered consisted of dry-bulb temperature, wet-bulb temperature, wall temperature, and air velocity. The subject data was rectal, skin, and clothing temperature; oxygen consumption; heart rate, and sweat loss. Heat gain, heat loss, and heat storage were computed for the varying conditions and are expressed in several bar graphs. Convective and radiant heat gain and the compensatory evaporative heat loss showed increase with air movement.

90. "Influence of Environmental Temperature and Posture on Volume and Composition of the Blood", C. R. Spealman, et al., Am. J. Physiol., 150, 628 (1947).

Blood volume changes were measured during one week of changing temperature. Various components of the blood changed in quanitity; plasma protein and hemoglobin rising with heat and falling with cold.

91. "Initiation of Sweating in Response to Heat", E. F. Adolph, Am. J. Physiol., 145, 710-5 (March 1946).

Rates of evaporative loss were measured in men initially exposed to hot, dry air (122°F temperature, 10 percent relative humidity). It was found that the time lapse before the rate of sweating started to increase varied among the subjects and that it increased to a maximum rate of ten times that in a cool atmosphere. This maximum was reached in about 20 minutes. It is concluded that the promptness of onset of sweating is no indication of tolerance or acclimatization to heat. It is also stated that the slow onset of full sweating suggests that the stimulus required is an appreciable increase in the heat content of the body as a whole.

92. "Injury From Exposure to Low Temperature - Pathology", W. Blackwood, Brit. Med. Bull., 2, 138-41 (1944).

This article is a description of what happens when parts of the body are exposed to low temperatures. Recoverable damage occurs at skin temperatures from 59 to 63°F. Irrecoverable damage occurs at temperatures from 21 to 14°F.

93. "The Insensible Loss of Water", L. H. Newburgh and M. W. Johnson, Physiol. Rev., 22, 1 (1942).

A discussion of insensible water loss as compared to metabolism and environmental temperature. Details are presented concerning lung water loss as compared to skin water loss. Formulas for calculating water loss and graphs of percentage of evaporative loss under various temperatures are given.

94. "Investigations on the Exchanges of Energy Between the Body and Its Environment", C. Sheard, et al., A.S.H.V.E.Trans., 43, 115 (1937).

Tests were made on subjects to determine effects of sudden environmental changes on the skin temperatures of various regions of the body. Tests were conducted in rooms with temperatures of 66, 77, and 91°F with relative humidity at 40 percent. Thermocouples were placed on each large toe, upper leg, middle finger, inside of wrist, and on the forehead. Results show that the toes assume room temperatures throughout the range of environmental temperatures and that the heat loss from the body is largely regulated by the hands and lower arms. To study the effects of humidity on skin temperature, subjects were placed in a room at 75 percent relative humidity (77°F temperature) and then the relative humidity was lowered to 30 percent for 2 hours, after which it was raised again to 75 percent. Results showed that the regulation of heat loss by the fingers and wrists is more pronounced in low humidities.

(Note: Later investigations have shown that relative humidity plays little part in thermal exchanges unless the body is in the zone of evaporative regulation.)

95. "Life, Heat, and Altitude: Physiological Effects of Hot Climates and Great Heights", D. B. Dill, Harvard University Press, Cambridge, (1938).

This book contains the following pertinent chapters: I. Energy Exchange and Environment, II. Perspiration, III. Thirst, and IV. Man in Hot Climates. Chapter I discusses metabolic processes and measurement. Chapter II may be summarized: (1) Water is important to the regulation of body temperature; (2) Sweating is not always adjusted to the need of the organism, and (3) Acclimatization involves increase of capacity to produce sweat, greater sensitivity of the body's regulatory apparatus, and an economy of salt content. The reports are partially based on Boulder, Colorado, experiments and some charts and tables are given.

96. "Light, Temperature, Humidity; Effects in the Working Environment", A. M. Boedjer, Ind. Med., 13, 88 (January, 1944).

A short summary of effects of light, temperature, and humidity. Discussion is carried under the following headings: (a) acute effects of high and low temperatures (b) effects on resistance to disease, (c) relation of temperature to work and accidents, (d) optimum conditions of temperature, humidity, and air movement, and (e) preventive measures.

The conclusions reached are that (1) high temperature leads to heat cramps, heat stroke, and heat exhaustion, while low temperatures lead to acute inflammatory reactions; (2) pneumonia and rheumatism are more prevalent under continued high temperature; (3) work efficiency decreases and accidents increase at extreme temperatures; and (4) optimum temperatures for sedentary work are 68 to 73°F; for summer work, 75 to 80°F; for moderately hard work, 65°F, and for strenuous work, 60°F.

97. "Limits of Human Heat Regulation", L. H. Newburgh, et al., J. Aero. Scie., 10, 197-9 (June, 1943).

A broad discussion of the human thermostatic properties. An experiment is described which showed that skin temperature of 80°F or below on the trunk and 40°F or below on the extremities is beyond human endurance. High-air temperature effects and humidity effects are discussed briefly in a general manner.

98. "The Measurement of the Blood Pressure in Rats, With Special Reference to Temperature", G. G. Proskauer, et al., Am. J. Physiol., 143, 290 (1945).

Blood pressure change follows almost immediately on the rectal and skin temperature change in rats.

99. The Mechanism of Heat Loss and Regulation, E. F. DuBois, Stanford University Press, 1937.

This is a lecture given at Stanford University reviewing the history of metabolism measurements and surface area in their relation to body-heat regulation. The differing values of radiation, convection and evaporation are shown under various conditions, and measurement of radiation by a radiometer is described.

100. "Medical Department Problems in Cold Weather Operations", F. J. Knoblauch, Mil. Surg., 102, 283-5 (April, 1948).

A discussion of military supply, first aid, etc.

101. "Metabolic Acclimatization to Trpical Heat", C. A. Mills, Am. J. Trop. Med., 25, 59-61 (1945).

This article states that there are two fundamental acclimatization processes: (1) vasomotor, the transfer of waste heat to the skin, a process requiring from 3 to 5 days to develop; and (2) metabolic, in which there is less glandular activity, a fall in blood pressure, a drop resistance to infection, and an impairment of mental alertness, occurring in 3 to 4 weeks. At higher temperatures a need for greater amounts of thiamine is indicated.

102. Nutrition and Climatic Stress, H. H. Mitchell, Publisher Charles C. Thomas, Springfield, Illinois, 1951.

This book is primarily concerned with diet, but it also reviews and sums up the environmental responses at low and high temperatures. Discussion includes such topics as metabolism, lower and higher limits of tolerable temperatures, work capacity, acclimatization, sweat, heat and cold injuries, and the general physiological response to temperature. An extensive bibliography is given.

103. "Observations of Body Heat in Engine Room", A. L. Chambers, Can. M. A. J., 48, 214 (1943).

A table of oral temperature readings correlated with wet-and dry-bulb temperature readings over a series of days is presented on several subjects. The highest dry-bulb temperature was 132°F, while the wet bulb was 124°F (79 percent relative humidity). Slight ventilation was maintained. No ill effects of any kind were evident on the subjects.

Note: This is contrary to other findings which say that 92°F wet bulb is the upper limit.

104. "Observations on Men Sitting Quietly in Extreme Cold", S. M. Horvath, et al., J. Clin. Invest., 25, 709-16 (September, 1946).

Continuous observations were made of metabolic rate and skin and rectal temperatures of young men dressed in Arctic uniforms and sitting in temperatures of 32 to 40°F. It was found (1) that heat production was above basal values during the entire test, (2) that the fall in rectal temperatures was moderate, (3) that the mean skin temperatures fell sharply during the first hour of exposure, but were stabilized before the end of the test period, and (4) that, of the skin areas, the hands and feet exhibited the greatest temperature changes both in rate and degree of fall.

105. "Observations on Water Measurement in the Desert", E. F. Adolph and D. B. Dill, Am. J. Physiol., 123, 369 (1938).

Water intake and outgo were measured on persons in various activities and exposures. The daily turnover in water was 10 to 30 times the daily variation in body weight. Drinking before losing water did not make up what the body later drew. The human must ingest water many times daily.

106. "Performance in Relation to Environmental Temperature", W. B. Bean and L. W. Eichna, Fed. Proc., 2, 144 (1943).

107. "Performance in Relation to Environmental Temperature; Reactions of Normal Young Man to Hot, Humid (Simulated Jungle) Environment", L. W. Eichna, et al., Bull. Johns Hopkins Hosp., 76, 25-58 (January, 1945).

As men become acclimatized to humid heat, they work more efficiently and with less risk of illness than when first exposed. An acclimatized man has a lower pulse rate, a lower skin and rectal temperature, and a more stable blood pressure than an unacclimatized man. Acclimatization begins with first exposure and is achieved most rapidly and completely by progressively increasing work, and is complete in 7 to 10 days. Performance of acclimatized men in humid heat is impaired most seriously by lack of water and poor physical fitness, and less severely by lack of rest, by added clothing and equipment, by alcohol, and by long periods of work. Sweating in humid heat is profuse and very inefficient.

108. "Peripheral Type of Circulatory Failure in Experimental Heat Exhaustion; Role of Posture", R. W. Keeton, et al., Heat. Pip. and Air Cond., 12, 122-6 (February, 1940).

Several young medical students and nurses were exposed to a hot, dry environment (90°F dry bulb, 70°F wet bulb) and to a hot wet environment (99.5°F dry bulb, 90°F wet bulb). Control conditions were a comfortable environment (85°F dry bulb, 57°F wet bulb) and a cool environment (75.5°F dry bulb, 52°F wet bulb). Measurements were taken on arterial and venous blood pressures, pulse rate, and rectal temperatures. Tests were also carried out on the effect of posture on a feeling of fitness after exposure to hot atmospheres. It was found (1) that the arterial and venous pressures are normal in persons that are lying down in hot atmospheres, indicating good circulation, and (2) that the adjustment of the circulation in the erect position becomes more difficult as the environment gets hotter, and fever appears. This leads to fainting.

109. "Phase of the Problem of Acclimatization to High Temperatures", M. Mezincescu, J. Ind. Hyg., 19, 146-51 (March, 1937).

Acclimatization processes on successive days of exposure to high temperatures are shown through analyses of urine, sweat and basal metabolism. A slight decrease in salt content of sweat, and in basal metabolism rate is noted on acclimatization.

110. "Physiologic Effects (Heat); Council on Physical Medicine", K. G. Wahim, J.A.M.A., 138, 1091-7 (December, 1948).

111. "Physiologic Reactions Applicable to Workers in Hot Industries", F. C. Houghton, et al., Bull. Hyg., 19, 535, (July, 1944).

Workers were exposed to hot atmospheres with relative humidity being at 30 percent. Data are given as to the effect of environmental warmth on rectal temperature. The findings indicate that if the temperature of the solid surroundings is substantially that of the dry-bulb temperature, the rectal temperature is the same for a given Effective Temperature, even though it may be represent widely varying air temperatures and humidities. If the temperature of the solid surroundings is higher than that of the air, the effect of the additional radiation is to raise the body temperature. It was also found that persons standing while doing light work were more comfortable than those that were sitting.

112. "Physiologic Effects of High Temperatures", W. Machle, Mil. Surg., 95, 98-105, (August, 1944).

113. "Physiologic Effects of Heat and Cold", A. Hemingway, Ann. Rev. Physiol., 7, 163-80 (1945).

114. "Physiologic Responses of Man to Environmental Temperature", F. K. Hick, et al., Heat. Pip and Air Cond. 10, 196-201, (March, 1938).

Observations are given on basal metabolism, vital capacity, skin and rectal temperatures, and presence of sweating or shivering of humans under basal conditions and in varying temperature and air movement. Results show that (1) chemical regulation of body temperature is negligible, (2) radiation of heat is the principle means of heat loss in the range below 80°F Effective Temperature, (3) sweating occurs at about 81°F Effective Temperature, (4) rectal temperature does not rise until 91°F Effective Temperature,(5) there is evidence of a redistribution of blood as skin temperature rises, (6) hyperventilation is a transient response to intolerable heat, and (7) a better radiation factor of control and measurement is needed, but Effective Temperature comes closest to correlation with the above measurements.

115. "Physiological Adjustments of Human Beings to Sudden Change in Environment", N. Glickman, et al., A.S.H.V.E. Trans., 53, 327 (1947).

A study was made of (1) the speed and magnitude of physiological adjustments made by the body on exposure to a sudden change in environmental temperature, (2) the effect of different relative humidities in altering the adjustments when passing from a hot to a comfortable environment, and (3) the effect of relative humidity on physiological measurements with the body in equilibrium with the environment. There were five male subjects 19 to 23 years old. Results showed that adjustments were made rapidly and with little strain on the cardiovascular system on passing from either environment to the other.

116. "Physiological Adjustments of Normal Subjects and Cardiac Patients to Sudden Changes in Environment", N. Glickman, et al., Heat. Pip. and Air Cond., 21, 105-9 (February, 1949).

Little difference was found in the reactions of the two classes of subjects to sudden changes in environment.

117. "Physiological Effects of Heat", T. H. Hatch, Ind. Med., 13, 88 (January, 1944).

Discussion is made of the environmental changes which man must adapt himself to and the manner in which this is accomplished by means of conduction, evaporation, and radiation. The process of acclimatization and water requirements are also discussed for resting and working humans at different temperatures.

118. "Physiological Effects of Heat and Cold", R. Grant, Ann. Rev. Physiol., 13, 75-98 (1951).

119. "The Physiological Effects of High Temperature", W. Machle, Mil. Surg., 95, 98 (1944).

Work at the Army Ground Forces Medical Research Center is reported in this article. Factors in attaining and maintaining acclimatization in a hot environment are physical condition, activity prior to and during acclimatization, and the intensity of work from the first exposure to heat. Intolerance to heat at first does not retard acclimatization.

120. "Physiologically Equivalent Conditions of Air Temperature and Humidity", S. Robinson, et al., Am. J. Physiol., 143, 21-32 (1945).

An attempt was made to establish experimentally an evaluation of the effects of various environments based entirely on the heat regulatory responses of men. Using measurements of heart rate, skin temperature, rectal temperature, and rate of sweating, an index was formed. Six contour graphs were made for various activites and types of clothing plotted in relation to dry- and wet-bulb temperatures and relative humidity. Clothed men maintained equilibrium only in environments distinctly less severe than did men in shorts. Maximum equilibrium environments for walking included 34°C with 91 percent relative humidity and 50°C with 21 percent relative humidity. For resting the maximum equilibrium environments were 35°C with 96 percent relative humidity and 50°C with 32 percent relative humidity.

121. "Physiological Examination of the Effective Temperature Index", N. Glickman, et al., A.S.H.V.E. Trans., 56, 51 (1950).

Measurements were taken on fifteen male subjects to determine whether too much emphasis is placed on relative humidities in arriving at Effective Temperatures. The conclusion is that the present Effective Temperature index is adequate for subjects in a dynamic state except for corrections at higher temperatures; however, for subjects in a steady state too much emphasis is placed on the influence of relative humidity.

122. "Physiological Influence of Atmospheric Humidity", Report of A.S.H.V.E. Research T.A.C. on Physiological Reactions, A.S.H.V.E. Trans. 48, 317 (1942).

A review of the state of information in the field with respect to the influence of atmospheric humidity on (1) heat losses in cool air, (2) heat losses in warm air, and (3) the dryness of the membranes in the nose and throat. It has been found that a moist atmosphere in a cool environment is unimportant, although under very cold conditions it can be harmful. In a warm atmosphere humidity is of prime importance. The experimenters found that the drying effect on the nose and throat membranes was related to the absolute, not the relative humidity. There is no evidence, however, that drying out of the membranes is undesirable.

123. "Physiological Reactions and Sensations of Pleasantness Under Varying Atmospheric Conditions", C.E.A. Winslow, et al., A.S.H.V.E. Trans. 44, 179 (1938).

An analysis of the influence of widely varying conditions of air temperature, wall temperature, air movement, and humidity on physiological reactions and human comfort. Two subjects were tested, one being stout in build the other being thin. Wall temperatures ranged from 66 to 135°F and air temperatures ranged from 43 to 97°F. Relative humidity was held at 40 to 50 percent. Air movement was 15 to 20 linear ft per minute. It was found that for high humidity and low temperature, increased air movement increases heat tolerance. For low humidity and high temperature, increase in air velocity lowers heat tolerance. For hot, dry environments still air is more desirable than slightly moving air, but a large air movement is most desirable.

124. "Physiological Reactions Applicable to Workers in Hot Industries", F. C. Houghten, et al., Heat. Pip. and Air Cond., 15, 205-8 (April, 1943).

Observations are reported on people doing light work in hot atmospheres with various relative humidity and temperature levels. Results show that (1) rise in body temperature and increase in pulse rate shows the same reaction at a given Effective Temperature for 30 percent relative humidity and lower, as were previously found for higher relative humidity; (2) body temperature rise correlates well with Effective Temperature; and (3) that a person is comfortable at a slightly higher Effective Temperature when standing and moving about at work than when seated at rest.

125. "The Physiological Reaction of the Human Body to Varying Environmental Temperature", C.E.A. Winslow, L. P. Herrington, Am. J. Physiol., 120, (1937).

Mathematical investigation is made of each element of heat gain, heat storage, and heat loss in the human body. In summary the article states that (1) metabolism remained approximately constant with respect to skin temperature or evaporation, (2) the body maintains a high degree of thermal equilibrium at most temperatures except extreme cold, (3) sweating is closely correlated to skin temperature, (4) fall in skin temperature occurs in colder environments and vasoconstriction of surface blood vessels decrease conductivity, and (5) positive storage (chilling) occurs below 31°C and in coolest environments this equals the metabolism. Experiments took place in a heated copper-walled room with air temperature from 6.8 to 35°C, with relative humidity from 28 to 65 percent.

126. Physiological Regulations , E. F. Adolph, Cattell Press, Lancaster, Pennsylvania, (1943.)

Chapter XIV, pp 301-22, considers heat in terms of the human and animal regulatory apparatus. Heat intake, dispersion, storage, and recovery factors are investigated. Very little information concerning reaction to extreme temperatures is given, but the basic physiological factors involved are presented.

127. "Physiological Response of Man to Environmental Temperature", F. K. Hick, et al., A.S.H.V.E. Trans., 44, 145 (1938).

The subjects in this experiment included one medical student and several ambulatory patients who had no detectable heat regulation abnormalities. The variables on which daily observations were made were basal metabolism, vital capacity, skin temperatures, rectal temperature, and presence of sweating or shivering. Plots of these variables versus Effective Temperature were made. Conclusions reached were as follows: (1) Radiation of heat is a principle means of heat loss below 80°F Effective Temperature. It is controlled by a sensitive regulation of skin temperature in the extremities. (2) The point at which sweating occurs is at about 81°F Effective Temperature. Evidence indicates that an increase in evaporation occurs at about 77°F Effective Temperature. (3) Under basal conditions, rectal temperature does not rise until the Effective Temperature reaches 91°F.

128. "Physiological Responses of Hands and Feet to Cold in Relation to Body Temperature", C. H. Wyndham and W. G. Wilson-Dixon, J. Appl. Physiol. 4, 199-207 (September, 1951.)

Subjects in full protective clothing exposed for 3 hours at sea to temperatures ranging down to 10°F with varying wind showed rapid and marked cooling of the hands and feet during rest periods when the body was generally cooling to some extent. After cooling the hands and feet to the point of discomfort and loss of efficiency, they were consistently rewarmed when body heat content was restored as a result of light physical work.

129. "Physiological Response of Subjects Exposed to High Effective Temperatures and Elevated Mean Radiant Temperatures", C. M. Humphries, et al., A.S.H.V.E. Trans., 52, 153 (1946).

Tests were conducted on a group of male subjects to determine the physiological reactions of men exposed for 4 hours to hot atmospheres and surrounded by hot surfaces. The study included tests at Effective Temperatures ranging from 80 to 95°F with relative humidities of 30, 50, and 70 percent and Mean Radiant Temperatures up to 40°F above the dry-bulb temperature of the air. It was found that within this range of conditions all variables which affect a man's physiological reactions can be expressed in terms of Effective Temperature and Mean Radiant Temperature. The effect of Mean Radiant Temperature on such reactions is dependent on values of Effective Temperature and Mean Radiant Temperature and the effect of radiant heat decreases as Effective Temperature rises and becomes surprisingly small as the upper endurance limits are reached.

130. "Physiologically Equivalent Conditions of Air Temperature and Humidity", S. Robinson, Am. J. Physiol., 143, 21-32 (January, 1945).

Experiments were carried out with temperatures ranging from 23 to 50°C and at various relative humidities. Half of the subjects wore shorts and the other half wore army jungle uniforms. During each exposure measurements were made of rise of heart rate, rectal temperature, skin temperature, and rate of sweating, and these were correlated into an "index of physiological effect". Experiments were also run to determine the most severe conditions under which men could maintain thermal equilibrium. It was found that men in shorts could stand 34°C at 91 percent humidity or 50°C at 21 percent relative humidity. The clothed men maintained thermal equilibrium only at much less severe conditions.

131. "Physiology as a Guide to Combating Tropical Stress", D. H. K. Lee, New Eng. J. Med., 243, 723-30 (1950).

Man's evolution from the tropics, his culture and work habits, his reduced efficiency and activity level in tropical heat, and his mental attitude toward heat are discussed. The author stresses a wide view of heat problems, taking all aspects of human life into account. The overemphasis on salt tablets, as well as water replacement problems in general, are discussed.

132. The Physiology of Heat Regulation and the Science of Clothing, Edited by L. H. Newburgh, W. B. Saunder Co., Philadelphia, Pennsylvania, (1950,) p. 457.

This book is a series of articles, each by a leading man in his field, concerning all aspects of environmental temperature measurement, physiological adjustments, and the problems of cold and heat. Written in two parts, Part I is entitled: "Human Response to the Climatic Environment" and Part II is entitled: "Clothing, a Thermal Barrier".

Part I contains the Following chapter headings: (1) Adaptations to Climate Among Non-Europeans Peoples, (2) Thermometry (this consists of ways and means of measuring skin and other temperatures, humidity, and wind velocity), (3) Heat Transfer, (4) The Regulation of Body Temperatures, (5) Physiological Adjustments to Heat, (6) Physiological Adjustments to Cold, (7) Regional Heat Loss, (8) The Range of Physiological Response to Climatic Heat and Cold, and (9) Indices of Comfort. Part II consists of a discussion of the physical properties of fabrics, laboratory and field studies concerning clothing and relation to various types of environment, and a separate chapter on relation to climate.

133. Physiology of Man in the Desert, Edward F. Adolph, Interscience Publications, New York City,(1947.)

Pertinent chapters in this book include: (1) Resume of Investigation; (2) Human Body in the Desert; (3) Sweat Formation, Water Turnover; (4) Rates of Sweating in the Desert; (5) Heat Exchanges; (8) Water Requirements; (12) Relative Influence of Heat, Work, and Dehydration; (13) Dehydration Exhaustion; and (19) Man in the Tropics Compared With Man in the Desert.

This book is the result of an investigation under contract for the United States Office of Scientific Research and Development. Coverage of the subject is very complete and emphasis is continually placed on the need for a large supply of water being handy at all times, and the need for drinking as much as is wanted.

134. "Problems of Naval Warfare Under Climatic Extremes", M. Critchley, Brit. Med. J., 2, 173 (1945).

A review of the clothing policy of the British Navy with special emphasis on the requirements and experiments of World War II. Sections include: Clothing for Cold Climates, Clothing in the Tropics, Human Problem in Naval Warfare, Comparison With Industry Experiences, Ship Field Studies, and Laboratory Tests. The exposition is more of a general, rather a detailed, nature.

Part II of this article (p. 208) includes the following sections: Psychological Effects of Long Service in the Tropics and in Polar Regions, Selection of Personnel Best Fitted for Tropical or Arctic Service, and Peacetime Implications.

135. "Problems of Ventilation for Vessels of the Navy", A. R. Behnke, Mil. Surg., 88, 633 (1941).

A tabulation of air temperature, oral temperature, condition of the skin with respect to moisture, mental state, and subjective responses is made into a "Schneider Index" which gives an overall value of comfort. The article states that foot temperature within the shoe is a very good indication of comfort.

136. "Psycho-Motor Efficiency (as Measured by Time for Accurate Gun-Laying) Under Hot Conditions", Douglas H. K. Lee, et al., FLSR No. 3, Sir William MacGregor School of Physiology, University of Queensland., (January 18, 1945.)

Attempts were made to measure the time of onset and the degree of mental fatigue induced by hot conditions. This was done by measuring the speed with which a gunner laid and fired at a target suddenly appearing at an unknown spot on a landscape. The studies included the effects of (1) heat alone, (2) exercise in heat, (3) noise in heat (4) lack of sleep in heat, (5) meals in heat, and (6) use of respirators. Many conclusions are arrived at and discussions are presented of applications of the results and of further work.

137. "Psychophysiological Effects of Cold. I. The Role of Skin-Temperature and Sensory Sensitivity in Manual Performance Decrement", Robert A. McCleary, School of Aviation Medicine, Randolph Field, Tex., ASTIA Catalog No. AD-8093, (January, 1953.)

Seventy-two airmen were timed on manual performance tests at 70, 32, 0, -10, -20, and -40°F ambient. The decrement in performance increased as a positively accelerated function over the temperature range. The decrement resulting from temperature did not differ from that resulting from arctic clothing until the temperature dropped to 0°F. The rate of decline of digital skin-temperature and sensory sensitivity to cold differentiated twelve subjects significantly with respect to performance ability at low temperatures; the two criteria correlated positively, but were not identical measures. The relation of complexion differences to cold tolerance was also indicated. No relation was found between performances and the ability to vasodilate peripherally and raise the digital temperature. Negative results were also obtained from correlations between performance and (1) home state, (2) civilian experience, (3) weight, and (4) height.

138. "Radiation as a Factor in the Sensation of Warmth", F. C. Houghten, et al., A.S.H.V.E. Trans., 47, 93 (1941).

This experiment was designed to compare the sensation of warmth achieved by radiation to that achieved by convection. Eight male college students were chosen for the test. The tests were conducted in two rooms, identical except for methods of heating, one being heated by radiation and the other by convection. Results showed that the Effective Temperature for comfort in the radiation room was universally lower than for the convection room. The Effective Temperature demanded for comfort by the subjects was higher than the generally accepted 66° for warm-walled rooms.

139. "Rapid Acclimatization to Work in Hot Climates", S. Robinson, et al., Am. J. Physiol., 140, 168-76 (1943).

An attempt was made to quantitatively measure the improvement in ability to do work under hot conditions and to find time relationships for such measurements. It was also desired to determine to which physiological variables this improvement was related. Experiments were carried out using a treadmill in an artificially heated room at 104°F and 23 percent relative humidity, each man at the beginning walking until exhaustion. Under these conditions for 1 to 1-1/2 hours per day, acclimatization occurred after 1 week and was retained for 3 to 4 weeks without exposure. The acclimatization occurred swiftly for 7 days, then much more slowly for 23 days and was manifested in a decrease in heart rate, a decrease in average skin temperature and rectal temperature, and a decrease in metabolic rate.

140. "Reactions of the Human Body to Its Physical Environment", D. Brunt, Bull. Hyg., 19, 368 (May, 1944).

This is mainly a review and discussion of recent work on heat regulation of the human body, based to a large extent on the work of Gagge, Herrington, and Winslow. The author considers the various components of the physiological heat balance of both the nude and the clothed subject. From a theoretical treatment of the factors involved in the diffusion of water vapor from the skin, the author shows that the maximum evaporative area appears to be only one-third the area for convective heat loss. The present equations admit an effect of air movement on evaporative heat loss much smaller than the authors estimate. (Quart. J. Roy. Meteor. Soc., 69, 77-114 (April,1943)

141. "Reaction of Men Exposed to Cold and Winds", S. M. Horvath, Am. J. Physiol., 152, 242-9 (February, 1948).

Tests were made on five men at a temperature of -13°F and wind velocities of 0, 5, and 9.6 MPH. It was found that the fall in rectal temperature was not appreciably affected by either temperature or wind velocities. The principal effect of these environmental conditions was reflected in changes of mean skin temperatures. It was also found that exposure to rapid air movements shortens the time from initial exposure to the appearance of sensations of discomfort. General body comfort appears to be most readily influenced by wind. Shivering over a period of time is fatiguing and distracting and it impairs fine muscular control and concentration. Thus, it reduces overall efficiency.

142. "Regulation of Heat Loss from the Human Body", J. D. Hardy and E. F. DuBois, Proc. Nat. Acad. Scie., 23, 624-31 (1937).

A report of experiments concerning heat loss of the human body. The body eliminated a minimal amount of heat at 30 to 32°C. At lower temperatures greater heat loss is evident, but no change in metabolism takes place even up to the onset of chills. Also at higher temperatures greater heat loss is evident and the body adjusts more readily, eliminating heat by means of increased blood flow to the skin and by vaporization. Heat loss under cold conditions increased at the approximate rate of 3 calories per degree. Chill and exercise definitely increase oxygen consumption and heat production.

143. "Relations Between Atmospheric Conditions, Physiological Reactions, and Sensations of Pleasantness", C. E. A. Winslow, et al., Am. J. Hyg., 26, 103 (1937).

An attempt is made to show the correlation between environmental conditions and feelings of comfort. It was found that where the mean skin temperature is between 88 and 92°F conditions were reported by the subject as being pleasant. Here cooling of the body and sweating are both low. When the skin temperature falls below 88°F, body cooling increases and the feeling of unpleasantness increase. When skin temperature rises above 92°F, sweating increases and the feeling of unpleasantness increases in spite of the fact that thermal equilibrium is maintained.

144. "The Relative Roles of the Extremities in Dissipation of Heat From the Human Body Under Various Environmental Temperatures and Relative Humidities", O. L. Kirklin, Am. J. Physiol., 128, 782 (1940).

A report of measurements taken of skin temperatures of fingers and toes and of plots made of these values against air temperatures and relative humidity (73 to 82°F and 35 and 75 percent relative humidity). Results show that within this range relative humidity plays little part in changing skin temperature.

145. "The Role of the Extremities in the Dissipation of Heat From the Body in Various Atmospheric and Physiological Conditions", C. Sheard, et al., A.S.H.V.E. Trans., 45, 135 (1939).

Results are given of investigations on the temperatures of fingers and toes and the relative roles they play in the dissipation of body heat. Also reported are the effects of relative humidities and various temperatures on the temperatures of the extremities and the heating and cooling rates of the toes of subjects with normal circulation. Evidence is presented to show that dissipation of heat is initially controlled by hands and lower arms and then by the feet and lower legs. The report also states that, in the range of normal environmental and skin temperatures, large changes in relative humidity have little effect on the skin temperature of the fingers and toes.

146. "Salt Economy in Humid Heat", C. Daly and D. B. Dill, Am. J. Physiol., 118, 285 (1937).

The amount of salt secreted in moderate activity and temperature may contain less salt than sweat produced under extreme conditions. On acclimatization salt secretion declines.

147. "Seasonal Variations in Reactions to Hot Atmospheres", F. C. Houghten et al., A.S.H.V.E. Trans., 46, 185 (1940).

This is a continuation of the work reported in "Air Conditioning in Industry" by Fleischer, et al., A.S.H.V.E. Trans., 45, 59 (1939). Whereas all the data in that report were collected during the summer, this report was directed at other seasons of the year. The data indicates that a person's acclimatization to atmospheric environments during different seasons of the year not only affects his desire for some higher or lower Effective Temperature condition, but also affects certain physiological reactions.

148. "Shortcomings of Human Heat Regulation in Cold Weather", Otto Kestner; Brit. J. Phys. Med., 5, 33 (1942).

A comparison of skin temperature reactions of old people to young, showing the old do not adjust as fast to changing temperatures. This is explained by the fact that their blood vessels neither contract nor dilate as fast. Different metabolism rates are shown for boys under different climatic conditions.

149. "Skin Temperature of the Extremities and Basal Metabolism Rates in Individuals Having Normal Circulation", C. Sheard and M. M. Williams, Proc. Staff Meet. Mayo Clinic, 15, 758 (1940).

The experiments reported concern individuals in a comfortable room in a basal state. Metabolism and skin temperatures at various locations were taken. A linear relationship between metabolism and toe temperature was found.

150. "Skin Temperatures of the Extremities and Effective Temperatures", C. Shard, et al., A.S.H.V.E. Trans., 45, 153 (1939).

Results are shown of investigations concerning the skin temperature of fingers and toes under varying environmental condtions. Environmental temperatures ranged from 73 to 87°F and humidity from 35 to 70 percent. The authors conclude that the dissipation of heat is dependent chiefly on environmental temperatures and is little influenced by relative humidity.

151. "Slow Adaptations in the Heat Exchanges of Man to Changed Climatic Conditions", A. C. Burton, et al., Am. J. Physiol., 129,84 (1939).

A report of an investigation into heat loss, caloric intake, metabolism, blood conditions, and rectal temperature, determined in environmental temperatures ranging from 23.3 to 32.4°C. It was found that caloric intake was higher in cold and lower in heat and that body temperature is maintained more uniformly after acclimatization. On acclimatization, radiation and convection play a greater role in heat and a lesser role in cold.

152. "The Standardization of Temperature Regulatory Responses of Dogs to Cold", A. Hemingway, Am. J. Physiol., 128, 736-46 (1938).

The components of shivering, peripheral vasomotor regulation, and panting and sweating are investigated at a temperature of 22°C and relative humidity of 50 percent. These measurements are plotted against time.

153. "Stress of the Physical Environments; How Temperatures and Humidity Affect the Normal Subject and the Sick Patient", R. W. Keeton, Heat. Pip. and Air Cond., 22, 96-100 (December, 1950).

This article reports an investigation of the following: circulation, reaction of stress to hot environments, why people faint, sudden change of environment, heat retention or loss with body cooling, stress of a nonuniform environment, changes in barometric pressure and effect on adrenal and other glands.

154. "A Study of the Adjustments or Peripheral Vascular Tone to the Requirements of the Regulation of Body Temperature", E. G. Weir, Am. J. Physiol., 130, 608-11 (1939).

The report concludes that temperature regulation of vasomotor tone is a modification of an intrinsically rhythmical character.

155. "A Study of the Effect of Cold on Joint Temperature and Mobility", J. Hunter and M. G. Whilliams, Can. J. Med. Scie., 29, 255-6, (October, 1951).

Cats were exposed to cold down to -10°F and joint, skin and rectal temperatures were measured along with the force required to start the joint under consideration moving. The author found that as ambient temperature fell joint temperatures fell faster than either skin or rectal temperature and the force to start the joint moving increased.

156. "A Study of the Reflex Mechanism of Sweating in the Human Being", R. Gurney and I. L. Bunnel, J. Clin. Invest., 21, 269 (1942).

An attempt was made to determine whether the nervous reflex arc in whole or in part is essential for sweating in the human being. The investigators used two different means of isolating the sympathetic transmission of localized heat application: anesthesia and cutting of the nerve ends. The article concludes that (1) no histological change can be seen in sweat glands deprived of their sympathetic nerve supply, (2) the sweat glands themselves respond even though the sympathetic fibers must be intact for sweating response in an area remote from heated areas and (3) heat applied to an anesthetized area cause sweating in other areas.

157. "Survival Time of Various Warm-Blooded Animals in Extreme Cold", S. M. Horvath, et al., Science, 107, 171-2 (February, 1948).

Survival times of mice, pigeons, chickens, rabbits, and rats in -30°F ambient temperature are recorded in this article. They range from 0.4 hour for mice to 78 hours for pigeons. Graphs of rectal temperatures were kept.

158. "Symposium of Physiologic Contributions to War Problems; Clothing and Heat Exchanges", A. C. Burton, Fed. Proc., 5, 344-51 (September, 1946).

This is a discussion of the CLO unit, the insulating characteristics of clothes, the types of insulation and warmth protection needed, and the characteristics of different parts of the body under different activity conditions. Met units, corresponding to activity, and CLO units are correlated. Many aspects of the problem of protection against the cold and wet are discussed. A summary is given of the work done in the last war and the statement is made that a maximum of 4 or 5 CLO units is all a man can be given and still remain mobile enough for military tasks. An extensive bibliography is given.

159. "The Technique of Measuring Radiation and Convection", J. D. Hardy and E. F. DuBois, J. Nutrition, 15, 461 (1938).

A discussion of the history and difficulties of measurement of radiation and convection in regard to human heat loss. The Hardy radiometer, a heat radiation absorption and measurement instrument, is used to determine skin temperature and heat loss. Convection is found by determining total heat loss from both convection and radiation and subtracting the determined radiation. A calorimeter is used for measuring vaporization. By this method all classes of heat loss from the body can be determined.

160. Temperature and Human Life. C. E. A. Winslow and L. P. Herrington Princeton University Press, Princeton University, Princeton, New Jersey, 1949.

This book contains the following chapters: I. Production of Heat in the Life Process, II. Avenues of Heat Loss from the Body, III. Adaptations of the Human Body to Varying Thermal Changes, IV. Thermal Protective Influence of Clothing, V. Objectives of Air Conditioning, VI. Methods of Air Conditioning, and VII. The Influence of Climate and Season on Health. Original and other research is presented and a large bibliography.

161. "Thermal Interchanges Between the Body and Its Atmospheric Environment", C. Sheard Illinois Univ. Eng. Exp. Sta. Circ., 37, 138-51 (1939).

A discussion of the production, regulation, and disposal of heat, as found in the human. The skin is the important agent by which the body loses its heat by means of radiation, convection, and vaporization. When a fan was used the percentage lost by convection rose in two cases. Humidity and air movement are discussed in reference to moderate temperatures. Below 77°F, evaporation of sweat is hardly affected by change in humidity and circulation of air greatly increase heat loss from the body at normal temperatures.

162. "Thermal Interchanges Between the Human Body and Its Atmospheric Environment", A. P. Gagge, et al., Am. J. Hyg., 26, 84-102 (1937).

Mathematical expressions and contour diagrams are presented by which skin temperature and body cooling may be predicted from air and wall temperatures in a cool environment (below 86°F). In warm environments (above 89°F) body temperature is maintained at a constant value through sweating. Also presented are mathematical expressions and contour diagrams by which the amount of sweating can be predicted from environmental temperature and humidity. The effect of air movement on body temperature in the above described regions is discussed.

163. "Thermal Insulation of Clothing", C. P. Yaglou, A.S.H.V.E. Trans., 54, 291 (1948).

A discussion is presented of the two principal methods of evaluating clothing insulation, vix., the heat-loss method and the temperature-gradient method. It is stated that the heat-loss method gives from 10 to 30 percent higher insulation ratings than does the temperature-gradient method. Extraneous influences can produce irrelevant variations of overall gradients and of insulation values in the heat-loss method. The most serious limitation on the heat-loss method is that it deals only with overall insulation of whole assemblies. The temperature-gradient method, on the other hand, was developed especially for evaluating critical areas, gloves and boots, or whole assemblies.

164. "Thermal Regulation During Acclimatization in Hot, Dry (Desert-Type) Environment", L. W. Eichna, et al., Am. J. Physiol., 163, 585-97 (December, 1950).

Three soldiers were set to work (walking) in an environment of 123°F and 15 percent relative humidity. The quantities measured were skin temperature, rectal temperture, weight, water intake, heart rate, and metabolic rate. It was found that acclimatization process returned the rectal temperture to normal and set the skin temperature so that thermal equilibrium existed between the body and the atmosphere and so that deep heat could be transported to the periphery without taxing the circulation. The principle adaptive mechanism was that of increased sweat production. Increased evaporative cooling lowered skin temperature and thereby increased the heat gains by convection and radiation, necessitating an even larger sweat rate increase. It also increased the internal thermal gradient, which decreased the peripheral blood flow necessary to bring deep heat to the periphery.

165. "Thermal Responses and Efficiency of Sweating When Men are Dressed in Arctic Clothing and Exposed to Extreme Cold", H. S. Belding, et al., Am. J. Physiol., 149, 204-22, (April, 1947).

Men dressed in arctic uniforms were exposed to different levels of cold (40,20, 0, and -40°F) while performing various levels of activity. Data were obtained on sweating, moisture uptake of the clothing, energy expenditure, pulmonary ventilation, skin temperature, rectal temperature, and comfort. It was found that the sweating of different subjects under similar conditions varied widely and that those who sweated more had higher skin and rectal temperatures, higher pulse rates, and higher energy production. According to the author, when it becomes possible for men to modify their activity to the point of being cool, but comfortable during exposure to cold, sweating and accumulation of moisture will be at a minimum.

166. "Thermal Sweating", W. S. S. Ladell, Brit. Med. Bull., 3, 175, (1945).

This is a review and summation of much work on sweating characteristics. Sections include: general discussion, stimulus to thermal sweating, rate of sweating, acclimatization, and composition of sweat. The article summarizes: water loss is both sensible and insensible, the insensible loss being at temperatures below 88°F, fatigue can exist in the sweat glands, control of sweating is central, and there is great variation both within the individual and between individuals.

167. "Time Factors of Water Drinking in Dogs", R. T. Bellows, Am. J. Physiol., 125, 87-97 (1939).

Satisfaction of thirst was found to be not a single, but a multiple process.

168. "Tolerance of Men Toward Hot Atmospheres", E. F. Adolph, Public Health Report Supplement 192, U. S. Public Health Service, Washington, D. C.

An attempt is made to define hot conditions which prevent men from working. One part of the study had to do with the environment (dry-bulb temperature, wet-bulb temperature, duration of exposure, air motion, surfaces of contact, radiation, and clothing). The other part dealt with the organism (work, body size, acclimatization physical fitness, individual differences, posture, water content of body, salt content, and nutriment intake). This is a rather complete summary, with conclusions based on available published data. Many graphs and a large bibliography are presented.

169. "Trial Tank Air-Conditioning Equipment - Hot Room Tests", D. H. K. Lee, AFV 39, (October, 1943.)

Equipment designed for cooling tank crews under hot weather conditions was subjected to tests in a hot room where simulated climatic conditions were imposed. In addition to purely mechanical data, knowledge of personnel reaction was obtained in regard to subjective sensation, sweat loss, sweat evaporation, pulse rate, and mouth temperature. Among other conclusions it was found that the critical level of effective temperature for tolerance to heat lies somewhere between 92.5 and 88.4°F.

170. "Upper Limits of Environmental Heat and Humidity Tolerated By Acclimatized Men Working in Hot Environments", L. W. Eichna, et al., J. Ind. Hyg. 27, 59-84 (March, 1945).

The purpose of this investigation at Fort Knox was to determine (1) the upper limits of heat and humidity in which men can work effectively, (2) the role of environment as it affects work at hot temperatures, and (3) the relation of the physiological responses of man to his environment. Conclusions reached were: (1) the wet-bulb temperature is the limiting factor; dry bulb being of only minor importance. (2) A narrow range of 4 to 5°F wet bulb is "relatively easy" to separate from "impossible" environments. (3) Below a wet-bulb temperature of 91°F men work easily and efficiently. (4) The range in which men are capable of moderately hard work is 91 to 94° wet bulb, but decreased efficiency and alertness are evident. (5) Above 94°F wet bulb total disability soon occurs, the average limit being about 1 hour of work. (6) The limiting wet-bulb temperature is approximately 2 degrees higher at a dry-bulb reading below 100° than at 120° . (7) The average man sweats profusely. (8) Acclimatized men above the upper limits suffer similarly to unacclimatized men when first exposed to lesser heat.

171. "War Casualties From Prolonged Exposure to Wet and Cold", R. H. Patterson and F. M. Anderson, Surg. Gynic. and Obst., 80, 1-11 (January, 1945).

An analysis of the cold and exposure casualties of the Attu campaign. Concerning treatment, the following areas are discussed: mechanical respiration and oxygen therapy, gas inspection and x-ray findings, venous system complications, tissue damage and amputations, pathological findings, and foot deformities. There appear to be great individual differences in resistance to cold injuries.

172. "Wet-Cold II. A Theoretical Interpretation of the Sensation of Damp Cold Experienced by Clothed Man", A. H. Woodcock, Environmental Protection Branch Report No. 199, QM Climatic Research Laboratory, Lawrence, Massachusetts, (February, 1953.)

A discussion is presented concerning the sensation of coldness experienced at high humidities near the freezing point. The effects of insulation, ambient temperature of humidity, and solar radiation form the bases for discussion.

173. "Work in the Heat as Affected by Intake of Water, Salt, and Glucose", G. C. Pitts, et al., Am. J. Physiol., 142, 253-9 (1944).

Six healthy, acclimatized young men were placed under observation while marching in hot, dry environments (100°F, 35 percent relative humidity) and hot, moist environments (90-95°F, 80-83 percent relative humidity). They were given various amounts of water, salt and glucose and the following results were found: (1) best performance occurs when water is replaced hour by hour, any water deficiency leading to inefficiency and exhaustion in a matter of hours; (2) hourly salt replacement has no effect; (3) glucose is of little advantage when compared to water; (4) under undesirable nutritional conditions, salt may be needed in the drinking water.