

Effects of Heat and Cold

The environmental engineer, plant physician, personnel manager, and efficiency expert frequently need to consider the effect of the thermal environment on individuals exposed to it. They naturally welcome any scheme, device, or index which can guide them in making a simple and practical assessment of a situation which is usually complex. The scientific and technological literature contains several such schemes, but the best of them need to be used with considerable caution, and all of them call for a fairly deep understanding of the bodily reactions to thermal stress if they are to be applied intelligently and adequately to the varied circumstances that occur in natural, as opposed to laboratory, situations.

This monograph is designed to provide the basic understanding necessary to judgments of man's probable reactions to hot or cold environments, and of the limitations that such environments are likely to place upon his efficiency, well-being, or health, without recourse to the language and detail of the specialist in environmental physiology. The first chapter outlines the physical factors that make up the thermal environment—temperature, humidity, air movement, and radiant heat—and the basic nature of the processes by which heat is exchanged between the human body and its environment.

The second chapter describes the reactions that develop in the human body when the balance between these exchanges is so upset that heat tends to accumulate in the body. The primary reactions—dilatation of skin blood vessels, sweating, muscular relaxation, and so forth—are directed toward restoring the balance, either by increasing heat loss or by decreasing heat production. These compensations, in which man surpasses most other animals, unfortunately bring about other undesirable consequences. It is these secondary consequences which most frequently interfere with his efficiency and well-being and need to be understood. Inadequate blood supply, especially to the brain, loss of water and salt, continued skin wetness, and repercussions of all of these on nervous function are discussed. With continued or frequently repeated exposure, provided that the stress is not too severe, the body's reactions become less marked, and acclimatization is said to have occurred. An individual's tolerance for hot conditions can be greatly increased in this way, although the exact mechanism by which this takes place is not fully known. With repeated exposures, the nature and duration of the interval can be critical; an interval which is too short or insufficiently cool will obviously be inadequate, but one which is too long or too

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The accompanying summary covers the principal contents of Public Health Monograph No. 72. The author is chief of the Occupational Health Research and Training Facility, Public Health Service, Cincinnati, Ohio.

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cool may result in de-acclimatization. When exposures are too severe or too prolonged, failure will result. The mode of failure will vary greatly with circumstances. Acute failures will show varying proportions of hyperpyrexia (heat stroke), circulatory failure (heat exhaustion), low blood chloride (heat cramps), and dehydration. Sweat production may fall below the levels necessary to maintain adequate heat loss, either because of damage to sweat glands or through an ill-defined "fatigue" process which is still not understood. Both physical and mental productivity will decline when any of these acute failures develop, but even under less severe conditions some degree of inefficiency may be expected. Much of this appears to be psychological rather than physiological, and is susceptible to correction or amelioration.

The third chapter deals with the corresponding bodily reactions to cold situations, where the rate of heat loss from the body tends to be excessive. Constriction of skin blood vessels and increased heat production constitute the major primary reactions of compensation. Secondary physiological consequences include cooling of the superficial tissues and increased appetite. Acclimatization is less pronounced than with heat, but does apparently occur. Acute failure may occur from general body cooling, or by local tissue changes after freezing or prolonged cooling to near freezing temperatures. Performance is reduced in a variety of ways, and there may be some increased susceptibility to disease.

Chapter 4 discusses the modifications in heat transfer and heat balance that result from the

interposition of clothing between the skin and the environment, and the influence of fabric composition. The principles governing the design of clothing in relation to the thermal situation are presented in tabular form. A parallel is drawn between the effect of shelter design and that of clothing, but details are not discussed. Tables, however, present the principles of shelter design in similar form to those used for clothing.

The final chapter passes to some practical aspects of the information given in the preceding parts. The applicability and limitations of several predictive schemes or indices are discussed in some detail, with the belief that each of them will prove useful when handled with discretion and insight derived from the foregoing considerations. The effective temperature scheme of the American Society of Heating, Ventilating and Air-Conditioning Engineers, the heat stress index of Belding and Hatch, psychrometric plots of reported lines of equal effect, and the wet bulb-globe temperature of Yaglou and associates are considered for the assessment of hot conditions. Wind chill (Siple), thermal wind decrement (Burton), and a heat loss index developed by the author are described for cold conditions. It is emphasized, however, that the brief description given in this monograph needs to be supplemented by thorough practical tuition and supervised application if proper use is to be made of these indices and reliable advice developed. This final chapter also introduces the reader to some forms of thermal protection, but again with the warning that the ideas need to be applied with discretion and judgment to each particular case.