

Preface to the second edition

Since the first edition of *Human Thermal Environments* was published in 1993, the subject has moved into exciting times. While fundamental principles are accepted, knowledge has increased, methods of application are used and some are controversial. From a base in military research and studies of fit, young people, there is now a recognition of the importance of the subject in all aspects of life worldwide. Many of the ideas expressed in the first edition have come to fruition such as the recognition of the six basic parameters (variables) as an essential starting point and the use of computers. The first edition recorded work up until the 1990s and may have stimulated research and application after that. It was particularly important in describing work in the 1980s when the foundations for new approaches were established. Developments that were at an early stage are now accepted. This second edition reports activity and progress into the twenty-first century while maintaining the description of the fundamentals of the subject and its development.

Programmes of European research have been a feature of the 1990s and beyond as the European Community has integrated activities over its member countries, stimulated co-operative research across countries and laboratories, industry, the military, consumers and other interested parties. Globalisation including worldwide electronic communication has had significant effects. New approaches to health and safety requirements have stimulated research and 'useable methods' and risk assessment strategies have become an issue. In heat stress, the predicted heat strain assessment method has been developed, in cold stress working practices in industrial work are being established and the WCI reviewed, and in thermal comfort the PMV/PPD index hangs on, as the agenda has moved to behavioural and adaptive approaches. Global databases of the results of collections of laboratory and field studies, made available on the worldwide web, can now allow quality control and research across the world to perform analysis on raw data. There has been an interest in special groups (e.g. people with disabilities) and special environments (e.g. vehicles, chilled ceiling and displacement ventilation). Knowledge of human skin contact with hot, moderate and cold surfaces has been developed, integrated and reported

as part of the whole series of International Standards that were first described at an early stage in the first edition and are now fully updated in this second edition. They provide an influential role in determining the direction of the subject and in stimulating research activity. New developments have provided new opportunities but we should not forget that the integrated subject of human thermal environments is based upon responses of people and the same fundamental principles apply. The second edition has introduced new developments since the previous edition while still maintaining a comprehensive description of the essentials of the subject.

All chapters have been revised, most with significant additions and there are new chapters on dehydration and water requirements and on thermal comfort for special populations, special environments and adaptive modelling. Chapters 1-7 present fundamental principles. Chapter 1 describes the six basic variables that make up human thermal environments and now includes the effects of solar radiation. Improvements to the heat balance equation include the effects of clothing ventilation and practical application is enhanced with a description of the thermal audit which will become a fundamental starting point in all human thermal environments assessments. Chapters 2 and 3 describe physiological and psychological responses. The controversial selective brain cooling is discussed as well as developments in behavioural thermoregulation. Chapter 4 is a new chapter which marks the increasingly recognised importance of dehydration and water requirements in responses to human thermal environments. Control of body water, indicators of dehydration and practical recommendations for drinking are provided. Chapter 5 is concerned with measuring methods and now includes personal monitoring systems and specification of physiological instruments. Chapters 6 and 7 are concerned with metabolic heat and clothing. New techniques, including the doubly labelled water method and CO₂ build-up in rooms, are presented as well as developments in clothing ventilation and active clothing. Chapters 8, 9, 10 and 11 cover thermal comfort, heat stress and cold stress, all of which have had significant developments. The adaptive approaches to thermal comfort are described as well as response to specific populations and environments. New developments in heat stress assessment are presented, in particular the new Predicted Heat Strain method that is being proposed as an International Standard. The original research for the Wind Chill Index is now described in detail as it comes under scrutiny and new proposals are developed. Chapter 12 is enhanced with the description of recent studies and approaches, in particular, the importance of the role of distraction in reducing productivity. Chapter 13 is significantly enhanced beyond consideration of hot surfaces with the entirely new sections on contact with moderate and cold surfaces, reflecting much improved knowledge and data in those areas. Chapter 14 reflects a major development in the application of the subject with the publication, revision and development of International Standards, now essential reading for the practitioner. Chapter 15 has also

been updated with significant developments. As predicted in the first edition, thermal models have taken their place as an integrated part of the subject's activity and their role in computer aided environmental design is becoming established.

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Preface to the first edition

Responses to thermal environments play a major role in human existence. All humans have exhibited physiological and behavioural responses to heat and cold, from cave men, through ancient civilizations to the present day. Over the last few centuries, such responses have undergone systematic scientific investigation. In parallel with major scientific discoveries, principles have been established and during the twentieth century these have been formalized into methods used in environmental design and evaluation. Technology has played a supporting role and in recent years the so-called information technology revolution has provided new opportunities for the development and application of well established principles and understanding. For example, in areas of environmental measurement, thermal models and in computer aided environmental design. Much is known and the foundations have been laid; however there is still much to discover in this subject. What is certainly true is that there is greater than ever interest and activity in the area.

The book presents knowledge concerning human responses to hot, moderate, and cold thermal environments for people exposed to air at normal atmospheric pressure. A comprehensive and integrated approach to the subject is taken, defining human thermal environments in terms of six basic parameters: air temperature; radiant temperature; humidity and air velocity of the environment; the clothing worn and the activity of the person. Much of the book is concerned with how these parameters interact to produce physiological and psychological responses and how they, in turn, will affect human health, comfort, and performance.

The underlying principles, derived from the component disciplines of physics, physiology, and psychology are described, as are methods used in the practical assessment of thermal environments. A historical perspective is often taken to enhance description and understanding of current methods and techniques.

In Chapters 1-6, fundamental principles are presented. Chapter 1 defines the six basic parameters and demonstrates how they interact to influence heat exchange between the body and the environment. The analysis of heat transfer leads to the body heat balance equation, a fundamental concept in

the rational method for assessing human thermal environments. Chapters 2 and 3 cover physiological and psychological responses. Human thermoregulation and body temperature are described, as are psychological and psycho-physical responses and perspectives. Chapter 4 is concerned with measurement of the basic environmental parameters, physiological and psychological responses. The thermal index is introduced as a fundamental assessment technique. Chapters 5 and 6 are concerned with the principles and estimation of the basic parameters, metabolic heat production, and clothing insulation.

Chapters 7, 8 and 9 consider thermal comfort, heat stress, and cold stress. There has been much activity in this area and recent developments, particularly new rational thermal indices, are described. Interference with activity, performance, and productivity is considered in Chapter 10. A systematic approach is taken and fundamental research reviewed. A performance model is discussed, as well as ways forward, in this area of great economic concern.

Chapters 11, 12 and 13 present topics not previously presented in detail that will be of great interest and influence in the future. Skin reaction on contact with solid surfaces is difficult to study where burns occur, for ethical reasons. Knowledge of temperatures that produce burns is needed however to aid in the design of products. Scientific findings and practical suggestions are presented as a contribution to this highly controversial area. The development of International Standards has been a feature of the last ten years and, with segmented world markets, will continue to be of interest. Chapter 12 describes current developments.

Digital computers and developments in knowledge and techniques have led to the availability of thermal models. Fundamental principles and important and influential models are described. The possibility of computer aided design in this area is demonstrated.

There is no doubt that the practice of this subject is best performed using computers. For example, in recent years my students of climatic ergonomics, physiology, and psychology routinely use software in all aspects of their project and survey work. Sufficient detail is provided in the book to allow the production of software. Source listings of some important computer programs are provided in the appendices. In the first plan of the book a suite of programs was to be included. However, after consideration, I decided to refer to texts where software could be obtained in disk form. This will allow the reader access to easy updates and save errors and laborious typing of source code. All of the equations and models referred to in this book are available on disk for microcomputers from references provided in the text.

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