·THERMOELECTRICITY·

Theory
Thermometry
Tool

Daniel D. Pollock

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THERMOELECTRICITY
Theory, Thermometry, Tool

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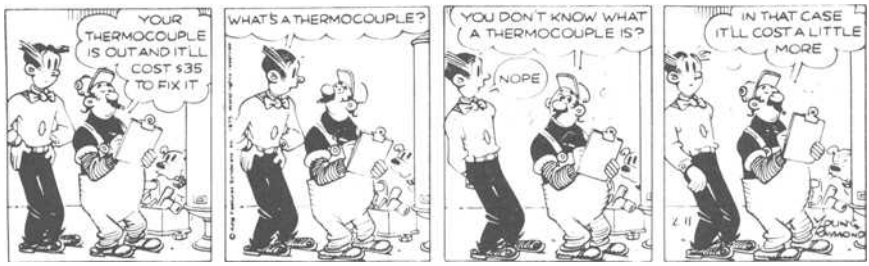

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Preface

This publication, sponsored by Committee E-20 on Temperature Measurement, is intended for engineers whose responsibilities include temperature measurement and control and for personnel charged with the application and maintenance of temperature-measuring/controlling systems. Many books and technical articles are available which clearly describe the methods and techniques which must be used in order to ensure that accurate data are obtained in industrial practice. Several books on the theoretical aspects of thermoelectricity have appeared in recent years. Most of these deal with the physical theory at very low temperatures and, if commonly used thermocouples are noted at all, they are mentioned in passing or in a way which is of little practical assistance. Both types fill important needs. The first class of publications is of the how-to-do-it variety; the second group is highly theoretical and usually is based upon the assumption that the reader is familiar with the physical and mathematical concepts which are employed. This book attempts to span this gap by explaining the "why" of practical thermoelectric properties in the least complicated manner possible.

The approach here is to explain the theory and the bases for thermoelectric materials in general and of those materials commonly used for thermoelectric purposes at elevated temperatures in particular. It is at these temperatures that the overwhelming preponderance of thermoelectric applications have been and are being made. To my knowledge the only other work which attempts to do this is *ASTM STP 492, The Theory and Properties of Thermocouple Elements*, 1971, by the present author. *STP 492* is somewhat limited in scope in that it presents only explanations for the properties of metals and alloys; semiconductors are not included. In addition, it contains just enough modern physical theory for the convenience of the reader with some familiarity with this field.

The present volume, *STP 852*, is considerably more than a revision of the prior work. The earlier publication has been expanded, brought up to date, and this one is intended to provide clearer explanations at a more basic level. Additional information on such topics as extension wires and less commonly used thermocouples has been included. In addition, considerable material on the thermoelectric properties of semiconductors has been added.

The physical theory has been expanded to make it much more accessible to those unfamiliar with this field. The mathematics have been kept as simple as possible without oversimplifying or distorting the concepts. In virtually all cases, only a familiarity with the elementary calculus is required to follow the

derivations. All of the steps are shown and none are considered to be obvious to the reader. The additional background required for this book includes first-year, college-level physics and chemistry and one course in physical metallurgy or materials science. Information required beyond these levels has been incorporated where needed. This permits readers unfamiliar with the field to follow the reasoning without recourse to other sources. In some cases alternative explanations have been provided for clarity. Readers with some background in this field will be able to follow the presentations with ease.

The introductory chapters are intended to act as a bridge between the classical mechanics, which is familiar to those technically engaged, and the quantum mechanics, which usually is unfamiliar. The limitations of the classical approach are shown in elementary ways and the need for the quantum mechanics is demonstrated. The quantum mechanics is developed directly from this by the use of uncomplicated examples of various phenomena, and only to the extent required to understand the physical properties discussed in the chapters which follow.

Introductory sections are provided to guide the reader to the topic under consideration. The basic physical relationships given are drawn from concepts and properties which are known to those with a technical background; they lead the reader into the topic of interest. In some cases small amounts of material are repeated for clarity and convenience.

The first four chapters introduce, explain, and develop the modern theory of solids and that portion of thermodynamics applicable to thermoelectricity. Sufficient theory and properties of semiconductor materials are given for the understanding of thermoelectric power generation and of Peltier cooling in Chapter 11. Those familiar with solid-state theory, and whose main interest is in thermoelectric thermometry, may omit these chapters and concentrate upon the ideas presented in Chapters 5 through 10.

The first four chapters are absolutely essential for readers who are unfamiliar with this field. The combined presentations given in Chapters 4–7 provide a broader basis for the insight into and for the understanding of thermoelectric phenomena than is possible from any single explanation. Some of the ways in which thermoelectricity may be used as a research tool are given in Chapter 12.

Basic material already well represented in the literature is included in a minimal way for the sake of completeness. Other material, such as that presented originally by Bridgman or by Mott and Jones, is given in more detail than in the original. This has been done in order to provide a simple and self-consistent presentation.

Note should be made that the units used are those currently employed by engineers working with thermoelectric applications. The use of a single system would be counterproductive.

References have been provided so that more detailed information may be acquired from a minimum number of widely available, reliable sources.

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Related ASTM Publications

Manual on the Use of Thermocouples in Temperature Measurement, STP 470B (1981), 04-470020-40

Evolution of the International Practical Temperature Scale of 1968, STP 565 (1974), 04-565000-40

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