Radiation Thermometry

Fundamentals and Applications in the Petrochemical Industry

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Peter Saunders

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Introduction to the Series

Since its conception in 1989, the Tutorial Texts series has grown to more than 70 titles covering many diverse fields of science and engineering. When the series was started, the goal of the series was to provide a way to make the material presented in SPIE short courses available to those who could not attend, and to provide a reference text for those who could. Many of the texts in this series are generated from notes that were presented during these short courses. But as stand-alone documents, short course notes do not generally serve the student or reader well. Short course notes typically are developed on the assumption that supporting material will be presented verbally to complement the notes, which are generally written in summary form to highlight key technical topics and therefore are not intended as stand-alone documents. Additionally, the figures, tables, and other graphically formatted information accompanying the notes require the further explanation given during the instructor's lecture. Thus, by adding the appropriate detail presented during the lecture, the course material can be read and used independently in a tutorial fashion.

What separates the books in this series from other technical monographs and textbooks is the way in which the material is presented. To keep in line with the tutorial nature of the series, many of the topics presented in these texts are followed by detailed examples that further explain the concepts presented. Many pictures and illustrations are included with each text and, where appropriate, tabular reference data are also included.

The topics within the series have grown from the initial areas of geometrical optics, optical detectors, and image processing to include the emerging fields of nanotechnology, biomedical optics, and micromachining. When a proposal for a text is received, each proposal is evaluated to determine the relevance of the proposed topic. This initial reviewing process has been very helpful to authors in identifying, early in the writing process, the need for additional material or other changes in approach that would serve to strengthen the text. Once a manuscript is completed, it is peer reviewed to ensure that chapters communicate accurately the essential ingredients of the processes and technologies under discussion.

It is my goal to maintain the style and quality of books in the series, and to further expand the topic areas to include new emerging fields as they become of interest to our reading audience.

Arthur R. Weeks, Jr.
University of Central Florida

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Preface

More than a decade ago, I embarked on a research program in the field of radiation thermometry. As a recent PhD graduate, I was (and still am) employed by the Measurement Standards Laboratory of New Zealand, New Zealand's national measurement institute. But rather than just being confined to the relative safety of a calibration laboratory, I was given the task of seeking solutions to industrial radiation thermometry problems "in the real world," particularly in the petrochemical industry. After visiting several plants, it soon became apparent that there was a lack of practical knowledge in the industry on how radiation thermometers should be used, and that most of the advice being followed was of an anecdotal nature. I was frequently met with the most fundamental of questions: "What emissivity setting should we use?" Over the years, the questions have become more difficult and my research activities more interesting and in-depth. The knowledge I have accumulated through a combination of theoretical modeling and practical experience forms the basis of this book.

The aim of this book is simple: to provide the means for petrochemical engineers to confidently assess the temperatures of their process tubes, whether they are in the methanol industry, the ammonia industry, the refining industry, or any industry utilizing fired furnaces for the heating of process tubes. This book is an introduction to the use of radiation thermometers for achieving this aim.

Radiation thermometry has been applied in the petrochemical industry for many decades, and while recognized as being the only viable method to measure temperatures in the harsh environment of flame exhausts, its credibility has suffered due to its many, sometimes puzzling, sources of error. In fact, some past researchers have stated that some of the problems associated with these errors are insoluble. I beg to differ. By understanding the nature and origin of the errors it is possible to unravel them from the radiation thermometer measurements to yield an estimate of both the true temperature and its all-important uncertainty.

The book is organized as follows. A brief introduction outlining the need for temperature measurement in industrial furnaces is given in Chapter 1. Chapter 2 then introduces the physical principles that are important to gaining an understanding of how radiation thermometers work, including the essential concept of blackbody radiation. Chapter 3 discusses a number of different types of radiation thermometer that are used in industrial furnaces. This chapter largely focuses on spectral-band thermometers as these are the most commonly used thermometers. The errors associated with the use of spectral-band thermometers are analyzed in Chapter 4 along with techniques or measurement strategies that can be used to minimize or eliminate the errors. Anyone serious about their temperature measurements should be equally serious about estimating the size of the uncertainty associated with their measurements, as the uncertainty provides a measure of the quality of the measurement. Methods for assessing uncertainties are given in Chapter 5. Calibration of radiation thermometers is discussed in Chapter 6, and a procedure is provided for those who wish to carry out their own in-house calibrations.

Finally, in Chapter 7, measurement and analysis procedures are presented for carrying out a full furnace tube temperature survey. These procedures are demonstrated through a series of detailed examples for a number of different furnace geometries and operating conditions. These examples are derived from real-life plants, with the details changed somewhat to protect the confidentiality of the original results.

I would like to express thanks to my colleague and long-time mentor, Rod White, for his constant encouragement and support for this book, for his insightful contributions to the development of many of the ideas that this book encompasses, and for his critical reviewing of the manuscript.

Peter Saunders
July, 2007