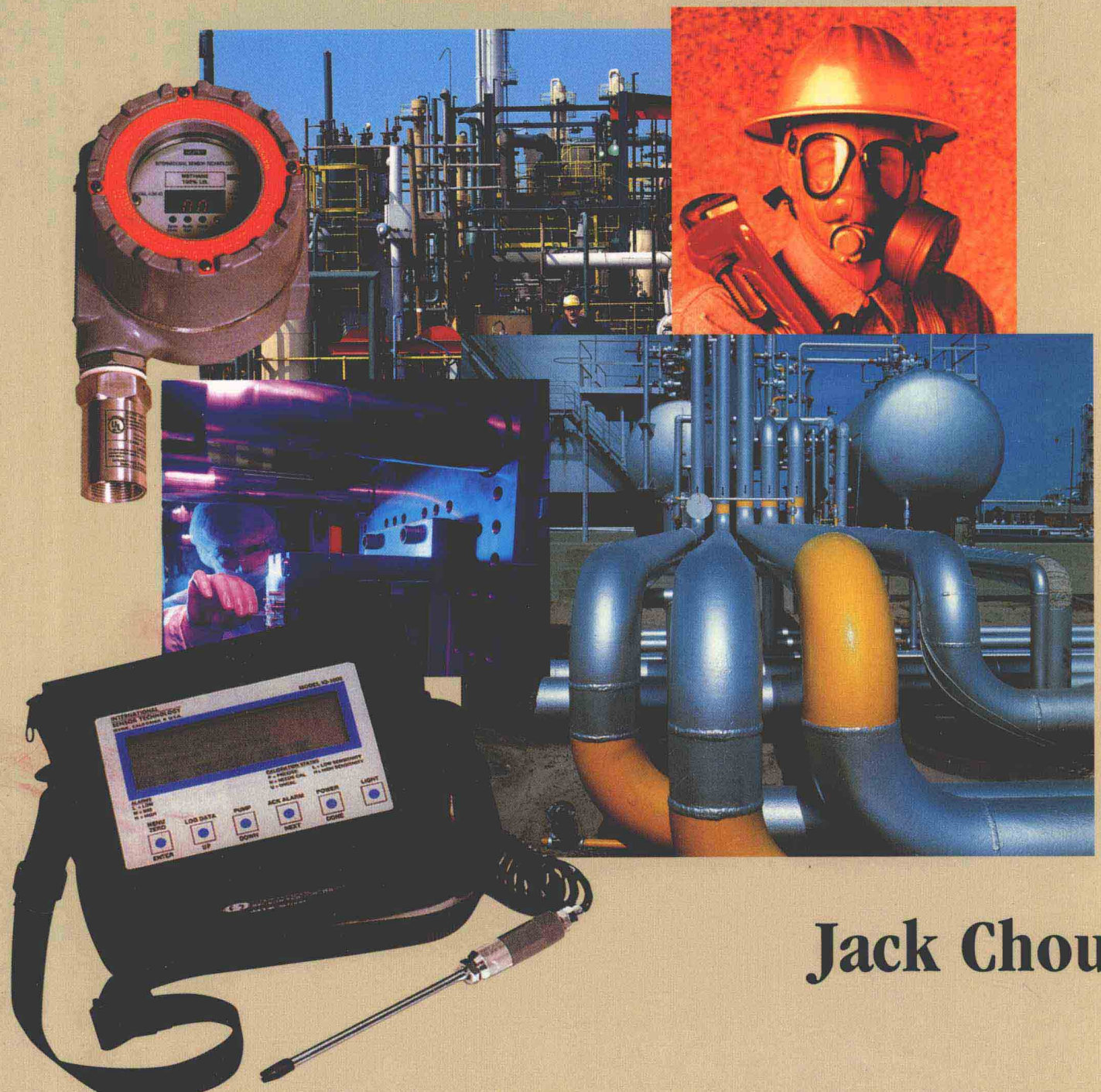
Hazardous Gas Monitors

A Practical Guide to Selection, Operation and Applications



Jack Chou

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JACK CHOU

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McGraw-Hill

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Published by McGraw-Hill Book Company, New York
ISBN 0-07-135876-5

Produced for McGraw-Hill Book Company by SciTech Publishing, Inc.
SciTech President: Dudley R. Kay
Composition and Illustration: Shyam Tony Reyes, Prasad Services
Cover Design: Janice Bakker and Tom Miller

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Printed in Korea

10 9 8 7 6 5 4 3 2 1

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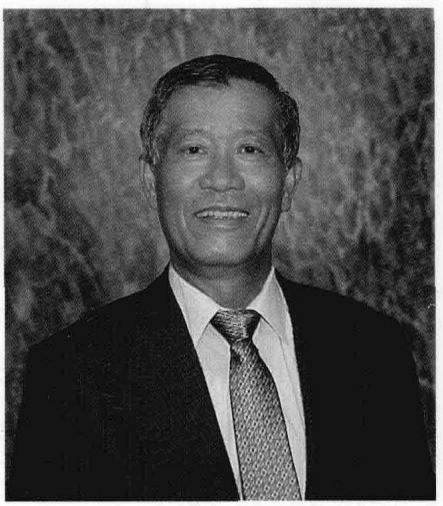
About the Author



Jack Chou is founder and chief executive of International Sensor Technology, Inc. in Irvine, California. He received his MS in Mechanical Engineering from Southern Methodist University and worked briefly in the aerospace industry at McDonnel Douglas prior to starting International Sensor Technology (IST) in 1972.

In his more than 30 years in the toxic and combustible gas monitoring instrument field, Chou has taken his company products from initial concept through research, testing, and final production and marketing. He has worked on thousands of complex gas detection applications, gaining knowledge and honing his expertise on projects for NASA's Space Shuttle program, USAF projects, the EPA, DOE, the Soviet Union, and numerous others.

Since its founding, Chou has spearheaded IST to leadership in the field of gas detection. Currently the company manufactures four types of sensors: solid-state, catalytic bead, infrared, and photoionization. The company was a pioneer in the field of solid-state sensor technology and has developed a family of these sensors able to detect over 150 different toxic and combustible gases, a number unmatched by any competing manufacturer. The company also offers, but does not manufacture, electrochemical sensors. For more information about IST, visit their website at *www.intlsensor.com.*

Preface

Checking air quality in the workplace for toxic and combustible gases has been done since at least the beginning of the Industrial Revolution and perhaps even earlier. "High-tech" monitoring once consisted of coal miners carrying caged canaries into the mines and observing their well being. If the sensitive birds seemed healthy, this was taken as a general indication of safe air quality. Fortunately for today's workers and the public at large, not to mention the canaries, today's monitoring devices are much more sophisticated.

The use of modern gas monitoring instruments has taken great strides since about 1970 when the Occupational Safety and Health Act (OSHA) came into existence in the United States and the concept of workplace environmental safety became a well-accepted idea around the world. The advent of the semiconductor and the integrated circuit further boosted the sophistication of monitoring instruments. However, the extreme complexity of modern day applications, which often involve large numbers of chemicals with radically different characteristics, makes it impossible for a single gas-sensing instrument to accomplish all the necessary tasks. In any given application, the user must be familiar with not only the types of instruments available that best suit the application, but also how to implement these instruments for maximum efficiency after the purchase, and how to test and maintain them over the years. This calls for a high

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degree of knowledge and experience, because there is frequently no consensus in the industry about which instruments to use in a given environment or how to deploy them.

The purpose of this book is to make the complex subject of gas detection as simple and practical as possible in order to aid those people who are involved in area air quality applications. This illustrated guide will help plant engineers, systems designers, safety and environmental health directors, industrial hygienists, technicians, and instrument vendors in petrochemical, semiconductor chemical, healthcare and related industries quickly grasp the basics of gas monitoring and determine the right instruments for the job. Nonspecialists in particular will benefit from the scores of technical definitions and health and fire safety terms, as well as explanations of the toxicity and combustibility of gases and how to monitor them.

Readers from all backgrounds and levels of knowledge will benefit from the detailed, feature-by-feature look at all the major sensors used for gas monitoring, plus a bird's eye view of ten additional analyzer technologies that are lesser known but still widely used.

Since 1972, when I founded International Sensor Technology, now a leading company in the field, I've been actively engaged in every aspect of gas monitoring. Throughout these 27 years I have been fortunate to have gained priceless experience by providing solutions for thousands of industrial applications including instruments used in the United States Space Shuttle program, highway tunnels, petrochemical facilities, food processing, agriculture, and the medical industry, just to name a few. This invaluable practical knowledge, including information learned during research, development, and design of new equipment, has been condensed into this book.

To make this review of gas monitoring devices and technology as visually appealing and as pleasant to read

as possible, the pages are generously laid out, with color illustrations and color photographs throughout the book. I feel it is important to make the book clear and exciting, so that your understanding of this material is enhanced and you get more value out of your reading. To me, the field is a fascinating discipline, in addition to being critical to the health and safety of workers everywhere. I hope this illustrated presentation will convey my interest and make you into a more knowledgeable professional.

Key Features of Each Chapter

Chapter One presents an overview of gas monitoring terminology and definitions of key terms, along with the basic principles of toxic and combustible gas monitoring. Although many people in industry are familiar with these subjects, I suspect that few understand them in any real depth. Enough information is presented in this chapter to understand both the range of a sensor and the type of enclosure needed for an application.

Chapters Two through Six present specific, point-by-point information on the sensors most commonly used for gas monitoring applications, including each sensor's principle of operation, characteristics, and most common applications. The technologies include electrochemical, catalytic combustible, solid state, infrared, and photoionization types. You will be able to evaluate the pros and cons of each sensor to aid you in determining the best type to use for a given application. *Chapter Seven* reviews ten additional analyzer technologies, their operating principles, and main applications in the field.

Chapter Eight summarizes the preceding information about the various sensors and organizes it into a convenient checklist and "shopping guide" covering key issues to consider when choosing sensors — including the different requirements of toxic *vs.* com-

bustible gases. *Chapter Nine* presents installation, configuration, and maintenance highlights, including electrical terminology commonly used in the field. The simple explanations of the electrical circuits will help many users to better understand the operating manuals that accompany most instruments.

The sampling system and sensor calibration information provided in *Chapters Ten and Eleven* is based on my own practical experience, including some original calibration techniques, and provides critical instructions essential to safety and accuracy in the operation of any gas monitoring system. *Chapter Twelve* reviews the chemistry and environmental activity of the most common hazardous gases.

An especially useful section of the book for many will be the three appendices. Here, you'll find practical, daily reference data on individual gases difficult to find elsewhere.

Photoionization detectors are capable of detecting many gases, but must be calibrated. *Appendix I* provides a color-coded list of PID correction factors for 253 gases to aid the user in obtaining the proper readings, using the three most widely used lamps (9.8, 10.8 and 11.7eV). The chart is courtesy of RAE Systems, Inc.

Appendix II gives critical exposure limits and explosive limits for 384 hazardous gases, along with useful physical and chemical data for each gas. Again, the information is presented in color-coded columns for easy reading.

Many gases have not only a chemical name but also a common and even a separate trade name. *Appendix III* lists the chemical name along with commonly known alternative names and synonyms for 384 gases to aid in correct identification. Knowing which gas is which, even though the names may be different, is essential to your own safety and that of others.

Acknowledgments

Many people assisted me in putting this book together. I would like to thank the following individuals for their valuable contributions which have helped make this book possible:

Allen Peart of the *Signal Instrument Company Ltd., Ambitech Division,* United Kingdom; Dr. Wen Yang of *Universal Sensors and Devices, Inc.,* Chatsworth, California; Dr. Mohammad Razag of *Analytical Industries,* Pomona, California; Edgar A. Geissler of *BARTEC US Corp.,* Tulsa, Oklahoma; Darryl Mendivil of *Matheson Gas Products,* Montgomeryville, Pennsylvania; Bob Ullrich of *Intec Measurement Systems,* Morristown, New Jersey; David Cima of *Eltec Instruments, Inc.,* Daytona Beach, Florida; Gary Cullen of *Cullen & Associates,* Anaheim, California; Peter Hsi of *Rae Systems, Inc.,* Sunnyvale, California; Mike Pryor of *E. I. Dupont,* Wilmington, Delaware; Werner Boleter of *Syscom,* Zurich, Switzerland; Ing Rudolf Auer, Vienna, Austria; Tony Bagnall of *Bagnall Direct Services PTY LTD,* Brighton, Australia; and Rob White of *City Technology Limited,* Portsmouth, England.

Special thanks are due to Dr. Mohammad Razag for his assistance in writing the chapter on electrochemical sensors, and Mr. John Schoepf, an environmental consultant who has had many years of experience in the environmental field, for his review and valuable contributions.

To bring the information and graphics together into such an accessible and interesting format, I thank my graphic artist and page layout designer Shyam Reyes. Copy editing and proofreading, as well as many suggestions for improvements to the text, were provided by Denise G. May, VP of SciTech Publishing. Not being an expert in professional and reference book publishing, I was fortunate to obtain the extensive advice and mentoring of Dudley R. Kay, founder and president of SciTech Publishing, who served as a

sounding board for my ideas and the liaison who brought us together with McGraw-Hill Publishing Company. With the help of Shyam, Denise, and Dudley, we have produced an exceptional book that will prove useful to a broad array of engineers, technicians, and personnel in the gas monitoring industry.

Finally, I want to express gratitude to members of my own family, including my sons, David, Daniel and Thomas (all MSEE), who gave me much advice and assistance in writing the book, and my wife, Doris (MS Chemistry; co-founder of IST and developer of IST's solid-state sensors) whose constant encouragement was invaluable.

I realize that some of the information and material covered in this book may be subject to other expert interpretations and opinions, and would appreciate suggestions or feedback to be incorporated into future editions.

Jack Chou, *Irvine, California*

Contents

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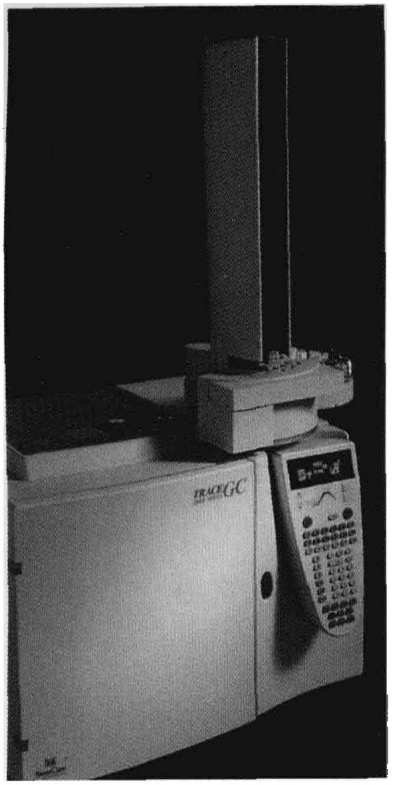
Chapter 1

Introduction

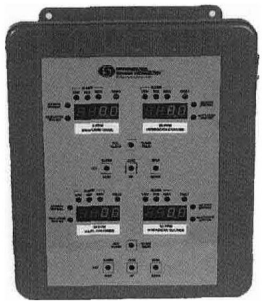
The detection of hazardous gases has always been a complex subject and makes choosing an appropriate gas monitoring instrument a difficult task. To address this problem, this book aims to provide the following essential tools:

- A simple guide to the various sensor technologies available
- Information to help you intelligently select the proper instruments for specific applications
- Information engineers can use to design a complete monitoring system
- Technical data and practical procedures that technicians can use to check and maintain a gas monitoring system

The main emphasis of the book is on gas detection technology that is used in the field of area air quality and safety. This field primarily involves the protection of personnel and property against toxic and combustible gases. The discussion includes the types of sensors used, the various instruments available, and the applications that incorporate these instruments.



An Analytical Instrument. The example shown above automates gas chromatography with the help of its built-in robotic technology. (Courtesy of CE Instruments)



A Gas Monitor. IST's MP-204 is a wall-mounted unit housed in weatherproof enclosure with four sensor channels.

Analytical Instruments and Monitoring Systems

To date, no gas sensors exist that are 100% selective to a single gas. Achieving such selectivity requires the use of instruments that employ analytical techniques to identify gases.

Examples of such instruments include *Fourier transform infrared* (FTIR) instruments that use the infrared spectral characteristics of gases, *gas chromatographs* that use analytical columns, and *mass spectrometers* that identify molecules through characteristic variable deflections from a magnetic field.

These instruments provide fairly accurate and selective gas readings. Some typical applications for these kinds of instruments include airport bomb detection, drug abuse screening, and analyzing air pollutants. However, these analytical instruments require skilled and knowledgeable operators, and are generally very expensive and designed for laboratory tabletops or specific on-line applications for in-plant installations.

In addition, many suffer from limitations such as high maintenance, slow response time, and large size, making them impractical monitors for area air quality and safety. Thus, they are typically used only as a last resort for applications in which a suitable sensor is not available.

For work area air quality and safety applications, monitoring systems must meet a number of practical criteria. These monitoring systems must be:

- rugged and corrosion-resistant
- weather- and dust-proof
- capable of being installed in hazardous areas
- durable and long-term
- operationally stable
- easy to maintain
- operated by a minimally skilled person

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