NONDESTRUCTIVE TESTING

HANDBOOK

Third Edition

Volume 7

Ultrasonic Testing

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Gary L. Workman
Doron Kishoni

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American Society for Nondestructive Testing

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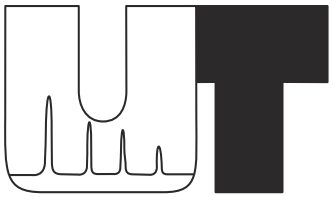

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President's Foreword

The mission of the American Society for Nondestructive Testing (ASNT) is to create a safer world through the promotion of the nondestructive testing (NDT) profession and the application of its technologies. Our society has a strong volunteer tradition and a talented staff. Together, they provide opportunities for NDT professionals to improve their skills and apply their talents through the exchange of information and experiences relating to NDT. Because of the nature of our work, our customers expect NDT professionals to perform at the highest possible level with little room for error. ASNT aids their initial and continued professional development through published materials and numerous activities — international, national and local. The *NDT Handbook* series continues to be one of the finest examples of what society volunteers and staff can accomplish when focused on a goal and working together to accomplish it.

ASNT's future depends on the creation, improvement and sharing of information so that safety and reliability stay at the forefront of product development and inservice evaluation of existing components. This volume of the *NDT Handbook* represents the efforts of many dedicated professionals who have embraced change and given freely of their time with the mission of making a difference in their profession. There were scores of individual contributors and reviewers, both volunteers and staff, in an essential ongoing partnership.

A special thanks is due to Handbook Coordinator Harb Hayre and to Technical Editors Gary Workman and Doron Kishoni for their commitment to this project. Their editing required an in-depth understanding of the technology. The job is long and tedious and must be driven first from the heart and then from the mind.

I also thank *NDT Handbook* Editor Patrick Moore and other ASNT staff for their guidance and continued pursuit of excellence. They have made sacrifices necessary to ensure quality and value to our members.

To our volunteers: you are our greatest asset. You do not appear on the financial balance sheet, but you make this society great. I would like to challenge each NDT professional to get involved in making our professional organization better, especially if you feel that important information is missing from any society publication. Each of you has unique knowledge and experiences. The volunteers who worked on this *NDT Handbook* were willing to share their expertise. When you study this volume, you will learn from their knowledge and experiences.

Please consider an active role in succeeding volumes of the *NDT Handbook*. Your participation will allow future readers to gain from your wisdom and experiences.

Again thanks to all who contributed.

Marvin W. Trimm
ASNT President, 2006-2007

Foreword

Aims of a Handbook

The volume you are holding in your hand is the seventh in the third edition of the *Nondestructive Testing Handbook*. In the beginning of each volume, it has been useful to state the purposes and nature of the *NDT Handbook* series.

Handbooks exist in many disciplines of science and technology, and certain features set them apart from other reference works. A handbook should ideally give the basic knowledge necessary for an understanding of the technology, including both scientific principles and means of application.

The typical reader may be assumed to have completed three years of college toward a degree in mechanical engineering or materials science and hence has the background of an elementary physics or mechanics course. Additionally, this volume provides a positive reinforcement for the use of computer based media that enhances its educational value and enlightens all levels of education and training.

Standards, specifications, recommended practices and inspection procedures may be discussed in a handbook for instructional purposes, but at a level of generalization that is illustrative rather than comprehensive. Standards writing bodies take great pains to ensure that their documents are definitive in wording and technical accuracy. People writing contracts or procedures should consult the actual standards when appropriate.

Those who design qualifying examinations or study for them draw on handbooks as a quick and convenient way of approximating the body of knowledge. Committees and individuals who write or anticipate questions are selective in what they draw from any source. The parts of a handbook that give scientific background, for instance, may have little bearing on a practical examination except to provide the physical foundation to assist handling of more challenging tasks. Other parts of a handbook are specific to a certain industry. This handbook provides a collection of perspectives on its subject to broaden its value and convenience to the nondestructive testing community.

The present volume is a worthy addition to the third edition. The editors, technical editors, ASNT staff, many contributors and reviewers worked together to bring the project to completion. For their scholarship and dedication, I thank them all.

Gary L. Workman
Handbook Development Director

Preface

The *Nondestrucive Testing Handbook: Ultrasonic Testing* continues to include a broad range of techniques and applications as shown in this handbook. This third edition volume builds upon the very extensive and in-depth information contained in the second edition and brings additional robust and up-to-date information on this rapidly changing field. Ultrasonic techniques are used for discontinuity detection, material property characterization and physical measurements such as thickness gaging. Many ultrasonic concepts that were primarily research topics for the second edition have now matured into well defined applications in the third edition. This volume offers more extensive contributions of techniques such as phased arrays, guided waves, laser ultrasonics and newer signal processing techniques; as well as a broader range of applications in the aerospace industry. We continue to profit from international contributions, promoting a larger knowledge base for nondestructive testing worldwide.

The third edition of *Ultrasonic Testing* includes many changes in the way ultrasonic inspections are performed because of advances in computer technology. New equipment and techniques enable improved data collection and analysis, both in the laboratory and in the field. These advances in technology also provide improved imaging capability and better understanding of ultrasonic measurements with theory.

This volume represents the work of many in the field who were able to contribute their time and effort to provide latest state-of-the-art information. In addition, many volunteers were able to review and return comments in short order. We are indebted to both groups for bringing this volume to publication in less than two years. We are also indebted to the Ultrasonic Testing Committee in ASNT's Technical and Education Council and to Harb Hayre, who provided support as the handbook coordinator. We also wish to express our gratitude to Patrick Moore and his staff for their thoroughness and diligence in preparing the volume for publication in a timely manner.

Gary L. Workman
Doron Kishoni
Technical Editors

Editor's Preface

It was a different world when ASNT was founded in 1941. The United States was not yet an ally in World War II. Acoustic tests using inaudibly high frequencies were called *supersonic* in the 1940s because that term had not yet been co-opted by aircraft traveling faster than sound. The first edition of the *Nondestructive Testing Handbook* was published in 1959. Ten years earlier, its editor, Robert McMaster, had published an extensive survey of nondestructive testing patents. At that time, in 1949, ultrasonic tests were called *mechanical vibration tests* and were lumped together with various modulus measurements and sonic techniques. In the 1950s, ultrasonic testing became well established as a method for discontinuity detection.

ASNT published the ultrasonic volume of the second edition in 1991, in time for ASNT's 50th anniversary. The text files for that volume were keyed entirely by ASNT staff working on a Wang™ word processor. Images in illustrations were all shot, imposed and archived as hard copy images and did not exist digitally, not anywhere. The text files for that book were archived and survived as ASCII files until 2003, when they were converted to word processing files formatted for use in desktop publishing.

The second edition *Ultrasonic Testing* remains the single largest book that ASNT has ever published. The technical editors for that volume were Robert Green and Albert Birks; the staff editor was Paul McIntire. The good effects of their work on the second edition have survived into the third. Half of the 1991 volume has been updated and survives as more than half of this 2007 edition.

Planning by ASNT's Ultrasonic Committee for the third edition became earnest at a meeting in Austin in Spring 2004. The book became more streamlined in concept as the committee agreed to eliminate redundancies in its coverage from one chapter to the next and to focus on providing information useful to Level II and Level III inspectors. The outline omitted reference tables available elsewhere and theoretical analyses of interest to a few. The committee affirmed the vision of the series as instructional. The result is the concise treatment of the subject in the book you are holding.

A fourth of ASNT's membership and half of its certification holders are overseas. Gradually and irrevocably, the United States is changing to international units of measurement. This volume's technical review is especially indebted to close attention by volunteers from the United States Metric Association. The accuracy and omnipresence of international units in the third edition of the *NDT Handbook* help to ensure that the series will be of value both to the world that ASNT serves and to posterity.

Likewise, alloys throughout are identified according to the Unified Numbering System.

I would personally like to thank members of ASNT staff who helped to make this book better. Hollis Humphries and Joy Grimm produced many excellent graphics. Grimm also laid out the chapters, and Humphries proofed the book and produced its CD-ROM version.

People listed as contributors in the acknowledgments below were also reviewers but are listed once, as contributors.

Patrick O. Moore
NDT Handbook Editor

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