NONDESTRUCTIVE TESTING

HANDBOOK

Third Edition

Volume 2

Liquid Penetrant Testing

Technical Editor
Noel A. Tracy

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President's Foreword

Liquid Penetrant Testing is the second volume of the third edition of the *Nondestructive Testing Handbook*. This volume continues to advance the series' mission of disseminating information about the technology.

Nondestructive testing contributes to public safety and to our quality of life in countless ways. The technology has made possible those advances in technology that are the hallmark of this turn of the century.

Technology typically relies on things that can be counted, on numbers — on measurements and data that can be quantified, processed and stored by computer. In such an age, liquid penetrant testing occupies a special place because it is a qualitative method that has defied quantification. At the same time, the method remains extremely sensitive, reliable, cost effective and useful to industry. Because liquid penetrant testing relies so much on the training and experience of the human inspector, an authoritative handbook is especially important.

ASNT has been fortunate that the Technical Council's Penetrant Committee is superbly qualified to provide the expertise needed to rewrite and review a book of such importance and scope. The collaboration between the volunteers and staff in the writing and review of this volume has made productive use of ASNT's volunteer resources. Scores of authors and reviewers have donated thousands of hours to this volume.

Liquid Penetrant Testing was produced under the guidance of ASNT's Handbook Development Committee. A special note of thanks is extended to Handbook Development Director Gary Workman; to recent Penetrant Committee Chairs William E. Mooz, Vilma G. Holmgren, Brian MacCracken and Michael L. White; to Technical Editor Noel A. Tracy; and to Handbook Editor Patrick Moore for their dedicated efforts.

The existence of *Liquid Penetrant Testing* is testimony to the commitment of the American Society for Nondestructive Testing (ASNT) to its missions of providing technical information and instructional materials and of promoting nondestructive testing technology as a profession.

Robert E. Green, Jr.
ASNT National President (1998-99)

Foreword

The Aims of a Handbook

The volume you are holding in your hand is the second in the third edition of the *Nondestructive Testing Handbook*. Now is a good time to reflect on the purposes and nature of a handbook.

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. Occasionally an engineer may be frustrated by the difficulty of the discussion in a handbook. That happens because the assumptions about the reader vary according to the subject in any given chapter. Computer science requires a sort of background different from nuclear physics, for example, and it is not possible for the handbook to give all the background knowledge ancillary to nondestructive testing.

A handbook offers a view of its subject at a certain period in time. Even before it is published, it starts to get obsolete. The authors and editors do their best to be current but the technology will continue to change even as the book goes to press.

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 real 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. Other parts of a handbook are specific to a certain industry. Although a handbook does not pretend to offer a complete treatment of its subject, its value and convenience are not to be denied.

The present volume is a worthy addition to the third edition. The editors, technical editors and 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

What could be simpler than directly viewing a part with a suitable light to see an indication of a discontinuity produced by dipping the part in a colored liquid, washing excess liquid off with a water hose and drying the part? As one gains experience with liquid penetrant testing, a more appropriate question may come to mind: how can a *simple* technique be so complex?

Because the liquid penetrant test is fundamentally simple and the equipment (if any) is easy to operate, untrained observers usually think they can save time and money by borrowing some liquid penetrant materials and performing the test themselves. However, as training and experience show, the best materials are worthless without strict adherence to processing guidelines that direct and control the test from the preparation of the inspection surface (including the crack surface), to the visual examination of the part to locate an indication. Furthermore, the materials themselves require some basic care so that they don't spoil. Even experienced inspectors must avoid the trap of apparent simplicity, which breeds complacency. Inattention to processing details and materials maintenance will result in a test that will fail because it is out of control. The editing of this volume has attempted to emphasize these issues.

Perhaps *complex* is the wrong word to describe the test; *methodical* is probably a better descriptor. Apparent disadvantages of the test can usually be overcome by modifying a step or applying a different set of steps. For example, inspectors could work in tandem when testing large areas, for which process control is more difficult, or use liquid penetrant that requires more than just water to remove it if removal of the liquid penetrant from shallow cracks is a concern. In another situation the requirement for strict process control may be turned into an advantage in that methodical adjustments in the process can adjust the sensitivity of the test so that only the relevant discontinuities are detected.

Despite its subtlety liquid penetrant testing does work. Large areas, small areas, plane surfaces, multifaceted surfaces, all can be inspected quickly and economically. Because of this advantage it is tempting to use liquid penetrant testing in place of other, more expensive point sensitive techniques such as eddy current testing. However, in some applications, especially where residual compressive stresses exist, the surface opening of a discontinuity may be too small for reliable liquid penetrant testing. A good example is a small fatigue crack.

Liquid penetrant materials are constantly being improved to meet general or specific application requirements, to make the test process more forgiving or to satisfy new environmental concerns. In some applications water washable liquid penetrants are as sensitive as postemulsifiable types. Equipment is also improving. Properly designed and monitored automated processing systems have the potential to more carefully control the liquid penetrant testing process while alleviating the monotony experienced by an inspector who applies the test steps repetitively.

The technology of liquid penetrant testing lacks a reliable and objective scientific test for evaluating the sensitivity of a liquid penetrant test. Photometers have been used in the laboratory to assign arbitrary sensitivity levels to liquid penetrant systems by measuring the luminance of fluorescent indications. However, even with precisely controlled processing parameters, the luminance measurements on a set of low cycle fatigue cracks have been reproducible only within 20 percent.

Part of the problem has been the difficulty of correlating the physical and chemical phenomena and properties of liquid penetrants to practical liquid penetrant test sensitivity. This difficulty influenced the decision to limit the theoretical discussions in this volume to the practical characteristics of liquid penetrant materials. Because an inspector is ultimately concerned about the presence or absence of a relevant indication, the more that is understood about how the test process affects those characteristics, the more likely a visible indication will be produced.

The future of liquid penetrant testing is sure to include continued efforts to bring machine vision and decision making up to the level of competency achieved with the human eye and brain. Initially, questions of economic feasibility will

have to be answered in light of the current economic advantages of liquid penetrant testing, but cheaper technology that works will be used.

The Technical Editor is indebted to the committee members, contributors, reviewers who volunteered to help assemble this book. The aim was to build on the work of those who contributed to previous editions, updating the technical content while preserving the technological story line of lessons learned. The guidance and assistance of the ASNT staff is also gratefully acknowledged.

Noel A. Tracy
Technical Editor

Editor's Preface

The third edition of the *Nondestructive Testing Handbook* continues as the second edition did, with a volume on liquid penetrant testing. This third edition volume is indebted to the preceding edition's volume in many ways. Much of the text is the same, despite significant additions and alterations.

The technical content of this third edition volume differs in several ways from that of the second. (1) Pages have been added to cover new applications, such as filtered particle testing of aerospace composites and quality control of down hole oil field tubular assemblies. (2) A new section on probability of detection may help some facilities to evaluate their inspection procedures. (3) The introduction includes new information on method history and measurement units. (4) The text reflects the fact that materials degrading to the environment have been regulated. (5) A comprehensive glossary is provided. (6) An extensive bibliography lists liquid penetrant testing publications, more than some practitioners of the method might have expected. (7) This third edition volume pays more attention to standards documents than did the second edition; references to current standards have been added throughout.

The contributors and reviewers all brought their gifts individually to this project — collectively they made it better than a product of one person could be. Among these volunteers, the editors would like to thank William E. Mooz for the time he invested in careful reading of the entire book.

ASNT is indebted to Technical Editor Noel A. Tracy and to all the technical experts listed at the end of this foreword. (Please note that people listed as contributors were also reviewers but are listed only once, as contributors.)

It is difficult to overstate the contributions of staff members Hollis Humphries and Joy Grimm to the art, layout and text of the book. I would also like to thank Publications Manager Paul McIntire for his support throughout production.

Patrick O. Moore
Editor

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