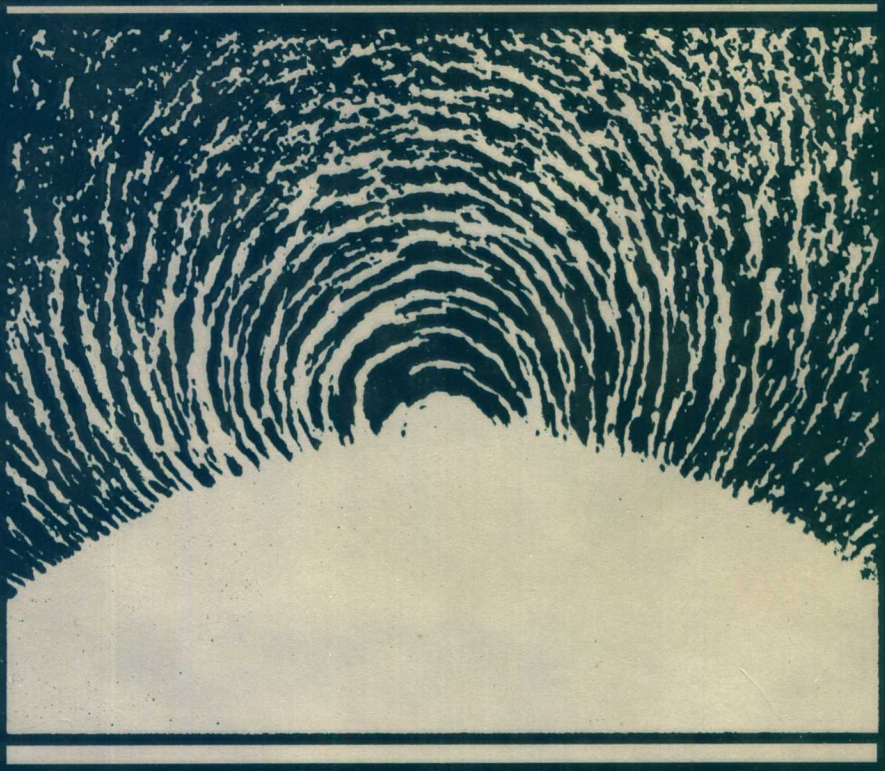
NONDESTRUCTIVE EVALUATION

A TOOL IN DESIGN, MANUFACTURING AND SERVICE

DON E. BRAY
RODERIC K. STANLEY



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Don E. Bray, Ph.D., P.E.

Department of Mechanical Engineering
Texas A & M University

Roderic K. Stanley, Ph.D.

International Pipe Inspectors Association

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ABOUT THE AUTHORS

Dr. Don E. Bray is Associate Professor of Mechanical Engineering at Texas A&M University. Dr. Bray's experience in Nondestructive Evaluation (NDE) spans over 20 years of work in industry, government, and academic teaching and research. Most recent research activities include inspection with critically refracted waves such as P, SV, and higher-order Rayleigh waves, ultrasonic angle-beam inspection in anisotropic media, and ultrasonic measurement of stress. He has authored several technical papers and reports on NDE topics and teaches undergraduate and graduate elective courses in NDE at Texas A&M University. His education includes a B.S.M.E. from Southern Methodist University, a M.S.M.E. from the University of Houston, and a Ph.D. from the University of Oklahoma. Dr. Bray is active in the NDE Engineering Dvision of the American Society of Mechanical Engineers (ASME). He has been certified at Level III in ultrasonics by ASNT examination and is a registered professional engineer in Texas and Oklahoma. In 1980, he jointly received the Achievement Award from The American Society for Nondestructive Testing (ASNT) for the outstanding publication in *Materials Evaluation*. ASNT awarded him the rank of Fellow in 1988. He has traveled in Europe, Japan, and the Soviet Union on NDE assignments.

Dr. Roderic K. Stanley is Executive Director of the International Pipe Inspectors Association. Dr. Stanley obtained his Ph.D. degree in solid state physics from Florida State University after teaching for several years in East Africa. His industrial experience includes seven years in the research group at Baker Tubular Service, where he assisted in the development of new tools for the inspection of oil field tubular products, and one year at NL McCullough, where he began development of down-hole inspection devices utilizing multifrequency

eddy-current methods. He also consults in inspection matters that utilize magnetic and electromagnetic techniques.

He has authored several papers on magnetic flux leakage inspection, and written one book on the subject for oil field inspectors. As an active member of ASNT, he chairs the Electromagnetics Committee, which currently oversees the production of Volume IV (Electromagnetic Tests) and Volume VII (Magnetic Testing) of the ASNT Handbook. Other professional societies include the Society of Petroleum Engineers and the American Physical Society.

"Magnetic testing techniques matured with inspection in the steel industry and this author seems unable to avoid it. Part III of this text is dedicated to my father, who worked all his life in the steel mills of Sheffield, England, rolling various types of plain carbon and high alloy steels with that great pride which is found in the craftsmen of his generation. Both of his sons are proud to work in the steel industry. It is my regret that he will not read this material."

RKS

PREFACE

In this book, nondestructive evaluation (NDE) topics are described in depth in order to provide sufficient technical background for the engineers and scientists who have responsibility for NDE activities. With this background, NDE inspection schemes and results may be proposed or evaluated with confidence. The primary techniques, i.e., ultrasonics, magnetics, radiography, penetrants, and eddy current are introduced from the fundamental laws of physics. Partial differential equations are used where needed to develop these fundamentals. In each part of the book, examples are given that show typical NDE applications of the physical principles. Research and future applications are also covered.

The material in this book is oriented toward fourth year undergraduate or first year graduate level engineering and science students who are familiar with calculus and engineering materials. The first part introduces the concept of Nondestructive Evaluation (NDE) and provides a review of probability, NDE in design, and NDE in manufacturing and maintenance. The probability topic is included simply to introduce some humility into the thought process. As much as we would like to design fail-free machines, we do not. As much as we would like to detect all cracks, we miss some. With the correct application of NDE, however, failures can be reduced and machinery and systems can be operated with confidence in an extended life mode. Thus, there are economic justifications for the growing interest in NDE.

There are several NDE techniques that are not discussed, e.g., thermal, acoustic emission, noise analysis, etc. Including these topics at a level of presentation equal to that given for the present material would involve considerably more time and would make the size of the book quite large. Those and other emerging NDE topics will be saved for a later volume.

Because nondestructive evaluation is a rapidly changing field, it is impossible to produce a textbook that covers the most recently released research. To stay up-to-date, the reader is directed to the most recent issues of the engineering and science journals and the regularly issued series of NDE reference books that are cited in each topical part of the text.

In the process of writing this book, it has been our pleasure to receive comments from several individuals. These comments have helped to assure that the material is more clearly presented and more oriented toward our audience. Dr. Alan Wolfenden, Dr. Sherif Noah, and Dr. Omer Jenkins of Texas A&M University and the late Merritt Goff are particularly recognized for their comments and advice. Others who gave useful comments on the material include Dr. Frank Iddings of Southwest Research Institute and Frank Malek, NDE consultant. Several individuals who have furnished material that has been used in this book have been cited in the text. Graduate students T. Leon-Salamanca and C. Salkowski have assisted with calculations and suggestions. We appreciate these contributions as well as the contributions of the following reviewers: David M. Egle, University of Oklahoma; Jerald E. Jones, Colorado School of Mines; Phillip L. Jones, Duke University; J. Bruce Nestleroth, Batelle Columbus Laboratories; Ramisamy Palanisamy, The Timken Company; and Stuart Stock, Georgia Institute of Technology.

Additional recognition goes to the students who have used the book and who offered comments that have been useful in correcting errors and improving the presentation. Further, our numerous NDE colleagues who through the years have shared thoughts and ideas on the subject and how to teach it to others should be acknowledged. And we acknowledge our families, who have tolerated the added endeavors that go along with the writing of a textbook. To all of these, we say thank you.

Don E. Bray
Roderic K. Stanley

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