PRACTICAL APPLICATIONS
OF NEUTRON RADIOGRAPHY
AND GAGING

A symposium
sponsored by the National
Bureau of Standards and
ASTM Committee E-7 on
Nondestructive Testing
AMERICAN SOCIETY FOR
TESTING AND MATERIALS
Gaithersburg, Md. 10–11 Feb. 1975

ASTM SPECIAL TECHNICAL PUBLICATION 586
Harold Berger, editor

List price $25.50
04–586000–22

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103
NOTE
The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

Printed in Baltimore, Md.
January 1976
Foreward

The Symposium on Practical Applications of Neutron Radiography and Gaging was held at the National Bureau of Standards (NBS) in Gaithersburg, Md., on 10–11 Feb. 1975. The meeting was sponsored jointly by NBS and The American Society for Testing and Materials (ASTM). ASTM Committee E-7 on Nondestructive Testing and Subcommittee E-7.05 on Neutron Radiography were the ASTM sponsors. Several other organizations assisted in arrangements for the symposium. These cooperating societies include the Air Transport Association of America, the American Nuclear Society, the American Society for Nondestructive Testing, and the Nuclear Division of the American Society for Quality Control. Harold Berger, NBS, served as chairman of the symposium, and John K. Aman, E. I. du Pont de Nemours & Company, and Daniel Polansky, Naval Surface Weapons Center, served as cochairmen.

The papers included in this volume were all presented at the symposium. Arrangements for the symposium were handled by a committee chaired by R. B. Johnson, NBS. The staff of ASTM assisted with the arrangements and also with the preparation of this special technical publication. Grateful acknowledgment for this assistance is made. Special thanks are given to Miss Jane Wheeler for her help throughout the symposium and the publication procedure.

The contributions of the session chairman at the meeting are also acknowledged. Mr. Richard L. Newacheck, Aerotest Operations; Mr. Oscar Hillig, Atomics International; Mr. Donald Garrett, Nuclear Systems, Inc.; Dr. Joseph John, IRT Corporation; Mr. J. J. Haskins, General Electric Company; and Prof. Frank A. Iddings, Louisiana State University, served as session chairmen. They kept the meeting on schedule and paved the way for the lively discussions that took place. The symposium committee is pleased to acknowledge their assistance.
Related
ASTM Publications

Monitoring Structural Integrity by Acoustic Emission, STP 571 (1975),
$23.75, 04–571000–22

Nondestructive Rapid Identification of Metals and Alloys by Spot Tests,
STP 550 (1973), $4.00, 04–550000–24

Acoustic Emission, STP 505 (1972), $22.50, 04–505000–22
A Note of Appreciation to Reviewers

This publication is made possible by the authors and, also, the unheralded efforts of the reviewers. This body of technical experts whose dedication, sacrifice of time and effort, and collective wisdom in reviewing the papers must be acknowledged. The quality level of ASTM publications is a direct function of their respected opinions. On behalf of ASTM we acknowledge with appreciation their contribution.

ASTM Committee on Publications
Editorial Staff

Jane B. Wheeler, Managing Editor
Helen M. Hoersch, Associate Editor
Charlotte E. DeFranco, Senior Assistant Editor
Ellen J. McGlinchey, Assistant Editor
Contents

Introduction

NONDESTRUCTIVE TESTING WITH NEUTRON RADIOGRAPHY AND GAGING

Neutron Radiography—An Overview—J. P. BARTON 5
Neutron Sources for Radiography and Gaging—D. C. CUTFORTH 20
Detection Systems for Neutron Radiography—HAROLD BERGER 35
Neutron Gaging Systems—G. M. REYNOLDS 58

BIOLOGICAL APPLICATIONS, TRAINING, REGULATIONS, AND STANDARDS

Applications of Neutron Radiography to Histopathology—
P. J. BOYNE AND W. L. WHITTEMORE 77
Personnel Training and Certification—W. L. WHITTEMORE 87
Regulatory Control for Neutron Radiography—G. W. KERR 93
ASTM Activities in Neutron Radiography—J. J. HASKINS 106

EXPLOSIVES AND ORDNANCE APPLICATIONS

Neutron Radiography as an “In-Line” Product Acceptance Tool—
P. L. JOHNSON 125

AEROSPACE APPLICATIONS

Neutron Radiographic Nondestructive Evaluation of Aerospace Structures—W. E. DANCE 137
Neutron Radiography to Detect Residual Core in Investment Cast Turbine Airfoils—N. B. EDENBOROUGH 152
Neutron Radiography with a Van de Graaff Accelerator for Aerospace Applications—F. R. SWANSON AND F. J. KUEHNE 158
Californium-Based Neutron Radiography for Corrosion Detection in Aircraft—JOSEPH JOHN 168

NUCLEAR APPLICATIONS

Neutron Radiography of Nuclear Fuels at the Battelle Research Reactor—K. D. KOK 183
Detecting Cladding Leaks in Irradiated Fuel Elements by Neutron Radiography—A. M. ROSS 195
Nuclear Applications of Neutron Radiography and Gaging—
J. J. HASKINS 235
# OTHER APPLICATIONS

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron Radiation in the Study of Soil and Rock—J. T. LEWIS AND E. L. KRINITZSKY</td>
<td></td>
<td>241</td>
</tr>
<tr>
<td>Miscellaneous Applications of Neutron Radiography—</td>
<td>P. E. UNDERHILL AND R. L. NEWACHECK</td>
<td>252</td>
</tr>
<tr>
<td>Testing for Moisture Content in Foods by Neutron Gaging—</td>
<td>SAMUEL HELF</td>
<td>277</td>
</tr>
<tr>
<td>Measurement of Consistency of Pulpwood-Water Slurry Based on Neutron Slowing-Down and Diffusion—</td>
<td>J. S. HEWITT AND V. M. SLOBODIAN</td>
<td>292</td>
</tr>
<tr>
<td>Miscellaneous Neutron Techniques—F. A. IDDINGS</td>
<td></td>
<td>303</td>
</tr>
</tbody>
</table>

CLOSING REMARKS

Summary 309
Index 313