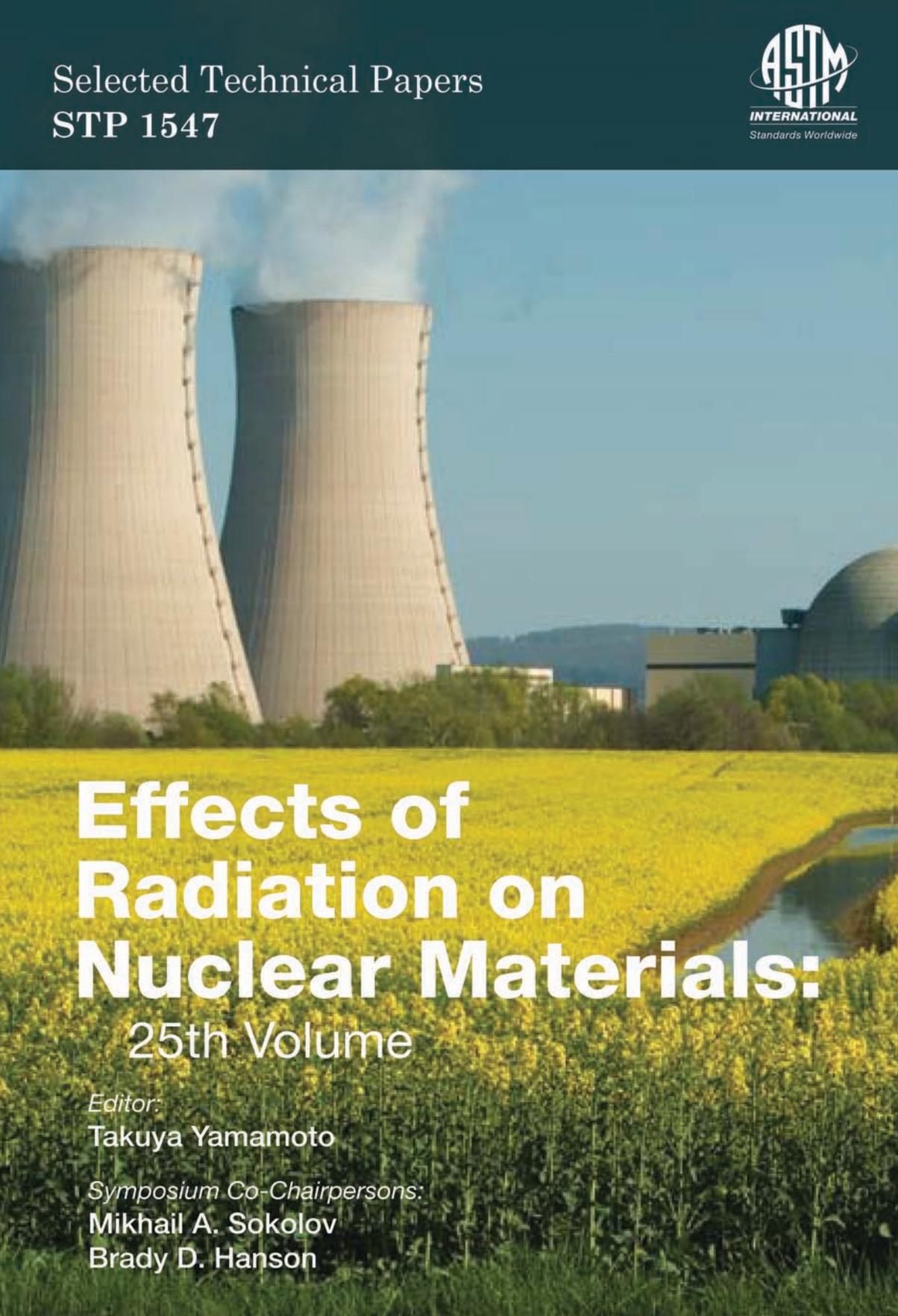


Selected Technical Papers
STP 1547

A photograph of a nuclear power plant with two large cooling towers emitting steam, set against a clear blue sky. In the foreground, there is a vibrant field of yellow flowers, possibly rapeseed, with a small stream or ditch winding through it.

Effects of Radiation on Nuclear Materials:

25th Volume

Editor:

Takuya Yamamoto

Symposium Co-Chairpersons:

Mikhail A. Sokolov

Brady D. Hanson

Selected Technical Papers STP1547 Effects of Radiation on Nuclear Materials: 25th Volume

Guest Editor:
Takuya Yamamoto



ASTM International
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19438-2959

Printed in the U.S.A.

ASTM Stock #: STP1547

Library of Congress Cataloging-in-Publication Data

ISBN: 978-0-8031-7533-4

ISSN: 1050-7515

Copyright © 2013 ASTM INTERNATIONAL, West Conshohocken, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

Photocopy Rights

Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by ASTM International provided that the appropriate fee is paid to ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9634; online: <http://www.astm.org/copyright>.

The Society is not responsible, as a body, for the statements and opinions expressed in this publication. ASTM International does not endorse any products represented in this publication.

Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM International Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of the peer reviewers. In keeping with long-standing publication practices, ASTM International maintains the anonymity of the peer reviewers. The ASTM International Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM International.

Citation of Papers

When citing papers from this publication, the appropriate citation includes the paper authors, "paper title", STP title and volume, STP number, Paper doi, ASTM International, West Conshohocken, PA, Paper, year listed in the footnote of the paper. A citation is provided as a footnote on page one of each paper.

Foreword

THIS COMPILATION OF *Selected Technical Papers, STP1547, Effects of Radiation on Nuclear Materials: 25th Volume*, contains peer-reviewed papers that were presented at a symposium held June 15–17, 2011 in Anaheim, CA, USA. The symposium was sponsored by ASTM International Committee E10 on Nuclear Technology and Applications.

The Symposium Co-Chairpersons were Takuya Yamamoto, University of California – Santa Barbara, Santa Barbara, CA, USA, Mikhail A. Sokolov, Oak Ridge National Laboratory, Oak Ridge, TN, USA, and Brady D. Hanson, Pacific Northwest National Laboratory, Richland, WA, USA. The STP Editor is Takuya Yamamoto.

Contents

Overview	vii
----------------	-----

Reactor Pressure Vessel Steels

Long Term Irradiation Phenomena in RPV Steels—The LONGLIFE Project E. Altstadt, F. Bergner, and H. Hein	3
A Wide-Range Embrittlement Trend Curve for Western Reactor Pressure Vessel Steels M. Kirk	20
Long Term Irradiation Effects on the Mechanical Properties of Reactor Pressure Vessel Steels from Two Commercial PWR Plants P. Efsing, J. Rouden, and M. Lundgren	52
Fracture Mechanics Characterisation of Forged Base Metal Ring of the Decommissioned Reactor Pressure Vessel of NPP Greifswald WWER-440 Unit 4 H.-W. Viehrig, M. Houska, E. Altstadt, and R. Kuechler	69
Microstructure Response of WWER-440 Reactor Pressure Vessel Weld Material After Irradiation and Annealing Treatment A. Zeman, A. Chernobaeva, V. Grafutin, S. Rogozhkin, L. Debarberis, A. Ballesteros, D. Erak, and A. Nikitin	85

Synergistic Effects of Helium and Displacement Damage

Approach of He/dpa Synergistic Effects in Iron-Based Materials Using JANNUS P. Trocellier, Y. Serruys, S. Miro, E. Bordas, H. Martin, L. Beck, S. Pellegrino, N. Chaâbane, S. Vaubailon, E. Meslin, A. Barbu, D. Brimbil, J. Henry, C. Robertson, B. Décamps, M. Fluss, S. Tumey, L. Hsiung, R. Schaublin, and B. K. Panigrahi	111
Modeling and TEM Investigation of Helium Bubble Growth in RAFM Steels Under Neutron Irradiation E. Gaganidze, C. Dethloff, O. J. Weiß, V. Svetukhin, M. Tikhonchev, and J. Aktaa	123
Use of MeV Ion Beams to Simulate the Irradiation Effects in Advanced Materials at JANNUS Saclay P. Trocellier, Y. Serruys, S. Miro, E. Bordas, H. Martin, L. Beck, S. Pellegrino, N. Chaâbane, S. Vaubailon, E. Meslin, A. Barbu, D. Brimbil, J. Henry, B. Décamps, M. Fluss, S. Tumey, and L. Hsiung	143

Austenitic Steels, Ni, Zr, and Al-Mg Alloys, and Polyethylene

Embrittlement of Nickel Alloys in a CANDU Reactor Environment C. D. Judge, M. Griffiths, L. Walters, M. Wright, G. A. Bickel, O. T. Woo, M. Stewart, S. R. Douglas, and F. A. Garner	161
Irradiation Testing of Zirconium Alloys and Stainless Steel in Fast Breeder Test Reactor, India S. Murugan, P. V. Kumar, J. Joseph, S. Venugopal, T. Jayakumar, and B. Raj	176

Material Investigations on Highly Irradiated Aluminum Magnesium Alloys for Lifetime Assessment of a Neutron Beam Tube in the BER II Research Reactor H. Hein, H. Schnabel, and S. Welzel	192
--	-----

(U)HMWPE as Neutron Radiation Shielding Materials: Impact of Gamma Radiation on Structure and Properties D. Wolff, K. von der Ehe, M. Jaunich, M. Böhning, and H. Goering	211
---	-----

Modeling of Radiation Effects

Atomistic Investigations of Intrinsic and Extrinsic Point Defects in bcc Uranium B. Beeler, C. Deo, M. Baskes, and M. Okuniewski	231
--	-----

Impact of Vacancy-Type Defects on Thermal Conductivity of β-SiC: Molecular Dynamics Versus an Analytical Approach G. D. Samolyuk, S. I. Golubov, Y. N. Osetsky, and R. E. Stoller	248
--	-----

A Phenomenological Micromechanical Model of FCC Metals under Radiation Induced Crystal Defects Y. Aoyagi, T. Tsuru, and Y. Kaji	269
---	-----

Development of Models for Irradiation-induced Changes to Microstructure and Stress–Strain Relations of Austenitic Steels S. Jitsukawa, Y. Abe, K. Suzuki, and N. Okubo	288
--	-----

Cluster Dynamics Simulation on Microstructure Evolution of Austenitic Stainless Steel and α-Iron Under Cascade Damage Condition Y. Abe, S. Jitsukawa, N. Okubo, H. Matsui, and T. Tsukada	313
---	-----

Dislocation Bias Calculations in Metals Using a Combined Finite-Element Rate-Theory Approach D. Seif and N. M. Ghoniem	338
--	-----

Author Index	351
-------------------------------	-----

Subject Index	353
--------------------------------	-----

Overview

The Effects of Radiation on Materials series began in 1956 with a meeting jointly sponsored by the E-10 Committee (called the Committee on Radioisotopes and Radiation Effects at the time) and the Atomic Industrial Forum. The symposium, subsequently sponsored by Committee E-10, began in 1960 and became international in 1963. The current 25th meeting continued an international emphasis, with nearly half of presentations originated outside of the United States involving lead authors from 11 countries.

The 25th Symposium on the Effects of Radiation on Nuclear Materials hosted two special sessions. The first, *Light Water Reactor Sustainability Issues and Programs*, focused on the current status of research around the world addressing the multiple challenges of extended reactor life. This session set the stage for others that provided more detailed coverage of irradiation embrittlement of reactor pressure vessel steels, which has traditionally been a core topic of this symposium. Indeed, the STP *Effects of Radiation on Nuclear Materials* series has long served as the primary archive for the evolving knowledge base on this critically important degradation phenomenon.

The second special session dealt with *The Synergistic Effects of Gas Atoms (i.e. helium and hydrogen) and Displacement Damage*, with an emphasis on the unprecedented challenge to structural and plasma-facing materials in nuclear fusion reactors. This session covered state-of-the art experimental approaches, based on dual and triple ion beam irradiation facilities and use of thermal neutron (n , α) reactions in fission reactors, to producing high levels of He and dpa. The session also included recent insight on the severe consequences He-dpa synergisms in conventional alloys, and the status of developing advance alloys that shows great promise of mitigating He enhanced degradation.

The technical program continued to the symposiums tradition of covering a broad spectrum of nuclear applications. This research involves both experiments and state-of-the art modeling tools. The editor wishes to express his gratitude to all the reviewers, without whom the quality of the publication would not be possible, and to the ASTM staff, who played key roles in publication of these proceedings. Most importantly, the editor would like to thank all the Symposium participants for presenting and authoring high quality papers as well as for facilitating many fruitful discussions.

Takuya Yamamoto
University of California
Santa Barbara



www.astm.org

ISBN: 978-0-8031-7533-4

Stock #: STP1547