

RADIATION EMBRITTLEMENT

*of Nuclear
Reactor Pressure
Vessel Steels*

AN INTERNATIONAL REVIEW

Third Volume

Lendell E. Steele,
editor

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Steels: An International Review
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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 these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

Foreword

This publication, *Radiation Embrittlement of Nuclear Reactor Pressure Vessel Steels: An International Review (Third Volume)*, contains papers presented at the symposium on Irradiation Embrittlement and Aging of Reactor Pressure Vessels, which was held 27–29 May 1987 in Philadelphia, PA. The symposium was sponsored by Committee E-10 on Nuclear Technology and Applications and by the International Atomic Energy Agency. Lendell E. Steele of Springfield, Virginia was the symposium chairman and editor of this publication.

Introduction

A critical issue in assuring the safety of nuclear power plants involves the integrity of the primary pressure vessel of light water reactors, which are the nuclear source of choice in most nations. Such integrity depends upon no serious degradation of the steel in the pressure vessel, which, in turn, depends upon the knowledge of neutron irradiation embrittlement and the means for minimizing such degradation of this key component. While research and operational surveillance of this phenomenon have been carried out for many years, it is essential that such efforts not stop until we have full assurance on an international basis that knowledge is adequate to provide the technical basis for preventing catastrophic vessel rupture. Further, in view of the Chernobyl accident, international collaboration in developing such knowledge should be condoned by all nations having or developing nuclear power.

This volume contains the record of the third in a series of conferences on this subject (these conferences convene every three years). The principal sponsors are the International Atomic Energy Agency's (IAEA) Working Group on Reliability of Reactor Pressure Components and ASTM Committee E-10 on Nuclear Technology and Applications. The conference was convened as a meeting of specialists with invitees from major nuclear power producing or developing nuclear power countries. The attendance thus was somewhat limited with the hope of encouraging general participation. The records of the two prior meetings in this series, held in Vienna in 1981 and 1984, were provided in two ASTM Special Technical Publications: *Radiation Embrittlement and Surveillance of Nuclear Reactor Pressure Vessels: An International Study*, ASTM STP 819, and *Radiation Embrittlement of Nuclear Reactor Pressure Vessel Steels: An International Review (Second Volume)*, ASTM STP 909.

While informal discussion is encouraged at these meetings, no detailed record is provided; however, the summary to this volume has recorded matters of future interest as well as projected technical needs. This latest volume records the four sessions, which respectively dealt with: (1) research developments in participating nations, in this case the Federal Republic of Germany, Switzerland, the United Kingdom, and the United States; (2) the results of ongoing surveillance program results from operating plants; (3) related research to support our knowledge base of vessel integrity assurance in spite of irradiation embrittlement; and (4) fundamental research to provide knowledge of the basic causes of radiation damage and means for minimizing or mitigating such damage.

The principal benefits of this volume arise from revelations of new information on operating and design modifications and annealing procedures for mitigating observed embrittlement before serious levels of vessel embrittlement occur. These technological bases have been highlighted by rising concerns for catastrophic plant failures with the release of radioactive elements from the reactor core and by the responses of national research programs toward technological solutions based on fundamental and statistical knowledge of possible consequences of neutron exposure as well as national regulatory research efforts and rules for operation, which are also highlighted in this conference. The phenomenon of neutron irradiation embrittlement was highlighted with a complementary recitation of our knowl-

edge of (a) the mechanics of steel fracture, (b) the regulatory or operational rules for the control of stresses at critical points along with (c) mitigating steps such as thermal annealing to correct embrittlement, and (d) fuel core management to reduce (minimize) neutron exposure at crucial locations on the vessel's wall. These interconnected and complementary topics discussed in a setting of concerned specialists help to produce a volume having value for all those, both technical and managerial, who must make decisions regarding nuclear power plant operations. This especially applies with regard to the matter of the degree and potential consequence of continuing degradation of the steels making up the first line of containment of the powerful core of nuclear power plants and the crucial control of cooling water flow over this core. Thus, all aspects of this conference contribute to the safe and efficient use of nuclear power for peaceful purposes and integrate this knowledge from many nations in one place.

Special recognition is due the knowledgeable and articulate authors and discussors, who provide a most valuable forum on critical topics of continuing concern. Others deserving of gratitude for their assistance are V. Lysckof, Scientific Secretary of the sponsoring IAEA Working Group, and C. Pugh, U.S. representative to this conference.

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