IRCONIUM in the NUCLEAR NDUSTRY

Eleventh International Symposium

E. ROSS BRADLEY
GEORGE P. SABOL

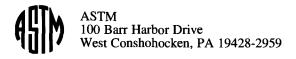
Editors



Zirconium in the Nuclear Industry: Eleventh International Symposium

E. Ross Bradley and George P. Sabol, editors

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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 to time and effort on behalf of ASTM.

Foreword

The Eleventh International Symposium on Zirconium in the Nuclear Industry was held in Garmisch-Partenkirchen, Germany on 11–14 Sept. 1995. The sponsor of the event was ASTM Committee B-10 on Reactive and Refractory Metals and Alloys.

The symposium chairman was E. Ross Bradley, Sandvik Special Metals Corporation, the symposium co-chairman was Erich Tenckhoff, Siemens AG, and the editorial chairman was George P. Sabol, Westinghouse Electric Corporation. Serving as editors of this publication were E. Ross Bradley and George P. Sabol.

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Overview

From its inaugural meeting in Philadelphia in 1968, the ASTM Symposium on Zirconium in the Nuclear Industry has been the premiere vehicle for discussion and documentation of the scientific and technological bases for the utilization of zirconium-based alloys in water-cooled reactors. The eleventh conference in this symposium series, held in September 1995 in Garmisch-Partenkirchen, Germany, continued this tradition of excellence. Attendees to this conference numbered 209, representing 16 countries. After careful peer review and editing, forty-one technical papers presented at this conference are published in this book. The highlights of the oral discussions have also been captured and appear at the end of each paper. This publication also includes two papers that are significant contributions to zirconium technology which served as the basis for the authors receiving the W. J. Kroll awards for 1993 and 1994. In Garmisch-Partenkirchen the awards for these years were presented to J. A. L. Robertson and to the team comprised of Friedrich Garzarolli, Heinz Stehle, and Eckard Steinberg, respectively. These Kroll Award papers represent historical as well as technical significance for the use of zirconium alloys in the nuclear industry.

Since their development in the 1950s and introduction into commercial nuclear power plants in the 1960s, the zirconium-based alloys Zircaloy-2 and -4, Zr-1Nb, and Zr-2.5Nb are the alloys currently used in the world's reactors. However, with increasing fuel duty, the margins displayed by these alloys have eroded, and considerable research has been conducted to improve these materials and also to develop more advanced alloys. Optimization of alloying constituents and processing parameters, coupled with a more basic understanding of performance-limiting phenomena, are the primary themes of most of the papers contained herein. Fully half of the papers are directly concerned with the corrosion of Zr-based alloys, and several trends are developing, which include: (1) uniform corrosion resistance is favored when oxide grains are columnar, rather than equiaxed in shape; (2) lithium-accelerated corrosion of Zircaloys corresponds to the formation of equiaxed grains in the oxide in preference to the usually occurring columnar grains; (3) in-reactor acceleration of corrosion observed in PWRs may be partially due to a lithium enhancement even at the low lithium concentrations used in PWRs, and (4) an effect due to hydrogen pickup and accumulation at the metal oxide interface may provide a significant contribution to the in-reactor acceleration of corrosion.

The detailed characterization of the effects of irradiation on the microstructure of irradiated Zircaloys has confirmed the loss of iron from second phase particles, with or without amorphization of the particles. Also, the correspondence between iron in solution in the matrix, the formation of $\langle c \rangle$ -type dislocations, and the onset of accelerated irradiation induced growth has been verified. Unfortunately, the role of dissolved iron in the matrix in the nucleation of $\langle c \rangle$ -type dislocations has not been established. One observation that has been verified, however, is the low irradiation growth in Zr-Nb-Sn-Fe alloys, also presumably due to suppression of $\langle c \rangle$ dislocation formation.

Several papers in the symposium focused on fuel clad modeling, and although a schism still exists between fundamental material properties and fuel performance predictive codes, the modeling papers presented are attempts to link component response to the quantifiable material behavior in a manner consistent with qualitative structural observations.

In summary, the data, analyses, hypotheses, and theories presented in this book represent the current state of zirconium technology as applied to nuclear power reactors. These contributions add strength to the foundation of our knowledge in this important and challenging technology.

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