

INDUSTRIAL APPLICATIONS OF TITANIUM AND ZIRCONIUM

E.W. Kleefisch, *editor*

 **STP 728**

AMERICAN SOCIETY FOR
TESTING AND MATERIALS

INDUSTRIAL APPLICATIONS OF TITANIUM AND ZIRCONIUM

A symposium
sponsored by ASTM
Committee B-10 on
Reactive and Refractory
Metals and Alloys
AMERICAN SOCIETY FOR
TESTING AND MATERIALS
New Orleans, La., 15-17 Oct. 1979

ASTM SPECIAL TECHNICAL PUBLICATION 728
E. W. Kleefisch, Nooter Corporation, editor

ASTM Publication Code Number (PCN)
04-728000-05



AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

Copyright © by AMERICAN SOCIETY FOR TESTING AND MATERIALS 1981
Library of Congress Catalog Card Number: 80-69065

NOTE

**The Society is not responsible, as a body,
for the statements and opinions
advanced in this publication.**

Printed in Baltimore, Md.
March 1981

Foreword

The symposium on Industrial Applications of Titanium and Zirconium was held on 15-17 Oct. 1979, in New Orleans, La. The American Society for Testing and Materials, through its Committee B-10 on Reactive and Refractory Metals and Alloys, sponsored the meeting. Presiding as chairman was R. E. Smallwood, E. I. du Pont de Nemours & Co., Inc., assisted by cochairman R. T. Webster, Teledyne Wah Chang Albany Co. E. W. Kleefisch, Nooter Corporation, served as editor of this publication.

Related ASTM Publications

**Zirconium in the Nuclear Industry: Third Conference, STP 633 (1977),
\$55.50, 04-633000-35**

**Zirconium in the Nuclear Industry: Fourth Conference, STP 681 (1979),
\$52.50, 04-681000-35**

Manual on Zirconium and Hafnium, STP 639 (1977), \$9.50, 04-639000-35

Zirconium in Nuclear Applications, STP 551 (1974), \$44.50, 04-551000-35

**Toughness and Fracture Behavior of Titanium, STP 651 (1978), \$28.50, 04-
651000-30**

**Unified Numbering System for Metals and Alloys and Cross Index of Chemi-
cally Similar Specifications, DS 56A (1977), \$49.00, 05-056001-01**

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*
Helen P. Mahy, *Senior Assistant Editor*
Allan S. Kleinberg, *Assistant Editor*

Contents

Introduction	1
Use of Titanium and Zirconium in Chemical Environments— R. D. KANE AND W. K. BOYD	3
Appropriate Use of Titanium in Process and Process Equipment Design—C. E. HULSWITT	9
Tube Sheet Alternatives for Reactive Metal Tubed Heat Ex- changers—J. D. THOMAS	16
Explosion Bonding of Titanium and Zirconium—W. E. MANCINI	27
Titanium for Mechanical Equipment in Industrial Corrosion Ser- vice—J. A. McMASTER	34
Fatigue Properties of Commercially Pure Titanium—T. L. WARDLAW AND J. A. HALL	45
Guidelines for Corrosion Testing of Titanium—R. W. SCHUTZ AND L. C. COVINGTON	59
Application of Surface Air Oxidizing to Prevent Hydrogen Embrittle- ment of Titanium in the Chemical Plant—TOSHIO FUKUZUKA, KAZUTOSHI SHIMOGORI, HIROSHI SATOH, FUMIO KAMIKUBO, AND HIROAKI HIROSE	71
Improving the Corrosion Resistance of Zirconium Weldments— B. S. FRECHEM, J. G. MORRISON, AND R. T. WEBSTER	85
Effects of Metal Chemistry on Behavior of Titanium in Industrial Applications—A. L. FORREST	109
Use of Zirconium Heat Exchangers in the Viscose Rayon Process— L. B. BOWEN	119
Titanium Use in the Pulp Industry—S. R. SEAGLE	126

Corrosion Characteristics of Titanium and Stainless Steel in Solutions Containing Nitric Acid, Citric Acid, and Magnesium Chloride—PETER CIRISCIOLI, J. M. YORK, AND G. J. DOOLEY III	138
Corrosion of Titanium and Zirconium Alloys in Zinc Chloride Solutions—R. E. SMALLWOOD	147
Effects of Iron on the Corrosion Resistance of Titanium—L. C. COVINGTON AND R. W. SCHUTZ	163
Applications of Zirconium in Sulfuric Acid—J. H. SCHEMEL	181
Corrosion Resistance of Zirconium and Zirconium Alloys in Inorganic Acids and Alkalies—D. R. KNITTEL AND R. T. WEBSTER	191
Summary	204
Index	207

