



Industrial Applications of Titanium and Zirconium: 4th Volume

Young / Durham *editors*

ASTM STP 917

INDUSTRIAL APPLICATIONS OF TITANIUM AND ZIRCONIUM: FOURTH VOLUME

A symposium sponsored by ASTM
Committee B-10 on Reactive
and Refractory Metals and Alloys
Philadelphia, PA, 10-11 Oct. 1984

ASTM SPECIAL PUBLICATION 917
Charles S. Young, Astro Metallurgical,
and John C. Durham, Timet, editors

ASTM Publication Code Number (PCN)
04-917000-05



1916 Race Street, Philadelphia, PA 19103

Library of Congress Cataloging-in-Publication Data

Industrial applications of titanium and zirconium.

(ASTM special technical publication; 917)

"Papers . . . presented during the Fourth Symposium on Titanium and Zirconium in Industrial Applications"—

"ASTM Publication code number (PCN) 04-899000-08

Includes bibliographies and index.

1. Titanium—Congresses. 2. Zirconium—Congresses.

I. Young, C. S. II. Durham, John C. III. ASTM Committee B-10 on Reactive and Refractory Metals and Alloys. IV. Symposium on Titanium and Zirconium in Industrial Applications (4th: 1984: Philadelphia, PA) V. Series

TA480.T54I514 1986 620.1'89322 86-14162

ISBN 0-8031-0484-7

Copyright © by AMERICAN SOCIETY FOR TESTING AND MATERIALS 1986
Library of Congress Catalog Card Number: 86-14162

NOTE

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

Foreword

The Fourth ASTM Symposium on Titanium and Zirconium in Industrial Applications was presented at Philadelphia, PA, 10-11 Oct. 1984. Charles S. Young, Astro Metallurgical, and John C. Durham, Timet, served as chairman of the symposium and are editors of the resulting publication.

Related ASTM Publications

**Industrial Applications of Titanium and Zirconium: Third Conference,
STP 830 (1984), 04-830000-05**

**Industrial Applications of Titanium and Zirconium STP 728 (1981),
04-728000-05**

**Applications Related Phenomena in Titanium Alloys, STP 432 (1968),
04-432000-05**

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

ASTM Editorial Staff

**Susan L. Gebremedhin
Janet R. Schroeder
Kathleen A. Greene
William T. Benzing**

Contents

Overview	ix
-----------------	----

APPLICATIONS OF TITANIUM

Titanium as Anode (and Cathode) Substrate Material for Industrial Electrolytic Applications—M. Y. C. WOO	3
The Application of Titanium and Its Alloys in Alkali Chloride and Refined Salt Industries—LI ZUOCHEN, WU QINGZHI, SHI XIAMEI, AND LI KAIBING	7
Use of Titanium for Treatment of Toxic and Hazardous Wastes—THOMAS P. OETTINGER, MARK C. HOFFMAN, AND MARS G. FONTANA	14
Discussion	29
Titanium for Flue Gas Desulfurization (FGD) Systems: Testing and Evaluation—CHARLES S. YOUNG, RONALD W. SCHUTZ, AND JAMES S. GRAUMAN	30
Ti-3Al-2.5V for Seawater Piping Applications—IVAN L. CAPLAN	43
Discussion	54

APPLICATIONS OF ZIRCONIUM AND OTHER REACTIVE METALS

Zirconium for Nitric Acid Solutions—TE-LIN YAU	57
The Use of Zirconium in Nitric Environment Corrosion Studies—MICHEL LEDUC, ALAIN LE DUIGOU, AND MAURICE PELRAS	69

Zirconium-Steel Bimetallic Tubing for Improved Sour Gas Corrosion Resistance in Oil and Gas Wells—CHUN T. WANG AND ROY HARDWICK	85
Discussion	97
Application and Process Metallurgical Aspects of Niobium, Tantalum, and Hafnium—TRIKKUR S. KRISHNAN AND CHIRANJIB K. GUPTA	99

TECHNOLOGY OF TITANIUM AND ZIRCONIUM

Required Reliability of Reactive Metal Mill Products and Process Equipment—ROBERT E. SMALLWOOD	115
Fundamental Corrosion Characterization of High-Strength Titanium Alloys—RONALD W. SCHUTZ AND JAMES S. GRAUMAN	130
Discussion	142
Beta-C: An Emerging Titanium Alloy for the Industrial Marketplace—DAVID E. THOMAS, S. ANKEM, WESLEY D. GOODIN, AND STANLEY R. SEAGLE	144
Discussion	162
Zirconium Fabrication and Junction Between Zirconium or Titanium and Stainless Steel—JACQUES DECOURS AND ROBERT DEMAY	164
Status of Titanium Net-Shape Technology—RUSSELL G. VOGT, DANIEL EYLON, AND FRANCIS H. FROES	194
Index	209

Overview

The papers contained in this publication were presented during the Fourth Symposium on Titanium and Zirconium in Industrial Applications in Philadelphia, PA, on 10–11 Oct., 1984. The symposium was sponsored by ASTM Committee B-10 on Reactive and Refractory Metals and Alloys in an effort to extend the understanding of the reactive metals and foster a technical interaction among potential users and suppliers.

The use of these metals in industrial applications, primarily related to their excellent corrosion resistance to a variety of environments, has expanded tremendously in the last 15 years. Titanium fabrications—heat exchangers, pressure vessels, piping systems, and electrolytic cell components are commonly found in chemical, petrochemical, and utility plants. Zirconium equipment is also found in a wide range of applications that make use of its corrosion resistance. In addition to the now standard applications that have been developed, titanium and zirconium are also considered to be excellent candidates for new applications requiring their enhanced corrosion resistance. Because some of these may also require enhanced mechanical or physical properties, new alloys are being developed or new fabrication techniques designed to further extend the use of the reactive metals.

Both traditional uses (nitric acid, seawater, or chlor-alkali) and new applications (electrolytic cells) are discussed in this publication in terms of the technical reasons for using one of the reactive metals. The use of titanium in equipment designed to prevent pollution is discussed in papers on toxic waste treatment and utility flue gas desulfurization systems. New technology, involving fabrication techniques for both titanium and zirconium, is discussed as well as the physical and mechanical properties of recently developed titanium alloys. In addition, the reliability of titanium and zirconium equipment used in the petrochemical industry is reviewed, and general guidelines to ensure excellent service life are given. Also, the applications and technical requirements of other reactive and refractory metals, niobium, tantalum, and hafnium are discussed.

Charles S. Young

Astro Metallurgical, Wooster, OH 44691;
symposium chairman and coeditor.

John C. Durham

Timet, Irvine, CA 92713; symposium co-
chairman and coeditor.

ISBN 0-8031-0484-7