

HYDROGEN EMBRITTLEMENT:

Prevention and Control

Louis Raymond, *editor*



STP 962

STP 962

Hydrogen Embrittlement: Prevention and Control

Louis Raymond, editor



ASTM
1916 Race Street
Philadelphia, PA 19103

Library of Congress Cataloging-in-Publication Data

Hydrogen embrittlement: prevention and control/[edited by] Louis Raymond.

(ASTM special technical publication; 962)

Papers from the Second National Symposium on Test Methods for Hydrogen Embrittlement: Prevention and Control, sponsored by ASTM Subcommittee F7.4 on Hydrogen Embrittlement and held in Los Angeles, May 24-26, 1985.

Includes bibliographies and index.

"ASTM publication code number (PCN) 04-962000-26."

ISBN 0-8031-0959-8

1. Metals—Hydrogen embrittlement—Congresses. 2. Metals—Testing—Congresses. I. Raymond, Louis, 1934–. II. National Symposium on Test Methods for Hydrogen Embrittlement: Prevention and Control (2nd: 1985: Los Angeles) III. ASTM Subcommittee F7.4 on Hydrogen Embrittlement. IV. Series.

TA460.H89 1988

620.1'623—dc19

88-3490
CIP

Copyright © by AMERICAN SOCIETY FOR TESTING AND MATERIALS 1988

NOTE

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

Peer Review Policy

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM 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 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, *Hydrogen Embrittlement: Prevention and Control*, contains papers presented at the Second National Symposium on Test Methods for Hydrogen Embrittlement: Prevention and Control, which was held in Los Angeles 24–26 May 1985. The symposium was sponsored by ASTM Subcommittee F7.4 on Hydrogen Embrittlement. Louis Raymond, Ph.D., L. Raymond & Associates, presided as symposium chairman and was editor of this publication.

Contents

Introduction—L. RAYMOND	1
 SECTION 1: OVERVIEW	
Opening Remarks—C. SONNINO	7
Overview: Sections 1 and 2—A. A. ANCTIL	8
Hydrogen Embrittlement Test Methods: Current Status and Projections—L. RAYMOND	10
Electrochemical Aspects of Hydrogen in Metals—J. J. DELUCCIA	17
 SECTION 2: CURRENT STANDARDS AND PROJECTIONS	
Hydrogen Embrittlement Coverage by U.S. Government Standardization Documents—E. T. CLEGG	37
Other ASTM Committees and ISO Committees Involved in Hydrogen Embrittlement Test Methods—A. W. GROBIN, JR.	46
Specifications for Hydrogen Control Testing of Materials—D. J. COATES	55
Accelerated Acceptance Testing for Hydrogen Embrittlement Control—R. V. DREHER	60
Assessment of the Degree of Hydrogen Embrittlement Produced in High-Strength 4340 Steel by Plating-and-Baking Processes Using Slow Strain Rate Testing—W. J. POLLOCK	68
Panel Discussion: Sections 1 and 2	81
 SECTION 3: HYDROGEN IN STEEL AND TITANIUM	
Opening Remarks—R. FRICIONI	89
Electrochemical Sensor for the Determination of Hydrogen in Metals by Potential Measurements—A. MACKOR, C. W. DE KREUK, AND J. SCHOONMAN	90
The Barnacle Electrode Method to Determine Diffusible Hydrogen in Steels—D. A. BERMAN AND V. S. AGARWALA	98
The Development of an In-Situ Sensor for Measuring the Hydrogen Content of Liquid Iron—T. OHTSUBO, H. KAWASE, AND S. YAMAZAKI	105

A Study of the Effect of Voids on Hydrogen Diffusion Through Electroslag Refined Steel—M. WANG AND P. G. SHEWMON	117
Panel Discussion: Section 3	125
Summary: Section 3—R. FRICIONI	128
 SECTION 4: RELATIVE SUSCEPTIBILITY	
Overview: Section 4—D. R. MCINTYRE	133
Sensitivity of Steels to Degradation in Gaseous Hydrogen—H. J. CIALONE AND J. H. HOLBROOK	134
Discussion	151
The Present Status of the Disk Pressure Test for Hydrogen Embrittlement—J.-P. FIDELLE	153
Discussion	171
Screening Tests for Hydrogen Stress Cracking Susceptibility—W. R. CRUMLY	173
Ranking Materials for Extreme Sour Gas Service Using the Slow Strain Rate Method—D. R. MCINTYRE	178
A Bent Beam Test Method for Hydrogen Sulfide Stress Corrosion Cracking Resistance—D. O. COX	190
Discussion	198
Selection of Petroleum Industry Materials Through Use of Environmental Cracking Tests—S. W. CIARALDI	200
Discussion	212
 SECTION 5: HYDROGEN IN WELDING	
Overview: Section 5—J. BLACKBURN	217
In Situ Measurement of Hydrogen in Weld Heat Affected Zones Thru Mass Spectrometry and Computer Analysis—G. M. PRESSOUYRE, V. LEMOINE, D. J. M. DUBOIS, J.-B. LEBLOND, P. R. SAILLARD, AND F. M. FAURE	219
Testing of Welding Electrodes for Diffusible Hydrogen and Coating Moisture—T. A. SIEWERT	238
Diffusible Hydrogen Testing by Gas Chromatography—M. A. QUINTANA AND J. R. DANNECKER	247
Panel Discussion: Gas Chromatography	269
The Effect of Weld Metal Diffusible Hydrogen on the Cracking Susceptibility of HY-80 Steel—R. J. WONG	274

In-Process Prediction of the Diffusible Hydrogen Content of Gas-Metal Arc—D. R. WHITE AND W. G. CHIONIS	287
Panel Discussion: Diffusible Hydrogen	299
 SECTION 6: PREVENTION AND CONTROL: CASE HISTORIES	
Overview: Section 6—W. FIELD	303
Prevention of Hydrogen Embrittlement by Surface Films—G. T. MURRAY	304
Discussion	316
Hydrogen Embrittlement and Relief Treatment Study of Zinc Phosphate-Coated Submunitions—G. P. VOORHIS	318
Discussion	334
Examination of Cadmium-Plated Aircraft Fasteners for Hydrogen Embrittlement—M. LEVY AND G. A. BRUGGEMAN	335
Discussion	341
Proof Test Logic for Hydrogen Embrittlement Control—W. E. KRAMS	343
Discussion	349
 SECTION 7: RESEARCH IN PROGRESS	
Quantitative Analysis of Critical Concentrations for Hydrogen-Induced Cracking—G. M. PRESSOUYRE AND F. M. FAURE	353
Assessment of the Degree of Hydrogen Embrittlement Produced in Plated High-Strength 4340 Steel by Paint Strippers Using Slow Strain Rate Testing—W. J. POLLOCK AND C. GREY	372
The Hydrogen Embrittlement Susceptibility of Ferrous Alloys: The Influence of Strain on Hydrogen Entry and Transport—J. R. SCULLY AND P. J. MORAN	387
Hydrogen Transport, Microstructure, and Hydrogen-Induced Cracking in Austenitic Stainless Steels—T. PERNG AND C. ALTSTETTER	403
Temperature Dependence of Fatigue Crack Propagation in Niobium-Hydrogen Alloys—N. POLVANICH AND K. SALAMA	417
Index	429



Lou Raymond
P.O. Box 7925
Newport Beach, CA 92658-7925