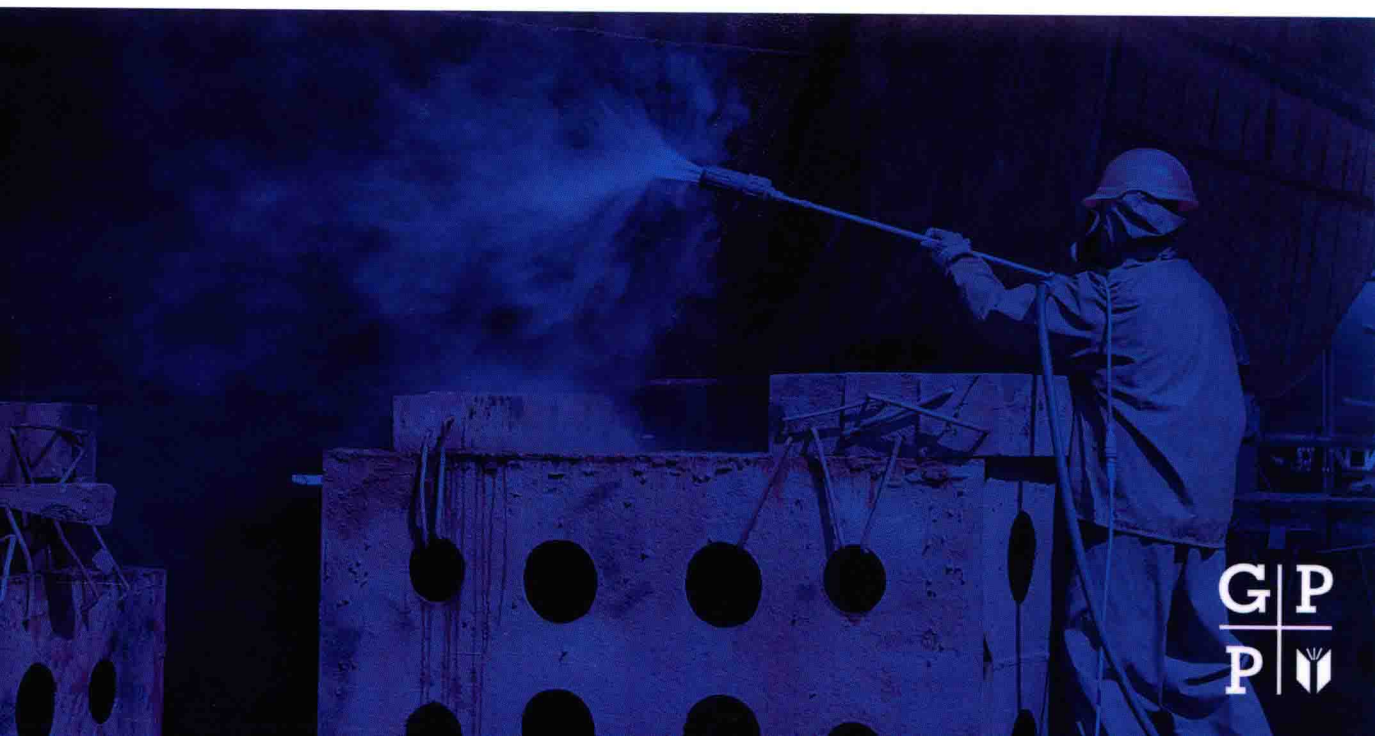




Essentials of Coating, Painting, and Lining for the Oil, Gas, and Petrochemical Industries

Alireza Bahadori, Ph.D.



Essentials of Coating, Painting, and Lining for the Oil, Gas, and Petrochemical Industries

Alireza Bahadori, Ph.D.

School of Environment, Science, and Engineering
Southern Cross University, Lismore, NSW, Australia



AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Gulf Professional Publishing is an Imprint of Elsevier



Gulf Professional Publishing is an imprint of Elsevier
225 Wyman Street, Waltham, MA 02451, USA
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK

Copyright © 2015 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

For information on all Gulf Professional Publishing
visit our website at <http://store.elsevier.com/>

This book has been manufactured using Print On Demand technology. Each copy is produced to order and is limited to black ink. The online version of this book will show color figures where appropriate.

ISBN: 978-0-12-801407-3



Working together
to grow libraries in
developing countries

www.elsevier.com • www.bookaid.org

*Dedicated to the loving memory of my parents, grandparents,
and everyone who contributed so much to my work over the years*

About the Author

Alireza Bahadori, Ph.D., is a member of the research staff of the School of Environment, Science, and Engineering at Southern Cross University in Lismore, NSW, Australia. He received his Ph.D. from Curtin University in Perth, Western Australia. During the past 20 years, Dr. Bahadori has held many process and petroleum engineering positions and was involved in several large-scale projects at the National Iranian Oil Co. (NIOC), Petroleum Development Oman (PDO), and Clough AMEC.

He is the author of about 250 articles and 12 books. His books have been published by many major publishers, including Elsevier.

Dr. Bahadori is the recipient of the highly competitive and prestigious Australian government's endeavour international postgraduate research award for his research in the oil and gas areas. He also received a Top-up Award from the State Government of Western Australia through the Western Australia Energy Research Alliance (WA:ERA) in 2009. Dr. Bahadori serves as an editorial board member and reviewer for a large number of journals.

Preface

The surface preparation process not only cleans steel, but also introduces a suitable profile for applying protective coating. The main task of such coating is to prevent or control the external corrosion of buried or submerged steel structures. The coating isolates metal from contact with the surrounding environment.

Since a perfect coating cannot be assured, cathodic protection is used in conjunction with the coating system to provide the first line of defense against corrosion. And since a properly selected and applied coating should provide 99% of the needed protection, it is of utmost importance to know the advantages and disadvantages of available coatings. The right coating material, properly used, will make all other aspects of corrosion control relatively easy. The number of coating systems available requires careful analysis of the many desired properties for an effective pipe coating.

Therefore, the optimum selection and proper application of protective coatings are vital to successful engineering. During extended periods of time, protective coatings deteriorate as a result of contact with moisture, oxygen, chemicals, fluctuating temperatures, abrasion, pressure, and many other factors. Therefore, proper and timely maintenance is required to get the optimum performance from a protective coating.

Meanwhile, selection and application of maintenance coating is more complicated than for initial construction. Climatic conditions, chemical exposure, available time, budget, health and safety, and grade of surface preparation have a significant influence on the planning of optimum design coating. To select the best coating system to fit the environment or oil condition, knowledge of operating and installation conditions is essential. The steel source and job location may limit the coatings available for each project. The choice of a high-quality applicator is the most important (but alas, also most neglected) consideration. Following coating and applicator selection, inspection at the coating, especially on the job site during construction, will go far in ensuring that a high-quality pipe coating system has been installed.

This engineering book covers the minimum requirements for the design and selection of coating systems for the external protection of pipes, storage tanks, and piling systems that will be buried or submerged in water. The contents define the essential elements of surface preparation, selection of coating systems, and repair of coating defects. It is intended to focus on corrosion protection of steel structures of the oil and gas and petrochemical industries, including refineries, chemical and petrochemical plants, gas plants, and oil exploration and production units.

This book covers the minimum requirements for the linings that will be used in various types of equipment (e.g., vessels, storage tanks, and pipelines). It is intended for use in refineries, petrochemical plants, oil and gas plants, and, where applicable, in exploration, production, and new ventures.

Several nonmetallic lining systems are discussed. They are classified into the following main groups:

- Thermoplastic materials
- Thermosetting materials
- Rubbers
- Mineral and bitumen materials

This book gives the essential details about the initial construction and maintenance painting of metal surfaces. It also describes the minimum requirements for the surface preparation and painting of piping, plant, equipment, storage tank, building, and other elements that will be exposed to different corrosive environments. Painting schedules, paint systems, and paint color schedules are included in this respect.

Alireza Bahadori

School of Environment, Science, and Engineering
Southern Cross University, Lismore, NSW, Australia

1 November 2014

Acknowledgments

I would like to thank the Elsevier editorial and production teams, Katie Hammon and Kattie Washington of Gulf Professional Publishing for their editorial assistance.

Contents

About the Author.....	xlvi
Preface.....	xlvi
Acknowledgments.....	xlix

CHAPTER 1 Surface Preparation for Coating, Painting, and Lining.....	1
1.1 Introduction	1
1.2 Selection of Cleaning Method.....	2
1.2.1 Initial Condition of Surface (Rust Grade)	2
1.2.2 New Construction (Uncoated Surfaces)	2
1.2.3 Maintenance (Coated Surface).....	2
1.3 Cleanliness of the Surfaces.....	2
1.3.1 Removal of Contaminants/Coats of Materials Other Than Metal	2
1.3.2 Removal of Coated Material Related to the Metal (Scale and Rust).....	3
1.3.3 Standard Level of Cleanliness	4
1.3.4 Rust Converters, Rust Stabilizers, and Penetrating Agents	9
1.3.5 Influence of Environmental Conditions on the Cleaning and Cleanliness of Surfaces	9
1.3.6 Testing of the Cleanliness of the Prepared Surfaces.....	9
1.3.7 Degree of Roughness (Surface Profile)	9
1.3.8 Methods of Measurement	10
1.4 Temporary Protection of Prepared Surfaces Against Corrosion and Contamination	11
1.5 Preparation of Surfaces Protected by Temporary Coatings.....	11
1.5.1 Preparation of Joint Areas (Welded, Riveted, and Bolted joints)	11
1.5.2 Preparation of Surfaces of Shop Primers, Base Coating, or Top Coatings.....	11
1.5.3 Preparation of Hot-Dip Galvanized or Hot-Dip Aluminum-Coated Surfaces.....	11
1.6 Inspection and Testing	12
1.7 Quality Systems.....	12
1.8 Procedure Qualification	12
1.8.1 Preparation Procedure Specifications	12
1.8.2 Preparation Procedure Approval Test	13
1.9 Degreasing	13
1.10 Hot Solvent Cleaning Method.....	13
1.10.1 Hot Solvent Cleaning—Not Water Rinsable	13
1.10.2 Hot Solvent Cleaning—Water Rinsable	17

1.10.3 Cold Solvent Cleaning	18
1.10.4 Cold Solvent–Not Water Rinsable	19
1.10.5 Cold Solvent–Water Rinsable	20
1.10.6 Emulsifiable Solvent Cleaning	21
1.11 Aqueous Alkaline and Detergent Cleaning	23
1.12 Steam Cleaning	26
1.13 Testing for Lack of Grease	27
1.13.1 Water Breaks Test	27
1.13.2 Grease Red Testing	27
1.13.3 Fluorescence Testing	28
1.14 Notes on Degreasing	28
1.14.1 Selection of Solvent	28
1.14.2 Reuse of Cleaning Solution	28
1.14.3 Protection of Cleaned Surfaces	28
1.14.4 Hazards of Solvent	29
1.15 Pickling	29
1.15.1 Pickling Methods	29
1.15.2 Hydrogen Embrittlement	29
1.16 Cleaning and Preparation of Metal Prior to Pickling	30
1.17 The Pickling Process	30
1.17.1 Sulphuric or Hydrochloric (Muriatic) Acid Pickling	30
1.17.2 Operations	30
1.17.3 Phosphoric Acid Pickling	31
1.17.4 Sulfuric Acid–Sodium Dichromated Pickling	32
1.17.5 Alkaline Pickling	32
1.18 Electrochemical Pickling	33
1.18.1 Cathodic Treatment in Acid Solution	33
1.18.2 Cathodic Treatment in Alkaline Solution	33
1.18.3 Anodic Treatment	33
1.19 Treatment of Metal After Pickling	34
1.19.1 Cold Rinsing	34
1.19.2 Final (Hot) Rinsing—Neutralizing	34
1.19.3 Preparing Metal for Painting	34
1.20 Appearance of Pickled Surfaces	35
1.21 Test Methods—Determining the Acid and Iron Content of Pickle Baths	35
1.21.1 Equipment Required	35
1.21.2 Reagents Required	35
1.21.3 Determining Acid and Iron Content in Sulfuric and Hydrochloric Acid Baths	36
1.21.4 Records	37

1.22	Precautions	37
1.23	Manual Cleaning (Hand and Power Tool Cleaning)	38
1.23.1	Surface Preparation Before and After Manual Cleaning	38
1.23.2	Hand Tool Cleaning	38
1.24	Power Tool Cleaning	39
1.24.1	Impact Cleaning Tools	39
1.24.2	Rotary Cleaning Tools	40
1.24.3	Rotary Impact Tools.....	41
1.25	Manual Cleaning of Nonferrous Metals.....	41
1.26	Precautions	41
1.27	Blast Cleaning	42
1.28	Choice of Method of Blast Cleaning.....	43
1.28.1	Shape and Size of Steelwork	43
1.28.2	Effect of the Stage at Which Is Carried Out	43
1.28.3	Throughput.....	43
1.28.4	Environmental Conditions	43
1.28.5	Types of Surface Deposit to be Removed.....	43
1.29	Abrasives	44
1.30	Before and After Blast Cleaning	45
1.30.1	Before Blast Cleaning.....	45
1.30.2	After Blast Cleaning	45
1.31	Testing the Cleanliness of the Blasted Surface	45
1.31.1	Visual or Field Testing	45
1.31.2	Instrumental or Laboratory Testing	46
1.32	Precautions	48
1.32.1	Dry Blasting.....	48
1.32.2	Water Blasting.....	48
1.33	Flame Cleaning	48
1.34	Surface Preparation of Iron and Steel	49
1.34.1	Cast Iron.....	49
1.34.2	Steels, Noncorrosion-Resisting.....	50
1.35	Chemical Smoothing Process for Steel.....	51
1.36	Anodic Etching for Ferrous Metals.....	51
1.36.1	Method A	51
1.36.2	Method B	52
1.36.3	Method C	52
1.37	Cleaning of Shop-Primed Steel Surfaces Prior to Overcoating	52
1.38	Surface Preparation of Stainless Steel.....	53
1.38.1	Degreasing of Stainless Steel.....	53
1.38.2	Cleaning of Welds and Weld-Joint Areas.....	53

1.38.3	Acid Pickling of Stainless Steel.....	54
1.38.4	Manual Cleaning of Stainless Steel.....	55
1.38.5	Abrasive Blasting of Stainless Steel	56
1.38.6	Final Cleaning.....	56
1.38.7	Passivation of Stainless Steel.....	56
1.39	Preparation of Stainless Steel for Electroplating	56
1.39.1	Degreasing	56
1.39.2	Blast Cleaning.....	56
1.39.3	Anodic Etching	57
1.39.4	Acid Pickling	57
1.39.5	Electrolytic Derusting.....	57
1.39.6	Nickel Strike	57
1.40	Surface Preparation of Nonferrous Metals.....	57
1.41	Surface Preparation of Metallic Surfaces for Maintenance	65
1.41.1	Choice of Maintenance Method.....	65
1.41.2	Choice of Procedures	65
1.41.3	Spot Repair (Patch-Paint)	65
1.41.4	Spot Repair Plus Full Topcoat	66
1.41.5	Complete Repaint	66
1.41.6	General Notes for Guidance	66
1.42	Surface Preparation of Imperfect Metallic Surfaces	67
1.42.1	Weld Spatter.....	67
1.42.2	Porosity	67
1.42.3	Sharp Edges	67
1.42.4	Pits	68
1.42.5	Laminations and Slivers.....	68
1.42.6	Crevice.....	68
1.43	Surface Preparation of Concrete	68
1.43.1	Types of Exposures.....	68
1.43.2	Types of Cementitious Surfaces.....	69
1.44	Types of Preparation.....	69
1.44.1	Air Blasting.....	69
1.44.2	Water Blasting.....	70
1.44.3	Hand or Power Tool Preparation.....	70
1.44.4	Treatment of Organic Growths	70
1.44.5	Stopping and Filling	70
1.44.6	Maintenance of Concrete Surfaces	70
1.45	Test Methods	70
1.45.1	Standard Test Method for pH Measurement of Chemically Cleaned Concrete Surfaces	70
1.45.2	Standard Test Method for Indicating Moisture in Concrete Using Plastic Sheets.....	71

1.46	Surface Preparation of Precast Concrete Blocks.....	72
1.46.1	Types of Blocks.....	72
1.46.2	Cleaning.....	72
1.46.3	Stopping and Filling	72
1.47	Inspection and Rejection.....	72
1.47.1	Surface Inspection	72
1.47.2	Access of Inspector	72
1.47.3	Facilities for Inspector	72
1.47.4	Inspection Guide.....	72
1.47.5	Qualified Inspectors	76
1.48	Application of Degreasing Methods.....	77
1.48.1	Immersion Cleaning Processes	77
1.48.2	Liquid Immersion Process	78
1.49	Spray or Jet Cleaning Process	78
1.49.1	Solvent/Detergent Cleaning	79
1.49.2	Steam Cleaning.....	79
1.50	Brushing or Wiping Process.....	79
1.51	Electrolytic Cleaning Process	80
1.52	Ultrasonic Cleaning Process	80
1.52.1	Size of Parts	81
1.53	Application Process of Blasting	81
1.53.1	Guide to Specifications of Abrasives	81
1.53.2	Metallic Abrasives	81
1.53.3	Nonmetallic abrasive	82
1.54	Abrasive Breakdown	83
1.54.1	Abrasive Breakdown Test and Rating Formula	83
1.55	General Notes on Use of Abrasives.....	88
1.56	Blasting Process and Equipment.....	88
1.56.1	Air-Blast Cleaning	88
1.56.2	Pressure-Type Blast Equipment.....	90
1.56.3	Suction Blast Equipment	90
1.56.4	Vacuum Blast Equipment.....	90
1.56.5	Recommendations on Air Blasting	90
1.57	Centrifugal Blasting	92
1.57.1	Table-Type Machine	92
1.57.2	Continuous-Flow Machines.....	92
1.57.3	Blasting-Tumbling Machines.....	93
1.57.4	Portable Equipment	93
1.57.5	Some Considerations About Centrifugal Blasting.....	93
1.57.6	Abrasives.....	94
1.57.7	Ventilation.....	94
1.58	Water Blasting (Hydroblasting).....	94

1.59	Drying Parts After Aqueous Cleaning and Before Coating	96
1.59.1	Drying by Heating	96
1.59.2	Centrifuging	97
1.59.3	Drying with Hot Solvent.....	97
1.59.4	Use of Water-Displacing Fluids.....	97
1.59.5	Blowing with Compressed Air.....	98
1.60	Surface Preparation of Plaster, Brick, Stone, and Wood.....	98
1.60.1	Preparation of Plaster.....	98
1.60.2	Cleaning	99
1.60.3	Stopping and Filling	99
1.61	Preparation of Brick and Stone	99
1.61.1	Types.....	99
1.61.2	Concrete Bricks	99
1.61.3	Stone	99
1.61.4	Cleaning.....	99
1.61.5	Filling and Stopping	100
1.62	Preparation of External Rendering.....	100
1.62.1	Types.....	100
1.62.2	Stucco	100
1.62.3	Cleaning.....	100
1.62.4	Stopping and Filling	100
1.63	Preparation of Wood.....	100
1.63.1	Cleaning	101
1.63.2	Sanding	101
1.63.3	Preservative Treatment.....	101
1.63.4	Stopping and Filling	101
1.64	Types and Application of Fillers and Stoppers for Nonmetallic Surfaces	102
1.64.1	Materials	102
1.64.2	Application.....	102
1.64.3	Stopping.....	102
1.64.4	Filling.....	103
1.65	Treatment of Organic Growths.....	103
1.65.1	External Surface.....	103
1.65.2	Internal Surface.....	105
CHAPTER 2	Engineering and Technical Guidelines for Painting	107
2.1	Corrosive Environments	108
2.1.1	Rural Environment.....	108
2.1.2	Industrial Environment	108
2.2	Water Immersion Environments	108
2.3	Chemical Environments	108

2.4	Marine Environments	109
2.4.1	Atmospheric Zones	109
2.4.2	Splash Zones	109
2.4.3	Submerged Zones	109
2.5	Underground Environments	109
2.6	Adhesion of Paint to the Substrate	109
2.7	Facilities for the Application of Coatings.....	110
2.8	Requirements.....	110
2.9	Surface Preparation	115
2.9.1	Selection of Cleaning Method(s)	115
2.9.2	Standards of Surface Preparation.....	115
2.9.3	Manual Cleaning.....	116
2.9.4	Chemical Cleaning.....	117
2.9.5	Surface Preparation for Maintenance	117
2.10	Paint Application	117
2.10.1	Paint Application Requirements	118
2.10.2	Standard of Paint Application	118
2.11	Priming and Painting	119
2.11.1	Steel Prepared by Blast Cleaning	120
2.11.2	Steel Prepared by Acid Pickling	120
2.11.3	Steel Prepared by Wire Brushing.....	121
2.11.4	Shop Preparation, Priming, and Painting.....	121
2.11.5	Preparing of Shop-Primed Surfaces for Overcoating	122
2.12	Treatment of Specific Surfaces.....	123
2.12.1	Edges.....	123
2.12.2	Faying Surfaces of Friction-Grip Joints.....	123
2.12.3	Fasteners	123
2.12.4	Welds.....	123
2.12.5	Sprayed Metal Plus Sealer System	125
2.12.6	Metal Plus Paint System	125
2.12.7	Zinc Coatings Plus Paint.....	125
2.12.8	Stainless Steel Plus Paint	126
2.13	High-Temperature Surfaces.....	126
2.14	Refrigerated Surfaces	127
2.14.1	Concrete Surfaces	128
2.14.2	Encasement in Concrete	128
2.14.3	Under Insulation Surfaces.....	128
2.14.4	Marine Structures.....	129
2.14.5	Steel Piping and Valves.....	129
2.15	Paint Schedule	129
2.16	Paint Color Schedule	130

2.17	Corrosion Prevention by Paint Coatings	130
2.18	Barriers	135
2.19	Electrical Methods	138
2.20	Chemical Inhibition.....	138
2.21	Characteristics of Protective Systems	138
2.21.1	Primers	139
2.21.2	Zinc-Rich Paints	139
2.21.3	Drying-Oil-Type Paints.....	140
2.21.4	One-Pack, Chemical-Resistant Paints.....	140
2.22	Two-Pack, Chemical-Resistant Paints.....	140
2.23	Bituminous Coatings.....	141
2.23.1	Coal-Tar Enamels	141
2.23.2	Asphaltic Coatings	141
2.23.3	Application of Coal-Tar and Asphalt Enamels	141
2.24	Characteristics of Metallic Coatings	142
2.24.1	Zinc Coatings.....	142
2.24.2	Sprayed-Metal Coatings	143
2.25	Characteristics of Some Other Protective Systems	143
2.25.1	Powder Coatings	143
2.25.2	Grease Paints.....	144
2.25.3	Wrapping Tapes and Sleeves	144
2.25.4	Protection of Steel by Cement and Allied Products.....	145
2.25.5	Cathodic Protection	145
2.26	Internal Painting of Aboveground Steel Tanks, LPG Spheres, and Vessels	147
2.26.1	Horizontal Tanks/Vessels	147
2.26.2	Spheres and Cylindrical Vessels for Liquefied Petroleum Gas (LPG) Under Pressure	148
2.26.3	Vertical Tanks.....	148
2.27	Typical Refinery Painting Systems Schedule for Steel Surfaces Recommended Scheme.....	152
CHAPTER 3	Application Methods of Paint and Preparation for Use	157
3.1	Introduction	157
3.2	Paint Materials.....	160
3.2.1	Selection of Paint Materials.....	160
3.2.2	Identification of Paint Materials	160
3.2.3	Storage of Paint Materials.....	160
3.3	Paint Application Color Coding	160
3.4	Components or Work Pieces.....	161
3.4.1	Component Identification	161
3.4.2	Protection of Weld and Preparations.....	162

3.4.3 Surface Preparation.....	162
3.4.4 Painting Procedure Tests.....	162
3.5 Inspection and Testing	163
3.6 Quality Systems.....	163
3.7 Procedure Qualifications	163
3.7.1 Painting Procedure Specifications	163
3.7.2 Coating Procedure Approval Tests.....	164
3.8 Metal Surface Treatment (Conversion Coatings)	164
3.9 Preparation of Paint Before Use	164
3.9.1 Storage and Appearance	164
3.9.2 Preparation of Paint for Application	165
3.10 Application Methods of Paint.....	166
3.10.1 Brush Application	167
3.10.2 Spray Application	167
3.10.3 Air Spraying.....	168
3.10.4 Low-Volume, Low-Pressure (LVLP) Spray	169
3.10.5 Airless Spray Application	170
3.10.6 Hot Spray	171
3.10.7 Electrostatic Spray	171
3.10.8 Paint Pads and Gloves.....	171
3.11 Application Procedures for Generic Groups of Paint.....	171
3.12 Vinyl and Chlorinated Rubber Paint.....	172
3.12.1 Bituminous Coatings	172
3.12.2 Chemically Cured Coatings	172
3.13 Zinc-Rich Paint	173
3.13.1 Inorganic, Zinc-Rich Paint.....	173
3.13.2 Organic, Zinc-Rich Paint	173
3.14 Urethane Coatings.....	173
3.15 Latex Paints for Steel	174
3.16 Painting of Ferrous Metals	174
3.16.1 Priming of Ferrous Metals	174
3.16.2 Priming of Steel Prepared by Blasting.....	175
3.16.3 Priming of Steel Prepared by Pickling.....	175
3.16.4 Priming of Steel Prepared by Wire Brushing (Tool Cleaning)	175
3.16.5 Shop Painting of Steel.....	176
3.16.6 Shop Painting in Cold Climates.....	176
3.17 Field and Touch-up Painting of Steel.....	176
3.18 Maintenance Painting of Steel	177
3.18.1 Painting of Specific Surfaces	178
3.18.2 Edges.....	178
3.18.3 Welds.....	178