

---

# Contents

<b>Chapter 1 Introduction to Coatings.....</b>	<b>1</b>
Principles of Corrosion Protection .....	2
Organic Coatings.....	3
Metallic Coatings.....	5
Corrosion Cell.....	5
EMF Control Protection.....	12
Cathodic Control Protection .....	13
Galvanic Action of Coating Layer.....	14
Anodic Control Protection.....	15
Single-Layer Coatings.....	16
Multilayer Coatings.....	16
Resistance Control Protection.....	17
References.....	18
<b>Chapter 2 Principles of Coating.....</b>	<b>19</b>
Rheology .....	20
Viscosity Behavior.....	21
Plasticity.....	21
Pseudoplasticity .....	21
Thixotropy.....	21
Dilatancy .....	22
Effect of Temperature.....	24
Effect of Solvents .....	24
Viscosity Measurement.....	24
Yield Value .....	25
Surface Chemistry.....	26
Surface Tension.....	27
Wetting .....	27
Coalescence.....	28
Surfactants.....	28
Sagging and Slumping.....	29
Leveling.....	30
Changes after Application.....	31
Edge and Corner Effects.....	31
Depressions: Bernard Cells and Craters .....	34
References.....	36

<b>Chapter 3 Theory of Adhesion . . . . .</b>	<b>37</b>
Introduction . . . . .	37
Mechanical Bonding . . . . .	37
Electrostatic Attraction . . . . .	39
Chemical Bonding . . . . .	39
Paint Diffusion . . . . .	40
Adhesion Testing . . . . .	41
Cross-Cut Test . . . . .	41
Tensile Methods . . . . .	41
Indentation Debonding . . . . .	43
Impact Tests . . . . .	45
Delamination Tests . . . . .	45
Knife Cutting Method . . . . .	46
Peel Test . . . . .	46
Blister Method . . . . .	47
Flaw Detection Methods . . . . .	48
Ultrasonic Pulse-Echo System . . . . .	49
Thermographic Detection . . . . .	49
Acoustic Emission Analysis . . . . .	50
Causes of Bond and Coating Failures . . . . .	51
Surface Preparation and Application . . . . .	51
Atmospheric Effects . . . . .	52
Arc-Type Sources . . . . .	54
Enclosed Carbon Arc (ASTM G-23) . . . . .	54
Sunshine Carbon Arc (open flame carbon arc: ASTM G-23) . . . . .	54
Xenon Arc (ASTM G-26) . . . . .	55
Fluorescent UV Lamps . . . . .	55
FS-40 Lamp (F40-UVB) (ASTM G-53) . . . . .	55
UVB-313 Lamp (ASTM G-53) . . . . .	55
UVA-340 Lamp (ASTM G-53) . . . . .	56
Types of Failures . . . . .	56
Strength of Paint Film . . . . .	56
Cohesive Failure . . . . .	58
Stress and Chemical Failures . . . . .	59
Types of Corrosion under Organic Coatings . . . . .	60
Wet Adhesion . . . . .	60
Osmosis . . . . .	61
Blistering . . . . .	61
Cathodic Delamination . . . . .	62
Anodic Undermining . . . . .	63
Filiform Corrosion . . . . .	63
Early Rusting . . . . .	64
Flash Rusting . . . . .	64

Stages of Corrosion.....	64
First Stages of Corrosion .....	64
Second Stage of Corrosion.....	65
Third Stage of Corrosion .....	65
Fourth Stage of Corrosion.....	65
Fifth Stage of Corrosion.....	65
Final Stage of Corrosion.....	65
References .....	66

**Chapter 4 Surface Preparation and Application . . . . .67**

Introduction .....	67
Metal Substrate Preparation.....	67
Abrasive Cleaning .....	69
Detergent Cleaning.....	69
Alkaline Cleaning.....	69
Emulsion Cleaning .....	70
Solvent Cleaning .....	70
Vapor Degreasing.....	70
Steam Cleaning.....	70
Metal Surface Pretreatment .....	70
Aluminum.....	70
Copper.....	71
Galvanized Steel.....	71
Steel .....	71
Stainless Steel.....	71
Titanium.....	71
Zinc and Cadmium.....	71
Plastic Substrate Preparation .....	71
Solvent Cleaning .....	72
Detergent Cleaning.....	73
Mechanical Treatments.....	73
Chemical Treatment.....	73
Other Treatments.....	75
Testing of Prepared Surface .....	76
Water Break Test.....	76
Tape Test .....	76
Quick Strip Test.....	76
Contact Angle Test.....	77
Environmental Testing .....	77
Application of Coatings.....	77
Application Methods.....	78
Brushing.....	78
Rolling .....	78

Roller Coating.....	79
Spray Painting.....	79
Powder Coating.....	80
Electrodeposition of Polymers.....	81
Multilayer Coatings.....	83
Curing.....	84
Air Drying.....	85
Baking.....	86
Conversion.....	86
Phase Change.....	86
Force Drying.....	86
Reflowing.....	86
Radiation Curing.....	87
Vapor Curing.....	87
Inspection.....	87
Chapter 5 Composition of Paint.....	89
Introduction.....	89
Binder.....	90
Pigments.....	90
Solvents.....	91
Additives.....	93
Fillers (Extenders).....	95
References.....	95
Chapter 6 Coating Materials (Paints).....	97
Etching Primer (Wash Primer).....	100
Acrylics.....	100
Alkyd Resins.....	102
Autooxidative Cross-linking Coatings.....	104
Bituminous.....	105
Chlorinated Rubber.....	105
Coal Tar Epoxy.....	106
Nitrocellulose.....	107
Oil-Based Paints.....	108
Polyamides.....	109
Epoxies.....	109
Polyamine Epoxies.....	110
Aliphatic Amines.....	110
Polyamide Epoxies.....	111
Polyvinyl Butyral.....	112
Polyvinyl Formal.....	112
Polyurethanes.....	113

Polyesters .....	115
Vinyl Esters .....	116
Vinyls.....	116
Water-Soluble Resins and Emulsion Coatings.....	117
Zinc-Rich Paints.....	118
Phenolics .....	1 2 0
Silicone.....	1 2 0
Corrosion Resistance Comparisons .....	1 2 1

**Chapter 7 Selecting a Paint System. . . . .153**

Introduction.....	1 5 3
Service Environment.....	153
Area 1: Mild Exposure.....	1 5 8
Area 2: Temporary Protection; Normally Dry Interiors.....	158
Area 3: Normally Dry Exteriors .....	159
Area 4: Freshwater Exposure.....	1 6 0
Area 5: Saltwater Exposure.....	161
Area 6: Freshwater Immersion.....	161
Area 7: Saltwater Immersion .....	161
Area 8: Acidic Chemical Exposure (pH 2.CL5.0) .....	161
Area 9: Neutral Chemical Exposure (pH 5.CL10.0).....	162
Area 10: Exposure to Mild Solvents .....	162
Area 11: Extreme pH Exposure.....	162
Summary .....	163
Expected Longevity .....	1 6 3
Cost.....	163
Environmental Compliance.....	165
Safety.....	1 6 5
Ease of Maintenance and Repair.....	166
Decoration/Aesthetics .....	166

**Chapter 8 Organic Coatings for Immersion. . . . .167**

Design of the Vessel.....	167
Coating Selection.....	172
Shell Construction.....	178
Shell Preparation .....	178
Coating Application .....	179
Curing of the Applied Coating .....	1 8 0
Inspection of the Lining.....	180
Sandpaper Test.....	1 8 2
Hardness Test.....	182
Adhesion .....	182
Film Thickness .....	182

Safety during Application.....	184
Causes of Coating Failure.....	185
Operating Instructions.....	186
Specific Liquid Coatings.....	186
Phenolics.....	186
Epoxy.....	187
Furans.....	192
Vinyl Esters.....	193
Epoxy Polyamide.....	196
Coal Tar Epoxy.....	199
Coal Tar.....	199
Urethanes.....	203
Neoprene.....	203
Polysulfide Rubber.....	205
Hypalon.....	205
Plastisols.....	210
Perfluoroalkoxy (PFA).....	213
Fluorinated Ethylene Propylene (FEP).....	216
PTFE (Teflon).....	6
Tefzel (ETFE).....	219
ECTFE (Halar).....	222
Fluoroelastomers (FKM).....	225
Polyvinylidene Fluoride (PVDF).....	231
Isophthalic Polyester.....	234
Bisphenol A Fumarate Polyesters.....	237
Halogenated Polyesters.....	243
Silicones.....	245
References.....	250

<b>Chapter 9 Comparative Resistance of Organic Coatings for Immersion Service.....</b>	<b>251</b>
Corrosion Tables.....	251

<b>Chapter 10 Metallic Coatings.....</b>	<b>309</b>
Methods of Producing Coatings.....	309
Electroplating.....	309
Electroless Plating.....	310
Electrophoretic Deposition.....	311
Cathodic Sputtering.....	311
Diffusion Coating.....	312
Sherardising Process.....	1 2
Calorizing Process.....	312
Metal Spraying (Combustion Flame Spraying).....	313
Hot Dipping.....	313

Vacuum Vapor Deposition .....	3 15
Gas Plating .....	315
Plasma Spraying .....	3 1 5
Fusion Bonding .....	315
Cladding (Explosive Bonding).....	316
Noble Coatings.....	316
Nickel Coatings .....	317
Satin Finish Nickel Coatings .....	324
Nickel–Iron Alloy Coatings .....	324
Chromium Coatings .....	324
The Armoloy Chromium Process.....	326
Chromium–Chromium Oxide Layers .....	328
Tin Coatings (Tinplate) .....	329
Lead Coatings.....	331
Terneplate.....	331
Gold Coatings.....	333
Copper Coatings.....	334
Nonnoble Coatings.....	336
Zinc Coatings .....	343
Corrosion of Zinc Coatings.....	344
White Rust (Wet Storage Stain).....	346
Intergranular Corrosion.....	349
Corrosion Fatigue.....	349
Stress Corrosion.....	349
Zinc–5% Aluminum Hot Dip Coatings .....	349
Zinc–55% Aluminum Hot Dip Coatings .....	351
Zinc–15% Aluminum Thermal Spray .....	353
Zinc–Iron Alloy Coatings.....	353
Aluminum Coatings .....	353
Cadmium Coatings .....	354
Manganese Coatings.....	355
References.....	355

**Chapter 11 Conversion Coatings . . . . . 357**

Introduction.....	357
Phosphate Coating.....	359
Chromate Coatings.....	361
Phosphate–Chromate Coatings .....	363
Anodized Coatings .....	363
Oxide Coatings.....	369
References.....	369

**Chapter 12 Cementitious Coatings . . . . . 371**

Introduction.....	371
Silicates .....	371

Calcium Aluminate.....	374
Portland Cement.....	374
Comparative Corrosion Resistance.....	375

**Chapter 13 Monolithic Surfacing . . . . .397**

Introduction.....	397
Surface Preparation.....	400
Surface Cleaning .....	400
Surface Abrading .....	401
Acid Etching.....	401
Coating Selection.....	401
Installation of Coatings.....	405
Hand Troweled .....	405
Power Troweling.....	406
Spray .....	406
Pour-in-Place/Self-Level.....	406
Broadcast .....	406
Chemical Resistance.....	406
Silicates.....	407
Epoxy and Epoxy Novolac Coatings.....	410
Furan Resins .....	414
Polyester Mortars.....	416
Phenolic Mortars .....	418
Vinyl Ester Resin.....	422
Acrylic Resins .....	422
Urethane Resins.....	424
Comparative Chemical Resistance .....	426
References.....	470

**Chapter 14 Comparative Resistance of Coatings and Paints . . . . .471**

Corrosion Resistance Tables.....	471
----------------------------------	-----

**Chapter 15 Tribological Synergistic Coatings . . . . .621**

Coating Systems.....	621
Polymer Coatings.....	621
Magnesium (Magnadize) and Titanium (Canadize).....	622
Titanium Nitride (Magnagold) .....	623

**Chapter 16 High-Temperature Coatings . . . . .625**

Introduction.....	625
Requirements of Coating–Substrate System .....	629
Protective Oxides .....	630
Methods of Coating .....	633
Diffusion Coatings.....	633



Pack Chromizing.....	633
Pack Aluminizing .....	634
Overlay Coatings.....	636
Weld Overlays .....	636
Flame and Plasma Spraying.....	636
Roll Bonding and Co-Extrusion.....	637
Vapor Deposition and Related Techniques .....	637
Ion Implantation .....	638
Thermal Barrier Coatings .....	639
Degradation of Coatings.....	640
Degradation via Diffusional Interaction between Coating and Substrate.....	640
Silicide Pest .....	644
Degradation via Reaction with the Environment.....	644
Durability of TBCs .....	646
References .....	647
<b>Index.....</b>	<b>649</b>