

CONTENTS

Chapter 1 MATERIALS SELECTION TEMPLATE	1
A. Introduction	1
B. Materials Selection Criteria	2
1. Mandatory Requirements	2
2. Design Conditions	2
3. Design Temperatures	5
4. Process Requirements	6
5. Special Requirements	8
6. Template Information	8
Chapter 2 BASIC MATERIALS ENGINEERING	17
Part 1: Corrosion	18
A. Introduction	18
B. Corrosion Basics	18
1. Cathodes	20
2. Anodes	20
C. Corrosion Control	21
1. Barrier Coatings: Interrupt or Reduce the Flow of Current	22
2. Cathodic Protection: Make Everything into a Cathode	24
3. Anodic Protection: Make Everything into an Anode	24
4. Passivation	25
5. Polarization	25
Part 2: Materials	27
A. Metallurgical Definitions	27
1. Heat Treatments	27
2. Microstructural Terms	32
3. Metallurgical Terms	33
B. Alloy Designations	37
C. Manufacturing Effects	37
D. Metals and Alloys	39
1. Cast Irons	39
2. Carbon Steels	41
3. Microalloyed Steels	43
4. Low-Alloy Steels	44
5. High Alloys	46

E.	Non-Metallic Materials	57
1.	Plastics	57
2.	Elastomers	71
3.	Carbon and Graphite	79
4.	Glass	82
5.	Cement	83
6.	Refractories	84
7.	Wood	87
F.	Coatings and Linings	89
1.	Introduction	89
2.	Thick Dielectric Barrier Coatings	90
3.	Thin Dielectric Barrier Coatings	99
4.	Thick Metallic Barrier Coatings	100
5.	Thin Metallic Barrier Coatings	103
6.	Sprayed Metal Coatings	104
7.	Galvanizing	106
8.	Other Metallic Coatings	107
 Chapter 3 FAILURE MODES		109
Part 1: Embrittlement Phenomena		109
A.	Introduction	109
B.	Carbon and Low-Alloy Steels	111
1.	Temper Embrittlement	111
2.	Creep Embrittlement	112
3.	Strain Ageing	113
4.	Hydrogen Embrittlement	113
5.	Caustic Embrittlement	115
6.	Low-Temperature Embrittlement	116
C.	Stainless Steels	116
1.	Ferritic Stainless Steels: 885°F (475°C) Embrittlement	116
2.	Martensitic Stainless Steels	117
3.	Austenitic Stainless Steels: Sigma Phase Embrittlement	117
4.	Duplex Stainless Steels	118
D.	High Alloys	118
E.	Hydriding	118
 Part 2: High-Temperature Effects		119
A.	Mechanical Effects	119
1.	Introduction	119
2.	Creep	119
3.	Stress Rupture	121

B.	Metallurgical Effects	121
1.	Sensitization	121
2.	Spheroidization and Graphitization of Carbon Steels	128
3.	Welding	129
C.	Chemical Effects	131
1.	Carburization	131
2.	Fuel Ash Corrosion	132
3.	Hydrogen Gas	133
4.	Nitriding	136
5.	Oxidation	136
6.	Sulfidation and Sulfidic Corrosion	138
D.	High-Temperature Alloys	140
Part 3: Corrosion		143
A.	Corrodents	143
1.	Acid, General	143
2.	Inorganic Acids	145
3.	organic Acids	150
4.	Acid Salts	154
5.	Amines	157
6.	Ammonia	157
7.	Carbon Dioxide	158
8.	Caustics	159
9.	Chlorides	160
10.	Flue Gas	163
11.	Hydrogen Sulfide	164
12.	Insulation	165
13.	Oxidants	165
14.	Water	166
15.	Seawater	170
B.	Microbiologically Influenced Corrosion	173
1.	Introduction	173
2.	Effect on Materials of Construction	175
3.	Mitigation Methods	176
C.	Stress Corrosion Cracking	177
1.	Introduction	177
2.	Crack-Inducing Agents	180
D.	Wet Sour Service	196
1.	Low-Risk Service	198
2.	Simple Wet Sour Services	199
3.	Severe Wet Sour Services	199

E.	Corrosion Allowance	201
1.	Design Life	202
2.	Vessels, Heat Exchangers and Tanks	202
3.	Piping	203
Chapter 4: CORROSION TESTING		206
A.	Introduction	206
B.	Important Variables	207
1.	Continuous Variables	207
2.	Batch Processes	208
3.	Temperature	208
4.	Pressure	209
5.	pH	210
6.	Velocity	211
7.	Process Chemistry	211
C.	Test Methods	213
1.	Real-Time Versus Accelerated Test	213
2.	Metals and Alloys	214
3.	Plastics and Elastomers	215
D.	Designing a Corrosion Testing Program	217
1.	Existing Processes	218
2.	New Processes	219
Chapter 5: THE PROCESS OF MATERIALS SELECTION		221
A.	Designing a Template	221
1.	Introduction	221
2.	Customizing a Template	222
B.	Materials Selection Steps	222
C.	Materials Selection Criteria	223
1.	Product Contamination	223
2.	Reliability	224
D.	Materials Selection Procedure: Exceptions	225
1.	Piping	225
2.	Pumps	225
3.	Fabricated Equipment	226
E.	Materials Selection Procedure	226
1.	Low-Temperature Toughness	226
2.	High-Temperature Degradation	227
3.	Grouping Process Regions	228
4.	Corrosion	228
5.	Upset Conditions	230
6.	Review	230

F. Materials Selection Diagram	232
G. Conclusions	234
SUPPLEMENT: EXAMPLES	243
A. Hydrocarbon Processes	243
B. Petrochemical Processes	252
C. Chemical Processes	256
APPENDICES	
1. Materials of Construction as a Function of Temperature	296
2. The de Waard – Milliams CO ₂ Nomograph	363
3. Caustic Soda Service	365
4. The Nelson Curves	367
5. The McConomy Curves	369
6. The Couper – Gorman Curves	374
7. Wet Sour Service Notes	385
8. Guidelines on Chloride Stress Corrosion Cracking of Austenitic Stainless Steels	387
9. Use of Ryznar and Langelier Indices for Predicting the Corrosivity of Waters	391
10. The Galvanic Series in Seawater	391
11. The NACE Graphs of Materials Selection for Sulfuric Acid, Hydrochloric Acid and Hydrofluoric Acid	396
12. Referenced Metals and Alloys	403
Index	405