

---

# **Advanced Materials for Water Handling: Composites and Thermoplastics**

---

**1st Edition**

**Derick Scott**



**ELSEVIER  
ADVANCED  
TECHNOLOGY**

---

# CONTENTS

---

Preface	v
Acknowledgements	vii
<b>Chapter 1 Introduction</b>	
1.1 Historical Background of the Water and Plastic Industries	2
1.2 Economical and Engineering Trends	5
<b>Chapter 2 The Water Industry</b>	
2.1 Water Treatment	10
2.1.1 Rainwater	10
2.1.2 Surface water	10
2.1.2.1 River water and lakes – upstream	10
2.1.2.2 River water and lakes – downstream	11
2.1.3 Underground sources	11
2.1.4 Sea or salty water	11
2.1.5 Miscellaneous water specifications	11
2.2 Potable Water	12
2.2.1 Quality standards	12
2.2.1.1 Microbiological	13
2.2.1.2 Physical and chemical	13
2.2.1.3 An example	13
2.2.2 Treatment process: potable water	14
2.2.2.1 Screening	15
2.2.2.2 Pre-disinfection or oxidation	15
2.2.2.3 Micro-screening	15
2.2.2.4 Coagulation and flocculation	15
2.2.2.5 Decantation	16
2.2.2.6 Filtration	16
2.2.2.7 Disinfection	16
2.2.2.8 Fluoridation and mineralisation	17

	2.2.2.9	Storage	17
	2.2.2.10	Distribution	17
2.3		Wastewater and Effluents	19
	2.3.1	Treatment processes	19
	2.3.1.1	Recuperation	19
	2.3.1.2	Screening and grit removal	20
	2.3.1.3	Grease and oil removal	20
	2.3.1.4	Flocculation, settling and flotation	20
	2.3.1.5	Aerobic and anaerobic biological treatment	21
	2.3.1.6	Dewatering and sludge thickening	21
	2.3.1.7	Odour control	21

### Chapter 3 Materials

3.1		Thermosets/Composite Materials	24
	3.1.1	Thermosetting resins	24
	3.1.2	Vinyl ester resins	28
	3.1.3	Bisphenol fumerate resins	30
	3.1.4	Liquid epoxy resins	31
	3.1.4.1	Anhydride cured epoxy resins	32
	3.1.4.2	Polyamine cured epoxy resins	33
	3.1.5	Solid epoxy resins	33
	3.1.6	Polyurethane resins	34
	3.1.7	Other thermosetting resins	34
	3.1.7.1	Furane resins	34
	3.1.7.2	Phenolic resins	34
	3.1.7.3	HET resins	34
	3.1.8	Curing and hardening agents	36
	3.1.9	Miscellaneous fillers/additives	36
	3.1.10	Reinforcing fibres	37
	3.1.10.1	Glass manufacture	37
	3.1.10.2	Forming	38
	3.1.10.3	Sizing	38
	3.1.10.4	Types of glass fibre	38
	3.1.10.5	Forms of glass fibre reinforcement	39
	3.1.11	Moulding compounds	42
3.2		Thermoplastics	44
	3.2.1	ABS — acrylonitrile butadiene styrene	44
	3.2.2	ECTFE — ethylene-chlorotrifluoroethylene	44
	3.2.3	FEP — fluorinated ethylene propylene	45
	3.2.4	PA — polyamide	45
	3.2.5	PBT — polybutylene terephthalate	45

3.2.6	PC — polycarbonate	45
3.2.7	Pe — polyethylene	45
3.2.8	PET — polyethylene terephthalate	45
3.2.9	PFA — perfluoro-alkoxy	45
3.2.10	Polyether ketone	46
3.2.11	PMMA — polymethylmethacrylate	46
3.2.12	POM — polyacetal	46
3.2.13	PP — polypropylene	46
3.2.14	PPE — polyphenylene ether (see PPO)	46
3.2.15	PPO — modified polyphenylene oxide	46
3.2.16	PPS — polyphenylene sulphone	46
3.2.17	PS — polystyrene	47
3.2.18	PTFE — polytetrafluoroethylene	47
3.2.19	PVC — polyvinyl chloride (PVC-U, PVC-C)	47
3.2.20	PVDF — polyvinylidene fluoride	47
3.3	Thermoplastic Materials for the Construction of Dual Laminates	48
3.4	Summary	50

## **Chapter 4 Production Technology**

4.1	Thermosets/Composite Materials	54
4.1.1	Contact moulding	58
4.1.2	Spray up moulding	59
4.1.3	Filament winding	60
4.1.4	Centrifugation or centrifugal casting	62
4.1.5	Resin transfer moulding	63
4.1.6	Compression moulding	64
4.1.7	Pultrusion	65
4.2	Thermoplastics	67
4.2.1	Injection, compression and transfer moulding	67
4.2.2	Extrusion	68
4.2.3	Rotational moulding	69
4.2.4	Thermoforming	70
4.2.5	High-frequency welding	70
4.2.6	Boiler work (welded tanks and other vessels)	71
4.2.7	Machining	71
4.2.8	Dip moulding or coating	72

## **Chapter 5 Design, Production and Testing Standards**

5.1	Composite Pipe Systems	75
5.1.1	North American standards	75
5.1.1.1	Specifying and testing of composite pipe systems	76

	5.1.1.2	Recommended practices	78
	5.1.1.3	Test methods	78
	5.1.1.4	Fire or flame resistance	83
	5.1.2	Individual national standards—	
		Europe	83
	5.1.2.1	France	83
	5.1.2.2	Germany	84
	5.1.2.3	UK	85
	5.1.3	European and cross-border standards (EN)	86
	5.1.4	International standards (ISO)	87
	5.1.5	Japanese standards	89
5.2		Composite Tanks and Vessels	91
	5.2.1	North America	91
	5.2.2	Europe	93
	5.2.2.1	France	94
	5.2.2.2	Germany	94
	5.2.2.3	UK	94
	5.2.3	Japan	94
5.3		Thermoplastic Pipe Systems	95
	5.3.1	North America	95
	5.3.2	Europe	96
	5.3.2.1	UK national standards	96
	5.3.2.2	German national standards	98
	5.3.2.3	French national standards	99
	5.3.3	Japanese standards	100
	5.3.4	Cross-border standards	101
	5.3.4.1	International standards (ISO)	101
	5.3.4.2	European standards (EN)	105
5.4		Thermoplastic Tanks and Vessels	108
5.5		Composite Profiles and Associated Constructions	109

## **Chapter 6 Using non-metallic Materials with Potable Water**

6.1		Laws and Regulations	112
6.2		Comparison of Standards in Europe and North America	114
	6.2.1	France	114
	6.2.2	Germany	115
	6.2.2.1	KTW recommendations	115
	6.2.2.2	DVGW W270 testing	115
	6.2.3	The Netherlands	115
	6.2.4	UK	116
	6.2.5	European legislation and directives	117
	6.2.6	North America	117

	6.2.6.1	FDA	117
	6.2.6.2	NSF Standard 61	118
6.3	Testing Organisations or Official Bodies where Relevant Information can be Obtained		121
	6.3.1	Austria	121
	6.3.2	Belgium	121
	6.3.3	Denmark	121
	6.3.4	Finland	121
	6.3.5	France	121
	6.3.6	Germany	122
	6.3.7	Italy	122
	6.3.8	The Netherlands	122
	6.3.9	Norway	122
	6.3.10	Spain	122
	6.3.11	Sweden	122
	6.3.12	UK	122
	6.3.13	North America	123

## Chapter 7 **Products and Applications — Composite and Thermoplastic Pipe Systems**

7.1	Composite Materials — Filament Wound Epoxy Pipes and Fittings		126
	7.1.1	General information	126
	7.1.2	Design basis	127
	7.1.3	Product range	127
	7.1.4	Jointing systems	128
	7.1.5	Installation	130
	7.1.6	Supporting documentation	132
	7.1.7	Typical suppliers, products, designation, sizes and pressure/ temperature ratings	132
	7.1.8	Recent developments	135
7.2	Composite Materials — Large Diameter Filament Wound and Centrifugally Cast Polyester and Vinyl Ester Pipes and Fittings		138
	7.2.1	General information	138
	7.2.2	Design basis	139
	7.2.3	Product range	139
	7.2.3.1	Continuous filament wound pipe systems, trademark: Flowtite	139
	7.2.3.2	Reciprocal filament wound pipe	140
	7.2.3.3	Centrifugal cast pipe—Hobas and licensed companies operating the Hobas license	140

7.2.4	Installation	141
7.2.5	Supporting documentation	141
7.3	Composite Materials — Small to Medium Diameter Filament Wound Polyester and Vinyl Ester Pipes and Fittings	142
7.3.1	General information	142
7.3.2	Design basis	142
7.3.3	Product range	144
7.4	Composite Materials — Small to Medium Diameter Centrifugally Cast Epoxy and Vinyl Ester Pipes and Fittings	145
7.5	Composite Materials — Filament Wound Epoxy and Vinyl Ester Pipe Fittings	146
7.6	Composite Materials — Resin Transfer and Compression Moulded Epoxy, Vinyl Ester and Polyester Fittings	147
7.7	Thermoplastic Pipes	148
7.7.1	Extruded pipe	149
7.7.1.1	PVC	149
7.7.1.2	PVC-C or chlorinated PVC	149
7.7.1.3	Bi-oriented PVC or otherwise strengthened PVC pipe	150
7.7.1.4	Polyethylene	151
7.7.1.5	Cross linked HdPe or PE-X	153
7.7.1.6	PB	154
7.7.1.7	PP	154
7.7.1.8	PVDF	154
7.7.1.9	Dual laminate pipe systems	154
7.7.1.10	Thermoplastic lined steel pipe system	155
7.7.2	Spiral wound pipe	155
7.7.3	Assembly of thermoplastic pipe systems	157
7.7.3.1	Solvent cement bonding	157
7.7.3.2	Mechanical joints	159
7.7.3.3	Compression joints	159
7.7.3.4	Spigot/socket with elastomeric seals	159
7.7.3.5	Flanged joints	160
7.7.3.6	Threaded joints	161
7.7.3.7	Welding	161
7.7.3.7.1	Socket fusion welding	162
7.7.3.7.2	Butt welded polyfusion	163
7.7.3.7.3	Electrically heated socket fusion welding	166

7.7.3.8	Qualification of welders	168
7.7.4	Thermoplastic pipe fittings	169
7.7.5	Design of thermoplastic pipe systems	169
7.7.5.1	Product design	169
7.7.5.2	System design	169
7.7.6	Pipe installation and testing	170
7.7.7	Large-diameter fittings and access chambers for water and effluent mains	172

## **Chapter 8 Products and Applications — Composite and Thermoplastic Tanks, Silos and Other Vessels**

8.1	Cylindrical Composite Tanks and Other Vessels	176
8.1.1	Design	179
8.1.2	Applications	183
8.2	Rectangular or Square Composite Storage Tanks	191
8.3	Thermoplastic and Dual Laminate Tanks and Vessels	195
8.3.1	Rotationally moulded thermoplastic tanks	195
8.3.2	Spiral wound and welded shell construction	196
8.3.3	Thermoplastic welded tank and vessel construction	197
8.4	Thermoplastic Welding Technology	198
8.4.1	Fusion welding	198
8.4.2	Hot gas welding	199
8.4.3	Extrusion welding	200
8.5	Dual Laminate Construction	201
8.6	High-Pressure Filters	203
8.7	Small Composite Low Pressure Filters, Containers and Storage Tanks	210

## **Chapter 9 Products and Applications — Miscellaneous Equipment**

9.1	Tank Covers and Odour Control Equipment in Wastewater Treatment plants	218
9.2	Well and Borehole Equipment	223
9.2.1	Thermoplastic well casings	223
9.2.2	Composite tubing and well casing/screens	228
9.3	Coating and Linings	231
9.3.1	Initial protection of new equipment	231
9.3.1.1	Pipe systems	231
9.3.1.2	Tanks, vessels and other constructions	231
9.3.2	In-situ lining of existing equipment	231
9.3.2.1	Pipe systems	231
9.3.2.2	Protection of other constructions for fluid containment	244



9.4	District Heating and Cooling Processes	253
9.5	Industrial Process, Demineralised and Deionised Water	255
9.6	Ultra-Pure Water and Similar Applications	256
9.7	Composite Structures and Gratings	257
9.8	Water Treatment Associated with Air Pollution Control	260
9.9	Miscellaneous Equipment for Water and Effluent Treatment	261
9.10	Onshore and Offshore Oilfield Applications	262
9.11	Buried Fire Mains	264
9.12	Jetties and Locks	265
9.13	Irrigation	268

## **Chapter 10 Novel Applications**

10.1	Composite Modular Settling Tanks	272
10.2	Package Sewage Treatment Plants	275
10.3	Prefabricated Pumping Stations	279
10.4	Modular Biomedia	281
10.5	Advanced Polymeric Membrane Systems for Potable and Wastewater Treatment	285
10.6	Cooling Towers and Cooling Tower Components	287
10.7	Restrained Joint PVC Pipe	293
10.8	Aeration and Oxidation — Aerators and Fine Bubble Air Diffusers	295
10.9	Dynamic Screening with the Discreen Family	298
10.10	Oblated FRP Tanks	300
10.11	Gravity Filter Floors in Composite Sandwich Construction	302
10.12	Articulated Lamellae Filters for Easy Cleaning	304
10.13	FlowGRiP Composite Planks	306

## **Chapter 11 Case Histories**

11.1	Nanofiltration Plant at Mery sur Oise, Paris, France	310
11.2	Water Treatment Plant — Odour Control at Howdon, UK	313
11.3	Geothermal Sourced District Heating	315
	11.3.1 Jonzac, France	315
	11.3.2 Le Mée sur Seine, France	317
	11.3.3 Down hole tubing and casing	318
11.4	Vertical Composite Sewer Pipe — Ipswich, UK	322
11.5	A 2100 Metre FRP Pipeline Insertion — Portland, USA	324
11.6	FRP Folding Covers — Farmoor, UK	326
11.7	FRP Storage Tanks — Massachusetts, USA	328

11.8	FRP Pipe in Wastewater Treatment Plant — Arizona, USA	330
11.9	FRP Pressure Pipe in Sewage Transfer Scheme in Grimmén, Germany	333
11.10	Polyethylene Relining of 5 500 Metres of 30 and 36 Inch Potable Water Pressure Mains	335
11.11	Renovation of 33 000 Meters of Sewer Pipe with 160–225 HdPe	337
11.12	HdPe Submarine Pipeline in Malaysia	339
11.13	Reverse Osmosis Disc Tube (DT) and Landfill Leachate Treatment	341

## **Chapter 12 Quality Systems and a Summary of Considerations Specific to the use of Thermoplastic and Composite Materials**

12.1	A Guide to the Design and Quality Control of Composite Vessels	346
12.1.1	Vents and overflows	349
12.1.2	Fitting design	349
12.1.3	Handling and installation	350
12.1.4	Inspection	350
12.1.5	External inspection	351
12.1.6	Internal inspection	351
12.1.7	Conclusion	352

## **Chapter 13 Raw Materials**

13.1	Trade and Registered Names of Raw Materials and the Relevant Producers	356
13.2	Suppliers of Raw Materials (for Composite Products)	362
13.2.1	Polyester/vinyl ester/bisphenol/HET resins	362
13.2.2	Epoxy resins	363
13.2.3	Phenolic and/or furane resins	364
13.2.4	Glass fibre reinforcements	364
13.2.5	Glass fibre and synthetic surfacing veils	365
13.2.6	Coating materials and formulations	366
13.2.7	Thermoplastic sheet and pipe designed specifically for incorporation into dual laminates	368

## **Chapter 14 Trademarks, Equipment Suppliers and Manufacturers**

14.1	Pipe Systems	370
14.1.1	Filament wound epoxy pipes and fittings	370
14.1.2	Filament wound polyester and vinyl ester pipes and fittings	371

14.1.3	Centrifugal cast and filament wound epoxy and vinyl ester pipes and fittings	373
14.1.4	Centrifugal cast polyester pipes and fittings	374
14.1.5	RTM epoxy, vinyl ester and polyester fittings	374
14.1.6	High-pressure filament wound pipe, tubing and casing	374
14.1.7	Low-pressure filament wound tubing and casing	375
14.1.8	Dual laminate pipe systems	375
14.1.9	Thermoplastic lined steel pipe	376
14.2	Thermoplastic Pipe Systems	377
14.2.1	Extruded thermoplastic pipes	377
14.2.2	Spiral wound thermoplastic pipes	381
14.2.3	Thermoplastic pipe fittings	381
14.2.4	Large diameter fabricated fittings and access chambers for water and effluent mains	383
14.2.5	Thermoplastic well casings and screens	383
14.2.6	Thermoplastic valves	384
14.3	Composite Vessels	385
14.3.1	Standard composite storage tanks, vessels for storage and treatment of water and silos	385
14.3.2	Custom fabricated vessels	388
14.3.3	Standard high- and low-pressure composite storage tanks/filter bodies	390
14.3.4	Modular composite storage tanks	390
14.3.5	Very large filament wound composite storage tanks (on-site manufacture, diameter above 8 m/25 ft)	392
14.4	Thermoplastic Vessels	393
14.4.1	Rotationally moulded thermoplastic storage tanks	393
14.4.2	Other standard thermoplastic storage tanks	393
14.5	Other Equipment	394
14.5.1	High-pressure filters	394
14.5.2	Reverse osmosis pressure vessels	394
14.5.3	Spiral wound membranes	395
14.5.3.1	Other membrane filtration technologies referred to in this handbook	396
14.5.4	Tank covers and odour control equipment	396
14.5.5	Biological carrier media	397
14.5.6	Cooling towers (and components)	398
14.6	Composite Structures and Gratings	400

14.6.1	Manufacturers of composite profiles and gratings	400
14.6.2	Companies specialised in the design and fabrication of composite structures from pultruded sections	403
14.7	Coating and Linings	405
14.7.1	Pipe linings	405
14.7.2	In-situ tank and vessel linings — applicators	406
14.8	Mini/modular Wastewater Treatment Plants	407
14.9	Thermoplastic Pipe and Sheet Welding Equipment	408
14.10	Specialised Water Treatment Equipment	410
14.11	Engineering and Contracting Companies	411
14.12	Consultants	412
<b>Chapter 15</b>	<b>Governing Bodies, Authorities, and Associations of Relevance to the Scope of this Handbook</b>	
15.1	The Field of Water Supply and Treatment	414
15.2	The Field of Composites and Thermoplastics, and Products Manufactured from these Materials	416
<b>Chapter 16</b>	<b>Glossary of Abbreviations/Technical Terms; Bibliography</b>	
16.1	Summary of Abbreviations and Technical Terms Frequently Used in the Water or Plastic Industries	420
16.2	Bibliography	424
16.2.1	The water industry	424
16.2.2	The composite and plastics industry	424
	<b>Editorial Index</b>	427