

# *Papermaking Science and Technology*

a book series  
covering the latest  
technology and  
future trends

*Book 8*

# Papermaking Part 1, Stock Preparation and Wet End

*Second Edition*

# Totally updated version

***Book editor***

Hannu Paulapuro, D. Sc. (Tech.), Professor, Department of Forest Products  
Technology, Paper Technology, Helsinki University of Technology

***Publisher***

Finnish Paper Engineers' Association/Paperi ja Puu Oy



**Paperi ja Puu Oy**

# Table of Contents

1	Mill operations in the production of main paper and board grades — an overview.....	9
2	History of papermaking .....	61
3	Slushing and defibration of pulp in the paper mill.....	77
4	Refining of chemical pulp fibres .....	92
5	Stock and water systems of the paper machine.....	140
6	Web forming.....	216
7	Air Forming .....	289
8	Forming fabrics.....	308
9	Wet pressing .....	343
10	Press fabrics .....	402
11	Paper machine rolls.....	445
12	Vacuum systems.....	477
13	Vacuum pumps .....	493
	Conversion factors.....	511
	Index.....	513

# CHAPTER 1

## Mill operations in the production of main paper and board grades — an overview

<b>1</b>	<b>Introduction.....</b>	<b>10</b>
<b>2</b>	<b>Paper mill structure.....</b>	<b>12</b>
2.1	Mill .....	12
2.2	Production lines .....	13
2.3	Process and paper machine area .....	14
	2.3.1 Process.....	14
	2.3.2 Paper machine area .....	17
2.4	Operating performance .....	18
<b>3</b>	<b>Various technical concepts.....</b>	<b>19</b>
3.1	Newsprint paper mill .....	19
3.2	SC and LWC paper mill .....	27
3.3	Fine paper mill .....	38
3.4	Linerboard mill .....	43
3.5	Board mill .....	48
3.6	Tissue mill .....	53
<b>4</b>	<b>Mill organisation.....</b>	<b>57</b>
<b>5</b>	<b>Trends.....</b>	<b>58</b>
	References .....	60

# CHAPTER 2

## History of papermaking

<b>1</b>	<b>Pre-paper era</b> .....	<b>62</b>
1.1	Early writing surfaces .....	62
1.2	Papyrus .....	62
1.3	Parchment .....	63
1.4	Other paper-type materials .....	64
<b>2</b>	<b>Entering the paper age</b> .....	<b>64</b>
2.1	China, the birthplace of paper .....	64
2.2	Art of papermaking moving westward .....	65
2.3	First use of paper in Europe .....	65
2.4	First paper mills in Europe .....	66
2.5	First paper mills in America .....	66
2.6	Hand papermaking .....	66
2.6.1	Main principles .....	66
2.6.2	Raw materials .....	67
2.6.3	Pretreatment of fibres .....	67
2.6.4	Sheet forming and drying of paper .....	68
2.6.5	Watermarks in hand-made paper .....	68
<b>3</b>	<b>Development of machines for papermaking</b> .....	<b>69</b>
3.1	The pioneer Nicolas-Louis Robert .....	69
3.2	Development of the fourdrinier paper machine .....	70
3.3	Development of the cylinder-mould machine .....	71
3.4	Development of other paper machine types .....	72
3.5	Breakthrough of machine-made paper .....	73
3.6	Milestones in paper machine development .....	73
<b>4</b>	<b>Technical development - but a faster decaying product</b> .....	<b>75</b>
	References .....	76
	For further reading .....	76

# Chapter 3

## Slushing and defibration of pulp in the paper mill

<b>1</b>	<b>Bale handling</b> .....	<b>78</b>
<b>2</b>	<b>Slushing</b> .....	<b>78</b>
2.1	Targets of slushing.....	79
2.2	Pulpers .....	80
2.2.1	Horizontal pulpers.....	80
2.2.2	Vertical pulpers.....	80
2.2.3	Pulper rotor.....	81
2.3	Slushing system.....	82
2.4	Instrumentation and control .....	83
2.5	Pulper operating characteristics and effect on pulp properties.....	83
2.6	Pulper operation mode.....	84
2.7	Slushing energy .....	85
2.7.1	Slushing consistency .....	85
2.7.2	Slushing temperature and water quality.....	86
<b>3</b>	<b>Wet storage</b> .....	<b>86</b>
<b>4</b>	<b>Defibration (defibering, deflaking, or disintegration)</b> .....	<b>86</b>
4.1	Targets of deflaking .....	87
4.2	Type of deflakers .....	87
4.3	Operating characteristics and effect on pulp properties.....	88
<b>5</b>	<b>Evaluation of the slushing and deflaking result</b> .....	<b>89</b>
5.1	Visual evaluation.....	89
5.2	Optical and other sheet quality measurements.....	89
5.3	Screening .....	89
5.4	Stock Quality Degree (Metso) .....	89
5.5	Energy Optimization Test (Fibre Technology Association).....	90
	References .....	91

# Chapter 4

## Refining of chemical pulp fibres

<b>1</b>	<b>Introduction.....</b>	<b>94</b>
<b>2</b>	<b>Fibre structural changes .....</b>	<b>95</b>
2.1	Internal fibrillation of fibre cell wall .....	96
2.2	Changes in fibre curl; fibre straightening.....	98
2.3	Fibre shortening.....	99
2.4	External fibrillation and formation of fines .....	100
2.5	Release of organic substances.....	101
<b>3</b>	<b>Historical development of refining.....</b>	<b>101</b>
3.1	Evolution of the Hollander beater.....	101
3.2	The important role of the beaterman .....	103
3.3	Evolution of disc and conical refiner .....	104
<b>4</b>	<b>Fibre-water suspension in low-consistency refining.....</b>	<b>105</b>
4.1	Orientation and state of fibres between refiner bars .....	106
4.1.1	Fibrage .....	106
4.1.2	Floc refining hypothesis .....	107
4.2	Suspension flowing through the refining zone .....	108
4.2.1	Primary flow in grooves and reverse flow.....	108
4.2.2	Why are grooves needed? .....	109
<b>5</b>	<b>Modern low-consistency refiners .....</b>	<b>110</b>
5.1	Conical Refiner.....	110
5.2	Disc refiner .....	111
5.3	Cylindrical refiner.....	112
5.4	Modern laboratory refiner .....	113
<b>6</b>	<b>Control and characterization of a low-consistency refiner .....</b>	<b>114</b>
6.1	Specific edge load and specific energy .....	115
6.2	Number of impacts and severity of impacts.....	117

6.3	Characterisation of pulp refiners by C-factor .....	118
6.4	Specific surface load.....	120
6.5	Other approaches to characterise low-consistency refining.....	122
<b>7</b>	<b>Refining as part of the stock approach system .....</b>	<b>122</b>
<b>8</b>	<b>High-consistency refining .....</b>	<b>124</b>
8.1	Potential of high-consistency refining in treating deinked pulps.....	125
8.2	Effect of high-consistency treatments on fibre structure of deinked pulps .....	125
<b>9</b>	<b>Operation of low-consistency refiners .....</b>	<b>126</b>
9.1	Effect of pulp consistency .....	126
9.2	pH and electrolyte content of pulp.....	127
9.3	Chemical additives in refining .....	127
9.4	Basic effect of intensity and specific energy on fibres .....	127
9.5	Refiner filling materials and production technology .....	128
<b>10</b>	<b>Energy consumption in low-consistency refining.....</b>	<b>129</b>
<b>11</b>	<b>Application of enzymes prior to refining .....</b>	<b>130</b>
<b>12</b>	<b>Summary .....</b>	<b>132</b>
	References .....	134

# CHAPTER 5

## Stock and water systems of the paper machine

<b>1</b>	<b>Definitions</b> .....	<b>142</b>
<b>2</b>	<b>Design principles</b> .....	<b>142</b>
2.1	Elements and operations.....	142
2.2	System stability .....	147
2.2.1	Grade changes.....	148
2.2.2	Pressure variations and pulsation.....	149
2.2.3	Stock consistency variations .....	151
2.2.4	Headbox approach flow stability.....	152
2.3	Stock and water balance.....	152
2.4	Multi-ply and multiple-layer systems .....	155
2.5	System cleanliness .....	156
2.6	Simulation tools .....	157
<b>3</b>	<b>Stock flow operations</b> .....	<b>158</b>
3.1	Stock blending.....	158
3.2	Stock dosage .....	160
3.3	Stock dilution.....	161
3.3.1	Principle.....	161
3.3.2	Mixing.....	161
3.3.3	Machine stock dilution .....	161
3.3.4	Headbox dilution system .....	164
3.3.5	Medium- and high-consistency stock dilution.....	164
3.4	Cleaning and screening.....	165
3.4.1	Hydro-cyclone cleaning .....	165
3.4.2	Screening .....	167
3.5	Deaeration .....	168
3.5.1	Air in stock and water .....	168
3.5.2	Effect of air on papermaking .....	169
3.5.3	Sources of air.....	170
3.5.4	Chemical deaeration .....	170
3.5.5	Deaeration tanks.....	171
3.5.6	Deaeration by other equipment .....	173
3.6	Chemical conditioning.....	174
3.6.1	Wet end chemistry .....	174



3.6.2	Dosage points .....	175
3.6.3	Dosing .....	175
3.6.4	Measurements .....	176
3.7	Stock transport .....	177
3.7.1	Piping .....	177
3.7.2	Pumping .....	178
3.8	Stock chests .....	180
3.8.1	Vertical chests.....	180
3.8.2	Storage silos .....	180
3.8.3	Agitators .....	181
3.8.4	Retention times.....	182
<b>4</b>	<b>Broke system .....</b>	<b>183</b>
4.1	Introduction .....	183
4.2	Broke system requirements .....	184
4.3	Broke handling.....	185
4.3.1	Transport and auxiliary equipment.....	185
4.3.2	Pulpers .....	185
4.3.3	Slushed broke-handling system .....	187
4.4	Broke dosage.....	188
4.5	Coated broke systems.....	189
<b>5</b>	<b>Fibre recovery and water clarification.....</b>	<b>189</b>
5.1	Filtration .....	190
5.1.1	Disc filter .....	190
5.1.2	Sweetener .....	194
5.1.3	Other filters.....	194
5.2	Flotation.....	195
5.3	Classification .....	198
5.4	Sedimentation.....	198
<b>6</b>	<b>Mill water systems .....</b>	<b>198</b>
6.1	Paper mill water household.....	198
6.2	Fresh water use .....	200
6.2.1	Dissolved and detrimental substances.....	202
6.2.2	Accumulation mechanisms .....	204
6.2.3	Vertically integrated mills .....	205
6.2.4	Horizontally integrated mills .....	206
6.3	Advanced water purification techniques.....	206
6.3.1	Membrane filtration.....	208
6.3.2	Evaporation.....	208
6.3.3	Biological in-process treatment.....	209
<b>7</b>	<b>Novel approaches and possible future .....</b>	<b>209</b>
	References .....	211

# Chapter 6

## Web forming

<b>1</b>	<b>Grammage variability</b> .....	<b>219</b>
1.1	Power spectrum .....	219
1.2	Fibre flocculation .....	220
1.2.1	Sediment concentration .....	221
1.2.2	Network generation .....	222
1.2.3	Crowding factor .....	223
1.2.4	Network strength .....	225
1.2.5	Floc stretching .....	225
1.2.6	Flocculation measurements .....	226
1.3	Formation .....	227
1.3.1	Optical methods .....	227
1.3.2	Beta ray methods .....	228
1.3.3	Formation characteristics .....	229
1.3.4	Formation of random sheets .....	230
1.3.5	Dewatering effects on formation .....	232
1.4	Medium-scale grammage variations .....	233
<b>2</b>	<b>Headboxes</b> .....	<b>233</b>
2.1	Cross-direction distribution .....	234
2.2	Air-cushion headboxes .....	235
2.3	Hydraulic headboxes .....	236
2.3.1	“Turbulence generator” effects .....	238
2.4	Headbox nozzle .....	238
2.4.1	Fibre orientation anisotropy .....	240
2.5	Jet angle and velocity .....	241
2.6	CD grammage profile .....	243
2.6.1	Dilution control .....	244

2.7	Multilayer headboxes .....	245
2.8	High-concentration headboxes .....	247
<b>3</b>	<b>Wire sections .....</b>	<b>247</b>
3.1	Fibre deposition .....	248
3.2	Forming fabrics .....	249
3.3	Dewatering resistance .....	250
3.4	Fourdrinier forming .....	252
	3.4.1 Table rolls .....	253
	3.4.2 Foil elements .....	254
	3.4.3 Dry suction boxes and couch roll .....	255
	3.4.4 Structure modification .....	255
3.5	Twin-wire forming .....	258
	3.5.1 Roll forming .....	259
	3.5.2 Blade forming .....	265
	3.5.3 Hybrid forming .....	270
	3.5.4 Roll-blade forming .....	270
	3.5.5 New STFI Former .....	273
3.6	Multi-ply/multilayer forming .....	276
	3.6.1 Separate forming .....	277
	3.6.2 Simultaneous forming .....	278
3.7	Forming and paper strength .....	279
	References .....	282

# Chapter 7

## Air Forming

<b>1</b>	<b>Introduction .....</b>	<b>290</b>
<b>2</b>	<b>Furnish composition .....</b>	<b>291</b>
2.1	Fibres .....	291
2.2	Binders .....	291
2.3	Additives .....	292
<b>3</b>	<b>Process.....</b>	<b>292</b>
3.1	Typical layout of a modern air-laid process .....	292
3.2	Kroyer and St. Anne's process.....	293
<b>4</b>	<b>Air-laid forming heads.....</b>	<b>294</b>
4.1	Sifting systems .....	294
4.1.1	Kroyer design (now M&J Fibretech).....	294
4.1.2	Dan-Web design .....	295
4.1.3	Honshu design .....	296
4.2	Direct laying design (VNIB) .....	297
<b>5</b>	<b>Features of air-laid forming .....</b>	<b>298</b>
5.1	Degree of pulp disintegration .....	298
5.2	Aerodynamics of air-fibre flow .....	299
5.3	Fibre concentration $C_f$ .....	300
5.4	Effect of fibre charging and electrostatic force .....	301
<b>6</b>	<b>Strength of air-laid network.....</b>	<b>302</b>
<b>7</b>	<b>Bonding of dry air-laid web.....</b>	<b>303</b>
<b>8</b>	<b>Future development of air-laid process.....</b>	<b>303</b>
	References .....	306

# Chapter 8

## Forming fabrics

<b>1</b>	<b>Function of forming fabric.....</b>	<b>310</b>
1.1	Weave structure.....	310
1.2	Materials .....	311
1.3	Manufacturing .....	312
<b>2</b>	<b>Classification of forming fabrics.....</b>	<b>313</b>
2.1	Single layer — SL.....	313
2.2	Double layer — DL.....	313
2.3	Triple weft — TW.....	314
2.4	Triple layer — TL.....	314
2.5	Self-support binding — SSB.....	314
<b>3</b>	<b>SSB forming fabrics.....</b>	<b>315</b>
<b>4</b>	<b>Properties of forming fabrics having an influence on the papermaking process .....</b>	<b>317</b>
4.1	Dewatering .....	317
4.1.1	Retention .....	319
4.1.2	Sheet structure .....	319
4.2	Stability .....	320
4.2.1	Elasticity .....	320
4.2.2	Stiffness.....	320
4.2.3	Diagonal stability.....	321
4.2.4	Tension profile.....	322
4.3	Wear resistance .....	322
4.4	Clean running .....	323
4.5	Wire marking .....	324
<b>5</b>	<b>Forming fabrics for different former types by paper grade.....</b>	<b>324</b>
5.1	Selection criteria.....	324
5.1.1	Runnability features .....	325
5.1.2	Paper quality features .....	325

5.2	Choosing a forming fabric .....	325
5.2.1	Paper grade .....	325
5.2.2	Former type .....	326
5.2.3	Fourdrinier and hybrid-former bottom position .....	327
5.2.3.1	Hybrid-former top position .....	327
5.2.3.2	Gap former.....	327
5.2.3.3	Multi-fabric formers .....	328
<b>6</b>	<b>Keeping forming fabrics clean .....</b>	<b>329</b>
6.1	Soiling of forming fabrics .....	329
6.2	Soiling mechanisms.....	329
6.3	Factors affecting soiling .....	330
6.4	Origin of soiling substances .....	330
6.5	Anti-soil fabrics.....	331
6.5.1	Anti-soil yarns.....	331
6.5.2	Anti-soiling treatments of fabrics.....	332
6.5.3	Anti-soil chemicals.....	332
6.6	Cleaning of forming fabrics .....	333
6.6.1	Cleaning during machine run .....	333
6.6.2	Cleaning during shut-down .....	334
6.7	Fabric damage during cleaning .....	334
<b>7</b>	<b>Forming fabrics on paper machine .....</b>	<b>335</b>
7.1	Installation of forming fabric.....	335
7.2	Start-up .....	336
7.3	Follow-up .....	336
7.3.1	Drainage measurement.....	336
7.3.2	Controlling wear .....	338
7.3.3	Bottom side wear .....	338
7.3.4	Paper side wear .....	339
7.3.5	Internal wear.....	340
	References .....	341

# Chapter 9

## Wet pressing

<b>1</b>	<b>Introduction.....</b>	<b>344</b>
<b>2</b>	<b>History and past developments.....</b>	<b>345</b>
<b>3</b>	<b>Fundamentals of wet pressing.....</b>	<b>347</b>
<b>4</b>	<b>Modeling of wet pressing.....</b>	<b>350</b>
<b>5</b>	<b>Water removal from the fibre wall .....</b>	<b>353</b>
<b>6</b>	<b>Wet pressing variables and their effects .....</b>	<b>354</b>
6.1	Types of variable.....	354
6.2	Process variables.....	355
6.2.1	Water removal.....	355
6.2.2	Sheet quality .....	364
6.3	Equipment parameters.....	369
6.3.1	Nip types.....	369
6.3.2	Roll parameters.....	372
6.3.3	Felt parameters.....	373
6.3.4	Press section configuration .....	378
<b>7</b>	<b>Runnability and web transfer.....</b>	<b>379</b>
7.1	Web transfer .....	379
7.2	Open draw .....	380
7.3	Closed transfer .....	382
7.4	Elimination of the open draw.....	383
<b>8</b>	<b>Different types of press section .....</b>	<b>385</b>
8.1	Press sections for printing and writing papers.....	385
8.2	Press sections for packaging and board grades .....	387
<b>9</b>	<b>Innovative pressing/drying techniques .....</b>	<b>389</b>
9.1	Condebelt process .....	390
9.2	Impulse drying .....	390
	References .....	391

# Chapter 10

## Press fabrics

<b>1</b>	<b>Press felts .....</b>	<b>404</b>
1.1	Function.....	404
1.2	Raw materials.....	405
1.2.1	Manufacturing of press felt .....	406
1.2.2	Modern press felt structures .....	408
1.3	Technical properties.....	409
1.3.1	Basis weight .....	409
1.3.2	Thickness .....	409
1.3.3	Stiffness and tensile strength .....	409
1.3.4	Compressibility .....	409
1.3.5	Air permeability and flow resistance.....	411
1.3.6	Surface uniformity.....	412
<b>2</b>	<b>The press felt as a part of the wet pressing process.....</b>	<b>413</b>
2.1	Sheet dewatering.....	413
2.2	Sheet transfer .....	415
2.3	Sheet quality.....	416
2.4	Directions for use .....	416
2.4.1	Installation and start-up .....	416
2.4.2	Guiding .....	417
2.4.3	Cleaning and Conditioning .....	418
2.5	Practical press section monitoring .....	423
2.5.1	Moisture profile meters .....	423
2.5.2	Press felt permeability.....	424
2.5.3	Monitoring of vibration .....	425
2.6	Special applications.....	426
2.6.1	Press felts for impulse drying .....	426
2.6.2	Seamed felts.....	427



<b>3</b>	<b>Shoe press belts .....</b>	<b>427</b>
3.1	Background .....	427
3.2	Shoe press belt construction .....	429
	3.2.1 Nonvented belt designs .....	429
	3.2.2 Vented belt designs .....	431
3.3	Press felt and belt interaction.....	433
3.4	Compound bending on closed end belts .....	433
3.5	Closed loop belt life.....	434
<b>4</b>	<b>Closed transfer and transfer belts .....</b>	<b>435</b>
4.1	Introduction .....	435
4.2	Sheet tension in the open draw.....	435
4.3	Closed draw presses.....	436
4.4	Sheet transfer from press to dryer section .....	437
4.5	Closed draw transfer between the press section and the dryer section.....	438
4.6	Transfer belt concepts.....	439
	4.6.1 Function of a transfer belt .....	439
	4.6.2 Impact on paper properties .....	440
4.7	Transfer belt operation .....	440
4.8	Transfer belt applications .....	441
	References .....	443

# Chapter 11

## Paper machine rolls

<b>1</b>	<b>Introduction.....</b>	<b>446</b>
2	Lead rolls.....	446
2.1	Lead roll dimensioning.....	447
2.2	Lead roll construction materials.....	451
2.3	Lead roll bearings and lubrication.....	452
2.4	Lead roll covers.....	452
2.5	Web spreading rolls.....	453
	2.5.1 Threaded roll.....	453
	2.5.2 Centre-supported roll.....	453
	2.5.3 Curved spreader roll.....	455
<b>3</b>	<b>Suction and forming rolls.....</b>	<b>457</b>
3.1	General.....	457
3.2	Forming rolls.....	457
3.3	Suction Rolls.....	458
	3.3.1 General.....	458
	3.3.2 Suction boxes of the suction roll.....	460
	3.3.3 Suction roll shell.....	461
<b>4</b>	<b>Deflection-compensated rolls.....</b>	<b>463</b>
4.1	Deflection of rolls.....	463
4.2	Deflection compensation.....	464
	4.2.1 Crowning.....	465
	4.2.2 Deflection-compensated rolls.....	466
	4.2.3 Zone-controlled deflection-compensated rolls.....	468
	4.2.4 Dimensioning of deflection-compensated rolls.....	469
<b>5</b>	<b>Centre rolls.....</b>	<b>470</b>
5.1	General.....	470
5.2	Granite roll.....	471
	5.2.1 Centre rolls replacing granite rolls.....	472
<b>6</b>	<b>Grooved and drilled press rolls.....</b>	<b>472</b>
<b>7</b>	<b>Calender rolls.....</b>	<b>473</b>
7.1	Chilled cast-iron rolls.....	473
7.2	Soft calender rolls.....	476

# Chapter 12

## Vacuum systems

<b>1</b>	<b>Introduction to high-vacuum dewatering</b> .....	<b>478</b>
1.1	Economic basis .....	478
1.2	Speed .....	479
1.3	High-vacuum zone in the wire section and dewatering equipment used .....	479
1.3.1	Flatboxes .....	479
1.3.2	Couch roll .....	480
1.3.3	Replacing couch roll .....	480
<b>2</b>	<b>Effect of process variables</b> .....	<b>481</b>
<b>3</b>	<b>Paper and board grades</b> .....	<b>482</b>
<b>4</b>	<b>Modelling of vacuum dewatering</b> .....	<b>482</b>
<b>5</b>	<b>Optimisation of vacuum profiles</b> .....	<b>483</b>
<b>6</b>	<b>Vacuum dewatering curves</b> .....	<b>483</b>
<b>7</b>	<b>An empirical model for vacuum dewatering</b> .....	<b>484</b>
<b>8</b>	<b>Effect of furnish type on dewatering equations</b> .....	<b>486</b>
8.1	Fine paper furnishes .....	486
8.2	Newsprint furnishes .....	487
8.3	SC and LWC paper furnishes .....	488
8.4	Effect of grammage on dewatering curves .....	488
8.5	Effect of temperature on dewatering .....	489
<b>9</b>	<b>Calculation of dewatering profile</b> .....	<b>490</b>
<b>10</b>	<b>A case study</b> .....	<b>490</b>
<b>11</b>	<b>Closing remarks</b> .....	<b>491</b>
	References .....	492

# Chapter 13

## Vacuum pumps

<b>1</b>	<b>Types .....</b>	<b>494</b>
1.1	Suction points and vacuum systems .....	496
<b>2</b>	<b>Vacuum piping .....</b>	<b>498</b>
2.1	Air flow velocities.....	498
2.2	Piping .....	499
2.3	Valves .....	500
2.4	Water separators .....	500
2.5	Seal pits for water separators .....	500
2.6	Header pipes for liquid ring pumps.....	501
2.7	Sealing water for liquid ring pumps.....	501
<b>3</b>	<b>Noise.....</b>	<b>504</b>
3.1	Vacuum pump noise levels.....	504
3.2	Noise abatement .....	504
<b>4</b>	<b>Instrumentation .....</b>	<b>508</b>
4.1	Main measurements for vacuum control .....	508
4.2	Vacuum level control.....	508
4.3	Sealing water for liquid ring pumps.....	508
4.4	Restriction of turbo blower air amount .....	509
<b>5</b>	<b>Electrical .....</b>	<b>509</b>
	References .....	510