

676.24
676.001

HANDBOOK OF PAPER SCIENCE

The Science and Technology of Papermaking, Paper Properties and
Paper Usage

VOLUME I

THE RAW MATERIALS AND PROCESSING OF PAPERMAKING

Edited by

H.F. RANCE

Rance Consulting, Bridge House, Castle Comb, Wiltshire, England
Former Director of Wiggins Teape Ltd., in charge of Research and Development



ELSEVIER SCIENTIFIC PUBLISHING COMPANY
Amsterdam — Oxford — New York 1980

ELSEVIER SCIENTIFIC PUBLISHING COMPANY
335 Jan van Galenstraat
P.O. Box 211, 1000 AE Amsterdam, The Netherlands

Distributors for the United States and Canada:

ELSEVIER/NORTH-HOLLAND INC.
52, Vanderbilt Avenue
New York, N.Y. 10017

ISBN: 0-444-41778-8 (Vol. 1).
ISBN: 0-444-41779-6 (Series)

© Elsevier Scientific Publishing Company, 1980

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the publisher, Elsevier Scientific Publishing Company, P.O. Box 330, 1000 AH Amsterdam, The Netherlands

Printed in The Netherlands

115185

CONTENTS

Preface	v
Chapter 1. Cellulose-water interactions, by H. Corte	1
1.1 Introduction	1
1.2 Cellulose and the structure of water	1
1.3 Cellulose-water interactions in fibre suspensions	12
1.3.1 Beating	14
1.3.2 Flocculation	19
1.3.3 Drainage	24
1.4 Cellulose-water interactions during consolidation	29
1.4.1 Pressing	29
1.4.1 Drying	32
1.4.3 Bonding	44
1.5 Cellulose-water interactions in the use of paper	52
1.5.1 Usage properties involving water	52
1.5.2 Other usage properties	65
1.5.3 How to reduce adverse effects of water	72
1.5.4 Recycling	77
1.6 Concluding remarks	81
1.7 References	81
Chapter 2. The fibrous raw materials of paper, by H.W. Emerton	91
2.1 Introduction	91
2.2 Wood — sources	92
2.3 Wood — as trees	94
2.4 Wood — gross structure	99
2.5 Wood — chemical nature	106
2.5.1 Cellulose	106
2.5.2 Hemicellulose	111
2.5.3 Lignin	114
2.5.4 Minor constituents	116
2.6 Wood — fine structure	117
2.6.1 Softwood tracheids	117

2.6.2	Parenchyma cells	122
2.6.3	Hardwood fibres	124
2.6.4	Hardwood vessel elements	125
2.7	Wood — reaction wood	126
2.7.1	Compression wood	127
2.7.2	Tension wood	127
2.8	Other papermaking fibres	129
2.8.1	Seed hairs	129
2.8.2	Bast fibres	131
2.8.3	Leaf fibres	133
2.8.4	Secondary fibre	134
2.9	Non-fibrous raw materials	135
2.9.1	Internal sizes	135
2.9.2	Adhesives	136
2.9.3	Fillers and loadings	136
2.9.4	Other materials	137
2.10	References	137
Chapter 3. Preparation of pulp fibres for papermaking, by H.W. Emerton		139
3.1	Introduction	139
3.2	The role of water	143
3.3	The role of the shear field	146
3.4	Disruption of the outer layers of the fibre	146
3.5	Swelling, flexing and internal fibrillation	148
3.6	Increased flexibility and plasticity	151
3.7	External fibrillation	153
3.8	Partial solvation	155
3.9	Removal of water	157
3.10	Bonding	159
3.11	Fibre shortening	161
3.12	Packing effect	162
3.13	Conclusion	162
3.14	References	163
Chapter 4. Forming the web of paper, by B. Radvan		165
4.1	Introduction	165
4.2	Forming the web as a process of filtration	166
4.3	Forming the web as a structure building process	174
4.3.1	Gross departure from uniformity in plane	175
4.3.2	Small-scale departures from uniformity of the web	182
4.3.3	Orientation of fibres in plane	197
4.3.4	Orientation of fibres out of plane	200
4.3.5	Distribution of loadings and fines in depth	203
4.4	References	204

Chapter 5. Consolidation of the paper web, by H.F. Rance	209
5.1 Introduction: the meaning, nature and purpose of consolidation . .	209
5.1.1 Meaning of consolidation	209
5.1.2 Nature of consolidation	210
5.1.3 Purpose and desirability of consolidation	212
5.1.4 General comments on presentation of Chapter 5	213
5.2 General relations between fibre treatment and consolidation	214
5.3 The influence of wet end forming on consolidation	218
5.4 Consolidation and water removal by wet pressing	219
5.4.1 Historic and general background	219
5.4.2 Early speculation and experiment	221
5.4.3 Formulation of broad concepts on dynamics of wet pressing	227
5.4.4 Growing doubts regarding dynamics of wet pressing	234
5.4.5 Critical comments and a return to basic considerations of the dynamics of wet pressing	239
5.4.6 Consolidating effects of wet pressing	244
5.5 The role of surface tension in consolidation	249
5.6 Consolidation in the dryer section of the papermachine	256
5.7 Transition from consolidation induced by surface tension to con- solidation induced by bonding between cellulose surfaces	258
5.8 Hydrogen bonding: the final act of wet web consolidation	277
5.9 Additional consolidation processes on the papermachine	279
5.9.1 Planar compaction	280
5.9.2 Calendering	283
5.10 References	288
Subject index	292