SECOND AND ENLARGED EDITION.

THE PAPERMAKERS' POCKET BOOK.

SPECIALLY COMPILED FOR
PAPER MILL OPERATIVES, ENGINEERS,
CHEMISTS, AND OFFICE OFFICIALS.

By JAMES BEVERIDGE.

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PREFACE TO FIRST EDITION.

THIS book has been compiled with a view to place before Paper-Mill Workers generally concise information relating to the Engineering, Chemical, and other departments of Paper Mills.

The author in his daily work has long felt the need of such a collection of data as is here given, and many years ago began to collect such items as were useful, with a view to publication. The present attempt to supply what is most useful is somewhat imperfect, owing partly to the character of the work itself and the wide range of subject which it covers; but the author hopes to bring it up in the course of time to the standard of other works of a similar class. Errors have doubtless crept into the text, and the author will thank any readers who may point them out or offer suggestions on the work itself for incorporation in future editions.

The author desires to thank those friends, too numerous to name individually, for the assistance they have rendered him in revising the text, &c.

LONDON, *March*, 1901.

PREFACE TO SECOND EDITION.

THE fact that the first edition has long been exhausted has induced the Author to prepare this, the second edition, on a larger scale with increased care. The book in its present form contains much new matter of a technical character, especially that relating to the preparation of paper-making fibres from wood and other raw plants by the sulphite, soda, and sulphate processes. That part dealing with the Soda Recovery and the preparation and composition of the Soda lyes has been greatly amplified.

A new chapter has been added on the subject of loadings and their properties, &c.

Special care has been devoted to the technical data culled from different sources, and only those items have been given which have been found to be reliable. It is hoped by the Author that the new data and other information will add to the value and usefulness of the book.

January, 1911.

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CHAPTER I.

WEIGHTS AND MEASURES, WITH METRICAL EQUIVALENTS.

Avoirdupois Weight.

16 drams	... =	1 ounce	=	28·3493 grammes.
16 ounces ...	... =	1 lb.	=	453·59 ,,
28 lbs ...	... =	1 qr. cwt.	=	12,700·00 ,,
112 ,, ...	... =	1 cwt.	=	50,802·38 ,,
20 cwts. ...	... =	1 ton	=	1,016,047·50 ,,

27·34 grains = 1 dram. 7,000 grains = 1 lb.
437½ grains = 1 oz.

Troy Weight.

24 grains	=	1 dwt.	=	1·555 grammes.
20 dwts.	=	1 oz.	=	31·103 ,,
12 ozs.	=	1 lb.	=	373·242 ,,

5,760 grains = 1 lb. troy. 480 grains = 1 oz. troy.

Apothecaries' Weight.

20 minims or grains	= 1 scruple.
3 scruples	= 1 dram.
8 drams	= 1 ounce.
12 ounces	= 1 lb.

Liquid Measure.

4 gills	=	1 pint	=	0·28394 litres.
2 pints	=	1 quart	=	1·13575 ,,
4 quarts	=	1 gallon	=	4·543 ,,

1 imperial gallon = 277·463 cubic inches = 10 lbs. of water @ 62° Fah.

1 litre = 7·04 gills = 1·76 pints = 0·88 quart = 0·22 gallon

Wine Measure.

2 pints	= 1 quart.
4 quarts	= 1 gallon.
42 gallons	= 1 tierce.
1½ tierces	= 1 hogshead.
1⅓ hogsheads	= 1 puncheon.
1½ puncheons	= 1 pipe.
2 pipes	= 1 tun.

Ale and Beer Measure.

2	pints	= 1	quart.
4	quarts	= 1	gallon.
9	gallons...	= 1	firkin.
2	firkins	= 1	kilderkin.
2	kilderkins	= 1	barrel.
$1\frac{1}{2}$	barrels	= 1	hogshead.
$1\frac{1}{3}$	hogsheads	= 1	puncheon.
$1\frac{1}{2}$	puncheons	= 1	butt.

Measure of Capacity (Dry Measure).

8	pints	= 1	gallon.
2	gallons	= 1	peck.
4	pecks	= 1	bushel.
8	bushels	= 1	quarter.
5	quarters	= 1	wey.
2	weys	= 1	last.

One cubic foot of water at 62° Fah. weighs = 62·355 lbs., and contains 6·2355 gallons, and nearly 1,000 ounces avoirdupois.

Long Measure.

12	inches	= 1 foot	=	0·3048 metres.
3	feet	= 1 yard	=	0·9144 „
2	yards (or 6 feet)	= 1 fathom	=	1·8267 „
$2\frac{3}{4}$	fathoms ...	= 1 pole	=	5·0291 „
40	poles	= 1 furlong	=	201·16 „
8	furlongs ...	= 1 mile	=	1,609·315 „

1 statute mile = 1,760 yards = 880 fathoms = 320 poles = 8 furlongs.

1 nautical mile or knot = 6,080 feet.

1 cable length = 120 fathoms. 7·92 inches = 1 link.

1 chain = 100 links = 66 feet = 22 yards.

1 metre = 3·2809 feet = 39·37 inches.

Square Measure.

144	parts	= 1	square inch.
144	square inches	= 1	„ foot.
9	„ feet	= 1	„ yard.
$272\frac{1}{4}$	„ „	= 1	„ rod or pole.
40	„ rods	= 1	„ rood.
4	„ roods		
160	„ rods		
4,840	„ yards ...	= 1	acre.
43,560	„ feet		
10	„ chains		
640	acres	= 1	square mile.

Solid or Cubic Measure.

1,728	cubic inches	... ...	= 1 cubic foot.
27	,, feet	... ...	= 1 ,, yard.
40	,, ,, of rough or		= 1 ton or load.
50	,, ,, ,, hewn timber		
42	,, ,, ,, timber	...	= 1 shipping ton.
108	,, ,,	... ...	= 1 stack of wood.
128	,, ,,	... ...	= 1 cord ,, ,,
216	,, ,,	... ...	= 1 cubic fathom of wood.
165	,, ,,	... ...	= 1 St. Petersburg Standard of sawn timber.

1 cubic yard = 0·764513 cubic metre.
1 cubic metre = 35·31658 cubic feet.

Coal.

112	lbs.	= 1 cwt.
2	cwts.	= 1 sack.
10	sacks	= 1 ton.
21	tons 4 cwts.	= 1 barge or keel.
20	keels or 424 tons	= 1 ship load.
140	cwts. or 7 tons	= 1 room.

Coke.

4	bushels	= 1 sack.
12	sacks	= 1 chaldron.
21	chaldrons	= 1 score.

MENSURATION OF SURFACES AND CAPACITIES.

Area of a square = side ^{2}

,, ,, a rectangle, rhombus or rhomboid = side × perpendicular height.

,, ,, a triangle = half the side × perpendicular height.

,, ,, a circle = 3·141593 × radius ^{2}

,, ,, an ellipse = 3·141593 × major semi-axis × minor semi-axis.

Surface of a cube = 6 × edge ^{2}

,, ,, a sphere = 12·566370 × radius ^{2}

,, ,, a cylinder = 6·283185 × radius of base × sum of height and radius of base.

,, ,, a spherical segment = 6·283185 × height × radius of circular base.

Volume of a cube = edge ^{3}

,, ,, a sphere = $\frac{4}{3}$ × 3·141593 × radius ^{3}

,, ,, a cylinder = 3·141593 × height × radius ^{2}

,, ,, a prism = base area × height.

,, ,, a cone or pyramid = $\frac{1}{3}$ × base area × height.

WAGES TABLE.—Rate per Hour in Pence.

Hours.	1d.			1¼d.			1½d.			1¾d.			2d.			2¼d.			2½d.			2¾d.			3d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
½	0	0	0½	0	0	0½	0	0	0¾	0	0	0¾	0	0	1	0	0	1	0	0	1¼	0	0	1¼	0	0	1½
¾	0	0	0¾	0	0	0¾	0	0	1	0	0	1¼	0	0	1½	0	0	1½	0	0	1¾	0	0	2	0	0	2¼
1	0	0	1	0	0	1¼	0	0	1½	0	0	1¾	0	0	2	0	0	2¼	0	0	2½	0	0	2¾	0	0	3
2	0	0	2	0	0	2½	0	0	3	0	0	3½	0	0	4	0	0	4½	0	0	5	0	0	5½	0	0	6
3	0	0	3	0	0	3¾	0	0	4½	0	0	5¼	0	0	6	0	0	6¾	0	0	7½	0	0	8¼	0	0	9
4	0	0	4	0	0	5	0	0	6	0	0	7	0	0	8	0	0	9	0	0	10	0	0	11	0	1	0
5	0	0	5	0	0	6¼	0	0	7½	0	0	8¾	0	0	10	0	0	11¼	0	1	0½	0	1	1¾	0	1	3
6	0	0	6	0	0	7½	0	0	9	0	0	10½	0	1	0	0	1	1½	0	1	3	0	1	4½	0	1	6
7	0	0	7	0	0	8¾	0	0	10½	0	1	0¼	0	1	2	0	1	3¾	0	1	5½	0	1	7¼	0	1	9
8	0	0	8	0	0	10	0	1	0	0	1	2	0	1	4	0	1	6	0	1	8	0	1	10	0	2	0
9	0	0	9	0	0	11¼	0	1	1½	0	1	3¾	0	1	6	0	1	8¼	0	1	10½	0	2	0¾	0	2	3
10	0	0	10	0	1	0½	0	1	3	0	1	5½	0	1	8	0	1	10½	0	2	1	0	2	3½	0	2	6
11	0	0	11	0	1	1¾	0	1	4½	0	1	7¼	0	1	10	0	2	0¾	0	2	3½	0	2	6¼	0	2	9
12	0	1	0	0	1	3	0	1	6	0	1	9	0	2	0	0	2	3	0	2	6	0	2	9	0	3	0
13	0	1	1	0	1	4¼	0	1	7½	0	1	10¾	0	2	2	0	2	5¼	0	2	8½	0	2	11¾	0	3	3
14	0	1	2	0	1	5½	0	1	9	0	2	0½	0	2	4	0	2	7½	0	2	11	0	3	2½	0	3	6
15	0	1	3	0	1	6¾	0	1	10½	0	2	2¼	0	2	6	0	2	9¾	0	3	1½	0	3	5¼	0	3	9
16	0	1	4	0	1	8	0	2	0	0	2	4	0	2	8	0	3	0	0	3	4	0	3	8	0	4	0
17	0	1	5	0	1	9¼	0	2	1½	0	2	5¾	0	2	10	0	3	2¼	0	3	6½	0	3	10¾	0	4	3
18	0	1	6	0	1	10½	0	2	3	0	2	7½	0	3	0	0	3	4½	0	3	9	0	4	1½	0	4	6
19	0	1	7	0	1	11¾	0	2	4½	0	2	9¼	0	3	2	0	3	6¾	0	3	11½	0	4	4¼	0	4	9
20	0	1	8	0	2	1	0	2	6	0	2	11	0	3	4	0	3	9	0	4	2	0	4	7	0	5	0
21	0	1	9	0	2	2¼	0	2	7½	0	3	0¾	0	3	6	0	3	11¼	0	4	4½	0	4	9¾	0	5	3
22	0	1	10	0	2	3½	0	2	9	0	3	2½	0	3	8	0	4	1½	0	4	7	0	5	0½	0	5	6
23	0	1	11	0	2	4¾	0	2	10½	0	3	4¼	0	3	10	0	4	3¾	0	4	9½	0	5	3¼	0	5	9

WAGES TABLE.—Rate per Hour in Pence.

Hours.	1d.			1¼d.			1½d.			1¾d.			2d.			2¼d.			2½d.			2¾d.			3d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s	d.
24	0	2	0	0	2	6	0	3	0	0	3	6	0	4	0	0	4	6	0	5	0	0	5	6	0	6	0
25	0	2	1	0	2	7¼	0	3	1½	0	3	7¾	0	4	2	0	4	8¼	0	5	2½	0	5	8¾	0	6	3
26	0	2	2	0	2	8½	0	3	3	0	3	9½	0	4	4	0	4	10½	0	5	5	0	5	11½	0	6	6
27	0	2	3	0	2	9¾	0	3	4½	0	3	11¼	0	4	6	0	5	0¾	0	5	7½	0	6	2¼	0	6	9
28	0	2	4	0	2	11	0	3	6	0	4	1	0	4	8	0	5	3	0	5	10	0	6	5	0	7	0
29	0	2	5	0	3	0¼	0	3	7½	0	4	2¾	0	4	10	0	5	5¼	0	6	0½	0	6	7¾	0	7	3
30	0	2	6	0	3	1½	0	3	9	0	4	4½	0	5	0	0	5	7½	0	6	3	0	6	10½	0	7	6
31	0	2	7	0	3	2¾	0	3	10½	0	4	6¼	0	5	2	0	5	9¾	0	6	5½	0	7	1¼	0	7	9
32	0	2	8	0	3	4	0	4	0	0	4	8	0	5	4	0	6	0	0	6	8	0	7	4	0	8	0
33	0	2	9	0	3	5¼	0	4	1½	0	4	9¾	0	5	6	0	6	2¼	0	6	10½	0	7	6¾	0	8	3
34	0	2	10	0	3	6½	0	4	3	0	4	11½	0	5	8	0	6	4½	0	7	1	0	7	9½	0	8	6
35	0	2	11	0	3	7¾	0	4	4½	0	5	1¼	0	5	10	0	6	6¾	0	7	3½	0	8	0¼	0	8	9
36	0	3	0	0	3	9	0	4	6	0	5	3	0	6	0	0	6	9	0	7	6	0	8	3	0	9	0
37	0	3	1	0	3	10¼	0	4	7½	0	5	4¾	0	6	2	0	6	11¼	0	7	8½	0	8	5¾	0	9	3
38	0	3	2	0	3	11½	0	4	9	0	5	6½	0	6	4	0	7	1½	0	7	11	0	8	8½	0	9	6
39	0	3	3	0	4	0¾	0	4	10½	0	5	8¼	0	6	6	0	7	3¾	0	8	1½	0	8	11¼	0	9	9
40	0	3	4	0	4	2	0	5	0	0	5	10	0	6	8	0	7	6	0	8	4	0	9	2	0	10	0
41	0	3	5	0	4	3¼	0	5	1½	0	5	11¾	0	6	10	0	7	8¼	0	8	6½	0	9	4¾	0	10	3
42	0	3	6	0	4	4½	0	5	3	0	6	1½	0	7	0	0	7	10½	0	8	9	0	9	7½	0	10	6
43	0	3	7	0	4	5¾	0	5	4½	0	6	3¼	0	7	2	0	8	0¾	0	8	11½	0	9	10¼	0	10	9
44	0	3	8	0	4	7	0	5	6	0	6	5	0	7	4	0	8	3	0	9	2	0	10	1	0	11	0
45	0	3	9	0	4	8¼	0	5	7½	0	6	6¾	0	7	6	0	8	5¼	0	9	4½	0	10	3¾	0	11	3
46	0	3	10	0	4	9½	0	5	9	0	6	8½	0	7	8	0	8	7½	0	9	7	0	10	6½	0	11	6
47	0	3	11	0	4	10¾	0	5	10½	0	6	10¼	0	7	10	0	8	9¾	0	9	9½	0	10	9¼	0	11	9
48	0	4	0	0	5	0	0	6	0	0	7	0	0	8	0	0	9	0	0	10	0	0	11	0	0	12	0

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Hours.	1d.			1¼d.			1½d.			1¾d.			2d.			2¼d.			2½d.			2¾d.			3d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
49	0	4	1	0	5	1¼	0	6	1½	0	7	1¾	0	8	2	0	9	2¼	0	10	2½	0	11	2¾	0	12	3
50	0	4	2	0	5	2½	0	6	3	0	7	3½	0	8	4	0	9	4½	0	10	5	0	11	5½	0	12	6
51	0	4	3	0	5	3¾	0	6	4½	0	7	5¼	0	8	6	0	9	6¾	0	10	7½	0	11	8¼	0	12	9
52	0	4	4	0	5	5	0	6	6	0	7	7	0	8	8	0	9	9	0	10	10	0	11	11	0	13	0
53	0	4	5	0	5	6¼	0	6	7½	0	7	8¾	0	8	10	0	9	11¼	0	11	0½	0	12	1¾	0	13	3
54	0	4	6	0	5	7½	0	6	9	0	7	10½	0	9	0	0	10	1½	0	11	3	0	12	4½	0	13	6
55	0	4	7	0	5	8¾	0	6	10½	0	8	0¼	0	9	2	0	10	3¾	0	11	5½	0	12	7¼	0	13	9
56	0	4	8	0	5	10	0	7	0	0	8	2	0	9	4	0	10	6	0	11	8	0	12	10	0	14	0
57	0	4	9	0	5	11¼	0	7	1½	0	8	3¾	0	9	6	0	10	8¼	0	11	10½	0	13	0¾	0	14	3
58	0	4	10	0	6	0½	0	7	3	0	8	5½	0	9	8	0	10	10½	0	12	1	0	13	3½	0	14	6
59	0	4	11	0	6	1¾	0	7	4½	0	8	7¼	0	9	10	0	11	0¾	0	12	3½	0	13	6¼	0	14	9
60	0	5	0	0	6	3	0	7	6	0	8	9	0	10	0	0	11	3	0	12	6	0	13	9	0	15	0
61	0	5	1	0	6	4¼	0	7	7½	0	8	10¾	0	10	2	0	11	5¼	0	12	8½	0	13	11¾	0	15	3
62	0	5	2	0	6	5½	0	7	9	0	9	0½	0	10	4	0	11	7½	0	12	11	0	14	2½	0	15	6
63	0	5	3	0	6	6¾	0	7	10½	0	9	2¼	0	10	6	0	11	9¾	0	13	1½	0	14	5¼	0	15	9
64	0	5	4	0	6	8	0	8	0	0	9	4	0	10	8	0	12	0	0	13	4	0	14	8	0	16	0
65	0	5	5	0	6	9¼	0	8	1½	0	9	5¾	0	10	10	0	12	2¼	0	13	6½	0	14	10¾	0	16	3
66	0	5	6	0	6	10½	0	8	3	0	9	7½	0	11	0	0	12	4½	0	13	9	0	15	1½	0	16	6
67	0	5	7	0	6	11¾	0	8	4½	0	9	9¼	0	11	2	0	12	6¾	0	13	11½	0	15	4¼	0	16	9
68	0	5	8	0	7	1	0	8	6	0	9	11	0	11	4	0	12	9	0	14	2	0	15	7	0	17	0
69	0	5	9	0	7	2¼	0	8	7½	0	10	0¾	0	11	6	0	12	11¼	0	14	4½	0	15	9¾	0	17	3
70	0	5	10	0	7	3½	0	8	9	0	10	2	0	11	8	0	13	1½	0	14	7	0	16	0½	0	17	6
71	0	5	11	0	7	4¾	0	8	10½	0	10	4¼	0	11	10	0	13	3¾	0	14	9½	0	16	3¼	0	17	9
72	0	6	0	0	7	6	0	9	0	0	10	6	0	12	0	0	13	6	0	15	0	0	16	6	0	18	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	3¼d. £	3¼d. s.	3¼d. d.	3½d. £	3½d. s.	3½d. d.	3¾d. £	3¾d. s.	3¾d. d.	4d. £	4d. s.	4d. d.	4¼d. £	4¼d. s.	4¼d. d.	4½d. £	4½d. s.	4½d. d.	4¾d. £	4¾d. s.	4¾d. d.	5d. £	5d. s.	5d. d.	5¼d. £	5¼d. s.	5¼d. d.
½	0	0	1½	0	0	1¾	0	0	1¾	0	0	2	0	0	2	0	0	2¼	0	0	2¼	0	0	2½	0	0	2½
¾	0	0	2¼	0	0	2½	0	0	2¾	0	0	3	0	0	3	0	0	3¼	0	0	3½	0	0	3¾	0	0	3¾
1	0	0	3¼	0	0	3½	0	0	3¾	0	0	4	0	0	4¼	0	0	4½	0	0	4¾	0	0	5	0	0	5¼
2	0	0	6½	0	0	7	0	0	7½	0	0	8	0	0	8½	0	0	9	0	0	9½	0	0	10	0	0	10½
3	0	0	9¾	0	0	10½	0	0	11¼	0	1	0	0	1	0¾	0	1	1½	0	1	2¼	0	1	3	0	1	3¾
4	0	1	1	0	1	2	0	1	3	0	1	4	0	1	5	0	1	6	0	1	7	0	1	8	0	1	9
5	0	1	4¼	0	1	5½	0	1	6¾	0	1	8	0	1	9¼	0	1	10½	0	1	11¾	0	2	1	0	2	2¼
6	0	1	7½	0	1	9	0	1	10½	0	2	0	0	2	1½	0	2	3	0	2	4½	0	2	6	0	2	7½
7	0	1	10¾	0	2	0½	0	2	2¼	0	2	4	0	2	5¾	0	2	7½	0	2	9¼	0	2	11	0	3	0¾
8	0	2	2	0	2	4	0	2	6	0	2	8	0	2	10	0	3	0	0	3	2	0	3	4	0	3	6
9	0	2	5¼	0	2	7½	0	2	9¾	0	3	0	0	3	2¼	0	3	4½	0	3	6¾	0	3	9	0	3	11¼
10	0	2	8½	0	2	11	0	3	1½	0	3	4	0	3	6½	0	3	9	0	3	11½	0	4	2	0	4	4½
11	0	2	11¾	0	3	2½	0	3	5¼	0	3	8	0	3	10¾	0	4	1½	0	4	4¼	0	4	7	0	4	9¾
12	0	3	3	0	3	6	0	3	9	0	4	0	0	4	3	0	4	6	0	4	9	0	5	0	0	5	3
13	0	3	6¼	0	3	9½	0	4	0¾	0	4	4	0	4	7¼	0	4	10½	0	5	1¾	0	5	5	0	5	8¼
14	0	3	9½	0	4	1	0	4	4½	0	4	8	0	4	11½	0	5	3	0	5	6½	0	5	10	0	6	1½
15	0	4	0¾	0	4	4½	0	4	8¼	0	5	0	0	5	3¾	0	5	7½	0	5	11¼	0	6	3	0	6	6¾
16	0	4	4	0	4	8	0	5	0	0	5	4	0	5	8	0	6	0	0	6	4	0	6	8	0	7	0
17	0	4	7¼	0	4	11½	0	5	3¾	0	5	8	0	6	0¼	0	6	4½	0	6	8¾	0	7	1	0	7	5¼
18	0	4	10½	0	5	3	0	5	7½	0	6	0	0	6	4½	0	6	9	0	7	1½	0	7	6	0	7	10½
19	0	5	1¾	0	5	6½	0	5	11¼	0	6	4	0	6	8¾	0	7	1½	0	7	6¼	0	7	11	0	8	3¾
20	0	5	5	0	5	10	0	6	3	0	6	8	0	7	1	0	7	6	0	7	11	0	8	4	0	8	9
21	0	5	8¼	0	6	1½	0	6	6¾	0	7	0	0	7	5¼	0	7	10½	0	8	3¾	0	8	9	0	9	2¼
22	0	5	11½	0	6	5	0	6	10½	0	7	4	0	7	9½	0	8	3	0	8	8½	0	9	2	0	9	7½
23	0	6	2¾	0	6	8½	0	7	2¼	0	7	8	0	8	1¾	0	8	7½	0	9	1¼	0	9	7	0	10	0¾

WAGES TABLE.—Rate per Hour in Pence.

Hours.	3¼d.			3½d.			3¾d.			4d.			4¼d.			4½d.			4¾d.			5d.			5¼d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
24	0	6	6	0	7	0	0	7	6	0	8	0	0	8	6	0	9	0	0	9	6	0	10	0	0	10	6
25	0	6	9¼	0	7	3½	0	7	9¾	0	8	4	0	8	10¼	0	9	4½	0	9	10¾	0	10	5	0	10	11¼
26	0	7	0½	0	7	7	0	8	1½	0	8	8	0	9	2½	0	9	9	0	10	3½	0	10	10	0	11	4½
27	0	7	3¾	0	7	10½	0	8	5¼	0	9	0	0	9	6¾	0	10	1½	0	10	8¼	0	11	3	0	11	9¾
28	0	7	7	0	8	2	0	8	9	0	9	4	0	9	11	0	10	6	0	11	1	0	11	8	0	12	3
29	0	7	10¼	0	8	5½	0	9	0¾	0	9	8	0	10	3¼	0	10	10½	0	11	5¾	0	12	1	0	12	8¼
30	0	8	1½	0	8	9	0	9	4½	0	10	0	0	10	7½	0	11	3	0	11	10½	0	12	6	0	13	1½
31	0	8	4¾	0	9	0½	0	9	8¼	0	10	4	0	10	11¾	0	11	7½	0	12	3¼	0	12	11	0	13	6¾
32	0	8	8	0	9	4	0	10	0	0	10	8	0	11	4	0	12	0	0	12	8	0	13	4	0	14	0
33	0	8	11¼	0	9	7½	0	10	3¾	0	11	0	0	11	8¼	0	12	4½	0	13	0¾	0	13	9	0	14	5¼
34	0	9	2½	0	9	11	0	10	7½	0	11	4	0	12	0½	0	12	9	0	13	5½	0	14	2	0	14	10½
35	0	9	5¾	0	10	2½	0	10	11¼	0	11	8	0	12	4¾	0	13	1½	0	13	10¼	0	14	7	0	15	3¾
36	0	9	9	0	10	6	0	11	3	0	12	0	0	12	9	0	13	6	0	14	3	0	15	0	0	15	9
37	0	10	0¼	0	10	9½	0	11	6¾	0	12	4	0	13	1¼	0	13	10½	0	14	7¾	0	15	5	0	16	2¼
38	0	10	3½	0	11	1	0	11	10½	0	12	8	0	13	5½	0	14	3	0	15	0½	0	15	10	0	16	7½
39	0	10	6¾	0	11	4½	0	12	2¼	0	13	0	0	13	9¾	0	14	7½	0	15	5¼	0	16	3	0	17	0¾
40	0	10	10	0	11	8	0	12	6	0	13	4	0	14	2	0	15	0	0	15	10	0	16	8	0	17	6
41	0	11	1¼	0	11	11½	0	12	9¾	0	13	8	0	14	6¼	0	15	4½	0	16	2¾	0	17	1	0	17	11¼
42	0	11	4½	0	12	3	0	13	1½	0	14	0	0	14	10½	0	15	9	0	16	7½	0	17	6	0	18	4½
43	0	11	7¾	0	12	6½	0	13	5¼	0	14	4	0	15	2¾	0	16	1½	0	17	0¼	0	17	11	0	18	9¾
44	0	11	11	0	12	10	0	13	9	0	14	8	0	15	7	0	16	6	0	17	5	0	18	4	0	19	3
45	0	12	2¼	0	13	1½	0	14	0¾	0	15	0	0	15	11¼	0	16	10½	0	17	9¾	0	18	9	0	19	8¼
46	0	12	5½	0	13	5	0	14	4½	0	15	4	0	16	3½	0	17	3	0	18	2½	0	19	2	1	0	1½
47	0	12	8¾	0	13	8½	0	14	8¼	0	15	8	0	16	7¾	0	17	7½	0	18	7¼	0	19	7	1	0	6¾
48	0	13	0	0	14	0	0	15	0	0	16	0	0	17	0	0	18	0	0	19	0	1	0	0	1	1	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	3¼d.			3½d.			3¾d.			4d.			4¼d.			4½d.			4¾d.			5d.			5¼d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
49	0	13	3¼	0	14	3½	0	15	3¾	0	16	4	0	17	4¼	0	18	4½	0	19	4¾	1	0	5	1	1	5¼
50	0	13	6½	0	14	7	0	15	7½	0	16	8	0	17	8½	0	18	9	0	19	9½	1	0	10	1	1	10½
51	0	13	9¾	0	14	10½	0	15	11¼	0	17	0	0	18	0¾	0	19	1½	1	0	2¼	1	1	3	1	2	3¾
52	0	14	1	0	15	2	0	16	3	0	17	4	0	18	5	0	19	6	1	0	7	1	1	8	1	2	9
53	0	14	4¼	0	15	5½	0	16	6¾	0	17	8	0	18	9¼	0	19	10½	1	0	11¾	1	2	1	1	3	2¼
54	0	14	7½	0	15	9	0	16	10½	0	18	0	0	19	1½	1	0	3	1	1	4½	1	2	6	1	3	7½
55	0	14	10¾	0	16	0½	0	17	2¼	0	18	4	0	19	5¾	1	0	7½	1	1	9¼	1	2	11	1	4	0¾
56	0	15	2	0	16	4	0	17	6	0	18	8	0	19	10	1	1	0	1	2	2	1	3	4	1	4	6
57	0	15	5¼	0	16	7½	0	17	9¾	0	19	0	1	0	2¼	1	1	4½	1	2	6¾	1	3	9	1	4	11¼
58	0	15	8½	0	16	11	0	18	1½	0	19	4	1	0	6½	1	1	9	1	2	11½	1	4	2	1	5	4½
59	0	15	11¾	0	17	2½	0	18	5¼	0	19	8	1	0	10¾	1	2	1½	1	3	4¼	1	4	7	1	5	9¾
60	0	16	3	0	17	6	0	18	9	1	0	0	1	1	3	1	2	6	1	3	9	1	5	0	1	6	3
61	0	16	6¼	0	17	9½	0	19	0¾	1	0	4	1	1	7¼	1	2	10½	1	4	1¾	1	5	5	1	6	8¼
62	0	16	9½	0	18	1	0	19	4½	1	0	8	1	1	11½	1	3	3	1	4	6½	1	5	10	1	7	1½
63	0	17	0¾	0	18	4½	0	19	8¼	1	1	0	1	2	3¾	1	3	7½	1	4	11¼	1	6	3	1	7	6¾
64	0	17	4	0	18	8	1	0	0	1	1	4	1	2	8	1	4	0	1	5	4	1	6	8	1	8	0
65	0	17	7¼	0	18	11½	1	0	3¾	1	1	8	1	3	0¼	1	4	4½	1	5	8¾	1	7	1	1	8	5¼
66	0	17	10½	0	19	3	1	0	7½	1	2	0	1	3	4½	1	4	9	1	6	1½	1	7	6	1	8	10½
67	0	18	1¾	0	19	6½	1	0	11¼	1	2	4	1	3	8¾	1	5	1½	1	6	6¼	1	7	11	1	9	3¾
68	0	18	5	0	19	10	1	1	3	1	2	8	1	4	1	1	5	6	1	6	11	1	8	4	1	9	9
69	0	18	8¼	1	0	1½	1	1	6¾	1	3	0	1	4	5¼	1	5	10½	1	7	3¾	1	8	9	1	10	2¼
70	0	18	11½	1	0	5	1	1	10½	1	3	4	1	4	9½	1	6	3	1	7	8½	1	9	2	1	10	7½
71	0	19	2¾	1	0	8½	1	2	2¼	1	3	8	1	5	1¾	1	6	7½	1	8	1¼	1	9	7	1	11	0¾
72	0	19	6	1	1	0	1	2	6	1	4	0	1	5	6	1	7	0	1	8	6	1	10	0	1	11	6

WAGES TABLE.—Rate per Hour in Pence.

Hours.	5½d.			5¾d.			6d.			6¼d.			6½d.			6¾d.			7d.			7¼d.			7½d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
½	0	0	2¾	0	0	2¾	0	0	3	0	0	3	0	0	3¼	0	0	3¼	0	0	3½	0	0	3½	0	0	3¾
¾	0	0	4	0	0	4¼	0	0	4½	0	0	4½	0	0	4¾	0	0	5	0	0	5¼	0	0	5¼	0	0	5½
1	0	0	5½	0	0	5¾	0	0	6	0	0	6¼	0	0	6½	0	0	6¾	0	0	7	0	0	7¼	0	0	7½
2	0	0	11	0	0	11½	0	1	0	0	1	0½	0	1	1	0	1	1½	0	1	2	0	1	2½	0	1	3
3	0	1	4½	0	1	5¼	0	1	6	0	1	6¾	0	1	7½	0	1	8¼	0	1	9	0	1	9¾	0	1	10½
4	0	1	10	0	1	11	0	2	0	0	2	1	0	2	2	0	2	3	0	2	4	0	2	5	0	2	6
5	0	2	3½	0	2	4¾	0	2	6	0	2	7¼	0	2	8½	0	2	9¾	0	2	11	0	3	0¼	0	3	1½
6	0	2	9	0	2	10½	0	3	0	0	3	1½	0	3	3	0	3	4½	0	3	6	0	3	7½	0	3	9
7	0	3	2½	0	3	4¼	0	3	6	0	3	7¾	0	3	9½	0	3	11¼	0	4	1	0	4	2¾	0	4	4½
8	0	3	8	0	3	10	0	4	0	0	4	2	0	4	4	0	4	6	0	4	8	0	4	10	0	5	0
9	0	4	1½	0	4	3¾	0	4	6	0	4	8¼	0	4	10½	0	5	0¾	0	5	3	0	5	5¼	0	5	7½
10	0	4	7	0	4	9½	0	5	0	0	5	2½	0	5	5	0	5	7½	0	5	10	0	6	0½	0	6	3
11	0	5	0½	0	5	3¼	0	5	6	0	5	8¾	0	5	11½	0	6	2¼	0	6	5	0	6	7¾	0	6	10½
12	0	5	6	0	5	9	0	6	0	0	6	3	0	6	6	0	6	9	0	7	0	0	7	3	0	7	6
13	0	5	11½	0	6	2¾	0	6	6	0	6	9¼	0	7	0½	0	7	3¾	0	7	7	0	7	10¼	0	8	1½
14	0	6	5	0	6	8½	0	7	0	0	7	3½	0	7	7	0	7	10½	0	8	2	0	8	5½	0	8	9
15	0	6	10½	0	7	2¼	0	7	6	0	7	9¾	0	8	1½	0	8	5¼	0	8	9	0	9	0¾	0	9	4½
16	0	7	4	0	7	8	0	8	0	0	8	4	0	8	8	0	9	0	0	9	4	0	9	8	0	10	0
17	0	7	9½	0	8	1¾	0	8	6	0	8	10¼	0	9	2½	0	9	6¾	0	9	11	0	10	3¼	0	10	7½
18	0	8	3	0	8	7½	0	9	0	0	9	4½	0	9	9	0	10	1½	0	10	6	0	10	10½	0	11	3
19	0	8	8½	0	9	1¼	0	9	6	0	9	10¾	0	10	3½	0	10	8¼	0	11	1	0	11	5¾	0	11	10½
20	0	9	2	0	9	7	0	10	0	0	10	5	0	10	10	0	11	3	0	11	8	0	12	1	0	12	6
21	0	9	7½	0	10	0¾	0	10	6	0	10	11¼	0	11	4½	0	11	9¾	0	12	3	0	12	8¼	0	13	1½
22	0	10	1	0	10	6½	0	11	0	0	11	5½	0	11	11	0	12	4½	0	12	10	0	13	3½	0	13	9
23	0	10	6½	0	11	0¼	0	11	6	0	11	11¾	0	12	5½	0	12	11¼	0	13	5	0	13	10¾	0	14	4½

WAGES TABLE.—Rate per Hour in Pence.

Hours.	5½d.			5¾d.			6d.			6¼d.			6½d.			6¾d.			7d.			7¼d.			7½d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
24	0	11	0	0	11	6	0	12	0	0	12	6	0	13	0	0	13	6	0	14	0	0	14	6	0	15	0
25	0	11	5½	0	11	11¾	0	12	6	0	13	0¼	0	13	6½	0	14	0¾	0	14	7	0	15	1¼	0	15	7½
26	0	11	11	0	12	5½	0	13	0	0	13	6½	0	14	1	0	14	7½	0	15	2	0	15	8½	0	16	3
27	0	12	4½	0	12	11¼	0	13	6	0	14	0¾	0	14	7½	0	15	2¼	0	15	9	0	16	3¾	0	16	10½
28	0	12	10	0	13	5	0	14	0	0	14	7	0	15	2	0	15	9	0	16	4	0	16	11	0	17	6
29	0	13	3½	0	13	10¾	0	14	6	0	15	1¼	0	15	8½	0	16	3¾	0	16	11	0	17	6¼	0	18	1½
30	0	13	9	0	14	4½	0	15	0	0	15	7½	0	16	3	0	16	10½	0	17	6	0	18	1½	0	18	9
31	0	14	2½	0	14	10¼	0	15	6	0	16	1¾	0	16	9½	0	17	5¼	0	18	1	0	18	8¾	0	19	4½
32	0	14	8	0	15	4	0	16	0	0	16	8	0	17	4	0	18	0	0	18	8	0	19	4	1	0	0
33	0	15	1½	0	15	9¾	0	16	6	0	17	2¼	0	17	10½	0	18	6¾	0	19	3	0	19	11¼	1	0	7½
34	0	15	7	0	16	3½	0	17	0	0	17	8½	0	18	5	0	19	1½	0	19	10	1	0	6½	1	1	3
35	0	16	0½	0	16	9¼	0	17	6	0	18	2¾	0	18	11½	0	19	8¼	1	0	5	1	1	1¾	1	1	10½
36	0	16	6	0	17	3	0	18	0	0	18	9	0	19	6	1	0	3	1	1	0	1	1	9	1	2	6
37	0	16	11½	0	17	8¾	0	18	6	0	19	3¼	1	0	0½	1	0	9¾	1	1	7	1	2	4¼	1	3	1½
38	0	17	5	0	18	2½	0	19	0	0	19	9½	1	0	7	1	1	4½	1	2	2	1	2	11½	1	3	9
39	0	17	10½	0	18	8¼	0	19	6	1	0	3¾	1	1	1½	1	1	11¼	1	2	9	1	3	6¾	1	4	4½
40	0	18	4	0	19	2	1	0	0	1	0	10	1	1	8	1	2	6	1	3	4	1	4	2	1	5	0
41	0	18	9½	0	19	7¾	1	0	6	1	1	4½	1	2	2½	1	3	0¾	1	3	11	1	4	9¼	1	5	7½
42	0	19	3	1	0	1½	1	1	0	1	1	10½	1	2	9	1	3	7½	1	4	6	1	5	4½	1	6	3
43	0	19	8½	1	0	7¼	1	1	6	1	2	4¾	1	3	3½	1	4	2¼	1	5	1	1	5	11¾	1	6	10½
44	1	0	2	1	1	1	1	2	0	1	2	11	1	3	10	1	4	9	1	5	8	1	6	7	1	7	6
45	1	0	7½	1	1	6¾	1	2	6	1	3	5¼	1	4	4½	1	5	3¾	1	6	3	1	7	2¼	1	8	1½
46	1	1	1	1	2	0½	1	3	0	1	3	11½	1	4	11	1	5	10½	1	6	10	1	7	9½	1	8	9
47	1	1	6½	1	2	6¼	1	3	6	1	4	5¾	1	5	5½	1	6	5¼	1	7	5	1	8	4¾	1	9	4½
48	1	2	0	1	3	0	1	4	0	1	5	0	1	6	0	1	7	0	1	8	0	1	9	0	1	10	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	5½d.			5¾d.			6d.			6¼d.			6½d.			6¾d.			7d.			7¼d.			7½d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s	d.	£	s.	d.
49	1	2	5½	1	3	5¾	1	4	6	1	5	6¼	1	6	6½	1	7	6¾	1	8	7	1	9	7¼	1	10	7½
50	1	2	11	1	3	11½	1	5	0	1	6	0½	1	7	1	1	8	1½	1	9	2	1	10	2½	1	11	3
51	1	3	4½	1	4	5¼	1	5	6	1	6	6¾	1	7	7½	1	8	8¼	1	9	9	1	10	9¾	1	11	10½
52	1	3	10	1	4	11	1	6	0	1	7	1	1	8	2	1	9	3	1	10	4	1	11	5	1	12	6
53	1	4	3½	1	5	4¾	1	6	6	1	7	7¼	1	8	8½	1	9	9¾	1	10	11	1	12	0¼	1	13	1½
54	1	4	9	1	5	10½	1	7	0	1	8	1½	1	9	3	1	10	4½	1	11	6	1	12	7½	1	13	9
55	1	5	2½	1	6	4¼	1	7	6	1	8	7¾	1	9	9½	1	10	11¼	1	12	1	1	13	2¾	1	14	4½
56	1	5	8	1	6	10	1	8	0	1	9	2	1	10	4	1	11	6	1	12	8	1	13	10	1	15	0
57	1	6	1½	1	7	3¾	1	8	6	1	9	8¼	1	10	10½	1	12	0¾	1	13	3	1	14	5¼	1	15	7½
58	1	6	7	1	7	9½	1	9	0	1	10	2½	1	11	5	1	12	7½	1	13	10	1	15	0½	1	16	3
59	1	7	0½	1	8	3¼	1	9	6	1	10	8¾	1	11	11½	1	13	2¼	1	14	5	1	15	7¾	1	16	10½
60	1	7	6	1	8	9	1	10	0	1	11	3	1	12	6	1	13	9	1	15	0	1	16	3	1	17	6
61	1	7	11½	1	9	2¾	1	10	6	1	11	9¼	1	13	0½	1	14	3¾	1	15	7	1	16	10¼	1	18	1½
62	1	8	5	1	9	8½	1	11	0	1	12	3½	1	13	7	1	14	10½	1	16	2	1	17	5½	1	18	9
63	1	8	10½	1	10	2¼	1	11	6	1	12	9¾	1	14	1½	1	15	5¼	1	16	9	1	18	0¾	1	19	4½
64	1	9	4	1	10	8	1	12	0	1	13	4	1	14	8	1	16	0	1	17	4	1	18	8	2	0	0
65	1	9	9½	1	11	1¾	1	12	6	1	13	10¼	1	15	2½	1	16	6¾	1	17	11	1	19	3¼	2	0	7½
66	1	10	3	1	11	7½	1	13	0	1	14	4½	1	15	9	1	17	1½	1	18	6	1	19	10½	2	1	3
67	1	10	8½	1	12	1¼	1	13	6	1	14	10¾	1	16	3½	1	17	8¼	1	19	1	2	0	5¾	2	1	10½
68	1	11	2	1	12	7	1	14	0	1	15	5	1	16	10	1	18	3	1	19	8	2	1	1	2	2	6
69	1	11	7½	1	13	0¾	1	14	6	1	15	11¼	1	17	4½	1	18	9¾	2	0	3	2	1	8¼	2	3	1½
70	1	12	1	1	13	6½	1	15	0	1	16	5½	1	17	11	1	19	4½	2	0	10	2	2	3½	2	3	9
71	1	12	6½	1	14	0¼	1	15	6	1	16	11¾	1	18	5½	1	19	11¼	2	1	5	2	2	10¾	2	4	4½
72	1	13	0	1	14	6	1	16	0	1	17	6	1	19	0	2	0	6	2	2	0	2	3	6	2	5	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	7¾d. £	7¾d. s.	7¾d. d.	8d. £	8d. s.	8d. d.	8¼d. £	8¼d. s.	8¼d. d.	8½d. £	8½d. s.	8½d. d.	8¾d. £	8¾d. s.	8¾d. d.
½	0	0	3¾	0	0	4	0	0	4	0	0	4¼	0	0	4¼
¾	0	0	5¾	0	0	6	0	0	6	0	0	6¼	0	0	6½
1	0	0	7¾	0	0	8	0	0	8	0	0	8½	0	0	8¾
2	0	1	3½	0	1	4	0	1	4½	0	1	5	0	1	5½
3	0	1	11¼	0	2	0	0	2	0¾	0	2	1½	0	2	2¼
4	0	2	7	0	2	8	0	2	9	0	2	10	0	2	11
5	0	3	2¾	0	3	4	0	3	5¼	0	3	6½	0	3	7¾
6	0	3	10½	0	4	0	0	4	1½	0	4	3	0	4	4½
7	0	4	6¼	0	4	8	0	4	9¾	0	4	11½	0	5	1¼
8	0	5	2	0	5	4	0	5	6	0	5	8	0	5	10
9	0	5	9¾	0	6	0	0	6	2¼	0	6	4½	0	6	6¾
10	0	6	5½	0	6	8	0	6	10½	0	7	1	0	7	3½
11	0	7	1¼	0	7	4	0	7	6¾	0	7	9½	0	8	0¼
12	0	7	9	0	8	0	0	8	3	0	8	6	0	8	9
13	0	8	4¾	0	8	8	0	8	11¼	0	9	2½	0	9	5¾
14	0	9	0½	0	9	4	0	9	7½	0	9	11	0	10	2½
15	0	9	8¼	0	10	0	0	10	3¾	0	10	7½	0	10	11¼
16	0	10	4	0	10	8	0	11	0	0	11	4	0	11	8
17	0	10	11¾	0	11	4	0	11	8¼	0	12	0½	0	12	4¾
18	0	11	7½	0	12	0	0	12	4½	0	12	9	0	13	1½
19	0	12	3¼	0	12	8	0	13	0¾	0	13	5½	0	13	10¼
20	0	12	11	0	13	4	0	13	9	0	14	2	0	14	7
21	0	13	6¾	0	14	0	0	14	5¼	0	14	10½	0	15	3¾
22	0	14	2½	0	14	8	0	15	1½	0	15	7	0	16	0½
23	0	14	10½	0	15	4	0	15	9¾	0	16	3½	0	16	9¼

Hours.	9d. £	9d. s.	9d. d.	9¼d. £	9¼d. s.	9¼d. d.	9½d. £	9½d. s.	9½d. d.	9¾d. £	9¾d. s.	9¾d. d.
½	0	0	4½	0	0	4½	0	0	4¾	0	0	4¾
¾	0	0	6¾	0	0	6¾	0	0	7	0	0	7¼
1	0	0	9	0	0	9¼	0	0	9½	0	0	9¾
2	0	1	6	0	1	6½	0	1	7	0	1	7½
3	0	2	3	0	2	3¾	0	2	4½	0	2	5¼
4	0	3	0	0	3	1	0	3	2	0	3	3
5	0	3	9	0	3	10¼	0	3	11½	0	4	0¾
6	0	4	6	0	4	7½	0	4	9	0	4	10½
7	0	5	3	0	5	4¾	0	5	6½	0	5	8¼
8	0	6	0	0	6	2	0	6	4	0	6	6
9	0	6	9	0	6	11¼	0	7	1½	0	7	3¾
10	0	7	6	0	7	8½	0	7	11	0	8	1½
11	0	8	3	0	8	5¾	0	8	8½	0	8	11¼
12	0	9	0	0	9	3	0	9	6	0	9	9
13	0	9	9	0	10	0¼	0	10	3½	0	10	6¾
14	0	10	6	0	10	9½	0	11	1	0	11	4½
15	0	11	3	0	11	6¾	0	11	10½	0	12	2¼
16	0	12	0	0	12	4	0	12	8	0	13	0
17	0	12	9	0	13	1¼	0	13	5½	0	13	9¾
18	0	13	6	0	13	10½	0	14	3	0	14	7½
19	0	14	3	0	14	7¾	0	15	0½	0	15	5¼
20	0	15	0	0	15	5	0	15	10	0	16	3
21	0	15	9	0	16	2¼	0	16	7½	0	17	0¾
22	0	16	6	0	16	11½	0	17	5	0	17	10½
23	0	17	3	0	17	8¾	0	18	2½	0	18	8¼

WAGES TABLE.—Rate per Hour in Pence.

Hours.	7¾d.			8d.			8¼d.			8½d.			8¾d.			9d.			9¼d.			9½d.			9¾d.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
24	0	15	6	0	16	0	0	16	6	0	17	0	0	17	6	0	18	0	0	18	6	0	19	0	0	19	6
25	0	16	1¾	0	16	8	0	17	2¼	0	17	8½	0	18	2¾	0	18	9	0	19	3¼	0	19	9½	1	0	3¾
26	0	16	9½	0	17	4	0	17	10½	0	18	5	0	18	11½	0	19	6	1	0	0½	1	0	7	1	1	1½
27	0	17	5¼	0	18	0	0	18	6¾	0	19	1½	0	19	8¼	1	0	3	1	0	9¾	1	1	4½	1	1	11¼
28	0	18	1	0	18	8	0	19	3	0	19	10	1	0	5	1	1	0	1	1	7	1	2	2	1	2	9
29	0	18	8¾	0	19	4	0	19	11¼	1	0	6½	1	1	1¾	1	1	9	1	2	4¼	1	2	11½	1	3	6¾
30	0	19	4½	1	0	0	1	0	7½	1	1	3	1	1	10½	1	2	6	1	3	1½	1	3	9	1	4	4½
31	1	0	0¼	1	0	8	1	1	3¾	1	1	11½	1	2	7¼	1	3	3	1	3	10¾	1	4	6½	1	5	2¼
32	1	0	8	1	1	4	1	2	0	1	2	8	1	3	4	1	4	0	1	4	8	1	5	4	1	6	0
33	1	1	3¾	1	2	0	1	2	8¼	1	3	4½	1	4	0¾	1	4	9	1	5	5¼	1	6	1½	1	6	9¾
34	1	1	11½	1	2	8	1	3	4½	1	4	1	1	4	9½	1	5	6	1	6	2½	1	6	11	1	7	7½
35	1	2	7¼	1	3	4	1	4	0¾	1	4	9½	1	5	6¼	1	6	3	1	6	11¾	1	7	8½	1	8	5¼
36	1	3	3	1	4	0	1	4	9	1	5	6	1	6	3	1	7	0	1	7	9	1	8	6	1	9	3
37	1	3	10¾	1	4	8	1	5	5¼	1	6	2½	1	6	11¾	1	7	9	1	8	6¼	1	9	3½	1	10	0¾
38	1	4	6½	1	5	4	1	6	1½	1	6	11	1	7	8½	1	8	6	1	9	3½	1	10	1	1	10	10½
39	1	5	2¼	1	6	0	1	6	9¾	1	7	7½	1	8	5¼	1	9	3	1	10	0¾	1	10	10½	1	11	8¼
40	1	5	10	1	6	8	1	7	6	1	8	4	1	9	2	1	10	0	1	10	10	1	11	8	1	12	6
41	1	6	5¾	1	7	4	1	8	2¼	1	9	0½	1	9	10¾	1	10	9	1	11	7¼	1	12	5½	1	13	3¾
42	1	7	1½	1	8	0	1	8	10½	1	9	9	1	10	7½	1	11	6	1	12	4½	1	13	3	1	14	1½
43	1	7	9¼	1	8	8	1	9	6¾	1	10	5½	1	11	4¼	1	12	3	1	13	1¾	1	14	0½	1	14	11¼
44	1	8	5	1	9	4	1	10	3	1	11	2	1	12	1	1	13	0	1	13	11	1	14	10	1	15	9
45	1	9	0¾	1	10	0	1	10	11¼	1	11	10½	1	12	9¾	1	13	9	1	14	8¼	1	15	7½	1	16	6¾
46	1	9	8½	1	10	8	1	11	7½	1	12	7	1	13	6½	1	14	6	1	15	5½	1	16	5	1	17	4½
47	1	10	4¼	1	11	4	1	12	3¾	1	13	3½	1	14	3¼	1	15	3	1	16	2¾	1	17	2½	1	18	2¼
48	1	11	0	1	12	0	1	13	0	1	14	0	1	15	0	1	16	0	1	17	0	1	18	0	1	19	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	7¾d.			8d.			8¼d.			8½d.			8¾d.			9d.			9¼d.			9½d.			9¾d		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
49	1	11	7¾	1	12	8	1	13	8¼	1	14	8½	1	15	8¾	1	16	9	1	17	9¼	1	18	9½	1	19	9¾
50	1	12	3½	1	13	4	1	14	4½	1	15	5	1	16	5½	1	17	6	1	18	6½	1	19	7	2	0	7½
51	1	12	11¼	1	14	0	1	15	0¾	1	16	1½	1	17	2¼	1	18	3	1	19	3¾	2	0	4½	2	1	5¼
52	1	13	7	1	14	8	1	15	9	1	16	10	1	17	11	1	19	0	2	0	1	2	1	2	2	2	3
53	1	14	2¾	1	15	4	1	16	5¼	1	17	6½	1	18	7¾	1	19	9	2	0	10¼	2	1	11½	2	3	0¾
54	1	14	10½	1	16	0	1	17	1½	1	18	3	1	19	4½	2	0	6	2	1	7½	2	2	9	2	3	10½
55	1	15	6¼	1	16	8	1	17	9¾	1	18	11½	2	0	1¼	2	1	3	2	2	4¾	2	3	6½	2	4	8¼
56	1	16	2	1	17	4	1	18	6	1	19	8	2	0	10	2	2	0	2	3	2	2	4	4	2	5	6
57	1	16	9¾	1	18	0	1	19	2¼	2	0	4½	2	1	6¾	2	2	9	2	3	11¼	2	5	1½	2	6	3¾
58	1	17	5½	1	18	8	1	19	10½	2	1	1	2	2	3½	2	3	6	2	4	8½	2	5	11	2	7	1½
59	1	18	1¼	1	19	4	2	0	6¾	2	1	9½	2	3	0¼	2	4	3	2	5	5¾	2	6	8½	2	7	11¼
60	1	18	9	2	0	0	2	1	3	2	2	6	2	3	9	2	5	0	2	6	3	2	7	6	2	8	9
61	1	19	4¾	2	0	8	2	1	11¼	2	3	2½	2	4	5¾	2	5	9	2	7	0¼	2	8	3½	2	9	6¾
62	2	0	0½	2	1	4	2	2	7½	2	3	11	2	5	2½	2	6	6	2	7	9½	2	9	1	2	10	4½
63	2	0	8¼	2	2	0	2	3	3¾	2	4	7½	2	5	11¼	2	7	3	2	8	6¾	2	9	10½	2	11	2¼
64	2	1	4	2	2	8	2	4	0	2	5	4	2	6	8	2	8	0	2	9	4	2	10	8	2	12	0
65	2	1	11¾	2	3	4	2	4	8¼	2	6	0½	2	7	4¾	2	8	9	2	10	1¼	2	11	5½	2	12	9¾
66	2	2	7½	2	4	0	2	5	4½	2	6	9	2	8	1½	2	9	6	2	10	10½	2	12	3	2	13	7½
67	2	3	3¼	2	4	8	2	6	0¾	2	7	5½	2	8	10¼	2	10	3	2	11	7¾	2	13	0½	2	14	5¼
68	2	3	11	2	5	4	2	6	9	2	8	2	2	9	7	2	11	0	2	12	5	2	13	10	2	15	3
69	2	4	6¾	2	6	0	2	7	5¼	2	8	10½	2	10	3¾	2	11	9	2	13	2¼	2	14	7½	2	16	0¾
70	2	5	2½	2	6	8	2	8	1½	2	9	7	2	11	0½	2	12	6	2	13	11½	2	15	5	2	16	10½
71	2	5	10¼	2	7	4	2	8	9¾	2	10	3½	2	11	9¼	2	13	3	2	14	8¾	2	16	2½	2	17	8¼
72	2	6	6	2	8	0	2	9	6	2	11	0	2	12	6	2	14	0	2	15	6	2	17	0	2	18	6

WAGES TABLE.—Rate per Hour in Pence.

Hours.	10d.			10¼d.			10½d.			10¾d.			11d.			11¼d.			11½d.			11¾d.			1s.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
½	0	0	5	0	0	5	0	0	5¼	0	0	5¼	0	0	5½	0	0	5½	0	0	5¾	0	0	5¾	0	0	6
¾	0	0	7½	0	0	7½	0	0	7¾	0	0	8	0	0	8¼	0	0	8¼	0	0	8½	0	0	8¾	0	0	9
1	0	0	10	0	0	10¼	0	0	10½	0	0	10¾	0	0	11	0	0	11¼	0	0	11½	0	0	11¾	0	1	0
2	0	1	8	0	1	8½	0	1	9	0	1	9½	0	1	10	0	1	10½	0	1	11	0	1	11½	0	2	0
3	0	2	6	0	2	6¾	0	2	7½	0	2	8¼	0	2	9	0	2	9¾	0	2	10½	0	2	11¼	0	3	0
4	0	3	4	0	3	5	0	3	6	0	3	7	0	3	8	0	3	9	0	3	10	0	3	11	0	4	0
5	0	4	2	0	4	3¼	0	4	4½	0	4	5¾	0	4	7	0	4	8¼	0	4	9½	0	4	10¾	0	5	0
6	0	5	0	0	5	1½	0	5	3	0	5	4½	0	5	6	0	5	7½	0	5	9	0	5	10½	0	6	0
7	0	5	10	0	5	11¾	0	6	1½	0	6	3¼	0	6	5	0	6	6¾	0	6	8½	0	6	10¼	0	7	0
8	0	6	8	0	6	10	0	7	0	0	7	2	0	7	4	0	7	6	0	7	8	0	7	10	0	8	0
9	0	7	6	0	7	8¼	0	7	10½	0	8	0¾	0	8	3	0	8	5¼	0	8	7½	0	8	9¾	0	9	0
10	0	8	4	0	8	6½	0	8	9	0	8	11½	0	9	2	0	9	4½	0	9	7	0	9	9½	0	10	0
11	0	9	2	0	9	4¾	0	9	7½	0	9	10¼	0	10	1	0	10	3¾	0	10	6½	0	10	9¼	0	11	0
12	0	10	0	0	10	3	0	10	6	0	10	9	0	11	0	0	11	3	0	11	6	0	11	9	0	12	0
13	0	10	10	0	11	1¼	0	11	4½	0	11	7¾	0	11	11	0	12	2¼	0	12	5½	0	12	8¾	0	13	0
14	0	11	8	0	11	11½	0	12	3	0	12	6½	0	12	10	0	13	1½	0	13	5	0	13	8½	0	14	0
15	0	12	6	0	12	9¾	0	13	1½	0	13	5¼	0	13	9	0	14	0¾	0	14	4½	0	14	8¼	0	15	0
16	0	13	4	0	13	8	0	14	0	0	14	4	0	14	8	0	15	0	0	15	4	0	15	8	0	16	0
17	0	14	2	0	14	6¼	0	14	10½	0	15	2¾	0	15	7	0	15	11¼	0	16	3½	0	16	7¾	0	17	0
18	0	15	0	0	15	4½	0	15	9	0	16	1½	0	16	6	0	16	10½	0	17	3	0	17	7½	0	18	0
19	0	15	10	0	16	2¾	0	16	7½	0	17	0¼	0	17	5	0	17	9¾	0	18	2½	0	18	7¼	0	19	0
20	0	16	8	0	17	1	0	17	6	0	17	11	0	18	4	0	18	9	0	19	2	0	19	7	1	0	0
21	0	17	6	0	17	11¼	0	18	4½	0	18	9¾	0	19	3	0	19	8¼	1	0	1½	1	0	6¾	1	1	0
22	0	18	4	0	18	9½	0	19	3	0	19	8½	1	0	2	1	0	7½	1	1	1	1	1	6½	1	2	0
23	0	19	2	0	19	7¾	1	0	1½	1	0	7¼	1	1	1	1	1	6¾	1	2	0½	1	2	6¼	1	3	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	10d.			10¼d.			10½d.			10¾d.			11d.			11¼d.			11½d.			11¾d.			1s.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
24	1	0	0	1	0	6	1	1	0	1	1	6	1	2	0	1	2	6	1	3	0	1	3	6	1	4	0
25	1	0	10	1	1	4¼	1	1	10½	1	2	4¾	1	2	11	1	3	5¼	1	3	11½	1	4	5¾	1	5	0
26	1	1	8	1	2	2½	1	2	9	1	3	3½	1	3	10	1	4	4½	1	4	11	1	5	5½	1	6	0
27	1	2	6	1	3	0¾	1	3	7½	1	4	2¼	1	4	9	1	5	3¾	1	5	10½	1	6	5¼	1	7	0
28	1	3	4	1	3	11	1	4	6	1	5	1	1	5	8	1	6	3	1	6	10	1	7	5	1	8	0
29	1	4	2	1	4	9¼	1	5	4½	1	5	11¾	1	6	7	1	7	2¼	1	7	9½	1	8	4¾	1	9	0
30	1	5	0	1	5	7½	1	6	3	1	6	10½	1	7	6	1	8	1½	1	8	9	1	9	4½	1	10	0
31	1	5	10	1	6	5¾	1	7	1½	1	7	9¼	1	8	5	1	9	0¾	1	9	8½	1	10	4¼	1	11	0
32	1	6	8	1	7	4	1	8	0	1	8	8	1	9	4	1	10	0	1	10	8	1	11	4	1	12	0
33	1	7	6	1	8	2¼	1	8	10½	1	9	6¾	1	10	3	1	10	11¼	1	11	7½	1	12	3¾	1	13	0
34	1	8	4	1	9	0½	1	9	9	1	10	5½	1	11	2	1	11	10½	1	12	7	1	13	3½	1	14	0
35	1	9	2	1	9	10¾	1	10	7½	1	11	4¼	1	12	1	1	12	9¾	1	13	6½	1	14	3¼	1	15	0
36	1	10	0	1	10	9	1	11	6	1	12	3	1	13	0	1	13	9	1	14	6	1	15	3	1	16	0
37	1	10	10	1	11	7¼	1	12	4½	1	13	1¾	1	13	11	1	14	8¼	1	15	5½	1	16	2¾	1	17	0
38	1	11	8	1	12	5½	1	13	3	1	14	0½	1	14	10	1	15	7½	1	16	5	1	17	2½	1	18	0
39	1	12	6	1	13	3¾	1	14	1½	1	14	11¼	1	15	9	1	16	6¾	1	17	4½	1	18	2¼	1	19	0
40	1	13	4	1	14	2	1	15	0	1	15	10	1	16	8	1	17	6	1	18	4	1	19	2	2	0	0
41	1	14	2	1	15	0¼	1	15	10½	1	16	8¾	1	17	7	1	18	5¼	1	19	3½	2	0	1¾	2	1	0
42	1	15	0	1	15	10½	1	16	9	1	17	7½	1	18	6	1	19	4½	2	0	3	2	1	1½	2	2	0
43	1	15	10	1	16	8¾	1	17	7½	1	18	6¼	1	19	5	2	0	3¾	2	1	2½	2	2	1¼	2	3	0
44	1	16	8	1	17	7	1	18	6	1	19	5	2	0	4	2	1	3	2	2	2	2	3	1	2	4	0
45	1	17	6	1	18	5¼	1	19	4½	2	0	3¾	2	1	3	2	2	2¼	2	3	1½	2	4	0¾	2	5	0
46	1	18	4	1	19	3½	2	0	3	2	1	2½	2	2	2	2	3	1½	2	4	1	2	5	0½	2	6	0
47	1	19	2	2	0	1¾	2	1	1½	2	2	1¼	2	3	1	2	4	0¾	2	5	0½	2	6	0¼	2	7	0
48	2	0	0	2	1	0	2	2	0	2	3	0	2	4	0	2	5	0	2	6	0	2	7	0	2	8	0

WAGES TABLE.—Rate per Hour in Pence.

Hours.	10d.			10¼d.			10½d.			10¾d.			11d.			11¼d.			11½d.			11¾d.			1s.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
49	2	0	10	2	1	10¼	2	2	10½	2	3	10¾	2	4	11	2	5	11¼	2	6	11½	2	7	11¾	2	9	0
50	2	1	8	2	2	8½	2	3	9	2	4	9½	2	5	10	2	6	10½	2	7	11	2	8	11½	2	10	0
51	2	2	6	2	3	6¾	2	4	7½	2	5	8¼	2	6	9	2	7	9¾	2	8	10½	2	9	11¼	2	11	0
52	2	3	4	2	4	5	2	5	6	2	6	7	2	7	8	2	8	9	2	9	10	2	10	11	2	12	0
53	2	4	2	2	5	3¼	2	6	4½	2	7	5¾	2	8	7	2	9	8¼	2	10	9½	2	11	10¾	2	13	0
54	2	5	0	2	6	1½	2	7	3	2	8	4½	2	9	6	2	10	7½	2	11	9	2	12	10½	2	14	0
55	2	5	10	2	6	11¾	2	8	1½	2	9	3¼	2	10	5	2	11	6¾	2	12	8½	2	13	10¼	2	15	0
56	2	6	8	2	7	10	2	9	0	2	10	2	2	11	4	2	12	6	2	13	8	2	14	10	2	16	0
57	2	7	6	2	8	8¼	2	9	10½	2	11	0¾	2	12	3	2	13	5¼	2	14	7½	2	15	9¾	2	17	0
58	2	8	4	2	9	6½	2	10	9	2	11	11½	2	13	2	2	14	4½	2	15	7	2	16	9½	2	18	0
59	2	9	2	2	10	4¾	2	11	7½	2	12	10¼	2	14	1	2	15	3¾	2	16	6½	2	17	9¼	2	19	0
60	2	10	0	2	11	3	2	12	6	2	13	9	2	15	0	2	16	3	2	17	6	2	18	9	3	0	0
61	2	10	10	2	12	1¼	2	13	4½	2	14	7¾	2	15	11	2	17	2¼	2	18	5½	2	19	8¾	3	1	0
62	2	11	8	2	11	11½	2	14	3	2	15	6½	2	16	10	2	18	1½	2	19	5	3	0	8½	3	2	0
63	2	12	6	2	13	9¾	2	15	1½	2	16	5¼	2	17	9	2	19	0¾	3	0	4½	3	1	8¼	3	3	0
64	2	13	4	2	14	8	2	16	0	2	17	4	2	18	8	3	0	0	3	1	4	3	2	8	3	4	0
65	2	14	2	2	15	6¼	2	16	10½	2	18	2¾	2	19	7	3	0	11¼	3	2	3½	3	3	7¾	3	5	0
66	2	15	0	2	16	4½	2	17	9	2	19	1½	3	0	6	3	1	10½	3	3	3	3	4	7½	3	6	0
67	2	15	10	2	17	2¾	2	18	7½	3	0	0¼	3	1	5	3	2	9¾	3	4	2½	3	5	7¼	3	7	0
68	2	16	8	2	18	1	2	19	6	3	0	11	3	2	4	3	3	9	3	5	2	3	6	7	3	8	0
69	2	17	6	2	18	11¼	3	0	4½	3	1	9¾	3	3	3	3	4	8¼	3	6	1½	3	7	6¾	3	9	0
70	2	18	4	2	19	9½	3	1	3	3	2	8½	3	4	2	3	5	7½	3	7	1	3	8	6½	3	10	0
71	2	19	2	3	0	7¾	3	2	1½	3	3	7¼	3	5	1	3	6	6¾	3	8	0½	3	9	6¼	3	11	0
72	3	0	0	3	1	6	3	3	0	3	4	6	3	6	0	3	7	6	3	9	0	3	10	6	3	12	0

SIZES OF PAPERS.

Drawing Papers.

	Inches.
Emperor	72 × 48
Antiquarian	53 × 31
Double Elephant	40 × 27
Atlas	34 × 26
Colombier	$34\frac{1}{2}$ × 24
Imperial	30 × 22
Elephant	28 × 23
Super Royal	$27\frac{1}{4}$ × $19\frac{1}{4}$
Royal	24 × 19
Medium	22 × $17\frac{1}{2}$
Demy	20 × $15\frac{1}{2}$
Foolscap	$16\frac{3}{4}$ × $13\frac{1}{4}$

Loan Papers.

Imperial	$29\frac{1}{2}$ × $21\frac{1}{2}$
Royal	$23\frac{1}{8}$ × $18\frac{3}{8}$
Medium	21 × 17
Double Foolscap	$25\frac{1}{2}$ × $16\frac{1}{4}$

Account Book and Writing Papers.

Atlas	$33\frac{1}{2}$ × $26\frac{1}{2}$
Imperial	30 × 22
Super Royal	27 × $19\frac{1}{4}$
Royal	24 × $19\frac{1}{4}$
Medium	22 × $17\frac{1}{2}$
Demy	20 × $15\frac{1}{2}$
Foolscap (hand made)	$16\frac{3}{4}$ × $13\frac{1}{4}$
,, (machine made)	$16\frac{1}{2}$ × $13\frac{1}{4}$
Double Foolscap	$26\frac{1}{2}$ × $16\frac{3}{4}$
Sheet and half Foolscap	$24\frac{1}{2}$ × $13\frac{1}{4}$
Sheet and third Foolscap	22 × $13\frac{1}{4}$
Extra Large Post	$22\frac{1}{2}$ × $17\frac{3}{4}$
Large Post	21 × $16\frac{1}{2}$
Copy	$20\frac{1}{4}$ × 16
Post	19 × $15\frac{1}{4}$
Pinched Post	$18\frac{1}{2}$ × $14\frac{3}{4}$
Pott	15 × $12\frac{1}{2}$
Sheet and half Pott	$22\frac{1}{2}$ × $12\frac{1}{2}$
Bank of England Note	$8\frac{1}{4}$ × $5\frac{1}{8}$

Copyings, &c.	Inches.
Medium	$22\frac{1}{4} \times 17\frac{1}{2}$
Royal	$23\frac{1}{2} \times 19\frac{1}{4}$
Double Foolscap	27×17
Medium Copying	$18\frac{1}{2} \times 22\frac{1}{2}$
Royal Copying	$24\frac{3}{4} \times 20\frac{3}{4}$

Printing Papers.	
Double Royal	40×25
,, Medium	$37 \times 23\frac{1}{2}$
,, Demy...	$35\frac{1}{2} \times 22\frac{1}{2}$
,, Copy	33×20
,, Large Post	33×21
,, Crown	30×20
,, Post	$31\frac{1}{4} \times 19\frac{3}{4}$
,, Foolscap	27×17
,, Pott	$25 \times 15\frac{1}{2}$
Sheet and half Demy, square	$26\frac{1}{2} \times 22\frac{1}{2}$
,, ,, ,, usual	$33\frac{3}{4} \times 17\frac{3}{4}$
,, ,, Post	$23\frac{1}{2} \times 19\frac{3}{4}$
Elephant	30×23
Imperial	30×22
Super Royal	28×20
Royal	25×20
Pasting Royal	$24 \times 19\frac{1}{2}$
Medium	$23\frac{1}{2} \times 18$
Demy	23×18
,, ...	$22\frac{1}{2} \times 17\frac{3}{4}$
,, ...	$22\frac{1}{2} \times 17\frac{1}{2}$

Plate Papers.	
Antiquarian	53×31
Double Imperial	44×30
,, Elephant	40×27
Atlas	34×27
Colombier	35×24
Imperial	30×22
Super Royal	28×20
Royal	25×20
Medium	$23\frac{1}{2} \times 18\frac{1}{2}$
Demy	$22\frac{1}{2} \times 17\frac{3}{4}$
Foolscap	$17 \times 13\frac{1}{2}$

Chart Papers.	
Double Elephant	$40\frac{1}{2} \times 27$
Atlas	34×26
Imperial	30×22
Royal	25×20
Demy	$22\frac{1}{2} \times 17\frac{3}{4}$

Cartridge Papers.

	Inches.
Elephant	28 × 23
Imperial	30 × 22
Cartridge size	26 × 21
Royal	25 × 20
Demy	22½ × 17¾
Copy	20 × 16½
Double Demy	35½ × 22½
„ Crown	30 × 20
Continuous	54 inches wide

Sugar and Grocers' Papers.

Double Lump	42 × 32
Titlers	35 × 29
Double Hambro	30 × 27
Extra Large Lump	36 × 24
Single Lump	34 × 24
Large Single	29 × 23
Small „	27 × 21½
Elephant	29 × 24
Purple, No. 4	28 × 18½
„ No. 3	26 × 17
Powder Loaf	26 × 18½
Single Hambro	24 × 18½
Large Double Loaf	23 × 16½
Small „ „	21 × 16½
Royal Hand	25 × 20
Double, 2 lbs.	24 × 16
„ 6 „	28½ × 19
„ Small Hand	31 × 21
Lumber Hand	23 × 18
Middle Hand	22 × 16

Brown Papers.

Casing	48 × 40
„	48 × 38
„	46 × 36
Double Imperial	45 × 29
„ Bag Cap	40 × 24
„ 4 lbs.	31 × 21
Large Imperial	32 × 24
Imperial	29 × 22½
Havon Cap	26 × 21
Bag Cap	24 × 20
Kent Cap	22 × 18

Brown Papers (Wrappers).

	Inches.
Plutarch	36 × 26
Saddle Back	45 × 36
Nicanee	45 × 28
Quad Royal	50 × 40
Double Nicanee	56 × 45
Elephant	34 × 27

Small Hands.

Double Crown Small Hand	30 × 20
Double Small Hand	29 × 20
,, ,, ,,	23 × 17
,, ,, ,,	28 × 18
,, ,, ,,	21 × 13
Single Small Hand	20 × 15

Blotting Papers.

Royal or Treasury	24 × 19
Demy	$22\frac{1}{2}$ × $17\frac{3}{4}$
Post	19 × $15\frac{1}{4}$
Double Foolscap	$26\frac{1}{2}$ × $16\frac{3}{4}$

Miscellaneous Papers.

Drying Royal	24 × $19\frac{1}{4}$
Tissue, Double Crown	30 × 20
,, Demy	$22\frac{1}{2}$ × $17\frac{3}{4}$
Middles	32 × 22
,,	30 × 20
,,	24 × 19
,,	$22\frac{1}{2}$ × $17\frac{1}{2}$
Filtering Papers	24 × 19
Scribbling Demy	$22\frac{1}{2}$ × $17\frac{1}{2}$
Copying, Medium	$22\frac{1}{2}$ × $18\frac{1}{2}$
,, Double Foolscap	27 × 17

Cardboards and Bristol Boards.

	Cardboards.	Bristol Boards
Foolscap	17 × $13\frac{3}{4}$	$15\frac{1}{4}$ × $12\frac{1}{2}$
Demy	$22\frac{1}{2}$ × $17\frac{1}{2}$	$18\frac{1}{2}$ × $14\frac{1}{2}$
Medium	—	21 × $16\frac{1}{2}$
Royal	25 × 20	$22\frac{1}{2}$ × 18
Super Royal	$27\frac{1}{2}$ × $20\frac{1}{2}$	$25\frac{1}{4}$ × 18
Imperial	30 × $22\frac{1}{2}$	$28\frac{1}{2}$ × 21
Double Crown	30 × 20	—
,, Foolscap	27 × 17	—

Note.—These sizes vary according to the maker.

Glazed Pressing Boards.

	Inches.
Large size, for dyers...	36 × 24
Long ...	32 × 19
Imperial ...	31 × 23
Double Crown	30½ × 20½
Super Royal ...	29 × 21½
Double Foolscap	29 × 18
Royal, Extra ...	25½ × 20½
" Writing	24 × 19
Demy "	22 × 18

Writing Parchments.

35 × 30	30 × 26	28 × 23	24 × 20	24 × 18
32 × 28	30 × 25	27 × 23	27 × 19	21 × 16
31 × 26	29 × 26	26 × 22	24 × 19	20 × 16
30 × 27	28 × 24	25 × 21	26 × 18	20 × 15

Portfolios.

Antiquarian ...	53 × 33
Double Elephant	41 × 27
Colombier ...	36 × 25
Large Atlas ...	35 × 27
Imperial ...	31 × 22½
Super Royal ...	28 × 20
Royal ...	25 × 20
Medium	23 × 18½
Demy ...	23 × 18
Crown...	19 × 15
Foolscap ...	18 × 14
Half Imperial	22½ × 15½
" Super Royal ...	20 × 14½
" Royal ...	20 × 13
" Medium...	18½ × 12
" Demy ...	18 × 12
" Crown ...	15 × 9½
" Foolscap	14 × 9
Quarto Imperial	15½ × 11½
" Super Royal...	14 × 10¼
" Royal...	12½ × 10¼
" Medium	11½ × 9

Binding Vellums.

Imperial ...	36 × 24
Super Royal ...	33 × 22
Royal ...	30 × 22
Medium ...	28 × 20
Long Demy ...	22 × 21
Broad Demy ...	14 × 17½

Binding Vellums (*cont.*)

	Inches.
Long Foolscap	$28\frac{1}{2} \times 17\frac{1}{2}$
Broad ,,	21×15
Royal 4to	$21 \times 13\frac{1}{2}$
Medium 4to	$21 \times 12\frac{1}{2}$
Sheet and half and thirds	$15 \times 14\frac{1}{2}$
Long Demy 4to	$17 \times 13\frac{1}{2}$
Broad ,, ,,	$19 \times 11\frac{1}{2}$
Long Foolscap 4to	$14 \times 11\frac{1}{2}$
Broad ,, ,,	$16\frac{1}{2} \times 9\frac{1}{2}$
Medium 8vo tucks	$17\frac{1}{2} \times 9\frac{1}{2}$
Demy ,, ,,	$16\frac{1}{2} \times 8\frac{1}{2}$
Foolscap ,, ,,	$15\frac{1}{2} \times 7\frac{1}{2}$

Millboards.

		Marks.
Pott	$17\frac{1}{4} \times 14\frac{1}{4}$	P.
Foolscap	$18\frac{1}{2} \times 14\frac{1}{2}$	F.C.
Crown	$20 \times 16\frac{1}{2}$	C.
Small Half Royal	$20\frac{1}{4} \times 13$	S.H.R.
Large ,, ,,	21×14	L.H.R.
Short	21×17	S.
Half Imperial	$23\frac{1}{2} \times 16\frac{1}{2}$	H.I.
Small Half Imperial	$22\frac{1}{4} \times 15$	S.H.I.
Middle or Small Demy	$22\frac{1}{2} \times 18\frac{1}{2}$	M.
Large Middle or Large Demy	$23\frac{3}{4} \times 18\frac{1}{2}$	L.M.
Large or Medium	24×19	L.
Small Whole Royal	$25\frac{1}{2} \times 19\frac{1}{2}$	S.R.
Large ,, ,,	$26\frac{3}{4} \times 20\frac{3}{4}$	L.R.
Extra Royal	$28\frac{1}{2} \times 21\frac{1}{2}$	Ex. R
Whole Imperial	$32 \times 22\frac{1}{2}$	I.
Long Thin	30×21	L.T.
Atlas	30×26	A.
Extra Atlas	$32\frac{1}{4} \times 26\frac{1}{2}$	Ex. A
Long Royal	34×21	L.R.
Colombier	36×24	COL.
Portfolio	34×27	P.F.
Great Eagle or Double Elephant	40×28	G.E.
Emperor	44×30	E.
Double Royal	46×21	D.R
Long Colombier	49×24	L.C.
Long Double Elephant	$50 \times 27\frac{1}{2}$	L.D.E.
Antiquarian	54×30	ANT.
Extra Antiquarian	54×34	Ex. ANT.

Strawboards. Usual Sizes.

19×24	22×32
20×30	25×30

Note.—From 3 ozs. to 5 lbs in weight

GERMAN CLASSIFICATION AND SIZES OF PAPERS.

Briefpapiere (Letter Papers).

Gross Median	46 × 59 cm.
Klein "	44 × 56 "
Register	42 × 53 "

Schreibpapiere (Writing Papers).

Median	45 × 58 cm.
Klein Median	44 × 56 "
Register	42 × 53 "
Klein Register...	41 × 51 "
Gross Propatria	37 × 45 "
Propatria	34 × 43 "
Schulformat	34 × 42 "

Buch and Zeichenpapiere (Book Papers).

Atlas	83 × 118 cm.
Gross Adler	70 × 107 "
Adler	62 × 90 "
Imperial	57 × 80 "
Super Regal	54 × 70 "
Regal	49 × 64 "
Klein Regal	47 × 60 "
Median	45 × 58 "
Gross Propatria	37 × 45 "

Kupferdruckpapiere (Copperplate Papers).

Colombier	60 × 90 cm.
Jesus	52 × 73 "
Regal	49 × 64 "
Median	45 × 58 "

Notendruckpapiere and Notenschreibpapiere.

Super Regal	54 × 70 cm.
Klein "	47 × 60 "

Druckpapiere (Printing Papers).

Gross Lexikon...	54 × 70 cm.
Lexikon	49 × 64 "
Hochquart	47 × 65 "
Quart	47 × 60 "
Gross Duodez	47 × 58 "
Gross Octav und Sedez	45 × 58 "
Octav und Klein Duodez	43 × 52 "
Klein Quart	42 × 52 "
Klein Octav	41 × 51 "
Leipsiger	37 × 49 "

Seidenpapiere (Tissue Papers).

Alt Super Regal	50 × 76 cm.
Copir Alt Regal	50 × 60 "
Cigaretten Alt Gr. Median	48 × 58 "
Goldschlag Alt Kl. Regal	40 × 50 "

FARBIGE UMSCHLAGPAPIERE (Coloured Wrapping Papers).

Regal	49 × 64 cm.
Gross Median	46 × 59 „

AFFICHENPAPIERE (Thin Poster Paper).

Farbige...	65 × 94 cm.
Weisse	45 × 73 „
Skips	42 × 60 „

Papers to be used for Certificates, Documents, &c., are as follows:—

Bienenkerb ...	37 × 46	cm.	Weight	19	Kilos. p. 1,000 Sheets.
Klein Median	41 × 51	„	„	25	„ „
Gross „	45 × 58	„	„	35	„ „
Royal	$49\frac{1}{2}$ × 61	„	„	42	„ „
Superroyal ...	50 × 70	„	„	50	„ „
Imperial... ...	55 × 76	„	„	64	„ „
Colombier ...	$63\frac{1}{2}$ × 88	„	„	90	„ „
Double Elephant	67 × 103	„	„	120	„ „

EXTRA FORMATE (Extra Sizes).

Kupferdruck Colombier	60 × 90 cm.
„ Jesus	52 × 73 „
Druckpapiere Hochquart	47 × 65 „
„ Gross Duodez	47 × 58 „
„ Octav und Duodez	43 × 52 „
„ Leipsiger	37 × 49 „
Affichen Gross	65 × 94 „
„ Klein	45 × 73 „
Blau, Rosa, Halbweiss, and Grau Papier ...	50 × 76 „
1 Pfund Beutil Doppeldüten	46 × 75 „
Extra Regal	56 × 66 „
½ Pfund Beutel	40 × 63 „
Düten	37 × 45 „
Roth Lösch	72 × 88 „
„ „	52 × 63 „
„ „	47 × 60 „
„ „	46 × 59 „
Carton	48 × 60 „
„	48 × 58 „

NEUE PAPIERNORMALFORMATE (New Normal Sizes).

No.		No.	
1	34 × 43 cm.	7	44 × 56 cm.
2	36 × 45 „	8	46 × 59 „
3	38 × 48 „	9	48 × 64 „
4	40 × 50 „	10	50 × 65 „
5	42 × 53 „	11	54 × 68 „
6	33 × 42 „	12	57 × 78 „

TABLE

Showing the Equivalent Weights per ream of

PRINTING PAPERS.

Demy $17\frac{1}{2}\times22\frac{1}{2}$	D. F'cap 17 × 27		Royal 20 × 25		S. Royal 20 × 28		Dbl. Cr. 20 × 30		Imperial 22 × 30		D.Demy $22\frac{1}{2}\times35$
lbs.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.
11	12	13	14	4	15	10	16	12	18	7	22
12	14	0	15	8	17	1	18	4	20	1	24
13	15	2	16	13	18	8	19	12	21	12	26
14	16	5	18	2	19	14	21	5	23	7	28
15	17	7	19	7	21	5	22	13	25	2	30
16	18	10	20	11	22	12	24	5	26	13	32
17	19	13	22	0	24	3	25	13	28	7	34
18	20	15	23	5	25	10	27	6	30	2	36
19	22	2	24	10	27	1	28	15	31	13	38
20	23	5	25	14	28	7	30	7	33	8	40
21	24	7	27	3	29	14	31	15	35	2	42
22	25	10	28	7	31	5	33	8	36	13	44
23	26	13	29	12	32	12	35	1	38	8	46
24	27	15	31	1	34	3	36	9	40	3	48
25	29	2	32	6	35	8	38	1	41	13	50
26	30	5	33	10	36	15	39	9	43	8	52
27	31	7	34	15	38	6	41	2	45	3	54
28	32	10	36	4	39	13	42	10	46	14	56
29	33	13	37	8	41	4	44	2	48	8	58
30	34	15	38	13	42	10	45	11	50	3	60
31	36	2	40	2	44	1	47	3	51	14	62
32	37	4	41	7	45	8	48	11	53	9	64
33	38	7	42	11	46	15	50	4	55	4	66
34	39	10	44	0	48	6	51	12	56	15	68
35	40	12	45	5	49	12	53	5	58	10	70
36	41	15	46	9	51	2	54	13	60	5	72
37	43	1	47	14	52	9	56	5	61	15	74
38	44	4	49	3	54	0	57	14	63	10	76
39	45	7	50	8	55	7	59	6	65	5	78
40	46	9	51	12	56	14	60	14	67	0	80

TABLE

Showing the Equivalent Weights per Ream of

WRITING PAPERS.

L. Post $16\frac{1}{2}\times21$	Pott $12\frac{1}{2}\times15$		F'cap $13\frac{1}{4}\times16\frac{1}{2}$		P. Post $14\frac{1}{2}\times18\frac{1}{2}$		Post $15\frac{1}{4}\times19$		Demy $15\frac{1}{2}\times20$		Med'm $17\frac{1}{2}\times22$		Royal 19×24	
lbs.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
11	5	15	6	15	8	8	9	3	9	13	12	8	14	7
12	6	7	7	9	9	4	10	0	10	11	13	10	15	12
13	7	0	8	3	10	1	10	14	11	10	14	12	17	2
14	7	9	8	13	10	13	11	11	12	8	15	14	18	7
15	8	1	9	7	11	9	12	9	13	6	17	0	19	12
16	8	10	10	1	12	6	13	6	14	5	18	3	21	1
17	9	3	10	11	13	2	14	4	15	3	19	5	22	6
18	9	11	11	5	13	15	15	1	16	1	20	7	23	11
19	10	4	11	15	14	11	15	15	17	0	21	9	25	0
20	10	13	12	9	15	7	16	12	17	14	22	11	26	5
21	11	7	13	3	16	4	17	9	18	12	23	13	27	10
22	11	14	13	13	17	0	18	6	19	10	24	15	28	15
23	12	7	14	7	17	13	19	4	20	9	26	2	30	4
24	13	0	15	2	18	9	20	1	21	7	27	4	31	9
25	13	8	15	12	19	5	20	15	22	5	28	6	32	14
26	14	1	16	6	20	2	21	12	23	4	29	8	34	3
27	14	9	17	0	20	14	22	10	24	2	30	11	35	8
28	15	2	17	10	21	10	23	7	25	0	31	13	36	14
29	15	11	18	4	22	7	24	4	25	15	32	15	38	3
30	16	3	18	14	23	3	25	1	26	13	34	1	39	8
31	16	12	19	8	24	0	25	15	27	11	35	3	40	13
32	17	5	20	3	24	12	26	12	28	10	36	6	42	2
33	17	13	20	13	25	8	27	10	29	8	37	8	43	7
34	18	6	21	7	26	5	28	7	30	6	38	10	44	12
35	18	15	22	1	27	1	29	4	31	5	39	12	46	1
36	19	7	22	11	27	14	30	1	32	3	40	14	47	6
37	20	0	23	5	28	10	30	15	33	1	42	0	48	11
38	20	8	23	15	29	6	31	13	34	1	43	2	50	0
39	21	1	24	9	30	3	32	10	34	14	44	5	51	5
40	21	10	25	4	30	15	33	7	35	12	45	7	52	10

TABLE

Showing Equivalent Sizes and Weights of

WRAPPING PAPERS.

Size. 36×45	lbs. 30	lbs. 35	lbs. 40	lbs. 45	lbs. 50	lbs. 55	lbs. 60	lbs. 65	lbs. 70	lbs. 75	lbs. 80
20×24	8·8	10·3	11·8	13·3	14·8	16·2	17·7	19·2	20·7	22·2	23·6
20×25	9·2	10·8	12·3	13·8	15·4	16·9	18·5	20	21·6	23·1	24·6
21×26	10·1	11·8	13·4	15·1	16·8	18·5	20·2	21·8	23·5	25·2	26·9
20×30	11·1	12·9	14·8	16·7	18·5	20·3	22·2	24	25·8	27·6	29·4
21×31	12	14	16	18	20	22	24	26	28	30	32
20×28	10·3	12	13·8	15·5	17·2	18·9	20·7	22·4	24·1	25·9	27·6
22½×29	12	14	16·1	18·1	20·1	22·1	24·1	26·1	28·1	30·2	32·2
22×32	13	15·1	17·3	19·5	21·6	23·8	26	28·1	30·3	32·5	34·6
21×34	13·2	15·4	17·6	19·8	22	24·2	26·4	28·6	30·8	33	35·2
22×35	14·2	16·6	19	21·3	23·7	26	28·3	30·8	33·2	35·6	38
23×34	14·4	16·8	19·2	21·6	24·1	26·5	28·9	31·3	33·7	36·1	38·5
24×30	13·3	15·5	17·7	20	22·2	24·4	26·6	28·9	31·1	33·3	35·5
24×32	14·2	16·5	18·9	21·2	23·6	26	28·3	30·7	33·1	35·5	37·9
24×36	15·9	18·5	21·2	23·9	26·6	29·2	32	34·6	37·3	40	42·6
24×40	17·7	20·7	23·7	26·6	29·6	32·6	35·5	38·5	41·5	44·4	47·4
26×36	17·3	20·2	23·1	26	28·8	31·7	34·6	37·5	40·4	43·3	46·2
27×34	17	19·8	22·6	25·4	28·3	31·1	34	36·8	39·6	42·5	45·3
28×45	23·3	27·2	31·1	35	38·8	42·7	46·7	50·5	54·5	58	62
29×44	23·6	27·5	31·5	35·4	39·3	43·3	47·2	51·1	55·1	59	63
29×45	24·1	28·1	32·2	36·2	40·2	44·3	48·3	52·3	56·3	60·4	64·4
30×38	21	24·5	28·1	31·6	35·1	38·7	42·2	45·7	49·2	52·7	56·3
30×46	25·5	29·7	34	38·2	42·5	46·7	51	55·2	59·5	63·7	68
31×46	26·4	30·8	35·2	39·6	44	48·4	52·8	57·2	61·6	66	70·4
34×36	22·6	26·4	30·2	34	37·7	41·5	45·3	49·1	52·9	56·7	60·4
36×36	24	28	32	36	40	44	48	52	56	60	64
36×46	30·6	35·7	40·8	46	51·1	56·2	61·3	66·4	71·5	76·6	81·7
36×48	32	37·3	42·6	47·9	53·3	58·6	64	69·3	74·6	80	85·3
38×48	33·8	39·3	45	50·6	56·3	61 9	67·5	73·1	78·8	84·4	90
40×48	35·5	41·4	47·4	53·3	59·3	65·2	71·1	77	83	88·9	94·8
40×50	36·8	43·2	49·3	55·4	61·6	67·7	74	80	86·2	92·3	98·4
45×56	46·6	54·4	62·2	70	77·7	85·5	93·3	101	109	116	124

TABLE

Showing Equivalent Sizes and Weights of

WRAPPING PAPERS—continued.

Size. 36×45	lbs. 85	lbs. 90	lbs. 95	lbs. 100	lbs. 105	lbs. 110	lbs. 115	lbs. 120	lbs. 125	lbs. 130	lbs. 135	lbs. 140
20×24	25·1	26·6	28·1	29·6	31·1	32·5	34	35·5	37	38·5	40	41·4
20×25	26·2	27·7	29·3	30·8	32·3	33·9	35·4	37	38·5	40	41·6	43·2
21×26	28·5	30·2	32	33·6	35·3	37	38·7	40·4	42	43·6	45·3	47·1
20×30	31·3	33·3	35·2	37	38·8	40·7	42·5	44·3	46·2	48	49·8	51·6
21×31	34	36	38	40	42	44	46	48	50	52	54	56
20×28	29·3	31	32·7	34·5	36·1	37·8	39·5	41·4	43·1	44·8	46·5	48·2
22½×29	34·2	36·2	38·2	40·2	42·2	44·3	46·3	48·3	50	52	54	56·5
22×32	36·8	39	41·2	43·4	45·5	47·6	49·8	52	54·1	56·2	58·4	60·6
21×34	37·4	39·6	41·8	44	46·2	48·4	50·6	52·8	55	57·2	59·4	61·6
22×35	40·3	42·7	45·1	47·5	49·8	52·2	54·6	57	59·3	61·7	64·1	66·4
23×34	40·9	43·3	45·7	48·2	50·6	53	55·4	57·8	60·2	62·6	65	67·4
24×30	37·7	39·9	42·2	44·4	46·6	48·8	51·1	53·3	55·5	57·7	60	62·2
24×32	40·2	42·6	45	47·4	49·7	52·1	54·5	56·9	59·2	61·6	64	66·3
24×36	45·3	48	50·6	53·3	56	58·6	61·3	64	66·6	69·3	72	74·6
24×40	50	53	56	59	62	65	68	71	74	77	80	83
26×36	49·1	52	54·8	57·7	60·6	63·5	66·4	69·3	72·2	75·1	77·9	80·8
27×34	48·1	51	53·8	56·6	59·5	62·3	65·6	68	70·8	73·6	76·5	79·3
28×45	66	70	73·5	77·5	81·5	85·5	89·5	93	97	101	105	109
29×44	66·9	70·8	74·8	78·7	82·6	86·6	90·5	94·5	98·4	102	106	110
29×45	68·4	72·5	76·5	80·5	84·5	88·6	92·6	96·7	100	104	108	113
30×38	59·8	63·3	66·8	70·3	73·8	77·3	80·9	84·4	87·9	91·4	95	98·5
30×46	72·2	76·5	80·7	85·1	89·3	93·5	97·7	102	106	110	114	119
31×46	74·8	79·2	83·6	88	92·4	96·8	101	105	110	114	119	123
34×36	64·2	68	71·8	75·5	79·3	83·1	86·9	90·7	94·5	98·2	102	106
36×36	68	72	76	80	84	88	92	96	100	104	108	112
36×46	86·8	92	97·1	102	107	112	117	122	127	132	138	143
36×48	90·6	96	101	106	112	117	122	128	133	138	144	149
38×48	95·6	101	107	112	118	124	129	135	140	146	152	157
40×48	100	106	112	118	124	130	136	142	148	154	160	166
40×50	104	110	117	123	129	135	141	148	154	160	166	172
45×56	132	140	147	155	163	171	179	186	194	202	210	218

TABLE

Showing Equivalent Sizes and Weights of

WRAPPING PAPERS—continued.

Size. 36×45	lbs. 145	lbs. 150	lbs. 155	lbs. 160	lbs. 165	lbs. 170	lbs. 175	lbs. 180	lbs. 185	lbs. 190	lbs. 195	lbs. 200
20×24	42·9	44·4	45·9	47·3	48·8	50·3	51·8	53·3	54·8	56·3	57·8	59·3
20×25	44·7	46·2	47·8	49·3	50·9	52·4	53·9	55·5	57	58·6	60·1	61·6
21×26	48·7	50·4	52·1	53·8	55·3	57	58·6	60·4	62·2	64	65·6	67·3
20×30	53·3	55·2	57	58·8	60·7	62·6	64·6	66·6	68·5	70·3	72·2	74
21×31	58	60	62	64	66	68	70	72	74	76	78	80
20×28	50	51·7	53·4	55·2	56·9	58·6	60·3	62	63·7	65·4	67·2	69
22½×29	58·5	60·5	62·5	64·5	66·5	68·5	70·5	72·5	74·5	76·5	78·5	80·5
22×32	62·8	65	67·1	69·3	71·5	73·6	75·8	78	80·2	82·4	84·6	86·8
21×34	63·8	66	68·2	70·4	72·6	74·8	77	79·2	81·4	83·6	85·8	88
22×35	68·8	71·2	73·6	76	78·3	80·7	83·1	85·5	87·9	90·3	92·6	95
23×34	69·8	72·3	74·7	77·1	79·5	81·9	84·5	86·9	89·3	91·7	93·9	96·4
24×30	64·4	66·6	68·8	71	73·3	75·5	77·7	79·9	82·2	84·4	86·6	88·8
24×32	68·7	71·1	73·5	75·9	78·2	80·6	83	85·4	87·8	90·2	92·5	94·8
24×36	77.3	80	82·6	85·3	88	90·6	93·3	96	98·6	101	104	106
24×40	86	89	91·5	94·5	97·5	100	103	106	109	112	115	118
26×36	83·7	86·6	89·5	92·4	95·3	98·2	101	104	107	109	110	111
27×34	82·1	85	87·8	90·6	93·5	96·3	99·1	102	105	108	110	113
28×45	112	116	120	124	128	132	136	140	143	147	151	155
29×44	114	118	122	126	130	134	138	141	145	149	153	157
29×45	117	121	125	129	133	137	141	145	149	153	157	161
30×38	102	105	109	112	116	119	123	126	130	133	137	140
30×46	123	127	131	136	140	144	148	153	157	161	165	170
31×46	127	132	136	141	145	149	154	158	163	167	171	176
34×36	109	113	117	121	124	128	132	136	140	143	147	151
36×36	116	120	124	128	132	136	140	144	148	152	156	160
36×46	148	153	158	163	168	173	178	184	189	194	199	204
36×48	154	160	165	170	176	181	186	192	197	202	207	213
38×48	163	169	174	180	185	191	197	202	208	214	219	225
40×48	172	178	183	189	195	201	207	213	219	224	230	236
40×50	179	185	191	197	203	209	215	222	228	234	240	246
45×56	225	233	241	249	256	264	272	280	287	295	303	311

COST TABLE

Showing Prices per Ton from 1d. to 3⅛d. per lb., less Discount.

	1d.	1⅛d.	1¼d.	1⅜d.	1½d.	1⅝d.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Net	9 6 8	10 10 0	11 13 4	12 16 8	14 0 0	15 3 4
1¼ %	9 4 4	10 7 4½	11 10 5	12 13 5½	13 16 6	14 19 6½
2½ %	9 2 0	10 4 9	11 7 6	12 10 3	13 13 0	14 15 9
3¾ %	8 19 8	10 2 1½	11 4 7	12 7 0½	13 9 6	14 11 11½
5 %	8 17 4	9 19 6	11 1 8	12 3 10	13 6 0	14 8 2
6¼ %	8 15 0	9 16 10½	10 18 9	12 0 7½	13 2 6	14 4 4½
7½ %	8 12 8	9 14 3	10 15 10	11 17 5	12 19 0	14 0 7
8¾ %	8 10 4	9 11 7½	10 12 11	11 14 2½	12 15 6	13 16 9½
10 %	8 8 0	9 9 0	10 10 0	11 11 0	12 12 0	13 13 0
11¼ %	8 5 8	9 6 4½	10 7 1	11 7 9½	12 8 6	13 9 2½
12½ %	8 3 4	9 3 9	10 4 2	11 4 7	12 5 0	13 5 5
13¾ %	8 1 0	9 1 1½	10 1 3	11 1 4½	12 1 6	13 1 7½
15 %	7 17 8	8 18 6	9 18 4	10 18 2	11 18 0	12 17 10

	1¾d.	1⅞d.	2d.	2⅛d.	2¼d.	2⅜d.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s d.
Net	16 6 8	17 10 0	18 13 4	19 16 8	21 0 0	22 3 4
1¼ %	16 2 7	17 5 7½	18 8 8	19 11 8½	20 14 9	21 17 9½
2½ %	15 18 6	17 1 3	18 4 0	19 6 9	20 9 6	21 12 3
3¾ %	15 14 5	16 16 10½	17 19 4	19 1 9½	20 4 3	21 6 8½
5 %	15 10 4	16 12 6	17 14 8	18 16 10	19 19 0	21 1 2
6¼ %	15 6 3	16 8 1½	17 10 0	18 11 10½	19 13 9	20 15 7½
7½ %	15 2 2	16 3 9	17 5 4	18 6 11	19 8 6	20 10 1
8¾ %	14 18 1	15 19 4½	17 0 8	18 1 11½	19 3 3	20 4 6½
10 %	14 14 0	15 15 0	16 16 0	17 17 0	18 18 0	19 19 0
11¼ %	14 9 11	15 10 7½	16 11 4	17 12 0½	18 12 9	19 13 5½
12½ %	14 5 10	15 6 3	16 6 8	17 7 1	18 7 6	19 7 11
13¾ %	14 1 9	15 1 10½	16 2 0	17 2 1½	18 2 3	19 2 4½
15 %	13 17 8	14 17 6	15 17 4	16 17 2	17 17 0	18 16 10

	2½d.	2⅝d.	2¾d.	2⅞d.	3d.	3⅛d.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Net	23 6 8	24 10 0	25 13 4	26 16 8	28 0 0	29 3 4
1¼ %	23 0 10	24 3 10½	25 6 11	26 9 11½	27 13 0	28 16 0½
2½ %	22 15 0	23 17 9	25 0 6	26 3 3	27 6 0	28 8 9
3¾ %	22 9 2	23 11 7½	24 14 1	25 16 6½	26 19 0	28 1 5½
5 %	22 3 4	23 5 6	24 7 8	25 9 10	26 12 9	27 14 2
6¼ %	21 17 6	22 19 4½	24 1 3	25 3 1½	26 5 0	27 6 10½
7½ %	21 11 8	22 13 3	23 14 10	24 16 5	25 18 0	26 19 7
8¾ %	21 5 10	22 7 1½	23 8 5	24 9 8½	25 11 0	26 12 3½
10 %	21 0 0	22 1 0	23 2 0	24 3 0	25 4 0	26 5 0
11¼ %	20 14 2	21 14 10½	22 15 7	23 16 3½	24 17 0	25 17 8½
12½ %	20 8 4	21 8 9	22 9 2	23 9 7	24 10 0	25 10 5
13¾ %	20 2 6	21 2 7½	22 2 9	23 2 10½	24 3 0	25 3 1½
15 %	19 16 8	20 16 6	21 16 4	22 16 2	23 16 0	24 15 10

COST TABLE

Showing Prices per Ton from 3¼d. to 5d. per lb., less Discount.

	3¼d.	3⅜d.	3½d.	3⅝d.	3¾d.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Net	30 6 8	31 10 0	32 13 4	33 16 8	35 0 0
1¼ %	29 19 1	31 2 1½	32 5 2	33 8 2½	34 11 3
2½ %	29 11 6	30 14 3	31 17 0	32 19 9	34 2 6
3¾ %	29 3 11	30 6 4½	31 8 10	32 11 3½	33 13 9
5 %	28 16 4	29 18 6	31 0 8	32 2 10	33 5 0
6¼ %	28 8 9	29 10 7½	30 12 6	31 14 4½	32 16 3
7½ %	28 2 2	29 2 9	30 4 4	31 5 11	32 7 6
8¾ %	27 13 7	28 14 10½	29 16 2	30 17 5½	31 18 9
10 %	27 6 0	28 7 0	29 8 0	30 9 0	31 10 0
11¼ %	26 18 5	27 19 1½	28 19 10	30 0 6½	31 1 3
12½ %	26 10 10	27 11 3	28 11 8	29 12 1	30 12 6
13¾ %	26 3 3	27 3 4½	28 3 6	29 3 7½	30 3 9
15 %	25 15 8	26 15 6	27 15 4	28 15 2	29 15 0

	3⅞d.	4d.	4⅛d.	4¼d.	4⅜d.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Net	36 3 4	37 6 8	38 10 0	39 13 4	40 16 8
1¼ %	35 14 3½	36 17 4	38 0 4½	39 3 5	40 6 5½
2½ %	35 5 3	36 8 0	37 10 9	38 13 6	39 16 3
3¾ %	34 16 2½	35 18 8	37 1 1½	38 3 7	39 6 0½
5 %	34 7 2	35 9 4	36 11 6	37 13 8	38 15 10
6¼ %	33 18 1½	35 0 0	36 1 10½	37 3 9	38 5 7½
7½ %	33 9 1	34 10 8	35 12 3	36 13 10	37 15 5
8¾ %	33 0 0½	34 1 4	35 2 7½	36 3 11	37 5 2½
10 %	32 11 0	33 12 0	34 13 0	35 14 0	36 15 0
11¼ %	32 1 11½	33 2 8	34 3 4½	35 4 1	36 4 9½
12½ %	31 12 11	32 13 4	33 13 9	34 14 2	35 14 7
13¾ %	31 3 10½	32 4 0	33 4 1½	34 4 3	35 4 4½
15 %	30 14 10	31 14 8	32 14 6	33 14 4	34 14 2

	4½d.	4⅝d.	4¾d.	4⅞d.	5d.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Net	42 0 0	43 3 4	44 6 8	45 10 0	46 13 4
1¼ %	41 9 6	42 12 6½	43 15 7	44 18 7½	46 1 8
2½ %	40 19 0	42 1 9	43 4 6	44 7 3	45 10 0
3¾ %	40 8 6	41 10 11½	42 13 5	43 15 10½	44 18 4
5 %	39 18 0	41 0 2	42 2 4	43 4 6	44 6 8
6¼ %	39 7 6	40 9 4½	41 11 3	42 13 1½	43 15 0
7½ %	38 17 0	39 18 7	41 0 2	42 1 9	43 3 4
8¾ %	38 6 6	39 7 9½	40 9 1	41 10 4½	42 11 8
10 %	37 16 0	38 17 0	39 18 0	40 19 0	42 0 0
11¼ %	37 5 6	38 6 2½	39 6 11	40 7 7½	41 8 4
12½ %	36 15 0	37 15 5	38 15 10	39 16 3	40 16 8
13¾ %	36 4 6	37 4 7½	38 4 9	39 4 10½	40 5 0
15 %	35 14 0	36 13 10	37 13 8	38 13 6	39 13 4

TABLE giving the Weight in lbs. per Ream from a given sheet of paper when the weight of this in grains is known.

Weight in lbs. per Ream.	Grains per Sheet of Ream.			Weight in lbs. per Ream.	Grains per Sheet of Ream.			Weight in lbs. per Ream.	Grains per Sheet of Ream.		
	480	500	516		480	500	516		480	500	516
1	14·58	14	13·56	18	262·4	252	244·1	35	510·4	490	474·7
2	29·16	28	27·12	19	277·0	266	257·7	36	524·9	504	488·3
3	43·79	32	40·68	20	291·6	280	271·3	37	539·5	518	501·8
4	58·32	56	54·24	21	306·2	294	284·7	38	554·1	532	515·4
5	72·90	70	67·80	22	320·7	308	298·3	39	568·7	546	528·9
6	87·48	84	81·36	23	335·3	322	311·9	40	583·3	560	542·6
7	102·0	98	94·9	24	349·9	336	325·4	41	597·8	574	556·2
8	116·6	112	108·48	25	364·5	350	339·0	42	612·4	588	569·7
9	131·2	126	122·04	26	379·1	364	352·6	43	627·0	602	583·3
10	145·8	140	135·6	27	393·6	378	366·1	44	641·6	616	596·8
11	160·4	154	149·3	28	408·2	392	379·7	45	656·2	630	610·4
12	174·9	168	162·7	29	422·8	406	393·2	46	670·7	644	623·9
13	189·5	182	176·3	30	437·5	420	406·9	47	685·4	658	637·5
14	204·1	196	189·8	31	452·1	434	420·5	48	699·9	672	651·1
15	218·7	210	203·4	32	466·6	448	434·0	49	714·5	686	664·6
16	233·3	224	216·9	33	481·2	462	447·6	50	729·1	700	678·2
17	247·8	238	230·5	34	495·8	476	461·6	51	743·7	714	691·7

TABLE giving the Weight in lbs. per Ream from a given sheet of paper when the weight of this in grains is known.

Weight in lbs. per Ream.	Grains per Sheet of Ream.			Weight in lbs. per Ream.	Grains per Sheet of Ream.			Weight in lbs. per Ream.	Grains per Sheet of Ream.		
	480	500	516		480	500	516		480	500	516
52	758·3	728	705·3	69	1006	966	936·0	85	1239	1200	1152
53	772·8	742	718·9	70	1021	980	949·6	86	1253	1214	1166
54	787·4	756	732·4	71	1035	994	963·1	87	1268	1228	1180
55	802·0	770	746·0	72	1050	1008	977·6	88	1283	1232	1193
56	816·6	784	759·6	73	1064	1022	991·2	89	1297	1246	1206
57	831·2	798	773·1	74	1079	1038	1005	90	1312	1260	1221
58	845·7	812	786·7	75	1094	1052	1018	91	1327	1274	1234
59	860·3	826	800·3	76	1108	1066	1032	92	1341	1288	1247
60	875·0	840	813·9	77	1123	1080	1045	93	1356	1302	1261
61	889·6	854	827·5	78	1137	1094	1059	94	1370	1316	1274
62	904·1	868	841·0	79	1152	1108	1072	95	1385	1330	1288
63	918·7	882	854·6	80	1166	1120	1085	96	1399	1344	1301
64	933·3	896	868·1	81	1181	1134	1098	97	1414	1358	1315
65	947·9	910	881·7	82	1195	1148	1112	98	1429	1372	1329
66	962·5	924	895·3	83	1210	1172	1125	99	1443	1386	1342
67	977·0	938	908·8	84	1224	1186	1139	100	1458	1400	1356
68	991·6	952	922·4								

TABLE

Giving the Weight in lbs. and ozs. of a Ream of Paper of different sizes from the weight in grammes of one sheet one mètre square.

(MAJER.)

Grammes per Square Metre.	Demy. 17½ × 22½	Royal. 20 × 25	Dble. F'scap. 17 × 27	Dble. Crown. 20 × 30	Imperial. 22 × 29	22 × 32	25 × 30	46 × 36
	lbs. oz.	lbs. oz	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.
20	5 6	6 13	6 4	8 3	8 11½	9 10	10 4	22 10
21	5 10½	7 3	6 1½	8 9½	9 2½	10 1½	10 12	23 12
22	5 15	7 8	6 14½	9 0	9 9½	10 9½	11 4½	24 14
23	6 3	7 13½	7 3½	9 7½	10 0½	11 1	11 12½	26 0
24	6 7½	8 3	7 8½	9 13	10 7½	11 8½	12 4½	27 2
25	6 12	8 8½	7 13½	10 4	10 14½	12 0	12 12½	28 4
26	7 0	8 14	8 2½	10 11	11 5½	12 8	13 4½	29 6
27	7 4½	9 3½	8 7½	11 1	11 12½	13 0	13 12½	30 8
28	7 8½	9 9½	8 12½	11 8	12 3½	13 8	14 4½	31 10
29	7 13	9 13½	9 1½	11 14	12 10½	14 0	14 12½	32 12
30	8 1	10 4	9 6½	12 4½	13 1½	14 6½	15 5½	33 14
31	8 5½	10 9	9 11½	12 11	13 8½	14 14½	15 14	35 0
32	8 10	10 15	10 0½	13 2	13 15½	15 6½	16 6	36 2
33	8 14	11 4	10 6	13 9	14 6½	15 14½	16 14	37 4
34	9 2	11 10	10 11	13 15	14 13½	16 6	17 6	38 6
35	9 7	11 15	11 0	14 6	15 5	16 14	17 14½	39 9
36	9 11	12 4½	11 5	14 12	15 12	17 6	18 6½	40 11
37	9 15½	12 10	11 10	15 3	16 3	17 14	18 15	41 13
38	10 3½	13 0	11 15	15 10	16 10	18 6	19 7	43 0
39	10 8	13 5	12 4	16 0	17 1	18 14	19 15	44 2
40	10 12	13 11	12 9	16 6	17 7	19 4	20 8	45 4
41	11 0½	14 0	12 14	16 13	17 4	19 11	21 0	46 6
42	11 5	14 5½	13 2	17 4	18 5	20 3	21 8	47 8
43	11 9	14 11	13 7	17 10	18 12	20 10	22 0	48 10
44	11 13½	15 1	13 12	18 0	19 3	21 2	22 8	49 12
45	12 2	15 6½	14 1	18 6	19 10	21 10	23 1	50 14
46	12 6	15 11½	14 6	18 13	20 1	22 1	23 9	52 0
47	12 10½	16 0½	14 11	19 3	20 8	22 9	24 1	53 4
48	12 14½	16 6	15 0	19 10	20 15	23 1	24 9	54 6
49	13 3	11 11½	15 5	20 0	21 6	23 8	25 1	55 8
50	13 7½	17 1	15 10	20 7½	21 13	24 1	25 10	56 10

BRITISH TRADE CUSTOMS.

The following are the recognised customs of the Trade relative to Paper Making, provided that no agreement to the contrary has been made at the time of the order between the vendor and the purchaser :—

I.—SALE.

Paper is sold either at a price per ream, based upon its nominal weight, or at the actual weight by the pound, packed in reams or in reels. Wrapping Paper is sold by cwt. at scale weight.

Machine-Made Papers.

(1) A ream of paper, unless otherwise specified, contains 480 sheets.

(2) An "Insides" ream contains 480 sheets all "Insides," *i.e.* 20 good or inside quires of 24 sheets each.

(3) A "Perfect" ream for printing papers contains 516 sheets.

(4) A ream of Envelope Paper contains 504 sheets.

(5) A ream of News contains 500 sheets.

(6) A "Mill" ream contains 480 sheets, and consists of 18 "good" or "Insides" quires of 24 sheets each, and two "Outsides" quires of 24 sheets each.

(7) Reams are classed as "Good," "Retree," and "Outsides." The price of "Retree" is 10 per cent., and of "Outsides" 20 per cent., lower than that of "Good."

Hand-Made Papers.

(8) A "Mill" ream, "Good," or "Retree," contains 472 sheets, and consists of 18 "Insides" quires of 24 sheets each, and two "Outsides" of 20 sheets each.

(9) An "Insides" ream, "Good," or "Retree," contains 480 sheets, and consists of 20 "Insides" quires of 24 sheets each.

In all cases the "Outsides" quires are placed one at the top and one at the bottom of the ream.

II.—VARIATIONS IN WEIGHT.

(1) If the total actual weight, or that of any individual ream or reel, does not vary by more than 5 per cent., either above or below the ordered weight, the order is duly executed.

(2) When the purchaser has fixed a maximum weight per ream, the order is duly executed if the paper be not more than 10 per cent. under weight.

(3) But for all papers of substance under 6 lbs. Demy ($17\frac{1}{2} \times 22\frac{1}{2}$), and above 50 lbs. Demy, the actual weight may vary 10 per cent., either over or under.

(4) In the case of reels, claims for short length can only be made when the shortage exceeds 5 per cent., and then only for the amount of any excess over and above such 5 per cent.

(5) Payment for paper in reels, according to the yield of saleable copies, cannot be claimed by the purchaser unless so stipulated at the time of the order.

III.—VARIATIONS IN MEASUREMENT.

(1) The size of the paper in reams may vary, but in "Good" reams the variation must not exceed $\frac{1}{2}$ per cent., with a minimum of $\frac{1}{8}$ inch either way.

(2) The width of paper in reels must not vary more than $\frac{1}{2}$ per cent.

N.B.—Clauses II. and III. are not applicable to hand-made paper.

IV.—SPECIAL MAKINGS.

(1) For makings of special weight, size, tint, water-mark, &c., not having a regular sale in the market the order is considered to be duly executed if the quantity made is not more than 5 per cent. under the quantity ordered, and the purchaser is bound to take at full price any reasonable excess. In Writing and Drawing Papers it is customary for the buyer to take with the "Good" the "Retree" and "Outsides."

(2) Where a maximum quantity is stipulated for when ordering, the order is considered duly executed if it amounts to not less than 90 per cent. of the stipulated quantity.

V.—MATERIALS.

(1) Unless otherwise expressly stipulated in the order, the maker is absolutely free as to what materials he shall use.

VI.—WRAPPING UP.

(1) The weight of necessary wrappers and string for reams and reels is to be included in the chargeable weight of the paper.

VII.—MODE OF PAYMENT.

(1) The customary terms of payment are cash within 30 days from the end of the month in which shipment was made for Export Sales, and within 30 days from the end of the month in which delivery was effected for Home Sales.

VIII.—RETURNED EMPTIES.

(1) Carriage on returned empty Frames, Centres, Boards, Boxes, Packing-Cases, &c., is payable by Customers returning same.

AMERICAN TRADE CUSTOMS.

The Book Paper Regulations as Amended by the Book Paper Division of the American Pulp and Paper Association.

The amended trade customs of the book paper division are as follows :—

1. Terms of all sales to be on a basis of cash in thirty (30) days, less three per cent. (3 %).

2. Minimum basis of weight for standard papers to be as follows: Machine finished, 25 by 38, 40 lbs. to 500 sheets; supercalendered, 25 by 38, 45 lbs. to 500 sheets. For lighter weight papers the extra cost of manufacture to be added according to weight, estimated as follows: On machine finished paper, for each lb. cut below 25 by 38, 40 lbs. to 500 sheets, to and including 25 by 38, 30 lbs. to 500 sheets, five (5) cents per 100 lbs. additional; for each lb. cut below 25 by 38, 30 lbs. 500 sheets, ten (10) cents per 100 lbs. additional. On supercalendered paper, for each lb. cut below 25 by 38, 45 lbs. to 500 sheets, to and including 25 by 38, 35 lbs. to 500 sheets, five (5) cents per 100 lbs. additional; for each lb. below 25 by 38, 35 lbs. to 500 sheets, ten (10) cents per 100 lbs. additional.

3. In all cases, on both sheet and roll orders, wrappers and twines to be charged at the price of the paper, the weight of wrappers and twine not to exceed three per cent. (3 %) of the weight billed.

4. Rolls to be charged at the gross weight, including cores and wrappers.

5. Customers to be credited with the net weight of cores returned, stripped, at the full selling price of the paper.

6. No printed waste to be returned and no paper taken back unless damaged before delivery; and in case customer desires to make claim for damaged paper same must be reported immediately to the manufacturer, in order that the paper may be inspected before it has been printed.

7. In billing paper no allowance to be made for waste.

8. Manufacturers to bear the cost of freight on cores, heads and rods returned.

9. When cores are returned no allowance to be made for paper remaining on same, except that allowance may be made for clean white waste at market price for such waste.

10. The average variation in the nominal weight not to exceed four per cent. (4 %) above or below the ordered weight, paper within this range to constitute a good delivery.

11. Paper shall be billed at the ordered weight, unless shortage is in excess of two and one-half per cent. (2½ %), in which case it shall be billed at actual scale weight.

12. No paper shall be made one weight and stencilled another.

13. Paper shall be marked by the manufacturer the ream weight ordered, and there shall be no evasion by substituting letters or symbols for figures.

14. The base selling price shall be for paper put up in rolls without heads and rods, and sheet paper put up in bundles soft fold.

15. For paper finished in any manner except as specified in Article 14, additional cost thereof shall be added, estimated as follows: If finished flat in skeleton frames, not less than ten (10) cents per 100 lbs. shall be added to the base selling price; if finished in solid board frames top and bottom, or in cases, not less than twenty (20) cents per 100 lbs. shall be added to the base selling price.

16. Case linings shall be charged at the selling price of the paper.

17. For trimming paper the cost thereof, estimated at not less than ten (10) cents per 100 lbs., shall be added to the base selling price.

18. For ream wrapping the cost thereof, estimated at not less than ten (10) cents per 100 lbs., shall be added to the base selling price.

19. For all paper of any shade other than white or natural the extra cost thereof, estimated at not less than twenty-five (25) cents per 100 lbs., shall be added to the base selling price.

20. Orders shall be accepted subject to over runs or under runs, as follows: Under two (2) tons, 15 per cent.; from two (2) to five (5) tons, 10 per cent.; from five (5) to twenty (20) tons, 5 per cent.: from twenty (20) tons upward, 3 per cent.

SIZES OF PAPERS

Current in France and Belgium.

	English Inches.	Centi-metres.	Cm. Carrés.
Cloche	11·78 × 15·72	30 × 40	= 1200
Pot	12·18 × 15·72	31 × 40	= 1240
Tellière Belge ...	13·36 × 16 90	34 × 43	= 1462
Tellière	13·36 × 17·29	34 × 44	= 1496
Couronne	14·15 × 18·08	36 × 46	= 1656
Double Procureur	13·73 × 20·82	35 × 53	= 1855
Ecu	15·72 × 20·43	40 × 52	= 2080
Ecu Belge	15·72 × 20·83	40 × 53	= 2120
Coquille	17·30 × 22 00	44 × 56	= 2464
Carré	17·68 × 22 00	45 × 56	= 2520
Cavalier	18 08 × 24·36	46 × 62	= 2852
Royal	18·86 × 24·76	48 × 63	= 3024
Raisin	19 65 × 25·54	50 × 65	= 3250
Petit Soleil	19·65 × 26·72	50 × 68	= 3400
Jésus	21·61 × 27·51	55 × 70	= 3850
Jésus Belge	21·22 × 28·69	54 × 73	= 3942
Grand Soleil... ..	22·40 × 31·44	57 × 80	= 4560
Eléphant	24·36 × 30·26	62 × 77	= 4774
Colombier Belge ...	24 36 × 33·40	62 × 85	= 5270
Colombier	24·36 × 33·80	62 × 86	= 5332
Grand Colombier...	24·75 × 35·37	63 × 90	= 5670
Grand Aigle ...	27·51 × 39·30	70 × 100	= 7000

The figures in the following tables indicate the weight in grammes of a sheet measuring one square mètre.

Weight per Ream of 500 Sheets } = K°		2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾
Cloche	30×40	41·7	45·8	50·0	54·2	58·3	62·5	66·7	70·8	75·0	79·2	83·3	87·5	91·7	95·8
Pot	31×40	40·3	44·4	48·4	52·4	56·5	60·5	64·5	68·5	72·6	76·6	80·6	84·7	88·7	92·7
Tellière Belge... ...	34×43	...	...	41·0	44·5	47·9	51·3	54·7	58·1	61·6	65·0	68·4	71·8	75·2	78·7
Tellière	34×44			40·1	43·4	46·8	50·1	53·5	56·8	60·2	63·5	66·8	70·2	73·5	76·9
Couronne...	36×46			...	39 3	42·3	45·3	48·3	51·3	54·3	57·4	60·4	63·4	66·4	69·4
Double Procureur ...	35×53			...	...	...	40·4	43·1	45·8	48·5	51·2	53·9	56·6	59·3	62·0
Ecu	40×52			...	...	...	...	...	40·9	43·3	45·7	48·1	50·5	52·9	55·3
Ecu Belge	40×53			...	...	...	...	...	40·1	42·5	44·8	47·2	49·5	51·9	54·3
Coquille	44×56			...	...	...	...	...	...	...	...	40·6	42·6	44·6	46·7
Carré...	45×56			...	...	...	...	...	...	...	...	39·7	41·7	43·7	45·6
Cavalier	46×62			...	...	...	...	...	...	...	...	...	...	...	40·3
Royal	48×63			...	...	...	...	...	...	...	...	...	...	...	...
Raisin	50×65			...	...	...	...	...	...	...	...	...	...	...	...
Petit Soleil	50×68			...	...	...	...	...	...	...	...	...	...	...	...
Jésus...	55×70			...	...	...	...	...	...	...	...	...	...	...	...
Jésus Belge	54×73			...	...	...	...	...	...	...	...	...	...	...	...
Grand Soleil	57×80			...	...	...	...	...	...	...	...	...	...	...	...
Eléphant	62×77			...	...	...	...	...	...	...	...	...	...	...	...
Colombier Belge ...	62×85			...	...	...	...	...	...	...	...	...	...	...	...
Colombier	62×86			...	...	...	...	...	...	...	...	...	...	...	...
Grand Colombier ...	63×90			...	...	...	...	...	...	...	...	...	...	...	...
Grand Aigle	70×100			...	...	...	...	...	...	...	...	...	...	...	...

The figures in these tables indicate the weight in grammes of a sheet one mètre square.

Weight per ream of 500 sheets.	= K°	6	6¼	6½	6¾	7	7¼	7½	7¾	8	8¼	8½	8¾	9
Cloche	30×40	100·0	104·2	108·3	112·5	116·7	120·8	125·0	129·2	133·3	137·5	141·7	145·8	150·0
Pot	31×40	96·8	100·8	104·8	108·9	112·9	116·9	121·0	125·0	129·0	133·1	137·1	141·1	145·2
Tellière Belge... ...	34×43	82·1	85·5	88·9	92·3	95·8	99·2	102·6	106·0	109·4	112·9	116·3	119·7	123·1
Tellière	34×44	80·2	83·6	86·9	90·2	93·6	96·9	100·3	103·6	107·0	110·3	113·6	117·0	120·3
Couronne...	36×46	72·5	75·5	78·5	81·5	84·5	87·6	90·6	93·6	96·6	99·6	102·7	105·7	108·7
Double Procureur ...	35×53	64·7	67·4	70·1	72·8	75·5	78·2	80·9	83·6	86·3	89·0	91·7	94·4	97·1
Ecu	40×52	57·7	60·1	62·5	64·9	67·3	69·7	72·1	74·5	76·9	79·3	81·7	84·1	86·5
Ecu Belge	40×53	56·6	59·0	61·3	63·7	66·1	68·4	70·8	73·1	75·5	77·9	80·2	82·6	84·9
Coquille	44×56	48·7	50·7	52·8	54·8	56·8	58·8	60·9	62·9	64·9	67·0	69·0	71·0	73·1
Carré	45×56	47·6	49·6	51·6	53·6	55·6	57·5	59·5	61·5	63·5	65·5	67·5	69·4	71·4
Cavalier	46×62	42·1	43·8	45·6	47·3	49·1	50·8	52·6	54·3	56·1	57·9	59·6	61·4	63·1
Royal	48×63	39·7	41·3	43·0	44·6	46·3	47·9	49·6	51·3	52·9	54·6	56·2	57·9	59·5
Raisin	50×65	...	...	40·0	41·5	43·1	44·6	46·2	47·7	49·2	50·8	52·3	53·8	55·4
Petit Soleil	50×68	...	...	...	39·7	41·2	42·7	44·1	45·6	47·1	48·5	50·0	51·5	52·9
Jésus	55×70	...	...	...	...	...	...	...	40·3	41·6	42·9	44·2	45·5	46·8
Jésus Belge	54×73	...	...	...	...	...	...	...	39·3	40·6	41·9	43·1	44·4	45·7
Grand Soleil	57×80	...	...	...	...	...	...	...	...	...	...	...	...	39·5
Eléphant	62×77	...	...	...	...	...	...	...	...	...	...	...	...	...
Colombier Belge ...	62×85	...	...	...	...	...	...	...	...	...	...	...	...	...
Colombier	62×86	...	...	...	...	...	...	...	...	...	...	...	...	...
Grand Colombier ...	63×90	...	...	...	...	...	...	...	...	...	...	...	...	...
Grand Aigle	70×100	...	...	...	...	...	...	...	...	...	...	...	...	...

Weight per Ream of 500 Sheets } = K^0		9¼	9½	9¾	10	10¼	10½	10¾	11	11¼	11½	11¾	12	12¼
Cloche	30×40	154·2	158·3	162·5	166·7	170·8	175·0	179·2	183·3	187·5	191·7	195·8	200·0	204·2
Pot	31×40	149·2	153·2	157·3	161·3	165·3	169·4	173·4	177·4	181·5	185·5	189·5	193·6	197·6
Tellière Belge... ...	34×43	126·5	130·0	133·4	136·8	140·2	143·6	147·1	150·5	153·9	157·3	160·7	164·2	167·6
Tellière	34×44	123·7	127·0	130·3	133·7	137·0	140·4	143·7	147·1	150·4	153·7	157·1	160·4	163·8
Couronne	36×46	111·7	114·7	117·8	120·8	123·8	126·8	129·8	132·8	135·9	138·9	141·9	144·9	147·9
Double Procureur ...	35×53	99·8	102·5	105·2	107·8	110·4	113·1	115·8	118·5	121·2	123·9	126·6	129·3	132·0
Ecu...	40×52	88·9	91·3	93·7	96·2	98·6	101·0	103·4	105·8	108·2	110·6	113·0	115·4	117·8
Ecu Belge	40×53	87·3	89·7	92·0	94·3	96·7	99·1	101·4	103·8	106·1	108·5	110·9	113·2	115·6
Coquille	44×56	75·1	77·1	79·1	81·2	83·2	85·2	87·3	89·3	91·3	93·3	95·4	97·4	99·4
Carré...	45×56	73·4	75·4	77·4	79·4	81·3	83·3	85·3	87·3	89·3	91·3	93·3	95·2	97·2
Cavalier	46×62	64·9	66·6	68·4	70·1	71·9	73·6	75·4	77·1	78·9	80·6	82·4	84·2	85·9
Royal...	48×63	61·2	62·8	64·5	66·1	67·8	69·5	71·1	72·8	74·4	76·1	77·7	79·4	81·0
Raisin	50×65	56·9	58·5	60·0	61·5	63·1	64·6	66·2	67·7	69·2	70·8	72·3	73·8	75·4
Petit Soleil	50×68	54·4	55·9	57·4	58·8	60·3	61·8	63·2	64·7	66·2	67·6	69·1	70·6	72·1
Jésus...	55×70	48·1	49·4	50·6	51·9	53·2	54·5	55·8	57·1	58·4	59·7	61·0	62·3	63·6
Jésus Belge	54×73	46·9	48·2	49·5	50·7	52·0	53·3	54·5	55·8	57·1	58·3	59·6	60·9	62·2
Grand Soleil	57×80	40·6	41·7	42·8	43·9	45·0	46·1	47·2	48·3	49·4	50·5	51·6	52·7	53·8
Eléphant	62×77	...	...	40·8	41·9	42·9	44·0	45·0	46·1	47·1	48·2	49·2	50·3	51·3
Colombier Belge ...	62×85	...	...	...	...	...	39·8	40·8	41·7	42·7	43·6	44·6	45·5	46·5
Colombier...	62×86	...	...	...	...	...	...	...	41·3	42·2	43·1	44·1	45·0	45·9
Grand Colombier ...	63×90	...	...	...	...	...	...	...	...	39·7	40·6	41·5	42·3	43·2
Grand Aigle	70×100	...	...	...	...	...	...	...	...	...	...	...	...	...

Weight per ream of 500 sheets.	= K°	$12\frac{1}{2}$	$12\frac{3}{4}$	13	$13\frac{1}{4}$	$13\frac{1}{2}$	$13\frac{3}{4}$	14	$14\frac{1}{4}$	$14\frac{1}{2}$	$14\frac{3}{4}$	15	$15\frac{1}{4}$	$15\frac{1}{2}$
Cloche	30 × 40	208·3	212·5	216·7	220·8	225·0	229·2	333·3	237·5	241·7	245·8	250·0	254·2	258·3
Pot	31 × 40	201·6	205·7	209·7	213·7	217·8	221·8	225·8	229·8	233·9	237·9	241·9	246·0	250·0
Tellière Belge... ...	34 × 43	171·0	174·4	177·8	181·3	184·7	188·1	191·5	194·9	198·4	201·8	205·2	208·6	212·0
Tellière	34 × 44	167·1	170·5	173·8	177·1	180·5	183·8	187·2	190·5	193·8	197·2	200·5	203·9	207·2
Couronne...	36 × 46	151·0	154·0	157·0	160·0	163·0	166·1	169·1	172·1	175·1	178·1	181·2	184·2	187·2
Double Procureur ...	35 × 53	134·7	137·4	140·1	142·8	145·5	148·2	150·9	153·6	156·3	159·0	161·7	164·4	167·1
Ecu	40 × 52	120·2	122·6	125·0	127·4	129·8	132·2	134·6	137·0	139·4	141·8	144·2	146·6	149·0
Ecu Belge	40 × 53	117·9	120·3	122·7	125·0	127·4	129·7	132·1	134·5	136·8	139·2	141·5	143·9	146·3
Coquille	44 × 56	101·5	103·5	105·5	107·5	109·6	111·6	113·6	115·7	117·7	119·7	121·8	123·8	125·8
Carré	45 × 56	99·2	101·2	103·2	105·2	107·1	109·1	111·1	113·1	115·1	117·1	119·0	121·0	123·0
Cavalier	46 × 62	87·7	89·4	91·2	92·9	94·7	96·4	98·2	99·9	101·7	103·4	105·2	106·9	108·7
Royal	48 × 63	82·7	84·3	86·0	87·6	89·3	90·9	92·6	94·2	95·9	97·5	99·2	100·9	102·5
Raisin	50 × 65	76·9	78·5	80·0	81·5	83·1	84·6	86·2	87·7	89·2	90·8	92·3	93·8	95·4
Petit Soleil	50 × 68	73·5	75·0	76·5	77·9	79·4	80·9	82·4	83·8	85·3	86·8	88·2	89·7	91·2
Jésus...	55 × 70	64·9	66·2	67·5	68·8	70·1	71·4	72·7	74·0	75·3	76·6	77·9	79·2	80·5
Jésus Belge	54 × 73	63·4	64·7	66·0	67·2	68·5	69·8	71·0	72·3	73·6	74·9	76·1	77·4	78·6
Grand Soleil	57 × 80	54·9	55·9	57·0	58·1	59·2	60·3	61·4	62·5	63·6	64·7	65·8	66·9	68·0
Eléphant	62 × 77	52·4	53·4	54·5	55·5	56·6	57·6	58·7	59·7	60·7	61·8	62·9	63·9	65·0
Colombier Belge ...	62 × 85	47·4	48·4	49·3	50·3	51·2	52·2	53·1	54·1	55·0	56·0	56·9	57·9	58·8
Colombier	62 × 86	46·9	47·8	48·8	49·7	50·6	51·6	52·5	53·4	54·4	55·3	56·3	57·2	58·1
Grand Colombier ...	63 × 90	44·1	45·0	45·9	46·7	47·6	48·5	49·4	50·3	51·1	52·0	52·9	53·8	54·7
Grand Aigle	70 × 100	...	...	...	...	...	...	40·0	40·7	41·4	42·1	42·9	43·6	44·3

Weight per Ream of 500 Sheets } = K°		$15\frac{3}{4}$	16	$16\frac{1}{4}$	$16\frac{1}{2}$	$16\frac{3}{4}$	17	$17\frac{1}{4}$	$17\frac{1}{2}$	$17\frac{3}{4}$	18	$18\frac{1}{4}$	$18\frac{1}{2}$	$18\frac{3}{4}$
Cloche	30×40	262·5	266·7	270·8	275·0	279·2	283·3	287·5	291·7	295·8	300·0	...	...	...
Pot	31×40	254·0	258·1	262·1	266·1	270·2	274·2	278·2	282·3	286·3	290·3	294·4	298·4	302·4
Tellière Belge... ...	34×43	215·5	218·9	222·3	225·7	229·1	232·6	236·0	239·4	242·8	246·2	249·7	253·1	256·5
Tellière	34×44	210·6	213·9	217·2	220·6	223·9	227·3	230·6	234·0	237·3	240·6	244·0	247·3	250·7
Couronne	36×46	190·2	193·2	196·3	199·3	202·3	205·3	208·3	211·4	214·4	217·4	220·4	223·4	226·4
Double Procureur ...	35×53	169·8	172·5	175·2	177·9	180·6	183·3	186·0	188·7	191·4	194·1	196·8	199·5	202·2
Ecu	40×52	151·4	153·8	156·2	158·7	161·1	163·5	165·9	168·3	170·7	173·1	175·5	177·9	180·3
Ecu Belge	40×53	148·6	151·0	153·3	155·7	158·1	160·4	162·8	165·1	167·5	169·9	172·2	174·6	176·9
Coquille	44×56	127·8	129·9	131·9	133·9	136·0	138·0	140·0	142·0	144·1	146·1	148·1	150·2	152·2
Carré	45×56	125·0	127·0	129·0	131·0	132·9	134·9	136·9	138·9	140·9	142·9	144·8	146·8	148·8
Cavalier	46×62	110·5	112·2	114·0	115·7	117·5	119·2	121·0	122·7	124·5	126·2	128·0	129·7	131·5
Royal	48×63	104·2	105·8	107·5	109·1	110·8	112·4	114·1	115·7	117·4	119·1	120·7	122·4	124·0
Raisin	50×65	96·9	98·5	100·0	101·5	103·1	104·6	106·2	107·7	109·2	110·8	112·3	113·8	115·4
Petit Soleil	50×68	92·6	94·1	95·6	97·1	98·5	100·0	101·5	102·9	104·4	105·9	107·4	108·8	110·3
Jésus...	55×70	81·8	83·1	84·4	85·7	87·0	88·3	89·6	90·9	92·2	93·5	94·8	96·1	97·4
Jésus Belge	54×73	79·9	81·2	82·4	83·7	85·0	86·3	87·5	88·8	90·1	91·3	92·6	93·9	95·1
Grand Soleil	57×80	69·1	70·2	71·3	72.4	73·5	74·6	75·7	76·8	77·9	78·9	80·0	81·1	82·2
Eléphant	62×77	66·0	67·0	68·1	69.1	70·2	71·2	72·3	73·3	74·4	75·4	76·5	77·5	78·6
Colombier Belge ...	62×85	59·8	60·7	61·7	62·6	63·6	64·5	65·5	66·4	67·4	68·3	69·3	70·2	71·2
Colombier	62×86	59·1	60·0	61·0	61·9	62·8	63·8	64·7	65·6	66·6	67·5	68·5	69·4	70·3
Grand Colombier ...	63×90	55·5	56·4	57·3	58·2	59·1	59·9	60·8	61·7	62·6	63·5	64·3	65·2	66·1
Grand Aigle	70×100	45·0	45·7	46·4	47·1	47·9	48·6	49·3	50·0	50·7	51·4	52·1	52·9	53·6

Weight per Ream of 500 Sheets	$=K^0$	19	19¼	19½	19¾	20	20¼	20½	20¾	21	21¼	21½	21¾	22
Cloche	30 × 40	...	...	...	...	...	...	...	...	...	...	...	...	...
Pot	31 × 40	...	...	...	..	...	...	...	...	...	...	...	...	...
Tellière Belge... ...	34 × 43	259·9	263·3	266·8	270·2	273·6	277·0	280·4	283·9	287·3	290·7	294·1	297·5	301·0
Tellière	34 × 44	254·0	257·3	260·7	264·0	267·4	270·7	274·1	277·4	280·7	284·1	287·4	290·8	294·1
Couronne...	36 × 46	229·5	232·5	235·5	238·5	241·5	244·6	247·6	250·6	253·6	256·6	259·7	262·7	265·7
Double Procureur ...	35 × 53	204·9	207·6	210·3	213·0	215·6	218·3	221·0	223·7	226·4	229·1	231·8	234·5	237·2
Ecu	40 × 52	182·7	185·1	187·5	189·9	192·3	194·7	197·1	199·5	201·9	204·3	206·7	209·1	211·5
Ecu Belge	40 × 53	179·3	181·7	184·0	186·4	188·7	191·0	193·4	195·8	198·1	200·5	202·8	205·2	207·6
Coquille	44 × 56	154·2	156·2	158·3	160·3	162·3	164·4	166·4	168·4	170·5	172·5	174·5	176·5	178·6
Carré	45 × 56	150·3	152·8	154·8	156·7	158·7	160·7	162·7	164·7	166·7	168·6	170·6	172·6	174·6
Cavalier	46 × 62	133·2	135·0	136·7	138·5	140·3	142·0	143·8	145·5	147·3	149·0	150·8	152·5	154·3
Royal	48 × 63	125·7	127·3	129·0	130·6	132·3	133·9	135·6	137·2	138·9	140·5	142·2	143·8	145·5
Raisin	50 × 65	116·9	118·5	120·0	121·5	123·1	124·6	126·2	127·7	129·2	130·8	132·3	133·8	135·4
Petit Soleil	50 × 68	111·8	113·2	114·7	116·2	117·6	119·1	120·6	122·1	123·5	125·0	126·5	127·9	129·4
Jésus...	55 × 70	98·7	100·0	101·3	102·6	103·9	105·2	106·5	107·8	109·1	110·4	111·7	113·0	114·3
Jésus Belge	54 × 73	96·4	97·7	99·0	100·2	101·5	102·7	104·0	105·3	106·5	107·8	109·1	110·3	111·6
Grand Soleil	57 × 80	83·3	84·4	85·5	86·6	87·7	88·8	89·9	90·9	92·0	93·1	94·2	95·3	96·4
Eléphant	62 × 77	79·6	80·7	81·7	82·8	83·8	84·8	85·9	86·9	88·0	89·0	90·1	91·1	92·2
Colombier Belge ...	62 × 85	72·1	73·1	74·0	74·9	75·9	76·9	77·8	78·8	79·7	80·7	81·6	82·6	83·5
Colombier	62 × 86	71·3	72·2	73·1	74·1	75·0	76·0	76·9	77·8	78·8	79·7	80·6	81·6	82·5
Grand Colombier ...	63 × 90	67·0	67·9	68·7	69·6	70·5	71·4	72·3	73·2	74·1	75·0	75·8	76·7	77·6
Grand Aigle	70 × 100	54·3	55·0	55·7	56·4	57·1	57·9	58·6	59·3	60·0	60·7	61·4	62·1	62·9

Weight per Ream of 500 Sheets	= K°	$22\frac{1}{4}$	$22\frac{1}{2}$	$22\frac{3}{4}$	23	$23\frac{1}{4}$	$23\frac{1}{2}$	$23\frac{3}{4}$	24	$24\frac{1}{4}$	$24\frac{1}{2}$	$24\frac{3}{4}$	25	$25\frac{1}{4}$
Cloche	30×40	...	...	...	...	...	...	...	...	...	...	...	...	...
Pot	31×40	...	...	...	...	...	...	...	...	...	...	...	...	...
Tellière Belge... ...	34×43	...	...	...	...	...	...	...	...	...	...	...	...	...
Tellière	34×44	297·5	...	...	...	...	...	...	...	...	...	...	...	...
Couronne...	36×46	268·7	271·7	274·8	277·8	280·8	283·8	286·8	289·9	292·9	295·9	298·9	301·9	...
Double Procureur ...	35×53	239·9	242·6	245·3	248·0	250·7	253·4	256·1	258·8	261·5	264·2	266·9	269·5	272·2
Ecu	40×52	213·9	216·3	218·7	221·2	223·6	226·0	228·4	230·8	233·2	235·6	238·0	240·4	242·8
Ecu Belge	40×53	209·9	212·3	214·6	217·0	219·4	221·7	224·1	226·4	228·8	231·2	233·5	235·9	238·2
Coquille	44×56	180·6	182·6	184·7	186·7	188·7	190·7	192·8	194·8	196·8	198·9	200·9	202·9	204·9
Carré	45×56	176·6	178·6	180·6	182·5	184·5	186·5	188·5	190·5	192·5	194·4	196·4	198·4	200·4
Cavalier	46×62	156·0	157·8	159·5	161·3	163·0	164·8	166·6	168·3	170·1	171·8	173·6	175·3	177·1
Royal	48×63	147·1	148·8	150·5	152·1	153·8	155·4	157·1	158·7	160·4	162·0	163·7	165·3	167·0
Raisin	50×65	136·9	138·5	140·0	141·5	143·1	144·6	146·2	147·7	149·2	150·8	152·3	153·8	155·4
Petit Soleil	50×68	130·9	132·4	133·8	135·3	136·8	138·2	139·7	141·2	142·6	144·1	145·6	147·1	148·5
Jésus...	55×70	115·6	116·9	118·2	119·5	120·8	122·1	123·4	124·7	126·0	127·3	128·6	129·9	131·2
Jésus Belge	54×73	112·9	114·2	115·4	116·7	118·0	119·2	120·5	121·8	123·0	124·3	125·6	126·8	128·1
Grand Soleil	57×80	97·5	98·7	99·8	100·9	102·0	103·1	104·2	105·3	106·4	107·4	108·5	109·7	110·7
Eléphant	62×77	93·2	94·3	95·3	96·4	97·4	98·5	99·5	100·6	101·6	102·7	103·7	104·7	105·8
Colombier Belge ...	62×85	84·5	85·4	86·4	87·3	88·3	89·2	90·2	91·1	92·1	93·0	94·0	94·9	95·8
Colombier	62×86	83·5	84·4	85·3	86·3	87·2	88·1	89·1	90·0	91·0	91·9	92·8	93·8	94·7
Grand Colombier ...	63×90	78·5	79·4	80·2	81·1	82·0	82·9	83·8	84·6	85·5	86·4	87·3	88·2	89·1
Grand Aigle	70×100	63·6	64·3	65·0	65·7	66·4	67·1	67·9	68·6	69·3	70·0	70·7	71·4	72·1

Weight per Ream of 500 Sheets	=K°	25½	25¾	26	26¼	26½	26¾	27	27¼	27½	27¾	28	28¼	28½
Cloche	30 × 40	...	...	...	...	...	...	...	...	...	...	...	...	...
Pot	31 × 40	...	...	...	...	...	...	...	...	...	...	...	...	...
Tellière Belge... ...	34 × 43	...	...	...	...	...	...	...	...	...	...	...	...	...
Tellière	34 × 44	...	...	...	...	...	...	...	...	...	...	...	...	...
Couronne...	36 × 46	...	...	...	...	...	...	...	...	...	...	...	...	...
Double Procureur ...	35 × 53	274·9	277·6	280·3	283·0	285·7	288·4	291·1	293·8	296·5	299·2	301·9	...	...
Ecu	40 × 52	245·2	247·6	250·0	252·4	254·8	257·2	259·6	262·0	264·4	266·8	269·2	271·6	274·0
Ecu Belge	40 × 53	240·6	242·9	245·3	247·7	250·0	252·4	254·7	257·1	259·4	261·8	264·2	266·5	268·9
Coquille	44 × 56	207·0	209·0	211·0	213·1	215·1	217·1	219·2	221·2	223·2	225·2	227·3	229·3	231·3
Carré	45 × 56	202·4	204·4	206·3	208·3	210·3	212·3	214·3	216·3	218·3	220·2	222·2	224·2	226·2
Cavalier	46 × 62	178·8	180·6	182·3	184·1	185·8	187·6	189·3	191·1	192·9	194·6	196·4	198·1	199·9
Royal	48 × 63	168·7	170·3	172·0	173·6	175·3	176·9	178·6	180·2	181·9	183·5	185·2	186·8	188·5
Raisin	50 × 65	156·9	158·5	160·0	161·5	163·1	164·6	166·2	167·7	169·2	170·8	172·3	173·8	175·4
Petit Soleil	50 × 68	150·0	151·5	152·9	154·4	155·9	157·4	158·8	160·3	161·8	163·2	164·7	166·2	167·6
Jésus...	55 × 70	132·5	133·8	135·1	136·4	137·7	139·0	140·3	141·6	142·9	144·2	145·5	146·8	148·1
Jésus Belge	54 × 73	129·4	130·6	131·9	133·2	134·4	135·7	137·0	138·3	139·5	140·8	142·1	143·3	144·6
Grand Soleil	57 × 80	111·8	112·9	114·0	115·1	116·2	117·3	118·4	119·4	120·6	121·7	122·8	123·9	125·0
Eléphant	62 × 77	106·8	107·9	108·9	110·0	111·0	112·1	113·1	114·2	115·2	116·3	117·3	118·4	119·4
Colombier Belge ...	62 × 85	96·8	97·7	98·7	99·6	100·6	101·5	102·5	103·4	104·4	105·3	106·2	107·2	108·1
Colombier	62 × 86	95·6	96·6	97·5	98·5	99·4	100·3	101·3	102·2	103·1	104·1	105·0	106·0	106·9
Grand Colombier ...	63 × 90	90·0	90·8	91·7	92·6	93·5	94·4	95·2	96·1	97·0	97·9	98·8	99·6	100·5
Grand Aigle	70 × 100	72·9	73·6	74·3	75·0	75·7	76·4	77·1	77·9	78·6	79·3	80·0	80·7	81·4

Weight per Ream of 500 Sheets	= K°	28¾	29	29¼	29½	29¾	30	30¼	30½	30¾	31	31¼	31½	31¾
Cloche … … …	30 × 40	…	…	…	…	…	…	…	…	…	…	…	…	…
Pot … … … …	31 × 40	…	…	…	…	…	…	…	…	…	…	…	…	…
Tellière Belge .. …	34 × 43	…	…	…	…	…	…	…	…	…	…	…	…	…
Tellière … … …	34 × 44	…	…	…	…	…	…	…	…	…	…	…	…	…
Couronne… … …	36 × 46	…	…	…	…	…	…	…	…	…	…	…	…	…
Double Procureur…	35 × 53	…	…	…	…	…	…	…	…	…	…	…	…	…
Ecu … … … …	40 × 52	276·4	278·8	281·2	283·7	286·1	288·5	290·9	293·3	295·7	298·1	300·5	…	…
Ecu Belge … …	40 × 53	271·2	273·6	276·0	278·3	280·7	283·0	285·4	287·7	290·1	292·5	294·8	297·2	299·5
Coquille … … …	44 × 56	233·4	235·4	237·4	239·4	241·5	243·5	245·5	247·6	249·6	251·6	253·7	255·7	257·7
Carré … … …	45 × 56	228·2	230·2	232·1	234·1	236·1	238·1	240·1	242·1	244·0	246·0	248·0	250·0	252·0
Cavalier … … …	46 × 62	201·6	203·4	205·1	206·9	208·6	210·4	212·1	213·9	215·6	217·4	219·2	220·9	222·7
Royal … … …	48 × 63	190·1	191·8	193·4	195·1	196·7	198·4	200·1	201·7	203·4	205·0	206·7	208·3	210·0
Raisin … … …	50 × 65	176·9	178·5	180·0	181·5	183·1	184·6	186·2	187·7	189·2	190·8	192·3	193·8	195·4
Petit Soleil … …	50 × 68	169·1	170·6	172·1	173·5	175·0	176·5	177·9	179·4	180·9	182·4	183·8	185·3	186·8
Jésus… … … …	55 × 70	149·4	150·6	151·9	153·2	154·5	155·8	157·1	158·4	159·7	161·0	162·3	163·6	164·9
Jésus Belge … …	54 × 73	145·9	147·1	148·4	149·7	151·0	152·2	153·5	154·7	156·0	157·3	158·5	159·8	161·1
Grand Soleil … …	57 × 80	126·1	127·2	128·3	129·4	130·5	131·6	132·7	133·8	134·9	136·0	137·1	138·2	139·3
Eléphant … … …	62 × 77	120·5	121·5	122·6	123·6	124·7	125·7	126·7	127·8	128·8	129·9	130·9	132·0	133·0
Colombier Belge …	62 × 85	109·1	110·0	111·0	111·9	112·9	113·9	114·8	115·8	116·7	117·7	118·6	119·6	120·5
Colombier … …	62 × 86	107·8	108·8	109·7	110·6	111·6	112·5	113·5	114·4	115·3	116·3	117·2	118·2	119·1
Grand Colombier …	63 × 90	101·4	102·3	103·2	104·0	104·9	105·8	106·7	107·6	108·5	109·4	110·2	111·1	112·0
Grand Aigle … …	70 × 100	82·1	82·9	83·6	84·3	85·0	85·7	86·4	87·1	87·9	88·0	89·3	90·0	90·7

Weight per Ream of 500 Sheets = K°		32	32¼	32½	32¾	33	33¼	33½	33¾	34	34¼	34½	34¾	35
Cloche … … …	30 × 40	…	…	…	…	…	…	…	…	…	…	…	…	…
Pot … … … …	31 × 40	…	…	…	…	…	…	…	…	…	…	…	…	…
Tellière Belge… …	34 × 43	…	…	…	…	…	…	…	…	…	…	…	…	…
Tellière … … …	34 × 44	…	…	…	…	…	…	…	…	…	…	…	…	…
Couronne… … …	36 × 46	…	…	…	…	…	…	…	…	…	…	…	…	…
Double Procureur …	35 × 53	…	…	…	…	…	…	…	…	…	…	…	…	…
Ecu … … … …	40 × 52	…	…	…	…	…	…	…	…	…	…	…	…	…
Ecu Belge … …	40 × 53	301·9	…	…	…	…	…	…	…	…	…	…	…	…
Coquille … … …	44 × 56	259·7	261·8	263·8	265·8	267·9	269·9	271·9	273·9	276·0	278·0	280·0	282·1	284·1
Carré … … …	45 × 56	254·0	256·0	257·9	259·9	261·9	263·9	265·9	267·9	269·8	271·8	273·8	275·8	277·8
Cavalier … … …	46 × 62	224·4	226·2	227·9	229·7	231·4	233·2	234·9	236·7	238·4	240·2	241·9	243·7	245·4
Royal … … …	48 × 63	211·6	213·3	214·9	216·6	218·3	219·9	221·6	223·2	224·9	226·5	228·2	229·8	231·5
Raisin … … …	50 × 65	196·9	198·5	200·0	201·5	203·1	204·6	206·2	207·7	209·2	210·8	212·3	213·8	215·4
Petit Soleil … …	50 × 68	188·2	189·7	191·2	192·6	194·1	195·6	197·1	198·5	200·0	201·5	202·9	204·4	205·9
Jèsus… … … …	55 × 70	166·2	167·5	168·8	170·1	171·4	172·6	174·0	175·3	176·6	177·9	179·2	180·5	181·8
Jèsus Belge … …	54 × 73	162·4	163·6	164·9	166·2	167·4	168·7	170·0	171·2	172·5	173·8	175·1	176·3	177·6
Grand Soleil … …	57 × 80	140·4	141·5	142·5	143·6	144·7	145·8	146·9	148·0	149·1	150·2	151·3	152·4	153·5
Elèphant … … …	62 × 77	134·1	135·1	136·2	137·2	138·3	139·3	140·4	141·4	142·5	143·5	144·5	145·6	146·6
Colombier Belge …	62 × 85	121·5	122·4	123·4	124·3	125·3	126·2	127·2	128·1	129·1	130·0	130·9	131·9	132·8
Colombier … …	62 × 86	120·0	121·0	121·9	122·8	123·8	124·7	125·7	126·6	127·5	128·5	129·4	130·3	131·3
Grand Colombier …	63 × 90	112·9	113·8	114·6	115·5	116·4	117·3	118·2	119·0	119·9	120·8	121·7	122·6	123·4
Grand Aigle … …	70 × 100	91·4	92·1	92·9	93·6	94·3	95·0	95·7	96·4	97·1	97·9	98·6	99·3	100·0

Weight per Ream of 500 Sheets	=K°	35¼	35½	35¾	36	36¼	36½	36¾	37	37¼	37½	37¾	38	38¼
Cloche	30 × 40	...	...	...	...	...	...	...	...	...	...	...	...	...
Pot	31 × 40	...	...	...	...	...	...	...	...	...	...	...	...	...
Tellière Belge... ...	34 × 43	...	...	...	...	...	...	...	...	...	...	...	...	...
Tellière	34 × 44	...	...	...	...	...	...	...	...	...	...	...	...	...
Couronne	36 × 46	...	...	...	...	...	...	...	...	...	...	...	...	...
Double Procureur ...	35 × 53	...	...	...	...	...	...	...	...	...	...	...	...	...
Ecu	40 × 52	...	...	...	...	...	...	...	...	...	...	...	...	...
Ecu Belge	40 × 53	...	...	...	...	...	...	...	...	...	...	...	...	...
Coquille	44 × 56	286·1	288·1	290·2	292·2	294·2	296·3	298·3	300·3	...	...	...	...	...
Carrè...	45 × 56	279·8	281·7	283·7	285·7	287·7	289·7	291·7	293·6	295·6	297·6	299·6	...	...
Cavalier	46 × 62	247·2	249·0	250·7	252·5	254·2	256·0	257·7	259·5	261·2	263·0	264·7	266·5	268·2
Royal...	48 × 63	233·1	234·8	236·4	238·1	239·7	241·4	243·1	244·7	246·4	248·0	249·7	251·3	253·0
Raisin	50 × 65	216·9	218·5	220·0	221·5	223·1	224·6	226·2	227·7	229·2	230·8	232·3	233·8	235·4
Petit Soleil	50 × 68	207·4	208·8	210·3	211·8	213·2	214·7	216·2	217·6	219·1	220·6	222·1	233·5	225·0
Jésus...	55 × 70	183·1	184·4	185·7	187·0	188·3	189·6	190·9	192·2	193·5	194·8	196·1	197·4	198·7
Jésus Belge	54 × 73	178·8	180·1	181·4	182·6	183·9	185·2	186·4	187·7	189·0	190·3	191·5	192·8	194·1
Grand Soleil	57 × 80	154·6	155·7	156·8	157·9	159·0	160·1	161·2	162·3	163·4	164·5	165·6	166·7	167·7
Elèphant	62 × 77	147·7	148·7	149·8	150·8	151·9	152·9	154·0	155·0	156·1	157·1	158·2	159·2	160·3
Colombier Belge ...	62 × 85	133·8	134·7	135·7	136·6	137·6	138·5	139·5	140·4	141·4	142·3	143·3	144·2	145·2
Colombier	62 × 86	132·2	133·2	134·1	135·0	136·0	136·9	137·8	138·8	139·7	140·7	141·6	142·5	143·5
Grand Colombier ...	63 × 90	124·3	125·2	126·1	127·0	127·8	128·7	129·6	130·5	131·4	132·2	133·1	134·0	134·9
Grand Aigle	70 × 100	100·7	101·4	102·1	102·9	103·6	104·3	105·0	105·7	106·4	107·1	107·9	108·6	109·3

CHAPTER II.

COMPARATIVE DEGREES OF TEMPERATURE

As indicated by the different thermometers, viz. :—
Fahrenheit, Centigrade, and Reaumur.

(C. = Centigrade ; F. = Fahrenheit ; R. = Reaumur.)

Fahrenheit to Centigrade $\frac{5}{9}$ (F.°—32) = C.°
Centigrade to Fahrenheit $\frac{9C}{5}$ + 32 = F.
Reaumur to Fahrenheit $\frac{9R}{4}$ + 32 = F.
Fahrenheit to Reaumur $\frac{4}{9}$ (F.°—32) = R.°
Centigrade to Reaumur $\frac{4C}{5}$ = R.
Reaumur to Centigrade $\frac{5R}{4}$ = C.

Degrees.			Degrees.		
Fah.	Centi.	Re.	Fah.	Centi.	Re.
212	100	80	187	86·11	68·89
211	99·44	79·56	186	85·55	68·44
210	98·89	79·11	185	85	68
209	98·33	78·67	184	84·44	67·56
208	97·78	78·22	183	83·89	67·11
207	97·22	77·78	182	83·33	66·67
206	96·67	77·33	181	82·78	66·22
205	96·11	76·89	180	82·22	65·78
204	95·55	76·44	179	81·67	65·33
203	95	76	178	81·11	64·89
202	94·44	75·56	177	80·55	64·44
201	93·89	75·11	176	80	64
200	93·33	74·67	175	79·44	63·56
199	92·78	74·22	174	78·89	63·11
198	92·22	73·78	173	78·33	62·67
197	91·67	73·33	172	77·78	62·22
196	91·11	72·89	171	77·22	61·78
195	90·55	72·44	170	76·67	61·33
194	90	72	169	76·11	60·89
193	89·44	71·56	168	75·55	60·44
192	88·89	71·11	167	75	60
191	88·33	70·67	166	74·44	59·56
190	87·78	70·22	165	73·89	59·11
189	87·22	69·78	164	73·33	58·67
188	86·67	69·33	163	72·78	58·22

COMPARATIVE DEGREES OF TEMPERATURE—*continued.*

Degrees.			Degrees.		
Fah.	Centi.	Re.	Fah.	Centi.	Re.
162	72·22	57·78	127	52·78	42·22
161	71·67	57·33	126	52·22	41·78
160	71·11	56·89	125	51·67	41·33
159	70·55	56·44	124	51·11	40·89
158	70	56	123	50·55	40·44
157	69·44	55·56	122	50	40
156	68·89	55·11	121	49·44	39·56
155	68·33	54·67	120	48·89	39·11
154	67·78	54·22	119	48·33	38·67
153	67·22	53·78	118	47·79	38·22
152	66·67	53·33	117	47·22	37·78
151	66·11	52·89	116	46·67	37·33
150	65·55	52·44	115	46·11	36·89
149	65	52	114	45·55	36·44
148	64·44	51·56	113	45	36
147	63·89	51·11	112	44·44	35·56
146	63·33	50·67	111	43·89	35·11
145	62·78	50·22	110	43·33	34·67
144	62·22	49·78	109	42·78	34·22
143	61·67	49 33	108	42·22	33·78
142	61·11	48·89	107	41·67	33·33
141	60·55	48·44	106	41·11	32·89
140	60	48	105	40·55	32·44
139	59·44	47·56	104	40	32
138	58·89	47·11	103	39·44	31·56
137	58·33	46·67	102	38·89	31·11
136	57·78	46·22	101	38·33	30·67
135	57·22	45·78	100	37·78	30·22
134	56·67	45·33	99	37·22	29·78
133	56·11	44·89	98	36·67	29·33
132	55·55	44·44	97	36·11	28·89
131	55	44	96	35·55	28·44
130	54·44	43·56	95	35	28
129	53·89	43·11	94	34·44	27·56
128	53·33	42·67	93	33·89	27·11

COMPARATIVE DEGREES OF TEMPERATURE—*continued.*

Degrees.			Degrees.		
Fah.	Centi.	Re.	Fah.	Centi.	Re.
92	33·33	26·67	61	16·11	12·89
91	32·78	26·22	60	15·55	12·44
90	32·22	25·78	59	15	12
89	31·67	25 33	58	14·44	11·56
88	31·11	24·89	57	13·89	11·11
87	30·55	24·44	56	13·33	10·67
86	30	24	55	12·78	10·22
85	29·44	23·56	54	12·22	9·78
84	28·89	23·11	53	11·67	9·33
83	28·33	22·67	52	11·11	8·89
82	27·78	22·22	51	10·55	8·44
81	27·22	21·78	50	10	8
80	26·67	21·33	49	9·44	7·56
79	26·11	20·89	48	8·89	7·11
78	25·55	20·44	47	8·33	6·67
77	25	20	46	7·78	6·22
76	24·44	19·56	45	7·22	5·78
75	23·89	19·11	44	6·67	5·33
74	23·33	18·67	43	6·11	4·89
73	22·78	18·22	42	5·55	4·44
72	22·22	17·78	41	5	4
71	21·67	17·33	40	4·44	3·56
70	21·11	16·89	39	3·89	3·11
69	20·55	16·44	38	3·33	2·67
68	20	16	37	2·78	2·22
67	19·44	15·56	36	2·22	1·78
66	18·89	15·11	35	1·67	1·33
65	18·33	14·67	34	1·11	0·89
64	17·78	14·22	33	0·55	0·44
63	17·22	13·78	32	0	0
62	16·67	13·33			

HEATING WITH STEAM.

A British thermal unit (B.T.U.) is that amount of heat required to raise 1 lb. of water at its maximum density (39·1° Fah.) through one degree Fahrenheit.

The capacity of a body for heat is measured by determining the number of units of heat required to raise that body one degree of temperature.

The specific heat of a body is the ratio of the quantity of heat required to raise that body one degree to the quantity required to raise an equal weight of water one degree. The following table gives the specific heats of various bodies:—

TABLE OF SPECIFIC HEATS.

	Specific Heat.		Specific Heat.
METALS.		LIQUIDS.	
Cast Iron	0·1298	Water	1·000
Wrought Iron ...	0·1138	Caustic Lye— 1·0780 Sp. Gr. ...	0·919
Zinc	0·0955	1·0480 ,, ,, ..	0·942
Copper	0·0951	1·0246 ,, ,, ...	0·968
		1·0124 ,, ,, ...	0·983
Brass	0·0939	EARTHS, &c.	
Tin	0·0569	Brick (burnt clay)	0·185
Lead	0·0314	GASES (under constant pressure).	
WOODS, &c.		Air	0·2379
		Oxygen	0·2182
Pine	0·650	Nitrogen	0·2440
Oak	0·570	Carbonic Acid ...	0·2164
Birch	0·480	,, Oxide .	0·2479
Esparto Straw,		Sulphurous Acid (SO_2)	0·1543
&c. (about) ..	0·550	Water Vapour ...	0·4750

Latent heat is the quantity of heat which must be communicated to a body in a given state, in order to convert it into another state without changing its temperature.

PROPERTIES OF SATURATED STEAM.

Absolute Pressure in lb. per Sq. In.	Pressure above atmosphere.	Temperature of Boiling Point in Degrees F.	Total Heat in Thermal Units per lb. of Steam from 0° F.	Weight of 1 Cubic Foot of Steam in lb.	Cubic Feet of Steam from 1 Cubic Foot of Water at 62° F.
1	—	102·1	1144·5	·0030	20582
2	—	126·3	1151·7	·0058	10721
3	—	141·6	1156·6	·0085	7322
4	—	153·1	1160·1	·0112	5583
5	—	162·3	1162·9	·0138	4527
6	—	170·2	1165·3	·0163	3813
7	—	176·9	1167·3	·0189	3298
8	—	182·9	1169·2	·0214	2909
9	—	188·3	1170·8	·0239	2604
10	—	193·3	1172·3	·0264	2358
11	—	197 8	1173·7	·0289	2157
12	—	202·0	1175·0	·0314	1986
13	—	205·9	1176·2	·0338	1842
14	—	209·6	1177·3	·0362	1720
14·7	0	212·0	1178·1	·0380	1642
15	0·3	213·1	1178·4	·0387	1610
16	1·3	216·3	1179·4	·0411	1515
17	2·3	219·6	1180·3	·0435	1431
18	3·3	222·4	1181·2	·0459	1357
19	4·3	225·3	1182·1	·0483	1290
20	5·3	228·0	1182·9	·0507	1229
21	6·3	230·6	1183·7	·0531	1174
22	7·3	233·1	1184·5	·0555	1123
23	8·3	235·5	1185·2	·0580	1075
24	9·3	237·8	1185·9	·0601	1036
25	10·3	240·1	1186·6	·0625	996
26	11 3	242·3	1187·3	·0650	958
27	12·3	244·4	1187·8	·0673	926
28	13·3	246·4	1188·4	·0696	895
29	14·3	248·4	1189·1	·0719	866
30	15·3	250·4	1189·8	·0743	838
31	16·3	252·2	1190·4	·0766	813
32	17·3	254·1	1190 9	·0789	789
33	18·3	255·9	1191·5	·0812	767
34	19·3	257·6	1192·0	·0835	746
35	20·3	259·3	1192·5	·0858	726
36	21·3	260·9	1193·0	·0881	707

PROPERTIES OF SATURATED STEAM—*continued.*

Absolute Pressure in lb. per Sq. In.	Pressure above atmosphere.	Temperature or Boiling Point in Degrees F.	Total Heat in Thermal Units per lb. of Steam from 0° F.	Weight of 1 Cubic Foot of Steam in lb.	Cubic Feet of Steam from 1 Cubic Foot of Water at 62° F.
37	22·3	262·6	1193·5	·0905	688
38	23·3	264·2	1194·0	·0929	671
39	24.3	265·8	1194·5	·0952	655
40	25·3	267·3	1194·9	·0974	640
41	26·3	268·7	1195·4	·0996	625
42	27·3	270·2	1195·8	·1020	611
43	28·3	271·6	1196·2	·1042	598
44	29·3	273·0	1196·6	·1065	585
45	30·3	274·4	1197·1	·1089	572
46	31·3	275·8	1197·5	·1111	561
47	32·3	277·1	1197·9	·1133	550
48	33·3	278·4	1198·3	·1156	539
49	34·3	279·7	1198·7	·1179	529
50	35·3	281·0	1199·1	·1202	518
51	36·3	282·3	1199·5	·1224	509
52	37·3	283·5	1199·9	·1246	500
53	38·3	284·7	1200·3	·1269	491
54	39·3	285·9	1200·6	·1291	482
55	40·3	287·1	1201·0	·1314	474
56	41·3	288·2	1201·3	·1336	466
57	42·3	289·3	1201·7	·1364	458
58	43·3	290·4	1202·0	·1380	451
59	44·3	291·6	1202·4	·1403	444
60	45·3	292·7	1202·7	·1425	437
61	46·3	293·8	1203·1	·1447	430
62	47·3	294·8	1203·4	·1469	424
63	48·3	295·9	1203·7	·1493	417
64	49·3	296·9	1204·0	·1516	411
65	50·3	298·0	1204·3	·1538	405
66	51·3	299·0	1204·6	·1560	399
67	52·3	300·0	1204·9	·1583	393
68	53·3	300·9	1205·2	·1605	388
69	54·3	301·9	1205·5	·1627	383
70	55·3	302·9	1205·8	·1648	378
71	56·3	303·9	1206·1	·1670	373
72	57·3	304·8	1206·3	·1692	368
73	58·3	305·7	1206·6	·1714	363

PROPERTIES OF SATURATED STEAM—*continued.*

Absolute Pressure in lb. per Sq. In.	Pressure above atmo-sphere.	Tempera-ture or Boiling Point in Degrees F.	Total Heat in Thermal Units per lb. of Steam from 0° F.	Weight of 1 Cubic Foot of Steam in lb.	Cubic Feet of Steam from 1 Cubic Foot of Water at 62° F.
74	59·3	306·6	1206·9	·1736	359
75	60·3	307·5	1207·2	·1759	353
76	61·3	308·4	1207·4	·1782	349
77	62·3	309·3	1207·7	·1804	345
78	63·3	310·2	1208·0	·1826	341
79	64 3	311·1	1208·3	·1848	337
80	65·3	312·0	1208·5	·1869	333
81	66·3	312·8	1208·8	·1891	329
82	67·3	313·6	1209·1	·1913	325
83	68 3	314·5	1209 4	·1935	321
84	69·3	315·3	1209·6	·1957	318
85	70·3	316·1	1209·9	·1980	314
86	71·3	316·9	1210·1	·2002	311
87	72·3	317·8	1210·4	·2024	308
88	73 3	318·6	1210·6	·2044	305
89	74·3	319·4	1210·9	·2067	301
90	75·3	320·2	1211·1	·2089	298
91	76·3	321·0	1211·3	2111	295
92	77·3	321·7	1211·5	·2133	292
93	78·3	322·5	1211·8	·2155	289
94	79 3	323·3	1212·0	·2176	286
95	80·3	324·1	1212·3	·2198	283
96	81·3	324·8	1212·5	·2219	281
97	82·3	325·6	1212·8	·2241	278
98	83·3	326·3	1213·0	·2263	275
99	84·3	327·1	1213·2	·2285	272
100	85·3	327·9	1213·4	·2307	270
101	86·3	328·5	1213·6	·2329	267
102	87·3	329·1	1113·8	·2351	265
103	88·3	329·9	1214·0	·2373	262
104	89·3	330·6	1214·2	·2393	260
105	90·3	331·3	1214·4	·2414	257
106	91·3	331·9	1214·6	·2435	255
107	92·3	332·6	1214·8	·2456	253
108	93·3	333·3	1215·0	·2477	251
109	94·3	334·0	1215·3	·2499	249
110	95·3	334·6	1215·5	·2521	247

Properties of Saturated Steam—*continued.*

Absolute Pressure in lb. per Sq. In.	Pressure above atmosphere.	Temperature or Boiling Point in Degrees F.	Total Heat in Thermal Units per lb. of Steam from 0° F.	Weight of 1 Cubic Foot of Steam in lb.	Cubic Feet of Steam from 1 Cubic Foot of Water at 62° F.
111	96·3	335·3	1215·7	·2543	245
112	97·3	336·0	1215·9	·2564	243
113	98·3	336·7	1216·1	·2586	241
114	99·3	337·4	1216·3	·2607	239
115	100·3	338·0	1216·5	·2628	237
116	101·3	338·6	1216·7	·2649	235
117	102·3	339·3	1216·9	·2674	233
118	103·3	339·9	1217·1	·2696	231
119	104·3	340·5	1217·3	·2738	229
120	105·3	341·1	1217·4	·2759	227
121	106·3	341·8	1217·6	·2780	225
122	107·3	342·4	1217.8	·2801	224
123	108·3	343·0	1218·0	·2822	222
124	109·3	343·6	1218·2	·2845	221
125	110·3	344·2	1218·4	·2867	219
126	111·3	344·8	1218·6	·2889	217
127	112·3	345·4	1218·8	·2911	215
128	113·3	346·0	1218·9	·2933	214
129	114·3	346·6	1219·1	·2955	212
130	115·3	347·2	1219·3	·2977	211
131	116·3	347·8	1219·5	·2999	209
132	117·3	348·3	1219·6	·3020	208
133	118·3	348·9	1219·8	·3040	206
134	119·3	349·5	1220·0	·3060	205
135	120·3	350·1	1220·2	·3080	203
136	121·3	350·6	1220·3	·3101	202
137	122·3	351·2	1220·5	·3121	200
138	123·3	351·8	1220·7	3142	199
139	124·3	352·4	1220·9	·3162	198
140	125·3	352·9	1221·0	·3184	197
141	126·3	353·5	1221·2	·3206	195
142	127·3	354·0	1221·4	·3228	194
143	128·3	354·5	1221·6	·3250	193
144	129·3	355·0	1221·7	3273	192
145	130·3	355·6	1221·9	·3294	190
146	131·3	356·1	1222·0	·3315	189
147	132·3	356·7	1222·2	·3336	188

PROPERTIES OF SATURATED STEAM—*continued.*

Absolute Pressure in lb. per Sq. In.	Pressure above atmosphere.	Temperature or Boiling Point in Degrees F.	Total Heat in Thermal Units per lb. of Steam from 0° F.	Weight of 1 Cubic Foot of Steam in lb.	Cubic Feet of Steam from 1 Cubic Foot of Water at 62° F.
148	133·3	357·2	1222·3	·3357	187
149	134·3	357·8	1222·5	·3377	186
150	135·3	358·3	1222·7	·3397	184
155	140·3	361·0	1223·5	·3500	179
160	145·3	363·4	1224·2	·3607	174
165	150·3	366·0	1224·9	·3714	169
170	155·3	368·2	1225·7	·3821	164
175	160·3	370·8	1226·4	·3928	159
180	165·3	372·9	1227·1	·4035	155
185	170·3	375·3	1227·8	·4142	151
190	175·3	377·5	1228·5	·4250	148
195	180·3	379·7	1229·2	·4357	144
200	185·3	381·7	1229·8	·4464	141
210	195·3	386·0	1231·1	·4668	135
220	205·3	389·9	1232·3	·4872	129
230	215·3	393·8	1233·5	·5072	123

Heat can best be conveyed from one point of a factory to another by means of steam. To do so economically the steam pipes should be well arranged and protected by non-radiating felt, or other like substance, and be superheated. The various operations of heating, boiling, and drying are carried out in paper mills by means of steam, and the following modes of calculating the quantity of steam required in the different processes of manufacture are based upon well-known scientific methods and data.

Heating liquids, &c., with steam:—When steam condenses to water of temperature t, the British thermal units which 1 lb. of it will give out is represented by the equation $T - t = x$; in which T represents the total units of heat reckoned from 0° Fah., which 1 lb. of the steam contains (see table, page 40), and x the total thermal units made available for heating. Thus, 1 lb. of steam at 70 lbs. pressure above atmosphere (= 85 lbs. pressure in col. 1 of the table, page 42) contains 1,209·9 British thermal units, and if it be condensed to water of 120° Fah. (t in the formula), the heat rendered available for heating is equal to 1,209·9—120 = 1,089·9 units.

A liquid may be heated by injecting steam into it, or by passing steam through a coil immersed in it, or by means of a steam jacketed pan. The simplest case occurring in paper mills is heating water or other liquids, &c., in metal tanks or boilers, and the steam used to raise the temperature of the vessel and its contents may be ascertained from the following formula:—

$$\frac{(w s + ms')(t_f - t_1)}{T - t_f} = S.$$

in which S = lbs. of steam required.
T = British thermal units contained in 1 lb. of steam at the prevailing pressure.
t_f = The final temperature in °Fah. to which the water or other definite liquid has to be heated.
t_i = The temperature in °Fah. of the water or liquid before heating.
w = The weight in lbs. of the water or liquid.
s = The specific heat of water or other liquid.
m = Weight in lbs. of the metal vessel.
s^1 = The specific heat of the metal of which the vessel is composed.

Example:—A wrought-iron vessel, weighing 10 cwts. (1,120 lbs.), contained 300 gallons of water (3,000 lbs.) at a temperature of 72° Fah. (t_i), and it was desired to heat the same to 184° Fah. by injecting steam of 70 lbs. pressure above atmosphere into it. In this case w = 3,000 lbs.; s = 1·00; m = 1,120; s^1 = 0·113; T = 1,209·9; t_f = 184°, and t_i = 72°. Substituting these values in the above formula, we have

$$\frac{(3{,}000 \times 1{\cdot}00 + 1{,}120 \times 0{\cdot}113)(184 - 72)}{1{,}209{\cdot}9 - 184.} = 341{\cdot}3.$$

Or, in other words, 341·3 lbs. of the steam were required to raise the vessel and water from 72° Fah. to 184° Fah., or through 112 degrees.

Instances in which liquids together with solids, in different proportions, and possessing different specific heat values, are to be heated are frequently met with, as in the heating of a pocher of pulp while bleaching; or in digesting esparto, straw or wood in caustic soda lyes; or "bisulphite" of lime, soda, or magnesia. The weights of the various solids and liquids composing the charge, and that part of the apparatus which must be heated, may be represented by w, w', w'', w''', . . &c.,

and their respective specific heat values by s, s', s'', s''', ... and a general formula may be written applicable to all cases in which simple heating by injected steam takes place, viz. :—

$$\frac{(w\,s + w'\,s' + w''\,s'' + w'''\,s''' + \,.\,\,.\,\,.\,\,.\,)(t_f - t_i)}{T - t_f} = S.$$

As examples of the application of this formula to three different but commonly occurring cases in paper mill work we give the following:—

Hot Bleaching:—A cast-iron pocher, 30 feet long × 12 feet broad × 4 feet 6 inches deep, of a total calculated capacity of 1,316 cubic feet contained 1,170 cubic feet of a mixture of pulp and water (very weak bleach liquor). One cubic foot of the mixture of pulp and water contained 1·833 lbs. of air-dry pulp (10% water), or the total quantity of air-dry pulp in the pocher was 2,144 lbs. (w'). The weight of water associated with it was nearly 71,000 lbs. (w); the cast-iron pocher itself weighed nearly 10 tons = 22,400 lbs. (w''). The initial temperature of pulp, water, and pocher was 54° Fah. (t_i), and this was to be heated to 120° Fah. (t_f), or through 66° Fah. with steam of 85 pressure per square inch above atmosphere (T). The specific heat values of cellulose = 0·55, of water 1·00, and of cast-iron 0·130. Substituting these values in the above formula, we have—

$$\frac{(71{,}000 \times 1{\cdot}00 + 2{,}144 \times 0{\cdot}55 + 22{,}400 \times 0{\cdot}13)(120 - 54)}{1{,}213{\cdot}4 - 120} = 4{,}532 = S.$$

Or, 4,532 lbs. of steam were required to perform the above work. Assuming one ton of air-dry pulp to yield one ton of paper, the amount of steam required for hot bleaching in the above case was 4,735 lbs. (nearly).

Digesting Esparto in Vomiting Boilers.

Weight of caustic lye
= 15,751 lbs. = w; specific heat of caustic lye = 0·96 = s.

Weight of esparto
= 5,600 lbs. = w'; specific heat of esparto = 0·60 = s'

Weight of wrought-iron boiler
= 11,200 lbs. = w''; specific heat of wrought iron = 0·113 = s''

Initial temperature t_i = 120° Fah., final temperature t_f = 259·3° Fah., equal to 20 lbs. pressure per square inch above atmosphere. The pressure of steam used for heating was 90 lbs. above atmosphere, and 1 lb. of it contained 1214·4 B.T. units, T in the formula. We have therefore by substitution as in the previous case—

$$\frac{(15,751 \times 0 \cdot 96 + 5,600 \times 0 \cdot 60 + 11,200 \times 0 \cdot 113)(259 \cdot 3 - 120)}{1,214 \cdot 4 - 259 \cdot 3} = 2,880.$$

Or, S equals 2,880 lbs. of steam required to heat the esparto boiler and its contents from 120° Fah. to a temperature of 259·3° Fah.

Digesting Straw in Revolving Boilers.

Weight of caustic lye
= 16,926 lbs. = w; specific heat of caustic lye = 0·96 = s.

Weight of straw
= 4,480 lbs. = w'; specific heat of straw = 0·60 = s'.

Weight of wrought-iron boiler
= 15,680 lbs. = w''; specific heat of wrought-iron = 0·113 = s''.

Initial temperature t_i = 110° Fah., final temperature t_f = 287·1° Fah., equal to 40 lbs. of steam pressure per square inch above atmosphere. The pressure of steam used for heating was 90 lbs. above atmosphere, and 1 lb. of it contained 1,214·4 B.T. units, T in the formula. We have therefore by substitution, as above—

$$\frac{(16,926 \times 0 \cdot 96 + 4,480 \times 0 \cdot 60 + 15,680 \times 0 \cdot 113)(287 \cdot 1 - 110)}{1,214 \cdot 4 - 287 \cdot 1} = 3,955.$$

Or, S in this case equals 3,955 lbs. of steam required to heat the boiler and its contents from 110° Fah. to 287·1° Fah.

Digesting Wood in Caustic Soda Lye.

In this case the item of moisture in the wood chips should be taken into account, as it varies from 15 to 40 per cent., according to circumstances of climate. &c. Instead of adding the quantity of water in the wood to the weight of the caustic lye, it is best to treat it as a separate item in the formula, w''' representing its weight in lbs. and s''' the specific heat of water. The particulars of the "charge," &c., and the conditions of boiling are represented by the following:—

Weight of wood chips (dried at 212° Fah.)
4,892 lbs. = w ; specific heat of wood =0·55 = s

Weight of caustic lye (5·0 per cent. Na_2O)
21,400 lbs. = w' ; specific heat of caustic lye =0·94 = s'

Weight of wrought-iron digester
13,440 lbs. $= w''$; specific heat of wrought-iron $= 0{\cdot}113 = s''$
Weight of water in wood chips
1,380 lbs. $= w'''$; specific heat of water $= 1{\cdot}00 = s'''$

Initial temperature $t_i = 150°$ Fah., final temperature $t_f =$ 350·1° Fah., equal to a pressure of 120 lbs. per square inch above atmosphere. The pressure of steam used for heating was 130 lbs. per square inch above atmosphere, and therefore $T = 1221{\cdot}9$ B.T. units. Again, by substitution as before, we have—

$$\frac{(4{,}892 \times 0{\cdot}55 + 21{,}400 \times 0{\cdot}94 + 13{,}440 \times 0{\cdot}113 + 1{,}380 \times 1{\cdot}00)\,(350{\cdot}1 - 150)}{1{,}221{\cdot}9 - 350{\cdot}1} = 5{,}900.$$

Or S equals 5,900 lbs. of steam, the amount required to heat the digester and its contents to maximum temperature or pressure.

N.B.—In all the foregoing cases the steam is injected direct into the contents of the digester, and the formula is applicable only to such cases.

The formula requires alteration when the digester and its contents are heated by means of a steam jacket or steam coil. Were the heating to take place by very gradual and equal increments of heat, then the mean temperature $\frac{t_i + t_f}{2}$ would represent the average temperature of the condensed water. As a matter of fact, however, the ejected water is always higher than the contents of the digester, especially when a steam jacket is used. The difference is not so much with steam coils. The divisor $T - t_f$ in the above general formula should be changed to $T - \frac{t_i + t_f}{2}$ in each case, but for the reason stated, it is best to take periodic observations of the temperature of the condensed water flowing from the coil or jacket, and use this average temperature t_a instead of $\frac{t_i + t_f}{2}$. In all cases, therefore, in which heating by steam coil or jacket takes place the following formula is applicable, viz. :—

$$\frac{(w\,s + w'\,s' + w''\,s'' + w'''\,s''' + \ldots)\,(t_f - t_i)}{T - t_a} = S.$$

in which t_a is the average observed temperature of the condensed water passing away from the coils or jacket, the other factors in the formula having the same significance as before.

Digesting Wood in Steam Jacketed Boilers (Bisulphite process).—As an example of the application of this formula, a steam jacketed, lead lined, sulphite digester, in which wood pulp was being prepared, was heated with steam of 90 lbs. pressure per square inch above atmosphere, the weight of digester and its "charge," &c., being as follows:—

Weight of wood chips dried at 212° Fah.
4,655 lbs. $= w$; specific heat of wood $= 0{\cdot}55 = s$

Weight of bisulphite liquor
24,800 lbs. $= w'$; specific heat of liquor $= 0{\cdot}98 = s'$

Weight of water in the wood
1,482 lbs. $= w''$; specific heat of water $= 1{\cdot}00 = s''$

Weight of wrought-iron digester
29,120 lbs. $= w'''$; specific heat of wrought iron $= 0{\cdot}113 = s'''$

Weight of lead lining
6,496 lbs. $= w''''$; specific heat of lead $= 0{\cdot}0314 = s''''$

Initial temperature $t_i = 70°$ Fah., final temperature $t_f = 278°$ Fah. The average temperature of condensed water from the jacket, having due regard to quantity in equal intervals of time, was 209° Fah. $= t_a$. T $= 1{,}214{\cdot}4$ B.T. units, equivalent to 90 lbs. steam pressure above atmosphere. By substitution, we have:—

$$\frac{(4{,}655 \times 0{\cdot}55 + 24{,}800 \times 0{\cdot}98 + 1{,}482 \times 1{\cdot}00 + 29{,}120 \times 0{\cdot}113 + 6{,}496 \times 0{\cdot}0314)\,(278-70)}{1{,}214{\cdot}4 - 209} = 6{,}587$$

Or S equals 6,587 lbs., the amount of steam required to heat the digester and its contents to maximum temperature 278° Fah.

Note.—As this digester yielded $23\frac{1}{2}$ cwts. of air-dry cellulose per charge, the steam required per ton was $\frac{6{,}587 \times 20}{23{\cdot}5}$ or 5,606 lbs. (nearly).

As above indicated, careful observations of the temperature and volume of the condensed water from the jacket should be made at equal intervals of time throughout the cooking, but having regard to the difficulties of making these observations accurately, the simplest mode of ascertaining the steam used is to measure the condensed water. A series of observations made in this way with digesters of the jacketed type, protected with non-radiating cement, &c., and yielding $23\frac{1}{2}$ cwt. of air-dry pulp, gave an average of 8,556 lbs. of steam for heating per charge or 6,587 lbs. steam per ton of air-dry cellulose. This amount includes that condensed through loss of heat by radiation from the sides of the digester, and also the amount of steam blown off from the interior of the digester during the cooking operation. The difference between that found by calculation and by measurement—viz., 8,556—6,587 = 1,960 —represents these two losses plus errors of observation, &c. This difference is equivalent to 23·0 per cent. of the total steam used.

No allowance has been made in these formulæ for loss of heat by radiation from the sides of the digester or boiler, and therefore this loss should be ascertained with a water calorimeter, and the amount added to the figure obtained by calculation. The moisture in the steam in those works, where superheating is absent, may also be allowed for. Although there is no definite evidence to show that heat is generated or absorbed in the chemical action going on inside the digester between the resolving fluid and the raw fibrous stock, yet it is perhaps reasonable to infer that some such absorption or generation of heat does take place in specific cases, but the amount is small compared with that required to raise the digester and contents to maximum temperature, and may therefore be neglected.

Drying Pulp or Paper.

The steam required to dry one ton of pulp on the machine may be ascertained by the following formula:—

$$S = \frac{x\,(T - t_i) + w\,s\,(t_f - t_i)}{T^1 - t_f}$$

in which S = lbs. of steam required.

- x = Weight of water in lbs. which has to be evaporated for each ton of air-dry cellulose made.
- w = Weight of air-dry cellulose (= 2,240 lbs.).
- s = Specific heat of air-dry cellulose.
- t_i = The initial temperature of pulp and water running on to the wire.
- t_f = The final or maximum temperature to which the pulp is heated on the drying cylinders.
- T = The total heat units contained in 1 lb. of steam at 212° Fah. under atmospheric pressure.
- T^1 = The total heat units contained in 1 lb. of steam at the pressure prevailing within the drying cylinders.

x is ascertained by estimating the water in pulp after passing the press rolls, and again after having passed over the drying cylinders. By a simple calculation the water to be evaporated by the drying cylinders can be obtained. For well-known reasons t_f cannot very well exceed 212° Fah.

Example:— $x = 3{,}065$ lbs. $w = 2{,}240$. $s = 0{\cdot}55$.
$t_i = 59°$ Fah. $t_f = 240°$ Fah.
$T = 1{,}178$ and $T^1 = 1{,}190$.

By substitution we have:—

$$\frac{3{,}065\,(1{,}178 - 59) + 2{,}240 \times 0{\cdot}55\,(240 - 59)}{1{,}190 - 240.} = 3{,}845 = S.$$

Or, the amount of steam required to dry one ton of cellulose. The foregoing is the actual work done on a pulp drying machine.

The water condensed inside the drying cylinders of the machine gave by measurement 5,080 lbs. per ton of air-dry pulp, and deducting from this the 3,845 lbs. found by calculation, leaves 1,235 lbs., representing loss of heat by radiation, moisture in steam, &c.

The following (Wockenblatt No. 43, 1901) is an example from a Continental News Mill:—

Paper was composed of 80 per cent. ground wood and 20 per cent. of wood cellulose.

Speed of paper machine = 80 metres (262½ feet) per minute and an hourly production of 475 kilos. (1,045 lbs.) paper.

The condensed water from the drying cylinders, which is a direct measure of the steam required per hour, was 593 kilos. (1,304·6 lbs.).

(∴ 100 kilos. of paper required 125 kilos. of steam.)

NOTE.—Many other tests gave only slight variations from the above.

CHAPTER III.

RAW FIBROUS STOCK.

COTTON AND LINEN RAGS.

Cotton and linen rags are usually boiled in weak milk-of-lime to which a small quantity of soda is sometimes added. The volume of the milk-of-lime used is carefully regulated and should be such that the rags are always covered or immersed in the liquid during the boiling. If the volume of liquor taken is insufficient for this purpose, the rags are exposed to the action of dry steam, which, in presence of free alkali or lime, has a tendency to "rot" or "tender" the fibres and also to discolour them. The steam pressure (or temperature) and the proportion of dry soda or lime, or both, together with the time required, all vary with the kind of rags operated upon. Old white cotton or linen rags do not require such a drastic treatment as new cotton or linen rags. The former having been washed and scoured many times before they reach the papermaker are partly free from foreign matter, and the fibres themselves are softened. New rags, on the other hand, are impregnated with "size" and loadings used in the preparation of the cloth and also retain the original impurities existing in the raw fibre (see page 128), the bulk of which must be removed prior to their conversion into paper. In the boiling and cleansing process to which new rags are subjected, the fibres are softened.

Speaking broadly, rag stock suitable for papermaking may be roughly divided into two great classes, namely—cotton and linen. These, again, may be subdivided into old and new cotton and old and new linen, the exact line of demarcation between what is old and new in both cases not being well defined. The skill of the papermaker in this department of the manufacture consists largely in treating these various grades, both chemically and mechanically, in the process of making half-stock from them, and in blending them together so as to form a sheet of paper in accordance with his requirements. This requires much experience, and his success depends largely upon the adequate knowledge which he possesses of the various properties of the different grades of old and new cotton and old and new linen rags at his disposal, with particular reference to their strength, softness, and purity. These have to be graded by careful sorting, then cut, boiled with soda or lime or both under pressure to remove foreign matters, and finally washed and broken in in the breaker and bleached. The breaking in is carried out so that the whole texture of the rag is completely destroyed, and the fibres themselves partly beaten to that degree of fineness required for the beating engine. These operations involve considerable losses, which have been classified as follows:—

TREATMENT OF RAGS.

TABLE showing Losses on Raw Material during the various operations.

The percentage of moisture in rags varies from 3 to 6 %.

(J. W. WYATT.)

	Moisture.	Sorting.	Cutting.	Boiling.	Breaking and Bleaching.	Total, Excluding Moisture.
	%	%	%	%	%	%
English New Pieces ...	3	0·5	1·0	3·0	12·5	15·15
French ,, ,, ..	3	0·5	1·2	7·3	13·2	19·60
German ,, ,, ...	3	0·5	1·2	11·8	11·6	22·03
No. 1 Cotton ...	3	0·9	2·0	3·0	12·4	15·04
,, 2 ,, ...	4	1·2	2·5	7·94	14·8	21·60
,, 3 ,, ...	4	1·5	3·8	11·16	13·6	23·26
,, 4 ,, ...	5	2·0	4·0	14·3	17·4	29·27
New Soft Tabs.	4	0·5	1·0	3·0	8·4	11·14
Best White ,, ...	4	1·0	4·0	8·6	16·6	23·78
Grey Tabs.	4	0·8	2·5	15·1	9·8	23·46
Unbleached Cotton ..	4	0·8	2·0	12·28	13·4	24·05
White Moleskins ...	4	0·8	2·0	11·00	8·9	18·99
Drab ,, ..	4	1·0	2·0	13·00	10·1	21·79
Jean Cuttings	4	1·0	2·0	17·40	6·1	22·48
Green Cords	5	1·0	2·5	21·30	8·0	27·64
Old Blue Cotton... ..	5	1·5	3·8	14·40	9·2	22·32
Shirtings	4	0·5	2·6	11·60	12·4	22·59
S. P. F. F. F. Linen ..	4	0·8	2·0	8·50	11·8	19·38
S. P. F. F. ,, ..	5	1·3	2·4	11·10	12·8	22·51
S. P. F. ,, ...	6	1·8	2·7	17·36	19·6	33·62
No. 1 Linen	4	0·5	2·0	6·8	7·4	13·77
,, 2 ,, ...	5	0·8	2·4	14·5	8·2	21·54
,, 3 ,, ...	6	1·0	2·7	19·15	9·8	27·11
,, 1 Russian Linen ...	6	1·5	2·4	18·7	10·0	26·90
,, 4 ,, ,, ...	6	3·0	5·0	30·0	20·7	44·53
Linen Duck Clippings	4	0·5	2·0	15·4	9·6	23·58
,, Threads	4	0·5	2·0	12·5	12·6	23·55
New Blue Linens ...	4	0·8	2·0	15·1	13·9	26·90
Unbleached Linen ...	4	0·5	2·4	19·2	16·0	32·14

Mr. Clayton Beadle has also determined the loss of weight in boiling and bleaching cotton rags, with the following results :—

	Percentage loss on Boiling.	Bleaching.
Best new cotton pieces	8 71	3·29
Low quality cotton pieces	12·20	7·70
Cotton rags, No. 1	5 80	6·20
,, ,, No. 2	5·70	6·90
,, ,, No. 3	12·50	4 30
,, ,, No. 4	13 30	13·70
New unbleached cotton cuttings ...	23·50	13 00

JUTE.

It is scarcely possible to prepare a pure white pulp from jute owing to the tannin-like bodies distributed throughout the mass of the fibre (see page 129). Generally the jute cuttings are boiled in lime and soda according to the conditions named below, and it is said if the jute is treated first in this way, then partly bleached with hypochlorites and again given a second boiling in weak caustic soda lye alone, and after washing, finally bleached with additional hypochlorite, the resulting pulp approaches a good white colour. Silicate of soda has been recommended as a substitute for the caustic soda in the second boiling.

The following proportions of lime, &c., are recommended for the treatment of this fibre.

Boiling.—

	New fine quality Jute.	Coarse old quality Jute.
100 parts require—		
Lime	20	25
Caustic Soda (as Na_2O) ...	—	4
Pressure per square inch ...	30	60
Temperature	248° Fah.	290° Fah.
Hours under pressure... ...	10	8

Losses in the treatment in mill, &c.—

Moisture	6 %	10 %
Dusting	2 %	2·5 %
Cutting	2·5 %	2·5 %
Dressing	3·5 %	5·0 %
Boiling and Washing ...	16·0 %	20·0 %
Breaking	2·5 %	3·0 %
1st Bleaching	10·0 %	8·0 %
2nd ,, ...	5·0 %	4·0 %
Totals ...	47·5 %	55·0 %

ESPARTO.

The treatment of esparto by the soda method is typical of the preparation of paper pulp from nearly all fibre-yielding plants, such as bamboo, straw, wood, &c. The isolation of the cellulose is brought about by digesting the prepared plant in an alkaline solution, having for its base caustic soda, at variable temperatures, and under variable lengths of time. The chemical reaction which takes place during this digesting process is not known, that is to say, has not been isolated, because of the complicated character of the encrusting substances surrounding the fibre in the plant. The caustic soda in aqueous solution forms soluble compounds with these encrusting bodies and dissolves any silica which forms a part of the plant's structure, so that by subsequent draining, washing and bleaching, the liberated cellulose is obtained in a comparatively pure state. Cellulose, from whatever source it is obtained, is, however, soluble in aqueous solutions of caustic soda. Moreover, the solvent action of the caustic is accelerated by heat and by the length of time (within limits) in which the two bodies are heated together. It is therefore apparent that if the maximum yield of cellulose is desired when using this method, due regard must be paid to the laws regulating the yield. These laws may be expressed thus: The yield of cellulose obtained from any plant by the caustic soda method depends upon (1st) the proportion of caustic soda (Na HO) used per unit weight of plant, (2nd) the temperature employed, and (3rd) the length of time the digesting operation is continued. If any one of these conditions be alte ed and the other two kept constant, the yield varies inversely as the altered condition. Thus in the case of esparto, the author performed a series of experiments in which the proportion of caustic to unit weight of esparto was varied, whilst the temperature and duration of the time of digesting were both kept constant, with the following results;—

EXPERIMENTS *Re* YIELD OF AIR-DRY BLEACHED PULP FROM FINE ORAN ESPARTO.

AIR-DRY PULP CONTAINING 10 PER CENT. WATER.

(PAPER TRADE REVIEW.)

No. of Experiment.	Esparto.		Soda Liquid.		Conditions of Boiling.			Weight of Dry Pulp. Grammes.	Dry Pulp on Dry Esparto. %	Air-dry Pulp on Air-dry Esparto. %	Bleach 35% Chlorine. %
	Weight taken. Grams.	% Water.	Volume taken. C.C.S.	% Na_2O.	Time. Hours.	Temp. degrees C.	Pressure. lbs.				
I.	200	10·5	800	1·58	3	142	55	78·6	43·91	43·66	29 to 30
II.	200	10·5	800	2·13	3	142	55	72·6	40·55	40·35	18 to 19
III.	200	10·5	800	2·69	3	142	55	64·8	36·20	36·00	10 to 11

PRACTICAL DATA DEDUCED FROM EXPERIMENTS.

No. of Experiment.	Boiling		Weight of Esparto to produce One Ton of a/d. Pulp.	Total Quantity of 60% Caustic required to digest Esparto.	Cwts. of 35% Bleaching Powder required to Bleach One Ton of a/d. Pulp.	Lbs. of 35% Bleaching Powder to Bleach Pulp from One Cwt. of Esparto.	Lbs. of 60% Caustic Soda used for digesting one Cwt. of Esparto.
	Time. Hours.	Pressure. Lbs.	Cwts.	Lbs.	Cwts.		
I.	3	55	45·8	482	5·26	13·1	10·5
II.	3	55	49·5	703	3·39	7·6	14·1
III.	3	55	55·5	995	1·96	3·9	17·9

NOTE.—The different trials were made in wrought-iron tubes fitted with screw caps, all three being heated together in an oil bath for three hours at a temperature of 302° Fah. (55 lbs. above atmosphere).

These experiments clearly show the influence of caustic soda on the yield of cellulose, and also that the amount of bleaching powder (or chlorine) required to bleach the fibre thus prepared varies directly with the yield. The same holds good if the proportion of caustic soda to esparto and the time of digesting be kept constant, whilst the temperature is varied, namely, the lower the temperature the greater the yield. So also, when the proportion of caustic soda and temperature are both kept constant and the time varied, the yield decreases, as the time of digesting is prolonged; or, the yield varies inversely with the time. A long series of tests made by the author with spruce wood and other plants confirm the foregoing.

COMPOSITION OF ESPARTOS. (Müller.)

	Spanish.	African.
Cellulose	48·28%	45·08%
Fat and wax	2·07%	2·62%
Aqueous extract	10·19%	9·81%
Pectous substances ...	26·39%	29·30%
Water	9·38%	8·80%
Ash	3·72%	3·67%
	100·00	100·00

The percentage of available cellulose obtained in manufacturing practice never corresponds to that shown by the above analysis. It varies with the conditions of manufacture as outlined above, and with the quality of the grass itself. The coarse, unmatured plant requires more soda than the matured. The best results are obtained when the time and temperature (or pressure) of digesting are kept constant, and the minimum proportion of soda used in accordance with the nature of the grass operated upon and the quality of the pulp required. Setting aside the amount of soda which combines with the silica in the plant to form a silicate, the amount of organic extractive matter removed by the caustic, and the proportion of the latter used per 100 parts of the former in ordinary manufacturing practice as set forth in the following table is substantially true, viz.:—

		Cwts.		Lbs.
Total esparto used per charge	=	52	=	5,824
Less—		Lbs.		
9% water	=	524·1		
40% yield oven dry fibre...	=	2,329·6		
3% ash	=	174·7		
				3,028·4
Total soluble organic matter per charge ...			=	2,795·6

Soda used, reckoned as 58% ash, 18 lbs. per cwt. grass ... ... = 936·0

$\frac{2795 \cdot 6}{936}$ = 2·98 lbs. organic matter are associated with one pound recovered ash in the black lye. This organic matter, when dry, is very inflammable, and of high calorific value. The heat evolved from its combustion is almost sufficient to evaporate the water, generally associated with it in the black lye (and washings) provided efficient evaporating and calcining apparatus is used.

The operations involved in the manufacture of esparto pulp consist of (1st) cleaning by means of a willow, by which soil and dust are removed, and by hand-picking to separate the roots; (2nd) boiling in caustic soda under pressure; and (3rd) washing, breaking, screening, and bleaching. The bleached fibre is usually run off as a thick sheet of pulp on a "Press Pâte" machine for convenience of handling. The loss in weight during the cleaning process varies from 1 to 6 per cent. of the weight of grass treated. The dust consists of sand and other mineral matter and of fat or wax. An analysis of the fine dust collected from the willow gave organic matter (by ignition), 64·6 per cent.; water (at 212), 6·2 per cent.; and mineral matter, 29·2 per cent. Fully 90 per cent. of this organic matter consisted of fat or wax. The mineral left after ignition was composed of silica, 56·43 per cent.; carbonate of lime, 19·17 per cent.; carbonate of magnesia, 3·76 per cent.; and alumina, 20·57 per cent. The silicious substance which forms the outer coat of the grass is not removed during dusting, the greater part of the silica in the dust being simply sand derived from the soil. The grass after cleansing contains about 3·5 per cent. ash, the greater part of which consists of silica. It is this silica which contaminates the soda lyes. Assuming that the silica forms $Na_2\,Si\,O_3$, with the $Na_2\,O$, 112 lbs. of $Si\,O_2$ will accordingly combine with 228 lbs. of $Na_2\,O$ to form silicate of soda. Silicate of soda has practically no influence in the boiling operation.

The manufacturing conditions for boiling esparto, *i.e.*, the steam pressure or temperature, the proportionate weight of caustic soda to grass, and the length of time the charge is kept under pressure, vary almost in every factory. Some manufacturers employ a high pressure with a moderate excess of caustic, and thus reduce the time for digesting, and obtain the maximum yield of cellulose.

The following figures are taken from actual practice, and represent fairly good work :—

	Variety of Esparto.	
	Spanish.	Tripoli.
Weight of charge	50 cwts.	50 cwts
Gallons of Caustic Lye per charge ...	1,570	1,570
Lbs. of 60 % Caustic Soda per gallon of Lye...	0·509	0·649
Total lbs. of dry 60 % Caustic Soda per charge	900	1,020
Lbs. of 60 % Caustic Soda per cwt. of Esparto	18	20·4
Steam pressure maximum	20	20
Time under pressure in hours	$2\frac{1}{2}$	3
Yield of unbleached air-dry pulp (10 % water)	44/45%	41/42%

NOTES.—The caustic lye above was partly from recovered ash and partly from cream caustic soda. The above volume of lye, and the soda it contained, were in both cases accurately measured, the latter by chemical test.

The capacity of the esparto boiler in use was 540 cubic feet (8 ft. 9 in. diameter by 9 ft. high), and of the usual vomiting type. The space within the boiler, occupied by 50 cwts. of the grass after it was cooked and drained, was 300 cubic feet.

The yield of fibre from espartos is generally reckoned on the amount of paper they produce. On an average 100 parts of grass will yield from 43 to 50 parts finished paper, depending upon the class and composition of the paper, and general equipment of the paper mill, with regard to economical working.

For purposes of comparison it is best to ascertain the yield from espartos by a uniform and exact method, expressing the results in terms of air-dry fibre (10 per cent. of water) on 100 parts of dry grass (dried at 212° Fah.). This can be done by heating in an oil bath for three hours or so a weighed quantity of the dried grass (25 grammes) with proportionate quantity of a 2 per cent. solution of caustic soda in a wrought-iron cylinder fitted with a screw cap, at a temperature or pressure corresponding to the practice prevailing in the boiling room of the mill. By careful washing, bleaching, and drying the pulp, strictly comparable results are obtained. This method affords a basis upon which the pulp yielding qualities of all fibrous plants can be compared almost without exception. In this way the following figures were obtained, which show the difference in yield between espartos of different origin, and between matured and unmatured espartos of the same origin.

	Matured (Yellow).	Unmatured (Green).	Difference.
Spanish	46·4%	—	—
Oran	44·4%	41·0%	3·4%
Tripoli (fair average) ...	42·5%	39·3%	3·2%

NOTE.—The distinguishing features of the matured and unmatured blades of grass in these trials were very marked; the unmatured being of a deep green colour, whilst the matured was a bright yellow.

STRAW.

Kinds of straw employed—barley, oat, wheat, and rye.

Barley straw yields a short, very soft fibre of low felting power Knots and husks are soft, and straw is easily digested.

Oat straw is usually harder, and knots and husks are more difficult to digest. Fibres are comparatively long, soft, and of medium felting power.

Wheat and rye straws are somewhat closely allied to one another, they both yield long fibres of good felting power. Rye straw yields excellent cellulose.

Manufacturing operations:—The straw is first of all freed from weeds by hand picking, then dusted and cut by machinery into chaff ½ inch to 1½ inch long. Both the picking and dusting should be done thoroughly to ensure the product being clean. The cut straw is then digested in caustic soda lye in rotary digesters.

The following figures represent the proportion of lye and straw and other conditions of the digester charge:—

Weight of straw (mixture of oat and wheat).	4,480 lbs. (40 cwts.)
Gallons of caustic lye	1,610 ,,
Hours under steam pressure ...	4
Steam pressure above atmosphere	60 lbs. per sq. in.
Maximum temperature	307° Fah.

Composition of above caustic lye:

Twaddell	$10\frac{1}{2}$°
Total weight in lbs.	16,945
Percentage by volume of Na_2O (soda)	3·249
,, ,, ,, 60% caustic soda	5·416
Total 60% caustic soda in lbs. ...	872
Lbs. of 60% caustic used per 1 cwt. of straw =	21·8

These figures are from actual practice.

The caustic lye was made partly from recovered ash.

An average of equal quantities of barley, oat, wheat, and rye straws will yield 40 to 41 per cent. of air-dry bleached cellulose. The bleaching powder required to bleach one ton of straw cellulose is from 3 cwts. 2 qrs. 10 lbs. to 4 cwts. dry 35 per cent. bleach. This varies, however, with the proportion of caustic to straw and temperature used for digesting, as also the method of bleaching.

Barley straw requires 20 per cent. less caustic soda than oat, wheat, or rye. The amount of digester capacity required per ton of bleached air-dry straw pulp per week varies from 120 to 150 cubic feet. The mechanical power required in straw pulp factories is about 3 to $3\frac{1}{4}$ I.H.P. per ton of air-dry pulp made per week.

COMPOSITION OF STRAW. (Müller).

	Winter Rye.	Winter Wheat.	Summer Barley.	Winter Barley.	Oats.
Water	14·3%	14·3%	14·3%	14·3%	14·3%
Organic constituents	82·5	80·2	79·7	80·2	80·7
Ash	3·2	5·5	...	5·5	5·0
Fat and wax	1·3	1·5	1·4	1·4	2·0
Nitrogenous bodies	1·5	2·0	3·0	2·0	2·5
Starch, gum, &c.	25·7	28·7	31·3	28·4	36·2
Cellulose	54·0	48·0	43·0	48·4	40·0
Per cent. of dry cellulose on dry straw	63·0	56·0	50·1	56·4	46·6
*,, ,, ,, air-dry cellulose in air-dry straw ...	60·0	53·3	47·7	53·7	44·4

* Air-dry cellulose containing 10 per cent. moisture. Air-dry straw containing 14·3 per cent. of moisture.

COMPOSITION OF THE ASHES OF STRAW (Wolff's "Ashen Analysen").

	Total Mineral matter in Straw.	Percentage Composition of the Ash.								
		K_2O.	Na_2O.	Ca O.	MgO.	Fe_2O_3.	P_2O_5.	SO_3.	SiO_2.	Cl.
Barley Straw, average of 4 analyses	8·10	23·75	1·92	7·53	2·62	2·19	3·94	3·91	51·43	3·75
Oat ,, ,, ,, 8 ,,	7·77	38·37	3·99	4·23	2·53	1·79	2·66	3·06	35·68	7·99
Rye ,, ,, ,, 3 ,,	4·32	26·28	0·74	11·10	4·45	3·19	8·97	5·57	36·86	3·68
Wheat ,, 1 analysis	3·25	12·16	1·00	6·82	4·00	1·02	3·20	5·78	65·34	0·60

W. Roth's table, showing the yield, &c., of air-dry cellulose from straw by soda process.—*P. Zeitung*, No. 75, 1890.

Situation of Works.	1,000 Kilos. of Straw required.			1,000 Kilos. of Straw yielded	100 parts of Air-dry Pulp required.		
	Soda Ash.	Lime.	Bleach.		Soda Ash.	Lime.	Bleach.
	Kilos	Kilos	Kilos	Kilos	%	%	%
South Germany	225	160	105	450	50·0	35·5	23·3
Austria... ...	225	160	72	400	56·25	40·0	18·0
Saxony... ...	240	150	85	435	55·1	34·4	19·5
Bohemia ...	200	160	175	500	40·0	32·0	35·0

NOTE.—From these results it is obvious that the yield of air-dry pulp from straw varies indirectly with the amount of caustic soda used for digesting, and that the bleaching powder required to bleach the pulp increases directly with the percentage yield obtained from the raw plant.

COMPOSITION OF STRAW (Beveridge)

(By the method of digesting in Bisulphite of Soda).

	French Wheat.	Zealand Wheat.	Dutch Wheat Ijpolden.	Dutch Oat.	Dutch Rye.	Dutch Barley.
Water	11·8%	8·2%	12·5%	11·2%	7·6%	11·0%
Ash	7·2	10·0	7·5	5·5	1·8	7·2
Cellulose (unbleached)	36·6	37·6	36·4	37·3	41·3	34·1
Organic matter other than cellulose	44·1	44·2	43·6	46·0	49·3	47·7
	100·0	100·0	100·0	100·0	100·0	100·0
Per cent. dry cellulose on dry straw	41·5	40·9	41·6	42·0	44·7	38·3
*Per cent. of air-dry cellulose on air-dry straw	40·6	41·8	40·4	41·7	45·9	37·9
Silica ($Si O_2$) in straw	4·40%	6·24%	5·17%	2·35%	0·92%	2·06%
Cwts. straw to produce 1 ton of air-dry cellulose	49·0	47·8	49·5	47·9	43·5	52·7
" silica from 1 ton of air-dry cellulose ..	2·15	2·98	2·56	1·12	0·40	1·08
Cwts. of 60 % caustic required to form $Na_2 Si O_3$ with the total silica	3·70	5·11	4·39	1·93	1·02	1·85

* Air-dry cellulose containing 10 per cent. moisture. Air-dry straw containing moisture as shown above.

Note.—The above percentage yields closely correspond to those obtained by the soda process on the manufacturing scale.

BAMBOO.

Bamboo, like esparto, was first introduced as a fibre-yielding plant by the late Mr. Routledge, who suggested it as an ally to esparto. It is not so easily reduced as esparto by either the soda or sulphite processes, but yields a fibre strong and flexible, possessing good felting properties. It bulks well and can be treated in the beater with ease to yield a close sheet of paper. The plant itself is very abundant, of rapid growth, and comparatively cheap. It belongs to the same botanical order as straw. Length of fibre is 0·354 inches. Diameter = 0·00063 of an inch. The fibres are fine, regular, and smooth; walls uniform, and central canal small. They are surrounded by much intercellular matter, the bulk of which can be removed by washing. The author has submitted various kinds of bamboo cane to both the soda and sulphite treatment, with the following results:—

Soda Process.—The cane contained 1·62 per cent. of ash, of the following composition: 51·25 per cent. $Si\ O_2$, 9·25 per cent. $Ca\ CO_3$, and 6·07 per cent. $Mg\ CO_3$. It was crushed before placing in the digester—

Weight of bamboo per charge	52 cwts.
Volume of C. soda per charge	1,600 gals.
Weight of 60 per cent. C. soda per charge	1,741 lbs.
Steam pressure (maximum)	90 lbs.
Maximum temperature	331° Fah.
Number of hours under pressure ...	15

Proportion of 60 per cent. C. soda to 1 cwt. of cane = 33·6 lbs.

The black lye, after blowing off pressure = 16½ Twaddell at 60° Fah.

The pulp obtained was well boiled but dark in appearance, resembling soda wood pulp. It bleached readily at a temperature of 120° Fah. to a pale yellow colour, with 25 per cent. of its weight of bleaching powder (35 per cent. avail. chlorine), The yield did not exceed 40 per cent. of air-dry fibre on air-dry cane.

Bisulphite Process.—A similar cane to the above was crushed between rollers and boiled in bisulphite of lime solution having a sp. gr. of 1·040 = 8° Twaddell, and of the usual composition prevailing in sulphite pulp works, precisely as in the case of wood boiling. The pulp obtained was soft, a pale yellow colour, and was readily washed with water. The boiled fibre was lighter in colour than the corresponding pulp obtained by the soda process, but turned a deep red on addition of bleaching powder solution. With 23 per cent. of its weight of bleaching powder it remained a pale yellow tint, which could only be removed with permanganates. The actual yield of bleached air-dry pulp (10 per cent. water) obtained was 42·7 parts per 100 parts operated upon.

MEGASS, OR CRUSHED SUGAR CANE.

This material is closely allied to bamboo in its nature, but yields less fibre. The fibres are fine, smooth, only moderately long, and are surrounded with much intercellular matter. Its analysis is as follows:—Cellulose = 50·13 per cent., fat and wax = 0·78 per cent., aqueous extract = 10·56 per cent., lignin and pectous substances = 24·84 per cent., water = 8·56 per cent., ash = 5·13 per cent. The above percentage of cellulose is never obtained in practice. Dalheim gives a yield of 29·15 per cent. after treatment by the soda process, which closely corresponds with the author's experience, namely: The megass for examination was obtained direct from a West Indian sugar factory, where it had been crushed and air-dried before shipment. It contained 8·4 per cent. of water (dried at 212° Fah.) and 1·17 per cent. of ash. The ash consisted largely of sand, doubtless derived from the soil. 100 parts of megass yielded, by the soda treatment, 32·25 parts of bleached air-dry fibre containing 10 per cent. water. The amount of bleaching powder required to bleach it to a good white colour was 20 per cent. The fibre by itself will make a very close sheet of paper, somewhat lacking in strength, but is very suitable for blending with other fibres in the production of printing and writing papers.

WOOD CELLULOSE MANUFACTURE.

The operations involved in this manufacture consist of, first, the preparation of the chips; second, the preparation of the sulphide of sodium or caustic soda, or "bisulphite" liquor; third, digesting or "cooking" the wood; fourth, washing, screening, drying and packing the pulp; fifth, recovering the alkali or sulphurous acid, as the case may be.

Nearly every variety of wood can be reduced to pulp by one or other of these chemical processes, but spruce, silver fir, scotch fir, hemlock, or juniper, among the conifers, and the poplars among the broad-leafed trees are the most usually employed. Spruce (*pinus picea*) yields a long, strong cellulose of great felting power, which bleaches easily in presence of hypochlorites to a pure white colour, and is the most extensively used wood for the production of sulphite cellulose. Scotch fir is not so well adapted to the sulphite process, and is seldom used, but by the soda process it yields a somewhat shorter fibre than spruce, possesses less felting power, and is not so easily bleached with hypochlorites. Hemlock (or juniper), a member of the pine family, extensively distributed over North America, yields a long, strong fibre by the sulphite process, but owing to the presence of tannin-like bodies it is difficult to bleach. The poplars (*populus tremulata, populus alba*) are all readily reduced to pulp, both by the bisulphite and soda methods, yielding short, soft fibres, differing but slightly from one another, and all readily bleachable with hypochlorites. Their fibres possess low felting properties, and are used in the production of printing (or book) and writing papers mixed with spruce cellulose or other fibre. By nature of their fineness poplar pulps serve to close the sheet of paper besides imparting to it a degree of softness or impressionability.

Pulp Wood, consisting of either spruce, hemlock, poplar or other kind, is invariably purchased by measurement, and according to local custom. In Northern Europe, the general standard of measurement is the cubic metre. A space metre (raummeter) consists of a pile of logs measuring one metre cube. A solid metre (festmeter), on the other hand, consists of a solid cubic metre of wood based on the solid contents of each log. One space metre (35·31 cubic feet) of logs, having a diameter of about 8 inches, contains from 23 to 24 cubic feet of solid wood. This is equivalent to 72 per cent. of 35·31. One solid metre of wood of the above size is therefore equivalent to nearly 1·55 space metres. In England the cubic fathom (*i.e.*, a pile of logs measuring 6 feet by 6 feet by 6 feet = 216 cubic feet) is the recognised standard. Very occasionally it is bought by the load or 50 cubic feet solid measurement, calculated as usual from the diameter and length of the log. Obviously the cubic fathom is space measurement. In North America (U.S.A. and Canada) the recognised standards of measurements are, first, the "cord," or 128 cubic feet of piled wood (8 feet by 4 feet by 4 feet); and second, 1,000 superficial feet board measure (B.M.). As the name implies, this latter consists of that quantity of logs of variable length and diameter which, when sawn, will yield 1,000 square feet of boards 1 inch in thickness. The contents of each log is calculated from its diameter at the small end, and its length, and expressed in "board measure." This is known as the "survey," or scale. The survey in point of liberality varies within narrow limits according to locality. That quantity of logs which would yield 1,000 superficial feet B.M., if cut into equal lengths and piled parallel with one another will measure from 218 to 230 cubic feet, equivalent to 1·70 to 1·80 cords of 128 cubic feet each. Imported pulp wood in England and America is usually "rossed," or peeled, before shipment. The loss of weight due to peeling varies from 15 to 30 per cent., depending upon the size and diameter of the logs and the mode of peeling them. The number of pieces, 4 feet in length, in a cord, varies according to the diameter of the log. Thus Mr. H. M. Price, of Quebec, found by actual measurement that a cord of 128 cubic feet contained:—

174	pieces when dia. of logs averaged				$4\frac{3}{4}$	inches.
122	,,	,,	,,	,,	$5\frac{1}{2}$	,,
100	,,	,,	,,	,,	$6\frac{1}{5}$	,,
82	,,	,,	,,	,,	$7\frac{1}{10}$	,,

He also found that a cord of spruce pulp wood, peeled and shipped the following winter or spring, weighed 3,000 lbs. Unbarked spruce wood, direct from the forest, weighs about 3,800 lbs. per cord, and contains 32 to 33 per cent. water dried at 212° Fah.

First. *Cleaning the wood and preparation of the chips.*—The pulp wood is deprived of its bark either by hand labour or with a barking machine. Both systems of cleaning are in vogue, but peeling by machinery is by far the more universal. The peeled wood is then cut into slices, diagonal to the grain, with a machine called a chopper; the slices thus obtained are broken up in a disentegrator, and the resulting chips sorted into different grades, from which different qualities of pulp are produced. In the case of peeled wood, delivered as such to the factory, the shavings, if any, are kept by themselves and converted into a lower grade product. In some factories the knots are removed from the peeled logs with a boring machine, prior to their conversion into chips, and these chips are, where labour is cheap, frequently again freed from knots by hand picking.

Loss incurred in preparing chips, &c.—The foregoing operations involve more or less loss of wood. 3,117 solid cubic feet of peeled wood weighing 98,263 lbs., in lengths of about 16 feet, and of $6\frac{1}{2}$ inches average diameter, when passed through the various operations, gave the following losses, viz.:—

Shavings (hand peeling) ...	3,421 lbs.	=	3·50%
Sawing into halves with band saw	1,925 ,,	=	2·00%
Sawing into 3-feet lengths with band saw	757 ,,	=	0·80%
Boring out knots with boring machine	154 ,,	=	0·02%
Waste from splitting	286 ,,	=	0·03%
Knots from sorting table ...	5,967 ,,	=	6·10%
Waste (unclassified)	775 ,,	=	0·85%
	13,285 lbs.	=	13·30%

Deducting the quantity lost in cleaning (13,285 lbs.) from the total weight operated upon (98,263 lbs.) we have a yield of 84,978 lbs. of cleaned chips, which produced 36,921·5 lbs. of air-dry (10 per cent. water) first quality unbleached sulphite pulp, equivalent to 43·4 per cent. on the actual wood boiled.—*Kirchner,* Vol. III.

The author, using imported wood freed from outer bark with the axe before shipment, and after exposure to the drying influence of the air for some months, obtained the following, viz. : Total wood taken, 7·18 cubic fathoms = 1,551 cubic feet stacked logs = 1,163 cubic feet of solid wood = 23·36 loads (50 cubic feet to the load). Total weight of wood = 38,584 lbs. (48·32 cwts.) per fathom. Average diameter of logs = 6½ to 6¾ inches. Percentage of water in prepared chips = 24·6 per cent. (dried at 212° Fah.).

Sawdust from cross-cut saw ...	150 lbs.	=	0·39%
Shavings from barking machines	2,817 ,,	=	7·36%
Refuse from beneath chipper...	1,060 ,,	=	2·75%
Fine sawdust from sieve ...	640 ,,	=	1·66%
Coarse sawdust from sieve ...	836 ,,	=	2·16%
Knots	455 ,,	=	1·18%
Cleaned and prepared chips ...	32,626 ,,	=	84·50%
	38,584 lbs.	=	100·00%

It is possible to use the whole of the above wood for the manufacture of pulp, and this is done in some works, the shavings, sawdust, &c., in fact all excepting the prepared chips, being boiled separately, yielding a third quality fibre, whilst the chips themselves, freed from the above impurities, can again be separated into 90 per cent. of first quality and 10 per cent. of second quality. Where pulp wood is dear this is certainly the most rational way of treating it. There are two systems of cleaning the chips, viz. :—

The water system, employed both in Europe and America, which consists of placing the chips in a flow of water to allow the specifically heavier knots to fall to the bottom, whilst the pure wood floats and passes onward to be mechanically removed, partly dried, and finally conveyed to the chip loft over the digesters.

The air blast system consists of subjecting the chips in an oblong box, the bottom of which forms a series of three hoppers, to a blast of air introduced at the end and below the entrance of the chips. The strength of the air current is under control, and is so regulated that the heavy knots and large pieces of wood fall into the first hopper, the lighter and cleaner pieces into the second, whilst any sawdust still remaining is blown into a third hopper, or into a depositing chamber. Both of these systems of separating the chips had their origin in Europe.

The quantity of cleaned white wood obtained from the logs taken direct from the forest depends upon the diameter of the logs, the thickness of the bark, and the amount of shaving taken off whilst cleaning. Many trials have established the following :—

100 cubic feet of stacked logs, 4 inches to 8 inches diameter at small end, yields 66 to 72 cubic feet solid wood.

100 cubic feet of stacked logs, 4 inches to 6 inches diameter at small end, yields 61 to 65 cubic feet solid wood.

100 cubic feet of stacked logs, $2\frac{3}{4}$ inches by 4 inches diameter at small end, yields 48 to 50 cubic feet solid wood.

It is therefore apparent that the smaller the diameter of logs the less cleaned wood can be obtained from them. In point of fact, the loss in barking pulp wood is controlled by many conditions, and varies enormously in different factories. Less care is observed in preparing the chips for the soda than for the sulphite process.

There are three distinct processes of manufacture in use at present—viz., the caustic soda process, the so-called "sulphate" process, and the "sulphite" or "bisulphite" process.

SODA PROCESS.

This is the oldest method, and consists in digesting wood in caustic soda lye at temperatures ranging from 338° to 355° Fah., corresponding to a steam pressure of 100 to 130 lbs. per square inch above atmosphere. The yield of pulp varies indirectly with the proportion of caustic soda used, as in the preparation of straw cellulose. Originally the digesters were heated by direct fire, but now injected high-pressure steam is used, the boilers being either rotating spheres or upright stationary cylinders. In the latter case, the heating is effected by injecting high-pressure steam into the charge at the lowest part of the digester; in the former, the steam is injected through the trunnion ends.

E. Hennefeld gives the following as representing Swedish practice. There are two varieties of timber suitable for pulp making in that country, Föhre and Gran—*i.e.*, pine and white spruce. Size of the trees are about 15 cm. dia. (= 6 inches). The trees are separated into three different sizes—viz., 15 — 25 cm. dia., 25 — 35 cm., and 35 cm. and over. The logs, after being barked by hand or machine, are cut into pieces 12 mm. × 12 mm. × 4 mm. thick. The pulp digester in this particular case held 8½ cubic metres of chopped and cleaned wood. The volume of caustic soda lye per charge = 6,000 litres (=1,320·7 gallons), and contained 75 kilos. of soda (Na_2O) per cubic metre of wood. The pulp boilers were heated by direct steam to 125 lbs. pressure above atmosphere (353° Fah.). The length of time this pressure was maintained varied with the size (or age) of the pulp wood, thus:—

35 cm. dia. and above, the pressure is maintained for 2 hours.						
35 — 25 cm.	,,	,,	,,	,,	1½	,,
25 — 15 ,,	,,	,,	,,	,,	1 hour	

Each charge of the digester yields 1,240 kilos. = to 24·35 cwts. of air-dry unbleached pulp = 145·9 kilos. per cubic metre of pulp wood.

From the above figures the following are deduced:—

60% caustic soda required per ton of air-dry pulp = 14·75 cwts.

Air-dry pulp per charge ... ... = 24·35 ,, Zeigelmeyer has performed an extensive series of experiments to ascertain the yield of cellulose from various kinds of wood, and other figures relating to this manufacture. The following table gives his results :—

YIELD OF PULP FROM DIFFERENT KINDS OF WOOD.—SODA PROCESS.

Kind of Wood.		Weight of one C. Metre of Fresh Cut Wood.	Loss in Peeling and Cleaning.		Loss in Drying at 212° Fah.		Yield of Pulp from one C. Metre of Wood.	Weight of Clean Dry Wood per C. Metre.	Yield of Pulp on Dry Wood.
German Name.	Botanical Name.								
		Kilos.	Kilos.	%	Kilos.	%	Kilos.	Kilos.	%
Fichte	Pinus Picea	617·5	80.0	12·9	230.0	37·2	108·2	307·5	35·1
Tanne	,, Abies	566·0	136.0	24·0	191·7	33·8	88·2	238·3	37·0
Weissföhre ...	,, Sylvestris ...	697·5	170.0	24·3	252·2	36·1	105·7	275·3	38·4
Schwarzföhre ...	,, Austriaca ...	707·5	147.0	20·7	285·6	40·3	89.0	274·9	32·3
Lärche	,, Larix	597·5	90.0	15·0	160·3	26·8	116·8	347·1	33·7
Legföhre ..	,, Pumilio ...	449·3	55·1	12·2	128·4	28·5	99·8	265·8	37·5
Rothbuche ...	Fagus Silvatica ...	865·0	70.0	8·1	327·5	37·8	139·8	467·4	29·9
Weissbirke ...	Betula Alba	623·5	111·5	17·8	215·0	34·4	85·6	296·9	28·8
Aspe	Populus Tremula ...	695·0	135.0	19·4	227·3	32·7	108·4	332·6	32·9
Pappel	,, Alba... ..	650·0	175.0	26·9	226·5	34·8	88·1	248·5	35·4
Vogelbeere ...	Sorbus Aucuparia ...	725·5	131·5	18·1	269·6	37·1	100·6	324·3	31·0
Elsbeere... ...	,, Tominalis ...	7[illegible]6·5	166·5	22·0	224·2	29·6	103·9	365·8	28·4
Sahlweide ...	Salix Capre	572·5	80·5	14·0	241·0	42·1	85·7	251·0	34·1
Bruchweide ...	,, Fragilis... ..	583·5	111.0	19·0	181·4	31·1	104·8	291·1	36·0
Esche	Fraxinus Excelsior ..	593·5	91.0	15·3	10[illegible]·1	16·8	103·9	402·4	35·8
Erle	Alnus Glutinosa ...	516·5	97·5	18·8	181·0	35·0	81·3	238.0	34·3

Note.—Young trees give less pulp than those which are full grown, and the branches usually yield less than the stem.

The yield of pulp from the different *Coniferæ* varies considerably In Germany and elsewhere *Pinus sylvestris* and *Pinus abies* are commonly used, the yield in actual manufacturing practice being as follows:—

Yield of unbleached Cellulose from *Coniferæ* by Caustic Soda process.
(Manufacturing practice).—MÜLLER.

One Ton of air-dry unbleached Wood pulp required.	*Pinus sylvestris.*	*Pinus abies.*
Cubic feet of piled logs	336	369
,, fathoms of piled pulp wood	1·55	1·71
Cords of piled pulp wood	2·62	2·88
Loads (one load = 50 cubic feet solid wood)	5·44	5·69
One cubic fathom of piled pulp wood logs will yield of unbleached air dry pulp	1,445 lbs.	1,309 lbs.

"KRAFT" PULP (Caustic Soda Process).—The pulp wood is barked by hand or machine, and chopped in the usual way. For every cubic metre (raummeter) of raw wood there are used 750 litres of a caustic soda solution varying from 11 to 13° Bé. The boiling is carried out by gradually heating with direct steam (injected into the contents of the digester) till the temperature of the charge reaches 169½° Cent., equal to 7 atmospheres pressure, at which point it is maintained for 1½ hours. The charge is then blown off, broken up, screened, washed, and pressed into bales, or otherwise transformed into "Kraft" paper. One hundred kilos. of "Kraft" pulp made by this process require 0·65 raummeter of raw pulp wood; 13 kilos. of 58 per cent. ammonia soda ash; 40 kilos. of lime; and 250 kilos. of coal.

SULPHATE PROCESS.

The digesting fluid in this process consists of a mixture of caustic soda and sulphide of sodium. The sulphide of sodium is obtained by adding salt cake or sulphate of soda to the ash in the calcining or smelting furnace. During the ignition of the mixture, the sulphate of soda is reduced to sulphide by the carbonaceous matter derived from the wood, by the well-known reaction $Na_2\ SO_4 + C_4 = Na_2\ S + 4\ CO$. The reaction is similar to that which takes place in the Le Blanc method of making soda. The furnaces used are specially constructed to avoid an excess of air passing over or through the ignited mass, thereby preventing the oxidation of the sulphide of sodium formed. This substance forms at a dull red heat a fusible flux with the sulphate and carbonate of soda present, which runs from the furnace into a covered pit or into a tank containing water. This flux should possess a reddish colour if it is rich in sulphide of sodium, and nominally have the following composition :—

$Na_2\ CO_3$	70·89%	Soluble in water
$Na_2\ S$	14·45%	
$Na_2\ SO_4$	4·87%	
SiO_2	2·35%	
$Al_2\ O_3$ & $Fe_2\ O_3$	trace.	
Insoluble in water	6·18 %	MÜLLER.

Sulphide of sodium by itself will act upon the incrusting materials of wood, but its action is not so vigorous as caustic soda. When the flux or recovered ash is dissolved in water, and the resulting liquor causticised in the usual way, a fluid is obtained of the following nominal composition, viz. :—

$Na_2\ CO_3$	... ...	11 to 12 grms. per litre.
$Na\ OH$	... ...	90 ,, 100 ,, ,,
$Na_2\ S$	... ...	25 ,, 28 ,, ,,

This process is used in the preparation of straw cellulose as well as wood cellulose (see page 115).

The conditions for digesting are somewhat similar to those prevailing in the caustic soda method. The proportion of soda (caustic and sulphide) to wood is a little greater, and the pressure or temperature is higher—140 lbs. per square inch above atmosphere. The yield of pulp from spruce wood is also higher, and the pulp is stronger. The latter property, however, depends greatly upon the mode of manufacture.

Yield of unbleached Cellulose from *Coniferæ* by the "Sulphate" process.
(Manufacturing practice).—MÜLLER.

One Ton of air-dry unbleached Wood pulp required.	*Pinus sylvestris.*	*Pinus abies.*
Cubic feet of piled logs	300	328
,, fathoms of piled pulp wood...	1·39	1·52
Cords of piled pulp wood	2·34	2·56
Loads (one load = 50 cubic feet solid wood)	4·86	5·09
One cubic fathom of piled pulp wood logs will yield of unbleached air dry pulp	1,611 lbs.	1,473 lbs.

Further yields are as follows :—

German Practice.—100 kilos. of air-dry sulphate cellulose required 0·85 raummeter of spruce wood ; 15 to 16 kilos. salt cake or dry sulphate of soda, and 35 kilos. of burnt lime. (*Papier Zeitung*, No. 94, 1897.)

Scandinavian Practice.—100 kilos. air-dry sulphate cellulose required 0·74 raummeter of Norway spruce ; 27 kilos. salt cake and 35·1 kilos. of lime and 0·19 raummeter of fuel wood for soda recovery.

A comparison of soda and sulphite wood cellulose under the microscope shows that a not inconsiderable quantity of the cellulose in the *soda* process is dissolved during digesting, whilst in the sulphite process, bodies other than real cellulose are left behind.

"Kraft" Pulp by the Sulphate Process.—1,000 litres of 13° Bé. sulphate-lye are used per 1 raummeter of raw pulp wood (35·31 cubic feet). The steam from a finished digester is blown into another freshly prepared at a pressure of 7 atmospheres, and then afterwards heated to 169½° Cent. with direct steam. This temperature is reached in from 4 to 5 hours (the corresponding pressure being 7 atmospheres), and maintained for 1 or 2 hours as neces ity requires. 100 kilos. of sulphate "kraft" pulp requires 0·63 raummeter of raw wood ; 21 kilos. of salt cake or crude sulphate of soda ; 35 kilos. of lime, and 225 kilos. of coal.

SULPHITE PROCESS.

This method yields the maximum amount of cellulose from fibrous plants. It is mainly applicable to the treatment of wood, and consists in heating it at high temperature in an aqueous solution of sulphur dioxide (SO_2), in which a suitable normal sulphite is dissolved. The sulphite combines with the organic incrusting materials surrounding the cellulose forming soluble compounds, the separation of which is thus rendered possible by washing. The fluid used is technically known as "bisulphite liquor" and may contain either lime, magnesia, or soda as base, or a mixture of these. The proportion of SO_2 to base varies considerably. A normal bisulphite or one containing two equivalents of SO_2 to one of CaO, MgO or Na_2O, as the case may be, is never used, the SO_2 being invariably in excess of the two equivalents (see page 96) Tilghman, the inventor of the process, in his original patent specification (1866) distinctly stated that the acid liquid he used to carry out his invention was an aqueous solution of sulphurous acid in which lime or other base was dissolved, which substantially corresponds to what is now universally employed in sulphite pulp works. Although bisulphites from these bases are essentially alike in their chemical action and properties, yet in manufacturing practice the more stable solutions, viz., soda and magnesia, yield a somewhat purer cellulose with less trouble. Under certain conditions $Ca\ SO_3$ separates during the "cooking" operation, owing to its greater insolubility, but where every precaution is taken to ensure proper proportion of CaO to SO_2 in the liquor prepared for the digester, and care bestowed on the "cooking" operation, the product from bisulphite of lime very closely resembles that obtained from either bisulphite of soda or magnesia. Bearing this in mind, the question of choice of base is naturally regulated by the cost. A mixture of CaO and MgO occurs in nature, in the mineral "dolomite" (double carbonates of lime and magnesia) and offers the advantage of yielding a bisulphite liquor whose base consists largely of magnesia, the normal sulphite of which, $Mg\ SO_3$ is more soluble than the corresponding lime salt (see page 100) The operations in the process of preparing bisulphite liquor on the large scale consist of first producing SO_2 by burning sulphur (or brimstone) or pyrites (FeS_2) in the air, and secondly, forming bisulphites by absorbing this SO_2 in water in presence of the above bases or their corresponding carbonates.

SO_2 from Sulphur or Pyrites.—When *sulphur* burns in the air it unites with the oxygen to form SO_2, and during the combustion a definite quantity of heat is generated. One pound of sulphur will, theoretically, yield 2 lbs. of SO_2 and generate 3,996 British thermal units. There is no increase in the volume of the gases due to the combination of the sulphur with the oxygen, and since air contains nearly 21 per cent. by volume of O and 79 per cent. by volume of N, it follows that the maximum percentage of SO_2 in the kilns gases at atmospheric temperature and pressure cannot exceed 21 per cent. by volume. This is seldom or never obtained in manufacture practice; usually from 15 to 17 per cent. may be considered good work. The quantity of air measured under normal atmospheric pressure (760 mm.) and temperature (62° Fah.) containing the necessary oxygen for the complete combustion of 1 lb. of sulphur into SO_2 is 56 cubic feet nearly. If the products of combustion from the sulphur kilns be analysed (see page 149), and the percentage volume of SO_2 thus ascertained, the following table will give the corresponding volume of air used.

Volumes of air required to burn 1 lb. (avoirdupois) of sulphur, according to the percentage of SO_2, in the exit gases from the kilns :—

Percentage by volume SO_2.				Volume of air.
4	...	...	...	296·1 cubic feet.
5	...	...	...	236·8 ,, ,,
6	...	...	...	197·4 ,, ,,
7	...	...	...	169·2 ,, ,,
8	...	...	...	148·0 ,, ,,
9	...	...	...	131·6 ,, ,,
10	...	...	...	118·4 ,, ,,
11	...	...	...	107·7 ,, ,,
12	...	...	...	98·7 ,, ,,
13	...	...	...	91·0 ,, ,,
14	...	...	...	84·6 ,, ,,
15	...	...	...	78·9 ,, ,,
16	...	...	...	74·0 ,, ,,
17	...	...	...	69·7 ,, ,,
18	...	...	...	65·8 ,, ,,
19	...	...	...	62·3 ,, ,,
20	...	...	...	59·2 ,, ,,

NOTE.—The percentage by volume of SO_2 in kiln gases can be ascertained by method described on page 149.

NOTE.—One cubic foot of air 62° Fah. weighs 0·0761 lb. Air contains 23 per cent. by weight of oxygen and 77 per cent. by weight of nitrogen.

Sulphur kilns are constructed of either wrought or cast iron, the latter being more usual. They occur in different forms, stationary, with or without agitators, and rotary. The draught should be carefully regulated and the upper part of the kiln kept at a uniform temperature. For this purpose the upper part of stationary kilns are sometimes covered with a water-jacket. Too little air or too high a temperature causes sublimation of the sulphur which fouls the pipes leading to the towers or other absorbing apparatus.

SO_2 FROM PYRITES.—What takes place during the combustion of sulphur is essentially the same when pyrites is burnt, excepting that the volume of air required, the total heat generated, and the maximum temperature produced are all relatively greater per unit of sulphur converted into SO_2. The kilns for burning pyrites, with the necessary dust chamber and scrubber, the latter for removing SO_2, are of a more complicated character. The pyrites in lumps of about 2 to 3 in. cube may be burnt in the ordinary kilns designed for the purpose and largely adopted in sulphuric acid factories, or in the well-known Herreshoff kiln, in the form of dust, "fines," or "smalls." The ordinary kilns for lumps are worked in groups and fed with the mineral at equal intervals of time and with equal quantities per charge. Pyrites ($Fe\,S_2$) of the best quality contains about 50 per cent. of S ; of these about 47 per cent. are burnt off in good practice, the remaining 3 per cent. being left in the cinders or burnt ore. As the iron is oxidised to $Fe_2 O_3$ the burnt ore or cinders withdrawn from the kiln represents about 73 or 74 per cent. of the weight of the green or fresh ore used. A part of the SO_2 formed in burning sulphur and pyrites is always converted into SO_3 which escapes with the other gases and forms sulphates in the bisulphite liquor apparatus. If present in large quantities it forms a hard scale on the surface of the limestone (marble) in the towers. As a general rule when burning sulphur from 2 to 3 per cent. are converted by oxidation into SO_3, whilst in the case of pyrites, as much as 13 per cent. may be converted into SO_3. In the former case the presence of SO_3 may be neglected, but the gases from pyrites kilns should be purified by passing them through a small tower called a scrubber, containing wet coke or limestone (Kellner), before conducting them to the towers. Theoretically, the maximum quantity of SO_2 possible in gases from pyrites is 16·2 per cent. by volume. The total heat of combustion of pyrites varies with the composition of the ore.

The kiln gases, whether from sulphur or pyrites, require to be cooled to about 25° Cent. before they enter the towers or absorbing apparatus.

This is done by passing them first through cast-iron pipes until their temperature is reduced below the melting point of lead, and then through leaden ones immersed in cold water. Sometimes a brick chamber is used containing coils of strong antimonial lead pipes kept cool by a current of cold water passing through them.

There are several methods in practical use for absorbing the SO_2 in the preparation of the bisulphite liquor.

First.—Bisulphite of lime prepared by the Tower systems (Flodquist, Frank of Korndall, Mitcherlich, Kellner, Ekman, and others). These limestone towers are usually upright cylinders built of wood (oregon or pitch pine) braced together with iron rods, from 5 feet to 6 feet in diameter, and of varying heights, each being provided with hard wood top and bottom. In the bottom of each tower an open wood grid is fixed about 6 feet from the base, which slopes towards a door in front to allow the small pieces of limestone, &c., to be removed from time to time that accumulate at the lowest part of the column. Leaden pipes 12 inches to 18 inches diameter convey the gases from the sulphur kilns and cooler to the towers beneath this grid, and another pipe, 3 inches to 4 inches diameter, the prepared liquor from the towers to the storage tank.

The water is distributed equally over the limestone at the top by means of a perforated wooden disc fixed inside. The draught is produced artificially with a fan and may be forced or induced. In the former case the fan is placed between the cooler and tower, whilst in the latter it is connected with the exit pipes from the top of the last tower. Sometimes a steam jet (Korting) composed of hard lead is employed instead of a fan.

When the towers are of moderate height, or about 20 feet high, as in Flodquist's system, they are worked in groups of six or eight, and in direct series, the cooled kiln gases being drawn through them in succession by pipes connecting the top of the first with the bottom of the second, and so on from second to third throughout the whole series. In this case the weak liquors produced in the back towers of the series are pumped on to the front towers, which receive the strong gas, the flow being so regulated as to yield a bisulphite liquor of the required density issuing from them. Mitcherlich's towers are usually 36 metres high (118 feet) by 1·6 metres diameter (5 feet 3 inches). Four towers of this size will yield bisulphite of lime liquor using soft limestone for 10,000 tons sulphite wood pulp a year.

Usually a soft variety of white limestone is used, either marble or that found at Tofte, in Norway. Ekman, the base of whose bisulphite liquor was magnesia, used MgO obtained by calcined magnesite, the MgO being previously hydrated by sprinkling with water, in small towers of moderate size (6 feet diameter by 20 feet high).

Dolomite (double carbonates of lime and magnesia) can be used either alone or mixed with marble, but in the former case the results are unsatisfactory, owing to the hardness of the stone, unless the available tower capacity is very large.

The descending stream of water in these towers absorbs the SO_2 as the cooled kiln gases ascend through the body of limestone, forming an aqueous solution of SO_2 which, acting on the $Ca\,CO_3$ forms $Ca\,SO_3$. This salt, which is insoluble in water, is dissolved and held in solution by the excess of SO_2 in the liquid. The liquor flowing from the towers can be expressed by the formula $Ca\,SO_3\ x\,SO_2$ Aqua, x being always greater than one equivalent. The temperature of the gases entering the tower is kept uniform or nearly so throughout the year, at about 25° Cent. The kiln gases should contain on an average from 15 to 16 per cent. by volume of SO_2, and if this varies, so also must the flow of water entering the top of the towers in order that the bisulphite liquor flowing to the storage tanks register from 6 to 6½° Bé at 30° Cent. Heat is generated by the action of the SO_2 on the $Ca\,CO_3$. Under normal conditions the bisulphite of lime liquor should possess the following composition, viz. :—

Scandinavian Practice, using Flodquist's Towers and Soft Tofte Limestone.

	Composition of "Acid" from Sulphur.	Pyrites.
Free SO_2	2·422%	2·305%
Combined SO_2	1·152%	1·386%
Total SO_2	3·574%	3·691%
CaO (by calculation)	1·008%	1·213%
Degrees Bé	6·2	6·0
Degrees Centigrade	16·5	12·0
Free SO_2 on 100 pts., total SO_2 ...	67·7%	62·4%
Combined SO_2 on 100 pts., total SO_2	32·3%	37·6%

COMPOSITION OF BISULPHITE OF LIME PRODUCED IN MITCHERLICH'S TOWERS, AS ASCERTAINED BY Dr. HARFP.

Degrees Baumé.	Total SO_2 %	Free SO_2 %	Combined SO_2 %	Per 100 of Total SO_2 Free.	Combined.
3½	2·183	1·421	0·762	65	35
3¾	2·288	1·490	0·798	65	35
4	2·483	1·592	0·911	63	37
4¼	2·634	1·668	0·966	63·5	36½
4½	2·807	1·734	1·073	62	38
4¾	2·917	1·787	1·130	61	39
5	3·135	1·971	1·164	63	37
5¼	3·264	2·047	1·217	63	37
5½	3·408	2·092	1·376	60	40
5¾	3·591	2·122	1·469	59	41
6	3·784	2·306	1·478	61	39
6¼	3·959	2·368	1·591	60	40
6½	4·186	2·576	1·610	61·5	38·5
6¾	4·309	2·666	1·643	62	38
7	4·543	2·850	1·693	63	37

Note.—The "acid" flowing from the Towers loses free SO_2 on standing.

The temperature of the water and inflowing gases passing to the towers should be kept as constant as possible and within certain limits, so that the outflowing "acid" from the towers shall not exceed 30° Cent. When this temperature is exceeded, the proportion of SO_2 to CaO more nearly approaches two equivalents of the former to one of the latter. Before this point is reached, normal $Ca\,SO_3$ separates out as a white precipitate and the "acid" becomes milky in appearance.

Second.—Tub systems, using lime and magnesia (Frank, McDougall, Partington, Burgess, Stebbins and others). The principle involved in these systems is the absorption, at low temperatures, of the SO_2 gas, by forcing (Frank) or sucking (Partington, &c.) the kiln gases through weak milk of lime and magnesia prepared from calcined dolomite. For this purpose the milk of lime and magnesia is contained in a series of three or four tubs (about 12 ft. diameter by 5 ft. 6 in. deep inside), strongly built of hard pine to withstand a working pressure of about 11 lbs. per square inch. They are each provided with a mechanical agitator, driven overhead by bevel gears to keep their contents in continuous motion, and are placed at different levels so that the milk of lime and magnesia fed into the uppermost tub overflows by gravitation from one to the other in succession. Their overflow pipes are of lead, usually 4 in. diameter, and are so arranged that the liquid overflows from the surface of one tub to near the bottom of its lower neighbour throughout the whole series, until finally the overflow pipe from the lowest tub conveys the "acid" to the storage tanks. The tubs are also connected together by strong leaden pipes, 6 in. to 8 in. diameter, to convey the gases from the top of one to the bottom of the other, the pipe to the lowest tub coming direct from the sulphur or pyrites kilns (the so-called "gas cooler" intervening), whilst that from the top of the highest tub is connected with a belt driven, geared double-acting vacuum or exhaust pump. This pump sucks the kiln gases through the liquid in the tubs from the lowest to the highest; the direction in which the gases travel being obviously contrary to that of the milk of lime and magnesia. As the milk of lime and magnesia descends through the series of tubs it absorbs the SO_2, and finally loses its milky appearance, becoming quite clear by the time it leaves the lowest tub. In this state, of 100 parts of total SO_2 which it contains, usually 66 parts exist in the uncombined or free state, whilst 34 parts are combined with CaO and MgO as $Ca\,SO_3$ and $Mg\,SO_3$ respectively. Both of these normal sulphites are held in solution by the free SO_2 present. A gauge glass, with sample tap at its lower end, is fitted to the side of the lowest tub to register the depth of the liquid within and to note its appearance. Samples of the liquid may be withdrawn through this tap.

The milk of lime and magnesia is prepared by mixing the calcined "dolomite" with hot water into a thick cream, in a wrought-iron vessel, from which it is emptied into a large wooden tub, provided with a vertical agitator, where it is diluted with cold water, until it registers a density of from 1½ to 2° of Twaddell's hydrometer, according to requirements. It is then passed through a fine brass sieve (60 meshes to the linear inch) into a lower storage tank, also fitted with an agitator, and from thence is pumped to the highest of the absorbing tubs. The quantity allowed to enter the tub is carefully regulated. The following represents the composition of a calcined "dolomite" suitable for the preparation of bisulphite of lime and magnesia liquor, viz.:—

$Mg\,CO_3 = 44{\cdot}18\,\%$, $Ca\,CO_3 = 55{\cdot}25\,\%$, $Al_2\,O_3$ and $Fe_2\,O_3 = 0{\cdot}27\,\%$.

This calcined dolomite, when made into a weak milk for use in the absorbing tubs, gave, on actual analysis:—

CaO	... ...	6·31 grammes per litre.
MgO	... ...	4·19 ,, ,,
		10·50
Sp. gr.	... ...	1·0075 = 1·50° Twaddell.

The percentage of SO_2 in, and the temperature of, the kiln gases, as also the temperature of the milk of lime entering the tubs, play an important rôle in the efficiency of this apparatus, and the composition of the liquor produced. The following figures represent good manufacturing practice:—

Average percentage SO_2 in kiln gases ...	16·1
Average temperature of kiln gases entering tubs	24° Cent.
Composition of Acid—Free SO_2	2·03 %
Combined SO_2 ...	1·08 %
Total SO_2 ...	3·11 %

Sp. gr. at 17° Cent., 1·0315 = 6·3° Twaddell.

Of 100 parts of total SO_2 in this liquor, 34·7 parts are combined with CaO and MgO forming normal sulphites, whilst 65·3 parts exist in the uncombined or free state. The actual amount of bases (CaO and MgO) may be obtained by calculation from the amount of combined SO_2 and the relative quantities of CaO and MgO existing in the calcined "dolomite."

CAPACITY OF BISULPHITE OF LIME APPARATUS.—Dr. Frank's apparatus, consisting of sulphur kiln, coolers, lime mixing tank, and three absorbing vessels of the aggregate capacity of about 1,200 cubic feet, and all auxiliary apparatus, will yield 13,000 gallons of bisulphite of lime liquor from caustic lime or calcined dolomite per 24 hours. This is equal to a daily output of 8 to 9 tons (2,240 lbs.) of air-dry cellulose.

Bisulphite of Magnesia is prepared by passing the cooled kiln gases obtained by burning sulphur through small towers filled with hydrated calcined "magnesite" ($Mg\ CO_3$) in lumps, the latter being kept moist with a downflow of water. The towers are of small size, about 20 feet high by 5 feet or 6 feet in diameter, and yield indifferent results, chiefly due to the calcined "magnesite" packing so closely as to seriously interfere with the draught. A more satisfactory method is to pass milk of magnesia (prepared by grinding the calcined magnesite in an edge runner mill to a fine cream with water, then diluting largely), down a tower built of sheet lead, and filled with large flint stones while the kiln gases pass upward by induced draught. The proportion of magnesia to water forming the milk are carefully regulated. The bisulphite flowing from the tower has the following composition :—

Percentage of combined and free Sulphurous Acid (SO_2) in solutions of Bisulphite of Magnesia for Sulphite Pulp Manufacture.

Specific Gravity at 60° Fah.	Degrees Twaddell 60° Fah.	Total SO_2 %	Free SO_2 %	Combined SO_2 %
1·025	5	2·279	1·205	1·073
1·0275	5½	2·464	1·305	1·159
1·030	6	2·724	1·442	1·282
1·0325	6½	2·934	1·553	1·381
1·035	7	3·155	1·670	1·485
1·0375	7½	3·382	1·797	1·587
1·040	8	3·605	1·913	1·692
1·0425	8½	3·828	2·031	1·797
1·045	9	4·000	2·124	1·876
1·0475	9½	4·272	2·266	2·006
1·050	10	4·494	2·384	2·110
1·0525	10½	4·667	2·477	2·190
1·055	11	4·939	2·619	2·320

The above values are not absolute.

Bisulphite of Soda may be prepared from a weak aqueous solution of soda ash in the tubs in lieu of lime and magnesia, or by adding a nearly saturated solution of sulphate of soda to one of bisulphite of lime, when the following reaction takes place, viz., $Ca\,SO_3\,x\,SO_2\,Aq + Na_2\,SO_4 = Ca\,SO_4\,2H_2O + Na_2\,SO_2\,x\,SO_2\,Aq$. The decomposition of the bisulphite of lime by adding a slight excess of sulphate of soda is fairly complete—*i.e.*, from 90 to 95 per cent. The author has obtained good cellulose for some years by using this method. It is also understood to be in successful operation in one Austrian works.

Bisulphite of soda liquor prepared by this method, using a bisulphite of lime containing 3·66 per cent. total SO_2, 2·181 per cent. free SO_2, 1·53 per cent. SO_2 combined with CaO and a sulphate of soda solution obtained from salt cake or crude $Na_2\,SO_4$, from which the iron and alumina had been previously removed by precipitation with lime, and containing 189·2 grammes anhydrous $Na_2\,SO_4$ per litre, gave, on analysis :

Free SO_2	1·597 %
Combined SO_2	1·303 %
Total SO_2	2·900 %

This liquor contained $Ca\,SO_3$, 0·472 per cent. ; $Na_2\,SO_3$, 3·053 per cent. ; $Ca\,SO_4$, 0·090 per cent. ; $Na_2\,SO_4$, 0·488 per cent. The precipitation of the $Ca\,SO_4, + 2H_2\,O$, takes place very rapidly at 120° Fah., and in the above instance 5 per cent. excess of $Na_2\,SO_4$ was added. The precipitated $Ca\,SO_4, + 2H_2\,O$, is pure white, and when filtered, washed, dried, ground and sieved, yields an excellent loading ("pearl hardening") for paper manufacture.

BOILING.

There are various systems in general use for boiling the chips in the digester. The *slow* or *long* cook system was instituted by Mitcherlich, whose contributions to the science and technology of the industry have been of great importance. He employs horizontal, cylindrical digesters, with circular ends lined with glazed earthenware tiles, and heated by steam coils of hard lead. These digesters measure twelve (12) metres long by four (4) metres in diameter ; have a total cubic capacity of one hundred and thirty-four (134) cubic metres (4,706 cubic feet). They hold one hundred cubic metres of wood, sixty (60) cubic metres of bisulphite liquor, and yield about ten thousand (10,000) kilos. (ten tons) of cellulose per charge.

The mode of boiling is as follows :—The digester is first filled with chips, and these are steamed gently with direct steam to remove volatile oils, &c., the condensate being run away. During this operation the so-called turpentines and wood acids formed are removed and the air is expelled. After the steaming has been completed, all cocks are closed, excepting that directly connected with the acid storage tank, and in virtue of the partial vacuum formed within the digester by cooling, the acid is sucked into it until it is full. The acid valve is then shut, and the relief valve opened, and the heating or boiling of the charge begun. The temperature is raised very gradually by means of the coils, and is never allowed to exceed 120° Cent., the pressure is kept at forty-five (45) to fifty-two (52) lbs. above atmosphere. Frequent samples of the liquor are withdrawn from the digester and tested for sulphurous acid, more especially towards the end of the process, to ascertain how the chemical reaction is going on. When the percentage of SO_2 has sunk to that point in accordance with the prevailing practice consequent on the kind of pulp required, and the peculiarities of the particular apparatus in use, the steaming is stopped and the superincumbent pressure blown off. The pulp is then washed twice with water and finally removed. An analysis of the time occupied in the different operations is as follows:—

Filling with wood	2 hours.
Steaming...	4 ,,
Filling with liquor	2 ,,
Boiling	35 ,,
Blowing-off pressure, &c.	3 ,,
Washing twice	6 ,,
Emptying and getting ready for next charge	5 ,,
Total time for one boiling =	57 hours.

Eleven to twelve boilings per month, yielding 110 to 120 tons of air-dry cellulose.

Owing to the gentle nature of the chemical treatment which the wood receives under the low temperatures employed, the strength of the fibres is preserved, and by this process the strongest sulphite pulp is obtained.

On the other hand, in the quicker method of cooking, the chips are not subjected to a preliminary steaming, but the acid is added immediately the digester is filled with them. Nor are the contents, as a rule, heated by steam coils, but with injected steam admitted at the lowest part of the digester. In some cases the charge is heated up to a certain point with injected steam, and thereafter, with steam coils, but in all cases whenever quick cooking is desired the maximum temperature is seldom less than 135° Cent., and frequently reaches 144° Centi. The chemical action between the resinous matters surrounding the fibres in the wood and the bisulphite is accelerated by increase of temperature. Owing to the tension of the SO_2 gas inside the digester the pressure bears no definite relation to the temperature as is the case with water, so that during the "cooking" the pressure, varying from seventy-five (75) to ninety (90) lbs. per square inch above atmosphere, is kept constant, or nearly so, by means of a release valve, the SO_2 thus escaping being recovered as described below.

When the charge is finished, a point ascertained by examination of a sample of the liquor by chemical test (iodine), as also by its appearance and smell, the steam is shut off, and if the contents are to be "dumped" into a drainer in contradistinction to being blown off under the full pressure prevailing at the finishing point, the pressure within is blown off, the valve at the bottom of the digester opened, and the whole charge run by gravitation into a draining pit. In some works the liquor is drained from the pulp whilst the latter is still in the digester, and while the pressure is being blown down, due allowance in such cases being made in the amount of SO_2 left in the liquor at the so-called finishing point, to compensate for the extra time the charge is kept at a high temperature. In America, where the blow-off system of emptying the digesters is universally used, this point is carried as far as required. Immediately it is reached, a large valve at the bottom of the digester is opened, and the charge ejected into a large covered wooden tub, having a perforated false bottom to drain off the liquid contents, and a chimney to allow the steam to escape. In this tub the pulp is also washed. By the sudden release of the pressure and consequent generation of steam, as also the force of impact against the side of the tub, the bundles of fibres are thoroughly broken up in this act of blowing off, rendering unnecessary a special apparatus for this purpose. The pulp from these tubs is therefore passed direct to the screens without further disintegration.

The precise mode of handling the cooking operation varies almost in every factory, depending upon the quality of fibre required. Usually from 12 to 15 hours are occupied in cooking one charge and emptying and refilling the digester with acid and chips. In Mitcherlich's system, on the other hand, the same operations occupy from 60 to 70 hours.

RECLAIMING THE SO_2.

During the "cooking" operation, SO_2 is allowed to escape from the upper part of the digesters and is recovered for re-use, various forms of apparatus having been arranged for this purpose. In all cases the object in view is to enrich the freshly-prepared bisulphite liquor obtained from the limestone towers or absorption tubs with uncombined SO_2. The principle involved in this recovery process is simply one of cooling and absorption. The steam and SO_2 gas, with a little liquor from the digesters, are thoroughly cooled by being conducted through coils of hard lead immersed in cold water, the condensate and any cooled unabsorbed SO_2 gas being passed directly into the freshly-prepared bisulphite liquor. The latter readily absorbs the gaseous SO_2 and blends with the condensate. The amount of SO_2 thus circulating between the digesters and storage tank varies according to the extent of escape employed in the process of "cooking," but its magnitude may be gathered from the following trials performed by the author in a large Scandinavian sulphite pulp factory using bisulphite of lime. In this particular factory the freshly-made bisulphite of lime from the limestone tower was pumped into a lead-lined tank placed on a higher level than the digesters, and its volume in cubic metres, temperature and density carefully recorded, and its composition ascertained by chemical analysis. The escape from the digesters, without being cooled, was blown into the body of the cold liquor until its temperature was raised to 40° Centi. (at 50° Centi. the Ca SO_3 is precipitated), by which time practically all the recoverable SO_2 had passed away from the digester. The volume of the warm "acid" in the tank was then measured, and its temperature, density and composition ascertained with the following results:—

Recovery of SO_2 from Sulphite Digesters.

	Bisulphite of Lime Liquor.	
	Before receiving "Escape."	After receiving "Escape."
Cold bisulphite of lime liquor in tank	cm. 15·90	cm. 16·75
Density in degrees Bé	6·20	6·25
Temperature in degrees Centi....	17·0	40·0
Composition:		
Total SO_2	3·585	4·410
Free SO_2	2·480	3·330
Combined SO_2	1·090	1·080
Kilos of SO_2 in liquor	571·0	738·6
Volume of liquor used per charge in digester	12·5	12·5
Kilos SO_2 used per charge in digester ...		551·2

In this particular factory the digesters were of the revolving cylindrical type, had each an internal capacity of 1,072 cubic feet, contained per "charge" 910 cubic feet of prepared chips and 2,740 imperial gallons of bisulphite liquor, and yielded on an average per charge—4,200 lbs. of air-dry sulphite cellulose. From these figures one ton or 2,240 lbs. of air-dry pulp required 572 cubic feet digester space per charge. 485 cubic feet of chips, weighing from 12 to 14 lbs. per cubic foot (one cubic foot of prepared chips containing 22 per cent. H_2O—dried at 100° Centi.—weighed 12½ lbs.); 1,461 imperial gallons of prepared "acid" containing 4·41 per cent. SO_2 = 322 lbs. sulphur, of which 98 lbs. or 30·5 per cent. were recovered or sent back to the storage tanks for re-use, according to the above trials.

As above stated the most frequent practice is to pass the escaping gases, &c., from the digester *after cooling in coils* into the freshly-prepared liquor contained in the storage tank, the capacity of which, as a rule, is large. The following represents the average (of many months) composition of such liquors in a pulp factory using a mixture of bisulphite of lime and magnesia prepared in absorbing tubs from sulphur and calcined "dolomite," before and after receiving the recoverable SO_2 from the digesters:—

	Liquor before receiving Recovery.	Liquor after receiving Recovery.
	Per cent.	Per cent.
Free SO_2	2·03	3·22
Combined SO_2	1·08	·93
Total SO_2	3·11	4·15
Sp. gr. at 62° Fah.	1·0315	1·0350

Assuming that only a negligible quantity of liquor escaped from the digester with the steam and SO_2, as was actually the case in this instance, since the total quantity of combined SO_2 in the "acid" remains substantially constant, although the quantity expressed in per cents. by volume or in grammes per litre will diminish according to the extent of the dilution, it is obvious that the amount of dilution can be ascertained by calculation, thus:—1·08 : 0.93 : : 100 : 117; which means that 100 volumes of cold acid became 117 volumes after the addition of the products of recovery. Also that 100 × 3·11 : 117 × 4·15 : : 100 : 156 or the amount of SO_2

(or sulphur) received from the digester was 56 parts of that actually put into it (156 parts) and therefore the percentage recovered was equal to 35·9 (*i.e.*, 156 : 56 : : 100 : 35·9). This result nearly coincides with the author's foregoing figure obtained by actual measurement and was obtained from rotary digesters in which 1,458 imperial gallons of bisulphite liquor were used per ton (2,240 lbs.) of pulp produced.

In the case of upright stationary digesters, the volume of bisulphite liquor used per ton (2,240 lbs) of pulp made varies considerably and, as a rule, a larger excess is added than in the case of rotary digesters. Thus in one works in which upright stationary digesters of moderate capacity (3 tons per charge) were in use, the volume of bisulphite liquor added was 2,135 imperial gallons to the ton (2,240 lbs.) pulp, air-dry weight; whilst in another with digesters of three times this capacity, the volume was 2,200 gallons.

Summarising a long series of observations, the author has concluded that:—

1. The quantity of sulphur sent back from the digester to the storage tanks varies from 30 to 40 per cent. of the total added to the digester.
2. The percentage dilution varies according to the mode of recovery and to whether or not the whole of the liquor passing from the digester is allowed to flow through the cooling coils into the storage tanks. The variation amounts to from 17 to 38 per cent. reckoned on the cold acid into which the recovery is discharged.
3. The volume of acid required per ton of pulp made in rotary digesters varies from 1,450 to 1,600 imperial gallons; and in stationary digesters varies from 1,800 to 2,200 imperial gallons.

SODA RECOVERY.

The waste soda lyes from esparto, straw and wood boiling, by either the soda or sulphate processes, are evaporated to dryness, and the residue calcined in order to recover the soda for re-use. There are two types of evaporators used for this purpose, namely, open, or surface evaporators, of which there are a great many kinds, notably those introduced by Porion and Enderlein; and evaporators in which the liquid is concentrated with steam in vacuo to a high density, such as Chapman's, and the well-known Yaryan multiple evaporators. In respect to economy of fuel, the multiple evaporator, in conjunction with a steam generating plant at the end of the roaster in which the concentrated lye is incinerated, is the best, although Enderlein's apparatus very closely approaches it.

The organic matter associated with the soda, derived from the wood or fibrous plant, has a certain calorific value, which, if properly utilised, reduces to a minimum the quantity of fuel required. This calorific value can be ascertained by the aid of a calorimeter. Both its amount and heating value naturally vary with the kind of fibrous plant treated. The former can be ascertained either by analysis or by calculation and so also can the water associated with it. (See page 74.) There is approximately one ton of combustible matter obtained for every ton of air-dry pulp made from spruce wood by the caustic soda process.

The PORION Evaporator, into which the waste soda lye is fed from a tank overhead, consists of a spacious rectangular brick chamber, the bottom of which forms a shallow reservoir, containing two cross shafts driven from the outside and carrying a series of paddles which, revolving at a high speed, throws the lye in the form of a fine spray into the upper part of the chamber—that is, into the current of hot fuel gases passing through the chamber from the calcining hearth to the chimney. When the lye on the bottom of the chamber has reached a density of from 45 to 50° Twaddell it is drawn off and conveyed by a bucket elevator or pump to a storage tank placed over the roasting or calcining furnace. The final concentration and incineration of the residual soda is carried out on the hearth of this furnace by means of a coal fire placed at one end, the products of combustion passing as above indicated into the Porion chamber. It is claimed that by this mode of recovery, 5,600 gallons of 8° Twaddell lye containing one ton (2,240 lbs.) of recovered ash (45/46 per cent. Na_2O) are evaporated, and the residue calcined, with an expenditure of 2,770 lbs. of ordinary slack coal.

Enderlein's system of evaporation is similar in principle, but instead of a series of arms on the shaft revolving at a rapid rate to produce a spray of the liquid in the upper part of the chamber, he arranges a series of wrought-iron discs, about six inches apart, on the shafts, through the intervening spaces of which the fuel gases from the roaster—which may be stationary or revolving—must pass on their way to the chimney. The discs are partly immersed in the lye, and as they revolve they offer a large heating or evaporating surface to the passing hot fuel gases.

The complete apparatus for this system, which is specially adapted to the "sulphate" process, consists of :—First, a "smelter," 1·2 metres square area by 2 metres in height; second, a rotary roaster, 5 metres long by 2½ metres in diameter; and third, the evaporator specially constructed by Enderlein himself. This evaporator may be built of wrought iron. When this is done, it consists of a vessel about 16 feet long by about 7 feet deep and 14 feet wide, and contains two cross shafts, upon which are arranged the wrought-iron discs. These shafts, carrying the plates or discs, rotate about 10 revolutions per minute. The black lye from the digester is concentrated in this evaporator to about 38° Bé., and from thence is run into the rotary roaster, where the remaining water is driven off and where the organic matter is partly burned. Enderlein recommends, however, that the combustion in the roaster should be minimised, in order to prolong the life of the roaster itself, and to obtain the maximum temperature in the smelter. The heat from the smelter passes through the roaster and then through the evaporator. The black mass from the rotary roaster, as it falls on the floor, is mixed with a proportion of salt cake, or crude sulphate of soda, and then thrown into the smelter, where, by the aid of a blast of air, it is fused at a bright red heat and flows in liquid form from the furnace. Usually it flows direct to a vessel containing water, in which it rapidly dissolves. From thence the strong alkaline solution is pumped to the causticiser. The chemical reaction which takes place within the smelter is a very simple one. The sulphate of soda is reduced by the carbon derived from the wood, or other fibrous plant, at a red heat, thus :—$Na_2SO_4 + 4C = Na_2S + 4CO$.

The carbonate of soda remains unchanged.

In one such apparatus, containing two shafts, each with 32 discs, the latter having a total heating surface of 350 square metres and revolving nine times per minute, from 70 to 80 cubic metres of waste lye from the sulphate pulp process are concentrated from 16° Bé. to 35 or 38° Bé. Of this total heating surface one-sixth dips into the lye in the evaporator, leaving five-sixths available for active evaporation. This apparatus, in conjunction with a rotary roaster and smelter, is capable of producing 4,600 tons (1,000 kilos.) of smelt per year, equal to about 13,500 kilos. smelt per day of 24 hours.

If 15 per cent. be deducted from the daily output of smelt due to the addition of sulphate of soda, there remains 11,475 kilos. of smelt from the black waste lye. This waste lye enters the evaporator proper at 16° Bé. and leaves it at 38° B.é, which corresponds to 143 kilos. per cubic metre for the weak lye and 460 kilos. per cubic metre for the concentrated lye. We have, therefore, 11,475 ÷ 143, or 80 cubic metres weak lye, and 11,475 ÷ 460, or 25 cubic metres of strong lye, the difference of 55 cubic metres or 55,000 litres being the water evaporated in 24 hours for the 300 square metres available evaporating surface of the discs. The water evaporated per square metre of heating surface of the discs is 55,000 ÷ (24 × 300), or 7·64 kilos. per hour. (*Kirchner.*)

As a general rule, when the lye is fed to this apparatus at 16° Bé., no fuel is required beyond the organic matter associated with the soda. Enderlein states, on the other hand, that if the lye averages 10° Bé. the consumption of coal is 250 kilos per ton (1,000 kilos) of pulp produced. When the lye registers less than 10° Bé., such as that from esparto or straw, a multiple evaporator in conjunction with the Enderlein system is more economical. To obtain a high percentage of soda recovery such a combination is necessary.

(See page 116 for composition of smelt, &c.)

Quadruple or triple-effect multiple evaporators are very frequently employed to concentrate the weak soda lyes to a density of from 50° to 70° Twaddell, the final evaporation and calcining of the residual mass being carried out on the hearth of a reverberatory furnace, or rotary roaster, heated by a coal fire. The heat from the reverberatory furnace or roaster arising mostly from the combustion of the organic matter associated with the soda, is utilised in a variety of ways, but most frequently by generating steam for use in the evaporating pans. The high efficiency of the Yaryan, Chapman, and such-like evaporators in point of water evaporated per pound of steam used, makes such a system economical in respect to consumption of fuel. The following results were obtained from esparto liquors at Esk Mills, with *Triple* effect Yaryan and Jardin's reversible roaster. Liquors from esparto boiling.

Twaddell of feed liq...		7°	diff. 35° Twad.
,, concentrated liq. ...		42°	
70°/₀ caustic used, 190 cwts.	=	277	cwts. 48°/₀ ash.
48°/₀ soda ash recovered	=	512	,,
Total 48°/₀ used		789	cwts.
48°/₀ Ash recovered		606	cwts = 76·8°/₀

COAL.—

	Tons.		Cwts. per Ton of ash
Consumed at Yaryan ...	33·35	=	$21\frac{3}{4}$ at Yaryan boiler.
,, roaster ...	7·55	=	$4\frac{3}{4}$ at roaster.
Total for Yaryan and roaster			$26\frac{1}{2}$ cwts.

LABOUR.—Cost of labour at Yaryan and roaster, 5s. per ton of ash recovered.—*Paper Trade Review.*

With the Chapman apparatus at Henden Paper Works, which consisted of a quadruple effect evaporator of upright pans, in connection with a double-flued steam boiler into which the weak esparto liquors were pumped, and from which the necessary steam for the evaporators was generated with coal, the following results were obtained. The amount of coal required to complete the calcination of the ash in the roaster is not given, and therefore the coal consumption represents the concentration of the lye to $46\frac{1}{2}$° Twaddell only.

200,000 gallons of black liquor of $5\frac{3}{4}$°T. at 160° Fah. are reduced to 29,370 gallons of thick liquor of $46\frac{1}{2}$° T. at 125° Fah. ready for the roasters by an expenditure of 20 tons 11 cwt. 3 qrs. of small coal, equivalent to an evaporation of 37 lbs. of water per pound of coal used, and to $10\frac{1}{2}$ cwt. coal per ton of ash recovered, without counting the coal used at roaster.—*Paper Trade Review,* 1890.

At Croxley Paper Mills a trial was made on esparto liquors, lasting four hours, with quadruple Yaryan apparatus, the measurements and tests being taken by the then manager of the mill, Mr. J. W. Wyatt, with the following results (*Paper Trade Review*):—

STEAM BOILERS—	
Boiler pressure	65 lbs.
Coal used per hour	10 cwts.
Water evaporated per hour ...	572 galls. ($5\frac{1}{10}$ lb. per lb. coal).
WEAK LIQUOR—	
Amount of feed per hour ...	$1,537\frac{1}{2}$ galls.
Density of liquor in store tank	·4° Twad. at 90° Fah.
STRONG LIQUOR—	
Amount of concentrated liquor per hour	$176\frac{1}{2}$ galls.
Density of concentrated liquor .	36° Twad. at 138° Fah.
EVAPORATION IN YARYAN—	
Water evaporated from weak liquor per hour	1,361 galls.
Percentage of original volume .	$88\frac{1}{2}$ %
PRESSURE—	
Steam pressure in shell of first effect	17 lbs.
Steam pressure in first separating chamber	2 lbs.
Vacuum in second separating chamber	6 in.
Vacuum in third separating chamber	$14\frac{1}{2}$ in.
Vacuum in fourth separating chamber	23 in.
DISTILLED WATER—	
Amount of drip water per hour	$1,535\frac{1}{2}$ galls. at 176° Fah.
Amount of vacuum water per hour	372 galls. at 125° Fah.
Total amount of hot distilled water produced per hour ...	$1,907\frac{1}{2}$ galls.

STEAM USED IN EVAPORATOR—	
Amount of steam condensed in first effect (1,907½ galls., less 1,361 galls.)	546½ galls.
STEAM USED FOR PUMPS—	
Amount of steam used for working the pumps (572 galls., less 546½ galls.) ...	25½ galls.
COAL USED—	
For pumps	50 lbs.
To raise liquid from 90° Fah. to boiling point	390 lbs.
To evaporate 1,361 galls. from boiling point	680 lbs.
	1,120 lbs.

ACTUAL WORK PERFORMED BY THE YARYAN APPARATUS.—1,537½ galls. of liquor raised from 90° Fah. to boiling point, and 1,361 galls. of water evaporated out of it, at an expenditure of 1,070 lbs. of coal, or 12·72 lbs. of water actually evaporated per pound of coal used.

EVAPORATIVE RESULT OF THE YARYAN.—1,361 galls. of water evaporated from boiling point at an expenditure of 680 lbs. of coal, or 20 lbs. of water evaporated from boiling point per pound of coal, with only $5\frac{1}{10}$ lbs. evaporation in the steam boiler.

NOTE.—In the above calculation the amount of steam required to drive the pumps is not included, as the exhaust is utilised for purposes in the works other than evaporation in the Yaryan.

The boilers used gave the above low evaporation per pound of coal on account of the mechanical stokers not being at the time in order. If they had been arranged and fired so as to evaporate 8 lbs. of water per pound of coal (a low average for good steam boilers), the above "Evaporative Result" of the Yaryan would have been at the rate of 31½ lbs. of water per pound of coal.

Mr. Wyatt also published, in the *Paper Makers' Monthly Journal* of July, 1889, the results, among others, of the concentration of soda liquors in a poplar pulp manufactory in the United States of America, which is representative of American practice. The rotary roasters were heated by a coal fire, and the waste heat passing from the roasters was utilised for raising steam for driving the necessary pumps and feeding the Yaryans. This particular mill works three 11-coil triple-effect Yaryans in connection with three Warren rotaries, and produces about 40,000 lbs. of ash, testing 49 per cent. Na_2O, in 24 hours, from liquor at 6½° to 7° Bé. at 145° Fah., concentrated to 35° to 37° Bé. at 125° Fah., in the Yaryans.

The concentrated liquor is pumped into store tanks, from which it runs to the rotaries in a continuous stream.

The cost for the month of November, 1888, was as follows :—

$101\frac{2}{3}$ tons of coal at $3.15 per ton... ...	$320.91
Labour	357.85
Repairs	98.02
Total	$776.78

Ash recovered, 951,540 lbs.

Cost per 100 lbs. of ash = 8.16 cents.

The labour consists of :—

1 man per 12 hours for 3 Yaryans		at $1.75 per day.	
3 men „ „ 3 Rotaries	2	at $1.75	„
	1	at $1.50	„

= 8 men per 24 hours, at a cost of $13.50.

The coal used is a soft bituminous slack. The percentage of recovery is about 85 per cent.

The above item for repairs does not include the renewing of the brick lining to the rotaıy furnaces, which it is calculated will have to be done every six months, and would add another cent per 100 lbs. of ash to the cost of recovery.

The small amount of coal used in the recovery not only burns off the ash, but, with the fuel contained in the ash, raises steam for all the Yaryan purposes, drives the small steam engines that turn the furnaces, and gives back for use in the mill as surplus steam about 25 per cent. of the steam raised in the boilers behind the furnaces.

The cost of recovery in this mill, before the introduction of the Yaryan evaporator and rotary furnace, was as high as 42 cents per 100 lbs. of ash by the old system of open pans and long furnaces.

The following results, obtained by the author at Northfleet Paper Mills with a quadruple effect Yaryan evaporator, concentrating waste soda lyes from soda wood pulp manufacture, after making reasonable allowances, resemble the results obtained by Wyatt, and established the well-known fact that a machine of this nature will evaporate on an average 3·25 lbs. of water from and at 212° Fah. per pound of steam used.

Economy of fuel in the recovery process lies wholly in the utilisation of the heat evolved from the combustion of the organic matter in the waste lyes, and from the coal fire used to start this combustion. When this is efficiently done a ton of ash can be recovered with an expenditure of from 250 to 500 lbs. of coal, assuming a quadruple evaporator to be employed and lyes of about 5° to 7° Twaddell.

YARYAN QUADRUPLE EVAPORATOR (BEVERIDGE).

Results of Four Tests of Evaporator working on Waste Lye from Soda Wood Pulp Manufacture.

	No. of Trial.			
	No. 1.	No. 2.	No. 3.	No. 4.
Steam pressure at boilers, lbs. per square inch ...	55	55	55	55
Pressure of steam in 1st effect ,, ,, ...	24	23	22	22
,, ,, 1st separator ,, ,, ...	6	7	$6\frac{1}{4}$	7
Vacuum in 2nd ,, in inches mercury ...	$2\frac{1}{2}$	2	$3\frac{3}{4}$	2
,, in 3rd ,, ,, ,, ...	$12\frac{1}{2}$	13	$12\frac{1}{2}$	13
,, in 4th ,, ,, ,, ...	$23\frac{3}{4}$	23	$23\frac{1}{2}$	23
Twaddell of feed liquor ...	5	$7\frac{1}{2}$	7	$5\frac{3}{4}$
Temperature ,, ,, ° Fah. ...	158	151	164	188
Volume ,, ,, in gallons ...	1571	1528	1523	1431
Twaddell of concentrated liquor ...	59	50	59	59
Temperature ,, ,, ...	147	142	144	144
Temperature of injection water ...	54	54	54	54
,, ,, ejection ,, ...	112	112	101	106
,, ,, drip ,, ...	180	177	179	180
Ratio of strong liquor to weak liquor ...	1 : 10	1 : 6·25	1 : 7·37	1 : 7·61
Lbs. of coal used per hour to heat feed liquor to 212° Fah. in first effect ...	100	112	86	40
,, ,, to evaporate from 212° Fah. ...	340	347	337	334
,, ,, by pumps (calculated) ...	93	93	93	93
Total coal consumed per hour by Yaryan ...	533	552	516	467
Lbs. of water evaporated from feed liquor at 212° Fah. by 1 lb. of steam, including pumps ...	3·57	3·14	2·36	3·04

NOTE.—All coal data are based on the assumption that 9 lbs. water are evaporated from and at 212° Fah. per lb. of coal burnt in steam boilers.

COMPOSITION OF THE RECOVERED SODA AND LIQUORS.

In English manufacturing practice the sulphate process is practically unknown, but on the Continent and Scandinavia both straw and wood pulps are prepared by it on an extensive scale. The difficulty in realising the process successfully lies principally in the preparation of the smelt, which should contain a large proportion of sulphide of sodium (Na_2S). Instead of carbonate or caustic soda being used to make up the loss of alkali occurring in the manufacture, salt cake or crude sulphate of soda is mixed with the recovered ash, before the latter is calcined, and smelted together in specially constructed furnaces, whereby a smelt or recovered ash is obtained containing a large proportion of Na_2S. Schacht gives the following as the composition of the final product in the recovery process, viz.:—Na_2CO_3, 44·53 per cent.; Na_2SiO_3, 6·00 per cent.; Na_2O existing as $NaOH$, 4·65 per cent.; Na_2S, 30·25 per cent.; Na_2SO_4, 1·35 per cent. insoluble, 3·82 per cent. In this analysis, on 100 parts of total alkali (Na_2O) obtained by direct titration with acid (which includes Na_2O as carbonate, silicate, caustic and sulphide), 50·7 parts are in combination as sulphide Na_2S. It is obvious that this sulphate process is applicable equally to the preparation of paper pulp from esparto, bamboo, and other such like fibrous plants.

Kirchner (Vol. III) gives a long series of analyses representing the composition of the recovered ash and causticised liquor obtained in different works, of which the following are typical of Continental practice.

Soda Process.—Dr. Goldberg.—Straw pulp factory in which commercial soda ash is used to replace the loss of alkali.

Kind of Ash.	Na_2CO_3 %	$NaOH$ %	Na_2SO_4 %	SiO_2 %	Insoluble. %
1. Once regenerated, with much carbon	58·20	5·50	3·37	11·10	10·96
2. More than once regenerated	69·67	11·92	3·71	10·00	3·06
3. White burnt ash ..	73·49	6·83	3·20	10·58	0·94
4. Many times regenerated	75·32	1·79	5·21	10·08	3·52

More recently the same authority gives, for a recovered ash: Na_2CO_3, 55·67 per cent.; $NaOH$, 3·74 per cent.; Na_2S, 0·52 per cent.; SiO_2, 7·32 per cent.; Na_2SO_4, 4·74 per cent.; insoluble, 1·55 per cent. The 7·32 per cent. SiO_2 corresponds to 14·88 per cent. Na_2SiO_3.

Fresh causticised lye made from this ash, of sp. gr. 1·079 = $10\frac{1}{2}°$ Bé., contained by direct determination per litre, 59·000 grammes of total alkali (Na_2O), 48·800 grammes $NaOH$, 0·785 grammes SiO_2, 3·173 grammes SO_3, and 3·893 grammes SO_3, after oxidation of the sulphides present. From these figures he calculates that there are—

$NaOH$	48·640	grammes per litre.
Na_2CO_3	12·128	,, ,,
Na_2S	0·156	,, ,,
Na_2SiO_3	1·832	,, ,,
Na_2SO_4	5·632	,, ,,

Another authority, whose name is not revealed, gives the following composition of caustic soda lyes in a straw pulp factory in which the same conditions prevail as the foregoing:—

	Causticised Liquor.			Grammes per Litre.		
Total alkali Na_2CO_3 ..	96·98	98·16	94·92	92·75	86·07	84·80
Caustic alkali (reckoned as Na_2CO_3).. ..	87·45	80·88	85·15	85·33	81·62	75·26
Na_2CO_3	9·53	17·28	9·77	7·42	4·45	9·54

These caustic lyes contained besides from 4 to 5 grammes Na_2SO_4, from 0·05 to 0·20 grammes Na_2S, and about 0·5 grammes SiO_2, on an average, per litre. A large number of analyses of the recovered ash, by the same authority, gave 73·14 per cent. of total alkali, reckoned as Na_2CO_3 (of which 6·89 per cent. existed as $NaOH$), 0·08 per cent. as Na_2S, 4·29 per cent. Na_2SO_4, and 2·74 per cent. as SiO_2.

In connection with the foregoing the lime sludge from the causticisms, after washing on the vacuum filter, gave on analysis : — (*a*) 70·09 per cent. water ; 22·20 per cent. $CaCO_3$; 3·20 per cent. $Ca(OH)_2$; total alkali reckoned as Na_2CO_3, 0·57 per cent. (*b*) 68·09 per cent. water ; 22·19 per cent. $CaCO_3$; 3·06 per cent. $Ca(OH)_2$; total alkali (Na_2CO_3) 0·60 per cent ; 0·52 per cent. Fe_2O_3 and Al_2O_3 ; 3·00 per cent. SiO_2, and 0·08 per cent. P_2O_5. (*c*) *Dried Sludge.* 80·20 per cent. $CaCO_3$; 3·07 per cent. Na_2CO_3 ; 1·75 per cent. Al_2O_3 and Fe_2O_3 ; 8·60 per cent. insoluble and 7·04 per cent. water and loss on gentle ignition.

Sulphate Process.—According to W. Schacht and Dr. M. Müller, both of whom have a wide experience with this process, the composition of the smelt or recovered soda obtained in both the straw and wood pulp manufacture, when sulphate of soda is used to make up the loss of alkali, is represented by the following analyses :—

STRAW CELLULOSE (SULPHATE PROCESS).

No.	Alkali replaced by	Authority.	Soda Smelt contains per cent.						
			Na_2CO_3	Na OH	Na_2S	Na_2SiO_3	Na_2SO_4	Na_2SO_4	Insol.
1	25–30 parts sulphate	W. Schacht ..	33·45	12·99	23·25	15·91	5·67	4.45	7·84
2	on 100 parts smelt	,, ..	25·05	14·29	22·00	24·60	5·98	4·81	6·40
3	½–58 % soda ash .. and	,, ..	45·23	13·20	9·25	16·40	5·23	3·41	7·90
4	½ sulphate of soda ..	,, ..	40·53	14·00	9·25	21·23	4·10	3·08	7·40
5	25 parts sulphate ..	Anon.	61·00	16·00		10·25	—	6·50	—

WOOD CELLULOSE (SULPHATE PROCESS).

No.	Alkali replaced by	Authority.	Na_2CO_3	Na OH	Na_2S	Na_2SiO_3	Na_2SO_4	Na_2SO_4	Insol.
6	23·7 parts sulphate ..	Dr. M. Müller ..	56·60	0·40	22·60	—	2·80	12·70	—
7	11 parts sulphate ..	,, ..	71·40	0·50	11·60	—	1·40	9·80	—
8	8–10 parts sulphate ..	W. Schacht ..	80·26	1·04	7·15	—	—	5·36	1·89
9	on 100 parts smelt	,, ..	74 20	1·60	9·50	—	—	6·58	3·65
10	20–22 parts sulphate	,, ..	59 42	0·20	14·00	—	—	13·31	8·14
11	on	,, ..	62·07	2·20	17·75	—	—	8·04	5·10
12	100 parts smelt ..	,, ..	68·37	—	13·75	—	—	11·40	1·60

The causticised lyes prepared from the recovered soda-smelt by boiling with caustic lime (see page 119) have the following composition per litre :—

ANALYSES OF CAUSTICISED LYES (SULPHATE PROCESS).

No.	Smelt. Kilos.	Sulphate. Kilos.	Lime. Kilos.	Authority.	1 Litre at 15° C. contains Grammes. Na_2CO_3	$NaOH$	Na_2S	Na_2SO_3	Na_2SO_4	Remarks.
				A.—STRAW CELLULOSE.						
1	—	—	—	W. Schacht	19·61	61·40	26·72	—	—	—
2	—	—	—	,, ...	22·79	62·60	28·67	—	—	—
3	—	—	—	,, ...	16·43	64·00	32·37	—	—	—
				B.—WOOD CELLULOSE.						
4	70	30	32	Dahl	8·00	24·00	28·00	—	37·00	1884.
5	81	19	30	Dr. M. Müller ..	39·00	63·00	46·00	8·00	36·00	—
6	90	10	30	,, ..	24·00	45·00	13·00	2·00	14·00	—
7	—	—	—	W. Schacht	36·00	80·60	13·50	7·25	15·10	17·3 Bé
8	—	—	—	,, ...	45·05	77·80	11·25	8·19	12·18	18·5 ,,
9	—	—	—	,, ...	36·04	87·80	10·25	6·30	12·67	—

Taking an average of the first three analyses (1, 2, and 3) in the above table, which are fairly regular, the amount of Na_2S on 100 alkali Na_2O obtained by direct titration with standard acid, is 35·12. The author obtains constantly liquors containing over 50 per cent of the total alkalinity in the form of sulphide of sodium, Na_2S. The proportion of sulphide depends on the mode and apparatus used for reducing the Na_2SO_4 to Na_2S. Also, in the liquors 5 to 9 inclusive, there exists a large quantity of sulphite of sodium, Na_2SO_3, which is due to the partial oxidation of the Na_2S in the smelt, prior to causticising.

In the soda wood pulp works using soda ash it is frequently necessary to ascertain the amount of ash contained in large volumes of black lyes, and the following table will be found useful for this purpose :—

WASTE SODA LYES FROM WOOD PULP.

TABLE showing grammes per litre of recovered ash from waste soda lyes from wood boiling at 15° Cent. (*Practice of North German Wood Pulp Factory*)

Degrees Baumé.	Specific Gravity.	Grammes (about) of Recovered Ash from 1 Litre.	Na_2CO_3 in Ash.
6	1·045	40·5	
7	1·052	51·2	
8	1·060	61·9	
9	1·067	71·5	
10	1·075	81·0	
11	1·083	89·1	
12	1·091	97·2	
13	1·100	105·5	
14	1·108	113·5	
15	1·116	121·5	
16	1·125	130·0	Many samples of the recovered ash established an average of 80 % Na_2CO_3 = 44·8 % Na_2O.
17	1·134	138·5	
18	1·142	148·2	
19	1·152	159·1	
20	1·162	170·0	
21	1·171	180·0	
22	1·180	190·0	
23	1·190	201·5	
24	1·200	212·0	
25	1·210	222·5	
26	1·221	233·2	
27	1·231	244·0	
28	1·241	254·0	
29	1·252	264·2	
30	1·263	275·4	(*Kirchner, Vol. III.*)

LOSS OF ALKALI.

The losses of alkali ($Na_2 \cdot O$) occurring in the manufacture of straw, esparto, and wood cellulose are chiefly the following :—

(1) Chemical Losses.—Combination of the soda with silica and alumina contained in the plant and bricks of the furnaces to form silicate and aluminate of soda. These are subsequently decomposed in the causticiser. J. W. Kynaston has suggested the addition of bicarbonate of soda to the recovered ash liquor, whereby the silicate is decomposed thus :—$2\ Na\ H\ CO_3 + Na_2\ SiO_3 = 2\ Na_2\ CO_3 + SiO_2 + H_2\ O$.

(2) Mechanical Losses.—Leakages of every character; imperfect washing of the insoluble matter left after dissolving the recovered ash; imperfect washing of the pulp and the lime sludge on vacuum filters. Volatilisation of the soda in the smelting furnaces.

These losses amount in the aggregate to from 15 to 30 per cent. of the total soda put into the digester. In the wood pulp manufacture it should never be more than 15 to 20 per cent. with well-designed plant.

PREPARATION OF CAUSTIC SODA LYES.

These should be prepared from the purest form of commercial soda, such as ammonia soda ash containing 58 per cent. $Na_2\ O$, excepting in the case of the so-called "sulphate" process, when the presence of $Na_2\ SO_4$, NaCl, &c., cannot be avoided. The carbonate of soda is converted into caustic by boiling with caustic lime, the lime being either added direct in lumps to the vessel called the "causticiser," in which the ash is dissolved in water, or previously made into a thick cream with water in a separate vessel, strained through a sieve, and then pumped into the "causticiser."

The causticiser consists of a wrought-iron vessel fitted with an upright mechanical agitator to keep the fluid in motion, a drop syphon to run off the clear liquor, and a plug valve in the bottom to run off the residual lime. When the lime is added direct, it is placed in a perforated wrought-iron box called a cage, slung in the upper part of the causticiser, but when added in the form of a milk, the cage may be omitted.

Three batches of liquor, each varying in density, can be made in the causticiser before running off the residual lime sludge. The first batch should not exceed 28° Twaddell, the second, to which only a small quantity of fresh lime is added, should be 18° Twaddell; whilst the third, to which no fresh addition of lime, as a general rule, is required, need not exceed 10° Twaddell, all taken at 62° Fah. The foregoing densities refer to the carborated alkali liquor derived from either fresh or recovered ash. Each individual batch in the causticiser is boiled with an open steam pipe, both during and after the addition of the lime, and tested for the presence of CO_2 by filtering a small quantity of the liquor into a test tube and adding thereto a small quantity of a 10 per cent. aqueous solution of bichromate of potash, and then acidifying with HCL. If the whole of the soda has been converted into caustic, no appearance of escaping CO_2 will be visible. It is necessary to use $K_2 Cr_2 O_7$ in this test, as it oxidises any sulphides, &c., present which the acid would decompose and render visible by escaping H_2S, thus vitiating the test for CO_2. Obviously this is more especially necessary when causticising liquors in the "sulphate" process. After boiling in the causticiser and the conversion of the carbonate to caustic has been completed, the agitator is stopped, the lime allowed to settle, and the clear liquor syphoned off into a reservoir. Fresh carbonated liquor and water are then added to make up a second charge of 18° Twaddell, and thoroughly boiled. If, after testing with acid as above, the carbonate is not all converted into caustic, more lime is added in slight excess, the liquor again boiled, allowed to settle, and when clear syphoned off as before. A third batch of about 10° Twaddell is then made, which will usually be found to require no addition of lime. When this is syphoned off, the lime sludge remaining in the causticiser is washed by decantation several times with hot water, the washings being either added to the freshly causticised lye or run into a storage tank for use instead of water in the causticising operation. The lime sludge may be run off into a pit whose bottom is covered with ashes, or into a filter, the bed of which is about 12 inches thick and composed of varying sizes of limestone and coal ashes or clinker, the finer material being uppermost. The filter bed rests on a perforated wrought-iron false bottom, and frequently suction by means of a pump is applied below the false bottom to accelerate the filtration. Theoretically 100 parts of $Na_2 CO_3$ require 52·83 parts CaO for complete causticisation. In practice under the best conditions from 60 to 65 parts are required.

Recovered ash and liquors derived from it are contaminated with more or less silicate of soda, depending upon the amount of silica contained in the raw fibrous plant treated (see page 79). When the alkali $Na_2 CO_3$ is prepared by the Le Blanc process, in which $Na_2 SO_4$ is roasted at a red heat with coal and limestone according to the reaction $Na_2 SO_4 + Ca CO_3 + 4 C = Na_2 CO_3 + Ca S + 4 CO$, and subsequent lixiviation of the ball soda in Shanks' vats, the crude carbonate of soda liquor contains $Na_2 S$ and undecomposed Na_2SO_4, together with small quantities of Na Cl. Also, in the so-called "sulphate" process (applied to straw and wood), the loss of alkali is made good by addition of salt cake or crude Na_2SO_4 to the thickened mass from the rotary roaster before throwing it into the smelter, and during the subsequent ignition the sulphate is reduced to sulphide. The liquor prepared from this "flux" contains large quantities of Na_2S and undecomposed Na_2SO_4 (see page 117). In both of these cases the liquors are causticised in the same way as described above.

Lunge has investigated the transformation of carbonate of soda into caustic in aqueous solution by boiling with lime under ordinary atmospheric pressure, with the following results :—

Before Causticising.		After Causticising. Carbonate of Soda converted into Caustic.	
% Na_2CO_3.	Specific Gravity.	Expt. No. 1.	Expt. No. 2.
2	1·022 at 15° Cent.	99·4%	99·3%
5	1·052 at 15° ,,	99·0%	99·2%
10	1·107 at 15° ,,	97·2%	97·4%
12	1·127 at 15° ,,	96·8%	96·2%
14	1·150 at 15° ,,	94·5%	95·4%
16	1·169 at 30° ,,	93·7%	94·0%
20	1·215 at 30° ,,	90·7%	91·0%

Similar experiments, but conducted at a temperature of 148° to 153° Cent., gave :—

Before Causticising.		After Causticising. Carbonate of Soda converted into Caustic.	
% Na_2CO_3.	Specific Gravity.	Expt. No. 1.	Expt. No. 2.
10	1·107 at 15° Cent.	97·06%	97·5%
12	1·127 at 15° ,,	96·35%	96·8%
14	1·150 at 15° ,,	95·60%	96·6%
16	1·169 at 30° ,,	95·40%	94·8%
20	1·215 at 30° ,,	91·66%	91·61%

Obviously from the above (1) the percentage of carbonate of soda ($Na_2 CO_3$) transformed into caustic ($Na OH$) decreases as the Specific gravity of the solution increases; and (2) increase of temperature during causticising (*i.e.*, causticising the $Na_2 CO_3$ under pressure above that of the atmosphere) yields no advantage.

For the preparation of five tons of caustic soda (77 per cent.) from ammonia ash per day, four causticisers are necessary, each of a capacity of 500 cubic feet. (See page 184 for Specific gravity of solutions of carbonate of soda.)

The following table shows the influence of temperature from 0 to 65° Cent. on the density (Bé) of caustic soda lyes.

TEMPERATURE IN DEGREES CENTIGRADE.

	0	5	10	15	20	25	30	35	40	45	50	55	60	65
Degrees Baumé.	2·0	1·9	1·6	1·4	1·1	1·0	0·9	0·6	0·3	—	—	—	—	—
	3·3	3·2	2·9	2·8	2·5	2·4	2·3	2·0	1·7	1·4	1·1	0·9	0·4	—
	4·6	4·5	4·3	4·1	3·9	3·7	3·5	3·3	3·0	2·8	2·5	2·2	1·9	1·4
	5·9	5·8	5·5	5·4	5·1	5·0	4·9	4·6	4·4	4·1	3·9	3·6	3·1	2·8
	7·3	7·1	6·9	6·7	6·4	6·3	6 2	5·9	5·6	5·4	5·1	4·9	4·5	4·1
	8·6	8·4	8·2	8·0	7·8	7·6	7·5	7·3	7·0	6·7	6·4	6·2	5·8	5·4
	9·9	9·8	9·5	9·4	9·1	9·0	8·9	8·6	8·3	.8·0	7·8	7·5	7·1	6·7
	11·1	11·0	10·8	10·6	10·4	10·3	10·1	9·9	9·6	9·4	9·1	8·9	8·4	8·0
	12·3	12·2	12·0	11·9	11·6	11·5	11·4	11·1	10·9	10·6	10·4	10·0	9·8	9·5
	13·6	13·4	13·3	13·0	12·8	12·6	12·4	12·2	12·1	11·9	11·5	11·1	10·9	10·5
	14·9	14·6	14·5	14·3	14·0	13·8	13·5	13·2	13·0	12·9	12·7	12·3	12·0	11·8
	16·1	15·9	15·7	15·4	15·2	15·0	14·8	14·5	14·3	14·0	13·8	13·4	13·0	12·7
	17·3	17·0	16·8	16·5	16 3	16·1	15·9	15·7	15·5	15·2	15·0	14·6	14·3	13·9
	18·4	18 2	18·0	17·8	17·5	17·3	17·0	16·8	16·5	16·2	16·0	15·7	15·4	15·1
	19·4	19·2	19·0	18·8	18·6	18·4	18·2	18·0	17·8	17·4	17·1	16·8	16·5	16·2
	20·4	20·2	20 0	19·8	19·5	19·3	19·1	18·9	18·6	18·4	18·2	18·0	17·6	17·3
	21·6	21·3	21·2	20·9	20·5	20·3	20·1	19·9	19·6	19·4	19·2	19·0	18·7	18·4
	22·7	22·5	22·2	22·0	21·7	21·4	21·2	20·9	20·7	20 4	20·2	20·0	19·7	19·4
	23·7	23·5	23·2	23·0	22·7	22·5	22·3	22·0	21·8	21·6	21·3	21·1	20·8	20·4
	24·7	24·5	24·2	24·0	23·7	23·5	23·3	23·0	22·8	22·6	22·4	22·2	22·0	21·7
	25·7	25·5	25·2	25·0	24·7	24·4	24·3	24·0	23·8	23·5	23·2	23·1	22·9	22·6

BAUMÉ AND SPECIFIC GRAVITY OF MILK OF LIME AT 15° CENT.
(*Blattner.*)

Baumé.	One Litre weighs Grammes.	One Litre contains CaO Grammes.
1	1,007	7·5
2	1,014	16·5
3	1,022	26·0
4	1,029	36·0
5	1,037	46·0
6	1,045	56·0
7	1,052	65·0
8	1,060	75·0

Baumé and Specific Gravity of Milk of Lime—*Continued.*

Baumé	One Litre weighs Grammes.	One Litre contains CaO Grammes.
9	1,067	84·0
10	1,075	94·0
11	1,083	104·0
12	1,091	115·0
13	1,100	126·0
14	1,108	137·0
15	1,116	148·0
16	1,125	159·0
17	1,134	170·0
18	1,142	181·0
19	1,152	193·0
20	1,162	206·0
21	1,171	218·0
22	1,180	229·0
23	1,190	242·0
24	1,200	255·0
25	1,210	268·0
26	1,220	281·0

MECHANICAL WOOD PULP MANUFACTURE.

German Practice.

(I. M. Voith, *Papier Calender.*)

The pulp wood is peeled either by hand or by machine, and cut into lengths suitable for the machines or grinders ; knots removed by boring if a particularly clean pulp is desired.

The wood, if for white pulp, is conveyed direct to the grinders; if for "brown" pulp, it is taken to the boilers to be steamed. There are two systems of grinding distinguished by the terms "cross" grinding (*querschliff*), and "long" grinding (*langschliff*), according to the motion of the surface of the stone towards the wood fibres. Fine "cross" ground, short fibred pulp is suitable for nearly all purposes, whilst "long" ground pulp is more suitable for document, envelope and printing papers, and especially for cardboards. Cross grinders are built with horizontal and vertical shafts, the former being by far the more numerous. Vertical shaft grinders are more suitable for powers of great height, so that the grinder alone can be fixed upon the turbine shaft. The stones vary in size from 1,200 to 1,500 mm. in diameter (48 to 60 inches), from 440 to 580 mm. in breadth (18 to 24 inches), and revolve at a speed of from 150 to 180 revolutions per minute, according to size. Long grinders (patent Schmidt) are built with horizontal shaft having two presses, which are actuated by a chain and weights raised and lowered by a winch arrangement. The stones are 1,000 mm. ($39\frac{1}{2}$ inches) in diameter. Speed, 220 to 240 revolutions per minute, and maximum power required = 30 H.P. per stone.

The water required, including that for sorting (screening), &c., for—

"Cross" grinding = 500 litres (132 gallons) per minute per 100 H.P.

"Long" grinding = 600 litres (159 gallons) per minute per 100 H.P.

The stuff direct from the stones flows first through a coarse sieve which retains the coarse chips, then upon the sorting machines or screens. Voith's patent sorting machine has three sieves, the uppermost one acts as a rough sorter, and separates those particles that are too coarse for the raffineur. Special sorters are considered superfluous. The stuff retained by the middle and bottom sorters or sieves is collected in a stuff chest with mechanical agitator, common to all the sorting machines, and is then pumped up and fed regularly to the raffineur. The stones of this machine are 1,200 mm. (48 inches) in diameter, and revolve 150 revolutions per minute. The pulp flowing from the raffineur is mixed with the freshly-ground wood and screened. The separation of the pulp from the water is now exclusively carried out with the pulp or "wet" machine. With one press roll, pulp containing 38 per cent. of air-dry weight can be obtained, and with a second press roll 50 per cent. air-dry weight. The pulp may be scraped off the roll if desired.

According to the size and arrangement of the pulp installation one worker will prepare from 100 to 170 kilos (220 to 374 lbs.) of air-dry pulp per 24 hours, including peeling the wood, attending the machines and packing. For the preparation of 100 kilos (220 lbs.) packed air-dry pulp per 24 hours, there are required about—

7 to 8 H.P. for "cross" grinding, and
6 ,, 7 H.P. ,, "long" ,,

100 kilos (220 lbs.) of air-dry pulp require 0·28 to 0·38 solid metre of wood (9·88 to 12·36 cubic feet).

The necessary requirements for successful work are:—First: A driving power, usually water power, not under 60 to 80 H.P., effective. Second: Convenient supply of wood, preferably spruce (white or black), also aspen. Fir (Scotch), poplar, and beech are less often used. Young freshly-cut stem wood, of 120 to 150 mm. diameter ($4\frac{3}{4}$ inches to 6 inches). Third: Cheap freights, cheap wood, and facilities for delivering same by water or rail to factory, play an important part in the commercial success of the manufacture. Fourth: Pure water. Spring water is not absolutely necessary, but by its use exceptionally clean pulp is obtained. Fifth: Cheap labour.

Another German authority ("E.N.," *Papier Zeitung*, August, 1892) gives the following:—Three grinders. Stones, 1·25 metres diameter by 0·50 metres broad ($49\frac{1}{4}$ inches by 20 inches), can be used down to 1 metre in diameter. All three stones are fixed on main shaft, which revolves 180 per minute. The pressure in accumulator for presses and spray pipes amounts to four atmospheres (60 lbs. per square inch). One turbine of 300 E.H.P. drives the whole installation, of which 280 E.H.P. are consumed by the grinders and 20 E.H.P. by the other machines, pumps, &c. The daily production amounts to 4 tons of air-dry pulp, equivalent to 24 tons per week of six days. (100 kilos of 220 lbs. air-dry pulp made per 24 hours required 7 E.H.P.) Sixteen cubic metres (raummeters) of spruce pulp wood were used per day, or 4 cubic metres of peeled wood per ton of pulp, equivalent to 142 cubic feet, or $1\frac{1}{10}$th cord of 128 cubic feet.

American Practice

differs but slightly from the foregoing, the manufacture being of a less refined nature and substantially confined to "cross" grinding. In a mill having 20 grinders, each with stones of 50 inches in diameter by 18 inches wide, three hydraulic press boxes and consuming 250 E.H.P., the output is 75 to 80 tons, of 2,000 lbs. each, per 24 hours. What is known as "hot" grinding is, as a general rule, followed, that is, the pulp flowing from the stones has a temperature of about 125 to 130° Fah., the heat being produced by the friction caused by the pressure of the wood against the revolving stone. No raffineur is used to work up the screenings. Twenty suction screens of the Packer type are used for screening. The fineness of the pulp depends on the fineness of the slits in the screen plates. These are graded so that for fine papers a slit of $\frac{11}{1000}$ths of an inch is employed; for common "news" a slit of $\frac{13}{1000}$ths of an inch. The stuff from the grinders, properly diluted with water, is first allowed to flow over the finer plates, then over the others, and finally over plates having slits $\frac{15}{1000}$ths of an inch wide. The fibre passing the last set of screens is returned to the original mass coming from the grinders. Everything that has not passed through the screens is allowed to flow into the river, and is lost. The power consumed per ton of pulp produced is substantially the same in both German and American works. The foregoing gives 6·88 E.H.P. per 100 kilos (220 lbs.) of pulp made per 24 hours, For "cross" grinding, the following figures may be given as representing average practice per ton (2,240 lbs.) of air-dry pulp per 24 hours.:—

Power required	= 72 E.H.P.
Spruce pulp wood	= $1\frac{1}{10}$ to $1\frac{1}{5}$ cords.
Water	= 100 to 200 thousand gallons.

BROWN WOOD PULP.

Brown paper made almost exclusively from wood constitutes an important branch of the paper trade in Germany and Scandinavia. Fry, it appears, was the first to attempt the manufacture of brown paper pulp from wood by simply subjecting it to the action of steam at a high temperature. For this purpose the wood chips were placed in large boilers, and heated with high pressure steam for several hours; the temperature required being about 332° Fah., corresponding to a pressure of 90 lbs. per square inch above the atmosphere. The action of the steam upon the incrusting substances surrounding the fibre of the wood was not found to be very vigorous. Very little of these substances are, in fact, rendered soluble, but some of them are transformed into useful organic acids (acetic, &c.), which, however, react on the shell of the boiler, causing inordinate wear and tear. In order to obviate this corrosive action of the acids, attempts have been made with greater or less success to steam the wood in the presence of an alkaline body such as lime, which combines with the organic acids forming compounds that exert no corrosive action on the boiler plate. When this system is carried out it is obvious that the acids or their compounds are lost.

For many years past boilers constructed of wrought iron or steel plate, and covered inside with a coating of thin sheet copper, have been used for the purpose of preparing brown wood pulp. The inside coating of copper forms an acid-resisting lining, upon which the organic acids formed during the steaming process have practically no solvent action. These boilers are of considerable size, being, as a general rule, about 15 feet long by 6 feet in diameter, their total cubic capacity being about 425 cubic feet. As there is no necessity for them to revolve, they are of the horizontal stationary type.

As the wood is ground after being steamed in these boilers, it must, accordingly, be put into them in pieces to suit the grinding machines. This is done by two workmen, one of whom packs the pieces of wood in layers within the boiler, while the other passes them to him through one of the two manholes placed at each end. Steam of about six atmospheres

(90 lbs.) is then admitted through a suitable valve, and the pressure, which is recorded by a steam gauge, maintained from 8 to 18 hours as the necessities of the case may be, or until the wood has been rendered soft and of a dark brown colour. The water condensed inside the boiler is allowed to flow away through a tap fixed at the bottom. The acid and oil products distilled from the wood are contained in this condensed water, and are usually collected together in a reservoir. The oil of turpentine, as it is commonly called, floats on the surface, and is separated from the water beneath by means of a ladle. It is very inflammable, and, because of its value, is sold.

When the wood has been sufficiently steamed, the pressure is blown off, and the boiler filled and emptied three times with cold water, the object in view being twofold, viz.:—First, to cool the wood so that the workmen can easily remove it; and, second, to wash it free from impurities, thus making it more suitable for the grinding machines. The boiler is then emptied by manual labour, the pieces being passed out through the manholes.

CHAPTER IV.

COLOURED PAPERS.

CHEMICAL PROPERTIES OF PAPER-MAKING FIBRES.

COTTON.—Cotton is almost pure cellulose ($C_6H_{10}O_5$). In the raw state it contains about 5 per cent. of impurities, which are soluble to a certain extent in caustic or carbonate of soda. These impurities consist of pectic acid, brown colouring matter, cotton wax, fatty acids (margaric acids), and albuminous matter. *Cellulose* is closely allied in composition to starch glucose, starch, and dextrine (Sp. Gr. 1·50). It is insoluble in ordinary solvents—water, alcohol, &c.—but is soluble in ammoniacal solution of cupric hydrate. Cold dilute mineral acids have little or no action on it; in the concentrated state they act injuriously upon the fibre, especially if heated. Concentrated sulphuric acid causes it to swell up and form a gelatinous mass—the vegetable parchment of commerce—which is coloured blue with a solution of iodine. [Vegetable parchment has a greater affinity for the basic coal tar dyes than pure cotton.] If completely disorganised by acids it is converted into what is known as hydro-cellulose. When steeped in a mixture of cold nitric and sulphuric acids it increases in weight, and is converted into gun-cotton of powerful explosive properties. When this is dissolved in a mixture of alcohol and ether, collodion is formed. Weak solutions of the alkalies, potash, and soda have little or no action upon cotton, but in the concentrated state they tender and otherwise destroy the fibre. Lime in water has little or no action upon the fibre, provided the cotton is immersed in the liquid. Any portion exposed to the air becomes much tendered by the oxidation of the fibre. Chlorine gas quickly tenders the fibre if exposed to sunlight. Hypochlorites (bleaching powder) tender cotton more or less rapidly, according to the strength and temperature of the solution, and the duration of their action. When these are used in the cold diluted state the action is inappreciable, and confined to the bleaching of the colouring matter. Cotton dipped in a solution of bleaching powder of 5° Twaddell, exposed to the air for an hour and then washed, exhibits an increased attraction for basic coal tar dyes, and possesses the property of decomposing normal salts of iron, alumina, &c. This remarkable change is due to the action of the hypochlorous acid liberated by the carbonic acid of the air. The cotton has become thereby changed to oxy-cellulose (Witz). With few exceptions colouring matters are not attracted by the cotton fibre, and hence "mordanting" must be resorted to in dyeing it.

Linen.—The raw fibre is cleansed or purified by passing it through the various processes of retting, breaking, scutching, hackling, &c. It consists essentially of cellulose. In the raw state it contains from 15 to 30 per cent. of foreign substances, chiefly pectic acid. The action of various chemicals upon it is much the same as upon cotton, but generally speaking linen is more susceptible to disintegration under the influence of caustic alkalies, lime, and strong oxidising agents—*e.g.*, chlorine, hypochlorites, &c. Great care must therefore be exercised in bleaching to preserve the strength of the fibre. Linen is more easily dyed than cotton.

Jute.—Owing to its great strength is much admired as a paper-making fibre. The raw fibre is separated from the plant by processes similar to those employed in obtaining the flax fibre—viz., retting, beating, washing, &c. The jute fibre is not identical with, although closely allied to, cellulose, and hence it has been called "bastose" (Cross & Bevan). Acted upon by chlorine, and subsequently by a solution of sulphite of soda, a brilliant magenta colour is produced, a reaction similar to that obtained from tannin-mordanted cotton. Tannin-like bodies are distributed throughout the mass of the jute fibre, and hence it has a powerful attraction for basic coal tar dyes, and can be dyed direct by them. Alkalies dissolve the tannin bodies, leaving cellulose. When exposed in a damp state it is decomposed into two groups of bodies—namely, acids of the pectic class and tannin-like substances. Acids, especially mineral acids, disintegrate jute at low temperatures. Chlorine and hypochlorites produce chlorinated compounds which are more or less partially removed by solutions of the alkalies. The Leykam-Josepthal process of bleaching jute is founded upon these reactions. Weak solutions of hypochlorites of lime bleach the fibre to a pale cream colour, at the same time oxidising it and forming compounds which decompose calcium salts. For this reason weak hypochlorite of soda yields better results than hypochlorite of lime. The loss of weight in bleaching varies from 2 to 8 per cent., according to the method used.

The papermaker has to deal almost entirely with fibres of vegetable origin, very seldom wool being used. In many cases these vegetable fibres are not in a physical condition to absorb dyes direct from aqueous solution. A chemical agent, called a "mordant," is therefore employed to fix the dye upon the fibre, or in some cases to develop the colour itself. Mordants are usually metallic salts, the oxides of which combine with the colouring principle of the dye to form insoluble coloured lakes. These lakes adhere to the surface of the fibres. The oxides or their basic salts may be fixed upon the surface of the fibre previous to dyeing it, or the coloured lake may be formed by itself, and then added to the pulp. The choice of a suitable mordant should be carefully made.

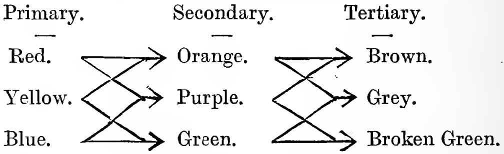
The colouring of paper pulp can therefore be carried out in two ways:—

1st—Dyeing the pulp by means of soluble dyes, or dye-stuff, with or without the use of mordants.

2nd—Colouring the pulp with pigments and other mineral colours.

DYEING PAPER PULP.

Combination of Colours.



The arrows point to the colour produced by mixing red and yellow, &c.

Dyes may be divided into two great classes—namely (1), those which dye the pulp by themselves, called "substantive" dyes; and (2) those that require the application of a chemical agent or mordant to produce the colour itself, called "adjective" dyes. The basic aniline dyes belong to the former class, whilst the vegetable dyes, logwood, fustic, quercitron, &c., and others of the aniline (acid) series of dyes belong to the latter.

Substantive or Basic Dyes.—Of the aniline dyes of this series that will dye cotton fibre direct, *i.e.*, without the intervention of a mordant, the following are the most important:—

Water Blue.	Safranine.
Höchst Scarlet.	Brilliant Green.
Eosine.	Malachite Green.
Rose Bengal.	Erythrosine.
Magenta.	Phloxine.
Acid Brown.	Methyl Violet.

Adjective or Acid Dyes.—These are best used with a mordant. Mordants consist chiefly of metallic salts, and are added to the pulp in the engine before the addition of the dye. These salts are deposited with or without the aid of a precipitant or heat in a more or less modified state upon the surfaces of the fibres, rendering the latter capable of absorbing the colouring matter. Heat usually facilitates the deposition of the oxides, especially when the metallic mordants are previously rendered basic. The salts most commonly employed are those of aluminum, iron, copper, chromium, tin, and lead. The former of these, especially iron, require no precipitant to fix them upon the fibre, and most of them form different coloured lakes with the same dye. Thus in the case of the vegetable dye logwood there is formed—

Grey and black precipitates with bichromate of potash and sulphate of iron.

Violet precipitates with tin salts.

Blue precipitates with sulphate of copper.

Bluish-violet precipitates with alum or sulphate of alumina.

Blue-black precipitates with alum or sulphate of alumina and bichromate of potash.

The following are the most important and commonly used mordants:—

Salts of alumina, potash alum, $K_2\ Al_2\ 4\ SO_4 + 24\ H_2\ O$; ammonia alum, $(N\ H_4)_2\ Al_2\ 4\ SO_4 + 24\ H_2\ O$; sulphate of alumina, $Al_2\ 3\ (SO_4) + 50\%$ Aq. These salts give an acid reaction with blue litmus paper, but can be rendered basic, or their acid character partly destroyed, by adding a weak solution of soda crystals to their hot solution till a slight permanent precipitate of hydrate of alumina is formed. Both potash and ammonia alum are met with in the market of great purity—*i.e.*, freedom from iron; sulphate of alumina occurs, on the other hand, in many degrees of purity. The chief impurity in all three is iron, and the presence of this may be ascertained by adding a drop of an aqueous solution of ferro-cyanide of potassium (yellow prussiate of potash) to one of the alum. If iron be present, the well-known blue colouration of Prussian blue will be formed. (For composition of the alums, &c., see page 183.) The alums are used most extensively for fixing vegetable dyes, more especially logwood, redwood, yellow-wood, quercitron, catechu. But these dyes are now seldom used, owing to the cheapness, great tintorial power, and great brilliancy of the aniline dyes. Resinate of alumina—the body formed by precipitating resin soap (or size) with sulphate of alumina or alum—acts as an admirable mordant for both acid and basic coal tar dyes. The amount of resin soap should bear a definite ratio to the amount of dye-stuff—*e.g.*, water blue and ponceau require 3—4 times, and crystal violet $2\frac{1}{2}$ times, their weight of resin in the form of soap for complete precipitation. The same holds good with regard to many of the vegetable dyes—*e.g.*, quercitron—provided the stuff be kept faintly acid to litmus, by using an excess of sulphate of alumina. The following coal tar dyes are completely precipitated by alumina resin soap, and the back-water from the machine should be practically colourless if the proper proportion of mordant and dye is used :—

Cotton Scarlet.
Roccelline.
Crocein Orange.
Azoflavin
Diphenylamine Orange.
Indazine.
Nigrosin.
Brilliant Crocein M.
Mandarin.
Orange II.
Metanil Yellow.
Victoria Blue.
Induline.
Phosphine.
Bismarck Brown.

Acetate of alumina is recommended as a mordant for paper containing much mechanical wood. This mordant is prepared by the decomposition of alum, with acetate (sugar) of lead in aqueous solution, the proportions being 25 parts alum to 10 parts of the lead salt. The clear solution is alone used, and if required it may be rendered basic by an addition of 5 per cent. of soda crystals dissolved in water. This is a good mordant for methyl violet, crocein scarlet, and crocein orange.

TIN SALTS.—Of these the so-called "tin crystals" (Stannous chloride) is the most universally used, both as a mordant and as a means of brightening the colours. Oxide of tin forms rich coloured lakes with logwood, cochineal, &c.; it is, however, usually employed in conjunction with alum. Tin crystals with acetate of alumina is a good mordant for producing quercitron yellow.

IRON MORDANTS.—Of these ferrous sulphate or green vitriol, and the so-called "nitrate" of iron, are the most common; the former produces grey-blacks with catechu and logwood extract. Both are used for producing chamoise yellows, but the "nitrate" of iron is the most suitable for this purpose. Nitrate or acetate of iron yields better dark greys and blacks than the sulphate.

COPPER MORDANTS.—Sulphate of copper yields with logwood extract blue coloured lakes which can only be applied for the production of unsized papers as the colour is changed to violet by alum. It may be used in combination with sulphate of iron and bichromate of potash for the formation of brown, grey, and black colours.

TANNIN MORDANTS.—Tannic acid (catechu) is used for greys and blacks, and yields these better than sulphate of iron. For fixing the mordant a high temperature must be employed. Tannic acid in combination with tartar emetic imparts a property to the fibre which causes the latter to absorb many of the coal tar dyes, the colours produced being brilliant in shade and fast towards light. Tannin and sodium acetate are applied to papers which have been only slightly sized, and are dyed with the basic coal tar dyes. For full deep shades tannin is suitable for fuchsine, methyl violet, brilliant green, solid green, chrysodine, Manchester brown, Bismarck brown, and naphthol yellow.

LEAD SALTS.—Acetate of lead is used for eosine, erythrosine, phosphine, phloxine, rose bengal, fluorescine, and orange; also for water blue, ponceau, alkali blue, tropäoline, crocein, induline, nigrosine, metanil yellow.

Nearly all the aniline dyes which are soluble in water can be used. In order to obtain good results the properties of the dye in respect to its affinity for the fibre should be observed, and the proper precipitant or mordant used. Heating the pulp facilitates the deposition of the dye, and is recommended for deep shades. Brilliant shades and pure colours, especially light tints, can only be obtained when the stuff in the beater has been primarily bleached to a pure white. The following dyes can be recommended:—

FUCHSINE OR MAGENTA (3 per cent. solution) is dissolved in soft or condensed water—*i.e.*, water free from lime salts—as the latter precipitates the dye. A little acetic or hydrochloric acid counteracts the act of the lime. This dye is extensively used for shading white papers, news, printings, &c., and should be used very dilute. The solution should also be made daily and used cold. Paper-making fibres, especially mechanical wood, have a strong attraction for this colouring matter. Methyl violet, benzal, malachite, and brilliant greens (3 per cent. solution) should be treated like fuchsine (magenta).

METANIL YELLOW, BENZOFLAVINE, ORANGE AND AURAMINE, KASTAINIEN BROWN, &c. (10 per cent. solution) are added to the paper pulp as hot solutions, as the dye separates out on cooling.

WATER BLUE AND COTTON BLUE (8-10 per cent. solution) are dissolved in hot water, cooled, and then a little sulphuric acid (oil of vitriol) or acid sulphate of soda added, so as to develop the colour. Dye either hot or cold, but in either case the stuff must show a decided acid reaction with litmus paper by the use of an excess of alum or sulphate of alumina.

EOSINE (10-12 per cent. solution) should be used in a nearly neutral pulp. Excess of sulphate of alumina turns the shade yellowish brown. Acetate, or sugar of lead, yields a pink shade, whilst tin crystals produce a fiery red.

ROSE BENGAL AND ERYTHROSINE (10 per cent. solution) behave like eosine. The dyeing can be carried out either before or after sizing, and either in the hot or cold state.

SAFRANINE, TURKEY RED, CROCEIN, INDULIN, SOLID BLUE, ÆTHYLENE BLUE, AND METHYLENE BLUE (8 per cent. solution) require the paper stuff to be slightly acid in character. These dyes are best added to the engine before sizing. Safranine must be used in the cold, the others warm.

PHOSPHINE AND GRENADINE (5 per cent. solution) are treated like fuchsine or magenta.

ALKALI BLUE (8 per cent. solution) is often used because of its greater fastness towards light. Dissolve the dye in hot water which has been rendered alkaline with soda, and then cool. The cold solution is very stable, but must be used dilute. Dye in the cold, and after sizing. The paper stuff must have an acid reaction.

VEGETABLE DYE-STUFFS.

YELLOW.—Quercitron for light shades is the colouring matter obtained from the bark of the North American black oak (*Quercus nigra*). The dye is extracted by digesting the bark, wrapped in a bag, in successive quantities of fresh water at 212° Fah. The liquors are then mixed and purified from tannin bodies by addition of a weak solution of glue, otherwise the shade is apt to be of a greenish tone due to the formation of black-coloured lakes by the tannin, with traces of iron salts contained in the alum, &c. Quercitron is best suited for deepening blacks, and for this purpose it is not necessary to remove the tannin. In combination with weld extract (1 pt. weld to 10 pts. quercitron) purer yellow tones are obtained. The shade in this case is brightened with tin crystals. Quercitron does not yield bright tones of yellow. *Weld* (*reseda luteola*) produces the most stable and brightest yellows of the vegetable dyes. The presence of iron salts imparts a greenish shade to the colour. *Curcuma* is not extensively used. *Yellow or Brazil Wood* yields yellows of a greenish shade, which also limits its application. Mordant with acetate and sulphate of alumina. *Annatto.*—This extract is prepared by digesting 10 lbs. of the dye-stuff in 30 gallons of boiling water, in which 10 lbs. of soda crystals have been previously dissolved. Filter through a linen bag. Excess of alkali intensifies the yellow colour, whilst a diminished quantity turns it red. Applicable in combination with weld and quercitron for golden yellow and orange tones. The pulp should be dyed first and alum added afterwards. Brighten with magenta, crocein scarlet, or orange.

RED.—*Red Wood, Pernambuco Wood, &c.* These colouring matters are not extensively used, owing to their fugitive character. They form red lakes with alumina, which are brightened with tin crystals. *Cochineal.*—This is really an animal dye, being the body of a female insect found in Central America. The large grey variety is the best. The dye is extracted by boiling the cochineal repeatedly in water. Mordant with alum or sulphate of alumina. $Al_2 O_3$ produces beautiful carmine lakes with this colouring matter. Alkalies yield bluish shades, and therefore slight excess of alum should be used. Tin crystals yield pure tones, especially in combination with oxalic acid, the latter tending to produce yellowish shades. Another excellent preparation of cochineal is obtained by placing 20 parts of the ground dye in a large glass vessel, together with 60 parts of ammonia, and setting the whole aside for a few days in a warm room till the fluid thickens. Filter before use. This is used with greatest advantage with alum and tartaric acid. Brighten with tin crystals.

Blue.—*Logwood* is seldom or never used alone, but in conjunction with other colours, for the production of deep, dark blues. It is obtained in the form of extract. Mordant with sulphate of alumina.

Brown.—*Catechu*, in combination with sulphate of copper and bichromate of potash, is the most important vegetable dye for the production of browns—*e.g.*, pure brown: 4 lbs. catechu, 6 ozs. sulphate of copper, $1\frac{1}{2}$ ozs. sal-ammoniac, the "stuff" being then heated to about 130° Fah., and finally 12 ozs. bichromate of potash, all on 100 lbs. paper. It is advantageous to heat the "stuff" before the addition of the bichromate. All these salts should be previously dissolved in water before being added to the beater.

Blacks are usually produced from logwood and catechu by the action of certain mordants and oxidising agents. Thus, on 100 pts. paper, 4 pts. catechu, $\frac{1}{4}$ pt. sulphate of copper, heat to 130—140° Fah., $1\frac{1}{2}$ pts. bichromate of potash, 8 pts. sulphate of iron or 16 pts. acetate of iron. After the "stuff" has circulated in the beater, wash for a short time, and then colour with 8 pts. logwood extract and $1\frac{1}{2}$ pts. quercitron.

Note.—Owing to the greater tintorial power and brighter shades of the aniline dyes, these vegetable dye stuffs are now seldom used, excepting in special cases—*e.g.*, in the production of blacks, deep blues, and browns.

Colouring Pulp with Lakes and Mineral Pigments.—Mineral pigments, as a rule, yield the most stable colours towards light and atmospheric influences, although they are not the most brilliant. Compound colours—*e.g.*, green, orange, drabs, &c.—can all be produced by the admixture of mineral pigments, and some of them are very beautiful, in accordance with the purity of the pigments employed and the whiteness of the pulp.

The most important of the mineral pigments or lakes are for yellow. CHROME YELLOW, produced by admixture of bichromate of potash and acetate or nitrate of lead. The shade may be varied from pale canary-yellow to deep orange, in proportion to the amount of lead salt used. The colour is stable to light. [NOTE.—Ultramarine should not be used with chrome yellow.] OCHRES.—These vary greatly in shade, and yield chamoise yellows. Nitrate of iron yields the same colours, and occurs as a thick brown liquid, having the following composition:—Sp. gr. = 1·210 (= 42° Twad.) Fe_2O_3 as FeO = 13·61 grms. per litre. Fe_2O_3 = 168·00 grms. per litre. Total, 181·61. The ferric oxide exists as $Fe_2 3 (SO_4)$, and is therefore a normal salt.

RED.—Venetian red—an oxide of iron—yields somewhat fiery red colours when used by itself. Shade may be changed to bluish-red with Prussian blue or ultramarine. The finest qualities of Venetian red yield bright colours on a white ground.

BLUE.—Ultramarine, the most extensively used coloured pigment by papermakers, occurs in a variety of shades, from greenish blue to reddish blue. In conjunction with cochineal or magenta it is used to produce a white from bleached paper stock, possessing a slightly yellow tint. It has great distributing power, and is suitable for compound shading with nearly all colours except chrome yellow (chromate of lead). It has a tendency to blacken these yellows. It is decomposed by acids, giving off sulphuretted hydrogen. The more stable kinds resist the action of tolerably strong solutions of alum or sulphate of alumina. Those samples that are more or less bleached by sulphate of alumina solutions should be avoided. The mineral is remarkably stable towards light and other atmospheric influences.

PRUSSIAN BLUE (PASTE BLUE).—As the name implies, this colour occurs as a paste having a deep bronze-blue lustre. It contains 65 to 66 per cent. water and 34 to 35 per cent. dry colour (at 212° Fah.). The shades of blue which it produces are inclined to greenish; this is counteracted, however, by addition of red. Also used with chrome yellow for greens. Paper pulp can be dyed Prussian blue for "mottled" papers by first mordanting the pulp with iron (preferably "nitrate" of iron), and then adding yellow prussiate of potash with alum. The colour is brightened with addition of bleach liquor and a little oil of vitriol. The deposition of the iron on the pulp, and subsequent formation of the blue, is facilitated by heating to 120 or 140° Fah. The dyed pulp should be well washed before using it for "mottled" papers.

BROWNS.—Paste Umber yields dark brown shades. It has the following composition:—Moisture 24·88 per cent., ferric-oxide, &c., 41·88 per cent., loss on ignition 5·04, insoluble (in HCl) 28·20 per cent. It is essentially a hydrated oxide of iron, mixed more or less with organic matter. It is used extensively for brown papers. Manganese brown can be prepared by the use of sulphate of manganese, and subsequent addition of bleach liquor, and final washing before sizing. The depth of shade produced is in proportion to the amount of sulphate of manganese used. The colour is fairly stable towards light.

CHAPTER V.

GENERAL PAPER MILL ANALYSES.

ATOMIC WEIGHTS AND SYMBOLS OF THE MOST IMPORTANT CHEMICAL ELEMENTS.

Element.	Symbol.	Atomic Weight.	Element	Symbol.	Atomic Weight.
Aluminium...	Al	27·1	Molybdenum	Mo	96
Antimony ...	Sb	120	Nickel	Ni	58·7
Arsenic ...	As	75	Niobium ..	Nb	94
Barium ...	Ba	137·4	Nitrogen ...	N	14
Bismuth ...	Bi	208	Osmium ...	Os	191
Boron	B	11	Oxygen ...	O	16
Bromine ...	Br	80	Palladium ...	Pd	106
Cadmium ...	Cd	112	Phosphorus...	P	31
Cæsium ...	Cs	133	Platinum ...	Pt	194·8
Calcium ...	Ca	40	Potassium ...	K	39
Carbon ...	C	12	Rhodium ...	Rh	103
Cerium ...	Ce	140	Rubidium ...	Rb	85·4
Chlorine ...	Cl	35·5	Ruthenium...	Ru	101·7
Chromium ...	Cr	52	Scandium ...	Sc	44
Cobalt	Co	59	Selenium ...	Se	79
Copper ...	Cu	63·6	Silver	Ag	108
Didymium ...	D	144	Silicon... ...	Si	28
Erbium ...	E	170·6	Sodium ...	Na	23
Fluorine ...	F	19	Strontium ...	Sr	87·5
Gallium ...	Ga	69·6	Sulphur ...	S	32
Gold	Au	197	Tellurium ...	Te	127
Hydrogen ...	H	1	Thallium ...	Tl	204
Indium ...	In	113	Thorium ...	Th	231·5
Iodine	I	127	Tin	Sn	118·5
Iridium ...	Ir	193	Titanium ...	Ti	48
Iron	Fe	56	Tungsten ...	W	183·4
Lanthanum...	La	139	Uranium ...	U	240
Lead	Fb	207	Vanadium ...	V	51
Lithium ...	Li	7	Yttrium ...	Y	89
Magnesium ..	Mg	24	Zinc	Zn	65·4
Manganese ...	Mn	55	Zirconium ...	Zr	90·6
Mercury ...	Hg	200			

MOLECULAR WEIGHT AND PERCENTAGE COMPOSITION OF COMPOUNDS IMPORTANT TO THE PAPER INDUSTRY.

	Name of Compound.	Molecular formula.	Mole. Weight.	Percentage Composition.
Al	Aluminum Oxide (Alumina) ...	$Al_2 O_3$	102·80	Al 53·30 : O 46·70
	,, hydrate	$Al_2 O_3$ 3 H O	156·80	Al 35·07 : H 3·82 : O 61·11
	,, (Sulphate anhydrous)	Al_2 3 (S O_4)	342·80	$Al_2 O_3$ 30·00 : S O_3 70·00
	,, (crystallised) ...	Al_2 3 (S O_4) +18 H_2 O	666·80	Al_2O_3 15·40 : SO_3 36·00 : H_2 O 48·60
	,, silicate	Al Si O_7	222·80	$Al_2 O_3$ 46·14 : Si O_2 53·86
1	Potash alum...	$Al_2 3(SO_4) K_2 SO_4$ +24 H_2 O	948·80	Al O 10·83 : SO_3 33·70 H_2 O 45·53 K_2 O 9·94
	Ammonia alum	Al_2 3 (S O_4) (N H_4)$_2$ S O_4 +24 H_2 O	907·00	$Al_2 O_3$ 11·35 ; NH_3 3·75 S O_3 35·29 ; H_2 O 49·61.
As	Arsenic oxide	$As_2 O_5$	230·00	As 65·30 : O 34·70
	Arsenious oxide	$As_2 O_3$	198·00	As 75·75 : O 24·25
Ba	Barium carbonate	Ba C O_3	197·00	Ba O 77·60 : C O_2 22·40
	,, chloride	Ba Cl_2 + 2 H_2 O	244·00	Ba 56·15 : Cl 29·10 : H_2 O 14·75
	,, oxide	Ba O	153·00	Ba 89·54 : O 10·46
	,, sulphate	Ba S O_4	233·00	Ba O 65·67 : S O_3 34·33
Ca	Calcium monoxide	Ca O	56·00	Ca 71·43 : O 28·57

MOLECULAR WEIGHT AND PERCENTAGE COMPOSITION—*continued.*

	Name of Compound.	Molecular formula.	Mole. Weight.	Percentage Composition.
	Calcium hydrate	$Ca\ H_2\ O_2$	74·00	Ca O 75·67 : H_2 O 24·33
	,, carbonate	$Ca\ C\ O_3$	100·00	Ca O 56·00 : C O_2 44·00
	,, chloride	$Ca\ Cl_2$	111·00	Ca 36·05 : Cl 63·95
	,, hypochlorite	$Ca\ (O\ Cl)_2$	143·00	Ca O 39·16 : Cl 49·65 : O 11·19
	,, oxalate	$Ca\ C_2\ O_4$	128·00	Ca O 43·75 : C_2 O_3 56·25
	,, sulphate (anhydrous) ...	$Ca\ S\ O_4$	136·00	Ca O 41·18 : S O_3 58 82
	,, ,, (cryst.) ...	$Ca\ S\ O_4 + 2\ H_2O$	172·00	Ca O 32·56 : S O_3 46·51 : H_2 O 20·93
	,, sulphite	$Ca\ S\ O_3$	120·00	Cal O 46·67 : S O_2 53·33
	,, sulphide	Ca S	72·00	Ca 55·56 : S 44·44
C	Carbonic acid, dioxide	$C\ O_2$	44·00	C 27·27 : O 72·73
	,, oxide	C O	28·00	C 42·85 : O 57·15
	Carburetted hydrogen, methane	$C\ H_4$	16·00	C 75·00 : H 25·00
	,, ,, ethylene	$C_2\ H_4$	28·00	C 85·72 : H 14·28
Cu	Copper sulphate	$Cu\ S\ O_4 + 5\ H_2O$	249·5	Cu O 31·86 : S O_3 32·06 : H_2 O 36·08
Cl	Hydrochloric acid	H Cl	36·5	Cl 97·26 : H 2·74
Fe	Iron oxide, ferric.	$Fe_2\ O_3$	160·0	Fe 70·00 : O 30·00
	,, ferrous chloride (cryst.) ...	$Fe\ Cl_2 + 4\ H_2\ O$	199·0	Fe Cl_2 63·82 : H_2 O 36·18
	,, ferric chloride	$Fe_2\ Cl_6$	325·0	Fe 34·46 : Cl 65·54
	,, bisulphide (pyrites) ..	$Fe\ S_2$	120·0	Fe 46·67 : S 53·33

MOLECULAR WEIGHT AND PERCENTAGE COMPOSITION—*continued.*

	Name of Compound.	Molecular formula.	Mole. Weight.	Percentage Composition.
	Iron protosulphate	$Fe SO_4 + 7 H_2O$	278·0	Fe 20 14 : O 5·76 : SO_3 28·78 : H_2O 45·32
Pb	Lead nitrate	$Pb_2 (NO_3)$	331·00	Pb O 67·37 : N_2O_5 32·63
	,, acetate	$Pb (C_2H_3O_2)_2 + 3 H_2O$	379·00	Pb O 58·84 : $(C_2H_4O_4)$ O 26·91 H_2O 14·25
	,, chromate	$Pb Cr O_4$	323·20	Pb O 69·00 : Cr O_3 31·00
	,, monoxide	Pb O	223·00	Pb 92·80 : O 7·20
Mg	Magnesium oxide	Mg O	40·00	Mg 60·00 : O 40·00
	,, hydrate	$Mg H_2O_2$	58·00	Mg O 68·96 : H_2O 31·04
	,, carbonate	$Mg CO_3$	84·00	Mg O 47·62 : CO_2 52·38
	,, sulphate	$Mg SO_4 + 7 H_2O$	246·	Mg O 16·26 : SO_3 32·52 : H_2O 51·22
	,, pyrophosphate ...	$Mg_2 P_2O_7$	222·	Mg O 36·04 : P_2O_5 63·96
Mn	Manganese dioxide	$Mn O_2$	87·	Mn 63·22 : O 36·78
	,, sulphate	$Mn SO_4$	151·	Mn O 47·02 : SO_3 52·98
N	Nitric a id	$HN O_3$	63·	N_2O_5 85·71 : H_2O 14·29
K	Potassium bichromate	$K_2 Cr_2 O_7$	295·	K_2O 31·86 : Cr O_3 68·14
	,, carbonate	$K_2 CO_3$	138·	K_2O 68·12 : CO_2 31·88
	,, chlorate	$K Cl O_3$	122·5	K_2O 38·45 : Cl_2O_5 61·55
	,, ferrocyanide ...	$K_4 (Fe CN)_6$ 3 H_2O	422·	K 37·03 : Fe 13·25 : C N 36·93 : H_2O 12·79

Molecular Weight and Percentage Composition—*continued.*

	Name of Compound.	Molecular formula.	Mole. Weight.	Percentage Composition.
	Potassium iodide	KI	166·	K 23·49 : I 76·51
	,, permanganate ...	$KMnO_4$	158·	K_2O 29·75 : Mn_2O_7 70·25
	,, silicate	K_2SiO_3	154·	K_2O 61·04 : SiO_2 38·96
	,, sulphite	$K_2SO_3 + 2H_2O$	194·	K_2O 48·45 : SO_2 33·00 : H_2O 18·55
	,, oxide	K_2O	94·	K 82·98 : O 17·02
	,, hydrate	KOH	56·	K_2O 83·93 : H_2O 16·07
Si	Silicic acid (anhydride) ...	SiO_2	60·	Si 46·67 : O 53·33
Ag	Silver chloride	$AgCl$	143·5	Ag 75·26 : Cl 24·74
	,, nitrate	$AgNO_3$	170·	Ag 63·53 : NO_3 36·47
Na	Sodium oxide	Na_2O	62·	Na 74·19 : O 25·81
	,, hydrate	$NaOH$	40·	Na_2O 77·50 : H_2O 22·50
	,, chloride	$NaCl$	58·5	Na 39·32 : Cl 60·68
	,, aluminate	$Na_6Al_2O_6$	289·	Na_2O 64·36 : Al_2O_3 35·64
	,, borate	$Na_2B_4O_7 + 10H_2O$	382·	Na_2O 16·23 : B_2O_3 36·65 : H_2O 47·12
	,, carbonate anhydrous ...	Na_2CO_3	106·	Na_2O 58·49 : Co_2 41·51
	,, ,, monohydrate	$Na_2CO_3 \times H_2O$	124·	Na_2O 50·00 : CO_2 35·48 : H_2O 14·52
	,, ,, "crystals" ...	$Na_2CO_3 \times 10H_2O$	286·	Na_2O 21·68 : CO_2 15·39 : H_2O 62·93
	,, hypochlorite	$NaOCl$	74·5	Na_2O 41·61 : Cl_2O 58·39

Molecular Weight and Percentage Composition—*continued.*

	Name of Compound.	Molecular formula.	Mole. Weight.	Percentage Composition.
	Sodium phosphate	$Na_2HPO_4 + 12H_2O$	358·	Na_2O 17·32 : P_2O_5 19·84 : H_2O 62·84
	,, silicate	Na_2SiO_3	122·	Na_2O 50·82 : SiO_2 49·18
	,, sulphate anhydrous ...	Na_2SO_4	142·	Na_2O 43·66 : SO_3 56·34
	,, ,, cryst.	$Na_2SO_4 + 10H_2O$	322·	Na_2O 19·25 : SO_3 24·84 : H_2O 55·91
	,, sulphite	$Na_2SO_3 + 6H_2O$	234·	Na_2O 26·50 : SO_2 27·35 : H_2O 46·15
	,, thiosulphate (hypo-sulphite).	$Na_2S_2O_3 + 5H_2O$	248·	Na_2O 25·00 : S 12·90 : SO_2 25·80 H_2O 36·30
	,, sulphide	Na_2S	78·	Na 58·97 : S 41·03
	,, hydrogen sulphide ...	$NaSH$	56·	Na_2S 69·65 : H_2S 30·35
S	Sulphurous anhydride	SO_2	64·	S 50·00 : O 50·00
	Sulphuric ,, ...	SO_3	80·	S 40·00 : O 60·00
	,, acid	H_2SO_4	98·	SO_3 81·63 : H_2O 18·37
H	Water	H_2O	18·	H 11·11 : O 88·89
Zn	Zinc oxide	ZnO	81·	Zn 80·25 : O 19·75
	,, chloride	$ZnCl_2$	136·	Zn 47·79 : Cl 52·21
	,, sulphate	$ZnSO_4 + 7H_2O$	287·	ZnO 28·22 : SO_3 27·87 : H_2O 43·91

ALKALIMETRY.

The principle upon which alkalimetry is based, is the neutralization of the alkali with an acid. The acid commonly used for this purpose is sulphuric acid, $H_2 SO_4$. Thus, in the case of determining the alkali or soda (Na_2O) in alkaline soda products—*e.g.*, soda ash, the following chemical reaction takes place:—$Na_2 CO_3 + H_2 SO_4 = Na_2 SO_4 + H_2 O + CO_2$. That is to say, one equivalent, or 98 parts of sulphuric acid, combines with or exactly neutralizes one equivalent, or 62 parts of soda ($Na_2 O$). The method is applicable to alkaline soda products, such as carbonate, caustic, and silicate of soda.

Preparation of a solution of sulphuric acid of known neutralizing power. According to the above equations, one gramme — equivalent of $H_2 SO_4$ (98)—will exactly neutralize one gramme — equivalent of soda $Na_2 O$ (62). If, therefore, a solution of the acid be made up so that 1 litre of it will contain exactly 98 grammes of $H_2 SO_4$, it follows that 1 c.c. of this solution will contain $\frac{98}{1000}$ $H_2 SO_4$, and be capable of exactly neutralizing $\frac{62}{1000}$, or 0·062 gramme $Na_2 O$. Such a solution of sulphuric acid is known as "normal" sulphuric acid. Many workers prefer, however, to use a solution containing one half of a gramme — equivalent, or 49 grammes of $H_2 SO_4$ to the litre, which is called "half-normal" sulphuric acid, each c.c. of which will exactly neutralize 0·031 gramme $Na_2 O$. This solution we recommend for general use. It is made as follows:—56 grammes of pure concentrated sulphuric acid are diluted with 500 c.cs. of cold distilled water, care being taken to pour the acid INTO the water, and not *vice versa*. The mixture is set aside to cool to the normal temperature—viz., 62° Fah., and when cold it is made up to 1,100 c.cs. by volume with cold water and thoroughly mixed. One litre (1,000 c.cs.) of this fluid will contain more than 49 grammes $H_2 SO_4$, and it is now necessary to determine its exact strength, in order that it may be diluted to exact "half normal strength." This is done by ascertaining how many c.cs. of the mixture are required to neutralize the $Na_2 O$ contained in a known weight of pure $Na_2 CO_3$, as follows:—A small quantity of guaranteed pure carbonate of soda is placed in a porcelain crucible and ignited, till perfectly dry, over the flame of a spirit lamp. It is then cooled in the desiccator, and 5·3 grammes of the cold dry soda salt, weighed off, transferred to a flat porcelain dish or glass flask, and dissolved in luke warm water. The alkaline fluid is now coloured with a few drops of neutral litmus solution, and the diluted acid cautiously added from a burette till the blue colour is changed to reddish violet. While the acid is being added an effervescence, more or less violent, will take place due to the evolution of carbonic acid gas CO_2, and as this is partly held in solution it is necessary to boil the mixture to expel it. After boiling, the blue colour will reappear, and additional portions of the acid must be run in with subsequent boiling after each addition, until finally one drop is found sufficient to turn the blue colour to a permanent red. The whole of the soda—viz., 3·1 grammes contained in the 5·3 grammes of the pure carbonate—is now converted into sulphate of soda, $Na_2 SO_4$, and as the 5·3 grammes, $Na_2 CO_3$, will, according to the above equation, exactly neutralize 4·9 grammes of $H_2 SO_4$, it follows that the number of c.cs. of the diluted acid used from the burette will contain 4·9 grammes $H_2 SO_4$. We will assume the quantity of diluted acid used to be 98·2 c.cs., in order to show the method of adjusting its strength with water, so as to obtain "half normal acid."

By ordinary proportion we have 98·2 : 4·9 :: 1,000 : 49·89. That is, one litre of the diluted acid contains 49·89 grammes $H_2 SO_4$, or 0·89 gramme too much. The quantity of water required to dilute it to the precise strength is found thus:—49 : 100 :: 49·89 : 1,018·1. That is to say, 18·1 c.cs. of cold water must be added to every litre of the diluted acid. The acid thus made is preserved in well stoppered bottles for future use. It should be labelled "half normal $H_2 SO_4$." One c.c. of this acid is equal to 0·031 grammes $Na_2 O$.

NOTE.—Before finally adjusting the strength of the acid, it is always advisable to test it twice or thrice with pure $Na_2 CO_3$, and to take the mean of the tests as representing its true value.

VALUATION OF SODA ASH, CAUSTIC SODA, &c., and in all products in which the soda exists as carbonate or caustic. The value of soda ash and caustic sodas depends upon the amount of available soda they contain. 3·1 grammes of the ash or caustic are weighed off, and transferred to a flask containing about 100 c.cs. of distilled water. After the contents of the flask have been heated and coloured blue by the addition of a few drops of neutral litmus solution, the half normal sulphuric acid is added from a burette, and the titration carried out as above described. The number of c.cs. of acid required to change the colour of the solution to permanent red represents the percentage of available soda ($Na_2 O$) in the sample.

In addition to available alkali ($Na_2 O$), alkaline liquors, recovered ash, as well as caustic sodas, contain other salts, the quantities of which it is frequently desirable to ascertain. Of these salts, sulphate, chloride and silicate of soda are the most important. Silicate of soda occurs in all liquors made from recovered ash from esparto and straw boiling, but not to any great extent from wood pulp manufacture. Sulphide of sodium not infrequently exists in large quantity in liquors made from recovered ash, and especially in the "smelt" from the so-called "sulphate" wood pulp process.

These salts may be estimated in the following manner:—10 grammes of the ash are dissolved in hot water and filtered through a tared (or weighed) filter into a 500 c.c. flask, the insoluble matter collected in the filter as also the filter itself and beaker glass in which the ash is dissolved, all being thoroughly washed with hot water. The washings are, of course, collected in the graduated flask. The clear filtrate is shaken, allowed to cool, and then diluted with cold distilled water to the graduated mark on the neck—*i.e.*, the volume is made up to exactly 500 c.cs. When this fluid is mixed it is ready for use. For convenience we will call it "A." The filter and contents are dried at 212° Fah. in a water oven and weighed. Deduct the tare of the filter paper, multiply by 10 = % of insoluble matter.

Sulphate of Soda.—Withdraw 50 c.cs. of the fluid equal to one gramme of the ash from the flask by means of a pipette and place in a beaker glass, add a few drops of a clear solution of bleaching powder, then acidify with 5 c.cs. of pure hydrochloric acid, and boil gently till all free chlorine has been expelled. The bleaching powder or hypochlorite solution oxidises any sulphide of sodium present. When all chlorine has been expelled, a clear concentrated solution of barium chloride is added in slight excess, and the whole mixture set aside in a warm place (on a sand plate kept hot by a lamp flame) for two or three hours. The precipitate of barium sulphate is then collected in a filter in the usual way, and washed, dried, ignited, and weighed. Multiply the weight of the precipitate by 0·6098 and then by 100 = % of sulphide and sulphate of soda in the ash, *expressed in terms of sulphate*. When the sulphide of sodium exists in large quantity, and it is desired to know the percentage, proceed as described in page 159.

Chloride of Sodium (Na Cl).—This is best estimated volumetrically by means of a $\frac{1}{10}$th normal solution of nitrate of silver, according to the reaction $Ag. NO_3 + Na Cl = Ag Cl + Na NO_3$.

Preparation of $\frac{1}{10}$th Normal Ag NO_3 Solution.—Seventeen grammes of pure crystallised nitrate of silver are dissolved in pure cold distilled water, and the solution made up to exactly one litre. One c.c. of this fluid is capable of precipitating 0·00585 gramme Na Cl.

To estimate the Na Cl, 50 c.cs. of the liquor "A" are transferred to a clean porcelain dish, acidified with pure nitric acid, and then evaporated to complete dryness in a water bath

The residue is lixiviated in water, the fluid filtered into a clean beaker glass, and the dish and filter washed as usual. Two or three drops of a concentrated solution of chromate of potash are added to the filtrate, and then the $\frac{1}{10}$th normal nitrate of silver from a burette is cautiously poured in, constantly stirring the while till one drop changes the colour of the mixture from pale yellow to a reddish orange. The number of c.cs. of $\frac{1}{10}$th normal $Ag\ NO_3$ solution taken, multiplied by $0{\cdot}00585 \times 100 =$ % of Na Cl in the sample.

Silica or Silicate of Soda.—200 c.cs. of solution "A" are transferred to a porcelain basin and carefully acidified with pure hydrochloric acid. The solution is then evaporated to dryness in a water bath, and the residue left in the dish again drenched with H Cl, and a second time evaporated. It is finally heated for an hour or so in an air bath at 260° or 270° Fah., and then lixiviated in dilute H Cl (10 per cent. solution) with the aid of heat. The Silica ($Si\ O_2$) will then be in an insoluble state. Filter off the precipitate, and thoroughly wash with hot distilled water till the washings from the filter are free from chlorides. Dry the filter and its contents, ignite and weigh the SiO_2. The weight multiplied by 25 = % silica in the sample.

Note.—For the purpose of daily comparison, the quantities of sodium sulphate, sulphide, chloride and silica are frequently expressed on 25 or 50 parts of alkali ($Na_2\ O$). In this way any change in the composition of the liquors can be detected at once.

ACIDIMETRY

Is the reverse of alkalimetry—that is to say, acids are estimated by standard alkaline solution, caustic soda being most commonly used.

Standard Caustic Soda Solution.—The strength of this solution should be such that 1 c.c. of it will exactly neutralize one c.c. of half normal sulphuric acid (see page), and therefore it is "half normal caustic soda"—*i.e.*, one litre should contain half an equivalent or 31 grammes of soda, $Na_2\ O$. It is made up as follows:—Dissolve 50 grammes of pure caustic soda in 500 c.cs. distilled water, cool, and then dilute to 1,100 c.cs. Draw off 50 c.cs. with a pipette, transfer to a porcelain dish, add a few drops of neutral litmus, and then titrate with half-normal sulphuric acid till one drop of the latter changes the litmus to red. If the caustic soda is free from carbonate the transition from blue to red should be decided. The number of c.cs. of $\frac{N}{2}$ H_2SO_4 taken represents the extent to which every 50 c.cs. of the caustic soda solution must be diluted. Assuming, by way of example, that 60 c.cs. of half-normal acid were required to produce the change of colour, or neutralise the soda, then 50 c.cs. of the caustic soda will require to be diluted to 60 c.cs. or 1,000 c.cs. to 1,200 c.cs.

BISULPHITE OF LIME, SODA, OR MAGNESIA

In the sulphite wood pulp manufacture, the "bisulphite liquors should be tested for percentage of "free" and "combined" SO_2. This is done by first estimating the total SO_2 with $\frac{1}{10}$th normal iodine, and deducting from this result the amount of "free" acid ascertained by titration with $\frac{1}{20}$th normal soda (1 c.c. = 0·0031 Na_2O).

PREPARATION OF "$\frac{1}{10}$TH NORMAL IODINE."—Weigh off 12·7 grammes of pure resublimed iodine and 25 grammes of pure iodide of potassium, and place both in a beaker glass. Dissolve in 250 c.cs. or so of *cold* water by continued agitation When the whole of the iodine is dissolved, transfer the solution to a litre flask, and make up the volume to 1,000 c.cs. According to the reaction $I_2 + SO_2 + 2\,H_2O = 2\,HI + H_2SO_4$, two equivalents, or 254 parts iodine, are equal to one equivalent, or 64 parts of SO_2. Therefore, 12·7 parts iodine are equal to 3·2 parts SO_2. One c.c. of the $\frac{1}{10}$th normal iodine is equal to 0·0032 SO_2.

(*a*) TOTAL SO_2.—Dilute 10 c.cs. of the "bisulphite" liquor to 100 c.cs. with water, mix and withdraw 10 c.cs. (= 1 c.c. of the original liquor) of the solution with a pipette, and transfer to a small flask containing about 100 c.cs. water. Now add a few drops of a solution of starch, and then the iodine from a burette, till a pale permanent blue colour of iodide of starch is formed. This solution is kept for the "free" acid test, as described below. The number of c.cs. of iodine consumed multiplied by $0·0032 \times 100 = \%$ of total SO_2 by volume in the bisulphite liquor.

(*b*) FREE SO_2.—The fluid in the flask from "*a*," after the above test is performed, is decolorised with a drop of the weak solution of the bisulphite liquor, then a drop of a 5 per cent. solution of phenolphthaline in alcohol added, and the amount of acid found by titration with $\frac{1}{20}$th normal caustic soda (100 c.cs. of half normal caustic soda made up to 1,000 c.cs. by volume with water). The fluid turns pink whenever an excess of alkali is present. By deducting the number of c.cs. of iodine found in "*a*" from the number of c.cs. of soda found in "*b*," and multiplying the remainder by 0·0032 × 100, the percentage of free SO_2 is obtained.

The base—*i.e.*, lime soda or magnesia—is usually found by calculation from the percentage of combined SO_2 found above. Thus, by multiplying percentage of combined SO_2 by 0·875, the amount of lime (CaO) in combination with the SO_2 will be obtained.

(*c*) LIME AS BASE.—If it be desired to ascertain the amount of lime (CaO) by actual test in solutions of *bisulphite of lime*, 5 c.cs. of the strong liquor are transferred to a flask, diluted with a 100 c.cs. or so of water, and ammonium hydrate added in *slight* excess. The ammonia precipitates the $CaSO_3$. The mixture is then gently boiled till all smell of ammonia has disappeared, the precipitated $CaSO_3$ filtered off, and washed with hot water, and finally transferred, together with the filter paper, to a beaker glass containing about 250 c.cs. of water, and after acidifying with 5 c.cs. of acetic acid, titrating with $\frac{1}{10}$th normal iodine. Number of c.cs. of iodine consumed multiplied by 0·0028 × 20 will give the percentage by volume of CaO or "lime-base."

(*d*) SODA AS BASE.—The percentage of combined SO_2 found in pure solutions of bisulphite of soda multiplied by 0·969 will give the percentage of Na_2O as "soda-base."

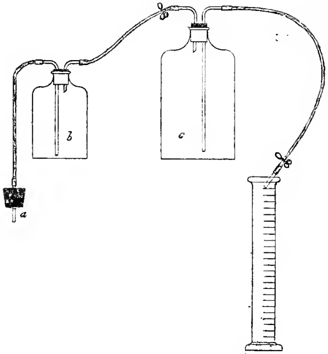
(*e*) MAGNESIA AS BASE.—The percentage of combined SO_2 found in pure solutions of bisulphite of magnesia multiplied by 0·625 will give the percentage of MgO as "magnesia-base."

DETERMINATION OF SO_2 IN GASES FROM SULPHUR OR PYRITES KILNS.

REICH'S METHOD.

The percentage by volume of SO_2 in these gases is best ascertained as follows, with the aid of the apparatus shown in the accompanying sketch. Ten c.cs. of $\frac{1}{10}$th normal iodine is placed in *b*, together with 100 c.cs. water, a few drops of starch solution, and a pinch of bicarbonate of soda. The bottle aspirator *c* is filled with water, and the syphon pipe "set" by sucking the water past the pinch cock *d*. The tube (*a*) is then inserted into the pipe conveying the gases from the sulphur or pyrites kilns, and by opening the pinch cock on the syphon arm the kiln gases are drawn through the iodine solution in *b*, where the SO_2 is absorbed. Instantly the blue colour in *b* disappears the pinch cock is closed. Before beginning the operation the measuring glass should be empty, but the water caught in it during the test is a direct measure of the amount of air which has passed through the iodine solution in *b*. We will call this volume of air x. The 10 c.cs. of iodine correspond to 11·14 c.cs. of gaseous SO_2, and by adding this to x we obtain the total volume of gases which passed into *a*. The percentage volume of SO_2 is therefore found thus—

$$\frac{11 \cdot 14 \times 100}{x + 11 \cdot 14} = \% \ SO_2 \text{ by volume in kiln gases.}$$



DETERMINATION OF FREE RESIN, ETC., IN RESIN SIZE.

Dr. Scheufelen's Method.

(*a*) Free Resin.—100 c.cs. of the cold sizing liquor are taken and mixed with about 25 c.cs. of sulphuric ether in a separating funnel of vase-like shape, and well shaken for a minute. After standing for a little the liquor will separate into two sharply defined layers. The ether will have completely taken up the milky free resin and assumed a brownish colour, while underneath, the aqueous layer will be perfectly clear. This contains the dissolved soda and resin soap, of which not a trace has passed into the ether solution. A separation of the two liquids can be easily made by the funnel. The aqueous solution is first run off into a small alembic, and set aside for treatment as at *b*, and then the ether into a previously weighed cup or small flask, according as the ether is to be evaporated or distilled.

The ether part is then heated in a water bath till all the ether has been expelled. The residue is then melted, dried, and weighed. The weight represents the amount of free resin in the 100 c.cs. of size liquor taken.

(*b*) Combined or Saponified Resin.—The aqueous solution containing the resin soap and free soda is acidified with dilute H Cl. or, better still, acetic acid. The acid which combines with the soda, causes a precipitation of free resin in the form of flakes. This, as in the previous case, is determined by shaking up with ether, &c., as in *a*. The weight thus obtained represents the resin existing in the size as resin soap. It is best to add the ether to the solution before acidifying. The sum of *a* and *b* represents the total resin, but, as a check, the total resin can be estimated by acidifying 100 c.cs. of the sizing liquor and proceeding as in *a*.

Note.—If starch is present in the size, some precautionary measures must be taken. In analysing the resin liquor the ether liquor does not separate so readily from the watery part, but by adding a few grains of table salt and shaking, the separation ensues at once.

BLEACHING POWDER AND BLEACH LIQUORS.

The value of a bleaching powder or bleach liquor depends upon the amount of available chlorine it contains. Penot's method of analysis is most frequently used, and is based upon the following reaction:—

$$As_2O_3 + Ca\,(Cl\,O)_2 = As_2O_5 + Ca\,Cl_2$$

Alkaline arsenite is converted into arsenate by the bleaching powder. The end of the reaction is indicated with potassium iodide and starch. One equivalent of As_2O_3 are equal to two of O or four of Cl.

Preparation of Alkaline Arsenite.—4·95 grammes of pure resublimed arsenious acid are dissolved by gently boiling in 200 c.cs. of water containing 25 grammes of crystallised carbonate of soda. When the $As_2\,O_3$ is dissolved and the solution cooled, make up the volume to exactly one litre. One c.c. of this solution is equivalent to 0·00355 Cl.

Preparation of Iodo Starch.—Three grammes of wheat starch rubbed into a cream with a little water, and then poured into 200 c.cs. of warm water. Heat, with constant stirring, till the mixture boils. Add 1 gramme of potassium iodide, and dilute to $\frac{1}{2}$ a litre.

Iodide and Starch Test Papers are made by dipping strips of Swedish filter paper in the above mixture, and drying in a pure atmosphere.

The Valuation of Bleach.—Weigh off 3·55 grammes of the sample, place in a small porcelain mortar, and rub in water to a thin cream. Transfer to a litre flask, and make up the volume to one litre. Mix, and while the solution is still cloudy draw off 100 c.cs. of the fluid (corresponding to 0·355 grammes dry bleaching powder) and place in a beaker. Dilute with a further addition of 100 c.cs. water. Now pour in the standard solution of arsenite of soda, stirring meanwhile till one drop transferred with a glass rod to a piece of the iodide and starch test papers does not produce a blue colouration. The number of c.cs. of standard arsenic solution consumed is directly equivalent to the percentage of available chlorine in the sample—*e.g.*, if 35·4 c.cs. are consumed, then the percentage of available chlorine in the sample is 35·4.

Bleach liquors are tested for available chlorine in the same way, but the final calculation is made in accordance with the volume of bleach liquor used, and the value of the arsenite solution, in terms of available chlorine. Thus, if 5 c.cs. of bleach liquor be diluted with 200 c.cs. of water, and the arsenite solution run in till the blue iodide of starch ceases to be formed on the test papers, the number of c.cs. run off multiplied by $0·00355 \times 20$ will give the percentage by volume of available chlorine in the liquor.

To obtain grammes available chlorine per litre $\times$ 10.

To obtain grammes 35 per cent. bleaching powder per litre $\times$ grammes available chlorine by 10, then by 100, and divide by 35.

EXAMINATION OF ULTRAMARINE.

Samples of ultramarine should be compared with a standard sample when examining them for *shade.* Small portions of the samples are placed side by side upon a sheet of white paper, and after folding the paper over and flattening them are compared for *shade.*

Colouring Power.—This is usually ascertained by mixing the ultramarine with china clay or pearl hardening, and noting the depth of shade which it yields. The amount of ultramarine taken should be in proportion to its price. Thus, two samples, *a* and *b*, each costing, say, 50s. and 40s. respectively per cwt., are examined against a standard sample costing 45s. per cwt., as follows:—0·40 grammes of *a*, 0·50 grammes of *b*, and 0·45 grammes of the "standard" are each mixed separately with 25 grammes of china clay or pearl hardening, and the depth of shade compared. The sample yielding the deepest shade of blue is the best value.

Their Power to Withstand Acids.—Ultramarines for paper manufacture should not be readily decomposed by weak acids. To ascertain this a weighed portion of the sample is shaken up in a clear glass bottle with a solution of oxalic acid, containing 50 grammes of the crystallized acid per litre. This is compared with an equal weight of the standard sample treated in a precisely similar way.

Its Power to Withstand Alum or Sulphate of Alumina.—The sample is submitted to the same treatment as the foregoing, but instead of a solution of oxalic acid a solution of alum or sulphate of alumina is used, containing 50 grammes of the salt to the litre. Both acids and alums have the property of decomposing and decolourizing ultramarines.

ALUM AND SULPHATE OF ALUMINA, ALUMINOUS CAKES, AND ALUMINO-FERRIC CAKE.

Aluminous Cake is prepared from finely ground calcined china clay and sulphuric acid. The china clay, as free from iron and undecomposed rock as possible, is calcined in a reverberatory or muffle furnace to expel the combined water, and after being withdrawn is cooled, ground to a fine powder and sieved. The sieved clay is then mixed with an equivalent quantity of oil of vitriol of Sp. gr. 1·615 in a mixing vessel, enough water being added to reduce the oil of vitriol to Sp. gr. 1·375. The mixture is heated slightly to induce chemical action, which becomes more or less violent. Three-fourths of the alumina and practically the whole of the iron of the clay combines with the sulphuric acid to form soluble sulphates. The mixed mass, after the chemical action has all but ceased, is dumped into a mould and allowed to remain in this till the greater part of the sulphuric acid has been neutralised by alumina, or until it cools. The sides of the mould are then removed, and the cake cut by a guillotine into small pieces. The cake thus produced contains all the impurities of the clay and acid. The following represents the composition of commercial aluminous cake. $Al_2 O_3$ 11·54 per cent. = 38·53 per cent. $Al_2 3 (SO_4)$. $Fe_2 O_3$ 0·16 per cent., SO_3 28·00 per cent., CaO 0·12, Free acid 0·50 per cent. Insoluble matter, 22·40 per cent.; water, Mg O, &c., 37·28 per cent.

Alumino-ferric Cake is prepared by the action of sulphuric acid on bauxite, a hydrated alumina found in natural deposits in Ireland, France, &c. The bauxite is partly dried, ground to a fine powder, and mixed with oil of vitriol. The apparatus required for this purpose is a large wooden or cast-iron tank fitted with a mechanical agitator, which is driven overhead by gears. Both vessel and agitator are protected by a covering of lead. A lead plug and seat are provided in the bottom of the vessel, so that the charge when finished may be run off. A plentiful supply of water must be near at hand, and also a small open steam pipe dips into the tub nearly to its bottom, so that the charge may be heated when necessary.

Into this vessel there are run about 67 cubic feet of oil of vitriol of Sp. gr. 1·615 (123° Twad.) cold, and after heating slightly by the injection of steam, there are added about twenty hundredweights of "bauxite" or of "alum clay." After a short time a violent chemical action sets in with the evolution of much heat, causing the mass to swell and rise in the vessel. When this has nearly ceased more bauxite or alum clay is added, in portions of about two or three hundredweights at a time. After each addition the chemical reaction is renewed, and in this way maintained until thirty hundredweights or so of the aluminous material has been added. A quantity of water is added to prevent the mass from "settling," and steam is injected until all or nearly all the acid has been saturated with alumina. Finally it is diluted by the addition of cold water until it registers a density of about 40° Twad., and is run off into settlers, where the insoluble matter is allowed to deposit. The clear, cool sulphate of alumina liquor contains fully 90 per cent. of the alumina and iron originally contained in the bauxite or alum clay. It will show a density of about 37° Twad. when cold, and assuming first quality bauxite to have been used, will yield on analysis about 400 grammes of real $Al_2\,3(SO_4) + 18\,H_2O$, with which are associated from 2·0 to 2·5 grammes of metallic iron. The iron exists partly as ferrous and partly as ferric salt. There is always present a quantity of free acid amounting to seldom more than three grammes per litre, which represents about 1·75 per cent. of the total acid used; as also all the arsenic contained in the acid, and any lime, magnesia, and (if any) alkalis of the aluminous material.

The following is an actual analysis of one of these liquors made from first quality bauxite and ordinary arsenical oil of vitriol:—

Sp. gr. = 1181 = 36·2° Twaddell.

	Grammes per Litre.	
$Al_2\,3(SO_4)$	= 193·42	= 57·92 grammes Al_2O_3.
$Fe_2\,3(SO_4)$	= 1·80	= 1·794 Fe. (both)
$FeSO_4$	= 3·52	
Free Acid	= 1·57	
$CaSO_4$	= 2·69	
Water	= 977·13	
	1180·13	

Total solids by actual test, including free acid = 203·03 grammes.

Alumino-ferric cake is obtained by evaporating the above crude sulphate of alumina liquor to a suitable density and solidifying in moulds.

Nearly all these products are fairly constant in composition, and seldom require to be analysed in full. The only impurity of importance to papermakers which they contain is iron, and if this be present in large quantity it can be estimated with $\frac{1}{10}$th normal permanganate solution, or by the colour test, using sulpho-cyanide of potassium, or ferro-cyanide of potassium as the reagent.

Aluminous cakes prepared from china clay and sulphuric acid should be examined for dirt and grit. The latter is derived from the undecomposed rock frequently mixed with the china clay. Twenty grammes of the aluminous cake are dissolved in hot water, and after diluting largely, and allowing to stand five minutes, the milky fluid is decanted. The sediment is again washed in the same way four or five times, and finally examined on a fine wire gauze or filter.

The following method of analysis is applicable to aluminous cakes, alumino-ferric and sulphate of alumina :—

(1) Insoluble Matter.—Dissolve 10 grammes of the finely-ground sample in hot water, and filter the solution through Swedish filter paper (previously treated with carbonate of ammonium solution) into a 250 c.c. flask. When the whole of the insoluble matter has been brought into the filter it is thoroughly washed with hot water till free from SO_3. The filter and its contents are then dried, ignited in a platinum dish and finally weighed. The Wt. × 10 = per cent. insoluble matter.

The filtrate from above is cooled, made up to 250 c.cs. by volume with cold distilled water and thoroughly mixed.

(2) Aluminic and Ferric Oxides.—25 c.cs. (=1 gramme of the original salt) of the filtrate from (1) are transferred to a beaker glass, 5 c.cs. of pure H Cl added, and after diluting somewhat largely with water, ammonium hydrate added till the liquid smells slightly of ammonia. The iron and aluminum are precipitated as hydrated oxides. The contents are then boiled till all smell of ammonia vapour has ceased, after which the precipitate is filtered through Swedish filter paper and thoroughly washed with hot water. As it is usually impossible to obtain the alumina precipitate sufficiently pure with one precipitation, it is advisable to redissolve it in H Cl, and reprecipitate it with ammonium hydrate, taking the precaution to boil off all smell of ammonia before finally filtering off the Al_2O_3. The precipitate should be washed

on the filter with hot water till the filtrate coming away is free from chlorine. The precipitated oxides with the filter are then dried and ignited first over a Bunsen's lamp, and finally over the blow-pipe flame—the latter to expel the last traces of water from the alumina.

The Wt. of precipitate × 100 = per cent. Al_2O_3 and Fe_2O_3.

(3) Ferric Oxide.—This is best ascertained by the colour test. 10 c.cs. of the filtrate from (1) are oxidised with a few drops of a clear solution of calcium hypochlorite acidified with 5 c.cs. of pure H Cl and boiled till all trace of free Cl has been expelled. Dilute to one litre, add sulpho-cyanide of potassium till no alteration in the depth of tint is observed. To another beaker of the same size add 5 c.cs. of pure H Cl the same quantity of water and sulpho-cyanide of potassium. From a burette add $\frac{N}{200}$ iron solution (1 c.c. = 0·0004 Fe_2O_3) till the tint is the same depth as that of the aluminous cake solution. Multiply the c.cs. of standard iron solution by 250 to get per cent. of Fe_2O_3 in the sample.

(4) Lime.—The filtrate from the first precipitate of alumina in (2) is again rendered alkaline with a few drops of ammonia and solution of ammonium oxalate added in slight excess to precipitate the lime as oxalate. The liquid is boiled and set aside in a warm place for a few hours, and if any precipitate appears this is filtered off, washed till free from soluble salts, dried, ignited and weighed. During the ignition the oxalate of lime is transformed into carbonate, and hence the precipitate is finally weighed as Ca CO_3. As a general rule before finally weighing, the precipitate is cooled, moistened with a strong solution of ammonium carbonate, and finally ignited until no trace of ammonium vapour is noticed escaping from the crucible. As the precipitate (x) is finally weighed as Ca CO_3, the following proportion must be followed to ascertain the lime (y) thus :—

$$100 : 56 :: x : y. \qquad y \times 100 = \text{per cent. CaO}$$

Note.—If necessary the filtrate from the alumina test (2) may be evaporated to smaller bulk before precipitating the CaO.

(5) Total SO_3.—25 c.cs. of the filtrate from (1) are transferred to a beaker, diluted with about 200 c.cs. of water, acidified with 5 c.cs. of pure H Cl and heated to boiling. Barium chloride solution is then added in slight excess whereby the SO_3 is precipitated as insoluble Ba SO_4. The solution is boiled gently on the sand bath for 15 minutes or so, and then set aside to cool. When cold the clear liquid is decanted off through a Swedish filter paper and the residue (precipitate) washed by decantation several times with hot water acidified with a few drops of H Cl, and then finally brought on to the

filter. Here it is further washed till the washings are free from Chlorine. After drying the filter and its contents in the water bath, they are ignited in a platinum crucible or dish at a bright red heat, till all trace of carbon has disappeared. To find the SO_3 (y) corresponding to the weight of precipitate (x) obtained, the following proportion must be followed, viz. :—233 : 80 : : x : y. $y \times 100$ = per cent. SO_3.

The moisture, Mg O, alkalies, &c., may be ascertained by difference.

NOTE.—Calculate the results as follows :—x being Wt. of precipitate in each case.

(a) SO_3 combined with $Al_2 O_3$ to form $Al_2 3(SO_4)$
= 102·8 : 240 : : x : a.

(b) SO_3 combined with Fe_2O_3 to form $Fe_2 3(SO_4)$
= 160 : 280 : : x : b.

(c) SO_3 existing as free acid ($H_2 SO_4$). The sum $a + b$ deducted from total $S O_3$ found in 5 gives C: and C is converted into $H_2 SO_4$ (d) thus :—80 : 98 : : c : d.

The CaO may be expressed as such or as $Ca SO_4$ in which case the corresponding SO_3 has to be deducted from c.

ANALYSIS OF SALT CAKE OR CRUDE SULPHATE OF SODA.

Salt cake is a granular white powder possessing a slightly yellowish or greenish yellow tint. It is obtained by acting upon common salt with oil of vitriol in cast-iron pans heated by a fire, and subsequent roasting at a red heat in specially constructed furnaces. It is freely soluble in water, and evolves heat on solution. The impurities it contains are free sulphuric acid, common salt, sulphate of lime, and ferric and aluminic sulphates, with a small quantity of insoluble matter. It is usually sold on the basis of 96 per cent. sulphate of soda, but a much richer product can be obtained if desired. It is used in the paper trade for the production (1) of caustic soda lyes (Le Blanc process), (2) pearl hardening, and (3) sulphate wood pulp.

1. Insoluble matter.—Dissolve 50 grammes of the sample in hot water in a beaker, and filter the solution through a tared filter into a 500 c.c. flask. Transfer the insoluble matter from the beaker to the filter and wash with hot water. Dry the filter and contents and weigh. The increase in weight $\times$ 2 = per cent. of insoluble matter.

2. Free sulphuric acid.—The solution in the flask is cooled and made up to 500 c.cs. with distilled water. After it is mixed draw off 100 c.cs., and titrate with $\frac{1}{10}$th normal

caustic soda, using red litmus paper as indicator. The number of c.cs., of $\frac{1}{10}$th normal caustic soda taken × 0·0049 × 10=per cent. free acid.

3. Sodium chloride or common salt.—Ten c.cs. of the filtered liquor from 1 are transferred to a small beaker, a drop or two of chromate of potash solution added, and the chlorine estimated with $\frac{1}{10}$th normal nitrate of silver, as set forth at page 146. The number of c.cs. of $\frac{1}{10}$th normal Ag No_3 taken ×0·00585×100= per cent. of Na Cl.

4. Ferric and aluminic oxides.—These are usually estimated together by precipitation with ammonia. Take 100 c.cs. of the fluid from 1 place in a beaker, dilute with an equal volume of water, and then add ammonia in slight excess. Boil till the smell of ammonia has disappeared, and filter off the precipitated oxides, collecting the filtrate in a clean flask. Wash the precipitate thoroughly with hot water, adding the washings to the bulk in the flask. The filter and contents are then dried, ignited, and weighed. Weight × 10 = per cent. Fe_2 O_3 and Al_2 O_3. During ignition a bright yellow heat should be employed.

5. Calcium sulphate.—The filtrate from the iron and alumina test (4) is rendered again slightly alkaline with ammonia heated to boiling and excess of oxalate of ammonia added. Set aside in a warm place for two or three hours, and then filter off the precipitated oxalate of lime. After washing well with water, the filter and contents are dried, ignited, and weighed. During ignition the oxalate of lime is converted into carbonate. Multiply weight of precipitate by 1·360, and then by 10 = per cent. of sulphate of lime in the sample.

6. Moisture is estimated as usual by drying 10 grammes in the water bath at 212° Fah. till the weight is constant. Loss of weight × 10 = per cent. moisture.

7. The sulphate of soda is usually not determined, but is found "by difference"—*i.e.*, the sum of the impurities deducted from 100 yields substantially the percentage of pure sulphate of soda in the sample.

ANALYSIS OF SODA-SMELT. "SULPHATE PROCESS."

Fifty grammes of the sample are dissolved in about one-half a litre of water at 45° Centi. (the water being previously boiled to expel CO_2 and O) in a large stoppered flask and repeatedly shaken for two hours.

A. Insoluble.—The above solution is filtered off through a filter into a litre flask, the insoluble residue being washed with cold water (freed from CO_2 and O as above described), dried and weighed with the filter. After this, the filter and its contents are ignited in a weighed crucible with free access of air till the residue is burnt free from carbonaceous matter. The weight of the remaining ash is then ascertained. This weight, after deducting the weight of the filter, gives the insoluble matter; whilst the difference between it and the second weighing represents the carbonaceous matter in 50 grammes of the sample.

The filtrate in the latter flask is made up to 1,000 c.cs. with cold distilled water, thoroughly mixed and submitted to analysis as follows:—

B. Total Alkali expressed in terms of Na_2O.—Twenty c.cs. of the solution (= 1 gramme of the smelt) are withdrawn with a pipette, placed in a white porcelain dish, diluted with cold water (preferably at 0° Centi.) and titrated with normal acid (1 c.c. = 0·031 Na_2O), using methyl orange as the indicator. The c.cs. of acid consumed × 0·031 × 100 represents the alkali (Na_2O) existing in the solution as Na_2CO_3, $NaOH$, Na_2SiO_3 and Na_2S. The last three constituents are determined separately as set forth below in C, D and E.

C. Soda as NaOH.—Forty c.cs. of the smelt solution are transferred to a stoppered 100 c.c. flask heated to boiling and 10 c.cs. of a solution of barium chloride (10 per cent. $BaCl_2$ + 2 Aqua) added, and the flask filled to the mark in the neck with boiling water. Replace the stopper and shake. After a few minutes, when the precipitate has settled, 50 c.cs. of the clear liquid are withdrawn and titrated with methyl orange and normal acid as in B. Each c.c. of the acid corresponds to 0·031 Na_2O or 0·040 NaOH. In this test the Na_2S is determined as well, so that allowance must be made for this in E. One part by weight of NaOH corresponds to 1·325 parts by weight of Na_2CO_3.

D. Silicate of Soda Na_2SiO_3. Twenty c.cs. of the solution are carefully acidified with pure HCl in a porcelain dish and evaporated to dryness in a water bath, and the SiO_2 determined, as set forth in page 147. One part of SiO_2 corresponds to 2·033 parts Na_2SiO_3 or 1·033 parts Na_2O.

E. Sulphide of Sodium Na_2S.—In 10 c.cs. of the fluid (= ·5 grammes of the smelt) the sulphide of sodium is determined by titrate with ammoniacal silver solution prepared by dissolving 17·00 grammes of $AgNO_3$ in distilled water, rendered alkaline with 25 c.cs. of ammonium hydrate, and the whole made up exactly to 1 litre in volume. Each c.c. of this solution corresponds to 0·0039 Na_2S. The standard ammoniacal silver solution is added drop by drop to the test solution previously heated to boiling until no more black precipitate of Ag_2S is formed. The end reaction can best be ascertained by filtering off a drop of the test solution on to a porcelain slab and adding thereto a drop of the standard silver. The c.cs. silver solution consumed $\times$ 0·0039 $\times$ 250 = % Na_2S in the original smelt. One part by weight of Na_2 S corresponds to 0·794 part of Na_2O, 1·026 parts NaOH and 1·359 parts of Na_2 CO_3.

F. SULPHITE OF SODA Na_2 SO_3.—Acidify 20 c.cs. of the fluid with acetic acid, add starch solution and then titrate with $\frac{N}{10}$ iodine solution (12·7 grammes iodine per litre) till permanent blue tint is produced. The iodine is a direct measure of the Na_2 S (E) and Na_2 SO_3. The c.cs. consumed $\times$ 0·0063 $\times$ 100 = % Na_2 SO_3. From this has to be deducted the Na_2 S found in E. One part Na_2 S corresponds to 1·615 parts Na_2 SO_3.

G. SULPHATE OF SODA, Na_2 SO_4.—The filtrate from D (= 1 gramme of the sample) is acidified with HCl, raised to boiling point, barium chloride added in slight excess, and the mixture kept hot on a sand plate for a few hours. The precipitated Ba SO_4 is then filtered off, washed, dried, ignited and weighed. The weight of the precipitated $\times$ 0·6094 $\times$ 100 = % Na_2 SO_4.

The soda smelt rapidly absorbs moisture from the air, and in consequence, care must be taken to keep the sample in closely-stoppered bottles. Moreover, on exposure to the air, the sulphide of sodium is converted by oxidation into sulphite (Na_2 SO_3). When the smelt is run in the molten state direct into water, this oxidation is avoided. The analysis of the liquors thus obtained may be carried out as above, but in ordinary manufacturing practice it is scarcely necessary to determine more than the total alkali (Na_2 O, Na_2 CO_3, NaOH and Na_2 S). This can best be done by first determining the total alkalinity with normal acid and methyl orange; second, the caustic soda NaOH with normal acid and phenol-phthalein; and, third, the sulphide with $\frac{N}{10}$ iodine, using starch as the indicator. The phenol-phthalein test gives the caustic, and this deducted from the total alkali gives the soda existing as carbonate and sulphide, from which the sulphide is deducted to obtain the soda present as carbonate. The author has found it advantageous to reckon the Na_2 CO_3 and Na_2 S on 100 alkali (Na_2 O) obtained by the methyl orange test, as by this mode of expressing the results any change from day to day in the composition of the liquors can be accurately observed.

CHINA CLAYS.

Colour, fineness, and plasticity are the necessary features of china clays for papermaking. The examination of clays is carried out as follows :—

Water. — Ignite 2 grammes of the clay in a porcelain crucible at a red heat. The loss in weight $\times$ 50 = per cent. of water (free and combined).

Iron.—Digest one gramme of the clay about 212° Fah. in pure hydrochloric acid for a few hours, dilute with distilled water, filter, and add a few small crystals of yellow prussiate of potash to the filtrate. The depth of the colour (Prussian blue) formed is a measure of the amount of iron.

Lime.—The presence of lime is deleterious to the sizing, due to the formation of lime soap. One gramme of the dry clay is fused in a platinum crucible with 5 grammes of a mixture of carbonates of soda and potash, at a red heat till the fused mass becomes quiescent. The flux is allowed to cool, dissolved in H Cl, the fluid neutralized with ammonia, and then filtered. Add to the filtrate ammonium oxalate. If lime be present in any quantity a white precipitate will be formed.

Fineness.—To ascertain whether sand, undecomposed rock, and other coarse bodies are present, 20 grammes of the clay are rubbed up with water in a mortar, and then sieved through wire gauze, 100 meshes to the inch. The residue remaining on the sieve may be weighed.

Plasticity.—The measure of the plasticity of a clay for papermaking is best carried out in the following way :—Make up a thin starch paste by boiling 1 gramme of starch in a litre of water. Place 100 c.cs. of this paste together with 5 grammes of the sample of clay in a graduated glass, and shake well. Allow to stand at rest for 24 hours. The finer and more plastic the clay, the greater its miscibility with the starch paste—*i.e.*, the less it settles to the bottom of the vessel. Various samples may be compared in this way.

Colour.—The comparison of different clays for colour or whiteness is carried out by separately mixing the different samples with water to a thick paste, and placing them on a porcelain slab side by side for examination.

STARCH.

Starch is sometimes adulterated with gypsum, clay, or chalk, and in order to examine it for these bodies ignite 5 grammes or so of the sample in a platinum crucible, with free admission of air ill the carbon is burnt off. The residue is weighed, and the percentage of ash calculated. Pure starch should leave on burning only traces of ash. If there is considerable ash left, divide it into three parts, to one add dilute $H_2 S O_4$, and if effervescence takes place carbonate of lime is present. If the effervescence is not so marked, gypsum or clay may be present. To ascertain whether the former is so, a second portion of the residue is placed upon a filter and washed with cold distilled water. Heat the filtrate and add alcohol. If the fluid turns turbid, gypsum is present; if, on the other hand, no turbidity is produced, the third portion of the ash is gently heated with concentrated H_2SO_4 in a platinum dish over a spirit lamp, and, after cooling, the thin pasty fluid is diluted by pouring it into distilled water. Filter and add carbonate of soda solution to the filtrate till no further effervescence takes place. If a precipitate is formed, clay is present.

In the foregoing tests the water and chemical reagents must be perfectly pure.

Starch is sometimes adulterated with woody fibre, and in order to ascertain whether or not this is present, 20 grammes starch are rubbed down with 200 c.cs. of diluted hydrochloric acid, and boiled a quarter of an hour. The starch is thus converted into a soluble combination. The fluid is filtered whilst warm, and the residue in the filter boiled for a short time in a dilute solution of potash lye. The residue is again filtered off, washed with hot water till the washings are free from alkali, and dried at 212° Fah. and weighed.

RESIN.

Examination of Resin.—Good resin should on breaking show a glistening fracture, and should appear clear and transparent when held towards the light. It usually contains 5 per cent. of mechanically mixed impurities, and when it contains turpentine it appears turbid or cloudy. The following process has been recommended as a means of ascertaining its value for paper manufacture. 100 grammes are dissolved in a capacious glass vessel with 25 grammes of carbonate of soda, and water. When effervescence has ceased, the mixture is allowed to cool, and the black or brown lye removed by decantation. Dissolve 25 grammes of ammonia soda in $\frac{1}{8}$th of a litre of water, add to the resin soap, and shake well, heat to boiling, allow to cool, and finally pour off the separated lye. The resin soap is now dissolved in a litre of distilled water, and then decomposed with the addition of dilute sulphuric acid—*i.e.*, the acid is added till the mixture shows a strong acid reaction with blue litmus paper. The precipitated resin sinks to the bottom, pour off the clear liquid, and wash several times by decantation with pure water. The precipitate is then removed, and placed upon a piece of blotting paper to drain, then dried in the air on a porous earthenware tile, and, lastly, weighed. If the fluid remains turbid or milky after the addition of the dilute sulphuric acid it may be filtered.

WATER.

The bodies present in water which have an influence on the operations of papermaking are chiefly lime, sulphuric acid (sulphates), chlorine (chlorides), and iron.

The presence of LIME may be detected by adding oxalate of ammonia to a quantity of the water placed in a clean test tube, and if a white precipitate is formed after heating, lime salts are present.

SULPHATES may be detected by acidifying a small quantity of the water with a drop or two of H Cl, and adding barium chloride. A white precipitate indicates the presence of sulphuric acid (sulphates).

CHLORIDES are detected by adding nitrate of silver to the water, acidified with a drop of pure nitric acid. A white precipitate of chloride of silver indicates the presence of chlorides.

IRON is usually detected by means of yellow prussiate of potash. This salt forms Prussian blue with iron salts. A test tube, 12 inches long by $1\frac{1}{2}$ inches in diameter, is filled with the sample of water, and a small crystal of yellow prussiate of potash added. Shake, and allow to stand 15 minutes or so. By looking down the tube very small quantities of Prussian blue, due to the presence of iron, can be detected.

Lime salts (and magnesia) are almost invariably present in all natural waters, and hence these are more or less "hard." On heating such waters the carbonic acid holding the lime in solution is driven off, and carbonate of lime is precipitated. The sulphates and chlorides remain in solution for the most part. The "total hardness" of a natural water is therefore divided into "temporary hardness" and "permanent hardness"—the former representing the bodies (chiefly lime) which are precipitated by boiling the water to, say, $\frac{1}{5}$th of its bulk, whilst permanent hardness represents those bodies which remain in solution after such treatment. The hardness of a water is expressed in degrees, each one of which, according to Frankland's scale, represents 1 grain of calcic carbonate, or its equivalent of any other calcium or magnesium salt, in 100,000 grains of water (=0·01 grm. per litre). On the other hand, one degree of hardness, as indicated by Dr. Clark's soap test, is equivalent to one grain of calcic carbonate per gallon. Dr.

Clark's soap test is carried out as follows:—*Total hardness.* —Place 70 c.cs. of the water in a well-stoppered glass bottle, and add a standard Clark's soap solution from a burette, little by little at a time, and shaking up well after each addition, until a permanent froth is formed on the surface of the water. The c.cs. soap solution = degrees of total hardness. *Permanent hardness.*—70 c.cs. of the water are evaporated to $\frac{1}{5}$th of its bulk, filtered through a small filter of Swedish paper, and the filtrate, after being made up to 70 c.cs. with distilled water, treated with the soap solution in the above way. The number of c.cs. consumed represents the degrees of permanent hardness of the water. *Temporary hardness* is obtained by deducting the number of degrees of permanent hardness from the degrees of "total hardness."

EXAMINATION OF COAL.

1. Moisture.—Heat 100 grammes of the sample to 105° C. (not above) for two hours or so in a covered crucible, to prevent free ingress of air. The crucible must be covered to avoid partial oxidation and escape of volatile matter. Towards the end of the drying process the weight should remain constant. Loss of weight = per cent. of moisture.

2. Fixed Carbon or Residual Coke.—5 grammes of the sample are placed in a deep, narrow platinum crucible, provided with a tight-fitting cover, and heated to a dull redness over the flame of a Bunsen's burner until volatile matter ceases to escape. The flame of the burner should be large enough to envelope the crucible and maintain it in a state of uniform redness. The crucible should be supported on a triangle of thin platinum wire. The test is repeated two or three times, and the average weight of coke obtained, multiplied by 20, noted as the true percentage of fixed carbon.

3. Ash. The fixed carbon or coke obtained from the tests in 2, is pulverised in a mortar, dried, and one gramme weighed off, placed in a platinum crucible, and ignited over the flame of the Bunsen burner till all carbon is burnt off. The weight of ash obtained, multiplied by the percentage of fixed carbon, gives the per cent. of ash. The crucible should be supported on a thin platinum triangle, and tilted slightly on one side, to allow freer access of air; or, better, it is fitted in a hole in an asbestos board, and placed in a slanting position on a tripod stand. The asbestos board serves to separate the air required for oxidation from the gases of the burner, and thus greatly hastens the combustion of the carbon * * * * If the ash in a coal is to be determined, then one gramme of the coal is weighed off and ignited as above, the result being multiplied by 100 to find per cent.

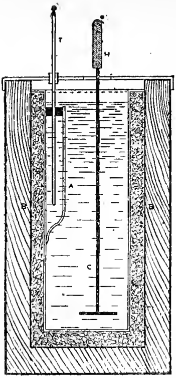
4. VOLATILE MATTER. — This is usually obtained by difference; that is to say, the sum of the percentages of moisture, coke, and ash found above, are deducted from 100, the remainder being noted as volatile matter.

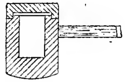
CHIMNEY GASES.

In these CO_2, O, CO, and N (by difference) are most conveniently estimated by means of the well-known Orsat's apparatus. In this apparatus the CO_2 is estimated by absorbtion with aqueous solution of caustic potash of specific gravity 1.20 – 1·28. The oxygen by absorbtion with thin sticks of phosphorus, $\frac{1}{8}$th inch diameter, kept at a temperature of 18° C. under water, and free from light and tarry matters, &c. The absorbtion is too slow at a less temperature than 18° C. Pyrogallate of potash—pyrogallic acid in aqueous solution of caustic potash—is frequently used for determining the oxygen. Phosphorus is preferable. The carbonic oxide CO, is determined by absorption in cupric chloride dissolved in hydrochloric acid in the presence of metallic copper (10 grammes Cu Cl_2 90 c.cs. of concentrated H Cl, 20 c.cs., water and sheet copper sufficient to reduce it, the whole brought together at least 24 hours before using). This solution should be frequently renewed.

TEMPERATURE OF FLUES.

Up to 300° C. the temperature of flues can be taken by means of long mercurial thermometers, taking care that the bulb of the thermometer is well in the stream of the flowing gases, or towards the centre of the flue. The stem should be long enough that the readings can be taken while the thermometer is in place. For temperatures higher than this, Fischer's Calorimetric Pyrometer is the most suitable apparatus. It consists of (1) a wrought-iron box with lid, welded to the end of a long rod, by means of which it can be thrust into the space whose temperature is required. (2.) A small cylinder of wrought-iron, copper, or platinum, preferably the former, say, 2 c. long by 1 c. diameter, whose weight is accurately known. This cylinder is placed in the iron box, and exposed to the heat of the furnace or flue. (3.) The Calorimeter, a cylindrical vessel made of thin sheet copper, about 6 c. diameter by 15 c. deep. This vessel is enveloped by a wrapping of soft loose wool, fur, or such like





substance, and then by a thick wooden jacket. It is provided with a brass cover, having two holes, through one of which a fine stencilled thermometer graduated in tenths of degrees is passed, whilst the other, 2 c. in diameter, is for dropping in the hot cylinder. Through this hole the wire handle of a copper disc, a little less in diameter than the vessel, also passes, which serves as a stirrer. The operation of taking the temperature is performed as follows:—The Calorimeter is filled two-thirds with an accurately weighed or measured quantity of water, and its temperature t°, taken with the thermometer, is read off and noted. Immediately afterwards, the small iron cylinder (2), which should have been exposed in the iron box (1) for at least twenty minutes in the flue or furnace, whose temperature is to be ascertained, is rapidly withdrawn and dropped into the Calorimeter. The cylinder falls upon the disc of the stirrer, which is rapidly moved up and down, the temperature meanwhile being constantly watched. When this is at its maximum it is read off and noted as t^1. If p = the weight of the metal cylinder, and c = its specific heat (specific heat of copper = 0·094 : of wrought-iron 0·114 ; for platinum 0·032, but these increase with the temperature, so that there is here a source of inaccuracy) ; p^1 = the weight of the water within the Calorimeter, added to the water-weight of the copper vessel and stirrer itself (water-weight means the actual weight multiplied by the specific heat, *i.e.*, 0·094 for copper; the thermometer, if very slender, may be left out of the calculation). The temperature of the hot cylinder T is found by the formula:—

$$T = t^1 + p^1 \frac{(t^1 - t^\circ)}{p\ c}$$

If p^1 and p are constant, the magnitude $\frac{p^1}{pc}$ can be converted into a factor, by which the difference of thermometer readings is multiplied, thus at once yielding the temperature sought, after the first temperature t^1 has been added to the product. For practical purposes it is convenient to choose the quantities, so that this factor becomes a simple number. For very high temperatures the value $\frac{p^1}{p\,c}$ should not be less than 50. For lower ones it will be sufficient if it is 25, but it should not be chosen less than 25. The same factor will, with the same apparatus, yield Fahrenheit degrees if a Fahrenheit thermometer is used instead of a Centigrade one. The mean specific heat of iron between o° C. and t° C. is $G = 0{\cdot}1053 + 0{\cdot}000071\ t^\circ$ (Bède). By means of this value for the mean specific heat of iron, the temperature can be calculated according to the formula:—

$$= \sqrt{\left(\frac{p^1\,(t^1 - t^0) + pt^1\,(0{\cdot}1053 + 0{\cdot}000071t^1)}{0{\cdot}000071\ p} + 549822\right)} \quad 741{\cdot}47$$

(Akali Maker's Handbook.)

PAPER TESTING (Machine Made).

(Based on Hertzberg's "*Papier Prüfung.*")

1. The *absolute strength* of a paper is determined by ascertaining the weight necessary to break a strip of standard width, but as the strain which is required to break the strip varies with the thickness of the paper, Hartig expresses the results in so-called "breaking length." This is calculated from the power used to break the strips, and from their weight. *Breaking length* is defined as that length of paper of any breadth and thickness which when suspended would break by its own weight at the point of suspension. Breadth and thickness have no influence on this value.

Machine-made paper is stronger in the direction in which the machine runs than at right angles to it or across the machine, the difference being usually in the proportion of 15 to 12. The expansion also varies, being less in the machine direction than across, the proportions being very nearly the same as those of the strength. The same differences are found in hand-made papers, but in a less degree.

To determine the "tensile strength" it is first of all necessary to ascertain the "machine" and "cross" direction of the sheet of paper under examination. In the case of sized papers, cut a disc, three inches diameter, float it on water to thoroughly wet one side only, remove to the palm of the hand, wet side downwards, until two sides bend and curl inwards. A line drawn through the centre of the sides which have curved upwards is the direction across the machine, and one at right angles to this indicates the "machine" direction. Cut off five strips parallel to each direction, 180 cm. long by 15 mm. wide (best done by a machine constructed for the purpose, but, failing this, with an iron ruler, zinc plate, and sharp knife), and carefully mark each. It is necessary to make five individual tests with the strips cut from the two "directions" in order to average them. The best machine for ascertaining the breaking weight of the strips is that invented by Louis Schopper. This machine registers automatically the breaking weight in kilogrammes, and the amount of stretch in per cents. and millimetres, which the strip of normal length—viz., 180 mm. long—undergoes during the trial. It is not necessary to make more than five trials with strips cut from the sample in each direction. The average breaking weight and expansion or stretch is recorded in each case, and the strips torn off from between the clamps of the testing machine should be rolled up and afterwards weighed, the total weight of the five strips and the average being duly recorded. The length between the clamps is exactly 180 mm. These figures may be catalogued as follows:—

Machine Direction.				Cross Direction.			
Strip No.	Breaking Strains. Kg.	Expansion. %	Weights. grammes.	Strip No.	Breaking Strains. Kg.	Expansion. %	Weights grammes.
Total				Total			
Average				Average			

Assuming the average breaking weight expressed in kilogrammes to be a, and the average weight of the five strips, each 180 mm. long, to be b, and x the breaking length in metres, then,

$$\frac{0{\cdot}180}{b} = \frac{x}{a \times 1{,}000}; \text{ or } x = \frac{0{\cdot}180}{b} \times a \times 1{,}000.$$

If, for example, $a = 2{\cdot}44$ kilogrammes, and $b = 0{\cdot}210$ gramme,

$$\text{then } x = \frac{0{\cdot}180}{{\cdot}210} \times 1{,}000 \times 2{\cdot}44; \text{ or}$$

$$\frac{0{\cdot}180 \times 1{,}000 \times 2{\cdot}44}{{\cdot}210} = 2{,}091 = x.$$

If x is expressed in kilometres, then this result is 2·091.

It is obvious that, 0·180 being a constant and b a variable, a table can be constructed giving the values of the quotient $\frac{0{\cdot}180}{b}$ for different values of b, and such has been given by Hertzberg. This table is useful in simplifying the calculations, and will be found at the end of the late Mr. P. Norman Evans' translation of Hertzberg's work, "Papier-Prüfung."

It has been observed by Hertzberg and others that a small increase in the percentage of moisture in a paper diminishes its strength, and therefore the humidity and temperature of the air in which the paper has lain for some time should be ascertained with a per cent. hygrometer, and duly recorded.

2. *Resistance to folding and crumpling.*—This was formerly ascertained empirically by rubbing or "washing" the paper by hand, but a very ingenious machine has recently been invented whereby the resistance to folding and crushing is recorded in figures. This machine is patented and made by L. Schopper, of Leipsic, but is too complicated for description here.

3. *Determination of thickness.*—The thickness of a paper can be roughly ascertained by placing a known number of sheets one upon another, pressing the pile, and then measuring it. The figure giving the height of the pile divided by the number of sheets gives the thickness. Two handy forms of apparatus are, however, now commonly used for this purpose, viz., Reitz's and Schopper's micrometers. Schopper's micrometer is, perhaps, the best and most reliable, as the pressure is always the same. The thickness of the sheet in fractions of a millimetre is read off directly from the scale of the instrument.

4. *Determination of the ash.*—This is invariably ascertained by incinerating a known weight, say one gramme of the paper in a platinum or porcelain crucible till all carbon has been burnt. The weight of the whitish residue, when one gramme is taken for the test, multiplied by 100 gives the per cent. of ash. The ash represents the mineral matter or inorganic

compounds contained in the paper, and chiefly consists of some of the well-known mineral loadings, such as china clay, pearl hardening (precipitated sulphate of lime), and gypsum; "*blanc fixe*" (precipitated barium sulphate), heavy spar (native barium sulphate); ochres, umber, asbestine, &c. The composition of the ash can only be ascertained by an exhaustive chemical analysis.

5. *Microscopical investigation.*—The object of such an investigation is to ascertain the fibres from which the paper is made, their physical condition, and their relative proportions to one another. It is only possible to do this by studying the physical structure of the most commonly occurring fibres, such as wood cellulose, esparto, straw, jute, cotton, linen, hemp, and mechanical wood, so that these may be recognised with certainty under the microscope. The subject is too large to be treated exhaustively in this book, but the mode of preparing the fibres for such an examination, and the behaviour of the commonly occurring fibres towards well-defined chemical solutions, can be profitably given, as also the main features of the fibres themselves.

Hertzberg, in a recent communication to the Königl. techn. Versuchanst zu Berlin, recommends the following mode of treating the paper preparatory to examination:—Cut small pieces of the paper from different sheets, place them in a porcelain basin and mascerate for a short time in a cold 4 per cent. aqueous solution of soda, add water, and finally heat to boiling. If mechanically ground wood is present, the paper will assume a pea-yellow coloration. Boil for 15 minutes, and throw the whole on to a small sieve of fine wire gauze and thoroughly wash. Remove the pulp to a wide-mouth, glass-stoppered bottle containing a number of glass balls (small garnets are very suitable), add some water, and shake till a thin uniform pulp is produced. Drain the pulp on a fine sieve.

In the above treatment any wool present disappears, since it is soluble in caustic soda; and therefore papers containing wool fibre must be treated with water only. Coloured papers do not, as a rule, require any special treatment. If, however, the colour refuses to disappear, it may be removed by a solvent or reagent such as alcohol, hydrochloric or nitric acids, hypochlorite of lime, &c.

A small portion of the prepared pulp is then removed from the sieve by means of a platinum needle with lancet-shaped point, pressed between clean filter paper or on a porous slab of porcelain, and placed upon a microscopical glass slide by a fine platinum needle. The recognition of the fibres is greatly facilitated by the use of certain colouring solutions, of which the two following are recommended, viz.:—

Solution I.—Water, 20 c.cs.; potassium iodide, 2 grammes; iodine, 1·15 grammes; glycerine, 2 c.cs.

Solution II.—Prepare first (*a*) 20 grammes of dry zinc chloride in 10 c.cs. of water; (*b*) 2·1 grammes of potassium iodide, and 0·1 gramme of iodine in 5 grammes of water. Mix *a* and *b* together, allow the precipitate to settle, and decant off the clear fluid. Finally, add a little iodine.

The micro-chemical reaction, or the coloration produced in the different fibres by these solutions, is as follows:—

Fibres.	Coloration.	
	Solution No. 1.	Solution No. 2.
Linen, hemp, and cotton	Pale to dark brown. Thin scales almost colourless.	Pale to dark wine-red.
Wood cellulose... ...	Grey to brown.	Blue to reddish-violet.
Straw cellulose and jute	Grey.	Blue to bluish-violet.
Esparto	Part grey and part brown	Part blue and part wine-red.
Manilla hemp	Part grey, part brown, and part yellowish brown.	Blue, bluish-violet, reddish violet, dirty yellow. greenish-yellow.
Wood (ground) and raw jute	Part yellowish brown and part yellow.	Lemon yellow to dark yellow.
Straw	Part yellowish brown, part yellow and part grey.	Part yellow, part blue, and part bluish-violet.

The prepared fibres on the glass slide are saturated with a drop or two of either of the above solutions, the individual fibres separated from one another by stirring with the platinum needle, and then a glass cover carefully placed over the drop of liquid containing the fibres. The excess of fluid surrounding the glass cover is removed with blotting or filter paper before placing the slide under the microscope.

A microscope capable of magnifying from 300 to 550 times will cover all necessary requirements.

The following are the main structural characteristics of the fibres commonly used in paper-making:—

Linen.—Maximum length of original plant fibres, 4 centimetres. They are about one-half the thickness of cotton, with tapering ends, and chiefly characterised by the repeated thickening of the cell walls, forming knots at short intervals. The knots are often flattened during the beating process, causing the fibre to break at the point where they occur.

Central canal very narrow, frequently appearing as a dark line. Walls of cells are perforated with numerous pores, running from the interior to the exterior, and appearing as dark lines.

HEMP.—Closely resembles linen; the central canal is, however, broader, being about a quarter to one-half the diameter of the cell. The membrane of the cell is distinctly marked (striated) in the direction of its length.

COTTON.—Fibres have a maximum length of 5 centimetres, and are formed of single tapering cells. The diameter of the cell is about two-thirds of the total diameter, and the walls are flattened and twisted spirally. The treatment in caustic soda and in the beating engine counteracts to a large extent this tendency of the fibre to twist.

MECHANICAL WOOD.—(*Pinus sylvestris*, *pinus picea*, *pinus abies*.)—The structure of the fibres is very similar in the whole group of pines, and are distinguished by minute differences in their cells. These cells have their walls characterised by spots or pores, generally appearing as two concentric rings. Spots on cell wall in autumn and spring wood appear more or less elliptical. Note also the cells of the medullary rays, which run from the centre to the outside of the stem in the shape of a star, and are remarkable for their latticed structure. (See chemical tests for mechanical wood in papers, page 174.)

WOOD CELLULOSE.—What is true of mechanical wood is also true of pine wood cellulose. This is characterised by the ring-surrounded pores or the dotted wood cells. Frequently, however, these characteristics are destroyed, owing to the chemical treatment to which the wood has been subjected. The cells of the medullary rays are generally absent. Many of the fibres show the same spiral twisting as cotton, and a latticed striping of the cell membrane. Pine cellulose remains colourless, whilst cotton cellulose is turned brown with iodine solution. If the cellulose has been badly prepared, iodine will colour the fibres slightly yellow.

STRAW CELLULOSE.—From wheat, rye, barley, and oat straw. Note the characteristic cells of the epidermis, which are thick-walled, more or less silicious, with jagged edges. These cells are joined to one another by their ragged edges, and very occasionally are grouped. They occur in various sizes. The edges are frequently deeply serrated, sometimes only slightly uneven. The most numerous cells, however, are the bast cells—long thin fibres of regular structure, with a small internal canal. At regular intervals the walls thicken, giving the fibre a knotted appearance, and the central canal narrows at these points, broadening out again on either side. Note also numerous pores, which appear as dark lines running from the canal to the exterior. Also the great number of very thin-walled parenchyma cells, rounded at both ends at times, sometimes almost circular, sometimes long, and covered more or less with simple pores. The presence of these cells distinguishes with certainty straw from esparto cellulose. Further, notice the sclerenchyma—very thick-walled silicious cells, somewhat bluish in appearance.

ESPARTO CELLULOSE.—Structure of cells similar to that of straw cellulose. As a general rule esparto cells are finer and dimensions smaller than in straw. The bast cells are very short, are unevenly built with thick walls, so that frequently the central canal appears only as a line, while the irregularities in the curves of the canal so noticeable in straw are not to be found in esparto. Epidermic cells resemble those of straw cellulose. The large thin-walled parenchyma cells are entirely absent in esparto, but the sclerenchyma cells are found. The presence of small teeth-like bodies, which come from the leaves of the plant serves to prove the presence of esparto cellulose.

JUTE.—The walls are sometimes very thin and suddenly thicken, narrowing the central canal to a mere line. The fibres are often joined together in bundles, which prevents the identification of the cell structure. Occasionally they exhibit pores and knots similar to those in linen cellulose, and possessing a yellow-brown colour.

NOTE ON THE MICROSCOPICAL EXAMINATION OF PAPERS.—No written description of the characteristics of the different varieties of fibres used in the paper manufacture will suffice as a safe guide, and the investigator is recommended to use the numerous charts published, to give him the correct forms. With these charts there is no difficulty in ascertaining the true characteristics of each fibre, and in that way more certainly isolate them in the examination of any individual paper.

6. The chemical examination of papers:—

ANIMAL SIZE.—A small quantity of the paper is macerated in hot water and the liquid filtered. Add a small quantity of tannic acid to the filtrate. The formation of a turbid precipitate or cloudiness indicates the presence of animal size. Hefelmann recommends the following method:—Boil 10 grammes of the paper in pieces, in a porcelain dish, with 120 c.cs. of water till about 25 c.cs. water are left, filter off the liquid into a flask, add 5 grammes of potassium sulphate, and shake well, in order to precipitate the gelatine or glue in a flocculent state. The precipitate is then filtered off, washed to the bottom of the filter, the top part of the latter torn off, and the lower part, with the precipitate, dried by pressing between blotting paper. This is then mixed with soda lime, placed in a small combustion tube, and the latter heated in a furnace or over a long gas flame. The gases issuing from the tube are then tested for ammonia with moistened red litmus paper, or by vapour of HCl in the usual way.

Resin Size.—Half a sheet of the sample is torn up into small pieces, placed in a beaker, and absolute alcohol poured over it. Place the beaker and contents in hot water for 30 minutes or so. Both resin and resinate of alumina are dissolved by the alcohol, and if the solution be poured into distilled water a milky precipitate (or cloudiness) will be produced if resin is present.

Starch.—The presence of starch is best ascertained by immersing a strip of the paper in a very weak solution of iodine (in aqueous potassium iodide). A blue coloration will be formed if this body is present.

Free Acid.—"Congo red" is recommended by Hertzberg as a reagent for showing the presence of free acid in papers, also methyorange (Dimethylaniline-orange). The latter is transformed from bright yellow to purple red by acids, whilst acid salts—*e.g.*, alum and sulphate alumina—effect no such change.

Mechanical Wood. — There are many reagents for indicating the presence of mechanical wood in papers, the following being the most important.

Sulphate of Aniline.—Paper containing mechanical wood steeped in a hot 5 per cent. aqueous solution of this salt turns a bright yellow, the depth of colour being proportionate to the amount of wood present. Pure cellulose papers are not changed. Esparto papers turn a faint pink. An alcoholic solution of Orcin, to which H Cl has been added, yields a powerful dark red coloration with mechanical wood.

Resorcine, dissolved in alcohol containing H Cl, colours wood blue-violet. Pure cellulose papers remain unchanged.

Phloroglucine (4 grammes in 25 c.cs. alcohol and 5 c.cs. pure concentrated H Cl) colours wood an intense red. This is the most delicate test for mechanical wood in papers.

7. Determination of the Strength of the Sizing.—The Leonhardi-Post method consists in placing uniform drops of an aqueous solution of chloride of iron, containing 1·531 per cent. of iron, upon samples of the paper, and allowing the iron solution to soak into the sheet for as many seconds as the paper weighs in grammes per square metre. The unabsorbed fluid

is then immediately removed with blotting or filter paper, and the water allowed to evaporate. When this has been repeated 4 or 5 times, the paper is reversed and painted with an aqueous solution of tannic acid, the excess of this fluid being removed with filter paper as formerly. The tannic acid acts upon the chloride of iron which has passed through the paper, causing a black stain, the intensity of which is a measure of the strength of the sizing. A number of tests should be made in each case to obtain an average.

WOOD PULPS.

Sindall has made exhaustive experiments respecting the methods of sampling, &c., wood pulps, and recommends the following:—

The sample.—*Moist Pulp.* Two per cent. of the number of bales composing the consignment is considered sufficient, provided the weight of the whole bulk calculated from this 2 per cent. agrees with the gross weight actually found. Five sheets are taken from each bale to be sampled—one from the centre, two on each side midway from centre to outside, and two taken one inch from the outside of the bale. These sheets are then divided by imaginary lines into four rectangular parts, and pieces are cut out from the centre of the four rectangles. These pieces are at once transferred to a light glass bottle which may be previously tared. *Dry Pulp.* Sheets are selected from different parts of the bale as above described, and small strips, 6 inches long by half an inch wide, cut from a spot near to each of the four corners, and one from the centre. These strips are also at once transferred to a clean, dry bottle. Samples can be taken in duplicate.

Testing the samples.—The bottle and its contents should be weighed previous to removing the sample to the water bath for drying, and by deducting the tare of the bottle the correct weight of the moist sample is obtained. The moist sample may also be weighed by itself before drying, as a check on the other weight. The sample is then placed on a shallow tray of wire gauze and transferred to a water bath, where it remains till the weight is constant. The temperature of the bath or water oven should not be less than 212° Fah. An air bath may also be used, whose temperature should never exceed 219° Fah. Schopper's apparatus, consisting of a balance and air bath, permits of the operation of drying and weighing the dried sample without removing it from the air bath, and can be recommended for testing all kinds of moist and air-dry pulps.

The results are usually expressed in per cents. of air-dry pulp—that is, pulp containing 10 per cent. of moisture (England). Obviously oven-dry weight, multiplied by 100 and divided by 90, gives this air-dry weight. The following table of simple formulæ has been constructed with a view to tersely express the various calculations in ascertaining the moisture, &c., in pulps:—

Found. Letter A =	Required.	Formula.
% Absolutely dry pulp.	% Air-dry pulp.	$\frac{100\,A}{90}$
% Air-dry pulp.	% Absolutely dry pulp.	$\frac{90\,A}{100}$
% Total moisture.	% Air-dry pulp.	$\frac{(100-A)\,100}{90}$
% Excess moisture.	% Air-dry pulp.	$100-A$
% Excess moisture.	% Absolutely dry pulp.	$\frac{(100-A)\,90}{100}$

The British Wood Pulp Association and the English and Scottish Paper Makers' Association have officially compiled and issued a test certificate form for the use of analysts, of which the following is a copy:—

WOOD PULP MOISTURE TEST.

ANALYST'S CERTIFICATE. Adopted by the British Wood Pulp Association and the English and Scottish Paper Makers' Associations.

________________________19

This is to Certify that I/we have tested for moisture a parcel of__________pulp, said to consist of__________ bales, marked____________________
lying at____________________.

The samples were drawn by__________on__________

Number of bales sampled ... ...____________________

	Tons.	Cwts.	Qrs.	Lbs.
Total gross weight of (intact) bales sampled. (*For numbers and detailed weights see below*)	:	:	:	
Weight of parcel calculated from above	:	:	:	

Percentage of absolutely dry pulp in the sample... ... ...__________per cent.

Percentage of moisture in the sample ... ...__________per cent

Percentage of air dry or moist pulp in the sample, on the basis of—

90=100 (Air-dry) ... ...__________per cent

45=100 (Moist) ... ...__________per cent

Percentage of excess ... ... {Moisture / Fibre ...} __________per cent.

	Tons.	Cwts.	Qrs.	Lbs.
Weight of pulp to be invoiced...	:	:	:	

	£	s.	d.
Fees ...	:	:	
Expenses	:	:	

*Analyst*____________________

____

*Date*____________________

*To*____________________

____

CHAPTER VI.

LOADING MATERIALS.

Loadings are employed to give weight to a sheet of paper, to render it opaque, and to impart a certain smoothness of surface (especially in the case of china clay or kaolin) to make the sheet of paper more absorbent or susceptible to printing inks. Their properties vary somewhat as detailed below.

China Clay is the most important mineral loading used in the manufacture of paper and is essentially a hydrated silicate of alumina of the general formula Al_2O_3 2 SiO_2 2 H_2O. According to this formula it should contain 39·72 per cent. Al_2O_3; 46·36 per cent. SiO_2 and 13·92 per cent. of water, which is substantially the composition of the commercial clay when freed from undecomposed rock. Sp. gr. 2·20 to 2·60. It is the product of the natural disintegration of felspar, and occurs in large deposits in Cornwall and Dorsetshire, which counties have provided the main sources of supply in England for many years. To prepare it for industrial purposes, the clay deposits are largely diluted with pure water and the resulting milky fluid passed in succession through a series of settling areas in which the fine clay deposits. By this system of levigation deposits of varying degrees of fineness are obtained. When the areas are full, the surface water is drained off and the clay allowed to dry sufficiently to be handled with a shovel in blocks. The partly-dried clay is then removed and further dried in stacks before shipment. In the air-dried state, china clay is white or nearly so. When moistened with water it assumes a more or less greyish tint, which, however, disappears again on drying at 212 Fah. It loses water on ignition at a red heat, and if iron be present in quantity the ignited clay assumes a yellow colour due to the presence of ferric oxide. China clay may be added direct to the beating engine for most printing and cheap writing papers, but if it be preferred, it may be previously mixed into a thick cream with water in a tank containing an agitator and passed through a fine brass sieve having 70 meshes to the linear inch. The impurities separated by the sieve are grit and jute fibres, the latter derived from the jute bags in which it is frequently packed for export. Some manufacturers add from 5 to 10 per cent. of starch to the clay prior to or after heating and straining, in order to cause it to adhere more readily to the fibres. In some cases this is advantageous. Rosin size no doubt facilitates the adhesion of the clay to the fibres as well. The peculiarities imparted to the paper by the presence of this loading are opaqueness, whiteness, and increased softness of surface. It also increases the absorbing power of the paper to printers' ink, thereby allowing a clear impression of the type and illustration to be run off rapidly. The soft greasy character of the clay produces this effect, while its great fineness enables it to be distributed very evenly and intimately throughout the texture of the paper. It has also a certain affinity for aniline dyes that adds to its value in the production of tinted papers. Next to colour, the most important item in the purity of china clay is its freedom from grit and dirt. Of 100 parts of clay added to the beater, from 60 to 75 parts can be obtained direct in the paper, depending upon the amount of mineral matter required as ash in the finished sheet, but if an efficient system of utilising the sedimentary matter in the "back" water from the paper machine be in use, the yield can be increased to 85 or 90 per cent. The following is an analysis of a commercial china clay, viz. :—$Al_2 O_3$, 39·37 per cent. ; SiO_2 45·89 per cent. ; CaO 00·35 per cent. ; MgO 00·4 per cent. ; FeO, 00·23 per cent. ; combined water, 10·80 per cent. ; hygroscopic water, 2·45 per cent. ; alkaline bases, &c., 00·50 per cent. The iron in china clays usually exists in the ferrous state.

Sulphate of Lime.—This loading is known in commerce under various names, such as pearl and crystal hardening, terra alba, gypsum, &c. These various kinds although alike in chemical composition, namely. $Ca SO_4 + 2 H_2O$ yet differ from one another in physical properties and in the effects they produce. Pearl and crystal hardening are the purest and finest forms of this loading. When dry they correspond in composition to pure sulphate of lime, $Ca SO_4 + 2 H_2 O$, and contain 79·07 per cent. $Ca SO_4$, and 20·93 per cent. of water of crystallisation. Both are prepared artificially by precipitation. For this purpose a solution of saltcake or crude sulphate of soda, previously freed from iron and sedimentary matter by precipitation with lime or soda, is added to a solution of chloride of calcium, whereby hydrated sulphate of lime is thrown down from the solution thus :— $Na_2 SO_4 + CaCl_2 + aqua = Ca SO_4 + 2 H_2O + 2 NaCl$. The precipitate is washed and finally dried in a hydro extractor. As it occurs in the market it is a pure, soft, white substance, somewhat plastic to the touch, free from grit or large crystals and contains about 13 per cent. of hygroscopic water. An analysis of the commercial article gave $Ca SO_4 + 2 H_2O$ =86·8 per cent.; hygroscopic water, 13·2 per cent. It imparts to the paper a greater degree of whiteness than china clay, but does not bulk so well. It has a tendency to stiffen the paper, and papers loaded with it glaze and print well. Owing to its opacity, great whiteness, &c., it is used for the finest grades of writing papers. *Terra Alba, Gypsum.*—Both of these are sulphate of lime, found in extensive natural deposits in England and Nova Scotia, &c., of greater or less purity. The rock from which terra alba is prepared is colourless, or nearly so, and is practically pure $Ca\,SO_4 + 2\,H_2O$. The crystalline material is ground to an impalpable powder while perfectly dry, and contains a greater percentage of $Ca\,SO_4 + 2\,H_2O$ than pearl hardening. It is also specifically heavier and has a greater tendency to settle out in the sand trap. It imparts somewhat different characteristics to the paper loaded with it, the surface being harder and less absorbent. It does not absorb aniline dyes so readily nor possesses such whitening properties as the artificial loading. As these different forms of sulphate of lime are all soluble to a certain extent in water, there is loss through solution while using them. Artificially prepared pearl hardening passes into solution more readily than the native mineral, terra alba, due to the difference in their physical condition. To minimise this tendency to dissolve, the pearl hardening is mixed with 10 per cent. of its weight of starch and the mixture made into a thick paste with water by boiling. One hundred parts of water (10 galls.) dissolve at the normal temperature 0·224 parts of anhydrous sulphate of lime $Ca\,SO_4$ = 0·283 parts (0·283 lbs.) of the crystalline salt, $Ca\,SO_4 + 2\,H_2\,O$. It is more soluble in cold than in hot water between limits. Owing to its solubility it is obvious that as the volume of water used in the beating engine and on the paper machine is nearly constant for similar classes of papers, the less mineral required, the greater is the proportionate loss; or, the more sulphate of lime required in the paper, the greater the proportionate yield on the weight of sulphate used. This loss is greatly lessened by the use of the "back" water in the beating engines and service or mixing box of the paper machine. As hydrated sulphate of lime does not lose its water of hydration when heated to 212 Fah., it follows that the loading retains this water of hydration in the paper after passing over the drying cylinders, and that the ash of the paper obtained by ignition at a red heat represents substantially the loading less its water of hydration. An allowance or addition should therefore be made for the latter. The same holds good for china clay. As one part of anhydrous $Ca\,SO_4$ is equivalent to 1·264 parts of $Ca\,SO_4 + 2\,H_2\,O$, the percentage of $Ca\,SO_4$ found in the ash multiplied by 1·264 will give the true percentage of dry loading, whether this be pearl hardening or terra alba, *i.e.*, dry as far as hygroscopic water is concerned. In the case of china clay, since this contains 13·92 per cent. of combined water, one parts of anhydrous clay (such as is obtained as ash in the paper) corresponds to 1·161 part of dry hydrated clay. Multiply, therefore, the percentage of ash by 1·161 to find the true percentage of dry clay used. These facts should not be overlooked when comparing the relative yields of sulphate of lime loadings with china clay.

TALC is essentially a silicate of magnesia of the formula 4 MgO 5 SiO_2 H_2O, and occurs in Nature very widely distributed in masses as the mineral steatite or soap-stone. Its composition according to the formula is SiO_2 = 62·14 per cent.; MgO = 32·92 per cent.; water = 4·94 per cent. As a rule the mineral varies but little from this composition. Occasionally it contains ferric oxide, but these varieties are rejected when the mineral is intended for paper making. Sp. gr. 2·6 to 2·8. It occurs in a great variety of colours, but only the white or nearly white mineral is used as a loading. This is ground by suitable machinery to an impalpable powder and sieved, the sieved portion being alone used. It is, of course, insoluble in water, and when made from the nearly white mineral yields results in point of colour superior to the general run of china clays. It being specifically heavier than china clay and also artificially ground, it has a greater tendency to settle in the sand trap of the machine, but in ordinary cases the yield obtained from it is as great as that from china clay. Notwithstanding this mineral has a soapy feel when rubbed between the fingers like china clay, it imparts a slightly different property to the paper, but only in degree, not in kind.

ASBESTINE closely resembles talc in properties, and as the name implies, is made from asbestos rock by grinding and sifting. The powder is anhydrous, of a pure white colour, sp. gr. 2·99, and, examined under the microscope, has a somewhat fibrous appearance, in virtue of which it is claimed to possess greater adhesive properties than other loadings. Papers containing it when subjected to great pressure or friction become highly glazed, and owing to its non-hygroscopic properties it is said the gloss is more lasting than that obtained with other loadings. The surface, however, is hard and unyielding. As a general rule a yield of from 70 to 85 per cent. is obtained with ordinary care in papers containing average quantities of the mineral.

BLANC-FIXE AND BARYTES.—Both of these are sulphate of barium, $BaSO_4$, the former artificially prepared, whilst the latter is found native. Barytes is a heavy mineral very abundantly distributed, and when used as a loading is ground to a fine powder. Its sp. gr. is very high, viz.: 4·73, and application in the paper manufacture somewhat limited. Blanc-fixe on the other hand, occurs in commerce as a thick paste, and is thrown down as a pure white, very finely divided precipitate when a soluble sulphate such as sulphate of soda or magnesia is added to an aqueous solution of chloride of barium. The precipitate is allowed to subside, is washed frequently by decantation, and finally dried to the consistency of a thick paste. In this form, mixed frequently with hydrate of alumina, it is used for coating papers, either white or coloured. As a loading it is best produced in the beating engine itself by adding crystallised barium chloride dissolved in hot water and filtered through a linen cloth to the stuff in the beater after sizing. The $BaSO_4$ thus formed is in a very fine state of division, is pure white and imparts this characteristic to the paper. It is not extensively used in this way, and only then for special papers.

Satin White is often employed in place of blanc-fixe in the production of stained and other papers, and according to the *Papier Zeitung* is essentially a mixture of precipitated carbonates of magnesia or lime and hydrate of alumina. It can be made in three grades as follows:—

Grade I is produced by dissolving 100 kilos of magnesium chloride in 200 or 300 litres of hot water and filtering through a linen filter cloth into a large vat. To this solution there is added, while hot, a filtered hot solution of ammonia soda so long as a precipitate of carbonate of magnesia is formed which can readily be ascertained by the fluccose separation of $MgCO_3$. In a small vessel dissolve 75 kilos of carbonate of soda in hot water, filter through linen cloth into a larger vat and add to it with constant stirring a clear solution of 100 kilos of sulphate of alumina free from iron. The aluminium hydrate thus obtained is then washed a few times by decantation with hot water, and afterwards the precipitated carbonate of magnesia is added with constant stirring. Finally, the mixed precipitates are filtered and pressed in linen bags. To obtain the satin white of a good colour it is necessary to use pure water and sulphate of alumina and magnesium chloride free from iron salts.

Grade II is obtained by grinding 100 kilos of burnt lime in a wet mill (edge runners), preparing same into a finely-divided milk of lime and washing into a vat through a fine brass sieve. In a smaller receptacle dissolve about 45 kilos of soda ash in hot water, and, after filtration, slowly add this solution to the lime, stirring incessantly. It is essential to dilute as much as possible. In another vessel dissolve 100 kilos pure sulphate of alumina in hot water, filter and add to the contents of the first vat with continued stirring. After stirring for some time, wash with pure hot water, filter and press thoroughly.

Grade III is obtained in the same manner as Grade II excepting that 130 or 140 kilos of burnt lime are used.

CHAPTER VII.

GENERAL CHEMICAL TABLES.

AMMONIA SODA (Carbonate) is almost pure carbonate of soda, having the following composition:—Carbonate of soda, 98·94 %; sulphate of soda, 0·34 %; chloride of sodium, 0·36 %; moisture, 0·20 %; insoluble matter, ferric oxide, alumina, &c., 0·10 %. This is the purest form of commercial carbonate of soda known.

COMPOSITION OF COMMERCIAL SULPHATE OF ALUMINA AND ALUMINOUS CAKES

	Sulphate of Alumina.		Aluminous Cake.	
	No. 1 (pure).	No. 2.	No. 1.	No. 2.
	%	%	%	%
*Alumina ($Al_2 O_3$) ..	14·75	17·10	11·54	12·40
Ferric oxide ($Fe_2 O_3$) ..	Trace.	...	·21	·20
Sulphuric anhydride (SO_3) in combination	34·43	39·92	28·38	31·00
Free sulphuric acid ($H_2 SO_4$)	·30	Nil.	1·83	·92
Insoluble matter	Nil.	0·51	20·08	24·70
Water, lime, magnesia, alkalies, &c.	50·52	42·47	37·96	30·78
	100·00	100·00	100·00	100·00
*Equal to anhydrous sulphate of alumina $Al_2 3 (SO_4)$	48·94	57·02	38·53	41·40

COMPOSITION OF CAUSTIC SODAS.

	Cream, 60 %.	White, 60 %.	70 % Caustic.	77 % Caustic.
	%	%	%	%
Common salt (Na Cl) ..	3·00	17·51	4·30	1·54
Sulphate of soda ($Na_2 SO_4$)	1·50	4·05	3·30	0·98
Sodium hydrate (Na H O)	69·67	72·76	88·70	96·22
Sodium carbonate ($Na_2 CO_3$)	6·80	5·79	3·84	1·26
Water ($H_2 O$)	19·03	Nil.	Nil.	Nil.
	100·00	100·11	100·14	100·00
Total soda ($Na_2 O$) ...	59·00	59 78	71·0	74·6

Specific Gravity of Solutions of Sodium Carbonate.

@ 60° Fah. = 15° C. (Lunge).

Specific Gravity.	Twaddell.	Percentage by Weight.		1 cubic foot of solution contains		
		Na_2O.	Na_2CO_3	Na_2O.	Na_2CO_3	48% Ash.
1·005	1	0·28	0·47	0·172	0·294	0·358
1·010	2	0.56	0·95	0·350	0·598	0·728
1·015	3	0·84	1·42	0·525	0·888	1·094
1·020	4	1·11	1·90	0·707	1·209	1·473
1·025	5	1·39	2·38	0·889	1·521	1·853
1·030	6	1·67	2·85	1·070	1·830	2·230
1·035	7	1·95	3·33	1·257	2·149	2·618
1·040	8	2·22	3·80	1·441	2·464	3·002
1·045	9	2·50	4 28	1·631	2·788	3·397
1·050	10	2·78	4·76	1·852	3·116	3·797
1·055	11	3·06	5·23	2·012	3·440	4·192
1·060	12	3·34	5·71	2·206	3·772	4·596
1·065	13	3·61	6·17	2·396	4·097	4·992
1·070	14	3·88	6·64	2·591	4·430	5·397
1·075	15	4·16	7·10	2·783	4·759	5·799
1·080	16	4·42	7·57	2·981	5·098	6·211
1·085	17	4·70	8·04	3·181	5·439	6·627
1·090	18	4.97	8·51	3·382	5·783	7·046
1·095	19	5·24	8·97	3·582	6·125	7·462
1·100	20	5·52	9·43	3·783	6·468	7·880
1·105	21	5·79	9·90	3·989	6·821	8·311
1·110	22	6·06	10·37	4·197	7·177	8·745
1·115	23	6·33	10·83	4·403	7·529	9·174
1·120	24	6·61	11·30	4·615	7·891	9·613
1.125	25	6·88	11·76	4·825	8·249	10·050
1·130	26	7·15	12·23	5·040	8·617	10·500
1·135	27	7·42	12·70	5·256	8·988	10·951
1·140	28	7·70	13·16	5·465	9·354	11·396
1·145	29	7·97	13·63	5·691	9·731	11·857
1·150	30	8·24	14·09	5·908	10·103	12·310

SPECIFIC GRAVITY OF SOLUTIONS OF CAUSTIC SODA

@ 60° FAH. = 15° C.

(LUNGE.)

Twaddell.	Grammes per litre Na_2O.	Twaddell.	Grammes per litre Na_2O.	Twaddell.	Grammes per litre Na_2O.
1	3·7	26	100·5	51	223·4
2	7·5	27	105·0	52	228·9
3	11·3	28	109·6	53	234·4
4	15·1	29	114·1	54	240·0
5	18·8	30	118·6	55	245·5
6	22·6	31	123·2	56	251·0
7	26·4	32	127·7	57	256·6
8	30·2	33	132.2	58	262·1
9	33·9	34	136·8	59	267·6
10	37·7	35	141·3	60	273·2
11	41·6	36	145·8	61	279·3
12	45·5	37	150·4	62	285·4
13	49·4	38	154·9	63	291·5
14	53·2	39	159·4	64	297·7
15	57·1	40	164·0	65	303·8
16	61·0	41	169·4	66	309·9
17	64·9	42	174·7	67	316·0
18	68·8	43	180·1	68	322·2
19	72·7	44	185·5	69	328·3
20	76·5	45	190·9	70	334·4
21	80·4	46	196·3	71	340·8
22	84·3	47	201·7	72	347·2
23	88·2	48	207·0	73	353·6
24	92·1	49	212·4	74	360·1
25	96·0	50	217·8	75	366·5

NOTE —To find lbs. soda (Na_2O) per cubic foot divide grammes per litre by 16.

TABLE

Showing the amount of 70 per cent., 60 per cent., and "Cream" Caustic Sodas, and of Real Soda (Na_2O) in their solutions of different densities.

(Beveridge.)

Specific Gravity at 62° Fah.	Degrees Twaddell at 62° Fah.	White 70% Caustic. 100 cc. contain		White 60% Caustic. 100 cc. contain		Cream Caustic 60% Na_2O. 100 cc. contain	
		Dry 70% Caustic.	Soda (Na_2O).	Dry 60% Caustic.	Soda (Na_2O).	Dry Cream Caustic.	Soda (Na_2O).
		grms.	grms.	grms.	grms.	grms.	grms.
1·005	1	·44	·30	·46	·27	·50	·29
1·010	2	·89	·61	·94	·55	1·00	·59
1·015	3	1·33	·91	1·41	·83	1·51	·89
1·020	4	1·78	1·22	1·97	1·15	2·02	1·19
1·025	5	2·22	1·53	2·38	1·41	2·52	1·49
1·030	6	2·67	1·84	2·81	1·66	3·02	1·78
1·035	7	3·12	2·15	3·30	1·95	3·50	2·07
1·040	8	3·61	2·49	3·83	2·26	3·98	2·35
1·045	9	4·11	2·84	4·36	2·58	4·52	2·67
1·050	10	4·61	3·18	4·83	2·88	5·06	2·99
1·055	11	5·10	3·52	5·41	3·20	5·60	3·31
1·060	12	5·60	3·87	5·94	3·51	6·14	3·63
1·065	13	6·10	4·21	6·48	3·83	6·69	3·96
1·070	14	6·60	4·56	7·02	4·15	7·26	4·29
1·075	15	7·16	4·94	7·57	4·48	7·85	4·64
1·080	16	7·73	5·34	8·12	4·80	8·43	4·99
1·085	17	8·29	5·72	8·67	5·13	9·03	5·34
1·090	18	8·86	6·12	9·23	5·46	9·65	5·71
1·095	19	9·43	6·51	9·81	5·80	10·28	6·08
1·100	20	9·99	6·90	10·41	6·16	10·93	6·47
1·105	21	10·56	7·29	11·02	6·52	11·60	6·86
1·110	22	11·12	7·68	11·66	6·90	12·28	7·27
1·115	23	11·69	8·07	12·32	7·29	12·99	7·59
1·120	24	12·26	8·47	13·00	7·69	13·70	8·11
1·125	25	12·82	8·85	13·70	8·11	14·41	8·53
1·130	26	13·40	9·26	14·42	8·53	15·20	8·99

Note.—The above values are not absolute.

BLEACHING POWDER AND BLEACH LIQUOR.

Bleaching powder should contain at least 35 per cent. of available chlorine. The following analysis shows the composition of the English-made article—viz., available chlorine, 35·60 %; chlorine as calcium chloride, 2·80 %; chlorine as calcium chlorate, "traces"; carbonic acid, 1·40 %; lime (Ca O) 46 11 %. Water, &c. (by difference), 14·09 %.

One cwt. (112 lbs.) of dry bleaching powder, containing 36 to 36½ % of available chlorine, will yield—

250 gallons of bleach liquor of 5° Twaddell.
208 " " " 6° "
178½ " " " 7° "
156 " " " 8° "
139 " " " 9° "
125 " " " 10° "

The loss in making bleach liquor in paper mills varies from 2½ to 7½ per cent., reckoned on the dry weight used, according to the mode of making and apparatus employed.

TABLE showing the available chlorine and dry bleaching powder in bleach liquor of different densities at 15° C. (Founded on LUNGE AND BEICHOFEN.)

Specific Gravity @ 15° C.	Degrees Twaddell. @ 15° C.	Available Chlorine, grammes per litre.	Available Chlorine, lbs. per gallon.	Dry 35 % Bleaching Powder, lbs. per gallon.
1·000	0	trace	...	...
1·0025	½	1·40	0·0140	0·040
1·0050	1	2·71	0·0271	0·0774
1·0100	2	5·58	0·0558	0·1594
1·0150	3	8·48	0·0848	0·2420
1·020	4	11·41	0·1141	0·3260
1·025	5	14·47	0·1447	0·4134
1·030	6	17·36	0·1736	0·4960
1·035	7	20·44	0·2044	0·5840
1·040	8	23·75	0·2375	0·6785
1·045	9	26·62	0·2662	0·7605
1·050	10	29·41	0·2941	0·8402
1·055	11	32·68	0·3268	0·9408
1·060	12	35·81	0·3581	1·0231
1·065	13	39·10	0 3910	1·1171
1·070	14	42·31	0·4231	1·2089
1·075	15	45·70	0·4570	1·3057
1·080	16	48·96	0·4896	1·3971
1·085	17	52·27	0·5227	1·4914
1·090	18	55·18	0·5518	1·5765
1·095	19	58·33	0·5833	1·6637
1·100	20	61·50	0·6150	1·7571
1·105	21	64·50	0·6450	1·8428

Specific Gravity of Solutions of Pure Sulphate of Alumina @ 60° Fah. = 15° C.

100 Litres of the Sulphate of Alumina Solution contain

Specific Gravity.	Degrees Twaddell.	Al_2O_3 Kilos.	SO_3 Kilos.	Sulphate with 13% Al_2O_3 Kilos.	Sulphate with 14% Al_2O_3 Kilos.	Sulphate with 15% Al_2O_3 Kilos.
1·005	1	0·14	0·33	1·1	1	0·9
1·010	2	0·28	0·65	2·2	2	1·9
1·016	3·2	0·42	9·98	3·2	3	2·8
1·021	4·2	0·56	1·31	4·3	4	3·7
1·026	5·2	0·70	1·63	5·4	5	4·7
1·031	6·2	0·84	1·96	6·5	6	5·6
1·036	7·2	0.98	2·28	7·5	7	6·5
1·040	8·0	1·12	2·61	8·6	8	7·5
1·045	9·0	1·26	2·94	9·7	9	8·4
1·050	10·0	1·40	3·26	10·8	10	9·3
1·055	11·0	1·54	3·59	11·8	11	10·3
1·059	11·8	1·68	3·91	12·9	12	11·2
1·064	12·8	1·82	4·24	14·0	13	12·1
1·068	13·6	1·96	4·57	15·1	14	13·1
1·073	14·6	2·10	4·89	16·2	15	14·0
1·078	15·6	2·24	5·22	17·2	16	14·9
1·082	16·4	2·38	5·55	18·3	17	15·9
1·087	17·2	2·58	5·87	19·4	18	16·8
1·092	18·4	2·66	6·20	20·5	19	17·7
1·096	19·2	2·80	6·52	21·5	20	18·7
1·101	20·2	2·94	6·85	22·6	21	19·6
1·105	21·0	3·08	7·18	23·7	22	20·5
1·110	22·0	3·22	7·50	24·8	23	21·5
1·114	22·8	3·36	7·83	25·9	24	22·4
1·119	23·8	3·50	8·16	26·9	25	23·3
1·123	24·6	3·64	8·44	28·0	26	24·3
1·128	25·6	3·78	8·81	29·1	27	25·2
1·132	26·4	3·92	9·13	30·2	28	26·1
1·137	27·2	4·06	9·46	31·2	29	27·1
1·141	28·2	4·20	9·79	32·3	30	28·0
1·145	29·0	4·34	10·11	33·4	31	28·9
1·150	30·0	4·48	10·44	34·5	32	29·9
1·154	30·8	4·64	10·76	35·5	33	30·8
1·159	31·8	4·76	11·09	36·6	34	31·7
1·163	32·6	4·90	11·42	37·7	35	32·7
1·168	33·6	5·04	11·74	38·8	36	33·6
1·172	34·4	5·18	12·07	39·9	37	34·5
1·176	35·2	5·32	12·40	40·9	38	35·5
1·181	36·2	5·46	12·72	42·0	39	36·4
1·185	37·0	5·60	13·05	43·1	40	37·3
1·190	38·0	5·74	13·38	44·2	41	38·3
1·194	38·8	5·88	13·70	45·2	42	39·2

Specific Gravity of Solutions of Pure Sulphate of Alumina @ 60° Fah.=15° C.

100 Litres of the Sulphate of Alumina Solution contain

Specific Gravity.	Degrees Twaddell.	Al_2O_3 Kilos.	SO_3 Kilos.	Sulphate with 13% Al_2O_3 Kilos.	Sulphate with 14% Al_2O_3 Kilos.	Sulphate with 15% Al_2O_3 Kilos.
1·198	39.6	6·02	14.03	46·3	43	40·1
1·203	40·6	6·16	14·35	47·4	44	41·1
1·207	41·4	6·30	14·68	48·5	45	42·0
1·211	42·2	6·44	15·01	49·5	46	42·9
1·215	43·0	6·58	15·33	50·6	47	43·9
1·220	44·0	6·72	15·66	51·7	48	44·8
1·224	44·8	6·86	15·99	52·8	49	45·7
1·228	45·6	7·00	16·31	53·9	50	46·7
1·232	46·4	7·14	16·64	54·9	51	47·6
1·236	47·2	7·28	16·96	56·0	52	48·5
1·240	48·0	7·42	17·29	57·1	53	49·5
1·244	48·8	7·56	17·62	58·2	54	50·4
1·248	49·6	7·70	17·94	59·2	55	51·3
1·252	50·4	7·84	18·27	60·3	56	52·3
1·256	51·2	7·98	18·59	61·4	57	53·2
1·261	52·2	8·12	18·92	62·5	58	54·1
1·265	53·0	8·26	19·25	63·5	59	55·1
1·269	53·8	8·40	19·57	64·6	60	56·0
1·273	54·6	8·54	19·90	65·7	61	56·9
1·277	55·4	8·68	20·23	66·8	62	57·9
1·281	56·2	8·82	20·55	67·9	63	58·8
1·285	57·0	8·96	20·88	68·9	64	59·7
1·289	57·8	9·10	21·20	70·0	65	60·7
1·293	58·6	9·24	21·53	71·1	66	61·6
1·297	59·4	9·38	21·86	72·2	67	62·5
1·301	60·2	9·52	22·18	73·2	68	63·5
1·305	61·0	9·66	22·51	74·3	69	64·4
1·309	61·8	9·80	22·84	75·4	70	65·3
1·312	62·4	9·94	23·16	76·5	71	66·3
1·316	63·2	10·08	23·49	77·5	72	67·2
1·320	64·0	10·22	23·81	78·6	73	68·1
1·324	64·8	10·36	24·14	79·7	74	69·1
1·328	65·6	10·50	24·47	80·8	75	70·0
1·331	66·2	10·64	24·79	81·8	76	70·9
1·335	67·0	10·78	25·12	82·9	77	71·9
1·339	67·8	10·92	25·45	84·0	78	72·8

ALUMINOFERRIC.

Composition.—14·00 % soluble Al_2O_3, 0·75 % Fe_2O_3, 0·50 % Free Acid, 0·15 % insoluble matter.

100 parts by weight of water at 60° Fah. dissolve 122 parts by weight of Aluminoferric, forming a saturated solution having a sp. gravity of 1·33, equal to 66° Twaddell.

One gallon of this saturated solution at 60° Fah. contains 7·5 lbs. of solid Aluminoferric.

PERCENTAGE OF SULPHUROUS ACID (SO_2) IN AQUEOUS SOLUTIONS OF THE GAS.

Specific Gravity at 15° C.	Degrees Twaddell.	% SO_2.
1·0056	1·12	1·0
1·0113	2·65	2·0
1·0221	4·45	3·0
1·0275	5·50	4·0
1·0328	6·56	5·0
1·0377	7·54	6·0
1·0426	8·52	7·0
1·0474	9·48	8·0
1·0520	10·40	9·0

Specific Gravity of the Saturated Solutions of Some Salts and the Percentage of Anhydrous Salt contained in the Solutions at Saturated Point. (Gerlach & Kremer's.)

Name of the Salt		Temperature ° C.	Saturated Solution.	
			Specific Gravity.	% Anhydrous Salt.
Chloride of Sodium ...	$NaCl$	15	1·20433	26·395
,, Calcium ...	$CaCl_2$	15	1·41104	40·66
,, Barium ...	$BaCl_2$	15	1·28267	25·97
Carbonate of Soda ...	Na_2CO_3	15	1·15350	14·354
Sulphate of Soda ...	Na_2SO_4	15	1·11170	11·952

Specific Gravity of Solutions of Common Salt, Barium Chloride, Calcium Chloride, Magnesium Chloride, Crystallised Sulphate of Soda, Sulphate of Iron, Bichromate of Potash, Acetate of Lead, and Yellow Prussiate of Potash @ 59° Fah.

(Gerlach and Others.)

% of Salt in Solution.	Na Cl.	Ba Cl_2.	Ca Cl_2.	Mg Cl_2.	$Na_2 SO_4 + 10 H_2 O$.	$Fe SO_4 + 7 H_2 O$.	K_2, Cr_2, O_7, (@ 68° Fah.	Acetate of Lead.	K_3 Fe Cy_6.
2	1·01450	1·01834	1·01704	1·01689	1·0079	1·011	1·015	1·0127	1·0103
4	1·02899	1·03667	1·03667	1·03379	1·0158	1·021	1·029	1·0255	1·0208
6	1·04366	1·05569	1·05146	1·05096	1·0238	1·032	1·043	1·0386	1·0315
8	1·05851	1·07538	1·06921	1·06844	1·0318	1·043	1·056	1·0520	1·0426
10	1·07335	1·09508	1·08695	1·08592	1·0398	1·054	1·073	1·0654	1·0538
12	1·08859	1·11643	1·10561	1·10398	1·0479	1·065	1·090	1·0796	1·0653
14	1·10384	1·13778	1·12427	1·12203	1·0560	1·077	1·103	1·0939	1·0820
16	1·11938	1·15999	1·14332	1·14045	1·0642	1·088		1·1084	1·0990
18	1·13523	1·18305	1·16277	1·15922	1·0725	1·100		1·1234	1·1145
20	1·15107	1·20611	1·18222	1·17800	1·0807	1·112		1·1384	1·1300
22	1·16755	1·23173	1·20279	1·19775	1·0890	1·125		1·1544	
24	1·18404	1·25736	1·22336	1·21750	1·0973	1·137		1·1704	
26	1·20090		1·24450	1·23777	1·1057	1·149		1·1869	
28			1·26619	1·25857	1·1142	1·161		1·2040	
30			1·28789	1·27937	1·1226	1·174		1·2211	
32			1·31045	1·30121		1·187		1·2395	
34			1·33302	1·32305		1·200		1·2578	
36			1·35610			1·213		1·2768	
38			1·37970			1·226		1·2966	
40			1·40330			1·239		1·3163	

Note.—100 parts of Crystallised Sulphate of Soda ($Na_2 SO_4 + 10 H_2 O$) contain 44·1 parts of Anhydrous Sulphate of Soda ($Na_2 SO_4$).

Specific Gravity of Hydrochloric Acid @ 15° C.

Twaddell.	Specific Gravity $\frac{15^\circ}{4^\circ}$ in vacuo.	100 parts contain H Cl.	1 litre contains grammes H Cl.	Twaddell.	Specific Gravity $\frac{15^\circ}{4^\circ}$ in vacuo.	100 parts contain H Cl.	1 litre contains grammes H Cl.
0	1·000	0·16	1·60	21	1·105	20·97	232
1	1·005	1·15	12	22	1·110	21·92	243
2	1·010	2·14	22	23	1·115	22·86	255
3	1·015	3·12	32	24	1·120	23·82	267
4	1·020	4·13	42	25	1·125	24·78	278
5	1·025	5·15	53	26	1·130	25·75	291
6	1·030	6·15	64	27	1·135	26·70	303
7	1·035	7·15	74	28	1·140	27·66	315
8	1·040	8·16	85	29	1·145	28·61	328
9	1·045	9·16	96	30	1·150	29·57	340
10	1·050	10·17	107	31	1·155	30·55	353
11	1·055	11·18	118	32	1·160	31·52	366
12	1·060	12·19	129	44	1·165	32·49	379
13	1·065	13·19	141	34	1·170	33·46	392
14	1·070	14·17	152	35	1·175	34·42	404
15	1·075	15·16	163	36	1·180	35·39	418
16	1·080	16·15	174	37	1·185	36·31	430
17	1·085	17·13	186	38	1·190	37·23	443
18	1·090	18·11	197	39	1·195	38·16	456
19	1·095	19·06	209	40	1·200	39·11	469
20	1·100	20·01	220				

SPECIFIC GRAVITY OF SULPHURIC ACID @ 60° FAH. = 15° C. (LUNGE & ISLER.)

Twaddell.	100 parts by weight contained.		Kilos per litre.	Twaddell.	100 parts by weight contained.		Kilos per litre.
	SO_3	H_2SO_4	H_2SO_4		SO_3	H_2SO_4	H_2SO_4
40	22·30	27·32	0·328	62	32·94	40·35	0·529
41	22·82	27·95	0·337	63	33·41	40·93	0·538
42	23·33	28·58	0·346	64	33·88	41·50	0·548
43	23·84	29·21	0·355	65	34·35	42·08	0·557
44	24·36	29·84	0·364	66	34·80	42·66	0·567
45	24·88	30·48	0·373	67	35·27	43·20	0·577
46	25·39	31·11	0·382	68	35·71	43·74	0·586
47	25·88	31·70	0·391	69	36·14	44·28	0·596
48	26·35	32·28	0·400	70	36·58	44·82	0·605
49	26·83	32·86	0·409	71	37·02	45·35	0·614
50	27·29	33·43	0·418	72	37·45	45·88	0·624
51	27·76	34·00	0·426	73	37·89	46·41	0·633
52	28·22	34·57	0·435	74	38·32	46·94	0·643
53	28·69	35·14	0·444	75	38·75	47·47	0·653
54	29·15	35·71	0·454	76	39·18	48·00	0·662
55	29·62	36·29	0·462	77	39·62	48·53	0·672
56	30·10	36·87	0·472	78	40·05	49·06	0·682
57	30·57	37·45	0·481	79	40·48	49·59	0·692
58	31·04	38·03	0·490	80	40·91	50·11	0·702
59	31·52	38·61	0·500	81	41·33	50·63	0·711
60	31·99	39·19	0·510	82	41·76	51·15	0·721
61	32·46	39·77	0·519	83	42·17	51·66	0·730

Specific Gravity of Sulphuric Acid @ 60° Fah. = 15° C. (Lunge & Isler.)

Twaddell.	100 parts by weight contained.		Kilos per litre.	Twaddell.	100 parts by weight contained.		Kilos per litre.
	SO_3	H_2SO_4	H_2SO_4		SO_3	H_2SO_4	H_2SO_4
84	42·57	52·15	0·740	106	51·04	62·53	0·957
85	42·96	52·63	0·750	107	51·43	63·00	0·967
86	43·36	53·11	0·759	108	51·78	63·43	0·977
87	43·75	53·59	0·769	109	52·12	63·85	0·987
88	44·14	54·07	0·779	110	52·46	64·26	0·996
89	44·53	54·55	0·789	111	52·79	64·67	1·006
90	45·92	55·03	0·799	112	53·12	65·08	1·015
91	45·31	55·50	0·808	133	53·46	65·49	1·025
92	45·69	55·97	0·817	114	53·80	65·90	1·035
93	46·07	56·43	0·827	115	54·13	66·30	1·044
94	46·45	56·90	0·837	116	54·46	66·71	1·054
95	46·83	57·37	0·846	117	54·80	67·13	1·064
96	47·21	57·83	0·856	118	55·18	67·59	1·075
97	47·57	58·28	0·866	119	55·55	68·05	1·085
98	47·95	58·74	0·876	120	55·93	68·51	1·096
99	48·34	59·22	0·886	121	56·30	68·97	1·107
100	48·73	59·70	0·896	122	56·68	69·43	1·118
101	49·12	60·18	0·906	123	57·05	69·89	1·128
102	49·51	60·65	0·916	124	57·40	70·32	1·139
103	49·89	61·12	0·926	125	57·75	70·74	1·150
104	50·28	61·59	0·936	126	58·09	71·16	1·160
105	50·66	62·06	0·946	127	58·43	71·57	1·170

SPECIFIC GRAVITY OF SULPHURIC ACID @ 60° FAH. = 15° C. (LUNGE & ISLER.)

Twaddell.	100 parts by weight contained.		Kilos per litre.	Twaddell.	100 parts by weight contained.		Kilos per litre.
	SO_3	H_2SO_4	H_2SO_4		SO_3	H_2SO_4	H_2SO_4
128	58·77	71·99	1·181	149	66·22	81·12	1·416
129	59·10	72·40	1·192	150	66·58	81·56	1·422
130	59·45	78·87	1·202	151	66·94	82·00	1·439
131	59·78	73·23	1·212	152	67·30	82·44	1·451
132	60·11	73·64	1·222	153	67·65	82·88	1·463
133	60·46	74·07	1·233	154	68·02	83·32	1·475
134	60·82	74·51	1·244	155	68·49	83·90	1·489
135	61·20	74·97	1·256	156	68·98	84·50	1·504
136	61·57	75·42	1·267	157	69·47	85·10	1·519
137	61·93	75·86	1·278	158	69·96	85·70	1·534
138	62·29	76·30	1·289	159	70·45	86·30	1·549
139	62·64	76·73	1·301	160	70·94	86·90	1·564
140	63·00	77·17	1·312	161	75·50	87·60	1·581
141	63·35	77·60	1·323	162	72·08	88·30	1·598
142	63·70	78·04	1·334	163	72·69	89·05	1·621
143	64·70	78·48	1·346	164	73·51	90·05	1·639
144	64 43	78·92	1·357	165	74·29	91·00	1·661
145	64·78	79·36	1·369	166	75·19	92·10	1·685
146	65·14	79·80	1·381	167	76·27	93·43	1·713
147	65·50	80·24	1·392	168	78·04	95·60	1·759
148	65·86	80·68	1·404				

WEIGHTS OF ONE CUBIC FOOT OF DIFFERENT KINDS OF RAW MATERIALS, &c.

Name of Material.	Lbs.
Pyrites, broken pieces	156
,, dust or "smalls"	146½
,, burnt	95
Salt	43
"Salt cake," or sulphate of soda	73½
Limestone "small pieces"	87½
Soda ash	74·5
Bleaching powder	45/52
Manganese ore...	138
Coke, lumps, hard burnt	26/33
Flints	100
Mechanical wood pulp, individual bales, 50 % water	59¾
,, ,, ,, in store, packed close ...	54/56
Sulphite wood pulp, bale, 10 % water	39
,, ,, ,, in store	36/37
Aluminous cake	66
Sulphate of alumina, in small pieces, 17 % ...	
,, ,, ,, ground, 17 %	64
Magnesia	70
Brimstone	92
Coal, steam	47/54
,, slack	45/60
,, anthracite	56/58
Sand for gravity filters	83
Lime Caustic	62½/66

Comparison of Degrees Baumé Specific Gravity and Degrees Twaddell @ 12·5° C.

Rules:—Bé = Degrees Baumé ; Tw = Degrees Twaddell
Sp. Gr. = Specific Gravity.

$$\frac{144{\cdot}3 \times 1000}{144{\cdot}3 - \text{Bé}} = \text{Sp. Gr.} \quad \text{When Water} = 1{,}000.$$

$$\frac{\text{Sp. Gr.} - 1{,}000}{5} = \text{Tw.} \quad \text{When Water} = 1{,}000.$$

Degrees Baumé.	Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Specific Gravity.	Degrees Twaddell.
1	1·0069	1·4	37	1·3447	68·94
2	1·0140	2·8	38	1·3574	71·48
3	1·0212	4·2	39	1·3703	74·06
4	1·0285	5·7	40	1·3834	76·68
5	1·0358	7·16	41	1·3968	79·36
6	1·0434	8·68	42	1·4105	82·10
7	1·0509	10·18	43	1·4244	84·88
8	1·0587	11·74	44	1·4386	87·72
9	1·0665	13·30	45	1·4531	90·62
10	1·0745	14·90	46	1·4678	93·56
11	1·0825	16·50	47	1·4828	96·56
12	1·0907	18·01	48	1·4984	99·68
13	1·0990	19·80	49	1·5141	102·82
14	1·1074	21·48	50	1·5301	106·02
15	1·1160	23·20	51	1·5466	109·32
16	1·1247	24·94	52	1·5633	112·66
17	1·1335	26·70	53	1·5804	116·08
18	1·1425	28·50	54	1·5978	119·56
19	1·1516	30·32	55	1·6158	123·1
20	1·1608	32·16	56	1·6342	126·8
21	1·1702	34·04	57	1·6529	130·6
22	1·1798	35·96	58	1·6720	134·4
23	1·1896	37·92	59	1·6916	138·3
24	1·1994	39·88	60	1·7116	142·3
25	1·2095	41·90	61	1·7322	146·4
26	1·2198	43·96	62	1·7532	150·6
27	1·2301	46·00	63	1·7748	154·9
28	1·2407	48·01	64	1·7960	159·2
29	1·2515	50·03	65	1·8195	163·9
30	1·2624	52·48	66	1·8428	168·6
31	1·2736	54·72	67	1·859	171·8
32	1·2849	56·98	68	1·864	172·8
33	1·2965	59·30	69	1·885	177·0
34	1·3082	61·64	70	1·909	181·8
35	1·3202	64·04	71	1·935	187·0
36	1·3324	66·48	72	1·960	192·0

NOTE.—The above is for Baumé's hydrometer, generally used on the Continent of Europe. Another scale is in use in America, to which the above table is not applicable.

CHAPTER VIII.

PAPER MILL MACHINERY.

Rag Cutter, consisting of strong cast-iron wheel, with three cast steel knives revolving against a cast steel dead knife; fluted feed rollers, cast-iron stand, shaft, fast and loose pulleys complete, weighs about 25 cwts.; revolves 160 per minute, making 480 cwts, and requires from 2 to 4 h.p., in accordance with material operated upon.

Nuttall's Guillotine Rag Cutter.—Large size: Cuts 30 cwts. per hour, and is driven by a pair of fast and loose pulleys 3 feet $10\frac{1}{2}$ inches in diameter × $5\frac{1}{2}$ inches wide; 120 revolutions per minute; weighs 5 tons, and requires 4 h.p. *Small size:* Cuts 20 cwts. per hour, driven by a pair of fast and loose pulleys 3 feet diameter × $4\frac{1}{2}$ inches wide; 100 revolutions per minute, weighs 3 tons, and requires 3 h.p.

Rag Duster.—Drum sieve, 7 feet 6 inches to 8 feet long, covered with iron wire gauze $\frac{1}{4}$-inch mesh, 2 feet 9 inches diameter at narrow end and 3 feet 6 inches diameter at wide end. Wooden revolving shaft inside, with pegs, 34—40 revolutions per minute. Requires 1 h.p. and dusts 3 cwts. per hour. Sieve enclosed in wooden box. Larger size 4 feet diameter × 14 feet long on slight incline, drum covered with $\frac{1}{4}$-inch mesh wire gauze, 15 revolutions per minute.

Grass Duster.—Conical drum placed horizontally, with several rows of spikes passing through spaces of similar rows in the conical cover. Bottom of conical casing is of open wirework, through which dust is sucked by a fan. Grass fed in through hopper at small end of cone. Revolutions of drum 260 per minute.

Spherical Boilers for Rag, Straw, Waste Papers, &c.—Shells of wrought-iron or mild steel plates; two manhole covers, taps, safety-valve, pressure gauge, steam and water connections, blow-off cock. Cast-iron stands, with worm gearing and worm wheel attached to trunnion of boiler, shaft fast and loose pulleys. Makes 12 revolutions per hour or $\frac{1}{5}$th of a revolution per minute.

Diameter in Feet.	Capacity in Cubic Feet.	Rags per Charge.	Straw per Charge.
5	65	5 cwts.	$2\frac{3}{4}$ cwts.
6	113	$8\frac{1}{2}$,,	$4\frac{3}{4}$,,
7	180	14 ,,	$7\frac{1}{2}$,,
8	268	20 ,,	$11\frac{1}{5}$,,
9	381	30 ,,	16 ,,
10	523	40 ,,	22 ,,
11	697	$53\frac{1}{2}$,,	29 ,,
12	905	70 ,,	$37\frac{3}{4}$,,
13	1149	90 ,,	48 ,,
14	1436	113 ,,	60 ,,

Esparto Boilers.—Upright cylinders of wrought iron or mild steel, 9 feet diameter by 9 feet high; butt joints double riveted, capable of withstanding a pressure of 100 lbs. per square inch, and provided with side door and door in dome for filling, vomiting arrangement, run-off cock, safety valve, blow-off valve, pressure gauge, &c. Capacity about 572 cubic feet, will take a charge of 50 cwts. Esparto.

Soda Wood Pulp Digesters.—Usually upright cylinders of mild steel plates, cone shaped at top and bottom; provided with manhole and cover on top cone, run-off valve, blow-off valve at bottom, pressure gauge. No vomiting pipe, but charge heated direct with injected steam. Shell of digester double riveted with butt joints, and capable of withstanding a working pressure of 140 lbs. per square inch above atmosphere. From 60 to 100 cubic feet of boiler space are required per ton of air-dry soda pulp produced per week, according to quality.

Sulphite Pulp Digesters.—Upright cylinders of mild steel plate of unusual thickness, butt joints with the inside rivet-heads countersunk, cone or egg-shaped top and bottom. Top and bottom neck pieces of cast steel, man-lid with bronze blow-off valve, bronze run-off valve to bottom; steam wheel and check valves; thermometer tube and testing cock at side, pressure gauge. The following are the sizes of upright digester shells, and then approximate capacity *per charge* expressed in tons of air-dry pulp:—

10	feet	diameter	× 30	feet	high	= 3	tons	per charge.
14	,,	,,	× 35	,,	,,	= 6	,,	,,
14	,,	,,	× 38	,,	,,	= 8	,,	,,
14	,,	,,	× 40	,,	,,	= 9	,,	,,
14	,,	,,	× 45	,,	,,	= 10	,,	,,
15	,,	,,	× 42	,,	,,	= 10	,,	,,
15	,,	,,	× 45	,,	,,	= 15	,,	,,

NOTE.—After deducting the thickness of cement and tile lining with which these digesters are usually lined, the net boiler space required per ton of pulp per charge is about 480 cubic feet.

The boiler space required per ton of pulp made per week depends upon the system of cooking employed. In the Mitcherlich slow method of cooking there are about 280 cubic feet of space required per ton of air-dry pulp made per week, whilst 50 to 55 cubic feet will suffice for the quickest method of boiling.

Kollergang.—Cast-iron pan, 10 feet diameter × 18 inches deep, with granite bedstone 6 feet diameter × about 12 inches thick. Two granite runners 6 feet diameter, one 18 inches wide on face and one 21 inches wide on face. Under driven with bevel gear 90 and 12 cogs, 2 inches pitch, 5 inches wide. Cast-iron stands, shaft, fast and loose pulleys, &c. Speed of stones, 14 revolutions per minute. Speed of shaft = 105 revolutions per minute Size of pulley = 42 inches diameter × $7\frac{1}{2}$ inches on face. Weight about 16 tons. 14 to 15 h.p. with full load.

Pochers.—Cast-iron trough in parts, with mid-feather or wall 26 feet long × 14 feet 6 inches wide × 3 feet deep; area = 321 square feet. Total cubic capacity about 900 cubic feet. Wooden paddles in cast-iron arms fixed on wrought-iron shaft. Shaft revolves 33 per minute. Will hold 15 to 20 cwts. air-dry pulp. 4 h.p. Weight about $6\frac{1}{2}$ tons. Drum washer 5 feet × 4 feet 6 inches diameter; makes 6 to 7 revolutions per minute.

Breakers.—(Capacity, 10 cwts.) Cast-iron trough in parts, and joints caulked with iron borings 19 feet long × 9 feet 3 inches wide (equal to 157 square feet area); 2 feet 6 inches deep at shallow end and 2 feet 11 inches deep at deep end; usual back fall and mid-wall. Recess for washing water 4 feet 9 inches long × $7\frac{1}{2}$ inches wide, 5 inches deep, and covered with brass plate 4,000 holes $\frac{1}{16}$ inch diameter; 4-inch supply pipe (water). Cast-iron roll 4 feet 6 inches diameter × 4 feet 6 inches wide; 84 bars in 21 clumps, bars of Bessemer steel $1\frac{3}{4}$ inches projection, 4 feet 6 inches long × 6 inches wide × $\frac{7}{16}$ths thick, and bevelled $1\frac{1}{4}$ inches. Pulley on roll shaft 5 feet diameter × 12 inches on face. 110 revolutions per minute. Bed-plate. 22 knives, 4 feet 6 inches × 6 inches × $\frac{1}{4}$ inch; 1-inch bevel.

Two drum washers, 3 feet 3 inches diameter × 3 feet 9 inches wide, covered with honeycombed sheet brass and wire gauze; 12 revolutions per minute. Weight complete, 16 tons.

Beating Engines (Capacity, 5 cwts).—Ordinary type of Hollander. Cast-iron trough in one piece, 16 ft. long × 8 ft. broad (equal to 114 sq. ft. area), 2 ft. 4 in. deep at shallow or front end and 2 ft. $7\frac{1}{2}$ in. at deep or back end. Recess in bottom at front of roll for inlet washing water 4 ft. 3 in. long, covered with perforated brass plate, 2,500 holes, $\frac{1}{16}$ in. diameter. Bottom of engine dished. Cast-iron roll, 4 ft. diameter × 4 ft. wide; weight, 3 to 4 tons. 100 bars in 25 clumps of four each. Bars, 4 ft. long × $5\frac{1}{2}$ in. broad × $\frac{3}{8}$ in. thick, bevelled $1\frac{1}{2}$ in. Leading bar in each clump of gun-metal, others of cast steel. 150 revolutions per minute. Pulley, in roll shaft, 4 ft. diameter × $12\frac{1}{2}$ in. on face. Bed-plate of cast steel, 24 bars 4 ft. long × $5\frac{1}{2}$ in. broad $\frac{5}{16}$ in. thick. 23 zinc dividers, $\frac{1}{16}$ in. thick, 4 ft. long × 9 in. broad, placed in cast-iron box. Drum washer, 3 ft. long × 3 ft. diameter, covered with copper honeycombed backing plates and fine wire gauze, 60 meshes to the lineal inch. 12 revolutions per minute. Nominal capacity of engine, 525, 540, and 620 lbs. paper. Total weight, 11 tons.

The following are approximate dimensions of beating engines of various capacities:—

PRINCIPAL INSIDE DIMENSIONS OF RAG ENGINES.

Nominal Capacity in lbs of Paper.	Number.	Length.		Width.		DEPTH.				RAG ROLL.							DRUM WASHER.			
						Deep End.		Shallow End.		Diameter.					Length of Bar.		Diameter.		Width.	
		ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.		ft.	in.	ft.	in.	ft.	in.	ft.	in.
200	0	10	0	5	0	2	3	1	11	3	0	to	3	6	2	6	2	6	1	6
250	1	11	0	5	6	2	3	1	11	3	0	to	3	6	2	8	2	6	1	9
275	2	11	6	5	10	2	3½	1	10	3	0	to	3	6	2	10	2	9	2	0
330	3	13	0	6	3	2	3½	1	11½	3	3	to	4	0	3	0	2	9	2	3
375	4	13	0	6	6	2	3½	1	11½	3	3	to	4	0	3	3	3	0	2	3
425	5	13	8	7	0	2	3½	1	11½	3	4	to	4	0	3	6	3	0	2	6
450	6	14	0	7	6	2	3½	1	11½	3	4	to	4	0	3	9	3	0	2	6
500	7	14	6	7	8	2	3½	1	11½	3	4	to	4	0	3	9	3	0	2	6
540	8	16	0	8	0	2	7½	2	4	3	4	to	4	0	4	0	3	0	3	0

Umpherston's beating Engine:—Particulars of various sizes.

NOMINAL SIZES OF ENGINES.	2 cwt.	3 cwt. or 3 cwt.		4 cwt.	5 cwt.	6 cwt.	7 cwt.	8 cwt.	10 cwt.
Working Capacity in cubic feet	66	93	87	120	150	174	217	250	300
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Length of Trough inside	10 0	10 0	11 0	11 6	12 0	12 6	13 0	13 6	15 0
Width of Trough inside	3 3	4 3	3 3	4 3	4 6	4 9	5 3	5 6	5 9
Diameter of Roll	2 6	2 6	3 0	3 0	3 0	3 6	3 6	4 0	4 0
Length of Roll...	3 0	4 0	3 0	4 0	4 3	4 6	5 0	5 3	5 6
Total breadth from front end of Roll Spindle to over Driving Pulley	6 3	7 3	6 6	7 7	7 10	8 1	8 9	9 1	9 4
Height of centre of Roll above floor	2 10	2 10	3 2	3 2	3 2	3 4	3 4	3 6	3 6
Height from floor level to under side of Delivery Pipe for stuff	1 10	1 10	2 0	2 0	2 4	2 7	2 8	3 0	3 2
Distance between centres of two Engines, with a mutual passage between	7 3	9 3	7 3	9 3	9 9	10 9	11 9	12 3	13 0
Distance between centres of two Engines, with room for two pulleys between	7 6	8 9	8 0	9 0	9 4	9 8	10 9	11 0	11 6
Distance from centre of Engine to side wall, with room for side passage	5 9	6 6	5 9	6 6	7 0	7 6	8 3	9 0	9 6
Total weight approximately in tons	$5\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{1}{2}$	7	$7\frac{3}{4}$	$8\frac{3}{4}$	10	$11\frac{1}{4}$	$12\frac{1}{2}$

Reed's Beating Engine.—Cast-iron trough in pieces 20 feet long × 12 feet wide over all, with roll elevated above level of stuff. Bronze propeller, in pipe 24 inches diameter, at end to elevate stuff to bed-plate; speed of propeller, 135 to 140 revolutions per minute. Roll 3 feet diameter × 4 feet wide. 150 bars of Bessemer steel, set equidistant from one another, each bar 6 inches wide × $\frac{3}{16}$ in. thick, no bevel, but cut square across; pitch $\frac{3}{4}$ inch, projection $\frac{3}{4}$ inch. Speed of roll, 230 revolutions per minute. Pulley on roll shaft 3 feet 6 inches diameter × 8 inches broad.

Bed-plate 30 bars, each $5\frac{1}{2}$ inches broad × $\frac{1}{8}$ in. thick except outside one, which is $\frac{3}{8}$ in. or $\frac{1}{4}$ inch; $\frac{1}{8}$ in. zinc dividers.

Capacity, 670 lbs. dry paper. Weight complete = $10\frac{1}{2}$ tons.

The Taylor Patent Beating and Refining Engines are made in sizes of from 400 lbs. capacity to 1,200 lbs. capacity of dry paper with the horizontal trough, and up to 2,000 lbs. or more capacity with vertical tower trough. The rolls are 3 feet, 4 feet, and 5 feet wide on face respectively. The circulation of the pulp in the engine is accomplished by means of Masson Scott & Co.'s Patent Stuff Circulator, which also delivers the pulp into the stuff chests, and empties the engine, and to a level above the level of the beating engines if necessary.

The floor space required for the horizontal beating engines is as follows:—

	ft.	in.		ft.	in.
For 400 lbs. capacity engine	14	0	×	6	8
,, 600 to 700 lbs. engine...	14	0	×	8	3
,, 900 lbs. capacity engine	15	6	×	9	3
,, 1,200 lbs. ,, ,, ...	19	7	×	9	3

The space required for the vertical tower beating engine, to carry about 1,500 lbs. to 2,000 lbs. of dry paper, is 9 feet 8 inches × 9 feet 8 inches.

"ACME" BEATERS—The following are the general dimensions, &c., of this Engine.

Capacity—Lbs. of paper.	Trough.				Roll.					Bed Plate. No. of Bars.	Screw.			Floor Space, including Pulley.		Weight.
	Length.	Width.	Depth.	Depth below Floor.	Diameter.	Width.	No. of Bars.	Revolutions per Minute	Pulley.		Diameter.	Revolutions per Minute.	Pulley.	Length.	Width.	
	ft. in.	ft. in.	ft. in	ft. in.	in	in.			in.		in.		in.	ft. in.	ft. in.	tons.
1,600	13 6	6 3	5 9	3 0	36	72	120	210	45×15	22	30	160	36×6	18 0	9 9	17
1,300	11 6	6 3	5 9	3 0	36	72	120	210	45×15	22	30	160	36×6	16 0	9 9	15½
1,000	10 6	5 9	5 9	3 0	30	66	100	250	42×15	22	30	160	36×6	14 9	9 3	14
600	10 0	4 6	4 9	2 6	30	51	100	250	36×15	22	24	160	24×6	13 9	8 0	11

Pearson & Bertram's Refining Engine. The following are particulars of sizes, &c. :—

Diameter of Discs.	No. of Bars on each face.	Revolutions per Minute.	Pulley.	Floor space.	Weight.
inches.			inches. inches.	ft. in. ft. in.	
39	180	250	42 × 10	8 0 × 4 10	$4\frac{1}{4}$ Tons.
33	148	300	36 × 10	8 0 × 4 10	4 ,,
29	132	340	32 × 9	8 0 × 4 10	$3\frac{3}{4}$,,

Marshall's Refining Engines. The following are particulars of sizes, &c. :—

No.	Refines per hour. lbs. Stuff.	Floor space occupied.	Driving Pulley.		Revolutions per Minute.	Approximate I.H.P.
			Diameter.	Width.		
		ft. in. ft. in.	ft. in.	ft. in.		
1	1,200/1,400	12 4 × 4 4	2 10	1 2	300	40
2	900/1,000	11 0 × 3 10	2 9	1 0	320	30
3	600/700	9 0 × 3 2	2 8	0 $10\frac{1}{2}$	350	20

Roger's Wandel Strainer.—Revolving drum, 85 inches long × 28 inches in diameter, making 2 to $2\frac{1}{2}$ revolutions per minute. Flow of stuff from inside to outside self-cleaning. Speed of cam shaft 180 revolutions per minute; number of knocks per minute, 900. Size of pulley on cam shaft 12 inches diameter × 4 inches on face. Cast-iron stands and trough. Total weight, 25 cwt.

Reinicke and Jasper's Revolving Strainer.—Revolving drum, $94\frac{1}{2}$ inches long × 24 inches diameter, in cast-iron trough, flow of stuff from outside to inside self-cleaning. Drum makes about one revolution per minute, and has no knock. Shaft producing suction, revolutions 420 per minute, pulley on same=$8\frac{1}{2}$ inches diameter × $4\frac{1}{2}$ inches on face. Cast-iron stand complete weighs 80 cwts.

White's Oscillating Strainer.—Flat straining surface, 7 feet × 2 feet = 14 square feet area, in cast-iron oscillating frame 7 feet 2 inches × 2 feet 10 inches inside measurement, with automatic valves at sides for coarse stuff. Self-cleaning, oscillations per minute = 10. Rubber diaphragm dilates = 570 per minute. Speed of shaft, 570 revolutions per minute, pulley on shaft $10\frac{1}{2}$ inches diameter × $4\frac{1}{2}$ inches on face. Cast-iron stands and bed-plate; total weight 50 cwts. With $4\frac{1}{2}$ cwt. (Watson's) strainer will pass 700 to 800 lbs. esparto stuff per hour.

Paper machine speeds, &c.—

	No. of rams.	Dia.	Stroke.	Revs. per min.
Steam engines				90 to 100
Stuff chest agitators				8 to 10
Back-water pumps	2	8 in.	18 in.	46
Stuff pump	1	6 "	12 "	11
Vacuum	3	6 "	10 "	60
Hogs in breast box				36
Pulp "Save all" Wandles				7
Felt washer rolls...				33
Ventilators (Blackman's)				900
Damping brush				200/300

Roll.—Calender, 80 inches wide, consisting of strong cast-iron upright frames, with compound levers and weights, eight rolls—four of paper, cotton, or asbestos, and four of hard chilled iron—reeling off and on brackets, spreading roll, platform with stair and handrails, fast and loose pulleys, and gear arrangement for two speeds; weighs complete from 19 to 20 tons. Feeding speed, 14 feet per minute. Running speed, 200 to 240 feet per minute. Requires 35 to 40 horse power.

Revolving Cutters.—Average strokes on fly knife, 30; usually 3-step or cone pulley is fixed to cutters, to rise or fall 10 cuts per minute, which will give 20, 30, and 40 cuts per minute. Requires $1\frac{1}{2}$ to 3 horse power.

Papier Zeitung.

POWER REQUIRED TO DRIVE A FOURDRINIER PAPER MACHINE.

The following figures were obtained by Messrs. Korn & Bock in their paper mill at Sacraw.

Particulars of Machine, &c.—Wire 66 in. wide (1670 m.m.). Speed 217 ft. per min. (66·2 metres). Paper, reeled news, about 22 lbs. double crown. Steam engine, cyl. $11\frac{13}{16}$ in. diam. by $23\frac{5}{8}$ in. stroke, 100 revols. per min. Machinery driven by this engine was as follows:—

a—Two stuff chest agitaters.
b—One Kron's backwater screw pump; speed 412 revols. per min.; height of lift, 4 ft. 9 in.
c—One cir. revolving knotter (Reinecke & Jasper). Cut No. 4, length 8 feet (2,450 mm.), $23\frac{5}{8}$ in. dia.; 350 revols. per min.
d—Pulp stirrer in breast box ("hog"). Box 7 ft. 9 × 38 in. × $28\frac{3}{4}$ in.; "hog" revolved 36 times per min.
e—One wire cloth with 2 suction boxes.
f—Friction shake apparatus. Disc on working shaft 98 revols. per min., the wet end of machine 170 vibrations per min. to or fro.
g—First press rolls, bottom covered with rubber, $9\frac{5}{8}$ in. dia., lever press on journals.
h—Second press rolls. Two chilled iron $10\frac{1}{4}$ in. dia., $66\frac{3}{4}$ in. on face Handscrew press at journal ends.
j—Four drying cylinders $38\frac{3}{4}$ in. dia. by 66 in. on face, and one felt drying cylinder $28\frac{3}{4}$ in. by 66 in. on face.
k—Three drying cylinders as above, and one felt drying cylinder $27\frac{1}{2}$ in. dia.
l—One pair intermediate smoothing rolls, similar to 2nd press.
m—One large drying cylinder, 59 in. dia. by 66 in. on face, with one felt drying cylinder $23\frac{5}{8}$ in. dia.
n—One pair smoothing rolls as at "*l*," similar to 2nd press.
o—One large drying cylinder, 59 in. dia. by 66 in. on face.
p—One stack of calenders, 6 rolls, bottom roll $16\frac{1}{2}$ in. dia. by 66 in. on face, the others $8\frac{1}{8}$ in. dia. by 66 in. on face.
q—One of Kron's dampers.
r—One slitter and counter.
s—Friction reeler for 4 reels.
t—Pulp save-all wire cloth drum, 25 in. dia. by 24 in. wide; 7 revols. per min.
w—Felt washer rolls, 12 in. dia.; 39 in. wide; 33 revols. per min.
v—One of Schiele's rotating ventilators, $25\frac{1}{2}$ in. dia.; 900 revols. per min.
x—Hot-water feed pump for steam boiler. Ram, $2\frac{3}{4}$ in. dia.; 4 in. stroke; 80 revols. per min. Press. in boiler, 90 lbs. per sq. in.

CONSUMPTION OF POWER.

		I.H.P.
By the	Felt-washer was estimated to be	0·25
,,	Pulp save-all ,, ,, ...	0·20
,,	Pulp stirrer or "hog" ,, ...	0·10
,,	Feed pump was calculated ,, ...	0·65
,,	Ventilator taken from reliable sources	0·60
,,	Smoothing rolls, calculated from investigations	0·90

The work of each large drying cylinder was assumed to be equal to 2 small ones, and the necessary power for the latter calculated from the diagrams.

TABLE A.—WHEN THE MACHINE IS RUNNING EMPTY.

		I.H.P.
1.	The steam engine alone at 100 revols. per min. ...	5·02
2.	The foregoing, together with the whole line of shafting	12·73
3.	Do. do. with 1 felt washer, 1 ventilator, 1 "hog," 2 large drying cylinders, and 2 smoothing rolls	17·38
4.	Do. do. with 1 pulp chest full of pulp... ...	18·76
5.	Do. do. do. 1 knotter with water	19·78
6.	Do. do. do. the shake motion	20·32
7.	Do. do. do. 1st press rolls and lever pressure on	21·70
8.	Do. do. do. 2nd do. do. screw do.	23·26
9.	Do. do. do. 7 drying cylinders and 2 felt driers	28·19
10.	Do. do. do. calenders (6 rolls)...	30·77
11.	Do. do. do. wire cloth, without pulp or suction on suction boxes	31·96

TABLE B.—WHEN PULP WAS RUNNING ON MACHINE.

			I.H.P
1.	When	all is going excepting the wire cloth, 1st and 2nd press rolls and reeler	32·41
2.	,,	the wire cloth, where suction boxes were added	34·69
3.	,,	1st and 2nd press rolls were added	36·64
4.	,,	drying cylinders ,, ...	37·06
5.	,,	calenders ,, ...	37·25
6.	,,	cutter, damper, and reeler ,, ...	38·25

The sum of the differences between 6 and 7, 7 and 8, and 10 and 11 in Table A gives 4·13 i.h.p. as the quantity required to drive those parts of the machine which are not in motion in No. 1, Table B, and, deducting this from the total i.h.p of A, we have 31·94—4·13=27·81. If then we deduct this from B, thus: 32·41—27·81=4·58 i.h.p., we obtain the amount of power required to drive the boiler feed pump (calculated to consume 0·65 h.p.); one pulp save-all (estimated to require 0·20 h.p.); the knotter and Kron's screw pump. If the knotter requires

0·50 h.p. more when it works paper pulp than when passing water as already obtained (giving a total of 1·52 h.p.), there remains a difference of 2·23, which is placed against the Kron pump, thus: 4·58—(0·65+0·2+1·5) = 2·23.

The wire cloth, No. 11 on Table A (difference between 10 and 11) absorbs 1·19 i.h.p., whilst in No. 2, Table B, the total power required to overcome friction, &c., due to the application of the suction, and also to drive the wire when empty is plainly seen. The press rolls give in B the required power of 2 i.h.p. when the machine was working pulp, whilst when running empty the power required was equal to 2·80 i.h.p. Apparently the difference in these figures is due to the press rolls in 8 A being tightly screwed down while running empty, and less pressure being put on when making paper. When the paper web passed over the drying cylinders the power required by them was 0·42 i.h.p more than when the machine ran empty. The calenders likewise indicated a similar difference of 0·19 i.h.p. The ripper, damping and friction reeling apparatus, required altogether 1·10 i.h.p., of which 0·9 should be debited to the reeling apparatus.

Apportioning the quantities of power required by the several parts of the machine the following figures are obtained, viz.:—

	I.H.P.
Steam engine with wheels	5,02
Shafting alone	7.71
Stuff chests	1.38
Kron's pump	2·23
Knotter	1·52
Wire cloth and suction boxes	2·28
One pulp stirrer, "hog"	0·10
Shake	0·54
Drying cylinders	8·15
Smoothing rolls	2·45
Calenders	2·77
Ripper, damper, and reeler	1·10
Pulp "save-all"	0·20
Felt washer	0·25
Ventilator	0·60
Force pump for boilers	0·65
	38·40

Note.—The exhaust steam from the engine was *not* used for drying the paper.

APPENDIX.

Yield of unbleached Cellulose from Spruce by "Sulphite" Process.

Manufacturing practice (Beveridge).

One ton of air-dry unbleached wood pulp required.	*Pinus Picea.*
Cubic feet of piled logs	227
„ fathoms of piled pulp wood	1·05
Cords of piled pulp wood	1·77
Loads (one load=50 cubic feet solid wood) ...	3·49
One cubic fathom of imported piled pulp wood logs will yield of unbleached air-dry pulp.	2,130 lbs.

Note.—These figures are from imported wood, freed from outer bark, and of usual sizes.

AMERICAN

Tissue Paper Trade Customs.

Standard Basis.—White tissue, 20 × 30—480 sheets, 7 pounds; 24 × 36—480 sheets, 10 pounds. Manila tissue, 24 × 36—480 sheets, 10 pounds. For sizes smaller than 20 × 30, if required, 5 cents additional to base price.

Rolls, Cores, Sheet Paper, &c.—Paper sold in Jumbo rolls by the pound, 12 pound paper, three-quarters of a cent per pound; less than 10 pound, 14 to 15 pound paper, one-quarter of a cent less than 12 pound; 16 to 18 pound paper, one-quarter of a cent less than 14 to 15 pound. When shipped in rolls or wound on wooden or iron cores, paper to be removed therefrom by purchaser, and cores returned to the manufacturers at invoiced price.

Miscellaneous Conditions, Minimum Orders, &c.—All paper heavier than 10 pounds to the ream, 24 × 36—480 sheets, to be sold by the pound, the weight to include wrappers and twine. All sizes of paper sold by ream, ordered a fraction of an inch smaller than regular sizes, to be billed as regular sizes. The limit in weight shall be 17 pounds to the ream, 24 × 36—480 sheets; tissue paper in excess of this weight to come under the classification of light weight manila.

Trimming, Finishing, Case Linings, Ream Wrapping, &c.—Ten cents per cwt. extra for string tying. Five cents per cwt. extra for irregular counts. For finishing in large sheets for toilet paper, 12½ cents per cwt. extra will be charged. Ream wrapping, 20 cents per cwt.

Over-runs and Under-runs.—On orders for special sizes or colours, 10 per cent. above or below the quantity ordered to be considered a good delivery and accepted by purchaser.

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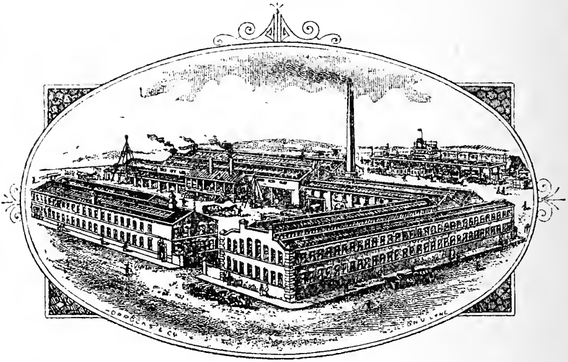

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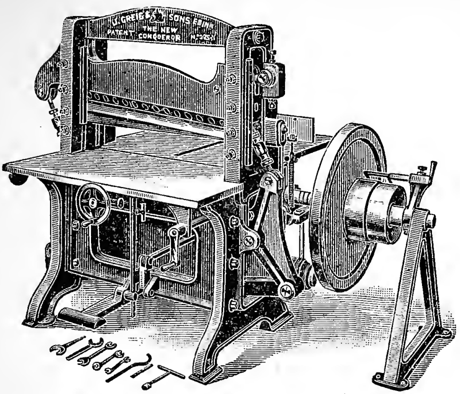

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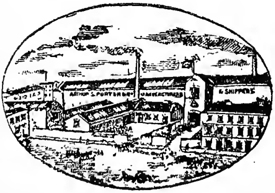

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