Tropical Products Institute

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SUMMARY

The pulping characteristics of three trees of *Pinus caribaea* var *hondurensis* with different densities grown in Jamaica were determined using the sulphate method.

Ten trees, ten years old, had been selected at random from a single plantation in Jamaica and the first, fifth and ninth in order of density were pulped to assess the differences in pulping characteristics that might be due to density. Two digestions, one with 17.5% active alkali, one with 20% were made on each tree using otherwise identical conditions.

Physical, microscopic and chemical characteristics of woods from the three trees were:

Tree no.	G1/23	G1/54	G1/34
Density, kg/m^3 $(\frac{\text{Oven dry weight}}{\text{Green volume}})$	325	390	480
Alcohol–Benzene solubility, %	1.2	2.5	1.1
Alpha–cellulose, %	37.8	41.1	44.8
Lignin, %	31.7	29.7	28.2
Fibre length, mm	2.32	2.81	2.76
Fibre width, microns	59.1	53.0	51.8
Fibre wall thickness, microns	4.6	5.0	6.1
Lumen width, microns	49.9	43.0	39.6
After cooking with 17.5% Active Alkali:			
Yield of unscreened unbleached pulp, %	40.0	45.8	47.6
Kappa number of unbleached pulp	28.9	39.0	31.6
Pulps beaten to 500° CSf:			
Bulk, ml/g	1.36	1.64	1.69
Burst Factor	58	59	45
Breaking length, m	9400	8400	7000
Tear Factor	81	175	155

At both alkali doses yields of pulp increased with increasing density of the wood and, unexpectedly, the Kappa numbers of the pulps from the medium density wood were higher than those of either of the others.

The breaking lengths and bursting strengths decreased and the bulk increased with increasing density. When compared at equal digestion conditions, the tearing strengths increased but to a peak with medium density. This was influenced by the higher Kappa numbers of the pulps from medium density wood and, when compared at equal Kappa numbers, the tearing strength showed a marked increase as the wood density increased from low to medium, and a smaller increase as it increased from medium to high density. The same trends held in the case of bleached pulps.

Because of the limited scale of this trial and the fact that the medium density sample yielded pulps with Kappa numbers completely out of line with the pulps from the other two samples, it is not possible to draw firm conclusions about the relationship between density and pulping characteristics, or the merit of density for predicting the quality of pulp. However, in this and in earlier similar work (Tropical Products Institute Report L25) it appears that low density trees can have the economic disadvantage of not only higher handling costs but also lower pulp yields per bone dry ton, and the technical disadvantage of giving the lowest tearing strength although with somewhat higher bonding strengths. The choice between medium and highest density is obscure. The conclusion might be different with trees at a different age and site conditions because both these affect the general level of pulp strength and they also affect the relationship between bonding and tearing strength.

SOMMAIRE

On a mesuré les caractéristiques de la pâte à papier de trois arbres de *Pinus caribaea* var *hondurensis* à densités différentes ayant poussé à la Jamaïque, par le procédé au sulfate.

Dix arbres de 10 ans furent choisis au hasard dans une plantation jamaïquaine et le premier, le cinquième et le neuvième en ordre de densité furent réduits en pâte à papier afin d'évaluer les différences de caractéristiques papetières pouvant être dûes à la densité. Deux lessivages, un avec 17,5% d'alcali actif sur bois et l'autre avec 20% mais autrement identiques, furent entrepris pour chaque arbre.

Les caractéristiques physique, microscopique et chimique des bois des trois arbres étaient les suivantes:

Arbre no.	G1/23	G1/54	G1/34
Densité, kg/m^3 $(\frac{\text{Poids sec absolu}}{\text{Volume vert}})$	325	390	480
Solubilité alcool–benzène, %	1,2	2,5	1,1
Alpha–cellulose, %	37,8	41,1	44,8
Lignine, %	31,7	29,7	28,2
Longueur des fibres, en mm	2,32	2,81	2,76
Largeur des fibres en microns	59,1	53,0	51,8
Epaisseur de paroi des fibres en microns	4,6	5,0	6,1
Largeur des cavités en microns	49,9	43,0	39,6
Après cuisson avec 17,5% d'alcali actif sur bois sec absolu			
Rendement en pâte écrue, non-classée, %	40,0	45,8	47,6
Indice Kappa de la pâte écrue classée	28,9	39,0	31,6
Pâtes battues à 500° CSf:			
Main, ml/g	1,36	1,64	1,69
Indice d'éclatement	58	59	45
Longueur de rupture, m	9400	8400	7000
Indice de déchirement	81	175	155

Aux deux doses d'alcali, les rendements en pâte augmentèrent avec la densité du bois, mais les indices Kappa des pâtes de bois de densité moyenne était plus élevé que celui des deux autres.

La longueur de rupture et la résistance à l'éclatement diminuèrent alors que la main augmenta avec la densité. Les résistances au déchirement, lorsque comparées pour des conditions réactionnelles identiques, augmentèrent mais avec un sommet pour les densités moyennes. Ceci fut influencé par les indices Kappa plus élevés de la pâte de bois à densité moyenne, et lorsque comparées pour des indices Kappa égaux, la résistance au déchirement augmenta beaucoup entre les pâtes de bois à densité faible et moyenne et peu entre celles à densité moyenne et élevée. Les mêmes tendances furent observées pour les pâtes blanchies.

A cause de l'échelle restreinte de ces essais, et du fait que l'échantillon de densité moyenne produisit des pâtes dont les indices Kappa étaient hors de ligne de ceux des autres échantillons, il n'est pas possible de tirer des conclusions définitives concernant la relation entre la densité et les caractéristiques papetières ou de se servir de la densité pour prédire la qualité de la pâte. Cependant, il semblerait d'après ces travaux et d'autres travaux similaires (Rapport TPI, L25) que les arbres à densité faible ont le désavantage économique d'être plus coûteux au manutention et au transport mais aussi d'avoir des rendements en pâte plus faibles par tonne de bois sec absolu, et ont l'inconvénient technique de produire les résistances au déchirure les plus faibles tout en étant d'une liaison entre fibres plus forte. Le choix entre les densités moyennes et élevées n'est pas clair. Il se peut que les conclusions pour des arbres d'âge et de conditions d'emplacement différents ne soient pas les mêmes étant donné qu'ils ont tous deux un effet sur la résistance de la pâte ainsi que sur il rapport entre les résistances au déchirure et la liaison entre fibres.

RESUMEN

Se determinaron las características de la pulpa de tres árboles de *Pinus caribaea* var *houndurensis* con diferentes densidades cultivados en Jamaica, usando para esto el método de sulfato.

Se han seleccionado al azar diez árboles, de 10 anos de edad, procedentes de un solo plantío en Jamaica y el primero, quinto y noveno en orden de densidad fueron convertidos en pulpa para determinar las diferencias en las propriedades como matéria prima para pulpa que puedan deberse a la densidad. Se hicieron en cada árbol dos coccíones, una con 17,5% de álcali activo, la otra con 20% usando de otro modo condiciones idénticas.

Las características físicas, microscópicas y químicas de los tres árboles fueron:

Arbol no.	G1/23	G1/54	G1/34
Densidad kg/m^3 $\left(\frac{\text{Peso seco absoluto}}{\text{Volumen verde}}\right)$	325	390	480
Alcohol—Benceno solubilidad, %	1,2	2,5	1,1
Alpha—celulosa, %	37,8	41,1	44,8
Lignina, %	31,7	29,7	28,2
Longitud de las fibras, mm	2,32	2,81	2,76
Anchura de las fibras, µm	59,1	53,0	51,8
Espesor pared fibra, µm	4,6	5,0	6,1
Ancho lumen, µm	49,9	43,0	39,6
Despues del cocimiento con 17,5% de Alcali Activo:			
Rendimiento de pulpa sin depurar ni blanquear, %	40,0	45,8	47,6
Número Kappa de pulpa sin blanquear	28,9	39,0	31,6
Pulpas batidas a 500° CSf:			
Cuerpo (1/densidad aparente), ml/g	1,36	1,64	1,69
Densidad aparente, g/ml	0,74	0,61	0,59
Factor de estallido	58	59	45
Longitud de ruptura, m	9400	8400	7000
Factor de rasgado	81	175	155

En ambas dosis de álcali se incrementó los rendimientos de pulpa con una aumentada densidad de la madera, y inesperadamente, los números Kappa de las pulpas de madera de mediana densidad fueron mas altos que cualesquiera de los otros.

Disminuyeron el longitud de ruptura y la resistencia al estallido, y el cuerpo se incrementó con aumentada densidad. Cuando se campararon bajo condiciones iguales de digestión la resistencia de rasgado aumentó pero a un máximo con una densidad mediana. Esto influenciado por los números Kappa más altos de la pulpa de madera de mediana densidad y cuando se comparó con números Kappa iguales, mostró al resistencia de rasgado un aumento acentuado a medida que la densidad se acrecentó de baja a mediana y un menor aumento a medida que la densidad se acrecentó de mediana a alta. Las mismas tendencias persistieron en el caso de pulpas blanqueadas.

Debido a la limitada escala de este ensayo y al hecho de que la prueba de mediana densidad produjó pulpas con números Kappa completamente fuera de línea con las pulpas de los otros dos ejemplos, no es posible esbozar conclusiones firmes acerca de la relación entre la densidad de la madera y sus propriedades como materia prima para pulpa, o el mérito de densidad para predecir la calidad de la pulpa. Sin embargo, en este como en trabajos anteriores similares (Reporte TPI L25) parece que los árboles de baja densidad pueden tener las desventajas económicas no solamente de costos de manejo, transporte etc más elevados sino que también de un más bajo rendimiento de pulpa por tonelada absolutamente seca la desventaja técnica de dar la más baja resistencia de rasgado aunque resistencia del entrelazamiento de las fibras un tanto más elevada. La elección entre la densidad media y la más alta no está clara. La conclusión puede diferir con árboles de una edad y condiciones de sitio diferentes ya que estos dos factores afectan el nivel general de la resistencia de la pulpa así como de la relación entre la fuerza de entrelazamiento de las fibras y la resistencia de rasgado.

Pulping characteristics of three trees of *Pinus caribaea* with different densities grown in Jamaica

INTRODUCTION

The many published accounts of the pulping qualities of *Pinus caribaea* of different ages and from different locations have shown that the species yields pulps of widely varying qualities. Efforts to relate the variations in pulping qualities to variations in such characteristics as density and fibre dimensions have had very limited success. It was thought that this was partly due to the very wide variation within samples.

In the present investigation pulping trials were made on three trees of widely different density, of exactly the same age from the same plantation in Jamaica.

G. Brown working on a research project at the Commonwealth Forestry Institute (CFI) had examined the physical and microscopical characteristics of ten trees. His findings are given in his unpublished thesis for the degree of D.Phil (Oxon) in 1969, a section of which describing the site conditions and growing stock is given as Appendix 1.

SAMPLING

In his work at Oxford, Brown considered a plantation of *Pinus caribaea* var *hondurensis* established in Jamaica in 1956 with seed from British Honduras and sampled in October 1966. He selected an area uniform in topography and in vegetational characteristics and where growth of trees appeared to be unimpeded by other vegetation. Within this area two adjacent plots, each approximately 0.25 acres, were demarcated. From each plot five trees were selected by use of a table of random numbers.

From each tree discs were taken at breast height and each 10% interval of height starting at 5%.

The samples sent to the Tropical Products Institute were from the first, fifth and ninth trees in order of density. Eight discs from each tree were taken at 5, 15, 25, 35, 45, 55, 65 and 75% of the height.

A composite sample representative of each tree was prepared for pulping by taking a complete disc 0.75 inch thick from each sampling level, chipping the whole disc and thoroughly mixing the chips. This composite sample was used for pulping trials and fibre measurements. Density and chemical characteristics were determined using individual discs or mixtures of discs depending on the amount of material available.

EXPERIMENTAL RESULTS AND DISCUSSION

Details of experimental techniques are given in Appendix 2.

Apparent density

The mean apparent density for each tree is given below, expressed as $\frac{\text{Oven Dry Weight}}{\text{Green (soaked) Volume}}$, as well as the range of the densities of the individual discs

Apparent density (from Table 1)

Tree	Determined by TPI			Determined by CFI
	Mean kg/m^3	Density Range kg/m^3	Mean lbs/ft^3	Mean kg/m^3
G1/23	325	290–350	20.3	331
G1/54	390	300–470	24.3	379
G1/34	480	400–530	30.0	474

The results of the two laboratories are in good agreement although the techniques used were different.

Details of the apparent densities of individual discs, given in Table 1, show that the lowest part of each tree was the most dense.

Chemical analysis

Ground samples of wood were analysed to determine the main chemical constituents affecting pulping, with the following results which are the averages of duplicate determinations, all expressed on oven dry wood:

Extractives, lignin and cellulose contents (from Table 2)

Tree	Wood density kg/m^3	Alcohol Benzene per cent	Holocellulose per cent	Alpha-cellulose per cent	Lignin per cent	1% NaOH Solubility per cent
G1/23	325	1.2	58.3	37.8	31.7	10.1
G1/54	390	2.5	59.3	41.1	29.7	11.5
G1/34	480	1.1	64.6	44.8	28.2	9.4

The results show an increasing cellulose and decreasing lignin content with increasing density.

The results for individual parts of two trees which are given in Table 2, show, for tree G1/54, decreasing cellulose and increasing lignin with increasing height of the tree. Since the density decreased with increasing height in this tree the relationship between chemical composition and density was the same both between trees and within this tree. The same relationship was not found in tree G1/23, possibly because the range of density within the tree was much smaller.

Fibre dimensions

The dimensions of fibres were measured using well cooked sulphate pulps representing each tree:

Mean dimensions of fibres in pulps

Tree	Wood density kg/m^3	Length, mm		Apparent fibre width, microns	Apparent thickness of one wall, microns	Lumen width, microns
		All fibres	Unbroken fibres only			
G1/23	325	1.98	2.32	59.1	4.6	49.9
G1/54	390	2.33	2.81	53.0	5.0	43.0
G1/34	480	2.25	2.76	51.8	6.1	39.6

The fibre length was measured twice, once including all fibrous elements, the second time including only complete fibres. Although there was no significant difference in the fibre length of the two more dense samples, the tendency was for fibre length to increase with density. The fibre wall thickness increased with density and the apparent width decreased. The fibres in pulp tend to collapse into ribbons, thick walled fibres do not collapse as much as thin walled ones, and this affected the difference in apparent width.

Digestion

Because of the limited amount of wood available, it was decided to do two digestions on each sample; it was hoped that one of each pair would give a pulp with a Kappa number about 40, and the other a pulp which would be bleachable, with a Kappa number about 25. Full details of the digestion conditions, yields and Kappa numbers of the pulps are given in Table 3, but as the summary below shows, the Kappa numbers of both of the pulps from the medium density sample were inconsistent with the others. The screening rejects after the cook with 17.5% active alkali were also exceptionally high with this sample.

Digestion — Summary of Table 3

Tree	Density kg/m^3	Active Alkali added % o.d. wood	Yield, screened oven-dry pulp % o.d. wood	Kappa number of screened pulp
G1/23	325	17.5	44.0	28.9
		20	41.9	21.3
G1/54	390	17.5	45.8	39.0
		20	43.7	27.3
G1/34	480	17.5	47.6	31.6
		20	45.3	21.5

This result was unexpected; it would be slightly more difficult for the digestion liquor to penetrate the more dense samples, but their lower lignin content was expected to counteract this, and result in small differences in Kappa numbers. However, with both sets of conditions the medium density wood had a significantly higher Kappa number. The yield of pulp from the dense sample was expected to be the highest, reflecting the highest alpha-cellulose content and this was found in practice.

Unfortunately, the amount of wood available made it impossible to repeat the digestions, but all analyses have been repeated and confirm the original results and since both cooks on the medium density sample were out of line we are confident that the analytical data were right in respect to these samples. We cannot explain it.

Pulp evaluation

Evaluations of the unbleached pulps by British Standard Methods are given in full in Table 4 and interpolated results at 500 and 300 Canadian Standard freeness in Table 5.

In general the bulk and tear factor of the pulp increases with the density of the original wood whilst the bonding strengths (breaking length and burst factor) fall. When compared at equal digestion conditions the tear factors of the pulps from medium density woods do not fit in with this statement, but when compared at approximately equal Kappa numbers they do.

Bleaching trials

The pulp from each sample with the lower Kappa number was bleached with a four stage sequence of chlorination, alkali extraction, sodium hypochlorite and chlorine dioxide. The details of bleaching conditions are given in Table 3.

The pulp from the medium density wood had the highest chlorine consumption and the lowest brightness. This was expected as this unbleached pulp had the highest Kappa number. Although the brightness achieved was not very high compared with the best bleached pulps that are available, the results were considered satisfactory because a fully bleached commercial pulp is produced using a sequence of six or more stages and the four stage sequence used in this trial is more like that used to produce a semi-bleached pulp.

Evaluations of the bleached pulps are given in full in Table 6 and interpolated results at 500 and 300 CSf in Table 5. As with the unbleached pulp the trend was for bulk and tear to increase with density of wood and for bonding strengths (breaking length and burst) to decrease. The tearing strength of the pulp from the medium density wood again departs from this, but this was most probably due to the higher Kappa number of the unbleached pulp.

When determining the optical properties of the pulp both the printing opacity of the sheets and the specific scattering co-efficient were determined. The printing opacity of the sheets was valid only for sheets of the substance measured (approximately 60 g/m^2) but the specific scattering co-efficient, depending on the fibre and the pulping method used, can be used to calculate the opacity at any substance. There was a significant difference in the specific scattering co-efficient of the fibres of the three trees, when unbeaten, showing a reduction in scattering co-efficient with increasing density. However there was much less difference when the pulps beaten had been beaten to 500 and 300 CSf, so that the differences were not of practical importance. In all cases the scattering co-efficients were lower than that usually found in commercial bleached Kraft pine pulps (185 to 210 for pulps at 500 CSf, 150 to 185 for pulps at 250 CSf) but similar to those we have found in other samples of *Pinus caribaea.*

COMPARISON WITH COMMERCIAL PULPS

It is not possible to draw any firm conclusions about the potential value of *Pinus caribaea* grown in Jamaica for pulpwood, because there was significant differences between the three trees and it is not known what proportion of each type there is in the plantations or how they behave when pulped in mixture. However some tentative conclusions by comparison with the results of pulp evaluations for a number of pulpwoods used commercially given in Table 7. It is likely that a pulp approaching the strength characteristics of Southern Pine pulp could be made.

CONCLUSIONS

With the exception of the Kappa number of unbleached pulp, the wood and pulp characteristics showed definite trends with increasing density of wood as follows:

1. Alpha-cellulose in wood increases
2. Lignin in wood decreases
3. Length and wall thickness of pulp fibres increase
4. Apparent width of pulp fibres decreases, partly because the greater wall thickness reduces the collapse of the fibres into ribbons
5. Pulp yield (total and screened) increases
6. Bulk and Tearing strength increase
7. Breaking Length and Bursting strength decrease

The one characteristic measured which showed no trend was the Kappa number of the unbleached pulp. (The Kappa number is a measure of the residual lignin in the pulp). When all three trees were pulped by identical conditions, there was little difference in the Kappa number of the pulps from the least and most dense trees but that of pulp from the medium density tree was much higher. This pattern was obtained at two levels of alkali dose. We can offer no explanation of this finding.

In some ways these conclusions are similar to our findings in an earlier study using *Pinus caribaea* from Sabah (TPI Report L25, 1971). In that investigation it was noted that the densities of the least dense tree (385 kg/m^3) and the most dense tree (550 kg/m^3) were far apart, so it was decided to make separate pulps from each and to compare them with pulp from a bulk sample from six trees with a mean density of 445 kg/m^3. On that occasion, when the same digestion conditions were applied to the two extreme trees and the bulk sample, the pulp from the extreme trees had the same Kappa number (34.4 and 34.6) but the Kappa number of the pulp from the bulk sample was significantly higher (39.7). When the strengths of pulps from the extreme trees were compared the same relationships were found as in the present work.

The results for the medium density sample did not fit in this pattern. However, in the case of the Sabah sample, the anomaly was thought to be due to the medium density sample being a mixture from six trees of different densities rather than from one tree.

Tables

Table 1

***Pinus caribaea* from Jamaica**

Apparent density

Tree number	G1/23		G1/54		G1/34	
Height of disc within tree % total height	Density		Density		Density	
	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3
5	347	21.7	471	29.4	530	33.1
15	340	21.2	408	25.5	528	32.9
25	312	19.5	384	24.0	481	30.0
35	320	20.0	360	22.5	467	29.1
45	306	19.1	341	21.3	435	27.2
55	305	19.0	334	20.8	423	26.4
65	316	19.7	328	20.5	416	26.0
75	290	18.1	302	18.8	400	25.0
Mean for tree	325	20.2	390	24.2	480	30.0

Table 2

***Pinus caribaea* from Jamaica**

Chemical analysis

Tree number	Height of sample disc % total height	Alcohol benzene extractives %	Holo cellulose %	Alpha cellulose %	Lignin %	% NaOH solubility %
G1/23	5, 15	1.4	55.2	36.0	33.0	11.5
	25, 35	1.0	62.8	40.2	31.3	9.8
	45, 55, 65, 75	1.1	57.0	37.2	30.8	9.0
G1/54	5	2.4	60.8	44.9	29.2	10.6
	15, 25	3.0	58.9	41.4	29.1	12.6
	35, 45	2.2	58.4	39.8	30.0	12.1
	55, 65, 75	2.2	59.2	38.4	30.4	10.6
G1/34	ALL	1.1	64.6	44.8	28.2	9.4

Table 3

***Pinus caribaea* from Jamaica**

Digestion and bleaching conditions

Tree number	G1/23		G1/54		G1/34	
Density of wood, kg/m^3	325		390		480	
Cook number	K378	K380	K371	K370	K382	K383
Digestion conditions:						
Active Alkali as Na_2O% oven dry wood	17.5	20	17.5	20	17.5	20
Sulphidity %	25	25	25	25	25	25
Liquor to oven dry wood ratio, litres/kg	6:1	6:1	6:1	6:1	6:1	6:1
Maximum temperature, °C	170	170	170	170	170	170
Time to reach max temperature, hours	1	1	1	1	1	1
Time at max temperature, hours	4	4	4	4	4	4
Active Alkali consumed as Na_2O% oven dry wood	14.4	14.4	13.5	15.2	13.7	14.5
Yield of unbleached pulp:						
Oven dry digested pulp % oven dry wood	44.0	41.9	45.8	43.7	47.6	45.3
Oven dry screenings on 0.15 mm slots % oven dry digested pulp	less than 0.1	less than 0.1	4.4	0.5	1.8	1.3
Oven dry Screened Pulp % oven dry wood	44.0	41.9	43.8	43.5	46.7	44.7
Kappa Number of Unbleached Pulp (Screened)	28.9	21.3	39.0	27.3	31.6	21.5
Bleaching conditions:						
1. CHLORINATION (Pulp consistency 3%, 1 hour, 20°C) Chlorine added as Cl_2% oven dry unbleached pulp		5.6		7.6		5.7
2. ALKALI EXTRACTION (Pulp consistency 6%, 1 hour, 60°C) NaOH% oven dry unbleached pulp		3		3		3
3. HYPOCHLORITE (Pulp consistency 6%, 2 hours, 35°C) Available chlorine added as Cl_2% oven dry unbleached pulp		1.0		1.0		1.0
4. CHLORINE DIOXIDE (Pulp consistency 6%, 3 hours, 70°C) Chlorine dioxide added as equivalent Cl_2% oven dry unbleached pulp		2.6		2.6		2.6
TOTAL CHLORINE ADDED as Cl_2% oven dry unbleached pulp		9.2		11.2		9.3
TOTAL CHLORINE CONSUMED as Cl_2% oven dry unbleached pulp		8.3		10.2		8.4
Yield of bleached pulp						
Oven dry bleached pulp % oven dry wood		40.0		41.0		42.6
Brightness, (Elrepho, 457 nm filter MgO = 100%)		81		76		80

Table 4

***Pinus caribaea* from Jamaica**

Unbleached sulphate pulp evaluation

Beaten PFI mill

Tree number and density	Cook number and digestion data	Beating time, minutes	Canadian Standard freeness	Drainage time, seconds	Basis weight, g/m^2	Air Porosity, 100 ml/in^2 seconds	Thickness, microns	Bulk, cm^3/g	Burst factor	Breaking length, metres	Stretch, per cent	Tear factor	Double folds Kohler-Molin 800 g
G1/23	K378	0	735	4.3	61.4	0.6	135	2.198	17.8	3313	3.4	137	64
	Active Alkali 17.5%	2	725	4.4	61.2	3.8	93	1.512	43.2	7079	3.9	105	2278
325 kg/m^3	Screened pulp yield 44.0%	4	680	4.5	59.0	12.0	85	1.448	51.0	8021	3.7	89	2257
	Kappa Number 28.9	6	600	4.5	58.6	40.8	81	1.383	56.4	9117	3.8	84	3163
		8	490	4.8	59.8	94.5	80	1.342	55.5	9398	3.7	75	2227
		10	340	5.1	61.0	672.7	80	1.307	60.0	9701	3.9	76	2596
		12	220	6.1	58.7	over 1000	76	1.297	63.4	9911	3.8	77	2885
	K380	0	740	4.4	57.4	0.9	124	2.168	20.2	3724	3.8	141	109
	Active Alkali 20%	2	725	4.4	60.3	5.2	90	1.488	39.4	6696	3.7	99	1872
	Screened pulp yield 41.9%	4	615	4.5	57.4	35.7	80	1.400	52.3	8456	3.7	86	1776
	Kappa Number 21.3	6	575	4.5	56.8	52.5	79	1.387	54.2	8819	3.6	82	2042
		8	390	5.0	58.8	439.7	77	1.317	56.6	9397	3.8	74	2153
		10	220	7.0	59.9	over 1000	75	1.260	58.6	9712	3.9	70	3078
		12	120	11.4	58.0	over 1000	73	1.256	59.8	10159	3.9	70	2810
G1/54	K371	0	745	4.3	61.4	0.2	161	2.617	15.8	3051	3.2	137	36
	Active Alkali 17.5%	2	725	4.4	58.9	0.5	105	1.790	38.3	6182	5.3	199	1955
390 kg/m^3	Screened pulp yield 45.8%	4	665	4.4	58.8	2.6	101	1.727	55.7	8002	5.4	184	3934
	Kappa Number 39.0	6	520	4.5	60.0	8.0	98	1.636	57.7	8165	5.7	180	3954
		8	380	4.9	58.8	35.1	94	1.600	60.9	8510	5.3	175	4105
		10	240	5.5	59.3	265.2	92	1.543	61.1	8998	4.9	161	4622
		12	160	7.9	60.6	over 1000	89	1.467	64.2	9317	5.1	151	4294
	K370	0	760	4.3	60.4	0.2	156	2.576	15.8	3123	3.1	134	22
	Active Alkali 20%	2	710	4.4	59.6	1.2	99	1.655	39.2	6425	4.8	171	2548
	Screened pulp yield 43.7%	4	605	4.4	58.5	4.9	91	1.550	49.5	7777	4.7	159	3260
	Kappa Number 27.3	6	450	4.6	59.4	26.2	89	1.503	55.5	8310	4.3	151	3786
		8	310	5.2	58.3	164.9	85	1.467	57.9	8759	4.3	144	3423
		10	165	7.0	59.2	994.2	83	1.405	60.2	9226	4.3	142	3963
		12	110	10.7	57.7	over 1000	80	1.387	61.7	9435	4.1	130	4374
G1/34	K382	0	750	4.4	63.4	0.1	190	2.996	5.7	1598	1.4	92	2
	Active Alkali 17.5%	2	725	4.5	60.3	0.3	114	1.891	32.3	5631	4.2	164	700
480 kg/m^3	Screened pulp yield 47.6%	4	590	4.6	60.1	3.5	106	1.767	41.9	6686	4.7	155	1240
	Kappa Number 31.6	6	350	5.0	59.2	24.9	98	1.655	47.6	7313	4.8	149	2324
		8	180	6.6	59.3	271.9	92	1.551	48.9	8050	3.4	152	2275
		10	90	14.3	57.1	over 1000	86	1.515	53.9	8328	3.3	142	2272
		12	60	46.1	58.5	over 1000	84	1.438	57.3	8473	3.7	133	3076
	K383	0	770	4.3	61.1	less than 0.1	179	2.923	5.5	1624	1.8	76	1
	Active Alkali 20%	2	720	4.5	59.7	less than 0.1	105	1.757	29.8	5405	3.8	146	314
	Screened pulp yield 45.3%	4	490	4.7	58.9	5.3	96	1.629	36.7	6233	3.8	142	1189
	Kappa Number 21.5	6	230	5.8	58.6	94.3	89	1.519	41.9	6884	3.6	128	1542
		8	120	10.5	58.2	over 1000	86	1.472	44.7	7537	3.4	129	1500
		10	55	44.0	59.3	over 1000	83	1.395	51.6	8222	3.6	119	2081

Table 5

Pinus caribaea **from Jamaica**

Pulp evaluations at 500 CSf and 300 CSf

	Cook number	Wood density, kg/m^3	Kappa Number*	Bulk, cm^3/g	Burst factor	Breaking length, m	Tear factor
Unbleached pulps at 500 CSf							
Cooks using 17.5% active alkali	K378	325	28.9	1.36	58	9400	81
	K371	390	39.0	1.64	59	8400	175
	K382	480	31.6	1.69	45	7000	155
Cooks using 20% active alkali	K380	325	21.3	1.34	56	9200	79
	K370	390	27.3	1.50	54	8200	153
	K383	480	21.5	1.61	38	6400	144
Unbleached pulps at 300 CSf							
Cooks using 17.5% active alkali	K378	325	28.9	1.30	61	9800	76
	K371	390	39.0	1.57	62	8900	166
	K382	480	31.6	1.62	48	7500	148
Cooks using 20% active alkali	K380	325	21.3	1.30	58	9600	75
	K370	390	27.3	1.45	58	8800	144
	K383	480	21.5	1.55	41	6800	136
Bleached pulps at 500 CSf			Pulp Bright-ness*				
Cooks using 20% active alkali	K380	325	81	1.34	52	8400	80
	K370	390	76	1.45	48	7900	142
	K383	480	80	1.68	36	6200	137
Bleached pulps at 300 CSf							
Cooks using 20% active alkali	K380	325	81	1.28	54	8900	76
	K370	390	76	1.41	53	8400	135
	K383	480	80	1.59	38	6600	123

*of unbeaten pulp

Table 6

Pinus caribaea **from Jamaica**

Bleached sulphate pulp evaluation

Beaten PFI mill

				PHYSICAL CHARACTERISTICS						STRENGTH PROPERTIES						OPTICAL PROPERTIES			
Sample and Cook number	Kappa number	Total chlorine % oven dry pulp Added	Total chlorine % oven dry pulp Used	Beating time, minutes	Canadian Standard freeness	Drainage time, seconds	Basis weight, g/m²	Air porosity, 100 ml/in² seconds	Thick-ness, microns	Bulk, cm³/g	Burst factor	Breaking length, metres	Stretch, per cent	Tear factor	Double folds Kohler Molin 800 g	Brightness 457 nm filter Elrepho % Mgo	Reflectance tristimulus green (Y) filter % Mgo	Printing opacity green (Y) filter	Specific scattering co-efficient
G1/23																			
	21.3	9.2	8.3	0	750	4.4	61.1	1.1	122	2.000	19.1	3399	4.0	137	73	81	89.3	78	385
K 380				2	690	4.4	58.6	9.0	85	1.446	42.8	6756	3.7	97	1245		85.8	63	208
				4	550	4.7	60.3	64.2	83	1.379	51.5	7828	3.8	84	1941		85.3	57	159
				6	415	4.9	59.4	194.7	78	1.318	51.3	8595	3.8	78	1583		82.2	54	138
				8	230	6.5	59.4	over 1000	75	1.263	55.0	9379	3.9	73	1994		78.0	52	121
				10	140	10.8	58.8	over 1000	72	1.229	56.1	9396	3.8	79	2771		77.2	48	107
				12	65	36.3	59.5	over 1000	70	1.183	60.7	9570	4.0	71	3104		74.0	44	84
G1/54																			
	27.3	11.2	10.2	0	750	4.5	64.3	0.2	166	2.578	10.9	2282	2.8	121	8	76	86.2	79	350
K 370				2	720	4.5	60.6	1.1	101	1.665	32.9	5573	4.2	178	1053		82.5	67	211
				4	670	4.5	59.3	2.6	91	1.529	42.9	7010	4.8	157	2297		81.5	61	169
				6	520	4.7	60.2	13.9	89	1.482	46.9	7520	4.3	154	2945		80.5	58	150
				8	290	5.3	59.9	199.4	80	1.343	51.0	8346	4.0	125	3465		78.4	55	130
				10	190	7.2	59.8	over 1000	84	1.402	55.1	8878	4.2	135	2600		75.4	56	127
				12	110	11.9	59.2	over 1000	78	1.316	61.1	9277	4.1	132	3585		76.4	53	118
G1/34																			
	21.5	9.3	8.4	0	770	4.2	61.5	less than 0.1	175	2.845	5.4	1599	2.0	85	2	80	88.9	71	286
K 383				2	715	4.3	59.3	0.5	110	1.860	27.8	5149	4.5	147	141		84.4	61	180
				4	470	4.5	58.1	8.1	98	1.680	36.5	6084	4.0	129	550		83.8	56	155
				6	205	6.0	59.7	173.0	92	1.550	40.0	6794	4.3	116	748		83.0	54	139
				8	95	16.0	59.2	over 1000	87	1.470	43.3	7389	3.9	109	1172		81.4	52	127
				10	45	57.1	59.0	over 1000	82	1.398	46.6	8046	3.8	99	1330		77.4	51	114
				12															

Table 7

Comparative evaluations of unbleached sulphate pulps from other woods

Values at 500 and 300 CSf

Species	Kappa number	Yield of unbleached pulp % wood: Total	Yield of unbleached pulp % wood: Screened	Canadian Standard freeness	Bulk, cm^3/g	Burst factor	Breaking length, metres	Tear factor
Pinus sylvestris	72.4	52.7	46.7	500	1.57	64	9200	175
UK grown				300	1.50	69	9800	155
	54.6	48.1	45.8	500	1.50	75	10400	165
				300	1.48	79	10900	155
	36.0	45.5	45.2	500	1.47	70	10000	165
				300	1.40	74	10500	155
	27.2	43.4	43.4	500	1.49	62	9400	165
				300	1.44	67	10100	155
Mixed Southern Pines	52.3	49.0	48.5	500	1.60	61	8600	175
USA grown				300	1.53	67	9500	165
	40.8	45.5	45.1	500	1.53	60	8500	185
				300	1.50	64	9000	175
	22.6	43.7	43.2	500	1.59	41	7000	100
				300	1.53	44	7400	90
Picea sitchensis	54.0	50.7	48.6	500	1.32	79	11200	110
UK grown				300	1.27	82	11600	105
	33.0	44.3	43.9	500	1.40	59	9100	95
				300	1.35	64	10000	85
	22.3	42.6	42.4	500	1.39	50	8100	80
				300	1.34	54	8900	75
Spruce	87.2	56.4	54.8	500	1.36	94	12800	115
USA grown				300	1.32	100	13000	100
	55.6	50.7	50.3	500	1.44	83	11450	140
				300	1.38	92	12400	130
	23.2	43.5	43.5	500	1.35	56	9100	90
				300	1.30	60	9600	85

Appendix 1
Description of site and growing conditions*

1. General comments

The material used in this study was collected in Jamaica where largescale planting of *Pinus caribaea* has been done since 1960. The plantation from which the samples were taken was established in 1956. It is situated at Gourie, in the north central part of the Island where the geographic co-ordinates are 18° 10′ latitude (North) and 77° 31′ longitude (West). The plantation was established from seeds imported from British Honduras, and records indicate that these seeds were collected from mother trees of the same provenance. However, because seeds were selected indiscriminately over the range of the provenance, it is reasonable to assume that a substantial proportion of the total variation within the provenance is represented in the Jamaican plantations.

The results contained in this study are based on *ten trees* sampled in October 1966 when the plantation was ten years old.

2. Climatic conditions

Climatological data are available from two stations in the area, namely Christiana and Holmwood, which are situated two and three miles respectively from the site of the plantation. These records are presented in Tables 2.1 and 2.2. The mean annual rainfall for the period 1954–60 was 69.04 inches with a wide variation between the driest year 1959 (52.03 inches) and the wettest year 1960 (83.40 inches). The ninety-one year average (1871–1962) for the area was 70.46 inches. Unfortunately, records for the year 1961 to 1966 were not available from the two stations mentioned. The wettest months over the reported period were May and October with an average rainfall of 7.98 and 9.98 inches respectively, whilst the driest months were February and December with averages of 2.68 and 3.53 inches respectively. In most years it seems that the distribution of rainfall would allow continuous growth of trees.

Here again the data up to 1966 was lacking at the two stations, but from experience with the area, large fluctuations are not usual. Mean annual maximum temperature was 79.3°F. The hottest months were July to November with mean temperatures in the low 80s. The coldest months were between December and February when the mean temperature ranged between 52.9 and 55.1°F.

*The whole of this appendix is reproduced from the thesis submitted by G. Brown in 1969 for the degree of D.Phil. (Oxon).

Table 2.1
Mean monthly rainfall at Christiana (inches)
1954–1960 plus 91 year average (1871–1962)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean for year
1954	3.53	6.08	5.89	5.59	4.97	5.28	2.85	7.53	13.51	7.63	3.40	0.86	67.12
1955	5.19	2.38	3.65	2.68	6.24	5.94	6.08	7.89	7.62	5.48	3.35	5.43	61.93
1956	3.14	0.52	7.21	3.34	12.51	6.95	4.65	3.82	6.13	13.59	5.48	7.28	74.62
1957	8.86	5.53	5.92	7.00	6.51	1.19	4.81	4.42	8.11	8.27	2.17	4.66	67.45
1958	7.53	0.85	0.61	1.71	10.74	15.81	4.64	7.10	8.33	17.50	1.25	0.70	76.77
1959	0.62	3.23	3.79	5.10	6.37	0.86	1.99	5.00	3.54	8.76	7.51	5.26	52.03
1960	13.41	0.2	5.53	9.88	8.57	12.37	4.17	7.74	4.19	8.64	8.14	0.56	83.40
Mean	6.04	2.68	4.65	5.04	7.98	6.91	4.17	6.21	7.34	9.98	4.47	3.53	69.04
1871–1962	2.35	2.75	3.91	6.64	8.38	6.06	4.30	7.15	8.57	11.38	6.23	2.74	60.46

Mean maximum and minimum temperature and relative humidity are shown in Table 2.2 for the years 1955 to 1959.

Table 2.2
Mean maximum and minimum temperatures and relative humidity at Holmwood 18°09′N 77°31′W – 3004 feet above M.S.L.
Period 1955–1959

	Mean maximum temperature	Mean minimum temperature	Mean relative humidity 7 am	Mean relative humidity 3 pm
Jan	76.3	54.6	95	82
Feb	76.7	54.6	94	85
Mar	78.5	55.1	93	83
Apr	79.1	56.1	92	82
May	79.1	57.3	92	85
June	79.4	58.1	92	87
July	80.3	58.4	92	88
Aug	83.2	58.5	88	84
Sept	81.4	59.5	91	86
Oct	80.0	56.6	94	90
Nov	80.1	55.5	95	87
Dec	78.0	52.9	93	86
Mean/Year	79.3	56.5	92	85

Mean relative humidity at 7.00 am was 92 per cent whilst at 3.00 pm it was 85 per cent over the four-year period.

3. Physical features and soil

The plantation from which samples were taken is situated at an altitude of approximately 3,000 feet above mean sea level on slopes ranging from between 10° and 20° with a predominantly South westerly aspect. Sampled plots were selected to ensure uniformity in site. This site type is typical of much of the area in use for the establishment of pine plantations in Jamaica.

The soil is derived from a yellow limestone. It has a good crumb structure with a top soil depth of 9 to 12 inches. Subsoil depth is usually about 7 inches, but this soon merges into limestone rock. Analytical soil data are presented in Table 2.3. It is shown that calcium carbonate content is quite high, ranging from 4 up to 53.7 per cent in different parts of the plantation. The soil is predominantly alkaline and where acidic only very slightly so, and primarily confined to the surface layer.

Table 2.3

Soil description and analytical data of 3 plots in the Gourie plantations

Location	Soil type	Slope	Soil description
Plot No 1 (1/5th acre)	Carron Hall Clay, Map No 94	10°–20°	9 in. Br.C. with good structure, over 7 in.Y. Br.C., over 5 in. rock fragments. Below 21 in. is hard yellow limestone rock.
Plot No 2 (1/10th acre)	Carron Hall Clay, Map No 94	10°–20°	9 in. Br.C. over 3 in. Y. Br.C.with some shot over 7 in. Br.C. with good structure, over 8 in. Br.C. with limestone fragments and streaks. Below 7 in. is limestone rock with numerous shells.
Plot No 3	Union Hill Stony Clay, Map No 75	10°–20°	8 in. Br.C. over 8 in. reddish Br.C. Below 16 in. is hard limestone rock containing numerous fossils. Boundary of soil and limestone is sharp.

Analytical data for these plots are as follows:

Location	Depth (in)	pH	% Ca CO_3	% Total N	ppm P205 YY	Available K20 YY YY
Plot No 1	0–9	8.2	12.1	0.28	X10	374
	9–16	8.4	13.7	0.09	M10	346
	16–21	8.5	53.7	0.07	10	500
Plot No 2	0–9	6.4	–	0.24	20.0	159
	9–12	6.7	–	0.13	10	76
	12–19	6.8	–	0.11	10	112
	19–27	8.2	26.9	0.06	10	434
Plot No 3	0–8	6.9	–	0.33	10	274
	8–16	7.8	0.4	0.18	10	130

YY Soluble in .002N H_2SO_4 buffered to pH 3.0

YY YY Soluble in 0.5N Acetic acid

4. Natural vegetation

There was a dense undergrowth of shrubs in all plots. These were up to 6 feet tall in places. Ground flora was predominantly grasses and herbs. The primary grass species present were: *Ichnanthus pollens* (Sw.) Munro and *Digitaria* spp. The herbaceous species included *Euphatorium odoratum* L, *Euphatorium riparium* Regel, *Verbesinia pinnatifolia* Sw. and *Triumfetta semitriloba* Jacq. Although weeds were abundant the ground cover was quite moderate.

5. Plantation history and growth

The plantation was established from potted seedlings which were about 7 months old at time of planting and about 12 inches in height. Planting was done at a spacing of 8 x 8 feet giving a stocking of 680 plants per acre. The only operations which were carried out within the plantation over the period was weeding, which was confined to the first three years of the life of the plantation; and a light pruning and thinning in 1964.

The plantation was always vigorous in growth averaging 5.1 feet in height growth per annum and 0.9 inches in diameter growth at breast height. Average stand height was 50 feet.

Appendix 2
Experimental methods

1. **Apparent density of wood**

The method used was TAPPI Standard method T 18m-53[1] using one piece approximately one inch thick from each log received.

The green volume was determined by weighing the disc, which had been soaked in water until it was saturated, immersed in water. The oven-dry weight was determined by weighing the disc after it had been dried to constant weight at 105° ± 3°C.

The apparent density is expressed as: $\dfrac{\text{oven-dry weight}}{\text{Green (soaked volume)}}$

2. **Chemical analysis**

The chemical analyses were carried out on a composite sample. A portion of the chips prepared for pulping trials was ground in an Apex knife mill and the fraction of groundwood which passed through a British Standard 40 mesh (420 microns) sieve and was retained on a British Standard mesh (250 microns) sieve used for analysis.

The methods used were:

Alcohol benzene solubility	TAPPI T 6m-59[1]
Holocellulose	Wise, Murphy, D'Addieco[2]
Alpha-cellulose	TAPPI T203 os-61[1]
1% Caustic Soda Solubility	TAPPI T 4m-59[1]
Lignin	TAPPI T 13m-54[1]

The fractions soluble in alcohol-benzene and 1% caustic soda are expressed as oven dry extractives per cent oven-dry wood.

The alpha-cellulose and lignin are expressed oven dry per cent oven dry wood.

The holocellulose was dried by washing in acetone and storing at room temperature in a desiccator until constant weight. Under these conditions the holocellulose was found to have a moisture content of 2 per cent. In calculating the result allowance was made for this moisture content and the result is reported as oven dry holocellulose per cent over dry wood.

3. **Microscopic examination**

The fibre measurements were made on re-dispersions of pieces of standard sheets made from unbeaten sulphate pulp and they are thus representative of a composite sample. The fibres were mounted in aqueous medium and the length, width and wall thickness of 100 fibres measured. The lengths of all fibre elements both whole and broken were determined by measuring a projected image with an electro-mechanical probe and a recorder which counted the total number of fibres measured, the sum of the lengths of the fibres and the number of fibres falling in each of 18 length groups, each group representing a 0.5 mm range of fibre length. In this way the average length of fibres in pulp and a distribution curve of lengths were obtained. The widths of the parially collapsed fibres and the wall thickness were determined by direct measurement of the projected image. Because pulping and the pressing during sheet making causes the fibres to collapse the widths are typical of the pulp only. Fibre wall thickness as measured may also differ from that observed on a cross section of wood.

4. Pulping methods

The chips used for pulping were prepared by sawing the log into discs approximately ¾ inch thick and then splitting along the grain with a mechanical guillotine to give a chip approximately ¾ inch x ¼ inch thick. This damages the fibres less than commercial chipping.

Laboratory pulping was carried out in an electrically-heated, stainless steel, rotating pressure vessel.

The method used was the sulphate (Kraft) process, which was selected as being the most promising process for use on tropical woods in tropical conditions. The active chemicals are sodium hydroxide and soium sulphide.

The concentration of chemicals is calculated according to the following definitions:

(a) Active Alkali = $NaOH + Na_2S$ expressed at Na_2O per cent on oven-dry wood.

(b) Sulphidity $= \frac{Na_2S \times 100}{NaOH + Na_2S,}$ all the compounds expressed as Na_2O.

A sulphidity of 25 per cent was used in each of these experiments, chosen because published information shows there to be generally little variation in pulp quality with changes in sulphidity in the range of 20 to 30 per cent.

The cooked chips were washed free of superficial black liquor and broken up in a propeller type disintegrator to simulate the disintegration occuring during blowing a commercial digester; the pulp was screened using a plate with 0.15 mm wide slits, to remove shive, and collected on a 150 mesh (per linear inch) sieve.

The yield of pulp was determined by drying the whole of the screened pulp in a stream of air to about 10% moisture. The total weight of air dry screened pulp and the moisture content of an aliquot were determined for calculating the yield of oven-dry pulp.

The total alkali in the black liquor was determined by titrating an ashed aliquot of black liquor with hydrochloric acid. The Active Alkali remaining was determined by titrating an aliquot of black liquor after removing the sodium salts which are the reaction products of digestion by precipitation with barium chloride. The Active Alkali consumed was the difference of these results.

5. Unbleached pulp evaluation

The Kappa Number was determined by TAPPI standard method T 236m-60[1]. This method is identical with the International Committee for Chemical Analyses Method ICCA 1:59 which has been adopted throughout the world.

The amount of permanganate consumed by pulp under specified conditions is measured and, for pulp yields of less than 70 per cent, the percentage of Klason lignin approximately equals Kappa Number XO.15.

The pulp was evaluated by preparing and testing standard sheets, from pulp which had been air dried, according to the proposals of the 'Second Report of the Pulp

Evaluation Committee to the Technical Section of the (British) Papermarkers' Association'[3]. The sheets of approximately 60g/m^2 were tested after conditioning at 20° ± 1°C and 65 per cent relative humidity. The methods given in this report are practically identical with those in TAPPI Standard T205m-58[1]. The effect of air drying is to lower the strength of the unbeaten pulp, but, except for specific scattering coefficient, the effect on beaten pulps is small.

The pulps were beaten in a PFI Mill using a pulp consistency of 10 per cent, a beating pressure of 3.4 kgF (33.3N) per cm of bar length and a difference between the peripheral speeds of the beating elements of 2 m/sec.

The methods used for physical examination of each set of sheets were:

(a) Thickness: Ten measurements made on ten sheets placed one on top of another using a dead weight micrometer.

(b) Breaking length and stretch: Twelve strips 15 mm wide tested using a Schopper-type tensile tester with the jaws initially 9 cm apart.

(c) Tear: Using a Marx-Elmendorf tear tester; normally a group of three were torn at one time through 44 mm in 2 places (i.e. total tearing distance is 3 x 2 x 44 = 264 mm), three readings being obtained in this way. Sheets with high tearing strength were torn either in pairs or singly and suitable adjustment was made to the calculation of the tear factor.

(d) Burst: Eighteen tests using a Frank Schopper-Dalen type pneumatic burst tester.

(e) Fold: 15 mm strips folded through 312° and the number of double folds recorded before the strip broke under a load of 7.85 N(800gF).

(f) Air porosity: Four sheets tested using a closed top Gurley Densometer with a 20 ounce inner cylinder. The time for 100 ml of air to pass through 1 sq inch was measured by the automatic timing attachment.

(g) Basic weight and moisture content: Determined by weighing six rectangles of 250 cm^2 after standard conditioning and after drying to constant weight at 105° + 3°C.

Results are reported as follows, where possible, independent of basis weight, but otherwise referring to an oven dry basis weight of approximately 60g/m^2.

Basic weight: Grams per square metre, oven dry (W)

Thickness: Thickness of a single sheet, in microns

Bulk* $\dfrac{\text{Thickness}}{W}$

Burst Factor* $\dfrac{\text{Average burst in g/cm}^2}{W}$

Tear Factor* $\dfrac{\text{Tearing force for a single sheet in gx100}}{W}$

Breaking Length* $\dfrac{\text{Average tensile strength in kg x 66,700}}{W}$

The result is expressed in metres.

*results which are independent of basis weight.

The ease with which water parts from the pulp was determined by two methods. The first, the drainage time determined on the standard sheet machine, is the time in seconds for water at 20°C to flow from a pulp suspension through the wire from a height 350 mm above the wire until the formed sheet is no longer immersed. The procedure used was that described in the 'Second Report of the Pulp Evaluation Committee'[3] and is similar to that given in TAPPI Standard T221os-63[1].

The second, the Canadian Standard freeness is an empirical measure of the rate at which water will separate from a one litre suspension of 3 grams of pulp through a standard perforated plate, in apparatus calibrated by the Pulp and Paper Research Institute of Canada. The method is described in the 'Second Report of the Pulp Evaluation Committee[3], TAPPI Standard T227m-58[1]' and in Canadian Pulp and Paper Association Standard C1.

6. Bleaching and bleached pulp evaluation

Bleaching trails were carried out by a four stage method of chlorination extraction, hypochlorite and chlorine dioxide (CEHD). This is the simplest sequence currently used to obtain a fully bleached sulphate pulp. The quantity of chlorine added, sufficient to give an excess that would not be consumed within the reaction time, was estimated from the Kappa number using data for the relationship between Kappa number and chlorine demand from earlier trials.

The brightness was determined using an Elrepho reflection photometer using a 'Tappi' filter (with an effective wavelength of 457 nm) and a Magnesium oxide standard as 100.

The printing opacity was determined using the same instrument with CIE tristimulus filters Y (green). The reflectance from a single 60 g/m^2 sheet (Ro) over a black background was compared with the reflectance from a pad sufficiently thick to ensure no light was transmitted ($R\infty$).

Then printing opacity = $\frac{Ro \times 100}{R\infty}$. This figure is dependent on the basic weight of the sheet.

The scattering power (SX) was determined from the relationship between the printing opacity $\frac{Ro \times 100}{R\infty}$ and the total reflectance. The specific scattering coefficient(s), which is independent of the basis weight is given by:

$$s = \frac{SX \times 10{,}000}{W}$$

where W = Basis Weight, oven dry in g/m^2.[4]

The strength characteristics of the bleached pulps were determined as described for unbleached pulps.

References

1 TAPPI Standard and Suggested Methods, Published by the Technical Association of the Pulp and Paper Industry, New York.

2 L. E. WISE, M. MURPHY and A. A. D'ADDIECO, *Paper Trade J.* 1946, **122,** No 2,35.

3 Second Report of the Pulp Evaluation Committee to the (British) Paper Makers' Association, London, 1936.

4 H. W. GIERTZ, *Svensk Papperstidning,* 1950, **53,** 673.

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