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KRAFT PULP PROPERTIES OF SELECTED NEW ZEALAND GROWN EUCALYPT (*E. NITENS* AND *E. REGNANS*) WOOD MATERIAL

R. PAUL KIBBLEWHITE AND JOHN A. LLOYD

REPORT 13 SEPT. 1993

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R. Paul Kibblewhite and John A. Lloyd

SUMMARY

E. nitens and *E. regnans* kraft pulp qualities are deficient in handsheet bulk when compared with currently acceptable eucalypt market kraft pulps. The poor handsheet bulk properties are explained by low fibre coarseness and thin walls for a given fibre cross section area of the *E. regnans* and *E. nitens* pulps.

Kraft pulp fibre quality is not indicated by log or chip basic density.

INTRODUCTION

Three *E. nitens* log supplies were classified into basic density groupings of low, medium and high. This material as well as a single *E. regnans* wood sample were chipped and trialed in the chemimechanical pulping plant at Caxton Papermills. Samples of the four chip samples were supplied to PAPRO for kraft pulping, bleaching and kraft pulp quality assessment.

EXPERIMENTAL

Sample origin

The *E. regnans* sample was obtained from 20-year-old whole-trees from NZFP Tokoroa forest. The *E. nitens* low, medium and high basic density samples were obtained from 18-year-old trees, Compartment 905, Kaingaroa Forest. Log basic densities were assessed using core samples and allocated into low, medium and high categories as follows: Low <420 kg/m^3, medium 420 - 445 kg/m^3, high >445 kg/m^3. Tree and log selection and allocation, and the procedure used for core density analysis were not the responsibility of PAPRO. Chip samples were supplied to PAPRO for pulping, bleaching, fibre quality and handsheet assessment.

The basic density of the four composite chip samples used in the pulping trials were determined following PAPRO standard method 1.201

The Aracruz reference market kraft eucalypt pulp from Brazil was reference material 8496 supplied by Aracruz Cellulose S.A., and distributed by National Institute of Standards and Technology, Standard Reference Materials Program, Building 202, Room 205, Gaithersburg, Maryland 20899, USA.

Pulping and bleaching

Four kraft pulps of varying kappa number were prepared from each chip sample by varying the H-factor at constant alkali charge. The pulping conditions were:

12% effective alkali (E.A.) as Na_2O
30% sulphidity
4:1 liquor-to-wood ratio
90 minutes to maximum temperature
170^{o}C maximum temperature
Approx. 15, 30, 45 or 60 minutes @ max. temperature

Pulps were prepared in 2.0 L Stalsvets reactors with 250 g (o.d. wt.) chip charges. The residual effective alkali in the black liquors was determined by titrating the supernatant after $BaCl_2$ addition and centrifuging, with 0.5M HCl to a pH9.5 endpoint. Pulps were disintegrated with a propeller stirrer and screened through a 0.25mm slotted flat screen. After dewatering and fluffing the kappa number, percent rejects and total yield were determined.

Pulps 3,7, 12 and 14 were fully bleached with constant chemical charges in each stage of a (DC)EoD sequence. Procedures used were in accordance with PAPRO standard method 1.604. Bleach conditions were: **(DC) stage:** 0.25 active chlorine multiple, 100% industrial chlorine dioxide, 10% consistency, 50^{o}C, 45 minutes. **Eo stage:** 2.0% NaOH, 25 MPa O_2, 10% consistency, 70^{o}C, 60 minutes. **D stage:** 1.0% ClO_2, 0.4% NaOH, 10% consistency, 70^{o}C, 180 minutes.

Fibre dimensions

Bleached pulp length weighted fibre lengths and coarseness values were determined using a Kajaani FS 200 instrument according to PAPRO standard method 1.306.

Cross section dimensions were measured on fibres rewetted from handsheets to allow direct comparison with those of corresponding eucalypt market kraft pulps (1). Fibre cross section dimensions were measured according to PAPRO methods 2.102 to 2.106.

Handsheet preparation and testing

Pulps were refined in a PFI mill using standard Appita conditions. The *E. nitens* and *E. regnans* pulps were refined and sheet made in the undried (never dried) state. The Aracruz reference market kraft dry lap pulp was rewetted using Appita standard procedures before refining and sheet making. Handsheets were prepared and their physical properties determined following Appita standard procedures. Optical properties of the handsheets were measured in accordance with PAPRO standard method 1.505. Test data were recorded on o.d. bases.

RESULTS and DISCUSSION

Pulping

The results from the laboratory pulping study are listed in Table 1. The Table shows that the cooking needed to be continued for at least 600 H-factors in order to obtain pulps with acceptable levels of rejects. The relative pulping rates for the four chip samples in terms of kappa number reached at a given H-factor are shown in Figure 1. *E.regnans* chips were the most easily pulped to a bleachable grade pulp, requiring only about 700 H-factors compared with the 800 H-factors needed for the medium and high density *E.nitens* samples. However the low density *E.nitens* chips were more difficult to pulp and probably require a higher effective alkali charge in order to be successfully pulped.

The pulp yield/kappa number relationships are shown in Figure 2. *E.regnans* gave higher pulp yields than *E.nitens*. When compared at 20 kappa number, the yield of

E.regnans pulp was 55% compared with 51-53.5% for *E.nitens*. High and low density *E.nitens* chips generally gave similar pulp yields whereas the yields from the low density chips were approximately 2% lower.

Table 1: Pulping data

Pulp	Chip type	H-factor	Kappa number	Rejects %	Total yield %	Residual effective alkali g/L	Effective alkali consumed g/L
1	High	357	37.4	44.2	70.6	5.4	24.6
2	*E.nitens*	599	23.7	5.8	54.2	4.2	25.8
3		869	17.6	1.4	52.9	3.8	26.2
4		1130	16.1	2.1	52.2	3.6	26.4
5	Medium	471	34.5	22.2	57.4	5.3	24.7
6	*E.nitens*	718	21.1	1.6	52.9	4.1	25.9
7		983	17.7	2.1	54.2	3.6	26.4
8		1157	15.1	0.4	52.2	3.4	26.6
9	Low	371	42.8	44.8	58.7	5.3	24.7
10	*E.nitens*	605	30.1	11.5	52.8	4	26
11		873	22.4	3	51.5	3.6	26.4
12		1077	19.2	1.3	50.7	3.6	26.4
13	*E.regnans*	423	32.7	14.2	57.7	7	23
14		698	19.3	1.4	55.5	5.1	24.9
15		924	14.2	0.4	53.7	4.2	25.8
16		1250	14	0.8	54.8	3.9	26.1

A previous study of the pulping characteristics of Australian-grown *E.regnans* chips found that the pulp yield varied both with tree age and chip density (2). Pulp yields at kappa 20 varied between 52% and 57%. with the highest yields being obtained from 30-60 year-old trees while both younger or older trees gave lower yields. Other pulping studies of *E.regnans* and *E.nitens* have reported yields similar to those obtained in the present study (3-5).

E.nitens low density chips consumed slightly less alkali during pulping than the medium or high density chips and *E.regnans* chips required more alkali to pulp to the same kappa number (Figure 3).

Pulp Bleachability

Approximately 20 kappa number pulps of each chip class were bleached using a standard (CD)EoD bleaching sequence and the final brightness of each pulp determined. All of the pulps were easy to bleach to good final brightness but there was a trend evident within the *E.nitens* group as the final brightnesses were 87.3, 87.5 and 88.1 percent for the low, medium and high density pulps respectively. The final brightness of the *E.regnans* pulp was 87.2%, about the same as the low density *E.nitens* pulp.

Fibre properties of bleached pulps

Chip basic density values for the *E. nitens* samples are in agreement with their low, medium and high density classification (Table 2). In contrast, the fibre properties of length and coarseness are inconsistent and not predictable from chip basic density since the chips of high density have fibres of intermediate length and coarseness. The medium coarseness fibres are the longest, largest in size (width x thickness) and most coarse. Fibre properties of the *E. regnans* pulp are roughly equivalent to those of the *E. nitens* pulp made from chips of high basic density.

Fibre dimensions of the reference Aracruz eucalypt market kraft pulp are roughly equivalent to those of the medium density *E. nitens* pulp except that wall area (coarseness) is slightly higher and wall thickness significantly higher.

Handsheet properties

Handsheet properties considered most relevant to an assessment of hardwood kraft quality are listed in Table 3. Selected handsheet data for the Aracruz reference pulp are also listed in Table 3, since these are indicative of acceptable eucalypt market pulp quality. **Note:** The Aracruz pulp was available only as a dry lap and required to be rewetted before refining. Furthermore, the Aracruz pulp required more refining than the undried laboratory pulps to develop papermaking properties, as expected (1). Additional test data for the four eucalypt pulps are appended (Appendix I).

The medium *E. nitens* pulp develops the highest tensile strength at the lowest apparent density or the highest bulk (the reciprocal of apparent density) (Figure 4, Table 3). Conversely, the low density *E. nitens* pulp develops tensile strengths at high sheet densities or low bulk values. The *E. regnans* and high density *E. nitens* pulps show intermediate tensile strength/apparent density properties, although the *E. regnans* minimum sheet density values are exceptionally high.

Optical properties as measured by light scattering coefficient are highest (best) for the low density *E. nitens* pulp and lowest for the medium density *E. nitens* pulp, when compared at given tensile strengths (Figure 5). Light scattering coefficients of the low density *E. nitens* and the *E. regnans* pulps are however only obtained at the expense of bulk at exceptionally high apparent densities (> 670-680 kg/m^3) (Figure 6, Table 3).

Comparison with the reference Aracruz market kraft eucalypt pulp shows the *E. nitens* and *E. regnans* pulps to have excellent optical properties and tensile strengths (Figures 7,8,9, Table 3). The deficiency of the New Zealand eucalypt pulps is their low bulk or high sheet density properties. Only the medium *E. nitens* pulp shows sheet density and bulk values equivalent to those of the Aracruz furnish.

Fibre size (width x thickness) and wall area values of the *E. regnans* and *E. nitens* pulps are equivalent to the lowest, or below those, of eucalypt kraft pulps currently available on world markets (1). Thus, wall thickness values relative to fibre size (width x thickness) are low for the *E. nitens* and *E. regnans* pulps, and fibres are readily collapsed when made into paper sheets, and sheet densities are unacceptably high. Fibres in the Aracruz pulp, on the other hand, clearly fit into the current eucalypt market pulp grouping, with high wall thickness and relatively small fibre size values (Table 2). The Aracruz fibres can, therefore, be expected to be less collapsed and form handsheets of high bulk compared with the *E. nitens* and *E. regnans* pulps.

From a genetic point of view it is suggested that for kraft pulps, *E. nitens* and *E. regnans* trees be selected for high fibre coarseness, low fibre size (width x thickness) , and thick walls

CONCLUSIONS

Fibre qualities of the *E. nitens* and *E. regnans* kraft pulps are somewhat deficient in handsheet bulk when compared with other eucalypt kraft pulps available on world markets. Thus, the development of increased fibre coarseness, decreased fibre size, and increased fibre wall thickness must be the primary aim of any *E. nitens* and *E. regnans* genetic improvement programme directed towards the manufacture of eucalypt kraft pulps of high quality. Pulp yield and the ease of pulping (H-factors) to a given kappa number are factors which should also be considered and it appears that low density *E.nitens* may be deficient in these areas.

Tree, wood or chip basic density is not indicative of kraft pulp fibre quality

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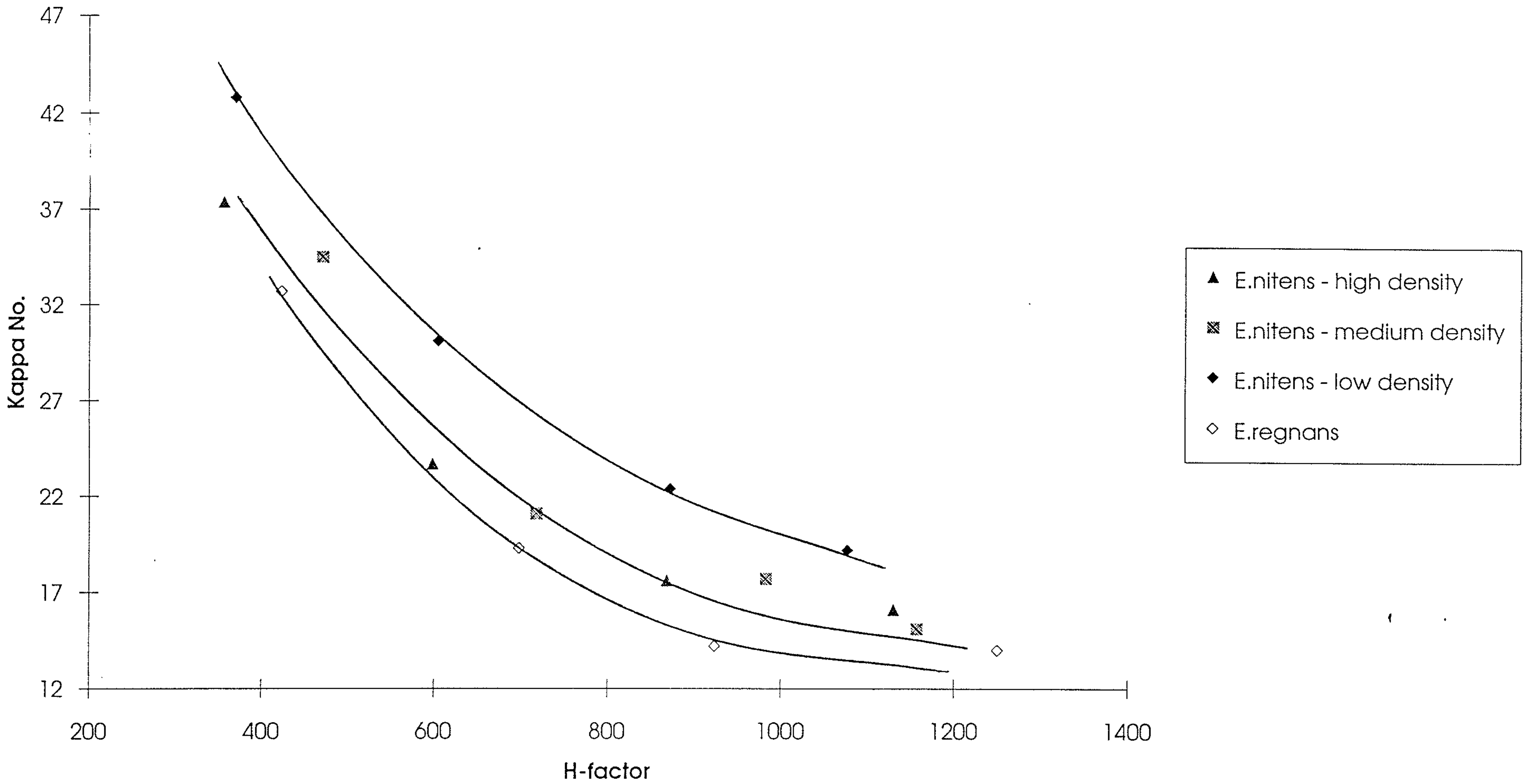


47
42
37
32
27
22
17
12
Kappa No.
200
400
600
800
1000
1200
1400
H-factor
E.nitens - high density
E.nitens - medium density
E.nitens - low density
E.regnans

FIGURE 1

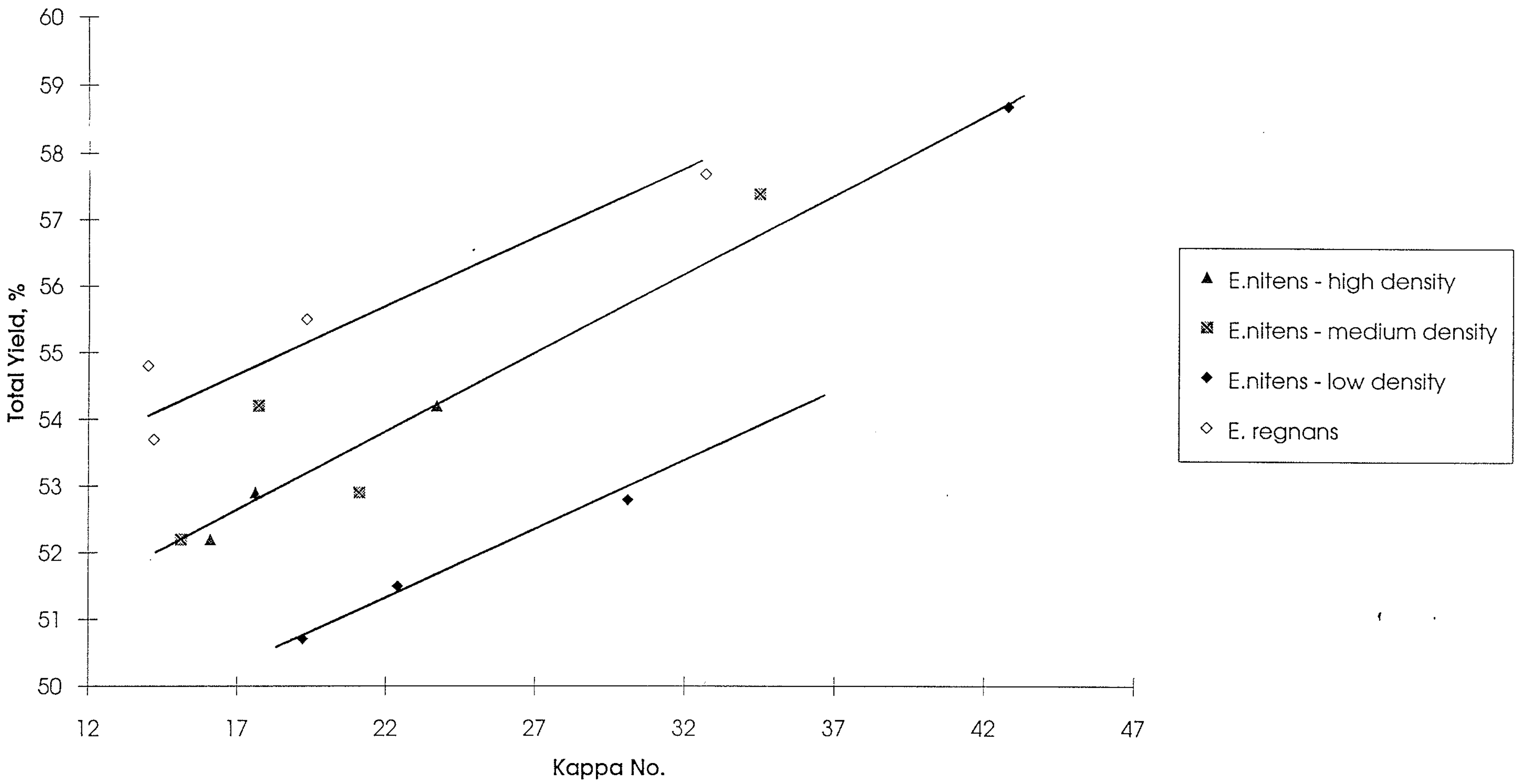
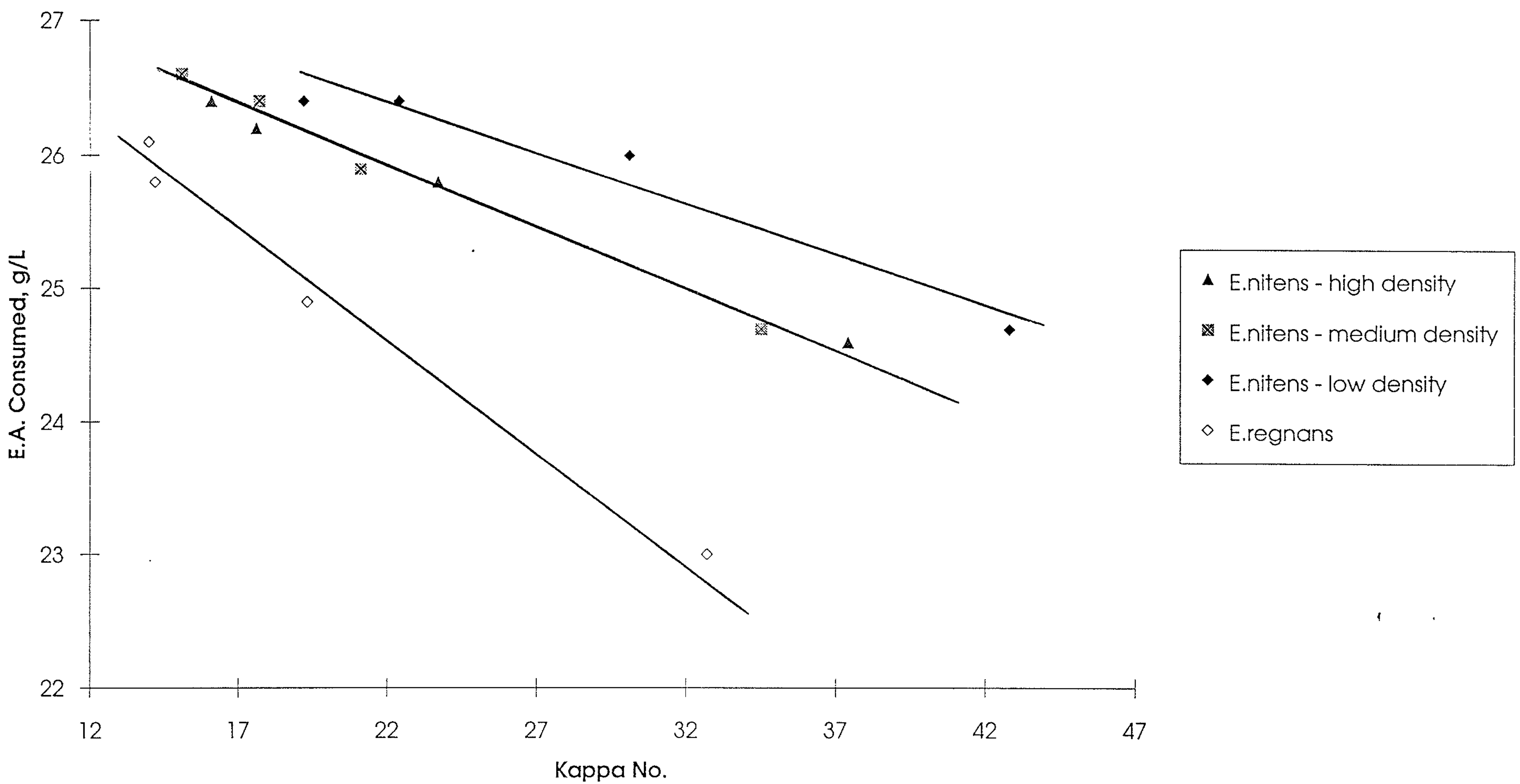

60
59
58
57
56
55
54
53
52
51
50
Total Yield, %
12
17
22
27
32
37
42
47
Kappa No.
E.nitens - high density
E.nitens - medium density
E.nitens - low density
E. regnans

FIGURE 2



27
26
25
24
23
22
E.A. Consumed, g/L
12
17
22
27
32
37
42
47
Kappa No.
E.nitens - high density
E.nitens - medium density
E.nitens - low density
E.regnans

FIGURE 3

Table 2: Fibre length, coarseness and cross section dimensions

Pulp	Chip basic density (kg/m^3)	Length weighted length (mm)	Coarseness (mg/m)	Width (um)	Thickness (um)	Width x thickness (um)	Wall area (um^2)	Wall thickness (um)	Width / thickness
Low *E. nitens*	431	0.71	0.062	13.4	6.7	90	58	2.12	2.07
Medium *E. niten*	455	0.79	0.069	13.2	7.2	97	60	2.18	1.93
High *E. nitens*	474	0.77	0.064	13.5	6.6	90	59	2.21	2.13
E. regnans	462	0.77	0.063	12.9	6.8	89	58	2.22	1.99
Aracruz	--	.76	--	13.5	6.6	89	60	2.36	2.17
LSD*				0.7	0.3	7	4	0.1	0.13

*LSD: Least significant difference between means at the 95% level of significance

Table 3: Pulp and handsheet properties

Pulp	PFI (rev)	Pulp freeness (Csf)	Apparent density (kg/m^3)	Bulk (cm^3/g)	Tensile index (Nm/g)	Stretch (%)	Light scattering coefficient (m^2/kg)
E. nitens Low	0	540	681	1.47	72.0	3.25	40.7
	500	448	739	1.35	95.6	3.92	35.0
	1000	381	761	1.31	107.0	4.02	32.2
	2000	321	782	1.28	123.0	4.45	28.5
E. nitens Medium	0	603	613	1.63	54.2	2.06	39.1
	500	491	668	1.50	80.2	2.95	35.9
	1000	427	693	1.44	91.3	3.14	32.6
	2000	433	718	1.39	111.0	3.79	28.6
E. nitens High	0	567	637	1.57	61.8	2.63	41.1
	500	530	684	1.46	83.3	3.38	36.6
	1000	473	704	1.42	97.8	3.93	34.0
	2000	433	732	1.37	118.0	4.28	30.5
E. regnans	0	570	671	1.49	59.2	2.55	39.0
	500	532	691	1.45	85.5	3.37	36.6
	1000	478	717	1.39	99.8	3.88	33.6
	2000	432	751	1.33	118.0	4.44	30.0
Aracruz Rewetted dry lap	1000		616	1.62	54	2.76	39.5
	2000		644	1.55	62	3.18	37.5
	4000		697	1.43	81	3.77	32.7
	8000		725	1.38	97	4.22	30.6

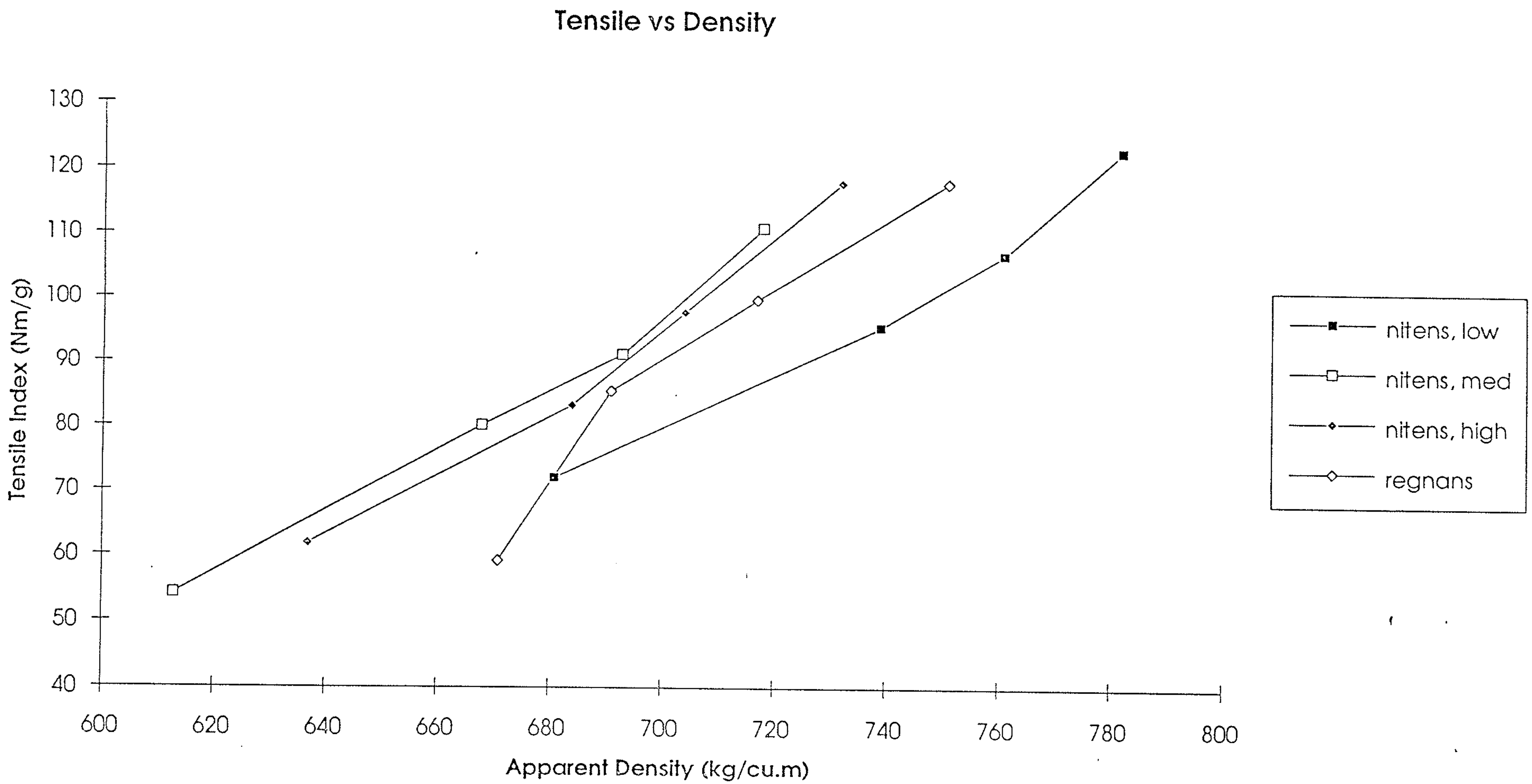
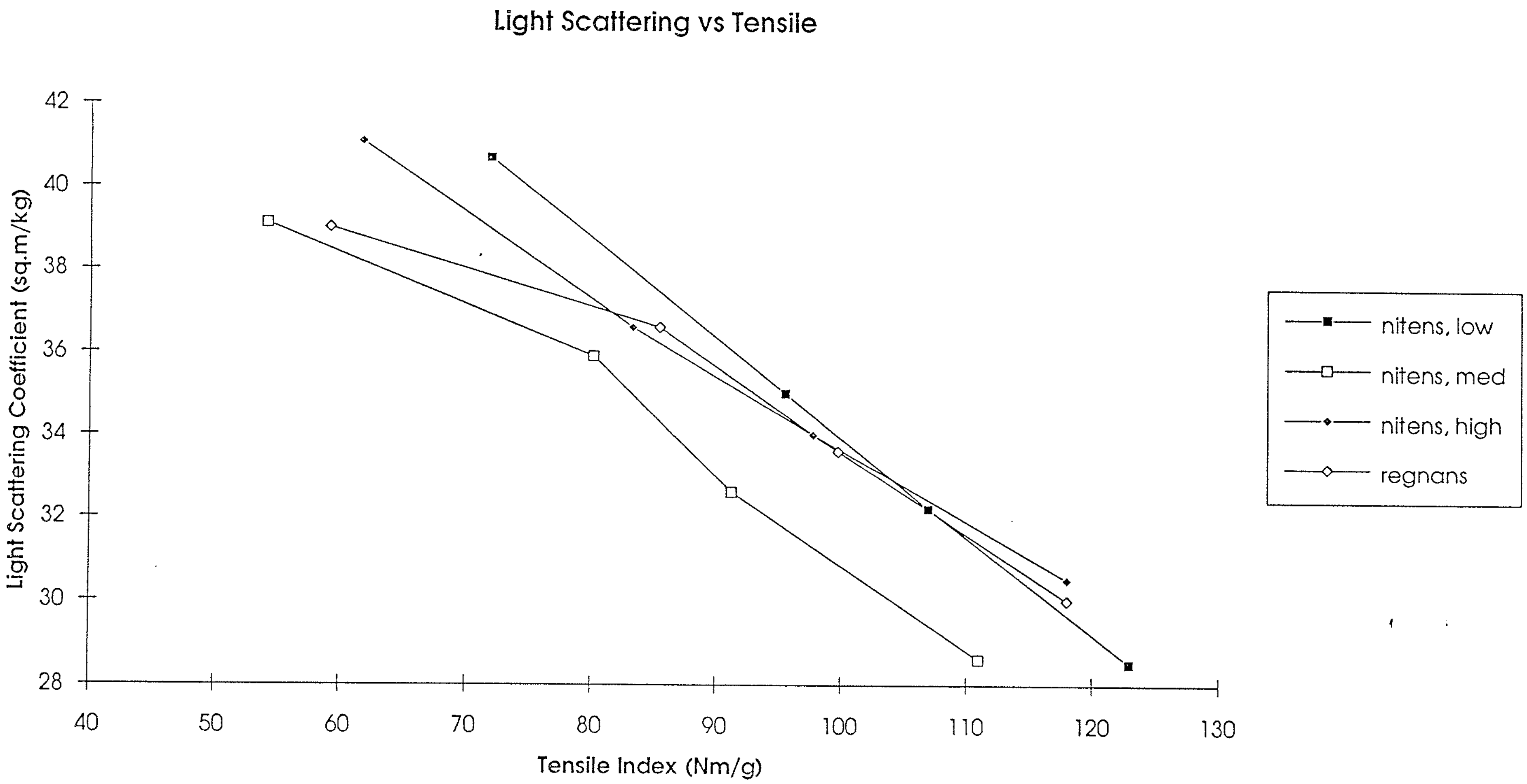

Tensile vs Density
Tensile Index (Nm/g)
130
120
110
100
90
80
70
60
50
40
600
620
640
660
680
700
720
740
760
780
800
Apparent Density (kg/cu.m)
nitens, low
nitens, med
nitens, high
regnans

FIGURE 4



Light Scattering vs Tensile
Light Scattering Coefficient (sq.m/kg)
42
40
38
36
34
32
30
28
40
50
60
70
80
90
100
110
120
130
Tensile Index (Nm/g)
nitens, low
nitens, med
nitens, high
regnans

FIGURE 5

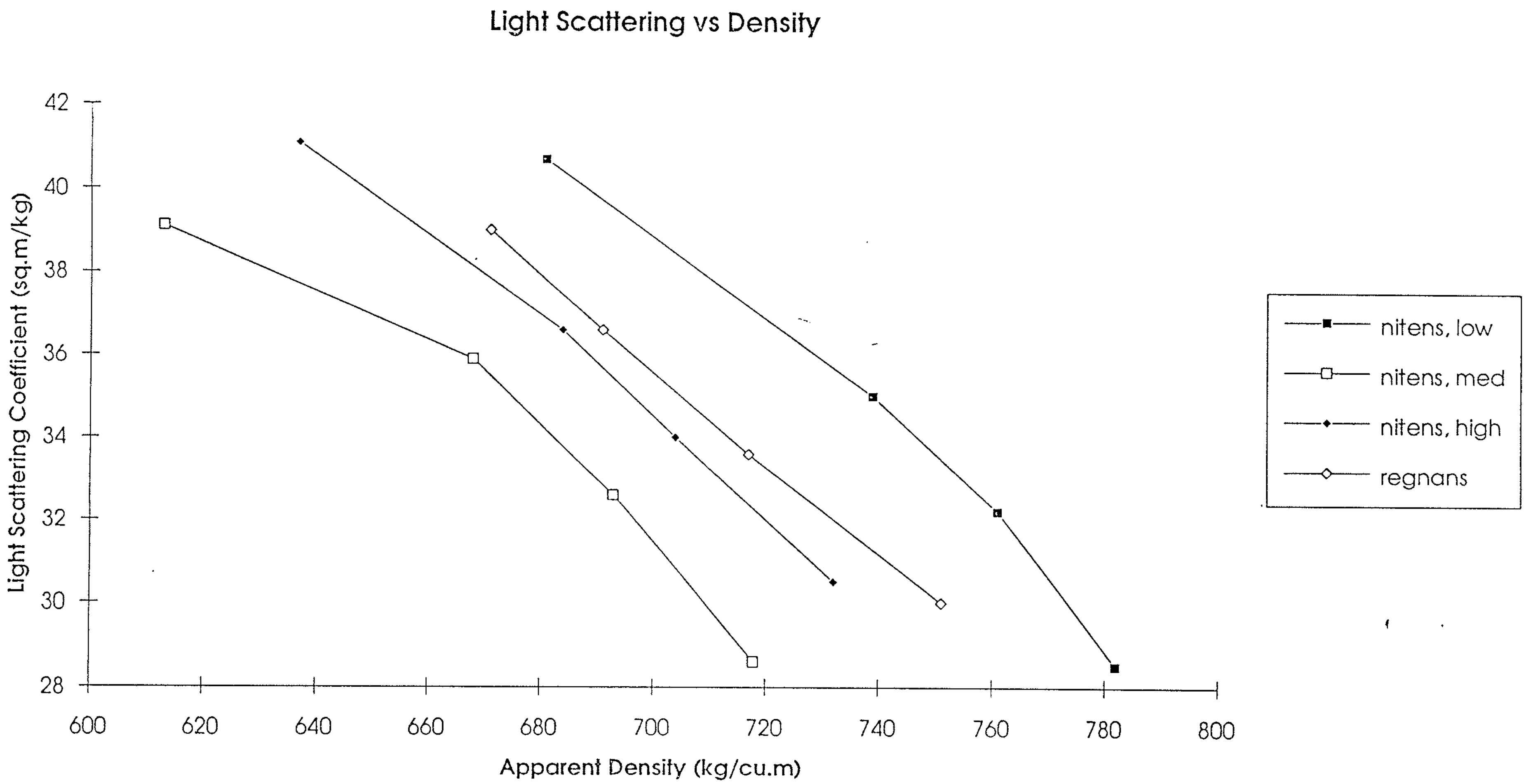

Light Scattering vs Density
Light Scattering Coefficient (sq.m/kg)
42
40
38
36
34
32
30
28
600
620
640
660
680
700
720
740
760
780
800
Apparent Density (kg/cu.m)
nitens, low
nitens, med
nitens, high
regnans

FIGURE 6

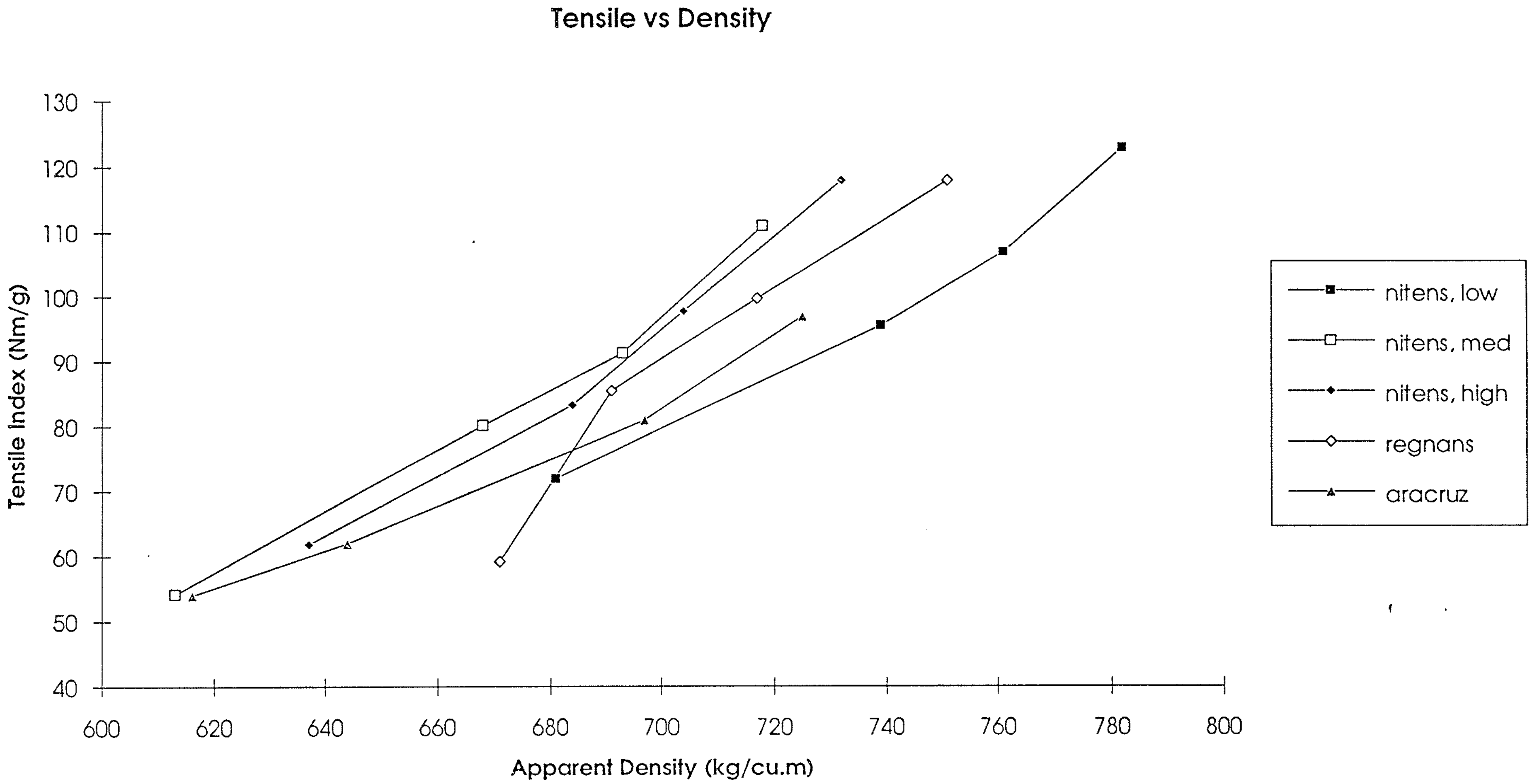

Tensile vs Density
Tensile Index (Nm/g)
130
120
110
100
90
80
70
60
50
40
600
620
640
660
680
700
720
740
760
780
800
Apparent Density (kg/cu.m)
nitens, low
nitens, med
nitens, high
regnans
aracruz

FIGURE 7

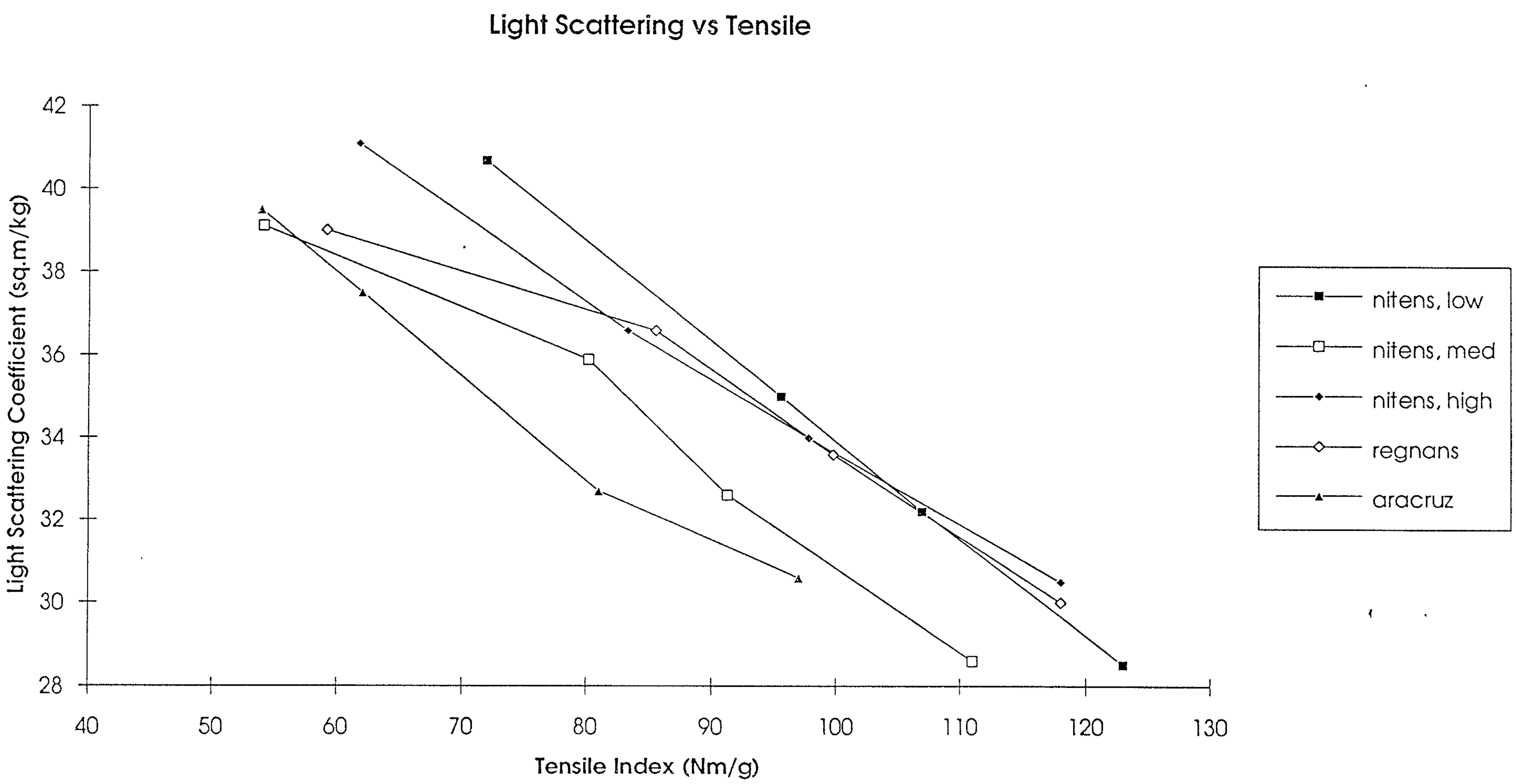

Light Scattering vs Tensile
Light Scattering Coefficient (sq.m/kg)
42
40
38
36
34
32
30
28
40
50
60
70
80
90
100
110
120
130
Tensile Index (Nm/g)
nitens, low
nitens, med
nitens, high
regnans
aracruz

FIGURE 8

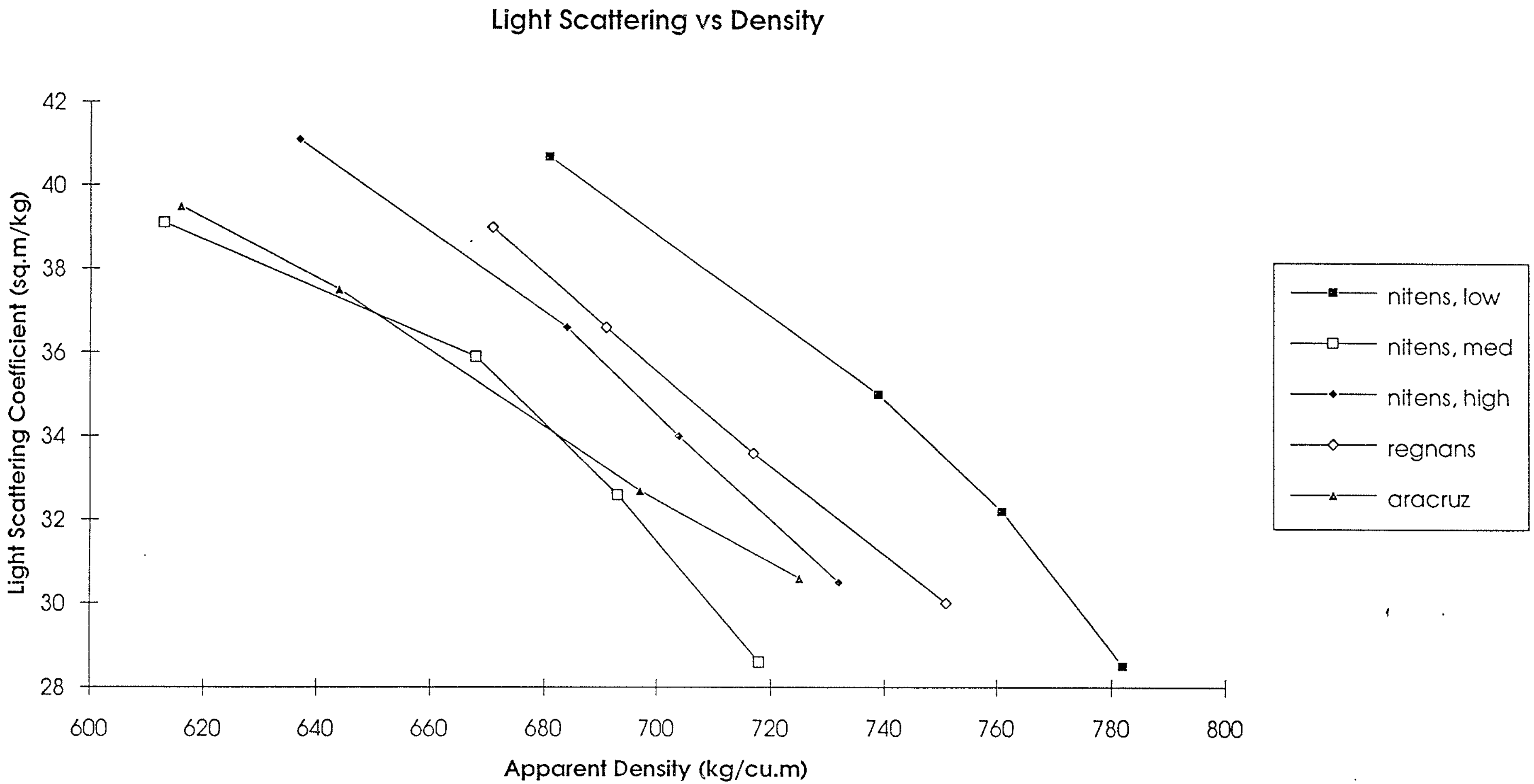

Light Scattering vs Density
Light Scattering Coefficient (sq.m/kg)
42
40
38
36
34
32
30
28
600
620
640
660
680
700
720
740
760
780
800
Apparent Density (kg/cu.m)
nitens, low
nitens, med
nitens, high
regnans
aracruz

FIGURE 9

APPENDIX I

Handsheet Physical Evaluation Data On O.D Bases

PULPING SUMMARY

OPERATOR : Gina Dorrian
DATE : 09/07/93
FIBRE CODE : 810
E. NITENS - LOW

BEATING	rev	0
FREENESS	Csf	540
NOMINAL GRAMMAGE(od)	g/(sq.m)	60.0
GRAMMAGE(od)	g/(sq.m)	58.0
MOISTURE CONTENT	%	7.92
MEAN TEAR	mN	605
Std Dev TEAR	mN	56.1
Number of valid TEARS		4
TEAR INDEX(od)	mN(sq.m)/g	10.4
MEAN BURST	kPa	253
Std Dev BURST	kPa	61.0
Number of valid BURSTS		8
BURST INDEX(od)	kPa(sq.m)/g	4.36
BULKING THICKNESS	um	85.1
Number of SHEETS		8
Number of valid tests		10
BULK (ad)	(cu.cm)/g	1.35
APPARENT BULK DEN(od)	g/(cu.cm)	0.681
MEAN GURLEY	s/100ml	8.59
Std Dev MEAN GURLEY	s/100ml	0.269
Number of valid tests		8
AIR PERMEANCE	um/(Pa.s)	14.8
MEAN TENSILE	N/m	4170
Std Dev TENSILE	N/m	177
Number of valid tests		8
TENSILE INDEX(od)	Nm/g	72.0
MEAN STRETCH	%	3.25
Std Dev STRETCH	%	0.281
Number of valid tests		8
MEAN T.E.AREA	J/(sq.m)	95.4
Std Dev T.E.AREA	J/(sq.m)	12.1
Number of valid tests		8
T.E.INDEX(od)	J/kg	1650
MEAN TENSILE STIFFNESS	kN/m	456
Std Dev TENSILE STIFFNESS	kN/m	8.49
Number of valid tests		8
TENSILE STIFFNSS INDEX(od)	kNm/g	7.87
MEAN BRIGHTNESS		87.3
MEAN OPACITY	%	76.4
Std Dev OPACITY	%	0.560
SCATT COEFF(od)	(sq.m)/kg	40.7
ABSORB COEFF(od)	(sq.m)/kg	0.173

OPERATOR : cath
DATE : 29/07/93
FIBRE CODE : 810o
E.NITENS - LOW

BEATING	rev	500	1000	2000
FREENESS	Csf	448	381	321
NOMINAL GRAMMAGE(od)	g/(sq.m)	60.0	60.0	60.0
GRAMMAGE(od)	g/(sq.m)	59.2	59.3	58.6
MOISTURE CONTENT	%	8.22	8.26	8.21
MEAN TEAR	mN	612	597	582
Std Dev TEAR	mN	47.8	13.8	19.3
Number of valid TEARS		4	4	4
TEAR INDEX(od)	mN(sq.m)/g	10.3	10.1	9.95
MEAN BURST	kPa	396	495	568
Std Dev BURST	kPa	13.2	16.3	20.6
Number of valid BURSTS		8	8	8
BURST INDEX(od)	kPa(sq.m)/g	6.69	8.34	9.70
BULKING THICKNESS	um	80.2	77.9	74.9
Number of SHEETS		8	8	8
Number of valid tests		10	10	10
BULK (ad)	(cu.cm)/g	1.24	1.20	1.17
APPARENT BULK DEN(od)	g/(cu.cm)	0.739	0.761	0.782
MEAN GURLEY	s/100ml	18.4	34.5	74.9
Std Dev MEAN GURLEY	s/100ml	1.38	2.98	5.07
Number of valid tests		8	8	8
AIR PERMEANCE	um/(Pa.s)	6.89	3.69	1.70
MEAN TENSILE	N/m	5660	6360	7180
Std Dev TENSILE	N/m	144	303	179
Number of valid tests		8	7	7
TENSILE INDEX(od)	Nm/g	95.6	107	123
MEAN STRETCH	%	3.92	4.02	4.45
Std Dev STRETCH	%	0.198	0.235	0.148
Number of valid tests		8	7	7
MEAN T.E.AREA	J/(sq.m)	150	170	209
Std Dev T.E.AREA	J/(sq.m)	11.1	16.3	9.35
Number of valid tests		8	7	7
T.E.INDEX(od)	J/kg	2540	2860	3570
MEAN TENSILE STIFFNESS	kN/m	515	546	555
Std Dev TENSILE STIFFNESS	kN/m	11.7	11.5	21.0
Number of valid tests		8	7	7
TENSILE STIFFNSS INDEX(od)	kNm/g	8.69	9.21	9.47
MEAN BRIGHTNESS		85.4	85.6	84.5
MEAN OPACITY	%	74.3	72.3	69.5
Std Dev OPACITY	%	0.460	0.420	0.440
SCATT COEFF(od)	(sq.m)/kg	35.0	32.2	28.5
ABSORB COEFF(od)	(sq.m)/kg	0.169	0.169	0.171

OPERATOR : Gina Dorrian
DATE : 09/07/93
FIBRE CODE : 811
E. NITENS - MEDIUM

BEATING	rev	0	500	1000	2000
FREENESS	Csf	603	491	427	433
NOMINAL GRAMMAGE(od)	g/(sq.m)	60.0	60.0	60.0	60.0
GRAMMAGE(od)	g/(sq.m)	59.1	59.4	59.6	59.1
MOISTURE CONTENT	%	8.00	7.86	7.89	8.11
MEAN TEAR	mN	533	639	685	704
Std Dev TEAR	mN	44.6	9.88	10.4	31.7
Number of valid TEARS		4	4	4	4
TEAR INDEX(od)	mN(sq.m)/g	9.03	10.8	11.5	11.9
MEAN BURST	kPa	178	302	389	467
Std Dev BURST	kPa	20.4	7.84	13.0	28.0
Number of valid BURSTS		8	8	8	8
BURST INDEX(od)	kPa(sq.m)/g	3.01	5.09	6.53	7.90
BULKING THICKNESS	um	96.4	89.0	85.9	82.4
Number of SHEETS		8	8	8	8
Number of valid tests		10	10	10	10
BULK (ad)	(cu.cm)/g	1.50	1.38	1.33	1.28
APPARENT BULK DEN(od)	g/(cu.cm)	0.613	0.668	0.693	0.718
MEAN GURLEY	s/100ml	2.20	6.10	10.7	22.8
Std Dev MEAN GURLEY	s/100ml	0.908	0.370	0.714	1.48
Number of valid tests		8	8	8	8
AIR PERMEANCE	um/(Pa.s)	57.8	20.8	11.9	5.57
MEAN TENSILE	N/m	3200	4760	5440	6570
Std Dev TENSILE	N/m	233	176	227	264
Number of valid tests		7	6	7	6
TENSILE INDEX(od)	Nm/g	54.2	80.2	91.3	111
MEAN STRETCH	%	2.06	2.95	3.14	3.79
Std Dev STRETCH	%	0.278	0.160	0.240	0.147
Number of valid tests		7	6	7	6
MEAN T.E.AREA	J/(sq.m)	46.9	96.3	115	164
Std Dev T.E.AREA	J/(sq.m)	9.10	7.95	12.4	10.9
Number of valid tests		7	6	7	6
T.E.INDEX(od)	J/kg	793	1620	1940	2770
MEAN TENSILE STIFFNESS	kN/m	446	515	559	566
Std Dev TENSILE STIFFNESS	kN/m	20.0	22.3	11.6	17.3
Number of valid tests		7	6	7	6
TENSILE STIFFNSS INDEX(od)	kNm/g	7.54	8.67	9.39	9.57
MEAN BRIGHTNESS		87.5	86.7	85.3	85.4
MEAN OPACITY	%	75.9	74.5	73.2	69.7
Std Dev OPACITY	%	0.300	0.380	0.620	0.780
SCATT COEFF(od)	(sq.m)/kg	39.1	35.9	32.6	28.6
ABSORB COEFF(od)	(sq.m)/kg	0.169	0.168	0.168	0.169

OPERATOR : Gina Dorrian
DATE : 09/07/93
FIBRE CODE : 812
E. NITENS - HIGH

BEATING	rev	0	500	1000	2000
FREENESS	Csf	567	530	473	433
NOMINAL GRAMMAGE(od)	g/(sq.m)	60.0	60.0	60.0	60.0
GRAMMAGE(od)	g/(sq.m)	58.6	59.3	58.5	58.0
MOISTURE CONTENT	%	7.80	8.08	8.12	8.16
MEAN TEAR	mN	588	737	712	678
Std Dev TEAR	mN	65.5	92.7	5.50	35.3
Number of valid TEARS		4	4	4	4
TEAR INDEX(od)	mN(sq.m)/g	10.0	12.4	12.2	11.7
MEAN BURST	kPa	226	339	412	511
Std Dev BURST	kPa	44.4	16.8	22.4	22.3
Number of valid BURSTS		8	8	8	8
BURST INDEX(od)	kPa(sq.m)/g	3.86	5.72	7.05	8.81
BULKING THICKNESS	um	92.0	86.8	83.1	79.2
Number of SHEETS		8	8	8	8
Number of valid tests		10	10	10	10
BULK (ad)	(cu.cm)/g	1.45	1.34	1.30	1.25
APPARENT BULK DEN(od)	g/(cu.cm)	0.637	0.684	0.704	0.732
MEAN GURLEY	s/100ml	3.62	7.26	11.0	23.9
Std Dev MEAN GURLEY	s/100ml	0.432	0.464	0.733	0.876
Number of valid tests		8	8	8	8
AIR PERMEANCE	um/(Pa.s)	35.0	17.5	11.5	5.30
MEAN TENSILE	N/m	3620	4940	5730	6860
Std Dev TENSILE	N/m	479	212	362	232
Number of valid tests		7	7	7	7
TENSILE INDEX(od)	Nm/g	61.8	83.3	97.8	118
MEAN STRETCH	%	2.63	3.38	3.93	4.28
Std Dev STRETCH	%	0.603	0.171	0.351	0.225
Number of valid tests		7	7	7	7
MEAN T.E.AREA	J/(sq.m)	68.2	113	150	190
Std Dev T.E.AREA	J/(sq.m)	21.1	9.26	21.3	14.6
Number of valid tests		7	7	7	7
T.E.INDEX(od)	J/kg	1160	1900	2560	3270
MEAN TENSILE STIFFNESS	kN/m	438	491	491	516
Std Dev TENSILE STIFFNESS	kN/m	8.02	19.2	15.0	14.2
Number of valid tests		7	7	7	7
TENSILE STIFFNSS INDEX(od)	kNm/g	7.47	8.28	8.38	8.91
MEAN BRIGHTNESS		88.1	86.9	86.6	86.0
MEAN OPACITY	%	76.4	74.8	72.9	70.5
Std Dev OPACITY	%	0.490	0.500	0.510	0.260
SCATT COEFF(od)	(sq.m)/kg	41.1	36.6	34.0	30.5
ABSORB COEFF(od)	(sq.m)/kg	0.171	0.169	0.171	0.173

PULPING SUMMARY

OPERATOR : Gina Dorrian
DATE : 09/07/93
FIBRE CODE : 813
E. REGNANS

BEATING	rev	0	500	1000	2000
FREENESS	Csf	570	532	478	432
NOMINAL GRAMMAGE(od)	g/(sq.m)	60.0	60.0	60.0	60.0
GRAMMAGE(od)	g/(sq.m)	61.5	56.6	58.1	58.3
MOISTURE CONTENT	%	7.97	8.12	7.98	8.16
MEAN TEAR	mN	716	680	701	634
Std Dev TEAR	mN	72.6	85.8	22.3	32.6
Number of valid TEARS		4	4	4	4
TEAR INDEX(od)	mN(sq.m)/g	11.6	12.0	12.1	10.9
MEAN BURST	kPa	228	341	402	518
Std Dev BURST	kPa	17.7	14.0	53.2	13.9
Number of valid BURSTS		8	8	8	8
BURST INDEX(od)	kPa(sq.m)/g	3.70	6.03	6.92	8.88
BULKING THICKNESS	um	91.7	81.9	81.0	77.6
Number of SHEETS		8	8	8	8
Number of valid tests		10	10	10	10
BULK (ad)	(cu.cm)/g	1.37	1.33	1.28	1.22
APPARENT BULK DEN(od)	g/(cu.cm)	0.671	0.691	0.717	0.751
MEAN GURLEY	s/100ml	4.67	8.50	13.3	29.9
Std Dev MEAN GURLEY	s/100ml	0.306	0.478	0.768	2.89
Number of valid tests		8	8	8	8
AIR PERMEANCE	um/(Pa.s)	27.2	14.9	9.54	4.24
MEAN TENSILE	N/m	3640	4840	5800	6900
Std Dev TENSILE	N/m	491	748	286	341
Number of valid tests		8	7	6	7
TENSILE INDEX(od)	Nm/g	59.2	85.5	99.8	118
MEAN STRETCH	%	2.55	3.37	3.88	4.44
Std Dev STRETCH	%	0.735	0.793	0.131	0.297
Number of valid tests		8	7	6	7
MEAN T.E.AREA	J/(sq.m)	67.5	113	150	200
Std Dev T.E.AREA	J/(sq.m)	25.4	35.4	11.5	21.6
Number of valid tests		8	7	6	7
T.E.INDEX(od)	J/kg	1100	2000	2580	3420
MEAN TENSILE STIFFNESS	kN/m	454	483	510	539
Std Dev TENSILE STIFFNESS	kN/m	17.3	20.7	16.9	11.8
Number of valid tests		8	7	6	7
TENSILE STIFFNSS INDEX(od)	kNm/g	7.39	8.54	8.78	9.25
MEAN BRIGHTNESS		87.2	86.4	85.0	84.9
MEAN OPACITY	%	76.6	73.8	73.2	70.6
Std Dev OPACITY	%	0.520	0.370	0.430	0.380
SCATT COEFF(od)	(sq.m)/kg	39.0	36.6	33.6	30.0
ABSORB COEFF(od)	(sq.m)/kg	0.163	0.177	0.172	0.172