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WOOD PROPERTIES OF 16-YEAR-OLD *EUCALYPTUS FASTIGATA* GROWN IN CENTRAL KAINGAROA

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Report No. 19 September 1996

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BACKGROUND

There has recently been an increased interest from the NZ Forest Industry into growing eucalypts, primarily for short-fibred pulp, and also to some extent for sawn timber. Under the initiation and sponsorship of the NZFRI-Industry Eucalypt Breeding Cooperative (EBC) several pulping studies focusing on differences between bulked samples of trees from different eucalyptus species and provenances have been completed.

The promising results from *E. fastigata* in the recent studies for both kraft and mechanical pulp and paper-making studies (Kibblewhite 1994; Kibblewhite & Lloyd 1993; Richardson 1994) have prompted an increased interest in this species. Additionally, because of the wide and often disjunct distribution of *E. fastigata* in New South Wales, there are possibilities for provenance selection as well as individual tree and family selection for this species. Information is needed on the extent of this variation in growth and form traits and in wood properties.

INTRODUCTION

Eucalyptus fastigata Deane *et* Maid. is a member of the ash eucalypt group which contains several major Australian timber species notably *Eucalyptus regnans, E. obliqua* and *E. delegatensis.* Fastigata or as it is named in Australia, brown barrel (from the colour of the bark) occurs naturally in the southern highlands, northern tablelands and coastal escarpments of New South Wales, along with a small scattering into the easternmost corner of Victoria (Clifton, 1990)

Eucalyptus fastigata has been grown in New Zealand since the turn of the century and over time most of these plantings were clear felled and replanted with conifers. Since then a large proportion of the *E. fastigata* stands have been largely confined to scattered farmlots (Weston, 1957) where it has been found to grow well in the Waikato, Rotorua, Bay of Plenty and Taranaki regions. In the 1950's and 1960's a number of forestry companies planted several eucalypt species including *E. fastigata,* in particular New Zealand Forest Products Ltd. at Tokoroa planted *E. fastigata* and *E. nitens* as a replacement for indigenous tawa (*Beilschmiedia tawa*) for use in manufacturing pulp for high quality papers (Anon 1995).

Attention was drawn to *Eucalyptus fastigata* following a workshop on tree species for special purpose end uses in 1979 (Viles and Smorti, 1979). Following that workshop fastigata was identified by the New Zealand Forest Service as one of the species warranting further emphasis in planting, utilisation and research (Anon, 1981).

The Utilisation Development Division of the New Zealand Forest Service subsequently included fastigata in their recommendations for end uses (Blakeney, 1982) and FRI carried out a wide range of studies on properties and utilisation culminating in the species inclusion in a bulletin on those subjects (Haslett, 1988).

Fastigata heartwood is pale brown in colour and sometimes characterised with a purplish fleck. The sapwood is lighter in colour and usually easy to distinguish. In comparison with Australian material the New Zealand-grown wood is generally lighter in colour with a slightly lower density. Despite the wood having a moderate texture, being straight grained, machining well and staining uniformly, it is currently grown more for paper pulp than sawn timber (Clifton, 1990). A number of undesirable processing characteristics typical to the ash eucalypt group could account for this which include:

i) the need for specific sawing patterns to reduce degrade due to growth stresses and subsequent drying practices,
ii) a well defined drying schedule incorporating air drying and reconditioning at the beginning and end of the drying process respectively and ,
iii) the incidence of internal checking in the dried timber although fastigata is less susceptible to internal checking than many of the ash eucalypts due to it's higher wood density.

Despite these problems fastigata timber that has been correctly dried and to the appropriate moisture content is suitable for a range of speciality uses for which radiata pine is not entirely satisfactory. Haslett suggests some high value options such as furniture, cabinet-making, veneers, turnery, handles, and panelling.

Three studies have been carried out specifically on wood properties. These were by Harris (1975) who examined five 43-year-old trees from Kaingaroa forest, unpublished data by Graeme Young on four 40-year-old trees from Atiamuri, and Young (1992) who examined 46 trees from six stands ranging in age from 12 to 23 years. A summary of some of the findings is given in Table 1.

Table 1 - Wood Properties from Previous Studies

Age (years)	No. Trees	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m^3)	Basic Density (kg/m^3)
12	20	45	127	1042	460
14	4	57	-	-	464
14	4	53	-	-	449
16	5	39	-	-	445
19	4	58	-	-	499
23	9	64	-	-	475
40	4	80	-	-	480
43	5	-	-	1010	500

This report is part of a series in a multi disciplinary project funded by a 1995/96 FRST Objective, Industry and NSOF and involves Biotechnology, PAPRO, Wood

Processing, Wood Products and Forest Technology Divisions of NZFRI. The project is modelled on a previous individual tree study on *E. nitens* (Lausberg *et. al.*,1996). These individual tree studies will enable relationships between wood and end-product properties between different species, provenances and ages to be established and will provide information about choosing wood properties for modification by genetic or silvicultural means to improve end-product quality.

OBJECTIVES

1. To characterise the variation in wood density amongst provenance and families n a 16-year-old field test of *E. fastigata* (to be reported separately) and select a group of 20 trees for intensive study, below.
2. To determine the extent of within- and between-tree variation in a comprehensive set of wood properties.
3. By sawing boards from a 1.4m long bolt from the base of the butt log of the 20 sample trees, to evaluate variation in solid wood properties and refine a procedure for evaluating variation in solid wood properties for future studies.

MATERIALS AND METHODS

A provenance-progeny trial in Compartment 1207 of Kaingaroa forest (Plot number RO 1975) previously studied for some wood properties by Young (1992) provided the material for this study, which can be segregated into two stages. The trial design is described by St Clair (1985) and Burger (1990) for the assessments completed in 1985 and 1990 respectively. Presented in Table 2 is the stand history.

Table 2 - Stand History Plot RO 1975 Cpt. 1207 Kaingaroa.

Date	Age (yrs)	Operation
1979	-	Established at 1333spha
1985	6	Assessment
1990	11	Assessment
1991	12	Minor thinning operation to some blocks
1995	16	Assessment and fell study trees

Stage 1 consisted of sampling 5mm breast height outerwood increment cores in conjunction with the latest trial assessment for growth and form traits which was last completed five years prior (Burger, 1990). Increment cores were sampled from 625 trees, being the larger trees more suited for solid wood processing ie. having a minimum breast height diameter over bark of 25cm and having reasonable growth form. Outerwood densities were established using the maximum moisture content method described by Smith (1954). The results from this study will be reported separately, aiming to:

1. compare growth, form and wood density of native provenances and exotic populations from New Zealand and South Africa, and of their component families, and
2. analyse variation between and within provenances and families, and to estimate heritabilities and genetic correlations of these traits.

Stage 2 which will be dealt with by this report, consisted of selecting the 20 trees for the pulping and solid wood studies initially from the three provenances (families) Oberon, Rossi and Natal. These provenances were identified by the Genetics and Tree Improvement (GTI) group of NZFRI as being most suitable for two reasons, in the case of Oberon and Rossi due to having an adequate number of families represented in the trial and for Natal due to many of the families in the breeding population being sourced from this provenance. Due to insufficient numbers of trees in these provenances meeting the specifications required (ie. DBH greater than 30cm and of reasonable growth form) a number of other families were included to satisfy the 20 tree sample.

In order to encompass the density range for the 20 trees, 6 of high, 6 of low and 8 of medium density were selected from all the trees assessed for density in stage 1 which met the above criteria on size and form, with the main focus on trees from the Oberon, Rossi and Natal families. Table 3 presents the GTI identification, family, breast height diameter and outerwood density for the selected trees. Diameter at breast height over bark averaged 37.5 cm ranging from 31.6 cm for tree 11 to 43.7cm for tree 3. Outerwood density averaged 465 kg/m^3 and ranged from 396 kg/m^3 for tree 2 to 553 kg/m^3 for tree 11 which recorded the lowest DBH. The outerwood density values will enable the establishment of outerwood to whole tree and log component density relationships.

A further 9 trees, 3 of high, 3 of medium and 3 of low density will be selected at a later date for further solid wood quality, and kraft and TMP pulp property assessments.

At the time of felling all stems were debarked using harvesting equipment (for practical reasons for the pulping component of this study) prior to the sampling of three discs each from the butt, 1.4m, 5.5m and at consecutive 5.5m intervals down to a small end diameter (SED) of approximately 100mm. A roundwood billet of 1m in length was removed from directly below breast height (1.4m) for solid wood assessment. The merchantable 5.5m logs were identified by log height class and tree number providing material for the individual tree pulping study, to be reported separately.

One set of discs were measured to provide data on diameters inside bark (dib) and heartwood and weight excluding bark. Further laboratory measurements were made to allow the assessment of:

heartwood percentage,
moisture content,
green density,
basic density,
log volumes.

Table 3 - GTI Identification, Family, Breast Height Diameter and Outerwood Density by Tree.

Tree No.	GTI Identification Block	Set	Rep.	Tree	Family	DBHOB (cm)	Outerwood Density (kg/m^3)	Density Class
1	1	2	5	32	Oakura	37.8	460	M
2	1	3	5	33	Rossi	35.0	396	L
3	1	2	4	24	Oakura	43.7	464	M
4	1	3	1	4	Robertson	37.8	491	M
5	2	1	7	26	Oberon	34.3	415	L
6	4	2	22	3	Robertson	43.6	428	M
7	2	2	11	1	Oakura	35.4	535	H
8	2	1	12	17	Oberon	39.0	406	L
9	2	1	9	33	Rossi	37.7	424	L
10	5	1	26	2	Oberon	41.0	498	H
11	5	1	25	7	Bombala	31.6	553	H
12	5	3	27	11	Rossi	40.5	511	H
13	5	3	26	10	Oberon	34.2	423	L
14	5	1	29	38	Oakura	34.1	530	H
15	6	3	33	37	Rossi	34.3	466	M
16	6	1	35	42	Rossi	37.6	533	H
17	3	1	16	4	Oberon	43.1	445	M
18	3	1	14	41	Natal	39.1	476	M
19	3	2	14	19	Oberon	33.8	404	L
20	2	3	10	31	Rossi	35.6	446	M

The second set of discs were sectioned in the laboratory to provide:

1. samples portioned into 60mm groups to give pith-to-bark radial trends for shrinkage to the air-dry (12%) moisture content before and after steam reconditioning, and basic density, and
2. samples for the measurement of spiral grain using two diametrically opposed radii (Young *et. al.* 1991). Measurements were taken at every alternate ring up to ring 16.

The third set of discs were sectioned in the laboratory to provide:

1. a half disc sample dried to 10% emc for the assessment of internal checking, and
2. a pith-to-bark radial strip for subsequent Silviscan assessment by R. Evans at CSIRO, Melbourne.

A preliminary study investigating growth stress was undertaken on the log end immediately above the 1.4m sampling height. This principally involved photographing the log end immediately after cross-cutting to assess the occurrence and severity of end splitting as result of growth stress. A scale in cm was attached to each log end for the assessment of split dimensions. The method used to assess each of the twenty photographs was devised by Hans Erensky Ltd (South Africa). Basically each split is scored according to the following grading system and summed:

Split extending from pith to bark	2
Split extending from pith part way to bark	1
Width of split <1cm	1
Width of split >1cm<2cm	2
Width of split >2cm<3cm	3

The 1m roundwood billet was radially sawn to yield a 25mm thick board across the diameter including the pith. During the sawing process the length and width of splits were recorded prior to the board being moved. A water proof sealant was applied to the board-ends prior to the boards being dried to 12% emc first by air drying and then using a kiln at 70/65^{o}C. The technique used here to assess solid wood performance is still being refined and hence the results for this study are less than complete and will be presented along with the shrinkage results. More comprehensive analyses will be completed on the additional 9 trees to be sampled in the near future.

All work was carried out using standard wood quality assessment techniques.

RESULTS AND DISCUSSION

For many of the properties described below the data for individual disc, log and tree values are included in the series of Appendices at the end of this report. In general, discussion of results will relate to mean values only. Needless to say, there is wide variation in many properties which is normally due to genetic effect.

Disc Dimensions and Wood Properties:

Table 4 details the average values for each disc sampling height, derived from the individual measurements (Appendix I). Heartwood percent was calculated as the proportion of cross-sectional area of the disc.

Diameter inside bark shows the expected trend from the butt to the top disc, averaging 342mm and decreasing to approximately 100 mm, for the butt and 23m discs respectively. Heartwood percent levels were similar up to 11.0m in the stem after which a rapid decrease was observed. Moisture content and green density showed the expected trends for the ash eucalypt group with high levels of moisture saturation (in both the heartwood and sapwood) and green densities in excess of 1000 kg/m³.

Table 4 - Average Wood Properties by Sampling Height

Disc Height (m)	DIB (mm)	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)	No. of Samples
0.0	342	55	142	1101	457	20
1.4	304	55	143	1095	453	20
5.5	266	49	136	1105	470	20
11.0	229	38	136	1112	473	20
16.5	171	17	147	1164	473	20
20.2	105	1	140	1121	469	14
23.0	107	2	134	1131	487	5
Mean	**238**	**36**	**140**	**1117**	**467**	**119**

Basic density increased from 457 kg/m³ at the butt disc to 487 kg/m³ at 23.0 m and this trend of increasing density with height in the stem repeats findings of many of the earlier studies. Overall basic density averaged 467 kg/m³ up slightly from Young's earlier study on this stand at age 12 years of 460 kg/m³. The five 16-year-old trees from Compartment 24 of Kaingaroa, also in Young's earlier study averaged 445 kg/m³, approximately 20 kg/m³ lower than the results shown here.

Log and Tree Wood Properties:
In Table 5 values from Table 4 have been used to calculate results for logs and whole trees. Values for individual trees are presented in Appendix II. Smalian's formulae was used for calculation of volume which may not be as accurate as other methods of volume calculation, but it does provide a reasonable guide to actual volumes and is more suited to applying weighted wood property values to establish these log and tree estimates.

Table 5 - Average Log and Tree Values

Log Height Class	Volume (m³)	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)
Butt	0.410	53	140	1102	462
2nd	0.270	44	136	1108	471
3rd	0.181	30	140	1133	473
4th	0.086	15	144	1161	477
Tree	**0.929**	**43**	**139**	**1114**	**468**

By 16 years these trees were averaging just under 1 m^3 of saw and pulp logs, with nearly half the volume contained in the butt log. When compared to Young's 16-year-old trees, the volumes found in this study were considerably higher due to the increased height and diameter of these trees. The disparity between the two stands could be due to one or a combination of site, stocking and seed source factors.

The trends for wood property variation described for the discs in Table 4 are mirrored here for log height class. The twenty trees showed heartwood to range from 30% for tree 1 to 59% for tree 6; moisture content from 109% for tree 14 to 169% for tree 19; green density from 1082 kg/m^3 for tree 19 to 1221 kg/m^3 for tree 16 and basic density from 402 kg/m^3 for tree 19 to 535 kg/m^3 for tree 11.

Variation in Basic Density from Pith to Bark:
Basic density, by the same 60mm groups used for shrinkage analysis from pith to bark, are presented in Table 6 and graphed in Figure 1. As the figure shows, the variation between disc heights can be quite significant. For the 0m, 1.4m, 5.5m and 11.0m heights there is a strong trend of increasing density by 60mm group from the pith to bark. At 16.5m the difference between the inner 60mm and 60-120mm groups was negligible with an increase of only 3 kg/m^3 which could possibly reflect the transition from heartwood to sapwood.

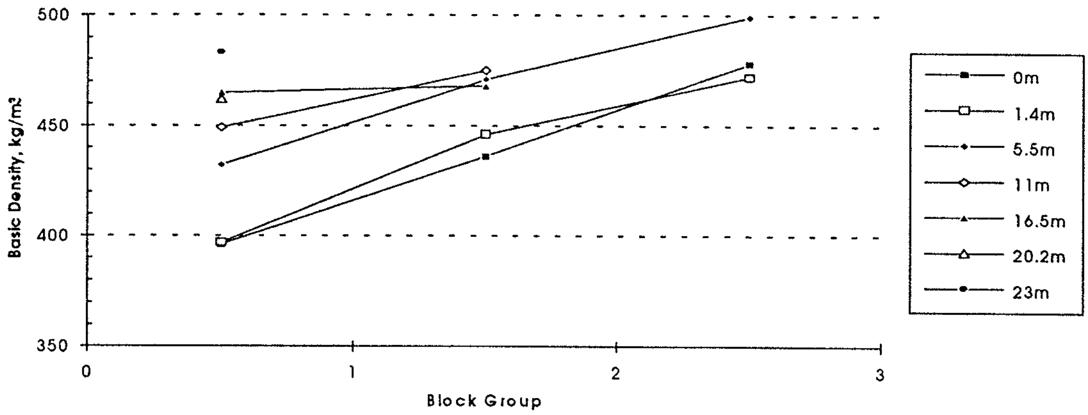
The densities for the inner 60mm groups compared favourably with results from Harris's (1975) study on 43-year-old trees from Cpt. 122 Kaingaroa, despite the different methods for sectioning samples ie. 5 ring groups versus 60mm groups.

Table 6 - Variation in Basic Density from Pith to Bark by Stem Position

Disc Height (m)	60mm Groups from Pith Inner 60	60-120	120+
Basic Density, kg/m^3			
0	396	436	478
1.4	397	446	472
5.5	432	471	499
11.0	449	475	
16.5	465	468	
20.2	462		
23.0	483		

The overall trends of eucalypt density change from pith to bark, in combination with variation up the stem have been grouped into four general classifications by Harris and Young (1988). The ash group of eucalypts (including *E. fastigata*) show a strong tendency for pith-to-bark density to increase with increasing height in the stem ie. wood density increases from the pith outwards, with the density curve being reproduced at higher values with increasing height in the tree. Fastigata differs from the other ash eucalypts where the gradients of wood density with formative age tend to be steeper and this was apparent for the results found in this study.

Figure 1 - Variation of Basic Density with 60mm Sections from the Pith



Relationship Between Density Measurements:

The relationship between breast height outerwood density and the density of the whole tree and also the relationships between whole tree density and the density of the individual logs are given in Table 7. These relationships are based on the twenty trees felled in this current study and were all found to be highly significant at the 99% level.

Table 7 - Relationships Between Breast Height Outerwood Density, Whole Tree Density and the Density of Individual Logs.

Log Height Class	No. of Logs	Intercept	*x* *	Correlation	R-Square	Residual St. Dev.
Butt	20	-22.6	+1.04	0.98	0.97	8
2nd	20	+12.2	+0.98	0.99	0.98	5
3rd	20	+16.7	+0.98	0.98	0.96	8
4th	16	+63.4	+0.88	0.95	0.91	12
Tree	20	+120.6	+0.75	0.92	0.85	16

* *x* = outerwood density

The following data forms the basis for a wood density data bank for *Eucalyptus fastigata*. The Wood Processing Division has a PC based wood density data bank for several species notably radiata pine and Douglas-fir which are continually updated as studies are completed. The additional nine fastigata trees due to be felled in the near future will be added to the newly established data bank for this eucalypt species.

The raw data used to produce the above regressions have been included in this report as Appendix III.

Shrinkage:
Air-dried shrinkage was measured for all 20 trees in the longitudinal, radial and tangential dimensions on blocks representing 60mm groups from the pith. Before and after steam reconditioning dimensions were measured for the radial and tangential directions, with the difference between these two measures representing collapse rather than shrinkage. Full results are detailed in Appendix IV with a summary of averages in Table 8.

Table 8 - Variation of Air-Dry (12%) Dimensional Shrinkage from Pith to Bark by Stem Position

Disc Height (m)	60mm Groups from Pith			60mm Groups from Pith		
	Inner 60	60-120	120+	Inner 60	60-120	120+
Longitudinal Shrinkage to Air-dry, %						
				After Reconditioning		
0				0.34	0.24	0.18
1.4				0.26	0.14	0.28
5.5				0.24	0.19	0.12
11.0				0.21	0.14	
16.5				0.18	0.17	
20.2				0.15		
23.0				0.14		
Radial Shrinkage to Air-dry, %						
	After Reconditioning			After Reconditioning		
0	5.0	3.0	3.3	2.7	2.2	2.8
1.4	4.7	3.4	3.6	2.6	2.6	3.1
5.5	4.4	3.9	3.8	2.7	3.1	3.5
11.0	3.4	3.7		2.5	3.1	
16.5	3.5	2.8		2.7	2.6	
20.2	3.0			2.6		
23.0	3.2			2.8		
Tangential Shrinkage to Air-dry, %						
	After Reconditioning			After Reconditioning		
0	15.5	10.5	8.2	6.2	5.7	6.0
1.4	15.5	10.0	8.8	6.5	6.4	6.4
5.5	9.6	9.1	8.4	5.4	6.5	6.7
11.0	8.3	7.7		5.0	6.0	
16.5	7.1	6.6		5.0	5.4	
20.2	5.4			4.6		
23.0	5.0			4.3		

Figures 2 and 3 reproduce data from Table 8 of radial and tangential shrinkages to air-dry. In each case the general trends are for increased shrinkage with distance from the pith, which is to be expected as wood density and shrinkage are positively related. The butt and 1.4m samples show slightly higher radial and tangential shrinkage values for the inner 60mm block. Possible reasons for this could include incomplete recovery of collapse and/or the lower region of the stem particularly the butt often producing confounding wood property results.

Figure 2 - Variation of Radial Shrinkage (to air-dry after reconditioning) with 60mm Sections from the Pith

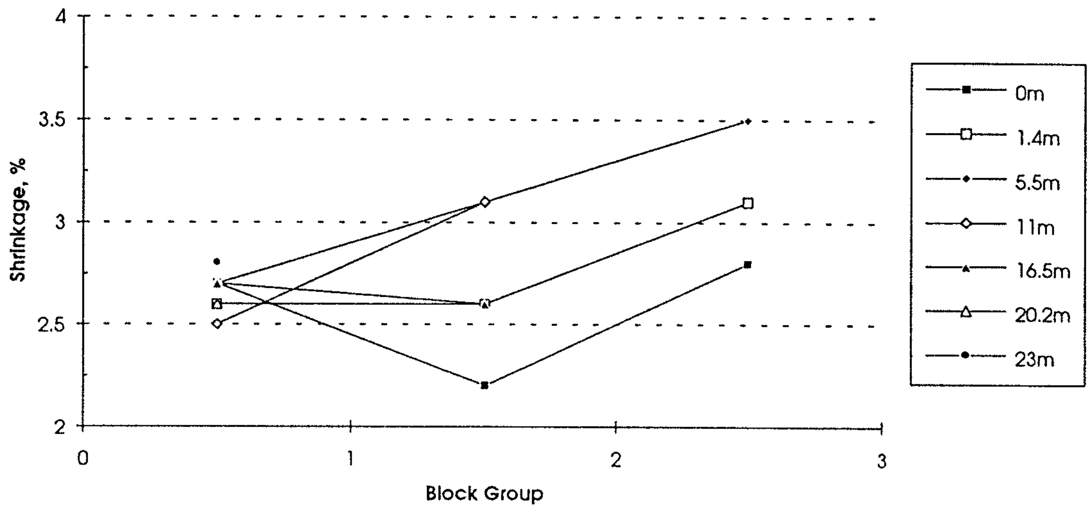
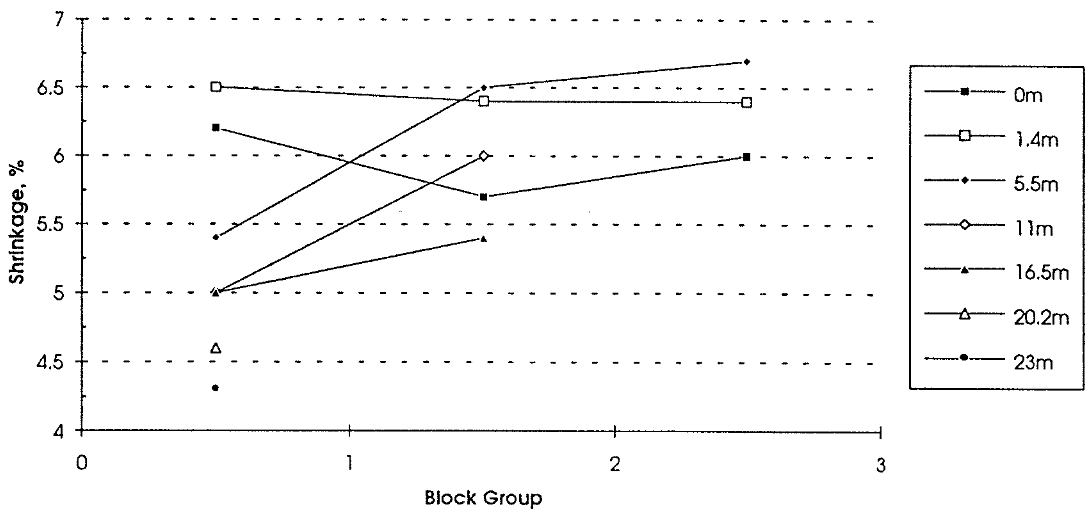


Figure 3 - Variation of Tangential Shrinkage (to air dry after reconditioning) with 60mm Sections from the Pith



The greatest recovery of collapse in the radial dimension occurred at lower stem levels (0, 1.4m and 5.5m) and in the zone closest to the pith. This was repeated in the tangential dimension except the collapse recovery was much greater ie. for the butt disc, inner 60mm sample 15.5% shrinkage before reconditioning reducing to 6.2% following reconditioning.

The 1m boards from the roundwood billet showed low levels of collapse after drying to 12% emc and this was largely recovered follow reconditioning. Figure 4 presents the sample with the most severe level of collapse observed along with the matched pair following reconditioning, showing the level of recovery possible. With the solid wood assessment techniques being refined, a more detailed analysis including end scanning will be completed on the additional 9 trees due to be felled in the near future.

From the data in Appendix IV mean dimensional shrinkage to air dry by stem position was calculated on a disc basis with the results presented in Table 9. As expected the longitudinal shrinkage values were very small and for practical purposes this dimension can largely be ignored.

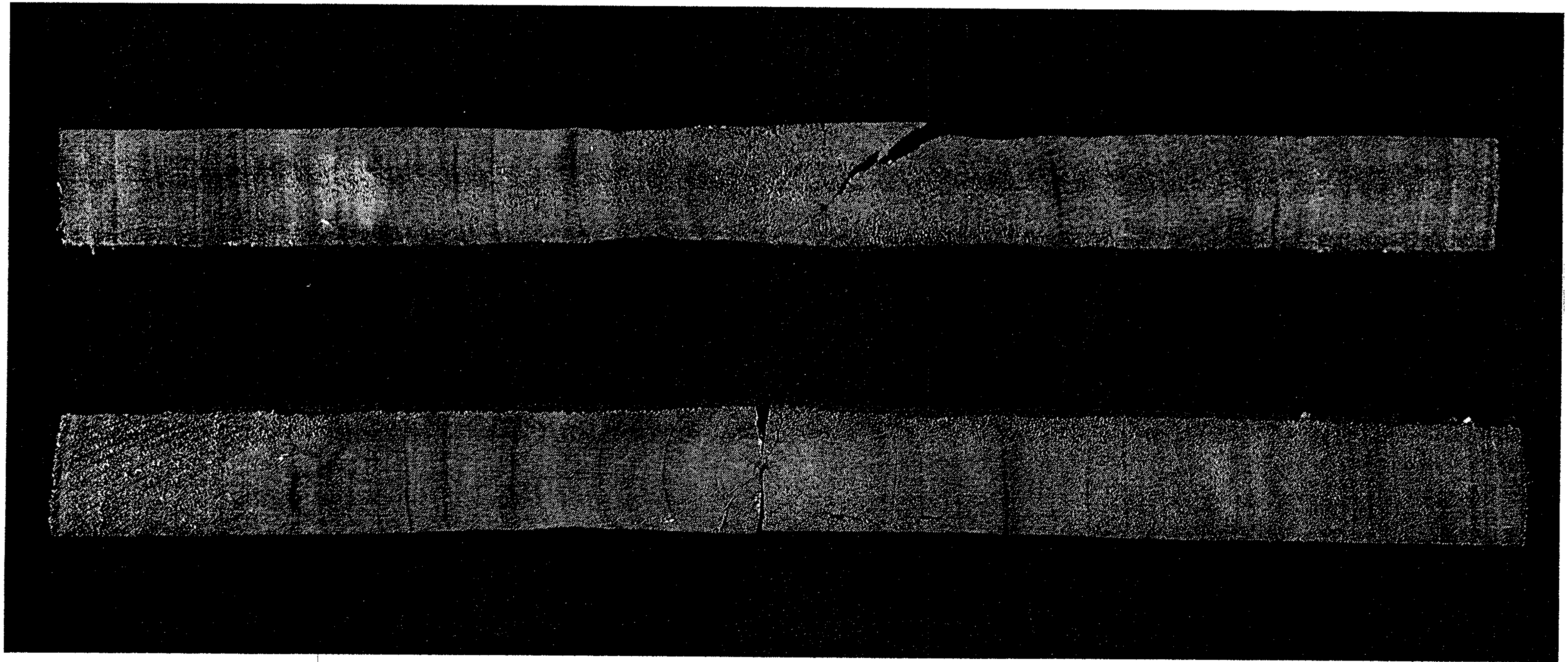
Table 9 - Mean Dimensional Shrinkage to Air-Dry (12%) by Stem Position

Disc Height (m)	Shrinkage, %				
	Longitudinal	Radial		Tangential	
	After	Before	After	Before	After
	Reconditioning				
Butt	0.25	3.8	2.6	11.2	6.0
1.4	0.21	4.0	2.7	11.9	6.5
5.5	0.20	4.2	3.0	9.3	6.1
11.0	0.17	3.6	2.8	8.0	5.5
16.5	0.18	3.5	2.7	6.9	5.0
20.2	0.15	3.0	2.6	5.4	4.6
23.0	0.14	3.2	2.8	5.0	4.3

As differences in radial and tangential shrinkage, and variation within trees can cause drying distortion, these data have been represented in Figure 5. The degree of collapse was clearly much worse in the tangential direction and for both dimensions, particularly tangential the collapse was more severe in the lower 5.5m of the stem. Both radial and tangential shrinkage were also greatest in the lower 5.5m of the stem and steadily decreased with increasing height in the stem. These results indicate the much higher likelihood of distortion in timber cut from the butt log.

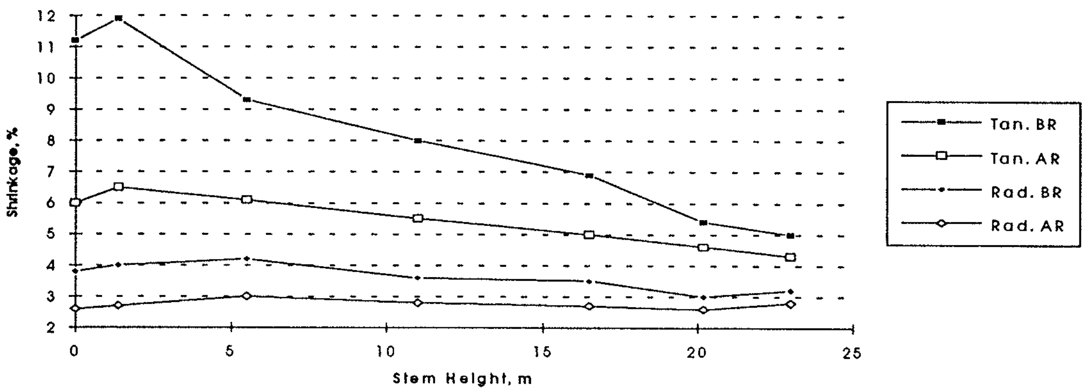
Figure 4 - Most severe level of collapse observed in 1m boards with the matched pair following reconditioning

Before reconditioning



After reconditioning

Figure 5 - Variation of Air Dry Dimensional Shrinkage With Stem Height Before (BR) and After (AR) Steam Reconditioning



The disc shrinkage data summarised in Table 9 was taken one step further to provide mean whole tree dimensional shrinkage values and the overall mean values for the study, and these results are presented in Table 10. Air-dry longitudinal shrinkage (after reconditioning) averaged around 0.2% with air-dry radial and tangential shrinkages (after reconditioning) being 2.8% and 5.8% respectively.

Table 10 - Mean Whole Tree Dimensional Shrinkage to Air-Dry (12%)

Tree No.	Shrinkage, % Longitudinal	Radial		Tangential	
	After	Before	After	Before	After
	Reconditioning				
1	0.14	4.6	2.9	13.8	6.7
2	0.30	3.4	2.6	7.5	5.6
3	0.15	3.3	2.5	9.6	5.5
4	0.17	4.0	3.2	8.8	6.3
5	0.35	4.3	2.9	11.0	6.1
6	0.38	2.4	2.0	7.9	5.4
7	0.05	5.0	3.4	10.4	6.1
8	0.36	2.8	2.0	9.1	5.1
9	0.12	3.4	2.6	7.4	5.1
10	0.16	3.1	3.0	7.0	5.4
11	0.31	4.4	3.5	7.4	6.0
12	0.23	3.5	3.1	7.1	5.9
13	0.27	3.3	2.7	7.7	5.6
14	0.20	4.7	3.2	11.4	6.2
15	0.12	4.0	3.0	9.5	5.9
16	0.07	3.5	2.9	9.2	6.4
17	0.23	3.0	2.2	8.4	5.2
18	0.15	3.8	2.6	8.6	5.1
19	0.21	5.2	2.6	10.8	5.4
20	0.16	4.7	3.0	11.2	6.0
Mean	**0.21**	**3.8**	**2.8**	**9.2**	**5.8**

Distortion in drying is often related to the ratio of radial to tangential shrinkage which is commonly referred to as about 1:2 (Young, 1992). For this study the value of 1:2.1 compares favourably, along with Haslett's (1988) 1:1.85 quoted for the fastigata species in general.

Spiral Grain:
This study involved the most detailed investigation to date, on variation of spiral grain in *Eucalyptus fastigata.*

Again full details are provided in Appendix V but the disc averages are listed in Table 11. It should be noted that large between tree variation was observed including variation in grain direction.

Table 11 - Mean Patterns of Spiral Grain Within Trees.

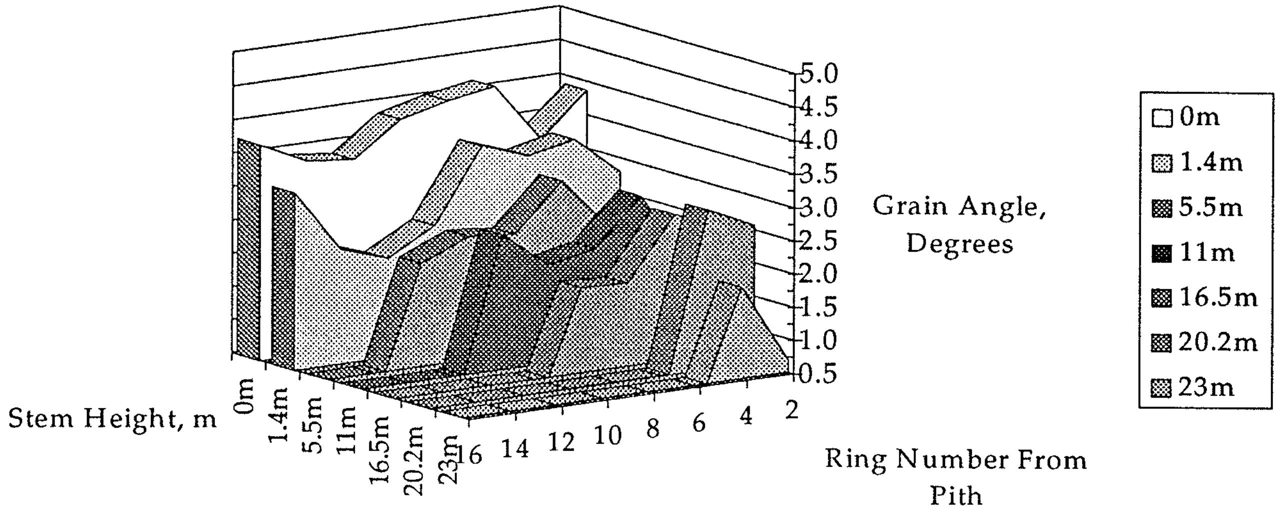
Disc Height (m)	Spiral grain (°) by ring number from the pith							
	2	4	6	8	10	12	14	16
0	3.9	3.2	4.1	4.0	3.8	3.3	3.4	3.7
1.4	2.8	3.4	3.2	3.5	2.4	2.0	2.2	3.2
5.5	2.2	2.2	3.0	2.3	2.4	2.1		
11	1.8	2.8	2.1	2.0	2.5			
17.4	2.4	2.7						
20.3	2.6	2.9						
23.3	0.7	1.9						

Cown *et. al.* (1991) completed an intensive examination of within and between tree variation of spiral grain in 25-year-old radiata pine. Their results showed that for the radiata juvenile wood zone (the inner 10 growth rings) spiral grain angles averaged 4.7° and considerable variation existed between trees. Those trees with levels above 5° are likely to cause significant problems in processing and marketing through drying degrade, strength loss, and movement in service.

Based on the twenty trees measured in this study, results show that on average spiral grain levels are low in comparison to radiata pine, with minimal deviation from pith-to-bark and decreasing angles with increasing height in the stem (Figure 6). The generally low levels indicate that this property is unlikely to have a significant impact when determining the extent of the juvenile wood zone.

Results from the recent *E. nitens* wood property study on which this study is based (Lausberg *et. al.*1996) also show spiral grain levels to decrease with increasing height in the stem. One difference in terms of spiral grain angles between the two eucalypt species however was the higher levels measured for *E. nitens* in the butt and 1.4m discs.

Figure 6 - Variation of Spiral Grain with Ring Number from the Pith



Growth Stress Assessment:

Presented in Table 12 are the individual end split scores and total score for each tree. None of the splits exceeded 1cm in width. Individual end split scores had a narrow range from 2 to 3 with some trees having 5 separate end splits. Total scores for the 20 trees ranged from 4 to 11 and averaged 6. The results presented here are preliminary and provide a benchmark for future studies.

Table 12 - End Split Assessment

Tree Number	Individual End Split Scores 1	2	3	4	5	Total Score
1	2	2				4
2	2	2				4
3	2	2				4
4	2	2	2			6
5	3	2	2			7
6	2	2				4
7	3	3	2	2		10
8	2	2	2			6
9	2	2				4
10	2	2				4
11	3	3	3			9
12	3	2	3	3		11
13	2	2	2	2	2	10
14	2	2	2	2		8
15	2	2	2	2		8
16	2	2	2			6
17	2	2	2			6
18	2	2				4
19	2	2	2			6
20	2	2	2			6

Internal Checking:

Internal checking, which occurs on drying can severely restrict the use of some eucalypts for solid wood purposes. The ash eucalypts vary in their susceptibility to this problem where *E. delegatensis* is by far the most susceptible and the higher density species *E. fastigata, E. obliqua,* and *E. sieberi* the least.

For this study, following drying to 10% emc (40°C and 60% RH) the half discs were resurfaced to provide a clean surface for the assessment of internal checking. Table 13 provides a summary of results by stem position. The severity of checking was graded visually, ring by ring on each disc according to the procedure adopted by King *et. al.* (1993). Briefly the grading description is as follows:

0 No checks in the ring
1 Small checks, entirely within the ring, and with width of 1-2mm
2 Larger checks but still entirely within the growth ring
3 A check that crossed one latewood boundary
4 A check that crossed more than one latewood boundary
5 A severe check extending the full radius of the disc

At butt, 80% of discs were affected by internal checking and for other discs over half the samples were checked with the exclusion of the discs sampled above 20m. This problem has been exacerbated due to the drying schedule which has taken the discs from a near saturated condition down to 10% moisture content.

The number of rings per disc affected by internal checking ranged between 2 and 3, with the ring position from the pith ranging from ring 3 to ring 8. Four grade 3 checks were observed with a similar number crossing the latewood boundary. Broadly speaking the degree of internal checking appeared much lower than the recent study on *Eucalyptus nitens* (Lausberg *et. al.* 1996)

Table 13 - Summary of Disc Internal Checking Assessment by Stem Position

Disc Ht. (m)	% of Discs Checked	No. of Rings Affected	1st Checked Ring			2nd Checked Ring			3rd Checked Ring		
			Ring Posn.	No. of Checks	Severity	Ring Posn.	No. of Checks	Severity	Ring Posn.	No. of Checks	Severity
Butt	80	3	4	3	2	6	3	2	6	3	2
1.4	60	2	7	3	2	7	2	2			
5.5	55	2	6	5	1	8	5	1			
11	70	2	5	4	2	5	4	2			
16.5	65	2	3	2	1	4	4	2			
20.9	15	2	3	2	2	5	2	2			

CONCLUSIONS

1. The results of this comprehensive study support and extend the current data available for *Eucalyptus fastigata* grown in the Bay of Plenty region. Outside this region, wood quality information is limited for how this species indicating a need for further research.

2. The data provides a useful base from which relationships between individual-tree wood properties can be established with end-product properties of solid wood, kraft and mechanical pulp.

3. The establishment of statistically significant relationships between breast height outerwood density and the tree and individual log densities provides the basis for a wood density database for *Eucalyptus fastigata* yielding a useful tool for predictive purposes

4. The generally low levels of spiral grain recorded in this study indicate that this property is unlikely to have a significant impact when determining the extent of the juvenile wood zone and is unlikely to cause major problems with regard to drying degrade providing the timber has been correctly dried.

5. The study has adopted some techniques not previously used in NZFRI's wood quality analysis and it is intended that these basic techniques will be incorporated into future studies investigating the potential of a range of hardwood species.

6. Indications are that this species can produce high density wood at a relatively young age with a lower incidence of checking than many other eucalypt species. More detailed work on the solid wood properties will help confirm that *E. fastigata* has potential for high value options such as furniture, cabinet-making, veneers, turnery and panelling.

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Appendix I - Individual Disc Wood Properties

Tree No.	Disc Height (m)	DIB (mm)	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m^3)	Basic Density (kg/m^3)
1	0	323	46	137	1099	465
1	1.4	290	42	138	1108	466
1	5.5	257	30	128	1123	492
1	11	214	26	125	1131	503
1	16.5	162	10	122	1147	505
1	20.5	107	0	128	1123	493
2	0	328	47	155	1090	428
2	1.4	283	43	163	1085	412
2	5.5	247	37	158	1086	421
2	11	211	27	160	1084	418
2	16.5	165	7	158	1108	430
2	21	97	0	149	1105	443
3	0	414	53	153	1094	432
3	1.4	356	62	153	1087	430
3	5.5	300	54	136	1085	459
3	11	259	41	135	1092	465
3	16.5	188	37	137	1121	473
3	20.3	119	9	120	1140	490
4	0	345	53	127	1114	491
4	1.4	304	55	133	1110	477
4	5.5	272	46	132	1099	474
4	11	242	38	128	1107	485
4	16.5	197	22	126	1144	506
4	21	107	0	141	1133	470
5	0	312	48	166	1094	412
5	1.4	277	50	165	1095	413
5	5.5	228	44	144	1117	458
5	11	197	16	154	1128	444
5	17.4	101	0	160	1091	419

Appendix I - Individual Disc Wood Properties (Contd.)

Tree No.	Disc Height (m)	DIB (mm)	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m^3)	Basic Density (kg/m^3)
6	0	375	68	162	1094	418
6	1.4	355	67	165	1091	411
6	5.5	328	68	144	1095	449
6	11	278	52	134	1112	475
6	16.5	216	48	142	1107	457
6	25	94	0	134	1097	469
7	0	314	66	126	1116	493
7	1.4	281	61	125	1138	506
7	5.5	253	53	125	1153	512
7	11	215	44	121	1144	518
7	16.5	174	24	122	1152	520
7	23	103	0	119	1142	522
8	0	361	60	178	1076	387
8	1.4	321	66	173	1070	392
8	5.5	285	56	171	1090	402
8	11	254	53	151	1119	420
8	16.5	188	9	169	1121	416
8	21	97	0	176	1116	404
9	0	328	53	141	1073	446
9	1.4	297	55	143	1060	436
9	5.5	257	54	133	1090	468
9	11	217	43	132	1093	471
9	16.5	172	27	141	1115	463
9	20.4	104	4	144	1114	457
10	0	378	65	125	1104	492
10	1.4	344	65	122	1104	496
10	5.5	306	62	120	1096	499
10	11	268	46	119	1113	508
10	16.5	196	27	125	1127	501
10	21.5	105	1	125	1143	508

Appendix I - Individual Disc Wood Properties (Contd.)

Tree No.	Disc Height (m)	DIB (mm)	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)
11	0	288	56	116	1144	530
11	1.4	259	51	118	1124	515
11	5.5	224	46	113	1135	533
11	11	183	34	111	1142	541
11	16.5	140	7	111	1155	547
11	21	99	1	116	1107	513
12	0	379	62	124	1107	495
12	1.4	330	61	123	1095	492
12	5.5	292	59	113	1108	521
12	11	250	55	116	1105	511
12	16.5	200	20	118	1125	517
12	22.1	116	7	124	1135	506
13	0	316	52	146	1085	430
13	1.4	270	55	151	1056	421
13	5.5	234	48	137	1073	453
13	11	208	39	144	1089	446
13	16.5	157	5	160	1111	428
13	19.2	115	1	174	1152	420
14	0	308	51	112	1131	533
14	1.4	283	50	111	1113	528
14	5.5	250	44	105	1105	538
14	11	215	37	108	1111	534
14	16.5	156	10	119	1132	516
14	19.7	109	2	113	1081	508
15	0	321	56	154	1103	435
15	1.4	291	55	152	1097	435
15	5.5	245	47	142	1115	460
15	11	208	39	143	1127	465
15	16.5	159	7	138	1143	481
15	20.2	105	0	124	1136	507

Appendix I - Individual Disc Wood Properties (Contd.)

Tree No.	Disc Height (m)	DIB (mm)	Heart-wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)
16	0	337	51	112	1105	522
16	1.4	305	47	119	1103	503
16	5.5	274	48	123	1100	492
16	11	250	51	131	1113	481
16	16.5	200	27	293	1851	471
16	21	102	0	126	1109	491
17	0	388	62	150	1100	430
17	1.4	348	64	147	1077	436
17	5.5	313	58	150	1097	439
17	11	268	46	151	1089	434
17	16.5	219	27	159	1115	431
17	23.2	117	0	166	1139	428
18	0	373	52	135	1128	481
18	1.4	319	52	139	1124	470
18	5.5	267	38	135	1137	484
18	11	229	13	129	1147	500
18	16.5	139	6	133	1161	499
18	19.1	98	0	124	1151	515
19	0	332	54	169	1065	396
19	1.4	281	53	170	1061	392
19	5.5	245	43	169	1086	404
19	11	202	27	170	1088	403
19	16.5	142	10	168	1111	414
19	19.5	107	1	165	1088	410
20	0	321	49	152	1090	433
20	1.4	293	47	153	1098	433
20	5.5	250	41	150	1109	443
20	11	214	29	156	1118	437
20	16.5	156	8	148	1146	462
20	19.4	105	0	154	1142	450

Appendix II - Log and Tree Values

Tree No.	Log Height Class	Volume (m³)	Heart-Wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)
1	Butt	0.368	40	133	1108	475
1	2nd	0.242	28	127	1126	496
1	3rd	0.156	20	124	1136	504
1	4th	0.059	7	124	1139	501
	Tree	0.824	30	129	1121	489
2	Butt	0.364	43	156	1088	425
2	2nd	0.228	33	159	1085	419
2	3rd	0.155	20	159	1093	422
2	4th	0.065	6	155	1107	433
	Tree	0.812	33	157	1090	424
3	Butt	0.565	53	147	1091	441
3	2nd	0.339	48	136	1088	462
3	3rd	0.221	39	135	1102	468
3	4th	0.074	29	132	1126	478
	Tree	1.199	48	141	1094	454
4	Butt	0.417	51	129	1108	485
4	2nd	0.286	43	130	1103	479
4	3rd	0.210	32	127	1121	493
4	4th	0.089	17	130	1141	498
	Tree	1.002	41	129	1112	486
5	Butt	0.323	47	158	1102	428
5	2nd	0.196	32	148	1122	452
5	3rd	0.123	13	155	1121	439
	Tree	0.642	36	154	1112	438

Appendix II - Log and Tree Values (Contd.)

Tree No.	Log Height Class	Volume (m^3)	Heart-Wood (%)	Moisture Content (%)	Green Density (kg/m^3)	Basic Density (kg/m^3)
6	Butt	0.536	68	154	1094	431
6	2nd	0.399	61	140	1102	460
6	3rd	0.268	50	137	1110	468
6	4th	0.185	41	141	1105	459
	Tree	1.388	59	145	1101	451
7	Butt	0.351	61	126	1131	500
7	2nd	0.238	49	123	1149	515
7	3rd	0.165	36	121	1147	519
7	4th	0.104	18	121	1150	521
	Tree	0.859	48	124	1141	510
8	Butt	0.457	59	175	1081	393
8	2nd	0.315	55	162	1103	410
8	3rd	0.216	37	157	1119	419
8	4th	0.079	7	171	1120	414
	Tree	1.066	49	168	1098	405
9	Butt	0.375	53	138	1080	455
9	2nd	0.244	49	133	1091	469
9	3rd	0.166	37	135	1102	468
9	4th	0.062	21	142	1115	462
	Tree	0.847	46	136	1090	462
10	Butt	0.511	64	123	1101	495
10	2nd	0.357	55	119	1104	503
10	3rd	0.238	39	121	1118	506
10	4th	0.097	21	125	1131	503
	Tree	1.203	53	121	1107	500

Appendix II - Log and Tree Values (Contd.)

Tree No.	Log Height Class	Volume (m³)	Heart-Wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)
11	Butt	0.288	52	115	1141	531
11	2nd	0.181	41	112	1138	536
11	3rd	0.115	24	111	1147	543
11	4th	0.052	5	113	1139	536
	Tree	0.635	40	113	1141	535
12	Butt	0.494	61	120	1107	505
12	2nd	0.319	57	114	1107	517
12	3rd	0.221	41	117	1113	513
12	4th	0.118	17	119	1127	514
	Tree	1.152	52	118	1110	511
13	Butt	0.334	51	143	1081	438
13	2nd	0.212	44	140	1080	450
13	3rd	0.147	27	150	1097	439
	Tree	0.692	44	143	1084	442
14	Butt	0.340	48	109	1120	535
14	2nd	0.235	41	106	1107	537
14	3rd	0.152	27	112	1118	528
14	4th	0.046	8	117	1115	514
	Tree	0.773	39	109	1116	533
15	Butt	0.352	53	150	1108	444
15	2nd	0.223	44	142	1120	462
15	3rd	0.148	27	141	1133	471
15	4th	0.053	5	133	1141	489
	Tree	0.776	42	145	1118	457

Appendix II - Log and Tree Values (Contd.)

Tree No.	Log Height Class	Volume (m³)	Heart-Wood (%)	Moisture Content (%)	Green Density (kg/m³)	Basic Density (kg/m³)
16	Butt	0.407	50	116	1103	510
16	2nd	0.297	49	127	1106	487
16	3rd	0.221	41	194	1401	477
16	4th	0.089	21	258	1698	475
	Tree	1.015	45	149	1221	493
17	Butt	0.537	60	150	1099	434
17	2nd	0.367	53	150	1093	437
17	3rd	0.259	38	154	1099	432
17	4th	0.162	21	161	1121	430
	Tree	1.324	49	152	1100	434
18	Butt	0.454	48	135	1131	482
18	2nd	0.267	28	133	1141	491
18	3rd	0.155	11	130	1151	500
	Tree	0.877	35	133	1137	488
19	Butt	0.368	50	169	1072	399
19	2nd	0.218	36	170	1087	403
19	3rd	0.132	21	170	1096	407
19	4th	0.037	7	167	1103	413
	Tree	0.754	39	169	1082	402
20	Butt	0.358	46	151	1097	437
20	2nd	0.234	36	153	1113	441
20	3rd	0.151	22	153	1128	446
	Tree	0.743	38	152	1108	440

Appendix III - Basic Density Data for Regression Analyses.

Tree No.	Basic Density, (kg/m^3)					
	Outerwood *	Butt Log	2nd Log	3rd Log	4th Log	Whole Tree
1	460	475	496	504	501	489
2	396	425	419	422	433	424
3	464	441	462	468	478	454
4	491	485	479	493	498	486
5	415	428	452	439		438
6	428	431	460	468	459	451
7	535	500	515	519	521	510
8	406	393	410	419	414	405
9	424	455	469	468	462	462
10	498	495	503	506	503	500
11	553	531	536	543	536	535
12	511	505	517	513	514	511
13	423	438	450	439		442
14	530	535	537	528	514	533
15	466	444	462	471	489	457
16	533	510	487	477	475	493
17	445	434	437	432	430	434
18	476	482	491	500		488
19	404	399	403	407	413	402
20	446	437	441	446		440

* Outer 50mm

Appendix IV - Dimensional Shrinkage to Air-Dry (12%)

Tree No.	Disc Height (m)	Shrinkage, %				
		Longitudinal	Radial		Tangential	
		Reconditioning				
		After	Before	After	Before	After
1	0	0.12	4.5	2.5	18.9	6.7
1	1.4	-0.03	6.0	2.6	20.4	7.3
1	5.5	0.05	5.4	3.1	12.8	7.0
1	11	0.20	4.0	2.9	13.7	6.9
1	16.5	0.26	4.1	2.8	7.1	6.2
1	20.5	0.20	3.4	3.1	6.2	5.5
2	0	0.18	2.8	2.6	8.2	5.4
2	1.4	0.23	3.8	2.8	11.8	6.5
2	5.5	0.38	4.6	3.0	7.7	6.4
2	11	0.34	2.6	2.3	7.6	5.2
2	16.5	0.31	3.6	2.6	6.1	5.1
2	21	0.18	2.2	2.2	4.7	4.5
3	0	0.24	3.4	2.3	11.6	5.6
3	1.4	0.15	3.0	2.3	13.5	6.2
3	5.5	0.09	4.0	2.6	11.1	5.9
3	11	0.13	2.7	2.6	6.3	5.2
3	16.5	0.10	2.7	2.5	6.6	4.8
3	20.3	0.33	3.5	3.3	7.7	5.4
4	0	0.11	3.9	2.7	11.3	6.4
4	1.4	0.01	3.9	3.2	12.4	7.2
4	5.5	0.24	4.5	3.6	8.7	6.7
4	11	0.06	3.8	3.3	7.1	6.1
4	16.5	0.32	3.3	3.0	7.8	5.8
4	21	0.23	4.5	4.0	7.4	5.9
5	0	0.32	4.4	2.6	15.3	6.3
5	1.4	0.43	3.5	2.1	13.8	7.5
5	5.5	0.53	5.4	3.6	10.8	6.7
5	11	0.25	2.9	2.5	7.2	5.3
5	17.4	-0.17	2.5	2.4	3.7	3.8

Appendix IV - Dimensional Shrinkage to Air-Dry (12%) (Cont.d)

Tree No.	Disc Height (m)	Shrinkage, %				
		Longitudinal	Radial		Tangential	
		Reconditioning				
		After	Before	After	Before	After
6	0	0.46	2.8	2.0	11.5	5.9
6	1.4	0.25	2.3	2.0	9.6	5.6
6	5.5	0.45	2.4	2.1	8.7	5.6
6	11	0.44	2.1	1.7	5.7	5.3
6	16.5	0.14	2.0	2.2	5.4	4.8
6	25	0.24	2.8	2.4	4.4	4.0
7	0	0.20	4.7	3.0	9.2	6.2
7	1.4	0.30	5.2	3.1	13.2	7.2
7	5.5	-0.02	5.0	3.4	10.7	6.2
7	11	0.06	5.5	3.8	11.1	6.3
7	16.5	-0.02	4.9	3.5	11.3	6.0
7	23	-0.14	4.6	3.8	5.7	4.6
8	0	0.26	3.3	2.1	11.4	5.1
8	1.4	0.15	3.1	2.2	10.6	5.9
8	5.5	0.58	2.9	2.1	8.9	5.2
8	11	0.26	2.5	1.8	8.6	5.4
8	16.5	0.21	2.3	2.0	6.5	4.5
8	21	0.21	2.4	1.8	5.3	4.0
9	0	0.20	3.2	2.4	7.8	4.8
9	1.4	0.22	2.8	2.4	7.6	5.2
9	5.5	0.05	3.0	2.5	6.6	5.2
9	11	0.05	4.0	3.1	8.6	5.3
9	16.5	0.27	4.0	2.6	7.0	5.2
9	20.4	0.02	3.1	2.4	4.5	4.1
10	0	0.19	2.9	2.8	7.3	5.5
10	1.4	0.39	3.6	3.0	9.6	5.4
10	5.5	0.17	3.1	3.3	6.9	5.5
10	11	0.14	3.3	2.9	6.6	5.5
10	16.5	0.18	3.1	2.7	7.8	5.1
10	21.5	0.00	2.9	2.6	4.7	4.2

Appendix IV - Dimensional Shrinkage to Air-Dry (12%) (Cont.d)

Tree No.	Disc Height (m)	Shrinkage, %				
		Longitudinal	Radial		Tangential	
		Reconditioning				
		After	Before	After	Before	After
11	0	0.60	4.1	3.2	8.0	6.2
11	1.4	0.15	4.4	3.1	9.5	6.8
11	5.5	0.15	4.1	3.3	7.6	6.2
11	11	0.39	5.5	4.6	7.5	6.2
11	16.5	-0.01	3.7	3.0	5.5	5.0
11	21	-0.01	3.9	3.0	5.4	4.4
12	0	0.18	4.2	2.9	7.5	5.5
12	1.4	0.27	3.1	2.9	9.5	6.7
12	5.5	0.16	3.4	3.4	7.8	6.6
12	11	0.40	3.0	3.0	6.4	5.7
12	16.5	0.24	3.1	3.2	6.5	5.7
12	22.1	0.22	3.1	2.8	5.0	4.6
13	0	0.48	3.1	2.3	10.0	6.3
13	1.4	0.01	3.7	2.7	12.1	6.7
13	5.5	0.27	4.0	3.2	7.6	6.0
13	11	0.23	3.0	2.7	6.6	4.7
13	16.5	-0.14	2.8	2.3	4.9	4.6
13	19.2	0.13	2.5	1.9	4.4	4.2
14	0	0.17	5.0	3.4	14.7	7.0
14	1.4	0.12	5.0	3.4	13.0	6.5
14	5.5	0.25	5.0	3.5	11.4	6.4
14	11	0.04	4.5	3.0	9.6	5.8
14	16.5	0.54	3.6	2.6	9.0	5.3
14	19.7	-0.11	3.5	3.1	5.6	4.1
15	0	0.13	3.2	2.5	12.9	6.7
15	1.4	0.21	4.6	3.1	11.5	6.6
15	5.5	0.11	4.4	3.1	9.0	6.1
15	11	0.06	4.5	3.2	8.6	5.3
15	16.5	0.22	4.1	3.1	5.8	4.9
15	20.2	0.05	1.9	2.0	4.9	4.7

Appendix IV - Dimensional Shrinkage to Air-Dry (12%) (Cont.d)

Tree No.	Disc Height (m)	Shrinkage, %				
		Longitudinal	Radial		Tangential	
		Reconditioning				
		After	Before	After	Before	After
16	0	0.11	3.0	2.5	10.0	6.1
16	1.4	0.23	3.4	2.7	13.3	6.7
16	5.5	0.08	4.5	3.4	10.6	7.0
16	11	0.00	2.9	2.7	7.7	6.3
16	16.5	0.12	3.5	2.8	8.2	6.0
16	21	-0.01	2.6	2.8	4.9	5.0
17	0	0.19	3.0	2.2	10.7	5.7
17	1.4	0.28	3.7	2.3	12.1	6.3
17	5.5	0.22	3.2	2.2	8.2	5.5
17	11	0.32	2.6	2.0	6.6	4.8
17	16.5	0.14	3.2	2.4	8.2	4.8
17	23.2	0.37	2.5	2.2	5.1	4.4
18	0	0.20	3.5	2.6	10.2	5.3
18	1.4	0.08	3.1	2.7	7.4	5.2
18	5.5	0.15	4.1	2.3	7.9	4.9
18	11	0.06	3.9	2.7	8.6	5.2
18	16.5	0.26	3.6	3.0	5.1	4.3
18	19.1	0.11	2.3	2.0	6.3	5.0
19	0	0.49	4.5	2.4	13.1	6.1
19	1.4	0.34	6.5	3.2	13.6	6.5
19	5.5	0.08	6.4	2.8	11.5	5.6
19	11	0.07	4.7	2.5	9.3	5.0
19	16.5	0.02	4.5	2.6	5.3	3.7
19	19.5	0.37	2.3	1.7	3.5	3.3
20	0	0.28	5.7	2.9	14.7	6.8
20	1.4	0.43	4.7	2.7	14.4	7.3
20	5.5	0.10	4.9	3.3	12.2	6.4
20	11	-0.05	3.2	2.5	7.3	5.1
20	16.5	0.55	5.1	3.2	9.3	5.1
20	19.4	0.41	3.3	2.8	4.7	4.0

Appendix V - Spiral Grain by Stem Position

Tree No.	Disc Height (m)	Spiral Grain (°) by Ring Number from the Pith 2	4	6	8	10	12	14	16
1	0	-7	7.25	-1	-4.75	-5.25	-4.75	-9.75	-6.75
1	1.4	-0.5	5	0.25	-1.5	-2.75	0.5	-0.75	
1	5.5	-2	-5	-2.75	-2.5	-2.5	2.25		
1	11	3.5	-7.25	-1.5	1.5				
1	16.5	0	-2.75	-0.5					
1	20.5	2	1.5						
2	0	-1.25	-3.25	3.25	2	-0.25	0.5	0.5	-1.75
2	1.4	-1.25	0.25	-3.5	1.25	0.25	2.75	-1.75	
2	5.5	1.5	0.75	-3.5	0.75	1.5	-1		
2	11	-1.25	0.25	2	0.75	-2.75			
2	16.5	-1	2	-0.5					
2	21	-2.75	-5						
3	0	knot	1.25	-9.5	-6	-6.25	-6.75	-7	-10
3	1.4	2.5	-3.75	-1.75	-6	-6.75	-6.75	-9.5	
3	5.5	4.75	-2.5	-2.75	-5.25	-3.5	-1		
3	11	-1.5	-3.5	0.5	-0.5	0			
3	16.5	6.75	4	3.25	-3.25				
3	20.3	-2	-6						
4	0	knot	-5.5	-2.25	-3	0	-3.75	-5.5	-8.5
4	1.4	-0.5	4	2	3.75	-2.5	1.75	1	
4	5.5	2.5	-1.5	-1.75	-0.5	-1	0.25		
4	11	0.5	0.25	1.75	-1	-1.25			
4	16.5	5.25	2.25	2	2.5				
4	21	-0.25	-0.25						
5	0	-0.75	0.5	-8.25	-7.25	-9	-8	-8	-7.75
5	1.4	4	-6	6.5	-2	-4.25	-1	-5.5	
5	5.5	-1	-3.5	-1.5	1.25	2.75	3		
5	11	-0.5	-2.75	-4.5	-4.5				
5	17.4	-5.5	-4.75						

Appendix V - Spiral Grain by Stem Position (Cont'd)

Tree No.	Disc Height (m)	Spiral Grain (°) by Ring Number from the Pith 2	4	6	8	10	12	14	16
6	0	-7.5	2.75	1.25	3.5	-1.75	0.75	4.25	-0.75
6	1.4	2.75	1.25	-3.5	-0.25	1.25	1.5	2.5	
6	5.5	0	3	7.5	5.75	-2.75	-1.25		
6	11	-4	4.75	-0.5	0.75	4.75			
6	16.5	-0.25	-2	0.75	-0.75				
6	25	-0.5	-3.5						
7	0	-4	1.75	0.25	-6	-4.25	-2.75	1.25	0.25
7	1.4	1.25	4.25	-3.5	-0.75	-1.5	-1.5	-1.75	
7	5.5	knot	-0.5	-0.25	0.75	-2	1.5	-3.75	
7	11	-3.25	0	1.5	-1.5	0			
7	16.5	2.25	-3.25	-2.25	0.25				
7	23	-0.5	-0.5						
8	0	1.5	3.5	6	5.75	4.25	1.5	-0.25	0
8	1.4	-2.5	0.25	-2.75	-3	0.5	-5.5	-2.25	5
8	5.5	-4.5	-6.25	2.5	-2	4.5	-2.75		
8	11	0.5	5	4	4.25	3.75			
8	16.5	2	-0.75	-3					
8	21	1	-1						
9	0	knot	knot	1.25	-0.5	5	4.25	3.75	-3.25
9	1.4	knot	-5.25	2.5	4.75	2.25	0.75	-3	
9	5.5	2.5	-2.75	9	8.25	5.5	3.5		
9	11	knot	7.25	3	3	3.75			
9	16.5	knot	-3.25	1	1.5				
9	20.4	-5	-2						
10	0	knot	-4	4.5	4	1.5	3.75	2.75	4
10	1.4	5.5	3.75	4.25	2	1.75	2.5	1.25	
10	5.5	knot	0.75	3	-1	1.5	4.5		
10	11	-1	1.25	5.5	2.5	5.75			
10	16.5	-2.25	2.75	0.5					
10	21.5	-3.25	-3.25						

Appendix V - Spiral Grain by Stem Position (Cont'd)

Tree No.	Disc Height (m)	Spiral Grain (°) by Ring Number from the Pith							
		2	4	6	8	10	12	14	16
11	0	knot	-1	-0.5	-1.5	-1.25	0.5	-0.75	-4.25
11	1.4	3.5	-0.5	-4.75	-0.5	-2.5	0	-0.25	
11	5.5	0	-0.75	-2.75	-3.5	-6.25	2		
11	11	1.25	0.5	0	-1	-1			
11	16.5	0	-4.25	-2.25	-4				
11	21	-2.25	-2.75						
12	0	2.25	-3	-1.25	-11.8	-1.25	-4.75	-3	-4
12	1.4	knot	3.75	-4	-6	-2.75	-1.25	-0.75	
12	5.5	3.5	-0.5	1.5	1.5	3	0		
12	11	2	-3.25	-0.25	-1.5	0.75			
12	16.5	-3.5	-2.5	-2					
12	22.1	1	0.5						
13	0	-7.25	-7.5	-8.25	-7	-4.5	-4	-5.75	-2
13	1.4	0.25	2	1.25	5.25	3.25	1.25	2.75	
13	5.5	-0.5	-0.75	0.75	0.75	0.5	-1		
13	11	-1	-2.5	-0.5	1	0.5			
13	16.5	0.5	-0.25	0.5					
13	19.2	-2.25	-3						
14	0	-2	-2.5	-2.5	-1.75	-2.25	-0.25	1	-4.5
14	1.4	-2	-6.25	-2	0.25	1.5	0.5	-2.5	
14	5.5	-2	-1.25	0	-1	-1.25	-3		
14	11	0	-6.25	-4.75	-4	-3.75			
14	16.5	-0.5	-2.25	-1.75	0.25				
14	19.7	-2.25	-5.5	-4					
15	0	-4	0.5	1.5	2	0	1.5	-0.25	1
15	1.4	2	-3.25	-3	-3.5	-1.25	-0.75	-0.5	
15	5.5	-1.25	-2.5	-3.75	-3.25	-3.5	-4.25		
15	11	-1.25	-3.25	-2.5	-2	-3.75			
15	16.5	-5.75	-4.5	-3					
15	20.2	-5	-2.75						

Appendix V - Spiral Grain by Stem Position (Cont'd)

Tree No.	Disc Height (m)	Spiral Grain (°) by Ring Number from the Pith							
		2	4	6	8	10	12	14	16
16	0	-1.5	-1.25	-1.5	-3.5	-6	-0.75	1	-2.5
16	1.4	-6.75	-2.25	-4	-7	-2	-4.5	0.25	2.5
16	5.5	-0.25	1.75	2.75	0	2.25	0.75	3.75	
16	11	-3.75	knot	knot	knot	0.5			
16	16.5	-2.5	3	4.75	1.5				
17	0	-3.25	-0.25	18.5	3.25	6	3.5	1.25	-2
17	1.4	8.75	4.25	6.5	7	2.75	0.25	-1.75	-2
17	5.5	4.5	0.5	7.25	3.25	2			
17	11	0.5	-2	1.75	3	5.75	2.5		
17	16.5	0.5	-4.5	-1.25	-2				
17	23.2	-0.75	-3						
18	0	-7	-4.5	-4.75	-6	-6.5	-7.25	-1.5	-4
18	1.4	-2.25	-3.75	-1.25	3.5	2	-1.75	-2	
18	5.5	-4.5	2.25	2	4	0.5			
18	11	-4.5	-1.25	2.25	-1				
18	16.5	-3.5	-2.25						
18	19.1	-2	-3.25						
19	0	-3.75	-10.5	2	0	4.75	1.75	-5.5	-3.75
19	1.4	-1.5	-0.5	-3	-3.75	-1.5	2.25	1	
19	5.5	-1.75	-3	-1	0.25	0.25	2		
19	11	knot	1	-1.25	-3				
19	16.5	knot	1	-0.5					
19	19.5	-4.5	-4						
20	0	-5	-0.75	4	0.5	-6.5	-5.5	-5	
20	1.4	-2.5	7.25	4.25	-7.5	-4.5	-2.75	-3.5	
20	5.5	-3	-5	-3.75	0.5	0.25	-3		
20	11	-1.75	1.25	2.5	1				
20	16.5	-0.5	-1.5						
20	19.4	-1.5	-0.25						