DRYING CHARACTERISTICS AND DEVELOPMENT OF KILN DRYING SCHEDULES FOR THE WOOD OF *ALSTONIA BOONEI*, *ANTROCARYON MICRASTER*, *BOMBAX BUONOPOZENSE*, *DIALIUM AUBREVILLEI* AND *STERCULIA RHINOPETALA*

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ABSTRACT

The susceptibility to drying defects and development of appropriate drying schedules was undertaken for the wood of five Ghanaian lesser used wood species: ***Alstonia boonei*** *(Sinduro),* ***Antrocaryon micraster****, (Aprokuma),* ***Bombax buonopozens*** *(Akata),* ***Dialium aubrevillei*** *(Duabankye) and* ***Sterculia rhinopetala*** *(Wawabima). Susceptibility to checking is severe in* ***D. aubrevillei*** *and* ***A. micraster*** *and mild in* ***S. rhinopetala****,* ***A. boonei*** *and* ***B. buonopozense****.* ***D. aubrevillei*** *is mildly susceptible to honeycombing and deformation, while* ***A. micraster, S. rhinopetala, A. boonei*** *and* ***B. buonopozense*** *are not susceptible. The following experimental dry kiln schedules for lumber of thickness up to 38mm corresponding to the FPL Madison schedules are proposed:* ***D. aubrevillei*** *[T4-B1],* ***A. micraster*** *[T4-B2],* ***S. rhinopetala*** *[T10-C4],* ***A. boonei*** *[T10-D4 – Moderate, T11-D5 – Severe], and* ***B. buonopozense*** *[T10-F4 – Moderate, T11-F5 – Severe].*

Keywords: Drying defect, checking, honeycomb, deformation, kiln drying schedule

INTRODUCTION

The Ghana timber export trade depends on a few species (Upton & Atta, 2003), and this represents an inefficient utilisation of the timber resource. In addition, for the large portion of wood exported from Ghana in the form of rough lumber, their unit value prices are very low compared to that for tertiary products such as furniture components, flooring, or profile boards (Ofori *et al*, 1993). To take advantage of the social and economic benefits created by each additional processing operation performed in the country, emphasis is being shifted towards the production of further processed wood products using both the primary species and the lesser-known species (LUS).

To allow for increased efficiency and a more judicious use of the forest resource, the Ghana Forest Sector Development Plan (Upton and Atta, 2003) which spans the period 1997-2010 sought to provide assistance and guidance through incentive schemes for the development of the kiln-drying sector, promotion of LUS and modernisation of existing plant and equipment. In addition, an export levy as a disincentive for export of primary species in green or air-dried lumber form has also been instituted. This is to help promote kiln drying of wood products as a first phase for the development of the value added sector.

Drying is one key step in processing wood products, and a solution to drying problems will help establish economic value for many tropical species. For many end uses and secondary manufacturing processes, lumber should be dried to avoid undesirable effects such as excessive shrinkage, stain and decay caused by fungal attack, and minimise drying defects such as warping, collapse, honeycomb, splitting and checking. It is therefore important that the susceptibility of the wood species to these drying defects which are related to its interaction with moisture, be studied to provide important information on the ability of particular species at particular moisture contents to be utilised for specific purposes and enhance its future utilization.

Measurements of these technological properties relevant to the drying of wood are also aimed at developing appropriate drying schedules for specific end-uses. Development of appropriate drying schedules would lead to improvement in the kiln drying process, and in the quality of lumber from Ghana.

The present kiln drying schedules in use in Ghana were developed for only the so-called primary species. Kiln-drying schedules for drying the wood species chosen for the companion study (Ofori & Brentuo, 2010a) and this study have so far not been developed. The only statements on drying provided by Upton and Attah (2003) on these species are:...‘ *Alstonia boonei (*Sinduro*)* air-dries easily...; *Bombax buonopozense (*Akata*)* dries quickly with little degrade...; *Dialium aubrevillei* dries slowly with care needed in air-drying to avoid splitting...; and *Sterculia rhinopetala (*Wawabima*)* should be air-dried slowly to minimise splitting...’. There is no such information on *Antrocaryon micraster (*Aprokuma*)*. There is therefore the need to draw up satisfactory drying schedules for these and the other numerous lesser-known species that may soon be exploited.

Experimental methods to determine a good schedule have more often involved the use of brute force. Kiln loads of lumber are dried by several schedules of varying severity. Drying time is then observed, and judgements are made about quality. These methods are acceptable, however, they can consume a lot of time and lumber if several species are involved (Simpson, 1992).

The method developed by Terazawa (1965) that was adopted attempts to estimate drying time, sensitivity to drying defects, and ultimately a kiln schedule by observing and characterising the various kinds of defects (initial checks, cross-sectional deformation, and honeycomb) that developed. The specimens (of size 2cm thick by 10cm wide by 20cm long) used dried much faster than would full-thickness lumber, so the method was very efficient in both time and material. The method has the limitation that subjecting specimens of that size to temperatures of about 100^{o}C imposed the severest conditions on them. However, the method at least indicates the mildest kiln schedule from which modifications could be made to obtain a commercial kiln schedule.

The objectives of this study were to determine the susceptibility of the five wood species (*A. boonei, A. micraster, B. buonopozense, D. aubrevillei* and *S. rhinopetala*) to drying defects (such as splits, checks, collapse, honeycomb, etc.), and to develop kiln schedules for drying the wood. This would lead to a greater utilisation of the forest resource through a wider exploitation, promotion and exportation of the many lesser-known species.

MATERIALS AND METHODS

Materials

The wood samples for this study were obtained from the same logs that were used in a companion study on the ‘green moisture content, basic density, and shrinkage characteristics of the wood of *A. boonei, A. micraster, B. buonopozense, D.*

aubrevillei and *S. rhinopetala*' (Ofori and Brentuo, 2010a).

Conversion and Sampling

The clear boles of 2.5m lengths which were split into quadrants and numbered were transported to the laboratory. After taking off the three discs for the companion study (Ofori and Brentuo, 2010a), 25cm thick sample discs were thereafter cut from each of the remaining quadrant logs for this drying characteristics and kiln schedule determination studies.

Susceptibility to Drying Defects and Kiln Schedule Determination

The method developed by Terazawa (1965), which attempts to estimate drying time, sensitivity to drying defects, and ultimately a kiln schedule was adopted. The 25cm thick log quadrant discs were sawn to 2.5cm by 12cm by 25cm flat-sawn sections and then planed to 2cm by 12cm by 25cm. The final specimen sizes used were 2cm by 10cm section, 20cm long with the 2cm by 10cm faces being flat sawn. The specimens used for this study were then wrapped in polythene bag and kept in a deep freezer.

When needed, six specimens per tree for each of the five species were taken out of the freezer and allowed to thaw. One end face of each specimen was marked and selected for end-checking observation. Two reference lines were drawn across the face of each 2cm x 10cm x 20cm specimen at right angles to each other and each 2cm from the left-most edge. The intersection of these two lines formed a reference point at which each micrometer reading was taken in the radial direction. The ends of the lines form reference points across which vernier calliper readings were taken. The longitudinal changes were measured along the longitudinal line. The dimensions of each specimen were measured using a micrometer screw gauge in the radial and tangential directions, and vernier callipers in the longitudinal direction or where the dimension could not be measured by micrometer. Each specimen was then weighed. At intervals of 10 minutes, one specimen out of six specimens was placed edge-wise in a well-ventilated drying oven that had been previously maintained at 103^{o}C - 105^{o}C.

Each of the specimens was taken from the oven every hour for the first four hours and then every two hours for the next four hours on the first day during working hours and twice daily on the second and subsequent days for re-weighing to obtain the moisture content. At the same time, end and surface checks that had developed during the drying were observed and noted down. This was repeated until the specimen was completely oven-dried. The condition of maximum checking was compared with the checking criteria set by Terazawa (1965) and the specimen was then awarded a corresponding checking classification.

At the end of drying, each specimen was sawn in the middle to give two approximately 2cm x 10cm x 10cm pieces in order to measure the honeycombing, and the cross-sectional deformation that might have occurred. The newly exposed faces were examined and the number of honeycombs recorded. The specimen was then awarded a honeycomb classification set by Terazawa (1965). The maximum and minimum thicknesses of each specimen along its freshly cut face were measured with micrometer screw gauge and the difference between the two measurements recorded as cross-sectional spool-like deformation. The specimen was then awarded a deformation classification set by Terazawa (1965).

RESULTS AND DISCUSSIONS

Susceptibility to Drying Defects

Visual observations were made with respect to seasoning defects which included checking and splitting, collapse, twisting (and cupping), and exudation.

The sapwood of all the species was susceptible to blue stain and pinhole borers when green. Therefore, rapid extraction, conversion and drying are necessary. Table 1 shows the results of the type of defects (checking, honeycomb and cross-sectional spool-like deformation) and class of drying defects obtained for each of the five wood species. It should be noted that defect type class 1 is the mildest and class 8 is the most severe.

Checks in the Early Stages of Drying

These were most severe in *D. aubrevillei* (Class 8) and *A. micraster* (Class 7), and to a lesser extent mild in *S. rhinopetala* (Class 3). There were moderate little checks in *A. boonei* and *B. buonopozense* (Class 2). Initial checking is strictly related to initial relative humidity, and less so to initial temperature. It is not related to either final temperature or final relative humidity. Thus low initial dry bulb temperatures (DBT) (45 - 47^{o}C) and very small initial wet bulb depressions (WBD) (1.8 - 2.0^{o}C) are thus critical to the drying of *D. aubrevillei* and *A. micraster* to prevent them from splitting in the early stages of kiln drying. Since *A. boonei* and *B. buonopozense* did not exhibit severe initial splitting, moderately higher initial temperatures (60-65^{o}C) and larger WBDs (4.3-5.5^{o}C) may be used.

Honeycombing (or Internal Checking)

There were no honeycombing (Class 1) in *A. micraster*, *S. rhinopetala*, *A. boonei*, and *B. buonopozense*, thus these four species are not susceptible to honeycomb (class 1). *D. aubrevillei* is mildly susceptible (Class 2) to honeycombing. In kiln drying, honeycombing is related to the initial and final temperatures and the initial relative humidity, but not to the final relative humidity. Since *A. micraster, S. rhinopetala, A. boonei*, and *B. buonopozense* did not honeycomb, they can thus tolerate high initial dry bulb temperatures (70^{o}C) and high initial WBDs (6.5^{o}C). However, moderate initial dry bulb temperatures (55^{o}C) and moderate initial WBDs (4.3^{o}C) should be employed for *D. aubrevillei*.

Cross-sectional Spool-like Deformation

There was no Deformation (Class 1) in *A. micraster, S. rhinopetala, A. boonei* and *B. buonopozense*. Deformation was little to mild (Class 2) in Duabankye. Deformation is related to the initial and final temperatures, and less so, to the initial relative humidity, but not to the final relative humidity. Relatively higher initial dry bulb temperatures (70^{o}C) and high initial WBDs (6.5^{o}C) may be employed for drying *A. micraster, S. rhinopetala, A. boonei* and *B. buonopozense*; while high initial dry bulb temperatures (66^{o}C) and high initial WBDs (6.0^{o}C) may be employed for drying *D. aubrevillei*.

Checks on early stages of drying are the most critical defect that governs the kiln drying of all the five species. Care must be taken in drying these because of their tendency to split and check. Splits and checks are aggravated by rapid drying or extremely fast, hot drying; slower drying will reduce these defects, except when they are a result of logging damage (Wengert 1991). There was a slight honeycombing in *D. aubrevillei*, and the wood is slightly susceptible to collapse. *A. micraster, S. rhinopetala, A. boonei* and *B. buonopozense* are not susceptible to collapse or deformation and honeycomb.

Table 1: Type and class of drying defects and their critical drying conditions

Wood Species	Defect Types or Initial Moisture Content	Defect Types Classes							Critical Drying Conditions Corresponding to Adopted Defect Type Class		
		Mean for Tree No.					Class Range & [Mean] or MC Range	Class Adopted *or Mean MC*	Initial Dry Bulb Temperature ^{O}C	Initial Wet Bulb Depression ^{O}C	Final Dry Bulb Temperature ^{O}C
		A	B	C	D	E					
D. aubrevillei	Initial Check	8.0	8.0	8.0	8.0	8.0	8 - 8 [8.0]	8	45	1.8	79
	Honeycomb	1	1	1	1	3	1 - 4 [1.33]	2	55	4.5	83
	Deformation	2.3	1.3	1.0	2.0	1.0	1 - 3 [1.6]	2	66	6.0	88
	Initial M.C. Range (%)	48	47	50	44	31	30 – 50	*44.6*			
A. micraster	Initial Check	7.0	7.0	7.0	7.0	7.0	7 - 7 [7.0]	7	47	2.0	80
	Honeycomb	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Deformation	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Initial M.C. Range (%)	38	43	48	45	44	37 – 50	*43.4*			
S. rhinopetala	Initial Check	2.8	3.0	3.0	3.0	2.8	2 - 3 [2.87]	3	60	4.3	85
	Honeycomb	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Deformation	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Initial M.C. Range (%)	66	61	64	68	74	53 – 84	*66.7*			
A. boonei	Initial Check	1.5	1.0	2.5	2.5	1.5	1 - 3 [1.9]	2 or 3	65 or 60	5.5 or 4.3	90 or 85
	Honeycomb	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Deformation	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Initial M.C. Range (%)	89	107	68	94	114	60 – 119	*97.3*			
B. buonopozense	Initial Check	3.0	2.8	2.5	1.5	1.0	1 - 3 [2.0]	2 or 3	65 or 60	5.5 or 4.3	90 or 85
	Honeycomb	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Deformation	1	1	1	1	1	1 - 1 [1.0]	1	70	6.5	95
	Initial M.C. Range (%)	132	102	110	118	140	86 – 164	*126.8*			

Table 2: Summary of initial moisture content and adopted classification of defect types used in proposing the critical drying conditions

Wood Species	Mean [Range] Initial Moisture Content (%)	Adopted Classification of Defect Types			Proposed Critical Drying Conditions			
		Check on early stage	Honeycomb	Deformation	Initial Temp. (^oC)	Wet Bulb Depression (^oC)	Final Temp. (^oC)	Corresponding Madison Kiln Schedule
D. aubrevillei	45 [30-50]	8	2	2	45	1.8	79	T4-B1
A. micraster	43 [37-49]	7	1	1	47	2.0	80	T4-B2
S. rhinopetala	67 [53-84]	3	1	1	60	4.3	85	T10-C4
A. boonei	97 [60-119]	2	1	1	65	5.5	90	T11-D5
		3	1	1	60	4.3	85	T10-D4
B. buonopozense	127 [86-165]	2	1	1	65	5.5	90	T11-F5
		3	1	1	60	4.3	85	T10-F4

Proposed Experimental Kiln Drying Schedules

A kiln-drying schedule determines both temperature and relative humidity based on the type and degree of defects. The experimentally determined susceptibility class relationship (or 'Critical Drying Conditions Corresponding to Adopted Defect Type Class') is summarized in Table 1. It shows the type and class of drying defects obtained for the lumber of the five species. The most prevalent class for each of the three drying defect types (initial check, honeycomb and collapse or deformation) was adopted. It also indicates the appropriate starting and final drying conditions (initial dry bulb temperature, initial wet bulb depression, and final dry bulb temperature) selected from tables in the study by Terazawa (1965). From each group of three possibilities, the mildest conditions (viz. overall lowest initial temperature, overall smallest initial wet bulb depression, and overall lowest final temperature) were selected, and are shown in Table 1.

It is observed that checks on early stages of drying are the most critical defect that governs the initial drying conditions (i.e. initial dry bulb temperature and initial wet bulb depression), and the final temperature in kiln drying the five species from Ghana.

A summary of the initial moisture content and adopted classification of defect types used in proposing the drying conditions is found in Table 2.

The average initial moisture contents (see column 2 of Table 2) and the initial mildest drying conditions so determined provided a starting criterion, which was applied in selecting the moisture content class, dry bulb temperature and wet bulb depression combinations from the tables provided by Simpson (1991), and used by Ofori and Appiah (1998), Ofori and Obese-Jecty (2001) and Ofori and Brentuo (2005) in previous studies.

The Forest Products Laboratory (FPL), Madison, USA has provided general temperature schedules for hardwoods ranging from a very mild schedule, T1, to a severe schedule, T14 (Rasmussen, 1961; Simpson, 1991). Initial temperatures, in all cases, are maintained until the average moisture content of the control specimens reach 30%. Wet-bulb depression schedules for six moisture content classes (A to F) that are related to the green moisture content of the wood (Class A being green moisture content of up to 40%, and class F being green moisture content of above 120%) are also provided. In addition, there are eight numbered wet-bulb depression schedules (No. 1 being the mildest and No. 8 the most severe).

The experimental dry kiln schedules for lumber of thickness up to 38mm have been assembled in Tables 3 to 7. In the schedule for *D. aubrevillei* the initial WBD of 1.8^{o}C was determined (see Table 2), however in the FPL wet bulb depression table, WBDs of either 1.5 or 2.0^{o}C are listed. In view of the specie's very high susceptibility to checking (Class 8) we used the milder WBD figure of 1.5^{o}C (Table 3) instead of the more severe value of 2.0^{o}C.

Similarly, in the schedule for *A. micraster* the initial dry bulb temperature determined was 47^{o}C (see Table 2), however in the FPL general temperature table, initial dry bulb temperature of either 45 or 50^{o}C are listed. In view of the specie's very high susceptibility to checking (Class 7) we used the milder DBT figure of 45^{o}C (Table 4) instead of the more severe value of 50^{o}C. In the schedule for *S. rhinopetala* (Table 5), an initial milder WBD of 4^{o}C was used instead of the 4.3^{o}C determined in Table 2.

Two types of schedules ('Moderate' and 'Severe') are being proposed for *A. boonei* and *B. buonopozense*. These are Schedules T10-D4 (Moderate) and T11-D5 (Severe) for *A. boonei* (Table 6), and Schedules T10-F4 (Moderate) and T11-F5 (Severe) for *B. buonopozense* (Table 7). The suggested schedule by Rasmussen (1961) and Simpson (1991) have been modified for *B. buonopozense* (Moderate), so that the wet bulb temperature (dry bulb temperature minus wet bulb depression) is never less than 32^{o}C even for continuous venting. The modification occurs in step 6. In the severe schedules the critical drying conditions are based on the checking class 2, and in the mild or moderate schedules the critical drying conditions are based on the checking class 3. The mild kiln schedules are recommended for kiln loads comprising a fair mixture of flatsawn and quartersawn or comprising mostly quartersawn material or squares or for more delicate loads. The severe kiln schedules are harsher and may be applied to thin loads, air-dry or mainly flatsawn loads, and for end-uses where the lumber quality is not exacting.

Overall, the following experimental dry kiln schedules (Tables 3 to 7) for lumber of thickness up to 38mm corresponding to the FPL Madison schedules are proposed: *D. aubrevillei* [T4-B1], *A. micraster* [T4-B2], *S. rhinopetala* [T10-C4], *A. boonei* [T10-D4 - Moderate, T11-D5 - Severe], and *B. buonopozense* [T10-F4 - Moderate, T11-F5 - Severe]. It is observed that the mildest schedules, involving high initial humidity and low temperature conditions, are employed for kiln drying *D. aubrevillei* and *A. micraster* to prevent checks on early stages of drying. These two species were far denser (Ofori and Brentuo, 2009a) than the other three species. Moderate initial temperatures and moderate initial humidity conditions are required to prevent checking and splitting of the less dense *S. rhinopetala*, *A. boonei* and *B. buonopozense* since they can tolerate relatively severe initial drying conditions.

The method developed by Terazawa (1965) that was adopted attempts to estimate drying time, sensitivity to drying defects, and ultimately a kiln schedule by observing drying time and characterising the various kinds of defects (initial checks, cross-sectional deformation, and honeycomb) that developed. The specimens (of size 2cm thick by 10cm wide by 20cm long) used dried much faster than would a full-thickness lumber, so the method was very efficient in both time and material. The method has the limitation that subjecting specimens of that size to temperatures of about 100°C imposed the severest conditions on them. However, the method at least indicates the mildest kiln schedule from which modifications could be made to obtain a commercial kiln schedule. The procedure above took into consideration, only initial check, cross-sectional deformation, and honeycomb. Other defects such as warp, properties such as drying rate and basic density, and grade of lumber should be taken into consideration in adjusting the experimental kiln drying schedules to suit the conditions of the wood to be dried in commercial kiln runs to improve upon them. Schedules for severely warped lumber or high basic density and slow drying species might be modified by lowering both the initial DBT and WBD; while schedules for upper grade lumbers or fast drying species might be modified by raising both the initial DBT and WBD (Terazawa, 1965).

Table 3: Experimental kiln drying schedule for *Dialium aubrevillei*

Step No.	Moisture Content Range %	Madison Kiln Schedule T4-B1			
		Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 35	45	1.5	91	19.7
2	35-30	45	2	89	18.3
3	30-25	50	3	84	16.0
4	25-20	55	5	76	12.8
5	20-15	60	12	52	7.6
6	15 to Final	80	25	30	4.0
	Equalize and condition as necessary				

Table 4: Experimental kiln drying schedule for *Antrocaryon micraster*

Step No.	Moisture Content Range %	Madison Kiln Schedule T4-B2			
		Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 35	45	2	89	18.3
2	35-30	45	3	83	16.0
3	30-25	50	5	75	12.8
4	25-20	55	8	64	9.9
5	20-15	60	18	35	5.4
6	15 to Final	80	30	22	3.1
	Equalize and condition as necessary				

Table 5: Experimental kiln drying schedule for *Sterculia rhinopetala*

Step No.	Moisture Content Range %	Madison Kiln Schedule T10-C4			
		Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 40	60	4	82	14.0
2	40-35	60	4	73	11.6
3	35-30	60	9	62	9.2
4	30-25	65	15	45	6.4
5	25-20	70	25	25	3.9
6	20-15	75	30	19	3.1
7	15 to Final	80	30	22	3.1
	Equalize and condition as necessary				

Table 6: Experimental kiln drying schedules for *Alstonia boonei*

Madison Kiln Schedule T10-D4 – Moderate					
Step No.	Moisture Content Range %	Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 50	60	4	82	14.0
2	50-40	60	6	73	11.6
3	40-35	60	9	62	9.2
4	35-30	60	15	43	6.4
5	30-25	65	25	23	3.8
6	25-20	70	30	17	2.9
7	20-15	75	30	19	3.1
8	15 to Final	80	30	25	3.1
	Equalize and condition as necessary				
Madison Kiln Schedule T11-D5 – Severe					
Step No.	Moisture Content Range %	Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 50	65	6	74	11.5
2	50-40	65	8	67	9.8
3	40-35	65	12	54	7.6
4	35-30	65	20	33	4.9
5	30-25	70	30	17	2.9
6	25-20	70	30	17	2.9
7	20-15	80	30	22	3.1
8	15 to Final	80	30	22	3.1
	Equalize and condition as necessary				

Table 7: Experimental kiln drying schedules for *Bombax buonopozense*

Madison Kiln Schedule T10-F4 – Moderate					
Step No.	Moisture Content Range %	Dry Bulb Temp. ^oC	Wet Bulb Depression ^oC	Relative Humidity %	Equilibrium Moisture Content %
1	Above 70	60	4	82	14.0
2	70-60	60	6	73	11.6
3	60-50	60	9	52	9.2
4	50-40	60	15	43	6.4
5	40-35	60	25	20	3.6
6	35-30	60	28*	14*	2.8*
7	30-25	65	30	17	2.7
8	25-20	70	30	17	2.9
9	20-15	75	30	19	3.1
10	15 to Final	80	30	22	3.1
	Equalize and condition as necessary				
Madison Kiln Schedule T11-F5 – Severe					
Step No.	Moisture Content Range %	Dry Bulb Temp. ^oC	Wet Bulb Depression ^oC	Relative Humidity %	Equilibrium Moisture Content %
1	Above 70	65	6	74	11.5
2	70-60	65	8	67	9.8
3	60-50	65	12	54	7.6
4	50-40	65	20	33	4.9
5	40-35	65	30	14	2.7
6	35-30	65	30	14	2.7
7	30-25	70	30	17	2.9
8	25-20	70	30	17	2.9
9	20-15	80	30	22	3.1
10	15 to Final	80	30	22	3.1
	Equalize and condition as necessary				

* Values modified so that the wet bulb temperature is never less than 32^{o}C

CONCLUSIONS

Susceptibility to Drying Defects

Checks in the early stages of drying were very mild in *A. boonei* and *B. buonopozense*, moderate in *S. rhinopetala*, and most severe in *D. Aubrevillei* and *A. micraster*. The wood of *A. boonei, B. buonopozense, S. rhinopetala* and *A. micraster* were not susceptible to collapse (or deformation) and honeycombing, but that of *D. aubrevillei* was mildly susceptible to both collapse and honeycombing.

Kiln Drying Schedules

The following experimental dry kiln schedules for lumber of thickness up to 38mm corresponding to the Forest Products Laboratory Madison schedules are proposed: *D. aubrevillei* [T4-B1], *A. micraster* [T4-B2], *S. rhinopetala* [T10-C4], *A. boonei* [Schedule T10-D4 – Moderate, T11-D5 – Severe], and *B. buonopozense* [T10-F4 – Moderate, T11-F5 – Severe].

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