Improving Drying Quality of Eucalyptus Nitens Timber

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EXECUTIVE SUMMARY

Eucalyptus nitens has a very high incidence of drying degrade, primarily caused by water tension stress occurring early in drying. This degrade reduces the recovery of sawn timber from nitens logs and is a barrier to producing significant volumes of sawn timber.
If drying degrade could be reduced, this would improve the economics of producing sawn timber from nitens, and could potentially lead to decreased drying times, increasing the throughput of nitens processors. Research to date into reducing degrade has primarily focussed on altering the drying conditions (air temperature etc.) during conventional drying. This has not produced promising results, so a different approach is required. Some promising research has been done freezing wood prior to drying to reduce water tension, but water tension forces are very difficult to quantify which hampers research in this area. Scion has an improved method of measuring water tension forces, which can be combined with existing methods of quantifying degrade to assess methods of reducing degrade more accurately than has been possible in the past.
This project aims to reduce drying degrade in nitens using non-traditional means. As an initial step, brief periods of freezing prior to drying are trialled.

SWP Initiatives

A review of processing issues for eucalypt species has been covered in Cown, et al. (2015) “Wood Processing Challenges and Opportunities for Douglas-fir and Several Eucalyptus Species”

The current work is based on the findings from Riley, et al. (2016) “Using freezing techniques to minimise collapse during drying”

This Project

In this project five small boards were cut from each of twenty different nitens trees from South Wood Exports in Southland. Four sets of twenty boards were briefly frozen (1 week or less), with the freezing temperature, freezing rate and time frozen varied between sets. One set of boards was not frozen at all. Boards were air dried under controlled conditions and the surface strain measured during drying to quantify the level of collapse-causing water tension stress. Once boards reached 30% MC they were kiln dried and conditioned to ~12%MC. The level of collapse and checking was visually assessed for each board, and the level of water tension stress calculated. Comparing the different freezing treatments there was no obvious differences in drying degrade or drying rate between the different treatments. Overall levels of degrade were lower than we would have expected, with around 20% of boards having unacceptable degrade. Reports of percentages of nitens boards affected by degrade vary considerably: 15-40%: Innes, et al. (2008), 15% Satchell (2015), and at Scion we have previously had 50% of commercially-sourced boards affected by degrade. These variable levels of degrade in nitens need to be understood better before further research can be done in this area.

Implications for SWP

None of the pre-freezing treatments had a noticeable effect on drying degrade or drying rate. There was no indication that pre-freezing had any effect on the wood stiffness during drying.
Overall levels of degrade were lower than expected, making it difficult to compare treatments, and suggesting that the drying method used was not representative of conditions used in practice. Future work of this kind would need to investigate lab scale drying techniques to ensure results are applicable to industrial scale drying.
It is known that checking behaviour varies widely between trees, and using a screening tool to identify trees prone to checking would ensure a greater proportion of check prone trees in each experiment.

INTRODUCTION

Drying degrade is a major processing concern for *Eucalyptus nitens*, and is seen as a major barrier to its utilisation for sawn timber. Drying degrade is not a single phenomenon, but consists of several types of failure, which are caused by different underlying mechanisms. Some types of degrade appear similar in terms of the final damage seen in the wood, but will be caused by a different underlying mechanism. Blakemore, et al. (2009) deal with this issue succinctly and their terminology and definitions will be used in this report. Collapse refers to the strain or deformations caused early in drying when cell lumens are full of liquid water and are connected to cells free of liquid water via small capillaries and the water tension forces are sufficient to overcome the cell wall strength. This deformation can be manifested as wash boarding (wavy surface) or as intra-ring checks. At lower moisture contents, as the cell wall starts to dry, cell wall shrinkage begins, and this causes other forms of drying degrade (e.g. between-ring checks and surface checks). Drying degrade caused by cell wall shrinkage can often be controlled by manipulating the drying and reconditioning conditions, but collapse and checking caused by water tension has proven much more difficult to control, and are thus the focus of the current research. Collapse, and within-ring checking are the result of several factors occurring simultaneously, and thus can be quite random and sporadic and thus it is difficult to quantify the efficacy of any attempts to control them. Since the liquid phase is highly implicated in water tension related degrade, freezing techniques (that bypass or manipulate the liquid phase) have long been proposed as a remedy for collapse and are often reported as the most promising technique, but freeze drying for long periods of time is considered uneconomic. There is some evidence in the literature that even very brief freezing times (~24h) is sufficient to impact on within-ring checking and collapse, so this was chosen as a starting point for our research, as this brief freezing time would be much easier and cheaper to adopt than extended drying at sub-zero temperatures.

METHODS

Wood preparation and drying

Twenty logs were sourced from South Wood Export in Southland and these were delivered to Scion with the cut ends sealed with Log Shield end grain sealer. For this study 2nd logs were chosen, to avoid the growth stresses present in the butt log. Seven logs were from Clark Forest, and thirteen were from Nicol Forest, both in Southland.

Checking and collapse behaviour can be very sporadic, with wood from some trees exhibiting no collapse, even with aggressive drying, and some trees will exhibit collapse even with very gentle drying. Cutting samples from 20 logs aimed to ensure that a wide range of collapse propensities would be covered in this work.

Each log was milled to give two square boards ~70x70mm, cut from the middle heartwood of the tree. Boards were selected to give maximum length without defects, and to have growth rings parallel to one face of the board.

Each board was ripped to 50x50mm, then ripped in half to give two flat-sawn boards 25x50mm. These were docked to give short boards 220mm long, and five of these short boards were selected for this study. Boards were chosen to have straight grain, parallel growth rings and no defects such as knots or resin pockets.

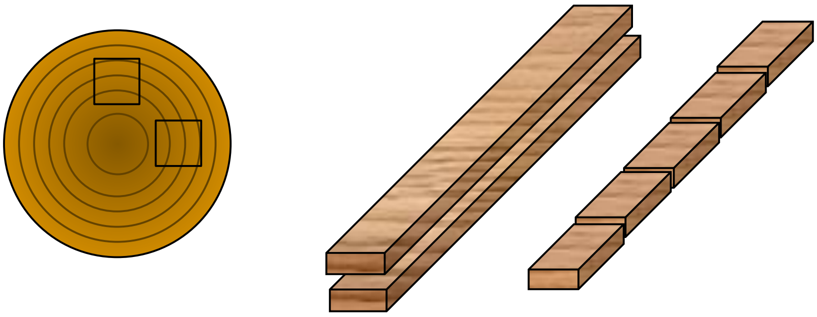

Figure 1 Cutting logs into individual sample boards

One board from each log was randomly assigned to the five treatments listed in Table 1.

Table 1. Treatments used in this study

Name	# reps	Freezing temp (°C)	Freezing rate	Freezing time (h)
Control	20	-	-	-
neg20	20	-20	max	24
neg7	20	-7	max	24
freeze_slow	20	-20	slow	24
freeze_long	20	-20	max	168

From the remaining short boards, one board per log was oven dried to estimate the log moisture content and two additional boards were assigned to each treatment for temperature monitoring during freezing and thawing.

All boards (excluding those to be oven dried) were coated on all faces with Carboguard epoxy paint, and a random speckle pattern applied to one face using a printable transfer.

Immediately prior to freezing, paint was removed from the two narrow faces of each board using a planer, the boards were weighed and their acoustic MOE (Modulus of Elasticity) measured.

To quantify water tension during drying, surface strains were measured using a Digital Image Correlation (DIC) technique where pairs of photographs were periodically taken of each board and software used to track the random speckle pattern between subsequent images. Four boards were imaged at a time, and the cameras set up so that each board was being weighed on a loadcell during imaging.

Control boards were imaged immediately after paint removal. Then the boards were dried in a room controlled to 20°C, 65% RH and re-imaged at every ~5% change in moisture content.

Boards to be frozen were sealed in plastic prior to freezing. Boards for temperature monitoring also had holes drilled in one face and a thermocouple inserted into the hole to give a tight fit with the wood.
Following each freezing treatment, boards were removed from their plastic bags, weighed and thawed overnight at 20°C. Following thawing the boards were weighed and their MOE measured again. They were then imaged and dried in the same way as the control boards (above).

Once the boards were estimated to be below 30% MC (according to the moisture content of each log calculated above) they were kiln dried at 70°C/55°C for 25 hours followed by 4 hours reconditioning at 75°C/74°C. Following drying the boards were weighed and equilibrated at 20°C 65% RH until a stable weight (less than 0.1% change in 24 hours). Acoustic MOE was measured again, then the boards were cross-cut in half, weighed and half of each board oven dried to estimate the board moisture content. The cut face of the other half was visually assessed for collapse and within-ring checking.

Data analysis

For each set of four boards, their series of images were analysed using VIC-3D software to produce a strain field of the surface of each board over time. These strain fields were averaged in the longitudinal and tangential board directions to give average strains in each direction over time.

RESULTS

Freezing and thawing rates

For each treatment, the temperatures of two reference boards were measured during freezing and thawing, to give an indication of the internal temperatures of the sample boards.

Graphs of individual thawing rates can be found in the appendix. In general the boards cooled rapidly to around -3°C, then cooled more slowly to the freezer temperature (either -7°C or -20°C), with the centre of the boards reaching a steady temperature in 10-15 hours. The Freeze Slow series cooled to -3°C in about twice the time of the other boards, and cooled very slowly after that. After 48 hours in the freezer, they had not reached -20°C.

Thawing rates were very similar between the treatments, with boards warming slowly to ~2-3°C then warming rapidly to 25°C before levelling off. Generally within 8-10 hours the board temperatures were above 20°C. Due to an equipment failure, temperatures were only measured in one board per treatment during thawing.

Drying rates

The average moisture contents of each treatment over time are shown in Figure 2. Drying rates are very similar for all treatments, giving no indication that pre-freezing has any effect on drying rate.

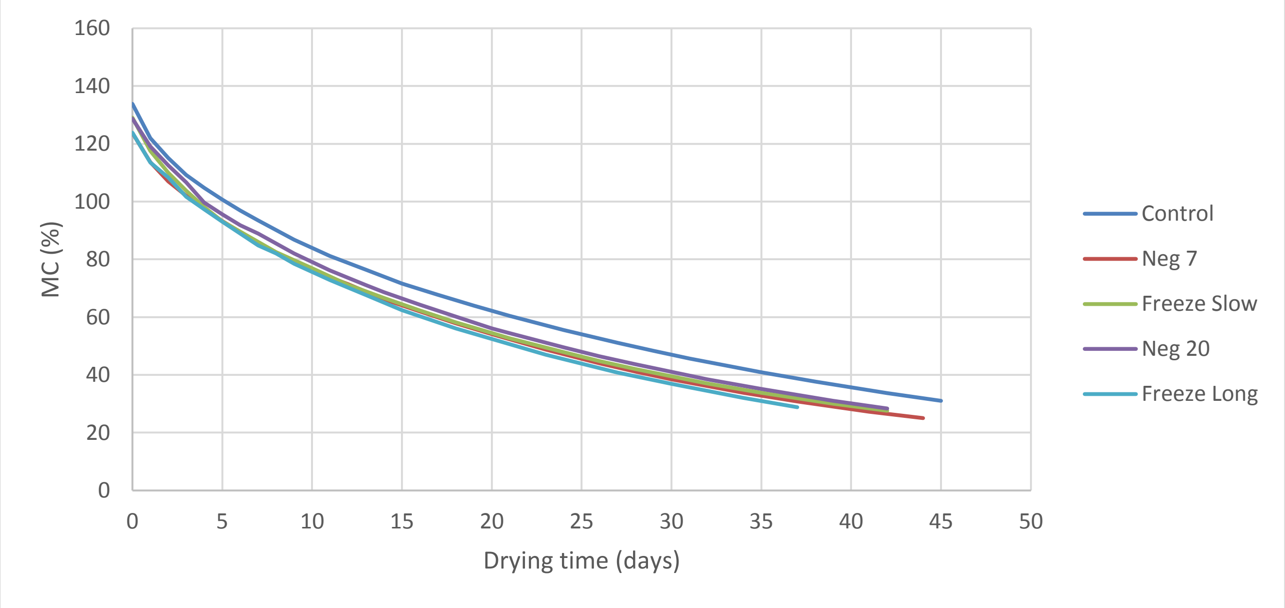

Figure 2. Average moisture contents over time for each treatment

Acoustic MOE

Freezing may alter the distribution of water within the wood, leading to an increase in stiffness, making the wood better able to resist collapse and checking. The stiffness of all boards was measured prior to freezing and again after thawing to see if freezing has an effect on the sample stiffness. The difference between these values is shown in Figure 3. Positive values indicate samples that are stiffer following freezing and thawing, and negative values are samples that are less stiff following freezing and thawing.

The stiffness of most samples was relatively unchanged, for the samples frozen slowly, there were three boards with a large decrease in stiffness following freezing and thawing. The boards frozen at -20°C had a slight increase in stiffness, and this was significantly different to the samples frozen slowly, but not significantly different to the other two treatments.

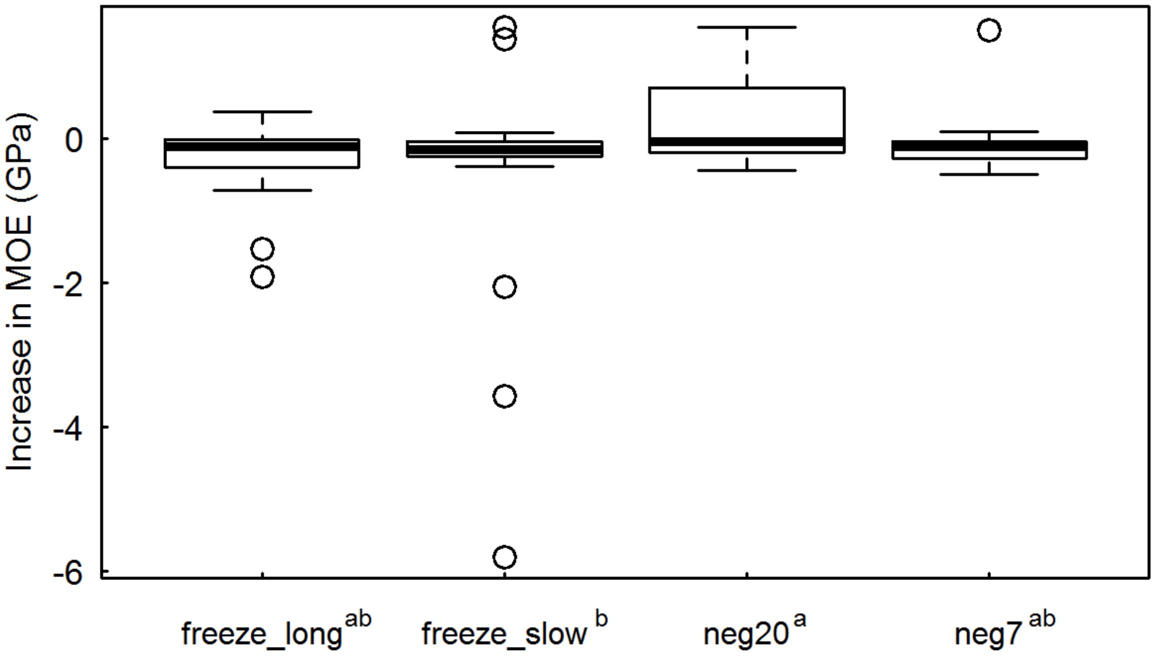

Figure 3. Change in MOE (stiffness) following freezing and thawing.

Visual assessment of drying degrade

The dried, equilibrated boards were cut in half and visually assessed for the presence of collapse and within-ring checking. For each type of degrade boards were classed as being “Acceptable” or “Unacceptable”. While such ratings are subjective, an acceptable rating is intended to cover boards with no degrade, or levels of degrade that are not likely to affect downstream processing (e.g. washboarding <1mm deep, or one or two very small within-ring checks). Each board was also given an overall rating of “Acceptable” or “Unacceptable” based on the worst rating it received of all the types of checking assessed.

A bar graph indicating the proportion of acceptable and unacceptable boards in each treatment is shown in Figure 4. Levels of degrade are almost identical across all treatments, and are lower than we were expecting (~20%). Commercial shipments of dried *E. nitens* received by Scion in previous studies have had up to 50% of boards affected by checking and collapse, even after careful air drying, including very slow drying at high moisture contents. Innes, et al. (2008) suggested that between 15 and 40% of Australian grown E. nitens would be expected to have significant levels of internal checks once dried. Satchell (2015) found 15% degrade from all causes (including internal checking and collapse). It is interesting to note that this study had the same commercial supplier as the Scion study mentioned above. This suggests that levels of degrade can be very variable between studies, and may be a combination of wood source and processing conditions. These variable levels of degrade in nitens need to be understood better before further research can be done in this area, so we can be confident that the research conducted by Scion is representative of the issues faced by industry.

Innes (1995) found that for E. regnans there was a collapse threshold temperature at around 20-25°C, below which collapse was unlikely to occur. This study dried at a constant 20°C, which may be below the threshold temperature for nitens, thus artificially reducing the level of collapse in all the samples. Future studies should look at higher drying temperatures.

The boards in this trial were dried at a uniform 65%RH, which is a much lower RH than recommended, especially during the initial part of drying. The boards were then kiln dried at 70°C once they had reached fibre saturation. The drying regime used was expected to be relatively severe, so it is surprising that levels of degrade are so low. Having only a small number of boards with degrade obviously makes it difficult to compare treatments, but it also calls into question the real-world applicability of the drying technique used here. Future experiments should compare several laboratory scale drying processes to see which gives reasonable agreement with drying quality seen in industry.

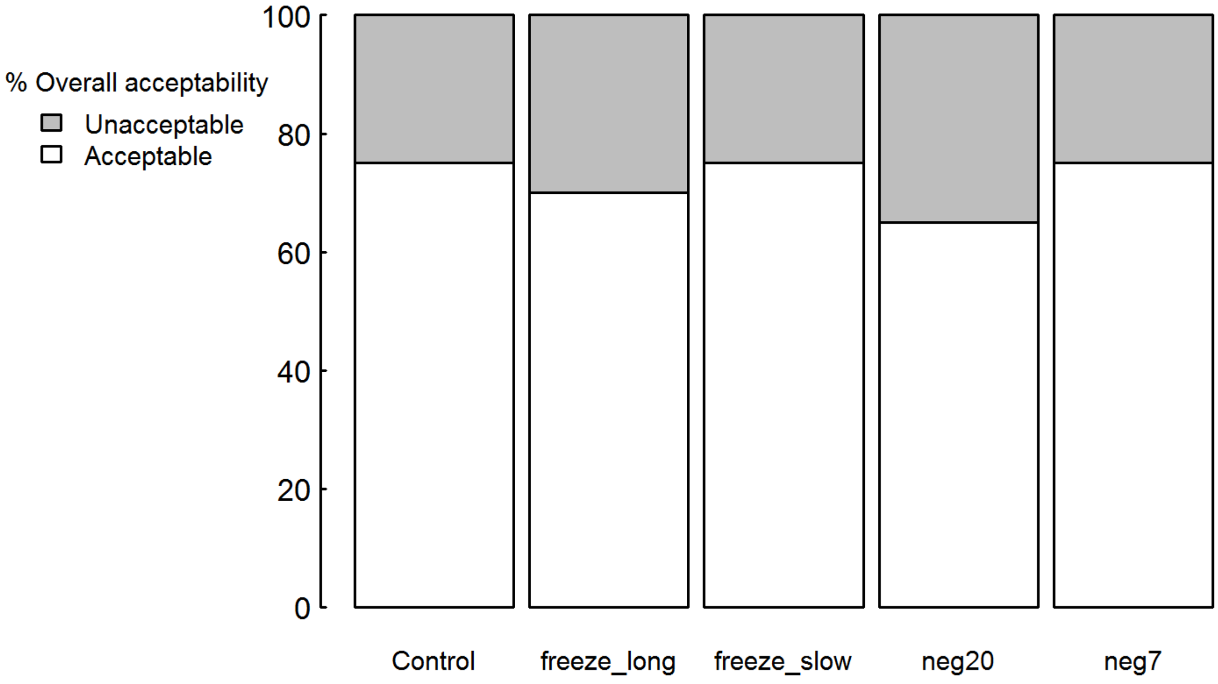

Figure 4. Proportion of boards with unacceptable checking or collapse for each treatment. Each treatment contains 20 boards.

Water Tension

The strain data collected for each sample had quite a lot of scatter, making it difficult to determine strain in the longitudinal direction. For this reason, it was not possible to calculate water tension forces, but strain data could be determined for the transverse (tangential) direction. Above fibre saturation, when the wood itself has not started shrinking, differences in tangential shrinkage between samples is likely to be caused by differences in water tension stress, or differences in levels of collapse between samples.

Boards which had extremely noisy strain values were assumed to have measurement or analysis errors and were excluded from subsequent analysis. Tangential strain development is shown as a function of moisture content for all the ‘good’ samples in Figure 5. Negative strain values indicate that the samples were shrinking. Note that in this figure drying time increases from right to left, as moisture content decreases.

This figure covers strain development until the average MC for each board was 50% - well above fibre saturation where cell-wall shrinkage starts occurring. Despite this, large levels of strain can be seen – in the control group, some samples have more than 10% strain at 50% MC. For comparison, nitens that has been dried to 12%MC without collapsing would be expected to have around 8% strain relative to its green dimensions. Many of the control boards have already developed strain of this magnitude before getting to fibre saturation. Overall the control treatment has the highest levels of strain, and the -7°C treatment (neg_7) has the lowest levels of strain. The three remaining treatments (which were all frozen at -20°C) all have levels of strain that are in-between these two treatments.

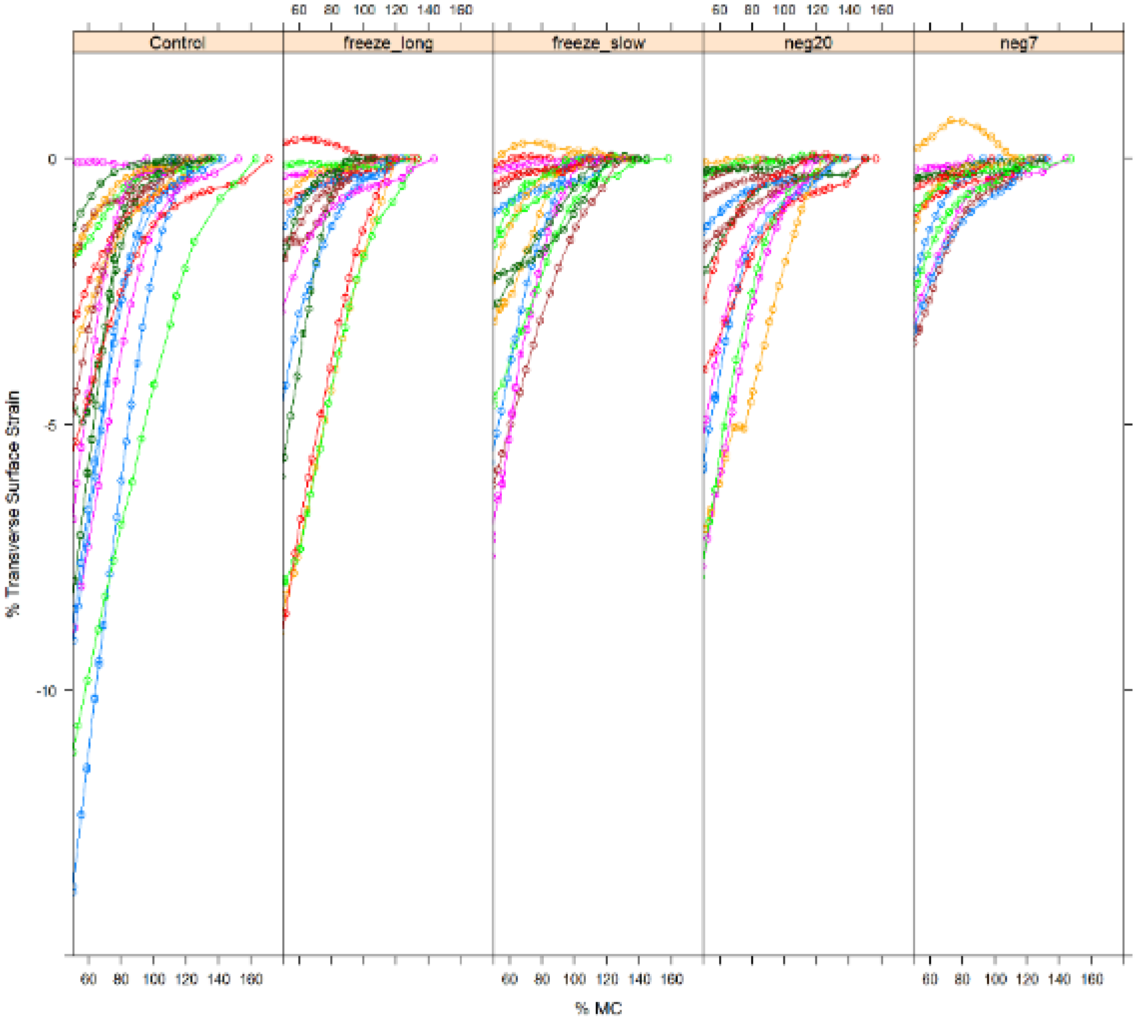

Figure 5. Tangential strain development vs. moisture content for each board, grouped by treatment.

A box and whisker plot of all the strain values at 50% MC is shown in Figure 6. Superscript letters indicate treatments that are not significantly different to each other (95% confidence level). Both the -7°C treatment, and the slow freezing rate treatment (freeze_slow) had significantly smaller levels of shrinkage compared to the control (unfrozen) treatment. The remaining two treatments, both frozen at -20°C, were not significantly different to either the control boards or the -7°C treatment. This suggests that freezing may have an effect on collapse formation, but this effect is likely to be small, or it has been masked by the low drying temperature, which may have reduced the level of collapse in all the treatments.

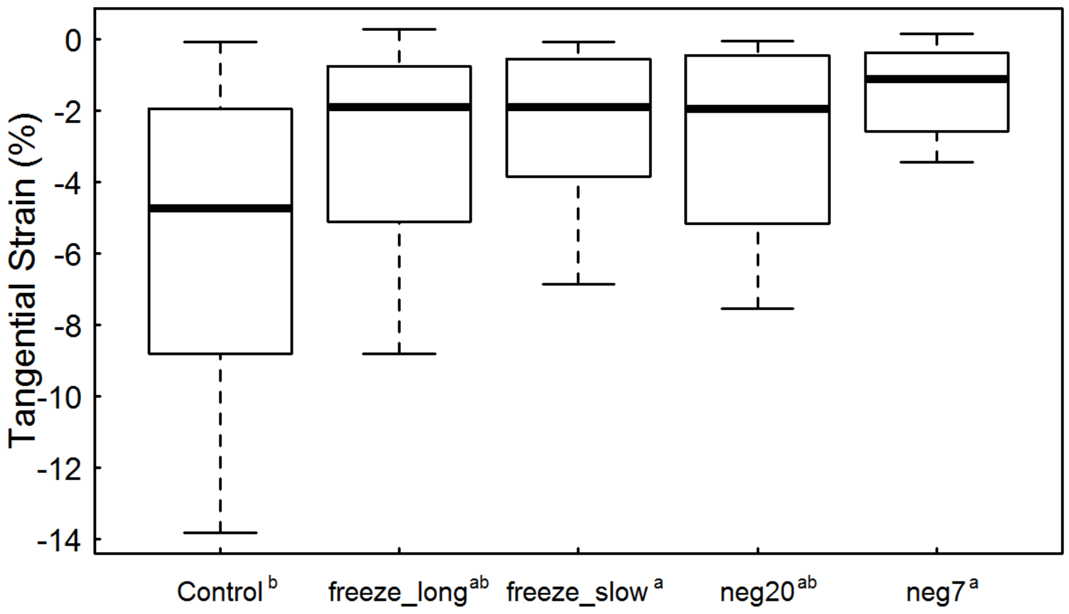

Figure 6. Tangential strain at 50% MC.

CONCLUSION

None of the pre-freezing treatments had a noticeable effect on drying degrade or drying rate. Stiffness change after freezing and thawing was very variable and did not show any effect of freezing on the sample stiffness.

Freezing appeared to have a small effect on the levels of tangential shrinkage above fibre saturation, especially in the -7°C, and slow freezing rate treatments.

Overall levels of degrade were lower than expected, making it difficult to compare treatments, and suggesting that the drying method used (constant 20°C) may not be representative of conditions used in practice. Future work will need to investigate lab scale drying techniques to ensure results are applicable to industrial scale drying.

It is known that checking behaviour varies widely between trees, and using a screening tool to identify trees prone to checking would ensure a greater proportion of check prone trees in each experiment.

It is recommended that the above findings be combined in a study to compare checking and collapse levels in boards dried under different conditions as well as discs and increment cores taken from the same logs. This would enable non-destructive identification of check prone trees, as well as identifying a suitable lab-scale air drying schedule for replicating levels of degrade seen in industry.

ACKNOWLEDGEMENTS

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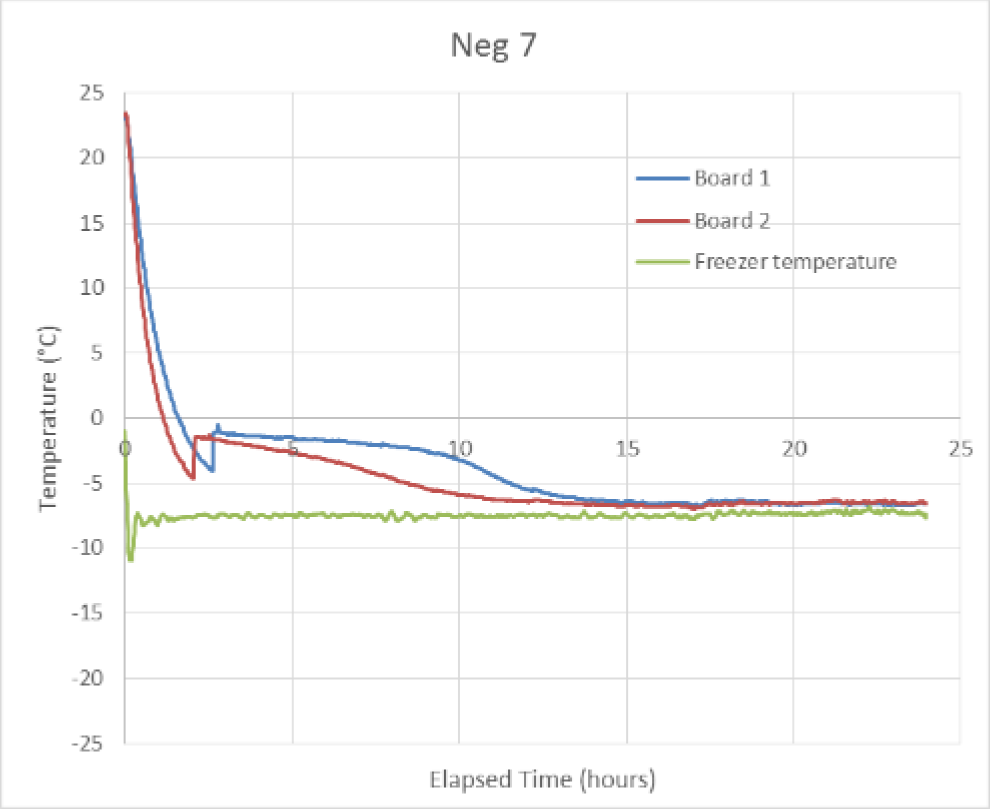
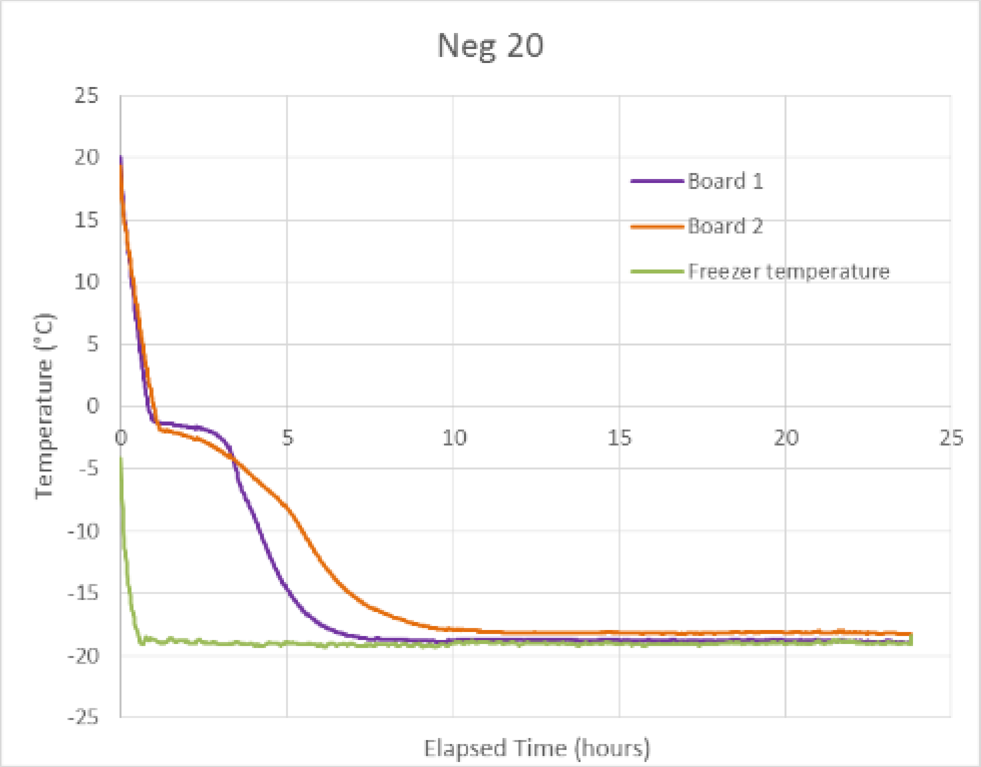
APPENDICES

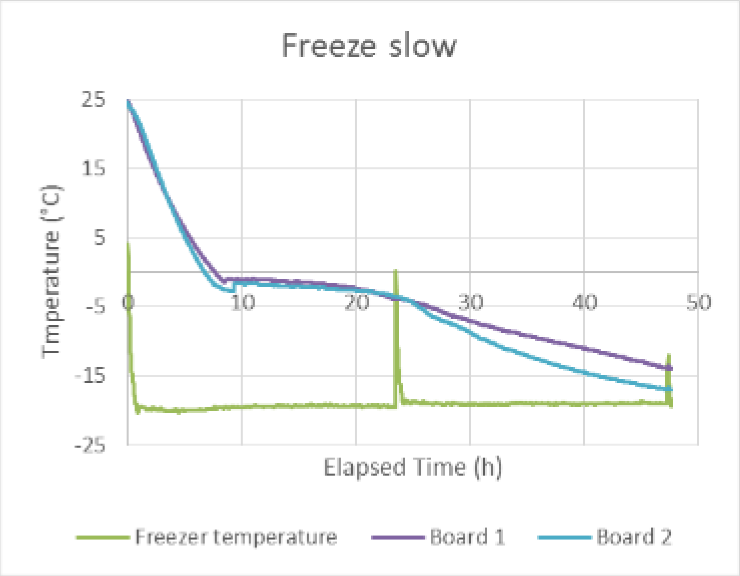
Appendix 1:

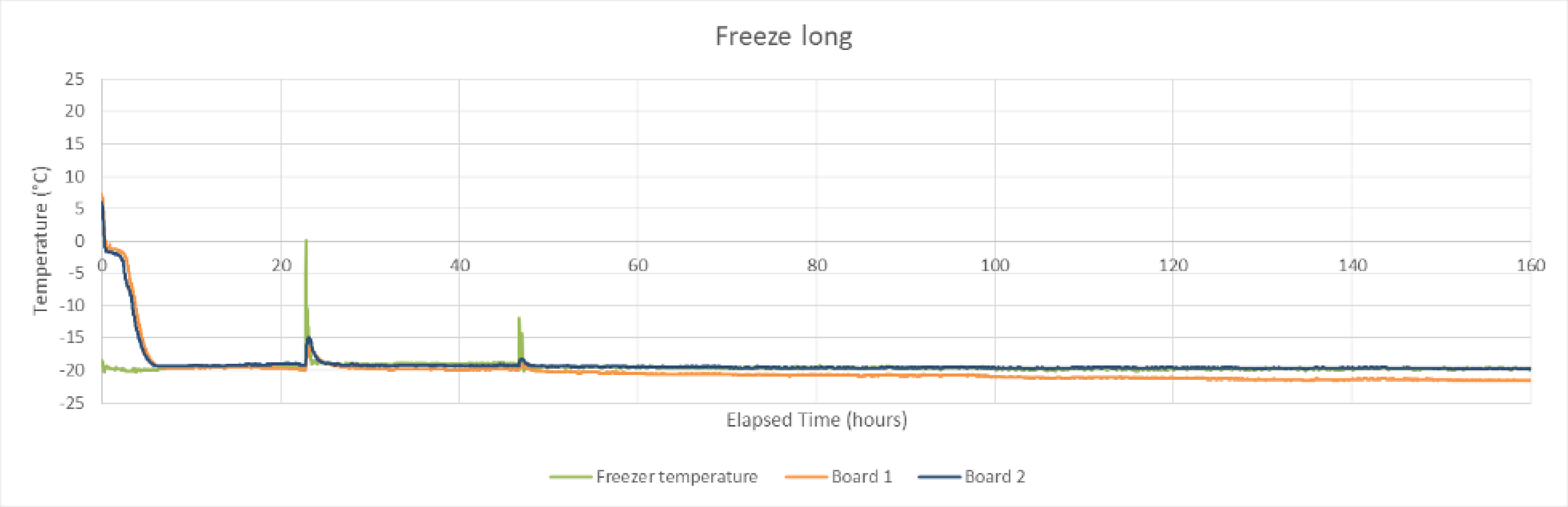
Freezing and thawing temperatures

Freezing temperatures for each treatment

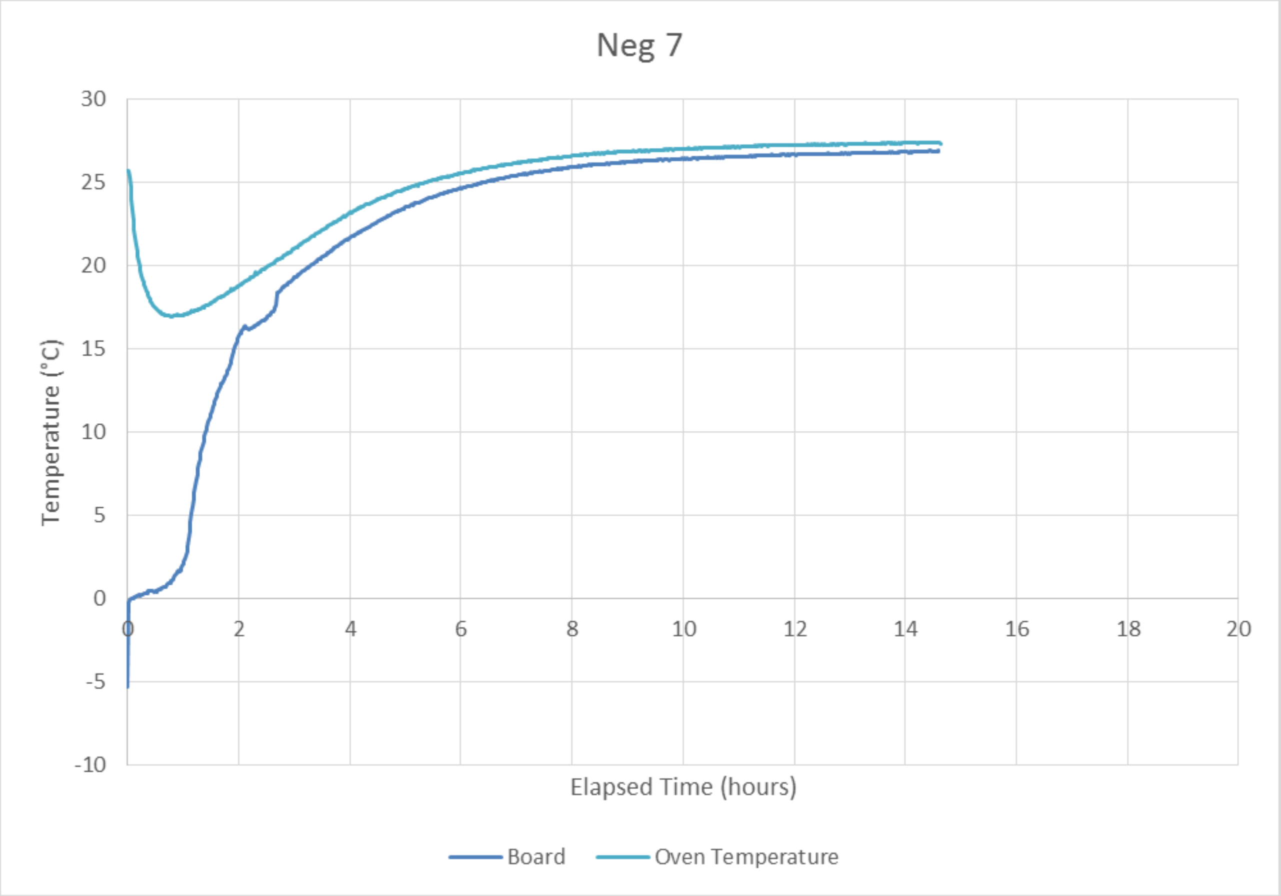


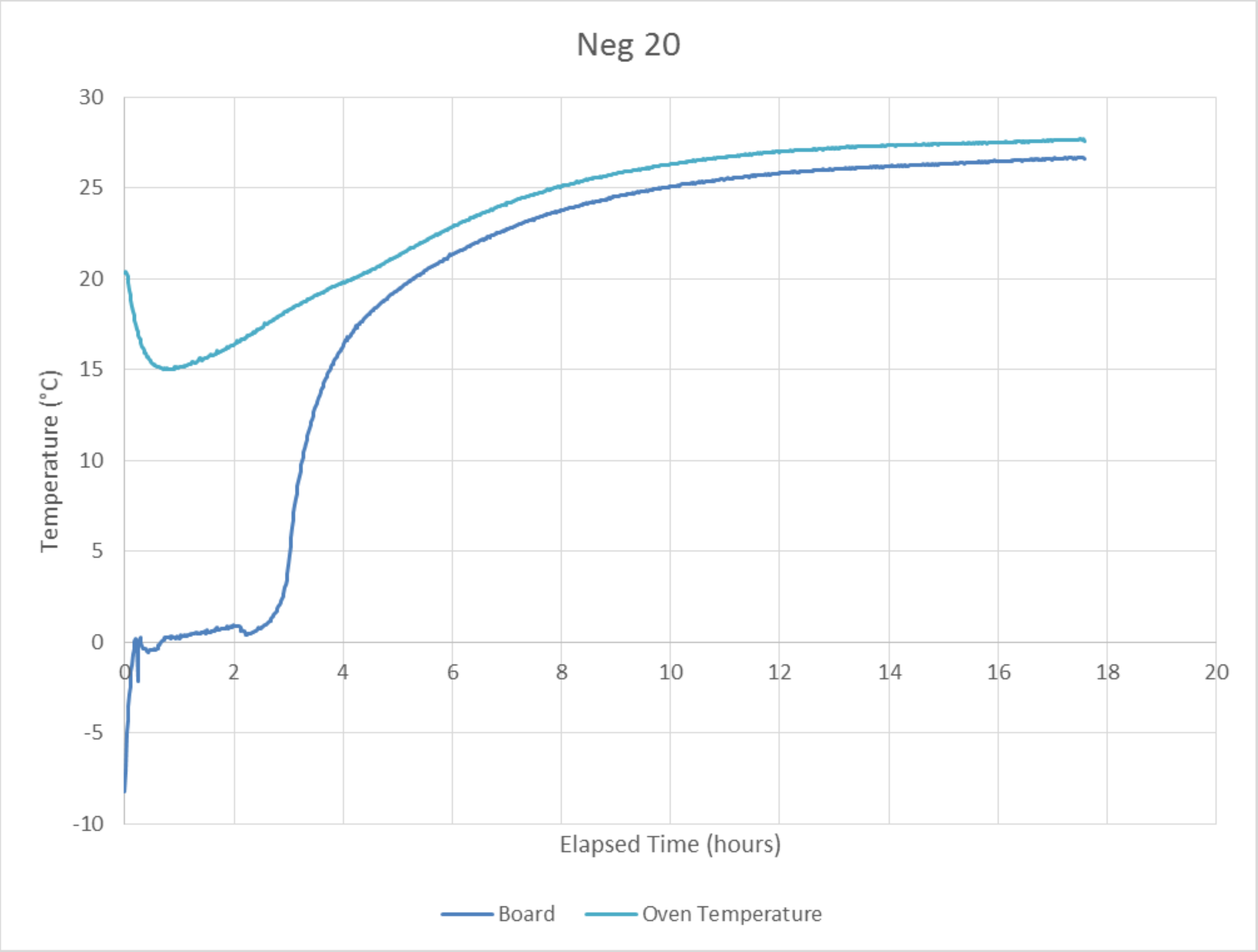


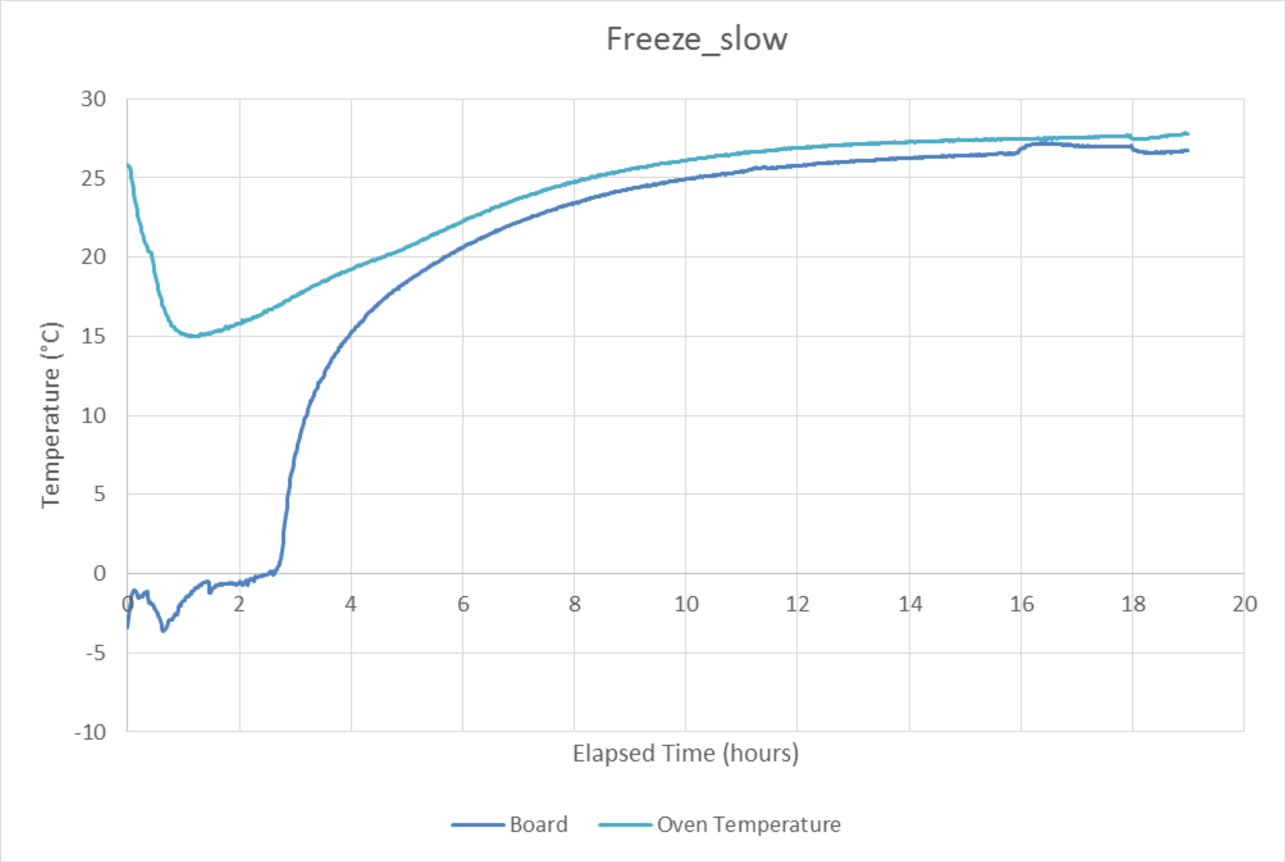

Freeze slow
Tmperature (°C)
25
15
5
-5
-15
-25
0
10
20
30
40
50
Elapsed Time (h)
Freezer temperature
Board 1
Board 2

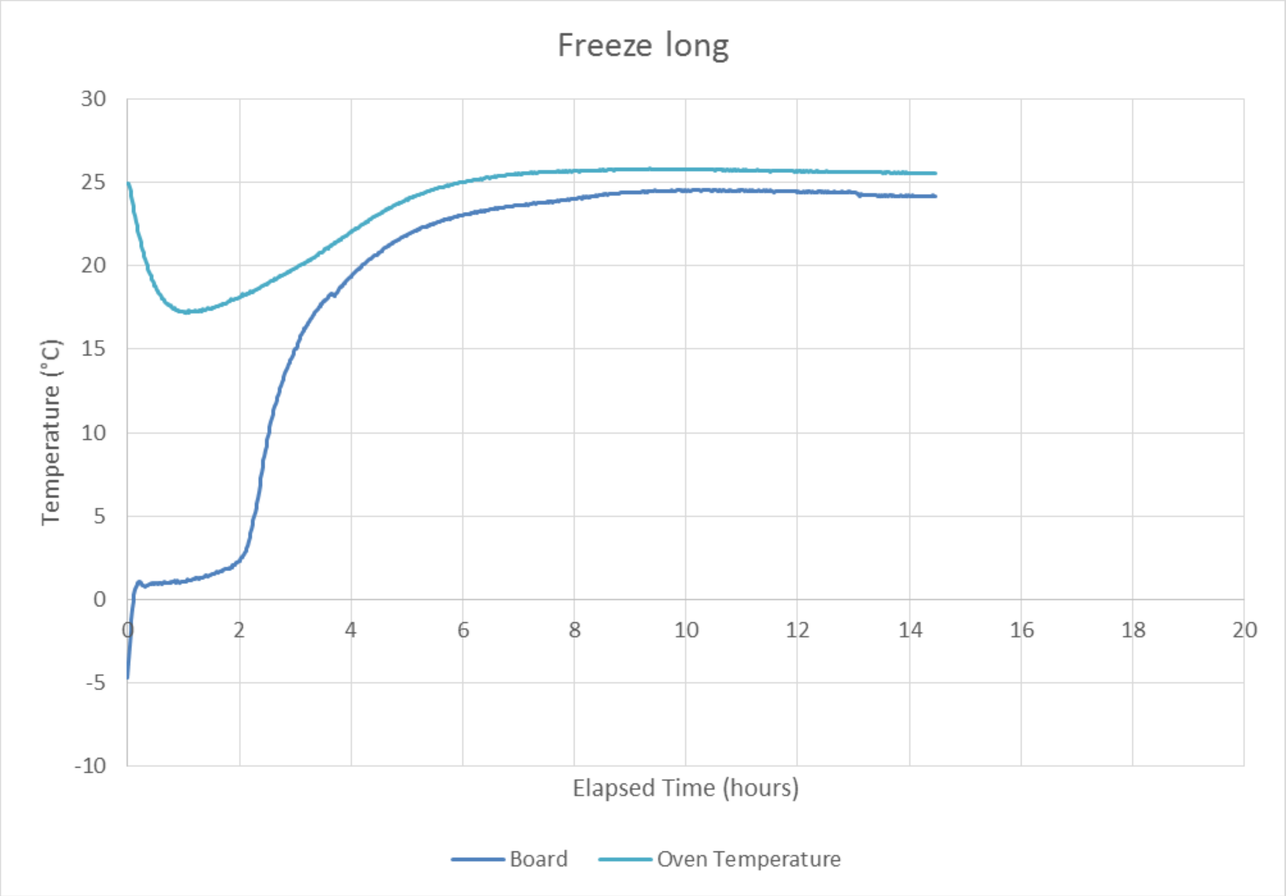

Freeze long
Temperature (°C)
25
20
15
10
5
0
-5
-10
-15
-20
-25
0
20
40
60
80
100
120
140
160
Elapsed Time (hours)
Freezer temperature
Board 1
Board 2

Thawing Temperatures for each Treatment






Freeze_slow
Temperature (°C)
30
25
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12
14
16
18
20
Elapsed Time (hours)
Board
Oven Temperature


Freeze long
Temperature (°C)
30
25
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12
14
16
18
20
Elapsed Time (hours)
Board
Oven Temperature