PRE-SORTING STRATEGIES: SUB-ALPINE FIR INDUSTRIAL TRIAL

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WOOD 493

A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN WOOD PRODUCTS PROCESSING

IN

THE DEPARTMENT OF WOOD SCIENCE

APRIL 9, 2012

ABSTRACT

Spruce-Pine-Fir (SPF) lumber is composed of different wood species with different drying properties. One comprising species, sub-alpine fir, has low permeability and the presence of wet pockets makes it challenging to dry. The projected increase in harvesting of sub-alpine fir has caused many mills to review how they can improve the way they dry wood of this species. An industrial trial was conducted to determine if the implementation of sawmill pre-sorting could be used to effectively dry sub-alpine fir after it was pre-sorted in the woodlands. The results of the trial showed that the use of three sorts could effectively dry 90 percent of the sub-alpine fir. In addition, balancing the variability between moisture sorts will achieve matching final moisture content variability between the dry sort group and mid sort group. The work is beneficial for mills with a desire of an increased production of higher margin SPF lumber.

List of key words: Pre-Sorting, Softwood, SPF, Sub-Alpine Fir, Lodgepole Pine, Drying, Moisture Content, Capacitance

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INTRODUCTION

Since the beginning of the global financial crisis in 2008, US housing starts have been at record low levels (Figure 1). The resulting decrease in demand for dimension lumber had an adverse effect on its price. Poor market conditions have caused many mills to experience production curtailment, work share, and mill closures. In 2011, a report by the United Nations Economic Commission for Europe describes the complexity of the situation: "North American mills struggled with uneven consumption and sluggish housing starts. Cost pressures continued to keep mills from adding extra capacity, and scheduled curtailments were an ongoing feature in the market."

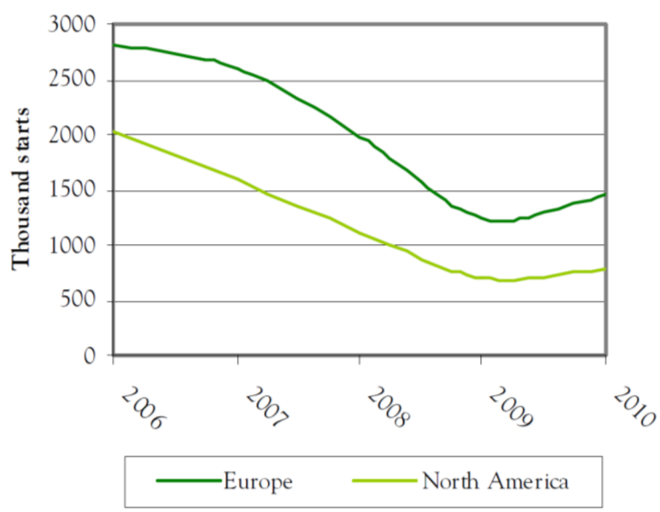

Figure 1. Housing starts in Europe and North America 2006-2010 (United Nations Economic Commission for Europe, 2011)

Existing mills have been analyzing drying operations in an effort to increase the value of their product. Drying operations are often overlooked when trying to increase the profitability of a mill - even though significant value can be lost or gained in drying operations. Quality control and process improvement practices in drying operations are not usually emphasized as much as other areas of mill operations. This is due to lack of understanding of the value that drying brings to the end product. SPF dimension lumber mills are now choosing to increase the quality of their drying operations in an effort to produce higher margin products.

This paper will conduct a literature review that assesses the value of drying lumber, outlines the drying properties of SPF species, and gives an overview of the SPF lumber industry's current pre-sorting strategies. An analysis of an industrial trial will also be performed. The trial will assess the benefits of pre-sorting sub-alpine fir in the sawmill after it has been pre-sorted in the woodlands. It will show how pre-sorting sub-alpine fir dimension lumber can decrease the amount of wet and over-dried lumber.

LITERATURE REVIEW – IMPORTANCE OF PRE-SORTING

VALUE OF DRYING

Customers are willing to pay a premium for kiln dried lumber. Through understanding the different properties of the lumber produced from SPF species, the drying process can be improved to be able to yield higher quality lumber. This section will discuss the importance of pre-sorting SPF dimension lumber during the drying process and how proper drying technique can increase the value of the final product.

Properties of SPF kiln dried lumber that customers value the most are as follows:

- **Minimum dimensional changes.** Wood shrinks and swells as it gains and loses moisture. If the wood is dried to moisture content that is equivalent to the equilibrium moisture content of the environment where it is used, changes in dimension will be imperceptible.
- **Reduced shipping costs.** Drying wood removes moisture and this reduces its weight. "Drying may reduce its weight by one-half or more" (Reeb, 1997). Since truck and rail freight costs are determined by weight, it is more profitable to transport dry wood.

- **Protected against decay or stain.** “Usually no fungal attack occurs when wood moisture content is 20% or less” (Bousquet, 2000). If wood is dried and kept dry it will have very low susceptibility to fungal attack in its use, storage, or transit.
- **Improved strength properties.** An increase in strength properties occurs as wood is dried below fiber saturation point. Dry wood has stiffness and strength properties that are almost double that of green wood (Wengert, 2006).
- **Better fastening.** Gluing requires proper moisture content for proper bonding to occur. Nails and screws hold better in dried wood (Gubu, et al., 2010).
- **Better finishing.** The adhesion of paints and finishes is best when wood is properly dried. “If MC of the wood exceeds 20 % when the wood is painted, the risk of blistering and peeling is increased” (Bousquet, 2000).

COST OF DEGRADE

Sub optimal mill drying operations can result in decreased profitability from over-drying or under-drying lumber. Lumber that is not dried to target specifications will reduce the profitability of the mill. Figure 2 shows how value loss changes as the average moisture content changes. As the average moisture content of a production run increases, the proportion of wets increases. Wet lumber is lumber that has a moisture content above 19%. As a result of the increased proportion of wets, the value lost due to the inability of the wet lumber to make grade increases.

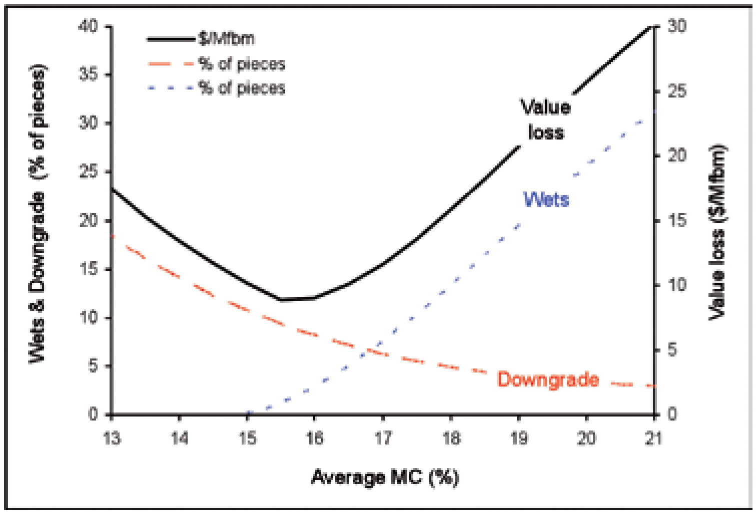

Figure 2. Value loss as a function of lumber average moisture content (Elustondo, et al., 2010)

Typically, mills will determine the percentage of wet and dry lumber they are willing to accept during the drying process. After setting the acceptance levels, they devise a strategy to achieve this goal. Often, mills will accept 5% of their lumber to be wet and 5% over-dried (Milota, et al., 2009). For a typical drying operation in conventional kilns, the target average moisture content is 15% - 16%. Once acceptance levels are determined, the mill can decide on how they can achieve their goal by analyzing where they can improve their drying operations.

OVER-DRYING

Over-drying can lead to degrade of the lumber by creating excess warp or shrinkage. Removal of moisture below the fibre saturation point causes dimensional shrinkage to occur in the width and thickness of the lumber. As the moisture content decreases, the thickness of the wood also decreases. This is an issue because it can cause lumber to shrink below target size or lead to excessive skip where planer knives do not make full contact with the lumber (Milota, et al., 2009).

Over-drying can also lead to different types of warp. Twist, crook, and bow become more pronounced as wood moisture content decrease (Denig, et al., 2000). Pith tends to shrink more than normal wood longitudinally (Wiedenbeck, et al., 1990). As the moisture content of lumber containing pith decreases, warp is more likely to occur. Reaction wood also causes longitudinal shrinkage; as more moisture is removed, stresses will develop that will cause the wood to warp (Simpso, 1991). The stresses are caused by differences in moisture content between the shell and core of the wood (Denig, et al., 2000). The low moisture content of the shell creates tension and the relatively higher moisture content core is in compression. Differences in wood cell microfibril angle can cause longitudinal shrinkage (Meylan, 1972). Spiral grain is another defect that will cause warp as moisture content decrease (Denig, et al., 2000). Warped lumber has limited value. As the severity of warp increases, the lumber's ability to make a higher grade decreases. Warped lumber also reduce productivity as they often cause planer jams (Milota, et al., 2009).

UNDER-DRYING

Lumber that fail to have moisture content below 19% after being dried will fail to make construction lumber grade requirements. This lumber has to be re-dried or downgraded to a lower grade. Re-drying increases handling costs and the increased handling increases the risk of damaging the lumber (Milota & Wu, 1997). Mills without the capabilities to re-dry their lumber are forced to downgrade or sell the lumber as wet lumber at a discounted price. Wet lumber has a trend of having a lower price in the market place compared to kiln dried lumber. An example of this trend can be seen in the comparison of Green and kiln dried Douglas fir in Figure 3.

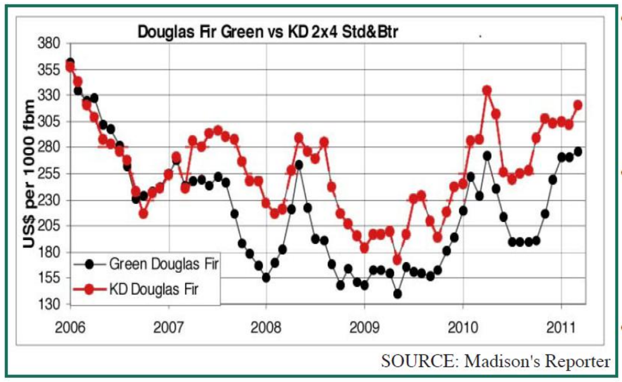

Figure 3. Value of green and KD Douglas fir (Heartwood & Kosman, 2011)

DIFFERENT DRYING PROPERTIES OF SPF

Spruce-Pine-Fir (SPF) lumber consists of multiple species of wood, including the spruce species black spruce (*Picea mariana)*, Engelmann spruce (*Picea engelmannii),* and red spruce (*Picea rubens)*; Pine species lodgepole pine (*Pinus contorta)* and jack pine (*Pinus banksiana)*; and Fir species balsam fir (*Abies balsamea)* and sub-alpine fir (*Abies lasiocarpa)* (USDA, 2010). These species grow in the same stands and are harvested together. Each species has its own set of drying properties that present certain opportunities and challenges during production.

If all three species start drying at the same initial moisture content with the same schedule, the spruce will dry faster and have a more uniform moisture content distribution than the pine due to its higher permeability (USDA, 2010). Fir will typically take two to three times as long to dry as a result of its low permeability and the presence of wet pockets (Garrahan, et al., 2008). The difference in the average drying rate of the three species can be seen in Figure 4.

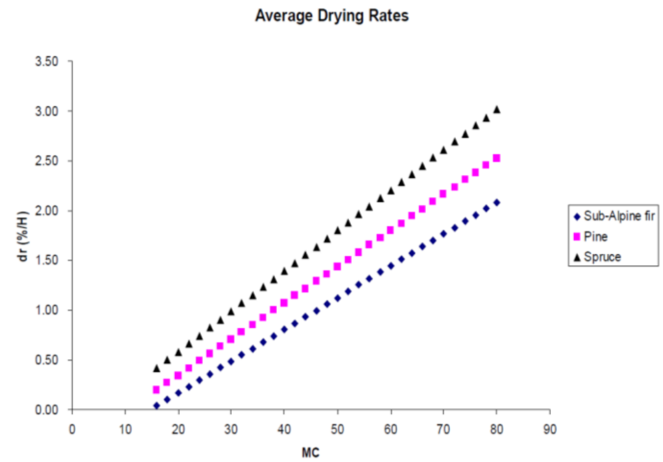

Figure 4. Average drying rate of spruce pine and fir (Oliveira, 2003)

SPRUCE

Harvested spruce usually contains highly variable initial moisture content between 50% - 60% and specific gravity between 0.280 - 0.425 (Garrahan, et al., 2008). When drying, spruce has a tendency to warp due to the presence of reaction wood, causing increased longitudinal shrinkage. Cupping can also be an issue due to the pronounced difference between tangential and radial shrinkage (Virta, et al., 2006). Drying spruce on a relatively aggressive schedule with a rapid temperature ramp-up and a high drying temperature can be performed with few issues (Garrahan, et al., 2008).

PINE

Pine logs come in a variety of sizes, however, most logs that are processed are in the small diameter class, and thus, the lumber produced will most likely contain pith. Pine lumber that contains pith is prone to twist (Wiedenbeck, et al., 1990). Pine will also have a higher degree of final moisture content variability when compared to spruce. Initial moisture content of a healthy pine tree can range between 40-140% and after a mountain pine beetle attack, the moisture content can drop to as low as 30% (Chow & Obermajer, 2007). Figure 5 shows the difference in moisture content of healthy lodgepole pine trees and mountain pine beetle attacked trees at different stages of the attack.

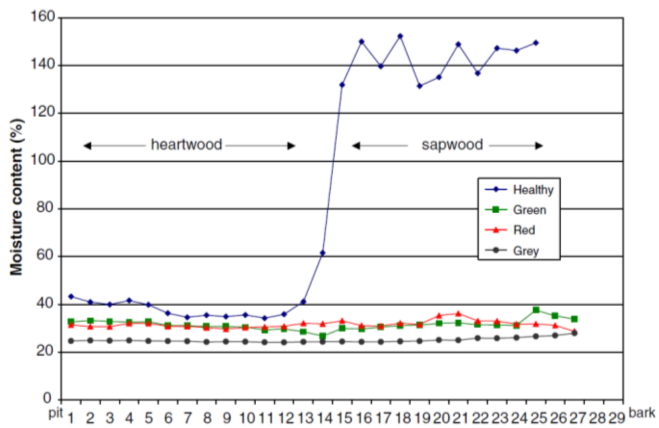

Figure 5. Moisture content of lodgepole pine as a function of distance from pith (Chow & Obermajer, 2007)

FIR

Sub-alpine fir is a difficult species to dry because it contains wet pockets and has a lower drying rate than spruce and pine (McFarling, et al., 2009). These wet pockets are areas that have a significantly higher moisture content than the wood surrounding it. Wet pockets are created by a bacterial infection in the living tree (Hadden & Hopper, 2004). The high moisture content and low permeability of wet pockets cause them to dry at a rate slower than the rest of the wood. High final moisture content variability is the dominant drying-related defect for this species, as “localized wet pockets can remain at 50 to 60% moisture content or higher even after extended drying cycles” (Garrahan, et al., 2008). Extended drying schedules may result in over-drying and warping of normal wood and high temperature drying conditions can cause collapse or internal checking.

CURRENT PRE-SORTING STRATEGIES

CURRENT PRE-SORTING IN THE WOODLANDS

A common problem that many mills face is a highly variable final moisture content distribution caused by mixing different species during the drying process in the mill. When spruce, pine, and sub-alpine fir are all dried together, the majority of the sub-alpine fir will not be able to reach moisture content below 19%. In order to force the fir (a slow drying species) below 19% moisture content, the duration of the charge has to be extended. Extending the charge causes the spruce and pine to over-dry. If over-drying is not desired, the sub-alpine fir will not be able to achieve moisture content below 19% without an extended schedule or a long equalization period. If the final moisture content distribution shows that the pine and spruce lumber are over-dried, and sub-alpine fir lumber are still wet, then the best solution is to start in the woodlands. By separating the sub-alpine fir in the woodlands, it can be processed and dried separately. If the sub-alpine fir can be separated from the other species, the mill will benefit from a more homogeneous drying mixture.

Sorting in the woodlands has a low capital cost, as it can be achieved using existing harvesting equipment. Once the desired species are separated, sawmills can carry out production runs of each species. This eliminates the need for increased bin requirements. The increased handling costs are the major deterrent for using this method to improve drying. Logs need to be sorted into multiple piles and then stored in the log yard into sometimes complex arrangements. An example of a dangle-head processor sorting logs in the woodlands can be seen in Figure 6. The logs are sorted as they are being de-limbed and bucked to length.

Figure 6. Harvester sorting species into piles in the woodlands

The higher proportion of sub-alpine fir that is processed by the mill, the more benefit will be seen from sorting it. Projections show that the proportion of sub-alpine fir can be increased to as much as 30% of the SPF mix for some mills (McFarling, et al., 2009). A Forintek study reported "up to a 30% increase in kiln productivity and 57% reduction in over-dried lumber resulting from implementation of species sorting at a mill with a 57:43 ratio of spruce to fir. Mills processing just pine and spruce will also benefit from species sorting but the gains are less since the two species have more similar drying characteristics" (Garrahan, et al., 2008). Mills that are processing larger volumes of sub-alpine fir are expected to adopt a woodlands pre-sorting strategy.

The preferred logging of lodgepole pine has resulted in the implementation of pre-sorting of wood infested by the mountain pine beetle (MPB). The advent of the MPB ravaging timber supplies has resulted in a cumulative total of 675 million cubic metres of affected lodgepole pine trees (Ministry of Forests, Lands and Natural Resources Operations, 2012). The moisture content of trees attacked by the MPB ranges from 25 - 40% (Chow & Obermajer, 2007). The mountain pine beetle also spreads blue stain fungus to the trees, which alters the drying properties of the logs by damaging pit membranes (Oliveira, et al., 2005). Figure 7 shows the higher diffusion coefficient of blue stain wood in comparison to normal wood (Oliveira, et al., 2005). The low moisture content and high diffusion coefficient of infested pine indicates that sorting these logs in the woodlands can be advantageous to mills.

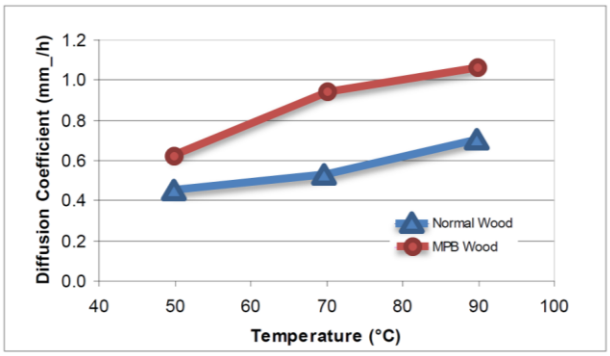

Figure 7. Difference in diffusion coefficient of normal wood compared to MPB wood at different temperatures (Oliveira, et al., 2005)

The benefit of sorting MPB logs in the bush is that it is possible to dry the lumber produced using a rapid heat treatment schedule. MPB logs often yield low grade lumber and a lengthy kiln charge would be costly. By minimizing the time and energy used to dry the lumber produced from these logs, the mill can increase its productivity and reduce the cost of processing them.

CURRENT PRE-SORTING IN THE SAWMILL

By pre-sorting in the sawmill, lumber can be categorized into homogeneous groups in order for the kilns to dry them efficiently and effectively. The benefits of the implementation of a sawmill pre-sorting system include improved grade outturn and energy savings (Warren & Johnson, 1997). Sorting can be optimized by selecting moisture sort set points that balance the variability between the sorts. By balancing the variability between sorts, similar variation in final moisture content can be expected in the planer mill. However, care should be taken to ensure that the volume of each sort is substantial enough to warrant a moisture sort.

Mills can select a variety of sorting technologies. The technologies sold by equipment manufacturers to sort lumber include infra-red technology, laser technology, weighing scales, electrical resistance, pH indicators, gamma rays, DC resistance, and capacitance sorting (Oliveira, 2003). Capacitance meters are widely used in sawmills to pre-sort green lumber. An example of a capacitance moisture sorter, manufactured by SCS Forest Products, can be seen in Figure 8. The meter scans each piece of lumber and measures dielectric properties that are related to the lumber's density and moisture content. It uses these measurements to determine the dryability of the wood on a scale of 0 to 100 (SCS Forest Products Inc., 2012). Near Infrared (NIR) technology can also be used to sort green lumber and even identify wet pockets in sub-alpine fir (Watanabe, et al., 2010). The benefit of NIR over widely used capacitance technology is it does not need to be corrected for wood density (Watanabe, et al., 2011).

Figure 8 Dielectric sawmill moisture meter (SCS Forest Products Inc., 2012)

The capital cost of pre-sorting equipment includes the cost of the moisture sorter and additional sorting bins. A study by Warren and Johnson (1997) showed that the capital cost of sorting equipment resulted in a payback of three months. Investing in pre-sorting equipment has proven to be profitable; large companies such as West Fraser and Canfor have implemented pre-sorting equipment in almost all of their BC mills.

SAWMILL PRE-SORTING TRIAL

BACKGROUND AND OBJECTIVE

A study was conducted at a SPF sawmill located in the northern interior of BC. The mill was interested in increasing the value of their sub-alpine fir by improving the quality of their drying operations. They had implemented a pre-sort strategy by sorting their sub-alpine fir in the woodlands and drying it separately from the spruce and pine. However this strategy alone was not able to give them the final moisture content distribution they desired. An industrial trial was conducted to determine if sawmill pre-sorting could reduce the final moisture content variability to a standard deviation of below 3% at a mean moisture content of 15% for 90% of the sub-alpine fir processed. Air dried lumber was deemed acceptable for further processing when less than 5% of the lumber is wet.

MATERIALS AND METHODS

Sawmill sorting was conducted using an NMI MC-Pro 1500 moisture density sorter. This capacitance moisture sorter comes with a software package that can create up to four moisture sorts; however, the mill only had available bin capacity to create three moisture sorts. A dry sort would be created to capture the lumber that would dry the fastest. A wet sort would be created to capture the lumber that would take the longest to dry, and mid sort would be created to capture the lumber in between the dry and wet sort.

A program was developed using Microsoft Visual Basic for Applications (VBA) and Excel to determine the setpoints for the three moisture sorts. The three sorts were calculated in VBA by balancing the variation of the dry sort and mid sort, while limiting the volume of the wet sort to below 10 % of the production. Figure 9 shows how the sawmill pre-sort histogram was divided into three moisture sorts.

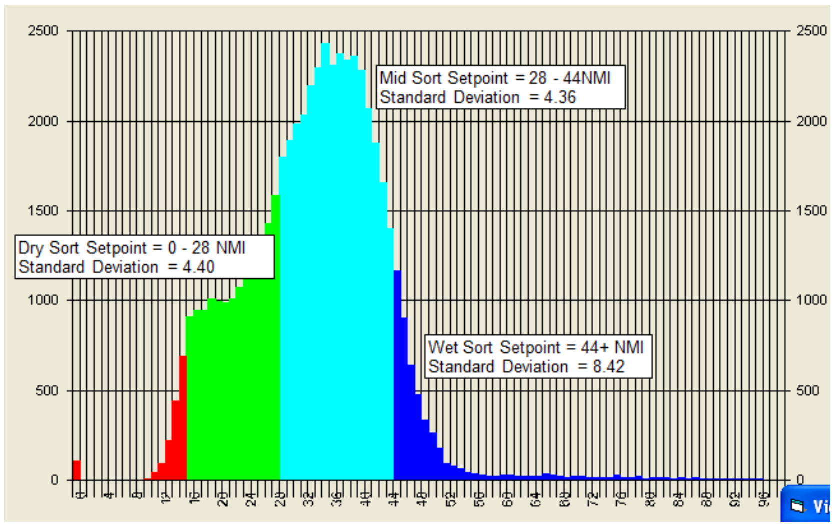

Figure 9. Sawmill NMI histogram with pre-sorting dry sort, mid sort, and wet sort setpoints

The setpoint calculator limits the wet sort volume to below 10% of production. This contains lumber that was predominantly associated with the presence of wet pockets and likely take the longest to dry. Although the wet sort is a small proportion volume of the run its variation is twice as high as the dry sort and mid sort. The high variation makes it a challenge to dry.

The setpoints for the remaining sorts were determined by balancing the variation of the dry sort and mid sort. Figure 10 shows the dry sort and mid sort setpoints were determined by balancing the standard deviation between the two sorts. By balancing the variation of the two sorts it was expected that the variation in the final moisture content would be similar. The dry sort accounted for 30% of the production volume and the mid sort, 60% of the production volume.

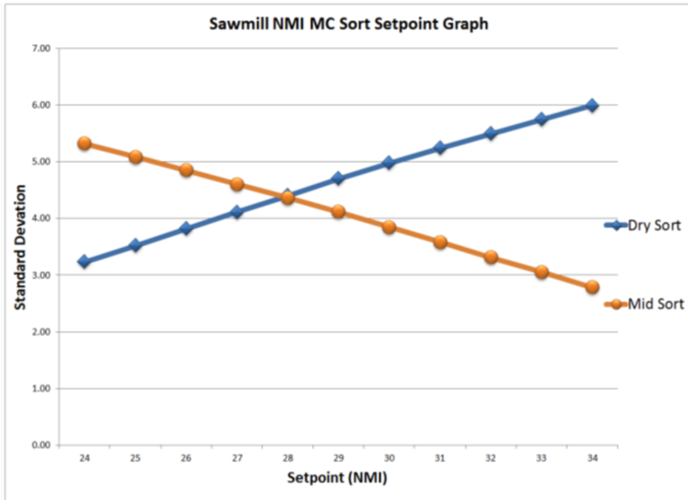

Figure 10. Sawmill dry sort/mid sort NMI pre-sort setpoint selection graph

Once the pre-sorting set points were determined, the lumber was kiln dried. The mid sort was kiln dried for a longer duration then the dry sort due to its higher moisture content. After each moisture sort had finished kiln drying the charge was placed in the air drying yard to equalize. Once the lumber had equalized it was planed and the final moisture content was measured using an inline moisture meter.

RESULTS AND DISCUSSION

The goal of this trail was to determine if pre-sorting in the sawmill would be able to achieve a standard deviation of below 3% and a mean moisture content of 15 percent by balancing the variability of the dry sort and mid sort. To assess the ability of the dry sort and mid sort to meet this goal, they were compared to a small sample of unsorted sub-alpine fir and historical sub-alpine fir moisture content measurements.

The moisture content of a total of 8,838 samples from the dry sort were measured after 43 days of air drying. The results showed that the dry sort was dried to an acceptable final moisture content with less than 5% of the lumber wet and less than 5% over-dried (Figure 12). The dry sort was able to achieve a standard deviation of below 3%and a mean moisture content of 15 percent in 43 days. In comparison, the moisture content of 231 unsorted sub-alpine fir was measured after 51 days of air drying. The results of the unsorted sub-alpine fir showed high variability and over half of the sample was wet (Figure 11). Historically, sub-alpine fir runs required an average air drying time of 90 days to reduce the proportion of wet wood to below 5%. By creating a dry sort, 30% of the production volume was able to be processed 54% faster than unsorted sub-alpine fir.

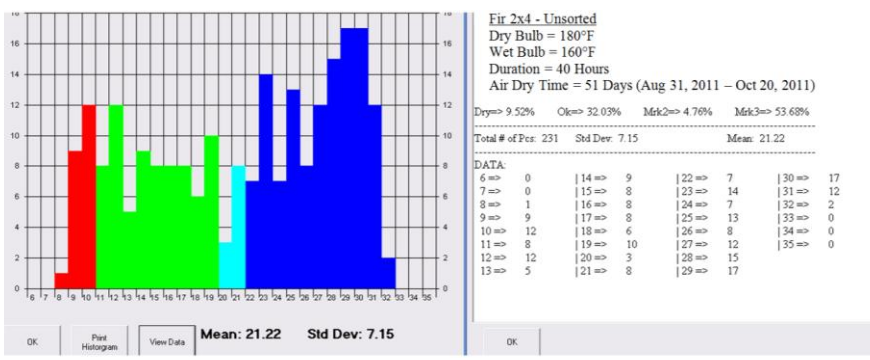

Figure 11. Unsorted sub-alpine fir (51 days of air drying)

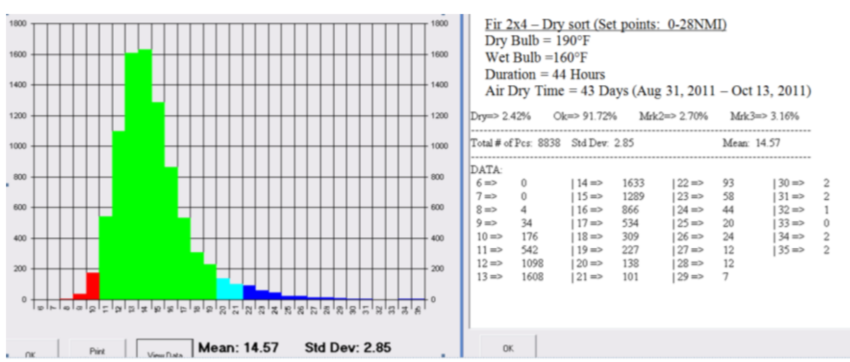

Figure 12. Dry sort sub-alpine fir (43 days of air drying)

The moisture content of a sample of 977 pieces of lumber from the mid sort was measured after 43 days of air drying (Figure 13). The mid sort still required additional air drying time as over 25% of the lumber was still wet after 43 days of air drying. The mid sort was measured again after 65 days. The results at this point in time showed that the 12,732 pieces of lumber sampled from the mid sort dried to acceptable levels (Figure 14). After 65 days of air drying, less than 5 % of the mid sort was wet and less than 5% was over-dried. The mid sort was able to achieve a standard deviation of below 3% and a mean moisture content of 15 percent in 65 days. The mid sort air dried 25% faster than historical unsorted sub-alpine fir production runs.

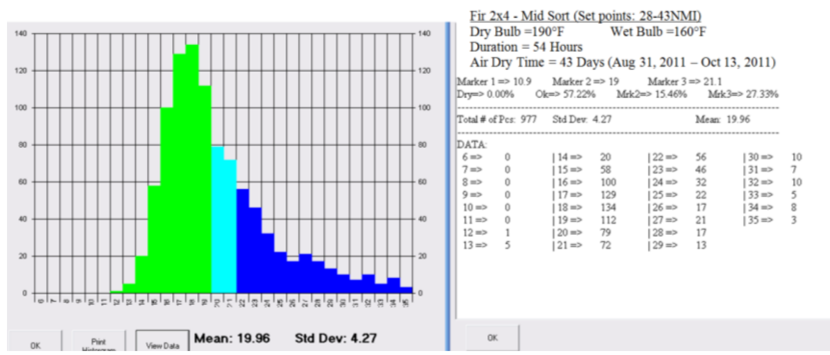

Figure 13. Mid sort sub-alpine fir (43 days of air drying)

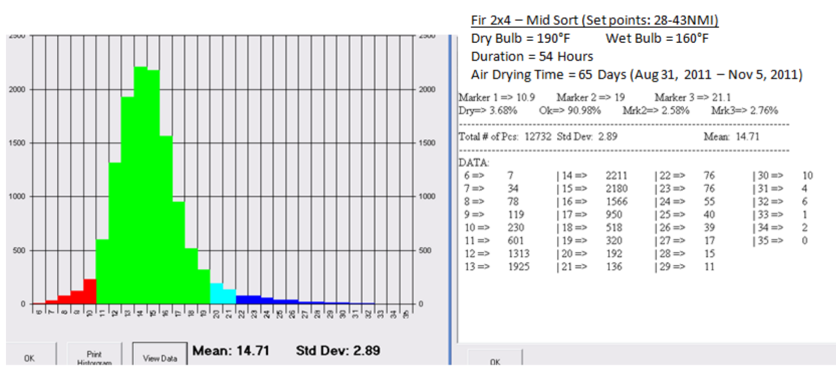

Figure 14. Mid sort sub-alpine fir (65 days of air drying)

Table 1 gives a summary of pre-sorting results. By matching the variability of the dry sort and the mid sort when pre-sorting, the variability in the final moisture content of the two sorts was matched. For the mid sort to achieve a final mean moisture content that was similar to that of the dry sort (Figure 12), the mid sort required an extra 10 hours of kiln drying and an extra 22 days of air drying (Figure 14). The wet sort was 10 percent of production and was not measured, as severe winter conditions hampered access to the air drying yard before it was dried to acceptable levels.

Table 1. Summary of pre-sorting results

Summary of Pre-Sorting Results

	NMI Setpoints	Pre-Sort Standard Deviation	Pre-Sort Volume (%)	Charge Duration (hours)	Total Air Drying Time (days)	Final Moisture Content Mean (%)	Final Standard Devation
Dry Sort	0-28.0	4.4	30.2	44	43	14.57	2.85
Mid Sort	28.1-44.0	4.36	60.7	54	65	14.71	2.89
Wet Sort	44.1-100	8.41	9.1	54	n/a		
Unsorted	0-100	9.86	n/a	40	51	21.22	7.15

CONCLUSIONS

The results of this trial showed that pre-sorting sub-alpine fir into three sorts in the sawmill after pre-sorting in the woodlands was able to increase the value of sub-alpine fir. 90 percent of the sub-alpine fir processed in a production run achieved a standard deviation of below 3% and a mean moisture content of 15 percent. By pre-sorting sub-alpine fir, SPF mills can reduce the amount of wet and over-dried lumber processed and quickly turnover air drying inventory.

By balancing the variability of the pre-sorted dry sort and mid sort, the final moisture content variability of each sort was also matched.

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