Analysis of Shear Damage to Southern Pine Lumber

by

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(ABSTRACT)

This study was conducted as a second part in the shear damage research project at Virginia Tech. The objectives were to verify the results obtained by Gallagher (1984) in the first study under normal mill operations as well as develop a method to compare and evaluate the extent of shear damage in relation to other defects present in southern pine lumber. This was accomplished through two sawmill studies and two kiln cart surveys performed in different geographic locations.

Visible indicators such as stump-pull that are used to determine shear damage extent are often misleading. Stump-pull, used as a scaling deduction for shear damage, does not fully determine the extent of shear damage present. Shatter is often present in greater amounts over the cross section of the butt of the log. The recommendation of six inches of butt trim that was determined to minimize value losses in the first study is supported by the results obtained in this research. A trim of six inches removed 94 to 99 percent of shear damage in this study.

Defects other than shear damage were present on dried and surfaced lumber. Drying checks and splits along with shake were often observed on the lumber ends. These defects often extend further up on the lumber ends, past the seven inch simulated trim. Shake was determined to be the limiting defect. Shatter, in the absence of shake, was determined to be limiting.

Kiln cart surveys conducted at mills that utilize a large percentage of sheared logs can be an inexpensive and effective tool to enable mill personnel to determine the extent of shear damage in relation to other defects present on lumber ends based on green trim already taken.

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I am indebted to my parents for all their love and support throughout my education. I also wish to thank all the friends I have made at Virginia Tech whose support and good humor helped me during my graduate work.

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Introduction

Shearing is now a common method of felling southern pine sawtimber. Shears are highly productive with common felling rates of two to three trees per minute. Bunching and directional felling permit the use of grapple skidders and gate delimbers. Shears also increase stand and stem utilization. Carrying stems vertically in a bunch reduces breakage of small stand components. Increased machine productivity has resulted in the lowering of minimum tree diameters harvested. Severance at groundline captures the material in the 5 to 12 inch stumps that are normally left by saw felling. Other benefits of shears are improved job safety and reduced site preparation and regeneration costs due to reduced stump heights.

Damage caused to the log at the point of shearing has long been recognized. Modifications in design to both the shear head and shear blades have been attempted to reduce damage.

Much of the research involving the impact of shear damage in sawmill operations has taken place on northern tree species, especially in areas where frozen wood is a problem. The results from these studies cannot be applied directly to southern yellow pine species, which are rarely harvested in a frozen condition. To evaluate the magnitude of lumber loss and develop strategies to minimize this loss, information was needed to determine the impacts of shear damage to southern pine sawlogs.

In 1983, a survey of field foresters and mill managers was conducted to determine the type and extent of damage and the magnitude of damage evident at the sawmill (Gallagher 1984). Phone interviews of nine additional southern pine sawmill managers were performed to gather further information on problems at their mill specifically due to shear damage and what measures they were taking to reduce this damage. Questions asked in these interviews are listed in Appendix A.

The mills surveyed all used tree-length or cut-to-length pine as their raw material. Their primary breakdown units consisted of Chip-N-Saws, although one mill was a combination bandmill and Chip-N-Saw. Production of the mills ranged from 150M bd.ft. to 200M bd.ft. per day[1], processing between 3,000 and 6,000 logs. The percentage of sheared logs in the mill's furnish ranged from 25 to 100 percent. The percentage of logs regarded as damaged at individual mills varied from no appreciable damage to 100 percent. Many mills observed all three forms of damage (shatter, splits, and stump-pull). Damage produced from shatter was of most concern to mill managers because it may only be obvious after drying. If shear damage was not removed, the lumber piece reached the grading table and would be trimmed two feet. Splits and stump-pull were considered less critical because, except in the most severe cases, they are usually removed at the slasher saw or green lumber trim saw. In Gallagher's 1983 survey, the occurrence of stump-pull was observed much more frequently than splitting or shatter damage. It was determined that shatter, inherent to the action of the shear blade, occurred on the majority of the sheared material but was not visible until after the drying process. Stump-pull however, was determined to be a function of operator skill and shear maintenance.

Several strategies for minimizing the effect of shear damage were found during the survey. Two of the more common practices include requiring extra trim allowance (in this case trim allowance ranged from 4 to 8 inches) to be removed at the green lumber trim saw, or removing a lily-pad at the log deck cut-off-saw. Mills included in the survey that received between 25 to 50 percent sheared material did not institute any special measures to reduce damage. Managers did state that

[1] 1 day = two 8-hour shifts

if shear damage is evident, most if not all, is removed on the green chain. If shear damage is observed at the planer mill, a two foot section is removed at the dry lumber trim saws.

All mill managers interviewed expressed concern about sheared logs on lumber quality. Even mills that did not use any operational measures to reduce shear damage expressed concern that it could be a potential problem at their mill.

The use of shears and their impact on lumber marketability has caused concern among purchasers of southern pine lumber and the forest industry itself. The Department of Forestry at Virginia Tech, in conjunction with members of the Industrial Forestry Operations Research Cooperative, has conducted two projects addressing the shear damage problem.

The first project, by Gallagher (1984), found that the damage caused by well-maintained, properly operated shears could be eliminated by a total of six inches of butt trim. Sawmills were experiencing additional damage because shears used by loggers were: 1) poorly maintained, 2) mounted on carriers with insufficient hydraulic capacity, and 3) operated using techniques which reduced felling time per tree but increased stump-pulls and barber chairs. From this, a shear maintenance videotape was produced and distributed to the industry and was widely accepted as a basis for several shear maintenance programs.

This second project, which is the basis of this thesis, was conducted in cooperation with two large southern pine sawmills who had implemented an extensive shear maintenance program for loggers supplying the mills. The first sawmill analysis was conducted in the lower Coastal Plain of North Carolina, the second in the upper Piedmont of Alabama.

The objectives of this study were to:

1. Determine if tree size and visible indicators of shearing damage such as stump-pull and splits could be used as predictors of the extent of lumber defect.

2. Determine recommended trim strategies to eliminate shear damage in lumber sawn from woods run logs in a normal mill environment.

3. Determine the extent of defects attributable to shearing versus defects caused by growth or drying related factors in dried and finished lumber.

4. Determine the feasibility of inspecting lumber ends on kiln carts after drying to assess the amount of shear damage incurred.

Literature Review

Types of Shears

There are basically three types of shears that are commonly used for harvesting trees. The two most common types are the scissor shear and directional felling shear (Conway 1981 and Johnston 1968). The third, less common type of shear is the guillotine shear, which utilizes one blade and falls trees parallel to the direction of travel.

The scissor shear is equipped with dual blades cutting into a tree from opposite sides and must be equipped with holding arms to allow control of the severed stem. Directional felling shears are equipped with a single blade that moves through the tree to a fixed anvil. Gallagher (1984) describes several advantages of both types. The major advantages of the scissor shear are:

- Shorter blades
- Faster cycle times
- Smaller hydraulic cylinders
- Effective on smaller timber (less than 20 inches diameter groundline)

The major advantages of directional shears are:

- Less complexity
- Machine design minimizes mechanical failures
- Effective on larger timber (greater than 20 inches diameter groundline)

Gallagher (1984) made comparisons to determine whether there were significant differences between damage from scissor and directional shears and the two shear types across diameter classes. He determined that scissor shears cause less damage than directional shears to trees below 17 inches in diameter. Directional shears caused less damage in the 18 to 20 inch class. The major premise was that cutting trees with butt diameters approaching the shear's rated limits created stress, resulting in increased damage.

Shear Force Requirements

Shear damage is a function of applied forces acting on the shear blade as it penetrates the tree. Kempe (1964) lists and defines three forces necessary to shear wood. They are:

1. Edge or actual cutting force
2. Separation or wedging force
3. Friction force

Edge, or cutting force, is defined as the force caused by the shear blade not being properly sharpened. In this case, when the blade is dull, fibers deflect or bend until rupture occurs. The duller the blade the more fibers will deflect before rupturing occurs.

Separation or wedging force is the force required for a triangle or a sharp edge to penetrate the wood. When the shear begins its cut the blades must separate wood fibers. The important factors are the edge angle and wedge angle.

Friction force is defined as the force caused by the friction between the wood and all surfaces of the blade except the edge.

Types of Shear Damage

There are three types of damage commonly caused by shears (Gallagher 1984):

1. Stump-pull or pullout - stump-pull occurs when the tree is lifted or felled before shearing is complete. Barber chair is a stump-pull that occurs along the edge of a tree, and is usually associated with a directional shear.
2. Splits - splits are failures and separation of wood fibers that are caused as the shear moves through the stem.
3. Shatter - shatter is the "broomstrawing" effect caused by compression forces acting on the wood fibers from above and below by the shear blade.

Offsets have also been defined as shear damage. Offsets occur when the blades on a scissor shear are misaligned or when the operator does not take the time to close the shears completely. This is usually caused by wear in the pins and bushings on the shear felling head. Offsets alone cause relatively minor damage, but may increase the extent of splits and shatter.

Shear Damage Research

Shear damage is influenced by the following (Gallagher 1984):

1. Type of shear head
2. Shear condition
3. Hydraulic system and carrier condition
4. Operator ability
5. Tree characteristics

The degree of force or stress produced by the shear as it moves through the tree is dependent on the factors, or combination of factors, mentioned above.

Powell and Myhrman (1977) conducted a study with an Earls ParaShear[2] feller-buncher to test damage levels in lodgepole pine produced by this attachment. Field assessments of shear damage were made on trees cut in summer and winter. In both cases there was visible damage to butt ends, with damage depth averaging seven inches in summer and 15 inches in winter on all logs sampled. Results show that small diameter trees had no shatter damage, while 3.2 percent of the lumber produced from the larger trees required trimming. Lumber loss was 0.33 percent of the lumber yield from butt logs, and reduction in the lumber recovery factor was small. Low production rates and high maintenance costs were associated with this felling head. The butt ends of the logs felled with the parashear attachment had to be squared in the log yard before being processed into lumber.

Johnston (1968) found blade geometry, friction, cutting conditions, and wood characteristics as factors that influence force requirements for shearing wood. He found blade thickness to have the greatest effect on cutting force required. Increasing blade thickness increases cutting force. Both

[2] The ParaShear name is derived from the saddle-formed surfaces of parabolic sections which the shear blades make when cutting trees.

Johnston (1968) and Kempe (1964) found a 50 percent increase in force requirements when doubling blade thickness. Arola and Grimm (1973) found splitting damage and force requirements to decrease when decreasing blade thickness, however, thin shear blades have limited structural stability and ultimately may buckle under stress.

Increasing blade wedge angle also increases shear force requirements. Kempe (1964) found lower force required when cutting spruce with a 45 degree wedge angle versus a 60 degree angle. Arola (1971) also found differences in force requirements using different wedge angles. He concluded that significant differences existed when using different wedge angles but that wedge angle had no consistent effect on the magnitude of the shearing force. He also found that no consistent trend could be established between wedge angle and depth of splitting. In addition, double wedge angles exhibited little variation in force requirements when compared to single wedge angles.

Arola (1971) investigated the effect of taper on shear force and splitting damage. Two shear blades were tested. Each had a 30 degree wedge angle and were 1/2 inch thick. One blade was tapered positively by +3 degrees and the other negatively by -1 degree. Results showed no drastic changes in force requirements. Splitting damage however, was greater for positively tapered blades compared to untapered blades. Splitting was also slightly greater, contrary to expectations, for negatively tapered blades.

Kempe (1964) and Johnston (1968) estimated friction force to be 1/3 of the total energy required to cut rectangular spruce specimens. Arola (1971) coated blades with Teflon-S, a non-stick self-lubricating finish. He recorded a 30 percent reduction in shearing force. Grease was also tested by smearing it on the blade surface, but was removed during the initial stages of the cut, and showed no apparent effects in reducing shear force requirements.

The condition of the shear blade refers to the alignment and sharpness of the blades and to the degree of play in the pins and bushings (Gallagher 1984). Careful maintenance of the shear blades can reduce damage, especially offsets that occur from a misaligned blade and splits occurring from a dull blade.

Operator ability is known to be a cause of shear damage. Folkema (1984) noted that many operators were bending trees in order to keep the kerf open to prevent the cutter from binding. The method the operator uses to keep the kerf open, and how the load is applied to the open kerf, will determine the direction of splitting. Many machines have a sidetilt feature for aligning the shear on the tree, but operators sometimes neglect to use it because of the extra time involved to position the head. Damage can also be caused if the operator does not allow enough time to complete the cut. If the operator stops shearing too soon, or stresses result from the positioning of the shear head on the tree, or the operator forces an excessive number of trees into the accumulator when bunching, damage may result (Gallagher 1984).

The physical properties of wood affect force and power requirements of shearing. Johnston and St-Laurent (1970) found that specific gravity and moisture content account for 56 to 64 percent of the variability of the required shearing force. Tree species of higher specific gravity require greater cutting force. Sapwood requires a higher cutting force than heartwood.

Directional felling shears exhibit higher force requirements than scissor shears. Cutting frozen wood requires a greater force than unfrozen wood. Consequently, shear damage for frozen wood is significantly higher than for unfrozen wood and splits tend to extend further up the log. Arola (1971) reported splits extending as far as two feet up the log when shearing frozen maple. Johnston and St-Laurent (1970) recommended shearing frozen wood below snow level since the wood temperature at that point is considerably higher and may result in less damage to the butt.

Economic Impacts of Shear Damage

Gallagher (1984) conducted a study to assess the losses from shear damage on lumber sawn from southern pine sawlogs. Two sawing studies were performed. The first study involved assessing alternate lengths on individual piece lumber trim as means of reducing grade loss. This method was considered analogous to green chain lumber trim. The second study involved removing a lily-pad of various lengths from the butt end of sheared logs. This process evaluated the feasibility of using log trim at mills that are equipped with merchandizers or slasher saws.

The study on individual piece trim involved sawing 96 logs into 2x4's, producing 955 sample pieces, 643 pieces from sheared logs. The sawing pattern maximized the number of 2x4's sawn from the butt cross section. Of these pieces, 312 were from chainsaw felled logs, 342 were from scissor sheared logs, and 301 were from logs felled with directional shears. Three size classes, 10-12, 14-16, and 18-20 inches diameter at groundline were used. The 2x4's sawn from each sample were randomly assigned a trim amount of 0, 2, 4, and 6 inches. The results from this study indicate one percent of the chainsaw material was damaged. This was attributed to growth stress or natural defects released during drying. Thirty-five percent of the sheared material contained some damage. Of the original 643 2x4's sawn from sheared logs, 377 met the minimum lumber dimension requirements for a full piece of lumber and were graded. The remainder of the pieces were not of sufficient length to be graded as a 2x4x8 piece. From the 377 pieces that were graded, 135 had damage sufficient to reduce grade. Of those 135 2x4's, 94 of them were graded three or better, and 82 of the 94 were reduced by at least one grade because of shear damage. Marginal value loss was minimized with a six inch trim. Table 1 shows the trade-off between shear damage, lumber recovery, and the value of residual chips (estimated per MBF).

Each end section was stained after grading. All samples were then evaluated for various dry trim lengths. A lumber trim of six inches returned 94 percent grade two or better. Gallagher concludes

Table 1. Dollar loss per MBF on individual piece trim (Gallagher 1984).

Green Lumber Trim	Value[1] Per MBF	Marginal Gain	Chip Value[1]	Marginal Chip Value	Marginal Lumber Value[2]	Total Gain
0″	143.92		0			
		+ 80.55		+ 1.40	-2.00	+ 79.95
2″	224.47		1.40			
		+ 9.80		+ 1.40	-2.00	+ 9.20
4″[3]	234.27		2.80			
		+ 10.17		+ 1.40	-2.00	+ 9.57
6″	244.81		4.20			
		+ .37		+ 1.40	-2.00	-.23
8″	244.81		5.60			

[1]Based on February 15, 1984 prices:
- $245/MBF for grade 1 and 2
- $195/MBF for grade 3
- $10/dry ton flake value for grade 4
- $25/green ton chip value

[2]This is an arbitrary value based on the loss of lumber due to taper. No previous studies have been found that put a value on this trim, but lumber value should be greater than chip value.

[3]"Normal" industry trim.

that for a mill which utilizes smaller diameter logs than those used in the study, a four inch trim may be sufficient to reduce shear damage to an acceptable level.

The second study, conducted using lily-pad trim, involved 90 logs which were sawn into 863 2x4's. Logs were separated by two diameter classes (14-16 and 18-20 inch butt diameter), by two shear types (directional and scissor), and by five trim classes (0, 2, 4, 6, and 8 inches). The results show that as trim lengths increase, there are corresponding decreases in the percent damaged between all classes. Table 2 shows the dollar loss in this study attributed to shear damage, along with the marginal loss or gain in lumber and chip value.

Gallagher found that to minimize losses, an eight inch trim was appropriate for the diameter distribution of the sample. He states however, that if smaller logs or a higher percentage of chainsaw material is common, 4 to 6 inches of trim may be sufficient to reduce damage.

Morris and Bunker (1982) conducted a pilot study in eastern Georgia to determine the magnitude of shear related damage and the potential economic impact of shear damage on lumber yield. In this study, 62 logs were inspected for butt damage. Fifty logs were sheared and 12 were felled with a chainsaw. The amount of butt damage was determined using the Bicycle-Wheel Method developed by FERIC (Guimier and McMorland 1981). Splitting damage was expressed as roundwood volume by determining the cross-sectional area containing splits in a two foot log section. Lumber recovery was then obtained by converting the roundwood volume to a board foot basis. The approach in this study was to take the difference between the average lumber value and the average value of shavings as the cost of damage. The assumption was made that damaged portions were removed just prior to grading and were reduced to the value of planer mill shavings. Diameter breast height distributions of the tree-length material ranged from 7.5 to 16.6 inches and average roundwood volume was 0.27 cords per stem. Data was analyzed to determine if a relationship existed between the level of damage and DBH.

Table 2. Dollar loss with lily-pad trim (Gallagher 1984).

Green Lumber Trim	Value[1] Per MBF	Marginal Gain	Chip Value[1]	Marginal Chip Value	Marginal Lumber Value[2]	Total Gain
0"	85.65		0			
		+102.93		+1.40	-2.00	+102.33
2"	188.58		1.40			
		+9.80		+1.40	-2.00	+9.20
4"[3]	234.27		2.80			
		-9.05		+1.40	-2.00	-9.65
6"	214.89[4]		4.20			
		+21.06		+1.40	-2.00	+20.46
8"	235.95		5.60			
		+3.16		+1.40	-2.00	+2.56
10"	239.11		7.00			
		+1.78		+1.40	-2.00	+1.18
12"	240.89		8.40			

[1]Based on February 15, 1984 prices:
$245/MBF for grade 1 and 2
$195/MBF for grade 3
$10/dry ton flake value for grade 4
$25/green ton chip value

[2]This is an arbitrary value based on the loss of lumber due to taper. No previous studies have been found that put a value on this trim, but lumber value should be greater than chip value.

[3]"Normal" industry trim.

[4]Deleting one log with excess damage increases this to $220.31.

The results showed the average percent area containing splits for chainsaw felled trees to be 2.42 percent, and for sheared trees 21.06 percent. For chainsawn material only one log in 12 showed any damage. No stump-pull was recorded for any of the chainsawn material. Forty-one of the 50 sheared logs exhibited splitting damage. The analysis showed that 90 percent of the sheared logs exhibiting damage did not contain splits extending further than six inches into the tree, excluding normal trim allowance. Overall roundwood damage was 1.38 percent for sheared trees compared to 0.12 percent for trees felled with a chainsaw. This was based on a 13.53 cord sheared sample, and a 3.46 cord chainsawn sample. On a board foot basis, lumber damage was estimated to be 6.04 percent for the sheared material and 0.7 percent for chainsawn material. There did not appear to be a strong relationship between damage level and DBH. Potential revenue loss was estimated at $11.25/MBF for sheared trees and $1.30/MBF for chainsawn trees. Loss carried back on a green volume basis indicated that felling with shears represent a potential loss of $4.22 per cord. Considering shear damage only, sales losses would be $9.45/MBF or $3.55/cord.

Folkema (1979) conducted a study of lumber losses due to shear damage in Ontario, Canada. One hundred and fifty butt logs averaging 16 feet in length were chosen for the study. All were shear felled. Logs were divided into three groups: unfrozen wood, slightly frozen wood, and severely frozen wood. Species mix included white spruce (90 percent) and jack pine (10 percent). Groups were also similar in diameter classes. Three different operators on three different machines felled the three groups of logs. Each shear was inspected for proper blade alignment and blade sharpness. Logs were sawn, and lumber was dried, planed, and graded with no end trim taken. Normal trim (that taken for wane and butt rot) and shear trim were compared. Normal trim accounted for two or three times as much trimming as shear trim across the three sample groups. Loss of value due to shear trim was calculated and was found to be $9.83/Mfbm for the unfrozen wood, $13.61/Mfbm for the slightly frozen wood, and $11.19/Mfbm for severely frozen wood. The lumber cut from frozen wood had slightly higher value loss than that cut from unfrozen wood. The results also indicated small differences in length of splitting between unfrozen and frozen wood. Although this was not expected, the author attributes it to operator variation.

Alternatives to Shear Felling

Hydraulically driven chainsaws, circle saws, felling discs, and augers have been developed as alternatives to shears for felling. Much of the experimentation on alternatives has been done in Canada because many Canadian mills are now refusing logs that have been shear felled due to the extensive damage. FERIC conducted a survey in 1976 to obtain industry's opinion regarding the need for saw felling attachments. The majority of respondents agreed that a reliable saw head attachment would be a desirable alternative to hydraulic shears.

Folkema (1979) investigated the performance of a chainsaw attachment for feller bunchers. This was accomplished with a Jonsereds saw felling head mounted on a Drott 40 feller buncher. Productivity for the chain saw attachment was 72 trees per productive machine hour (PMH)[3]. Average productivity of shears under the same conditions was 80 trees/PMH. The chainsaw head required frequent repairs and adjustments, which caused many operational delays. Eighty percent of repairs involved were for the chainsaw felling head. Saw bars were frequently damaged by the pinching action from the weight of the tree on the bar. In addition, the chainsaw attachment had electronic components making repairs difficult for operators. Operators developed a negative attitude towards the chainsaw attachment because of the necessity for frequent repairs.

Circular saw felling heads have become popular in Canada, especially when cutting frozen wood. Circular saws cause less damage than shears when cutting frozen wood, however, the main disadvantage is the 1 to 2 inch kerf that is removed when cutting the tree. The relative large size of the felling head compared with the shear felling head is also significant. Bjerklund (1983) stated the design criteria for alternate felling heads:

1. Reduce tree felling function costs to a level below that which is normal for blade shears

[3] Productive machine hours (PMH) is that time during which the machine is performing its primary function.

2. Minimize component wastage
3. Achieve operational versatility

Lumber Degrade in Southern Pine

Although shear damage can be a cause of lumber degrade, much of the degrade found in southern pine lumber is the result of the drying process. Drying is extremely important since it affects stability, strength, building quality, grip on nails, and insulating properties of wood (SPIB 1977). The fundamental cause of drying degrade is wood shrinkage, associated with growth related factors such as the amount of juvenile, compression, or pith wood present. Drying most often affects southern pine dimension lumber in the form of degrade due to splits, warp, and moisture content errors. If lumber shrinks too rapidly stresses build up which may ultimately cause drying defect (Wengert and Lamb 1983). Therefore southern pine must be dried at specific rates (schedules) to control shrinkage and its resultant stresses. See Appendix B for an overview on grading procedures.

Splits

Splits are defined as failures in wood fibers that occur in a radial direction. Splits caused exclusively by the drying process are usually limited to several inches at the ends of lumber, but may extend a foot or more in 8/4 or thicker material (Wengert and Lamb 1983). It is important to distinguish between a split caused by drying and a split caused by shearing. Splits inherent to drying occur in a radial direction along the ray cells. Any splitting evident which does not occur along ray cells has been caused by means other than drying, such as splitting caused by shatter. The pattern of splits caused by shearing on the resulting lumber is a function of the position of the shear blade as it moves through the tree.

Warp

Warp is the result of differential shrinkage of the wood during drying. It is affected by natural wood properties and the way the lumber is dried. Warp includes bow, crook, cup, and twist or any combination of these. In terms of severity of defect, crook and bow are the most serious type of warp with twist and cup the least serious. Some causal agents of warp are:

1. The presence of compression wood increases the likelihood of warp during drying.
2. The presence of juvenile wood increases the likelihood of warp during drying.
3. Lumber with the pith on the edge or face has an increased likelihood of warping.
4. Warp will be more severe on lumber with two or more of the above factors.
5. Warp becomes more severe as drying increases (moisture is lowered), thus overdrying increases warp.

Moisture Content

Proper control over moisture content in southern pine lumber is extremely important in controlling degrade. Variations in final moisture content leads to defect, warp being the most evident. Moisture content is expressed as the ratio of the weight of the water in the wood to the weight of the oven dry wood, where:

$$MC = [\text{wet weight/oven dry weight} - 1] \times 100 = \%$$

Warping caused by moisture content errors usually do not show up until several hours or days after manufacturing (Wengert and Lamb 1983). Moisture content may change as the lumber is exposed to the temperature and relative humidity of the environment. The lumber will then shrink and swell accordingly in an attempt to reach equilibrium moisture content.

Shake

Shake is a defect produced by outside stresses that may occur to a tree. These stresses can be caused by natural or mechanical means. Shake is characterized by the separation of annual growth rings. It is often evident in dried lumber, but the extent to which it occurs may be increased by either shearing or drying stress. Gallagher (1984) attempted to determine whether shear-induced shake damage occurred in a specific area of the tree. He observed that shake was commonly found in a transition zone in the annual growth rings, where the growth rate changed. No set pattern of shake damage could be observed using directional shears. In scissor-sheared material however, the study determined that shake generally occurred on the opposite side of the tree from the greatest shatter damage. It was concluded that as the shear closes, the squeezing effect of the shear on the tree results in shatter near the pivot point and shake on the outside, or away from the shear's pivot point.

Minimizing Lumber Degrade In The Sawmill Caused By Shearing

Sawmills receiving sheared logs use various operational measures in an attempt to minimize damage from shearing which causes lumber degrade. These measures vary according to mill layout and raw material furnish.

For mills accepting tree length material, "lily-pads" [4] may be cut from the butt end of each tree with the slasher saw on the cut-up-deck, removing all or most of the shear damaged material. The various costs incurred by this procedure are wear and tear on the slasher saw blade (assuming excess slasher saw capacity and no loss of production due to the lily-pad trim) as well as the cost of an additional cut to remove the lily-pad. Lily-pad trim will result in lumber volume loss since lumber recovery is "moved up" on each individual tree, and each log has a slightly smaller diameter then

[4] A "lily-pad" refers to a cross-sectional slice of wood sawn from the end of a log.

it would have without the lily-pad removal. Lower stump heights resulting from the use of shears however, often compensates for volume loss due to lily-pad removal. The stump heights resulting from chainsaw, directional shear, and scissor shear felling were measured by Gallagher (1984). He found the median chainsaw stump height to be five inches, while many shears cut at or slightly above ground line, resulting in a 0 to 5 inch gain in the butt log from shearing.

At mills that utilize cut-to-length logs, loggers may be required to trim the sheared end of the butt logs prior to loading, or add extra trim allowance to the butt logs of all shear felled trees to compensate for anticipated shear damage. A lily-pad may then be cut off each butt log to remove damage. This procedure requires the installation of a slasher saw on the infeed deck specifically for that purpose. An alternative procedure is to take lumber sawn from shear-felled butt logs (with extra trim allowance), and remove any damage present at the green lumber trim saws. This green lumber trim strategy is used extensively by mills that utilize cut-to-length logs, as well as many mills that utilize tree-length material.

After drying and planing, sheared-end lumber not trimmed at the green lumber trim saws would require a trim of two feet on the grading table if shear damage is evident. While this results in improved grade, it also causes excessive volume loss of processed and dried lumber.

The removal of a lily-pad (also sometimes referred to as a "wafer") may be done at the sawmill for reasons other than the removal of damage caused by shearing. Lily-pad trim may also be used to remove butt flare or swell (Figure 1). Excessive butt flare is often observed in shear felled logs because of the lower stump height resulting from shearing. Butt flare may have significant negative impacts on mill operations. Slab portions of flared ends may get stuck in the gang saw. Impact from flared ends on the infeed rolls may also increase the maintenance cost of the debarker and Chip-N-Saw headrig. It has also been observed that flared butts may decrease the speed and ultimately the production of the Chip-N-Saw, since the machine must pause to open (enlarge) the infeed rolls to accept a flared butt end. Some mills choose to run logs small end first in an attempt to eliminate this problem. Others believe this strategy results in a loss of lumber due to the log being angled (raised) as it passes through the scanner, which then measures a "pseudo" volume of wood, resulting in an incorrect sawing profile.

Figure 1. Log showing butt flare or swell.

Study Procedure

Two sawmill studies were conducted to meet the objectives of this research project. The first study was performed at Federal Paperboard Co. in the lower Coastal Plain of North Carolina and the second was performed at Bowater Lumber Co. in the upper Piedmont of Alabama.

Study procedures were divided into two phases, data collection and data analysis. The first phase (data collection) required two visits to each of the cooperating sawmills. The first visit involved obtaining the sheared log sample, making measurements and documenting log characteristics, and sawing the sample logs. A second visit was made after the resulting lumber sample had been dried, planed, and was ready for grading.

At Federal, each piece of lumber was measured and tallied, then placed on the grading table. The mill's lumber grader then graded each piece in the conventional manner. A professional grader from Timber Products Inspection, a commercial lumber grading service, then graded all pieces, observing the butt ends for damage. Grade, top, and butt trim were recorded for each piece. After grading, four foot butt end samples were removed from each piece. These four foot samples were gathered and taken to Virginia Tech for laboratory analysis.

At Bowater, the procedure varied slightly. Each piece of lumber was graded in the conventional manner. Grade, butt and top end trim, and dimension were tallied. Each piece was then trimmed two feet on the butt end. These two foot sample sections were also taken to Virginia Tech for laboratory analysis.

The second phase (data analysis), performed at Virginia Tech, involved end staining of the butt ends of all the sample pieces of lumber captured at the two mills. To determine depth of shear damage, each piece was repetitively end trimmed by one inch sections until a total of seven inches were removed. Visual inspections were performed on each piece at each stage recording the type and amount of defect evident on each of the sample pieces.

Sawmill Study 1 - Federal Paperboard Co.

Log Sample

A sample of 125 shear felled tree-length stems was chosen from the log inventory based on size and visible indicators of shearing quality. Log samples were selected with the cooperation of the mill scaler. Four sample groups were identified and defined as follows:

- Small acceptable sheared logs
- Small unacceptable sheared logs
- Large acceptable sheared logs
- Large unacceptable sheared logs

The logs were placed into the acceptable/unacceptable groups identified by the log scaling criteria used in the millyard. Stump-pull was used to determine acceptable and unacceptable shear damage as a visible indicator of shearing quality. It was the mill's policy to make scaling deductions for stump-pull that extends four inches or more either into or out of the butt log. Sample logs that did not require scaling deductions for stump-pull were considered acceptable, and those that required deductions were unacceptable (Figure 2). Visual inspection of butt sections for splits, stump-pull and visible shatter were also recorded for each log. Small and large logs were separated by diameter inside bark (dib) measurements at the large end as determined by the mill. For the log sample, 8.5 to 10.5 inches dib at the butt end were considered small logs, and logs measuring over 10.5 inches dib were considered large logs.

A stratified random sampling procedure was attempted. The study plan called for an equal number of logs placed in each of the four sample groups. Table 3 shows the number of logs actually placed in each sample group. Small unacceptable sheared logs were difficult to locate. A large percentage of the smaller material had little or no visible damage. Because of this, equal sample sizes between the four groups could not be obtained. Federal woodlands personnel explained that the major reason for the lack of small unacceptable material was a recently adopted shear maintenance program with their contract loggers. This program was enhanced by a shear maintenance videotape produced at Virginia Tech (Shaffer 1985). Since only a few small unacceptable shear damaged logs were available, the mill manager requested a greater number of large unacceptable logs be placed in the sample to compensate for this.

Logs chosen for the study were removed from the log inventory and transported to a designated area for measurement.

Taper measurements were then performed on each stem. All diameter measurements were taken to the tenth inch. These measurements included:

- Diameter inside bark (dib) at the large end of log.
- Diameter outside bark (dob) at 6 and 12 inches from the butt, and every one foot thereafter up to dbh.
- Diameter breast height (dbh) at 4.5 feet on the butt log.

Figure 2. Unacceptable log showing stump-pull extending from the butt.

Table 3. Separation of the logs into groups.

small acceptable (31)	small unacceptable (19)
large acceptable (31)	large unacceptable (44)

Sample size = 125
Total number of small logs = 50
Total number of large logs = 75
Total number of acceptable logs = 62
Total number of unacceptable logs = 63

- Diameter outside bark at 4 foot intervals along the remainder of the stem.
- Diameter outside bark at the small end of stem.
- Maximum sweep.
- Distance from the butt to the first visible green knot.

Measurements were taken to accurately profile taper and any butt swell that might occur in the logs. These measurements were necessary to estimate volume loss associated with various trim strategies used to remove shear damage.

The butt ends of the tree-length material were then bucked into 16 foot, 9 inch sample logs to match the average log length sawn at the mill. Top ends, not needed in the sawing study, were removed to the log deck and processed into lumber. The logs were then color-coded with paint on the butt ends by damage group. The small end of all logs were marked with black paint so lumber manufactured from the sample logs could be be identified at the planer mill.

Log Breakdown

The sample logs were sawn at the end of a shift when all material had been cleared from the log deck and green chain. The study logs were debarked and directed through the Chip-N-Saw headrig using conventional sawing patterns. A tally of the lumber produced is shown in Table 4.

Sample lumber pieces were not trimmed on the butt (sheared) end. This trim was avoided by raising the fixed (zero) trim saw on the Hemco drop trimmer, which normally trims two inches off all pieces coming through the mill. Lumber was top end trimmed as needed, and the trimmed ends were re-marked with black paint so the pieces could be identified at the planer mill. The lumber produced from the four damage groups was then sorted, stacked and dried according to the mill's normal kiln schedule. This involved 22 to 28 hours drying time to an average 12 percent moisture content.

Table 4. Lumber produced from the log sample.

Nominal Dimension Thick(in.) x Width(in.)	Length(ft.) 8	10	12	14	16	Total Pieces	Volume bd. ft.
1x4	4	15	14	19	69	121	581
1x6	1	2	6	4	11	24	166
2x4	1	7	10	15	92	125	1245
2x6	0	13	15	41	161	230	3460
2x8	0	0	1	5	17	23	471
Total	6	37	46	84	350	523	5923

Planer Mill

By the time the sawn lumber reached the planer mill, it had been mixed with the normal mill run. Painted sample lumber, after going through the planer, was pulled off the grading table before it proceeded to the trim saws, avoiding any dry trim. The sample lumber was collected in this manner and stacked beside the grading table.

Butt ends of all sample pieces were then covered with two inch masking tape to simulate normal trim allowance at the green lumber trim saw. Any defects present within two inches from the butt end would not be seen due to the masking effect of the tape. The lumber was next placed on the grading table with all butt ends facing the same direction, away from the grader, to simulate actual mill grading conditions. The lumber was graded twice. First, a Timber Products Inspection grader graded each piece from the butt end, determining butt trim for each piece. At the same time, the mill's grader graded each piece from the top end as he would under normal operating conditions on the grading chain. He determined and recorded bottom-end trim, top-end trim, and grade of each piece.

Four foot sections were then cut from the butt end of the sample lumber pieces, collected and transported to Virginia Tech for further laboratory analysis.

End Staining

The four foot sections, once back at Virginia Tech, were stacked and separated into the four size and damage groups. One inch of trim was removed from the butt end of each sample piece with a bandsaw to remove the marking paint and create a clean surface for end staining. A penetrating stain[5] was applied to the end sections with a sponge applicator until absorption ceased. The stain was used to highlight the depth and severity of butt end defects found on the sample pieces.

Six repetitive one inch cross sections were then removed from each piece with the bandsaw, making a total of seven inches removed from each piece of lumber. As each successive one inch cross section was removed, the penetrating effect of the stain made any hidden defects in the wood become evident.

Sawmill Study 2 - Bowater Lumber Co.

The study conducted at this sawmill closely follows the procedure outlined previously. Only procedural changes will be discussed in the following section.

Log Sample

A sample of 103 shear felled tree-length stems were chosen for the study. The separation of logs by damage group is shown in Table 5. A stratified random sampling procedure was again attempted but the same problem of locating a sufficient sample of small acceptable shear felled logs from the log inventory also occurred at this mill. Again, an extensive shear maintenance program had recently been introduced to the contract loggers, which had reduced the amount of unacceptable material on the log yard.

At this mill, logs under 12 inches dib at the butt end were considered small logs, and logs 12 inches and over were considered large logs. Log scaling procedures at Bowater Lumber Company did not

[5] A black leather dye (50%) and isopropyl alcohol (50%) mixture by volume.

call for any deductions for shear damage. Therefore the same criteria used at Federal's mill to determine acceptable and unacceptable shear felled logs was applied.

Taper measurements were performed in the same fashion, however the tree-length stems were bucked to a length of 16 feet, 4 inches, standard length for this mill.

Log Breakdown

The sample logs were sawn by both a Chip-N-Saw headrig and a bandsaw headrig. Logs were sawn at the end of a shift when all material had been cleared on the log deck and green chain. Sixty-four logs were directed through the Chip-N-Saw and thirty-nine, primarily the larger logs, were sawn at the bandmill. Lumber tally is shown in Table 6. Green lumber trim that would normally occur to square the butt ends was avoided. Lumber was top end trimmed, and trimmed ends were remarked with black paint before they proceeded to the drop sorter. The lumber was then sorted and stacked along with the other lumber produced during the day's run. The lumber sample was dried according to the mill's normal kiln schedule which involved 22 to 28 hours drying time to an average 12 percent moisture content.

Planer Mill

After drying, the lumber sample was planed and graded with the appropriate end trim indicated. After grading, sample pieces were removed prior to any end trim. The lumber, after being removed from the grading table, was bundled and and placed outside the planer mill in a storage area.

Once the sample was collected, a tally of grade, butt and top end trim, and lumber dimension was made. Each sample piece of lumber was also assigned a corresponding number for identification

Table 5. Separation of the logs into groups.

small acceptable (25)	small unacceptable (7)
large acceptable (43)	large unacceptable (28)

Sample size = 103
Total number of small logs = 32
Total number of large logs = 71
Total number of acceptable logs = 68
Total number of unacceptable logs = 35

Table 6. Lumber produced from the log sample.

Nominal Dimension Thick(in.) x Width(in.)	Length(ft.) 8	10	12	14	16	Total Pieces	Volume bd. ft.
1x6	0	2	4	6	11	23	164
2x4	1	4	7	32	80	124	1246
2x6	3	17	30	38	146	234	3422
2x8	0	4	8	13	57	82	1636
2x10	0	0	0	4	9	13	334
Total	4	27	49	93	303	476	6802

during end staining. Two-foot butt end sections were then removed from each piece of lumber and transported to Virginia Tech for staining and analysis.

End Staining

At Virginia Tech, the lumber sample was end stained and seven one inch increments were repetitively trimmed following the procedure outlined earlier.

Data Analysis

The first step in the data analysis involved visually inspecting each one inch segment to determine depth of damage produced from shearing, drying stress (splits and checks), growth stress (shake), or a combination of the above. Drawings were made showing the location and type of defects observed on each sample piece.

The results from the visual inspections were tabulated. A series of figures were developed for each sawmill from the visual inspection of the lumber ends. The figures show the percentage of pieces with indicated defect that were visible on the lumber ends with varying trim amounts for each log group.

Descriptive statistics were then calculated to examine the type and amount of defect attributable to shear felling in relation to other defects present. Means and frequencies were calculated for each of the defects present for each group. The Duncan's Multiple Range Test was used to compare means across the sample groups to determine if visible indicators of shearing quality (i.e. stump-pull) can be used as a predictor of shear damage extent.

Kiln Cart Survey

Damage caused by shearing is only one type of defect evident after lumber is sawn and dried. Natural defects and drying defects such as shake and honeycombing also become apparent after drying.

To quantify these types of defects a kiln cart survey was performed at each sawmill. Kiln carts of selected lumber sizes were visually inspected for various end defects that become noticeable after the drying process. Defects were categorized on the basis of:

- no damage
- defects caused by shearing (shatter and stump-pull)
- natural defect
- drying defect

Guidelines to distinguish between damage caused by shearing, natural defects, and drying defects were made by visual inspections. Defects were identified by the following characteristics:

Damage by Shearing

When observing lumber on the kiln carts for shear damage, close examination of the end sections is crucial. On some pieces the damage will be quite obvious and clearly visible, however it is important to remember that dried lumber has already been trimmed on the green chain, thereby making it more difficult to see any damage that might exist.

Observing lumber that has been processed from sheared logs often provides a characteristic pattern of shattered wood fibers on the face of the piece produced from compression forces by the shear blade. This pattern is determined by the direction of blade penetration in relation to annual growth ring orientation. In other words, shatter can occur along the growth rings (ring shatter) or across the growth rings (radial shatter) depending on the shear blade position as it penetrates the tree. Both ring and radial shatter can, and often does, occur on the same piece of lumber.

When observing ring shatter the zone of fracture or wood fiber separation occurs almost entirely in earlywood cells. This could possibly be explained by the differences in cell wall thickness between earlywood and latewood. Earlywood typically has light colored thin cell walls while latewood has dark colored thick cell walls. Ring shatter also may typically jump growth rings. The path of ring shatter damage may be seen along several growth rings. It is differentiated from ring shake in the tree by:

1. Lack of resin along the zone of fiber separation.
2. Ragged and torn surfaces.
3. Lack of continuity along the growth rings where damage has occurred.

Radial shatter as was stated before cuts across growth rings. It can be differentiated from drying checks by:

1. Jagged pathway - may run in a radial direction, then along a ring then radially again.
2. Lack of true radial orientation - the line of travel if projected through to the pith would not intersect the pith.
3. Torn and dislocated fiber bundles.
4. Multiple fractures near the same location - radial shatter usually occurs in groups, where drying checks often occur singly.

Figure 3 shows shearing damage on the middle piece compared to drying check above and ring shake below.

Natural Defects

Natural defects are the result of inherent growth stresses in trees. Shake is a major defect caused by growth stress in trees. There are two forms of shake that may be seen on lumber ends after drying. They are:

1. ring shake
2. heart shake

Ring shakes seem to exhibit themselves much more frequently than heart shake. Ring shake, as the name implies, is characterized by separation of wood fibers along the rings of annual growth. When observing ring shake the separation will appear to occur at the zone where earlywood and latewood join. Actually, the separation occurs in the outer portion of latewood cells along the compound middle lamellae. In some instances a ring shake will jump an annual ring by following a radial path and continue on a neighboring ring. The appearance of a ring shake is characteristic of smooth surfaces where failure of fibers has occurred.

Heart shakes seem to be less common than ring shake. Heart shake extends across the growth rings in a radial direction from the pith. Heart shakes may also extend through the pith. Some confusion might arise when trying to distinguish between a heart shake and a drying check. The Southern Pine Inspection Bureau[6] distinguishes a heart shake from a drying check by the fact that a heart shake's greatest width is nearest the pith, whereas the greatest width of a drying check in a pith centered piece is farthest from the pith. Figure 4 shows ring shake in a lumber piece.

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[6] See paragraph 740, Shake, in the Southern Pine Inspection Bureau's *Grading Rules*.

Drying (Seasoning) Defects

Drying defects mainly occur in the form of checks and splits. These checks almost always follow ray cells. Therefore, when observing lumber for drying defects, look for separation of fibers that occur in a radial direction from the pith. Invariably, the separation of wood fibers along the rays will be clean and distinct.

There are two types of checks to look for. The first is a surface check, which occurs only on one surface of a piece. The second is a through check, which extends from one surface of a piece to the opposite or adjoining surface. Figure 5 shows a through split caused by drying stress.

Obvious defects caused by shearing were painted one color and natural and drying defects were painted with a different color. Pieces with no damage were left unpainted. A tally was recorded for each piece of lumber as to what type of defect was present. Percentages of defect caused by shearing were computed from the total kiln carts surveyed.

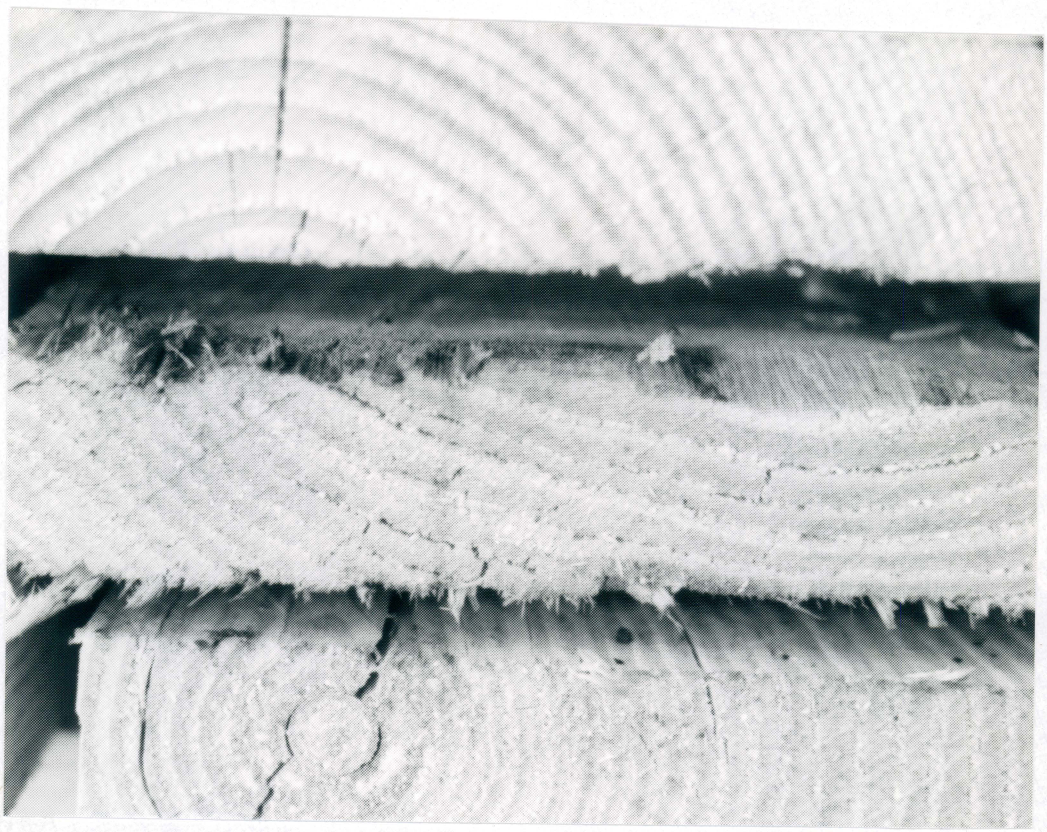

Figure 3. Lumber end showing shatter damage (middle piece).

Figure 4. Lumber end showing ring shake.

Figure 4. Lumber end showing ring shake.

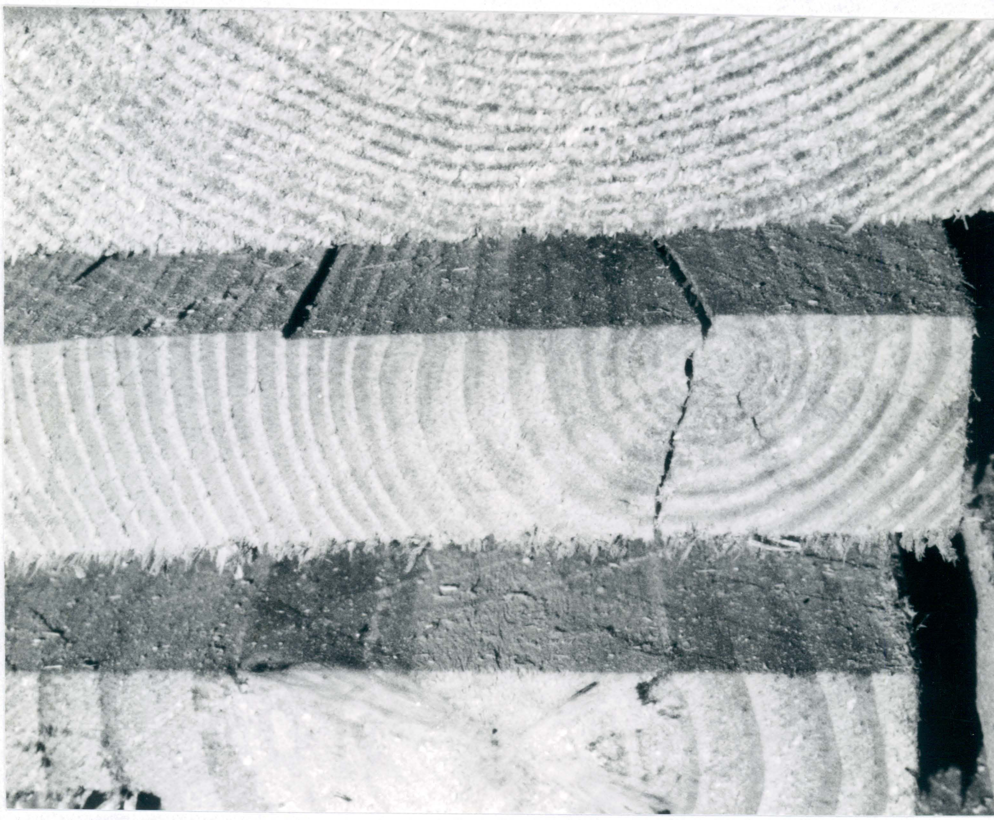

Figure 5. Lumber end showing drying split.

Results

The results of the analysis for each sawmill study will be discussed separately. The first section addresses the results obtained from the Federal study and the second discusses results obtained from the Bowater study.

The lumber sawn from the sample logs at both mills yielded 4/4 and 8/4 lumber. Discussion will be limited to 8/4 lumber since both mill managers agreed that shear damage complaints by lumber buyers are focused on the 8/4 lumber; very few complaints were associated with 4/4 material.

Federal Study

One hundred and twenty-five tree-length stems were obtained for this study. These logs were processed by the mill's conventional sawing schedule, maximizing lumber recovery. Table 7 shows the dimension lumber sawn from the sample logs, and lumber captured at the planer mill. Fifty-seven percent of the total pieces sawn were collected, including 78 percent of the 2x4's, 50 percent of the 2x6's, and 13 percent of the 2x8's. The remainder of the sample lumber was lost in the mill's normal production.

Table 7. Lumber recovery from the sample logs.

Lumber sawn from the sample logs

Nominal Dimension Thickness x Width	Length (feet)						
	8	10	12	14	16	Total	Bd.Ft.
2 x 4	1	7	10	15	92	125	1245
2 x 6	0	13	15	41	161	230	3460
2 x 8	0	0	1	5	17	23	471
Total	1	20	26	61	270	378	5176

Lumber captured at the planer mill

Nominal Dimension Thickness x Width	Length (feet)						
	8	10	12	14	16	Total	Bd.Ft.
2 x 4	0	6	0	9	83	98	976
2 x 6	0	0	0	31	83	114	1715
2 x 8	0	0	0	0	3	3	61
Total	0	5	0	39	174	215	2752

Separating the lumber by damage group: 57 pieces (26 percent) were from small acceptable logs, 32 pieces (15 percent) were from small unacceptable logs, 49 pieces (23 percent) were from large acceptable logs, and 77 pieces (36 percent) were from large unacceptable logs.

Table 8 shows the mean depth of shatter damage, along with the percent of pieces which showed damage for each log group. The mean depth of shatter was slightly greater in the small and large unacceptable groups compared to the small and large acceptable groups. The percent of pieces damaged ranged from 79 percent in the small acceptable class to 94 percent in the large unacceptable class. A large percentage of shatter damaged pieces was observed because the extent of this type of shear damage occurs across the whole surface of the butt log. Shatter was not isolated on the log surface. Damage occurred on 86 percent of the total number in the sample group with mean depth of damage of 4.0 inches.

Table 9 shows this information for stump-pull. Stump-pull comparisons of the large acceptable group with the large unacceptable group however, shows approximately a two inch difference in stump-pull depth, with the large unacceptable group having greater damage. A higher percent of damaged pieces occurred in the larger material, with the greatest damage occurring in the large unacceptable class. The unacceptable groups show a damage depth of four inches or greater because of the scaling parameters used to determine the acceptable and unacceptable groups outlined in the previous chapter. A smaller percentage of damaged pieces compared to shatter was evident because this damage occurs in the hinge area where the two shear blades meet. As a tree is sheared the operator may not wait long enough to complete the cut and the tree is pulled upward causing this damage. Stump-pull damage was isolated on the log surface and occurred in the hinge area. Damage occurred on 13 percent of the total number in the sample group with a mean depth of damage of 4.5 inches.

Table 10 shows shake damage which was relatively constant among the small log groups. In the large log groups, shake occurred one inch deeper in the unacceptable log group compared to the acceptable group. The extent of shake typically occurred at greater depths than the other defects present. Some of the shake damage extended past the seven inch trim taken. Shake may extend far up in the tree stem, further than shatter or stump-pull. This defect occurred on 19 percent of the total number in the sample group with a mean depth of damage of 6.6 inches.

Table 11 shows drying defect. The depth of drying defect in the form of checks and splits also remained constant across all four groups. Most of the drying defects were visible after the first two inches were removed from the end of the piece. Characteristically, drying defects often started as surface checks, became through splits, then tapered off as surface checks again. Drying defects were present to a mean depth of 5.9 inches on the lumber ends. Drying defects were not solely present just on the lumber ends. They can occur anywhere along the piece of lumber in the form of drying checks.

Duncan's Multiple Range Test ($\alpha = .05$) was used to compare the means of defect depth across the four groups to determine if significant differences existed between means. The results indicated that:

1. For shatter: the mean depth of the small unacceptable group is significantly greater than the mean depth of the other three groups.
2. For shake: the mean depth of the large unacceptable group is significantly greater than the mean depth of the small and large acceptable groups. The mean depth of the small unacceptable group is not significantly different from the other three groups.
3. For stump-pull: the mean depth of all three groups are not significantly different (small acceptable group was not included since no stump-pull was observed in this group).
4. For drying defects: the mean depth of all four groups are not significantly different.

The results from the Duncan's test indicate that stump-pull used to determine acceptable and unacceptable logs is not an adequate indicator of shear damage extent. Based on the results, stump-pull would not accurately determine the amount of shatter, shake, or drying defect present across the four groups. Stump-pull has no effect as to the amount of shatter, shake, or drying defect that are present on the lumber ends.

Table 8. Shatter depth and percent of damaged pieces by log group.

SHATTER

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	45	57	79	3.7
Small Unacceptable	27	32	84	4.6
Large Acceptable	41	49	84	3.8
Large Unacceptable	72	77	94	4.0
Totals	185	215	86	4.0

Table 9. Stump-pull depth and percent of damaged pieces by log group.

STUMP-PULL

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	0	57	0	0
Small Unacceptable	2	32	6	4.0
Large Acceptable	7	49	14	2.8
Large Unacceptable	20	77	26	5.1
Totals	29	215	13	4.5

Table 10. Shake depth and percent of damaged pieces by log group.

SHAKE

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	6	57	11	6.2
Small Unacceptable	8	32	25	6.6
Large Acceptable	12	49	24	6.1
Large Unacceptable	15	77	19	7.1
Totals	41	215	19	6.6

Table 11. Drying defect depth and percent damaged pieces by log group.

DRYING DEFECT

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	28	57	49	5.8
Small Unacceptable	12	32	38	6.3
Large Acceptable	18	49	37	6.1
Large Unacceptable	12	77	16	6.1
Totals	70	215	33	5.9

Figures were developed that show the percentage of pieces that exhibit damage by shatter, stump-pull, shake, and drying defect per trim class. Figure 6 shows this information for the small acceptable log class, Figure 7 shows the small unacceptable log class, Figure 8 shows the large acceptable log class, Figure 9 shows the large unacceptable log class, and Figure 10 shows combined data across all log classes.

Shatter across all four groups decreased substantially as trim amounts increased. At six inches of trim, 94 percent of the all pieces were free of shatter. The small unacceptable group had 81 percent of defect removed after six inches of trim. This is a substantially low figure compared with the other three groups, possibly because of the relatively small amount of lumber pieces in this group. Stump-pull is all but eliminated with six inches of trim except for the large unacceptable group in which 92 percent of the material was damage free. Ninety-seven percent of the pieces were free of stump-pull after six inches trim.

Shake and drying defects were reduced as the trim amount increased, however they still were present at greater depths than shear damage. Shake that was present on the ends often extended well up on the lumber piece, much further than the seven one inch increments taken. Drying splits and checks also were reduced with increased trim, and also may extend further than seven inches. Both these defects can also appear hidden within the lumber without being observed on both ends.

Seven inches of trim removed all of the shear damage (shatter and stump-pull); however some shake and drying defects were still present beyond this point.

Using Figure 10 on combined samples, the amount of damage or defect that is removed in a trim class can be determined. For example, at six inches of trim:

- 94 percent of the pieces were free of shatter.
- 97 percent of the pieces were free of stump-pull.
- 86 percent of the pieces were free of shake.

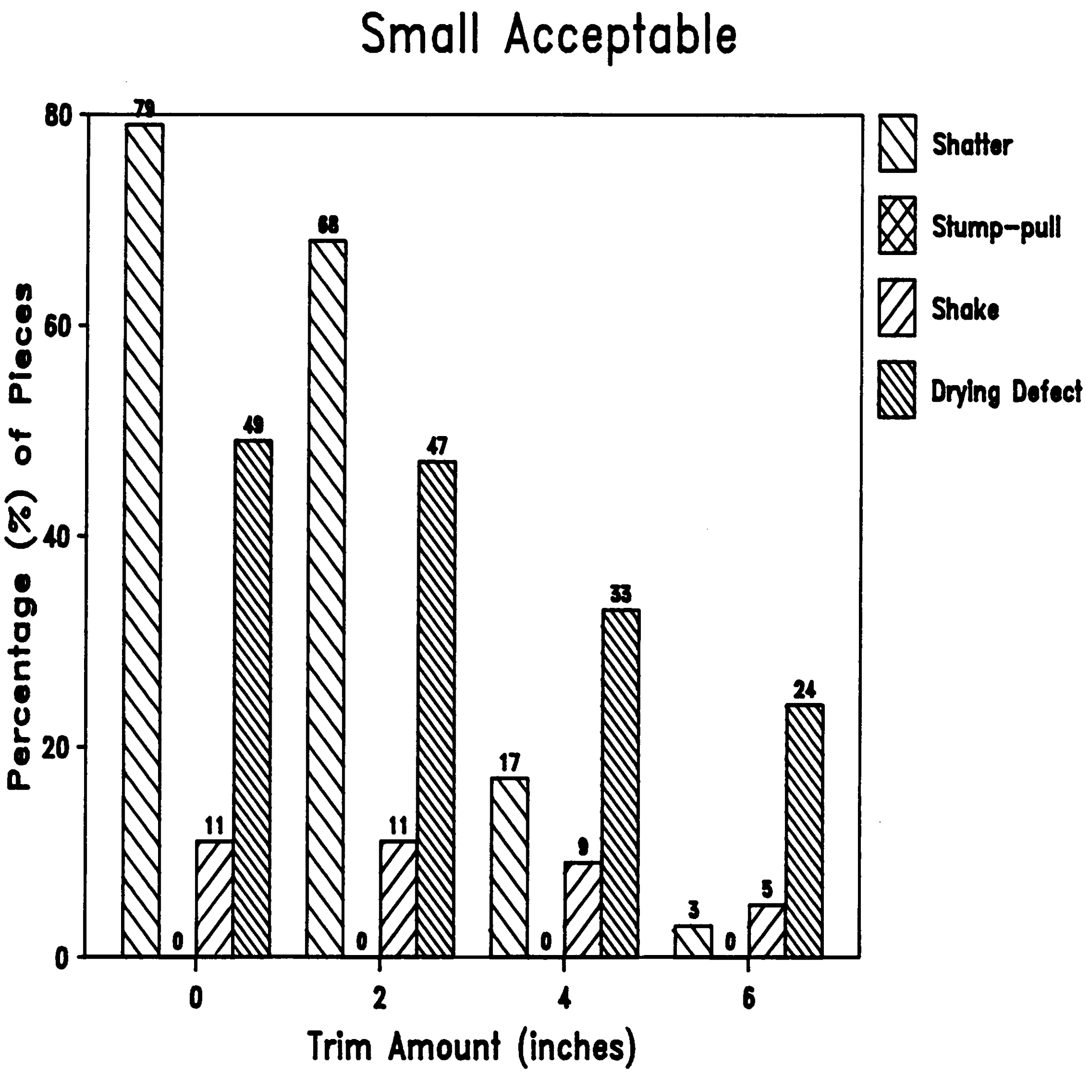

Figure 6. Percentage of pieces with indicated defects per trim class for the Small Acceptable Log Class (Federal Paperboard Co.).

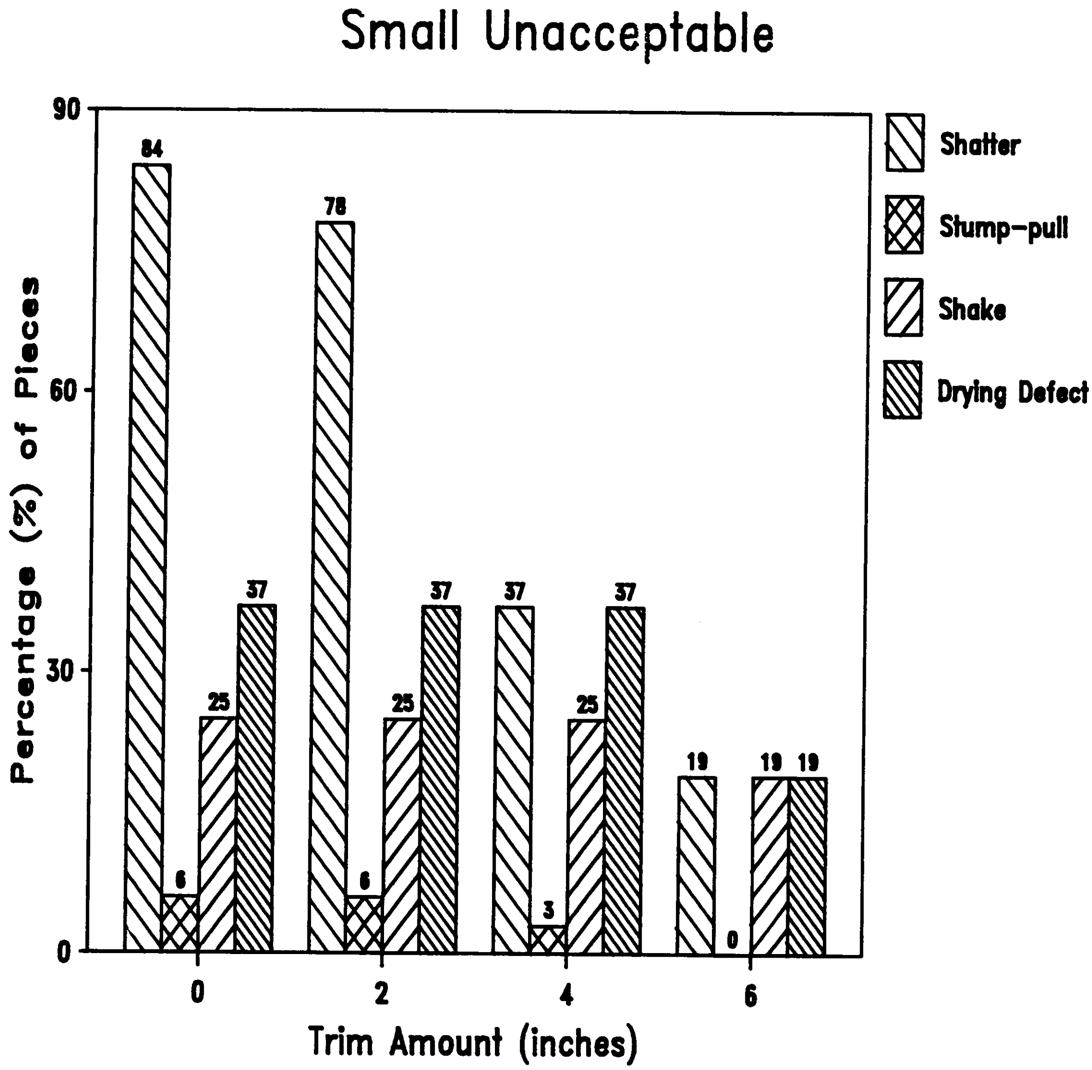

Figure 7. Percentage of pieces with indicated defects per trim class for the Small Unacceptable Log Class (Federal Paperboard Co.).

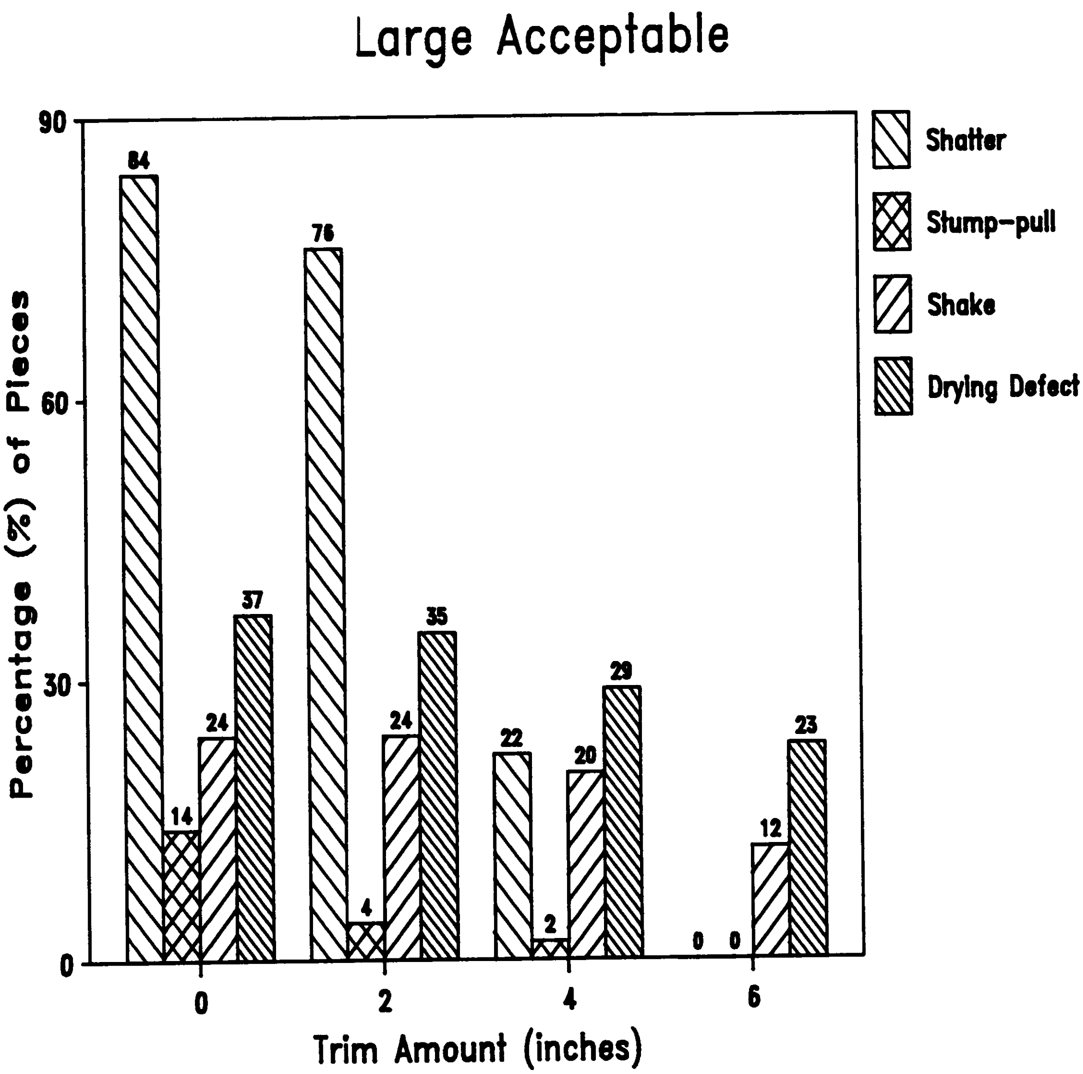

Figure 8. **Percentage of pieces with indicated defects per trim class for the Large Acceptable Log Class (Federal Paperboard Co.).**

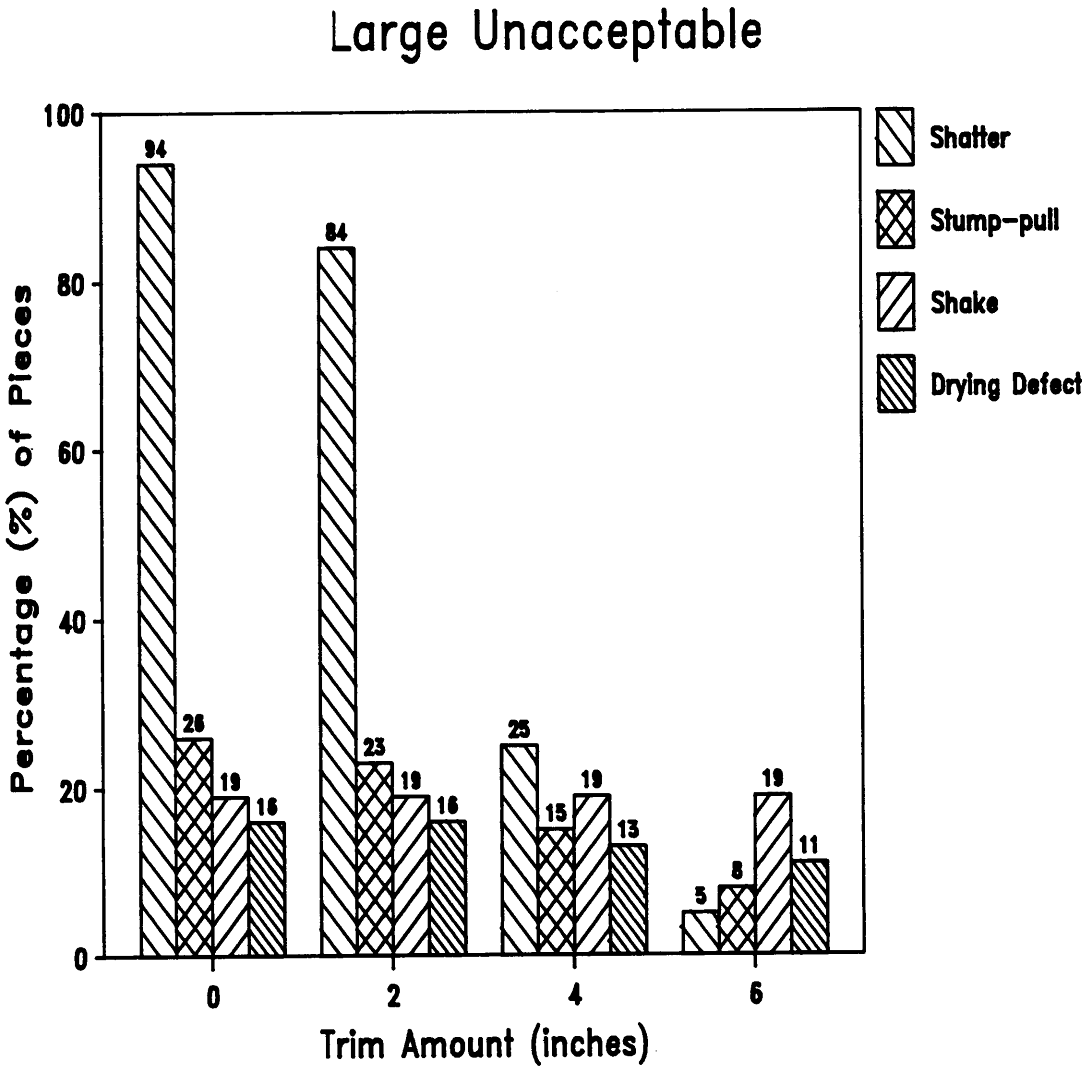

Figure 9. Percentage of pieces with indicated defects per trim class for the Large Unacceptable Log Class (Federal Paperboard Co.).

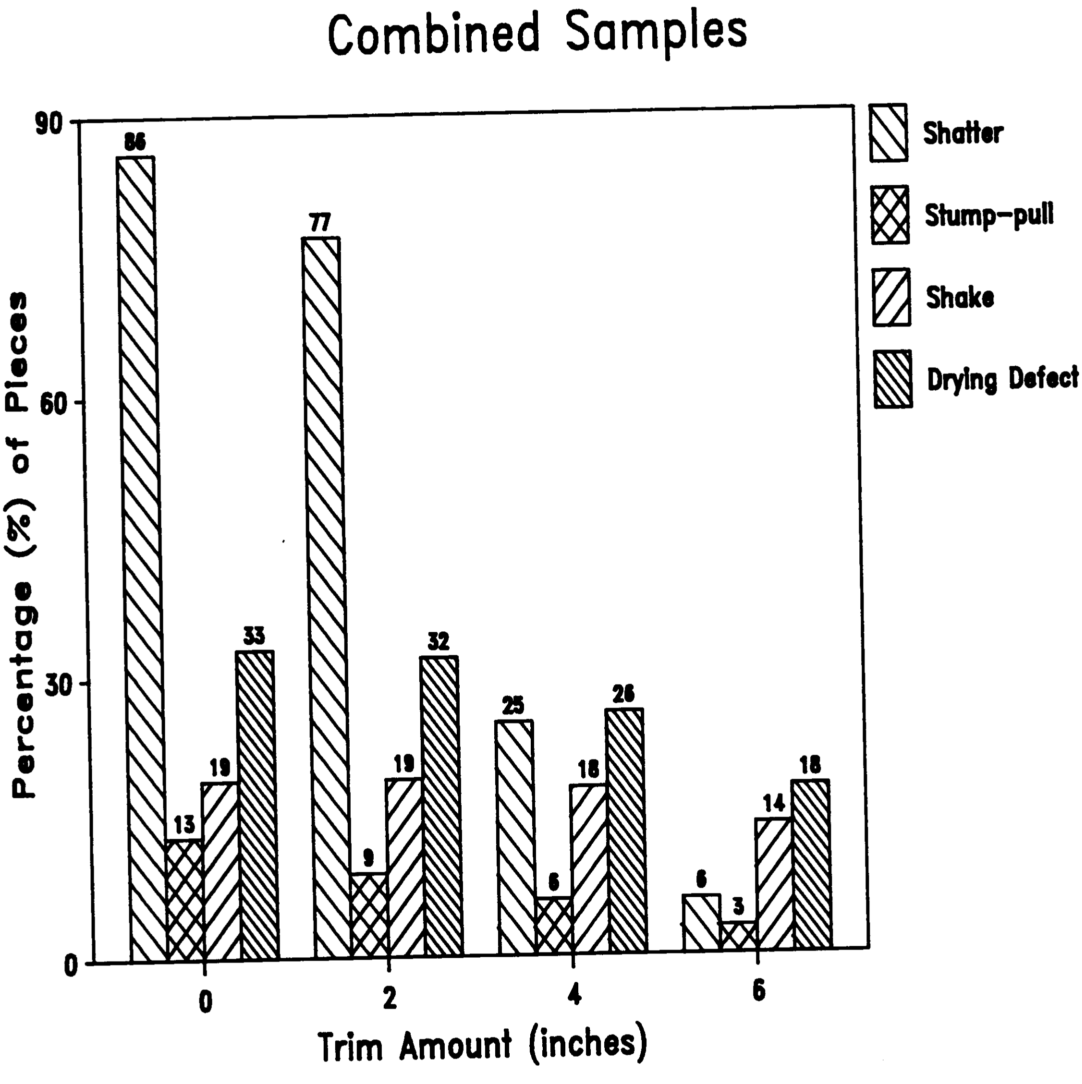

Figure 10. Percentage of pieces with indicated defects per trim class for the Combined Log Classes (Federal Paperboard Co.).

- 82 percent of the pieces were free of drying defect.

The amount of damage or defect that is evident on lumber ends given a certain trim class can also be determined for each representative size and acceptability group by these figures.

Listed in Appendix D are tables which show the effect of trim on the number and volume of damage free pieces for each of the defects observed (See Table 22, Table 23, Table 24, Table 25, and Table 26).

There were a total of 107 pieces (49 percent) from the sample of 215 that exhibited at least one of the grade reducing defects based on the shatter, stump-pull, shake, and drying defect criteria. This number does not reflect grade reductions based on other lumber defects that cause degrade such as warp (cup, bow, crook, and twist), moisture content errors, or wane. Grade reductions were made according to the SPIB grading rules for each of the end defects present. This total was also based on zero inch trim.

Fifty-six pieces (26 percent), with no end trimming had shatter extensive enough to cause grade reductions. Sixteen pieces (7 percent) had stump-pull that was grade reducing. Forty-three (20 percent) out of the 215 pieces in the sample showed shake damage that was grade reducing. Seventy pieces contained drying stress damage, and 16 of these (7 percent) contained through splits which would result in grade reductions. Table 12 shows the number and volume of pieces that met grade after trim is taken.

Table 13 points out that shatter limits through the three inch category, roughly equivalent to the total green chain and drying trim used by the mill. One additional inch of trim would increase the percentage of material meeting grade by roughly four percent. After the three inch trim category, shake becomes the limiting defect.

There were 72 pieces that contained shatter and stump-pull causing lumber degrade. Eighteen of these 72 pieces had grade trim (cut-backs of 2, 4, 6, or 8 feet) for reasons other than shear damage.

Table 12. Number, percent, and volume of sample pieces that met grade per trim class.

Trim Amount	No. of Pieces Meeting Grade	% of Pieces Meeting Grade	Volume of Pieces Meeting Grade (bd. ft.)
	-------------------------Shatter-------------------------		
0	159	74	2163
1	159	74	2163
2	159	74	2163
3	159	74	2163
4	182	85	2394
5	193	90	2517
6	209	97	2741
7	215	100	2827
	-------------------------Shake-------------------------		
0	172	80	2235
1	172	80	2235
2	172	80	2235
3	172	80	2235
4	175	81	2274
5	177	82	2299
6	183	85	2374
7 or >	215	100	2827
	-----------------------Stump-Pull-----------------------		
0	199	93	2591
1	199	93	2591
2	199	93	2591
3	200	94	2602
4	201	94	2613
5	206	96	2685
6	209	97	2733
7	215	100	2827
	----------------------Drying Defect----------------------		
0	199	93	2612
1	199	93	2612
2	199	93	2612
3	199	93	2612
4	199	93	2612
5	199	93	2612
6	200	94	2622
7 or >	215	100	2827

Table 13. Limiting defect on lumber ends by trim class including amount and percent of volume of pieces that meet grade.

Trim Amount	Volume of Pieces Meeting Grade (bd. ft.)	% of Volume Meeting Grade	Limiting Defect
0	2163	77	Shatter
1	2163	77	Shatter
2	2163	77	Shatter
3	2163	77	Shatter
4	2274	80	Shake
5	2299	81	Shake
6	2374	84	Shake
7 or >	2827	100	Shake

This left 54 pieces of the sample of 215 that had grade reducing shear damage after other grade reducing defects had been removed.

Bowater Study

One hundred and three tree-length stems were obtained for this study. The logs were sawn in the conventional manner maximizing lumber recovery. Table 14 shows the dimension lumber sawn from the sample logs, as well as the lumber captured at the planer mill. Eighty-nine percent of the total pieces were recovered, (90 percent of the 2x4's, 88 percent of the 2x6's, 95 percent of the 2x8's, and 69 percent of the 2x10's). The remainder of the sample lumber was lost in the mill's normal production processes.

Separating the lumber by damage group: 75 (19 percent) were from small acceptable logs, 18 (4 percent) were from small unacceptable logs, 189 (47 percent) were from large acceptable logs, and 123 (30 percent) were from large unacceptable logs.

Table 15 shows the mean depth of damage and percent of damaged pieces for shatter observed on the lumber ends by log group. The mean depth of shatter was slightly greater in the small and large acceptable groups. There was no constant pattern between log group or log size. The range of shatter depth was 3.1 to 3.8 inches. The percent of damaged pieces was constant among the log groups. The small acceptable group was lower with 89 percent of pieces observed with shatter damage compared to the other groups. This group however, had only 18 pieces in the class, 16 of which were damaged by shatter. Totals in all four classes recorded 98 percent of pieces damaged with a mean depth into the lumber ends of 3.7 inches.

Table 16 shows the mean depth of damage and percent of damaged pieces for stump-pull. Stump-pull was observed at greater depths in the unacceptable groups again because of the log scaling deductions used in the study procedure. Smaller percentages of damaged pieces were present

Table 14. Lumber recovery from the sample logs.

Lumber sawn from the sample logs

Nominal Dimension Thickness x Width	Length (feet)					Total	Bd.Ft.
	8	10	12	14	16		
2 x 4	1	4	7	32	80	124	1246
2 x 6	3	17	30	38	146	234	3422
2 x 8	0	4	8	13	57	82	1636
2 x 10	0	0	0	4	9	13	334
Total	4	25	45	87	292	453	6638

Lumber captured at the planer mill

Nominal Dimension Thickness x Width	Length (feet)					Total	Bd.Ft.
	8	10	12	14	16		
2 x 4	0	0	1	31	80	112	1125
2 x 6	0	5	30	37	134	206	3012
2 x 8	0	1	6	13	58	78	1556
2 x 10	0	0	0	0	9	9	231
Total	0	6	37	81	281	405	5924

because the damage takes place in the isolated area called the hinge. Total stump-pull damage was recorded on nine percent of the lumber ends with a mean damage depth of 3.6 inches.

Table 17 shows the mean depth of damage and percent of damaged pieces for shake. Shake was present on 20 percent of the total lumber pieces with a mean damage depth of 6.3 inches.

Table 18 shows the mean depth of damage and percent of damaged pieces for drying defect on lumber ends by log group. Drying defect was present on 19 percent of the total lumber pieces with a mean damage depth of 5.7 inches.

Comparing these tables to the previous study, similar trends exist between defect and log group. Mean damage depths were similar between the two studies, as well as the percentage of damaged pieces.

The Duncan's Multiple Range Test ($\alpha = .05$) was again used to compare the means of defect penetration across the four groups to determine if significant differences existed between means. The results indicate that:

1. For shatter: the mean depths of the small and large acceptable groups are significantly greater than the mean depth for the small unacceptable group. The mean depth of the large unacceptable group is not significantly different from the other three groups.
2. For shake: the mean depth of all four groups are not significantly different.
3. For stump-pull: the mean depth of the large unacceptable group is significantly greater than the small and large acceptable groups. The small unacceptable group is not significantly different from the other three groups.
4. For drying defects: the mean depth of all four groups are not significantly different.

The Duncan's test for this study again does not support the hypothesis that stump-pull is a valid indicator of shearing quality and damage extent. This test also reaffirms that there is no pattern for visually determining the extent of damage by log size.

Table 15. Shatter depth and percent of damaged pieces by log group.

SHATTER

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	74	75	99	3.8
Small Unacceptable	16	18	89	3.1
Large Acceptable	187	189	99	3.8
Large Unacceptable	123	123	100	3.5
Totals	400	405	98	3.7

Table 16. Stump-pull depth and percent of damaged pieces by log group.

STUMP-PULL

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	7	75	9	2.3
Small Unacceptable	3	18	17	3.3
Large Acceptable	6	189	3	2.2
Large Unacceptable	19	123	15	4.6
Totals	35	405	9	3.6

Table 17. Shake depth and percent of damaged pieces by log group.

SHAKE

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	13	75	17	6.5
Small Unacceptable	4	18	22	6.0
Large Acceptable	42	189	22	6.2
Large Unacceptable	23	123	19	6.5
Totals	82	405	20	6.3

Table 18. Drying defect depth and percent of damaged pieces by log group.

DRYING DEFECT

Log Group	Number of Damaged Pieces	Total Number in Class	Damaged Pieces (%)	Mean Depth of Damage (inches)
Small Acceptable	16	75	21	6.1
Small Unacceptable	6	18	33	4.8
Large Acceptable	34	189	18	5.6
Large Unacceptable	19	123	15	5.8
Totals	75	405	19	5.7

Figures similar to that of the previous study were constructed to show the percentage of pieces that showed damage per trim class. Figure 11, Figure 12, Figure 13, Figure 14, Figure 15 illustrates this information for this sawmill study.

The same pattern was evident in that the amount of shear damage decreased with increasing trim amounts. The extent of shatter decreases substantially as subsequent trim amounts increase. At six inches trim 97 percent of the shatter is removed across the four log classes. Stump-pull is all but eliminated with six inches of trim with 99 percent of the pieces damage free.

Shake and drying defects showed similar patterns when compared to the previous study. They were present on 13 and 10 percent of the lumber ends after six inches of trim. Even with six inches of trim these defects still extended further up the lumber piece.

An additional one inch trim or seven inches total trim would remove 100 percent of shear damage while shake and drying defect would still be present.

These figures can again be used to determine the amount of defect removal by various trim amounts. Using Figure 15, six inches of trim results in the following:

- 97 percent of the lumber pieces were free of shatter.
- 99 percent of the lumber pieces were free of stump-pull.
- 87 percent of the lumber pieces were free of shake.
- 90 percent of the lumber pieces were free of drying defects.

Again, the amount of damage or defect that is evident on lumber ends given a certain trim class can be determined for each size and acceptability group by these figures.

Listed in Appendix E are tables which show the effect of trim on the number and volume of damage free pieces for each of the defects observed (See Table 27, Table 28, Table 29, Table 30, Table 31).

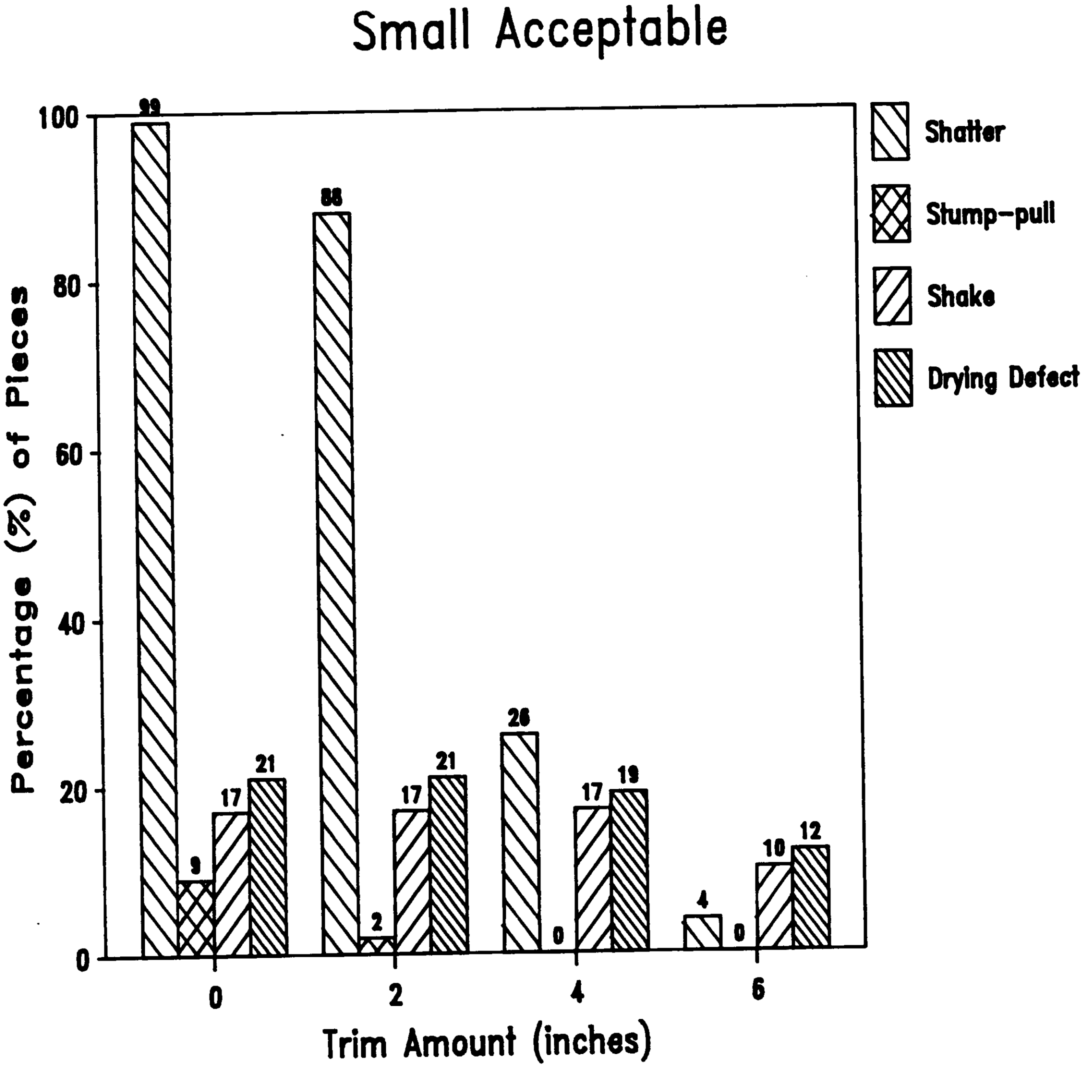

Figure 11. Percentage of pieces with indicated defects per trim class for the Small Acceptable Log Class (Bowater Lumber Co.).

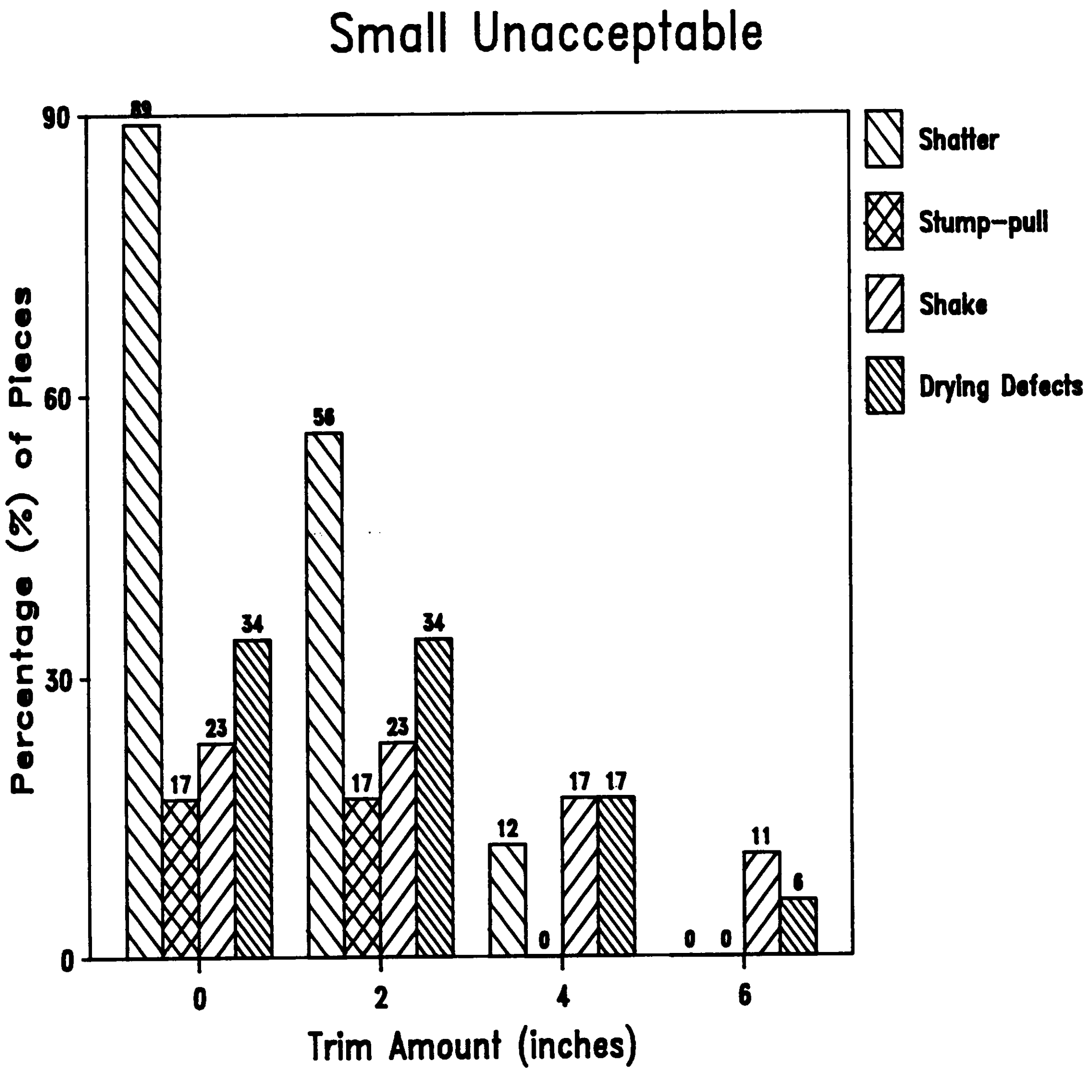

Figure 12. Percentage of pieces with indicated defects per trim class for the Small Unacceptable Log Class (Bowater Lumber Co.).

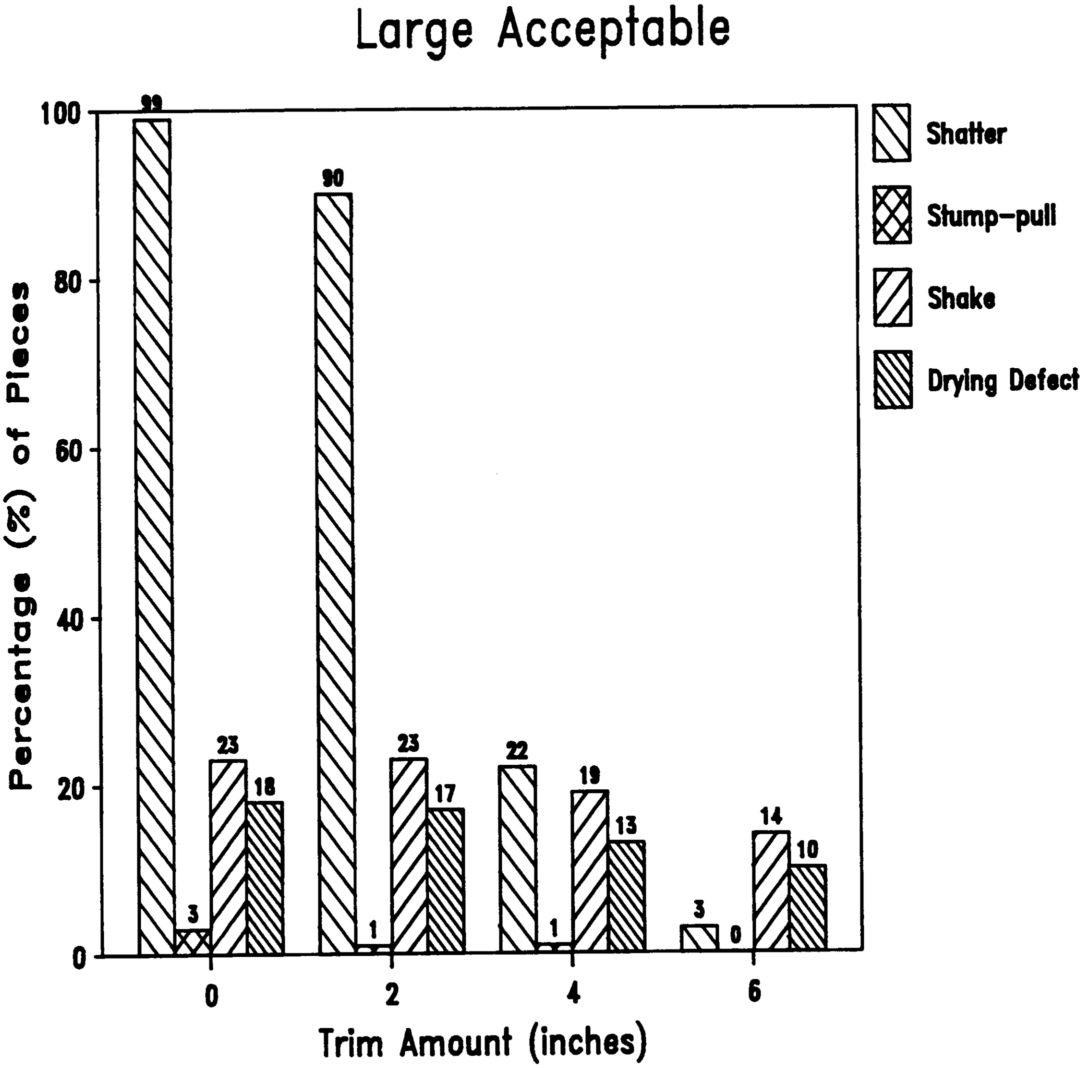

Figure 13. Percentage of pieces with indicated defects per trim class for the Large Acceptable Log Class (Bowater Lumber Co.).

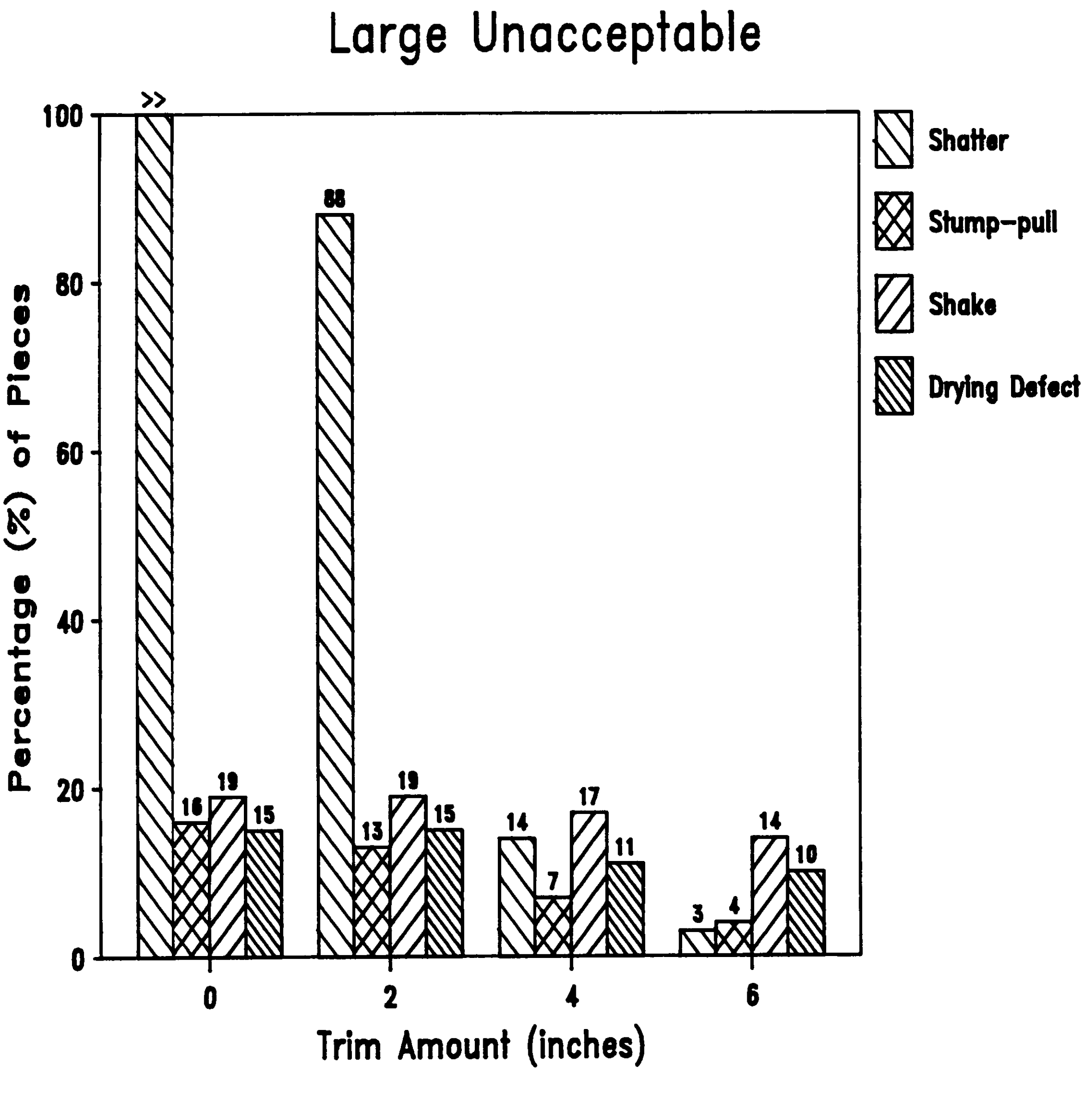

Figure 14. Percentage of pieces with indicated defects per trim class for the Large Unacceptable Log Class (Bowater Lumber Co.).

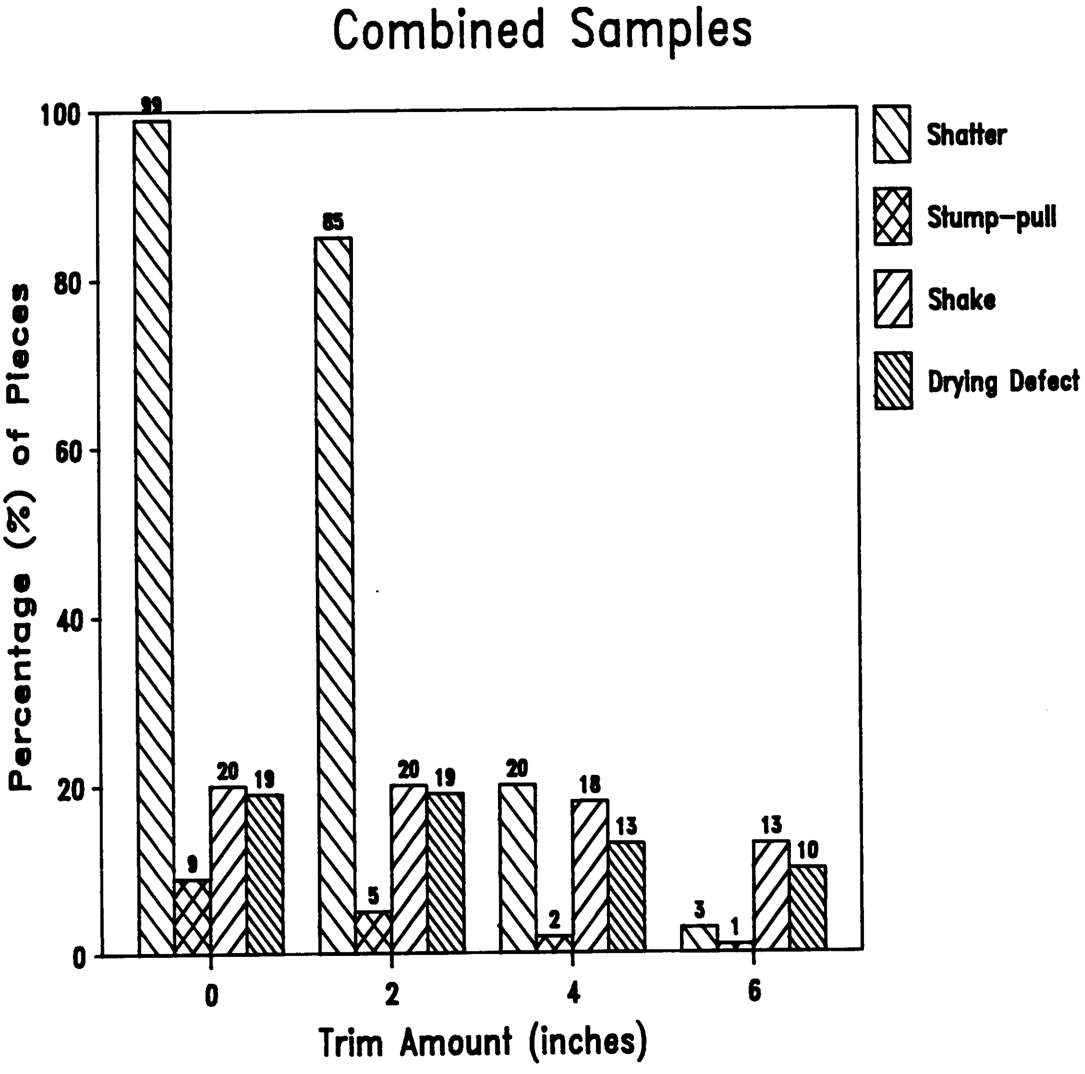

Figure 15. Percentage of pieces with indicated defects per trim class for the Combined Log Classes (Bowater Lumber Co.).

A total of 150 pieces (37 percent) from the sample of 405 exhibited grade reducing defects on the lumber ends (i.e. shatter, stump-pull, shake, and drying defect). Grade reductions were again based on the SPIB grading rules for each of the defects present. Other defects (warp, wane, moisture content errors) were not taken into consideration since only lumber ends were considered. Again this total is based on zero inch trim.

Sixty-one pieces or 15 percent had shatter extensive enough to cause grade reductions. Fifteen pieces or four percent had grade reducing stump-pull. Seventy-six total pieces (19 percent) were therefore affected by shear damage. Eighty-one of the 405 pieces (20 percent) in the sample showed shake damage severe enough to reduce grade. Seventeen (4 percent) had drying splits that were grade reducing. Table 19 shows the number, percent, and volume of pieces in the sample that met grade after a trim is taken to remove defects to an acceptable amount.

Table 20 points out that in none of the trim classes was shatter a limiting defect. Shake was the limiting defect for all trim classes.

As was shown previously, a total of 76 pieces had enough shear damage to be grade reducing. Twenty of the 73 pieces were grade trimmed for reasons other than shear damage. This left 56 pieces from the sample of 405 that had grade reducing shear damage after grade trim had taken place.

Kiln Cart Survey

This section discusses the results obtained from two kiln cart surveys performed at the same two sawmills referenced previously. Descriptions based on visual inspections were recorded for shear damage, drying defects, and shake or natural growth stresses. Table 21 shows the amount of shear damage, drying defect, shake that were present on the lumber ends.

Table 19. Number, percent, and volume of sample pieces that met grade per trim class.

Trim Amount	No. of Pieces Meeting Grade	% of Pieces Meeting Grade	Volume of Pieces Meeting Grade (bd. ft.)
	-------------------------Shatter-------------------------		
0	344	85	5387
1	344	85	5387
2	344	85	5387
3	344	85	5387
4	372	92	5675
5	388	96	5838
6	396	98	5939
7	405	100	6045
	-------------------------Shake-------------------------		
0	324	80	4861
1	324	80	4861
2	324	80	4861
3	324	80	4861
4	332	82	4974
5	338	84	5065
6	350	86	5231
7 or >	405	100	6045
	-----------------------Stump-Pull-----------------------		
0	390	96	5774
1	390	96	5774
2	390	96	5774
3	390	96	5774
4	396	98	5864
5	398	98	5901
6	400	99	5944
7	405	100	6045
	---------------------Drying Defect----------------------		
0	388	96	5779
1	388	96	5779
2	388	96	5779
3	388	96	5779
4	388	96	5779
5	388	96	5779
6	388	96	5779
7 or >	405	100	6045

Table 20. Limiting defect on lumber ends by trim class including amount and percent of volume of pieces that meet grade.

Trim Amount	Volume of Pieces Meeting Grade (bd. ft.)	% of Volume Meeting Grade	Limiting Defect
0	4861	80	Shake
1	4861	80	Shake
2	4861	80	Shake
3	4861	80	Shake
4	4974	82	Shake
5	5065	84	Shake
6	5231	86	Shake
7 or >	6045	100	Shake

The results between the two mills are similar. Shear damage was observed on the kiln carts at five and seven percent. Drying defect and shake resulted in the same percentages. There were a total of 6,942 pieces that were surveyed on the two carts. A total of 89 percent showed no damage, six percent was shear related, three percent was drying related, and two percent showed shake defect.

Comparing these figures in Table 21 to the previous sawmill studies show relatively low values for shear damage. This was due to the kiln carts containing lumber sawn from both butt as well as top logs. Lumber had already been trimmed on the green chain and would be trimmed again at the planer mill. Therefore, the shear damage percentages would be less than those presented in the table.

Table 21. Amount of defects present on the kiln carts after drying.

Federal Paperboard Co.					
Lumber Dimension	No Defect	Shear Damage	Drying Defect	Natural Defect	Total Pieces
	---- Number of Pieces ----				
2x4	985	26	20	9	1040
2x6	941	42	22	26	1031
2x8	594	74	41	32	741
2x10	369	24	8	11	412
Total	2889	166	91	78	3224
Percentage (%)	90	5	3	2	-

Bowater Lumber Co.					
Lumber Dimension	No Defect	Shear Damage	Drying Defect	Natural Defect	Total Pieces
	---- Number of Pieces ----				
2x4	1019	78	17	13	1127
2x6	648	53	16	16	733
2x8	1171	89	39	37	1336
2x10	437	40	21	24	522
Total	3275	260	93	90	3718
Percentage (%)	88	7	3	2	-

Summary and Conclusions

Sawmill Analysis

This research project was undertaken as the second part of the shear damage study at Virginia Tech. The objectives were to determine if tree size and visible indicators such as stump-pull could be used to predict lumber defect extent, to determine the associated trim necessary to remove shear damage and other defects present, and to determine the extent of other defects present on lumber ends in relation to shear damage.

These objectives were accomplished through two sawmill studies. Each study involved obtaining tree-length stems from the log yard, documenting shear damage using diameter and stump-pull criteria, and sawing the butt logs using conventional sawing patterns. Lumber was graded and collected for analysis. Analysis of lumber ends was performed at Virginia Tech by sawing one inch increments from each end. The type and depth of shear damage along with any shake or drying defects that may have been present on each end was recorded and documented. The amount of trim necessary to remove shear damage was determined by visually inspecting the lumber ends.

The results of both lumber samples showed:

1. Visible indicators of shearing quality such as stump-pull, used as a scaling parameter, were found to be ineffective as predictors of shear damage extent. Log size criteria specified in this study was not found to be a factor in determining shear damage extent.
2. Shatter was observed on 86 percent of the pieces in Sawmill Study 1 and 99 percent of the pieces in Study 2, based on zero trim. After six inches of trim, six percent still exhibited shatter damage in Study 1 and three percent in Study 2. Stump-pull was observed on 13 percent of pieces in Study 1 and eight percent in Study 2 (zero trim). After six inches of trim, three percent of pieces still showed stump-pull in Study 1 and one percent in Study 2. All shear damage was removed with seven inches of trim.
3. Shake was observed on 19 percent of the pieces in Sawmill Study 1 and 20 percent in Study 2 (zero trim). After six inches of trim, 14 percent still showed shake in Study 1 and 13 percent in Study 2.
4. Drying defect was observed on 33 percent of pieces in Sawmill Study 1 and 19 percent in Study 2 (zero trim). After six inches of trim, 18 percent still showed drying defect in Study 1, and 10 percent in Study 2.

A trim strategy based on these findings could be implemented to remove shear damage in a typical mill environment that contains logs harvested predominately with shears. A total trim allowance of 4 to 6 inches would remove 75 to 99 percent of shatter and stump-pull based upon the these two sawmill studies. Six inches of trim would be recommended to remove 94 to 99 percent of shear damage. The results of this analysis confirm Gallagher's work in which six inches of butt trim was recommended to minimize value losses under more controlled procedures.

Using stump-pull as a visible indicator to determine the extent of shear damage is misleading. A log that has severe stump-pull may not have shatter to the extent that it will cause lumber degrade after normal mill trim is taken. Shatter occurs at a much higher frequency on lumber ends since it seems to be inherent to the shearing process and covers the entire surface of the log end.

Stump-pull, which is readily visible, covers only the hinge area and occurs at a much lower frequency than shatter.

The reasons for using stump-pull as a criteria for scaling deductions in the log yard are obvious. Stump-pull is highly visible compared to shatter. Shatter is often not visible on a green log unless examined closely or put under magnification. It becomes much more evident and can be more readily observed when lumber is dried. For this reason, it is unrealistic to inspect every log for shatter. Another reason for deducting logs for stump-pull is when the pull is directed into the butt log. If stump-pull extends further up a log than normal mill trim, damage will be present on the lumber end and will reduce grade. Stump-pull extending out from a log may pose a manufacturing problem, depending how the logs are measured and processed. Stump-pull may hit up against the bump plate at the fixed trim saw on the green chain and may require more trim to remove the damage.

The presence of defects such as shake and drying defect on the lumber ends should not be ignored. Grade reductions are made based on severity and type of defect present. In both studies shake was determined to be the limiting defect when present. Shatter, in the absence of shake, ocurring over the entire surface of the lumber end was determined to be limiting. These determinations were based on grade reductions for defects on lumber ends according to SPIB grading rules. A lumber grader grades on the defects observed not only on the end but the whole piece. Shatter, which is difficult to see, may be missed and carried through to the finished product.

Kiln Cart Survey

The objective of the kiln cart survey was to determine the feasibility of inspecting lumber ends on kiln carts after drying to assess the the amount of shear damage incurred.

A kiln cart survey was developed and conducted at the two sawmills tabulating the number of shear damaged lumber pieces versus lumber that had been damaged by the drying process and/or natural causes (shake). This procedure was developed as a quick and efficient method to evaluate the impact of shear damage in relation to other defects present. A mill may determine their acceptable amount of shear damage based on percentages observed at the dry kiln. Alternate trim strategies at the green chain could be modified if shear damage is evident in unacceptable amounts.

Shear damage was evident on dried lumber and was generally distinguishable from other defects on lumber ends. Two forms of shatter most evident were ring and radial shatter. The form of shatter was determined by the direction of travel of the shear blade. Drying checks and splits follow ray cells and had this characteristic appearance. Natural defects in the form of shake were present in two forms. These were ring and heart shakes. Shake defect had the appearance of clean separation of wood fibers. The smooth surface where separation occurred distinguishes it from shear damage which was much less defined and exhibited a ragged appearance.

The results from these two surveys indicated that six percent of the lumber ends showed shear damage, three percent showed drying defect, two percent showed shake, and 89 percent no defect. The kiln carts contained lumber sawn from butt and top logs and was trimmed on the green chain. Shear damage values would be less after planer mill trim.

Additional kiln cart surveys have been performed to support the findings of this study. Results from this additional research showed similar values as to the amount of shear damage and defects present on the lumber ends.

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Appendix A. Survey Questions

1. Type of mill?
   - pine or hardwood
   - form of raw material
   - primary breakdown unit
2. Approximately what % of your total logs are sheared?
3. Approximately what % of the sheared logs that you recieve have butt damage due to shearing?
4. What is the most common type of damage - stump-pull, splits, shatter?
5. What is your daily production?
6. How many logs are processed?
7. What steps, if any, do you take at your mill to remove the shear damaged portion of the butt log?

Appendix B. National Grading Rules for Dimension Lumber

Dimension lumber refers to surfaced softwood lumber of nominal thickness from 2 through 4 inches which is designed for framing members such as joists, planks, rafters, studs, and small timbers[7].

The classification of dimension lumber is based on 2 dimension categories and 5 use categories. Dimensions up to 4 inches wide are classified as Structural Light Framing, Light Framing, and Studs. Dimensions 5 inches and wider are classified as Studs and Structural Joists and Planks. The final category is that of Appearance Framing grade, which is 2 inches and wider in dimension. This grade is designed for special uses where a high bending strength ratio and good appearance are needed.

Moisture content limits for all grades listed of 2 inch thickness, with widths 12 inches and less and lengths 24 feet and less should not exceed 19%. If marked kiln-dried (KD) however, the moisture content limit should not exceed 15% percent.

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[7] This section is written with reference to Chapter 3 in the Southern Pine Inspection Bureau's *Grading Rules* (1977) for southern pine dimension lumber.

Wood density may be specified in grading. Dense lumber must average not less than 6 annual rings per inch and 1/3 or more summerwood, measured on a representative radial line. Dense grain is specified in the Structural Light Framing and Structural Joists and Plank grades when higher design values are required. Lumber grading is based on characteristics of the lumber along with the limiting provisions of the specified grade. The characteristics permitted, along with the limiting provisions in grading southern pine lumber, are: checks, knots, manufacture defects, pitch and pitch streaks, pitch or bark pockets, shake, skips, slope of grain, splits, stain, wane, warp, and unsound wood[8] .

Specifications for determining lumber grades can be found in Section 300 of the SPIB lumber grading rules. The presence of shear damage may ultimately cause lumber degrade in the form of splits, wane from stump-pull, shake enhanced by the shearing process, or the brooming effect associated with severe fiber separation (shatter).

[8] See Glossary for definitions.

Appendix C. Glossary

Southern Pine Inspection Bureau Definitions

Check: A separation of the wood normally occurring across or through the rings of annual growth and usually is the result of seasoning. A surface check occurs only on one surface and a through check extends from one surface to the opposite or adjoining surface. A small check is not over 1/32 inch wide and not over 4 inches long. A medium check is not over 1/32 inch wide and not over 10 inches long. Large checks are larger than medium. A roller check is a crack in the wood caused by a piece of cupped lumber being flattened as it passes through the rollers.

Knots: A portion of a branch or limb that has become incorporated in a piece of lumber. In lumber, knots are classified as to form, size, quality and occurrence.

Manufacturing Imperfections: All imperfections or blemishes which are the result of manufacturing. Examples include grain imperfections (i.e. chipped, torn, raised, loosened), machine bite, machine gouge, chip marks, etc.

Pitch and Pitch Streaks: An accumulation of resinous material. Pitch streaks are a well-defined accumulation of pitch in the wood cells in a more or less regular streak.

Pitch or Bark Pockets: A well-defined opening between the rings of annual growth which contains pitch or bark.

Shake: A lengthwise separation of the wood which usually occurs between or through the rings of annual growth.

Skips: Skips are areas on a piece that failed to surface clean.

Slope of Grain: The deviation of the line of fibers from a straight line parallel to the sides of the piece.

Split: A separation of the wood due to the tearing apart of wood cells.

Stain: A marked variation from the woods natural color.

Wane: Bark or lack of wood from any cause, except eased edges, on the corner of a piece of lumber.

Warp: Any deviation from a true or planed surface, including bow, crook, cup, and twist or any combination thereof.

Unsound Wood: A disintegration of the wood substance due to action of wood-destroying fungi.

Appendix D. Federal Paperboard Company Sawmill Study

Table 22. Effect of trim on the number, percent, and volume of damage free pieces in the small acceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	----------Shatter----------		
0	12	21	124
1	12	21	124
2	18	32	185
3	35	62	377
4	47	83	493
5	53	94	563
6	55	97	584
7	57	100	606
	----------Shake----------		
0	51	89	544
1	51	89	544
2	51	89	544
3	51	89	544
4	52	91	553
5	52	91	553
6	54	95	574
7 or >	57	100	606
	----------Stump-Pull----------		
0	57	100	606
	----------Drying Defect----------		
0	29	51	320
1	29	51	320
2	30	53	330
3	33	58	360
4	38	67	398
5	41	72	422
6	43	76	439
7 or >	57	100	606

Table 23. Effect of trim on the number, percent, and volume of damage free pieces in the small unacceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	---Shatter---		
0	5	16	53
1	5	16	53
2	7	22	78
3	13	41	142
4	20	63	222
5	23	72	252
6	26	81	288
7	32	100	374
	---Shake---		
0	24	75	277
1	24	75	277
2	24	75	277
3	24	75	277
4	24	75	277
5	25	78	286
6	26	81	296
7 or >	32	100	374
	---Stump-Pull---		
0	30	94	354
1	30	94	354
2	30	94	354
3	31	97	364
4	31	97	364
5	32	100	374
	---Drying Defect---		
0	20	63	234
1	20	63	234
2	20	63	234
3	20	63	234
4	20	63	234
5	22	69	255
6	26	81	298
7 or >	32	100	374

Table 24. Effect of trim on the number, percent, and volume of damage free pieces in the large acceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	--------Shatter--------		
0	8	16	94
1	8	16	94
2	12	24	150
3	25	51	328
4	38	78	508
5	48	98	660
6	49	100	678
	--------Shake--------		
0	37	76	511
1	37	76	511
2	37	76	511
3	37	76	511
4	39	80	541
5	40	82	557
6	43	88	559
7 or >	49	100	678
	--------Stump-Pull--------		
0	42	86	585
1	42	86	585
2	47	96	652
3	47	96	662
4	48	98	662
5	48	98	662
6	49	100	678
	--------Drying Defect--------		
0	31	63	429
1	31	63	429
2	32	65	445
3	32	65	445
4	35	71	480
5	35	71	480
6	38	77	520
7 or >	49	100	678

Table 25. Effect of trim on the number, percent, and volume of damage free pieces in the large unacceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	-------------Shatter-------------		
0	5	6	78
1	8	10	126
2	13	16	192
3	26	33	390
4	58	75	874
5	67	87	1016
6	73	95	1112
7	77	100	1172
	-------------Shake-------------		
0	62	81	937
1	62	81	937
2	62	81	937
3	62	81	937
4	62	81	937
5	62	81	937
6	62	81	937
7 or >	77	100	1172
	-------------Stump-Pull-------------		
0	57	74	868
1	57	74	868
2	59	77	894
3	61	80	924
4	65	85	984
5	69	89	1046
6	71	92	1078
7 or >	77	99	1172
	-------------Drying Defect-------------		
0	65	84	986
1	65	84	986
2	65	84	986
3	67	87	1018
4	67	87	1018
5	68	88	1034
6	69	89	1050
7 or >	77	100	1172

Table 26. Effect of trim on the combined total for all damage groups.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	----Shatter----		
0	30	14	349
1	33	15	397
2	50	23	605
3	99	46	1237
4	163	75	2097
5	191	88	2491
6	203	94	2660
7	215	100	2827
	----Shake----		
0	174	81	2269
1	174	81	2269
2	174	81	2269
3	174	81	2269
4	177	82	2308
5	179	83	2333
6	185	86	2366
7 or >	215	100	2827
	----Stump-Pull----		
0	186	87	2413
1	186	87	2413
2	193	91	2506
3	196	92	2556
4	201	94	2616
5	206	96	2688
6	209	97	2736
7	215	100	2827
	----Drying Defect----		
0	145	67	1969
1	145	67	1969
2	147	68	1995
3	152	70	2057
4	160	74	2130
5	166	77	2191
6	176	82	2307
7 or >	215	100	2827

Appendix E. Bowater Lumber Company Sawmill Study

Table 27. Effect of trim on the number, percent, and volume of damage free pieces in the small acceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	------------------------Shatter------------------------		
0	1	1	14
1	1	1	14
2	9	12	116
3	34	45	423
4	56	74	699
5	68	90	851
6	72	96	902
7	75	100	932
	------------------------Shake------------------------		
0	62	83	774
1	62	83	774
2	62	83	774
3	62	83	774
4	62	83	774
5	64	86	800
6	67	90	834
7 or >	75	100	932
	----------------------Stump-Pull----------------------		
0	68	91	839
1	69	92	849
2	73	98	903
3	74	99	919
4	75	100	932
	---------------------Drying Defect---------------------		
0	59	79	706
1	59	79	706
2	59	79	706
3	61	81	734
4	61	81	734
5	63	84	760
6	66	88	806
7 or >	75	100	932

Table 28. Effect of trim on the number, percent, and volume of damage free pieces in the small unacceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	---Shatter---		
0	2	11	21
1	2	11	21
2	8	44	95
3	13	72	151
4	16	88	201
5	17	94	217
6	18	100	228
	---Shake---		
0	14	77	166
1	14	77	166
2	14	77	166
3	14	77	166
4	15	83	182
5	15	83	182
6	16	89	198
7 or >	18	100	228
	---Stump-Pull---		
0	15	83	190
1	15	83	190
2	15	83	190
3	17	94	212
4	18	100	228
	---Drying Defect---		
0	12	66	154
1	12	66	154
2	12	66	154
3	15	83	186
4	15	83	186
5	15	83	186
6	17	94	212
7 or >	18	100	228

Table 29. Effect of trim on the number, percent, and volume of damage free pieces in the large acceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	-------------------------Shatter-------------------------		
0	2	1	28
1	2	1	28
2	19	10	302
3	87	46	1324
4	148	78	2256
5	179	94	2715
6	184	97	2796
7	189	100	2866
	--------------------------Shake--------------------------		
0	147	77	2264
1	147	77	2264
2	147	77	2264
3	148	78	2276
4	153	81	2341
5	157	83	2410
6	162	86	2472
7 or >	189	100	2866
	-----------------------Stump-Pull-----------------------		
0	183	97	2764
1	185	98	2794
2	188	99	2847
3	188	99	2847
4	188	99	2847
5	189	100	2866
	----------------------Drying Defect----------------------		
0	155	82	2348
1	155	82	2348
2	156	83	2357
3	162	86	2439
4	165	87	2487
5	167	88	2519
6	171	90	2599
7	189	100	2866

Table 30. Effect of trim on the number, percent, and volume of damage free pieces in the large unacceptable log group.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	---Shatter---		
0	0	0	0
1	1	1	21
2	27	22	483
3	68	55	1139
4	106	86	1708
5	115	94	1842
6	119	97	1943
7	123	100	2018
	---Shake---		
0	100	81	1640
1	100	81	1640
2	100	81	1640
3	100	81	1640
4	102	83	1672
5	103	84	1688
6	106	86	1741
7 or >	123	100	2018
	---Stump-Pull---		
0	104	84	1672
1	104	84	1672
2	108	87	1741
3	110	89	1773
4	115	93	1859
5	116	94	1875
6	118	96	1917
7	123	100	2018
	---Drying Defect---		
0	104	85	1685
1	104	85	1685
2	104	85	1685
3	107	87	1722
4	110	89	1780
5	111	90	1796
6	111	90	1796
7 or >	123	100	2018

Table 31. Effect of trim on the combined total for all damage groups.

Trim Amount	No. of Pieces Damage Free	% of Pieces Damage Free	Volume of Damage Free Pieces (bd. ft.)
	---Shatter---		
0	5	1	63
1	6	1	84
2	63	15	996
3	202	49	3037
4	326	80	4864
5	379	93	5625
6	393	97	5868
7	405	100	6045
	---Shake---		
0	323	80	4844
1	323	80	4844
2	323	80	4844
3	324	80	4856
4	332	82	4969
5	339	84	5080
6	351	87	5245
7 or >	405	100	6045
	---Stump-Pull---		
0	370	91	5465
1	373	92	5505
2	384	95	5681
3	389	96	5751
4	396	98	5867
5	398	98.5	5904
6	400	99	5946
7	405	100	6045
	---Drying Defect---		
0	330	81	4893
1	330	81	4893
2	331	81	4902
3	345	85	5081
4	351	87	5187
5	356	88	5261
6	365	90	5413
7 or >	405	100	6045

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