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Discolorations in Southern Hardwood Logs: Biological and Non-biological Staining Control Practices

Nathan Edward Irby

DISCOLORATIONS IN SOUTHERN HARDWOOD LOGS: BIOLOGICAL AND NON-BIOLOGICAL STAINING CONTROL PRACTICES

By

Nathan Edward Irby

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Nathan Edward Irby

Approved:

Terry Amburgey Professor of Forest Products Major Professor	Rubin Shmulsky Department Head of Forest Products Committee Member
Laura Grace Professor of Forestry Committee Member	George M. Hopper Dean of the College of Forest Resources

Name: Nathan Edward Irby

Date of Degree: May 2, 2008

Institution: Mississippi State University

Major Field: Forest Products

Major Professor: Dr. Terry Amburgey

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Discolorations in highly valued southern hardwood species have been a costly problem for the U.S. forest products industry since its beginning. Both microbial (fungi) and non-microbial (enzyme-mediated) sapstain problems are more prevalent in the southeast than in other regions, so preventive measure must be done to keep hardwood logs and lumber discoloration-free.

Six full-scale field trials were conducted along the Mississippi River from Yokena, MS to Ripley, TN between March to October 2007. The basis for the research was a belief that discolorations that affect southern hardwood logs can be controlled by various techniques such as log end coating, inventory management, and combinations of each. These tests revealed important information such as chemical compatibility issues, storage facility upkeep, workforce development through scheduling and communication.

Key words: discolorations, microbial, enzyme-mediated, hardwood, southeastern

DEDICATION

I have progressed academically through her knowledge in the sciences and her passion to educate others; therefore, I dedicate this research to my mom, Carlleen Irby (1954-2004).

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My family supported me throughout the project, financially and lovingly. I am truly blessed for their presence and am thankful every day for each and every one of them. In closing I would like to thank my father, Buddy Irby. He not only taught me how to hunt, fish, and understand the business world, he did so by being my best friend. Thanks dad.

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CHAPTER I

INTRODUCTION

Cost/ History of Discolorations

Discolorations in highly valued southern hardwood species have been a costly problem for the U.S. forest products industry since its beginning. Sapwood discolorations (sapstains) and insects cause extensive degrade and a high subsequent monetary loss to the lumber market (Johnston, 1959). “Losses result principally from reductions in grade, value, and marketability of the discolored material.” (Scheffer and Lindgren, 1940). A direct result is also the overcutting of the timber resource to compensate for discolored stock accumulating in mill sort yards (Lindgren, Scheffer, and Chapman, 1932). Both microbial (fungi) and non-microbial (enzyme-mediated) sapstain problems can be initiated by climatic conditions such as high relative humidity, warmer temperatures (75-85 F; 24-29 C), and a moisture content in the wood greater than 20% (Log Home Council, 2000). The different types of sapwood discolorations are compared in Amburgey et al. (2001). Mineral stains will not be discussed in the scope of this manuscript.

Because conditions that favor stain development are prolonged after tree felling, within a few days logs in the southeast could begin to show sapwood discolorations if preventive measures are not begun.

Field observations have shown that the effectiveness of preventative methods against the growth of staining fungi is influenced primarily by temperature, assuming that wood moisture content remains high (Lindgren, 1942). Lengthy storage of logs associated with ends of hardwood logs being infected by fungi, or fungi introduced into logs by Ambrosia beetles, and slack time in the process from milling to chemical treatment are both core reasons for treatment of logs and lumber in the southeast (Verrall, 1941).

Microbial Staining

Sapstain fungi thrive on simple sugars and starches stored in sapwood parenchyma cells (Kirk and Cowling, 1984). Because the hyphae of sapstain fungi are pigmented, the sapwood colonized by them is discolored. As these fungi utilize contents of ray parenchyma cells of sapwood, their presence often appears as pie-shaped wedges, with the point of the wedge extending deep into the sapwood, as they colonize rays (Knaebe, 2002). Sapstain can be directly related to over 130 species of fungi (Abraham et al., 1997). Ceratostomella species (an Ascomycete) and species within the group Fungi Imperfecti are the dominant staining fungi affecting southern hardwoods (Lindgren,Scheffer, and Chapman, 1933). Sapstain and decay fungi develop and grow most rapidly during the summer months, which is why most deterioration occurs during this period (Mason et al., 1963).

Enzymatic Staining

Non-microbial sapwood discolorations that occur in logs and freshly-cut lumber are often referred to as “gray stain”, especially in the southern hardwood species such as

red oak (*Quercus spp*.), hackberry (*Celtis lavigata* Willd), ash (*Fraxinus spp*.), and poplar (*Liriodendron tulipifera* L.) (Forsyth, 1988). These stains are mediated by oxidative enzymes, in living wood cells, that form pigmented metabolic by-products (starch) in the sapwood of logs and lumber (Amburgey and Forsyth, 1987). Parenchyma cells in the sapwood are a fundamental key in the occurrence of both microbial and non-microbial staining. These non-microbial stains cannot be prevented by applications of fungicides/ insecticides. The initiation of this type of stain is associated with log storage practices. In sweetgum (*Liquidambar styraciflua* L.) freshly-sawn lumber also develops oxidative staining at the surfaces as a reddish-brown hue when exposed to air after milling (Scheffer and Lindgren, 1940).

Sawmill Inventory Management

In many instances, microbial and non-microbial discolorations at log ends due to poor log handling methods and storage procedures require that logs be cut back one foot or more on each end to obtain quality lumber. To solve these problems, mills must develop an inventory management scheme that is cost effective and feasible to operate, and that minimizes the time that logs are in storage by using the "first in, first out" philosophy. Sawmills in the Southeast have been operating virtually unaltered for many years and often view changes in log and lumber handling as unorthodox and wasteful.

Project Objectives

This research tested the hypothesis that sapwood discolorations causing degrade in southern hardwoods can be minimized by proper log-handling practices. This research project deals only with logs because grade-logs must be handled properly to obtain grade

lumber from them. Quality grade lumber can only be cut from hardwood logs that are fresh and sapstain-free (Verrall, 1941). Inventory management, along with proper use of fungicides/ insecticides (e.g. end coatings), can decrease or eliminate fungal growth (Knaebe, 2002). This research uses both on-site and laboratory testing and analysis. The objectives of this research on southern hardwood logs were:

1. Enhance/develop inventory management practices to decrease or eliminate sapstain fungi and/ or enzymatic gray stain.
2. Enhance/develop end coatings/exposed wood coatings that will decrease or eliminate the growth of sapstain fungi and/or enzymatic gray stain.
3. Couple a feasible inventory management system with proper use of fungicides/ insecticides (eg, end coatings) to prevent sapwood in logs from degrade caused by both microbial (stain fungi) and enzyme-mediated (e.g. gray stain) discolorations.

CHAPTER II

LITERATURE REVIEW

Hardwood Test Species

The sapwood of many southern hardwood (angiosperm) species is susceptible to microbial and enzyme-mediated discolorations, including: southern red oak (*Quercus spp*.), hackberry (*Celtis laevigata* Willd), and sweetgum (*Liquidambar styraciflua* L.). Sapwood discolorations in white oaks are rarely seen in lumber because of the narrow sapwood zone in most species. The occurrence of theses discolorations is influenced by warm and moist climatic conditions, lengthy log storage times, lack of drainage in holding facilities that results in exposure of logs to muddy, extractive-filled soil and debris, and other associated factors. Many southern hardwood sawmills consider the species mentioned above to be "sensitive," so special care is necessary to reduce possible discolorations. Other hardwoods including ash, yellow-poplar (*Liriodendron tulipifera* L.), cottonwood (*Populus deltoids* Bartr. ex Marsh.), sycamore (*Platanus occidentalis* L.), pecan (*Carya spp.)*, and many non-commercial hardwood species can also be degraded by these discolorations.

Southern red oaks have historically been the single most valued hardwood species group on the market. The group of trees commonly referred to "southern red oaks" includes cherrybark oak (*Quercus pagoda* Raf.), nuttall oak (*Quercus texana* Burkl.), pin oak (*Quercus palustris* Muenchh.), water oak (*Quercus nigra* L.*)*, and southern red oak *(Quercus falcate* Michx.*)* (Samuelson and Hogan, 2003). Because there is high market demand and extensive revenue generated from utilizing these species commercially, extensive research has been conducted to prevent any value-loss (Amburgey, 1979, 1985, 1987, 1992, 2001; Forsyth, 1987, 1988, 1992; Kitchens, 1995, 2001; Schmidt, 1997; and Sanders, 1997).

Hackberry is a member of the elm family and is a moderately dense wood and is widely distributed throughout North America. In the southern region of the United States the commercially utilized species is *C. laevigata*, or sugarberry, and this particular species is much larger than its sister species to the north, *Celtis occidentalis* Willd. (Gilman and Watson, 1993; Samuelson and Hogan, 2003).

Sweetgum, *L. styraciflua*, is another "sensitive" species that is commercially utilized for high-grade veneer, paneling, pallets, and some millwork. Other common names for this species include: redgum, satin walnut, and sapgum (Samuelson and Hogan, 2003). Sweetgum can undergo several discolorations that are detailed in the literature cited below.

Microbial Stains

Discolorations, other than mineral stain, that affect the sapwood can be controlled by various techniques. The sapwood region of a log is near the bark and is less resistant

to fungi and insects than the heartwood which, in durable species, is relatively unaffected by insects, stain fungi and decay fungi and, in general, is less permeable (UMN, 2002). Sapwood is the portion of the tree that contains living parenchyma cells that are strorage cells containing simple sugars, starches, and other compounds that can be utilized by sapstain fungi. Nitrogen, an essential element required for the growth of fungi, is very low in wood (0.1 to 0.3 % of the dry weight of wood) (Abraham et al., 1997). The conversion by fungi of natural wood nitrogen in proteins stored in ray parenchyma cells is necessary for fungi to colonize sapwood. Several sap-staining fungi produce enzymes that break down proteins and nitrogen thereby nitrogen available to support fungal growth and reproduction (Abraham et al., 1997).

Early studies on sapstain fungi came from the works of Robert Hartig and Irving W. Bailey, both in the early twentieth century, and A.F. Verrall, T.L. Scheffer, and R. Lindgren in the 1930's and 40's. "It was thought that any seasonal variations might be most pronounced in the southern U.S., where conditions are favorable for stain development during the greater part of the year" (Verrall, 1939). The value of lumber and the importance of an economical market for lumber increases every year; utilization of both sap-and heartwood of species, clear of stain, also increases in importance every year (Bailey, 1910). Bailey further writes, "In endeavoring to prevent the discoloration it is of importance to discover what agency or agencies produces the stain, and to study their mode of activity" (Scheffer and Lindgren, 1940). Present day losses attributed to stain of sapwood in both softwood and hardwood species would be hard to estimate quantitatively. However many softwood (conifer) species (e.g. southern pine) now are kiln-dried as lumber is produced, so their incidence of sapstains is decreasing.

There are two major types or groups of fungi that discolor wood: “stain” fungi and “mold” fungi. Mold and sapstain fungi cause a surface discoloration that colonize wood when microscopic reproductive spores in the air (or carried by insects) settle onto sapwood exposed at cross-sections of logs or surfaces of lumber. These spores germinate and form hyphae which grow throughout sapwood, often penetrating deeply through rays, and mold fungi eventually form pigmented spores on hyphae at log cross-sections or lumber surfaces. Mold fungi are very common and cause a variety of discolorations on the affected surfaces. These discolorations can be removed by surfacing or chemical treatment of lumber since the hyphae are colorless.

Sapstain fungi spores tend to be sticky and less prone to be carried by wind; they often are introduced into wood by insects that carry them on their bodies. Staining fungi commonly affecting hardwood species in the southern states include *Ceratostomella pluriannulata* (C. Moreau), *Diplodia natalensis* (Poll-Evans), *Endoconidiophora coerulescens* (Munch), and *Graphium rigidum* (Abellini) (Verrall, 1939). Verrall (1939) stated that, in his opinion, *Endoconidiophoia coerulescens* is the most important fungus that stains hardwoods.

Staining fungi can spread 12 inches into sapwood of the exposed ends of freshly felled logs and, because their hyphae are pigmented, can discolor the entire sapwood in areas in which they have grown. Their depth of penetration into logs depends mostly on the amount of oxygen present in the sapwood. Blue-stain fungi do not affect the heartwood of logs and lumber (Bailey, 1910; Scheffer and Lindgren, 1932, 1933, 1942; Verrall, 1939, 1941; Amburgey, 1987, 1995). An important factor in dealing with biological staining in the southeast is the use of fast-grown regenerated trees being cut

which have large amounts of sapwood due to fewer growth rings in the large diameters of the species being cut (Lindgren, 1942).

Ambrosia Beetles

Ambrosia beetles are a major cause of the introduction of stain fungi into hardwood logs and lumber. Ambrosia beetles can infest unseasoned wood and logs by boring holes into the sapwood (Verrall, 1941b; Levi, 1983). Adult ambrosia beetles attack unseasoned logs/lumber and leave frass at openings of tunnels which they bore into the unseasoned wood (O'Brien et al., 1987). They form egg cradles inside the tunneled sapwood on the sides of their main gallery and lay eggs in them. Spores of stain fungi carried on the backs of the beetles are introduced to the sapwood during the tunneling/boring process. The developing larvae do not cause damage to the sapwood. Rather, they feed on the mycelium of the stain the fungus (ambrosia fungus) introduced into the sapwood by the adult (Amburgey, 1985, 2006).

Enzymatic Staining

Non-microbial sapwood discolorations of biological origin often occur in the southern hardwood species such as red oak, hackberry, and poplar. These enzyme-mediated discolorations are discussed in many publications: (Baily, 1910; Scheffer and Lindgren, 1932, 1933, 1942; Schmidt, 1987; Amburgey, 1987, 1988, 1992, 1995, 2001; Forsyth, 1987, 1988, 1992; Kitchens, 1995, 2001). Parenchyma cells in the sapwood are a fundamental key in the occurrence of both microbial and enzyme-mediated staining. These stains are mediated by oxidative enzymes in living parenchyma cells that form pigmented metabolic by-products (starch granules) in the sapwood of logs and lumber

(Amburgey, 1987, 1988, 1995, 2001; Schmidt, 1987, 1988; and Forsyth, 1987, 1988, 1992). The chemical oxidation reaction can be simply classified as an act of Mother Nature. These stains cannot be prevented by applications of fungicides/ insecticides, but can be prevented by fumigating freshly-felled logs or by dip-treating freshly-cut lumber in sodium bisulfite followed by diffusion storage (Forsyth, 1988). The initiation of this type of stain is also affected by lengthy log storage practices.

Log Inventory/Storage Facility

For years storage of logs from felling to milling has been a complicated inventory management tool. Southern hardwood companies can be divided into two principal groups: market driven or resource driven firms. Resource driven companies rely on many decades of practical experience with regards to timber sustainability and lower log/lumber inventory schemes (Irby, 2004). Market-driven forest products companies (e.g. Anderson-Tully Co.) where these tests were conducted have checks and balances by which they operate and regulate the flow of incoming raw material. Sawmills that are market-driven do not base costs solely on log grade, but on what the log costs their company (Mayer and Wiedenbeck, 2005). Storage of highly valued logs should be done in a timely fashion to keep logs free of fungi and beetles (Amburgey, 1985)

Control/Prevention Methods

Anti-sapstains/Biocides

Another aspect of eliminating or decreasing fungal and/or insect growth is the use of fungicides/biocides especially by dip-treatment of freshly-cut lumber. Biocides which

prevent both fungal and insect growth also are a significant component of a program to maintain log grade/value. Depending on the length of time the logs are held in the storage yards, and the rate at which fungi and beetles can inhabit the fresh stock, preventative/protective procedures should be implemented such as fungicide/ insecticide application (Amburgey, 1985). Identification of the cause of discoloration (fungus or non-microbial) is fundamental when attempting to control it. The use of biocides to prevent the growth of fungi in air-drying lumber may be necessary only in the summer in cooler or drier climatic regions, but their use is necessary year- round in warm, humid regions such as the lower Mississippi Valley (Verrall,1945).

Logs in the southern climate undergo extreme changes once placed in a holding area. Chemical treatment to prevent discolorations of these logs should be done within 24 hours to increase effectiveness (Sheffer and Lindgren, 1940; Mcmillen, 1956; Amburgey, 1985). Chemicals used for sapstain control pre-1986 were based primarily on, or were derivatives of, pentachlorophenol (Laks et al.,1991). New generation biocides consist of many chemicals such as iodopropynil butyl carbamate, borate compounds, chlorothalonil, propiconazole, and many others.

Anti-sapstain products have become a huge market for various wood preservation firms. For example, Prosan 8 is a Buckman Laboratories Inc. product that is widely used in the market as a preventative of fungal stain in softwoods and hardwoods. Prosan 8 is comprised of 8% propiconazole active ingredient and has a pH range from 5.9-8.0, mild odor, and is very hazardous to humans so it is largely used to treat freshly-cut lumber in bulk-dip tanks where human contact can be minimized. This product also is being used in some log-end treating applications at a few sawmills located in the southeastern US.

Another of the many anti-sapstain products used currently in the hardwood industry is Arch Chemical Company's Anti-Blu XP. Anti-Blu XP contains IPBC (3-iodo-2-propynyl butylcarbamate) and BAC (benzalkonium chloride) along with propiconizole as the listed active ingredients. Unlike Prosan 8, Anti-Blu XP has a relatively low mammalian toxicity. Its neutral pH could help chemical compatibility issues and also be less corrosive to dip tanks and spray rigs.

Kop-Coat Company introduced an anti-sapstain product in the early 1990's named NP-2 whose active ingredient is IPBC and DDAC (didecyldimethylammonium chloride). This product was widely-distributed along the eastern-coast of the U.S. Many sawmill companies utilized NP-2 in lumber dip-tanks to protect freshly-sawn green hardwood lumber before kiln-drying could occur. EPA regulations became more stringent by the late 1990's which sparked awareness towards the toxic anti-sapstain formulation NP-2. Since "phasing-out" of NP-2 Kop-Coat has released a new line of anti-sapstain products named DiamondBrite containing the same actives, only reduced by half the original formulation concentrations, as NP-2, but distribution in the southeast has been limited.

Beetle Infestation

Ambrosia beetles can be prevented by water-spray storage or application of insecticides to log surfaces. In the early 1950's, oil solutions of insecticides such as benzene hexachloride were used to control ambrosia beetles in hardwood logs, which gave three to four months of adequate protection against the insect (Johnston, 1952). Coatings (wax & latex based) used commercially provide envelope protection against

beetle infestations, but only cover the ends of the log and are not marketed for this application.

Antioxidants

Another chemical treatment used to reduce oxidative staining is dip treatment in sodium bisulfite followed by diffusion storage (Amburgey and Forsyth, 1992). Sodium bisulfite, an antioxidant, is a very effective chemical treatment in lumber against "gray-stain" but it is corrosive (requires a stainless-steel dip tank) and has an unpleasant odor (requires well-ventilated dip facility). Use of water-spray storage of logs in large sawmill operations is very common in the southeast and is effective in minimizing both microbial staining and enzyme-mediated staining, if storage is kept under 3 to 4 months; however, logs stored under water, for several months, are susceptible to oxidative staining of the sapwood. Staining in lumber cut from these logs can be controlled by sodium bisulfite with a dip of 5% in lumber from fresh logs and 10% with lumber from water-stored logs followed by a period of diffusion storage (Amburgey and Forsyth, 1992). The extra handling of the lumber to be dipped into concentrations of sodium bisulfite is considered unfeasible to high-production southern sawmills (Amburgey and Forsyth, 1987, 1992; Amburgey, et al., 1997).

Butylated hydroxyl toluene (BHT), $C_{15}H_{24}O$, is another antioxidant that is commonly used as a food preservative and may prevent gray stain. Other common uses for BHT as an additive include: cosmetics, jet fuels, rubber, petroleum products, and embalming fluid. Consumer products that contain BHT are: McDonald's sausage patties, Trident and Orbit gum, Wheat Thins, Chiclets, and many other common groceries items.

Use of BHT in reference to preventing hardwood discolorations has not been published to date, but wood preservation work has been initiated (Schultz et al., 2004).

Fumigation

Fumigation of freshly cut logs can greatly reduce costly stain in such species as red oak and sugar hackberry (Amburgey, 1995). Fumigants such as methyl bromide, iodomethane, sulfuryl fluoride, and metamsodium have been shown to prevent gray stain in logs (Amburgey, et al., 1997). Fumigation is very effective in controlling enzymatic discolorations; however, it has many variables to be considered before being used in an industrial setting. The cost of fumigation is the initial negative, closely followed by the toxicity of the fumigants.

Other Methods to Control Enzymatic Discolorations

Other non-chemical processes used to control oxidative staining include using mechanical vibration/compression to eliminate enzymatic staining in hardwoods. A mechanical stressing device that uses vibration to "beat" the lumber has been used experimentally to inactivate parenchyma cells in the sapwood of the lumber (Amburgey, 1995).

Heating of logs/lumber is also an attempt to inhibit any sapwood stains that might occur. One project heated wood to 95 degrees Celsius followed by a gradual cooling to prevent rapid moisture loss and splitting and checking (Sartorio, 2004). The previously listed patent on mechanically vibrating/compressing decreases gray stain closely resembles other work done to eliminate enzyme mediated discolorations through non-chemical means.

The “Elder Process” also describes a non-chemical treatment to control or prevent enzymatic staining by pre-drying lumber in a manner that also limits drying defects (Elder, 1998; Wu and Clement, 2005). The elimination, by either chemical or non-chemicals means, of oxidation in parenchyma cells stops the pigmented starch-like granules (non-microbial stain) from forming in the wood, both in logs and sawn lumber.

The USDA has also tested non-chemical treatments to control enzymatic “gray-stain.” In research note FPL-RN-0306 by Wiemann, Knaebe, and Harriague (2007), full-scale testing to prevent oxidative stain was conducted in Bolivia. Some protocols developed and implemented in this particular research including hammer-punching of boards (which is cited as an MSU initial experiment), dropping boards from a two-story building for impact, and subjecting boards to reggae music being played through a loud speaker. None of these tests proved feasible in an industrial application, and, moreover, did not protect to any substantial extent the boards from discoloring.

Management practices, such as FIFO (first in-first out), clean holding yards, complete/adequate water storage of logs, cutting multiple length logs, and time tables to chart felling-milling-drying also will help (Amburgey,1979). These practices have been studied in great detail. Both dry and wet storage techniques of hardwood logs have been studied (Djerf, 1969, Lindgren, 1942, and Mason et al., 1963). Water-spray storage is a very important part of the southern sawmill industry and is done to minimize the incidence of chemical and fungus stains (Volkman, 1966).

CHAPTER III

METHODS AND MATERIALS

Testing was conducted to evaluate procedures for maintaining southern hardwood logs fresh and discoloration-free. The primary objective of the project was to alter the log-handling system to achieve timely utilization of logs and maintain their quality from felling to milling. "The proper use of forest resources demands that preventable waste and loss be eliminated through the development and adoption of feasible methods of control." (Scheffer and Lindgren, 1940). All tests were done on logs harvested along the Mississippi river and barged to Anderson Tully Company (ATCO) in Vicksburg, MS.

Methods used included documentation of barge trips from up-river down to the ATCO sawmill. The areas of emphasis in testing were sapstain studies (both microbial and enzyme-mediated), log inventory management, and chemical treatment of fresh logs to prevent sapstain discolorations. The overall desired result was development of a method for preventing microbial (stain fungi) and non-microbial (enzyme-mediated) discolorations from devaluing hardwood logs during transport and storage. This project was very time consuming and labor intensive. Scheduling of visits to up-river logging sites was coordinated with ATCO through operations auditor Mike Herrington.

Hardwood Test Species

The three species tested were southern red oak (*Quercus spp.*), sweetgum (*styraciflua.*), and southern hackberry *(laevigata*). These species occur commonly in the south and are present in high inventory levels at ATCO. These hardwood species also have very low levels of resistance to decay, making them highly susceptible to several types of fungi or insects (Carter et al., 1976). These species are highly susceptible to microbial stain degradation due to their wide sapwood layer, southeastern climatic conditions, lengthy storage times, lack of drainage in holding facilities that results in exposure of logs to muddy, extractive-filled soil and debris, and many other environmental and human factors. The host southern hardwood sawmill deems these particular species as "sensitive" so special care is provided to hinder discolorations. Therefore, this project included field tests with batches containing various numbers of replicates of each southern hardwood species.

Sapstain Study

The underlying theme of the initial study on discolorations of southern hardwood logs was that in almost every facet of the entire log to lumber process, documenting time of various steps of log processing was recorded to determine when sapstain would occur during a particular time of year. The first objective was to observe, by study of the three test species (red oak, sweetgum, and hackberry), the trees being felled and observe/record every step that log a takes until it reaches the ring debarker at the sawmill. Several variables were recorded such as temperature, relative humidity, precipitation, air flow in any mode of transport, and log handling constraints. This series of tests was done with

emphasis on controlling fungi, enzyme-mediated discolorations, and log quality (checking and splitting). It was anticipated that by coordinating all three processes, a useful handling/lumber processing system would be derived.

Inventory Management

Inventory control is a complex system that must operate adequately to supply a market-driven sawmill. Discoloration occurrences from March to October only increase the already strained and complex system of raw material flow. Testing in this particular part of the project focused mainly on log handling and log transportation to and at the sawmill. Barge evaluations such as average temperature inside at any given time, hazards associated with barge transportation, air flow inside a barge with respect to the stacks of logs, and many other variables to determine a time schedule from felling to milling were documented. Specific log (sample) data was recorded in regards to tag #, species, felled location, date and time felled, destination, arrival time, barge I.D., each piece of equipment that handled the log throughout the process, and many other important aspects of inventory management.

Chemical Treatment

End coatings were obtained from industry associates willing to research new or improved anti-sapstain chemicals. The industry representatives include Arch Chemical Co. based out of Conley,GA, Buckman Laboratories in Memphis,TN, and UC Coatings in Buffalo,NY. Products of these companies are designed to control fungal growth, wood-cell oxidation, and/or end checking/splitting by eliminating or reducing changes in factors such as moisture, oxygen, warmth, and food. Industrial biocide treatment was applied to

freshly-felled logs that were placed as in regular mill production (Figure 3.1). Fresh logs were coated via spray or brush-on applications covering the ends where exposed sapwood occured.

Figure 3.1

Application of End-Coats (Anti-Sapstain, Antioxidant, End-Sealer, or Combination(s) of Each) to Freshly Felled Logs Located on Log-Dumps Along the Mississippi River.

Preliminary Testing

In February of 2007 a laboratory test was conducted to determine properties of stain preventing chemicals to determine if they could be added to existing formulations. These chemicals included three antioxidants: sodium bisulfite, ascorbic acid, and citric acid along with an anti-sapstain formulation, Prosan 8 (propiconazole), and finally an end-coating that prevents checking named Anchorseal. These chemicals were placed in beakers with various mixtures to discern efficacy and mixing of chemicals. The percentages of the antioxidants were 0.05%, 1%, 2%, and 4%. The concentrations of

antisapstain product, Prosan 8, were 0.02%, 0.025%, and 0.05%. The end coating product, Anchorseal, was left at 5% as a baseline for this particular test. Testing variables included temperature, pH, and concentration levels. Observations of these emulsions/mixtures were done at times of 1, 2, 4, 12, and 24 hours. This process of observation, though highly subjective, was done to check if any one of the three chemicals seemed to "fall out" of solution by simply settling to the bottom of the beaker.

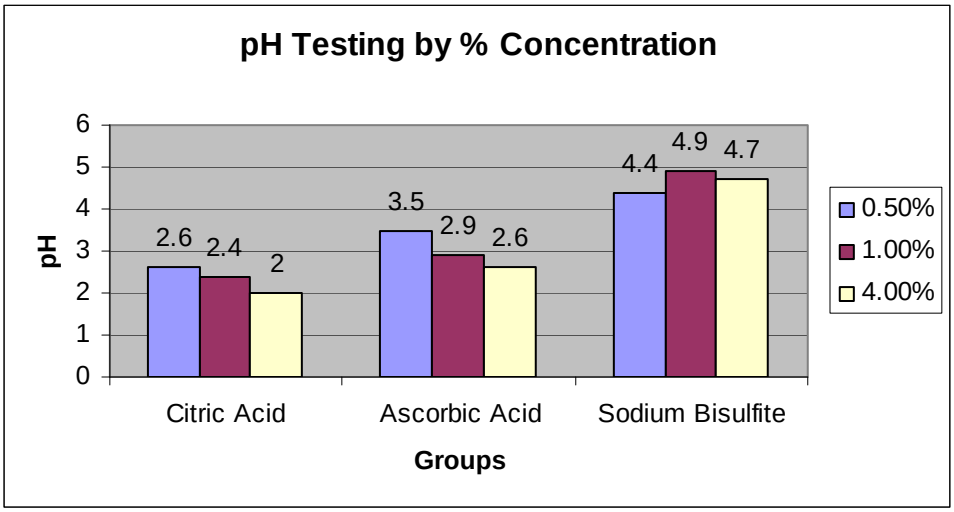


Figure 3.2

pH Mixtures of an Anti-Sapstain Formulation (Prosan 8) with Antioxidants.

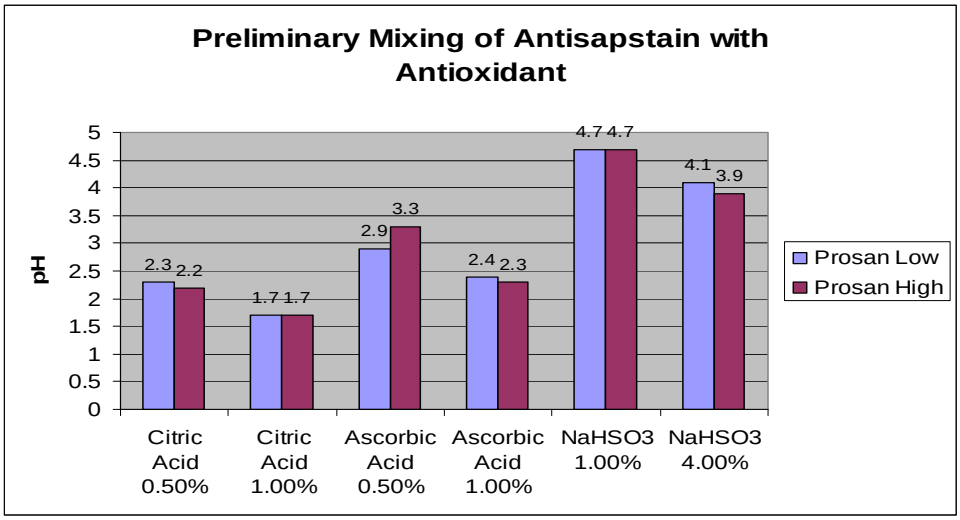


Figure 3.3

pH Mixtures of an Anti-Sapstian with Antioxidant at Different Concentrations. Prosan Low= 0.02%, Prosan High=0.05%

These preliminary lab tests revealed some interesting observations. The pH of each individual chemical determined the emulsion properties. Simply put, an anti-sapstain mixed with an antioxidant generated an emulsion rather than a solution that did not effectively incorporate the initial active ingredients (e.g. propiconazole, IPBC, BAC, sodium bisulfite) stain fungi and enzyme-mediated discolorations from forming when applied to logs in preliminary tests. The overall properties of the initial chemicals before mixture were ineffective, to an unknown degree, when mixed together and let stand for any amount of time, indicated that the blended chemicals had a short shelf life. Therefore, field testing was done using the "epoxy" method; mix the two chemicals (anti-sapstain formulation & antioxidant formulation) just prior to log application. This method eliminated any self-life negatives and provided a more "accurate" account for each treatment.

CHAPTER IV

RESULTS AND DISCUSSION

The following six tests comprise the raw data achieved while research was conducted utilizing full-scale tests up and down the Mississippi river. Anderson-Tully Co. generously offered assistance in procuring freshly-felled logs and secondary help/instruction. The logs were treated with a number of various chemicals and combinations of each during March and October of 2007.

Full-Scale Mill Tests

1. Test 1

a. Raw Material Treatment/Organization

Figure 4.1

Off-Loading Truck Transported Hardwood Logs Prior to Conducting Experiment One at Merigold Hunting Club Located in Benoit,MS.

This test was conducted outside of Benoit,MS at an Anderson-Tully river-side logging operation located at Merigold hunting club along Mississippi river at mile marker 581. Five different end-coating mixtures were prepared, approximately one day prior to use. These treatments consisted of different mixtures containing sodium bisulfite, Prosan 8, and Anchorseal (see figure 3.4). Prosan 8 was added as a biocide to prevent fungal discolorations, sodium bisulfite was added to prevent enzyme mediated discolorations and the end seal was used to adhere the other components to the log ends and to prevent log checking caused by rapid drying. Preliminary testing with these formulations helped refine further experiments conducted while following the overall objective of keeping logs from stain degradation.

Figure 4.2

Full-Scale Test One Initiated by End-Spraying of Fresh Logs at Merigold Hunting Club in Benoit, MS

All treatments were applied by spray to each end of southern hackberry, red oak, and sweetgum logs. The research participants included Mike Herrington, and Rodney

Wishard both with ATCO. Replicates of logs were sprayed with one of the five Prosan 8/sodium bisulfite mixtures within 24 hours of being felled (Figure 4.2). An identification tag was placed on one end of each log by both Mississippi State University and ATCO.

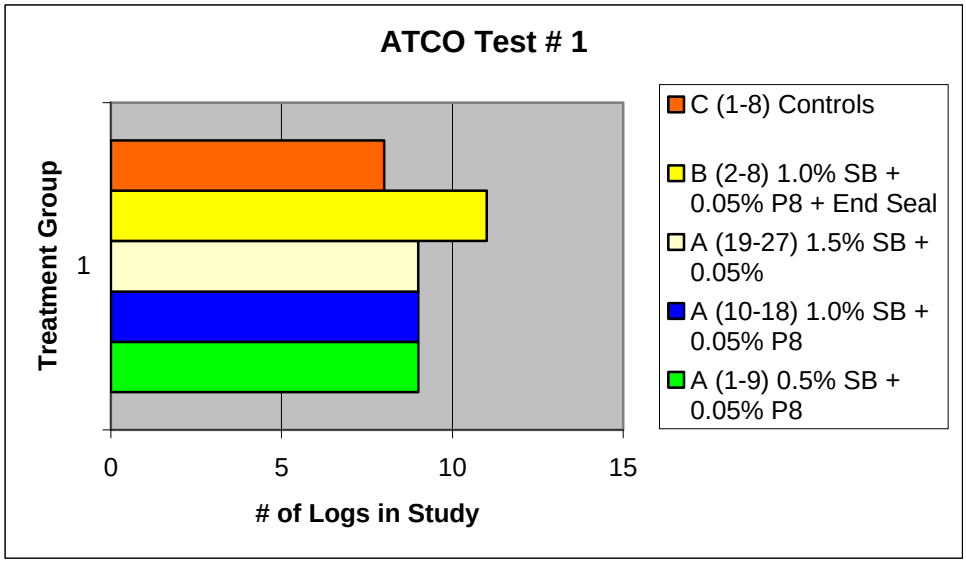


Figure 4.3

Overall Treatment Key and Log Group Identification for Test #1.

SB=Sodium bisulfite, P8=Prosan 8, End Seal= Anchorseal

Logs utilized in this preliminary study were loaded onto barge #7795 approximately the first week in April, 2007. On April 18th, 2007 the logs, once unloaded, were sorted on the yard at ATCO Mill D and then placed, by group, into production to further observe discolorations in both the logs and lumber.

Preliminary results of ATCO Test #1 reveal some peculiar observations. The chemicals used to treat these logs were deemed unsuccessful in preventing stain in the

three species, likely due to limited shelf life of the blended components. Initial contributing factors included the incompatibility of formulation components resulting in poor shelf-life prior to treatment of fresh log ends. Overall flow of formulations through the sprayer was unhindered except for some minor mechanical mishaps and human error. Only one log was lost in this experiment during transport to Mill D in Vicksburg,MS.

Preliminary testing using the method of spraying 4 different mixtures on 3 different species of hardwoods, and replicating each group for statistical analysis, was very time consuming, labor intensive, and somewhat logistically complex. Logs that are converted into lumber undergo 7 instances in which they are mechanically loaded/unloaded from fell time to stickered lumber. In this process, there are many opportunities for errors to occur. Further testing used fewer logs initially to narrow formulation concentrations and refine other variables.

b. Milling/Lumber Trial

Figure 4.4

Pre-Milling Identification of Test Groups Involved in Test #1 Located at ATCO Mill D Sawmill and River (Barge) Off-Loading Facility.

The purpose of this phase of the experiment was to process the test logs into lumber via Mill D processing machinery/method. The log end that was sprayed with the test formulations could not be evaluated for enzymatic stain control. Therefore, logs were milled into lumber to observe any preliminary fungal and non-biotic discolorations (e.g., iron stains) and to facilitate further drying of the lumber to facilitate the observation of enzyme-mediated discolorations.

Observations of the lumber that contained the log end that was end treated with these formulations was done by separating lumber into 5 different groups. Each group was placed onto the log deck, passed into the ring debarker, sent to the left side headrig, ripped, edged, graded, trimmed, and sorted. Anderson Tully computer operator Ellis

Screws wrote the software program to allot these groups into “test” groups that were placed into sorter-sling bays accordingly. The lumber was then partially packed, sent on a chain carriage to the stick stacker, stick stacked, transported to a covered holding area, and finally trucked to ATCO Mill K sticker shed for drying.

The lumber remained under the sticker shed until the end of May (5 weeks). Observations at that time noted that inadequate drying had occured, so the lumber was placed on the air-dry yard in run #958. Final observations were done on lumber from logs given each treatment including the untreated control group that were air dried and then planed which revealed both fungal and enzymatic discolorations.

This preliminary test showed that in this highly variable scenario, many factors can and will go wrong. End spraying the logs with certain paints for identification of treatment groups even yielded difficulty in observations inside the milling facility. While following the series of steps lumber undergoes to be produced, the lighter paint colors (yellow and white) were not easy to detect in the low light and dusty conditions inside the sawmill.

With respect to the efficacies of end-coat mixtures, the higher the concentration of the antioxidant sodium bisulfite, the less productive the anti-sapstain chemical was in preventing the colonization of logs by bluestain fungi (Figure 4.5). Factors influencing this seem to be incompatibility issues associated with the short shelf life of two stain-hindering treatments prior to use. The actual size of the test seemed very large and cumbersome for effective group tracking, spraying, and observation of the lumber throughout the system. Further testing was done to enhance these variables discussed in this test one.

Figure 4.5

Growth of Sapstain Fungi Observed in Lumber Cut from Logs Involved in Test #1.

Figure 4.6

Observations of Stain Development in Air-Dried Lumber Yielded from Test One Treated Logs After Skip-Planing.

Overall, test one went from initiation to processed lumber without many limiting catastrophes. The success of the flow of the process was due to the contributions of all employees involved at ATCO, and we are very much appreciative. Further testing

included smaller batch sizes, different chemical mixtures, protocol enhancement, and many other stain controlling methods.

2. Test 2

a. Green End

Figure; 4.7

Installation of Full-Scale Test #2 Located at Bell Island Just South of Greenville, MS.

Test two was conducted using freshly cut hackberry, red oak, and sweetgum logs felled near Greenville, MS and trucked to Bell Island log holding facility. A total of eighteen (18) logs, 2 hackberry-2 red oak-2 sweetgum/group, were end-treated with various combinations of sodium bisulfite, Prosan 8, and an end seal product to hinder stain degradation from occurring on the end log surfaces. In reference to the results of

ATCO test #1, the Prosan 8 concentration was doubled to test a possible of solution range enhancement. Also, as opposed to practices used in test one, the three chemicals were sprayed independently on the ends of the logs to try and prevent chemical incompatibilities as observed in test one.

Figure 4.8

Test #2 Being Tagged and End Treated Utilizing Freshly Felled Logs at River-Side Logging Facility Named Bell Island.

This test was used to accurately monitor raw material from treatment to milling processes. The test utilized 3 different groups of log treatments. Each group contained 6 logs consisting of 2 replicates of three hackberry, red oak, and sweetgum. The research participants included Mike Herrington with ATCO. Each log was sprayed with a Prosan 8/sodium bisulfite mixture within 24 hours of being felled (Figure 4.7). The treatment for

each group along with group identification is depicted in figure 4.9. An identification tag was placed on one end of each log by both Mississippi State University and ATCO.

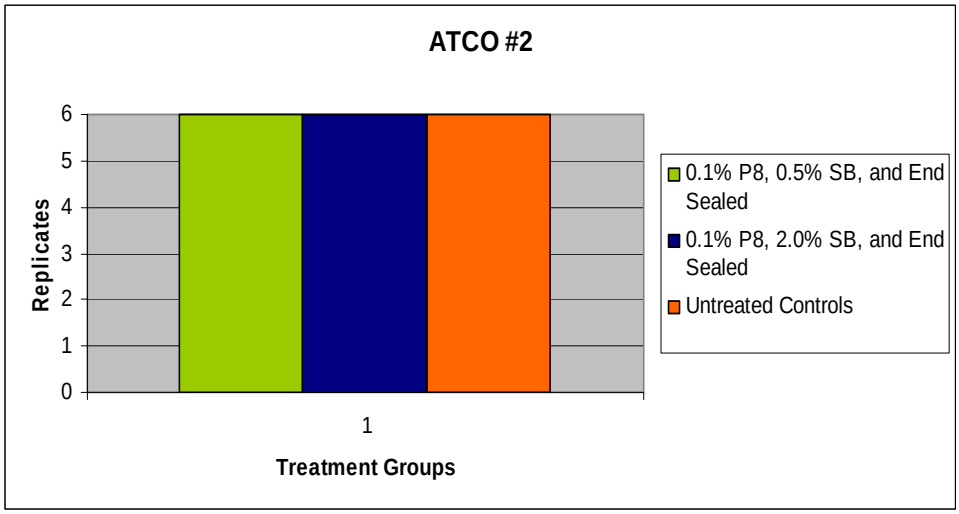


Figure 4.9

Overall Treatment Key and Log Group Identification for Test #2.

SB=Sodium bisulfite, P8=Prosan 8, End Seal= Anchorseal

Test two went very smoothly. The setup and test procedure used to treat these logs was far more effective and time efficient than in test #1. Log treatment was done effectively due to the smaller number of logs and a better stack orientation. The smaller batch size proved effective and non-interfering with production. Time of treatment application in test two from in the woods felling, hauling, and off-loading at an upriver log dump was considerably shorter, less than three hours.

In test two treating, tagging, flagging, and documentation were sufficient and done accordingly. The experiment went so well that the next test conducted used the same setup illustrated in this test. Further testing also was conducted with attention to

detail in reference to inventory management, hauling practices, concentration changes, and other important items dealing with southern hardwood harvesting.

b. Lumber Processing

Figure 4.10

Preparing to Mill Test #2 at ATCO Mill D Sawmill and River (Barge) Off-Loading Facility.

Test two was done to assure adequate observation of test materials at each stage of the milling process from debarking to stick stacking and further to air drying. Providing protection against stain was the primary concern, and monitoring these test samples as closely as possible provided valuable information in regards to test protocol as it affects the efficacy of treatments.

Figure 4.11 shows the segregation of each treatment group to be milled and bundled separately to evaluate chemical protection.

Figure 4.11

Treatment Group Identification of Test #2 Located at River-Side Log-Dump.

Logs were milled into lumber, and additional observations were done after air drying which helped to determine if stains occurred. Air drying usually takes approximately two months to adequately obtain a moisture content suitable to obtain final discoloration rating.

More discolorations in the logs/lumber occurred in ATCO test 2. Milling took place on June 19th, 2007 at ATCO Mill D while hackberry was being cut in regular production. This resulted in some of the test group hackberry being placed into sorter slings where regular production hackberry lumber was being sorted. Treatment groups were, in test one, colored accordingly to help keep them separate from regular production

items. Green-colored (0.01% P8 + 0.5%SB + Anchorseal) samples also became mixed in with orange-colored samples (untreated control group) in the same sorter sling at some point in the milling process. Because roughly 75% of the ends of these boards were double end trimmed, thereby removing the painted ends, total information gathering related to segregation was not possible due to the constraints of the sawmill system.

Figure 4.12

Appearance of Stain in Hackberry Lumber Treated with Prosan 8 the Current Treatment Used by ATCO.

Stain was observed in all treatment groups involved in this test. However, hackberry treated with the current chemical being used, Prosan 8,was more heavily stained than test #2 hackberry (Figure 4.12) treated with anti-sapstain mixed with an antioxidant . The conduct of test #2 was far less cumbersome than test #1 due to the smaller number of logs used. Some problems were seen on the lumber processing side of

the experiment and are ones that arose due to milling production and separation issues. Overall, things to be considered for future testing that would help reduce experimental error include avoiding end trimming (paint removal) or repainting if at all possible during test group lumber production, observe positive (Prosan 8) controls more closely, avoid test group mix-up, and many other factors that contribute to stain degradation.

Figure 4.13

Observation of Stain in Test #2 Samples During Milling Process Conducted at ATCO Mill D Facility.

3. Test 3

a. Raw Material Procurement/Treating

Figure 4.14

Installation of Test #3 Located at River-Side Log Dump Belle Island Just South of Greenville,MS.

Test three consisted of the same procurement and treating protocol used in tests one and two. Test three used the antisapstain AntiBlu XP, as in test two. Prosan 8 primarily contains propiconizole, whereas Anti-Blu XP contains IPBC (3-iodo-2-propynyl butylcarbonate), and BAC (benzalkonium chloride).

Figure 4.15

Installation and Treating of Test #3 at Bell Island.

Test three followed the same procedure of log end treatment as test two, and these two tests took place at the same log dump at Belle Island, MS. The experimental log-end treatment consisted of the sequential spray application of three chemicals: sodium bisulfite, Anti-Blu XP, and an end seal using three different sprayers to try and eliminate any unbalance in mixtures. Sodium bisulfite was used to control enzymatic gray stain, AntiBlu-XP was used to control mold/sapstain fungi, and the end seal was used to avoid excessive drying of log ends.

Very large (20 to 30” diameter) sweetgum and red oak logs were used in this experiment. Storage time at the river-side logging operation was reduced due to the fact that the derrick boat was actively loading logs for shipment to Vicksburg. Therefore, storage of these logs prior to milling took place at Mill D log yard.

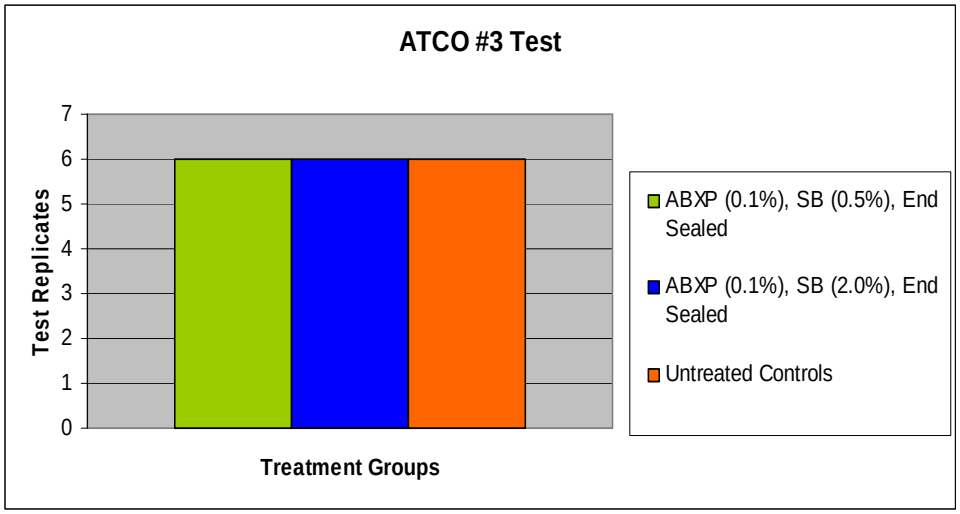


Figure 4.16

Replicates, Treatment Groups, and Chemicals/Concentrations Applied to Test #3.

ABXP= AntiBlu XP, SB=Sodium Bisulfite, End Seal=Anchorseal

Test three installation went far better than the two previous tests conducted on a full-scale. It took place at Bell Island, MS which already had sufficient numbers of each test species which were felled the morning of test three installation. The logs were end-treated, tagged, and flagged in less than two hours which left time for observation of inventory and some log scaling. Monitoring of this test group was done once the logs arrived at Mill D in Vicksburg. The flow of installation, treating of each end of the test logs, and transporting to Vicksburg was very effective and proved highly efficient. The time between felling and milling into lumber was quite a bit longer than in previous tests. The time frame in this experiment was nearly two months between initial felling and lumber production.

b. Lumber Production

During observation of the bulk-stored logs some interesting things arose. The ends of the logs on the bottom and pushed against the seawall (Figure 4.17) seemed very discolored, and decay was present in the log ends. Logs on top and away from this wall were not nearly as discolored and adversely affected when inspected more closely. The base of the wall itself is covered with old and rotting bark and chunks of multi-species debris. Also, that particular area seemed to retain water, containing wood/bark extractives, for an extremely long time, with absolutely no air flow. The actual milling of the lumber was then done by feeding experimental logs into the system while pecan (*Cary spp.*) production was taking place. Milling of experimental logs was done more efficiently since the current production in the Mill D was not one of the three species being utilized in the experiment.

Figure 4.17

Test #3 Being Stored Against the Seawall Prior to Milling Into Lumber to Observe Discoloration Growth.

As with the first two full-scale tests, this test utilized three different species, with each separated into three treatment groups. One group was an untreated control containing two replicates of each species. The other two groups contained two replicates of each species treated with two experimental mixtures of the three different chemicals being sprayed independently. There was a lower concentration of sodium bisulfite (0.5%) in one formulation and the other formulation contained a 2% concentration of sodium bisulfite. Unlike the first two experiments, this one utilized AB-XP, the anti-sapstain product, to control mold and sapstain fungi on the log ends.

Figure 4.18

Identification of Milled Test #3 Treatment Groups.

Test three was done after a storage time of two months at Mill D in Vicksburg. This extensive time, and inadequate anti-sapstain concentration issues, such as anti-sapstain and antioxidant pH's, directly related to less prevalent discolorations in

treatment groups versus the controls observed in the log ends before actual milling took place. The logs located against the seawall were severely discolored, likely due to inadequate drainage, wood/bark extractives, material decomposition around the logs, and air flow issues associated within the immediate environment around the logs.

Once milling took place, other issues (eg, not allowing production logs to be milled between test groups) arose that had been previously observed. This oversight led to test boards, from a given treatment group, being placed into two groups. Green treatment group (0.1% ABXP + 0.5% SB + Anchorseal) boards were placed into the orange treatment (untreated controls)group's board sorter sling. This problem was first observed and cited in test two and is compounded when painted ends of boards are trimmed off during the milling process.

Figure 4.19

Mixing of Test #3 Treatment Groups Post-Milling.

Test three revealed even more interesting facts/observations than the two previous full-scale tests. Along with lengthy storage time, these logs were placed in an area with poor drainage and covered in debris that proved very effective in stimulating the discoloration in these southern hardwood species. Chemical concentration inadequacies accounted from some of the discolorations observed (Figure 4.20) but most were directly attributable to the environment near the seawall (poor airflow) and lengthy storage practices. It is recommended that log storage time be limited to four weeks.

Figure 4.20

Extensive Discoloration Observed in Test #4 Due to Storage Facility Drainage and Time of Storage.

4. Summary of Tests 1-3

Test 1

With experiment #1 many observations gave hints whether to repeat or discard some previous actions taken. Testing of southern hardwood logs in a manner which does not affect production is quite challenging. Test one revealed that batch size and numbers of chemical formulation/concentrations had to be simplified and minimized to accurately observe and later alter details in future experiments. Tests utilizing cumbersome groups of formulations, and trying to achieve adequate replicates, is extremely time consuming and labor intensive when the tests are done on location in the Southeast.

Other details including the spraying of logs, outside on the log yard, with certain colors to obtain segregation of test groups were not visible inside the low-light conditions of the sawmill and grading deck. Also, pink flagging attached to the ends of the logs immediately after end-treating helps forklift operators and Prentice loaders/unloaders identify and segregate logs on the barges, log yards, and sawmill debarker decks. The chemical mixtures utilized in this test were no effective in preventing discolorations.

Test 2

Treating, tagging, flagging, and documentation were sufficient and done accordingly in test two. The experiment went so well that test three mirrored the simplified process. This improvement can be attributed to being less cumbersome than test one because utilization of smaller number of logs and chemical mixtures (treatment groups). One exception in test two was that the anti-sapstain product, Prosan 8, was

replaced by an Arch Chemical product called Anti-Blu XP. Microbial and enzymatic stain was observed in all treatment groups involved in test two. However, hackberry treated with, Prosan 8 in test one had more heavy microbial stain than test two hackberry (Figure 4.12). However, this difference may have been due to the short shelf life of the mixture. Some problems were seen on the lumber processing side of the experiment and are complications that arose due to milling production and separation issues. Overall, considerations for future testing include avoiding end trimming (paint removal) or repainting if at all possible during test group lumber production, observe positive Prosan 8 controls more closely, avoiding test group mix-up, and addressing many other factors that contribute to stain degradation. Additional testing also should be better monitored inventory management, hauling practices, concentration changes, and other important items dealing with southern hardwood harvesting.

Test 3

Test three revealed even more interesting facts/observations than the two previous full-scale tests. Along with lengthy storage time, these logs were placed against a barrier that proved very effective in stimulating discolorations in these southern hardwood log species. Test groups were again mixed while being produced into lumber at the sorter slings and then placed on sticks and bulk stacked. Chemical concentration inadequacies accounted from some of the discolorations observed (Figure.3.6) but the majorities were directly attributable to the seawall (poor airflow) and lengthy storage practices. It is recommended that log storage time be limited to four weeks.

5. Test 4

a. *End Treating*

Figure 4.21

Installation of Test #4 Utilizing only Hackberry Logs Located at River-Side Log Dump Near Ripley, TN.

Test four was done quite differently than the other experiments. This experiment utilized only one species of southern hardwoods, hackberry. Other differences involved the actual test groups segregated in the experiment. One group consisted of only true untreated controls that were cut and tagged within the same morning. A group of positive controls was the hackberry logs treated by ATCO employees with Prosan 8 (varying %) and a pink dye added for quality control purposes. The final group involved in this experiment was log ends treated with the antioxidant BHT, let stand for 3 hours, and then topped with a heavy coat of the end seal Anchorseal. This test took place just West of

Ripley,TN about 1.5 hours North of Memphis. Due to the constraints of logging practices and silviculture, production took place at this far north region of the company's property holdings.

Figure 4.22

Derrick Boat #13 with Work Barge Stationed at River Mile Marker #753.

Installation of this test went rather easily due to the logging area approximately 20 minutes due South. The log dump located on the Tennessee side of the river was where this test was actually installed. Another site was being utilized on an island a few miles north of the Derrick boat.

Figure 4.23

Test #4 Installed with 3 Unique Test Groups Consisting of Positive Controls (Prosan 8 Treated), BHT Plus Anchorseal, and True (untreated) Controls.

This particular test revealed some interesting data that were observed during milling occured. Other than travel constraints this test went very well during installation and documentation.

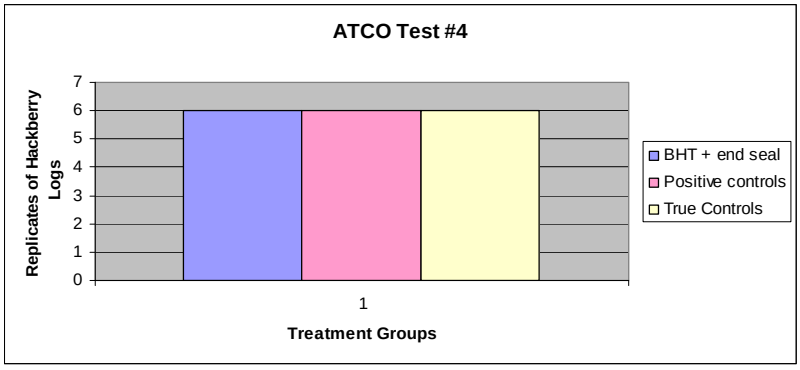


Figure 4.24

Depicting Treatment Groups, Replicates, and Treatment Applied to Test #4.

The logs were off-loaded at Vicksburg rock yard 8/17/2007. Mike Herrington observed on 8/20/2007 that the ends of the Z group (true controls) looked brand new. The X group (BHT + End Seal) appeared very black on the ends and the Y group (Prosan 8 + End Seal) also had discolorations present. The procedure conducted cut a disc, approximately one inch thick, off of one end of the logs in group Y and observed whether stain penetrated into the sapwood. Pictures and discs cut from logs from 2 test groups revealed microbial growth inside the end sealed hackberry logs (Figure 4.25).

Figure 4.25

Left Showing Cut Disc of Treatment Group. Right Side Showing Treatment Group, Before Disc Cut, Compared to True Control Group Above.

The main cause for treatment group X (BHT plus Anchorseal) to appear discolored is due to the fact that the end seal trapped moisture inside the log and no anti-microbial was present. This moisture, coupled with spores that landed on the log even

just hours after felling, developed intense microbial activity inside the protective end-seal layer. As for the untreated controls, which also contained no anti-microbial, were exposed to intense heat inside the barge can cause a “sterilizing” effect on the exposed sapwood cells as well as rapid drying resulting in checks and splits on the ends of these hackberry logs. Although treatment group Y (BHT and End Seal) was stained by microbial activity, the logs did not have the end degradation of the positive and true untreated control groups (Figure 4.26).

Figure 4.26

Checks and Splits in Positive (Prosan 8) and True (Untreated) Controls Due to Rapid Drying

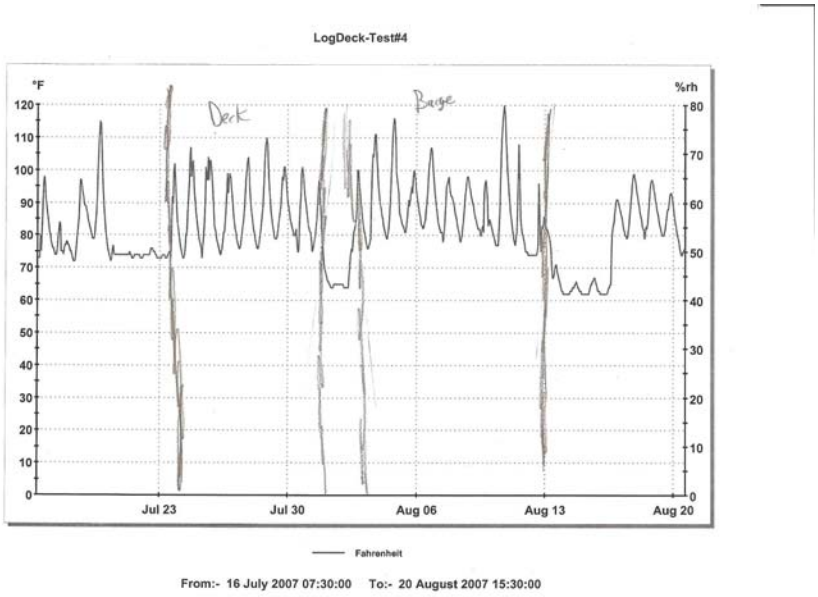


Figure 4.27

Graph Showing Temperature Achieved Before and at the Beginning of Test #4.

b. Lumber Production

Figure 4.28

Unloaded Barge at ATCO Mill D in Vicksburg, MS.

This test was conducted using 18 logs total, consisting of 3 different treatment groups, and 6 hackberry log replicates per treatment group. Positive control (Prosan 8) test group, painted with blue, was first loaded on the debarker rack and then followed by the "green" (BHT plus Anchorseal), and finally the "orange" test group (true untreated controls). Tally sheets were generated which depicted percentages of grade and actual footage in each group.

As in other tests conducted at ATCO Mill D, logs could not be placed along the seawall pre-milling for any length of time without deterioration. That area of the yard (Figure 4.29) is a breeding ground for molds, stains, and decay fungi along with standing water to further accelerate the process of fungal growth. Perhaps ATCO should construct a water drainage system at the base of the wall to deter some of the problematic situations or deem this area strictly for storage of lesser grade logs.

Figure 4.29

Test #4 Treated Logs Located Along the Seawall at ATCO Mill D.

Figure 4.30

Test Log Illustrating the Effects of Placing “any” Species of Hardwoods Along the Seawall at Mill D

Test four went very well during the spray application stage up to milling. This can be partly attributed to extreme heat, no fungicide added in that particular test group, and sealing the ends of the logs after a duration of a few hours

6. Test 5

a. Experimental End Treating

Figure 4.31

End Treating of Hackberry Logs in Test #5 Located South of Paine Lake in Yokena, MS
.

This experiment was designed to refine end treating on southern hackberry. The anti-sapstain product (AntiBluXP) was added to the treatment in test four to inhibit microbial growth on the ends of the test logs. The logs utilized in test four were sprayed just hours after felling and, once end sealed, the moisture was locked in which permitted fungi to develop and grow throughout the log. Test five was structured to have a group treated with AntiBlu XP with end sealant, and another treatment group treated with the

antioxidant sodium bisulfite and end sealed plus a third group consisting of true untreated controls.

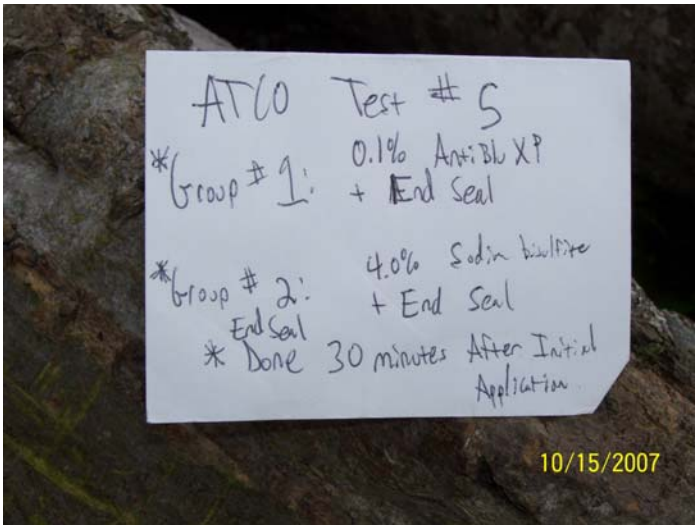


Figure 4.32

Treatment Identification and Application Details for Test #5.

Once the logs were procured, they were sprayed at the loading dump near Paine Lake near Yokena, MS. A preliminary treatment of AntiBlu XP was applied to the ends of the logs in test group A. Sodium bisulfite was added immediately to the ends of logs in, group B. These chemicals were left to suck in for thirty minutes and then end sealed with Anchorseal to help prevent rapid checking and splitting. Once treated, tagged, and flagged, these logs were trucked north to Mill K at ATCO Vicksburg, MS. Once at the Mill K site the logs were tagged and scaled by ATCO personnel and set directly behind the log yard office to undergo a mock-field scenario to mimic up-river operations.

Test five field work went exceptionally well due to location and help from Scott Carraway. He aligned the log placement as a segregated group away from skidding and log cutting operations/activities. New spraying rigs were introduced in this experiment that proved more efficient in energy used by operator and highly satisfactory in covering the freshly cut ends of the logs. The thirty minute stand-alone time for each the AntiBlu XP and the sodium bisulfite was done to let the chemicals be uninhibited by the end seal, and also allow any preliminary diffusion to occur.

Figure 4.33

Logging Crew Measuring and Cutting Mill-Sized Logs Pre-Loading.

b. Lumber Production

Figure 4.34

Test #5 Logs Arrival @ Mill D. *Milling Did **NOT** Take Place Until 10/26/2007 (11 days) Due to Scheduling and Sorter Availability.

Test five was designed to test log discoloration control associated with different chemicals and application times. Preliminary evaluation of this experiment was done pre and post milling. Pictures depicting heavy discolorations and moderate to light end drying and splitting were taken just before the logs were fed into the debarker and subsequently milled into lumber. (Figure 4.34)

As depicted in Figure 4.34, the logs were segregated into three different groups and an identifying color was sprayed onto the cross-sections of each log to designate the experimental group to which it belonged. Color spraying to determine test groups was

done on October 15th, 2007. Nonetheless, milling of test five logs took place on October 26th, 2007, eleven days after being transported to the mill site (Figure 4.35).

A.
Test #5 Logs Being Forked to Debarker.

B.
Debarked Logs Entering Mill.

Figure 4.35

Test #5 Logs Being Forked to Debarker.

Neither biocide tested was effective in preventing discolorations in hackberry logs. Discolorations in logs end-sprayed with sodium bisulfite indicates that the discoloration is fungal rather than enzyme-mediated. Figure 4.36 illustrates these discolorations.

A.
Orange (Control)

B.
Green (0.1% Prosan 8)

C.
Blue(4% Sodium Bisulfite)

Figure 4.36

Test Groups During Milling Process.

The lumber production portion of this particular experiment went well once finally initiated. Timing and production schedules were a hindrance in testing end treatments in this particular system. Other problems we have seen such as storing logs along the seawall, paint colors, and end trimming together make experiment action somewhat challenging. Regardless of these technical issues, continuous testing is recommended. This protocol that has been refined and utilized for 5 tests now seems to be an optimal way to test logs in this particular scenario.

7. Test 6

a. End Treatment

Figure 4.37

Installation of ATCO Test #6, October 15th, 2007.

Test six was designed to test the efficacy of the biocide AntiBlu XP and the water repellent product Cedar Shield during in-field use applied to southern hackberry. End sealers that are wax-based have been tested on Southern species with success in preventing rapid drying (end checking and splitting). This product is solvent-based and used commonly in exterior applications to shed water from such items as decking boards, window and door frames, and other heavily weathered exterior products.

Arch chemical's AntiBlu XP, sodium bisulfite, and Cedar Shield were tested on Southern Hackberry in mid October, 2007. The process consisted on an initial coat of 4.0% sodium bisulfite onto fresh (felled ~1 hour prior to treatment) hackberry logs. Initially the AntiBlu XP product (@ 0.1% solution wt./wt.) was mixed 50/50 with the Cedar Shield product. It was then applied to the hackberry logs thirty minutes after the initial coat of sodium bisulfite. Thirty minutes "delay" time was done to allow the sodium bisulfite to diffuse somewhat into the logs. Once end treated, the logs were marked for identification at the milling stage. Orange was used to verify logs that were untreated controls in this particular experiment. Green was used to illustrate the test group. This is depicted in figure 4.38.

A.
Log Groups Involved in ATCO Test #6.

B.
End Flagging to Help Operators Verify Test Logs for Yard Segregation.

Figure 4.38

Log Groups Involved in ATCO Test #6.

Logs involved in test six were attempted to be milled on several occasions throughout December 2007, but due to end-of-the-year production constraints and employee holidays this was not completed. Below are pictures of the logs prior to the holidays (Figure 4.39).

A.
Test #6 Mid-November @ Mill K Log Yard Facility Vicksburg,MS.

B.
Control Log Illustrating Discolorations Roughly 1 Month After Segregated.

Figure 4.39

Test #6 Mid-November @ Mill K Log Yard Facility Vicksburg, MS.

8. Tests 1-6

a. Summary of Results

Test #1

Table 4.1

ATCO Test #1 Treatment and Identification Protocol.

Test #1	**Installed: 3/7/2007**	**Milled: 4/18/2007**	
Group ID	**Treatment**	**ID Paint**	**Group**
A (1-9)	0.5% SB + 0.05% P8	*Green*	A (1-9)
A (10-18)	1.0% SB + 0.05% P8	*Blue*	A (10-18)
A (19-27)	1.5% SB + 0.05% P8	*White*	A (19-27)
C (1-8)	Controls	*Orange*	C (1-8)

SB=Sodium Bisulfite, P8= Prosan 8, ES= End Seal: Anchorseal

A.
A (1-9)
0.5% SB + 0.05% P8
Slight Discoloration

B.
A (10-18)
1.0% SB + 0.05% P8
Slight Discoloration

C.
A (19-27)
1.5% SB + 0.05% P8
Moderate Discoloration

D.
Controls C (1-8)
Untreated

Moderate Discoloration

Figure 4.40

Discoloration Ratings in Test #6.

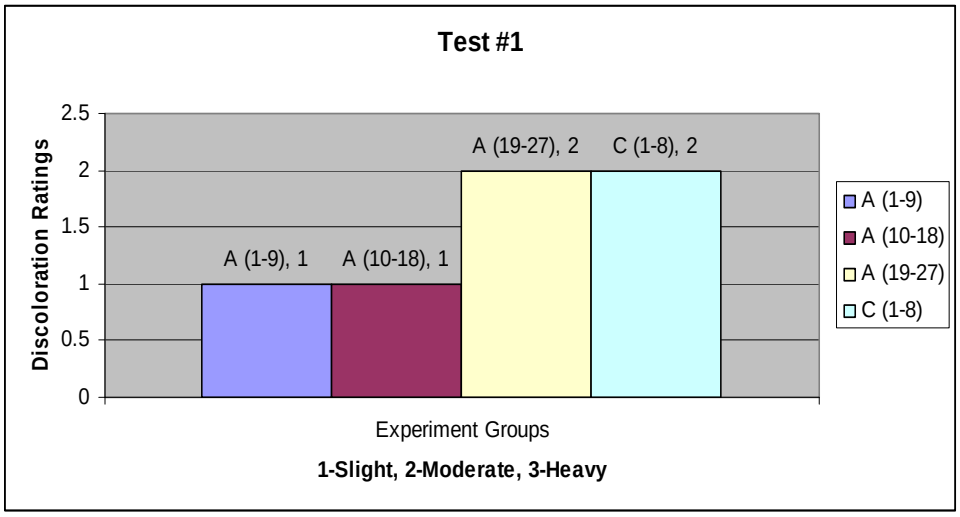


Figure 4.41

Test #1 Discoloration Rating on Lumber Derived from Test Logs.

Group (A 1-9)= 0.5% SB + 0.05% P8; Group (A 10-18)= 1.0% SB + 0.05% P8; Group (A 19-27)= 1.5% SB + 0.05% P8; Group (C 1-8)= True Untreated Controls.

Test #2

Table 4.2

ATCO Test #2 Treatment and Identification Protocol.

Test #2	**Installed: 5/14/2007** **Milled: 6/19/2007**	**ID Paint**
A (1-6)	0.5% SB + 0.05% P8 + ES	Green
B (1-6)	2.0% SB + 0.05% P8 + ES	Blue
C (1-6)	Controls	Orange

SB=Sodium Bisulfite, P8= Prosan 8, ES= End Seal; Anchorseal

A. Current ATCO Treatment

B. Test Groups

C. Controls

Figure 4.42

Discolorations Illustrated in Test #2 on Freshly-Cut Lumber.

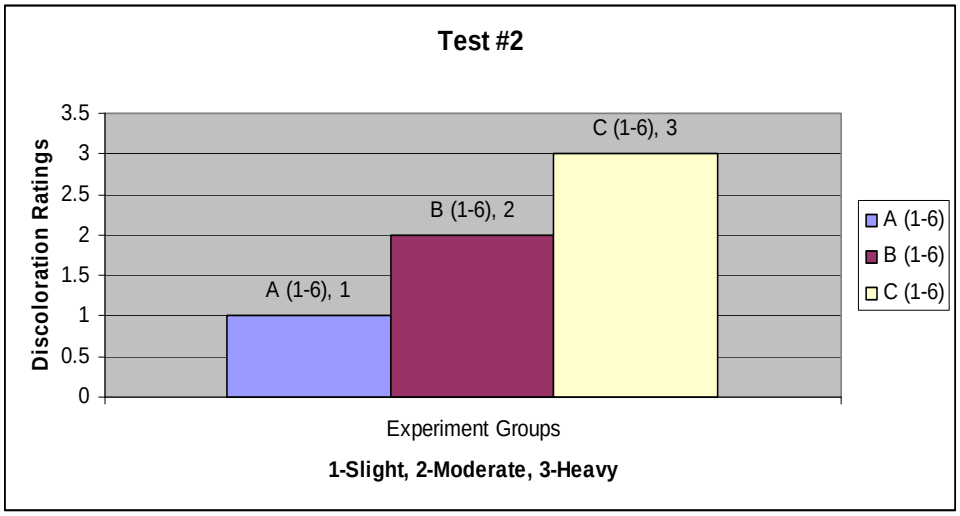


Figure 4.43

Test #2 Discoloration Rating on Lumber Derived from Test Logs.

Group (A 1-6)= 0.5% SB + 0.05% P8 + Anchorseal; Group (B 1-6)= 2.0% SB + 0.05% P8 + Anchorseal; Group (C 1-6)= True Untreated Controls

Test #3

Table 4.3

ATCO Test #3 Treatment and Identification Protocol.

Test #3	**Installed: 5/29/2007** **Milled: 7/25/2007**	
Group ID	**Treatment**	**ID Paint**
A (1-6)	0.01% ABXP* + 0.5% SB+ ES	*Green*
B (1-6)	0.01% ABXP* + 2.0% SB+ ES	*Blue*
C (1-6)	Controls	*Orange*
* ABXP= AntiBlu XP, Arch Chemicals		

ABXP=AntiBlu XP; SB= Sodium Bisulfite; ES= End Seal; Anchorseal

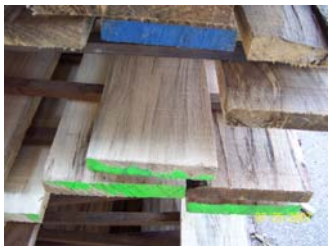
A.
Seawall @ Mill D

B.
Extensive Degradation caused by Seawall

C.
Mixing of Experiment Groups

Figure 4.44

Test #3 Complications and Errors at ATCO Mill D Facility.



A.
A (1-6) 0.5% SB + 0.01% ABXP + Anchorseal
Moderate Discolorations

B.
B (1-6) 2.0% SB + 0.01 ABXP + Anchorseal
Moderate to Heavy Discolorations

C.
Untreated Controls C (1-6)

Heavy Discolorations

Figure 4.45

Discolorations Illustrated in Test #3 on Freshly-Cut Lumber.

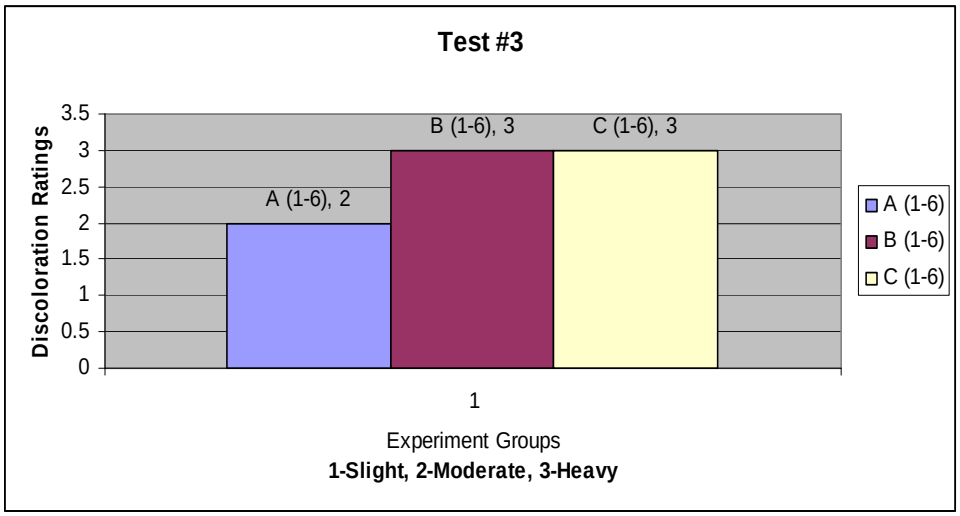


Figure 4.46

Test #3 Discoloration Rating on Lumber Derived from Test Logs.

Group (A 1-6)= 0.5% SB + 0.01% ABXP + Anchorseal; Group (B 1-6)= 2.0% SB + 0.01% ABXP + Anchorseal; Group (C 1-6)= True Untreated Controls

Test #4

Table 4.4

ATCO Test #4 Treatment and Identification Protocol.

Test #4	**Installed: 8/1/2007** **Milled: 9/27/2007**	
Group ID	**Treatment**	**ID Paint**
X (1-6)	3.0% BHT* + ES	*Green*
Y (1-6)	(+) controls; 0.05% P8+ ES	*Blue*
Z (1-6)	True Controls	*Orange*
*Butylated hydroxy Toluene 3 Hour Stand Between Initial Chemical Application and ES Application		

BHT=Butylated Hydroxy Toluene; P8= Prosan 8; ES=End Seal; Anchorseal

A.
Seawall @ Mill D

B.
Extensive Degradation

Figure 4.47

Extensive Degradation on Test Logs Caused by Seawall Area Containing Bark/Extractives.

A.
X (1-6) 3.0% BHT +
Anchorseal
Heavy Discoloration

B.
Y (1-6) 0.05% P8 +
Anchorseal
Moderate Discoloration

C.
Untreated Controls
Moderate Discoloration

Figure 4.48

Discolorations Illustrated in Test #4 on Freshly-Cut Lumber.

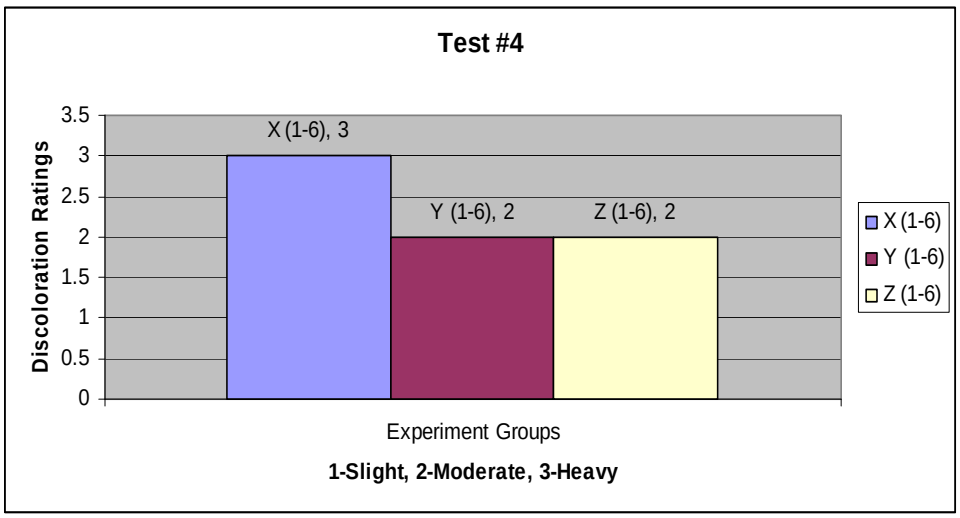


Figure 4.49

Test #4 Discoloration Rating on Lumber Derived from Test Logs.

Group (X 1-6)= 3.0% BHT; Group (Y 1-6)= 0.05A% P8 + Anchorseal; Group (Z 1-6)= Untreated Controls

Test #5

Table 4.5

ATCO Test #5 Treatment and Identification Protocol.

Test #5	**Installed: 8/24/2007** **Milled: 10/26/2007**	
Group ID	**Treatment**	**ID Paint**
X (1-5)	0.1% P8 + ES	*Green*
Y (1-5)	4.0% SB + ES	*Blue*
Z (1-5)	True Controls	*Orange*
30 minute Stand Between Initial Chemical Application. and ES Application.		

P8=Prosan 8; SB=Sodium Bisulfite; ES=End Seal; Anchorseal

A.
X (1-6) 0.1% P8 + Anchorseal
Moderate Discolorations

B.
Y (1-6) 4.0% SB + Anchorseal
Heavy Discolorations

C.
Untreated Controls Z (1-6)
Heavy Discolorations

Figure 4.50

Discolorations Illustrated in Test #5 on Freshly-Cut Lumber.

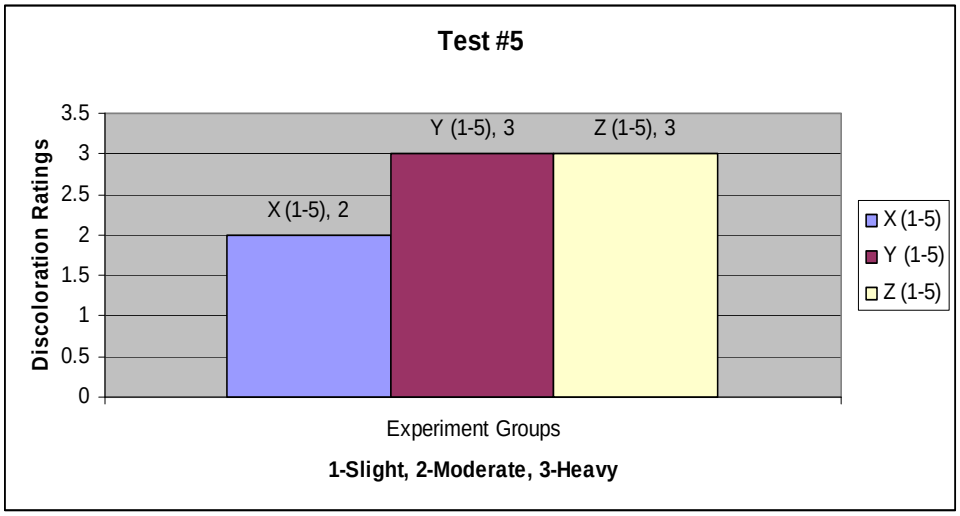


Figure 4.51

Test #5 Discoloration Rating on Lumber Derived from Test Logs.

Group (X 1-6)= 0.1% P8 + Anchorseal; Group (Y 1-6)= 4.0% Sodium Bisulfite + Anchorseal; Group (Z 1-6)= Untreated Controls

Test #6

Table 4.6

ATCO Test #6 Treatment and Identification Protocol.

Test #6	**Installed: 10/15/2007 Milled: N/A**	
Group ID	**Treatment**	**ID Paint**
Test	0.1% ABXP + 4.0%SB + CS*	*Green*
Control	Untreated	*Orange*
	*Cedar Shield, ES=End Seal	
30 Minute Stand Between Initial Chemical Application and ES Application ABXP= AntiBlu XP; SB= Sodium Bisulfite; CS= CedarShield		

A.
Installation of Test #6

B.
2-Month Check-up; Notice Relatively no Checks/Splits & Minimal Surface Discoloration.

Figure 4.52

Installation of Test #6 Which Utilized 1 Control Group and 1 Treatment Group (0.1% ABXP + 4.0% Sodium Bisulfite + Cedar Shield)
Located at Paine Lake near Yokena,MS.

Overall Summary

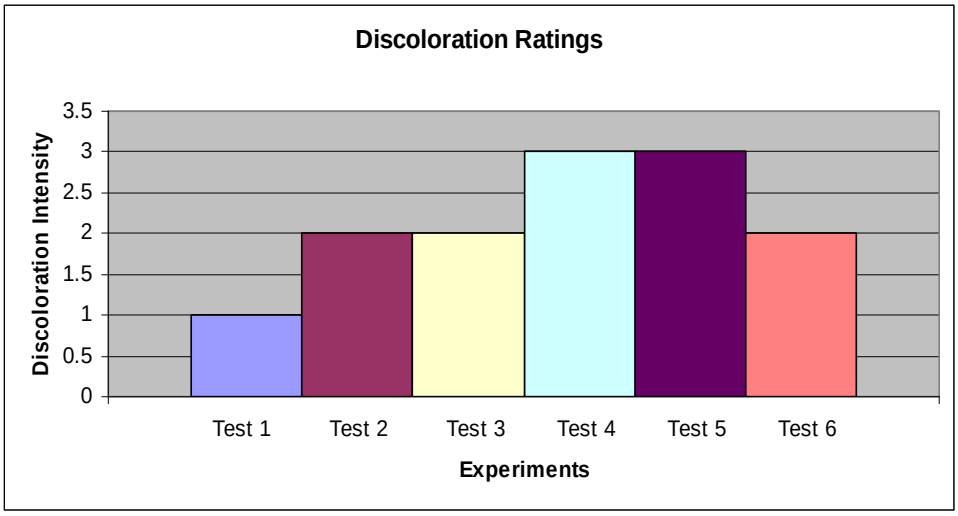


Figure 4.53

Overall Discoloration Ratings for Tests 1-6.

1= Slight Discoloration, 2= Moderate Discoloration, 3= Heavy Discoloration

b. General Discussion

Data generated from these six experiments conducted at ATCO up-river logging sites reveal some interesting observations. In most instances the log end-treatment mixtures created and applied did not effectively keep freshly-cut logs from discolorations under an eight week time scope. Compatibility issues of the treatment component are deemed the underlying problem. The variables causing incompatibility include pH differences (4.4-8.0), density (1.03 g/cm3- 1.48 g/cm3), and concentration ratios (0.01% to 8.0%) depending on product/application. Discolorations of both microbial and enzyme-mediated origin occurred on the test samples (logs) under the harsh southern climate (90 degree + temperatures & 80% + relative humidity) between the months of May through October.

Logs in tests one and two were barged to Vicksburg, MS and unloaded on the river-side temporary storage yard dubbed the “Rock Yard”. This particular area was being utilized due to equipment failure at the regular barge off-loading facility, Mill D. Therefore, experiments one and two were not exposed to the seawall holding area where logs in tests three, four, and 5 were stored. The seawall is a low-lying, air-blocked, poorly-drained area full of woody extractive (bark & wood chunks) debris that slow promotes slow log-end drying. Active fungal growth in that warm and moist area quickly develops on freshly-felled and stored hardwood logs. The utmost attention should be paid to that particular area for remediation purposes.

Logs in tests four and five had less checking/splitting but more discolorations. Reasons for this include: season (August), barging (open-air and high heat), and mill

scheduling that prevented milling from occurring when scheduled. A more specific reason is the anti-sapstain concentration being applied. Sales representatives from two different companies recommended a range from 0.05 to 0.1%. The further up the range the lower the pH (from 6~7 to 4.4=lowest) which causes an imbalance in the treatment mixtures (sodium bisulfite ~4.7 pH). All experiments began with concentrations being around 0.05% but this was proven (tests 1-4) far too weak to keep stain fungi from developing under the conditions of these tests. Further testing will be done in the spring of 2008 that will utilize 0.1% anti-sapstain formulations.

Logs in test six had less checking/splitting and discolorations than in tests one through five when observed two months after treatment application. These observations may be slightly misleading due to seasonal variations (October-December), storage facility (Mill K log yard), and end sealer (Cedar Shield). Typically, seasons of the year determine the extent that southern hardwood logs discolor. Literature and industrial experience deems May 15th through October 15th the window at which the "most" discoloring occurs. Mill K storage facility (log yard) is a wide-open, well-ventilated facility that has areas of densely-packed gravel foundations. Experiment six test samples were located on such an area and were exposed to relatively no compounding of dirt/sand/woody extractive on the cross-sections. The Cedar Shield product mixed well with the anti-sapstain just prior to application on freshly-felled hackberry logs. Logs treated with Cedar Shield also had fewer indications of rapid drying of the cross-sections and relatively low ratings of discolorations. Further testing with Cedar Shield will be conducted spring of 2008.

CHAPTER V

CONCLUSIONS

The field-work conducted during this research project illustrated the extensive challenges that hardwood lumber producers face in the production of marketable, clear/sound, and stain-free products. Discolorations decrease possible revenues generated and can develop quite quickly when variables such as adequate temperatures (90 + Fahrenheit), oxygen, nutrients (wood) thrive, and water (green logs) are all present. These factors create conditions necessary for organisms to propagate on green logs/lumber. Two casual agents highlighted in this research included stain fungi and enzyme-mediated discolorations. Experiments disclosed that application of mixtures of incompatable chemicals is quite troublesome, stringent log inventory management is a must, and the minimization of time between felling and lumber production is an important factor in preventing/controlling discolorations on fresh Southern hardwood logs/lumber.

The efficacies of chemical “cocktails” or mixtures are based on many factors composed of many limitations. Variables must work together for the mixtures to perform effectively in the field. Chemicals may perform well independently, but the mixing of chemicals may create ineffective treating solutions. Factors such as pH, shelf-life, application methods, worker safety, intended use, environment in which mixtures will be used, and many other traits/characteristics come into play that can affect the efficacy of

mixtures. This particular research project utilized three different types of commercially available chemical categories including: anti-sapstains (Prosan 8 & AntiBluXP), antioxidant (sodium bisulfite), and end sealer/water repellent (Anchorseal & Cedar Shield).

Anti-sapstain products perform well against mold and stain fungi once sprayed on the ends of logs or by dipping green lumber. The easiest and safest product tested was Arch Chemical's AntiBlu XP which consists of 5% IPBC and 5% propiconizole as the active ingredients. Sodium bisulfite was tested and proven to be effective in preventing enzyme-mediated discolorations in southern red oak and hackberry. End sealer products like Anchorseal effectively protect, for some time, logs end or cross-section from rapid drying which typically causes checking and splitting. The application of the end sealer should be generous on each end of the log. These chemicals have been researched and approved for purposes specific to each, but combining the chemicals into a "DO-ALL" has been unsuccessful. Further testing will be conducted using the "epoxy" method (mixing two chemicals at the time of application), higher concentrations of the anti-sapstain products, and a different water repellent (Cedar Shield).

Inventory management is a company-wide issue and is deemed important. Workforce development is a major key in inventory management to be effective and operate smoothly. A "protocol" or procedure in which raw materials are acquired, stored, and utilized with maximized efficiency and minimized time should be developed. Log procurement is the first step; trees being felled should be transported to holding areas without delay. Once the logs are bulk stacked, log-run orientation techniques, such as segregation of sensitive species for easier treatment application and barge loading should

be utilized. Trucking/barging should be scheduled in accordance with the sawmill's milling schedule. Problems arise if communication between each level of the operation is not achieved prior to raw material arrival. Opening sawmills up to receive raw material quicker not only results in more efficient production (increased bf), it keeps raw materials from degrading by either discolorations and/or checks and splits. Inventory management is essential in quality control development, and large production facilities must take time to enhance their particular systems to accommodate raw materials better, cleaner, and faster.

Excessive time on the ground is the single most important factor raw material producers must fight. Things spoil and lose anticipated value once the "spoiling" occurs. Means of reducing the impact of the time factor, some listed previously, include chemical application to log ends to extend storage time, log stack orientation which helps inventory management schemes, and open communication. Effective communication company-wide is vital for raw materials to be converted into quality products efficiently in a reduced time. Time constraints can be avoided if each facet of the operation is effectively communicated both vertically (managers, supervisors, programmers) and horizontally (scalers, forklift operators, loggers). If the time from felling to milling is reduced, logs/lumber can retain value and be sold competitively on the hardwood market.

Recommendations

Revised production systems illustrated below are suggested as means by which ATCO could increase their production of high-grade lumber without increasing log through-put.

Mill D

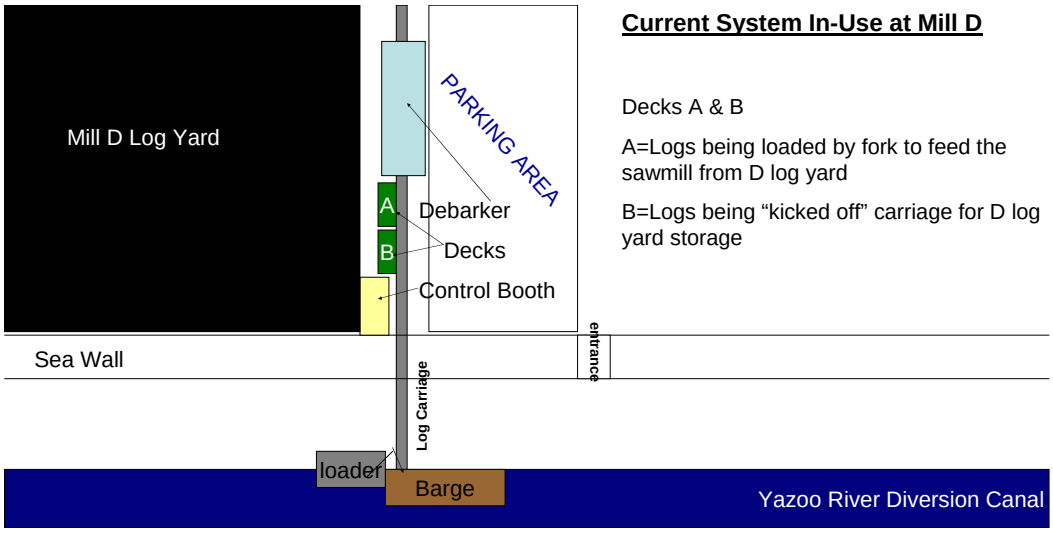


Figure 5.1

Current Unloading Configuration at ATCO Mill D River-Side Sawmill Facility Located in Vicksburg,MS.

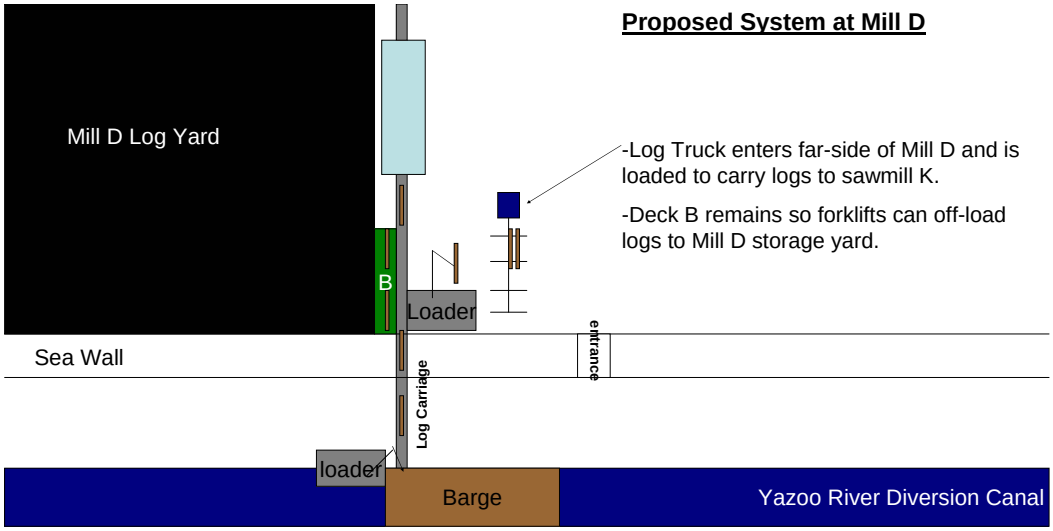


Figure 5.2

Proposed Unloading Configuration at ATCO Mill D River-Side Sawmill Facility Located in Vicksburg, MS.

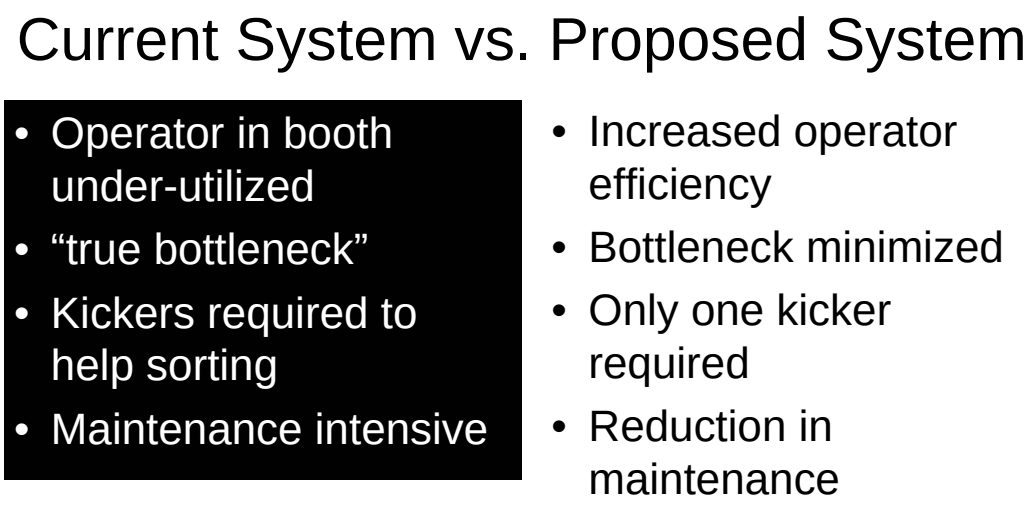


Figure 5.3

Current System Constraints and Proposed System Enhancements of Mill D River-Side Sawmill Facility Located in Vicksburg, MS.

Mill K

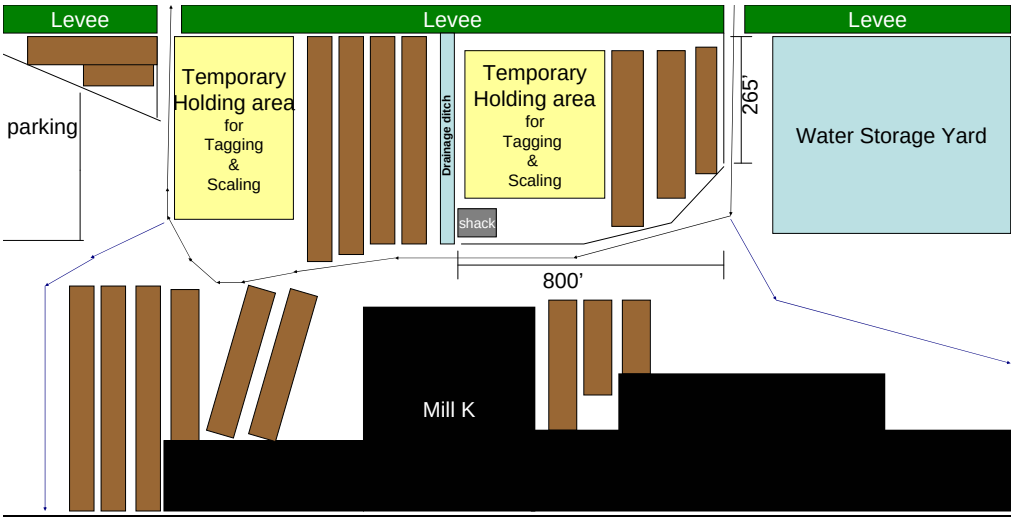


Figure 5.4

Current Log Inventory System in Use at ATCO Mill K Facility Located in Vicksburg, MS.

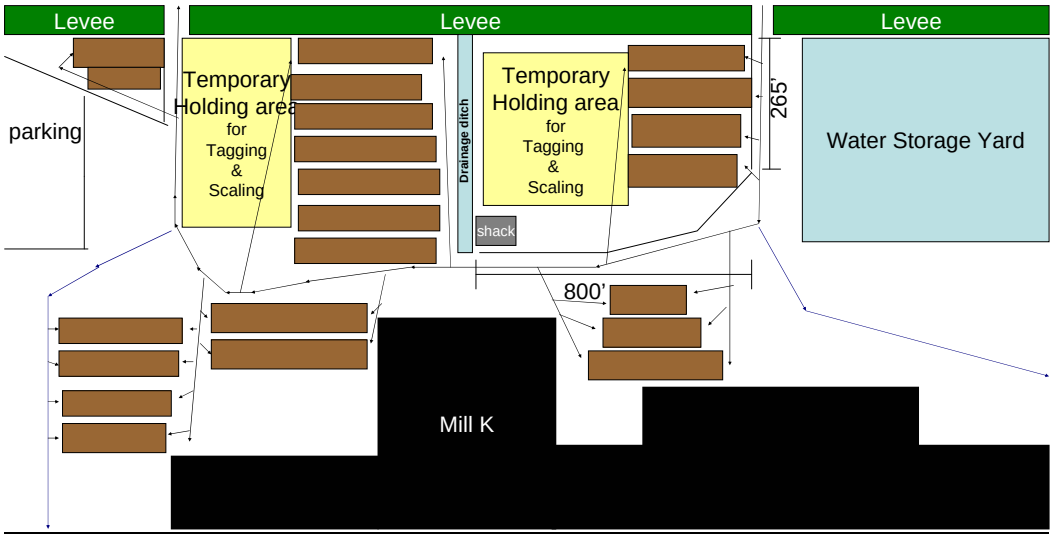


Figure 5.5

Proposed System: Improved Availability (FIFO) of Logs through Stack Re-alignment at Mill K Facility Located in Vicksburg, MS.

Up-River Logging Sites

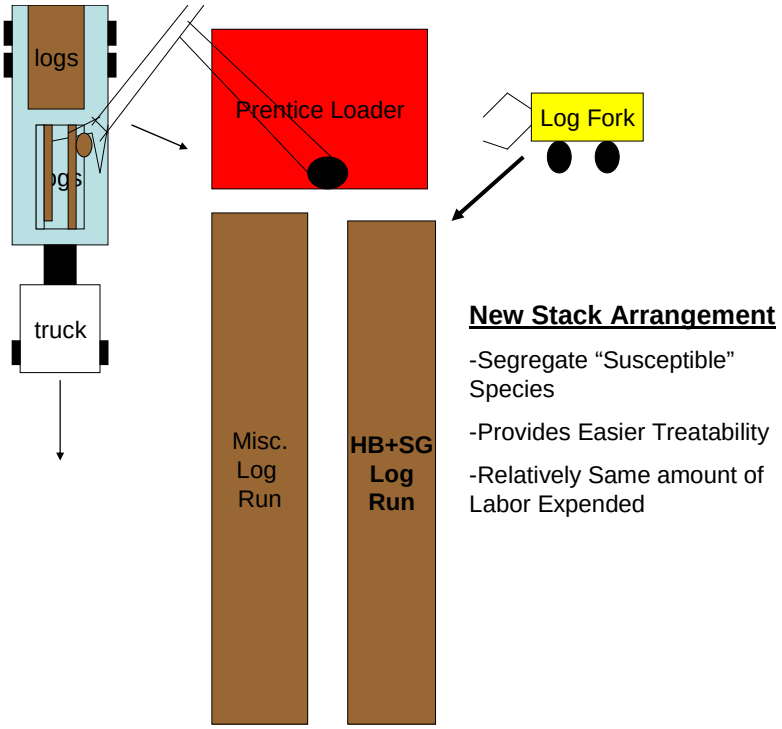


Figure 5.6

Improved Stack Orientation by Segregating Species: Eases Treatment of "Sensitive" Species

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