BLUE STAIN: A CAUSE OF SERIOUS LOSS TO MANUFACTURERS OF WHITE PINE LUMBER.

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INTRODUCTION

During the year 1928 blue stain caused a loss of approximately \$1,000,000.00 to the manufacturers of white pine lumber in Ontario. Losses occasioned by this defect during an ordinary season have been estimated to total between \$200,000 and \$300,000; but owing to the heavy rainfall and high humidity of 1928 the usual losses were more than trebled. These figures indicate that blue stain is a defect which, under existing methods of manufacture and seasoning of white pine lumber, is, even in an ordinary season, of sufficient importance to warrant attention; and that under unfavourable weather conditions the losses caused by its development may mount to very serious dimensions.

The object of the present paper is to explain the nature of the defect, conditions provocative of its development, and to indicate measures which effectively prevent its appearance or tend to control its spread.

NATURE OF BLUE STAIN

Blue stain is a fungous defect that is caused by the growth of fungi in wood. It is found in both hard- and softwoods, and several species of fungi have been associated with its development. Of the softwoods certain of the pines are most susceptible to its attack. No specific studies of blue stain in eastern white pine (*Pinus strobus*) have been recorded; but from observation of its general appearance in this wood, and of fruit bodies associated with it, it is evident that its origin is similar to that of the blue stain found in other species of pine.

Fungi are plants of simple structure, and are to be found on all kinds of organic matter exposed to warm, humid conditions. There are many kinds of fungi, and they vary as to the organic substances on which they can develop. Many grow in wood; and, when they do, they either disfigure it as in the case of blue-staining fungi, or they cause it to decay as in the case of wood-rotting fungi.

Close examination of an exposed surface of blue-stained pine will often reveal minute, spherical bodies with long hair-like beaks. They are dark in colour and just visible to the unaided eye. These are the fruits of the commonest fungi which cause blue stain. The spherical enlargement at the base of the fruit contains at maturity a considerable number of very tiny particles, which are known as spores, and which function as do the seeds of higher plants. They are forced out through the long beaks; and, when they reach the exterior, are borne away by water or through the air.

Each spore, when it reaches a surface of moist pine wood is capable of growing if conditions are favourable. Its initial development consists in the production of a tiny tubular outgrowth. This minute tube penetrates the wood and elongates until it reaches certain cells in the wood in which the tree has stored up food substances for its own future growth. The blue-staining fungi nourish themselves on these supplies of reserve food material, penetrating deeper and deeper into the wood wherever such storage cells are to be found.

Since these fungi live on the reserves of food in the wood and not on the wood substance proper, they do not materially weaken the wood; but the branching tubes of the fungus are dark in colour, and when they have ramified through the storage tissues, they give the entire board the unsightly blue discoloration which detracts greatly from its value. Every infected stick is, therefore, a source of danger to clear lumber in the vicinity.

The fungus may also spread without the production of spores. If an infected stick is placed in contact with sound wood the branching tubes of the fungus may simply elongate and pass from the diseased material into the sound tissues.

CONDITIONS PROVOCATIVE OF BLUE STAIN DEVELOPMENT

Since fungi are plants, they require in order to grow, food, air, moisture, and moderate temperature. Blue-staining fungi for the most part find the food they need in the storage cells of sapwood. Blue stain develops almost exclusively, therefore, in the sapwood. During the summer months in Ontario temperature conditions are likely to be optimum throughout considerable periods for the development of blue stain. Fungi causing this defect flourish at a temperature of 80°-85° F, and they will grow at temperatures ranging from 45°-110° F. Even throughout spring and fall, therefore, some stain may be expected to develop. During the seasoning period, food and temperature conditions will on the whole be extremely favourable for the development of blue stain in the highest grades of white pine lumber.

There remain the two other requisites: air and moisture. Blue stain rarely occurs in standing timber. The moisture content is too high; or, to speak more correctly, the amount of air in the wood is too limited. It is only when the balance between air and moisture in the wood has reached a certain point that the fungi concerned are able to penetrate the tissues. In certain cases, such as when a standing tree suffers root injury or is weakened by drought or fire, the normal moisture content may be so reduced that the sapwood becomes susceptible to attack; but under normal growth conditions standing timber is immune from this disease.

As soon, however, as the tree is felled, evaporation begins; and it is not long before exposed surfaces have reached the danger point as regards

the balance between moisture and air content. Studies of the growth of certain blueing fungi on test blocks of Scotch pine sapwood showed that these fungi were unable to penetrate freshly cut wood containing an undiminished water content. Some of the blocks had an original moisture content of 148% and others 155%, reckoned on the dry weight of the wood. A loss of 10% of the water content of the green wood permitted a rapid and thorough penetration; and the fungi grew with approximately the same vigor in blocks with water content reduced to as low as 40%, that is until as much as 74% of the original moisture had evaporated. With moisture contents lower than 40% blueing was retarded, but even blocks with 32% moisture showed some stain.

HANDLING OF WHITE PINE LUMBER

White pine logs are felled during fall and winter, logging sometimes commencing as early as August. They are for the most part stacked in the woods in skidways or rollways until the following spring. The majority of the companies cutting white pine transport their logs to the mills by water; some few bring them in by rail. The logs are in the water for periods varying from two weeks to two years. At the mills they are stored in water until manufactured into lumber.

The lumber is piled in air-seasoning yards, which vary in situation, arrangements, cleanliness, etc., and is allowed to dry out during the summer months.

DEVELOPMENT OF BLUE STAIN IN LOGS

As soon as timber is felled and the water content slightly reduced spores may develop on its exposed surfaces and infect the wood. Any wood debris in the vicinity may harbour spores. It is, therefore, advisable to have clearings in which logs are stacked clean and open.

Logs felled in August or September are immediately exposed to conditions provocative of the development of stain. It must, therefore, be not unusual to find that logs stacked during those months produce more stained lumber than logs cut later in the season. The freshly cut ends of the logs will be the surfaces most vulnerable to fungous attack. Painting these exposed surfaces with creosote or some other toxic material might effect a considerable saving by inhibiting fungus penetration.

The cold of late fall and winter effectively protects timber from stain; and once the logs are in the water the moisture content will soon become too high for development of the fungi. The water will in addition probably dissolve out of the wood a considerable portion of the substances which serve as food for staining fungi. This explains why lumber from water-cured logs is often found to be less susceptible to stain than that from logs which have not been in water for a lengthy period.

PREVENTION OR CONTROL OF BLUE STAIN

As soon as the logs are sawn into lumber the fresh wood offers broad exposed surfaces on which spores may fall. A slight decrease in moisture content will bring the wood to a condition in which infection may take place. Here then is the point in manufacture at which preventive or control measures should be introduced.

KILN DRYING

Kiln drying will prevent blue stain provided the kiln dried lumber is kept dry after treatment. In the kiln the moisture is removed so rapidly that stain has no chance to gain a foothold. The temperatures used in kiln drying are also sufficient to kill the blue-staining fungi in any centres of incipient stain which may have developed in the log. Tests made using sticks of blue-stained white pine 4 in. x 4 in. x 24 in. showed that the staining fungi were killed when the blocks were subjected to a temperature of 120° F. for 24 hrs., of 130 degrees F. for 9 hrs., of 140 degrees F. for 6 hrs., or of 170 degrees F. for 40 minutes. Subsequent spread of stain from or in infected boards so treated would therefore be precluded.

It is objected by some white pine lumber manufacturers that kiln drying of eastern white pine lumber is not feasible in practice, since it introduces other seasoning defects which are quite as detrimental to the lumber as is blue stain. Chief among these they mention an unsightly brown discoloration. It is undoubtedly true that this brown stain has given much trouble in seasoning, but it is also very probable that an experimental study might lead to the development of a suitable kiln-drying schedule for the seasoning of white pine which would eliminate the defects now encountered. It is known that a brown stain similar to that which develops in eastern white pine has given much trouble in the seasoning of pondosa pine in western Canada. This trouble has, however, been overcome; and it is now possible by maintaining in the kiln throughout the period of seasoning, careful relationships between temperature and humidity to turn out lumber with no sign of this defect. The bulk of the upper grade pondosa pine lumber in the west is, therefore, kiln dried.

AIR-SEASONING

Blue stain is initiated and spread by spores or by contact with infected wood; therefore every possible effort should be made to keep spores and infected wood out of the mill yard. It is fostered by humid conditions; therefore arrangements should aim at the best possible circulation of air and the most efficient utilization of the sun's heat throughout the yards. Consideration of these two facts, viz., sources of infection and effect of moisture content, leads to recommendations for control which are included in the following categories:

- (1) mill yard sanitation.
- (2) arrangements and methods of piling.

(1) MILL YARD SANITATION

The chief sources of infection in mill yards are the yard bottom, wood debris in the vicinity of the piles, pile foundation and tramway timbers, and crossers used in piling.

Recently correspondence was carried on with several white pine mills regarding mill yard conditions. Of 16 companies which supplied information regarding the composition of the yard bottom, 10 reported that sawdust fill was used in at least part of the yard. One of these companies replied that the yard bottom was swampy ground filled in with edgings, slabs, and sawdust; another stated that the yard was originally low and not well drained, and was therefore filled in with sawdust and hogged fuel.

A more perfect medium for fostering the development of fungi could not be provided. Sawdust, hogged fuel, slabs, etc., are all wood substance; and in the damp conditions supplied, form an admirable food supply for these harmful organisms. They will undoubtedly grow profusely and fruit abundantly, thus providing a prolific source of infection for successive piles of lumber. The same statements apply to wood debris carelessly left lying under and around the piles. The injurious effect of untidy yard conditions cannot be too strongly emphasized. To protect the lumber, sawdust fills and wood debris should be entirely excluded from the yards.

Similar danger results from the use of untreated timbers containing sapwood in the construction of pile foundations, tramways, etc. Any untreated wood held over from season to season may carry over the spores or other portions of the fungus, and initiate stain in fresh supplies of lumber as they enter the yard. All the companies which furnished information regarding pile foundations stated that untreated timbers were used in their yards. One mill uses culled pine and cedar logs; another, slabs and old lumber. The results are obvious: another source of infection is supplied and maintained.

In piling lumber the use of creosoted timbers resting on piers of concrete provides a sanitary type of foundation; and is to be recommended as an aid in excluding fungous infection. For the same reason the creosoting of ties and construction timbers throughout the yards cannot but be of benefit as a protection against the development of stain and decay in the lumber being seasoned in the yards.

Crossers used in piling may also carry infection or assist in its development. The benefit of crossing pine with lumber not susceptible to stain is recognized in the lumber industry. In eastern white pine mills the pine is frequently crossed with spruce heartwood; while in western Canada cedar, Douglas fir, and larch are used. Even, however, if crossers are of wood not itself susceptible to stain they may carry viable spores picked up as they are handled. If they themselves are capable of infection, they will undoubt-

edly become contaminated and spread the disease to the lumber with which they come in contact.

Stock crossers, even if not infected at the outset, may assist in the development of stain. Since they are themselves at the same moisture content as the stock being seasoned, there will be a retention of moisture at points at which stock and crossers are in contact. This high moisture content, continued as it must be over a prolonged period during warm weather, will undoubtedly render wood of both stock and crossers highly susceptible to infection in these areas of contact.

Dry treated crossers would be ideal from the standpoint of sanitation. Their use might not be practicable throughout the yard, but used in piling the upper grades of lumber they would undoubtedly effect a considerable saving.

(2) ARRANGEMENTS AND METHODS OF PILING

In planning the arrangement of the piles with a view to the control of blue stain the objective should be the best possible deposition of the piles for the most rapid elimination of moisture. Since, however, blue stain is but one of the defects which develops during seasoning, it may not always be desirable to keep this in view to the exclusion of other requirements. In very dry regions evaporation may be so rapid that defects due to checking may become as detrimental as blue stain. Piling practice in all yards must, therefore, be governed by local conditions and aims; no rules which are universally applicable can be laid down. The following discussion takes account of conditions likely to control blue stain, and merely offers a few suggestions directed to arrangements likely to promote the elimination of that defect.

The two drying agents upon which air-seasoning depends are the sun's rays and circulation of air. Maximum advantage will be taken of the former if the piles are spaced well apart, with lumber piles at right angles to main alleys, which run in a north to south direction. This will permit the sun's rays to strike farther down the piles for a longer period daily than will any other orientation. Alignment of the piles in the direction of the prevailing winds will provide most benefit from winds, since they will then strike the sides of the piles, and thus insure maximum movement of air through them. On the whole, however, it will be found better to disregard orientation in relation to wind and to lay out alleys in the north to south direction, since of the two drying agents it will be found that the sun's rays are the more effective. Both main and rear alleys should be as wide as possible; and under ordinary conditions a space of at least 3 ft. to 4 ft. should be left between piles. In some cases, however, a much more open spacing of the piles along the alleys will be found advantageous.

Ample provision should be made for circulation of air under the pile. To that end the foundations should elevate the pile, leaving a clear space

beneath which will permit free movement of air. It goes without saying that any vegetation or debris between or under the piles or in the alleys will impede circulation and thus hinder drying.

Internal movement of air in the piles is essential. As the lumber dries, heat is used up in the evaporation of water and the cooled air sinks, carrying moisture. Warm air enters at the top if the cold damp air is blown away from beneath. Effective drying depends to a great extent upon this internal vertical circulation.

Vertical movement of the air in piles is provided for by spaces left between the boards in successive courses of lumber. These form unbroken vertical flues in piles composed of even width stock. Chimneys, that is vertical channels wider than the flues, are sometimes left in the middle of or at intervals along the piles. In piling even width stock this practice is found to be less advantageous than the distribution of the same amount of space throughout the pile by the use of wider flues.

These provide uniform passages for air in both top and bottom of the piles. Since the lag in drying in the bottom of the pile in relation to that in the top is often considerable, it is sometimes desirable to vary the pile formation from top to bottom in order either to retard drying in the upper or to hasten drying in the lower portion. As an aid to drying in the lower part of the pile the use of thicker crossers, or of two or more ordinary crossers on top of one another between the courses of lumber in this portion of the pile, is advocated. This provides more space for the passage of air between successive courses, and thus tends to equalize drying throughout the pile.

CONTROL OF BLUE STAIN BY CHEMICAL DIPS OR SPRAYS

Attempts have been made to control blue stain by the application of chemicals to the surface of lumber. The idea upon which these efforts are based is that it may be possible to condition the surface chemically in such a way that the exposed wood will prove unfit for the development of blue-staining fungi.

The chemicals most frequently used have been substances which tend to give the surface of the wood an alkaline reaction. Most blue-staining fungi develop best when the wood is lightly acid, as is the condition in untreated green wood. Substances such as sodium carbonate, sodium bicarbonate, sodium hydroxide, borax, lime, etc., render the wood alkaline; and hence when present prevent the development of blue-staining organisms. Other substances sometimes employed, e.g., mercuric chloride, zinc chloride, sodium fluoride, sodium biferate, etc., have in themselves definite toxic properties which tend to inhibit fungous growth.

The chief difficulty in the use of any of these substances is that they are water soluble. Hence in rainy weather, which provides especially during

the hot months, the most favourable conditions for blue stain development, these chemicals are washed away and the wood is left unprotected. The efficacy of the alkaline substances used is also counteracted to some extent during seasoning by the fact that the slightly acid sap tends to pass out to the surface of the lumber, and to neutralize the applied alkali, thus leaving the wood again open to attack.

If any one of these chemicals could be applied to and retained on the surface of uninfected white pine throughout the seasoning period, there is no doubt but that it would prevent the development of blue stain. The difficulties are that stain is sometimes present in the lumber before the chemical is applied, and that the chemical does not remain on the lumber in full strength and unaltered condition during the period of danger. If blue-staining fungi are already in the lumber when it is treated, they will not be affected by the external application of alkali or poison, since neither they nor their food supply will come into contact with it. If the chemical remains on the surface it may prevent the fungi from fruiting, and thus control their spread; but stain in the interior of infected boards will proceed unhindered. And the chances are that the chemical will not remain on the surface of the lumber in sufficient strength to have much effect on blue stain if weather conditions are favourable for its spread.

This indeed has proved to be the case. No chemical applied to the surface of lumber has proved entirely effective against blue stain under conditions favourable to its development. Many experimental studies have been carried out with somewhat varying results. This variation is inevitable since the weather conditions are beyond control, and the experimental piles have been for the most part placed in the open.

Lime, the cheapest of the alkaline substances, was found unsuitable since it darkened the wood.

One investigator using boards of longleaf pine dipped in a 5% solution of borax, found this chemical quite ineffective; 75% of all the boards used were stained two weeks after treatment. The results of tests with New Zealand white pine (*Podocarpus dacrydioides*) were, however, quite different. In these tests the boards were dipped in 2% borax solution and then stacked in close or open piles; similar piles of untreated boards were built up for comparison. With the circulation afforded by open piling, the treatment was found to be fairly effective. At the end of the experiment, which was carried on for a period of seven months, 54% of the lumber was unstained, and only 4.6% exhibited heavy stain. Open piling untreated lumber was more effective than close piling treated stock; in the former case 35% was unstained after a period of seven months, and in the latter only 9.3% was free of stain.

In one series of tests with longleaf pine sapwood, of which the results are on record, the following chemicals were tested: calcium chloride, mag-

nesium chloride, borax, sodium carbonate, sodium hydroxide, sodium bicarbonate, carbolic acid, naphthalene flakes, copper sulphate, zinc chloride, and mercuric chloride. Under the conditions of the experiment 0.1% mercuric chloride and 12% sodium bicarbonate were found effective. After a period of one month lumber treated with 12% sodium bicarbonate and open-piled was unstained, and with 0.1% mercuric chloride the lumber remained clear in either close or open piles. The use of mercuric chloride is, however, impracticable owing to its poisonous and corrosive properties.

In another series of tests the fluorides, sodium fluoride, sodium bifluoride, and ammonium fluoride, were found effective against stain. It was also found that they were superior to sodium bicarbonate in that they did not themselves discolour the lumber. The tests were, however, carried on during dry weather, and are, therefore, not conclusive.

The results indicate that as far as our present knowledge goes chemical surface treatment is of doubtful value in the control of blue stain. There is undoubtedly a possibility that a satisfactory treatment might be evolved, but with our present knowledge no definite recommendations can be made.

SUMMARY

Blue stain is a fungous defect of sapwood, which develops during hot humid weather in either logs or lumber. It is spread by spores or by contact of sound with infected wood. Blue stain is fostered in the mill yard by any moist wood, such as sawdust, hogged fuel, slabs, wood debris, etc., which may be left in the vicinity of lumber piles. It may be carried over from year to year and spread from infected foundation or other construction timbers, or by pile crossers.

The development of blue stain is retarded by rapid drying of the lumber; and this is accomplished by making maximum use of the sun's rays, and by providing for the best possible circulation of air through the piles. The former is assured if the alignment of the main alleys is in a north to south direction, and the latter is provided for by proper elevation and spacing of the piles and by open-stacking of the lumber.

Kiln drying will effectively prevent blue stain. No effective chemical surface treatment has been evolved which will control stain under conditions favourable for its development. Nevertheless, it is not impossible that such a treatment might be worked out which would aid in the control of stain.