SPRAY TECHNOLOGY AND THE LUMBER INDUSTRY

by

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Today in British Columbia approximately 600 hydraulic spray nozzles are in use daily, spraying about 12,000 gallons each year, or about fifty million gallons each year, of anti-sapstain formulations on lumber. Such nozzles are combined in small longitudinal, or larger cross-chain (transverse) spray boxes to be an integral part of the process of producing export lumber. Why we need and use anti-sapstain formulations has been described elsewhere (1,2). Suffice to say that the B.C. export industry of softwood lumber, valued at over $2 billion annually, depends on the efficacy of such treatments. Much information is available on the types of chemicals being applied (3,4), but little attention has been given to its method of application. The recent trend by the lumber industry away from dipping lumber has resulted in about 65 mills in B.C. using about 88 spray boxes to apply about 450 tonnes of anti-sapstain chemical active ingredient annually. Since the efficacy of any lumber protecting chemical depends on its method of application, the theory, practice and use of spray systems are most important.

The spraying process can be divided up into the following steps (Figure 1): atomization, transportation to lumber, impact and deposit formation; these steps result finally in the protection of the lumber surface from subsequent fungal attack.

ATOMIZATION

Atomization is the main function of a nozzle. Other functions include the control of liquid flow, the dispersal of drops in a specific pattern and the generation of hydraulic momentum.

Atomization is the process by which a liquid is converted into a large number of drops, thereby becoming dispersed into a cloud or spray. The former is motionless in space and vulnerable to air currents, whereas the latter will have direction and the energy to reach a specified target. In lumber treatment the target will be the pieces of lumber, of various dimensions, which are always rectangular in cross section.

In simple terms, the liquid issuing from a nozzle first breaks down into a series of thin ligaments, which then break apart to form drops of a variety of sizes. It is characteristic of such an hydraulic nozzle that the range of drop sizes is very large, varying from as low as one or two microns (Um) to several hundred microns in diameter (25 Um is about one one-thousandth of an inch). The drop size distribution produced by specific nozzles has been measured by some manufacturers, although

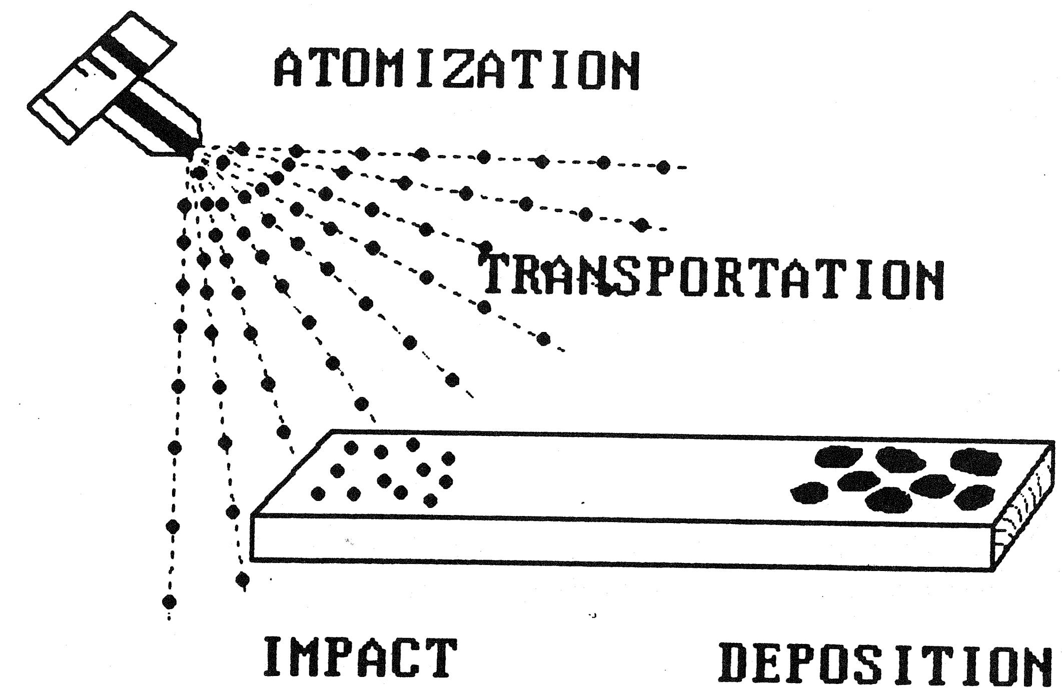

Figure 1

Four stages in the process of spraying antisapstain formulations on lumber.

different measuring devices can give different assessments of drop size. Typically, 65 percent of the volume (or mass) of the spray will be contained in less than 10 percent of the number of drops. A perspective of these sizes can be gained when you consider fog to contain drops in the 1-30 Um range, mist 30-100 Um and drizzle 100-300 Um.

The number of drops produced will depend on many factors, including nozzle shape and size, liquid pressure and temperature, liquid viscosity and surface tension. For a given nozzle, the important practical factor to consider in anti-sapstain treatments is the effect of pressure. As pressure increases, the drop diameter decreases. For a typical flat-fan pressure atomizer spraying 20 gallons per hour of water, an increase in pressure from 100 to 200 psi will result in a decrease in their sauter mean diameter*, from 135 Um to 105 Um.

From the viewpoint of anti-sapstain protection, a larger number of smaller drops will provide more even coverage of the lumber and therefore a greater chance of killing, or preventing the growth of, sapstain and mould fungi on the surface. Also, a more economic use of chemical would be expected, as seen from Figure 2. In this example, halving the diameter of a drop can produce eight drops with a total volume equivalent to that of the original drop. Therefore, by increasing spray pressure we should be able to use less chemical to provide equal protection. Other mitigating factors, however, come into play as spray pressure increases and these will be discussed under the later sections of this paper.

Another beneficial effect of increasing pressure will be the increased momentum given to the drop. This will affect the transportation of the anti-sapstain formulation to the lumber surface and is discussed in the next section of this paper.

Of equal practical importance to the effect of increased pressure on atomization is the accompanying increase in liquid flow rate. This alone would be expected to transport more chemical to lumber surfaces. Forintek measured this using a longitudinal spray box, within a B.C. mill, and found increased retention of chlorophenates as the pressure increased from 125 to 175 psi, but no change after the pressure was increased to 225 psi (Figure 3).

The process of drop formation by hydraulic atomization is most sensitive to the nozzle geometry. Nozzle design can produce spray patterns of various shapes, although in the lumber industry the use of flat-fan sprays seems to be most common. Mechanical wear of this nozzle, or partial blockage with wood or chemical particles, will change the spray pattern and size distribution of the drops. This will immediately affect the efficiency of the application process and the efficacy of the treatment in protecting lumber. In practice, keeping the spray nozzles clean at all times is of paramount importance.

*Sauter mean diameter is one of the several measurements of drop diameter used by scientists and manufacturers.

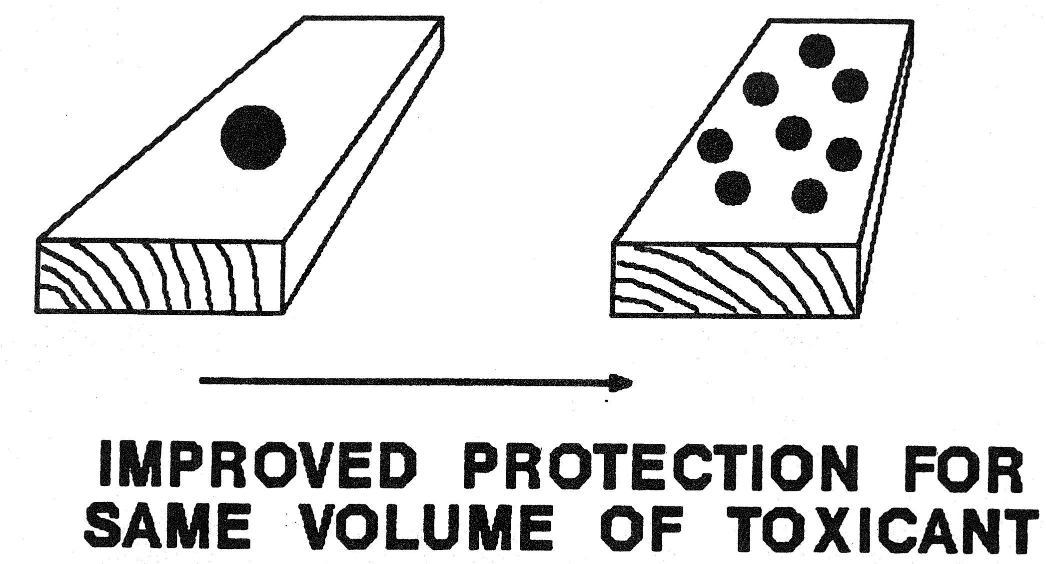

Figure 2

Improved coverage with reduced drop size

EFFECT OF SPRAY PRESSURE ON CHLOROPHENOL RETENTION

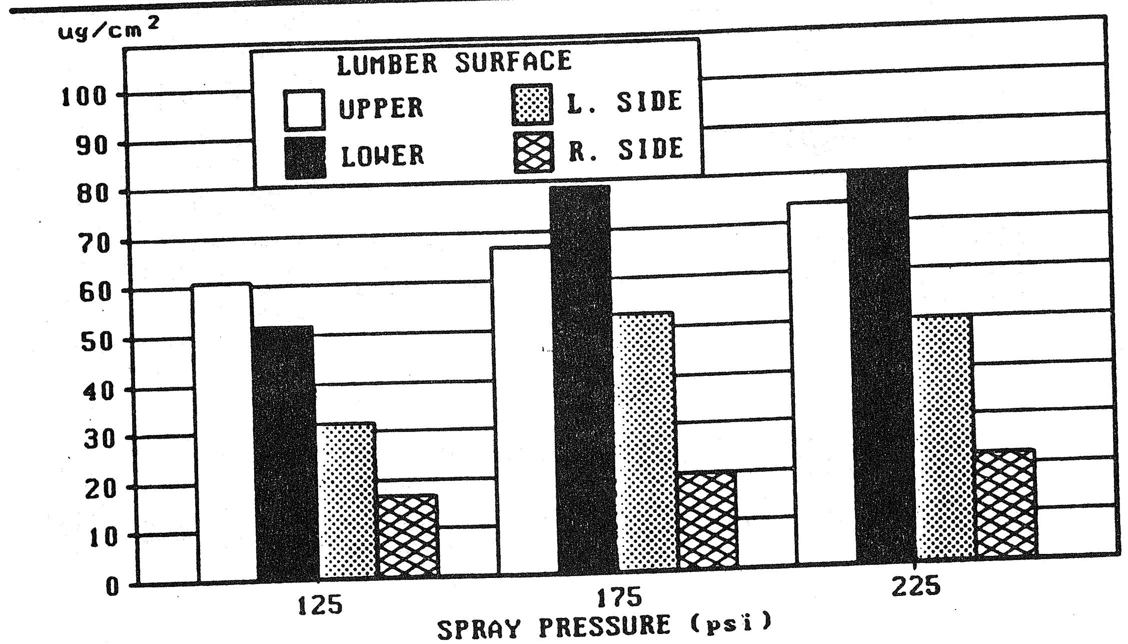

Figure 3

Chemical analysis of 2 x 6 in. lumber commercially produced through a six-nozzle, longitudinal spray system. One sample was taken from the geometric center of each face of each of 30 boards and the results averaged for each face.

In the above description of hydraulic atomization, the energy required to produce the drop and overcome the surface tension forces of the liquid, is obtained by pressurizing the liquid. Another form of atomization is being tested at Forintek Canada Corp., where a high electric voltage is applied to the liquid which subsequently blows apart into charged drops as it issues from a narrow orifice. This device, called an Electrodyn, was developed by Imperial Chemical Industries in the United Kingdom (5). The device has the ability to produce very small drops with a reduced spectrum of sizes (6). The drops produced are also electrically charged, which has advantages described later.

TRANSPORTATION TO LUMBER

The movement of drops from a nozzle to the lumber surface is caused by one or more of the following propulsive forces:

1. inertia
2. gravity
3. viscous drag
4. electric field.

Inertial force is given to drops when liquid is forced through a nozzle under pressure. In a similar way, inertial force is given to a baseball thrown by the pitcher. Gravity force acts only downwards, in the case of a baseball as it falls into the open glove of an outfielder. Both of these forces are dependent on mass, with the larger drops being capable of going a greater distance. Viscous drag is provided in air-assisted sprays where the air surrounding the drop is given momentum in the direction of the target, thereby allowing the drops to travel greater distances.

It is interesting to consider the relatively short distances that small drops produced from a hydraulic nozzle can travel. A 40 Um drop produced from a typical nozzle, with an initial velocity of 10 m/sec., will only travel 4 cm in still air. Of course, greater distances are obtained because of the entrapped air movement created by the spray. Drops falling under the force of gravity also have low terminal velocities. For example, the same 40 Um drop will reach a terminal velocity under gravity of only 8 cm/sec.

These low drop speeds result in drift problems for the spray system and a poor transfer efficiency. The latter is defined as the volume ratio (percentage) of chemical solution retained by the lumber compared to that issuing from the nozzle(s)(Figure 4). Typical transfer efficiencies for longitudinal spray systems used in the lumber industry would be between 15 to 30 percent. For transverse spray systems, the efficiency would fall to significantly less than 5 percent, depending on the number of nozzles.

It can now be understood why increasing the spray pressure in a typical lumber treated spray box does not necessarily result in improved retention of chemical on the lumber surface. Such a procedure will produce a smaller diameter drop, with lower energy, unable to impact on the lumber surface. Such small drops are subject to drift in the environment, resulting in chemical wastage, and sometimes odour problems surrounding the spray box.

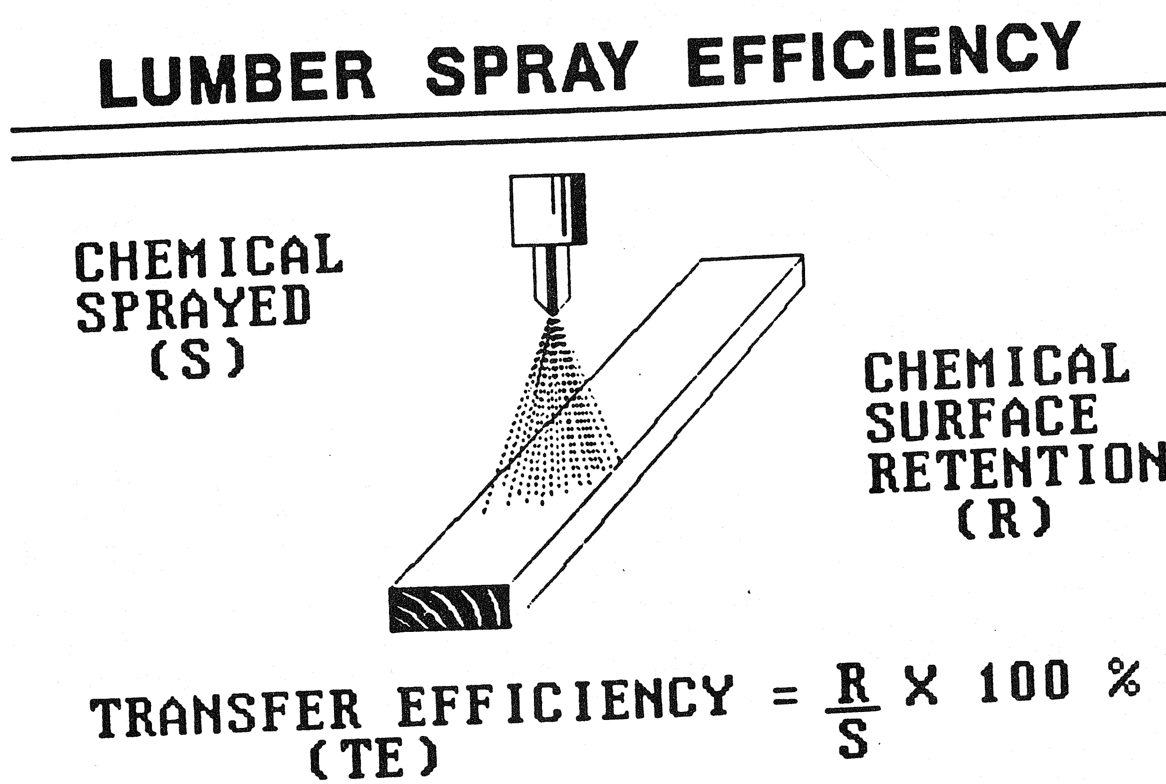

Figure 4

Method for calculation of transfer efficiency for a spray system

The last, and potentially perhaps most important, method of propulsion given to drops is electric field. Drops can be given an electric charge, as in a typical electrostatic paint sprayer or the Electrodyn sprayer from ICI. They will then move rapidly in the electric fields set up by the electrostatic device and the cloud of charged drops. By keeping the target (lumber) at an opposite charge, or ground potential, to the drop. the target can be efficiently coated by the solution (7).

The process of charged drops has been exploited by Forintek using the Electrodyn and special formulations of anti-sapstain solutions. Positively charged drops, produced by the device, can be transported rapidly and efficiently to coat lumber moving below the spray nozzle. The lumber acts as a ground source for the charged drops which are attracted towards it. Transfer efficiencies of over 80 percent have been obtained, with values closer to 95 percent being possible.

The speed at which charged drops move is much greater than that of similarly sized drops moving only under the force of gravity. For example, with the Electrodyn, a 100 Um diameter drop will move at ten times the speed of an uncharged drop moving under gravity (Figure 5). With a smaller drop, the difference in drop speeds is even greater, the charged drop moving at 100 times the speed of the uncharged drop. This factor can be utilized in spray technology where overspray and environmental pollution are important. Low diameter drops can be efficiently trapped onto the target (lumber), thereby reducing chemical costs as well as environmental problems.

The "wrap around" effect of a cloud of charged drops can be very efficiently utilized in spraying lumber. Edges and under surfaces of lumber can be treated as the charged drops move in electric fields around and underneath its surface. Tests with the Electrodyn, using a fluorescent tracer applied using one nozzle 28 cm above the lumber surface (7) gave about 66 percent coverage of the lower surface when compared to 100 percent on the upper surface (Figure 6).

Since all drops produced by an electrostatic device are similarly charged, they tend to repel one another, producing a cloud of uniformly spaced drops. This compares sharply with that produced by an hydraulic spray, where drops in the cloud can coalesce to form larger drops, thereby increasing the already large range of drop sizes produced by such a device.

The speed at which electrically charged drops move will increase as the charge to volume ratio increases. This effect has been utilized by Forintek in tests with the Electrodyn. Increasing voltages on the device, however, also decreases drop size, which can offset the benefits of faster drop transportation.

The transportation phase of spraying lumber with anti-sapstain solutions is also affected by the properties of the solution used. Losses can occur due to evaporation and volatilization, which is particularly evident with low boiling point solvents. This in turn will be dependent on atmospheric temperature and humidity. This situation could result in solvent odours and toxicant losses from the spray system.

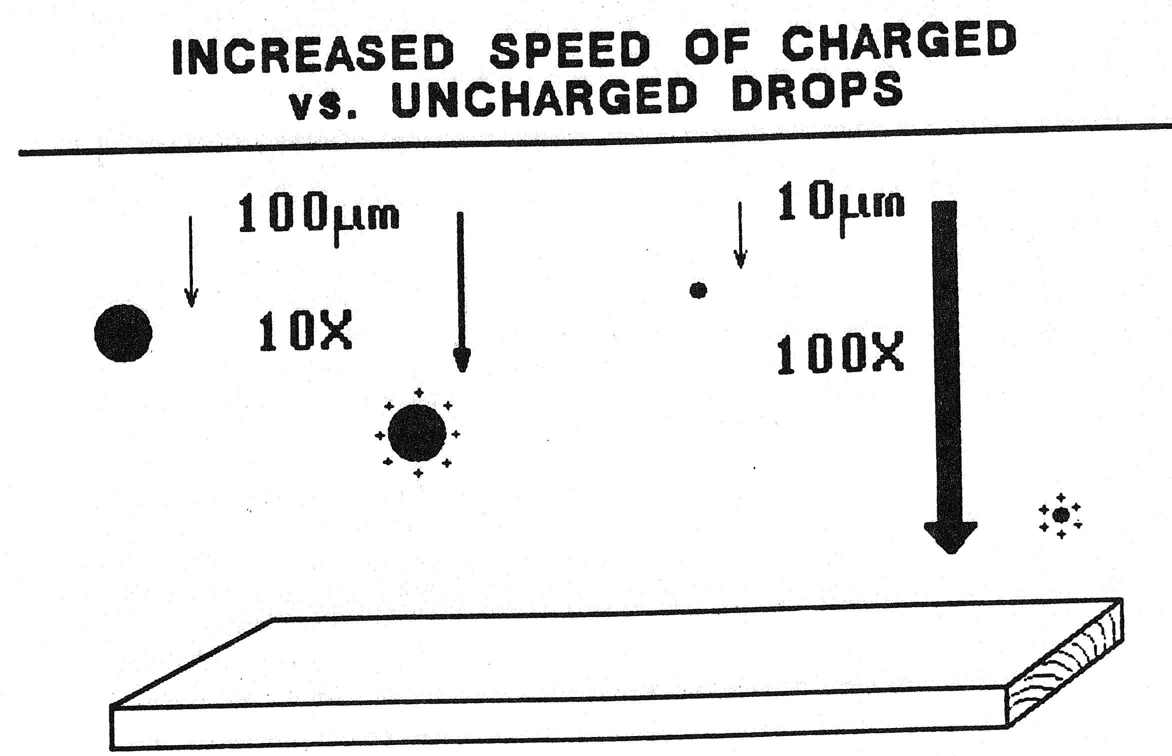

Figure 5

Increased momentum given to drops,
moving under gravity, when they are electrically charged

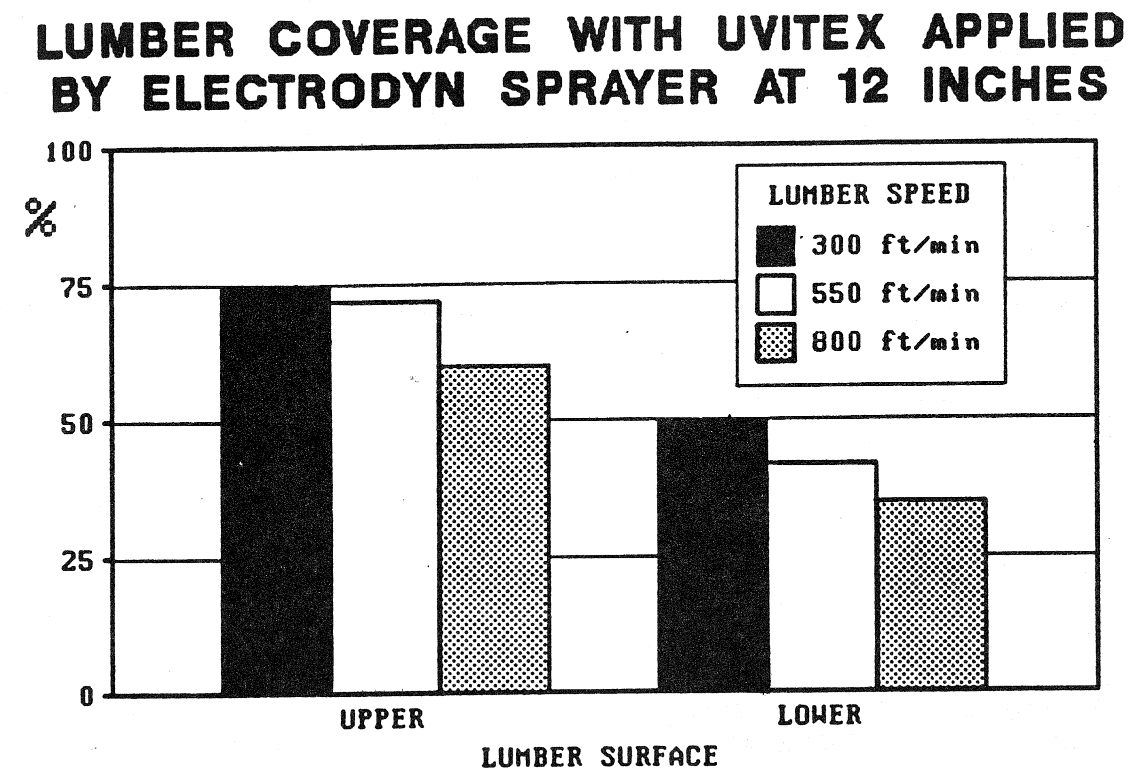

Figure 6

Coverage of lumber surface (visual rating %) using a fluorescent tracer (Uvitex) applied by electrodyn nozzle from 12 inches above the lumber surface.

Spray systems for lumber treatment will normally be contained within a box operating under negative pressure. This essential system reduces the amount of overspray and chemical odour passing into the workplace; however, strong air currents are set up within the box which generally make the transportation of drops from the nozzle to the lumber less efficient. The higher energies achieved by electrically charged drops would help to overcome this problem.

IMPACT

This occurs when the drop from a spray hits the target. In the lumber mill the target is a board, or lumber, moving at speeds from less than 100 to over 1,000 ft/min, depending on the type of spray system and operational requirements within the mill.

Drops within a spray may bounce off the wood surface or splatter on impact, splashing smaller drops back into the air. Smaller drops may be retained entirely by the moving lumber. The ability of lumber to hold the drop on impact will be affected by the surface properties of the lumber. Rough lumber may retain more sprayed chemical than smooth lumber. Tests at Forintek using a 4-nozzle hydraulic Timberpellor spray and a chlorophenol formulation, demonstrated an average 12 percent increase in chemical retention on the rough face of boards when compared with smooth faces for the same boards (Figure 7). In contrast, a 200 to 300 percent higher chemical retention is found on the rough versus smooth surfaces of dipped lumber. Further studies with the Timberpellor spray also showed an 18 percent increased chemical retention for the upper surface of sprayed lumber, versus the lower surface (Figure 8).

The speed at which the lumber is moving also will affect the impact of the drops and hence their retention on the surface. Overall, the effect of increasing lumber speed is to reduce the impact of drops and hence retention of anti-sapstain formulations. Chlorophenol retentions were measured at Forintek on lumber treated using the Timberpellor system and found to decrease by about 50 percent as the lumber speed increased from 300 to 800 ft/min (Figure 9). When the Electrodyn was used to apply a fluorescent tracer to lumber, however, the reduction in surface coverage was only about 34 percent as the lumber experienced a similar increase in speed (7). The powerful electrical forces attracting charged drops to the lumber surfaces seemed to provide an advantage in overcoming the increasing difficulties of hitting the lumber as its speed increases.

The movement of air over the lumber surface, or boundary layer effect, will also affect retention. With lumber speeds below about 400 ft/min, the air flow will be laminar, or smooth, over its surface. As speeds increase, however, there will be a change to turbulent air flow, with the production of eddies of air along the length of the lumber. This turbulent air flow could assist in increasing the efficiency of drop impact on the lumber.

INCREASED CHEMICAL RETENTION (HYDRAULIC SPRAY)

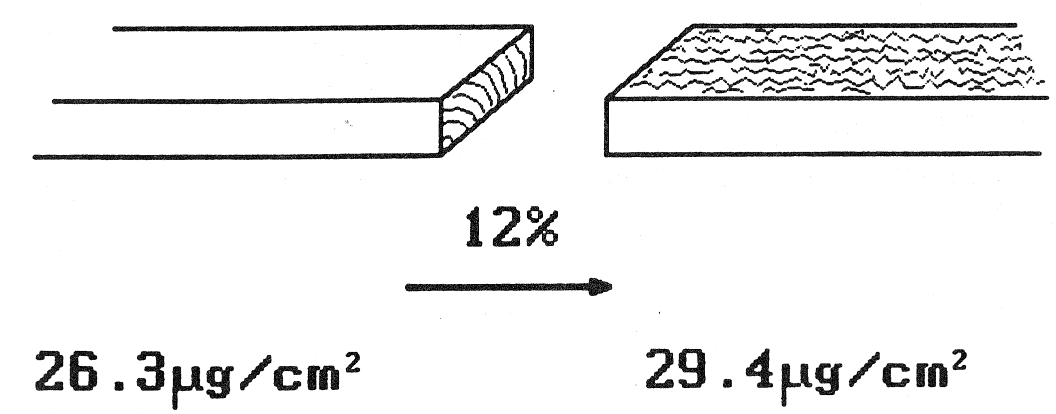

Figure 7

Effect of lumber roughness on retention of chlorophenol formulation, applied by a four-nozzle hydraulic spray system

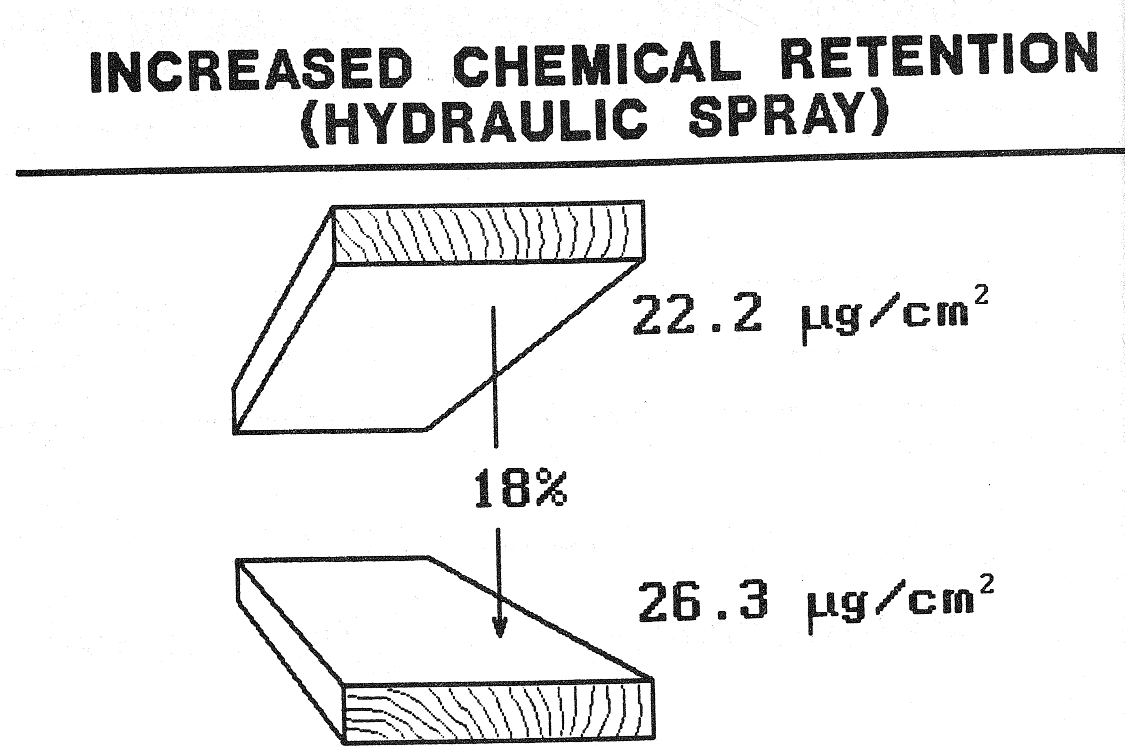

Figure 8

Increased retention of upper lumber surface, versus lower, for a chlorophenate antisapstain formulation applied by a four-nozzle hydraulic spray system.

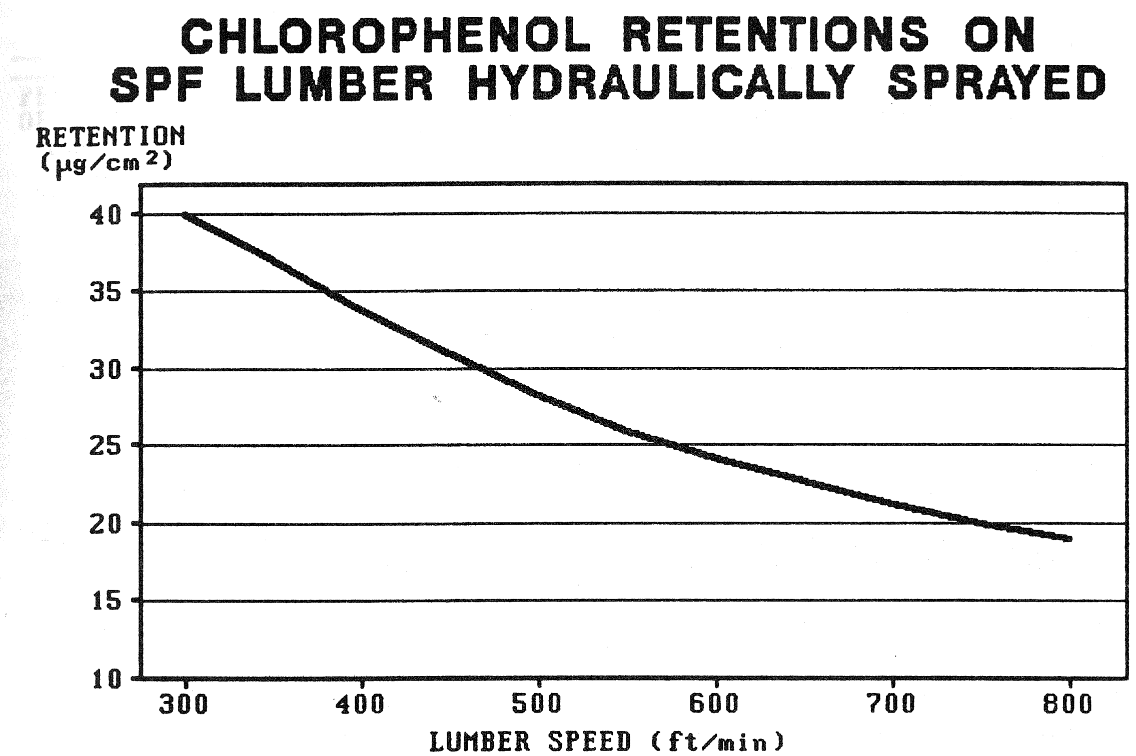

Figure 9

Reduction in chlorophenol retention on lumber passing through a four-nozzle hydraulic spray system with increasing speed

Finally, impact will be affected by the angle at which the drops approach the lumber. The shallower this angle, the greater the chance of bounce and splatter from the drop. Again, the electrically charged drops would have an advantage in that they follow the electric fields, which generally end perpendicular to the lumber surface.

DEPOSIT FORMATION

This occurs on the lumber surface immediately following impact. The liquid from each drop spreads, and in the case of most anti-sapstain formulations, the water solvent evaporates and/or diffuses into the upper layers of wood cells. The toxicant moves with the solvent, but it may react chemically with the wood substance during the process. Anti-sapstain chemicals such as the quaternary ammonium compounds have a powerful affinity for cellulose, to which they can bind rapidly. This should give some resistance to subsequent leaching by rainwater, and provide an advantage to the lumber industry.

Because the lumber surface is made up of longitudinal cells along its length, the chemical deposits will form in streaks along the surface of the lumber. The degree of streaking probably increases with increasing volume of liquid applied to the surface. If the lumber is also moving longitudinally past the spray nozzles, the streaking of the deposits will be accentuated. Conversely, if the lumber is moving transversely, as in one of the new transverse spray systems, the streaking along the boards would be reduced.

The evenness of chemical deposition on lumber is important to minimize undertreatment of some parts and overtreatment of other parts of the lumber. Forintek measurements of chemical retentions on lumber surfaces following anti-sapstain treatment using spray systems show a wide variation, both within, but particularly between different faces of boards (Figures 10 and 11). The variation observed depends on the particular spray equipment and conditions at the time of spraying.

The use of charged-drop sprays to treat lumber results in very even deposition patterns which would be most efficient in controlling the attack of the lumber by sapstain, mould and wood destroying fungi. This regular deposition patterning should also provide acceptable lumber protection with less chemical than that presently applied using conventional hydraulic spray systems. For example, recent studies with the Electrodyn and TCMTB [2-(thiocyanomethylthio)benzothiazole] showed effective control of stain and mould on Hem-Fir lumber at retentions of about half that normally required with an hydraulic spray (7).

Deposit formation could also be affected by the chemical properties of the wood, the particular wood species and the grain or figure of the wood. This has been demonstrated at Forintek using food colouring added to spray solutions. The different retentions of springwood and summerwood can be demonstrated clearly.

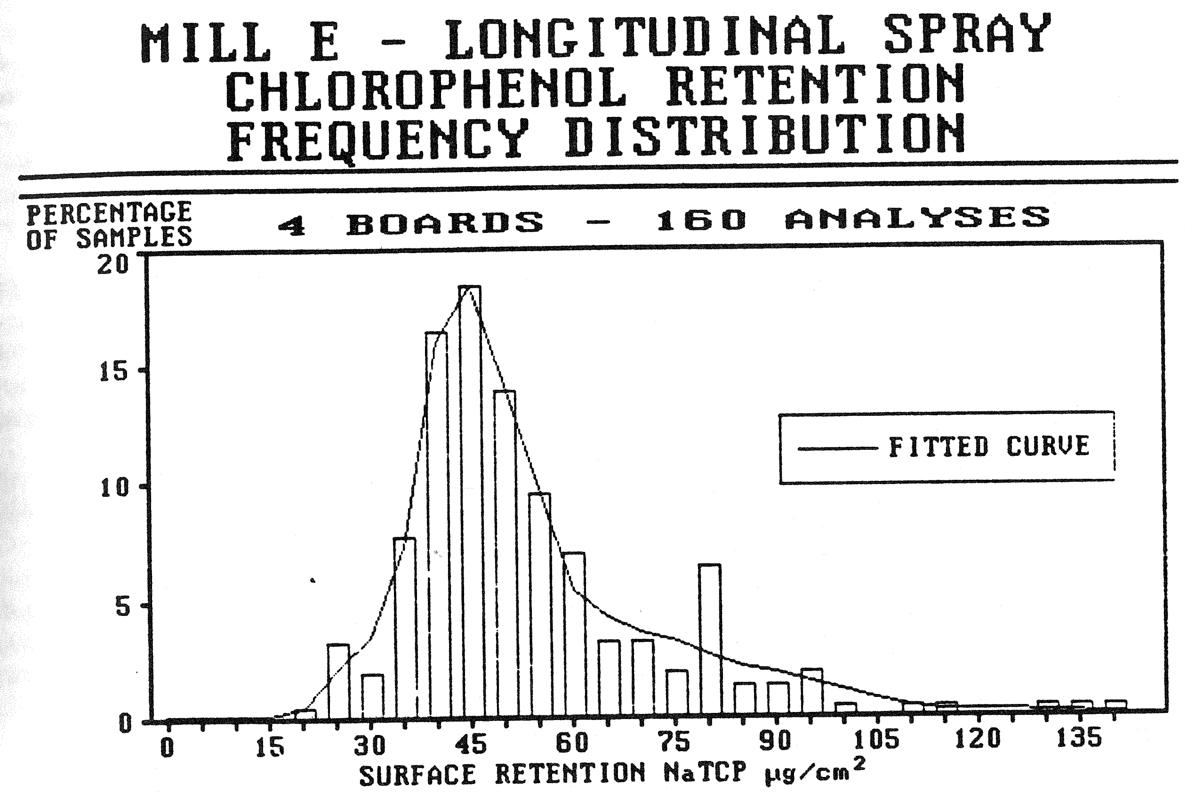

Figure 10

Variation in chlorophenate retentions from four boards run through a longitudinal spray box and analyzed every 22 cm. along the length on all four faces.

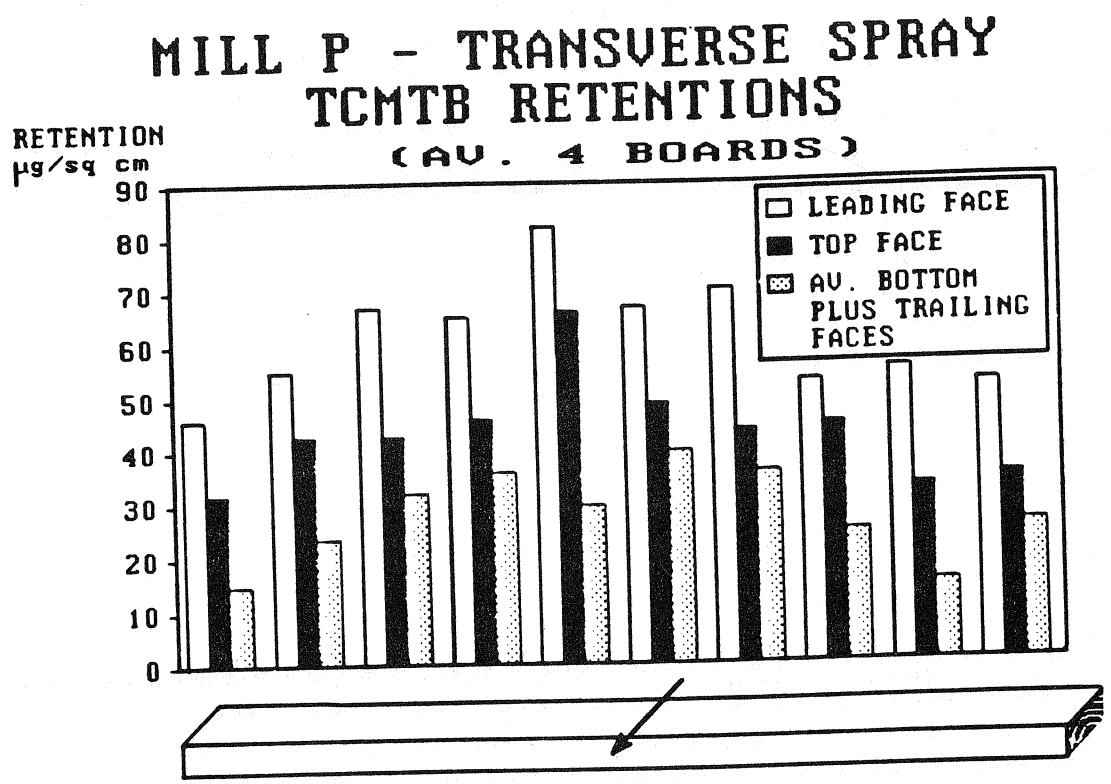

Figure 11

Variation in TCMTB retentions from four boards run through a transverse spray box and analyzed every 22 cm. along their length on all four faces.

PROTECTION

The end result of the anti-sapstain spraying process for a lumber mill should be the production of lumber adequately protected from fungal degrade during transit and storage. The steps described in this paper between liquid atomization and lumber protection are complicated and still poorly understood. Our knowledge of spray application in the lumber industry is largely empirical and in its infancy. Our ability to optimize spray operations and thereby maximize our profits, is dependent on a better understanding of how our systems work - or fail.

During the last few years, producers of spray equipment have made significant improvements in equipment design. These include the use of greatly improved filters, self-cleaning nozzles, improved systems to control overspray into the environment, and a degree of automation and computer control.

In spite of these advances in conventional hydraulic spray systems, it seems clear that electrostatic spraying could provide a major break-through in application technology for the lumber industry. It has the potential to greatly improve the chemical transfer efficiency, reduce the amount of chemical being used, significantly reduce the need for chemical recycling, reduce environmental contamination and improve the workplace environment. The immediate impact of the electrostatic technology is clearly beneficial and its conservational properties are unique.

CONCLUSIONS

The process of spraying anti-sapstain formulations on lumber to achieve protection against fungal degrade can be separated into: atomization, transportation, impact and deposition. These steps are dependent on nozzle geometry, liquid flow and pressure, liquid temperature and viscosity, possible electrical charges on the drop, structure and shape of the spray boxes, and finally, lumber speed. The interaction of these factors is complex and poorly understood by the lumber industry. Spray systems currently in use in mills are generally very inefficient, requiring the circulation and filtration of large volumes of fungicidal formulations. The use of electrically charged sprays could greatly improve the protection of lumber and reduce the risk of environmental contamination.

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