HIGH PRESSURE PULSATION PROCESS TREATMENT FOR WHITE SPRUCE WOOD

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SUMMARY

The refractory behaviour of spruce wood against pressure treatment with wood preservatives has been reviewed and the pulsation process presented. Previous work on the treatment of round wood with creosote using a high pressure pulsation process and recent research results on the potential of a high pressure pulsation process to treat lumber with CCA have been presented. The process shows great potential to improve treatment of spruce wood but more work has to be done to investigate and optimise treatment parameters to fully screen the possibilities of treating spruce wood to the standard requirements and to shorten the impregnation time.

1. INTRODUCTION

As only a few of the Canadian softwood species can be easily pressure treated with wood preservatives, many research projects have been presented in the past dealing with the impregnation of less treatable species. Among these more or less refractory species, special attention was brought to spruce wood. Spruce wood, which is certainly THE Canadian species, is in fact, very difficult to treat. Among the spruce species, white spruce was of main interest for wood preservation research as it has become clear during a previous literature study covering the period between 1900-1980 in which 60 percent of the papers dealt with the impregnation of white spruce (Hösli 1980).

The low permeability and refractory behaviour to pressure treatment of white spruce wood has been described by McLean (1935) in detail. However, the main reason had already been recognized by Griffin (1924) who thought that aspirated pits might be the major obstacles to liquid penetration. The occurrence and degree of pit aspiration has been described in detail by Philipps (1933) who found that all pits in the early wood are aspirated, and that 10 percent of the latewood pits remain unaspirated. This has been confirmed by Koran (1974) who examined in detail latewood pits and explains the often observed "zebra" treatment of spruce already described by Teesdale (194). Even if pit aspiration is generally accepted as the main cause for refractory behaviour of spruce wood to preservative

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pressure impregnation, the penetration problems of liquid into the wood is not fully understood. It is particularly not clear how the density of the wood (Olesen, 1977), the elements of rays (Sebastian et al, 1965) and the resin canals (Banks, 1970) are interfering with permeability.

Different methods to improve treatability or treatment of spruce wood have been presented during the past but, unfortunately, were largely unsuccessful under industrial conditions. It was attempted to overcome the blockage of pits through the pretreatment of the wood by solvent exchange drying (Comstock and Côté, 1968), by biological pre-treatment (Unligil, 1972), by mechanical precompression (Goulet et al, 1968) by steaming or vapour drying (Hauffe, 1970) or by drilling and incising (Ruddick, 1986), to improve preservative characteristics by adding strongly swelling chemicals (Prokopp, 1953) or by using strongly swelling solvents (Rak, 1977) and, finally to improve treatment processes.

According to McLean (1935), the choice of a particular impregnation process is based more on the experience of the treater than on scientific findings and that only very little work has been done in studying impregnation processes. This situation has not changed essentially and only a few papers have been presented dealing with the influence of particular treating factors on the success of treatment. However, not such factors alone, but their combination, are important in the success of a treatment. As far as preservative uptake is concerned, Walters and Whittington (1970) found that increased pressure increases preservative retention, while Hackbarth (1975) stated that the pressure is less efficient than the length of the pressure phase; and Hauffe (1970) thought that not only increased pressure, but also temperature enhances preservative uptake. During these experiments, the conditions were not severe enough. However, neither the temperature nor the pressure can be increased too far because the wood would then be damaged severely. As a maximum possible pressure for spruce, Anonymous (1947) indicated 1.0 MPa, Walters and Whittington (1970) 1.6 MPa, Hauffe (1970) 1.0 MPa and Riechert (1974) 1.6 MPa. To avoid mechanical damage due to elevated pressure and to make it possible to use a high pressure impregnation for refractory wood, the pulsation process has been developed and presented for the creosote impregnation of red heart beech sleepers (Hösli, 1980) and spruce round wood (Hösli and Filion, 1983).

2. THE PULSATION PROCESS

The pulsation process is essentially a Rueping process but differs from it in that the hydraulic pressure is not held constant but rapidly cycled between a pressure slightly above the initial air pressure (low pressure period) and a much higher pressure (high pressure period). In all the work done, the low pressure period was always 0.3 MPa held for one minute and the high pressure of 2.1 MPa period varied in length from seconds at the beginning of the process, an extended high pressure period and a final vacuum of one-half hour is added. The initial air pressure of 0.25 was held for one-half hour.

The process has an advantage over conventional pressure treatment methods in that greater pressure differences develop at obstacles such as pits present in the intrusion path, while the total pressure increases slowly (Hösli 1980). As a consequence, smaller pores can be penetrated. Because the high pressure period, at the beginning of the process, is applied only for a very short time, the danger of cell collapse due to the influence of the liquid pressure is diminished (Hösli and Filion, 1983). Later on in the pulsation phase of the process, a counter pressure inside the wood is built up and the periods of high pressure can be extended.

Since the mean conducting pore of spruce is very small in size (Hösli, 1985), permeability of the wood is extremely low (Orfila and Hösli, 1985). As a consequence, the length of the high pressure period at the beginning of the process has to be made very short and can only slowly be increased. The pulsation phase of the process consists of 50 up to 120 low/high pressure cycles.

3. THE TREATMENT OF SPRUCE ROUND WOOD WITH CREOSOTE

Hösli and Filion (1985) reported on the high pressure impregnation of 1.5 m long kerfed and peeled spruce round wood samples using four variants of the pulsation process with a six hour cycling phase. In the first variant, the length of the high pressure phases increased most rapidly, resulting in a pulsation phase with 50 pulsation cycles, and in the fourth variant the increase of the length of the high pressure phase increased most slowly, resulting in a pulsation phase of 120 pulsation cycles. For these processes, the lower hydraulic pressure was 0.3 MPa and the high pressure 2.1 MPa which is, according to the cited literature, far above the pressure required to provoke cell collapse. The wood was kerfed to allow tangential penetration in the more permeable latewood zones.

For both penetration and retention, the pulsation processes were much more effective than the Rueping process and the sapwood was for all pulsation processes completely penetrated. Cell collapse was observed only in samples where the Rueping process was used and no damage could be assessed for pulsation treated samples.

Comparing the four variants of the pulsation process, the proportion of the unpenetrated and poorly penetrated wood zones decreases sharply from about 60% to 20% when the number of pulsation cycles is higher than 70, whereby good penetration was assumed when at least the latewood was uniformly black coloured. Preservative retention was not affected by the increase of the number of pulsation cycles and was for all four variants of the process about 190 kg/m^3 against 140 kg/m^3 for the Rueping process.

PROCESS	Rueping	Pulsation1	Pulsation2	Pulsation3	Pulsation4
NUMBER OF CYCLES	1	51	78	100	117
RATIO OF POORLY TREATED WOOD	59%	57%	48%	22%	18%
RETENTION	138kg/m^3	194kg/m^3	172kg/m^3	183kg/m^3	190kg/mm^3

Table 1: Number of cycles and result of treatment for the Rueping process and the four variants of the pulsation process.

To evaluate creosote intrusion during the treatment, retention and distribution data have been taken after different times of treatment using the pulsation process. Assessing the penetration depth was not possible because penetration in the inner parts of the spruce heartwood occurred tangentially in the latewood zones starting from the kerf, whereby in many cases the latewood zone of one annual ring was completely impregnated for the whole length on the cross section while the adjacent ring was treated only on some few millimeters from the kerf. In the neighbourhood of the sapwood heartwood border, 20-50mm radial penetration in the heartwood has been observed. The predominance is in accordance with the above cited literature and the observation of the minute creosote distribution showed that the preservative was present in the latewood zones but not in the few last rows of cells of the annual ring. This is in accordance with Koran's (1977) observation that these last latewood cells have a different structure of pits than the other latewood cells of spruce.

The result of treatment indicated that the pulsation process can be used for the pressure treatment of spruce wood with creosote at much higher pressures than those which would cause cell collapse using conventional treatments. As this work included only limited variation of treating conditions, the results suggest that further improvement might be possible to increase heartwood penetration, particularly by varying further the duration increase of the high pressure periods.

4. THE TREATMENT OF SPRUCE LUMBER WITH CCA

4.1 Introduction

The purpose of this work was to assess the potential of a high pressure pulsation process to treat spruce with a waterborne preservative. Results could not be deduced from the previous work using creosote as a preservative because waterborne solutions have a much higher surface tension than organic preservatives, which means that the waterborne preservative creates higher pressure at obstacles when it is forced through. As a consequence, higher pressure must be applied to penetrate a

given pore and higher forces are acting on the wood which increases the danger of cell collapse. To create these higher pressures at the intrusion obstacles, the length of the high pressure periods have been slightly increased and a 60 and 80 cycle high pressure pulsation process has been compared with normal and high pressure empty and full cell processes.

4.2 Material and Methods

Charges of twelve or thirteen end sealed 4 x 8 x 46cm white spruce samples, containing both sapwood and heartwood, have been treated with 2.4% oxide based CCA solution using three different variants of a high pressure pulsation process, a conventional full cell process, an extended full cell process and a high pressure empty cell process. The untreated samples have been assessed for their cross sectional dimensions at mid length, their length and their weight. Additional samples have been used to determine the mean moisture content of charges to be treated, which was about 6 percent.

In the initial phase, the absolute air pressure applied was 0.025 MPa for the two full cell processes and 0.35 MPa for the four empty cell processes. The hydraulic pressure was 1.0 MPa for the two full cell processes, 2.1 MPa for the high pressure Rueping process and the high pressure periods in the pulsation phases, and 0.3 MPa for the low pressure periods in the pulsation phases, and 0.3 MPa for the low pressure periods in the pulsation processes. For the first pulsation process (PP#1), 60 pressure cycles were applied during a seven hour pulsation phase. Since this treatment resulted in heavy cell collapse of the wood, a second schedule (PP#2) was used where the pulsation of pressure was speeded up to 80 cycles. For this process, it was also decided to take the low permeability of the wood into account and to extend the last high pressure period until one percent refusal treatment that was achieved after twenty hours of treatment. As cell collapse was still high for this treatment, a third variant of the pulsation process (PP#3) was defined where, additionally, the pressure during the high pressure periods was not raised immediately to 2.1 MPa but gradually increased from 1.0 MPa to 2.1 MPa during the first 6 pulsation cycles. Similar to the previously presented pulsation treatment of spruce wood, the low pressure periods were always one minute long. To compare the results of the pulsation process, the hydraulic pressure of the two full cell processes was applied for seven hours and twenty hours, and a twenty hour hydraulic pressure was applied in the case of the empty cell high pressure process.

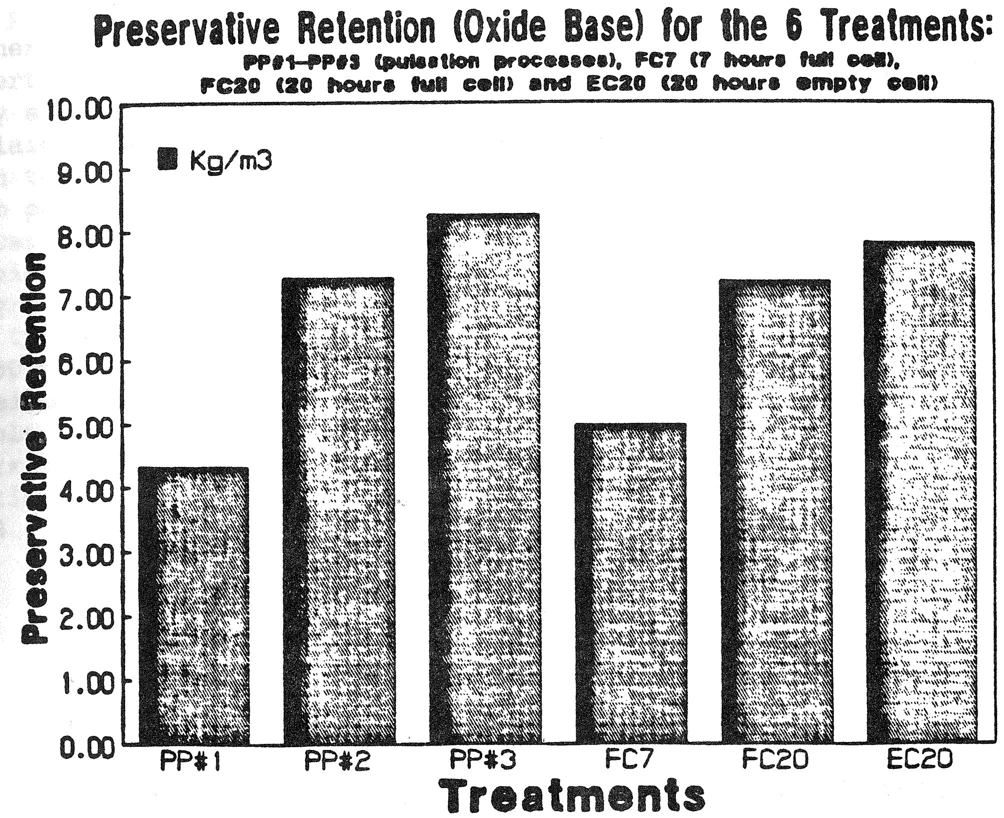
The treated samples were assessed for preservative retention using weight gain and sample volume, and also using the continuously measured preservative consumption. Preservative penetration was determined according to AWPA standard A2 (1986) after storage of the samples for at least three weeks. Two types of preservative penetration have been assessed, namely "preservative distribution" and "core penetration". To assess the preservative distribution, three lines parallel to the 4 cm face and 2 cm apart were used to measure the portion of the treated wood on the cross section at 10 cm distance from the resin sealed end, whereby a distinction was made between the completely treated outer shell and the inner part where partially penetrated rings were also taken into consideration. To assess the core penetration, a 4 mm large zone parallel to the 8 cm face was drawn in the middle of the mid cross section of the sample and considered as a split core of this location. In addition to the assessment of the penetration according to the standard, the average thickness of the completely treated outer shell was also determined.

Cell collapse was assessed in each sample using a mechanical device able to measure depressions of the wood between two latewood zones along a line across the grain chosen in each sample, on the most damaged parts. From these measurements, the mean depressions and the most severe depressions have been identified and their mean value calculated for each treatment. This procedure did not apply for the high pressure empty cell process because cell collapse for these samples was too severe to be measured by this method. In addition to the assessment of cell collapse, the mechanical damage due to treatment was also evaluated in the observation of the frequency and extent of earlywood/latewood separations.

4.3 Results

According to Figure 1, the retention of the samples treated with the two seven hour processes was 5 kg/m^3 for the full cell process and 4.3 kg/m^3 for the pulsation process, while all other samples submitted to a twenty hour long process were treated to a retention of over 7 kg/m^3. It appears therefore that the duration of treatment is far more important than the treatment schedule itself. Even if there is little difference between the processes, the third variant of the pulsation process shows, according to Figure 1, the highest preservative uptake, thus indicating the beneficial effect of this process. This might be due to the different rates of preservative uptake during the different treatments as measured through the preservative consumption during the treatments. In the pulsation processes, the preservative uptake proceeded at a lower rate at the beginning of the process and much higher rates in the later phases than the other types of treatment. Thus, preservative consumption during the pulsation processes was 0.2 1/minute after five minutes and 0.05 1/minute after thirty minutes of treatment, while these values were 0.4 and zero (too small to be measured) for the high pressure empty cell process.

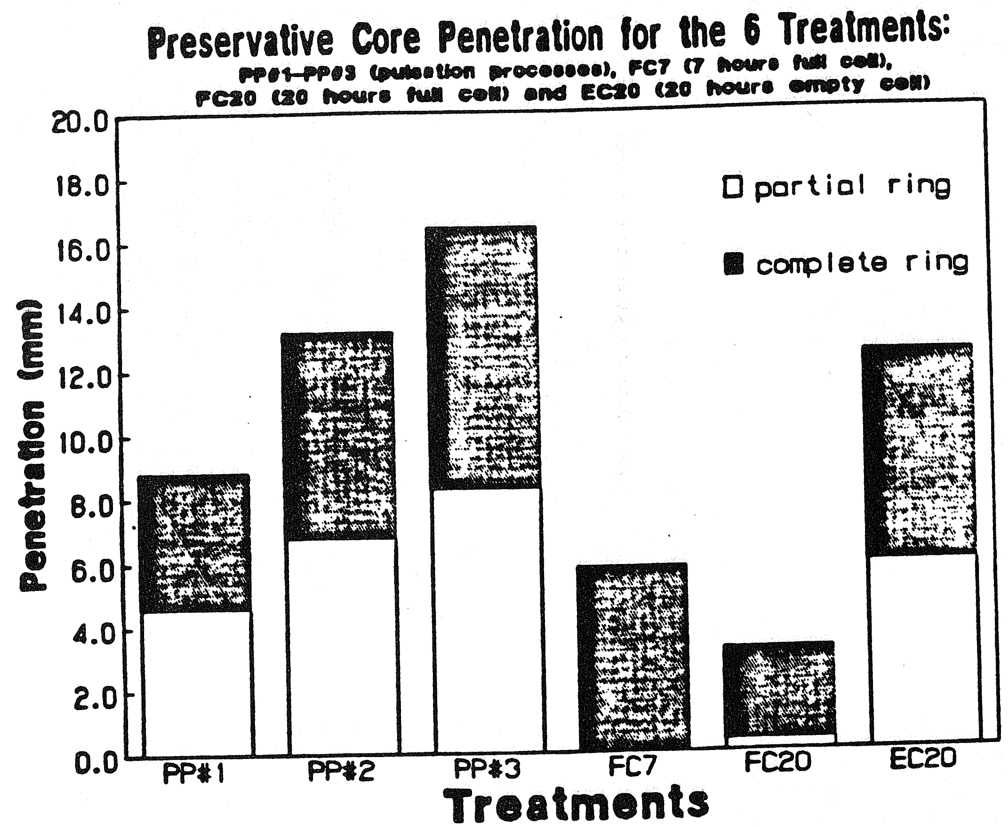
FIGURE 1



Even if spruce is not yet accepted for use in ground contact, CSA (1983) standard 080 requires a CCA retention of 6.4 kg/m^3 for lumber in ground contact which was fulfilled for about 75 percent of the samples treated with the four twenty hour processes, while only 14 percent of the samples treated with the short full cell process, and none of the samples treated with the short pulsation process could fulfill the standard requirements.

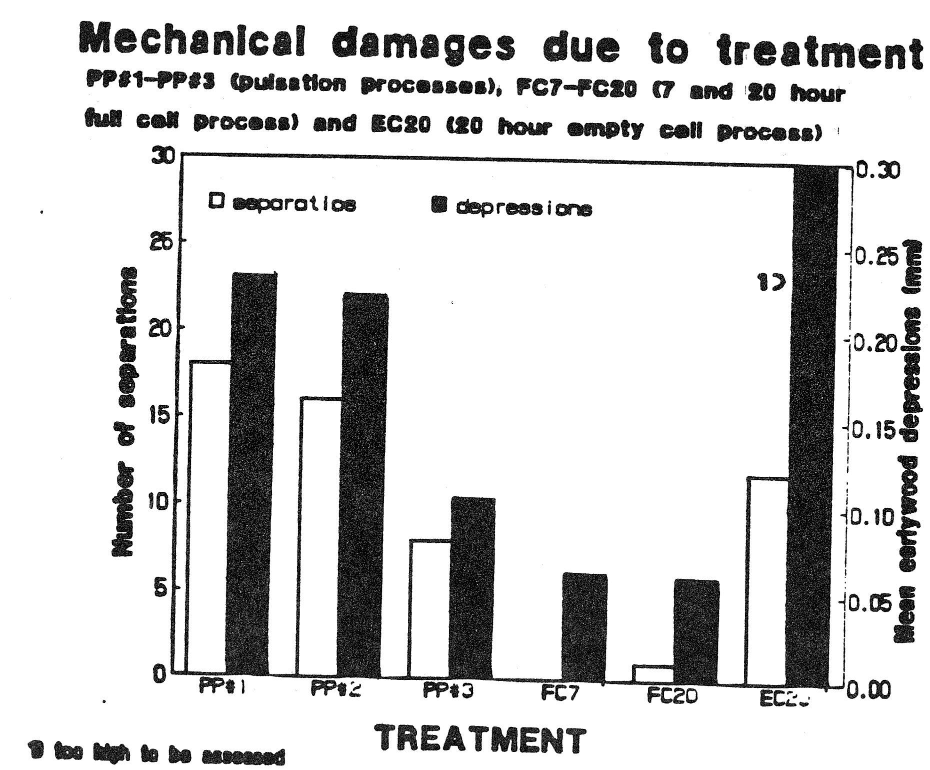
The results of the assessment of the "core penetration" are shown in Figure 2 and reflect the results which would have been achieved using the standard quality control method.

FIGURE 2



Highest values for the completely penetrated shell as well as for the partially penetrated zones have been achieved for the third variant of the pulsation process, followed by pulsation process #2 and the high pressure empty cell process. Comparing the completely treated outer shell only, the penetration by pulsation process #3 treated samples is not essentially higher than the one for the empty cell process treated samples. Nevertheless, the difference in the effectiveness of the two treatments is very significant when we consider the extent of the mechanical damage as explained below. As the standard penetration corresponds to the sum of both the completely treated zone of the outer shell and the zone where also partially penetrated rings are counted, 80 percent of the pulsation process PP#3 treated samples would fulfill the 10 mm penetration requirements for above ground use and 58 percent the 13 mm requirement for in ground use. Using the other two variations of the pulsation process and the empty cell process (which was heavily damaged), these values are 30-50 percent lower and only very few samples would fulfill the requirements when treated with the two full cell processes. Similar results have been achieved using the assessment of the "preservative distribution", whereby the portion of the treated surface on the cross section was 64 percent for the samples treated with pulsation process PP#3.

FIGURE 3



The mechanical damage due to treatment as shown in Figure 3 and as indicated by both the earlywood/latewood separations and the depressions of the earlywood zones, are mainly caused by the application of high pressure. Thus, very little damage can be observed when the wood is treated with the two low pressure full cell processes, while the damage is much higher when the high pressure systems, particularly the Rueping process (EC20), are applied.

As far as surface cell collapse is concerned, the beneficial effect of the pulsation process becomes evident when the processes PP#1-PP#3 are compared with the process EC20. The beneficial effect of the increase of the number of the pulsation cycles and the gradual increase of the pressure during the first cycles also reduce greatly the extent of surface cell collapse, thus indicating that the earlywood collapse in our experiments were, in fact, due to the treatment and not to the drying of the treated wood as it has been presented by Willeitner (1987).

The earlywood/latewood separations are significantly present in all samples treated with the high pressure systems, whereby their number might be much too small for the process EC20 because the extent of the surface collapse might have hidden many separations. However, their number per damaged sample decreases from 18 to 8 from process P#1 to PP#3, whereby 85 percent of the samples treated with the 60 cycle pulsation process showed separations while "only" 65 percent of the samples treated with PP#3 showed separations. However, the earlywood/latewood separations should not occur at all and the results indicate, therefore, only that the process has potential for improvement.

4.4 Conclusions

Preservative retention as well as penetration can be significantly enhanced when CCA is injected into spruce wood using a high pressure pulsation process. The considerable damage due to the pressure treatments can be significantly decreased when appropriate treatment conditions are applied such as the increase of pulsation cycles or the gradual increase of pressure during the first cycles. The results indicate therefore, that the pulsation process has potential for further improvements. More work has to be done to investigate and optimize the process to fully screen the possibilities to treat spruce wood to the standard requirements and to shorten the impregnation time.

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