# THE WORLD´s FIRST COMMERCIAL SUPERCRITICAL WOOD TREATMENT PLANT

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The paper describes a new wood treatment process, which is based on the use of environmentally friendly supercritical carbon dioxide technology. In the new process the wood is protected completely by use of an unharmful organic fungicide. Supercritical fluid treatment offers superior penetration, thus allowing impregnation of wood that normally can not be impregnated. The superior penetration adds durability and workability to the product, while maintaining the natural appearance of the wood. The application of this process in the world's first commercial supercritical wood treatment facility is described along with the operating experience from the plant.

## INTRODUCTION

Since the birth of modern wood treatment back in the 1830´s, little has changed and the majority of the industry is still turning out green-coloured treated wood. By far the most popular method world wide for wood protection is treatment with Chromated Copper Arsenate (CCA). In many countries, the future use of any metal containing wood has been called into question as the negative influence on the environment is coming under increasing scrutiny. People are concerned due to the leaching out and loss of trace metals during the service life of the wood and at the end of its service life. As a consequence, legislation on wood treatment has gradually been tightened such that CCA is being faced out from use in treated wood for use in most consumer and residential applications. A long time needed development in the wood treatment business along with increasing regulatory pressures have now led to the development of a new supercritical process for wood treatment that alleviates previous problems.

## PROCESS DESCRIPTION

The wood treatment process developed by FLS miljø is based on supercritical carbon dioxide as a carrier for the organic fungicide, which after treatment protects the wood against rot and decay. Like other gases $CO_2$ enters a supercritical state beyond a certain point (31 °C, 72,8 bar). In this state, the carbon dioxide has the ability to dissolve the fungicide and due to the low surface tension and gas like diffusivity, it has the capacity to penetrate the microcapillary network in wood. These properties combined with the capacity to act as a strong solvent, enables the supercritical $CO_2$ to penetrate the entire wood matrix. In the process, schematically shown figure 1, the wood to be treated is placed in a pressure vessel.

The wood is received in packages from a sawmill. Typical dimensions are a height and width of 1.1 m and a length that can vary from 2,4 to 6 m. The treatment vessel will typical have a length of 7 to 25 m and is designed for optimal filling of the wood packages. After the treatment vessel has been charged with wood packages, the vessel is pressurised using $CO_2$. After pressurisation the treatment vessel has a pressure of approx. 150 bar and a temperature of 40-60 °C. The $CO_2$ is then circulated through a small mixing vessel to which the fungicide

is added. The fungicide is completely dissolved in supercritical $CO_2$. After a certain treatment time the $CO_2$ containing fungicide has completely penetrated all the pores of the wood thereby providing a very efficient impregnation. Subsequently the vessel is depressurised, during which part of the process, the fungicide is deposited in the wood structure. $CO_2$ leaving the vessel during depressurisation is cleaned for excess fungicide and recycled to a $CO_2$ reservoir for reuse. The excess fungicide removed from the $CO_2$ can be recycled to the process.

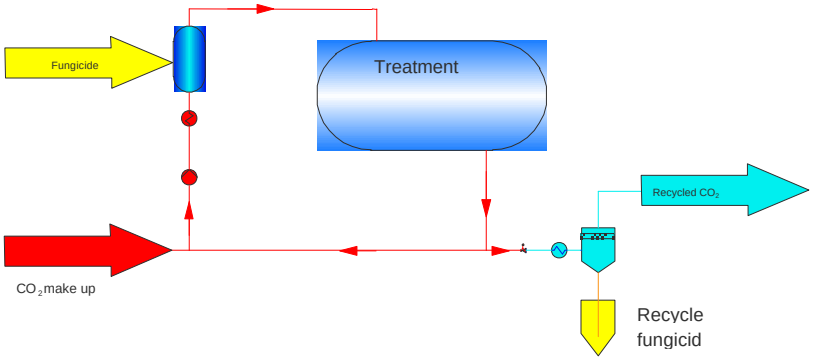


**Figure 1**: Schematic visualisation of the supercritical wood treatment process

The fungicide used in the supercritical wood treatment process is an unharmful, environmental friendly product. The company Supertræ (Superwood), operating the first full-scale supercritical wood treatment process has received an environmental award for environmental excellence and sustainable development.

Wood and timber products protected by the new supercritical wood treatment process has the trade name Superwood. The key features of the new wood treatment process are the following :

- environmentally firendly as no trace metals are used and, protection obtained by unharmful organic fungicide
- even distribution of fungicide inside the wood and in the wood package
- both sap wood and heart wood is impregnated
- no physical change to the wood and the wood is dry before and after treatment
- spruce can be impregnated
- flexible process – can be adjusted to various wood qualities and the concentration as well as the distribution of fungicide can be adjusted.
- wood can be disposed off in normal landfills

By the normal operation of the process the concentration of fungicide is lower in the heart wood part than in the sap wood part. This is an advantage as hard wood from nature side is more durable than sap wood. If for some reason it is desired to have a higher concentration in the hard wood the proces is flexible and can be adjusted to provide the desired concentration of fungicide. In the supercritical wood treatment process the wood keeps its natural colour and fragance and the fact that the wood has a natural appearance is a cultural and esthetic preference in many countries for exterior wood applications. The wood is dry and ready to use immediately after the process. Due to the superior penetration by the fungicide the wood can be maschined, without exposing unimpregnated areas. Furthermore, the lack of metals is less harsh on the tools. If required, the wood can be instantly surface treated. The workability of the supercritical treated wood is excellent. In contrary to conventional wood treatment processes, the supercritical process can be used also to protect spruce, which is abundant in

the northern hemisphere. The supercritical wood treatment can be performed even under severe winter conditions where the wood packages are frozen. Supercritical wood does not contain any hazardous trace metal and can after its service life be burned in normal waste-to-energy facilities or disposed off in ordinary landfills.

**PILOT PLANT EXPERIENCE**

A 4 year intensive development programme was performed in laboratory and pilot scale prior to building of the commercial facility. The development work has focused on resin containing wood like fir and spruce in dimensions up to 150 mm x 75 mm x 75 mm. The development work have focused on:

- Establishment of optimal treatment cycles for individual wood cuts
- Determination of the required fungicide retention level
- Controlling the level and distribution of deposited fungicides
- Controlling resin extrusion to the external surface
- Development of suitable wood characterization methods
- Mechanical properties of treated wood
- Field testing of the treated wood

Wood is a natural product with a wide variation in properties depending on factors such as wood type, growth conditions, wood dimensions and cross sectional shape, post growth treatment etc. All these factors play a role for the supercritical treatment cycle of the wood, and cycle conditions needs to be adapted to the specific wood characteristics.

The development work has proven that the required fungicide retention level can be achieved and be precisely controlled. An example of a Scanning Electron Microscopy (SEM) photo along with an elemental analysis mapping of the fungicide distribution in the cross section is shown below in figure 2.

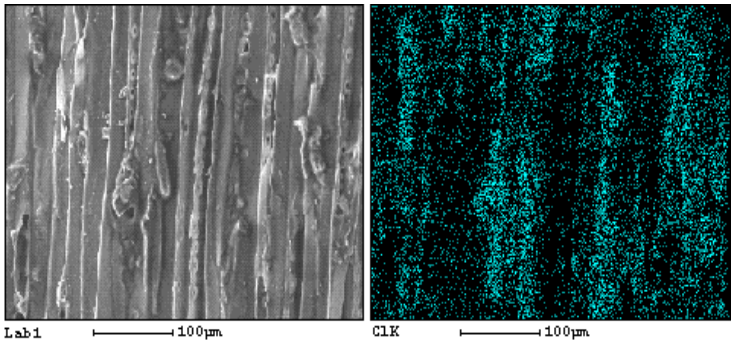


**Figure 2.** SEM photo and fungicide mapping of a wood cross section.

The fungides penetrates both the sap- and heartwood, and an even distribution can be obtained in both the longitudinal and also in the radial direction of the wood, if desired. However, as the heartwood has a better natural protection a lower deposition is desired in the heartwood. Hence, methods to control the fungicide distribution have been developed. The mechanical strength of the treated wood has been compared to the untreated wood by both visual and physical measurement methods, and has revealed that the mechanical properties remain unchanged after treatment. The long term duration of Superwood product is currently

being evaluated in a field test according to EN 12037. In this test lap-joints produced from Superwood are exposed to fungis under worst case conditions in a hot and humid atmosphere in Malaysia along with test species of untreated wood, and other types of treated wood. The test species are visually evaluated every 6 months. After two years of exposure the untreated wood is gone, while the Superwood shows no sign of rot or decay.

The development work in laboratory and pilot scale is continuing within the Supertræ company with other wood products and other impregnation chemicals such as insecticides and colorants.

## WORLD´s FIRST SUPERCRITICAL WOOD TREATMENT FACILITY

FLS miljø has for decades been designing and constructing supercritical and ultra supercritical coal fired boilers. The know-how and experience from supercritical water combined with the pilot plant experience with supercritical $CO_2$ processes gave FLS miljø a good position for entering into supercritical wood treatment. However, as the timber market was unknown for FLS miljø a/s, a new joint venture company named Supertræ (Superwood) was established in February 2000 in order to pursue the technology. The shareholders of the Superwood company are : Palsgaard Træ A/S (wood distribution and production), FLS miljø a/s (turnkey plants), LD (investment), FIH (banking), and Nykredit (real estate).

The world's first supercritical wood treatment plant with an annual capacity of 40-60.000 $m^3$ is situated in Hampen, Denmark. The plant started operation in March 2002. The plant is designed for a high availability, high flexibility, low energy consumption and low $CO_2$ loss. The key data of the plant is compared to the pilot plant in table 1 :

| | Pilot Plant | Hampen |
|---|---|---|
| Start up date | Nov. 1996 | March 2002 |
| Vessel size, l | 1 x 30 | 3 x 8000 |
| Maximum wood dimensions, mm | 150 x 75 x75 | 6600 x 1100 x1100 |
| $CO_2$ recovery, % | NA | > 96 % |
| Cycle time, hours | 1,5-5,0 | 2,0 – 5,0 |
| Annual Capacity, $m^3$ | NA | 40 – 60.000 $m^3$ |
| Scale up factor | NA | 260-800 |

**Table 1** : Key data of the world´s first supercritical wood treatment plant compared with pilot scale.

An artists view of the plant layout is shown in figure 3. The plant consists of the following major systems : a receiving, handling and storage system, three impregnation vessels, an advanced control system and an unique $CO_2$ cycle including systems for $CO_2$ storage, $CO_2$ conditioning, and $CO_2$ separation and recovery. In figure 4 and 5 the systems for $CO_2$ storage, separation and recovery, and receiving and handling are shown, respectively.

**Figure 3.** An artist view of the general plant layout of the world´s first commercial supercritical wood treatment plant.

**Figure 4.** The worlds first commercial supercritical wood treatment plant – $CO_2$ storage, separation and recovery system

**Figure 5.** The world´s first commercial supercritical wood treatment plant – receiving and handling system.

## OPERATING EXPERIENCE

The production was initiated in March 2002 after passing the performance test. From the beginning, the main equipment generally performed well, except for some problems encountered with the storage and transport system. Furthermore the deposition of fungicides have proved to scale well. The impregnation level was the same as obtained in previous pilot tests with an even distribution throughout each board, and with an even distibution within the wood packages as shown in figure 6. However, after 3 months operation major problems was encountered with the mechanical integrity of the wood, which led to uacceptable high failure rates due to grooves in some of the boards. These problems with grooves were not observed in pilot scale. A joint Supertræ/FLS miljø taskforce was established to find a solution to the problem. A nine months optimisation period with focused R&D efforts was needed before the problems with the mechanical integrity was solved for the whole product range. During this

optimisation period the equipment has shown capability to operate over a wide range of conditions, and the advanced control system has proved a high degree of flexibility over a wide range of operating conditions. By now the plant is in stable and successful operation, and is achieving the desired product quality.

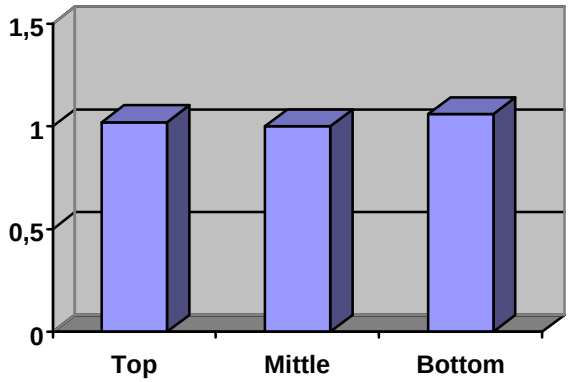


**Figure 6.** Distribution of fungicides within wood package. Target impregnation level is 1.0.

## FUTURE COMMERCIALISATION

All intellectual property rights on the new wood treatment process belong to Supertræ A/S, who will be the licensor for new plants. Contact can be taken to Managing Director Ole Dalsgaard Nielsen, Palsgårdvej 5, DK-7362 Hampen, Denmark, phone-no.: +45 76873202, e-mail: odn@supertrae.dk

## CONCLUSION

A unique, new wood treatment process based on the use of environmentally friendly supercritical carbon dioxide has been developed. The process uses an unharmful organic fungicide for the wood protection. The world's first supercritical wood treatment plant based on this process has been put into successful commercial operation.

This advanced wood treatment technology can help revitalise the wood protection industry; it gives it new opportunities and a promising future with an environmentally acceptable image.

## ACKNOWLEDGEMENT

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