IR BELT DRYER

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Introduction

IR-belt dryer

The goal with this description is to explain how we achieve high temperature efficiency, low specific energy in heat exchangers and in the drying process.

IR-belt dryer
Drying technology

Energy media:	Thermal oil Hot water Steam Combustion gas
Cooling water:	20 kg/s, 10^0 C -> 25^0 C
Installed effect: Thermal oil pump: Cooling water pump:	400 V, 10 kW (Belt conveyer motor, 2 fans)
Capacity:	Evaporate 1.5 kg/H_2O/sec.
Dimension:	L=18m, W=4.2m, H=4.5m
Weight:	45 metric tonnes

The process takes place in a closed box with 1 kg clean air, which circulates from the drying channel where the moisture is absorbed and then condensing on the upper lever, where it is also pre-heated before it goes down to the drying channel again.

This means it is a closed system.

IR-belt dryer
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Installed heat: 4-5 MW

Max condense effect:
1.5 x 2,500 = 3,700 kW

Specific energy:
Without condensation ~0.9kWh/kg moisture

Specific energy:
With recovery ~ 0.4 kWh/kg moisture

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IR-belt dryer
Drying technology

This drying technology is based on three characteristics:

- The highest absorption coefficient for water is in wavelengths of 5-10 µm.
- An oxidized surface has high absorption, transformation optics alloying the lamella with materials, which have low atomic numbers (z).
- High temperature efficiency on the inlet side of the heat exchanger is due to high transmittance.

This document has two chapters:

1. Lamella material
2. Drying channel

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Lamella material

The products we are drying give a low pH-value (3.5). Stainless steel with alloying is therefore a good solution. In order to increase the absorption at the surface of the lamella and the transmittance throughout the lamella we have:

1.1 Reducing the thickness of the lamella
1.2 Alloying the lamella

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1.1 Reducing the thickness of the lamella

Intensity reduction (-dI) in layer dx is assumed to be proportional to dx and dI:

$$-dI = \mu \times I \times dx$$

$$\frac{dI}{I} = -\mu \times dx$$

$$\ln I = c_1 \times -\mu x$$

$$I = c_2 e^{-\mu x}$$

Condition: $x = 0 \rightarrow I = I_0 = c_2$

$$I = I_0 e^{-\mu x}$$

$$I = \frac{I_0}{e^{-\mu x}}; \quad X \rightarrow 0 \rightarrow e^{-\mu x} \rightarrow 1 \rightarrow I = I_0$$

This means that thin lamellas give the transmitted heat a higher intensity.

From now on we have a thickness of t = 0.05 mm and a width of 1,250 mm. The material will be reinforced wherever necessary. In tube heat exchangers the lamellas are reinforced by the tubes. The thickness of the lamellas,

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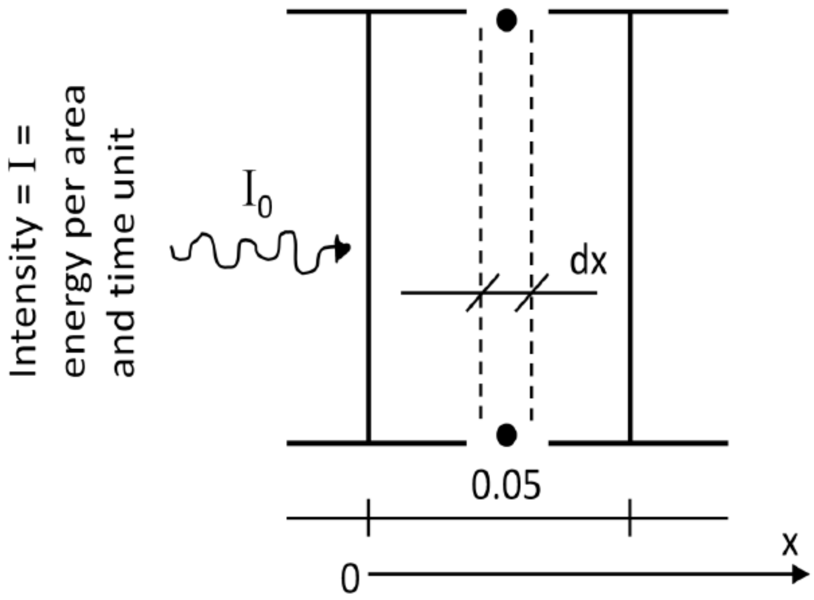
t = 0.05mm, is less than the penetration of the radiation heat, which is approximately 0.1mm.



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1.2 Lamella alloy

The lamella is alloyed in order to increase the absorption at the surface of the lamellas.

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1.3 Alloying the lamella

We can give this material the name of pentagon material. If the lamella, where the wavelength is transmitted, takes energy from the wave, absorption occurs and the intensity
($I = I_0 / e^{\mu x}$) will reduce along the wave.
The alloying can then reduce the absorption coefficient, μ (L^{-1}), throughout the lamella.

To summarize:

μ will reduce with lower Z (atomic number) as pentagon crystal are very resistant.

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2. Drying channel

The product has almost infinite surface area, which means the position on the belt will change continuously. Throughout the entire process, different parts of the product will be parallel to the radiators above and beneath the belt.

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Drying technology

2.1 Drying channel

The drying technology is based on four ideas:

- To dry in a closed circuit
- To dry continuously - progressive dryer
- To use radiating heat with wavelengths where water has a high energy absorption coefficient.
- Hygienisation

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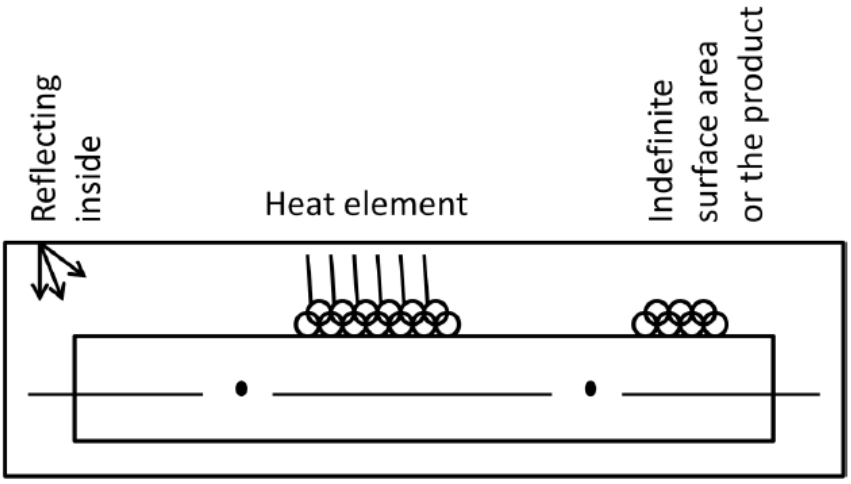
Drying technology

2.2 Drying channel

Cross section:



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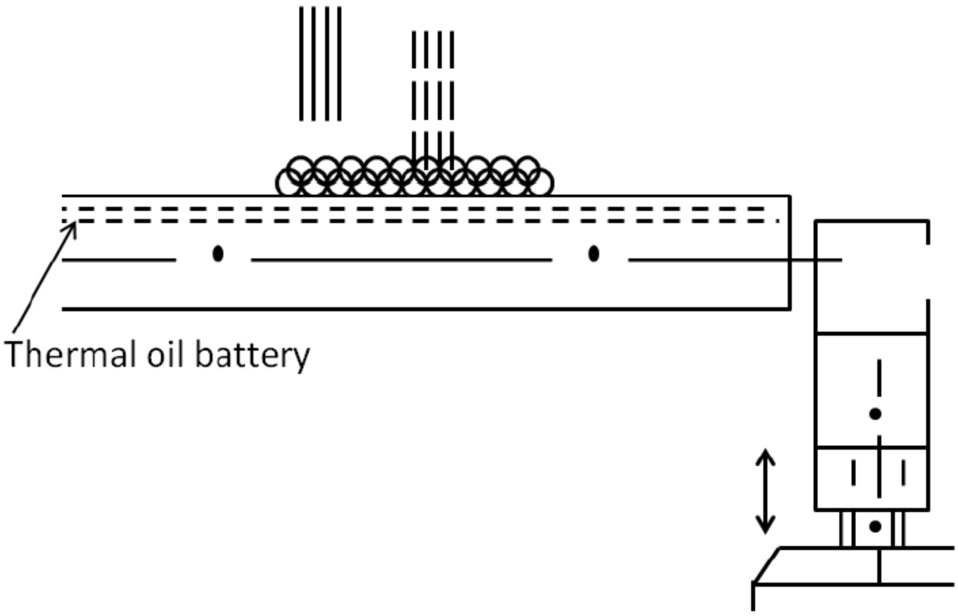
Drying technology

2.3 Drying channel

Radiator position and adjustment.
The design allows adjustments to be done to the distance between the radiators and the belt. We can even have the lamella partly touching the product.



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Drying technology

2.4 Drying channel

With Stefan Boltzman's law we are able to calculate the quantity of transmitted energy:

$$p = c_{12}\ A_1\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]; T_1=453\ K,\ T_2=333\ K$$

$$C_{12} = \frac{C_s}{\frac{1}{\varepsilon_1} - \frac{1}{\varepsilon_2} - 1}$$

$C_s = 5.67\ w/m^2\ K^4$

ε^1 = oxidized lamella = 0.97

ε2 = surface product = infinite area, wet and porous black body ≥ 0.97

$C12 = 5.34\ w/m^2\ K^4$

$A_1 = 2100 m^2$

The calculation is made 2015-01-11, version C.
$p = 5.34 \times 2100 \times (4.53^4 - 3.33^4)$
p = 3343 kW

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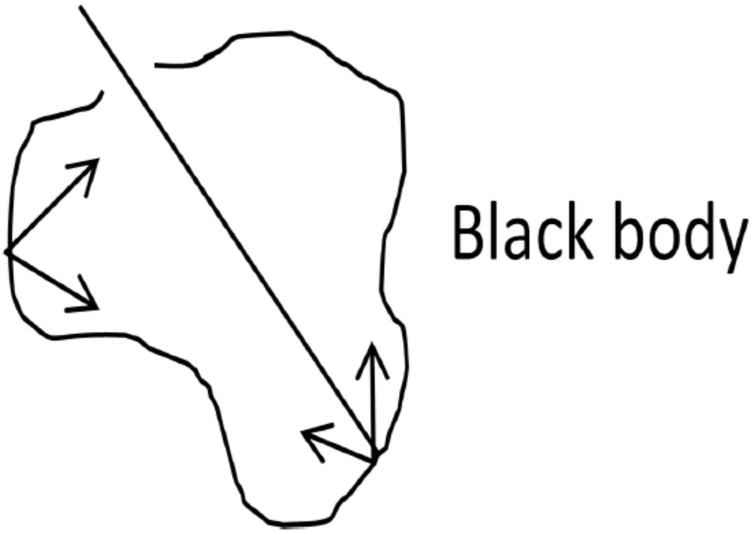
Drying technology

2.5 Drying channel

The product is porous



Radiation incidence

Small openings in the porous products absorps our wavelengths and reflects a number of times in the hollow void of the product. The walls are wet and very absorbant.

The probability that part of the radiation will penetrate the openings is very small and we are close to a black body.

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2.6 Drying channel

Wien's displacement law

It is important to know the wavelength of the radiated heat in order to evaluate of the quality of the heat transferred.

In this situation we have use of Wien's displacement law:

$\lambda_m \times T = 2.88 \times 10^{-3}$ m °K

This reaction state how the maximum value on the intensity curve changes as a function of the wavelength x_m at different temperatures.

The surface temperature of the radiators is

200 °C = 473 K and the maximum intensity is

$$\lambda_m = \frac{2.88 \times 10^{-3}}{473} \cong 6\ \mu m$$

We know that the highest energy absorption coefficient for H_2O occurs at these wavelengths.

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2.7 Hygienisation

Sludge is known to contain pathogens and this has also been shown in several studies.

Treatment method
Drying takes place during this process and hygienisation of the product occurs simultaneously.

The basic requirement is that the product is dried to a level of dryness where pathogenic bacteria can't form or grow, i.e at a dry substance of approx. 90%.

The product is dried and hygienised on the conveyor belt as it runs through the drying channel for about 5 minutes at an air temperature of approx. 180 ^{0}C.
This method can also be used when the product is to be pelletized.

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Drying technology

Validation

As indications of the degree of hygienisation for this method, we have chosen:
No salmonella bacteria are to be detected.
No parasite eggs are to be detected.
The degree of thermotolerant coliform bacteria should be < 2,500/g DS (dry substance)

Other indicators can be added, which will allow examination of several different microorganisms.

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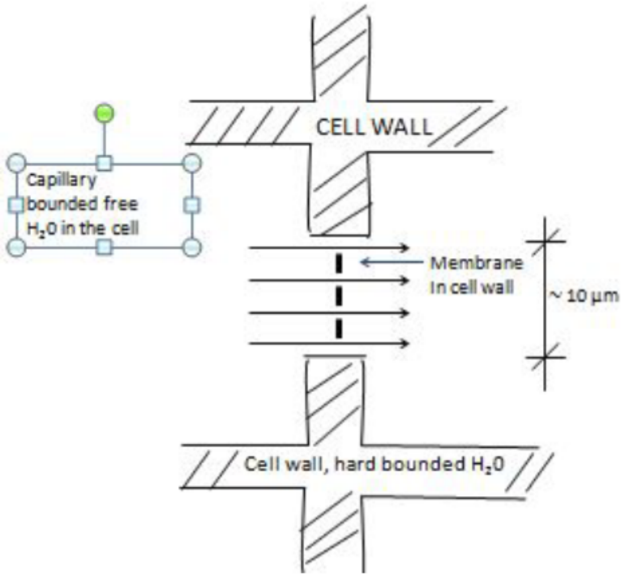
IR-belt dryer
Theory

Examples of material we dehumidify on the belt are sludge, sawdust, lignin and potato peel, potato chips, all of which are permeable cell structures.



95% of the product's granular size are in the 100-1,000µm range. The drying material, approximately 750kg lying on the conveyor belt, has a surface area that is much greater than the total surface area of the Netherlands.

The volume of the drying material remains constant throughout the drying process, i.e. dV=0.

IR-belt dryer

Theory

The most prevalent wavelengths are λ_{max} = 6-8 µm at a drying temperature of approx. 500K.
Shorter wavelengths λ penetrate the cell membranes more easily and are also carrying more energy according to

$$E = h \times f = \frac{h \times c}{\lambda} \; ; c = \text{speed of light}$$

The tests done by Södra it is evident the core temperature of the drying material is higher than on the surface. That also means the pressure is higher inside the drying material. At a raised diffusion pressure the moisture evaporation increases, kg/m^2s, and thereby the drying capacity of this drying process in comparison to a dryer that works with thermal conductivity with the opposite direction of pressure and temperature compared to the direction of the moisture diffusion.

IR-belt dryer
Theory

With a elevated core temperature in the drying material the disorder within the water molecules increases, i.e. the enthropy (S) increases.
Dehumidifying is a chemical thermodynamic process, which is the sum of the altered bindings n enthalpy (I) and altered disorder n enthropy (S).
When a mol (18.02g) $H_{2}0$ evaporates at $100^{o}C$ the following formula $\Delta S=S(g)$n $S(l)=109 J/mol\ K$ is known.

$H_{2}0$ (l) $\rightleftarrows$ $H_{2}0$ (g)
Liquid Steam

These reversible arrows symbolise that the evaporation (dehumidifying) is never complete, 100%.

The outlet temperature of the product is approximately 60^{0} C.

IR-belt dryer
Theory

The enthropy change in the drying material:
T_1 = the surface temperature of the material, approx. 373K. T_2 = the core temperature of the material, approx. 378K.

We end up with

$$S_2 - S_1 = \int_1^2 \frac{dQ}{T}$$

dQ = dU + dW
$dU = mc_{(s)}dT$ and dW=pdV
but dV=0 → dW=0 →

$$S_2 - S_1 = mc_{(s)} \int_1^2 mc_{(s)} \frac{dT}{T}$$

S_2-S_1 = 18.02 x 2257 (In378-In373)
S_2-S_1 = 542 J/mol K
(S_2-S_1) > 0 which means the heat must be taken from the surrounding area, i.e. from the outer parts of the drying material.
I.e. the radiation only needs to be applied to the surface, and the drying process is driven by the enthropy.

(S_2-S_1) / 5 = 542 / 5 ≅ 109 J/mol K   as above.

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Date
2009-02-16

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Kb Environment and Energy department
(Kb Miljö och Energi)
Christian Lyckehed

Test drying with TDS drier in Aurland

TDS drier

During this test, 10m^3 was dried and the energy consumption was registered. After this, the drier was run empty in order to determine the losses, with the same programme as used during the drying process.

A full drier, as per the size in Aurland, can dry 48 m^3 per load and the reference data was scaled up to simulate a full drier load. The loss was split across 48m^3 as this is more or less constant regardless of amount being dried.

The timber was measured for moisture content both before and after the drying process and density was established. The amount of water that had evaporated could then be determined and the energy consumption per kg evaporated moisture was calculated.
The energy consumption turned out to be **0.8kWh/kg evaporated.**

Chamber drying at Södra Timber Värö (STV).

The energy consumption in a progressive drier has been estimated to 80% of the energy consumption of a chamber drier and the production per year for a chamber drier at STV has now been set at 24,000 m^3. Production and energy data from 2007 was used for the calculation.
Inlet moisture content was established at 80% and outlet at 18%. Energy consumption is then **1.1 kWh/kg evaporated**.

Conclusion:

Nearly 30 % less energy per kg evaporated water is used by the TDS drier. A condensate of approximately 85°C is also obtained and if this heat is utilised, the overall efficiency increases even further.

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TEMPERATURE PROFILE IN THE TIMBER DURING THE DRYING PROCESS

Time	T centre	T surface
42	52	40
55	63	53
78	78	78
192	103	98
768	115	110
840	116	116
1080	124	121
1090	121	121
1120	69	74

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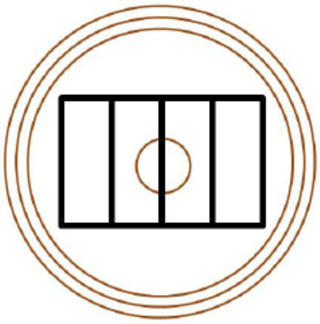

Test drying programme
White pine 47 x 200 [mm], 4-log

Step		Time (min.)	Medium	Moisture content (%)
I.	Heating	0-40	Steam	80
II.	Drying	-840	IR	10
III.	Equal.	-1090	Steam	18
IV.	Cooling	-1120	Air	18

The drying process finishes in step II with an average moisture content of approx. 10%, but with a significant standard deviation as the timber is part of individuals that have grown in soil of varying nutritional value.

In step III we add steam to equalise variations in moisture content.

The driest planks soak up more steam, so that the drying rate gets a standard deviation of 1.

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