Cost efficient drying with an expensive energy

Optimised Infrared Radiation combined with Hot Air

Wolf Heilmann

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COMPACT ENGINEERING

- Introduction
- Physics of drying
- Physics of infrared drying
- Application cases
- Summary

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Introduction

- Paper making is based on dilution and dewatering
- Most expensive part is the dewatering i.e. drying
- Optimizing drying delivers the biggest cost savings

Physics of drying

- Drying is a two step process.
  - Energy transfer – **heating** the matter to be dried.
  - Mass transfer – **evaporating** the water from the matter to be dried.
    - Water will move to the cooler side.
    - Steam enthalpy will cool matter to be dried.

Heating Principles

- Heating by means of
  - Conduction – Cylinder
  - Radiation – Infrared
  - Convection – hot air

Heating by infrared

- Most costly drying method.
- Most efficient coat drying method.
- Drying characteristic depends upon wave length.
- Heats either **surface** or **substrate**.

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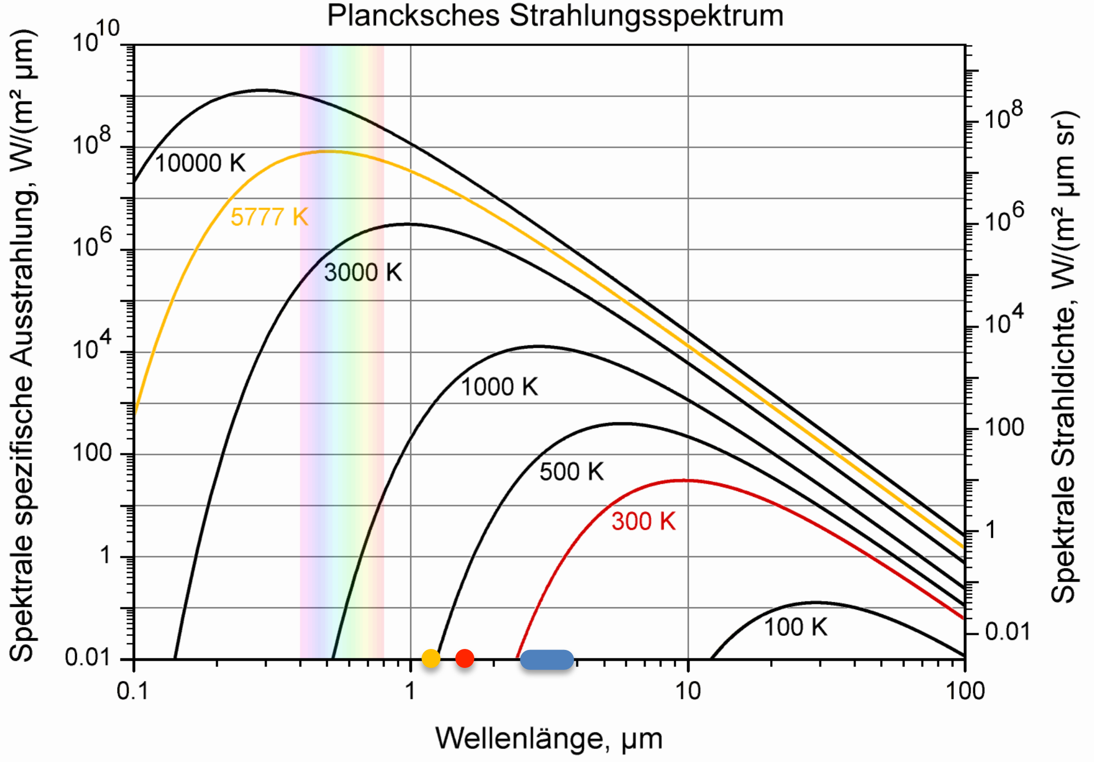
Drying by infrared – radiation



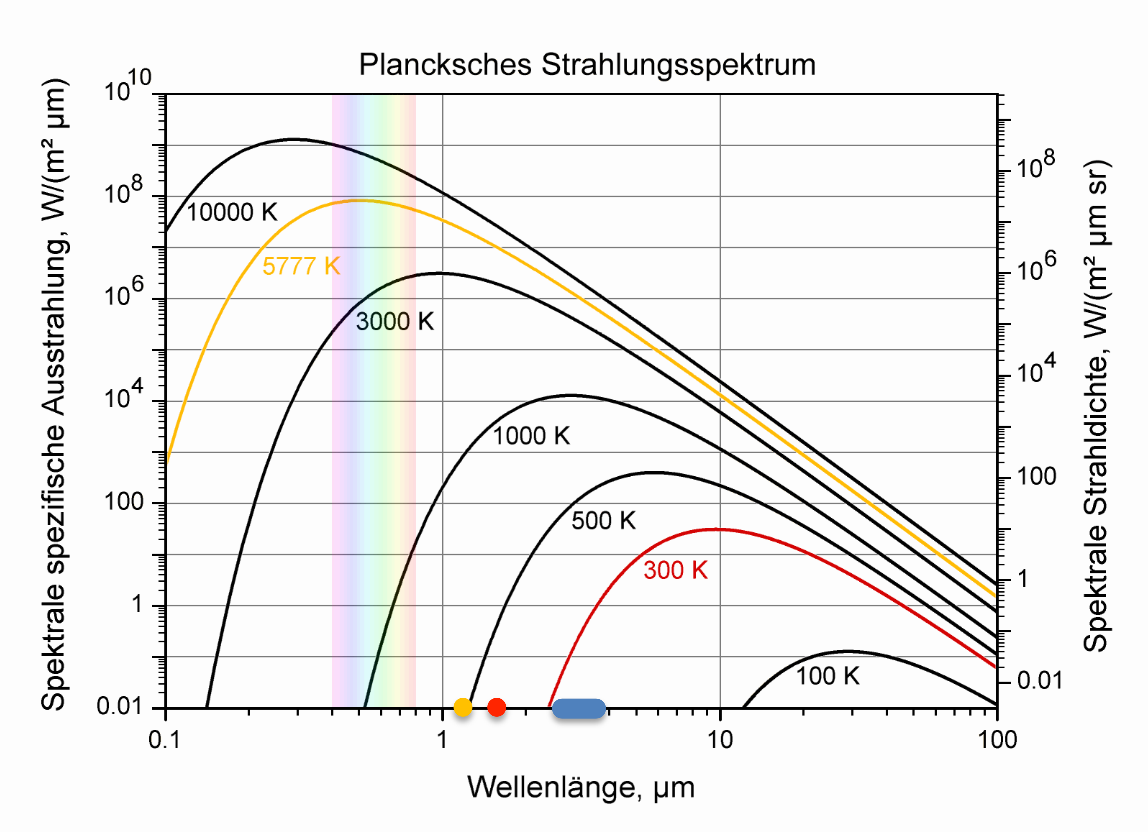
Gas fired MIR:
peak radiation between 2.5 and 3.5 µm, which corresponds to 1.160 to 830 K

Standard electrical NIR:
peak radiation at 1.18 µm, corresponding to 2.450 K

Enhanced electrical NIR:
peak radiation at 1.45 µm, corresponding to 2.000 K.

Temperatures following Stefan-Boltzmann and Wien's law of displacement

Drying by infrared – radiation



Energy density of the radiation increases by 4th power of temperature:

1.000 K: 1x

2.000 K: 16x

Drying by infrared – absorption

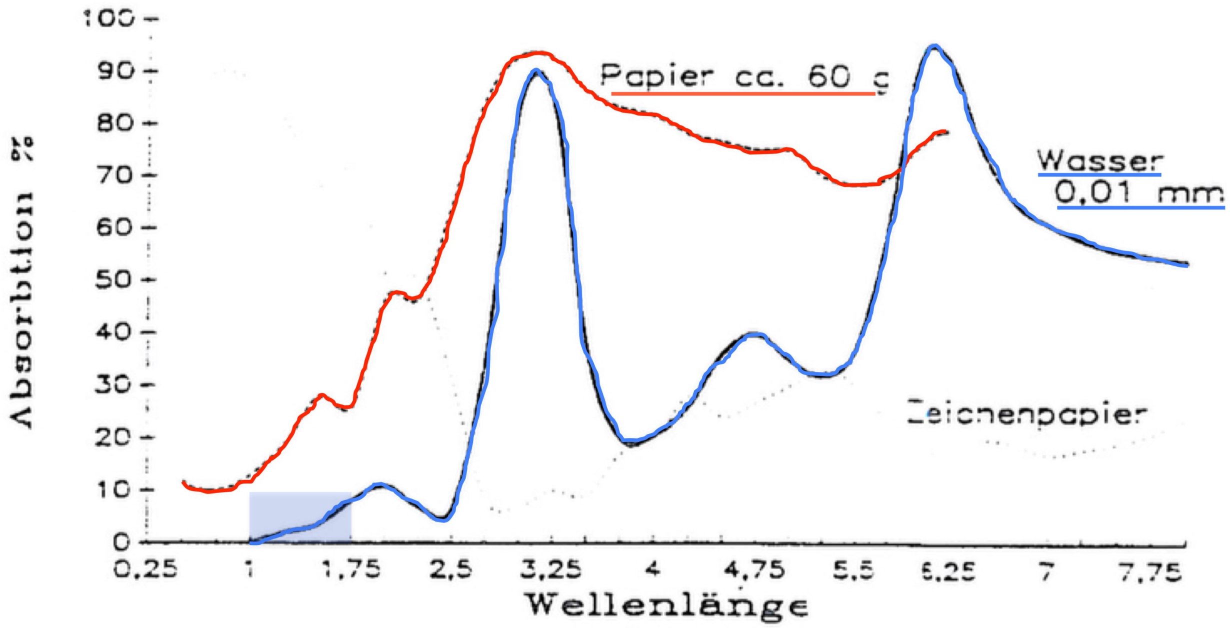


Abb. 7: IR-Reflexion und Absorption von Papier und Wasser

Source: Influence of emitter temperature of infrared emitters upon drying performance
Helmut Graab, Wochenblatt für Papierfabrikation 19/1991

Only the absorption of radiation delivers heat.

And thus drying potential.

Drying by infrared – absorption

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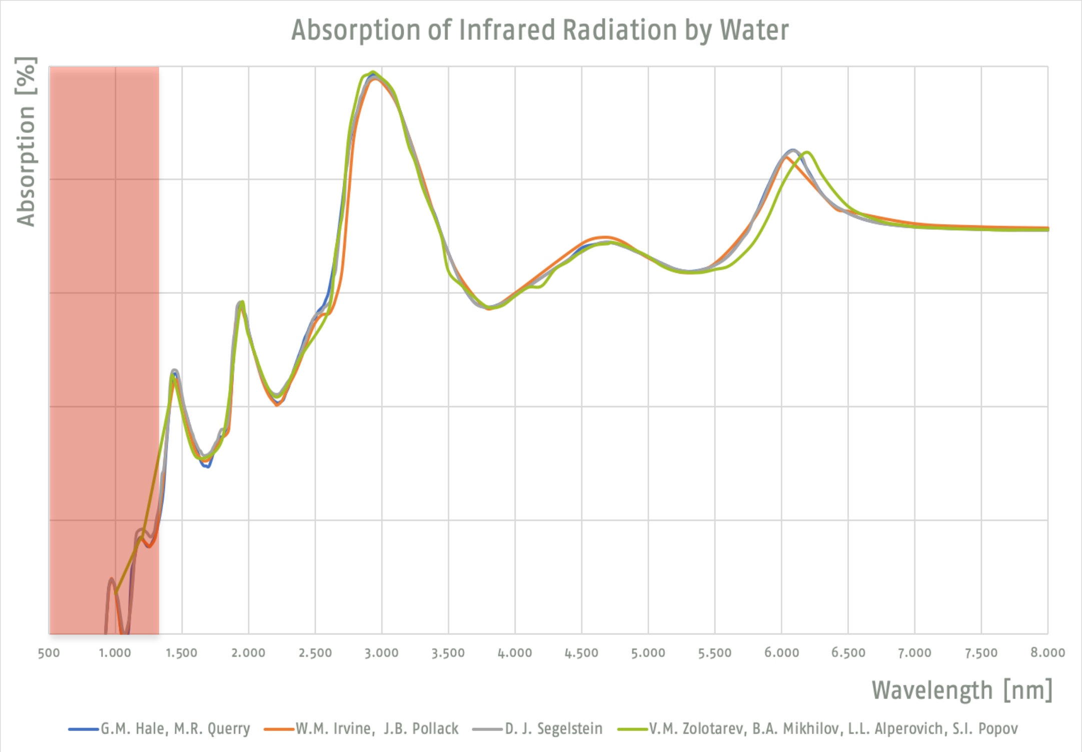


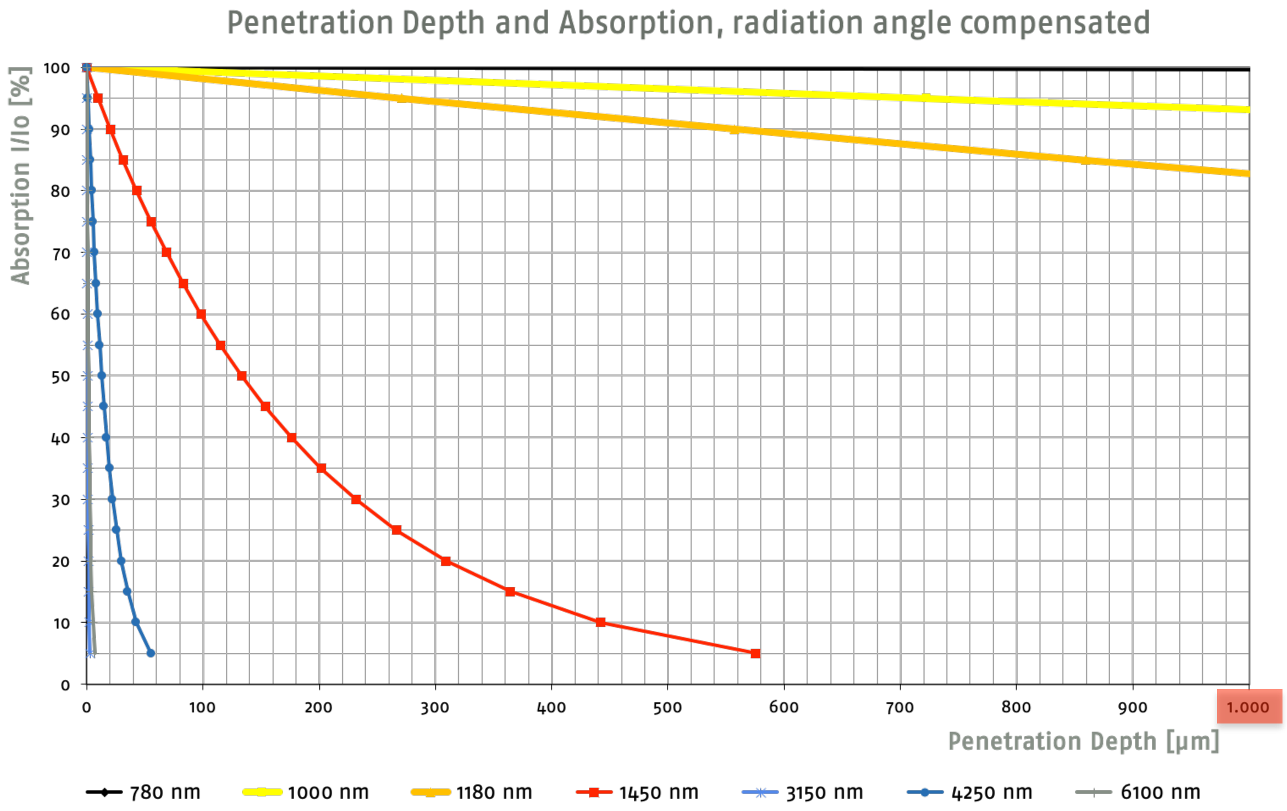
Virtually no absorption of infrared radiation by hydrogen bonds at wavelength below 1.3µm.

Strong peaks at 1.45µm and 1.95µm.

Very strong peaks at 3µm, 4.7µm and 6.1µm.

At 1.45µm energy density is 16 times as heigh as at 3µm.

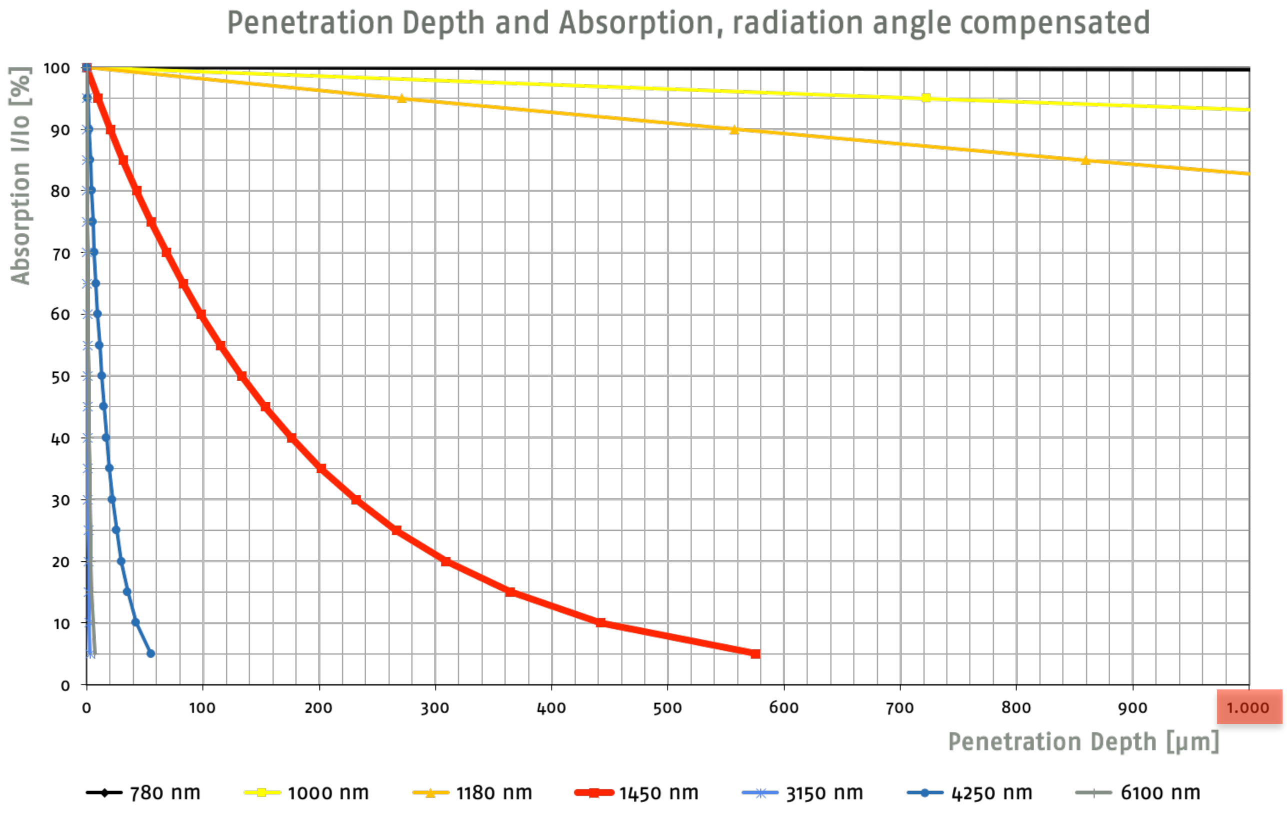
Drying by infrared – penetration of NIR



Radiation of electrically powered NIR emitters
(peak wavelength 1,18 µm) penetrates very deep with little absorption.

Penetration following law of Lambert-Beer

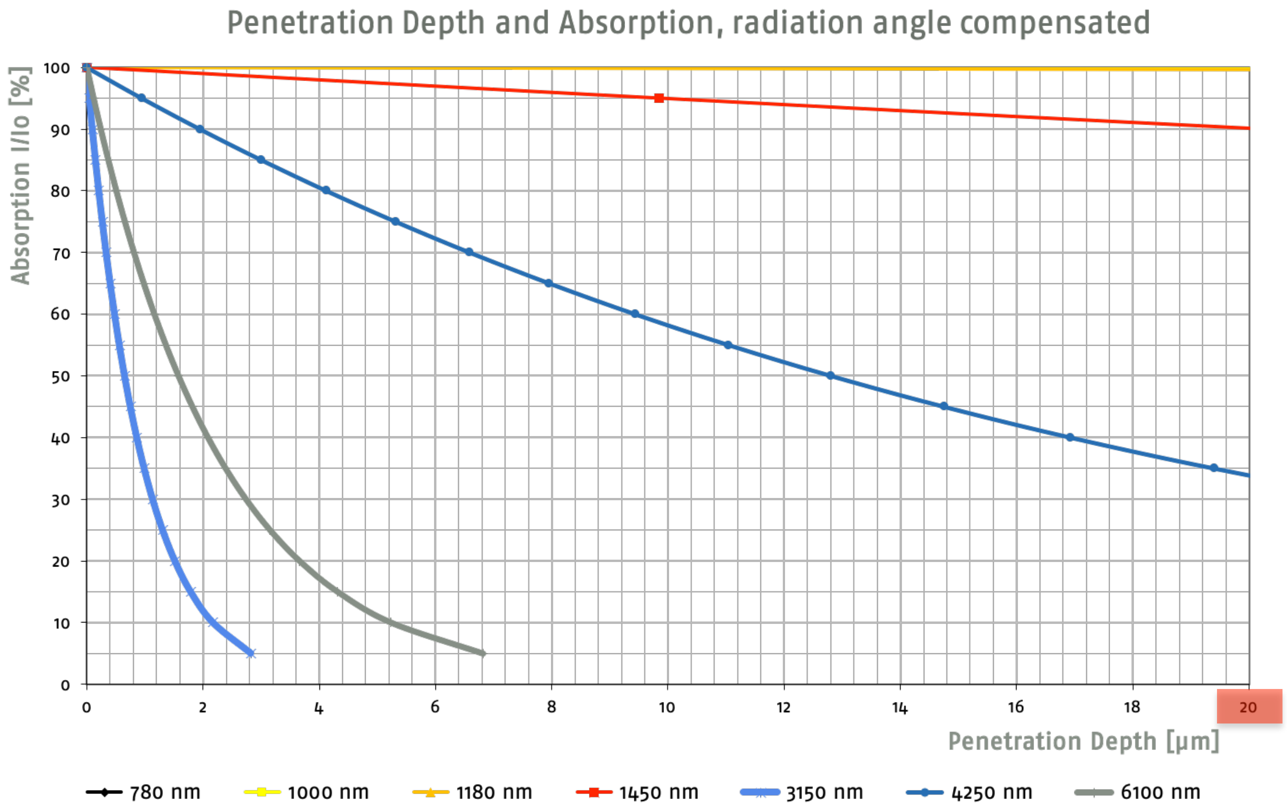
Drying by infrared – penetration of eNIR



Enhanced electrically powered NIR emitters
(peak wavelength 1,45 µm)
penetrates deep into the substrate with strong absorption.

Penetration following law of Lambert-Beer

Drying by infrared – penetration of MIR



Gas-generated MIR infrared radiation is absorbed within few microns.

Gas fired MIR heats the surface.

Penetration following law of Lambert-Beer

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Application Cases

- Specialty coat drying with hot air and booster
- Board pre coat drying with NIR and eNIR
- Profiling
- Impingement warming

Specialty coat drying with hot air

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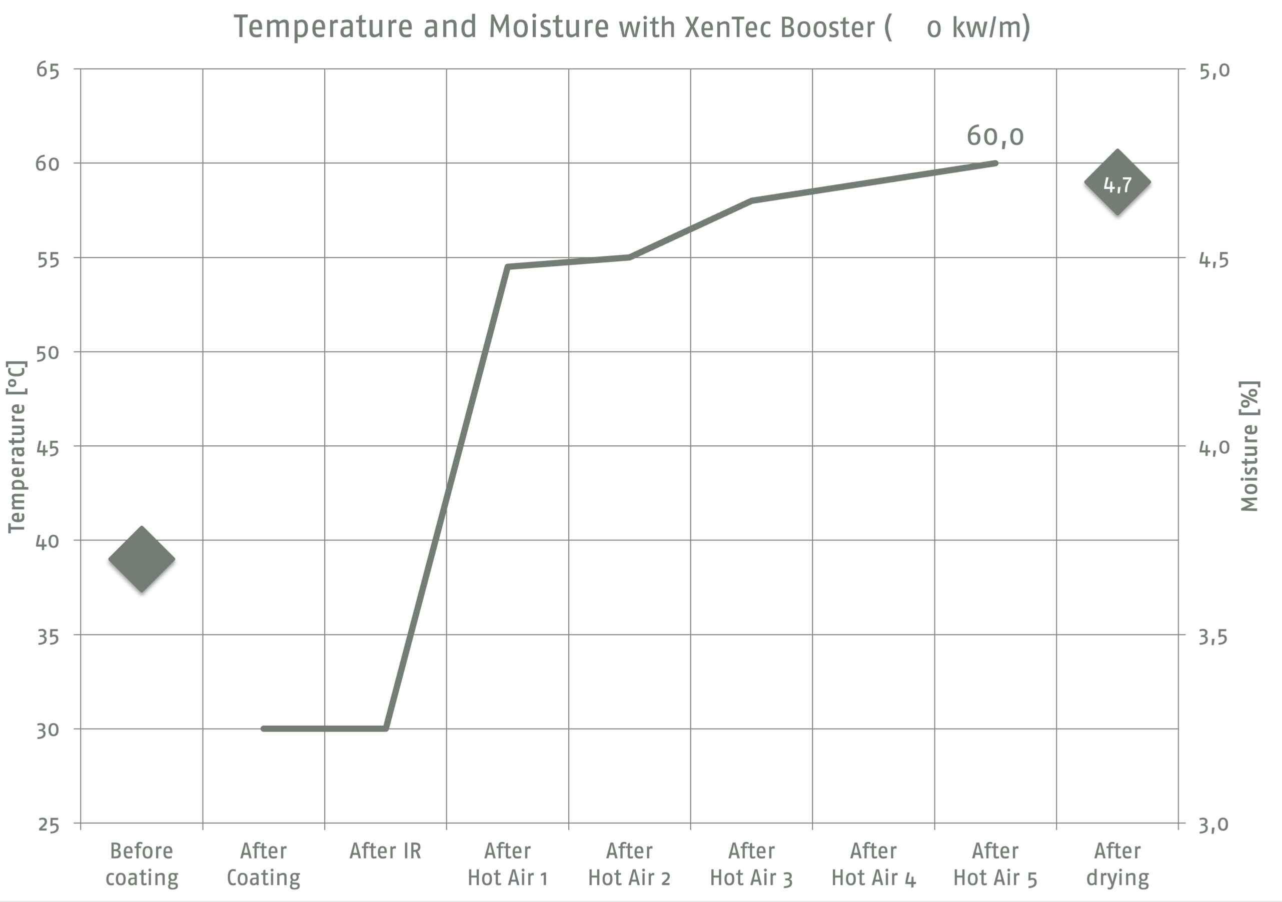
Specialty coat drying with hot air



Typical drying curve of a specialty paper coater.

Temperature curve must be controlled.

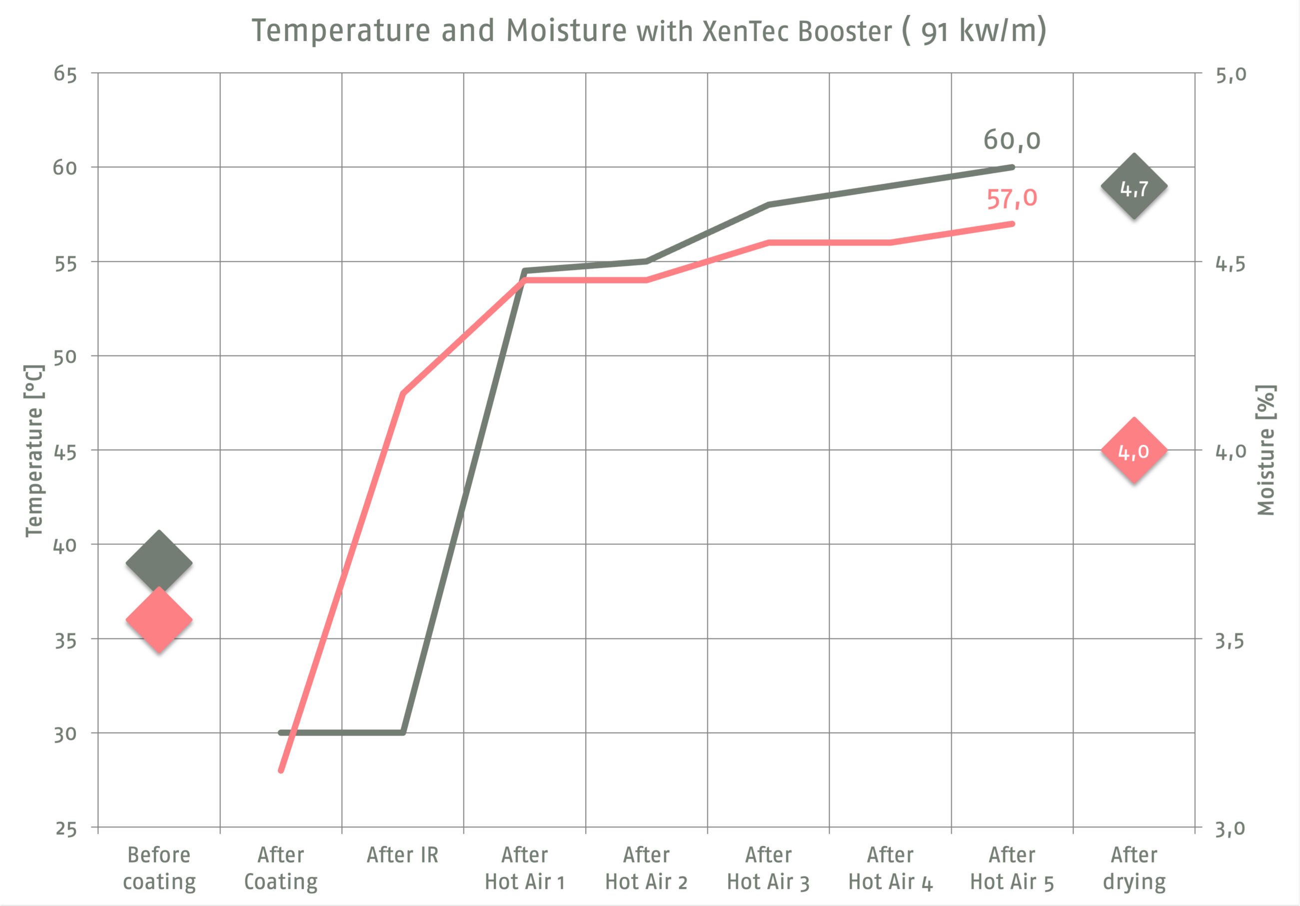
Overall moisture increases by 1.0%.

Part of water moved into substrate.

Therefor less evaporation.

Temperature reaches 60°C before reel.

Specialty coat drying with eNIR booster



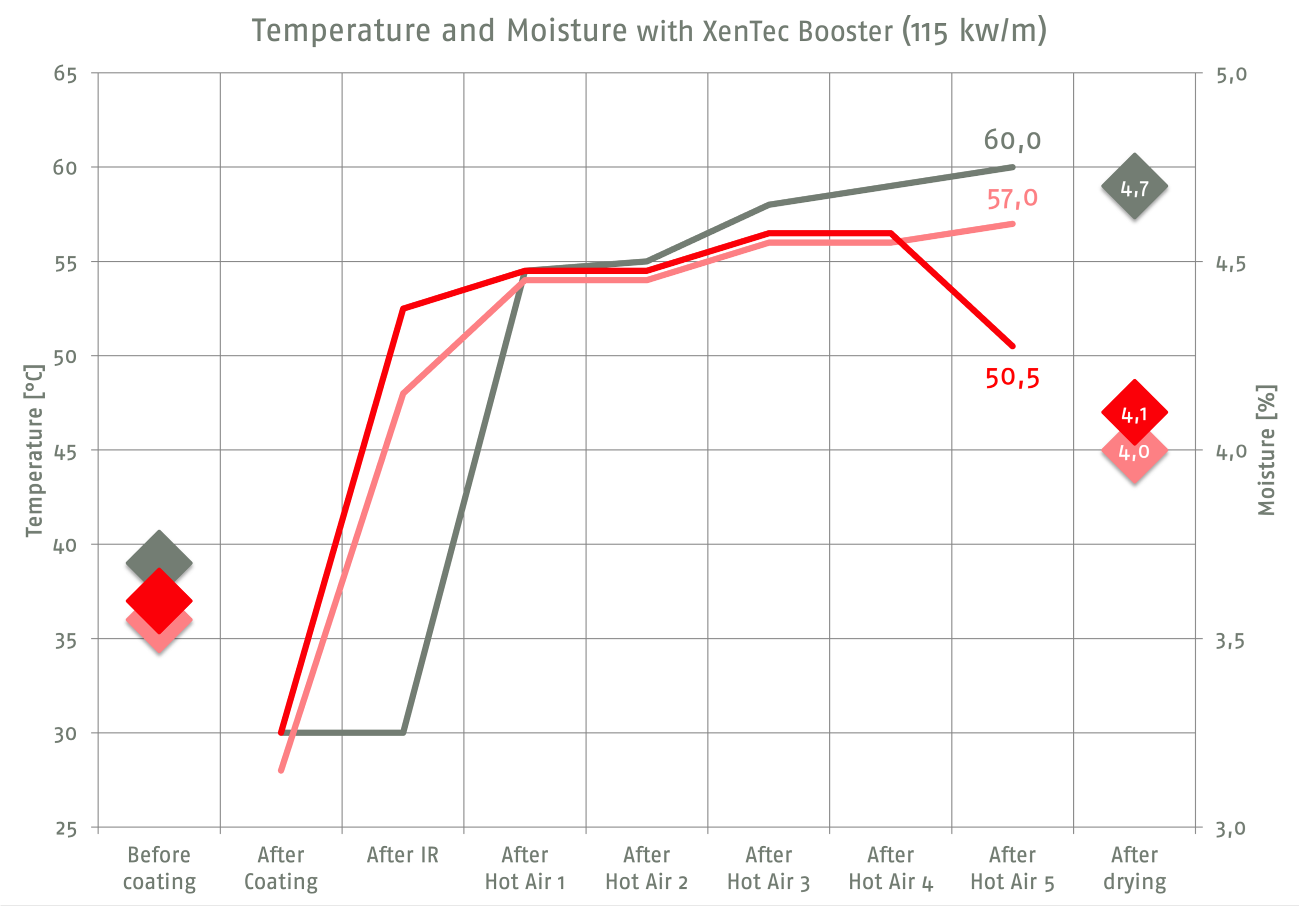
The booster at 57% power reduces the maximum temperature as during radiation water is evaporated, using steam enthalpy for cooling down the surface.

Hot air dryers setting fixed.

Overall moisture increases by 0.4%.

Speed is increased by 8.5%.

Specialty coat drying with eNIR booster



The booster at 73% power reduces the temperature by 9.5°C at reel with 3.5°C lower max. temperature as during radiation water is evaporated, using steam enthalpy for cooling down the surface.

Hot air dryers setting fixed.

Overall moisture increases by 0.5%.

Speed is increased by 12,5%.

Pre coat drying with NIR plus hot air

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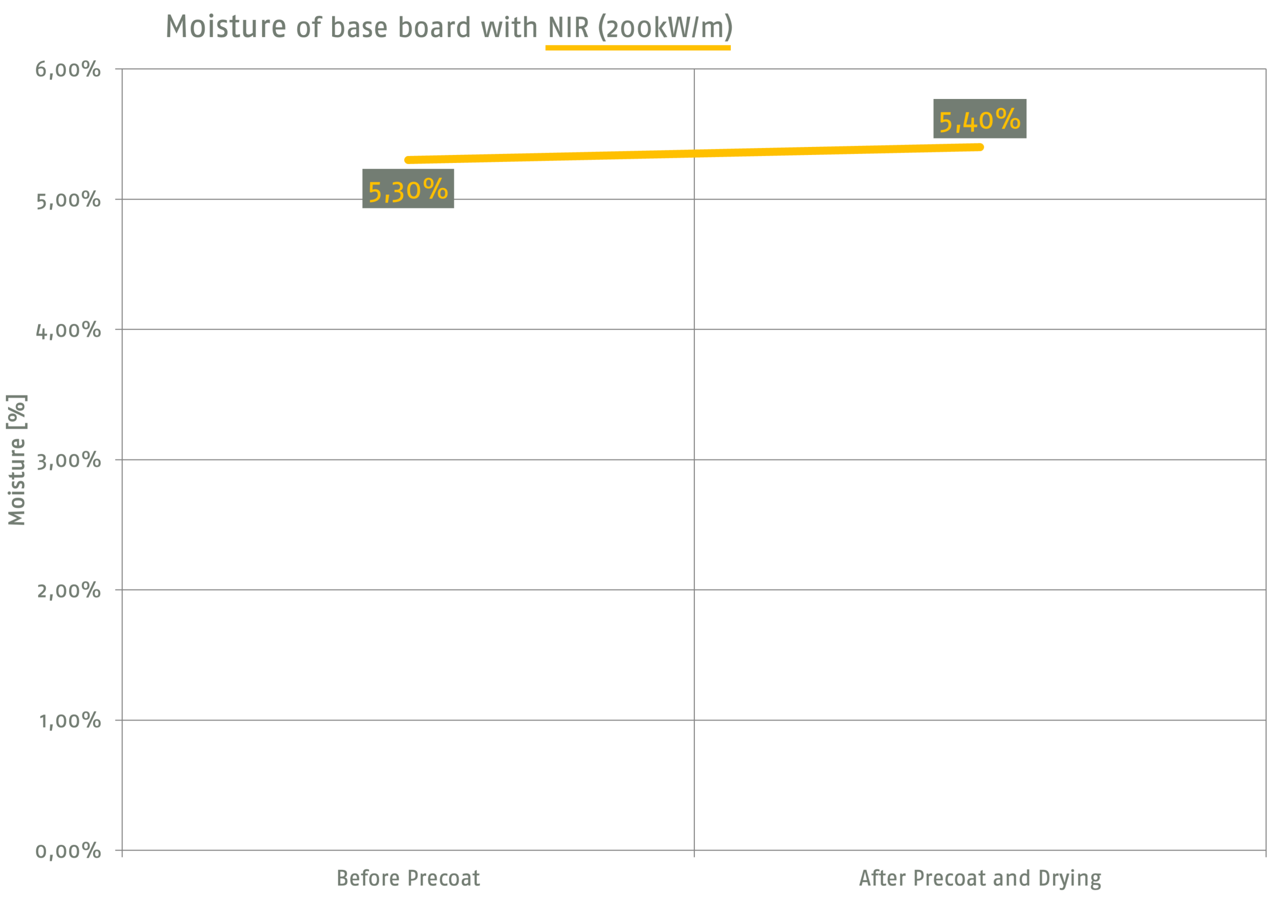
Pre coat drying with NIR plus hot air



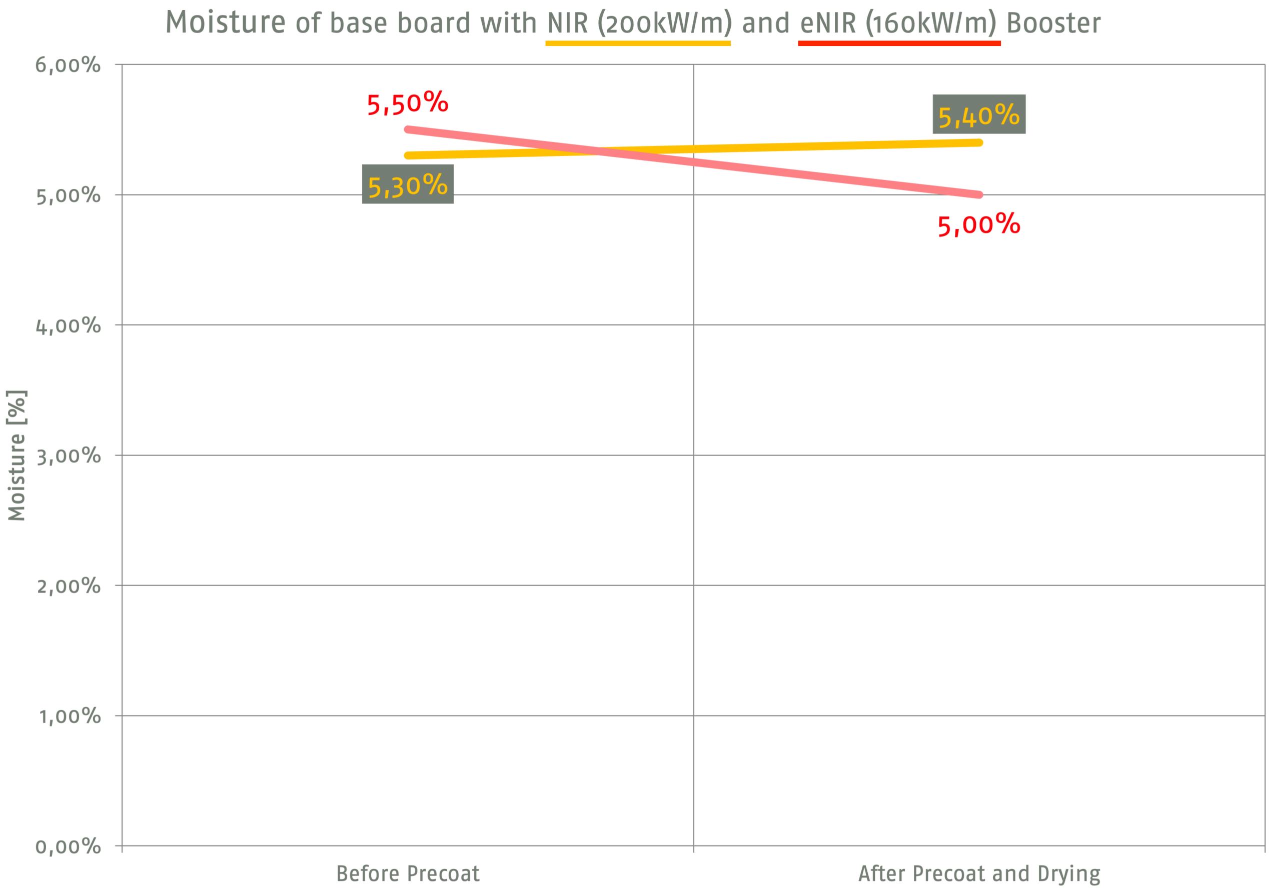
Substrate basis weight 280 gsm

Pre coat weight 15 gsm.

NIR penetrates deep into substrate.

Too much energy lost in visible spectrum, thus drying insufficient.

Pre coat drying with eNIR plus hot air

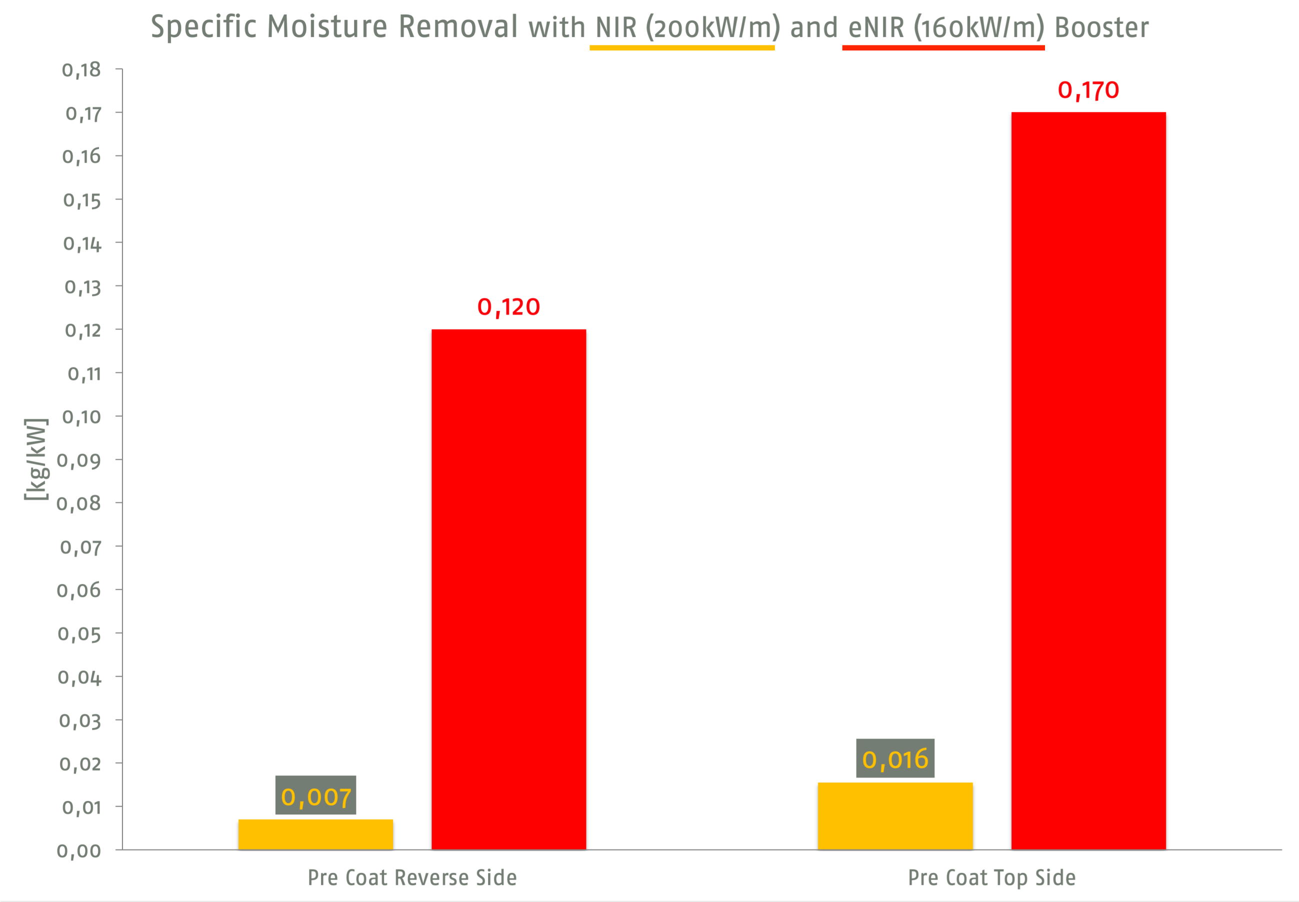


With enhanced wavelength, the substrate is heated with less losses.

Less energy evaporates more water.

Less water of coating penetrates into base board.

Pre coat drying with eNIR plus hot air



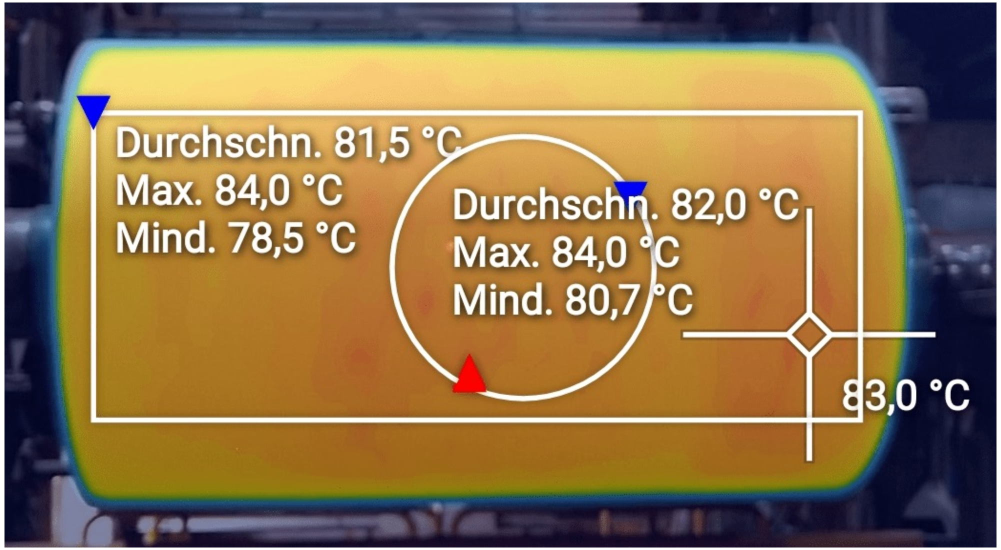
The specific evaporation was largely improved:

On the rough reverse side, it was improved 14 times.

On the smooth side, where the NIR delivered double the evaporation rate than on reverse side, it was improved tenfold.

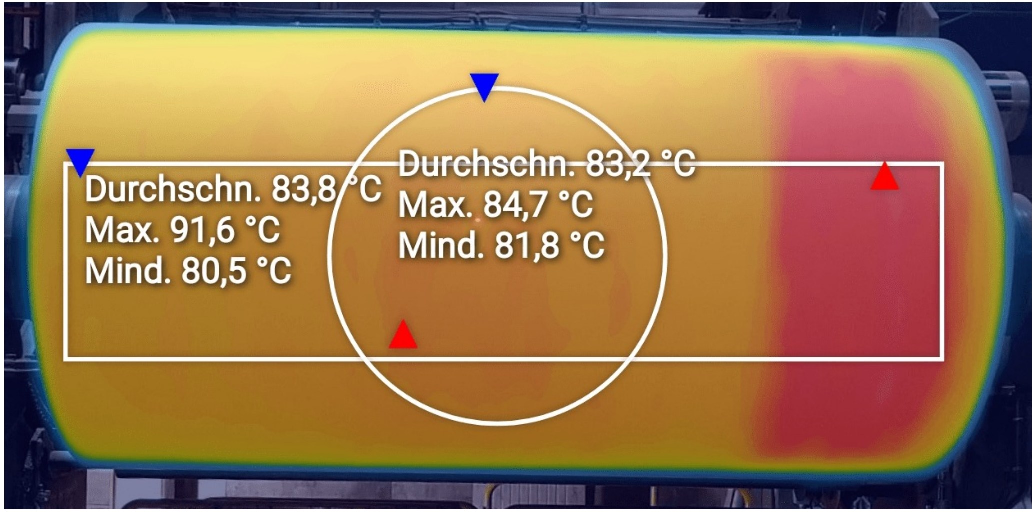
Profiling at 0 kW/m

Profiling at 0 kW/m



- emitter 0 kW/m
- Moisture variation visible through temperature variations
- Sheet is 1°C cooler on tender side as in center

Profiling at 320 kW/m



- Emitter at 320 kW/m
- On tender side, sheet is 6,9°C warmer as in centre, so +7.9°C as without radiation
- Machine was speeded up by 3,5% only
- Should have been 10% to 14% faster
- Tender side had 2,4% less moisture as rest of sheet

Profiling

- Applying 155 kW/m allows increasing production by 12%
  - At electrical cost of 0.15€/kWh this will cost 1,62 €/t
- Applying 450 kW/m allows increasing production by 24%
  - With 3,16 €/t additional cost

Impingement Drying

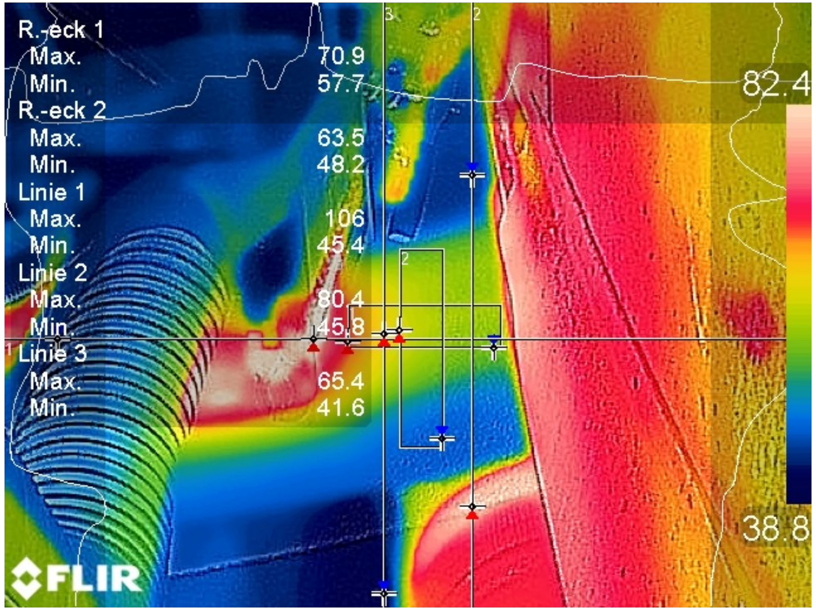
Impingement Drying

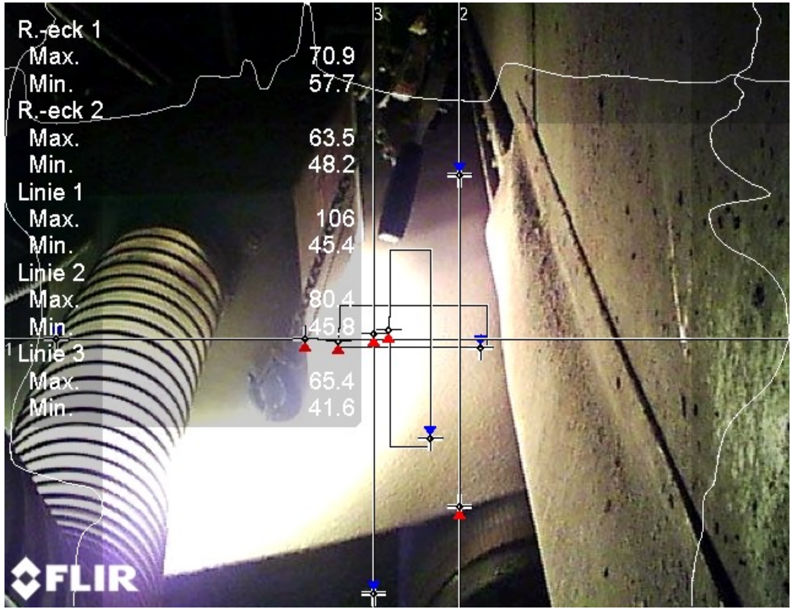
- Board up to 2.000 g/m^2

- At high V_{prod} risk of delamination increases
- Centre of board in z-direction isn't warmed sufficiently

Impingement Drying

- Trial installation between last press nip and hood entry





Impingement Drying

- Sheet starts evaporation at 2nd drying cylinder
  - More cylinders available from evaporation
- Production increase without affecting delamination
- Works perfectly on heavy grades

Impingement Drying

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- Applying 185 kW/m a production increase of 23% is achieved.

- Per additional ton of board 27 kW electricity required.
  - At presently 0,15€/kWh the additional cost is 4€/t board.

- The more cylinders are presently used for heating, the faster the investment pays back.

Impingement Drying

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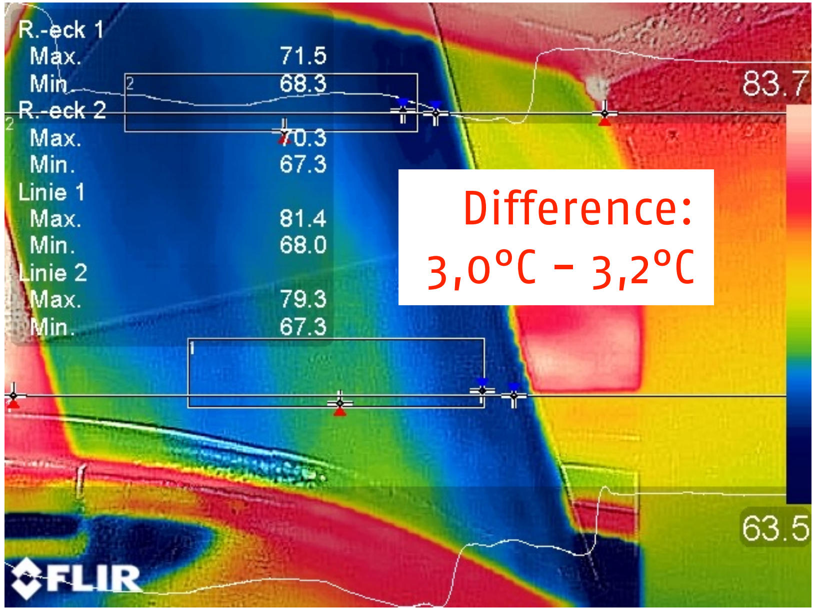
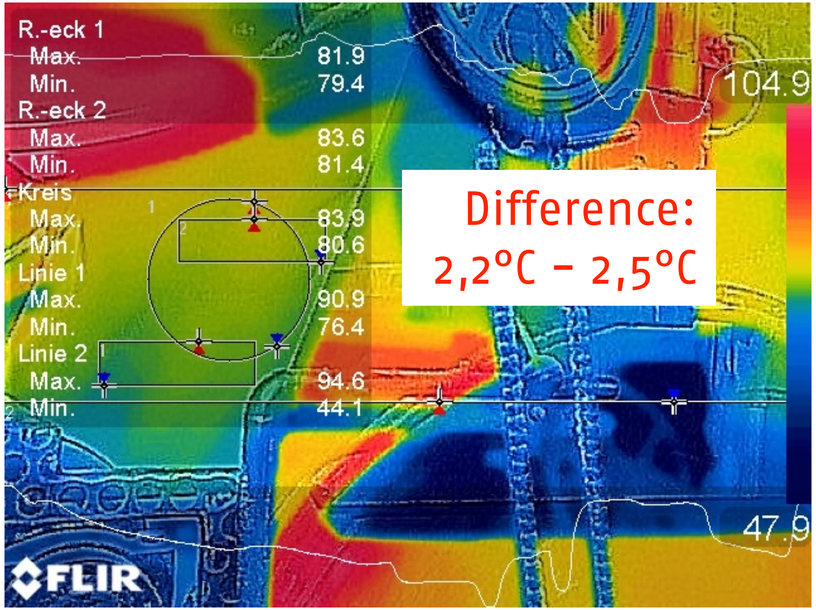
- Surface temperature radiated side (1st – 2nd cylinder)



- Surface temperature non-radiated side (2nd –3rd cylinder)



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Summary

- Drying with infrared is expensive but cost efficient when used right way:
  - Selecting the right wavelength for heating the substrate.
  - Selecting the right evaporation regime while heating.
  - Use infrareds as booster and whenever high energy density is needed.

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Thank you

Questions?