Drying of Functional Coatings

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Coating Symposium 2023

13. & 14. September · Bamberg

Drying of Functional Coatings

- Introduction
- Specifics in Drying Functional Coatings
- Required Drying Strategy
- Physics of Drying
- Defect Free Drying of Functional Coatings
- Summary

Introduction

- Drying process is more critical:
  - Function(s) of surface must be achieved.
  - Smooth surface is required frequently.
  - Blistering and pinholes must be prevented.
  - Normal drying regime may be insufficient.

Specifics in Drying Functional Coatings

- Functional coatings must be dried from the bottom to top for achieving full function of surface.

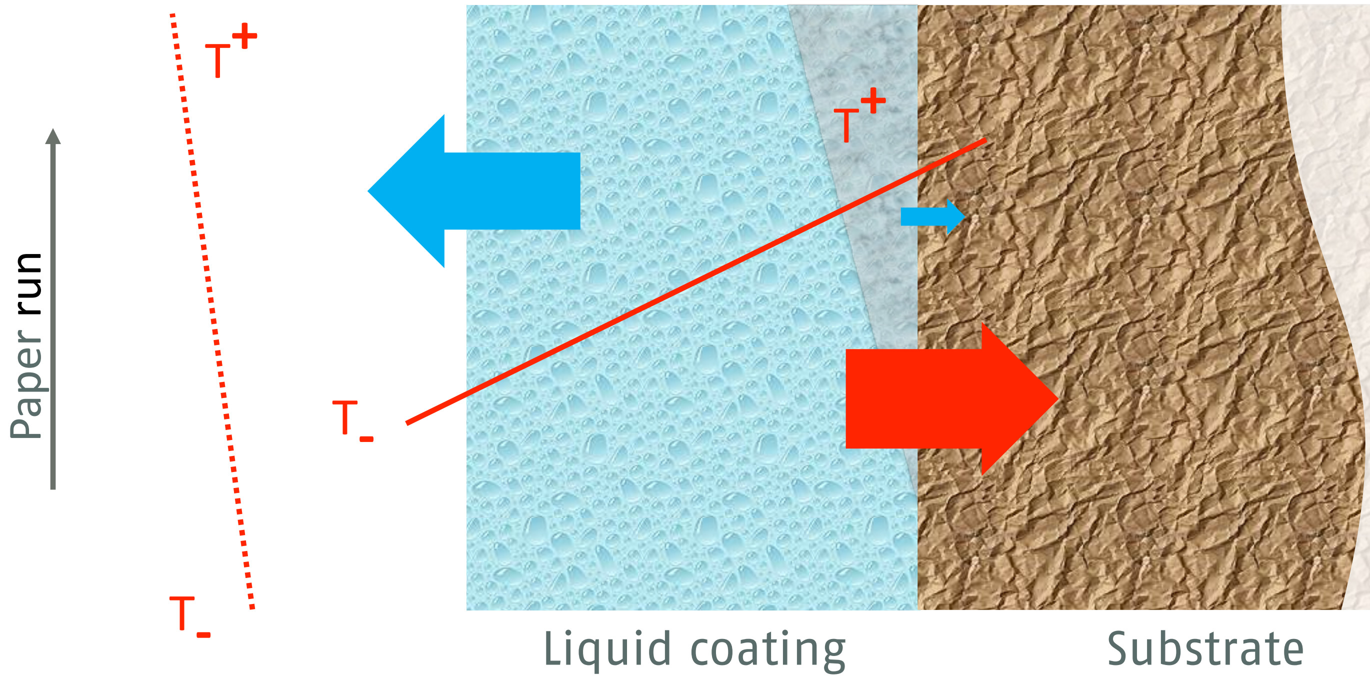
- Drying from surface towards substrate leads to
  - migration into substrate.
  - Increased cost as higher coat weight required.
  - Premature cross linking of surface leads to micro blistering.

Required drying strategy

- Water must be moved to surface:

  - positive temperature differential between substrate and coating.
  - drying matter must be heated starting at initial sedimentation layer.
  - evaporation capacity **while** heating must be higher than energy transmission.

Required drying strategy



Vertical temperature control in z-direction is more important than temperature control in md.

It can easily be achieved by evaporating water while putting heat into the substrate.

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 cylinder

- Most energy efficient drying method
- Only possibly after immobilisation of surface of coating.
- Heats just the **surface**.

Heating by hot air

- Least costly drying method.
- Slow heating curve to avoid premature film formation.
- Heats just the **surface**.
- Pushes coating into substrate.

Heating by infrared

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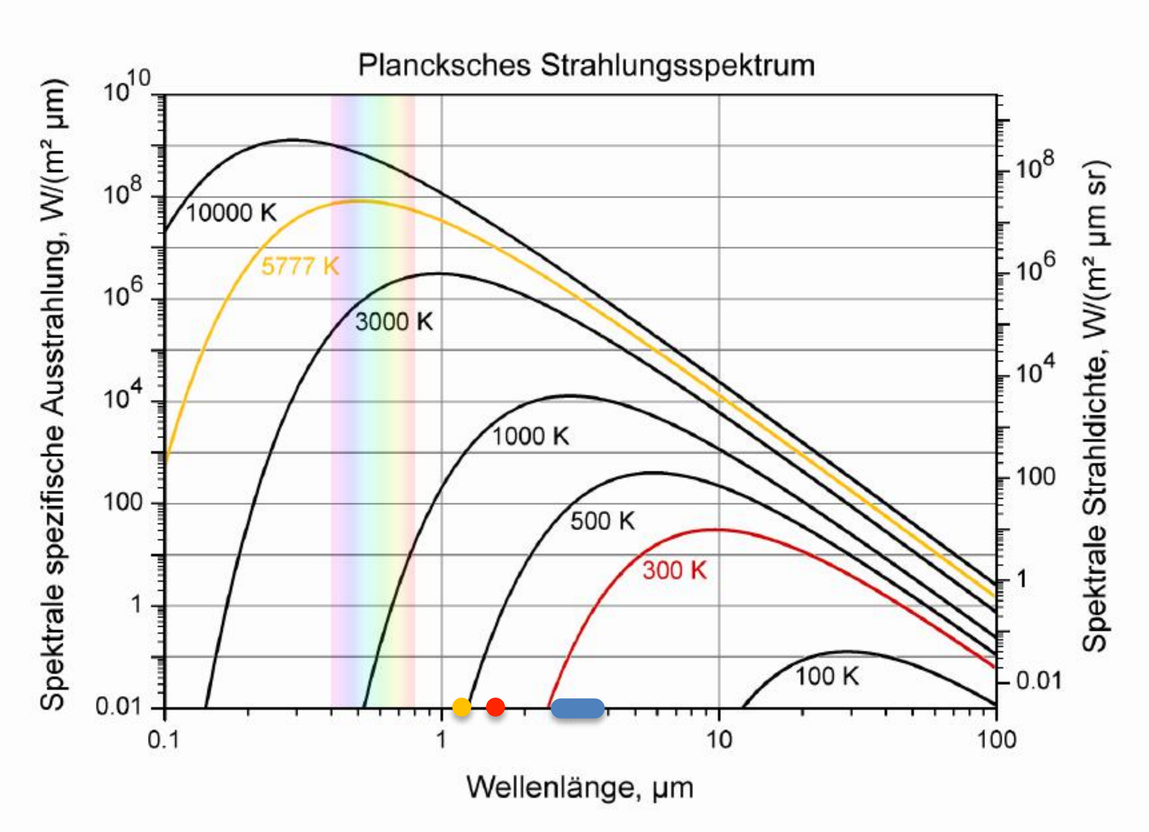
- Most costly drying method.
- Most efficient coat drying method.
- Drying characteristic depends upon wave length.
- Heats either **surface** or **substrate**.

Drying by infrared – radiation



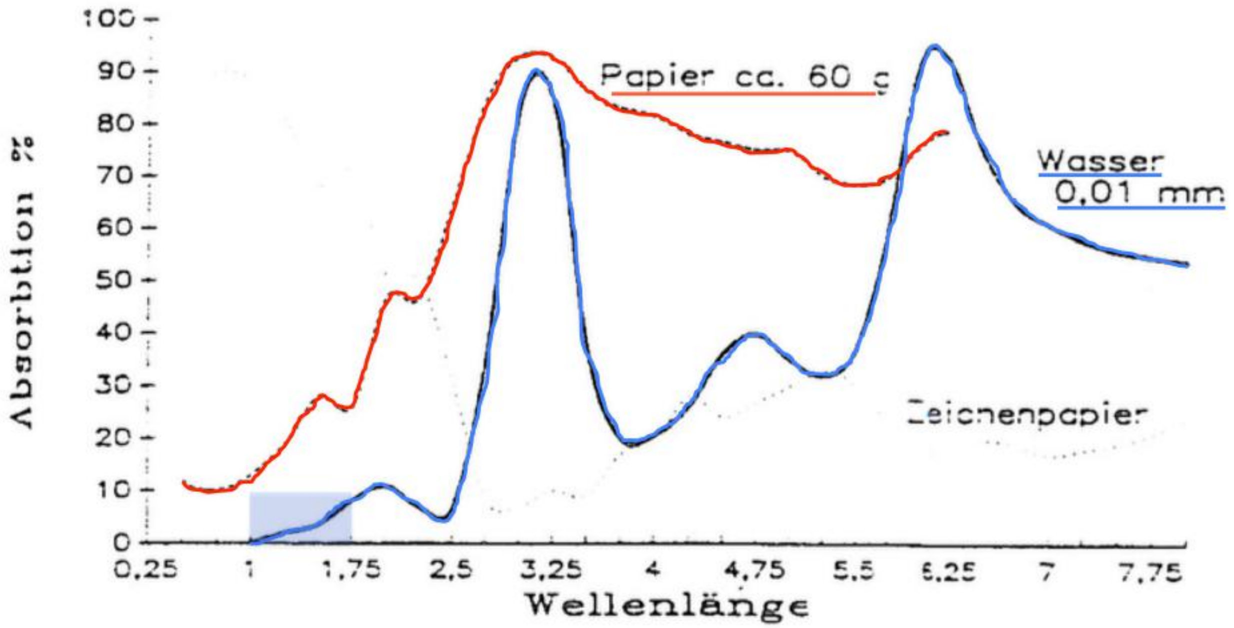
Gas fired MIR:
peak radiation between 2.5 and 3.5 µm, which corresponds to 1.160 to 830 K

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

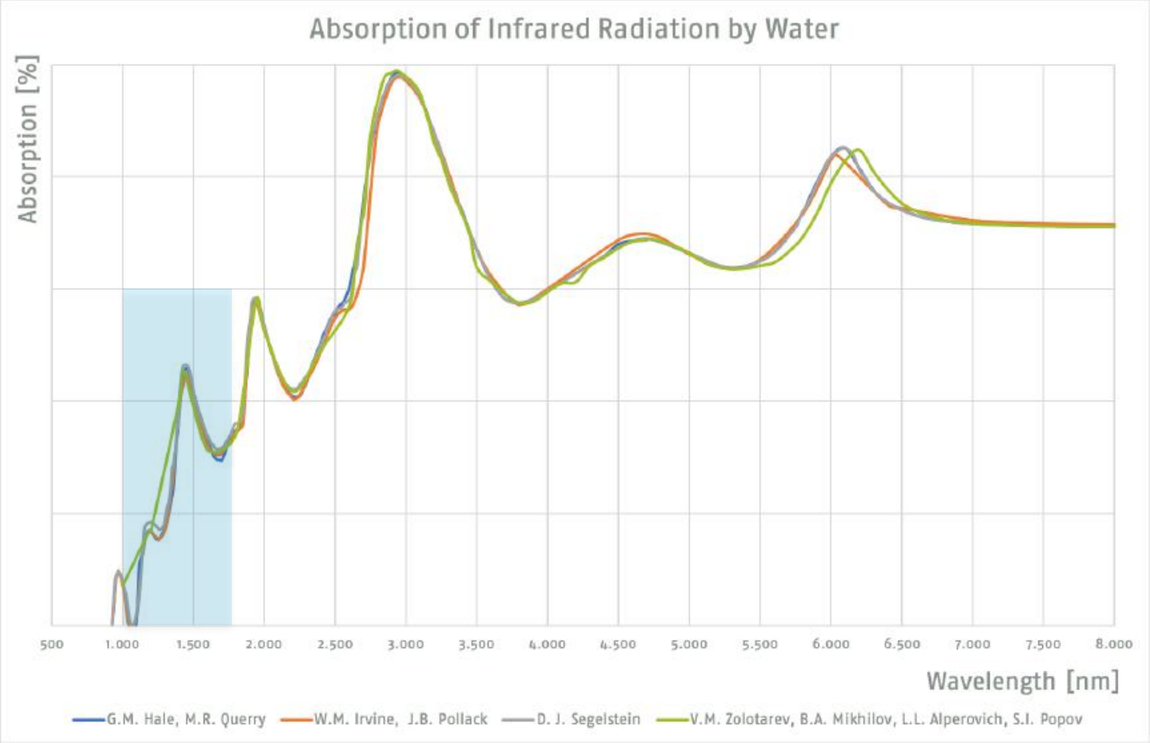
Drying by infrared – absorption



A b b. 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

Drying by infrared – absorption



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

Strong peak at 1.45µm

Drying by infrared – penetration of NIR

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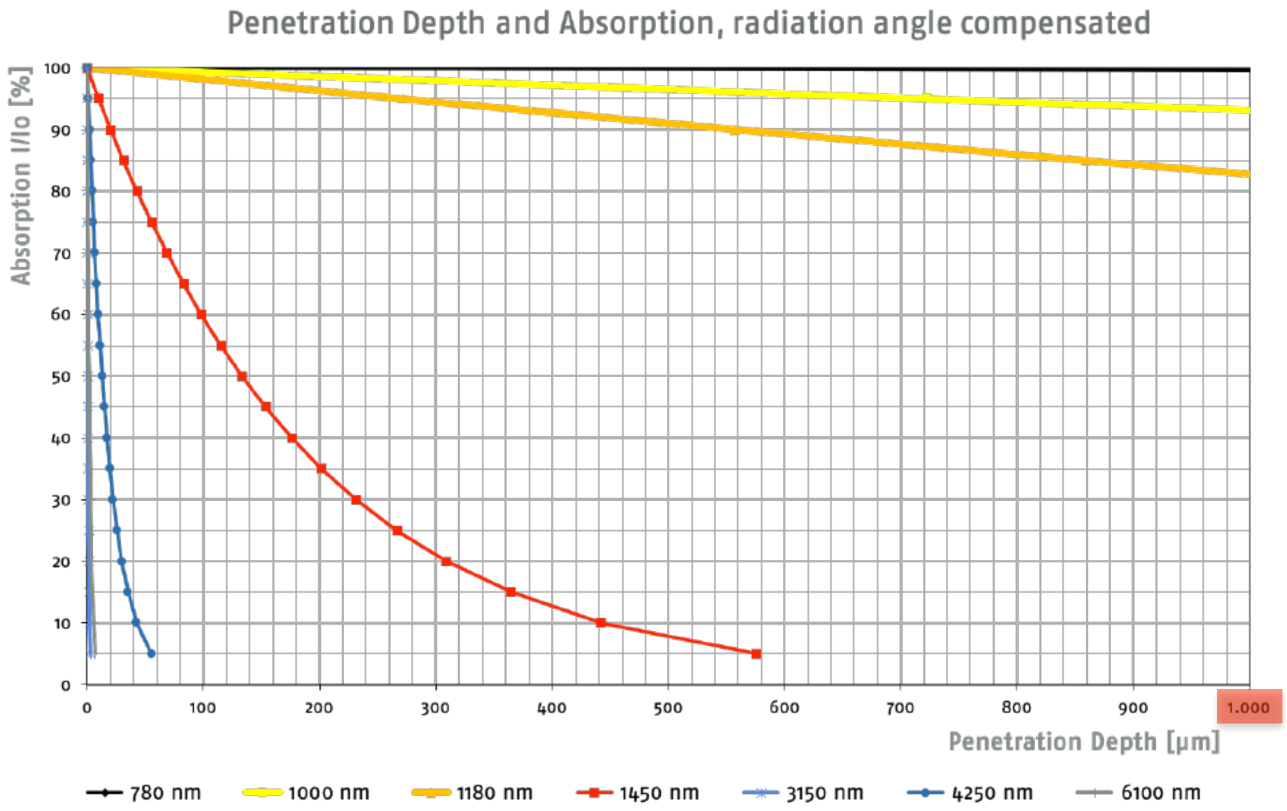
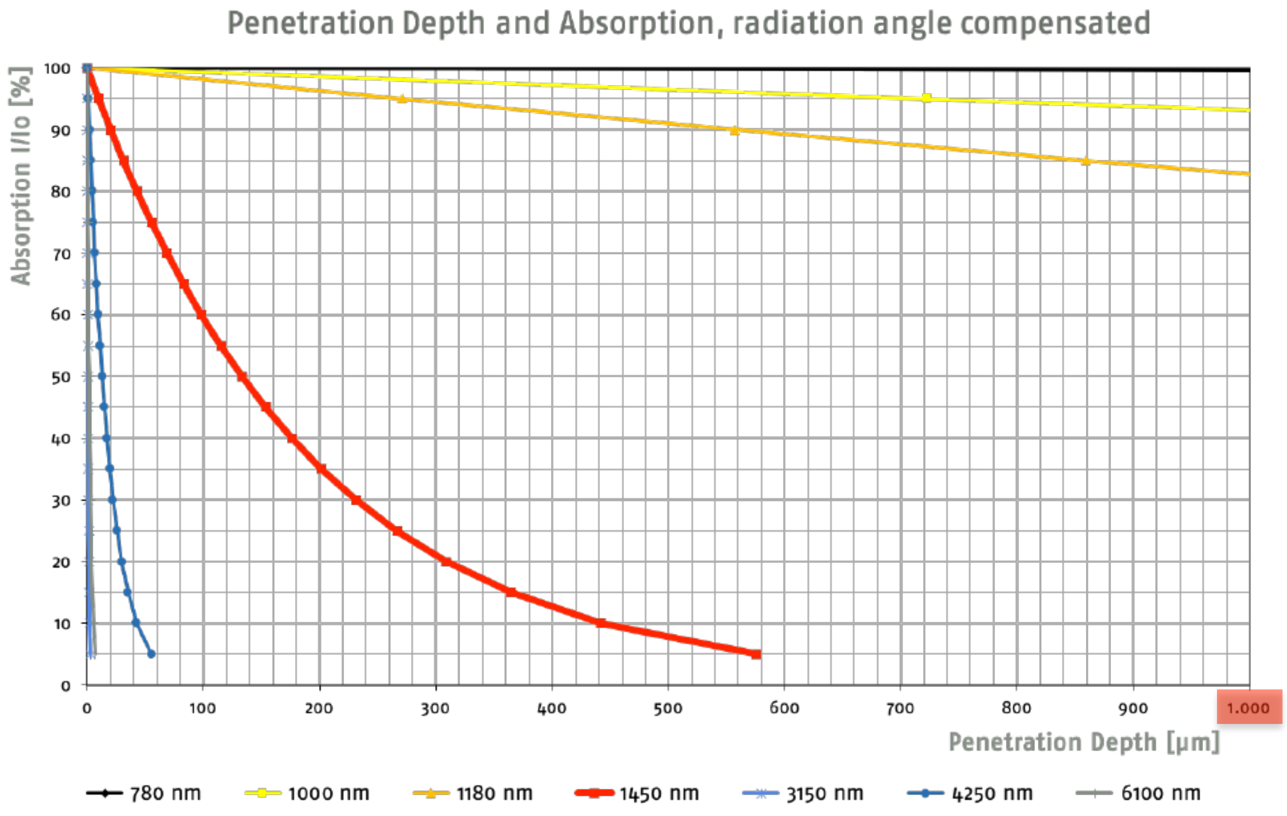


Radiation of electrically powered NIR emitters (peak wavelength 1,18 µm) penetrates very deep with little absorption.

Penetration underneath the coating, heating the substrate – but not sufficiently efficient.

Penetration following law of Lambert-Beer

Drying by infrared – penetration of eNIR



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

Penetration deep underneath the coating, with strong warming of the substrate.

Penetration following law of Lambert-Beer

Drying by infrared – penetration of MIR

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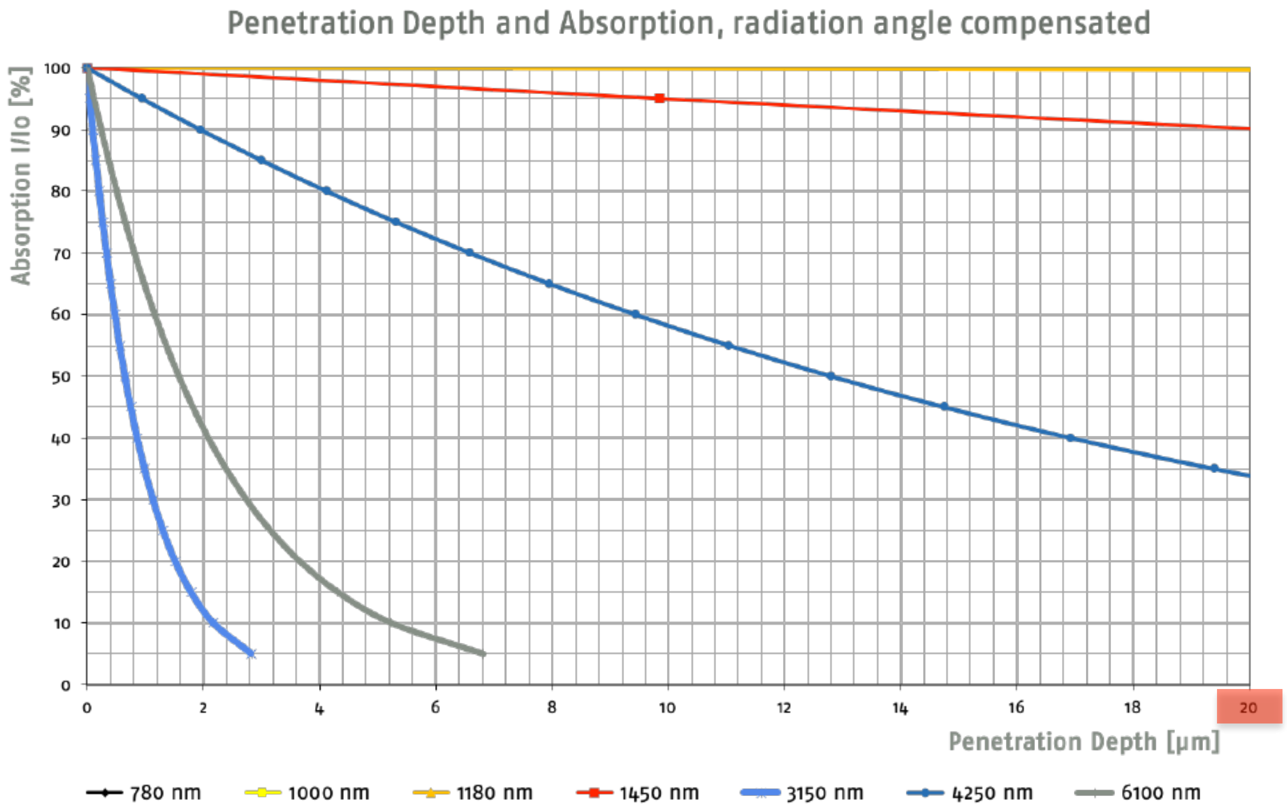

Gas-generated MIR infrared radiation is absorbed within few microns.

Gas fired MIR heats the surface.

Penetration following law of Lambert-Beer

Defect free drying

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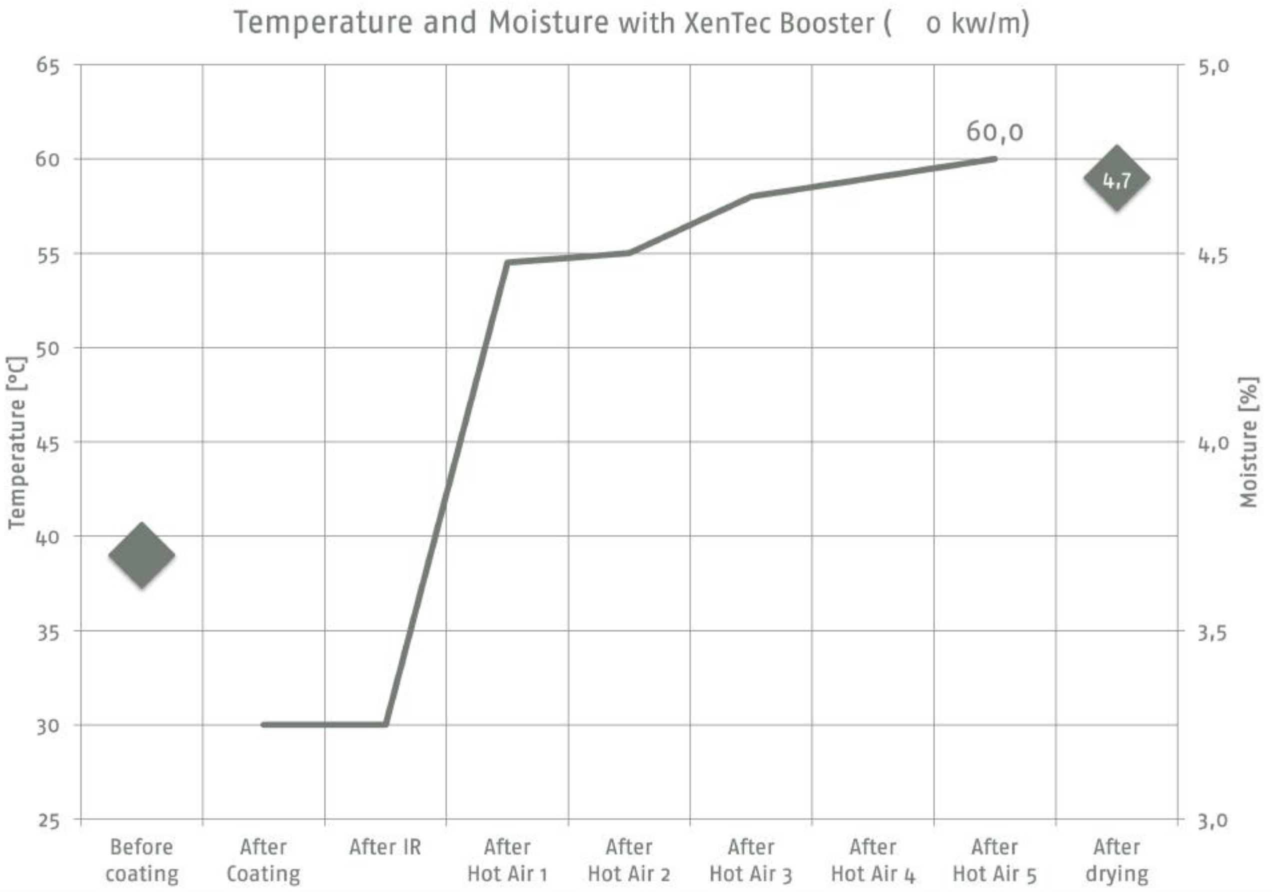
- Drying starts at initial sedimentation layer.
- Penetration of liquid phase must be restricted.
- Evaporation primarily through top of coating.

Drying with hot air



Typical drying curve of a specialty paper coater.

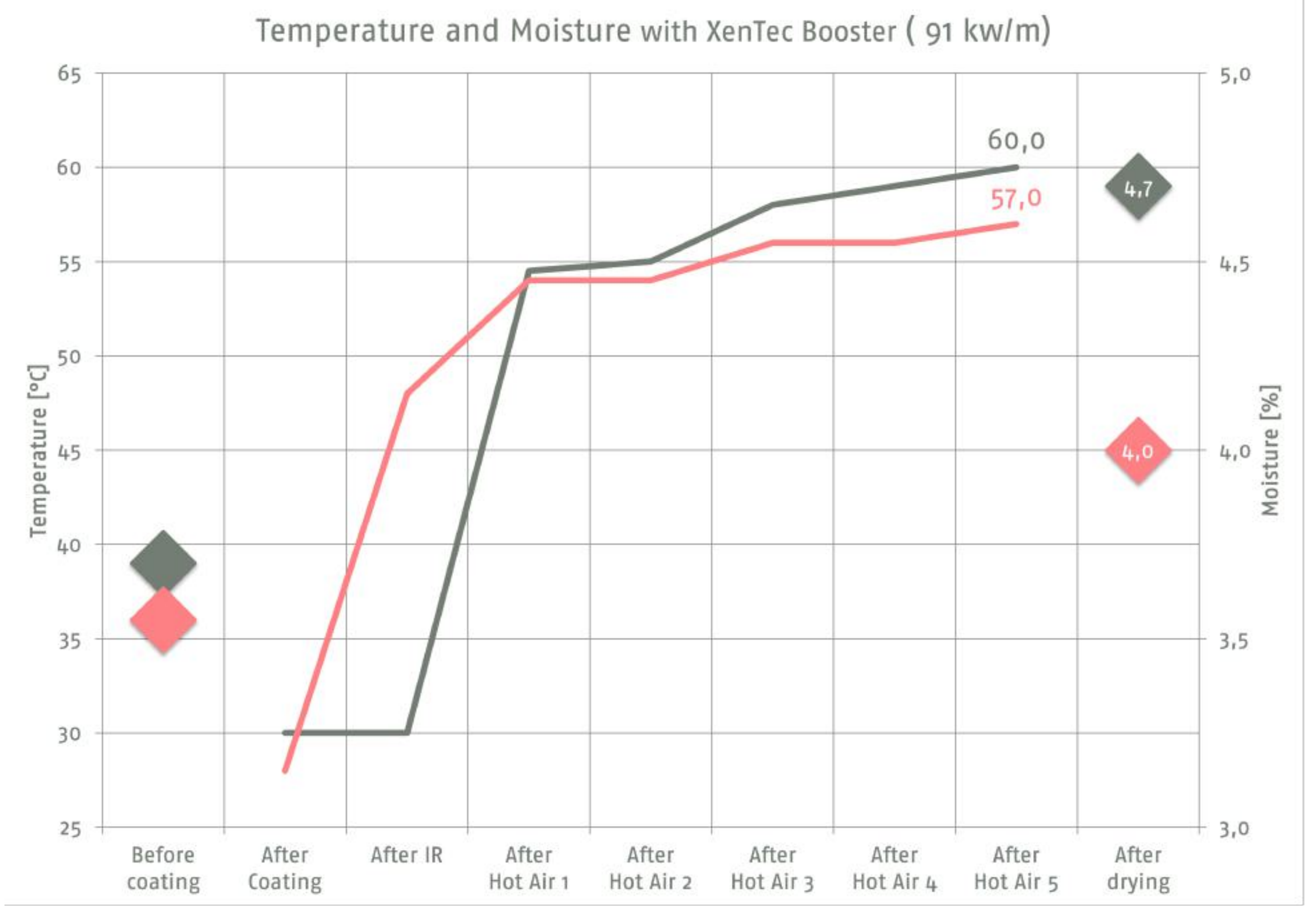
Temperature curve must be controlled.

Overall moisture increases by 1.0%.

Part of water moved into substrate.

Temperature reaches 60°C before reel.

Drying with eNIR booster plus hot air



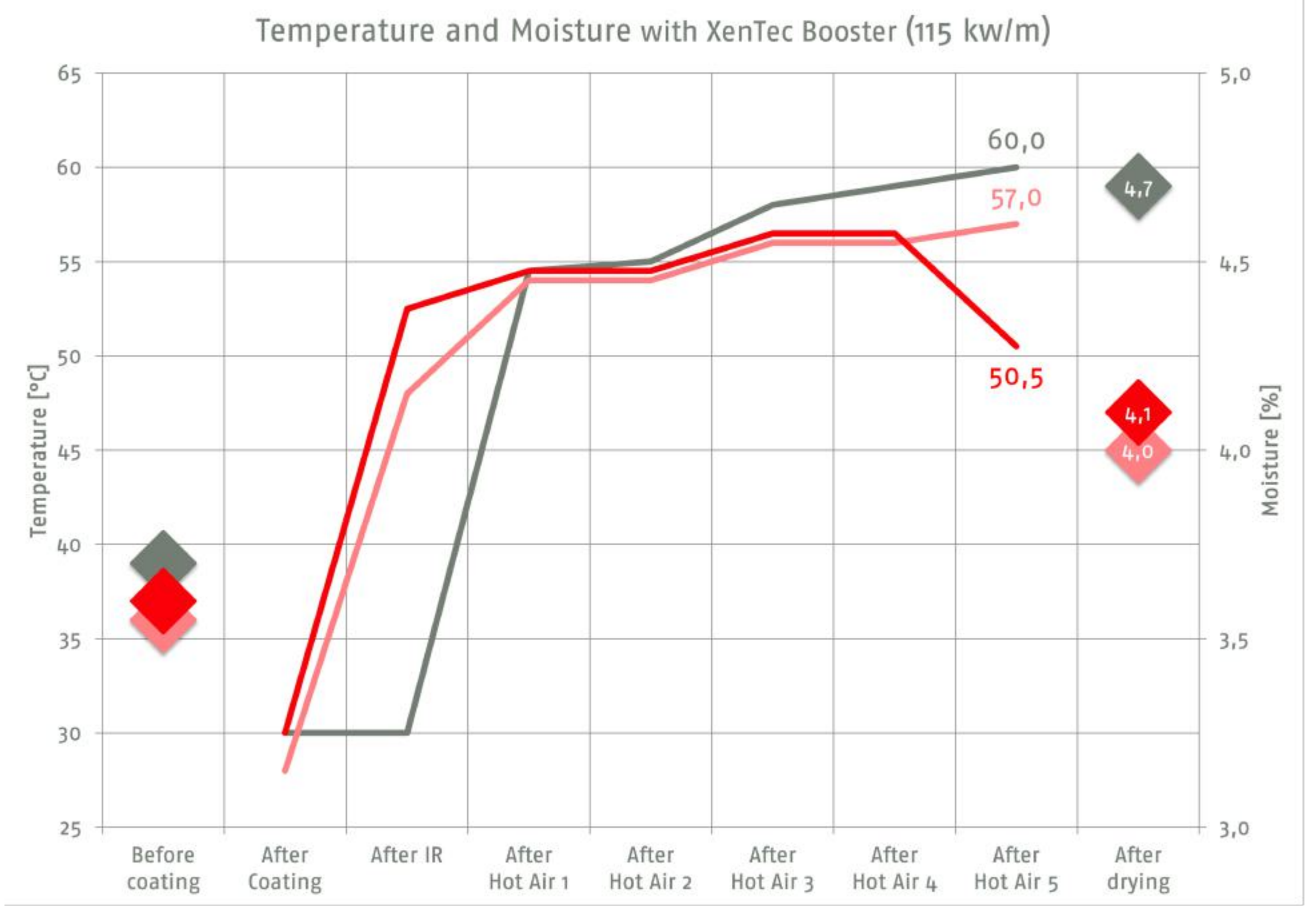
The booster at 57% power reduces the maximum temperature as during radiation water is evaporated, using steam enthalpy for cooling down the surface.

Hot air dryers setting fixed.

Overall moisture increases by 0.4%.

Speed is increased by 8.5%.

Drying with eNIR booster plus hot air



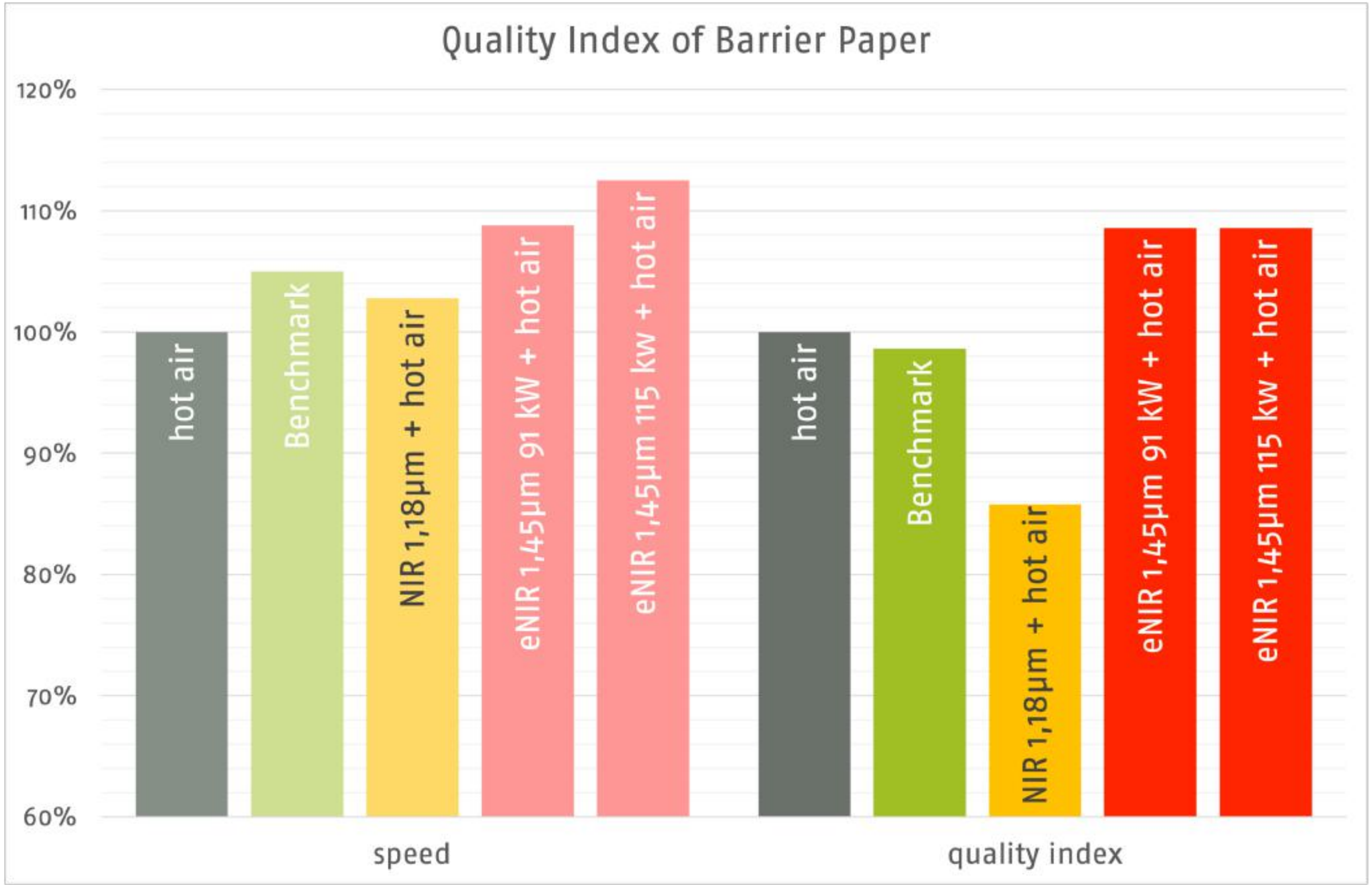
The booster at 73% power reduces the temperature by 9.5°C at reel with 3.5°C lower max. temperature as during radiation water is evaporated, using steam enthalpy for cooling down the surface.

Hot air dryers setting fixed.

Overall moisture increases by 0.5%.

Speed is increased by 12,5%.

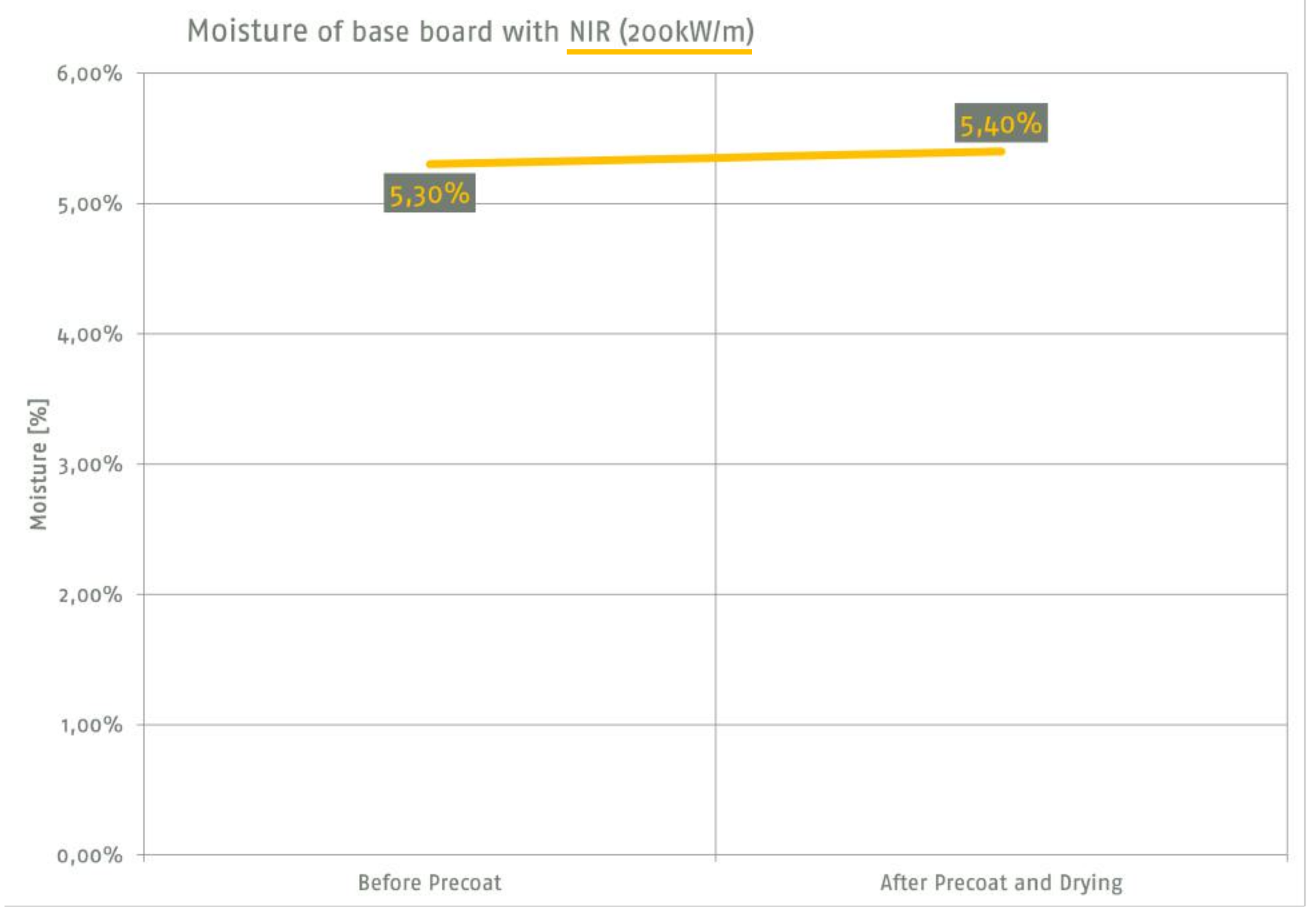
Drying with eNIR booster plus hot air



NIR delivers reduced quality

eNIR enhances the quality, as wave length is ideal to heat from the bottom and balance energy transfer and water removal to keep surface cooler as initial sedimentation layer

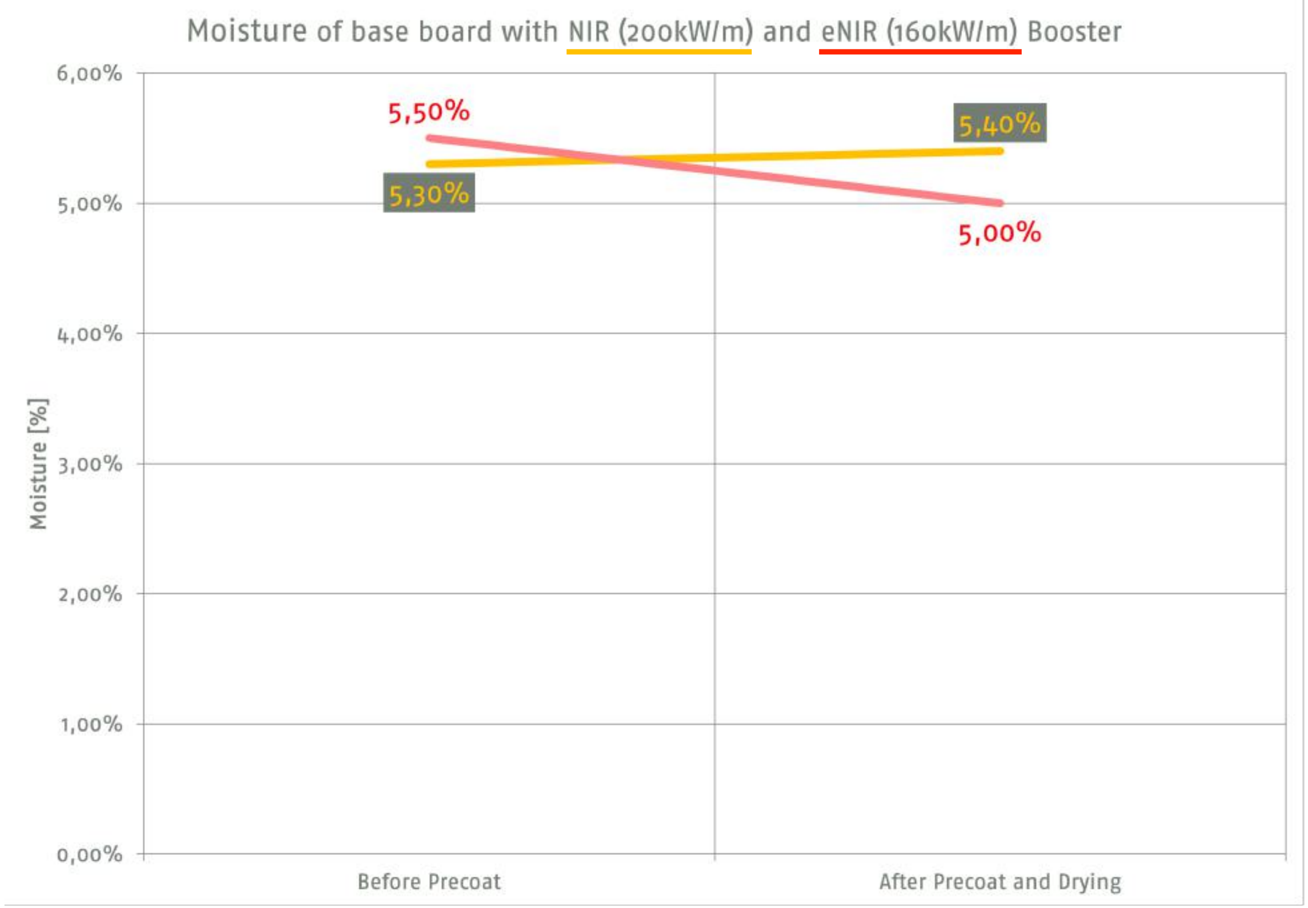
Drying with eNIR booster plus hot air



With correct wavelength, the substrate is heated and with less energy more water is evaporated.

In the given case the substrate basis weight was 280 gsm, the coat weight 15 gsm.

Drying with eNIR booster plus hot air



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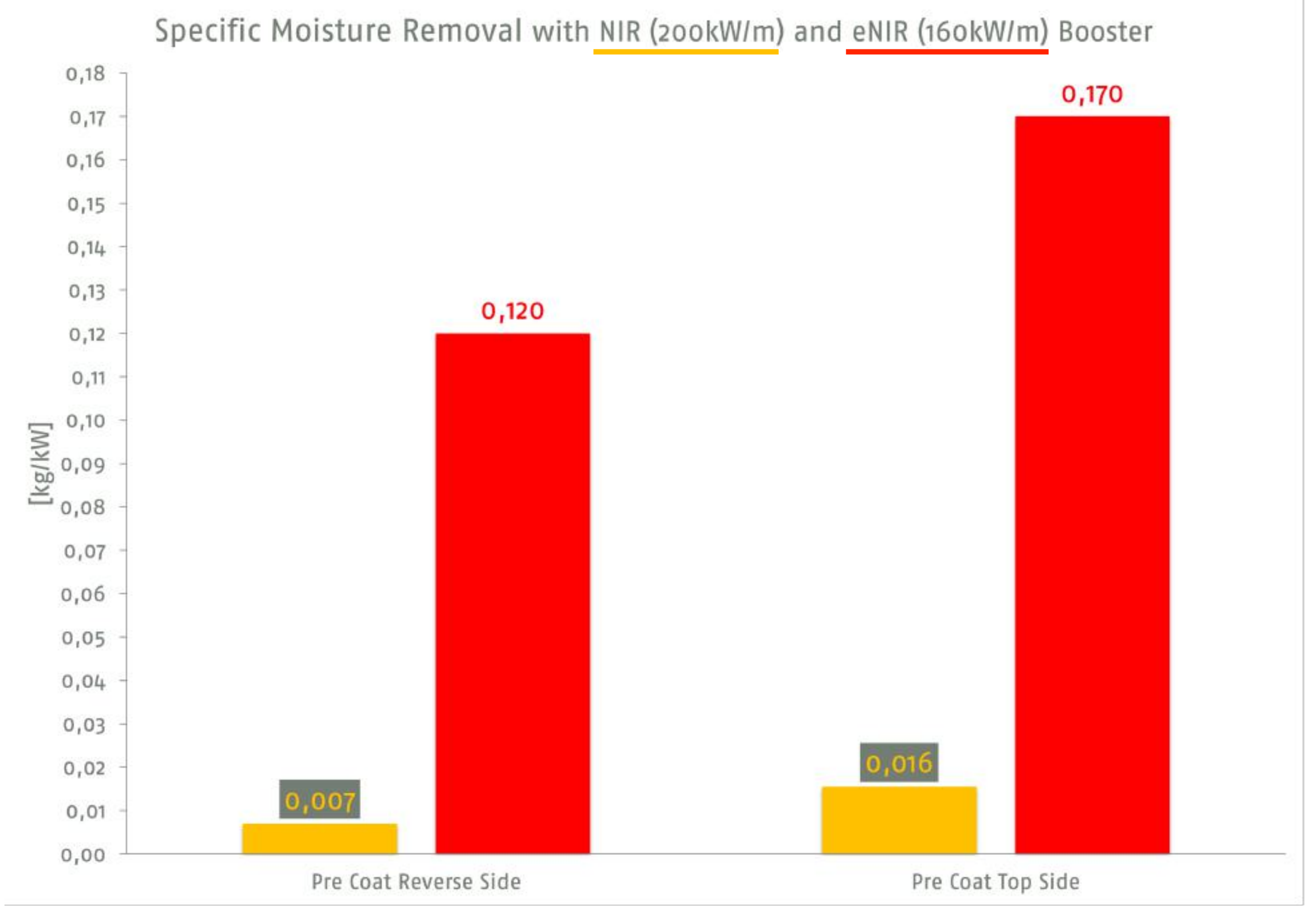

The specific evaporation was largely improved:

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

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

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Summary

- Drying of functional coatings without affecting negatively the functional properties is possible:
  - Selecting the right wavelength for heating the substrate.
  - Starting film formation at initial sedimentation layer.
  - Selecting the right evaporation regime to prevent premature film formation on the surface.

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Thank you

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Questions?