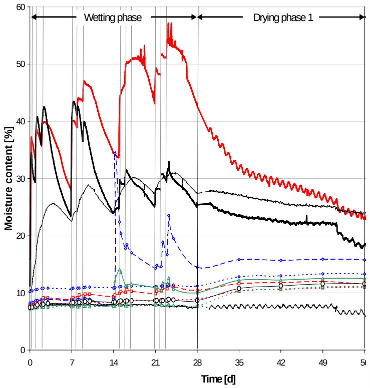
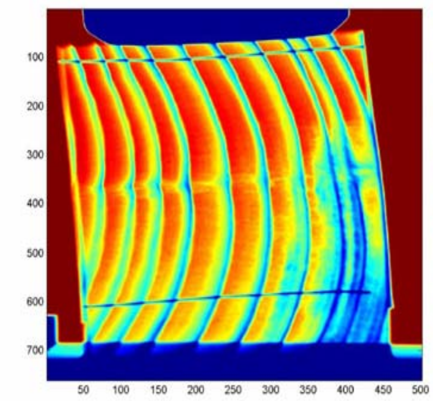
# Issues with moisture movement in walls




Constance Thivierge, eng.
Dominique Derome arch., eng., PhD
Building, Civil and Environmental Engineering Department
Concordia University

CWPA, October 17th, 2007

# What are we expecting?

- Energy efficiency
  - Heating cost
  - Comfort

- Durability
  - Lifetime
  - Easy maintenance
  - Investment

# Wood-framed housing

Flexible (styles, dimensions, design)

Performance (security, durability, fire resistance)

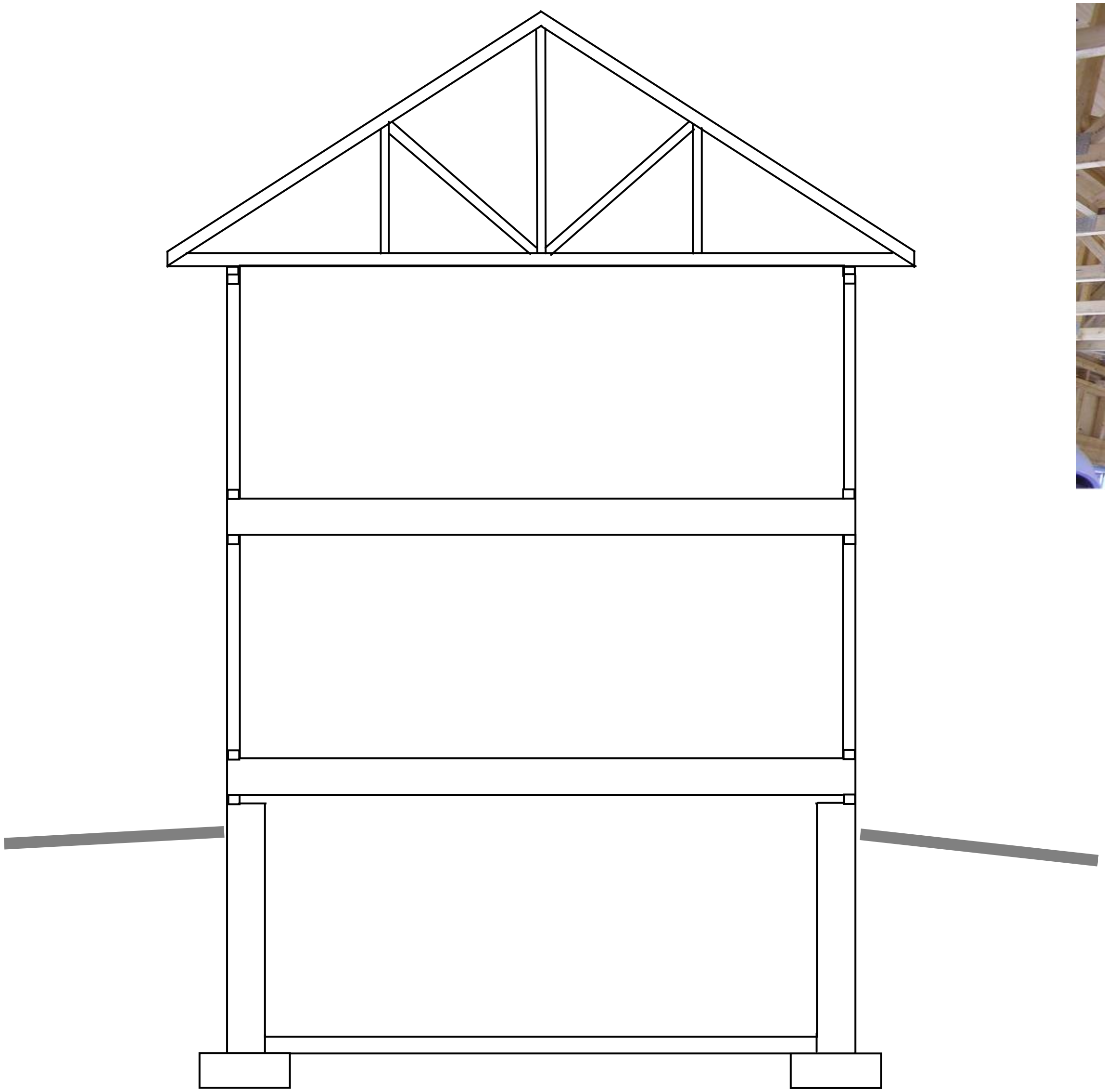
Energy efficient

Environmental friendly

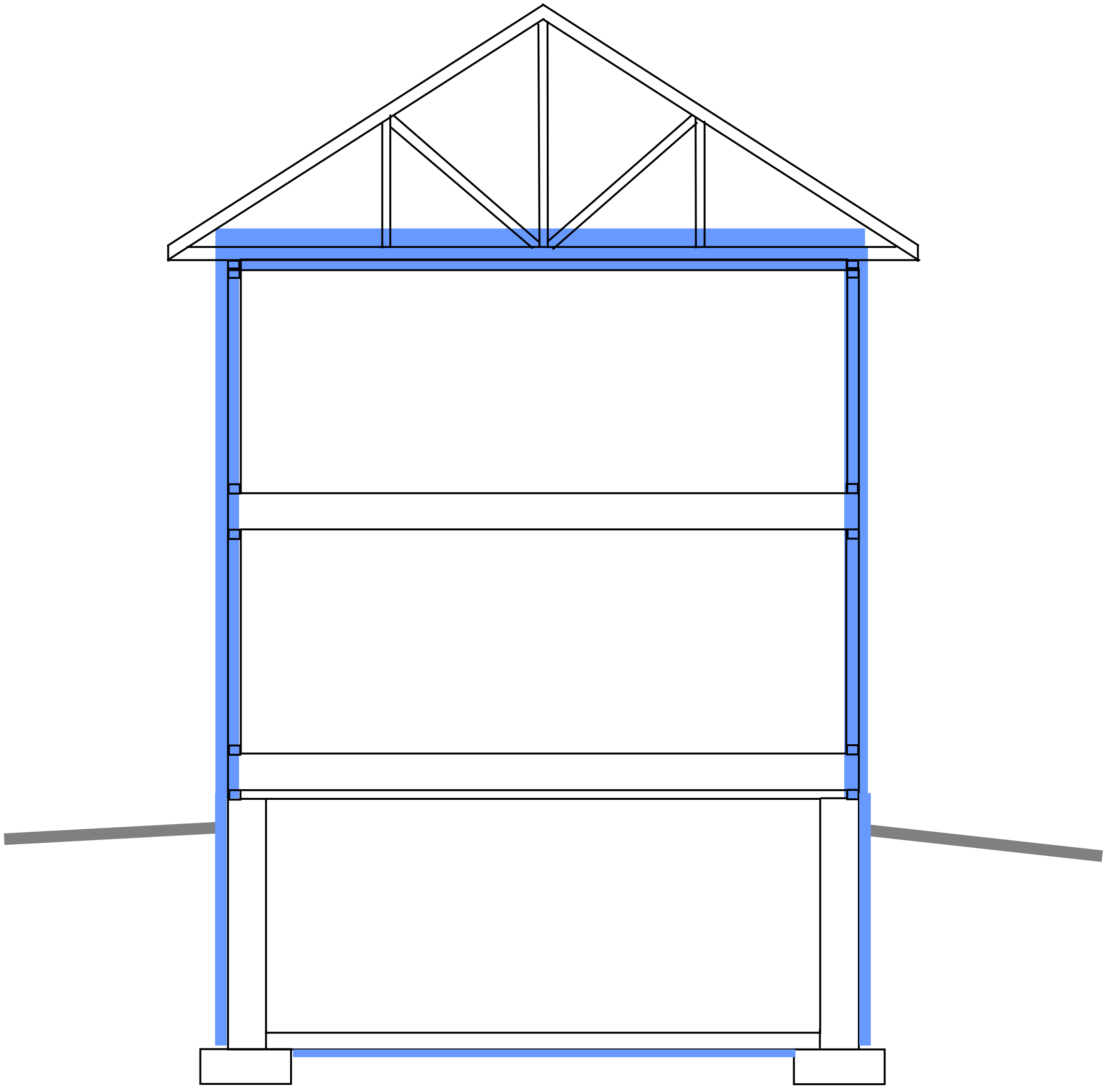
Quick and economic construction

# Wood-framed housing

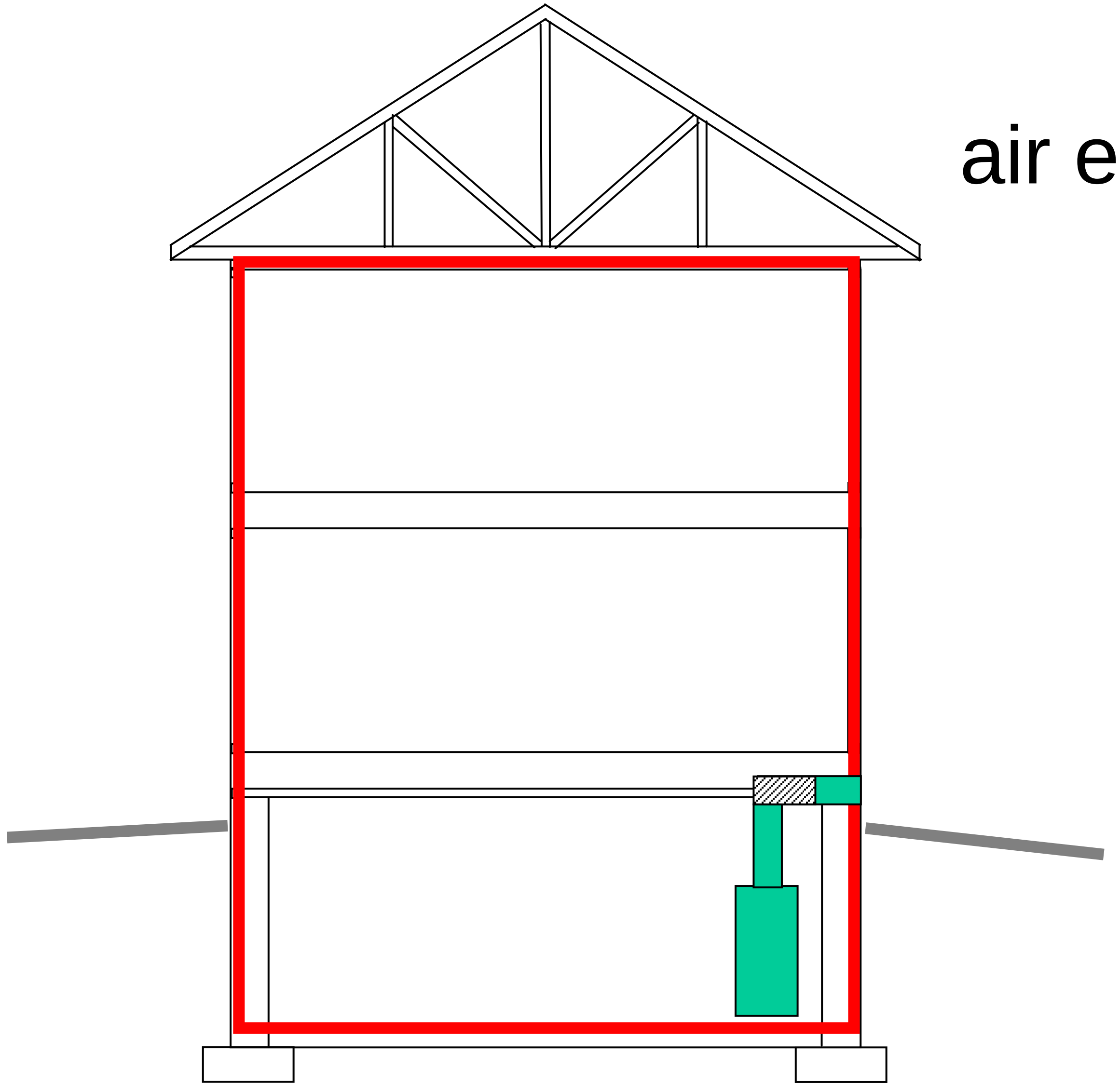
# Structure



# Insulation



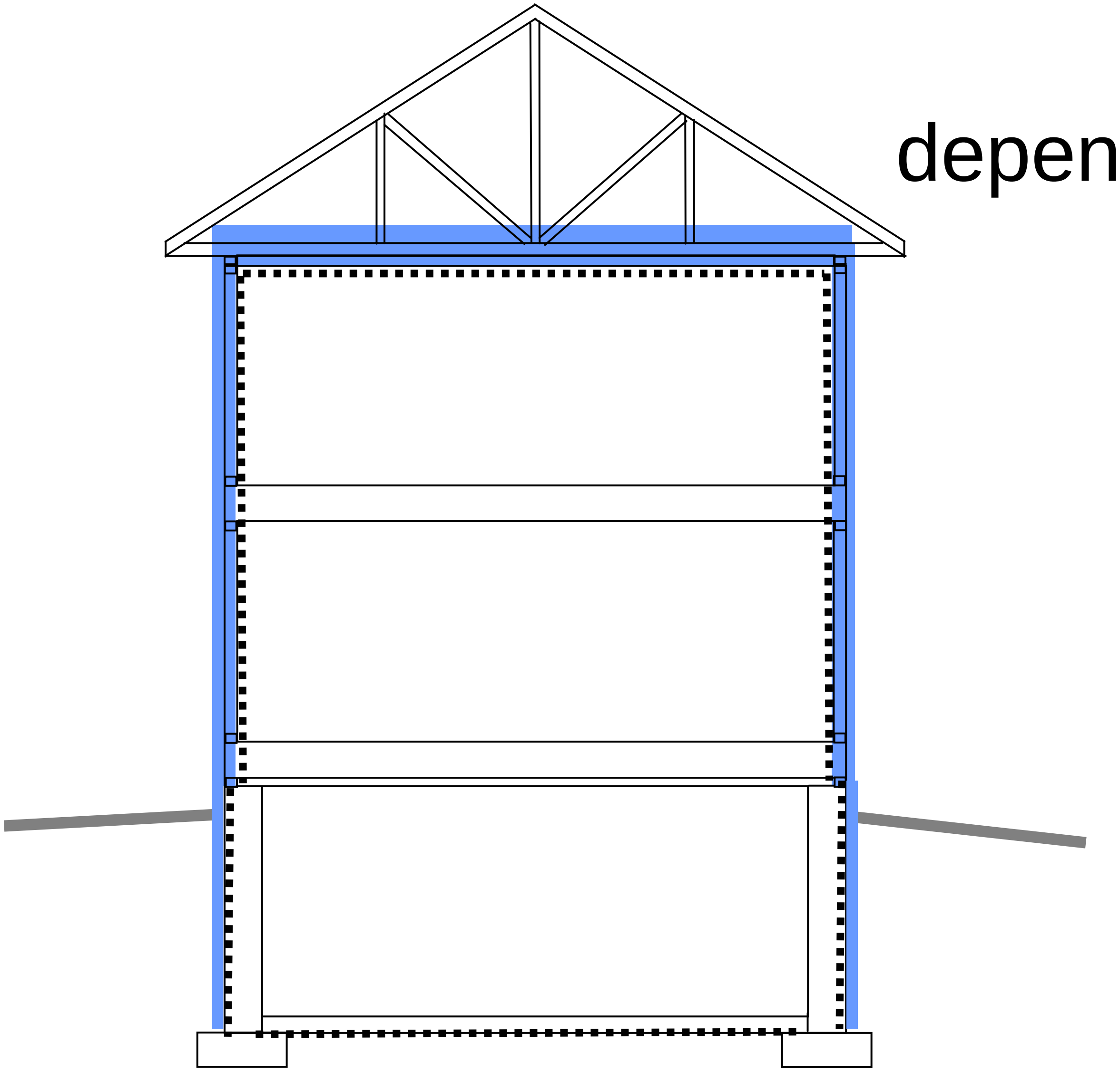
# Airtightness



air exchanger system

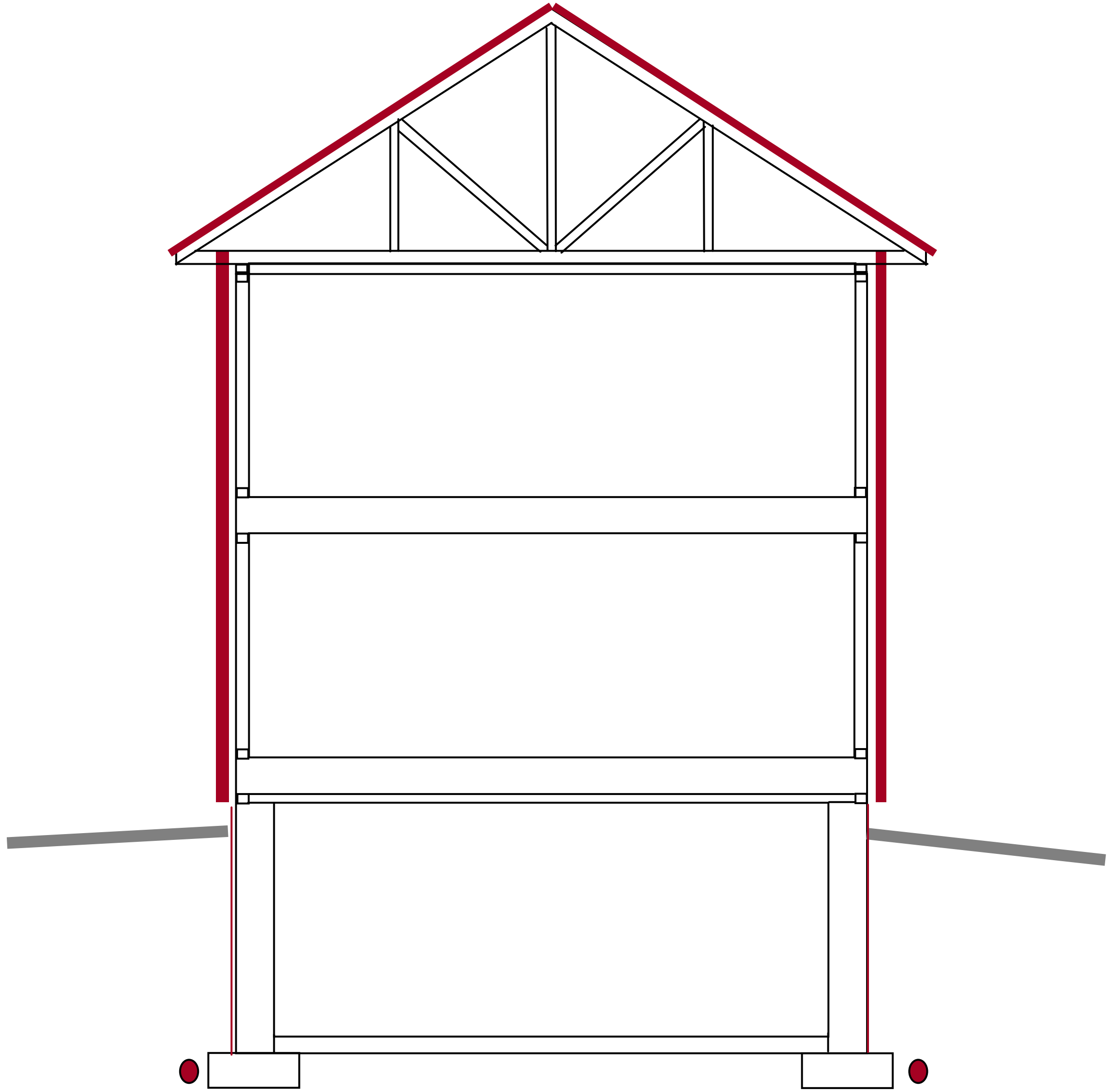
(heat recovery)

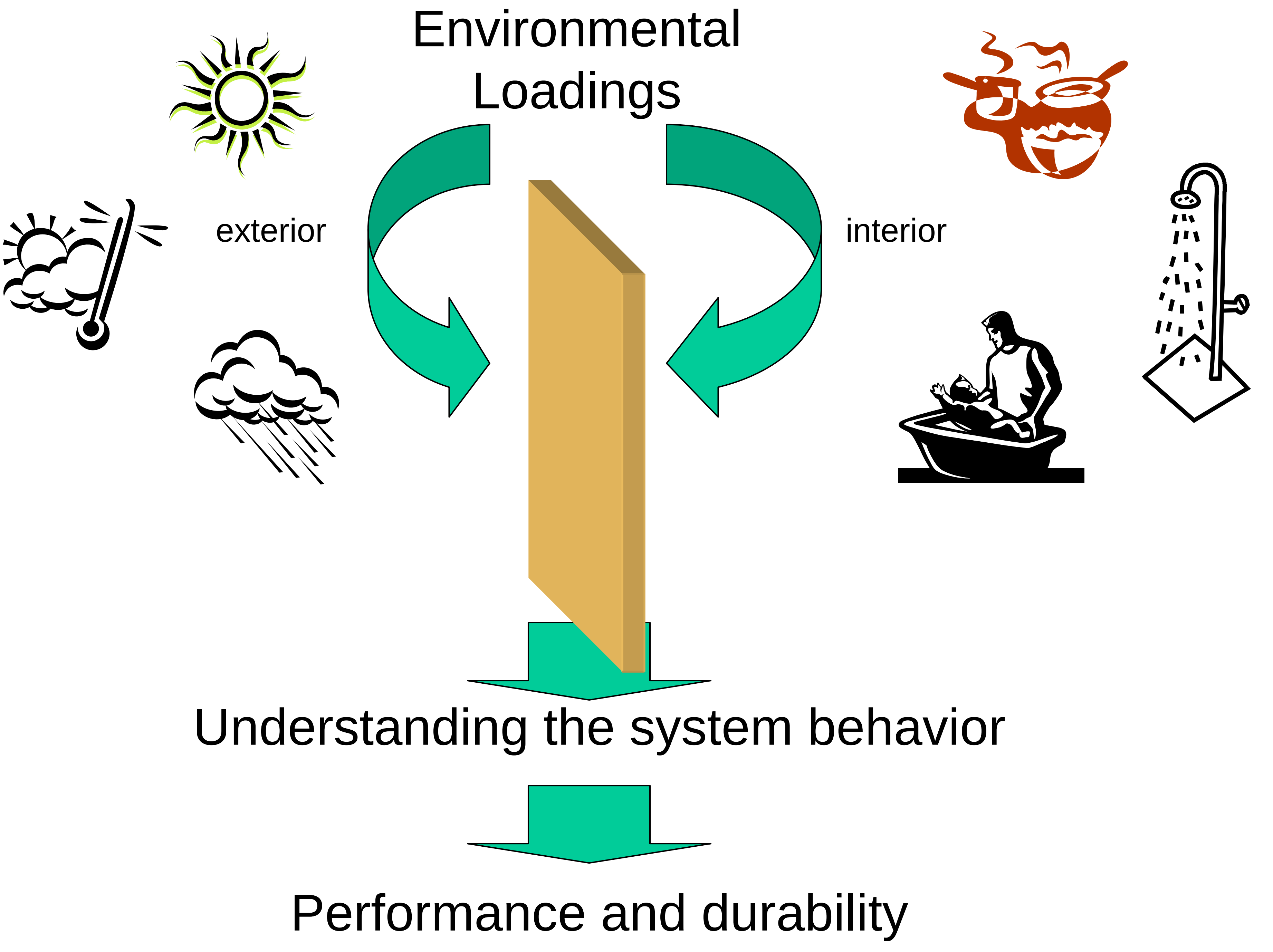
# Control of vapor movement



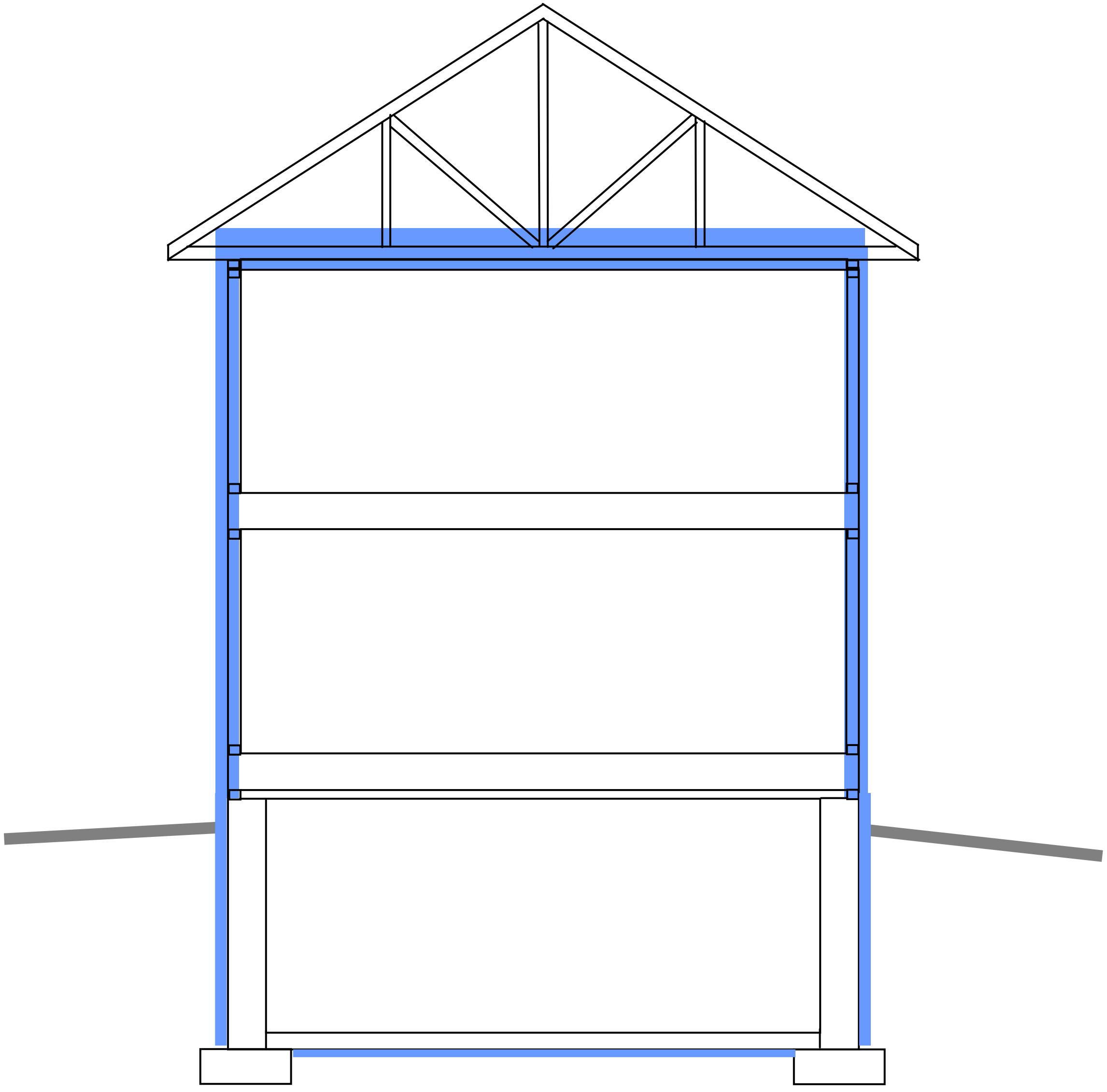
depends on climate

# Control of rain infiltration




Environmental
Loadings
exterior
interior
Understanding the system behavior
Performance and durability

# Insulation



# Energy efficiency standard

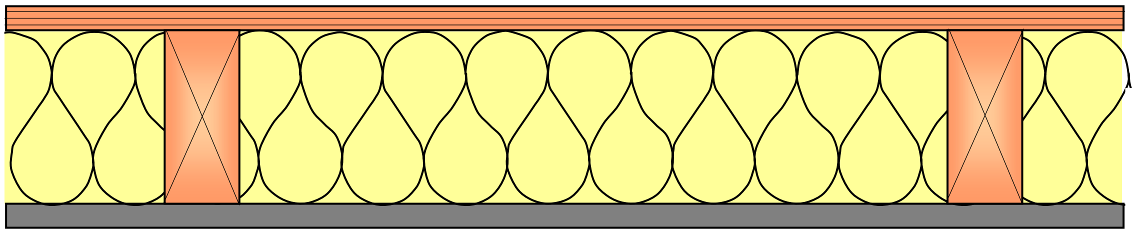
## Thermal resistance

| Components | Minimum[1] (RSI) | NovoClimat (RSI) |
| --- | --- | --- |
| Exterior walls | 3.4 | 4.3 |
| Roof | 5.3 | 7.3 |
| Foundation walls | 2.2 | 3.0 |
| Air exchange | No requirements | 2.5 / hour |

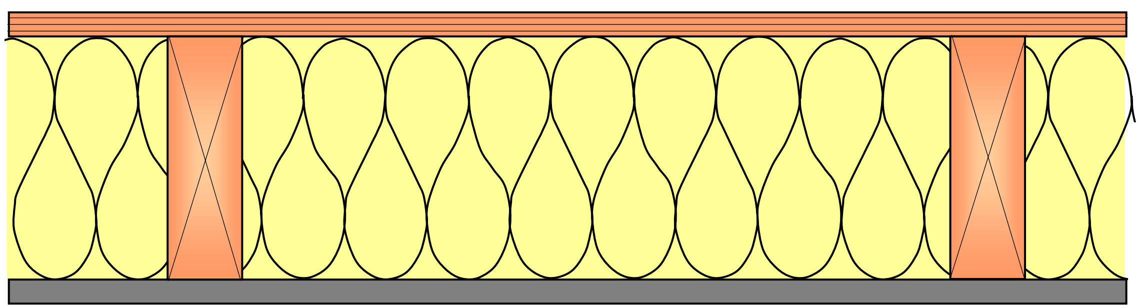
1 Canadian energy code for Quebec

# Thermal insulation

## thermal insulation between studs



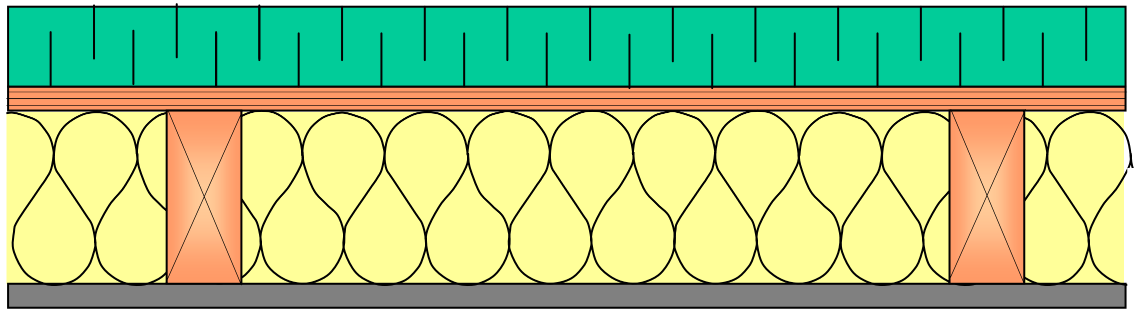
RSI 2,1 °C·m²/W



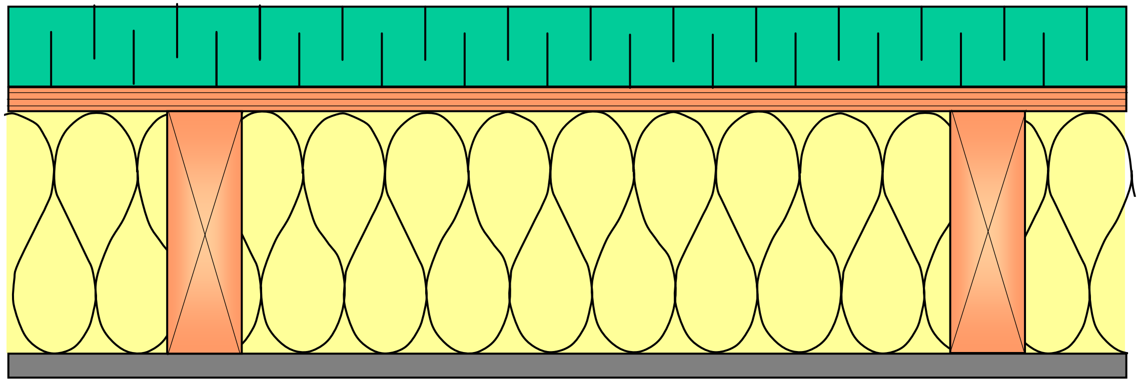
RSI 3,5 °C·m²/W

# Thermal insulation

## between studs and on exterior side



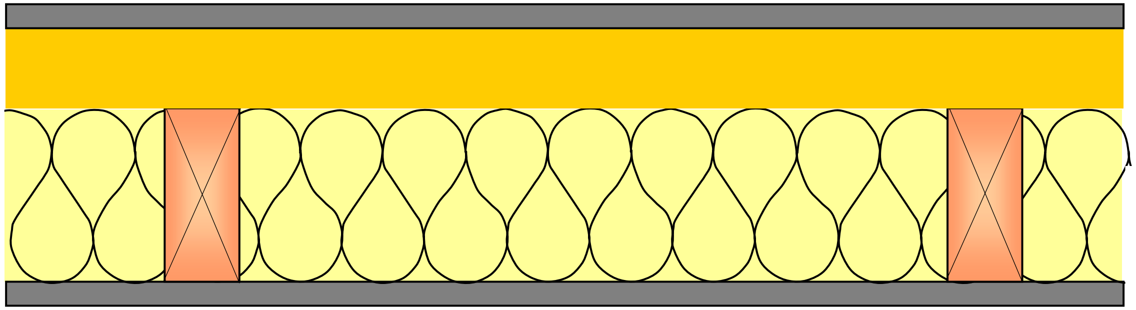
RSI 3,4 °C·m²/W



RSI 4,7 °C·m²/W

# Thermal insulation

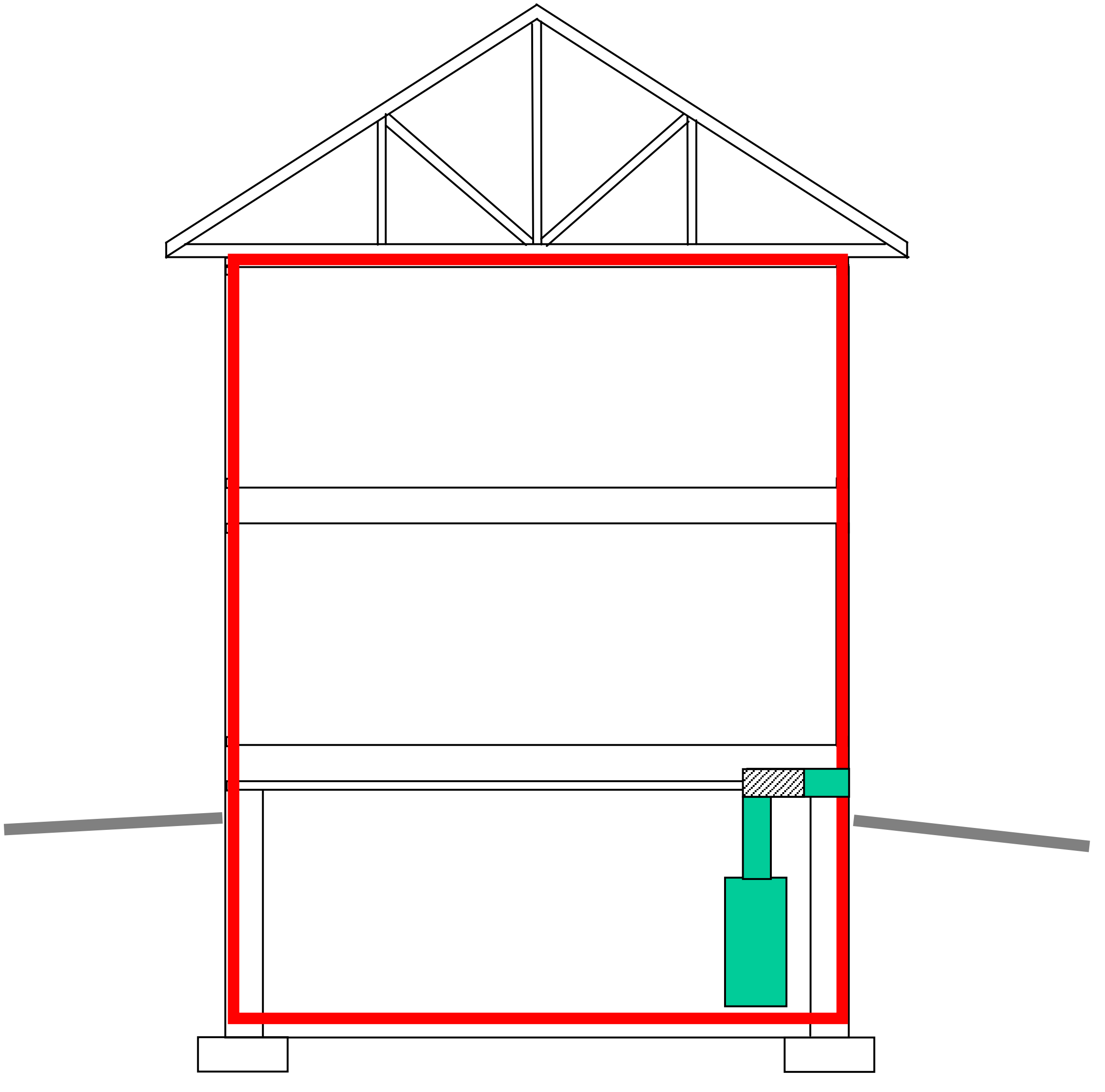
## between studs and on exterior side



RSI 3,4 °C·m²/W

polyurethane sprayed from inside against sheathing on furring

# Airtightness



# Diffusion versus exfiltration

# Air control

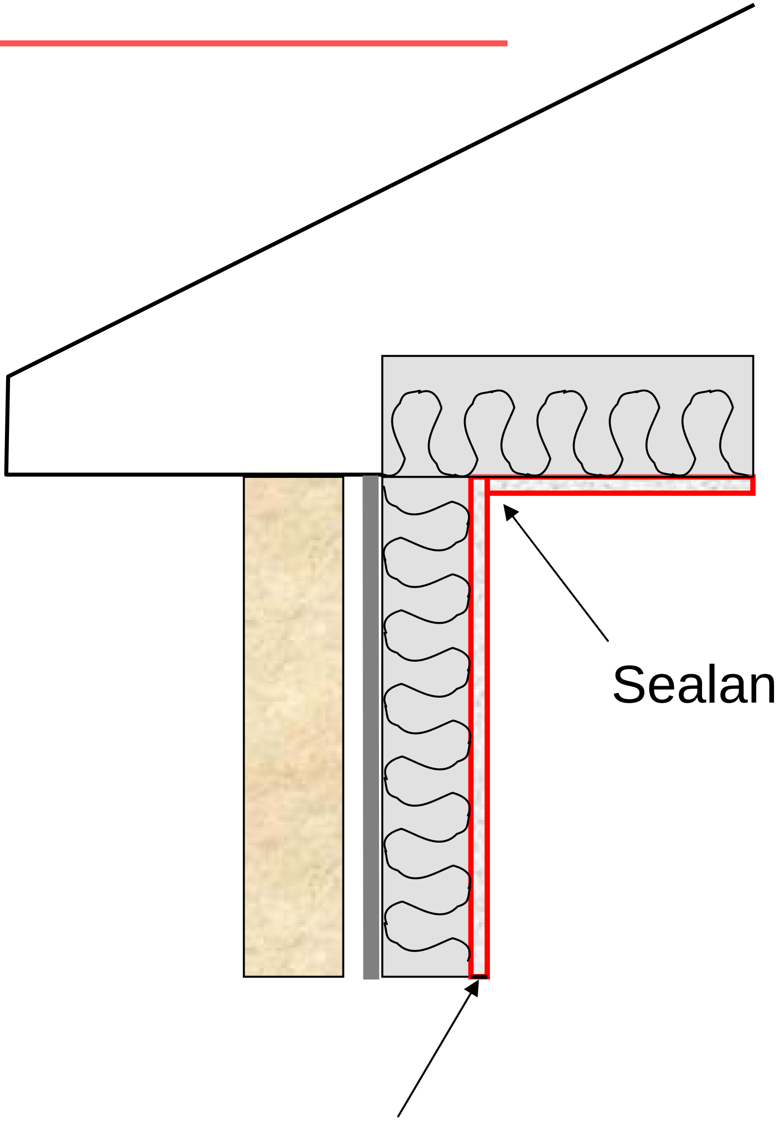
## Air-barrier system

Continuity

Junctions

Toughness

Durability



# Airtightness

Exfiltration due to $\Delta P$

- stack effect
- wind
- unbalanced mechanical systems

Conception methods

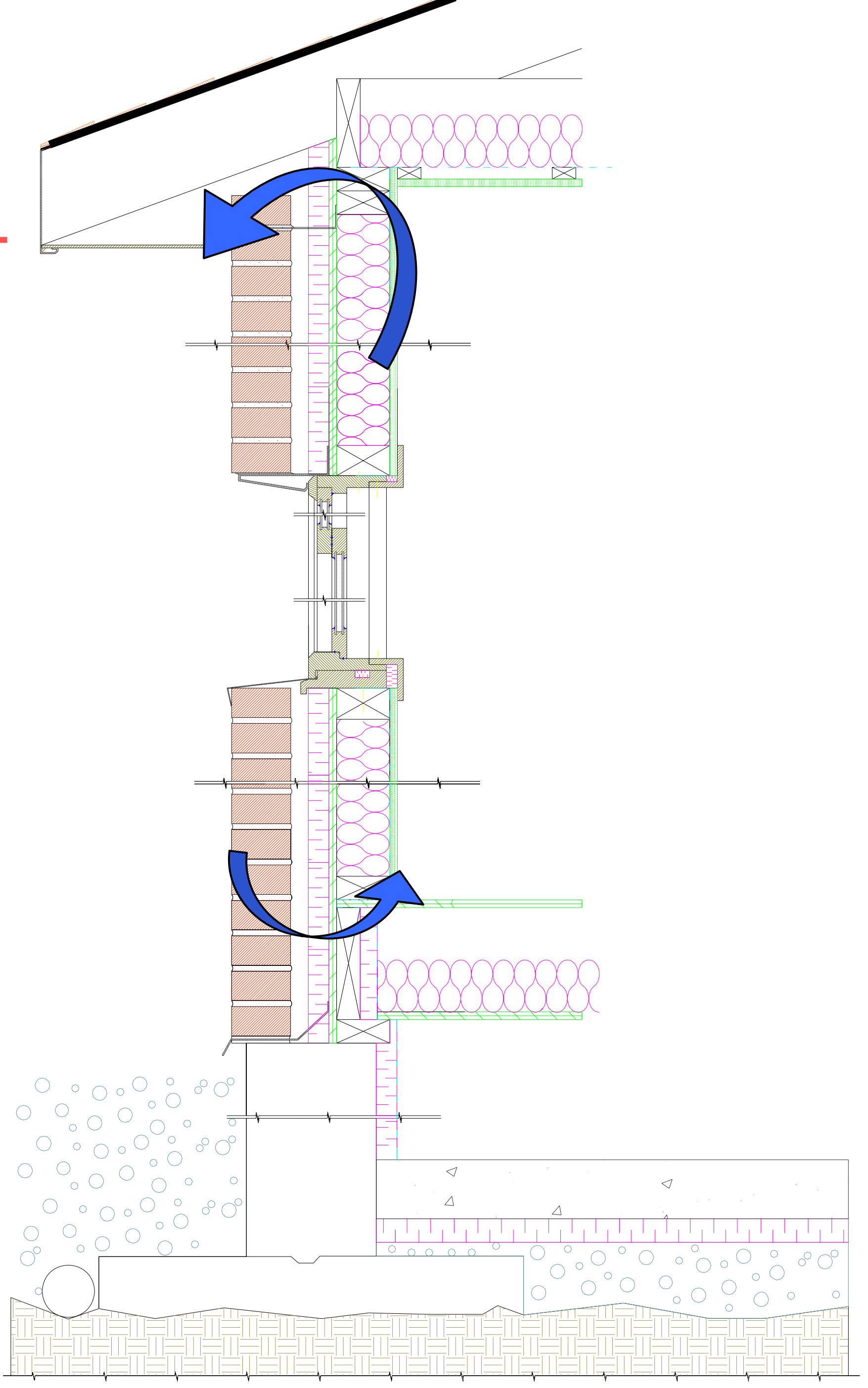
**continuous** air-barrier

be careful with junctions between components

# Problems resulting from air exfiltration

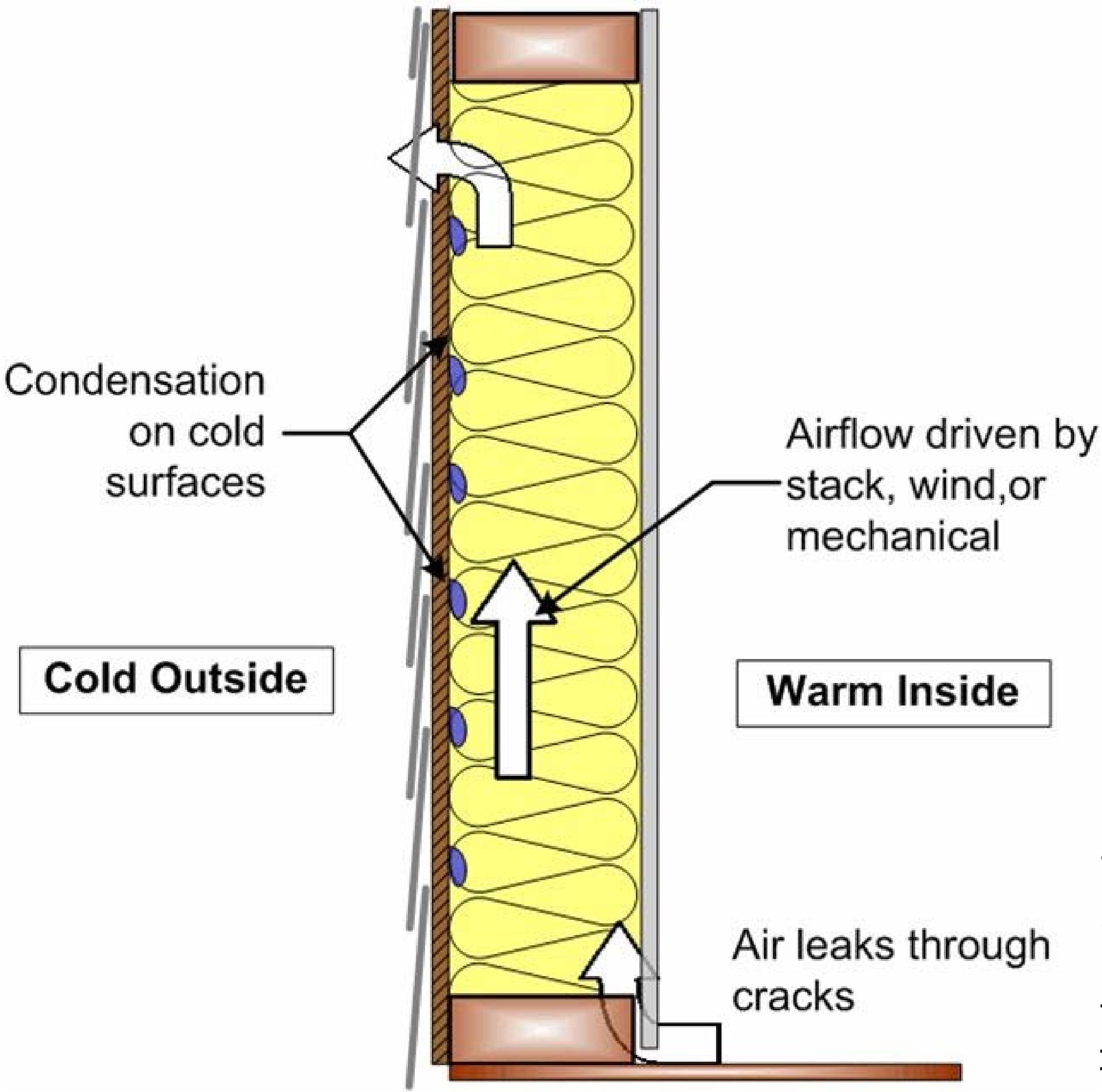
With the presence of a temperature gradient, the stack effect induce an air pressure differential

Unsealed components permit air to exit (above neutral plane) and to infiltrate (below neutral plane)



# Problems resulting from air exfiltration

As air cool down during its passage in the cavity, condensation may occur along the way and be deposit onto the sheathing




Graphics by J. Straube

# Controlling air exfiltration

In situ air-barrier

verification

Infiltrometry test (blower door)

Airtightness test of sections

# Airtightness evaluation

Evaluation during conception

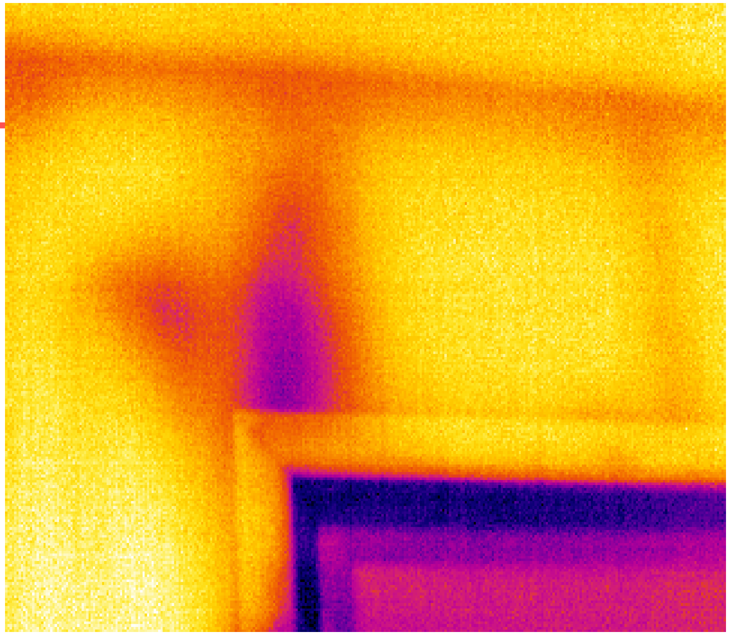
No tool
available

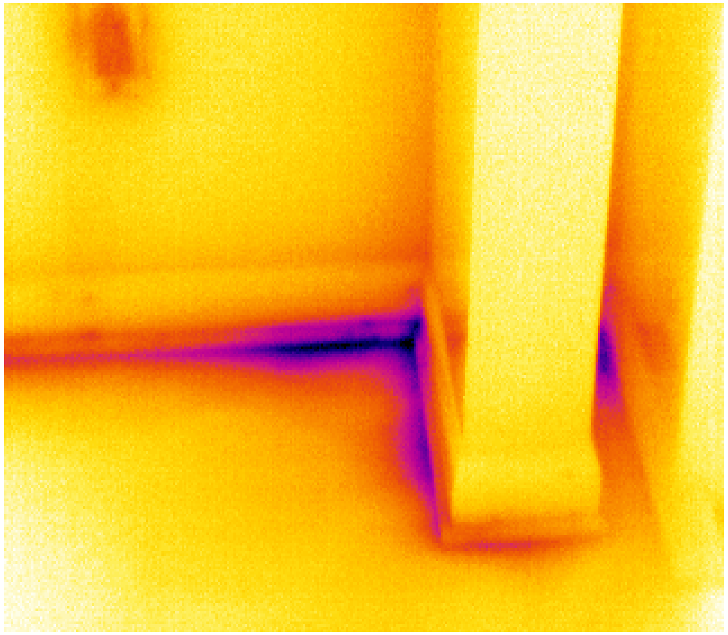
Evaluation after construction

- Infrared thermography
- Infiltrometry evaluation (blower door setup); determination of airtightness with a pressure differential of 50 Pa

# Air leakage

Infrared thermography helps detecting where air finds its way in, while the fan is extracting air from the house during the infiltrometry evaluation

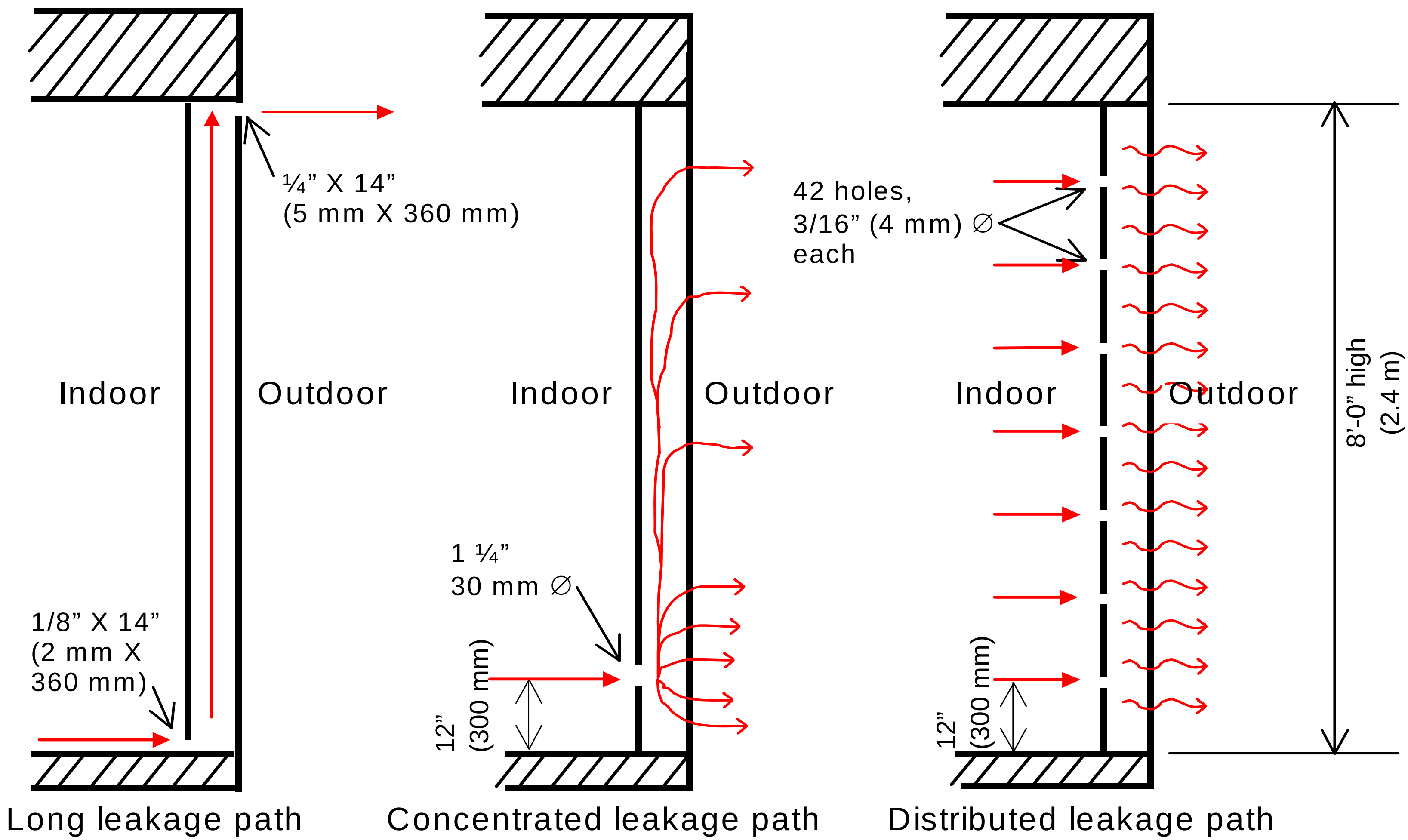




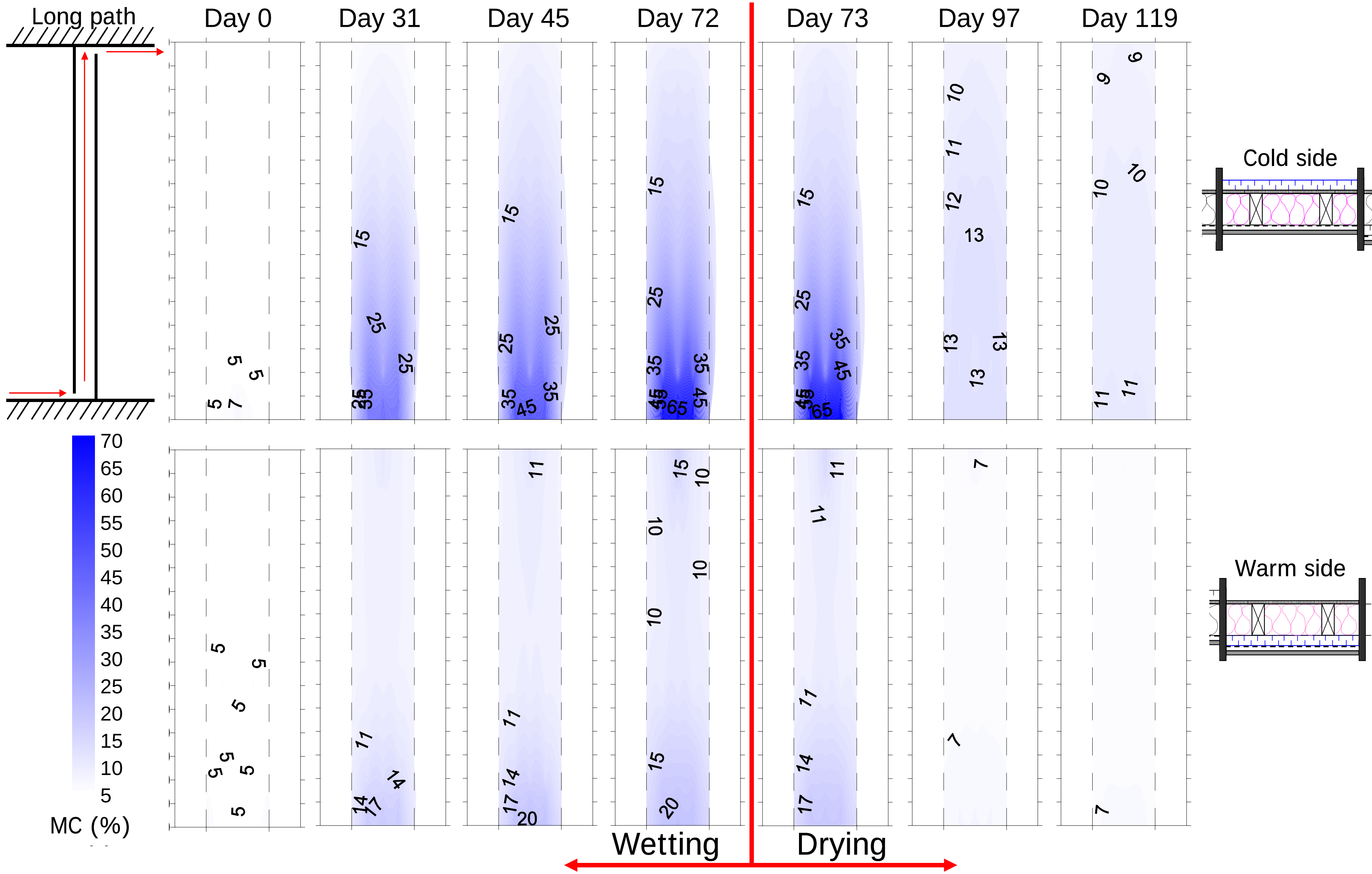
# Evaluation scale

| | |
|---|---|
| R-2000: | 1.5 CAH or less |
| NovoClimat : | 2.5 CAH or less |
| Average housing: | around 4-5 CAH |

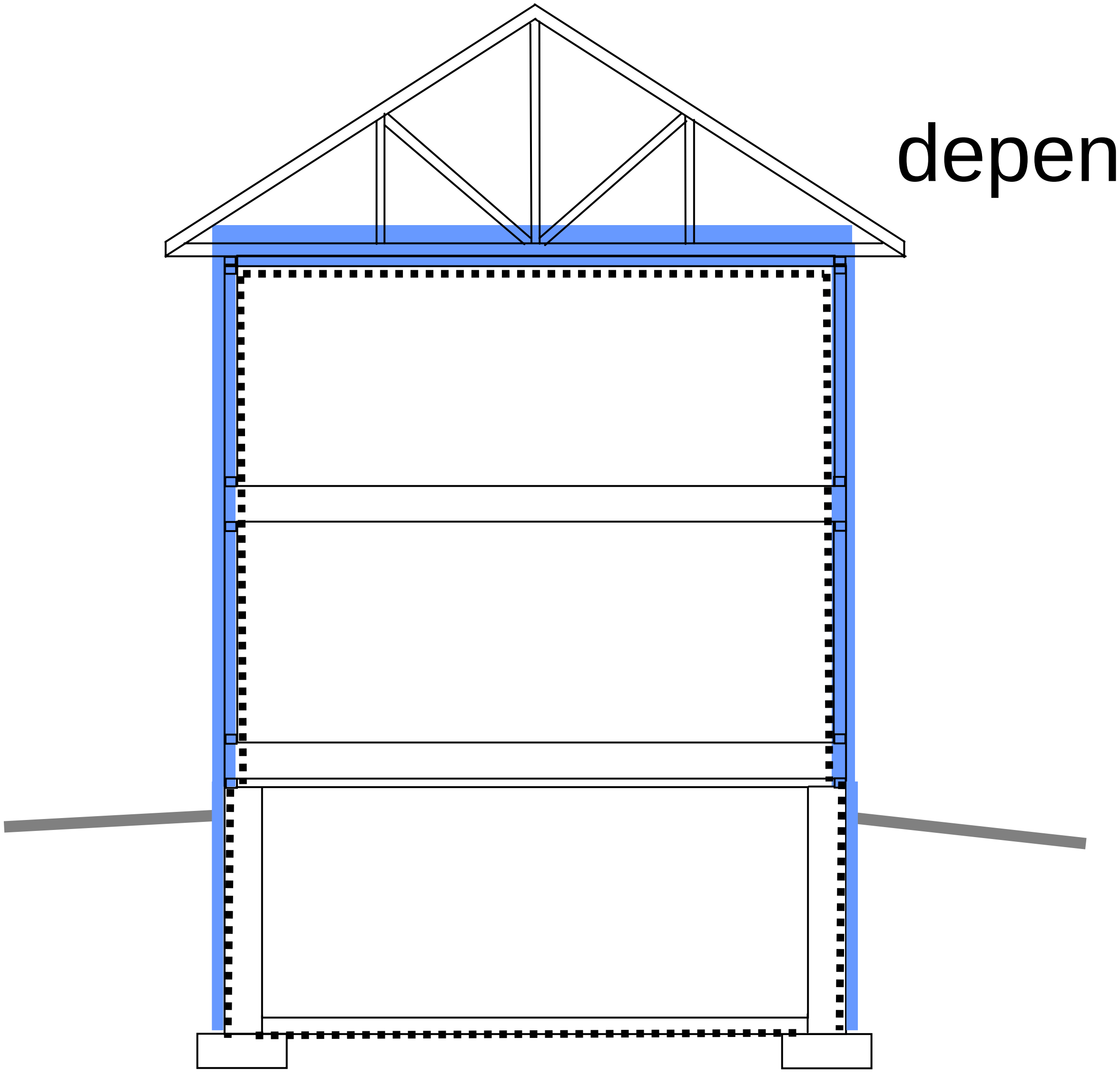
# Moisture Performance of Leaky Exterior Walls with Added Insulation Air leakage configurations



# Experimental data of moisture accumulation due to air exfiltration



# Controlling vapor movement



depends on climate

# Moisture management
# vapor movement by diffusion

Vapor diffusion

vapor transfer due to a vapor pressure gradient

Control is needed to prevent condensation

resistance to vapor flow

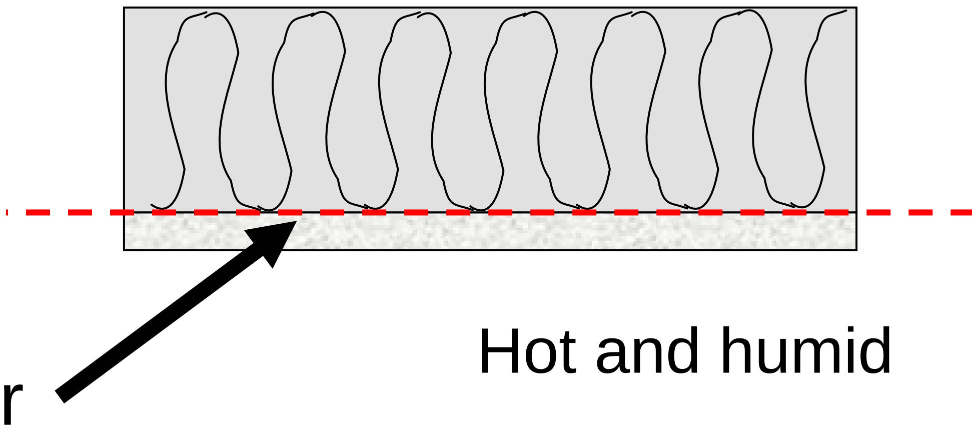
accumulation (storage) of moisture in materials

# Controlling vapor movement

Low permeance material

On hot and humid side of the envelope

Typically, polyethylene film



# Permeability and permeance

ASTM 96 method

wet cup/dry cup

More it is now known that more conditions are required (permeability is function of RH)

S. Roels 2007

# Codes

## Vapor barrier

Type 1 15 ng/Pa.s.m$^2$
Type 2 45 ng/Pa.s.m$^2$

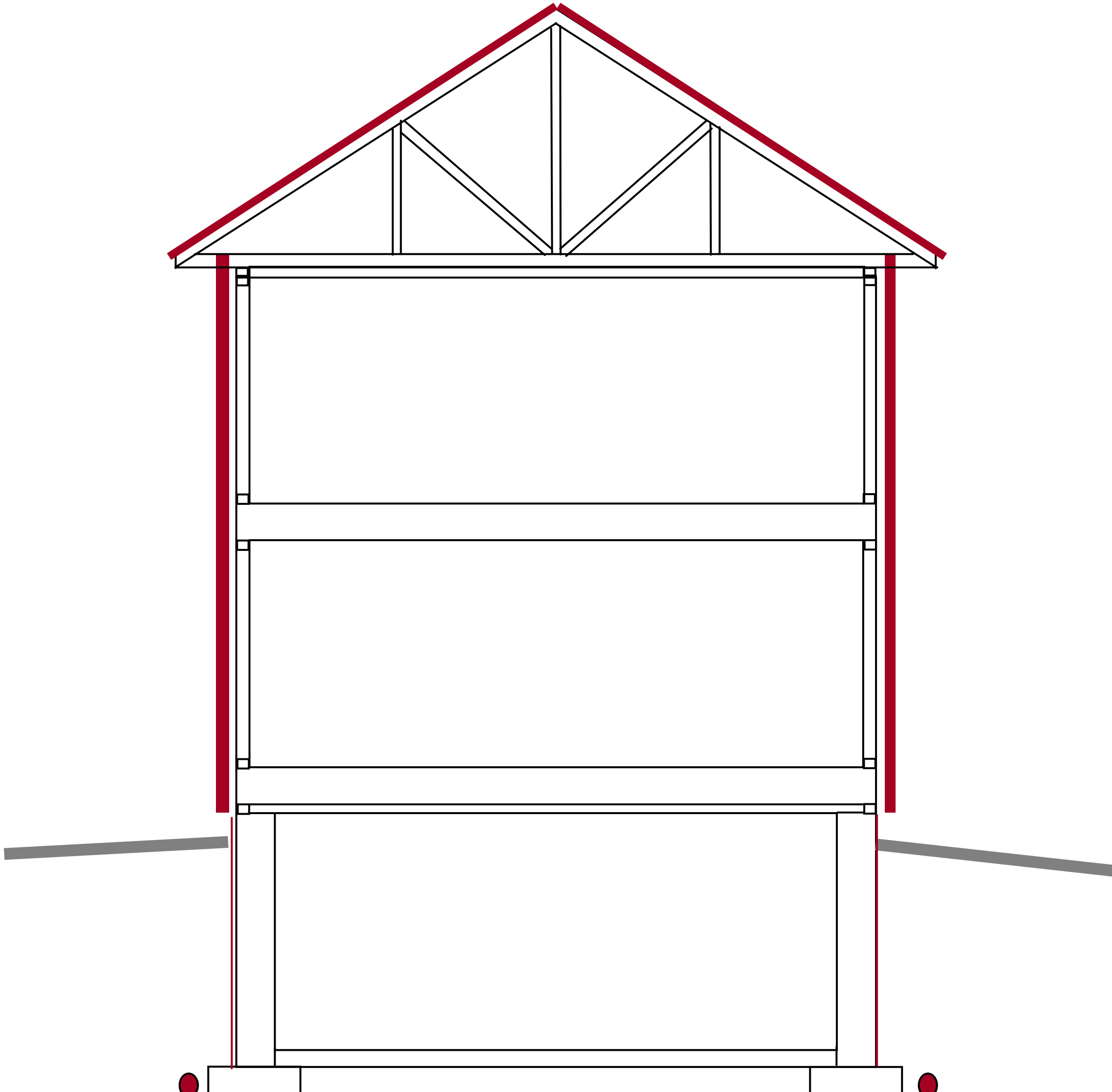
## Air barrier

Material: 0.02 L/s.m2 @75Pa

Assembly: (recommended, in Annex of NBC)

Class 1 (RH < 27%): 0.15 L/s/m$^2$
Class 2 (RH 27-55%): 0.10 L/s/m$^2$
Class 3 (RH > 55%): 0.05 L/s/m$^2$

# Rain control



# Rain control

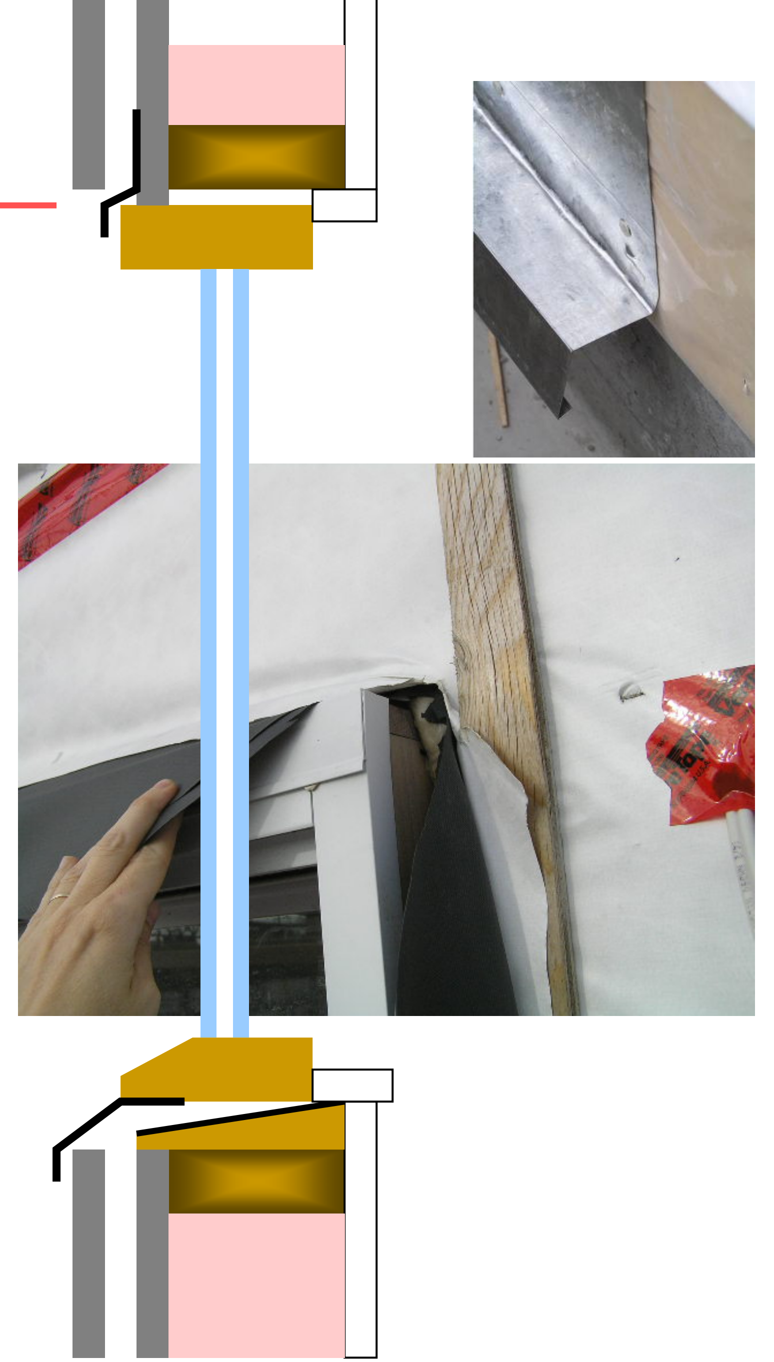
Rain screen design

Drainage

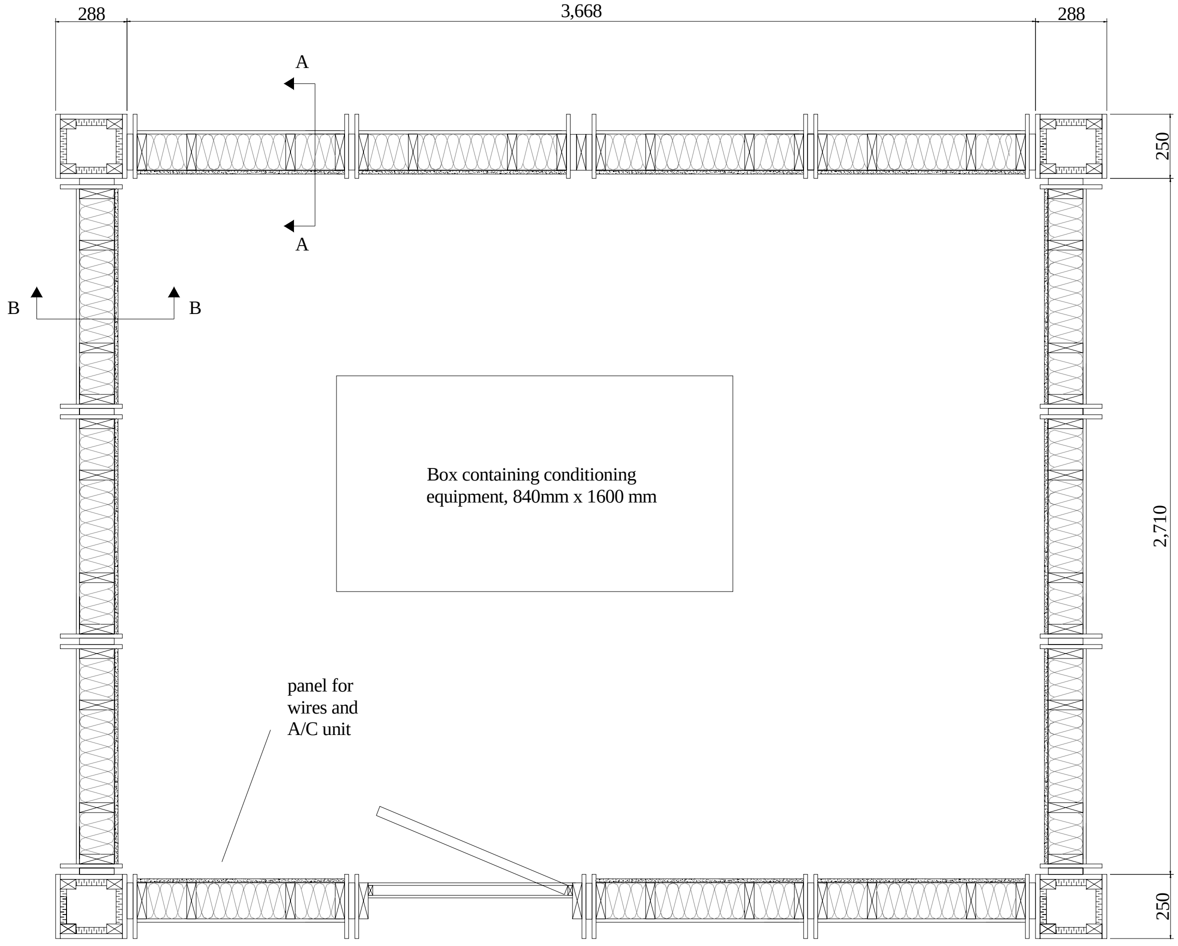
Roof, gutters, flashing

Wall/window assemblies

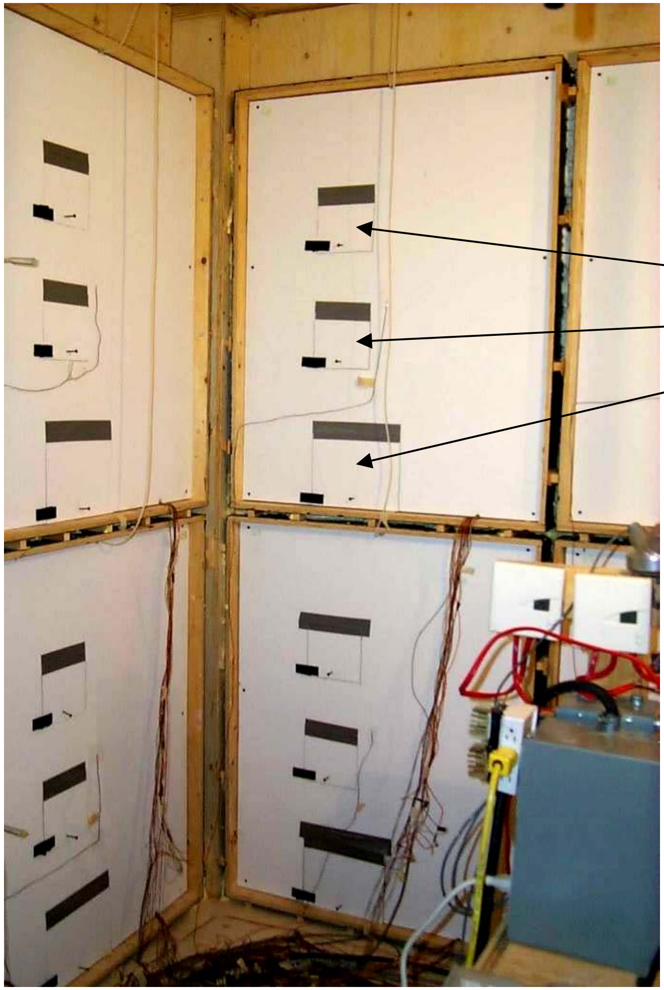
Beware with junctions!



# Test hut to reproduce wetting due to rain and allow drying by diffusion




# Set up of wall assemblies in the test hut



Gypsum access panels

for gravimetry

# Wetting

## Method of rainwater insertion



# Full height walls

Climate of

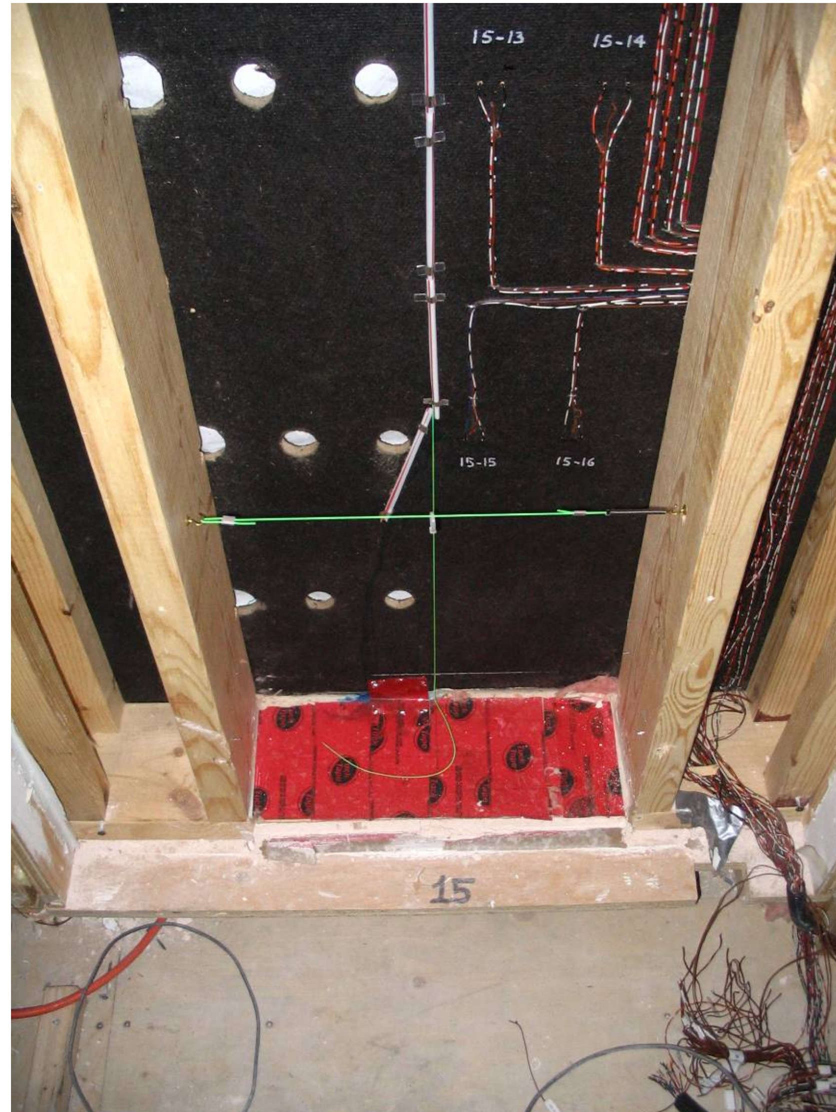
- august
- september
- october
- november

More control of water dripping pattern

Monitoring of moisture content gradient

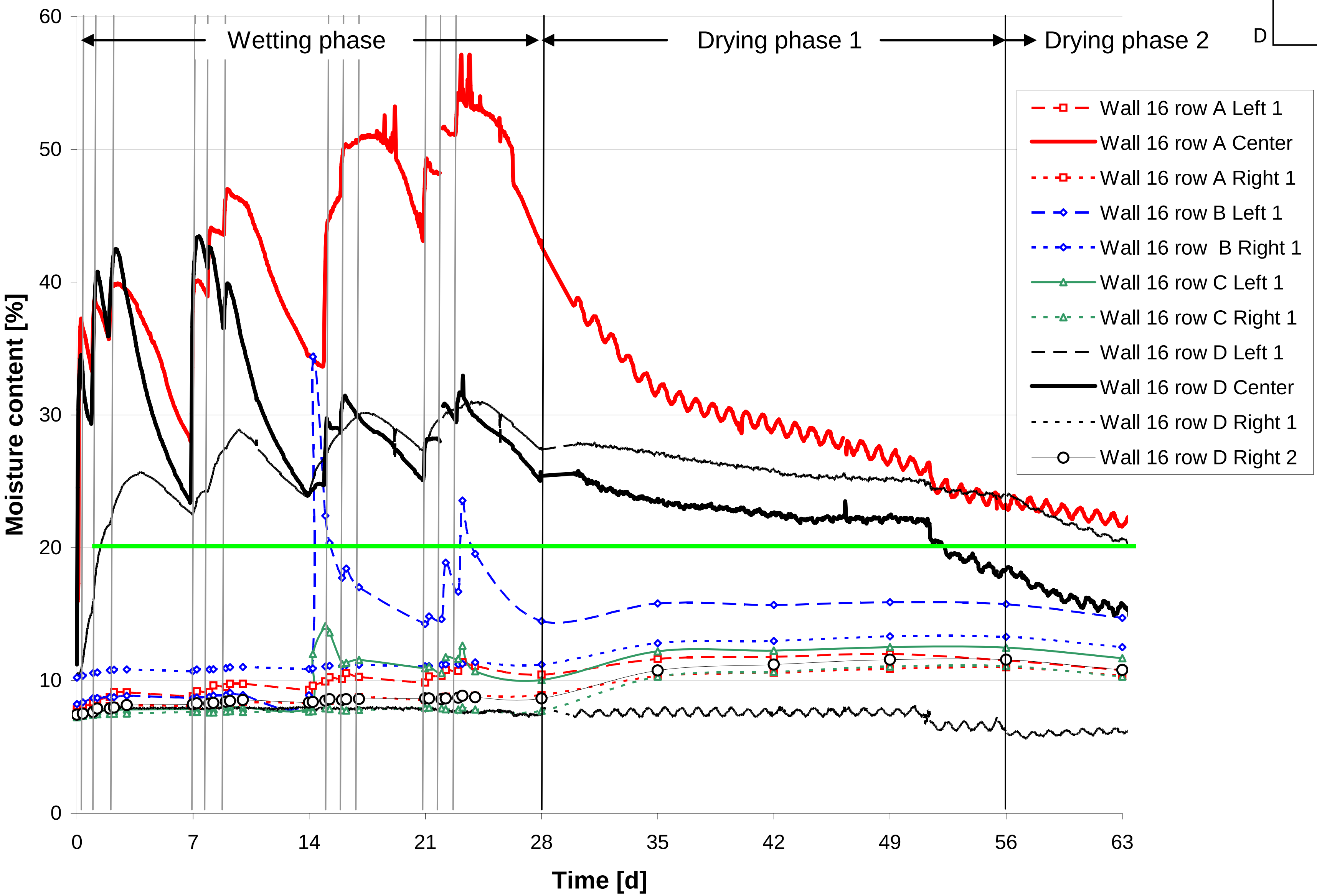
plywood

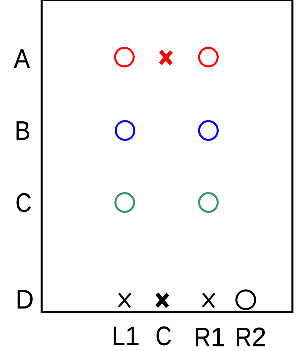

OSB



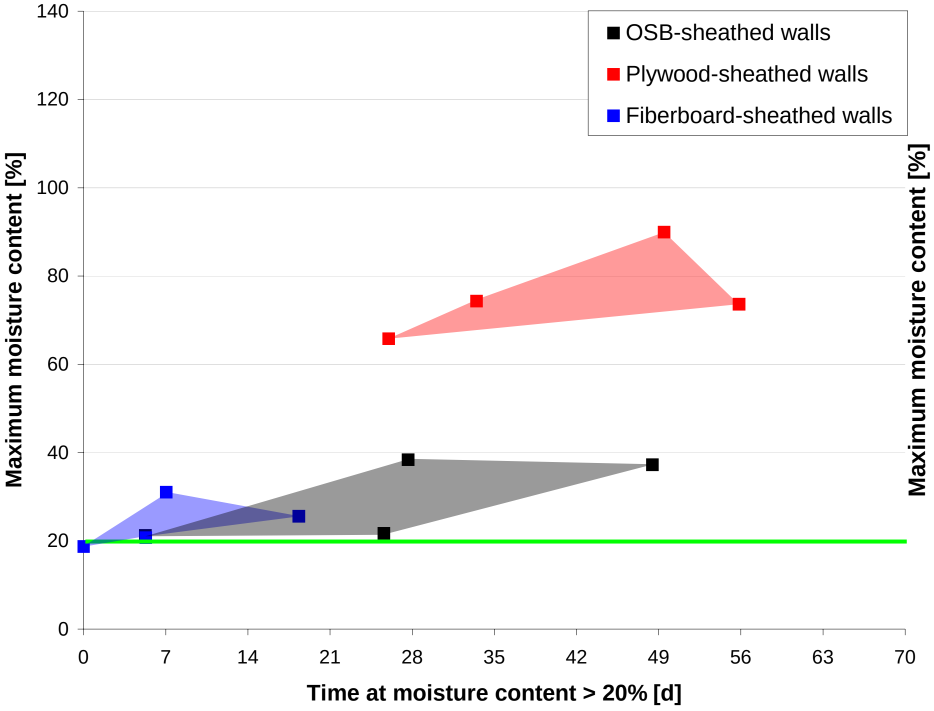

fiberboard

# Experimental Results

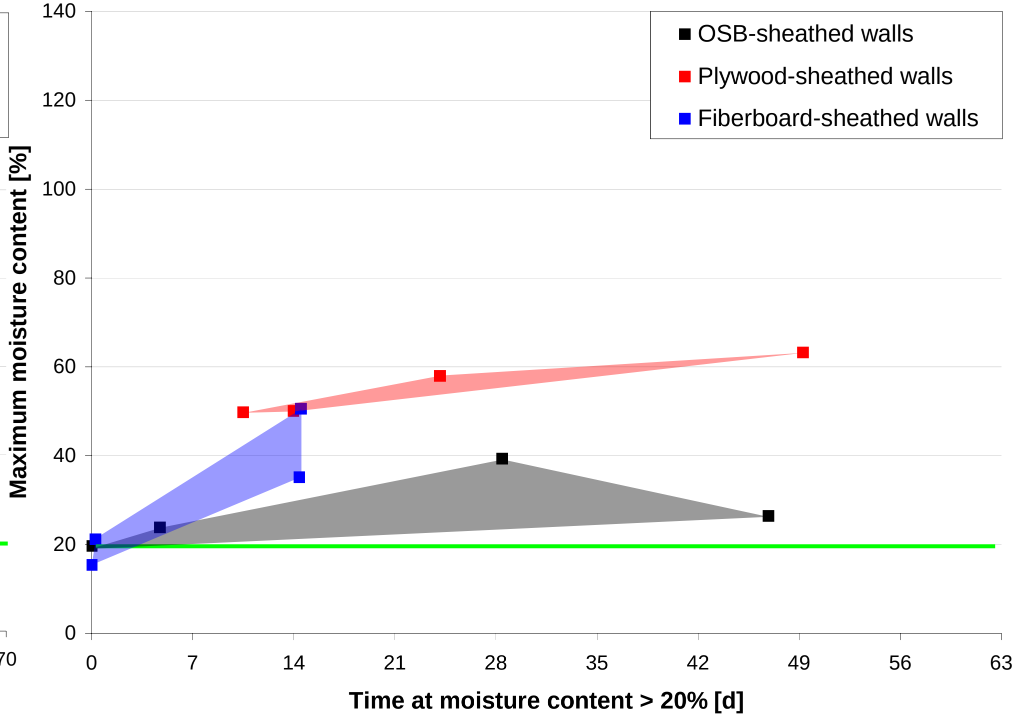


# Experimental Results – Sheathing

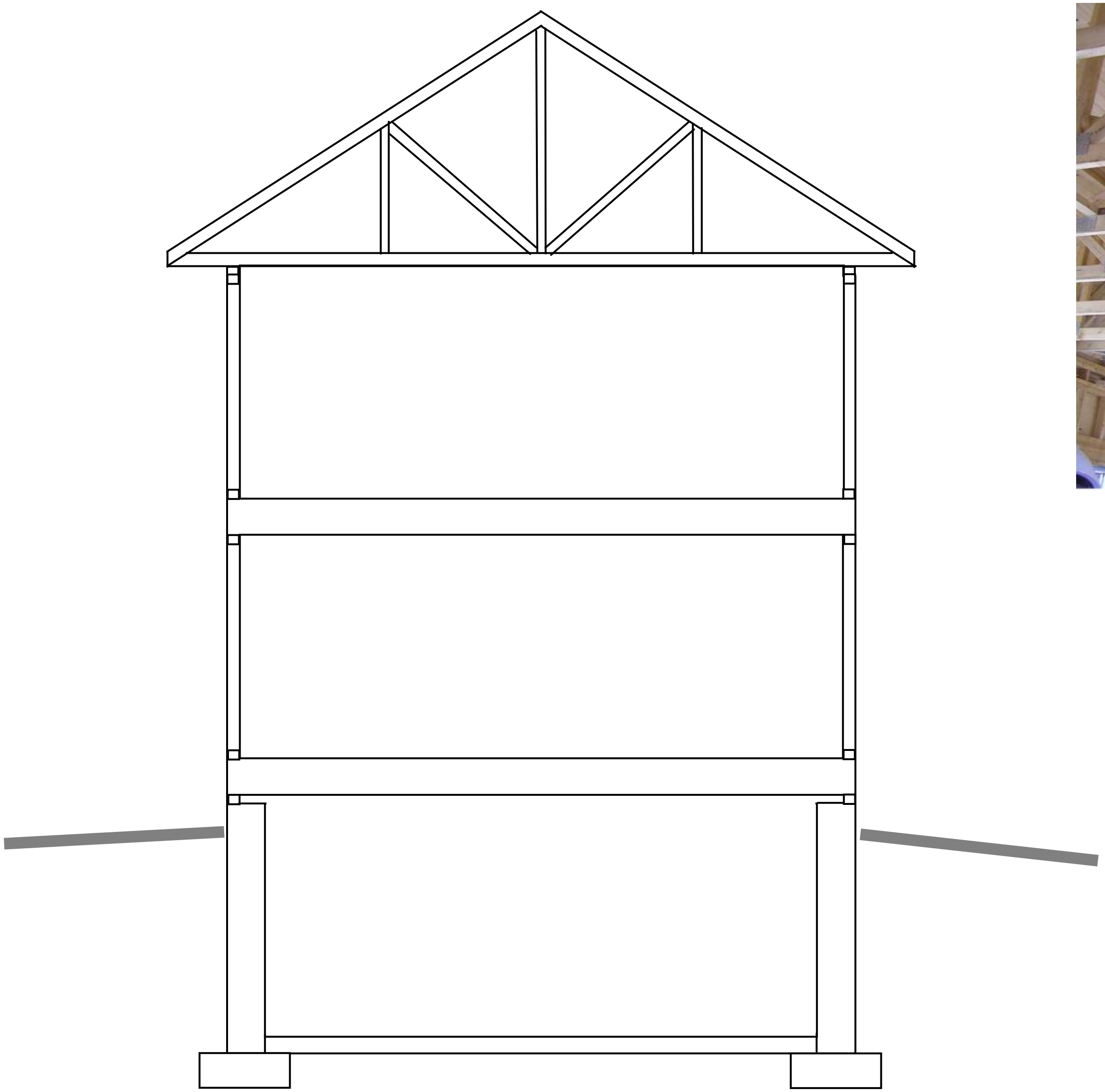



Test 1



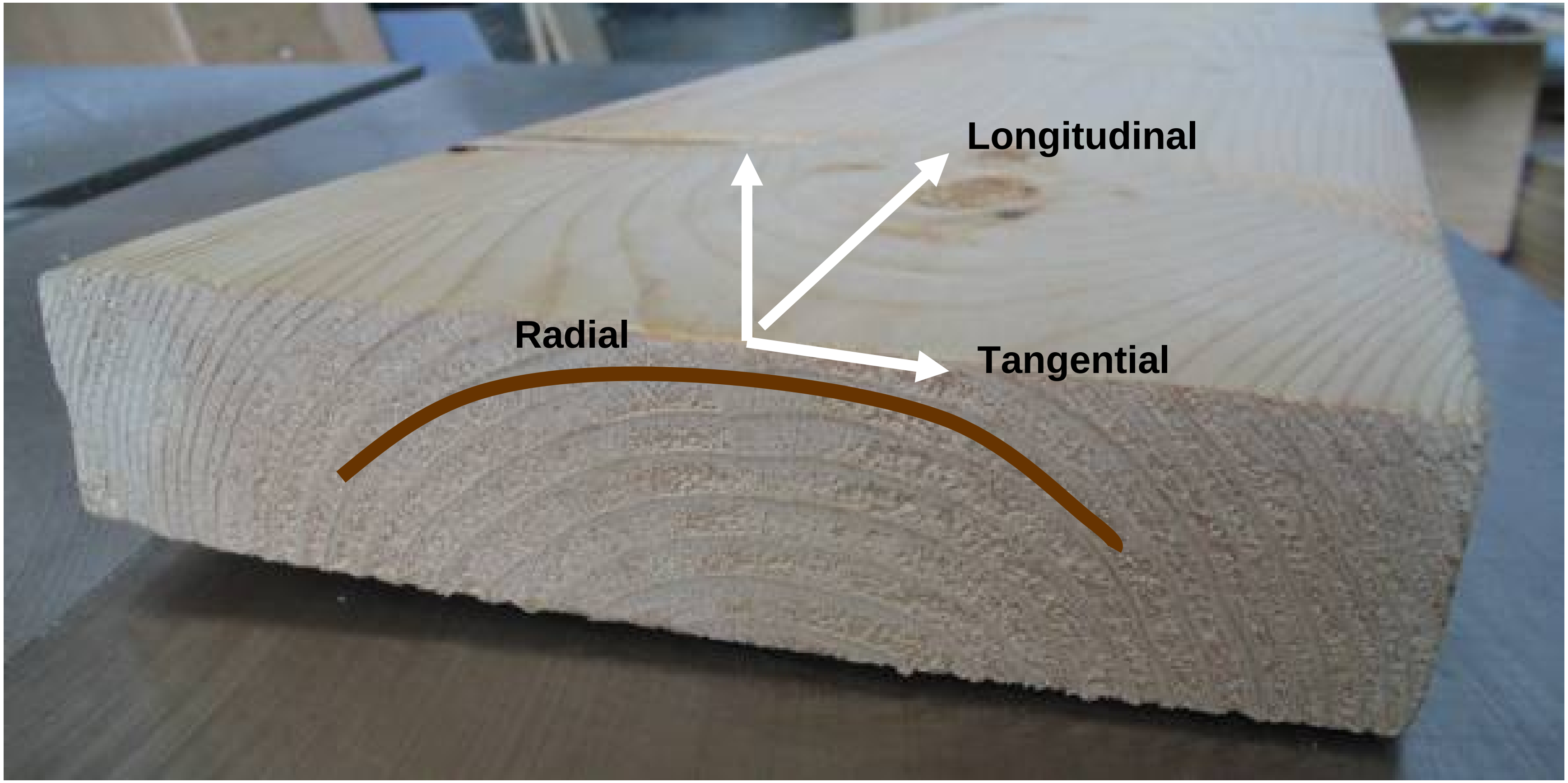

Test 2

# Structure



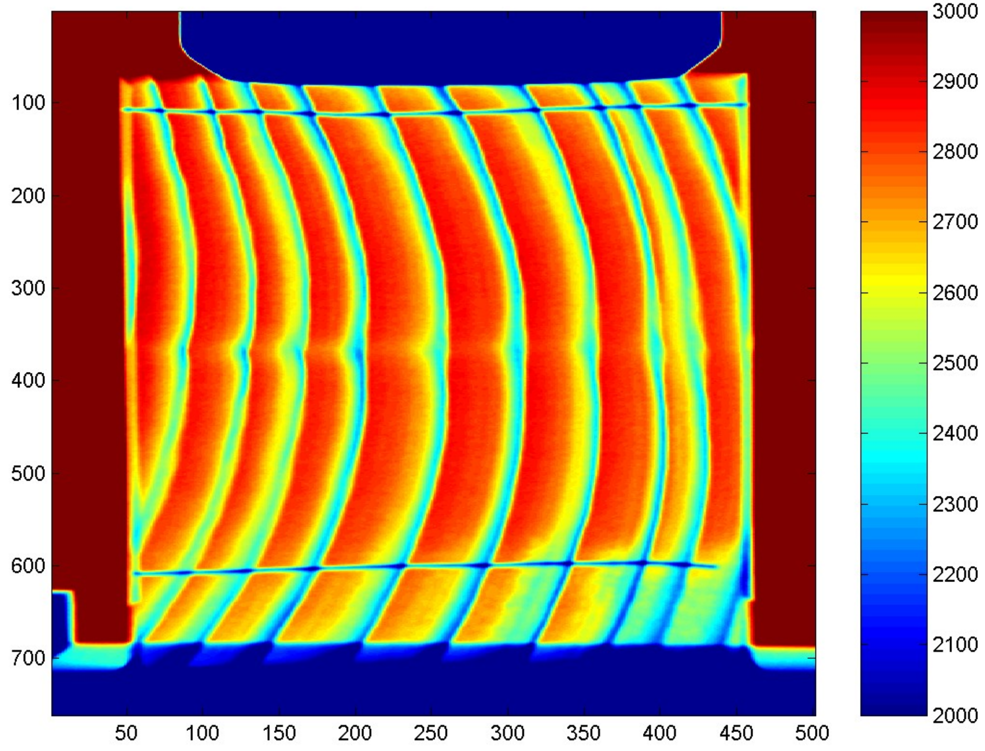
# Wood

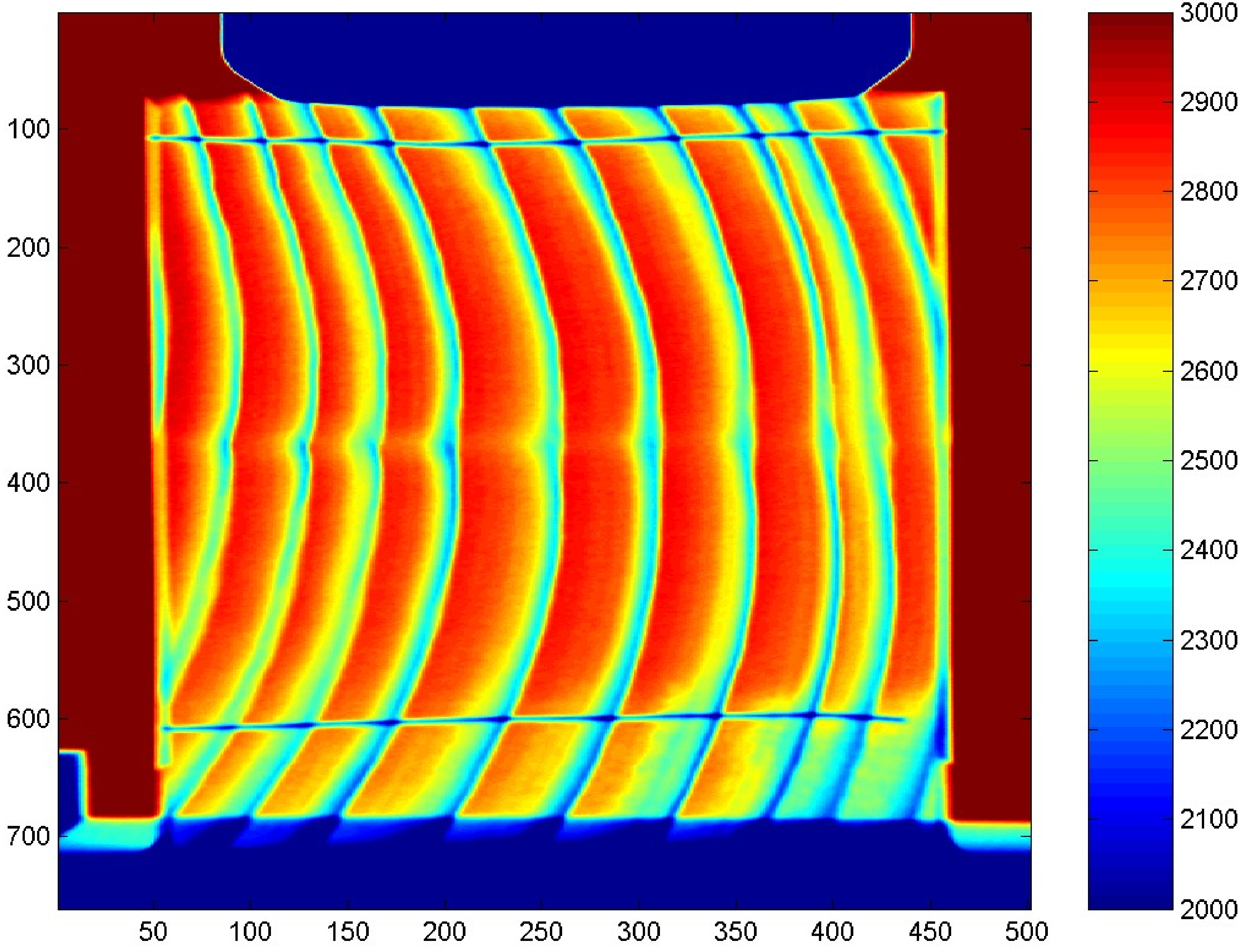
## orthotropic material



# Wood wetting

Micro-focus X-ray

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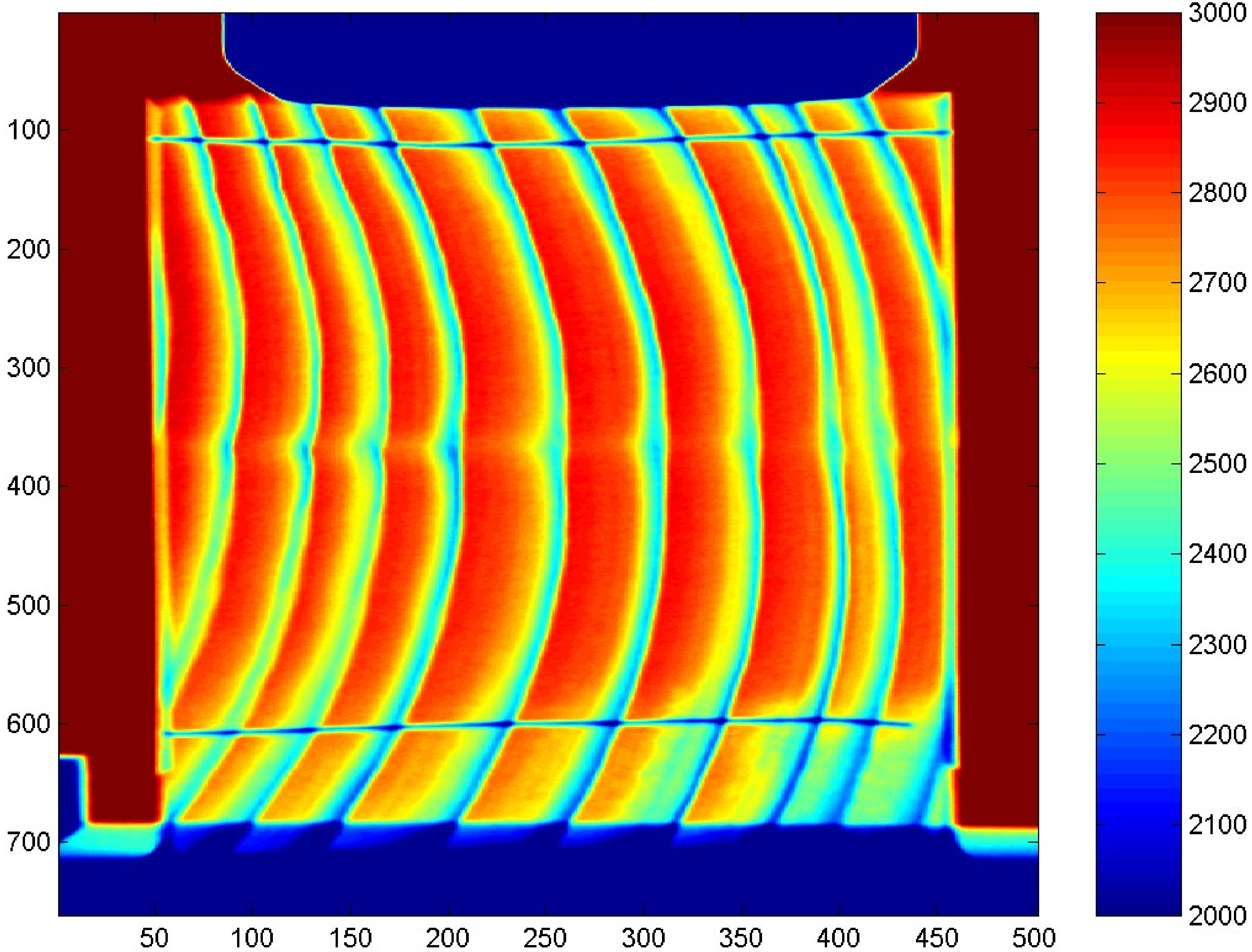

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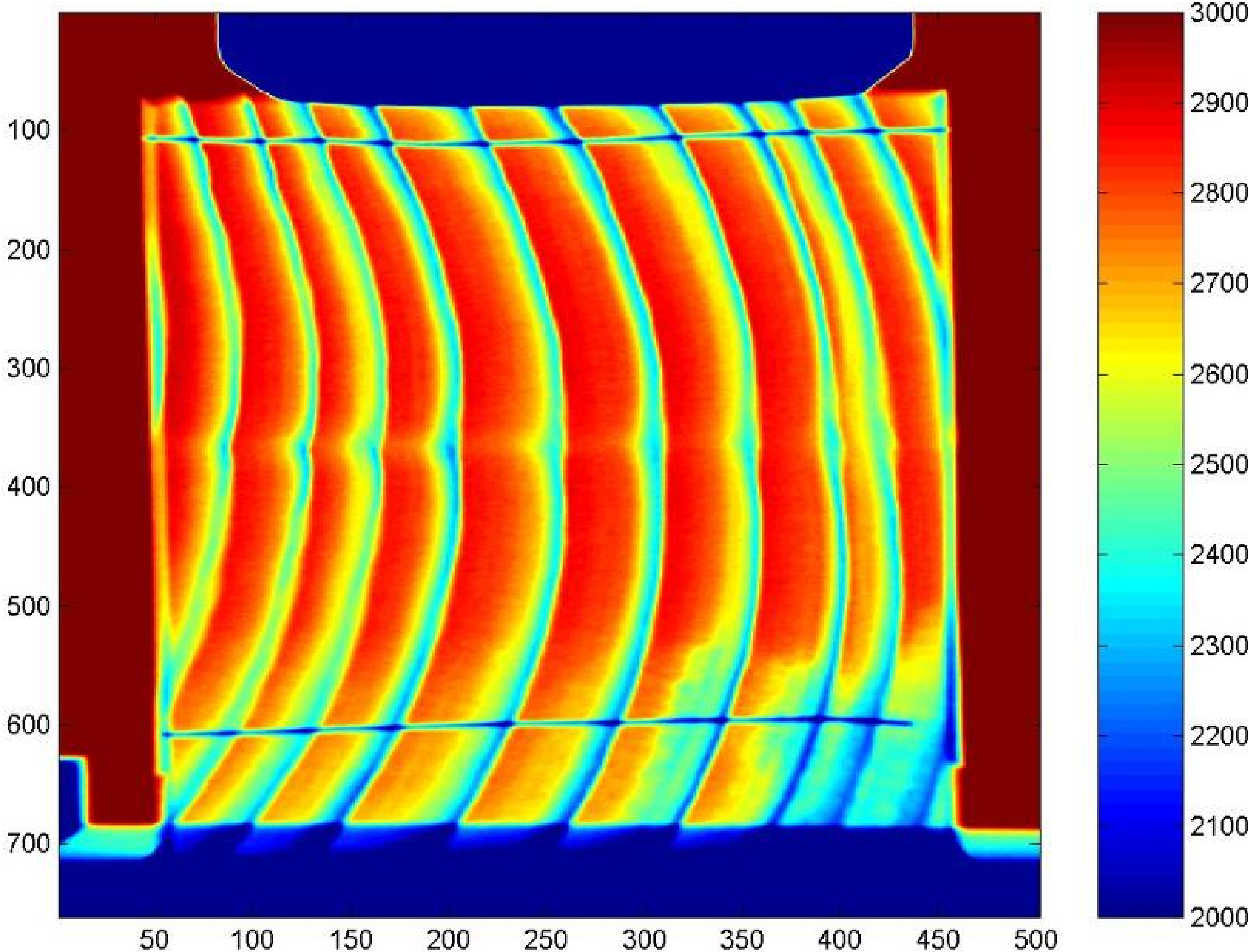

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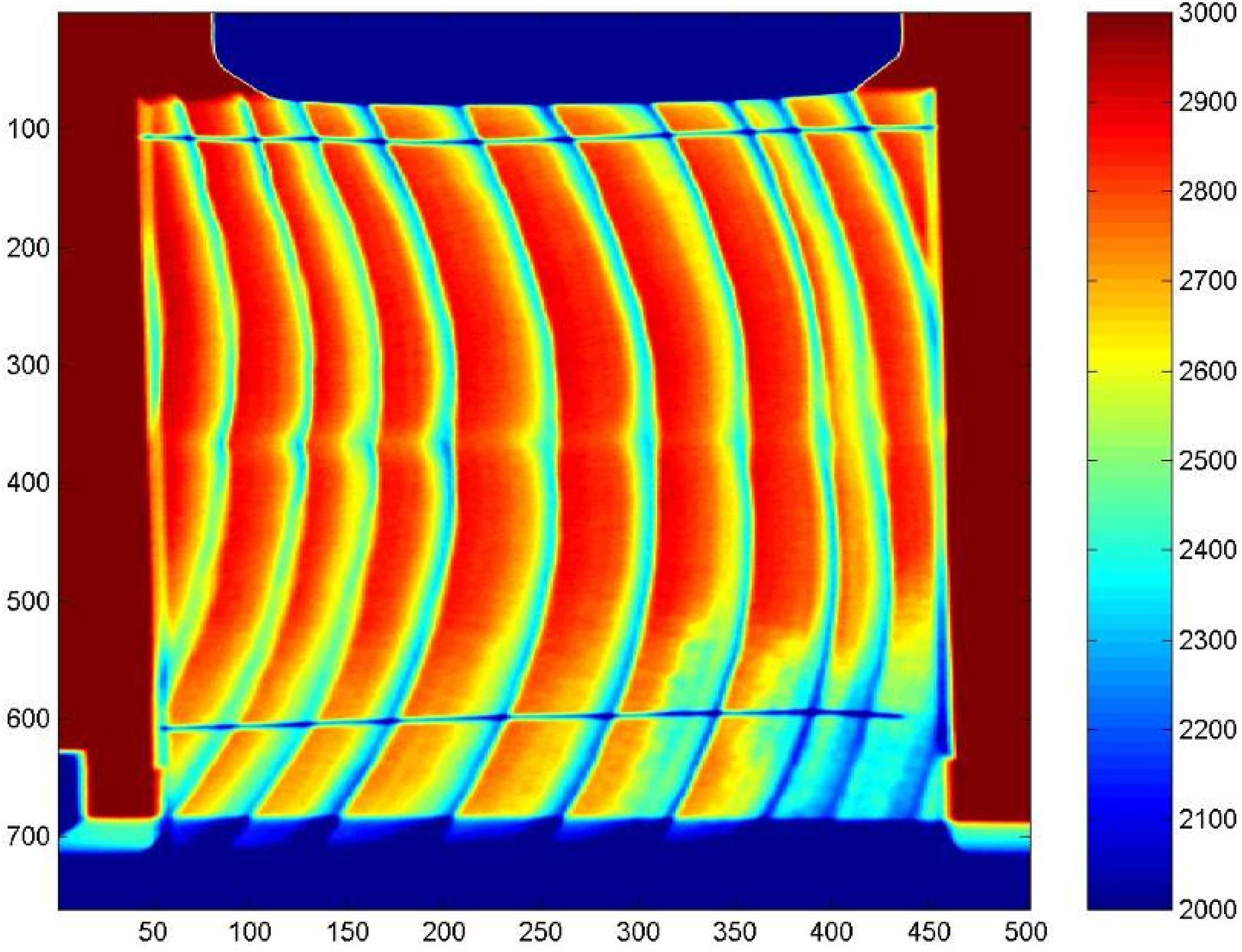
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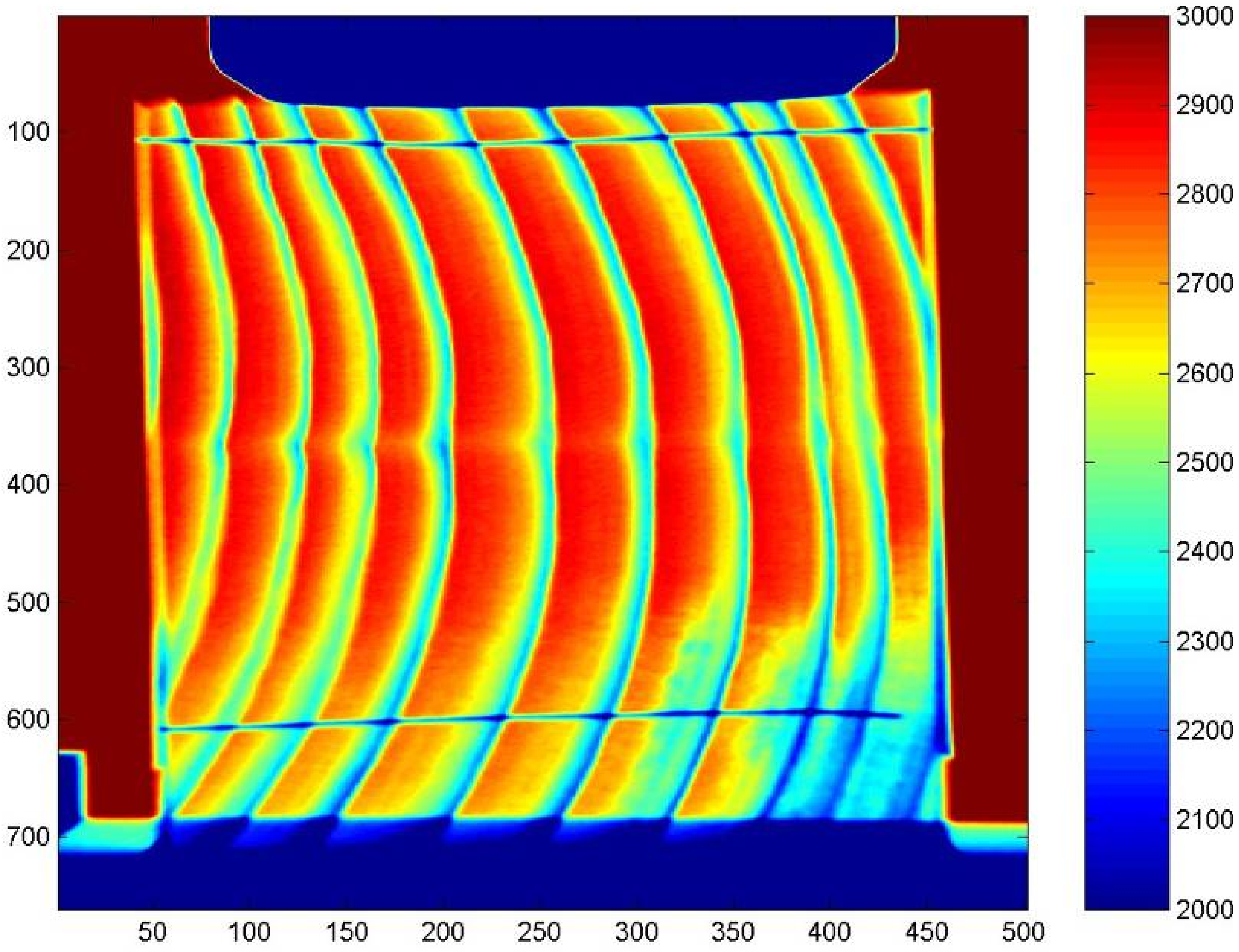

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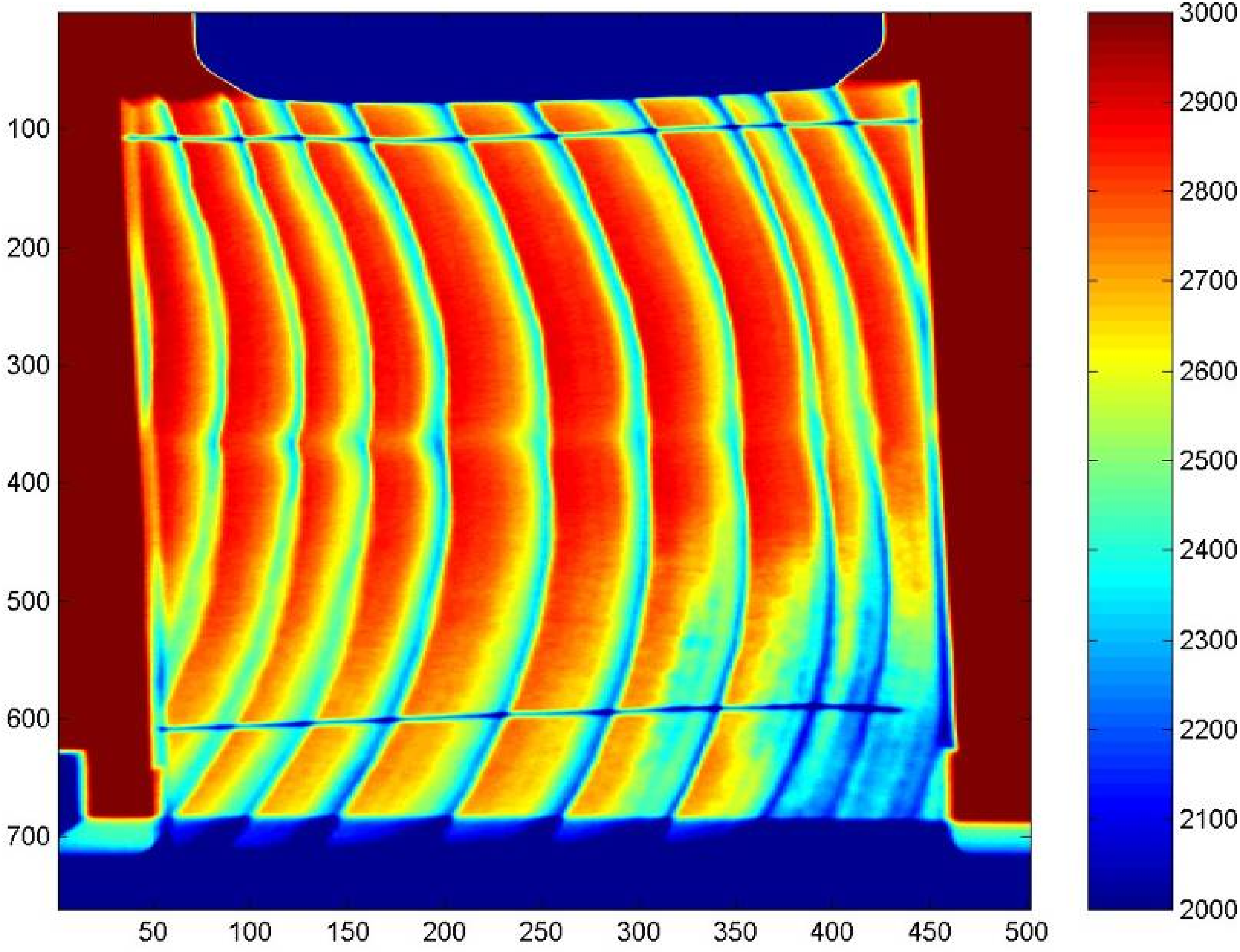
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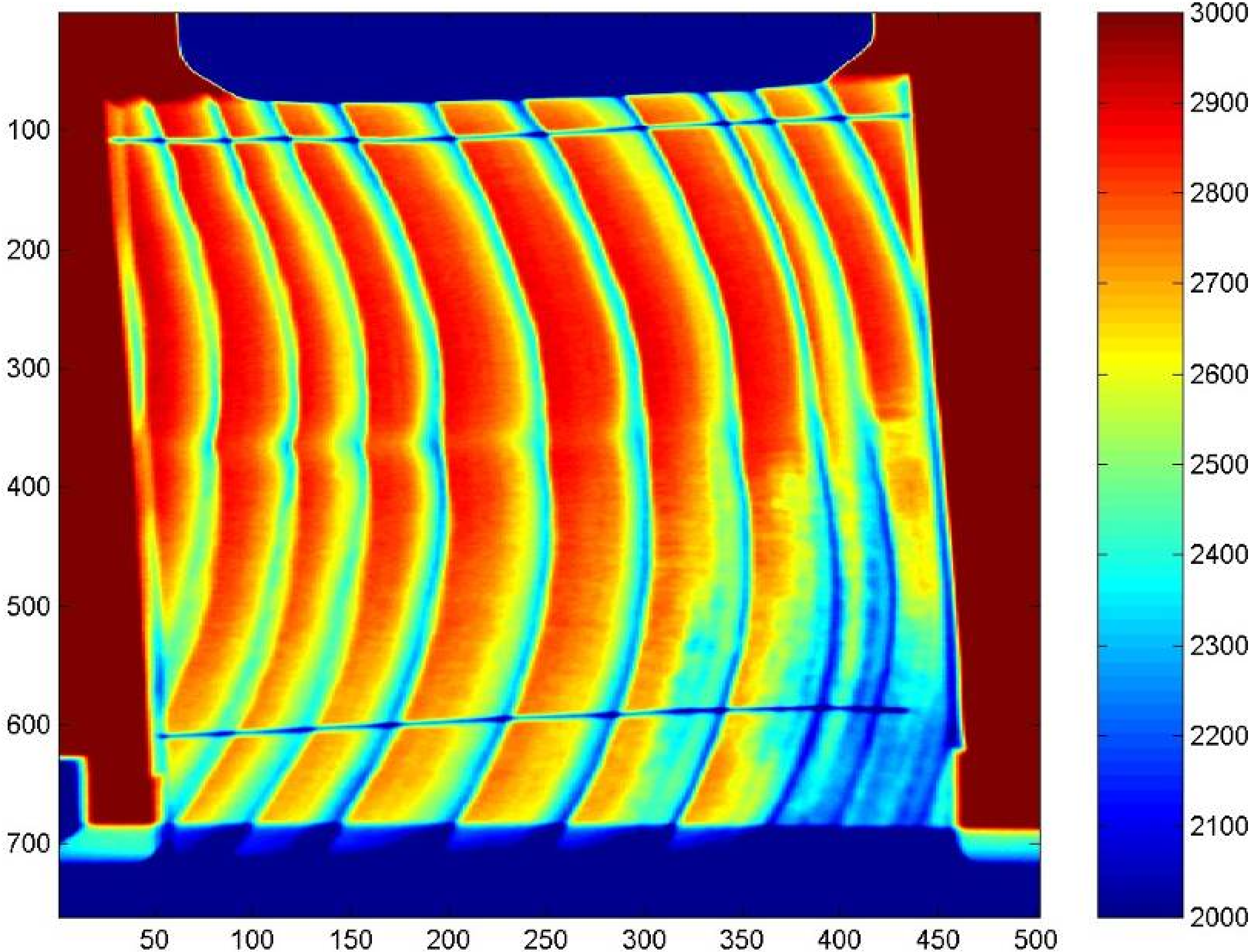
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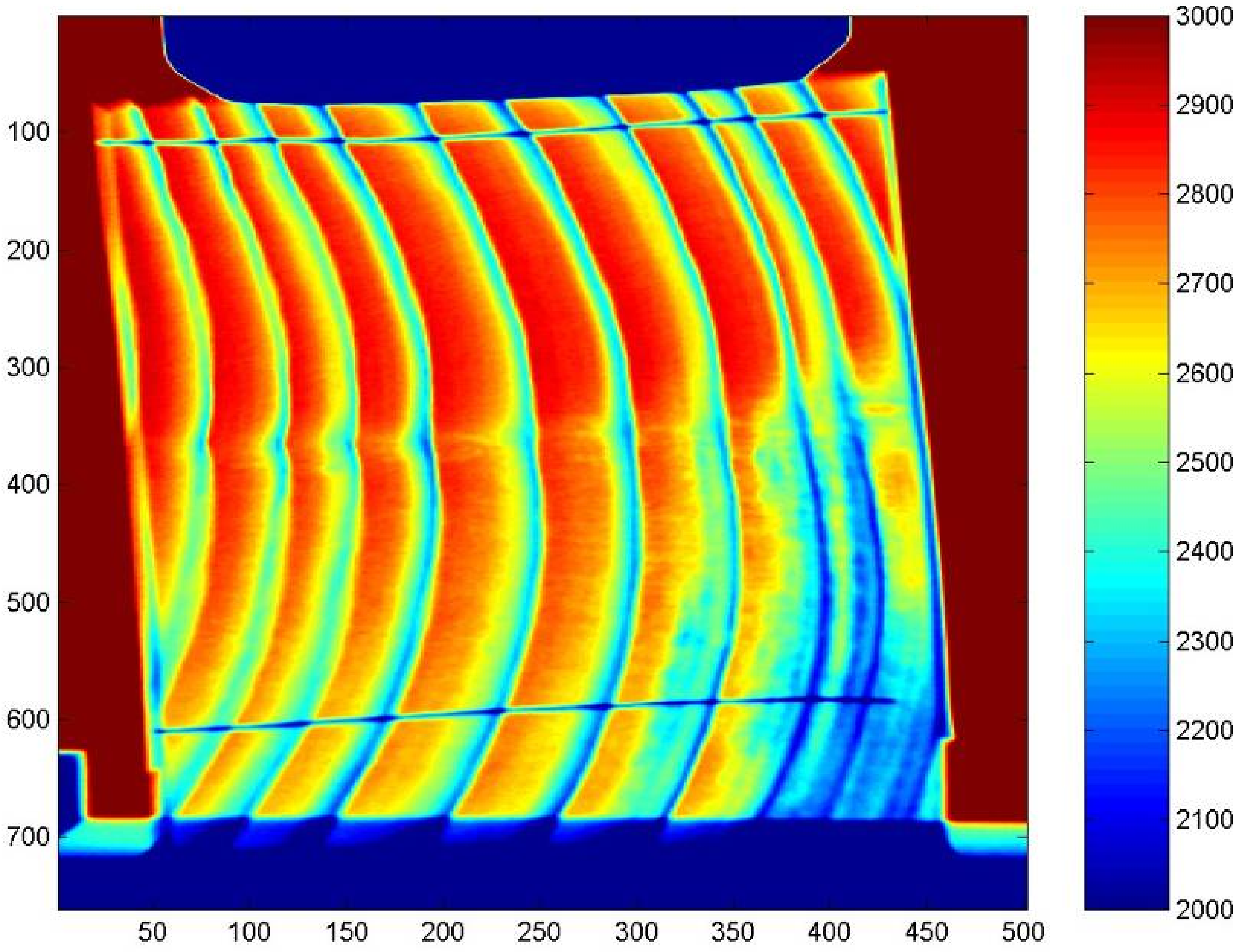
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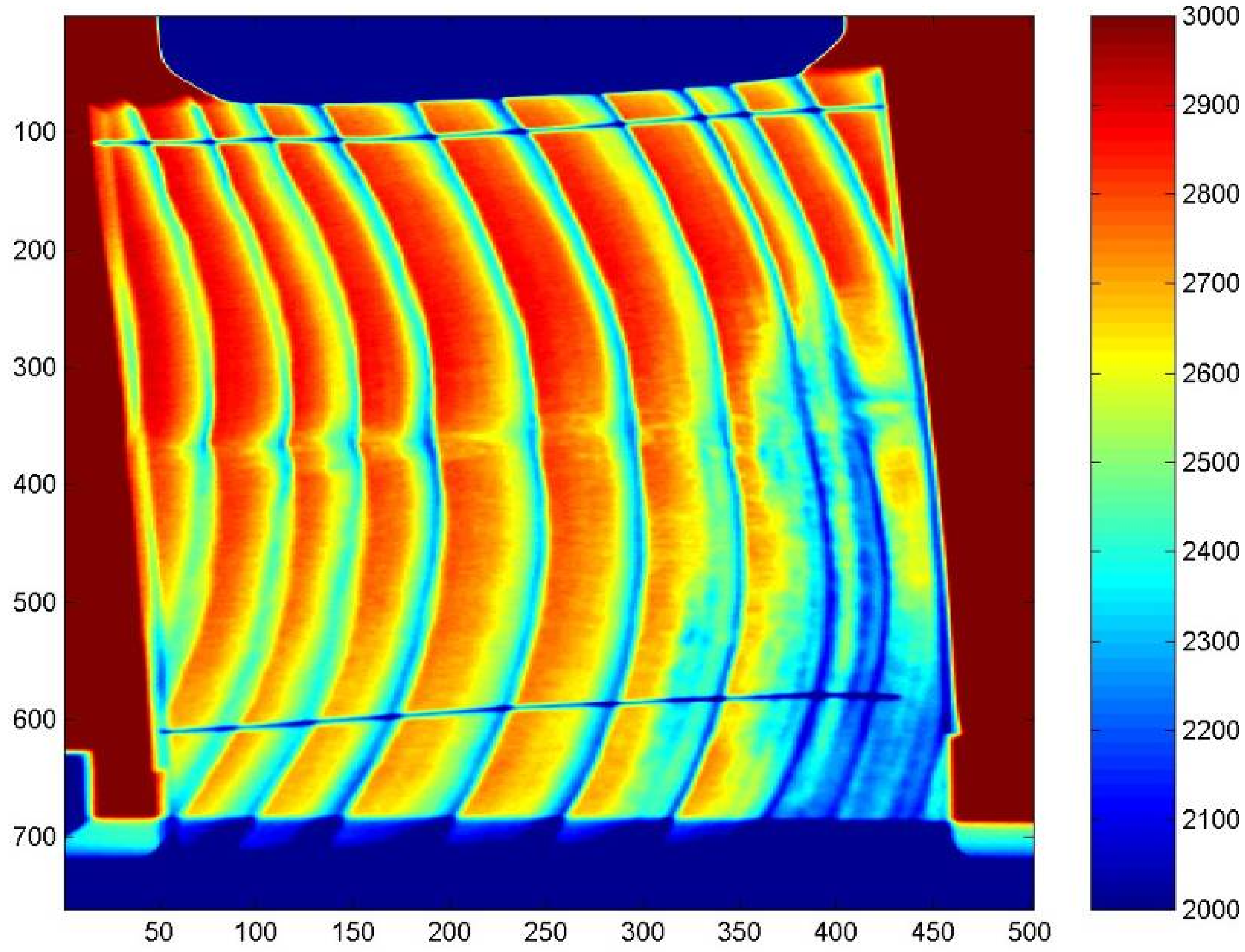

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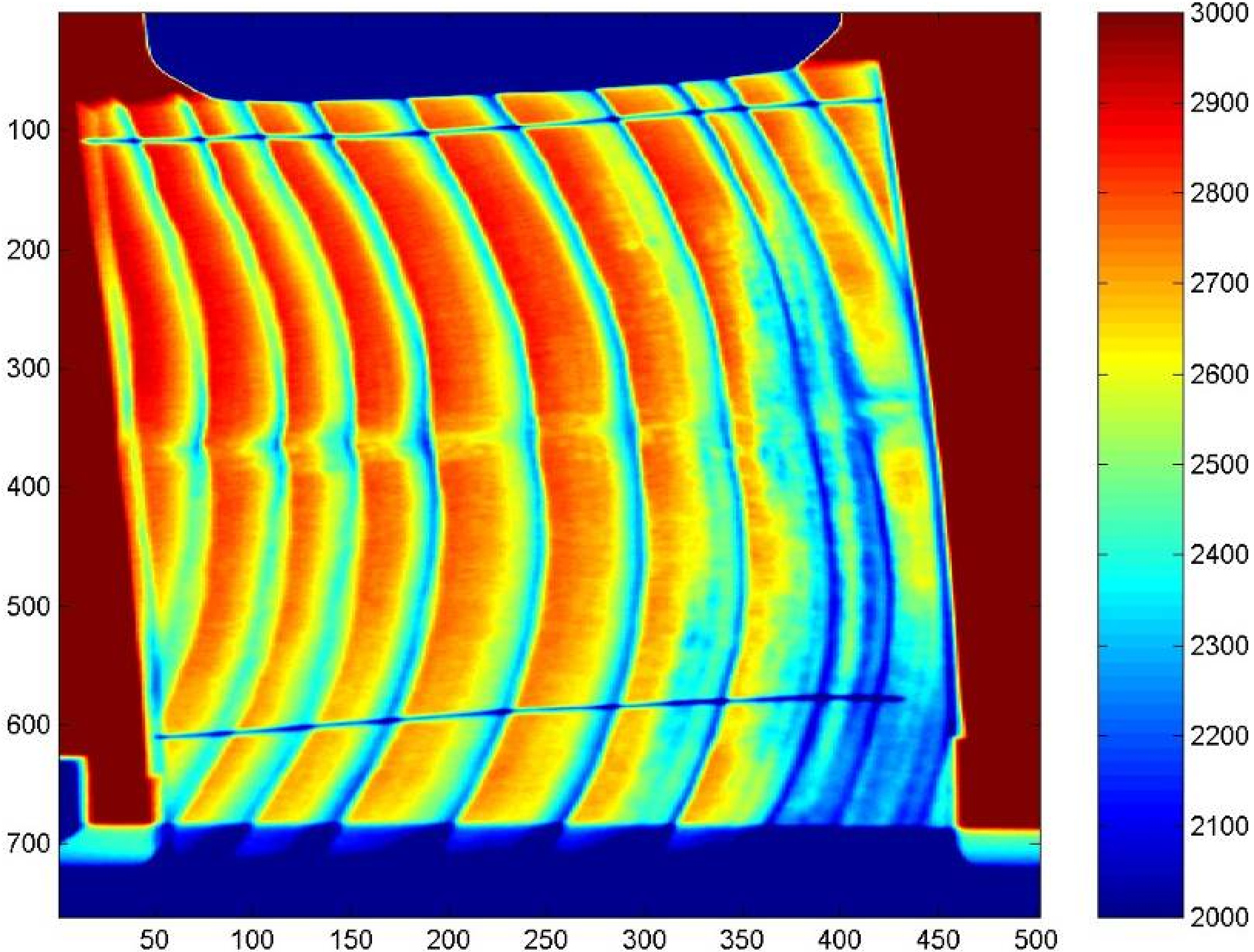

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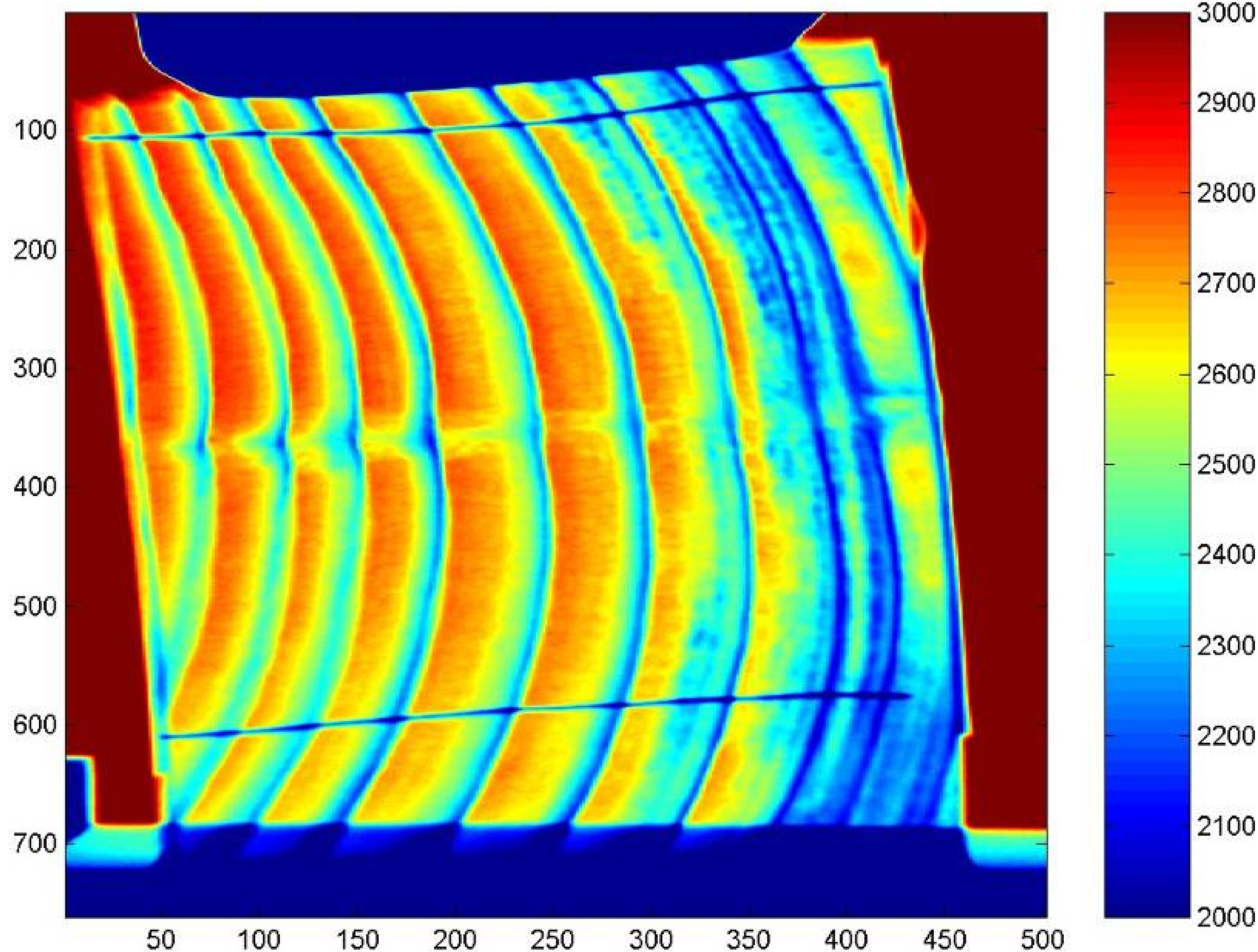
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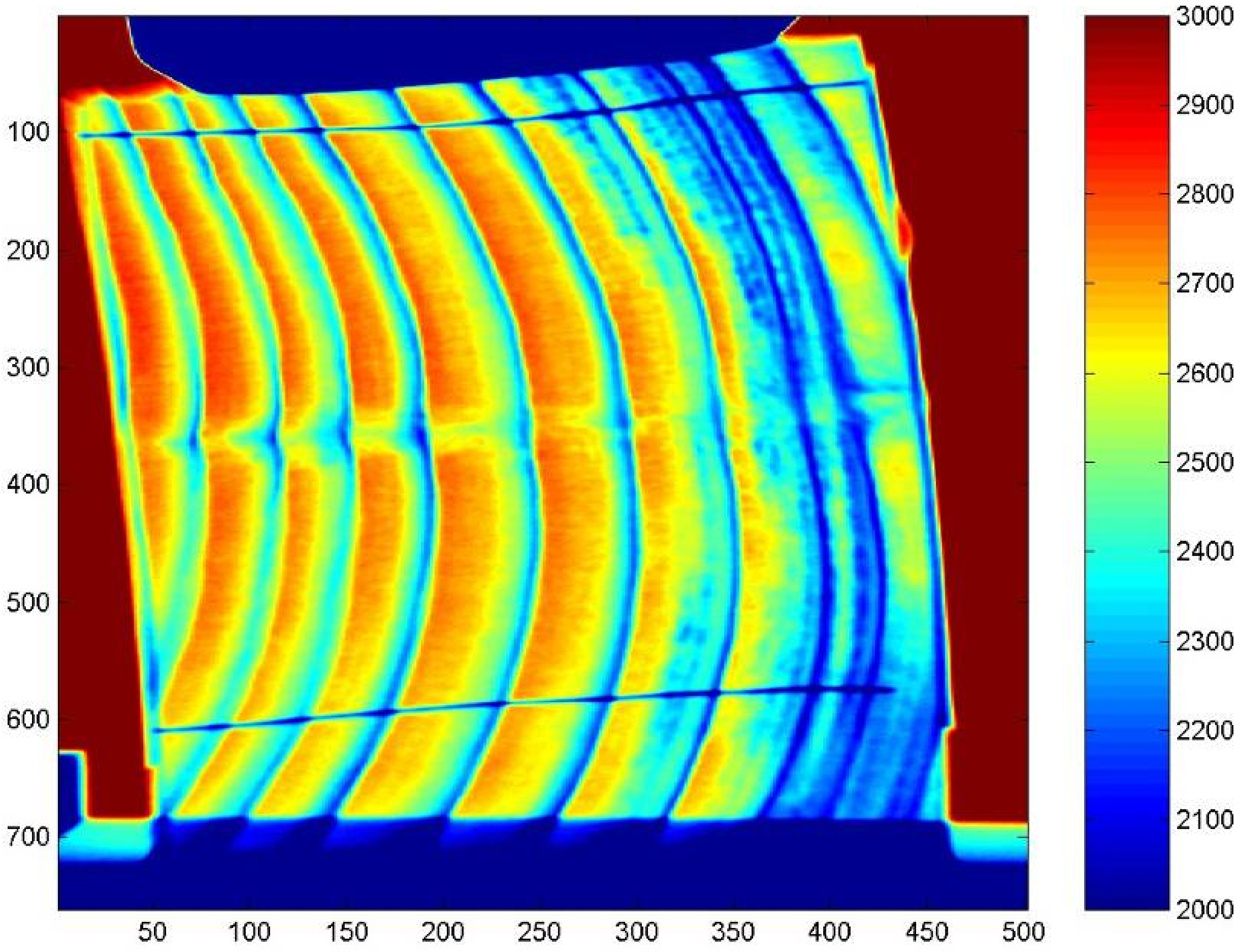
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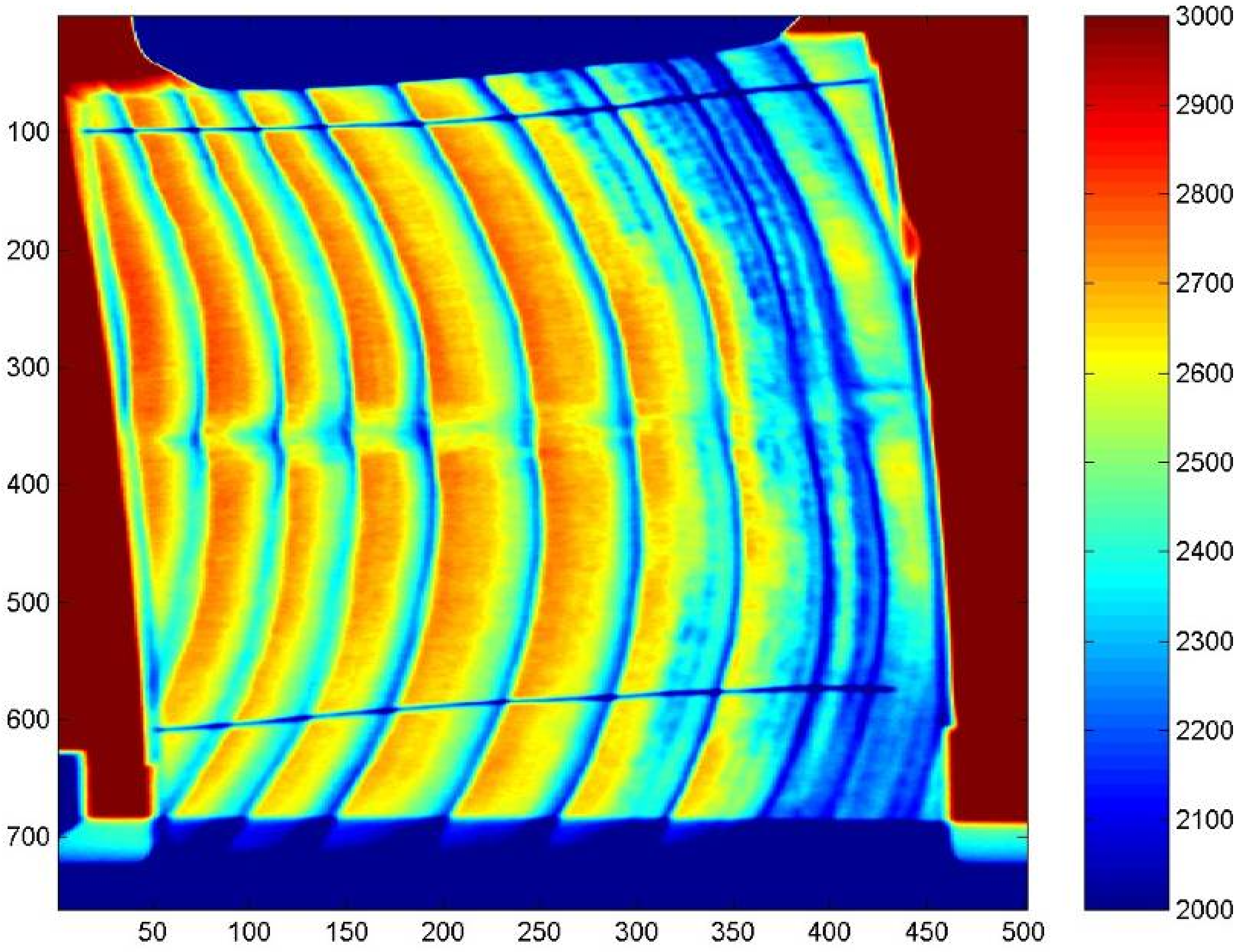
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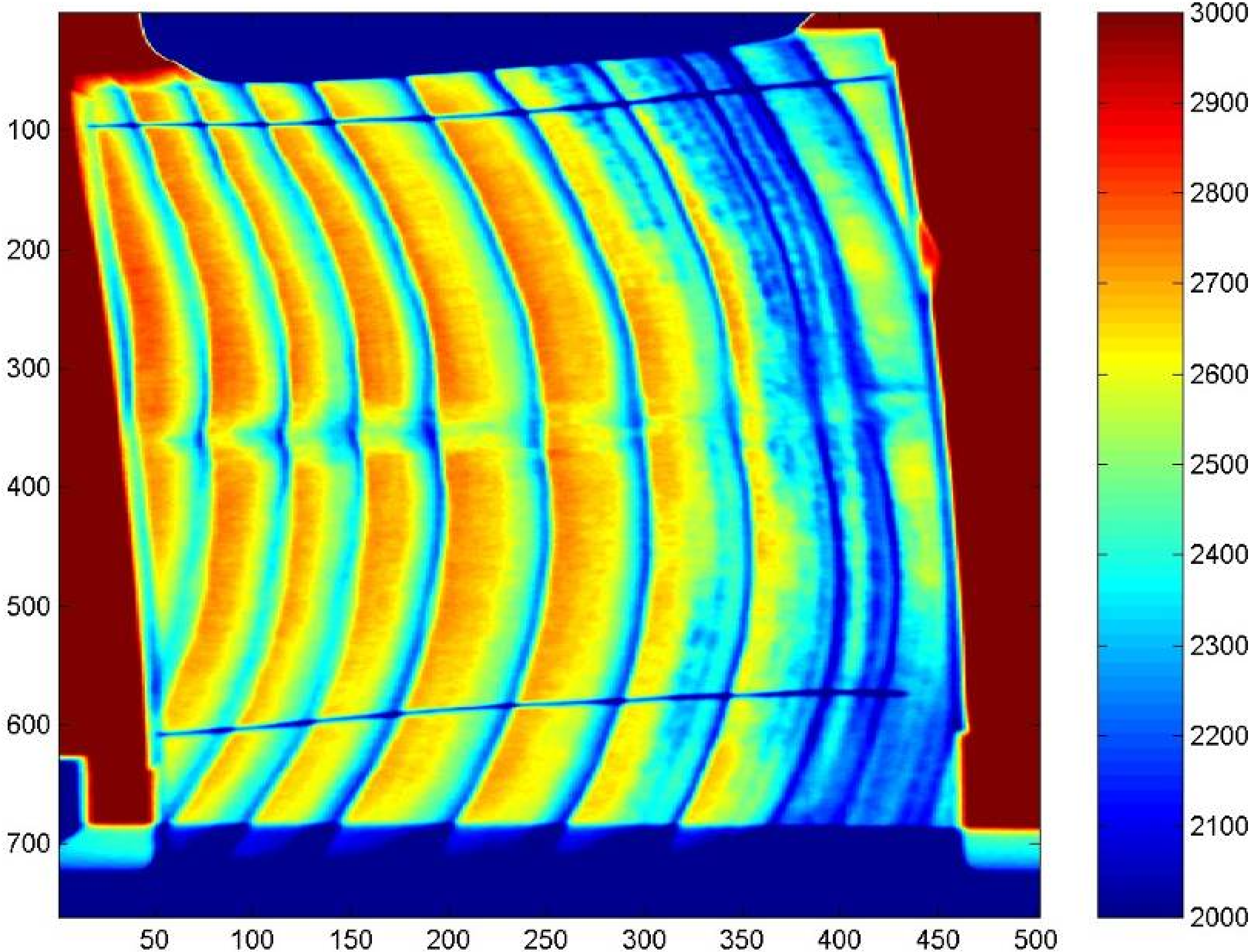

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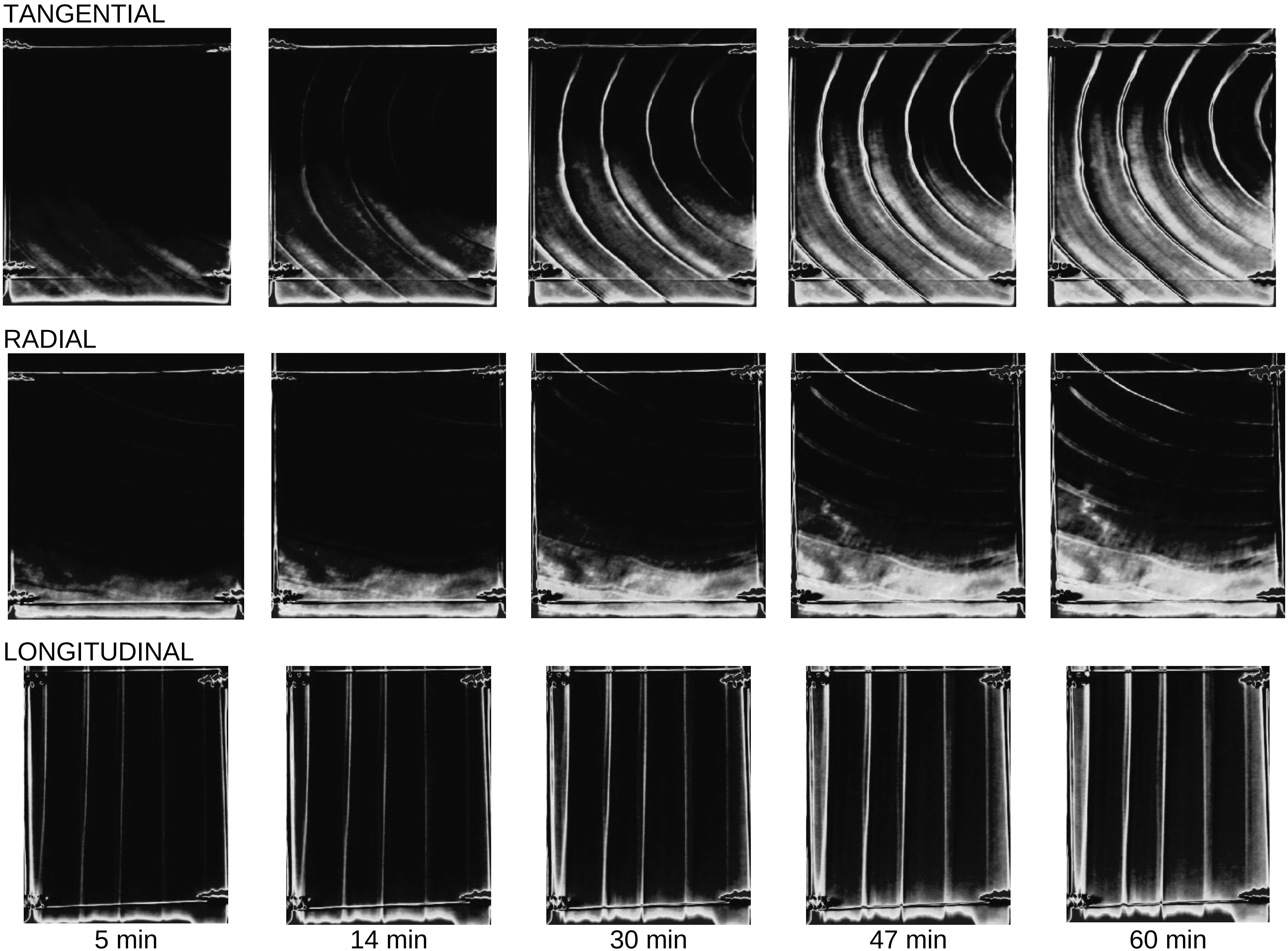
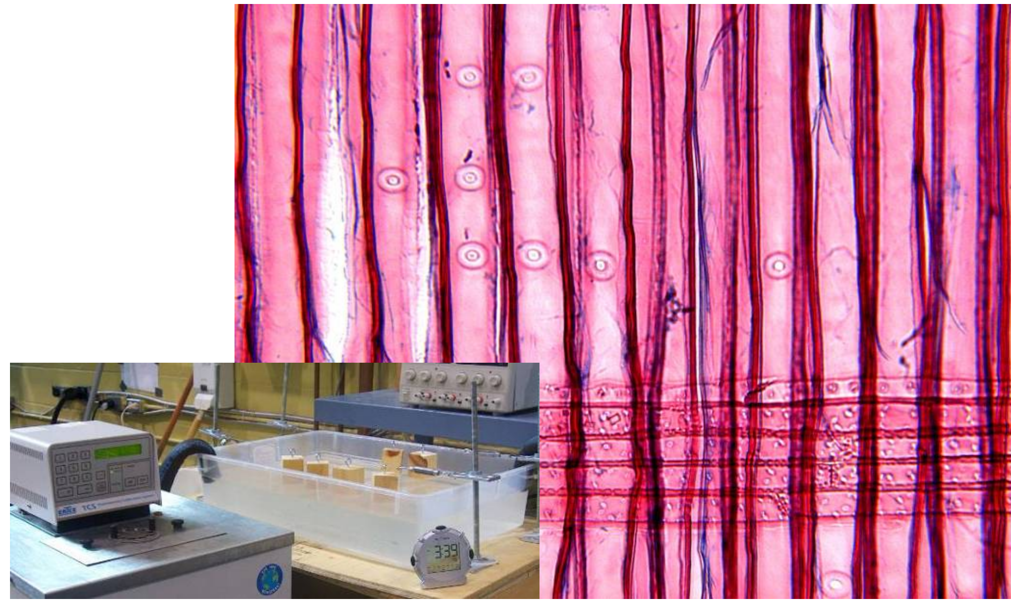
# X-ray measurements of free water uptake in spruce



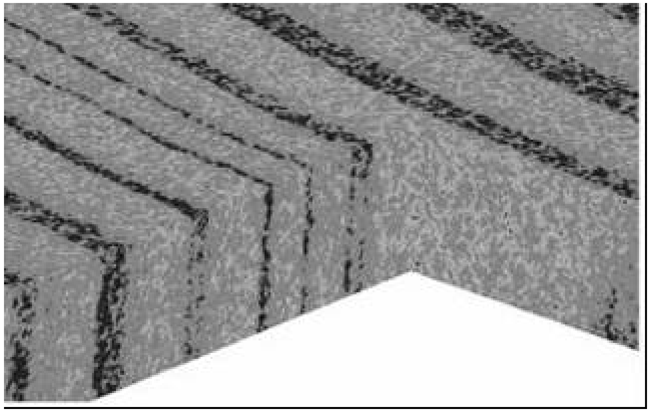
# Wood characterisation

- scanning electronic microscopy
- light microscopy
- mercury porosimetry
- helium pictometer
- pressure plates
- permeance tests
- sorption curves

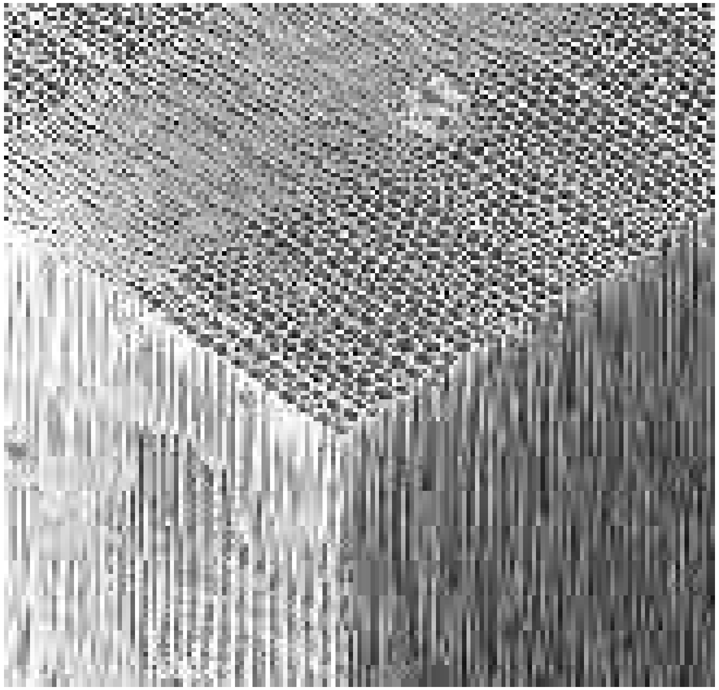


# Wood anatomy

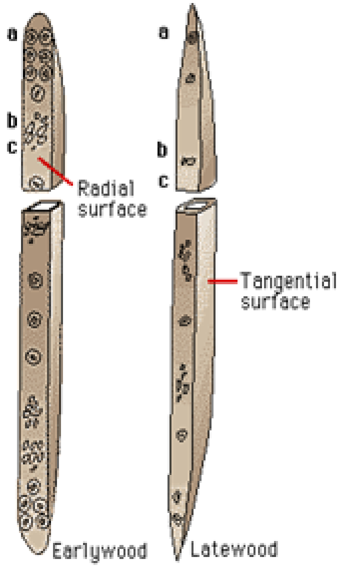
Using multi-scale approach



Macroscale



Mesoscale




Cellular scale

# Subcellular scale

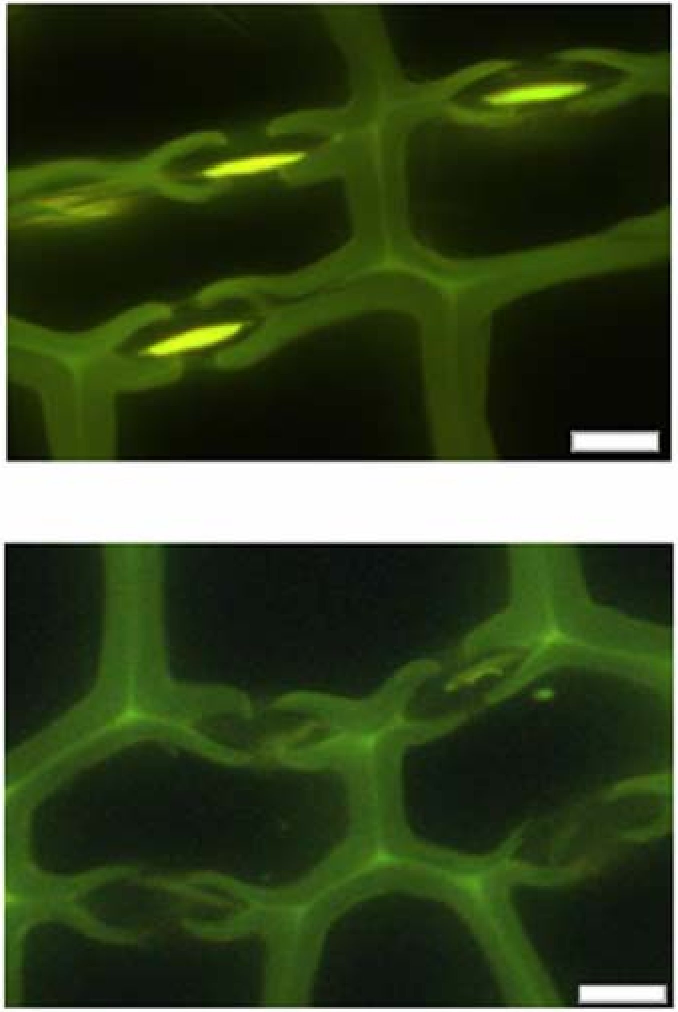
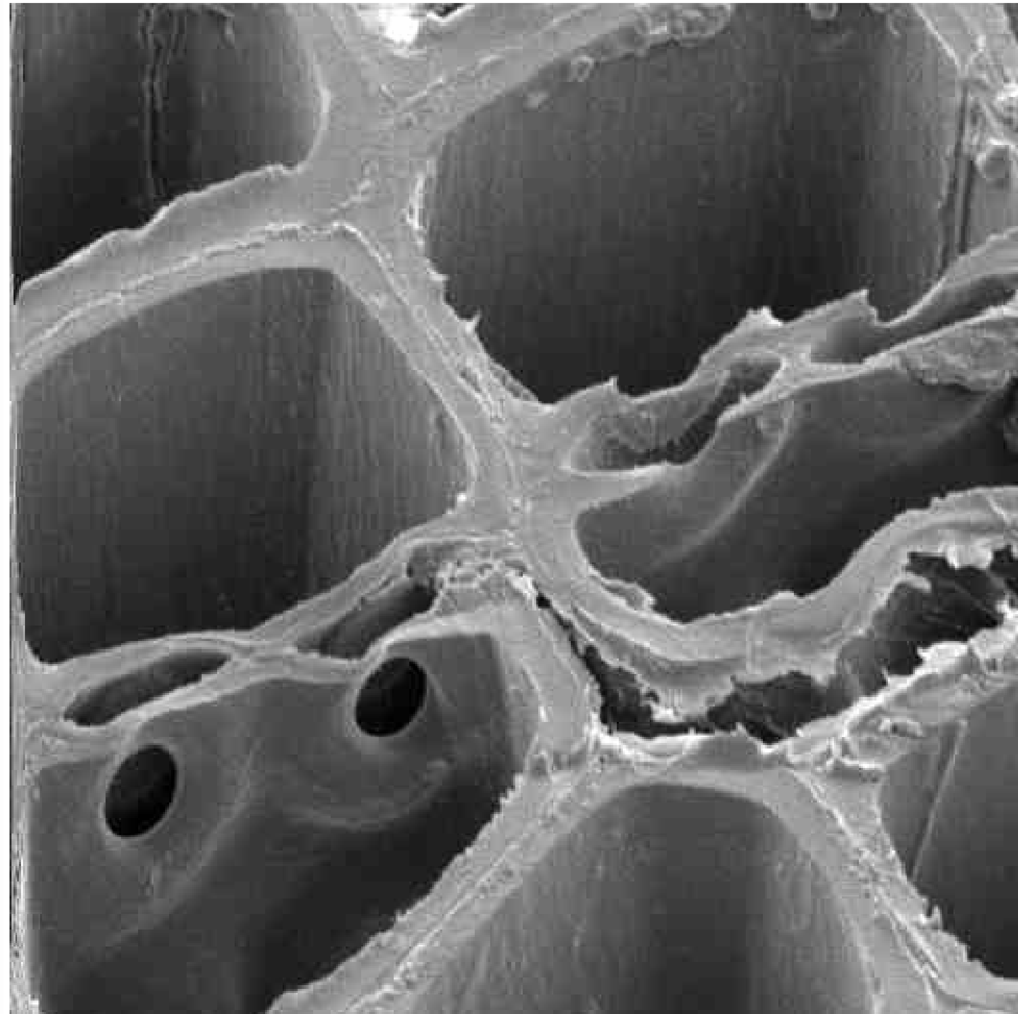
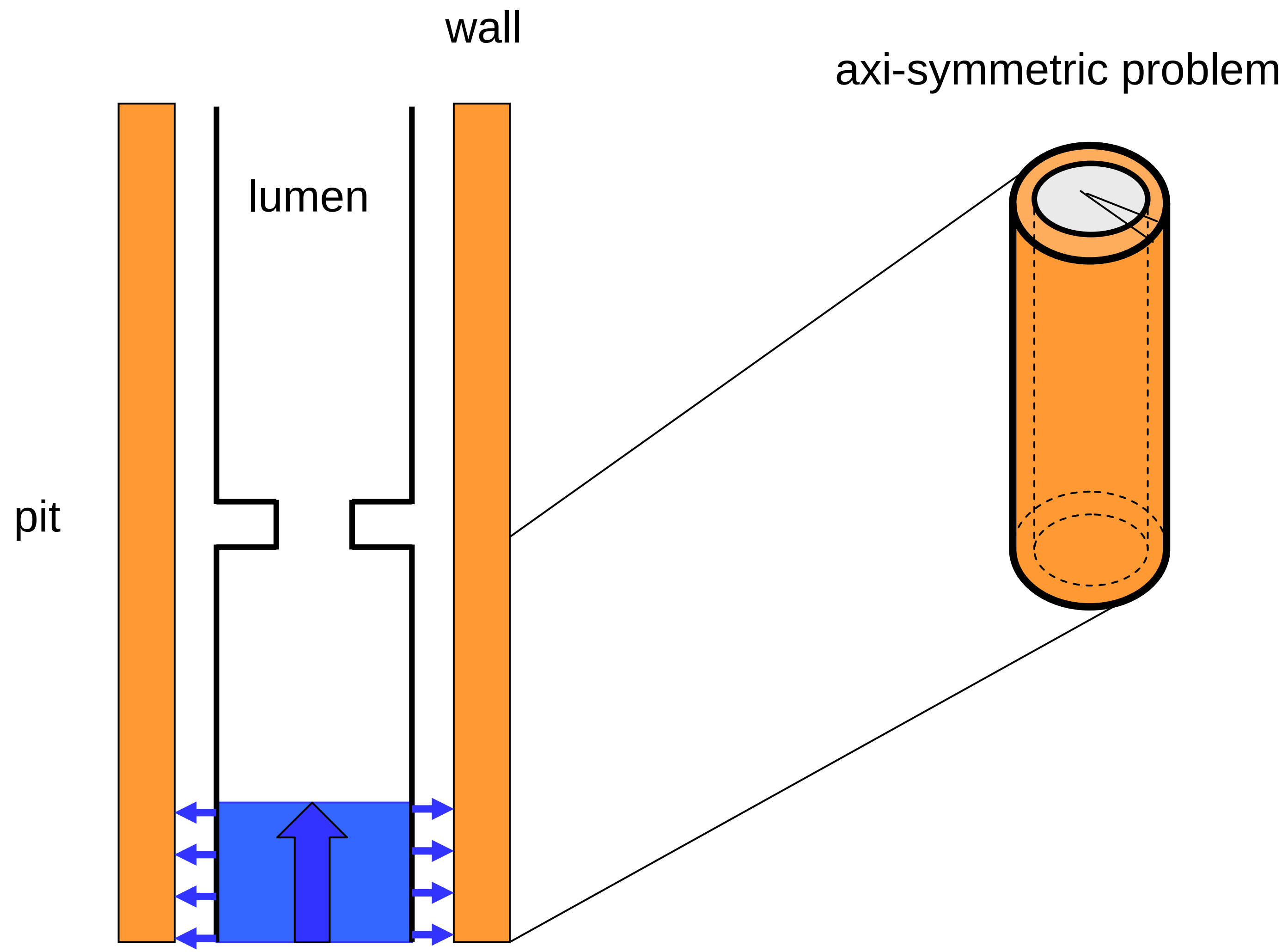


Figure 19. Fluorescent tori in water-sprinkled spruce (above) and tori in fresh spruce (below). Scale bar is 10 µm.



# Modeling at the cellular scale



# Water sources

Groundwater

Surface soil moisture

Melting snow

Rain during construction

Moisture in construction materials

Etc.

# Moisture accumulation in materials

- Hygroscopic materials
- Moisture content at equilibrium
- Sorption and desorption

# Wood and moisture?

maximum possible –175 to 250%

Living tree –100 to 150%

Lumber yard – between 15% and ??

NBCC – 19% or less - structural application

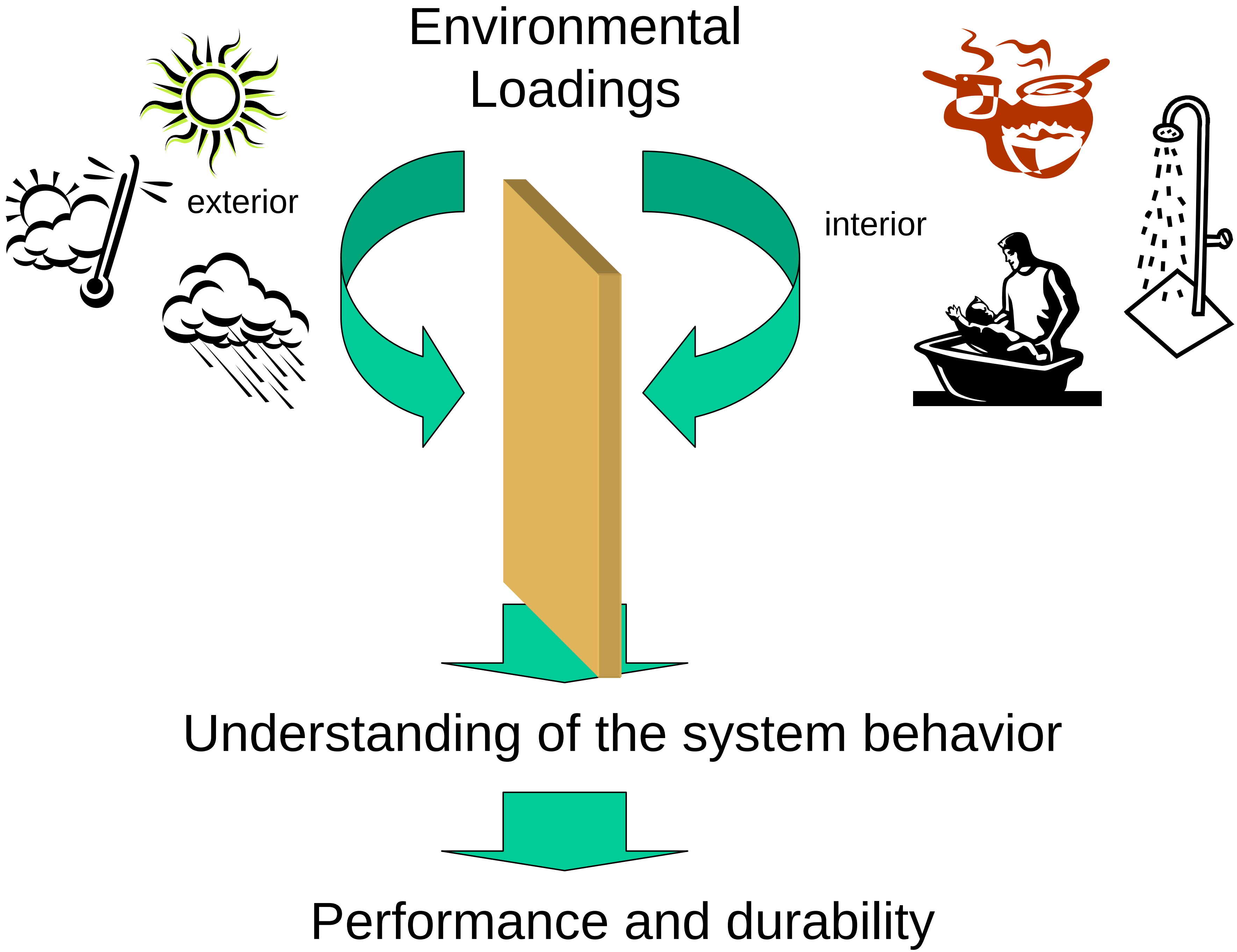
Wood flooring – 7 - 9%

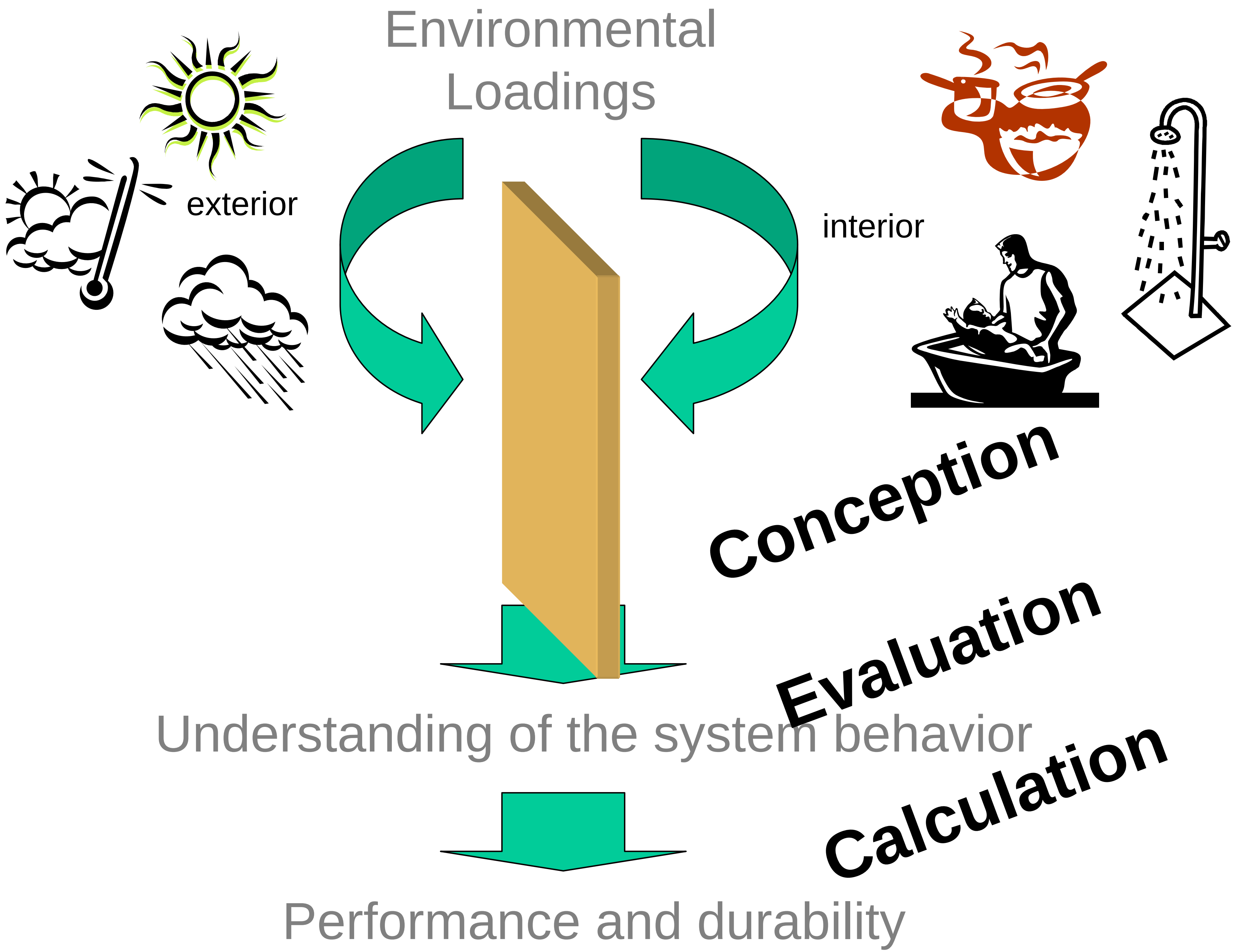
# Wood and moisture

- Wood has to stay dry

- Under good conditions, wood will dry (dimensional changes)

- Under bad conditions wood will stay wet and eventually there will be rotting and mold growth


Environmental
Loadings
exterior
interior
Understanding of the system behavior
Performance and durability


Environmental
Loadings
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