TENSILE MEMBRANE ACTION AND ROBUSTNESS
OF STRUCTURAL STEEL JOINTS UNDER NATURAL FIRE
EC FP5 HPRI – CV 5535

Cardington Fire Test
January 16. 2003

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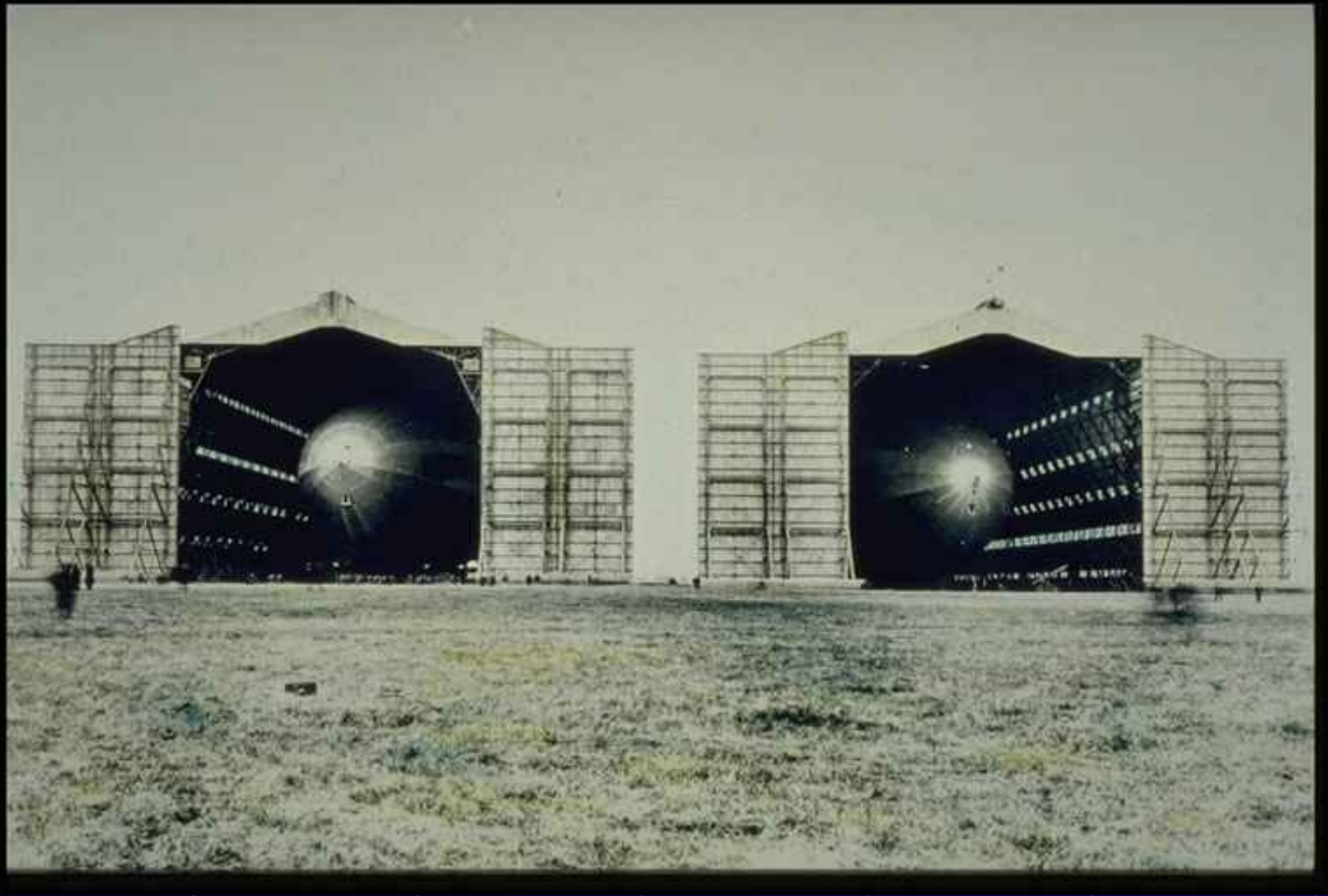
ECCS TC 10, Prague March 13-16, 2003

Contents

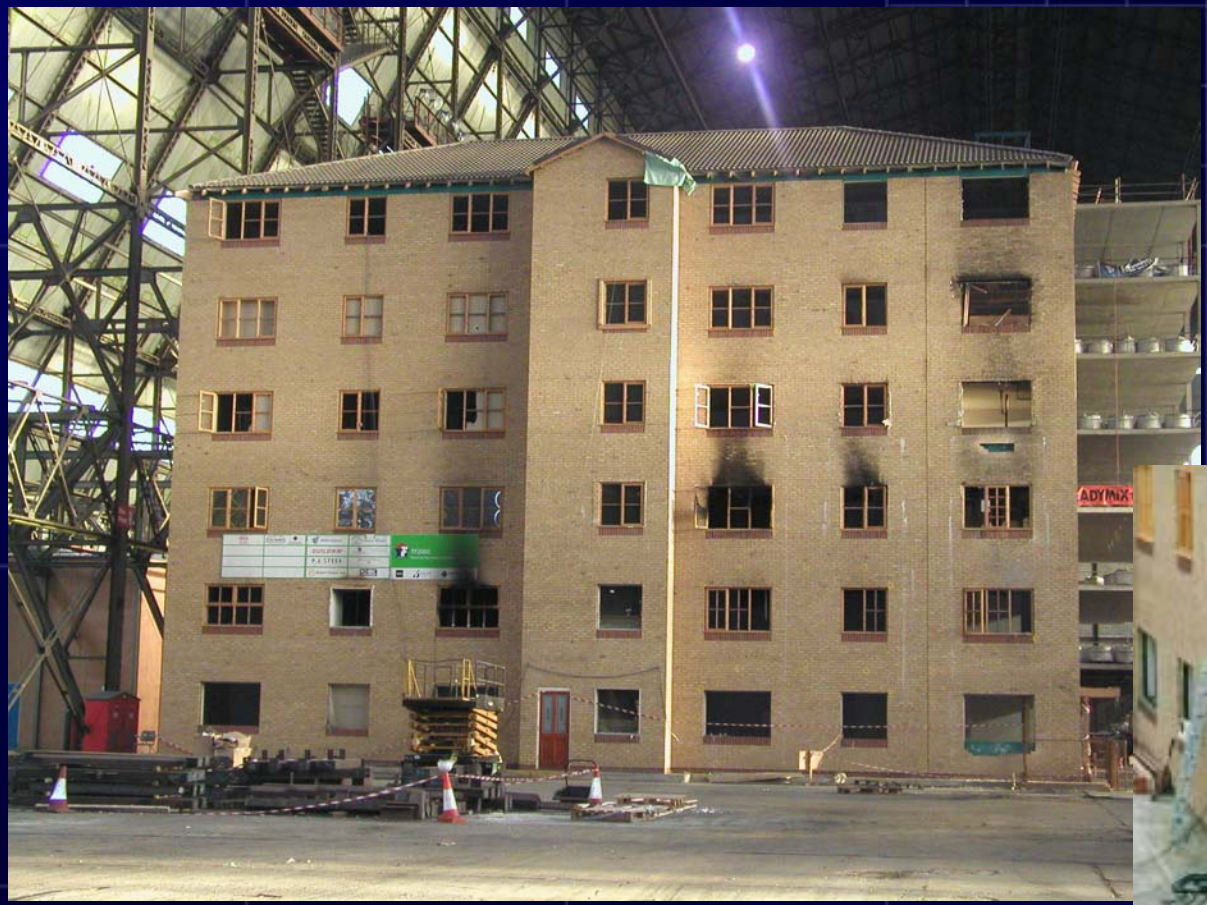
- Cardington Laboratory
- Structural Integrity Test
- Preparation
- Temperatures
- Connections
- Composite slab
- Conclusion



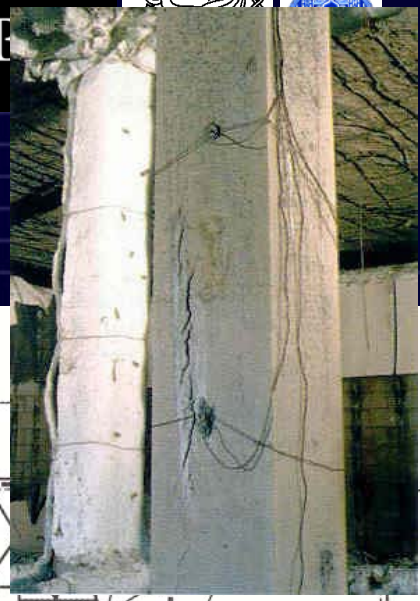
Cardington, Hangar

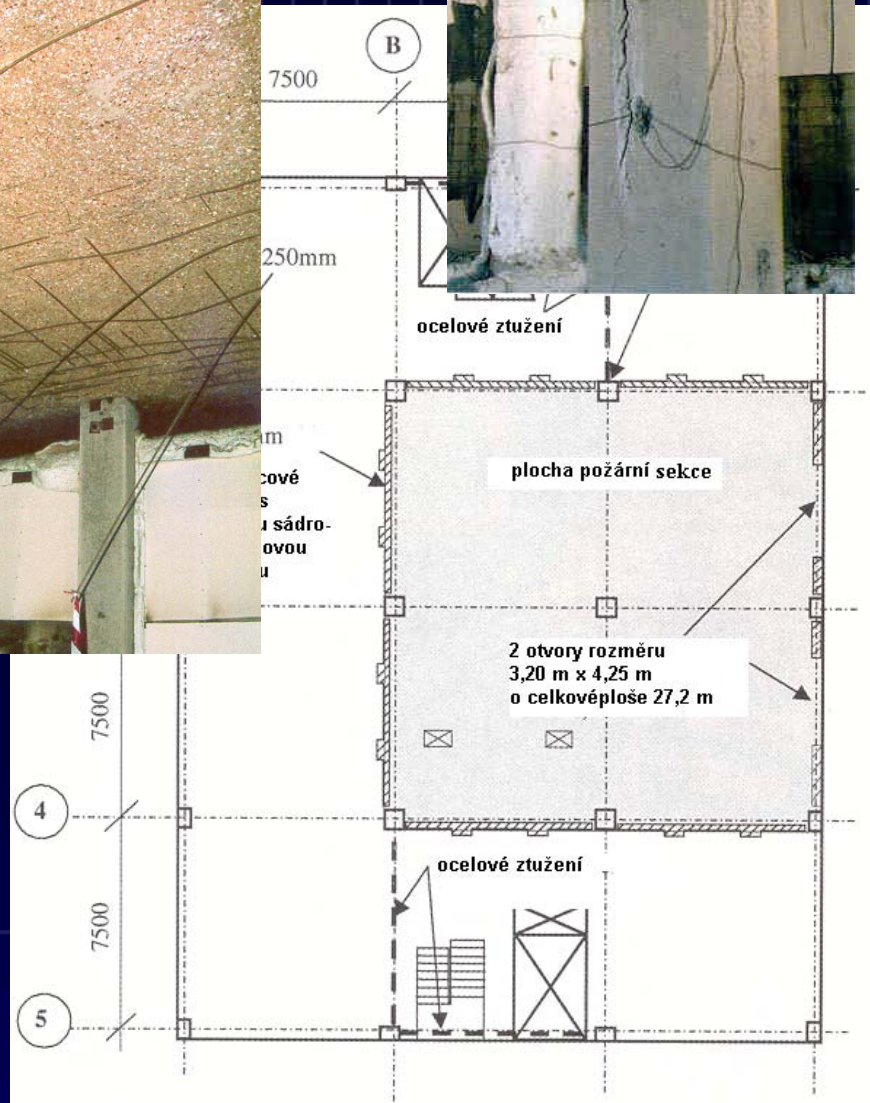
Experimental area 48 m x 65 m x 250 m

Timber structure - 6 floor



Concrete structure - 7 floor





Steel composite structure

Erected 1993

Eight floors

Plan area - 945 m^2

Steel braced frame

Connections:

beam-column connections:

flexible end plates

beam-beam connections:

fin plates

Typical composite structure

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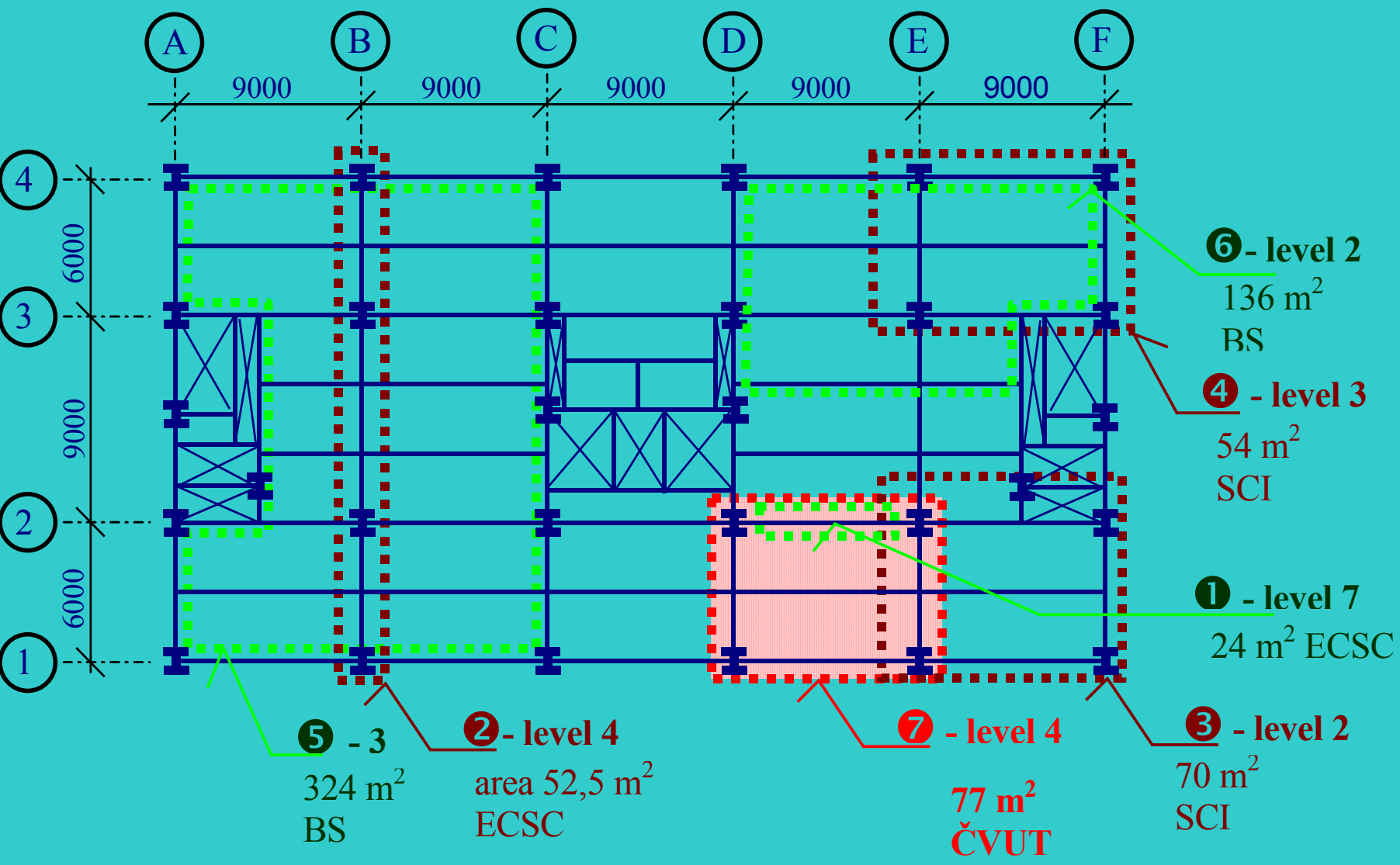
Fire experiments



Summary of fire tests

Test	Description	Fire compartment		Loading	
		size, m	area, m^2	Fire	Mech. G + % Q
1	One beam	8 x 3	24	Gas	30%
2	One frame	21 x 2,5	53	Gas	30%
3	Corner comp.	10 x 7	70	45 kgm^{-2}	30%
4	Corner comp.	9 x 6	54	45 kgm^{-2}	30%
5	Large comp.	21 x 18	342	40 kgm^{-2}	30%
6	Office	18 x 9	136	46 kgm^{-2}	30%
7	Integrity	11 x 7	77	40 kgm^{-2}	56%

Summary of duration, temp and deformations

Test	Org.	Level	Duration	Temperatures, °C		Deformation, mm	
			(mins).	atmos	steel	maximal	residual
1	BS	7	170	913	875	232	113
2	BS	4	125	820	800	445	265
3	BS	2	75	1020	950	325	425
4	BRE	3	114	1000	903	269	160
5	BRE	3	70		691	557	481
6	BS	2	40	1150	1060	610	-
7	ČVUT	4	55	1108	1088	~1200	925

Test 2 – BS, 1996 – Column shortening

Structural Integrity Test January, 16. 2003

Project team

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Dr. Jan Pašek	Research Group Member, CTU Prague
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Prof. Frantisek Wald	European Research Group Leader, Prague
Mr. David White	Project Leader , BRE Watford

Research Project

Tensile membrane action

and robustness of structural steel joints under natural fire

EC FP5 HPRI - CV 5535

Participanting Institutions

Building Research Establishment

Czech Technical University in Prague

Coimbra University,

Technical University, Bratislava

Objectives

To determine the:-

- Temperatures in elements and joints
- Internal forces in the connections
- Behaviour of the composite Slab

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Fire Compartment

Wall

3 layers of gypsum plasterboard

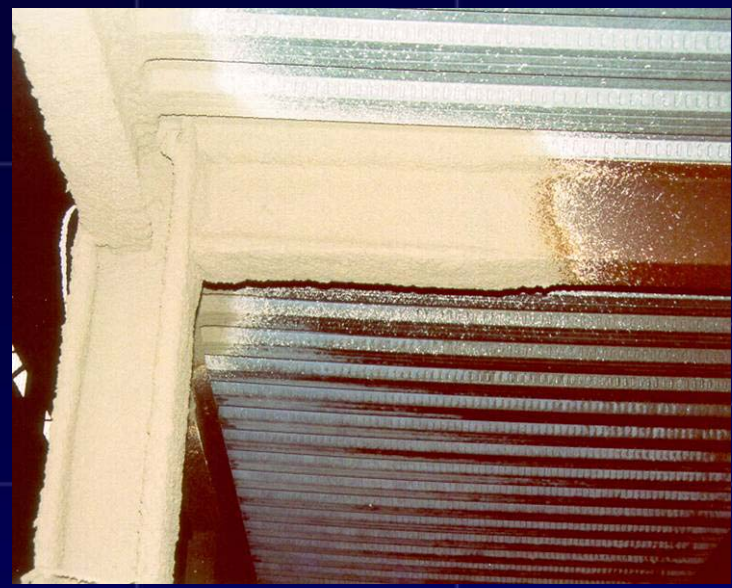
(15 mm + 12,5 mm + 15 mm)

with K = 0,19 – 0,24 W/mK

Window

9 m x 1,27 m

Protected Members



Columns

External joints

1 m of the primary beam

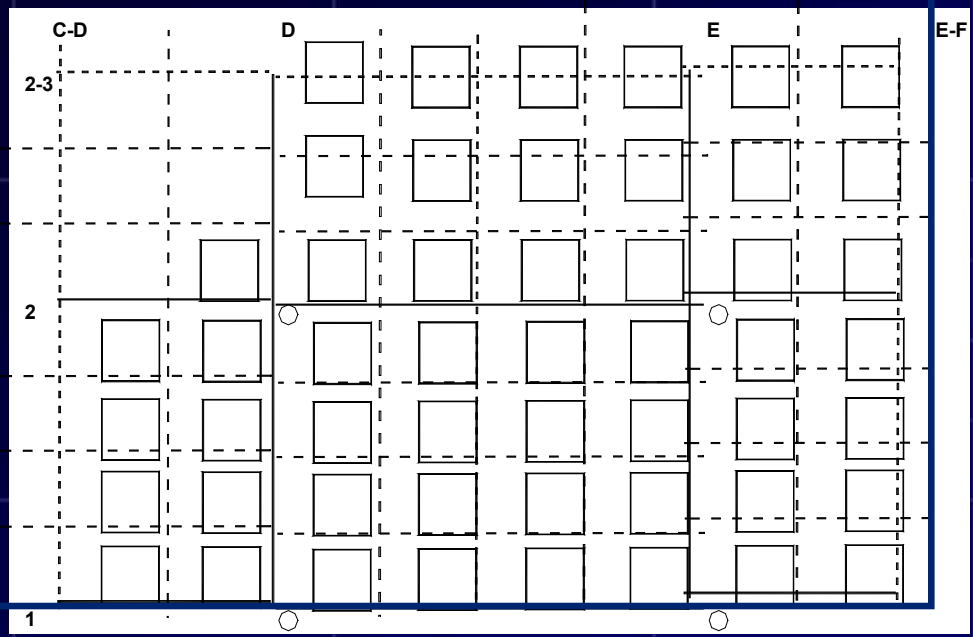
15 mm of Cafco300 vermiculite-cement spray

K = 0,078 W/mK

Mechanical Load

- Permanent 100%
- Variable permanent 100%
- Live 56%

by sand bags

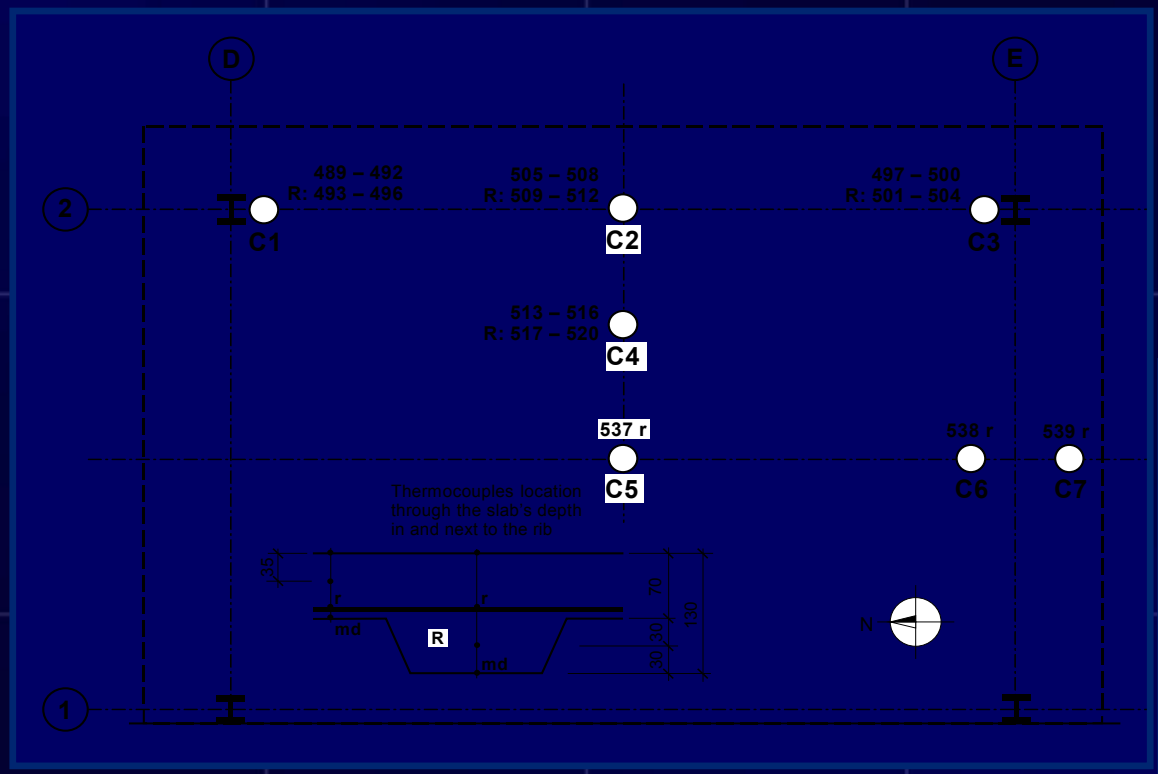


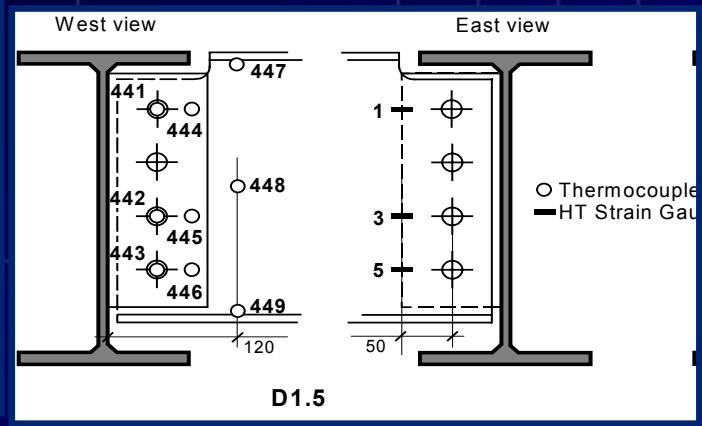
Fire Load

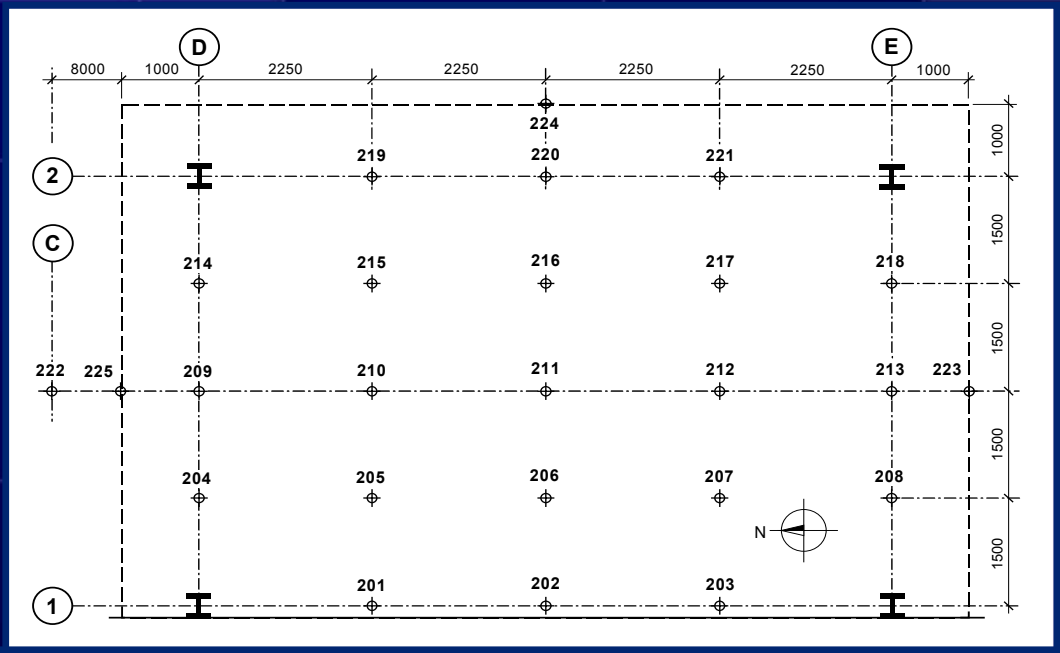
Timber cribs 50 x 50 mm - fire load 40 kg/m^2

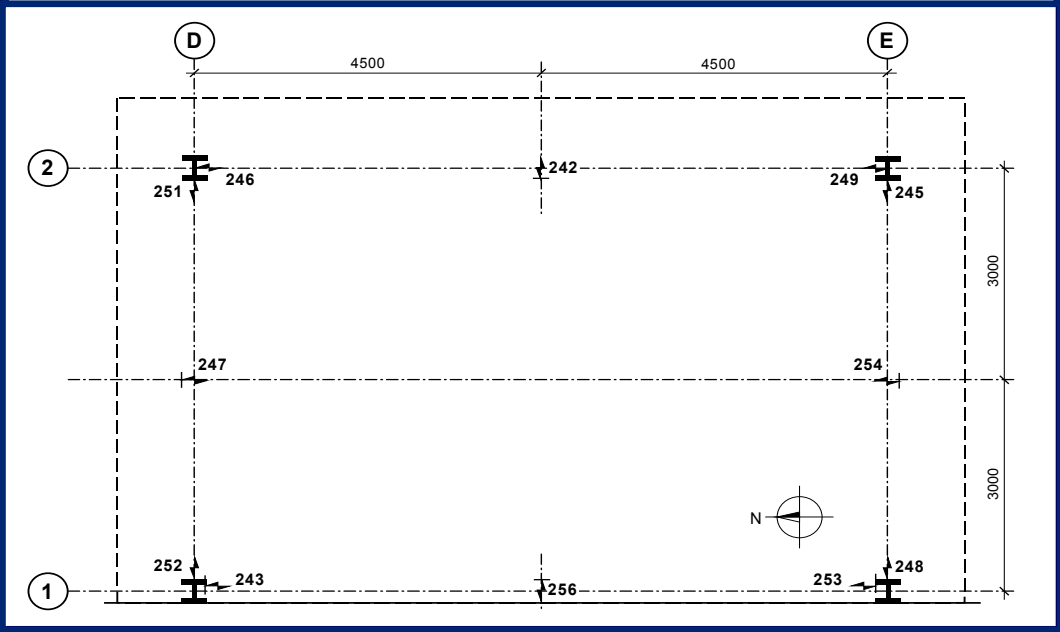
Instrumentation

- 148 thermocouples
- 57 strain gauges









- 37 deformations

- 10 video cameras
- 2 thermo cameras

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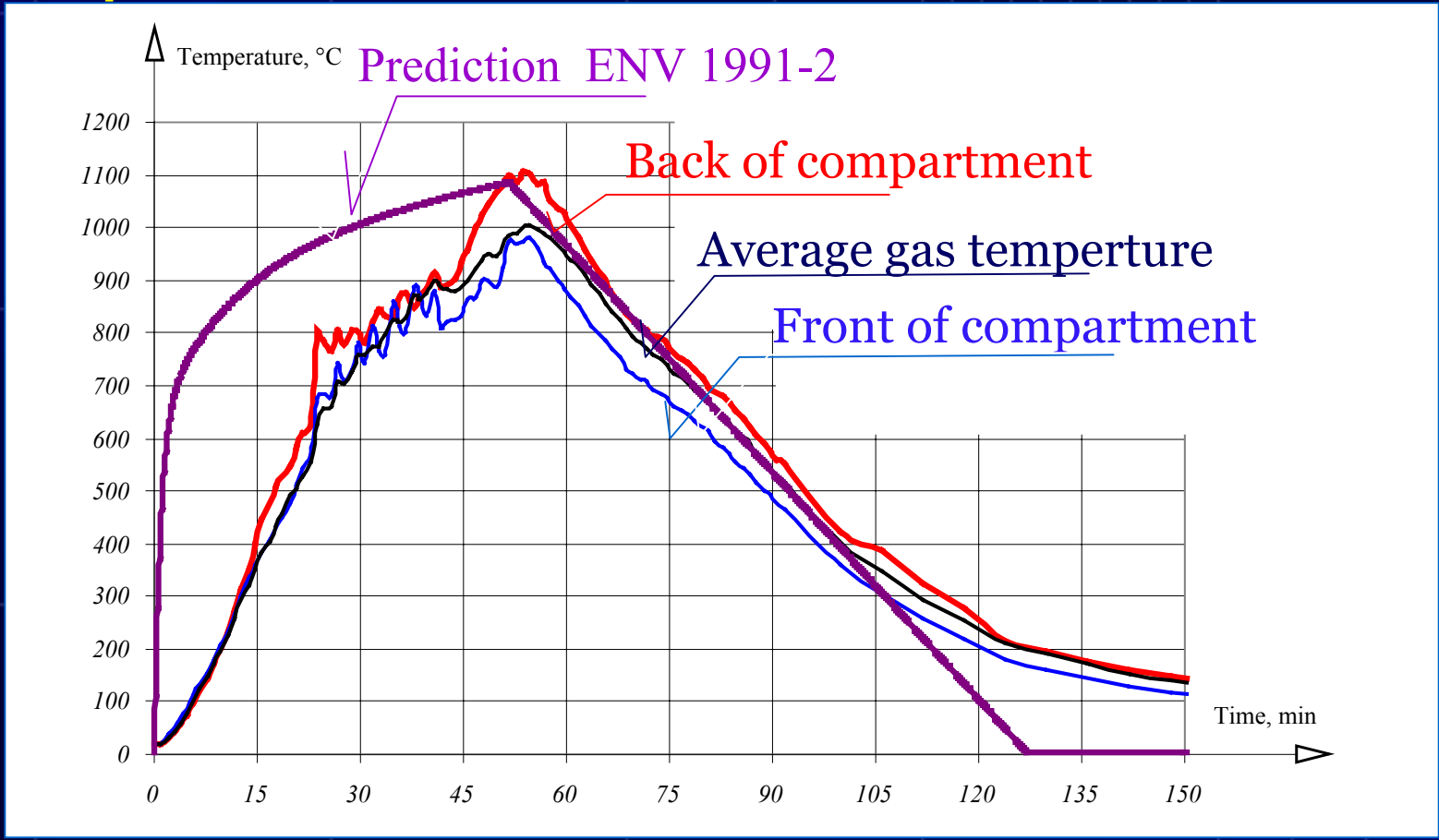
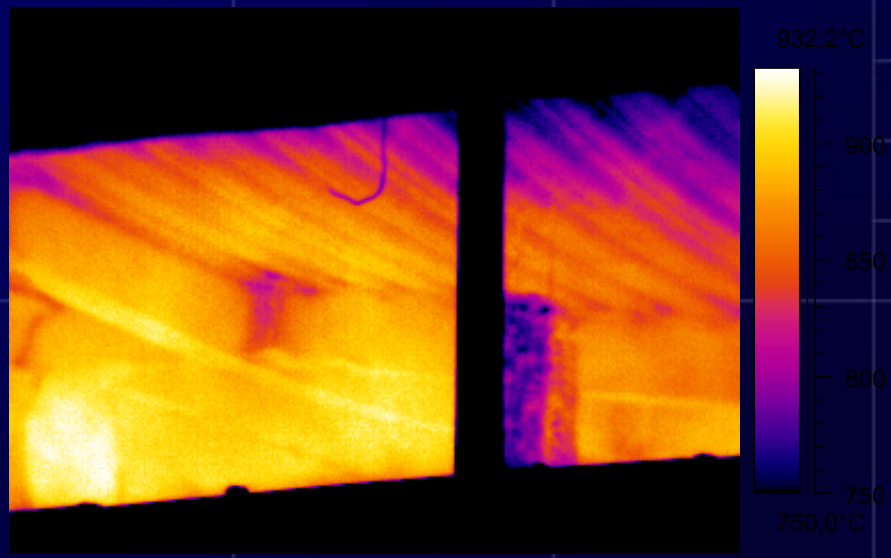
Temperatures



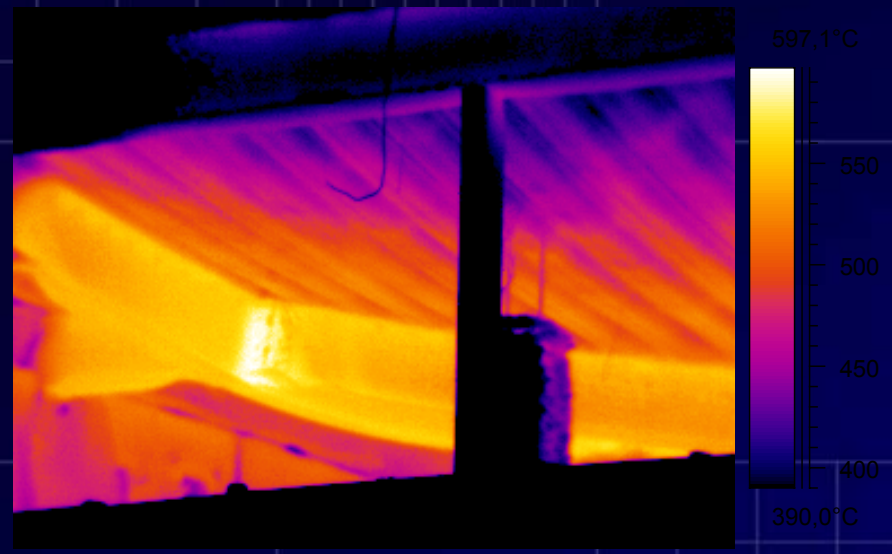
Gas 1108 °C in 55 min. (predicted 1078 °C in 53 min.)

Beam 1088 °C in 57min. (predicted 1067 °C in 54 min.)

Temperature profiles



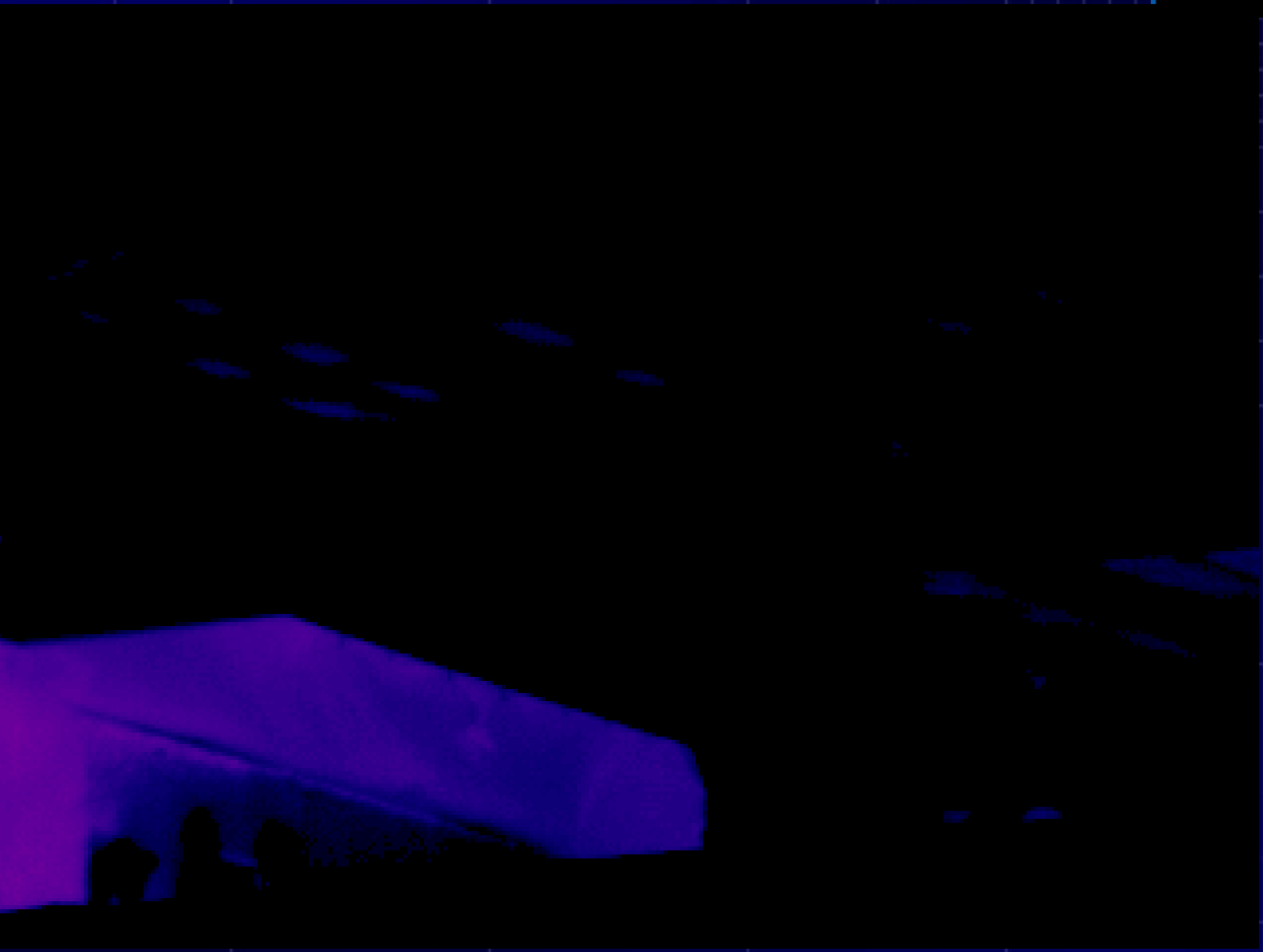
Heating



Cooling

Thermo-cameras

BRE



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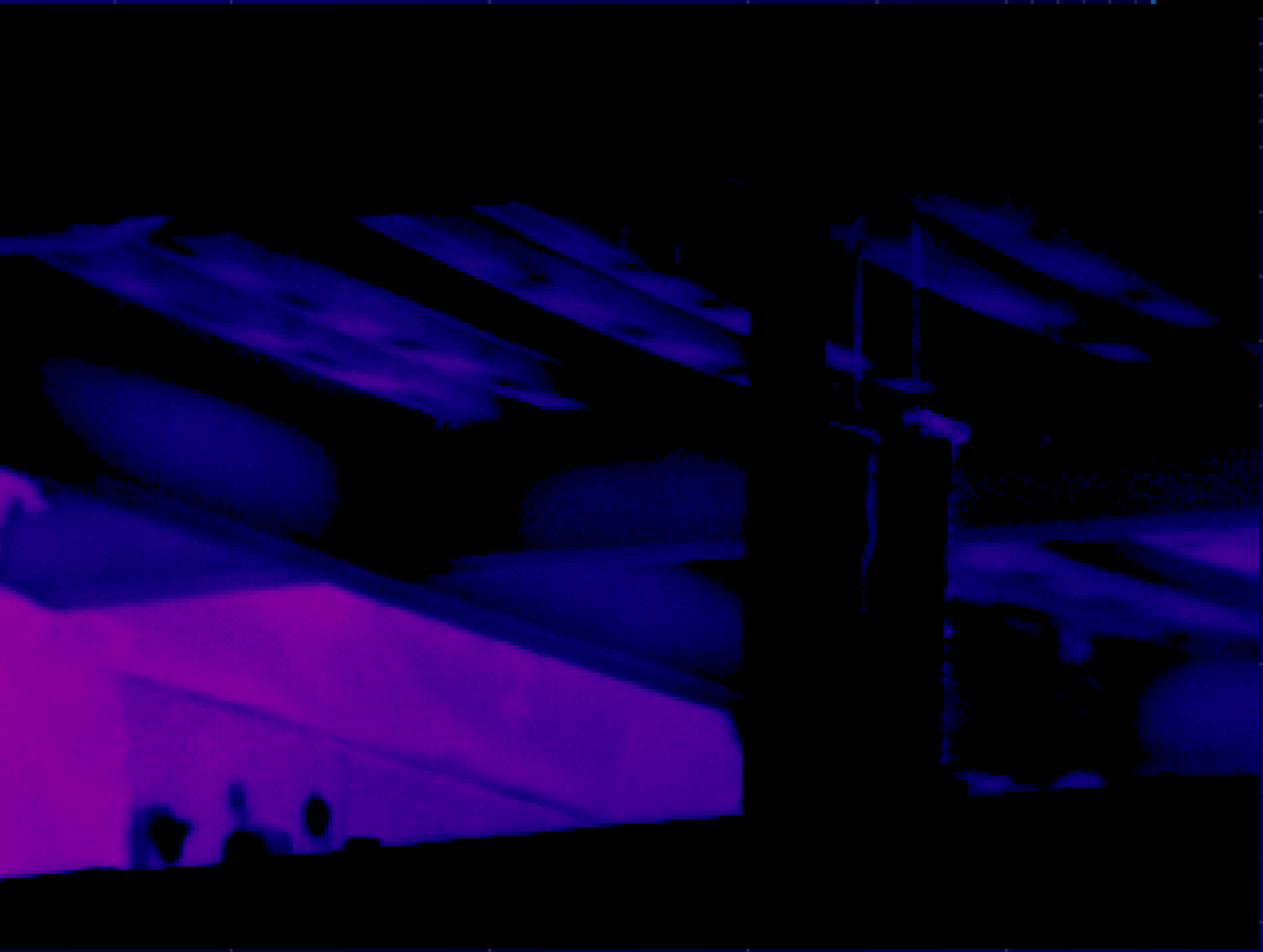

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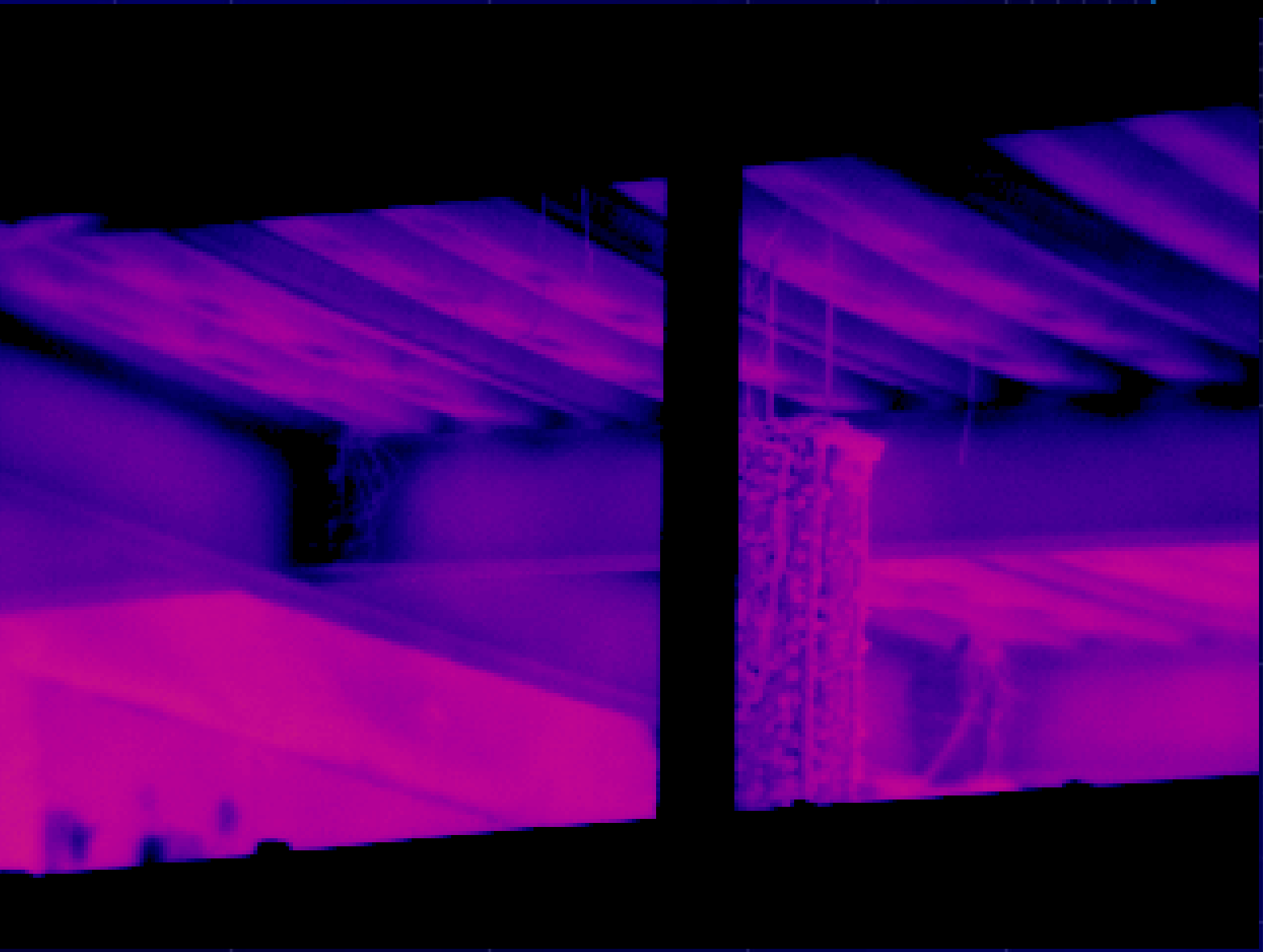

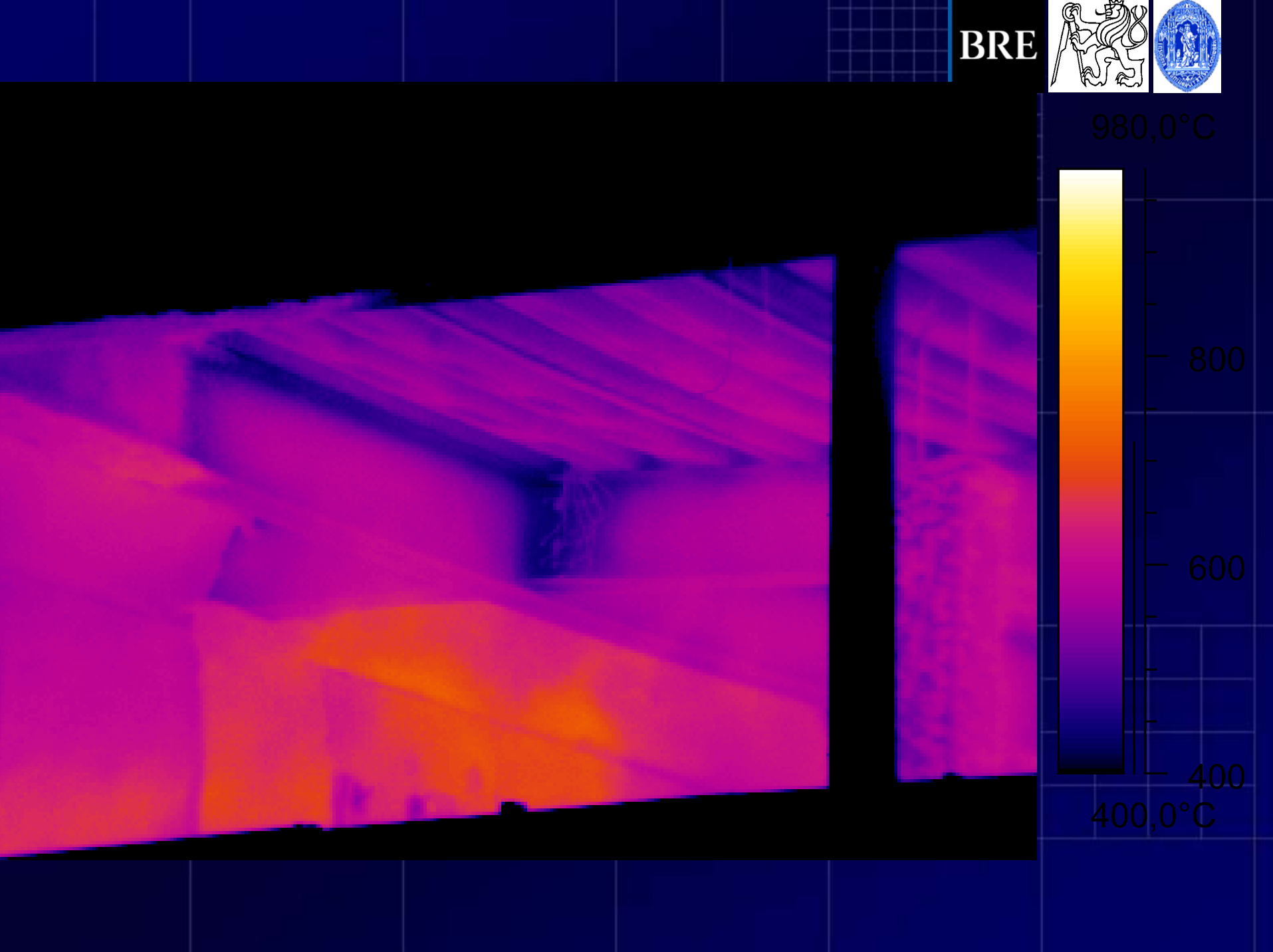
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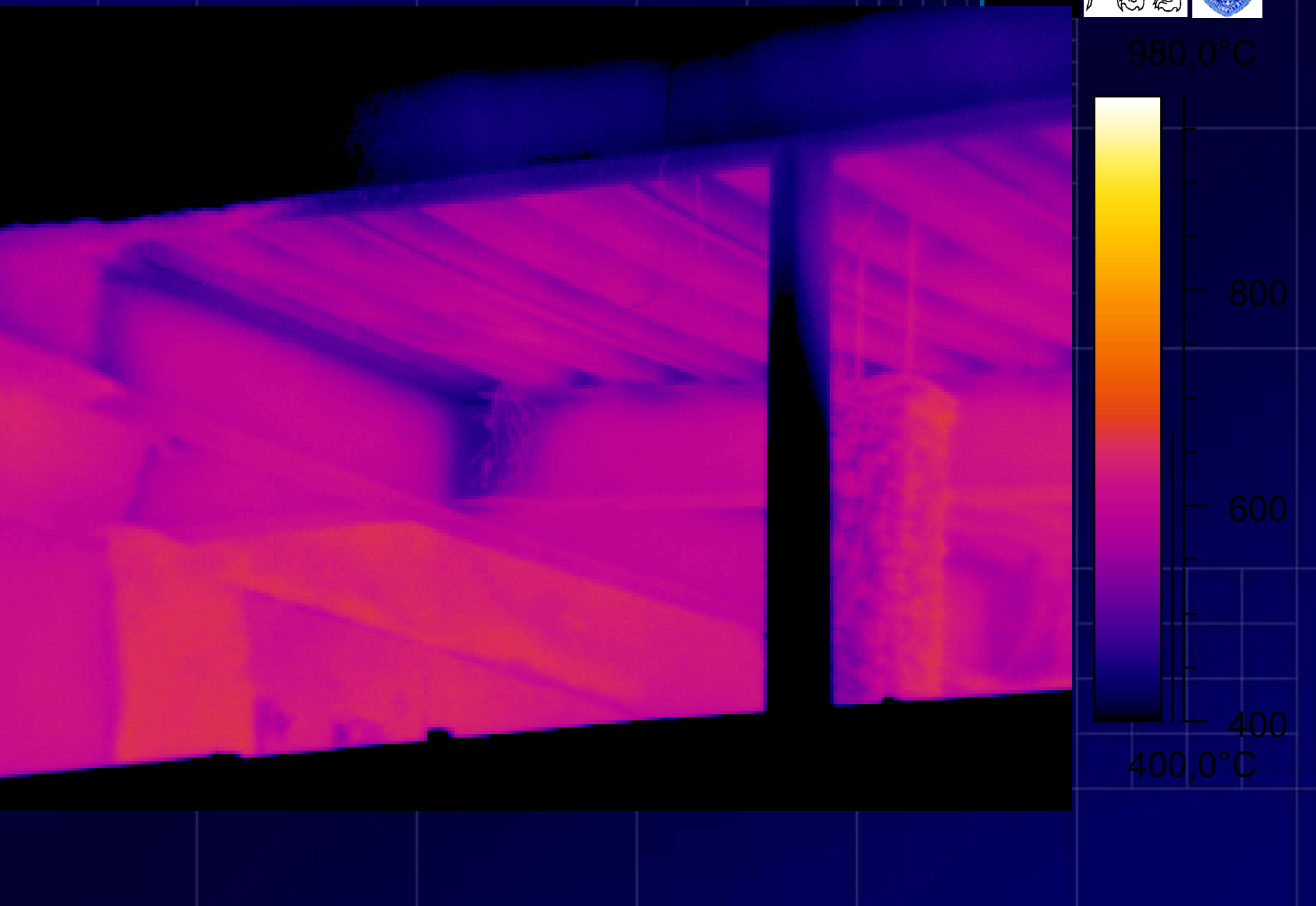
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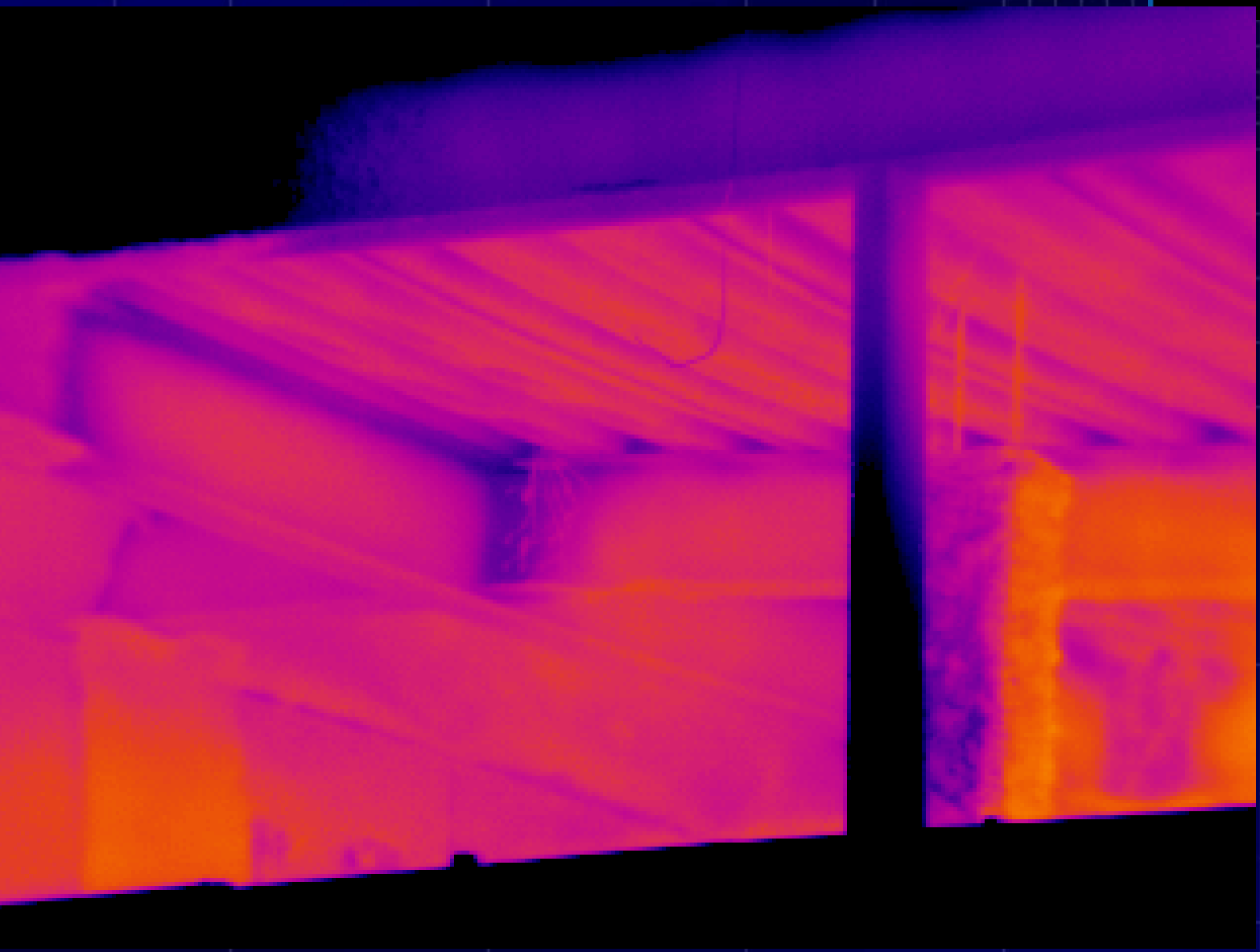

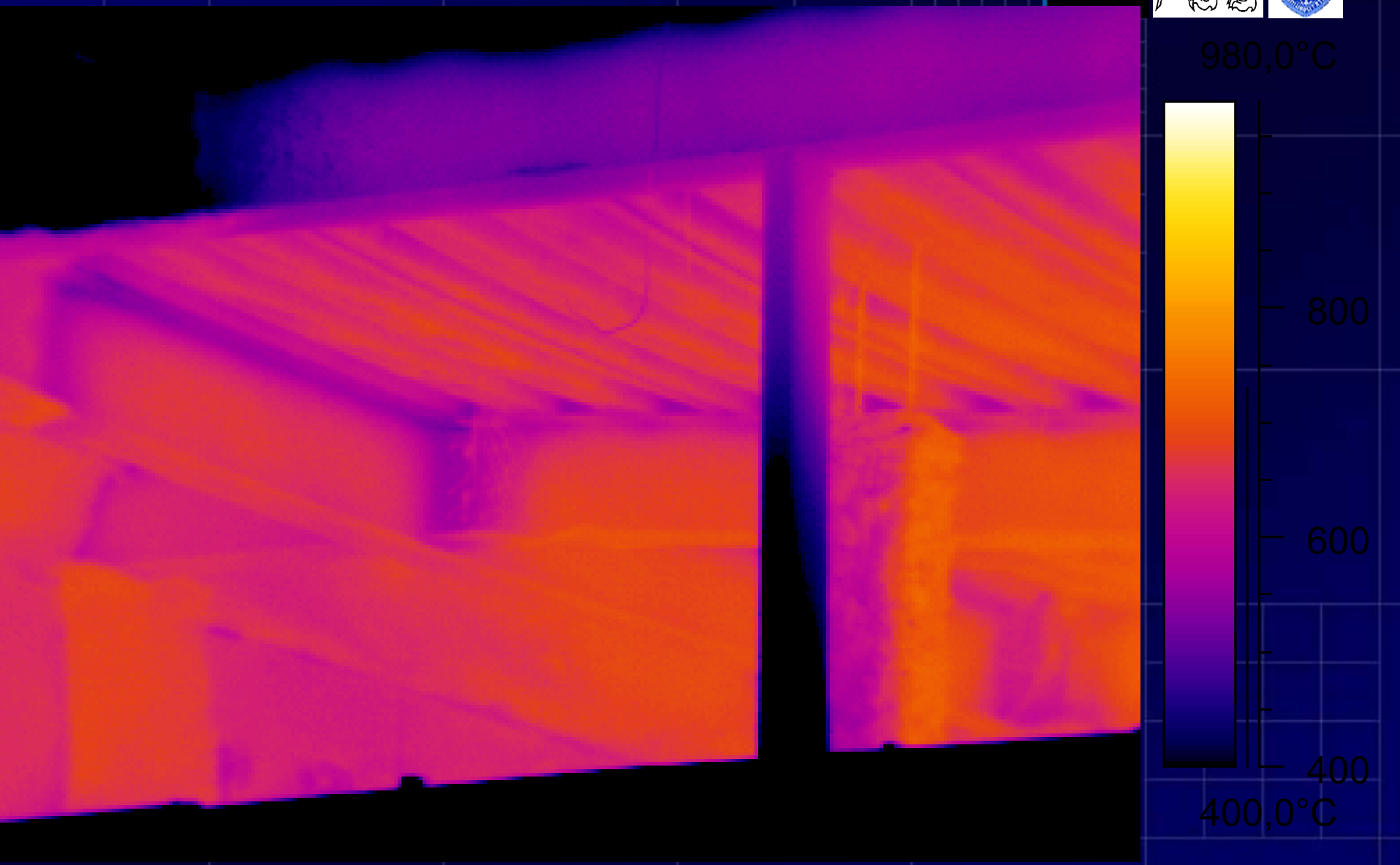
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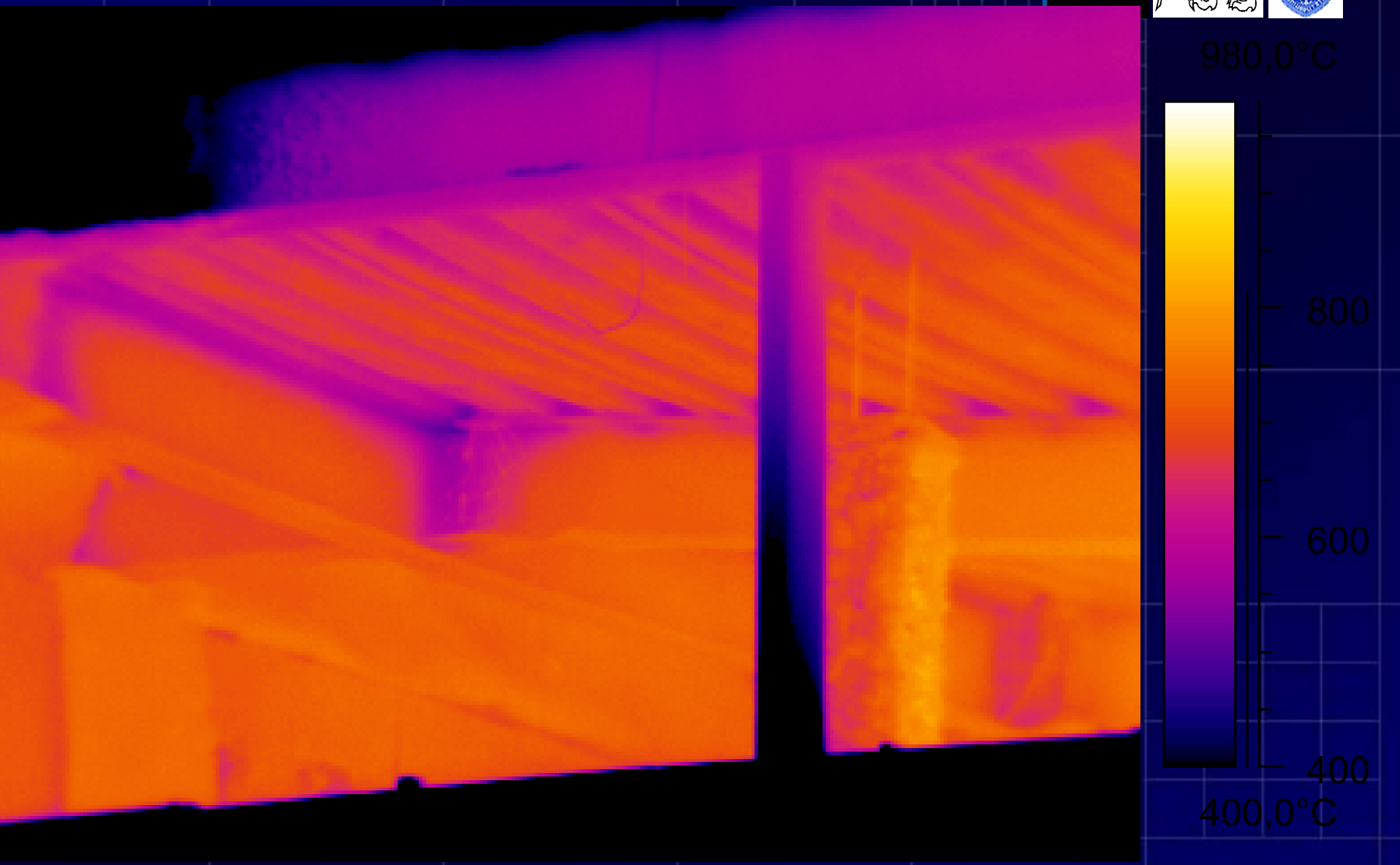
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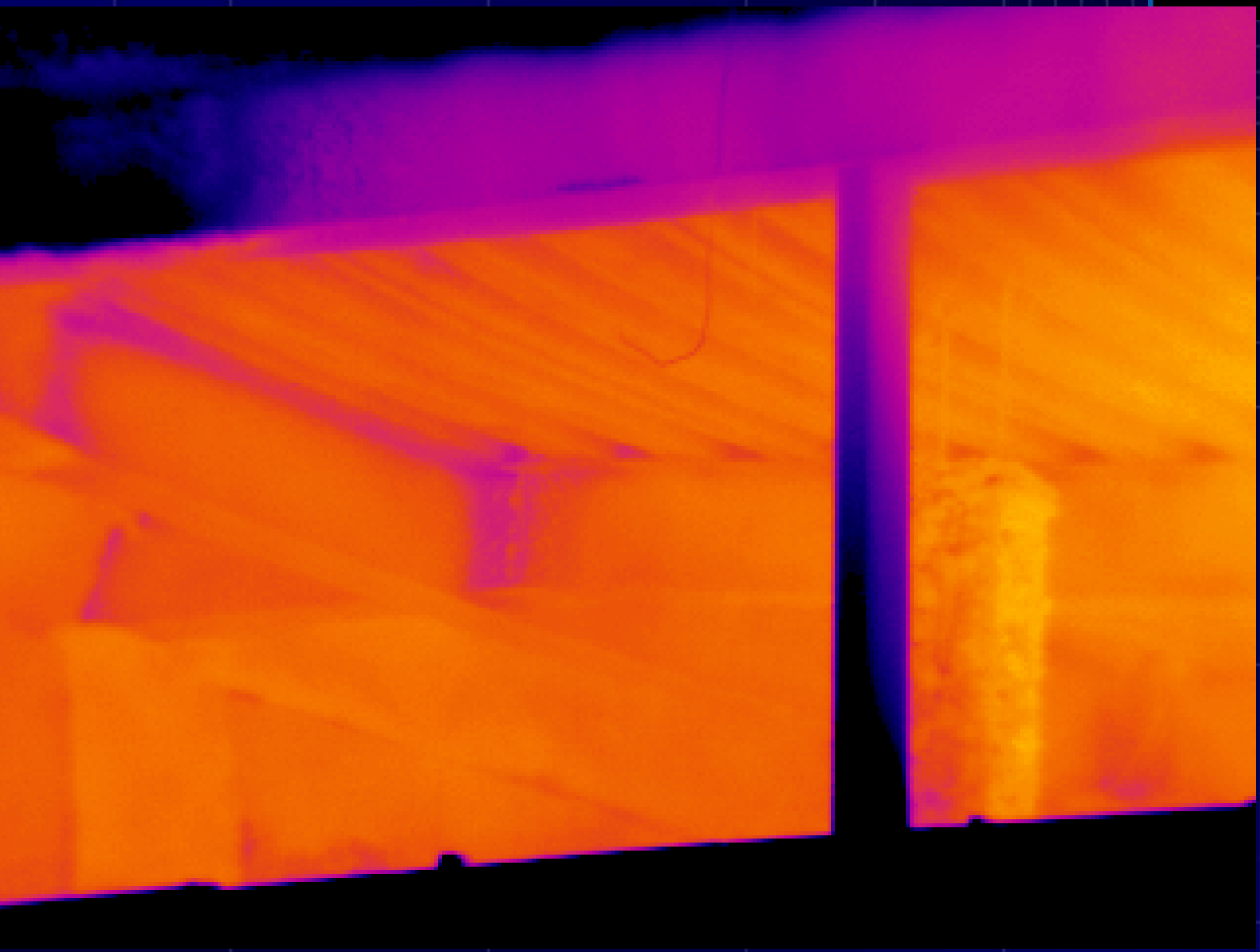

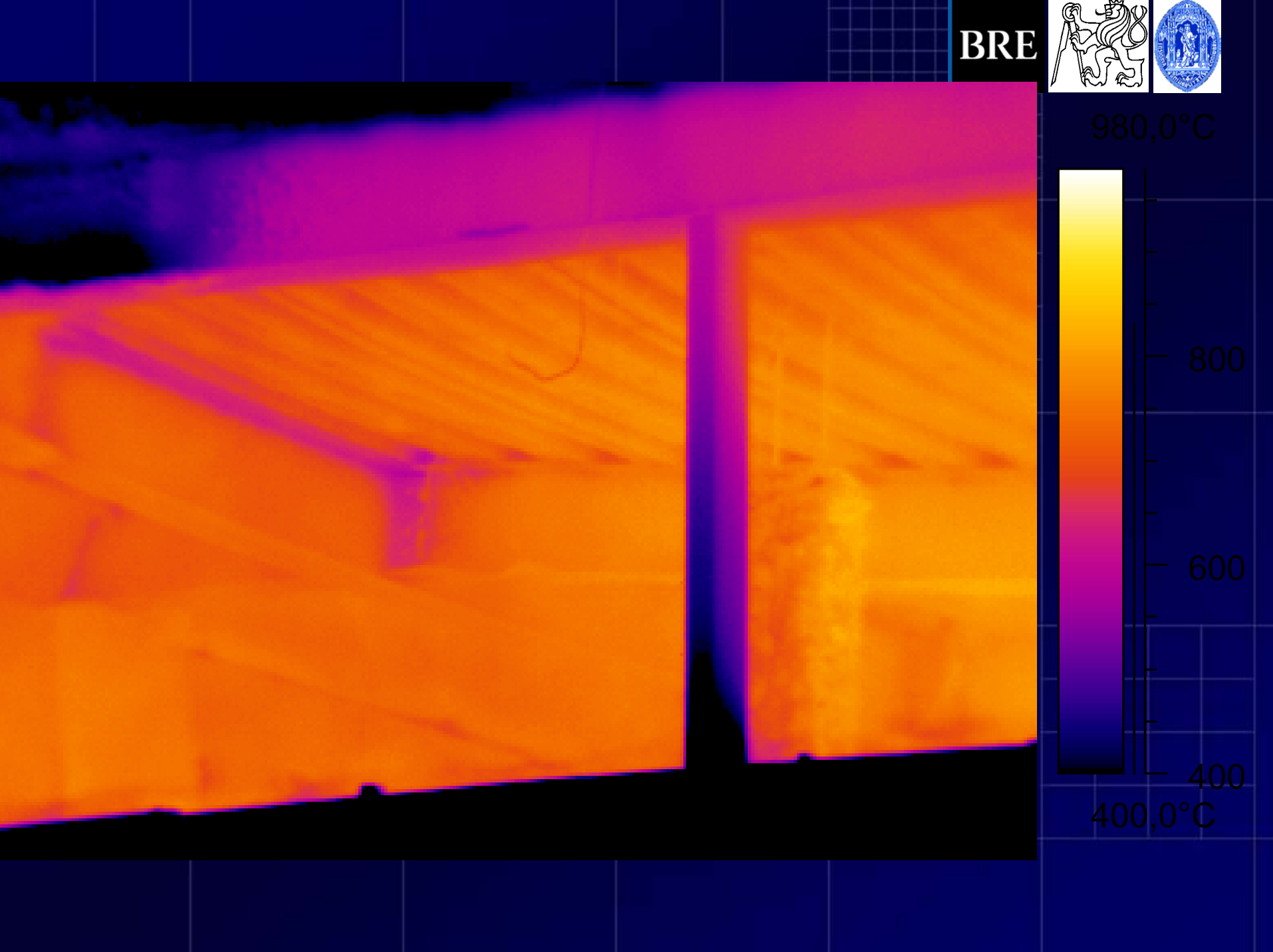
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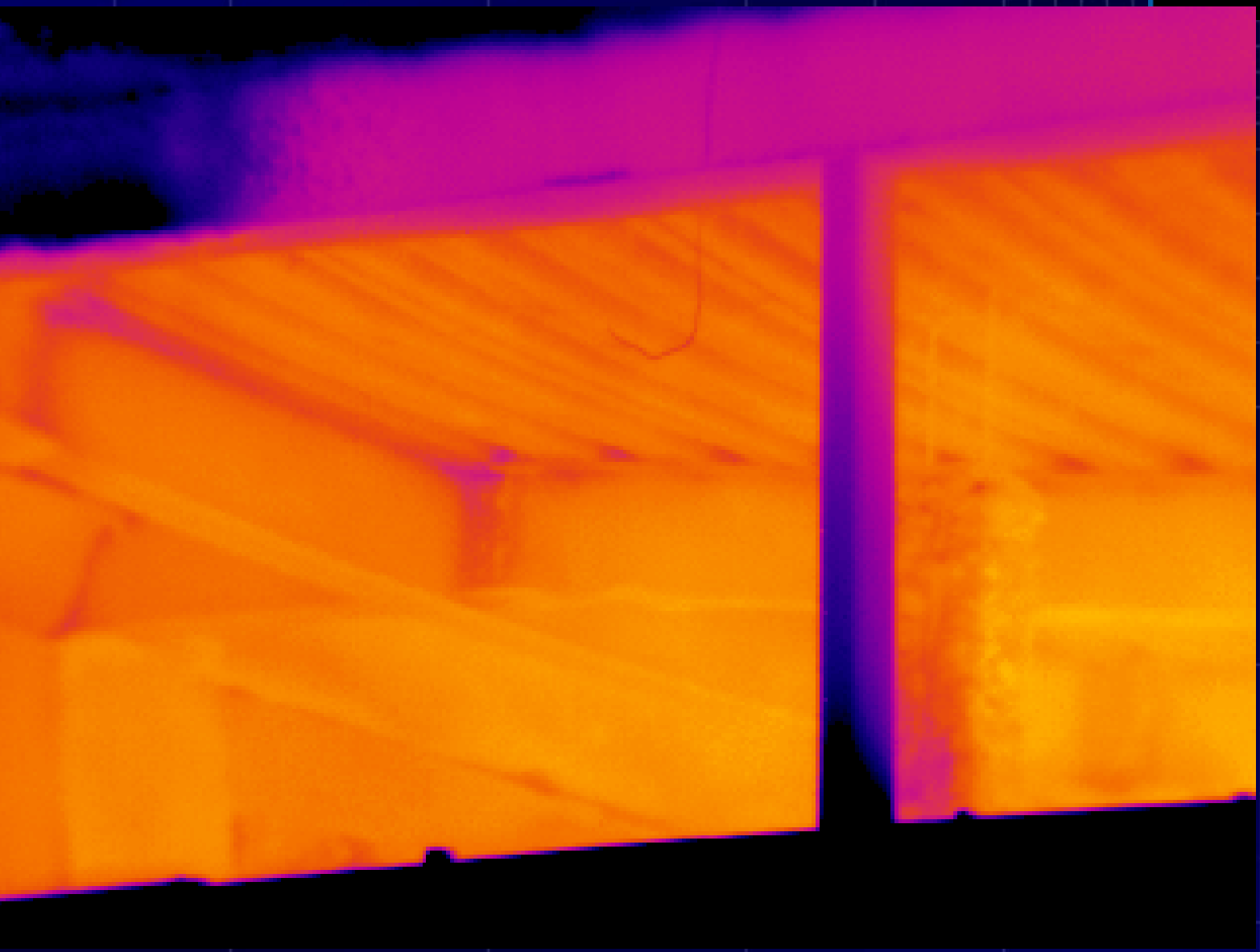
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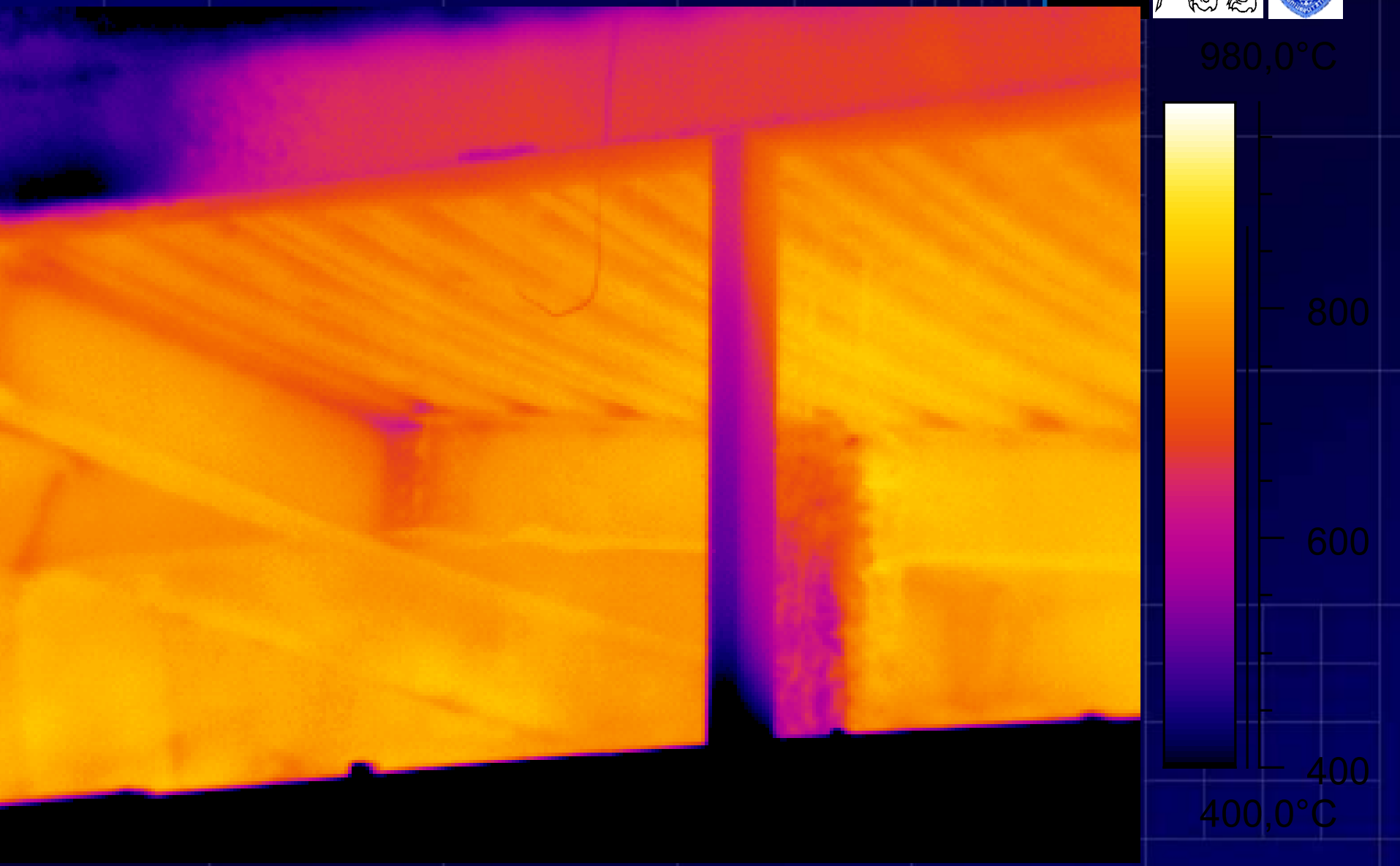
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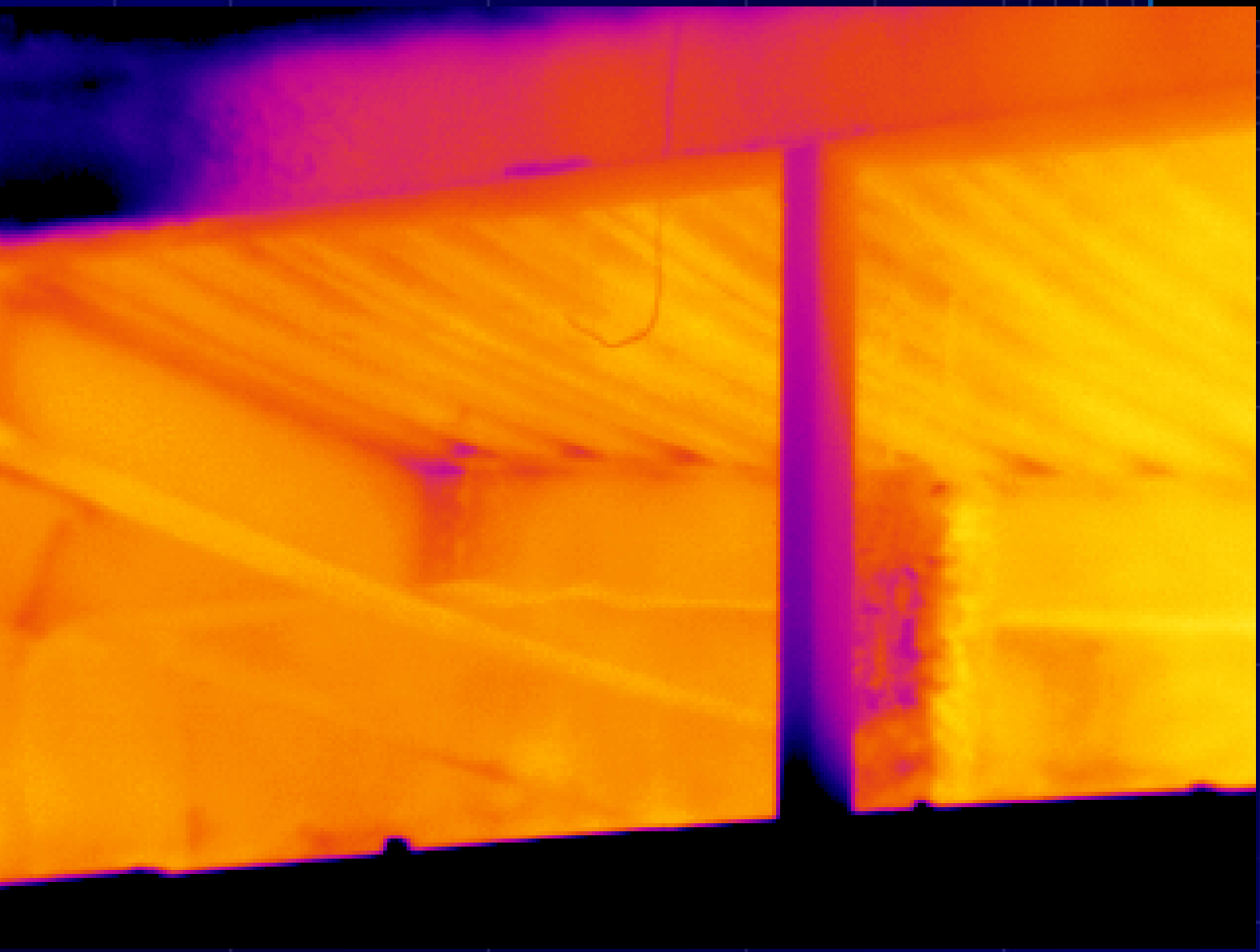

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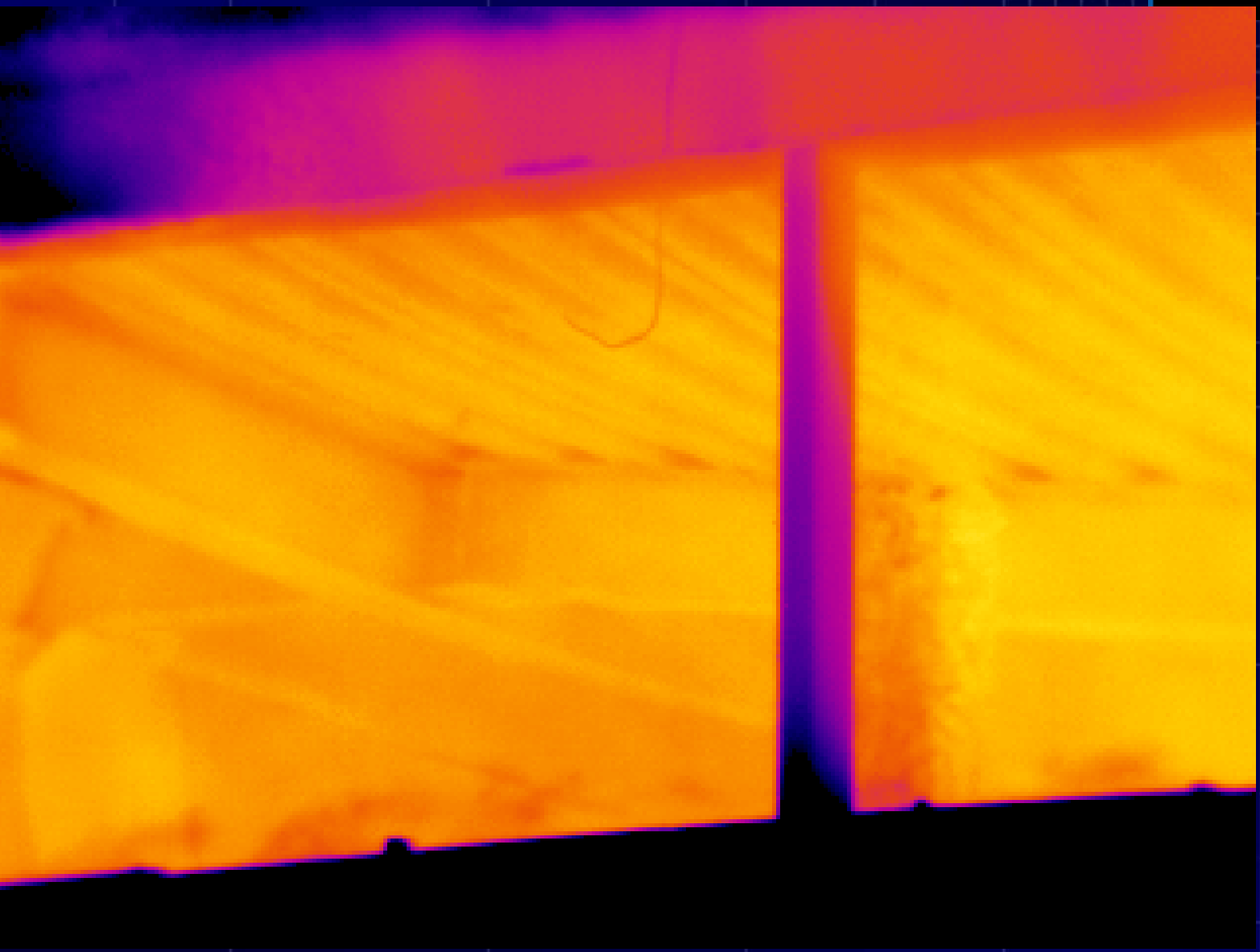

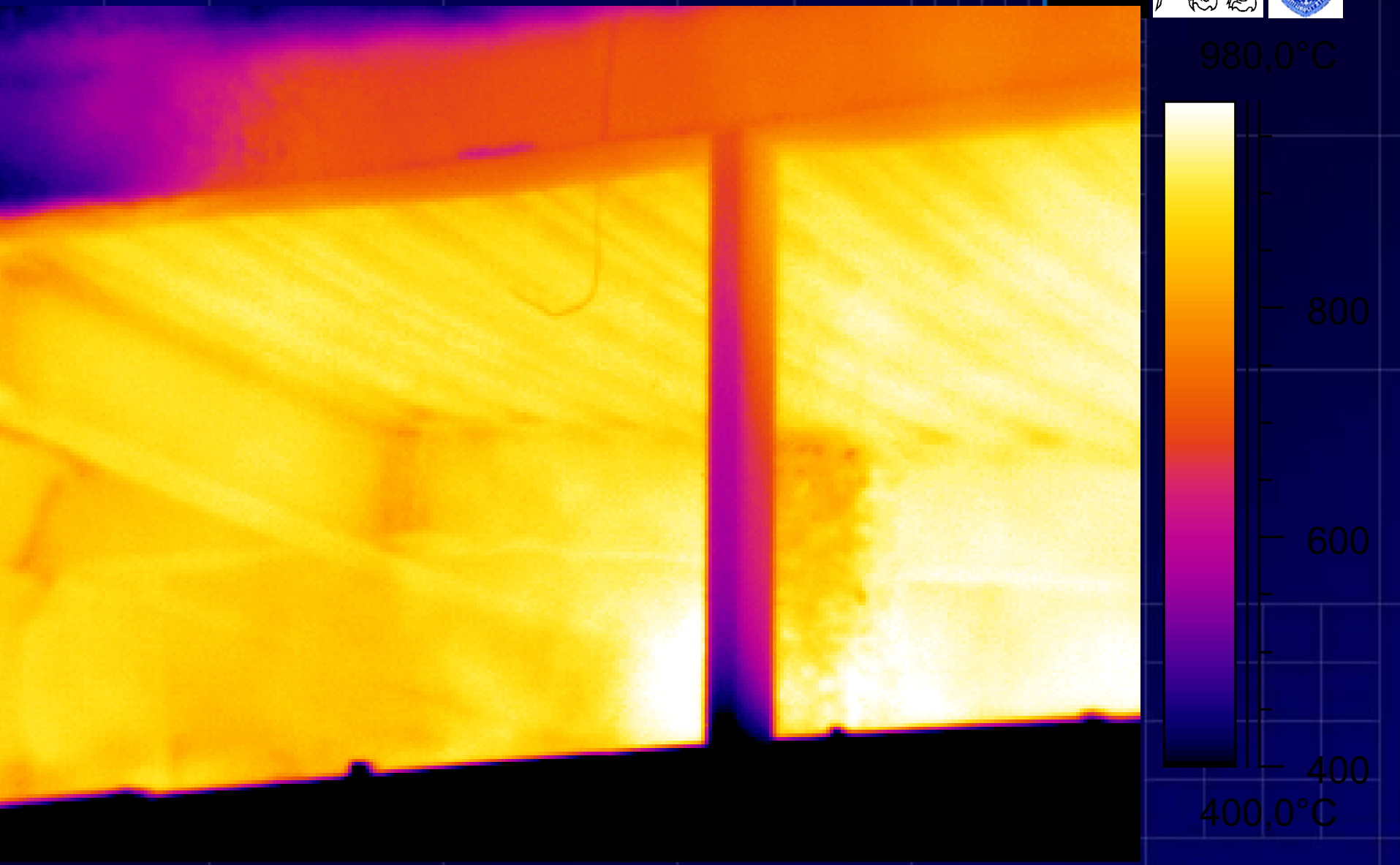
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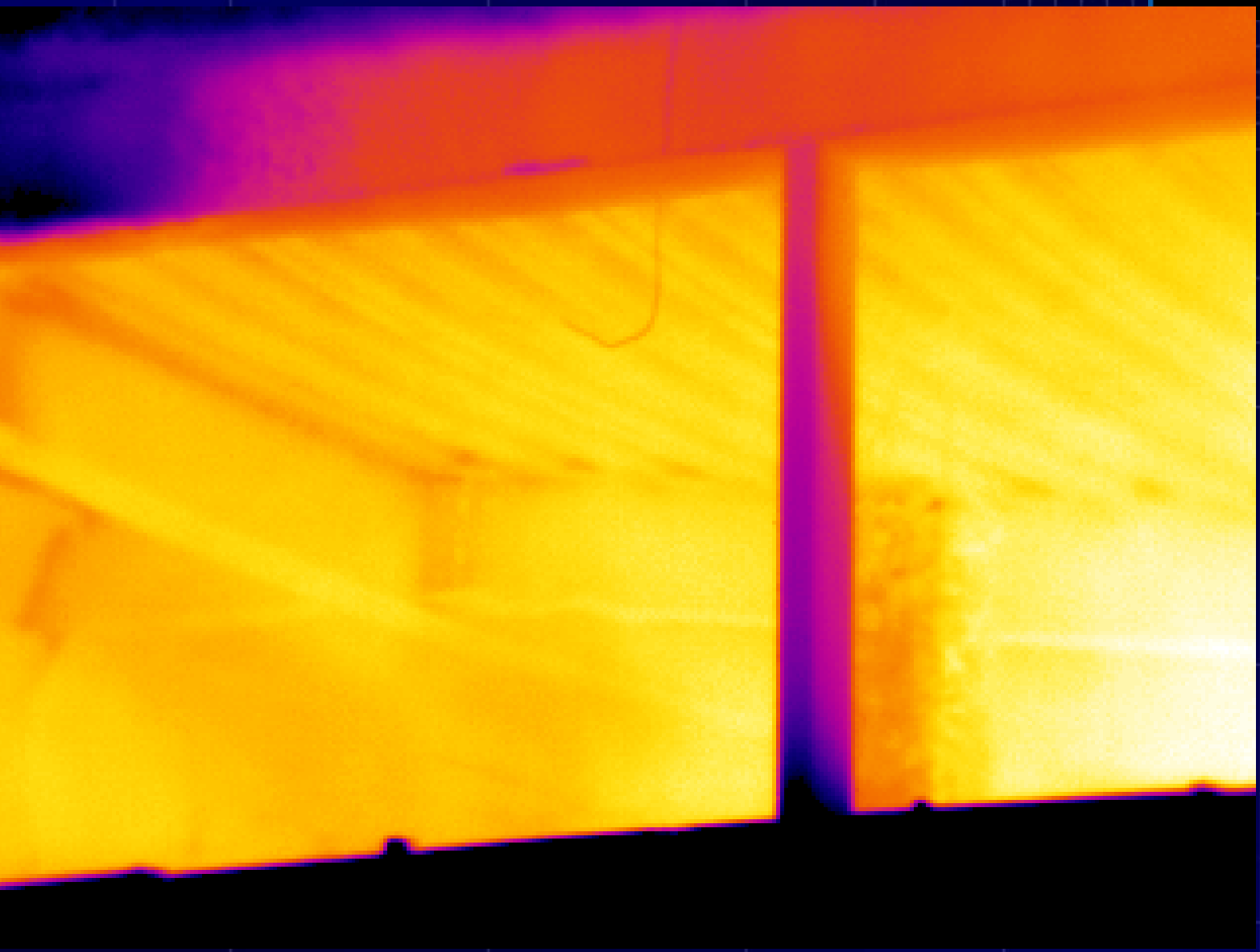

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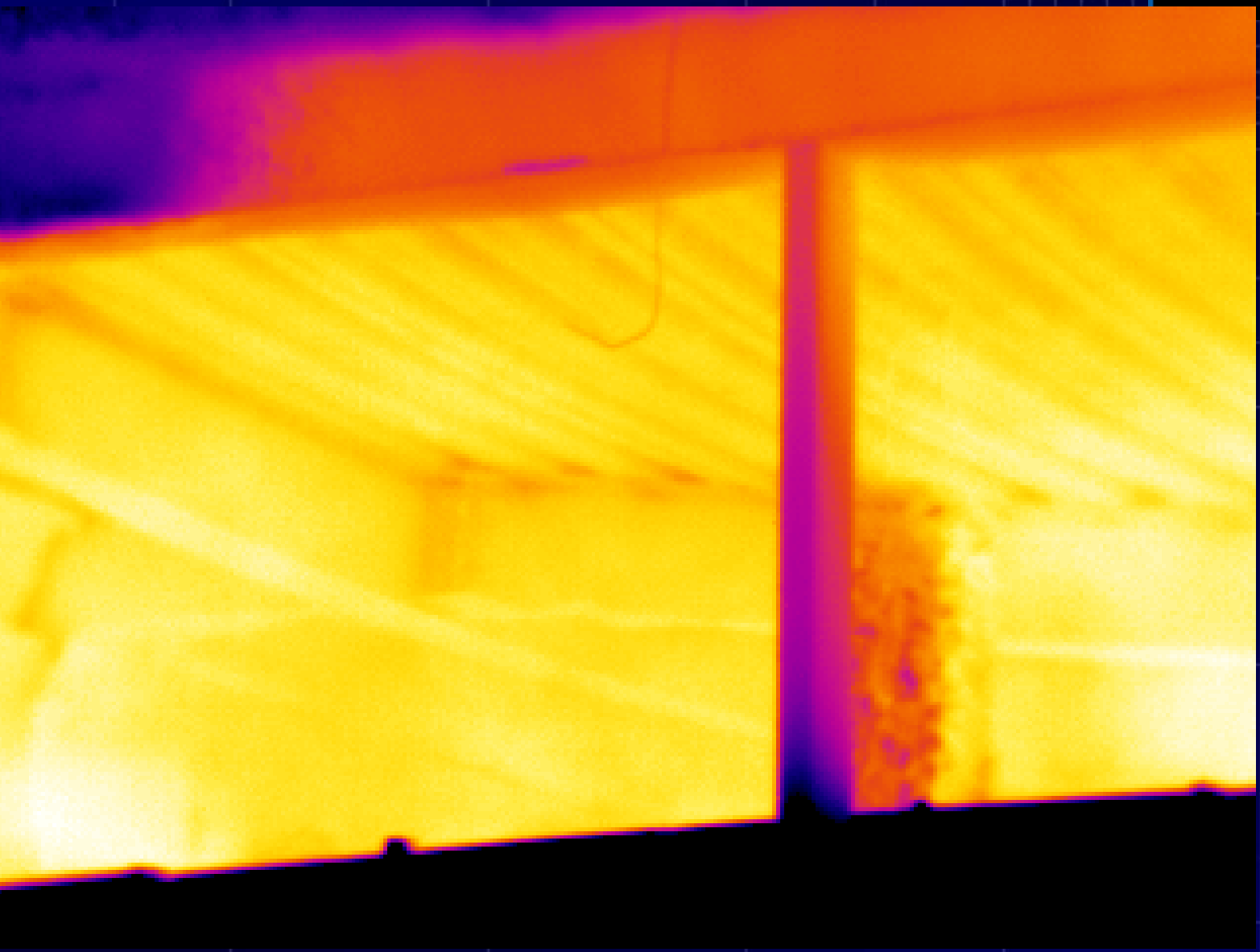

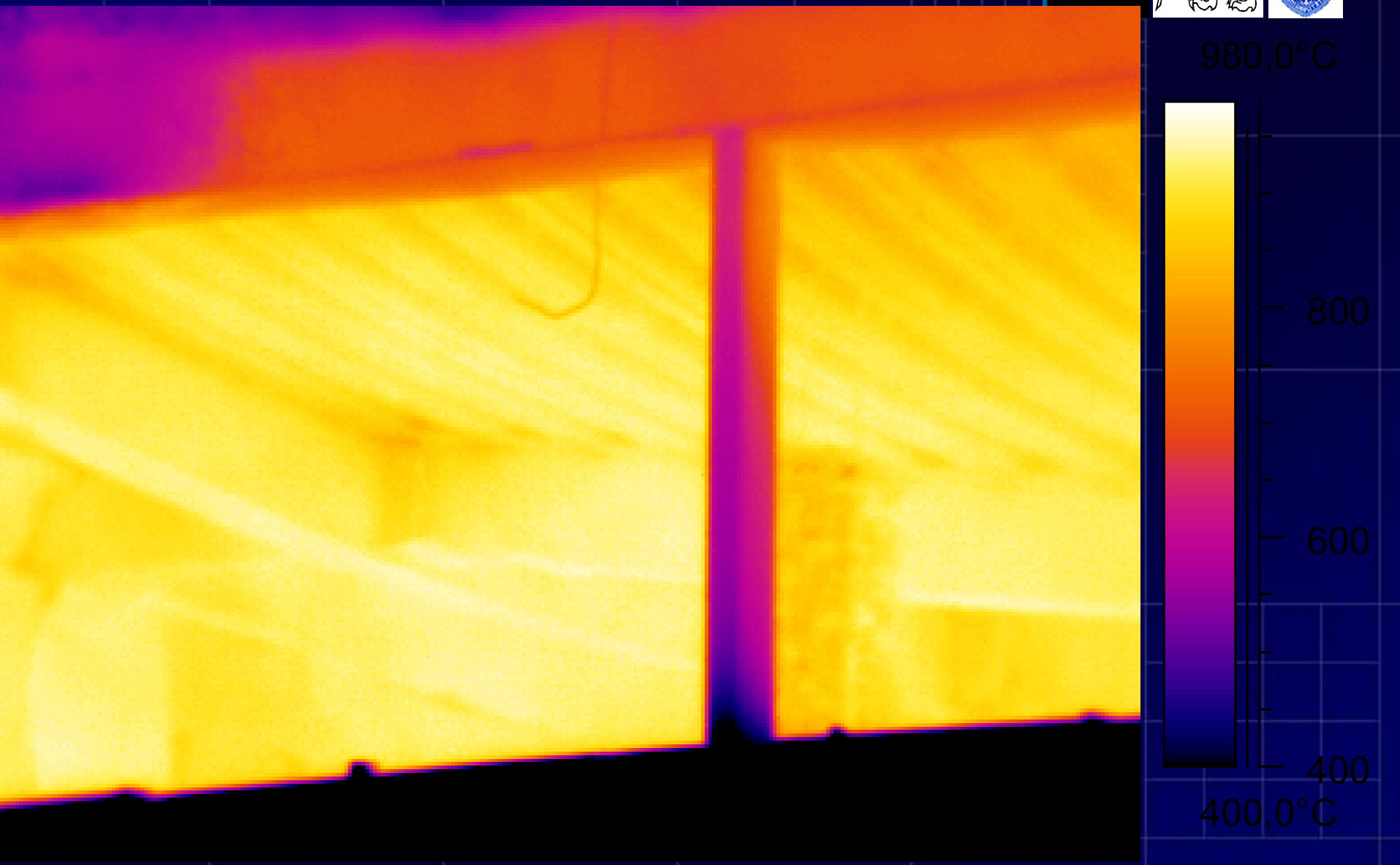
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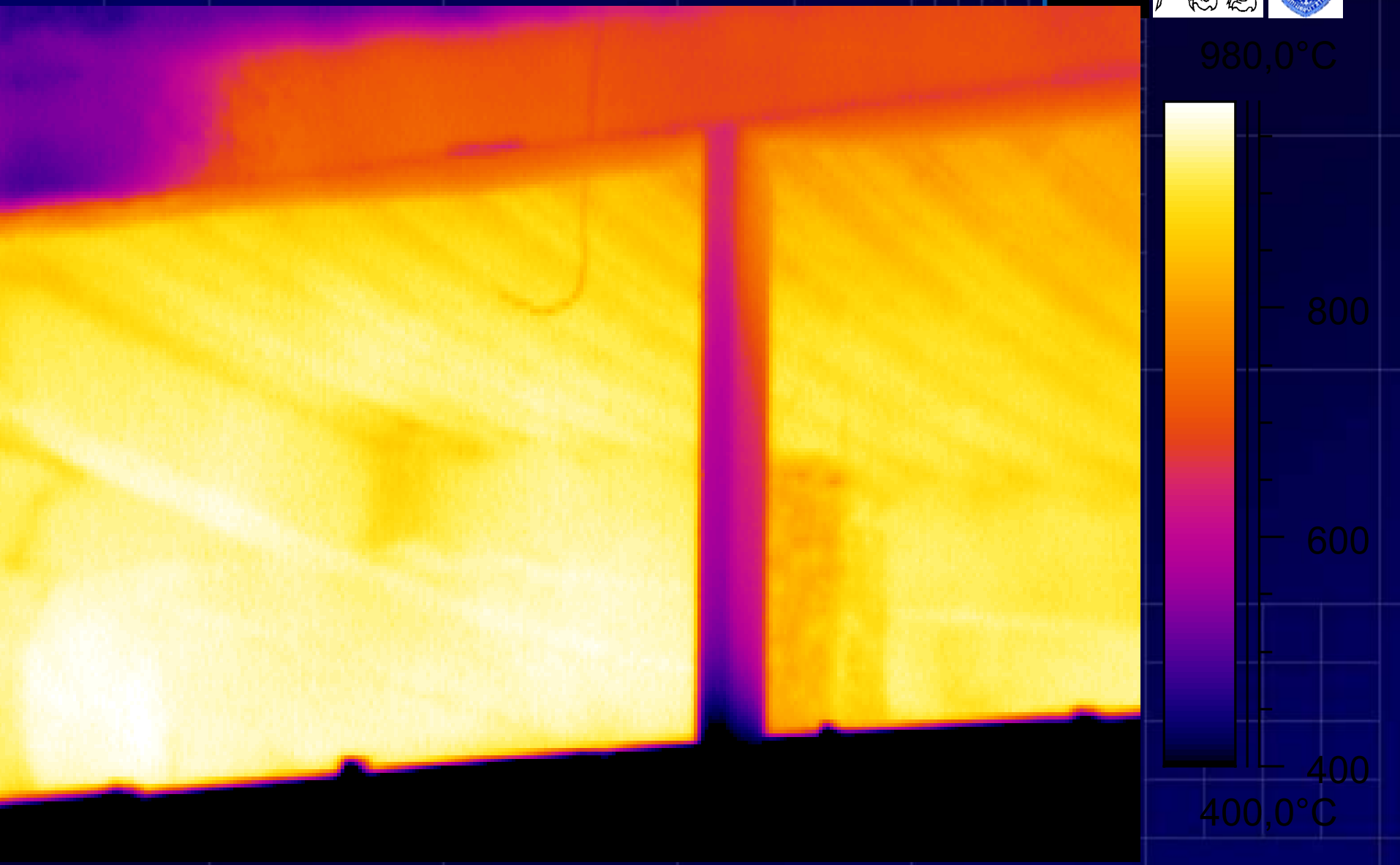
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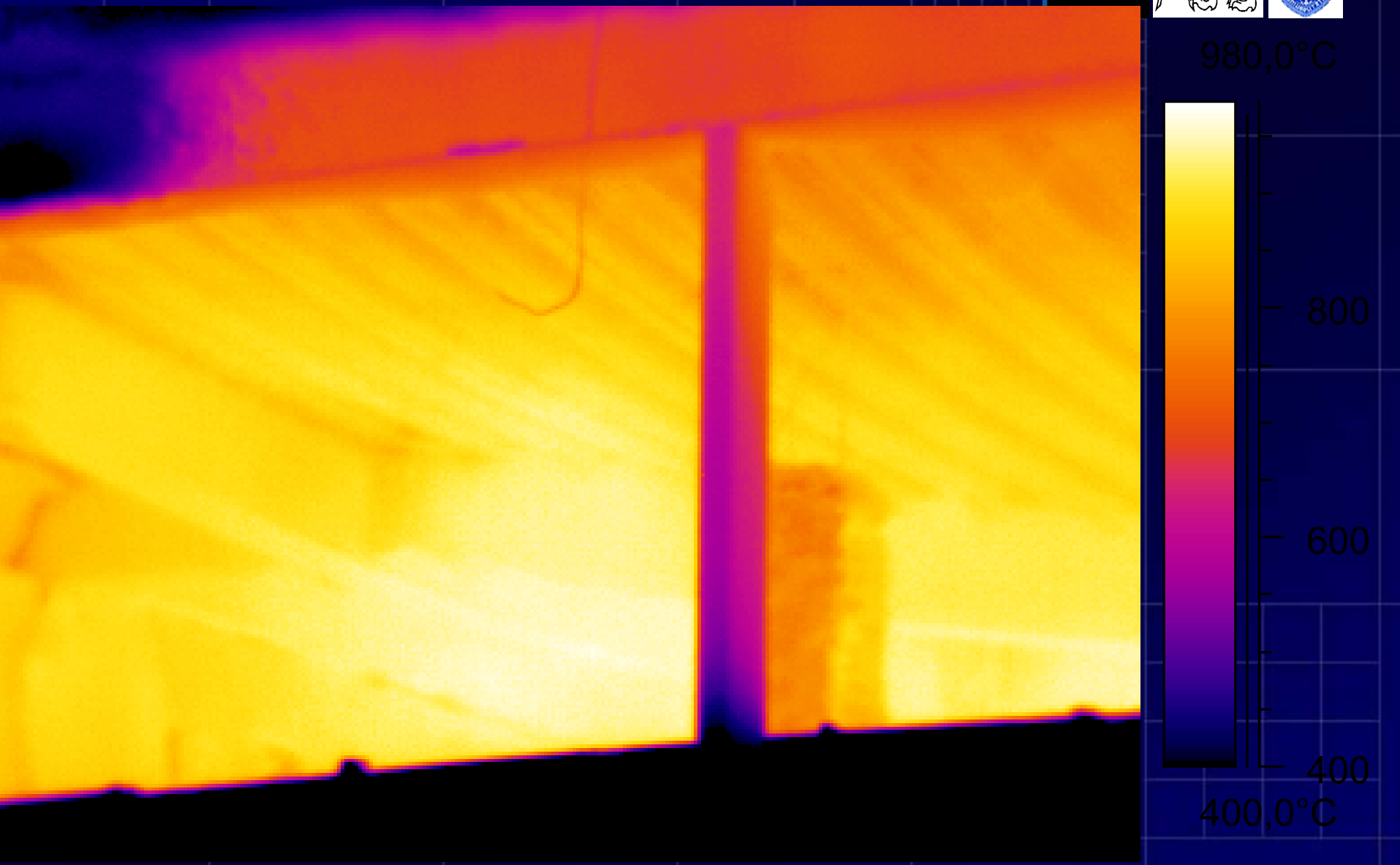
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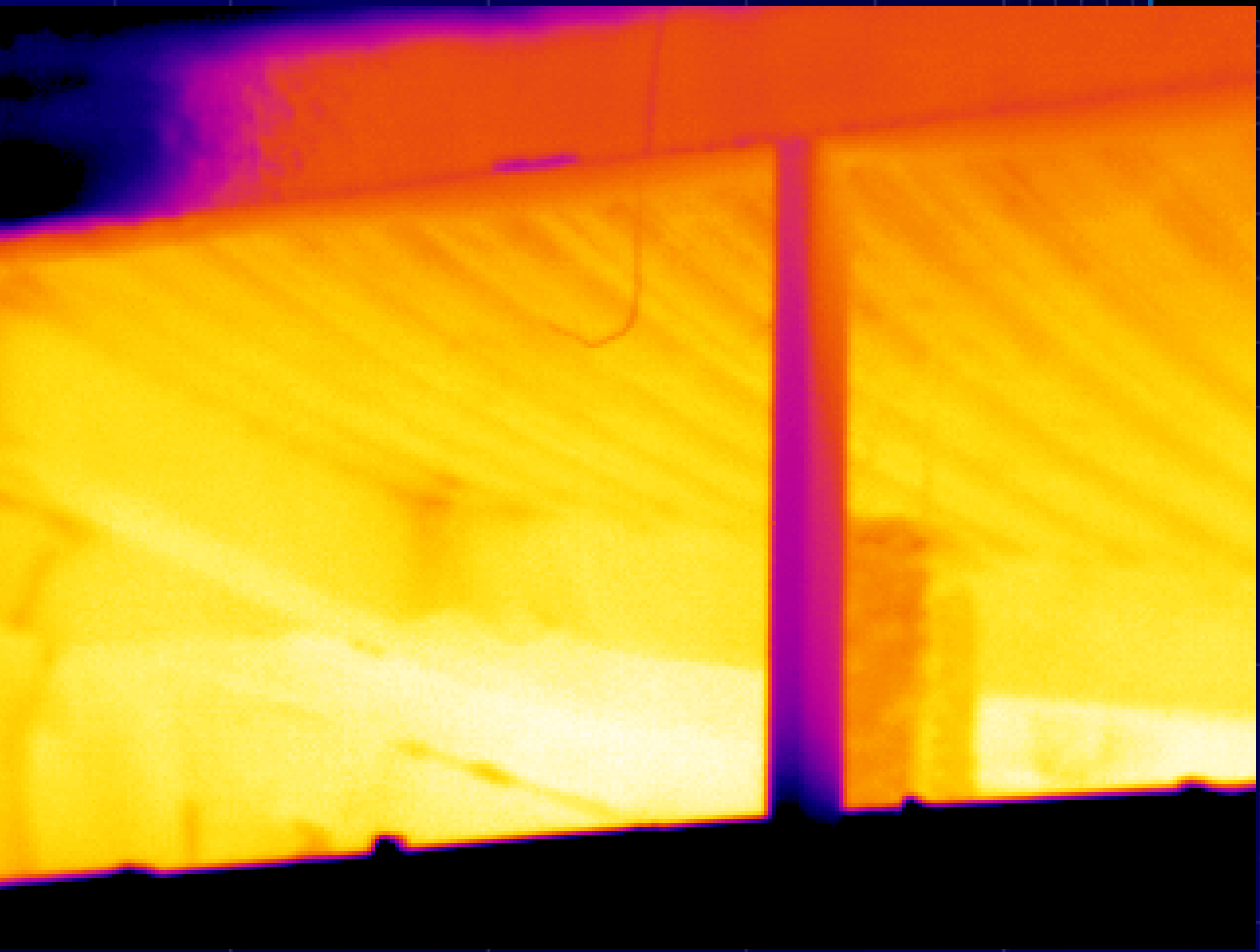

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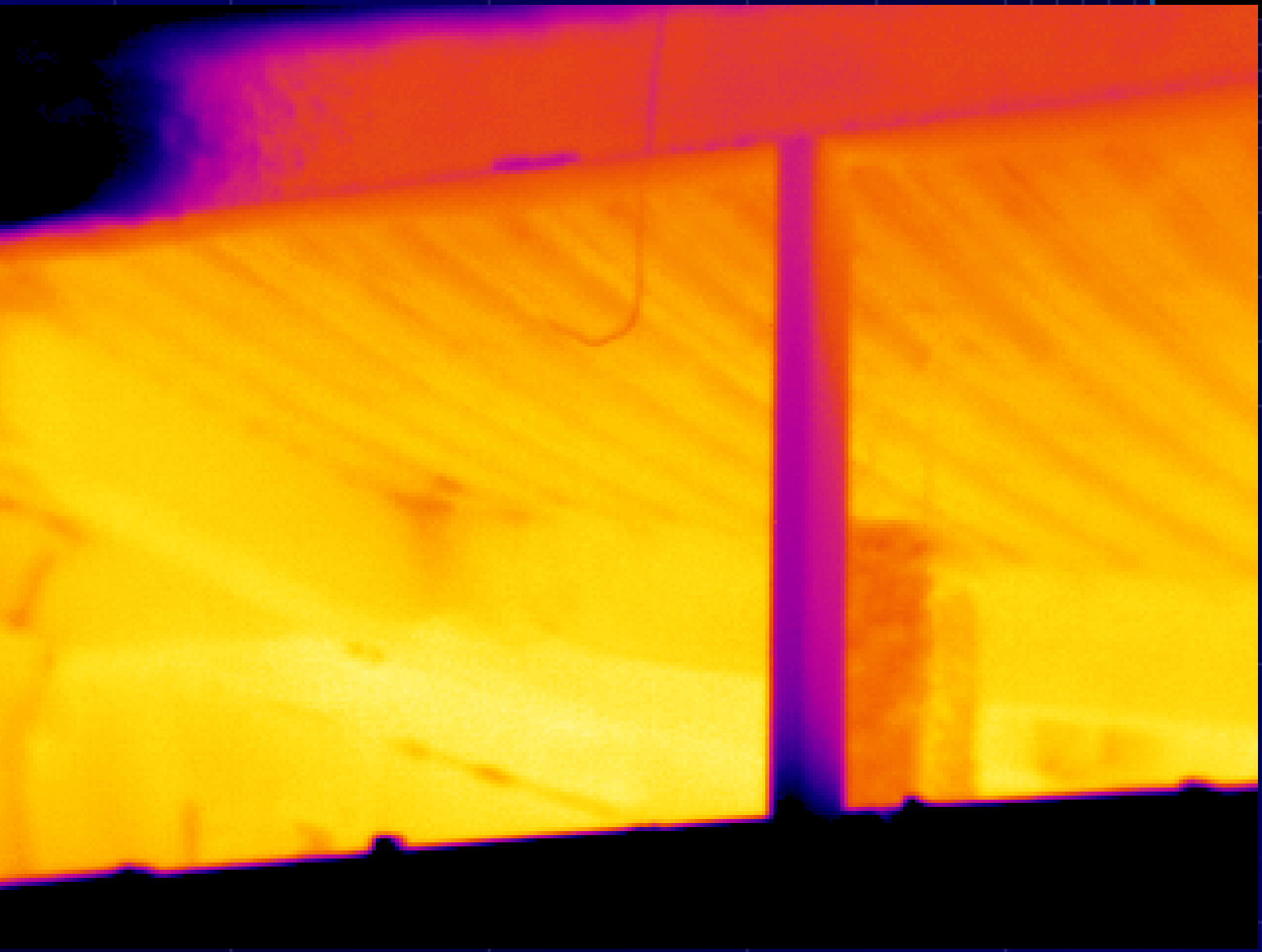

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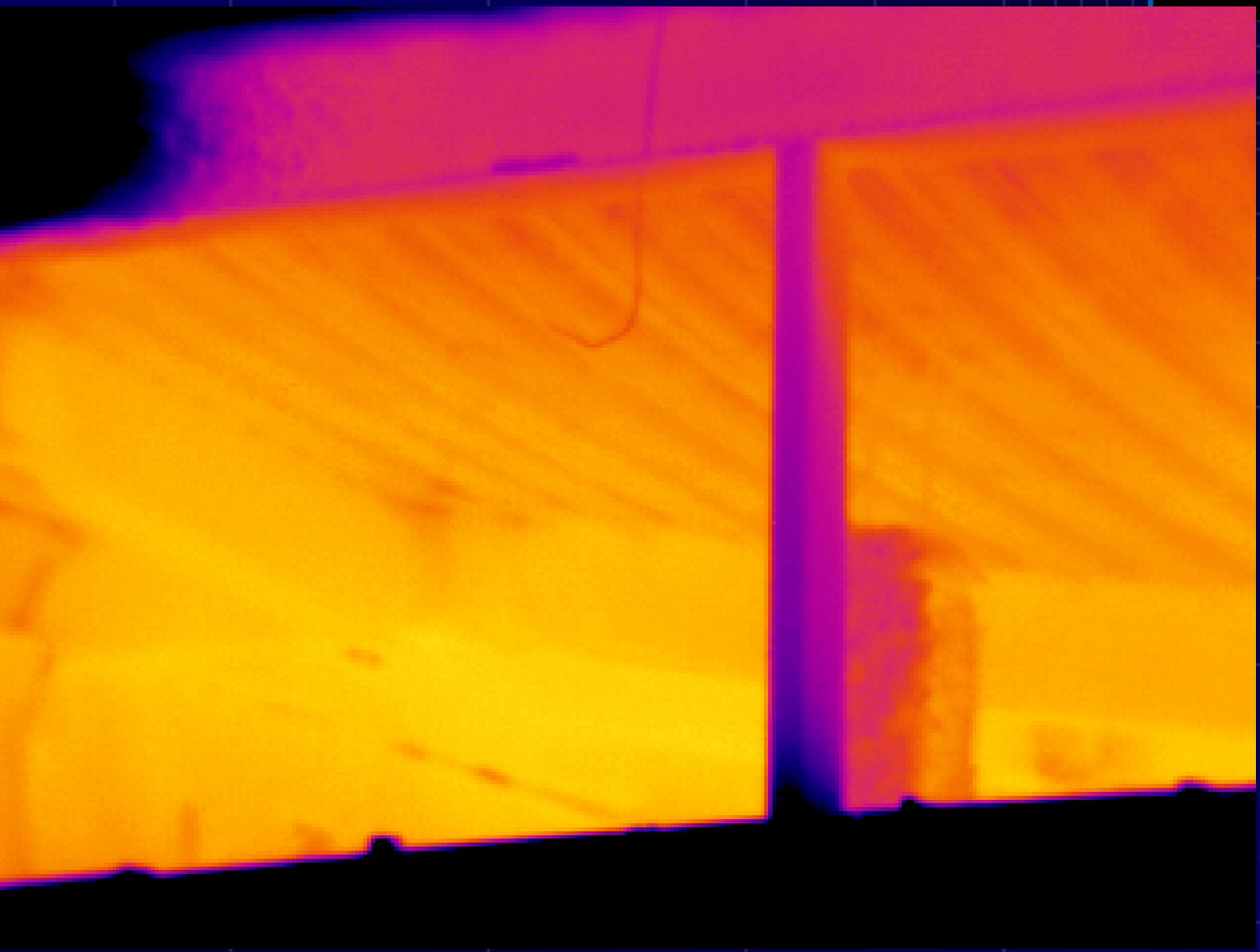

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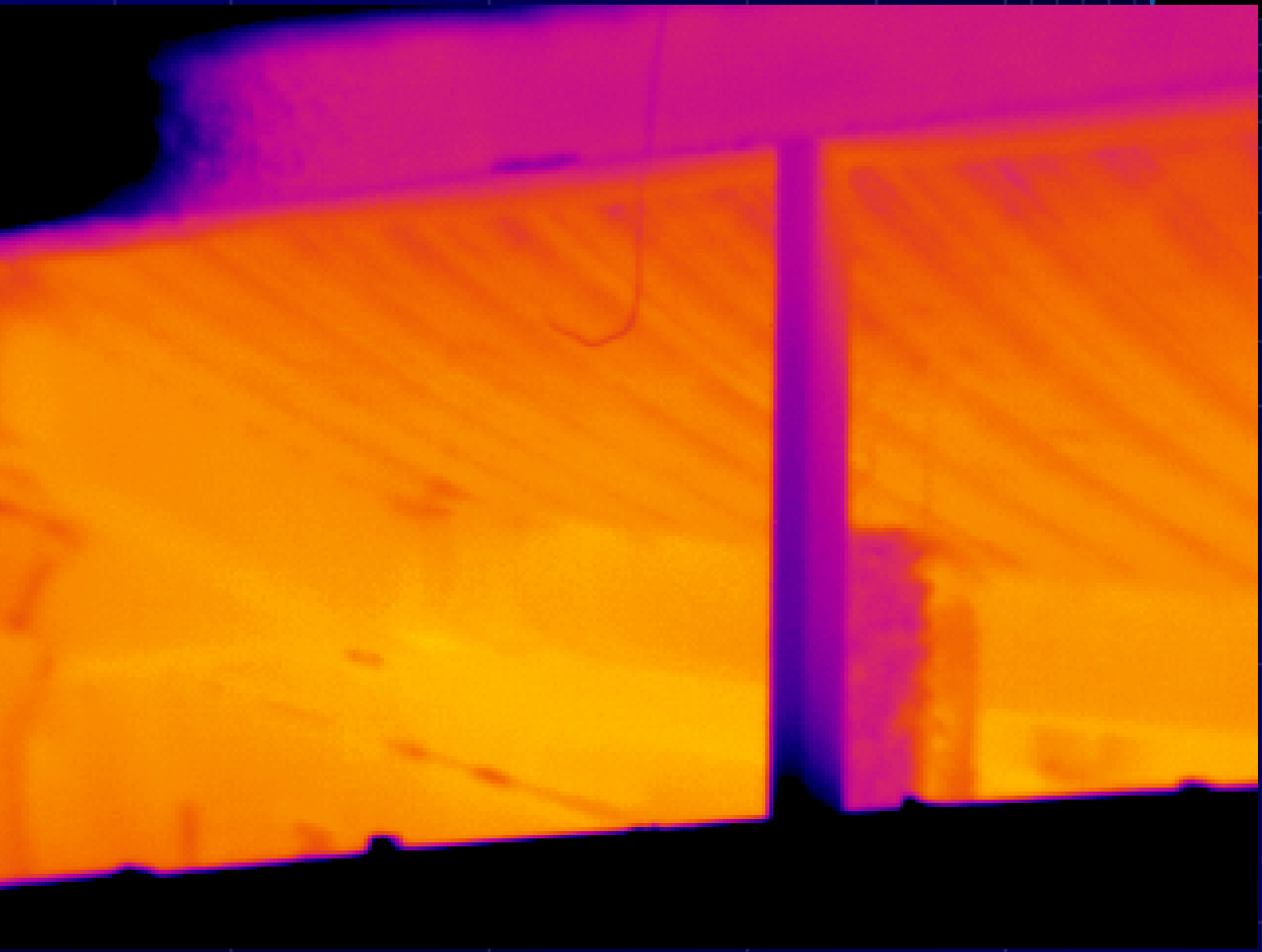

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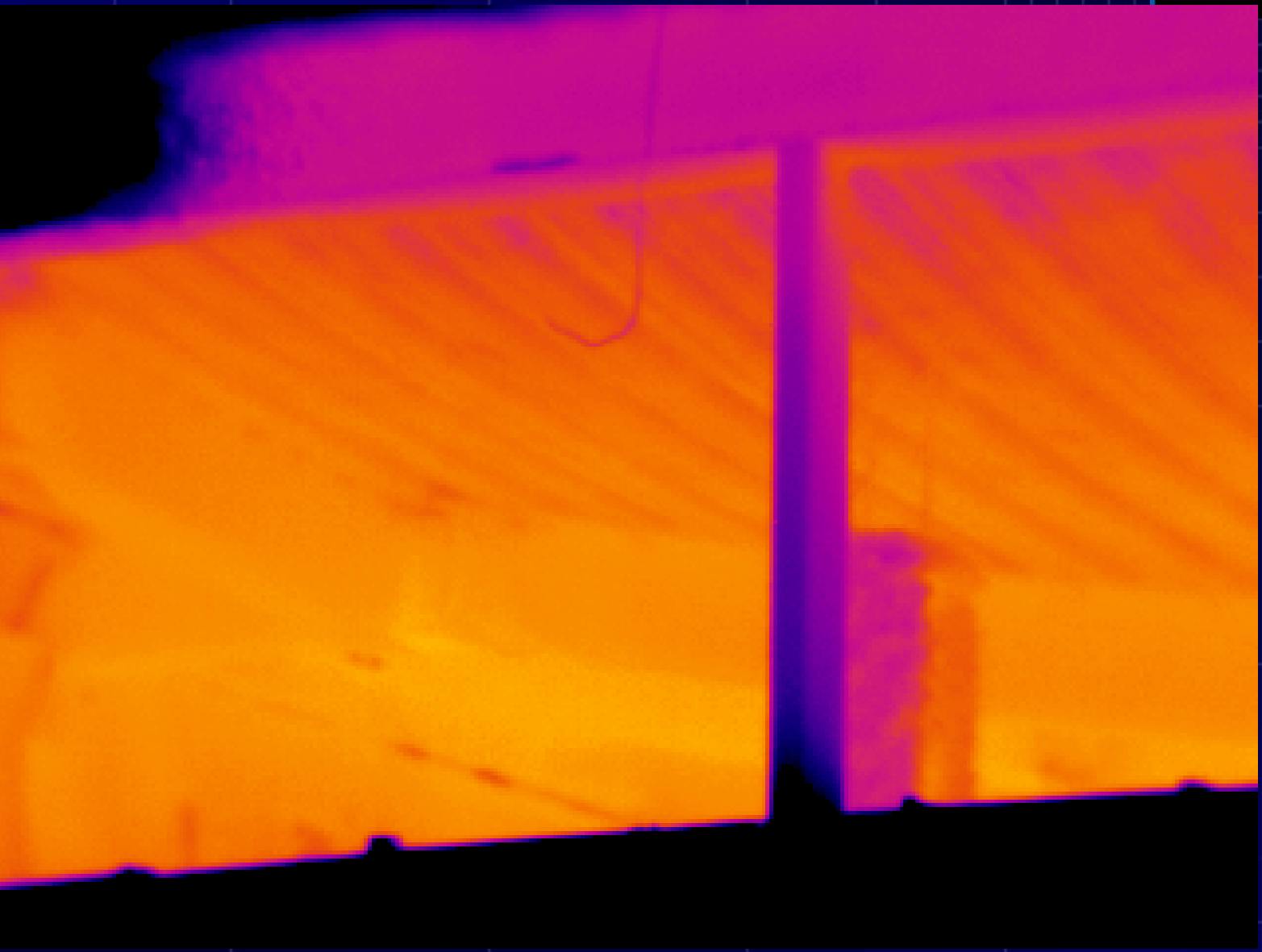

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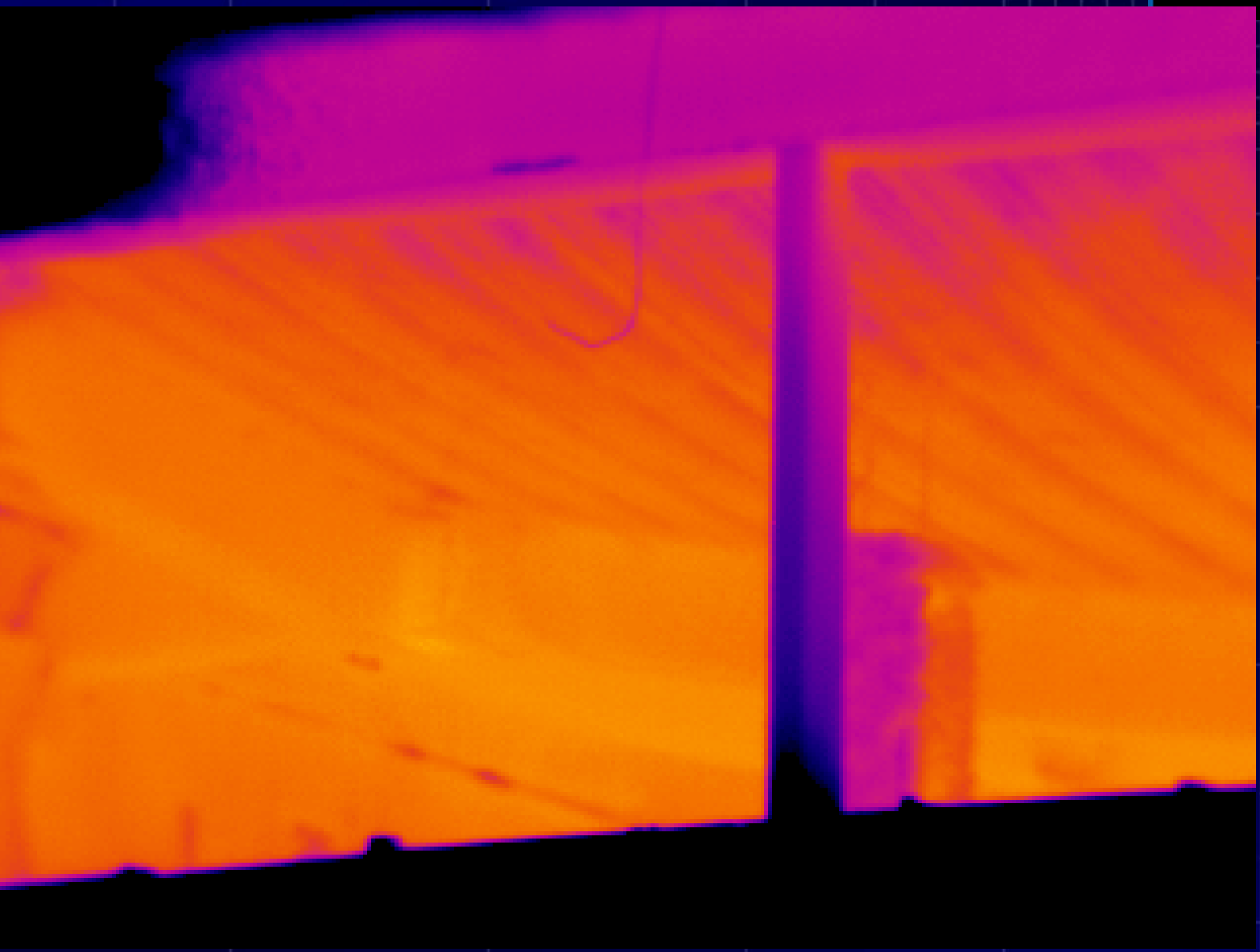

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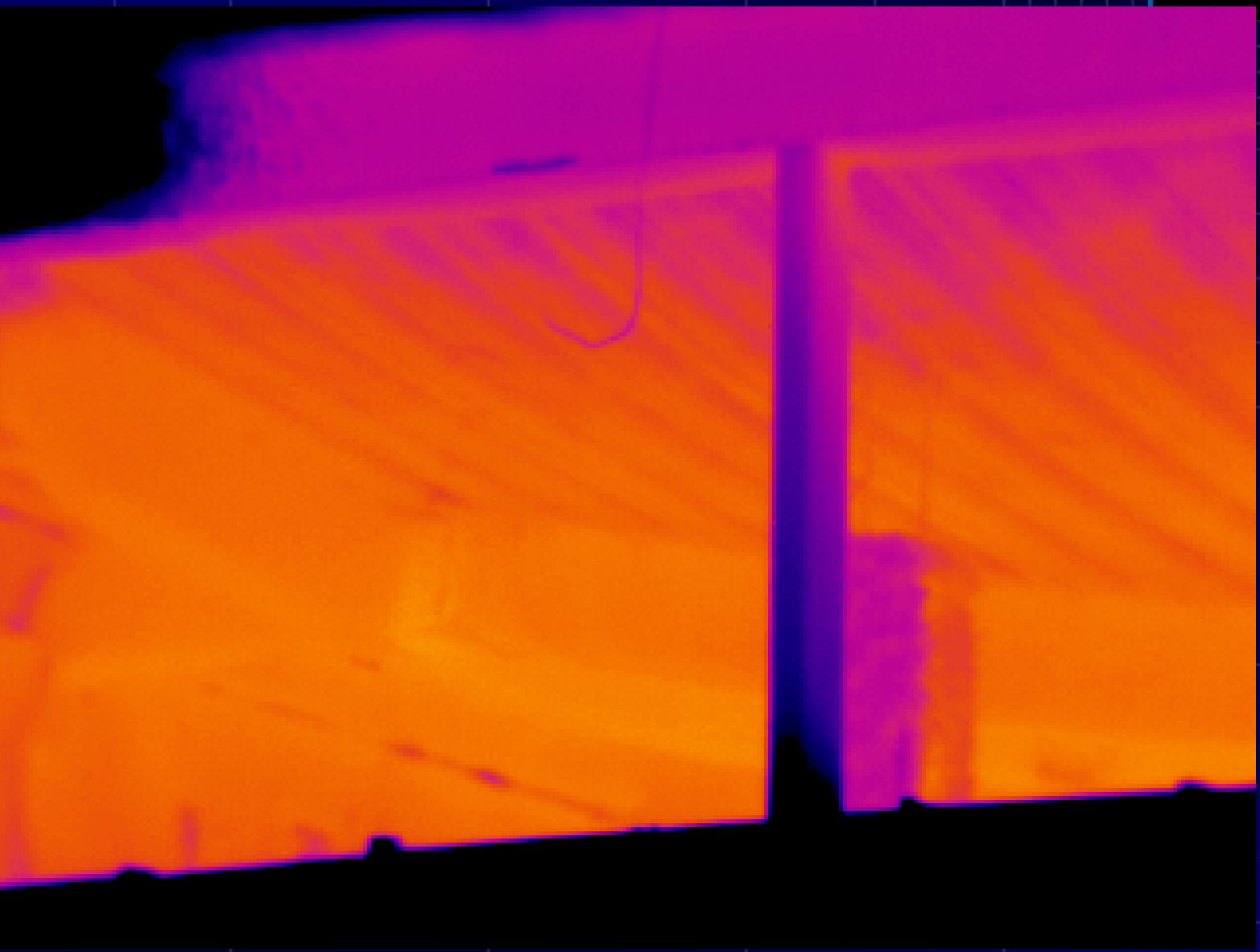

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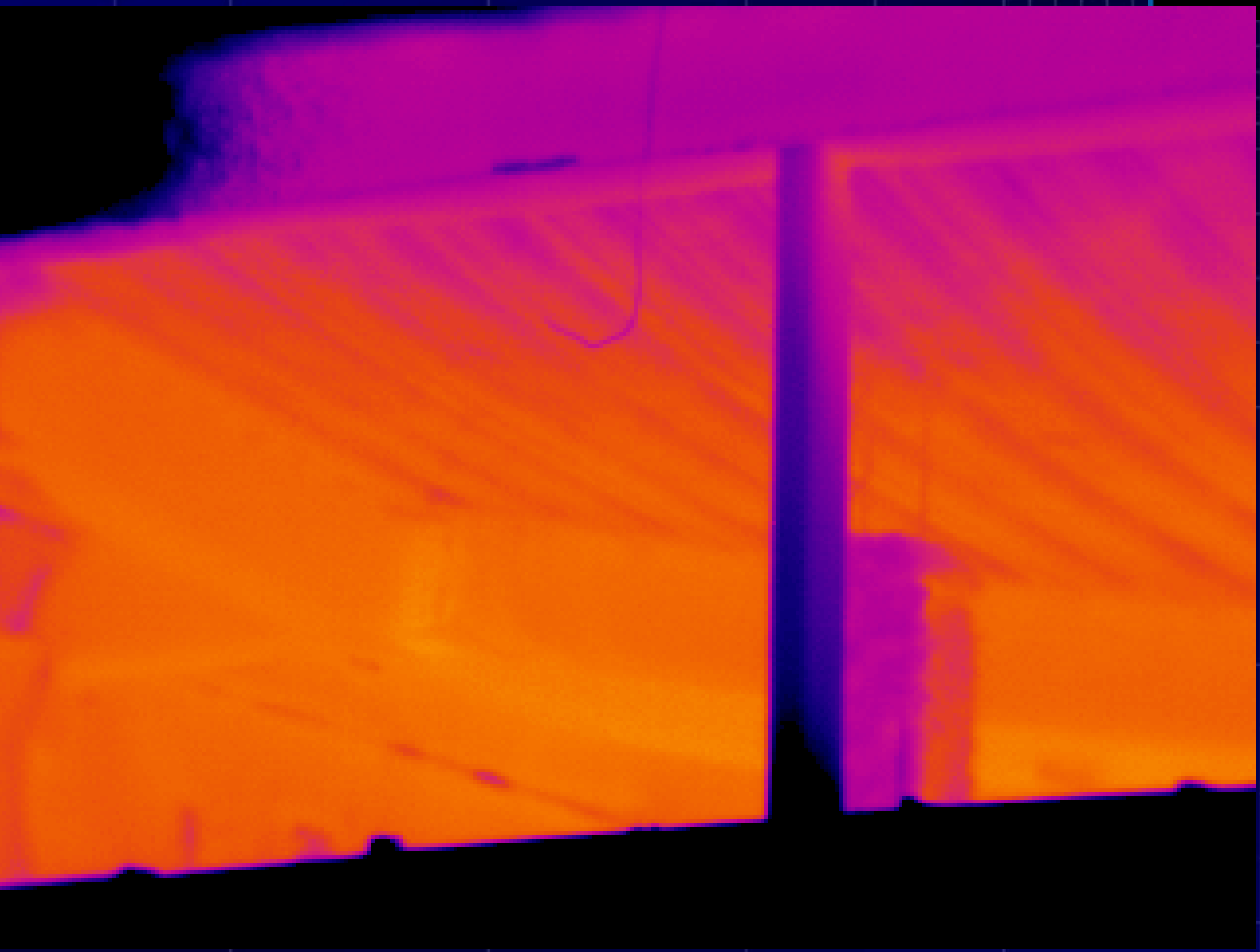

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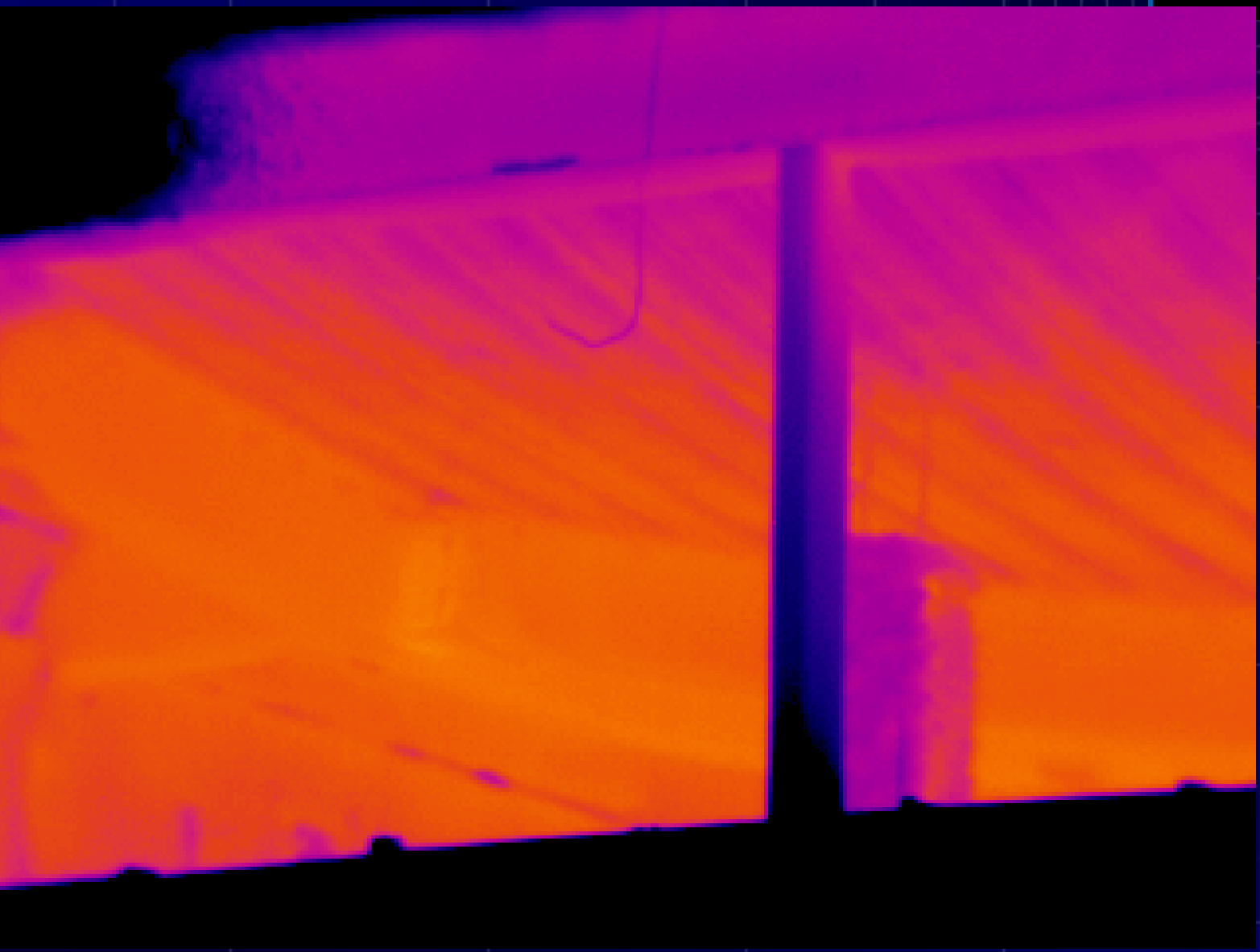

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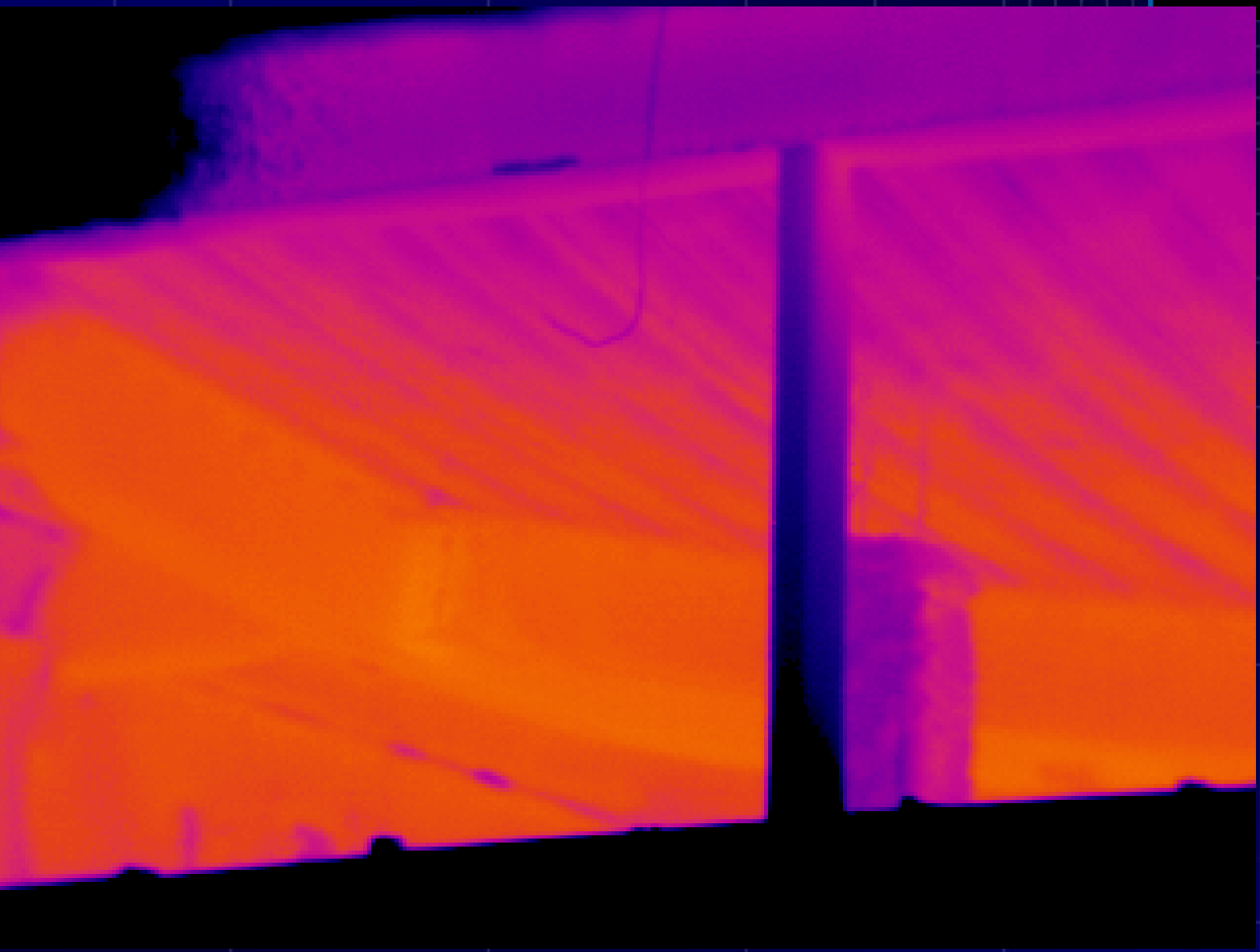

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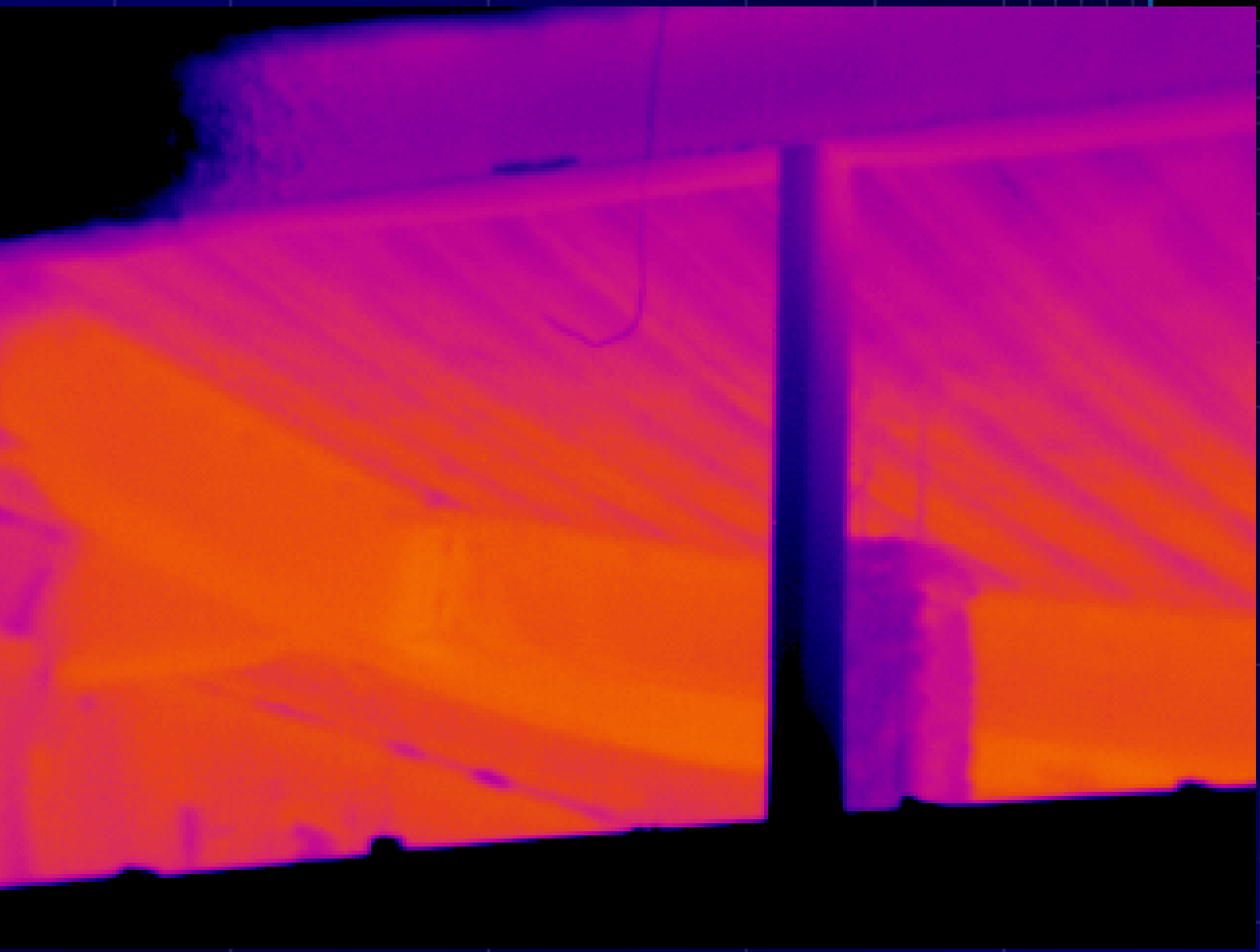

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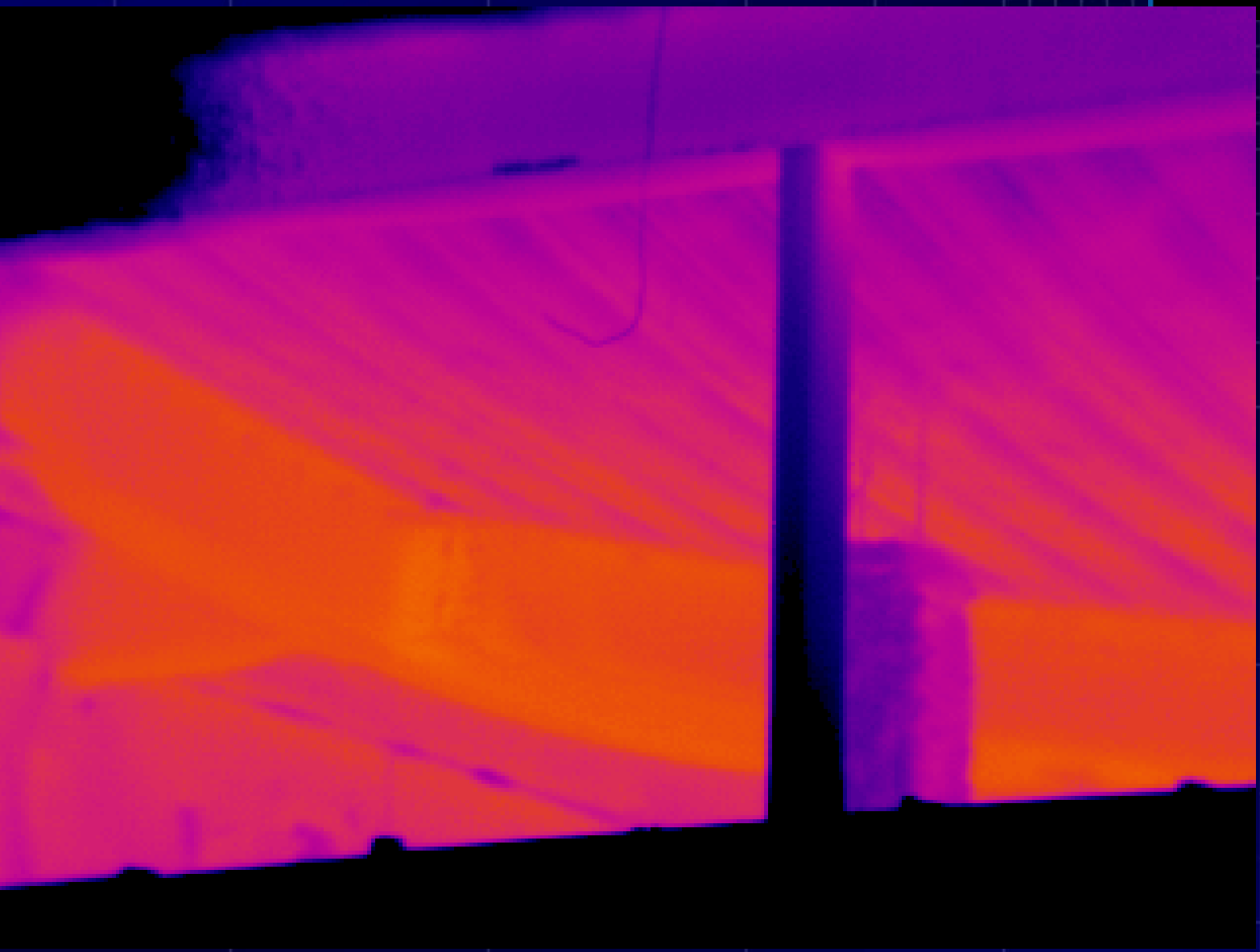

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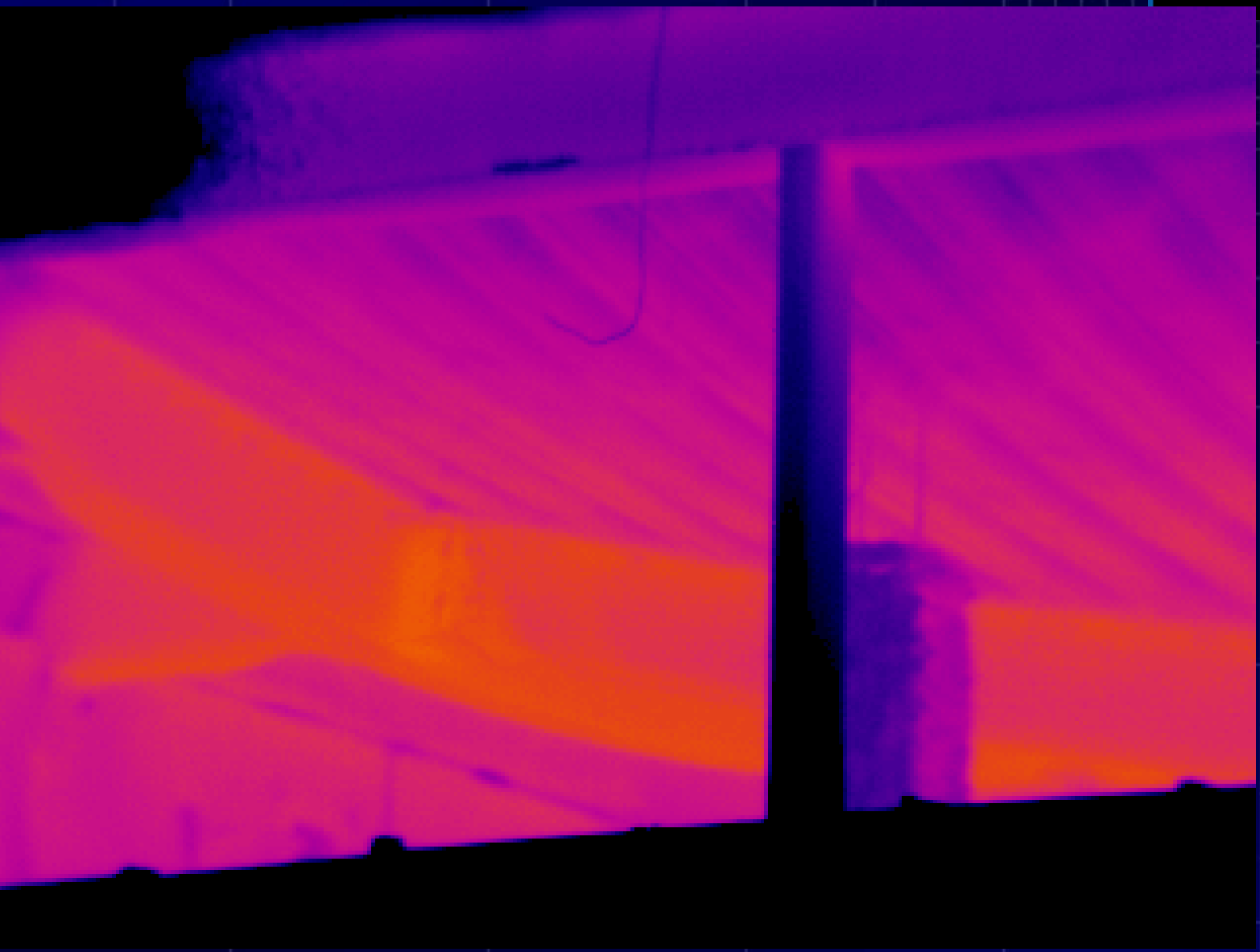

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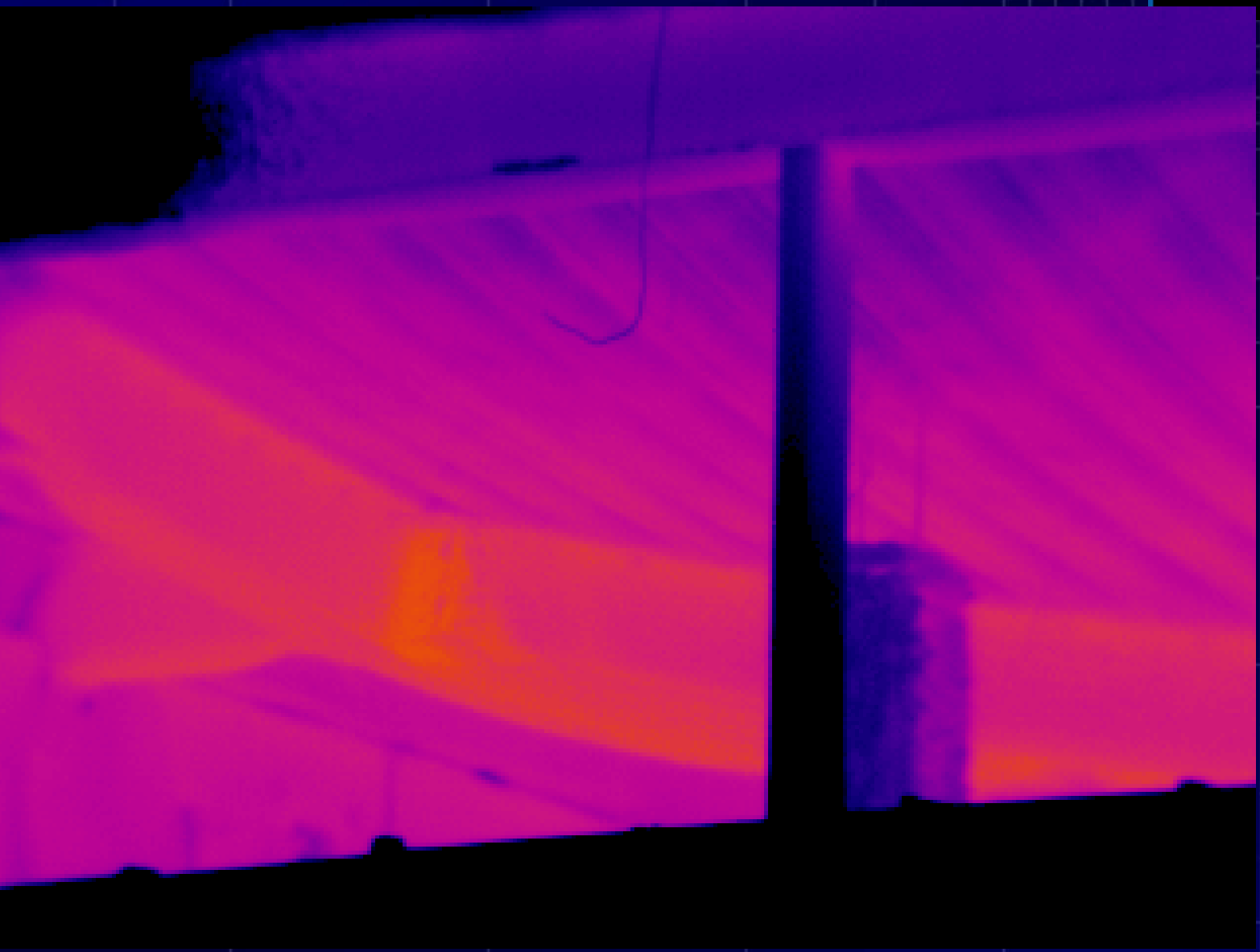

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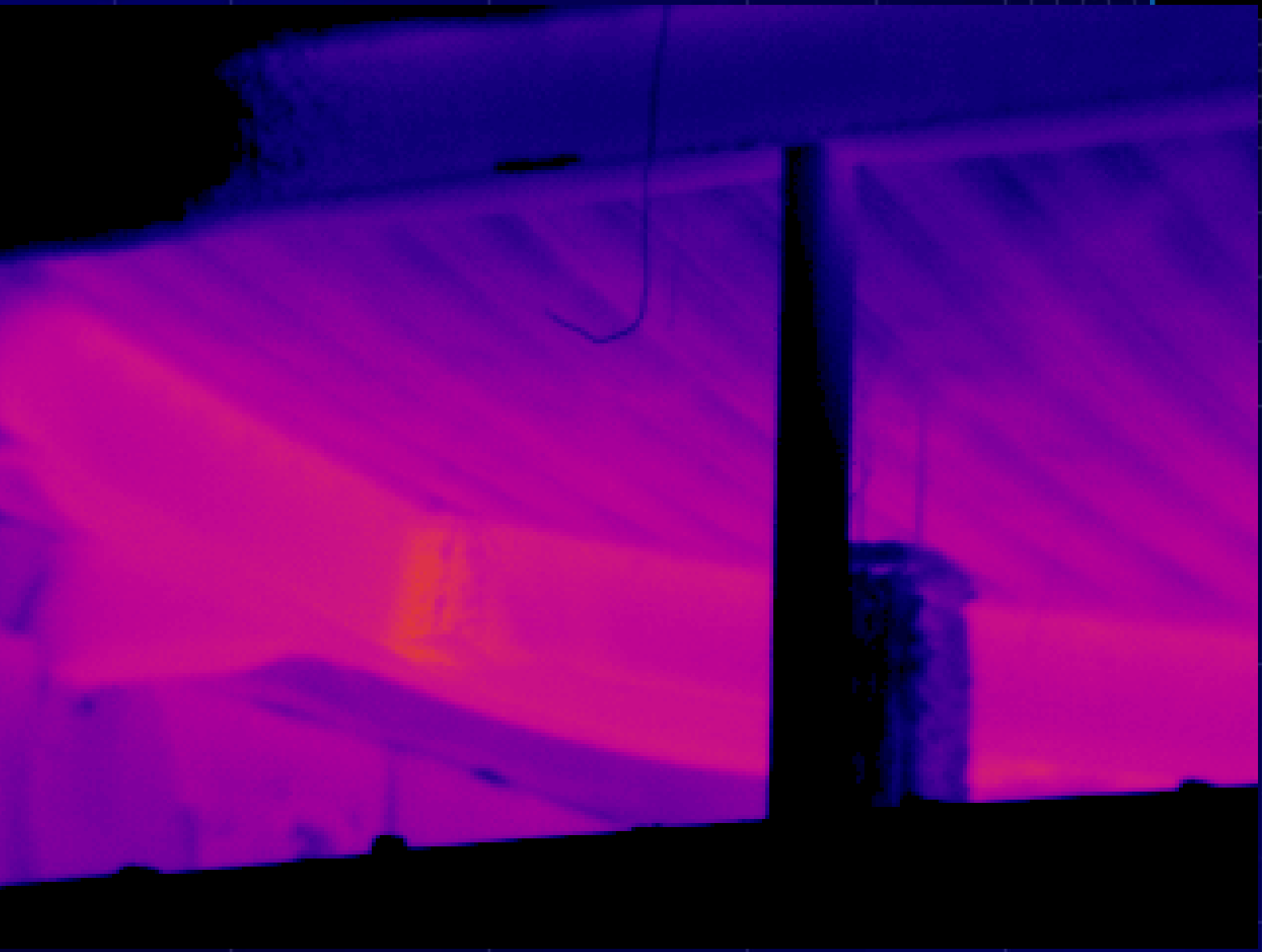

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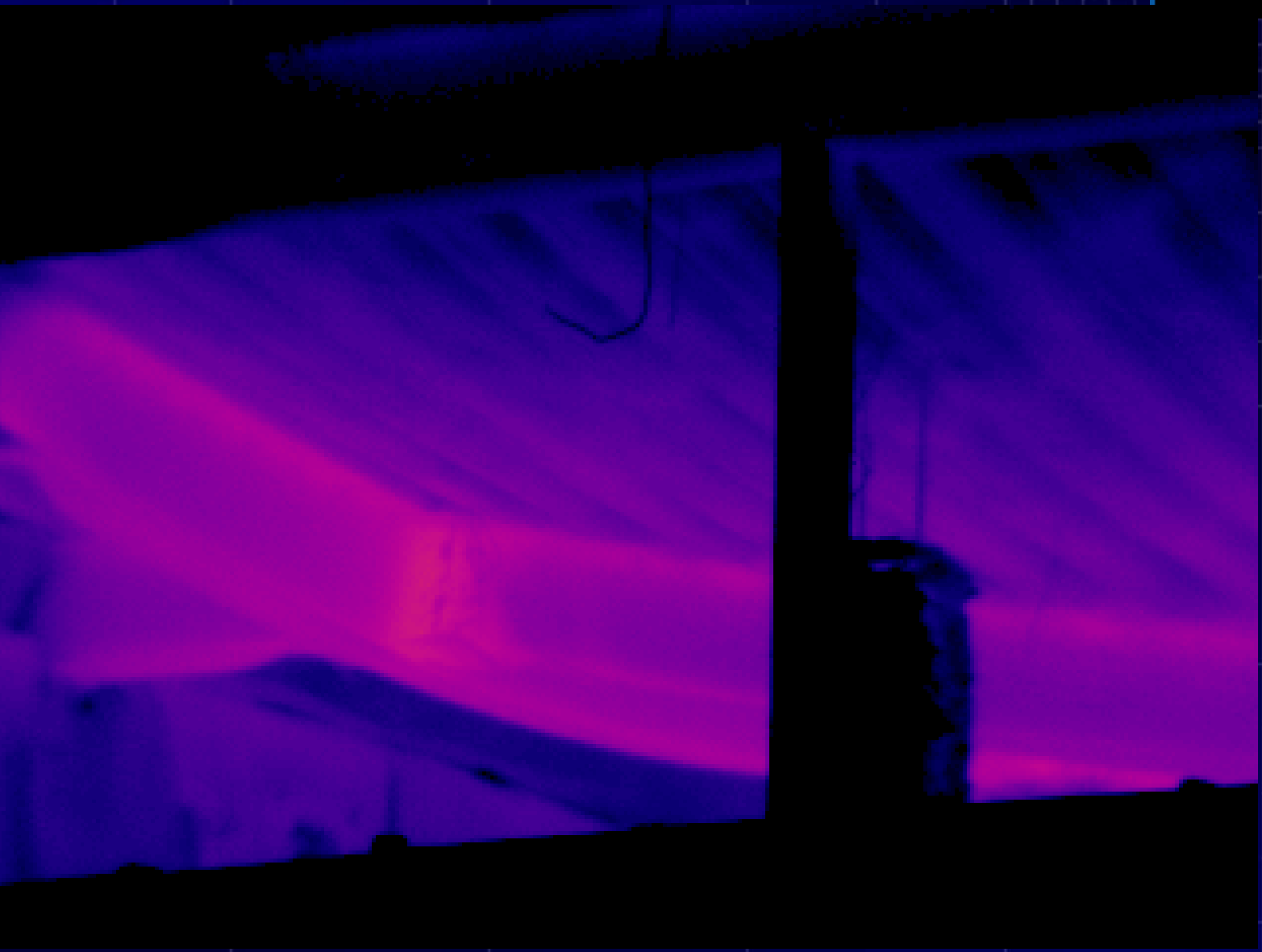

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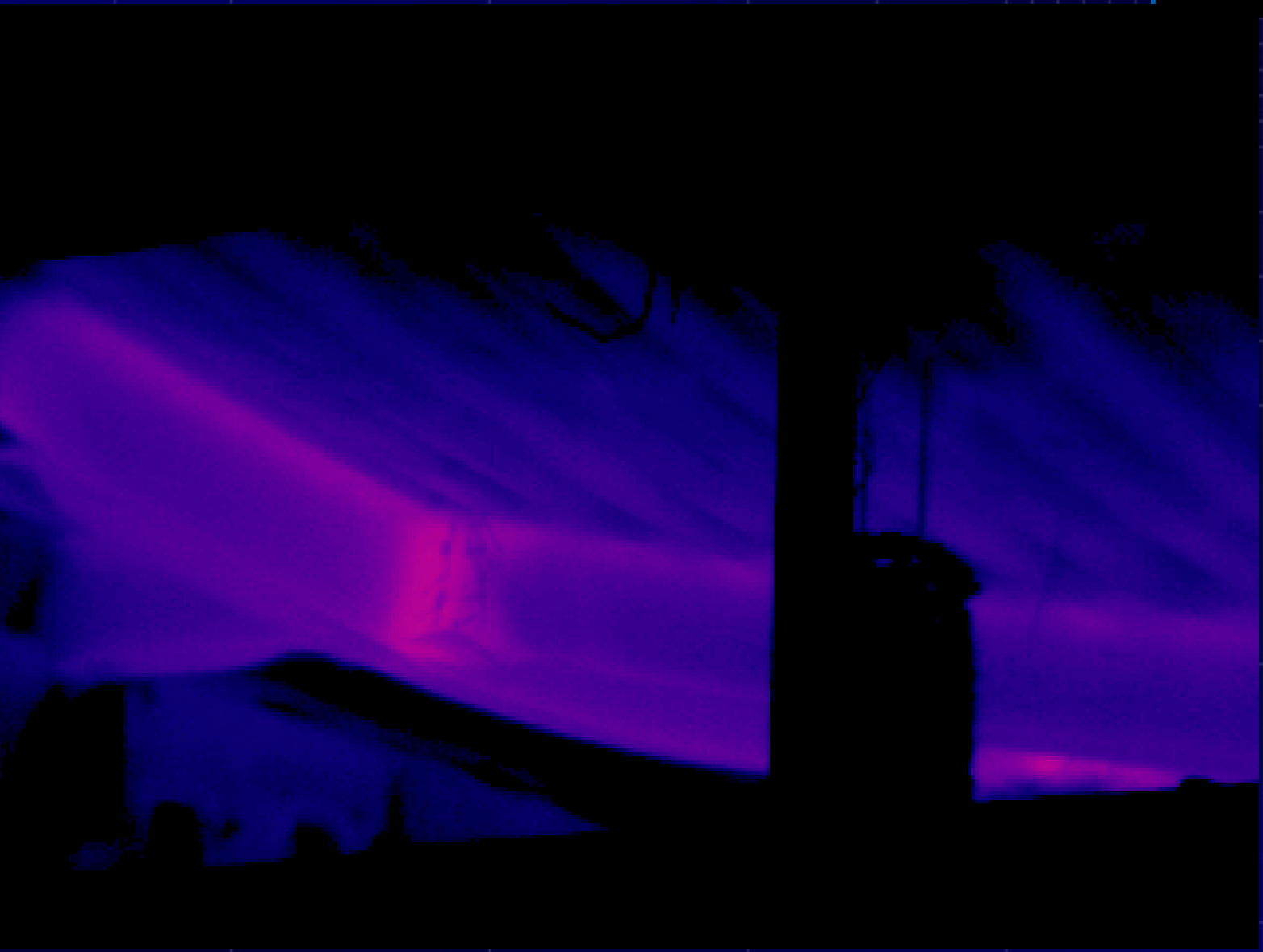

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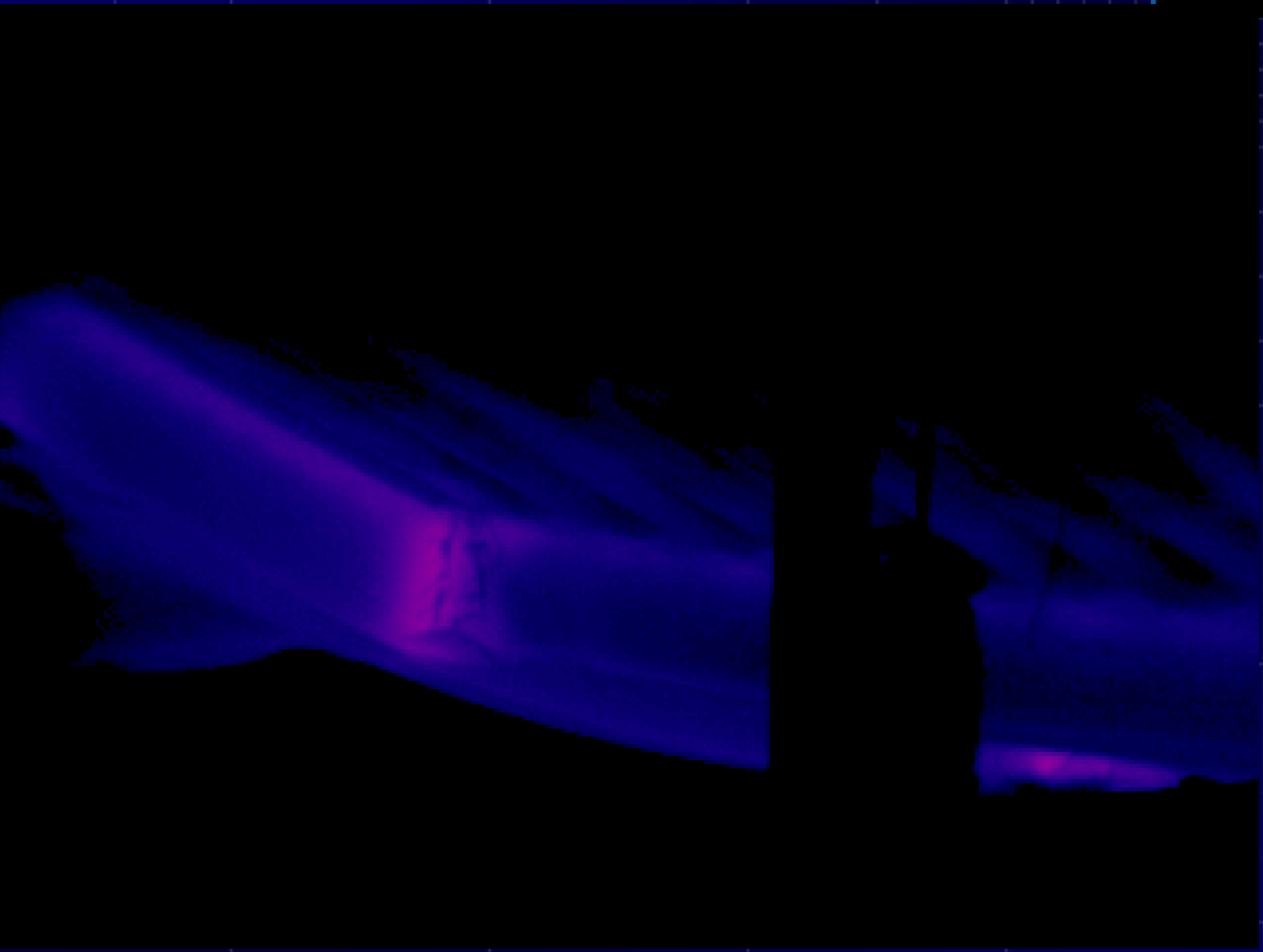

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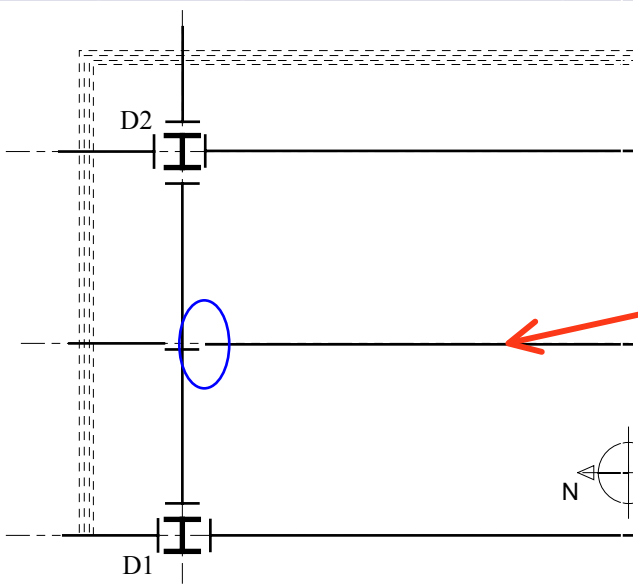
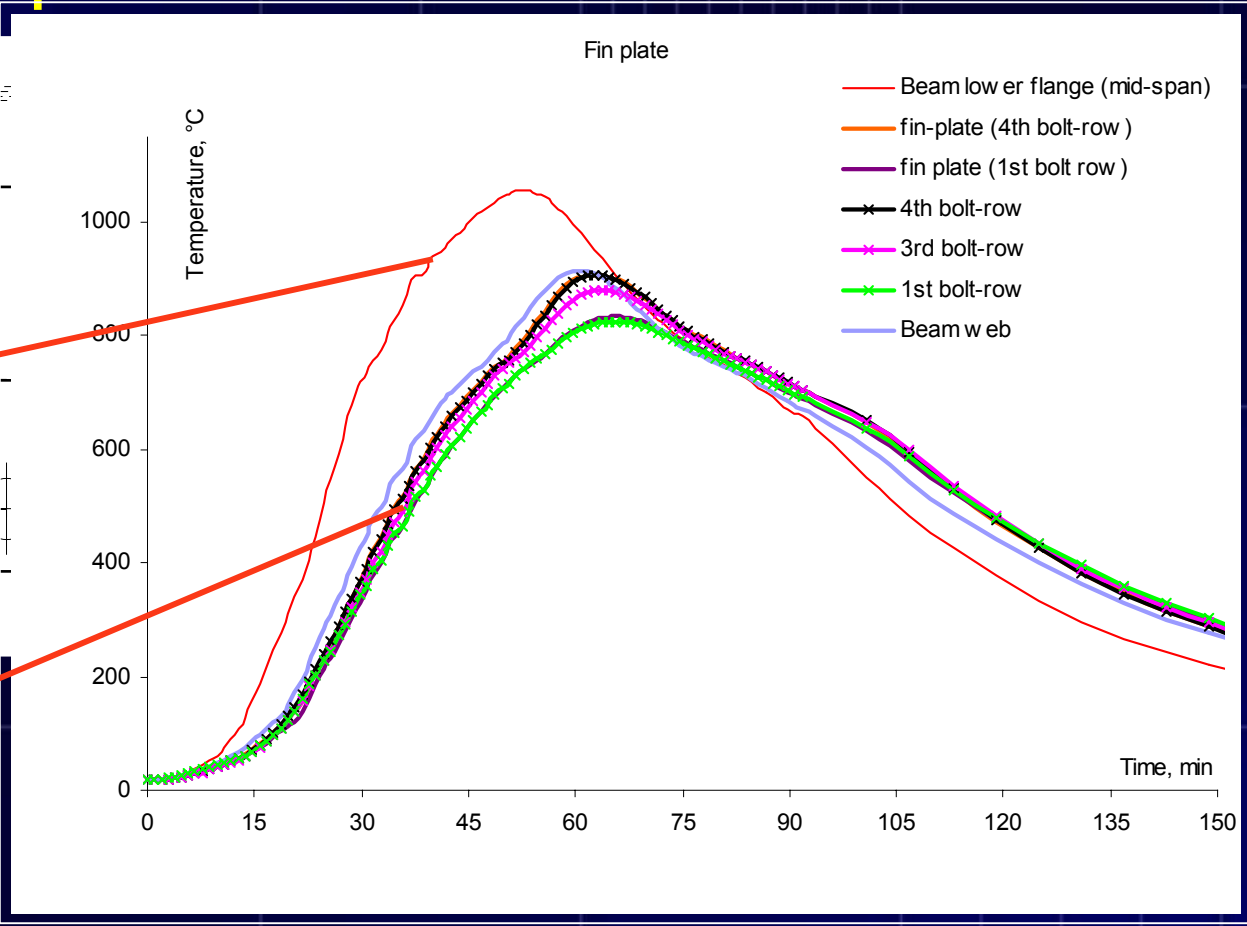
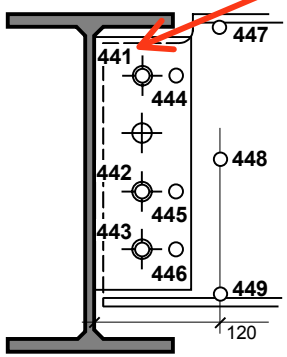
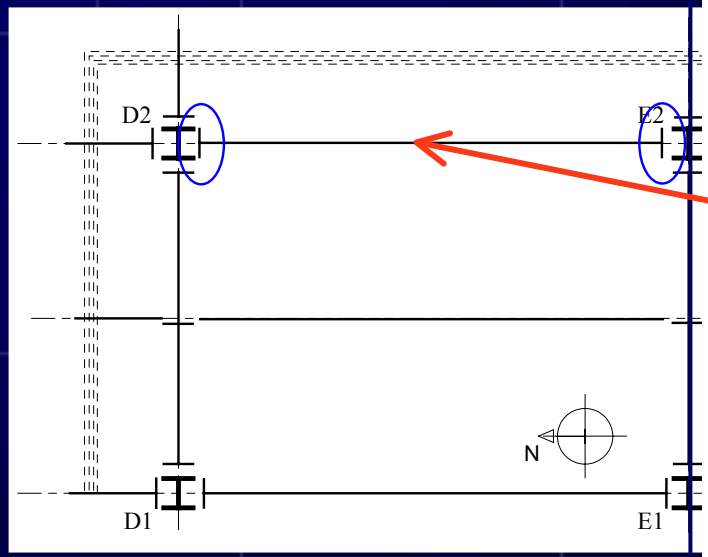
Fin Plate Temperature Profile

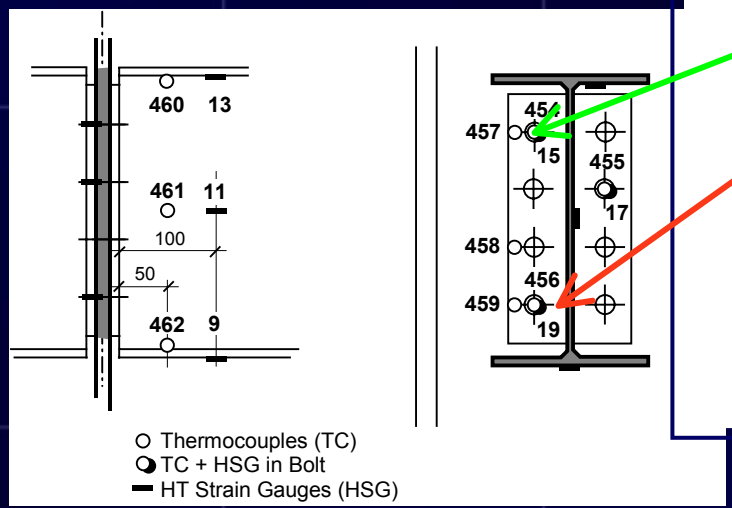


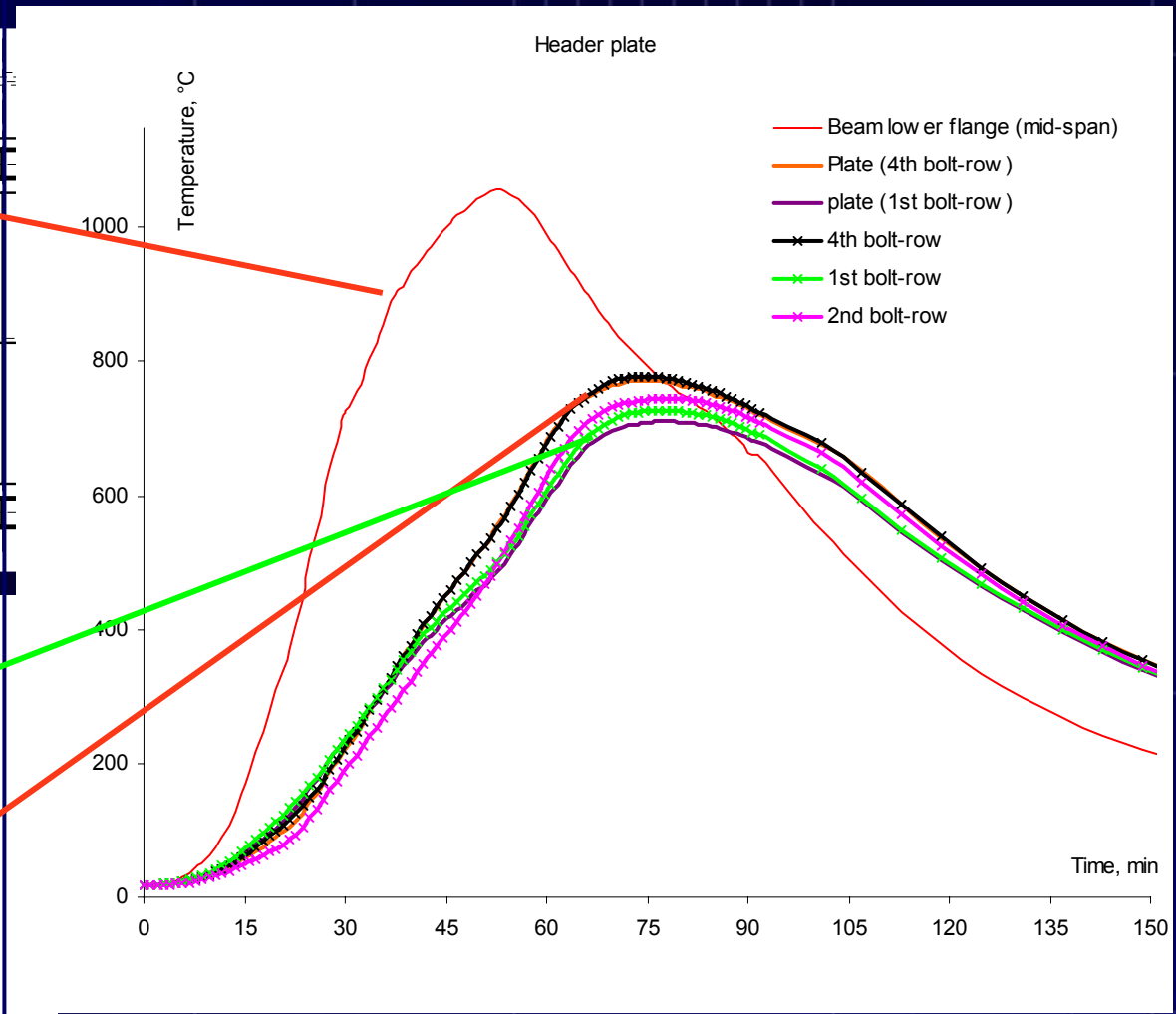




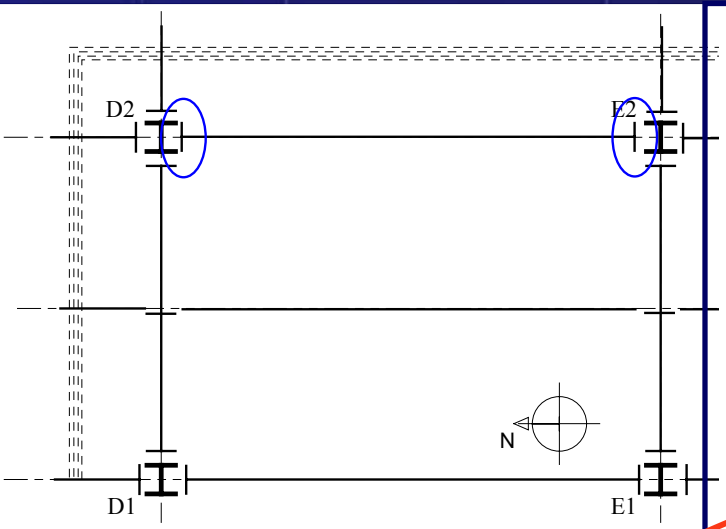
Header Plate Temperature Profile

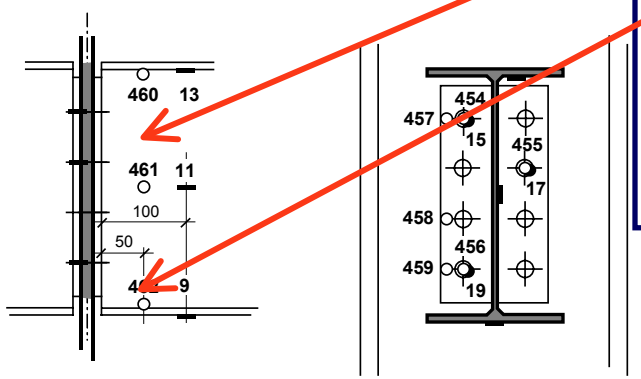


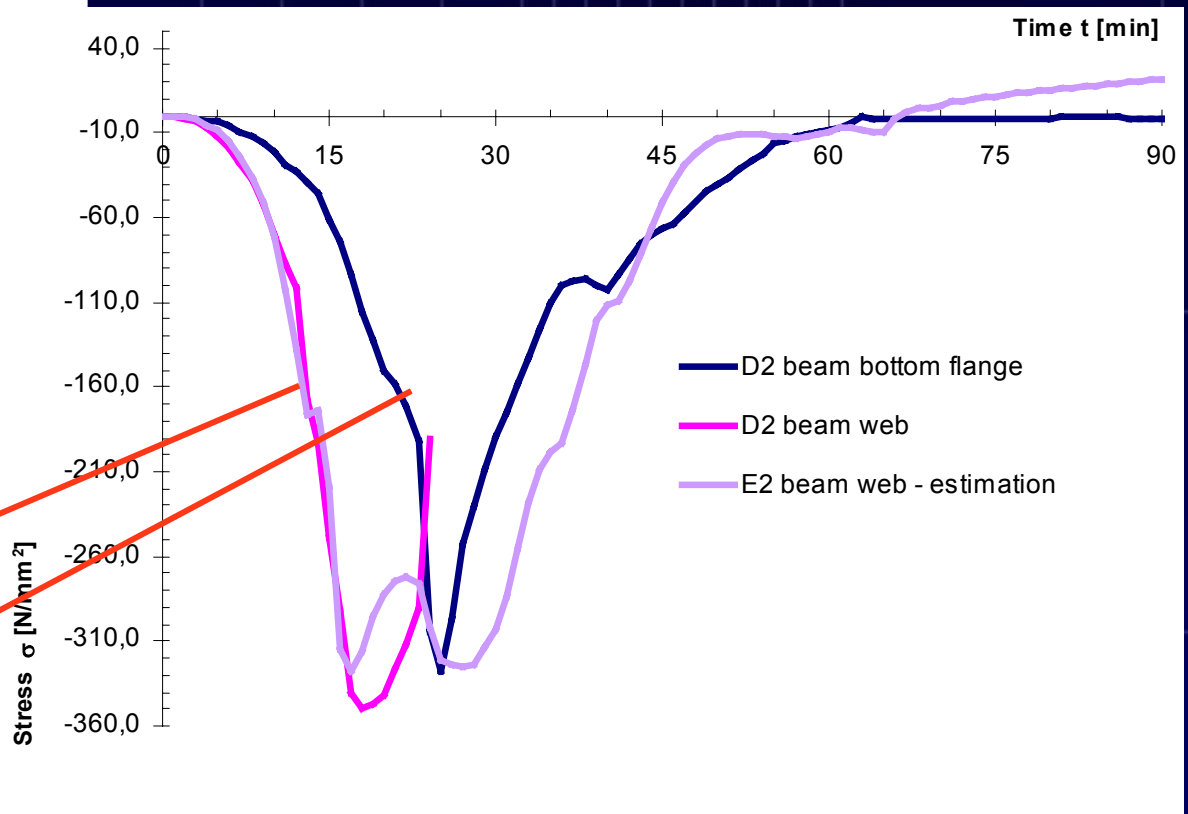




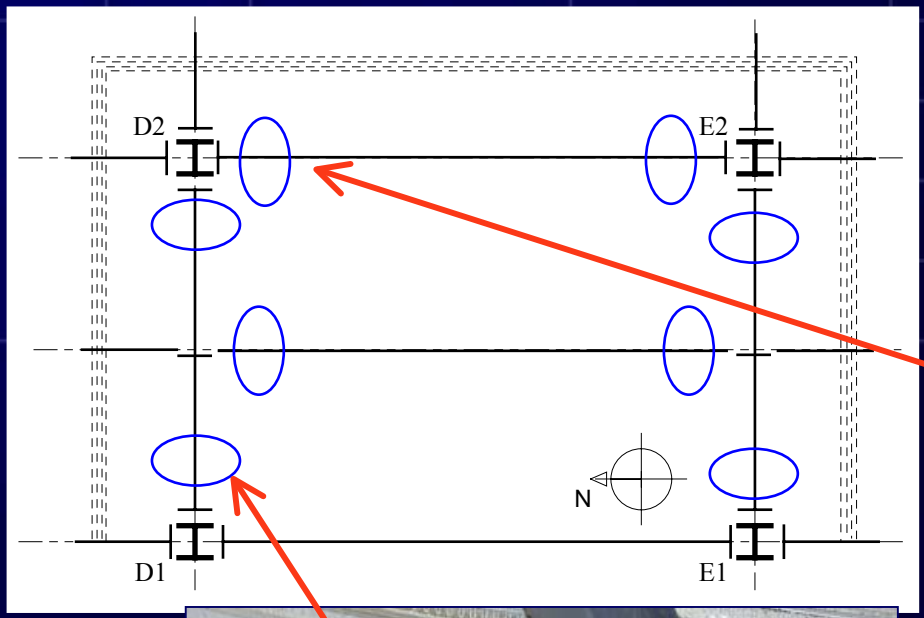
Header Plate Strain Gagues



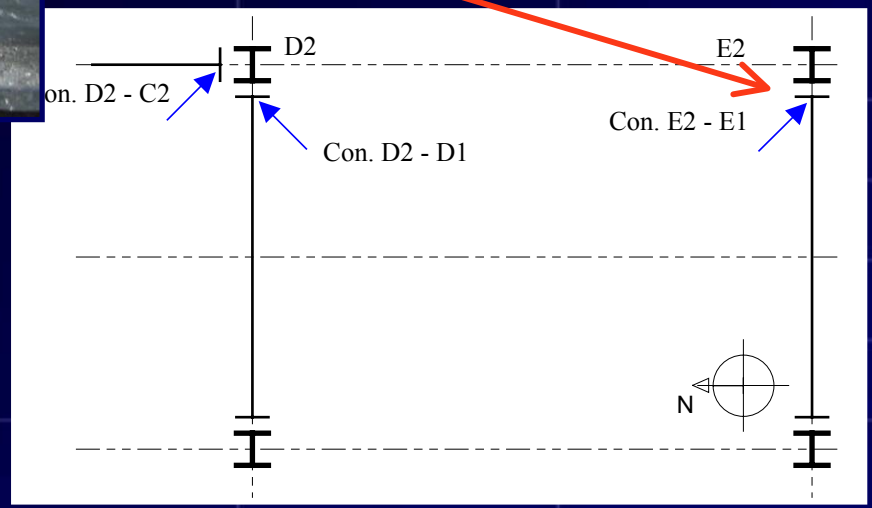




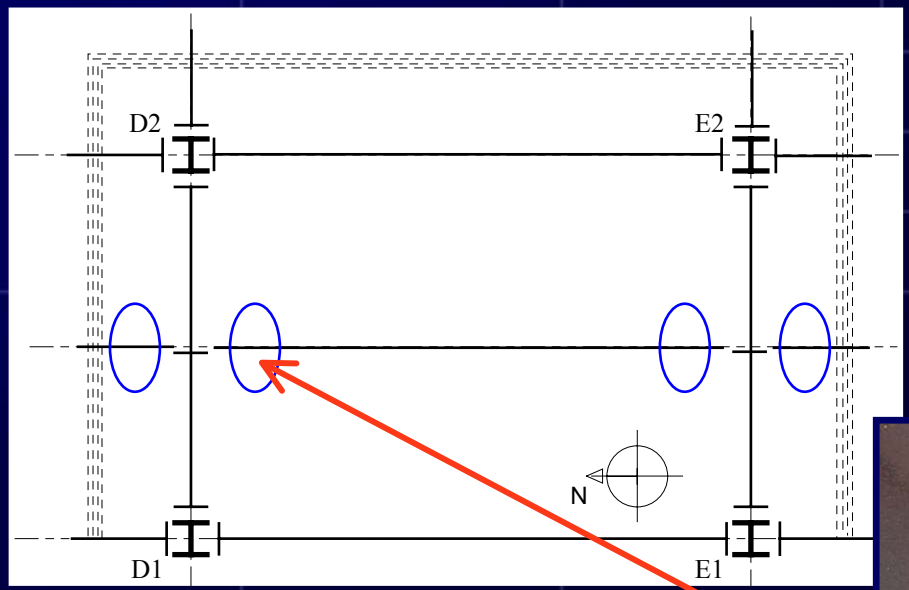
Local Buckling of Beam Lower Flanges



Fracture of End-Plates

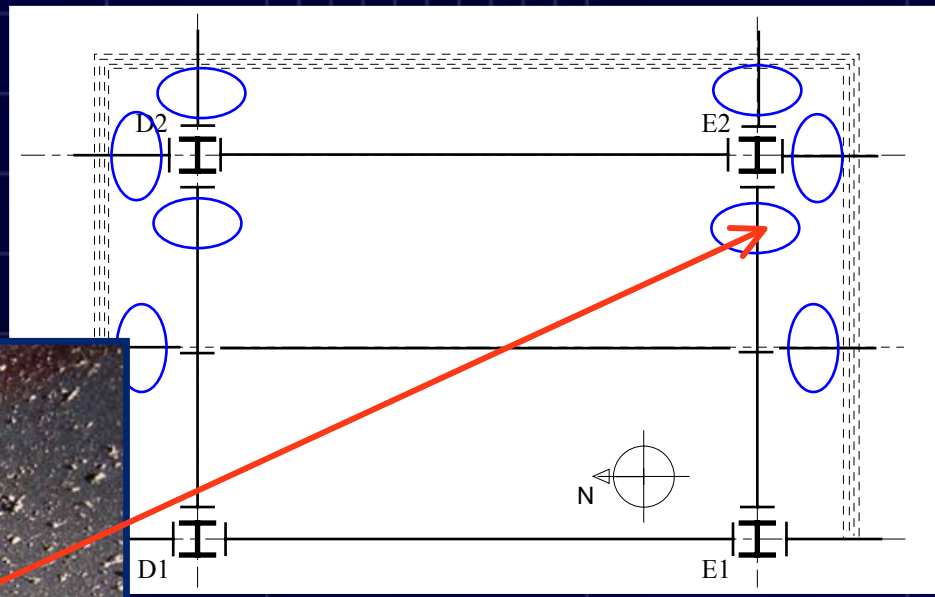


Ovalization of holes in the web beam in the fin plate joints



Column Flange Buckling

Beam Web Shear Zones



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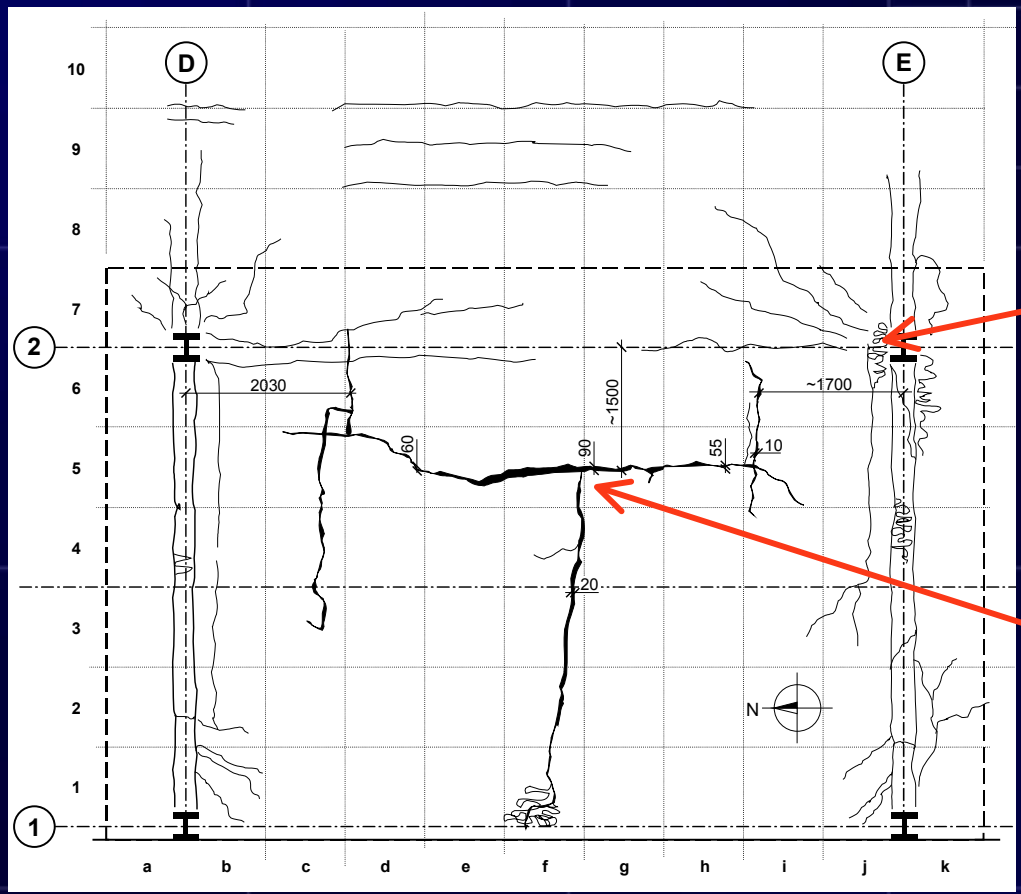
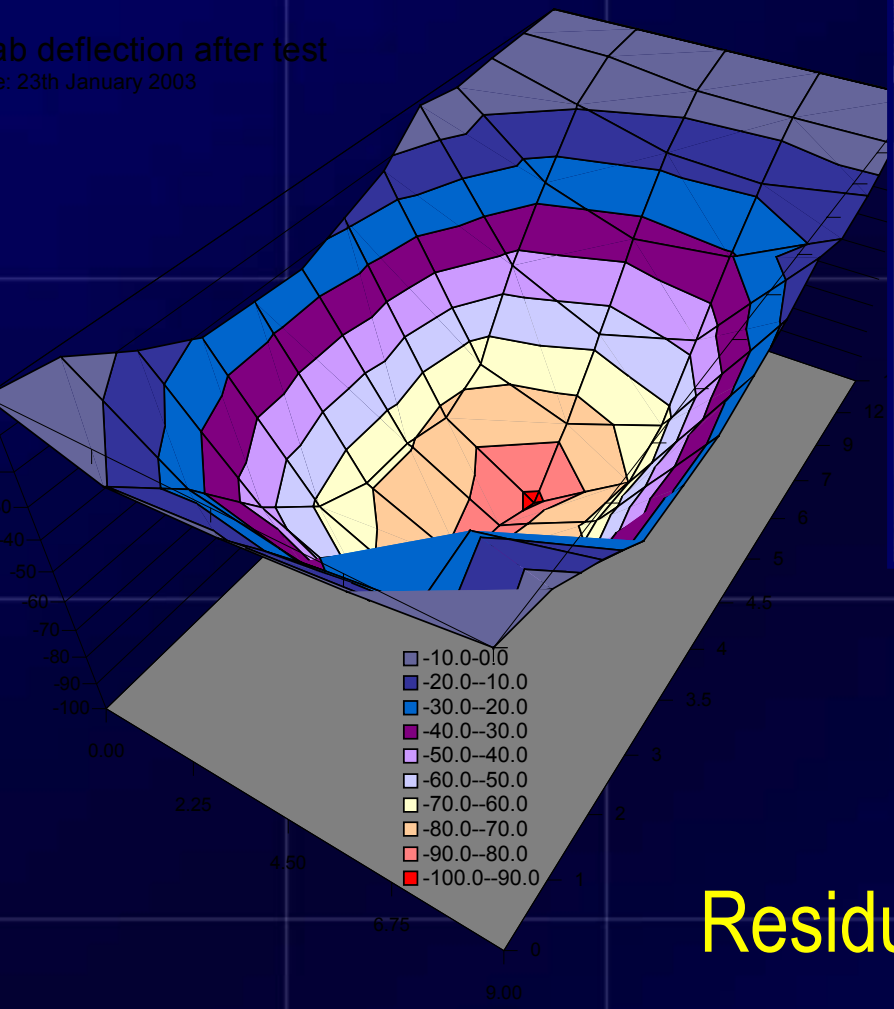
Concrete slab cracking



Concrete slab deformation



Residual deformation max 925 mm

Conclusions

- Fracture of end plates
- Elongation of holes in fin plates
- Integrity of composite slab
- Collapse of structure not reached
  - Mechanical load 56%
  - Fire load 40 kg/m^2


Thank you for your attention