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Use of air curtains on acclimatized commercial establishments – critical analysis

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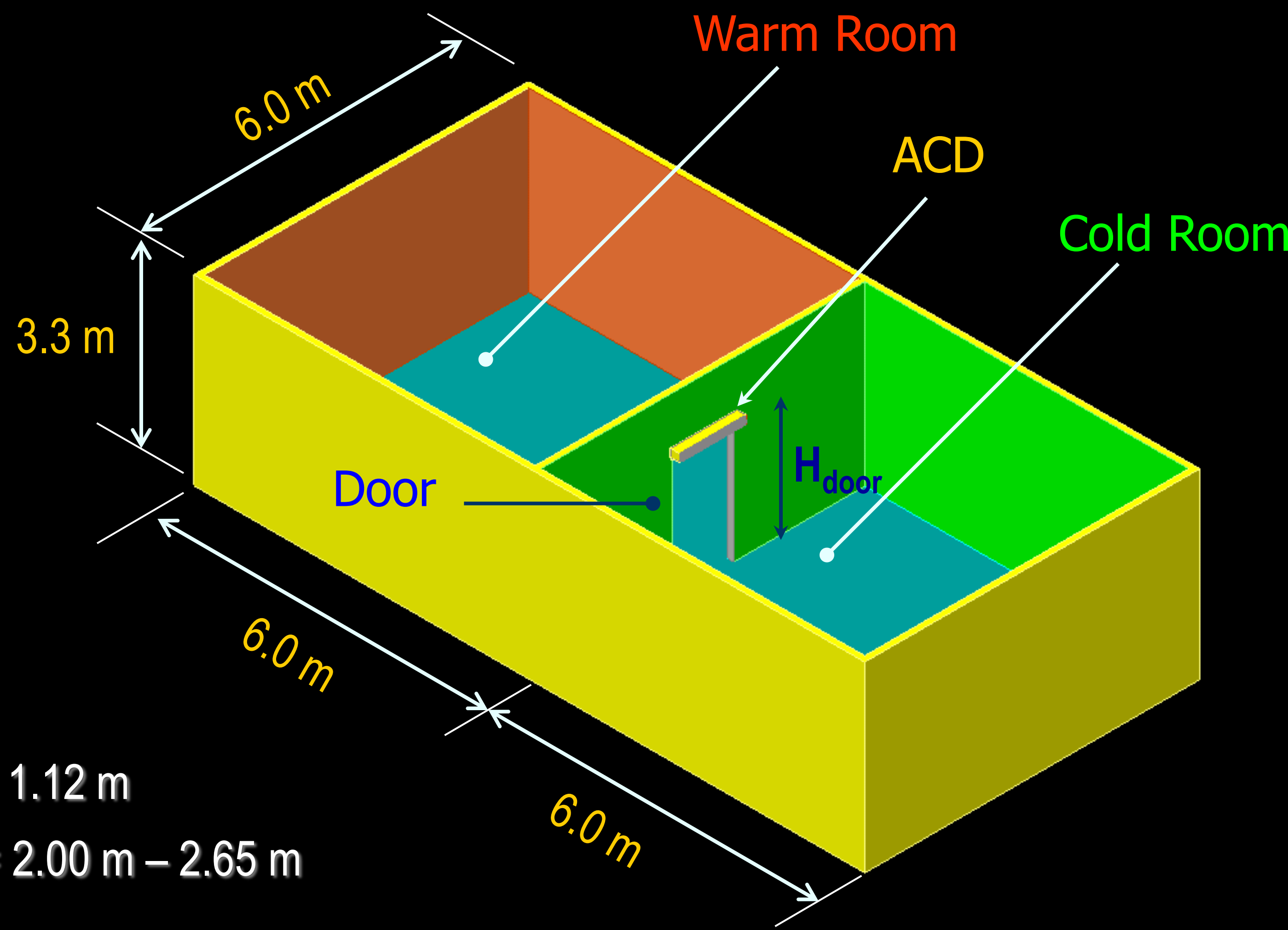
1. MAIN OBJECTIVES

- Experimental study of the flow originated by a plane, non-recirculating, vertical downward Air Curtain Device (ACD) acting as a thermal barrier between a comfortable room and a warmer outside environment:
  - to develop and test suitable methods to evaluate ACD performances;
  - to identify and optimize the most relevant parameters in the ACD efficiency and investigate their effects;
  - to establish mounting and operation guidelines for ACD's.

- In the next slides we will present:
  - examples of the influence of some geometric and dynamic parameters on sealing efficiency;
  - the energy and finance savings accomplished with the use of this kind of device as a mean to fence open public acclimatized spaces;
  - the results of some technical inspections conducted in commercial establishments that use this kind of solution.

2. EXPERIMENTAL SETUP

2.1 STUDIED GEOMETRY

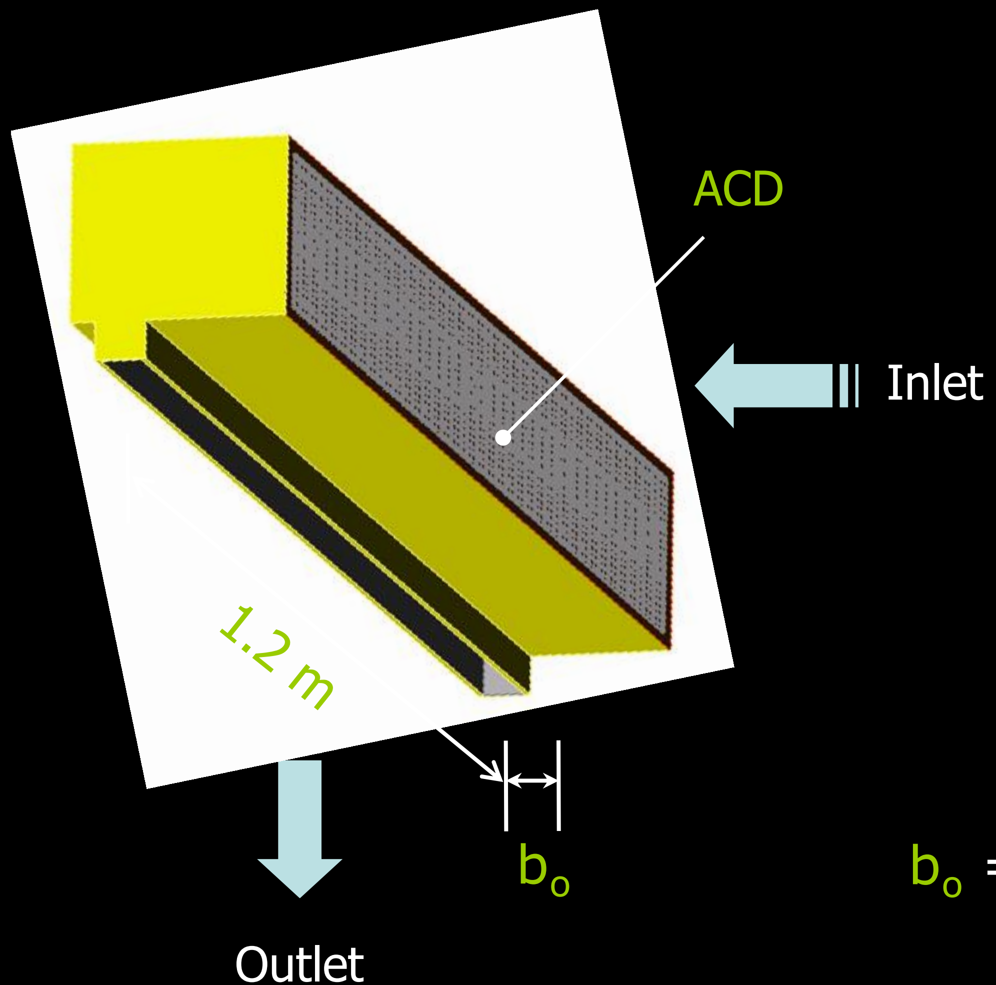


L_{door} = 1.12 m

H_{door} = 2.00 m – 2.65 m

2. EXPERIMENTAL SETUP

2.2 AIR CURTAIN DEVICE GEOMETRY



$b_o = 0.04$ m

2. EXPERIMENTAL SETUP

2.3 MAIN PARAMETERS

U_o	0 m/s – 7.8 m/s
H_{door}	2.10 m, 2.25 m, 2.40 m, 2.65 m
$H_{ACD} - H_{door}$	0.00 m, 0.15 m
α_o	-20º, -10º, 0º, +10º, +15º, +20º
ΔT	-10 ºC, 0 ºC, +5 ºC, +10 ºC, +15 ºC
Conf.	ISOT (20/20)
	AVAC (20/25, 20/30, 20/35)

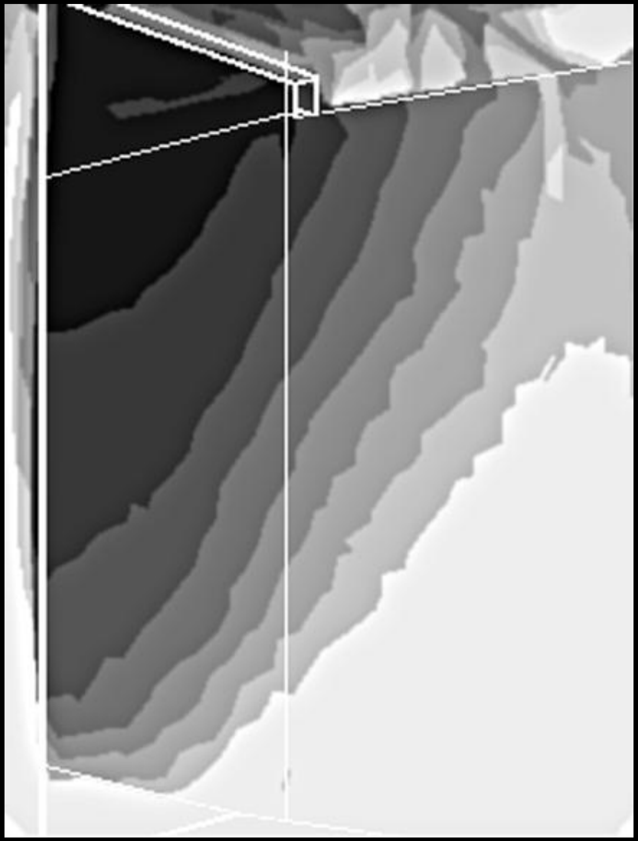
3. MEASURING TECHNIQUES

- Three different (but complementary) experimental techniques were used in this work:
  - Low Velocity Thermal Anemometer Probes
    - Temperature and Air Velocity field surveys *(point measuring technique)*
    - Detection of the impact point of the jet on the floor
  - Tracer Gas Techniques
    - Information about the gaseous exchanges between the two compartments
  - Infrared Thermographic Camera
    - Visualization of the airflow pattern in the whole near-zone of the air jet *(whole-field technique)*

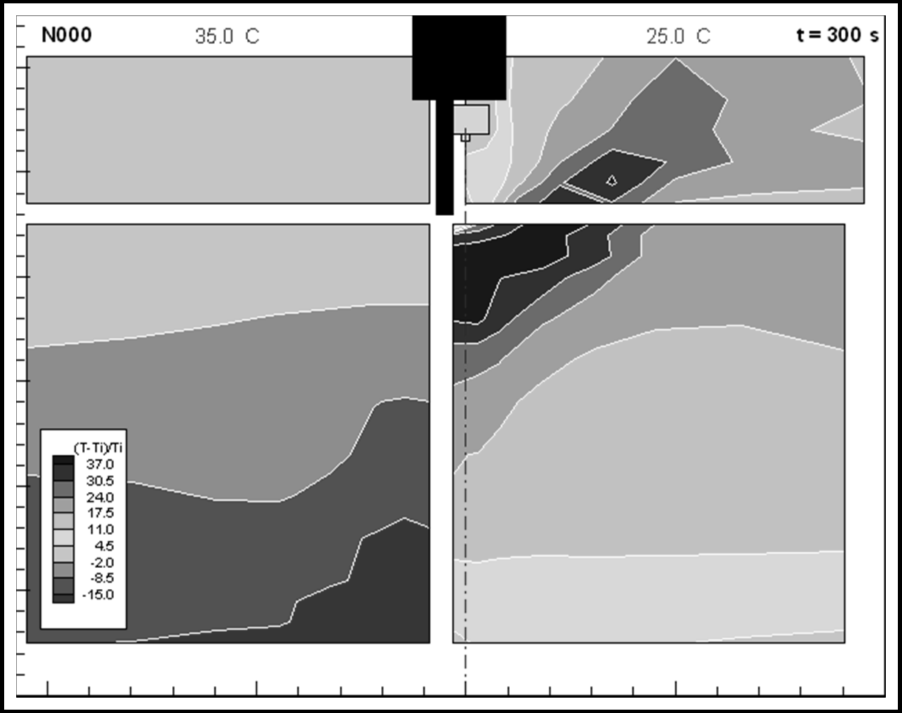
4. EXPERIMENTAL RESULTS

4.1 Reference case (ACD switched off)

H_{door} = 2.25 m , ΔT = 10 ºC
U_0 = 0.0 m/s



Infrared image
(whole field measuring technique)

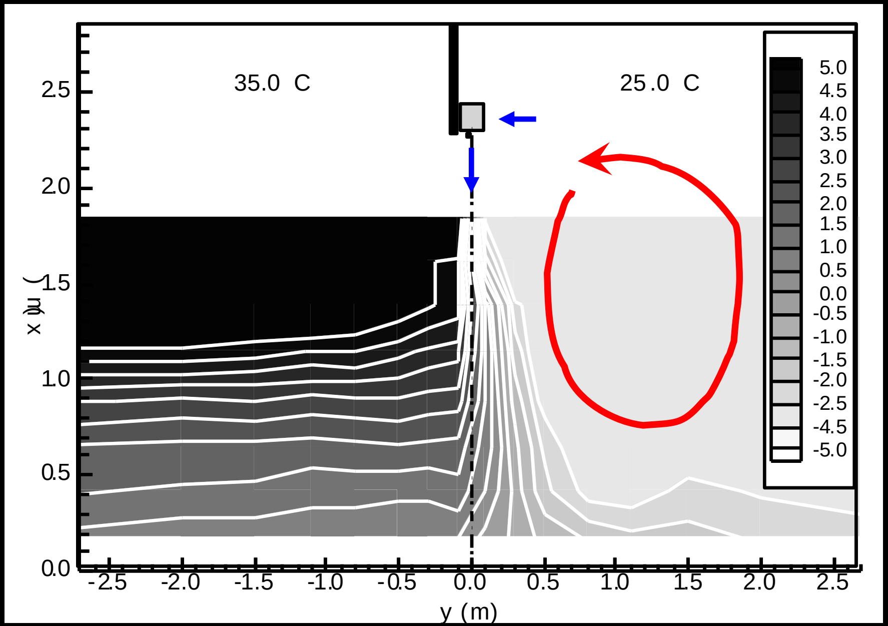


Flow field mapping with probes
(point measuring technique)

4. EXPERIMENTAL RESULTS

4.2 Non-recirculating ACD behavior

H_{door} = 2.10 m , ΔT = 10 ºC
$U_0 \approx 5.0$ m/s



Flow field mapping with probes

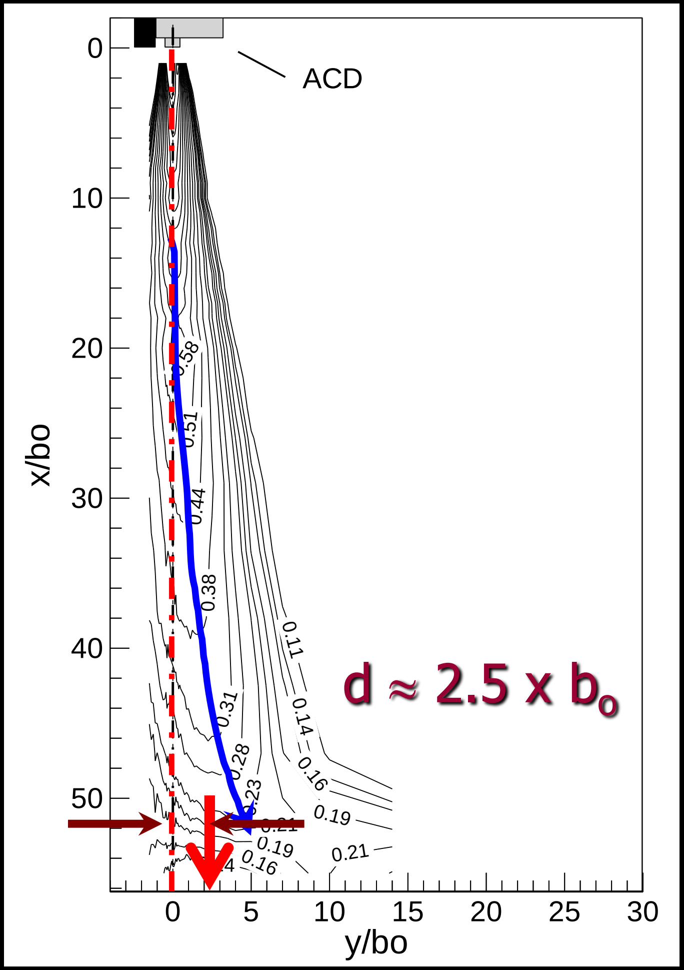
IR thermographic picture

- Deflection of the jet into the direction of the compartment where ACD is located;
- Air that was originally entrained from the other room spills back into it again at the floor;

4. EXPERIMENTAL RESULTS

4.2 Non-recirculating ACD behavior

H_{door} = 2.25 m , $U_0 \approx$ 5.0 m/s
ΔT = 0 ºC

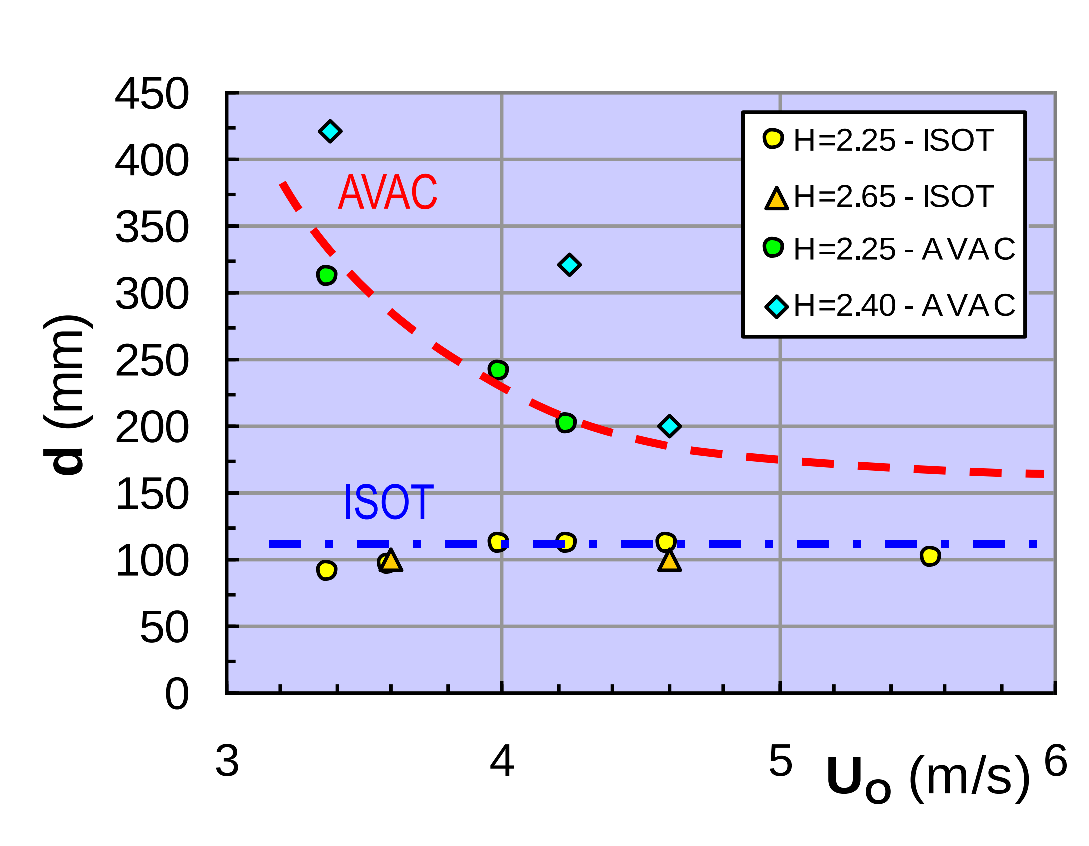


Iso-contours of U/U_0 for isothermal flow

- Tendency of the jet to curve in the direction of the inner compartment.
- Impact point of the jet on the ground is also moved to the inner side.

4. EXPERIMENTAL RESULTS

4.3 Location of the impact point on the floor, d



4. EXPERIMENTAL RESULTS

4.4 Jet initial velocity effect, U_0

H_{ACD} = 2.65 m , ΔT = 10 ºC
H_{door} = 2.25 m

U_0 = 3.4 m/s

Initial jet velocity is too weak:

- Jet "break's", don't reaching the ground
- Null sealing effect
- Air renewal rate in the "cold room" is 25% higher to the one collected in a situation where the air curtain is switched off !!!

4. EXPERIMENTAL RESULTS

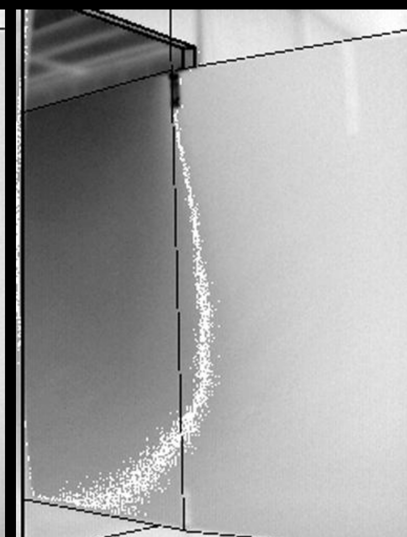
4.4 Jet initial velocity effect, U_0

H_{ACD} = 2.65 m , ΔT = 10 ºC

H_{door} = 2.25 m

U_0 = 3.4 m/s

U_0 = 5.1 m/s



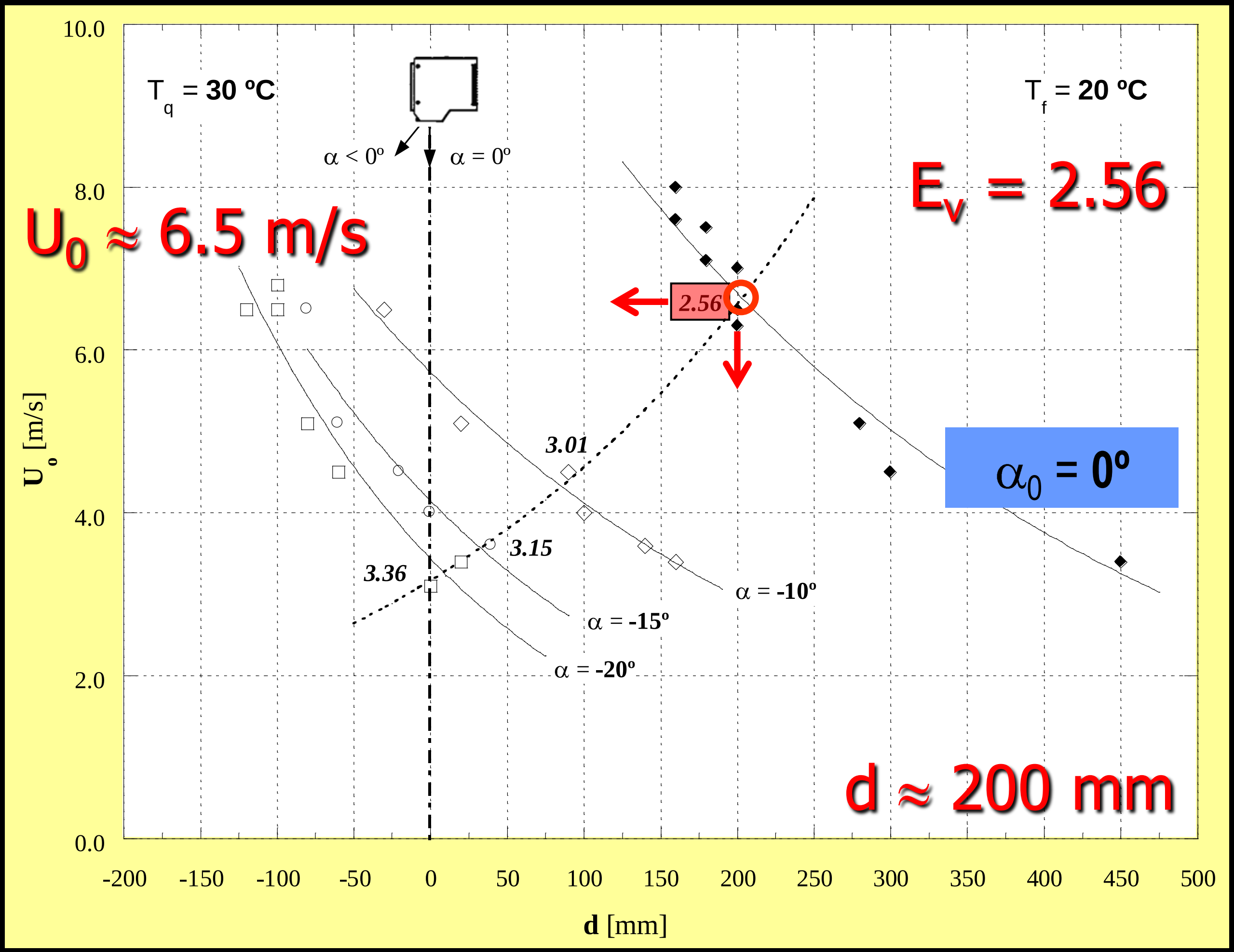
U_0 = 6.5 m/s

U_0 = 8.0 m/s

4. EXPERIMENTAL RESULTS

4.5 Jet initial angle effect, α_0

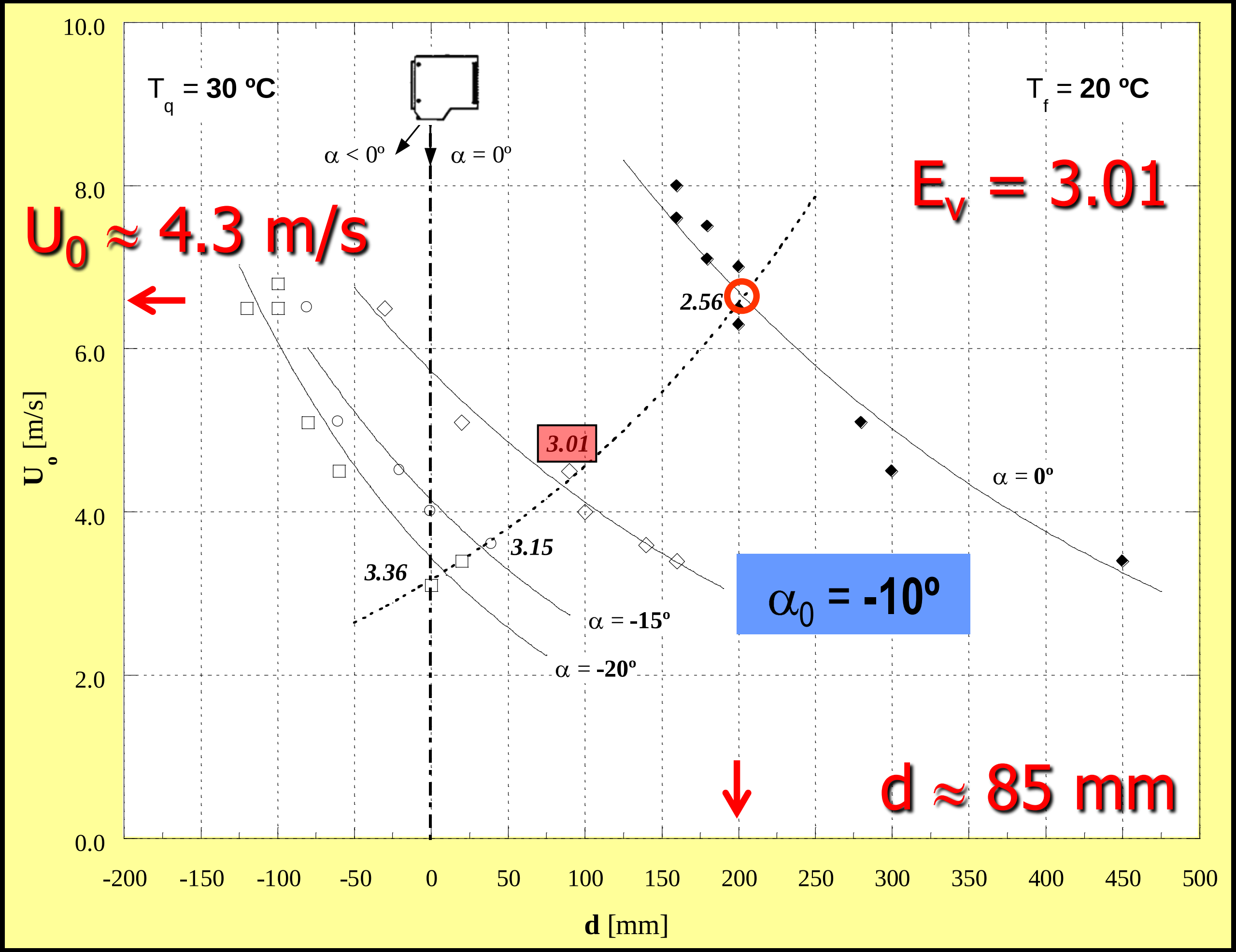
$H_{door} = 2.25$ m , $\Delta T = 10$ ºC



4. EXPERIMENTAL RESULTS

4.5 Jet initial angle effect, α_0

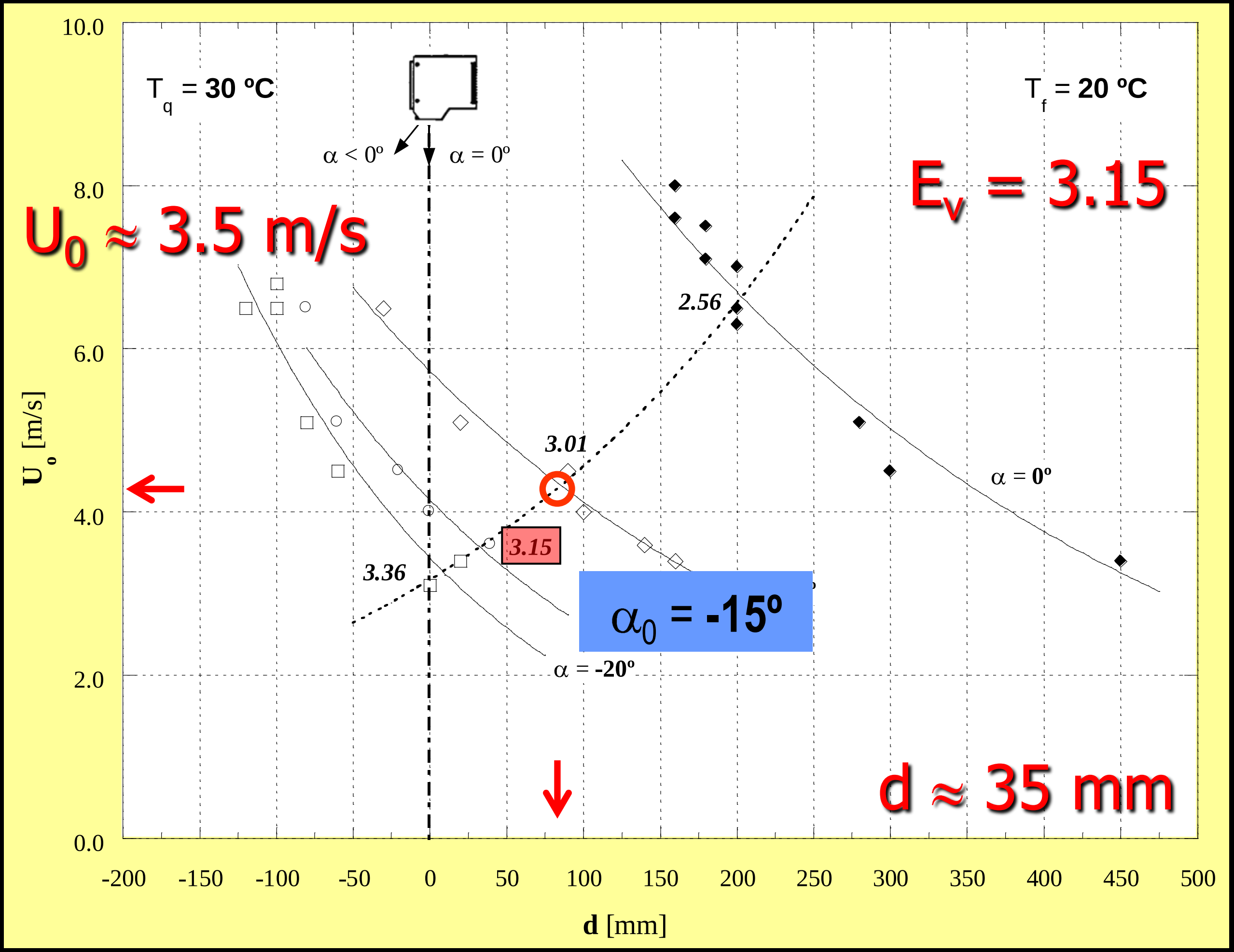
H_{door} = 2.25 m , ΔT = 10 ºC



4. EXPERIMENTAL RESULTS

4.5 Jet initial angle effect, α_0

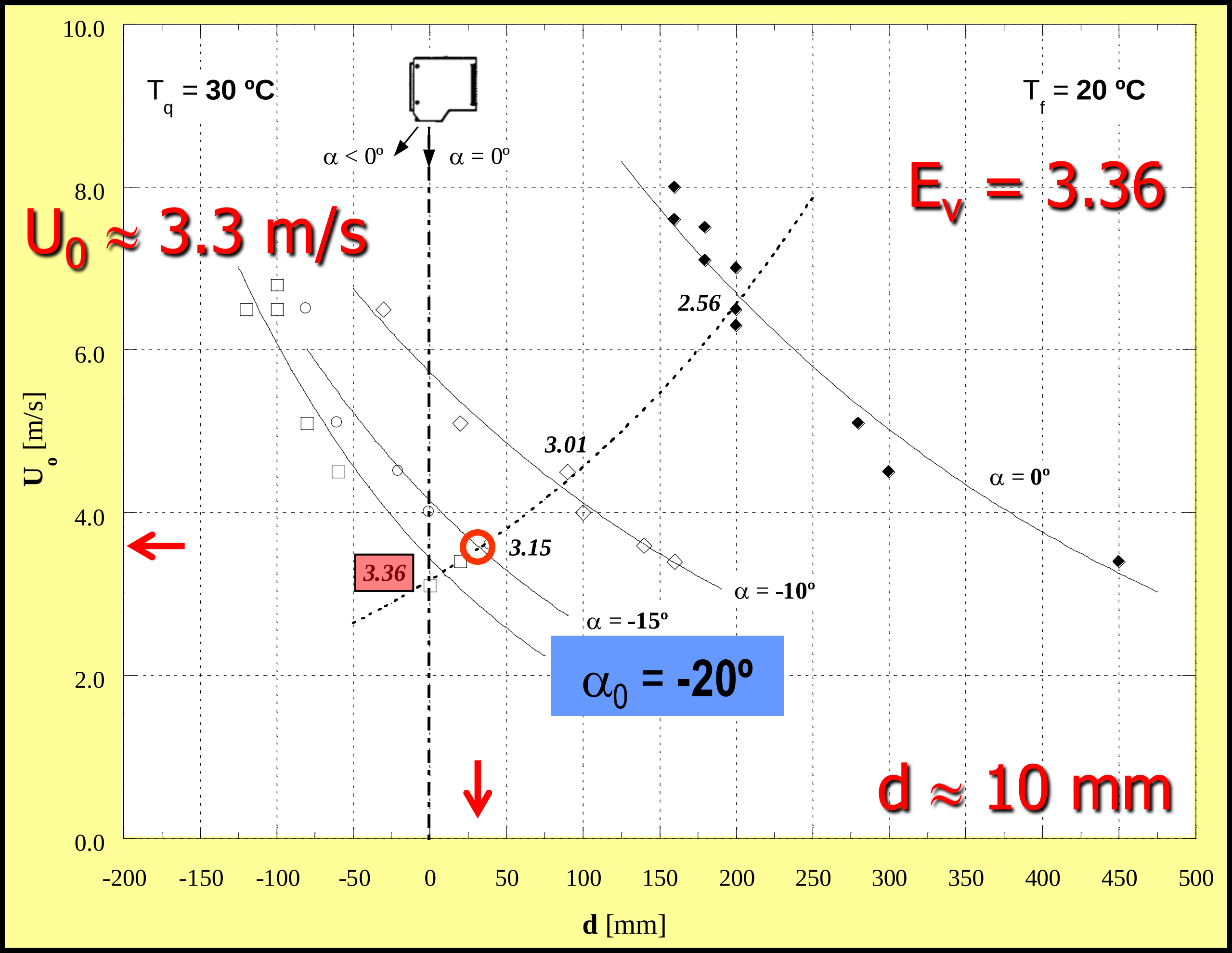
$H_{door} = 2.25$ m , $\Delta T = 10$ ºC



4. EXPERIMENTAL RESULTS

4.5 Jet initial angle effect, α_0

H_{door} = 2.25 m , ΔT = 10 ºC



4. EXPERIMENTAL RESULTS

4.5 Jet initial angle effect, α_0

Tilting the jet into the side of the warm room:

- ✓ Reduces significantly the distance d of the impact point to the door;
- ✓ The sealing efficiency E_v reaches higher values;
- ✓ The maximum sealing efficiency E_v is got for lower initial velocities of the jet U_0;

5. ENERGY AND FINANCIAL SAVINGS

5.1 Thermal energy transfered through the door

“Energy costs” ratio

$$\frac{\dot{Q}_j + \dot{Q}_{motor\ cortina}}{\dot{Q}_0} \times 100$$

Electric power of the air curtain motor, [W]

$$\dot{Q}_{motor\ cortina} = 120\ W$$

Sensitive heat losses through a open and unprotected door, [W]

$$\dot{Q}_0 = F_c \cdot A \cdot c_p \cdot (t_e - t_i) \cdot \rho_i \cdot \left(1 - \frac{\rho_e}{\rho_i}\right)^{0.5} \cdot (g \cdot H)^{0.5} \cdot \left(\frac{2}{1 + (\rho_i / \rho_e)^{1/3}}\right)^{1.5}$$

Sensitive heat losses through a door protected by an air curtain, [W]

$$\dot{Q}_j = \rho_i \cdot \left(\frac{n \cdot V_{sala}}{3600}\right) \cdot c_p \cdot (T_Q - T_F)$$

$$E_v = \frac{n_0}{n_j} = \frac{\dot{Q}_0}{\dot{Q}_j} \rightarrow \dot{Q}_j = \frac{\dot{Q}_0}{E_v}$$

5. ENERGY AND FINANCIAL SAVINGS

5.2 Energetic savings

H_{door} = 2.65 m , **ΔT = 10 ºC**

	U_0 [m/s] (**Ev**)				
	0.0 (1.0)	3.4 (1.5)	4.5 (3.5)	5.1 (3.1)	6.5 (3.0)
Q [W]	7 280	4 853	2 080	2 333	2 435
$Q_{ACD\ motor}$ [W]	–	120	120	120	120
Q_{Total} [W]	**7 280**	4 973	2 200	2 453	2 555
[%]	**100%**	68%	30%	34%	35%

5. ENERGY AND FINANCIAL SAVINGS

5.3 Financial savings

H_{door} = 2.65 m , **ΔT = 10 ºC**

$$\frac{\dot{Q}_0 - \dot{Q}_j}{COP} \times €/kWh$$

$$\frac{7280 - 2080}{2.9} \times 0.1$$

- 1 working hour:
  - Energetic savings – 0.180 €/hour
  - Motor consumption + 0.012 €/hour

  TOTAL **– 0.167 €/hour**

- Type: Open Public Acclimatized Space
- Working period: 8 hours/day & 22 days/month
- ACD acquisition/installation: 160 € → *Payback* ≈ **5 months !**

6. REAL USE OF AIR CURTAIN DEVICES

6.1 Technical inspections

- Technical inspections conducted in commercial establishments in order to assess the real working conditions of Air Curtains devices:
  - **36** technical inspections:
    - → Without deficiencies = **4**
    - → With deficiencies = **32**
      - ✘ Bad Air Curtain device selection
      - ✘ Incorrect instalation of the ACD
      - ✘ Inadequate selection of the initial jet velocity
      - ✘ Impossibility to alter the jet's discharge angle
      - ✘ Existence of "obstacles" very near of the door to fence
      - ✘ Lack of regular cleaning of inlet and outlets grids and other components

6. REAL USE OF AIR CURTAIN DEVICES

6.2 Some detected deficiencies and/or insufficiencies

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7. CONCLUSIONS

This study demonstrates:

- The sealing efficiency can be maximized when the velocity and the discharge angle of the air curtain are thoughtfully selected regarding the door height and the existing temperature difference;

- Although this type of adjustment may lead to considerable energy and financial savings, the reality has shown that most of the times those factors aren't taken in consideration regarding the selection, installation and working conditions of this type of equipment.