CRITICAL ELEMENTS FOR CORRECT CLIMATE CONTROL DESIGN FOR ELECTRICAL PANELS

Internal and external adduction coefficient calculation

The "Electrical cabinet thermal balance" WHITE PAPER discussed thermal transmittance and the formula used to calculate them. The formula components that deserve greater attention are the internal α_{in} and external α_{out} adduction thermal exchange. The numerical values of the latter can be read from the table shown in the previous WHITE PAPER, or calculated according to the **UNI EN ISO 6946** 6946standard as explained below.

The **adduction coefficients** α include thermal exchanges that take place both by convection and by radiation and are determined by the formula:

$\alpha = \alpha_{conv} + \alpha_{irr}$

1 - Radiative coefficient

$h_r = \varepsilon^* h_{r0}$ (real radiative coefficient)

$h_{r0} = 4\sigma T_m^3$ (black body radiative coefficient)

Where:

- ε it is the superficial emissivity and depends on the type of surface considered;

- σ is the Stefan-Boltzmann constant and equal to 5,67*10^(-8) W/m2K4 ;

- T_m is called "thermodynamic temperature" defined, as the function derived from internal energy **U** compared to entropy **S** constant volume **V**.

U=U(S,V,M) ; **S=S(U,V,M)**.

Considering constant mass **M**, the variations of **U** and **S** are independent of this parameter.

We can now define the formula for calculating the **thermodynamic temperature**:

$$Tm = \left(\frac{\partial U}{\partial S}\right)_{(V=cost)}$$

- h_{r0} , **black body radiative coefficient,** temperature-dependent and have tabular values shown in the following table:

T[°C]	h_{ro} [w/m²K]
-10	4,1
0	4,6
10	5,1
20	5,7
30	6,3

1 - Black body radiative coefficients h_{r0} according to temperature

The **surface emissivity ε** referred to the electrical cabinet walls must be know to calculate h_r.

In this case the structural materials of the electrical cabinets are considered to determine the values of ε:

A. Mild steel (sheet metal): **ε_A= 0,07**;

B. Plastic: **ε_B= 0,84**;

C. Stainless steel: **ε_C = 0,07**;

D. Aluminium: **ε_D = 0,89**;

E. PE (polyethylene): **ε_E =0,84**;

F. Paint on steel: **ε_F =0.265** (cabinet interior and exterior).

After calculating **h_{r0}**, **h_{ri}** and **h_{re}** are found by applying the formula **$h_r = \varepsilon * h_{r0}$** .

2 - Convective coefficients

The type of climate control (heating or cooling) requires different convective coefficients, because they depend on the air speed on the surfaces. For the definition of these coefficients we distinguish two cases:

-heating designs, for which the air is almost still in the electrical cabinet and therefore low values of the convection coefficients are to be assumed;

- cooling designs, for which the air is moved in the electrical cabinet and therefore it is appropriate to assume higher values for the convective coefficients.

The two solutions concern thermal exchanges, which however depend on air motions governed by different laws. In heating, emitted heat dominates the convective flows inside the cabinet because the solutions are or are almost “mechanically motionless”. In contrast, fans are integrated in almost every cooling system which makes convection air flow-dependent.

a) Heating designs for which convection is due to thermal power alone.
In this case, reference is made to the values in the following table:

HEAT FLOW DIRECTION	COEFF. CONV. INTERNAL h_{ci}[W/m²K]
ASCENDING	5
DESCENDING	0,7
HORIZONTAL	2,5

2 - Internal convective coefficients hci referred to the direction of heat flow

The heat flow is dominated by thermal temperature gradient and is directed from warmer areas to colder ones.

b) Areas where wind speed is relevant (electrical cabinet interior or exterior with high ventilation flows.

The following formula can be applied to calculate the convective coefficient:

$hc=4+4v$

*v = wind speed [m/s]

For the electrical cabinet interior, when using a fan filter or a running TCU, since both have a fan, you can hypothesize v of about **0.5m/s**.

Three reference cases were identified for the electrical cabinet exterior:

1) **Outdoor without wind or indoor**: low speed but not null, established around **1.1m/s**;

2) **Outdoor with weak wind**: speed around **4m/s**;

3) **Outdoor with strong wind**: speed around **8.6m/s**.

Using these inputs in an Excel thermal balance software, the coefficients were verified with laboratory tests.

From the radiative h_r and convective h_c values obtained, adduction coefficients are calculated:

$\alpha_i = h_{ci} + h_{ri}$ *Referred to the electrical cabinet interior

$\alpha_e = h_{ce} + h_{re}$ *Referred to the electrical cabinet exterior

In some cases examined in particular, fixed values were assigned to these coefficients, specifically:

- α_i=8.3W/m2K(Heating designs);
- α_i=10.5W/m2K(Cooling designs);
- α_e=13W/m2K(Outdoor without wind or indoor);
- α_e=24.8W/m2K(Outdoor with weak wind);
- α_e=43W/m2K(Outdoor with strong wind).

After calculating the values of α_i, R_{tot}, α_e, the cabinet wall transmittance U can be calculated with the following formula:

$U=1/(1/1in + s1/\lambda 1 + s2/\lambda 2 + ... sn/\lambda n + 1/\alpha out)$ [W/m²K].

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