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Energy losses by industrial door

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Energy losses by industrial door

Perte d'énergie par les portes industrielles

Energieverluste durch Industrietore

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Foreword

This document (CEN/TR 16676:2014) has been prepared by Technical Committee CEN/TC 33 “Doors, windows, shutters, building hardware and curtain walling”, the secretariat of which is held by AFNOR.

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Introduction

The calculation method in EN 12428 gives a U-value in W/m^2 · K for thermal resistance of an industrial door used for access of vehicles accompanied by pedestrians.

With a view to energy efficiency (energy saving) it should be remembered, however, that this performance is only achieved when the door is closed.

In practice the evidence shows that doors are left open for longer periods than is perhaps necessary or acceptable. Therefore, it is difficult to see how reducing U-values can improve energy efficiency without radical changes in work place practices or operation mode of the door.

In keeping with the whole building approach mandated by the EPBD[1)] building designers should be working on a whole building principle rather than an elemental basis which results in a beneficial evaluation of those factors in the construction of the building envelope that contribute significantly to energy conservation in the buildings use.

Therefore, it is important that building designers and specification writers should seek to:

- set achievable values for products calculated in accordance with EN 13241-1;
- consider awareness of the classification possibilities and the availability and need to implement appropriate technologies;
- consider specifying improved power operated doors specification including appropriate control systems;
- consider changes to supporting constructions (e.g. lobbies, screens);
- consider the use of double doors (e.g. insulated external doors, rapid acting internal doors for operational use).

There is a common misconception that energy conservation is best achieved (only) through U-value improvements.

Due to the nonlinear shape of the U-value/thickness graph there is a danger of achieving diminishing returns from additional thickness of doors. Up to the present time, for the U-values commonly specified for construction in the EU, there has been an approximately linear relationship but as the move to seek lower U-values continues this is no longer the case.

Concern has been expressed that much of this good work is wasted as long as the practice of leaving doors open for unnecessarily long periods prevails.

Therefore, a study with a simplified calculation basis has been undertaken by CEN/TC 33/WG 5 relating to the energy losses through doors. This Technical Report does not replace the requirements of EN 13241-1 regarding EN 12428.

For the purpose of this Technical Report the term “door” and/or “doorset” is used as a general term for “industrial door”.

[1)] Energy Performance of Buildings Directive (Directive 2002/91/EC).

1 Scope

This Technical Report gives simplified calculation relating to the energy losses through doors taking into account:

- heat transmission with closed door by temperature difference,
- air leakage through a closed door due to wind,
- air leakage through a closed door due to a chimney effect, and
- air infiltration with a door open (due to wind).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12428, *Industrial, commercial and garage doors - Thermal transmittance - Requirements for the calculation*

EN 13241-1, *Industrial, commercial and garage doors and gates - Product standard - Part 1: Products without fire resistance or smoke control characteristics*

3 Simplified calculation basis

3.1 Heat transmission with closed door by temperature difference

- Heat transmission coefficient U in W/m$^2 \cdot$ K is measured by notified bodies and calculated per door configuration (according to EN 13241-1).
- Outside temperature is taken out of Table 1.
- Heat transmission is then calculated with:

$$H_\mathrm{t} = A \cdot U \cdot (T_\mathrm{i} - T_\mathrm{o})$$

where

H_t is the power losses by heat transmission, in watts (W);

A is the area of exposed surface, in square metres (m^2);

T_i is the inside air temperature, in Celsius (°C);

T_o is the outside air temperature, in Celsius (°C).

- Energy losses per year will be calculated with:

$$E_\mathrm{t} = \frac{h \cdot C_\mathrm{h} \cdot H_\mathrm{t}}{1000}$$

where

E_t is the energy losses per year by heat transmission, in kilogram watts per hour (kWh);

h is the time per day exposed to $\Delta T = (T_i - T_o)$ (hours = heating hours);

C_h is the amount of heating days per year, meaning inside temperature above outside temperature.

3.2 Air leakage with closed door by wind

- Connection between pressure difference P (P_a (N/m^2)) and air leakage in m^3/m$^2 \cdot$ h$_r$ is measured by notified bodies and put in a graphic.
- Wind speed is taken out of Table 1.
- Wind pressure on door is calculated with:

$$P = \frac{1}{2} \cdot v^2 \cdot \rho$$

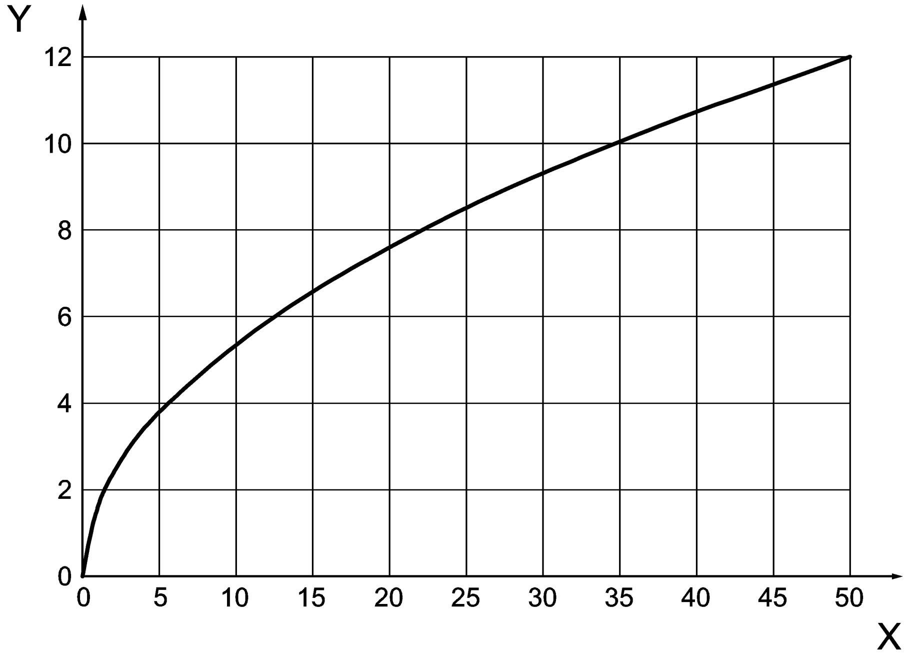
where

P is the wind pressure, in newtons per square metre (N/m^2);

v is the wind speed, in metres per second (m/s);

ρ is the density of air, in 1,293 kilograms per cubic metre (kg/m^3).

- With this wind pressure the air leakage is taken out of Figure 1.



Key

X pressure difference P (P_a (N/m^2))

Y leakage in m^3/m$^2 \cdot$ h

Figure 1 — Air leakage

- Air volume flow by wind pressure is calculated with:

$$Q_\mathrm{v} = \frac{\text{airleakage} \cdot A}{3\,600}$$

where

air leakage is in cubic metres/square metre × hour ($\mathrm{m^3/m^2 \cdot h}$);

Q_v is the air volume flow by wind pressure, in cubic metres/second ($\mathrm{m^3/s}$).

- Power losses by air leakage is calculated with:

$$H_\mathrm{v} = C_\mathrm{p} \cdot \rho \cdot Q_\mathrm{v} \cdot \left(T_\mathrm{i} - T_\mathrm{o}\right)$$

where

H_v is the power losses by air leakage, in W;

C_p is the specific heat capacity of air, in 1 007 J/kg · K).

- Energy losses per year will be calculated with:

$$E_\mathrm{v} = \frac{h \cdot C_\mathrm{h} \cdot C_\mathrm{w} \cdot H_\mathrm{v}}{1\,000}$$

where

E_v is the energy losses per year by air leakage, in (kWh);

C_w is corrected because of position of the door compared to wind direction.

3.3 Air leakage with closed door by chimney

Connection between pressure difference P (P_a in $\mathrm{N/m^2}$) and air leakage, in $\mathrm{m^3/m^2 \cdot h_r}$ measured by notified body and put in a graphic.

- Under pressure on inside of door because of chimney is calculated with:

$$P = \frac{9{,}81 \cdot \left(h - h_\mathrm{nph}\right) \cdot \rho \cdot \left(T_\mathrm{i} - T_\mathrm{o}\right)}{(T_\mathrm{o} + 273)^3}$$

where

P is the chimney pressure, in newtons per square metre ($\mathrm{N/m^2}$):

h is the height of interest (half of door height), in metres (m);

h_nph is the neutral pressure height in building (± half of inside building height), in metres (m).

- With this chimney pressure the leakage is taken out of Figure 1.
- Air volume flow by chimney is calculated with:

$$Q_\mathrm{v} = \frac{\mathrm{airleakage} \cdot A}{3\,600}$$

where

Q_v is the air volume flow by chimney, in m^3/s.

— Power losses by chimney is calculated with:

$$H_\mathrm{v} = C_\mathrm{p} \cdot \rho \cdot Q_\mathrm{v} \cdot (T_\mathrm{i} - T_\mathrm{o})$$

where

H_v is the power losses by chimney, in W.

— Energy losses per year will be calculated with:

$$E_\mathrm{v} = \frac{h \cdot C_\mathrm{h} \cdot H_\mathrm{v}}{1\,000}$$

where

E_v is the energy losses per year by chimney, in kWh.

3.4 Infiltration with door open (by wind)

— Wind speed is taken out of Figure 2.

— Air volume flow by infiltration is calculated with:

$$Q_\mathrm{i} = v \cdot A \cdot C$$

where

Q_i is the air volume flow by infiltration, in m^3/s;

C is the coefficient between 0,5 – 1 depending on building conditions.

Building without air leakage C = 0,5.

Air turbulence, which will affect this figure is not taken into consideration for this calculation method.

By a total open building C = 1.

The effect of building air leakage compared to the air flow through an open door is neglectable and is not taken into consideration for this calculation method.

— Total power flow out of the building is calculated with:

$$H_\mathrm{b} = C_\mathrm{p} \cdot \rho \cdot Q_\mathrm{i} \cdot (T_\mathrm{i} - T_\mathrm{o})$$

where

H_b is the total power flow out of the building, in W.

— Time needed to release the power out of the building is calculated with:

$$t_\mathrm{b} = \frac{V}{Q_\mathrm{i}}$$

where

t_b is the time needed to release the power out of the building, in s;

V is the volume of the building, in m^3.

— Building heater capacity is calculated with:

$$H_\mathrm{h} = F_\mathrm{h} \cdot V$$

where

H_h is the building heater capacity, in W;

F_h is the heater factor for industrial buildings, in W/m^3.

— The heater will be activated when the building temperature is decreased by 1 °C.

Time needed to activate the heater is calculated with:

$$t_\mathrm{h} = \frac{H_\mathrm{b} - H_\mathrm{b-1}}{H_\mathrm{b}} \cdot t_b$$

where

$H_\mathrm{b\text{-}1}$ is the total power (capacity) in the building by $T_{\mathrm{i\text{-}1}}$ °C.

$$\frac{H_\mathrm{b}}{H_\mathrm{b-1}} = \frac{T_\mathrm{i} - T_\mathrm{o}}{T_\mathrm{i-1} - T_\mathrm{o}} \text{ according to Figure 1}$$

$$t_\mathrm{h} = \left(\frac{H_\mathrm{b} - H_\mathrm{b} \cdot (T_\mathrm{i-1} - T_\mathrm{o})}{(T_\mathrm{i} - T_\mathrm{o}) \cdot H_\mathrm{b}}\right) \cdot t_b$$

$$T_\mathrm{h} = (1 - (\frac{(T_\mathrm{i-1} - T_\mathrm{o})}{T_\mathrm{i} - T_\mathrm{o}})) \cdot t_\mathrm{b}$$

where

t_h is the time needed to activate the heater, in s.

— Energy losses by infiltration is calculated with:

$$E_\mathrm{i} = E_\mathrm{b} + \square E_\mathrm{h}$$

$$E_\mathrm{i} = \frac{(H_\mathrm{b} \cdot t_\mathrm{b}) + (H_\mathrm{h} \cdot (t_\mathrm{c} - t_\mathrm{h})) \cdot n \cdot C_\mathrm{h} \cdot C_\mathrm{w}}{3\,600}$$

where

$t_b > t_c$ than $t_b = t_c$

and

$H_h > H_b$ than $H_h = H_b$

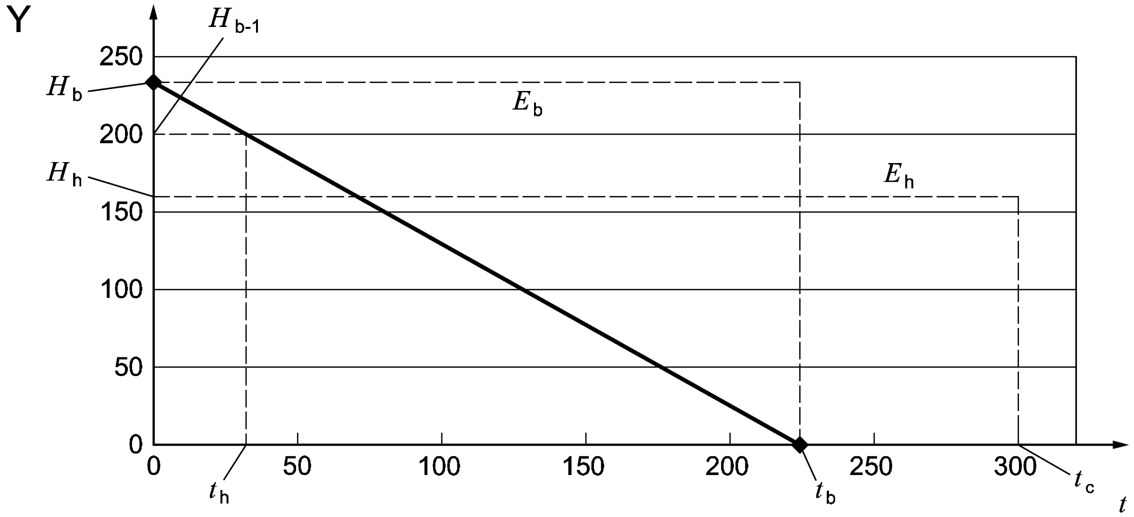
E is the amount of energy released out of the building, in kWh;

E_h is the amount of heater energy losses, in kWh;

E_i is the energy losses by infiltration, in kWh;

t_c is the door cycle time, in s;

n are the door cycles per day.



Key

X	time, in s
Y	capacity, in kW

Figure 2 — Infiltration (open door)

4 Results

4.1 General

To get an overview of the relationship between the different energy losses, a case has been calculated (simplified calculation) with the following values:

4.2 Local/metrological data[2)]

a) Building/door located in Paris, see Table 1;

b) door direction west-southwest, see Figure 3;

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2) Internet based metrological average values.

c) average air temperature in heating season T_o = 10 °C;

d) average wind speed in heating season 5,0 m/s;

e) correction due to position of door C_w = 34,7 %, see Table 2;

f) heating days C_h = 243 days.

4.3 Building/doors data (dimensions)

a) Building height 8 m;

b) volume V of the building 1 600 m^3, 8 000 m^3 and 16 000 m^3;

c) door sizes

  1) 3 m × 3 m,

  2) 4 m × 4 m;

d) door U-value = 1,5 W/m^2 · K;

e) air permeability Class 2 (12 m^3/m^2 · h);

f) heater capacity to calculation with 20 W/m^3.

4.4 Building data (intended use)

a) Temperature inside building T_i = 18 °C;

b) time door open per cycle t_c = 5 min;

c) door cycles per year n = 1 000;

d) working days per week = 5.

Table 1 — Metrological information of Paris (wind direction, speed, temperature)

Stats based on observations take between 7/2002–2/2009 daily from 7 am to 7 pm local time													
Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
	1	2	3	4	5	6	7	8	9	10	11	12	1–12
Average air temp. (°C)	6	6	9	13	17	21	22	21	18	14	9	6	**14**
Dominant wind direction	↑ ssw	↗ wsw	↗ wsw	↓ nne	↙ ene	↓ nne	→ w	↘ wnw	↓ nne	↑ ssw	↑ ssw	↑ ssw	
Wind probability > = 4 Beaufort (%)	39	34	47	32	34	22	31	27	28	32	28	36	**33**
Average wind speed													
in kts	11	10	11	9	9	9	9	9	9	9	9	10	**10**
in m/s	5,7	5,1	5,7	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	5,1	**5,0**

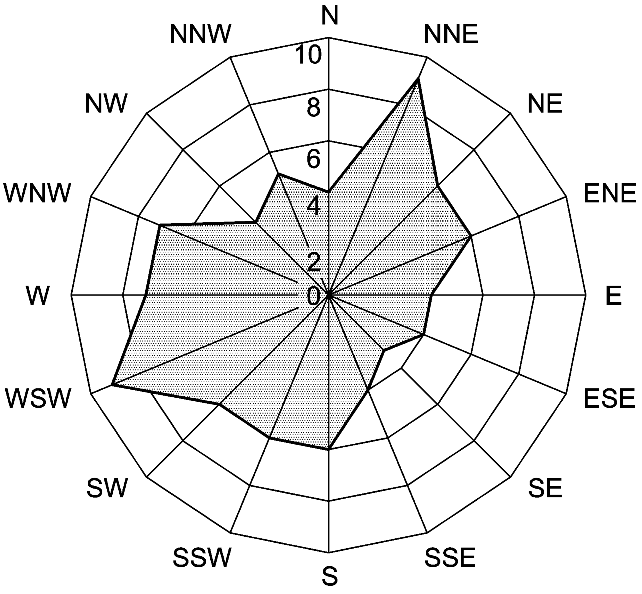

Figure 3 — Metrological information of Paris (wind rose diagram)

Table 2 — Correction due to position of door

West-South-West		% of direction	% correction	% of cor. direction
North	N	4	0	0
North-North-East	NNE	9	0	0
North-East	NE	6	0	0
East-North-East	ENE	6	0	0
East	E	4	0	0
East-South-East	ESE	4	0	0
South-East	SE	3	0	0
South-South-East	SSE	4	0	0
South	S	6	38,2	2,29
South-South-West	SSW	6	70,7	4,24
South-West	SW	6	97,6	5,86
West-South-West	WSW	9	100	9
West	W	7	97,6	6,83
West-North-West	WNW	7	70,7	4,95
North-West	NW	4	38,2	1,53
North-North-West	NNW	5	0	0
		90		34,7

5 Results for heat transmission

- U = 1,5 W/m^2 · K;
- Average air temperature for Paris in heating season is T_o = 10 °C;

$$H_t = A \cdot U \cdot (T_i - T_o) = A \cdot 1{,}5 \cdot (18 - 10)$$

where

A = 3 m × 3 m industrial doorset;

H_t = 108 W;

A = 4 m × 4 m industrial doorset;

H_t = 192 W.

$$E_t = \frac{h \cdot C_h \cdot H_t}{1\,000} = \frac{24 \cdot \frac{5}{7} \cdot 243 \cdot H_t}{1\,000}$$

where

A = 3 m × 3 m industrial doorset;

E_t = 450 kWh;

A = 4 m × 4 m industrial doorset;

E_t = 800 kWh.

6 Results for air leakage by wind

- Relation between pressure difference and air leakage of a class 2 door (see Figure 1)
- Average wind speed in heating season v = 5 m/s
- $P = \frac{1}{2} \cdot \rho \cdot v^2 = \frac{1}{2} \cdot 1{,}293 \cdot 5^2\ {}^{1}\!/_{2}* = 16{,}2 \quad \text{N/m}^2$
- Calculation with an air leakage of 6,8 m^3/m^2 · h$_r$

$$Q_v = \frac{\text{airleakage} \cdot A}{3\,600} = \frac{6{,}8 \cdot A}{3\,600}$$

$$H_v = C_p \cdot \rho \cdot Q_v \cdot (T_i - T_o) = 1\,007 \cdot 1{,}293 \cdot Q_v \cdot 8$$

where

A = 3 m × 3 m industrial doorset;

H_v = 177 W;

A = 4 m × 4 m industrial doorset;

H_v = 315 W.

$$E_v = \frac{h \cdot C_h \cdot C_w \cdot H_v}{1\,000} = \frac{24 \cdot \frac{5}{7} \cdot 243 \cdot 34{,}7\% \cdot H_v}{1\,000}$$

where

A = 3 m × 3 m industrial doorset;

E_t = 256 kWh;

A = 4 m × 4 m industrial doorset;

E_t = 455 kWh.

7 Results for air leakage by chimney effect

— Relation between pressure difference and air leakage of a class 2 door (see Figure 1)

$$P = \frac{9{,}81 \cdot (h - h_{nph}) \cdot \rho \cdot (T_i - T_o)}{T_o + 273} = \frac{9{,}81 \cdot (h - 4) \cdot 1{,}293 \cdot 8}{10 + 273}$$

where

A = 3 m × 3 m industrial doorset;

P = 0,90 N/m^2;

A = 4 m × 4 m industrial doorset;

P = 0,72 N/m^2.

— Calculation with an air leakage for a

— 3 m × 3 m industrial doorset with 1,7 m^3/m^2 · h$_r$

and

— 4 m × 4 m industrial doorset with 1,3 m^3/m^2 · $h_r \frac{m^3}{m^2 \cdot h_r}$.

$$Q_v = \frac{\text{airleakage} \cdot A}{3\,600}$$

$$H_v = C_p \cdot \rho \cdot Q_v \cdot (T_i - T_o) = \frac{1\,007 \cdot 1{,}293 \cdot 1{,}7 \cdot 3 \cdot 3 \cdot 8}{3\,600}$$

where

A = 3 m × 3 m industrial doorset;

H_v = 44 W;

A = 4 m × 4 m industrial doorset;

H_v = 60 W.

$$E_v = \frac{h \cdot C_h \cdot H_v}{1000} = \frac{24 \cdot \frac{5}{7} \cdot 243 \cdot H_v}{1000}$$

where

A = 3 m × 3 m industrial doorset;

E_v = 183 kWh;

A = 4 m × 4 m industrial doorset;

E_v = 250 kWh.

8 Infiltration (open door)

— Average wind speed in heating season v = 5 m/s;

— $Q_i = v \cdot A \cdot C = 5 \cdot A \cdot 0{,}5$

where

A = 3 m × 3 m industrial doorset;

Q_i = 22,5 m^3/s;

A = 4 m × 4 m industrial doorset;

Q_i = 40 m^3/s.

$$H_b = C_p \cdot \rho \cdot Q_i \cdot (T_i - T_o) = \frac{1007 \cdot 1{,}293 \cdot Q_i \cdot 8}{1000}$$

where

A = 3 m × 3 m industrial doorset;

H_b = 234 kW;

A = 4 m × 4 m industrial doorset;

H_b = 417 kW.

$$t_b = \frac{V}{Q_i}$$

where

V	1 600 m^3	8 000 m^3	16 000 m^3
A = 3 m × 3 m industrial doorset	71 s	355 s	710 s
A = 4 m × 4 m industrial doorset	40 s	200 s	400 s

$$H_\mathrm{h} = F_\mathrm{h} \cdot V = \frac{20 \cdot V}{1000}$$

where

V	1 600 m^3	8 000 m^3	16 000 m^3
H_h	32 kW	160 kW	320 kW

$$T_\mathrm{h} = (1 - (\frac{(T_{\mathrm{i}-1} - T_\mathrm{o})}{T_\mathrm{i} - T_\mathrm{o}})) \cdot t_\mathrm{b}$$

where

V	1 600 m^3	8 000 m^3	16 000 m^3
A = 3 m × 3 m industrial doorset	9 s	45 s	89 s
A = 4 m × 4 m industrial doorset	5 s	25 s	50 s

$$E_\mathrm{i} = \frac{(H_\mathrm{b} \cdot t_\mathrm{b}) + (H_\mathrm{h} \cdot (t_\mathrm{c} - t_\mathrm{h}))}{3\,600} \cdot n \cdot C_\mathrm{h} \cdot C_\mathrm{w}$$

where

V	1 600 m^3	8 000 m^3	16 000 m^3
A = 3 m × 3 m industrial doorset	1 664 kWh	7 123 kWh	8 837 kWh
A = 4 m × 4 m industrial doorset	1 676 kWh	8 175 kWh	13 161 kWh

9 Summary

Table 3 — Calculations results for Paris

Industrial doorset			A = 3 m × 3 m	A = 4 m × 4 m
Heat transmission	kWh		450	800
Air leakage	kWh		439	705
Infiltration	kWh	1 600 m^3	1 664	1 676
		8 000 m^3	7 123	8 175
		16 000 m^3	8 837	13 161

Table 4 — Calculations results for Paris t_c = 120 s

Industrial doorset			A = 3 m × 3 m	A = 4 m × 4 m
Heat transmission	kWh		450	800
Air leakage	kWh		439	705
Infiltration	kWh	1 600 m^3	1 294	1 307
		8 000 m^3	2 572	4 187
		16 000 m^3	2 439	4 649

Table 5 — Comparison of calculation results of Paris with Hanko, Finland

Industrial doorset			A = 3 m × 3 m	A = 4 m × 4 m
Heat transmission	kWh		877	1 558
Air leakage	kWh		1 201	1 902
Infiltration	kWh	1 600 m^3	3 446	3 426
		8 000 m^3	17 006	17 204
		16 000 m^3	25 035	33 990

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