ingenieursbureau voor kwaliteitszorg en bouwfysica
adviesburo NIEMAN

MANAGEMENT SUMMARY

Datum : 5 october 2010

Van : R.A.P. van Herpen MSc.

Pagina's : **5** (and 3 appendices)
Referentie : Nz090360aeA0.rhe
Betreft : **Thermal mass of walls;**
Consequences for the insulation layer in case of fire in normal compartments

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Introduction

The behaviour of thermal insulated outside walls depends on the thermal mass of these walls. In case of fire, the temperature of the insulation layer in thermal heavy walls hardly increases. However, the temperature of the insulation layer in thermal light walls follows the gas-temperature of the compartment with a small delay. The different behaviour of the walls leads to different consequences for the insulation material.

Only normal compartments are involved in this study. Normal compartments are, according to the Dutch building code, smaller than 1000 m^2 for office or residential use. For large compartments (> 1000 m^2, mostly industrial use) other mechanisms and constructions are important, see reports Wz090360aaA2 and Wz090360adA0.

Main points and boundary conditions

Two types of outside walls have been considered.

- Thermal light wall (from the inside out):
  10 mm gypsum board
  100 mm insulation layer (λ = 0,038 W/(m.K))
  100 mm masonry

- Thermal heavy wall (from the inside out):
  100 mm normal weight concrete
  100 mm insulation layer (λ = 0,038 W/(m.K))
  100 mm masonry

Adviesburo Nieman BV
Vestiging Utrecht
Sophialaan 1a
Postbus 40217
3504 AA Utrecht
T (030) 241 34 27
F (030) 241 02 66
ing. J.J. van den Engel
ing. H. Koekoek
Vestiging Zwolle
Dr. Van Lookeren -
Campagneweg 16
Postbus 40147
8004 DC Zwolle
T (038) 467 00 30
F (038) 467 00 40
ir. R.A.P. van Herpen
mw. ing. J.B. Dessing
Vestiging Rijswijk
Nassaulaan 1
Postbus 1757
2280 DT Rijswijk
T (070) 340 17 20
F (070) 340 17 37
ing. J.G. Bouwman
Vestiging Eindhoven
Verdunplein 17
Postbus 1385
5602 BJ Eindhoven
T (040) 264 58 20
F (040) 264 58 21
ing. A. de Jong
Internet
info@nieman.nl
www.nieman.nl
ABN-Amro
41.56.18.770
Rabobank
39.44.40.943
Handelsregister
Utrecht 30086383

Appendix 1 gives the plan and elevation of the floor in a multi-storey building with an office occupancy. Each storey is considered as a fire-compartment. In this compartment the fire develops in accordance with the natural fire concept (ontwerp-NEN 6055:2009). The glazing in this concept breaks at the start of the fire, so there is no risk of extinguishing the fire by lack of oxygen (conservative assumption).

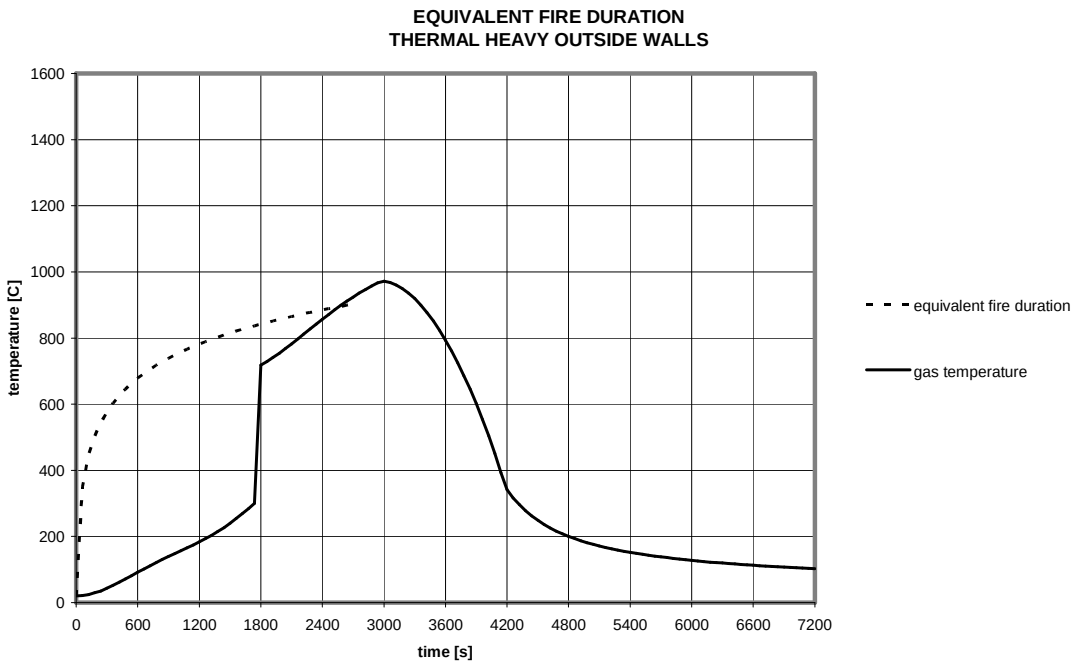
Fire characteristics in the pre flash-over stadium:
- Rate of heat release: 250 kW/m^2
- Fire growth rate: 300 s

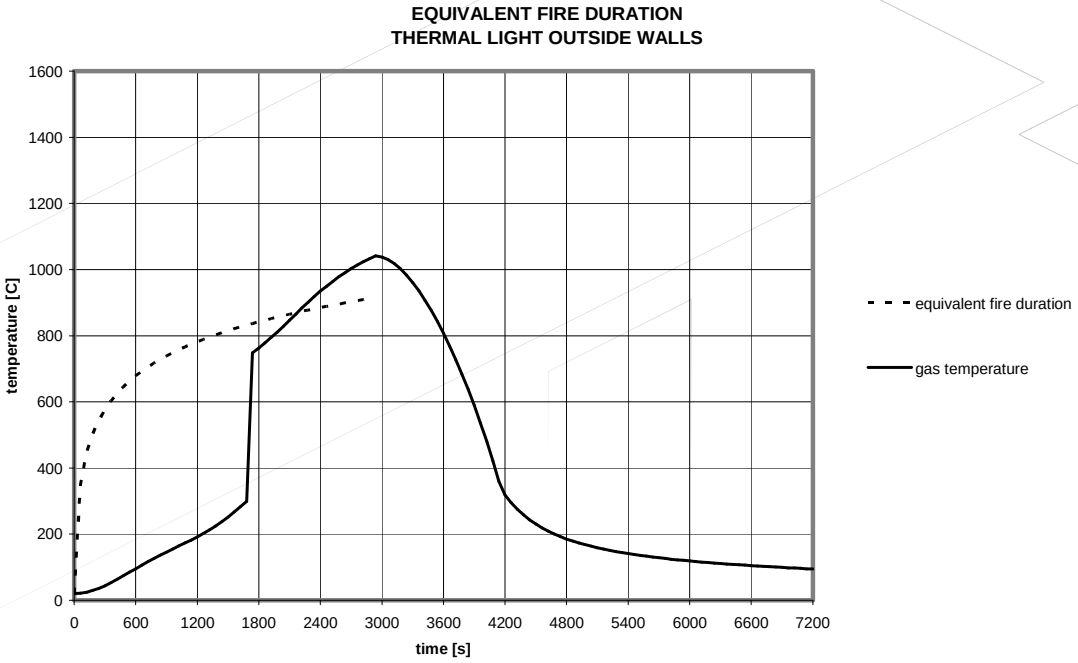
Fire characteristics in the post flash-over stadium:
- Fire load density: 570 MJ/m^2 (characteristic variable fire load)
- Combustion heat of fuel: 17,5 MJ/kg
- Combustion efficiency: 0,8
- Combustion model: extended fire duration (oxygen dependent)
- Danger of fire activation: 1 (no risk model, physical model only)

For both the thermal light-weight wall as the thermal heavy-weight wall the fire scenario and thermal load in the compartment as a result of the natural fire concept are calculated. When the storey has been divided in office cells, there are two flash-over moments. The first flash-over occurs in the office cell where the fire starts. Afterwards the flash-over in the compartment takes place. Both situations are calculated in appendix 2 (ozone, 2009).

The thermal response of the outside walls is calculated with a thermal dynamic simulation program in appendix 3 (voltra, 2005). In that case a post flash-over condition is simulated in the compartment by a temperature of 800 ^{o}C (conductive and radiative).

Thermal load, results





	Thermal load level	Flash-over [min]	Max. temperature [°C]	Eq. duration [min]
Thermal heavy-weight	Compartment	29	971	46
	Cell	8	957	-
Thermal light-weight	Compartment	28	1041	48
	Cell	8	1001	-

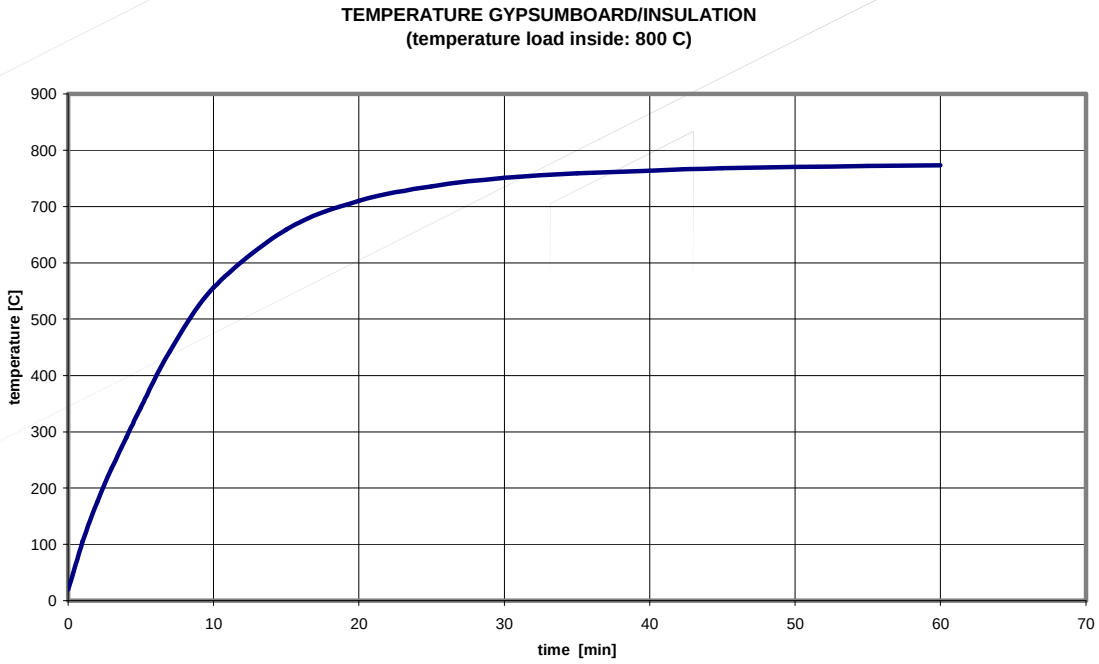
The thermal load as a result of the natural fire concept in the office building storey does not vary a lot. For heavy-weight outside walls, the maximum gas temperature is 971 °C and the equivalent fire duration (in standard fire curve) is 46 minutes. For light-weight outside walls, the maximum gas temperature is 1041 °C and the equivalent fire duration (in standard fire curve) is 48 minutes.

Thermal response, results

In the pre flash-over stadium the temperature load on the wall is relatively low. If the insulation layer is not fireproof there may be some risk in the upper part of a thermal light wall just before flash-over by deforming, melting or evaporating insulation material.

In the post flash-over stadium the temperature load in the wall is high. In a thermal heavy wall there are no consequences for the insulation layer. The temperature in a thermal heavy wall hardly increases in the insulation layer. In a thermal light wall the temperature in the insulation layer increases quickly. When the insulation material is

not fireproof it can deform, melt (EPS, XPS: above ca. 150 ^{o}C) or evaporate (PUR: above ca. 200 ^{o}C, PIR: above ca. 300 ^{o}C). Insulation material in liquid or gas phase can easily be transported in cavities. Since these fluids and gases are combustible and maybe also toxic, transport to other compartments or escape-routes must be prevented.



Temperature between insulation layer and gypsum board by a thermal load of 800 ^{o}C at the inside (compartment).

Within 5 minutes after flash-over these boundary values will be exceeded. In 5 a 10 minutes after flash-over plastic insulation material will burn in a thermal light wall. This can lead to an uncontrolled fire spread in a thermal light outside wall, also to adjacent compartments, as a result of using combustible insulation. With incombustible insulation this risk is eliminated. Of course other measures (creating fire barriers in the thermal light wall) are also possible, but will never fully eliminate the risk.

Conclusion

Combustible, especially plastic insulation in outside walls implements the risk of fire spread in thermal light walls, after flash-over has taken place in the fire compartment. Fire spread must be prevented by creating fire barriers in thermal light walls. Also the transport of combustible gases and fluids in cavities (before the insulation layer starts burning) must be prevented to adjacent compartments or escape-routes.

Instead of these risk reducing measures it is also possible to use incombustible insulation in thermal light walls. In that case there are no additional measures necessary.

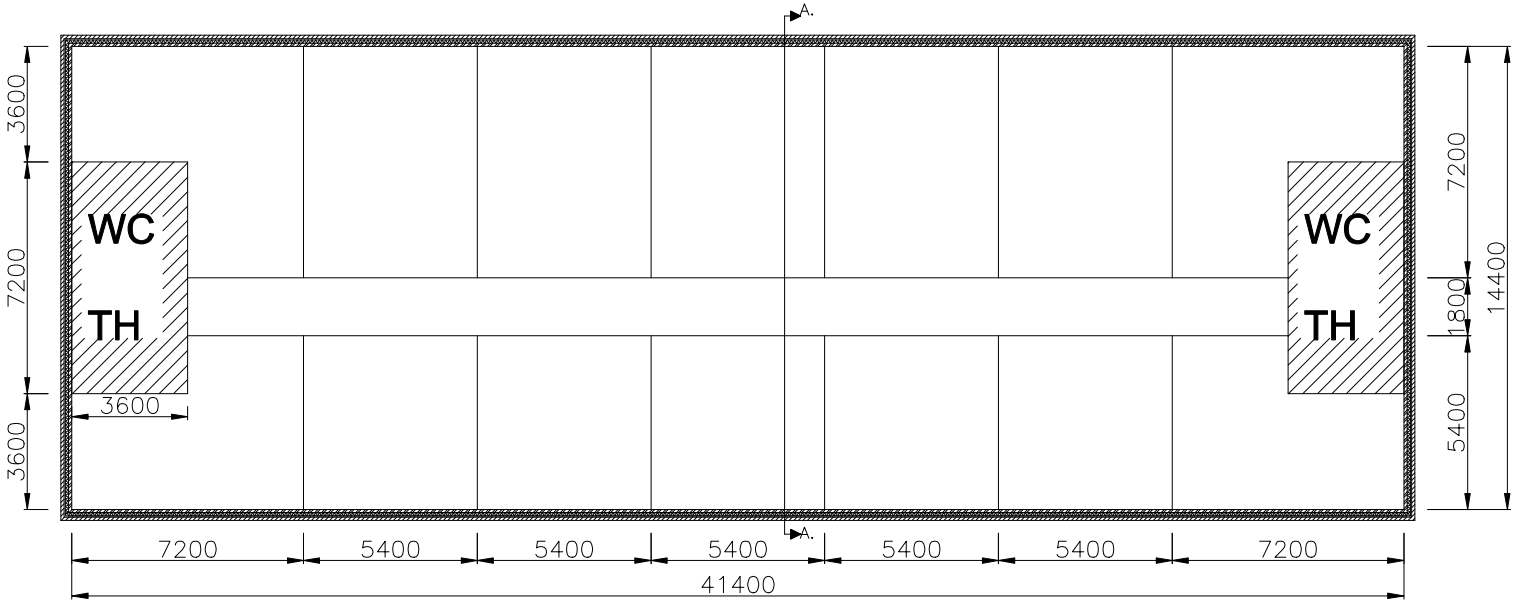
Zwolle, 5 oktober 2010
Adviesburo Nieman B.V.

R.A.P. van Herpen MSc.

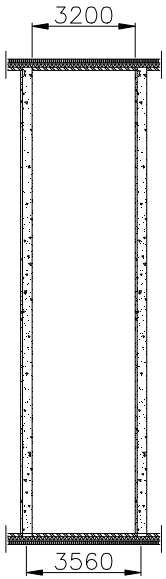
Appendices: 3

Appendix 1 Plan and elevation case study

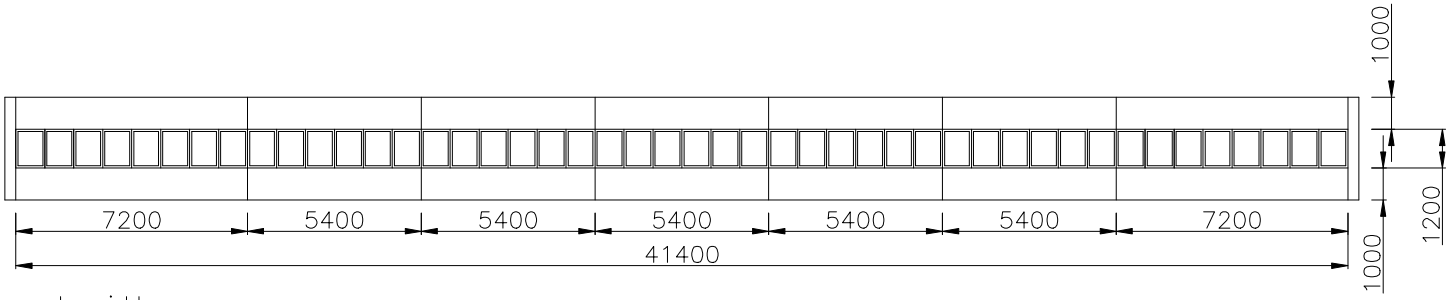
A. kantoorfunctie



plattegrond



doorsnede A–A



gevelaanzicht

Appendix 2 Thermal load by natural fire concept (Ozone)

OZone V 2.2.6 Report

Analysis Name:	**kantoorfunctie, thermisch zwaar**
File Name:	kantoor therm-zwaar.ozn
Created:	4-10-2010 at 17:41:46

ANALYSIS STRATEGY

Selected strategy:	Combination 2Zones - 1 Zone Model
Transition criteria from 2 Zones to 1 Zone	
Upper Layer Temperature	≥ 500°C
Combustible in Upper Layer + U.L. Temperature	≥ Combustible Ignition Temperature = 300 °C
Interface Height	≤ 0,2 Compartment Height
Fire Area	≥ 0,25 Floor Area

PARAMETERS

Openings

Radiation Through Closed Openings:	0,8
Bernoulli Coefficient:	0,7

Physical Characteristics of Compartment

Initial Temperature:	293 K
Initial Pressure:	100000 Pa

Parameters of Wall Material

Convection Coefficient at the Hot Surface:	25 W/m²K
Convection Coefficient at the Cold Surface:	9 W/m²K

Calculation Parameters

End of Calculation:	7200 sec
Time Step for Printing Results:	60 sec
Maximum Time Step for Calculation:	10 sec

Air Entrained Model:	Heskestad

COMPARTMENT

Form of Compartment:	Rectangular Floor	
Height:	3,2	m
Depth:	13,4	m
Length:	41,4	m
Roof Type:	Flat Roof	

DEFINITION OF ENCLOSURE BOUNDARIES

Floor

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Ceiling

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Wall 1

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	10	2300	1,6	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Wall 2

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	10	2300	1,6	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Openings

Sill Height [m]	Soffit Height [m]	Width [m]	Variation	Adiabatic
1	2,2	41	Constant	no

Wall 3

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	10	2300	1,6	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Wall 4

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	10	2300	1,6	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Openings

Sill Height [m]	Soffit Height [m]	Width [m]	Variation	Adiabatic
1	2,2	41	Constant	no

FIRE

Fire Curve:	NFSC Design Fire	
Maximum Fire Area:	554,76	m²
Fire Elevation:	0	m
Fuel Height:	1	m

Occupancy	Fire Growth Rate	RHRf [kw/m²]	Fire Load qf,k [MJ/m²]	Danger of Fire Activation
User Defined	300	250	570	1

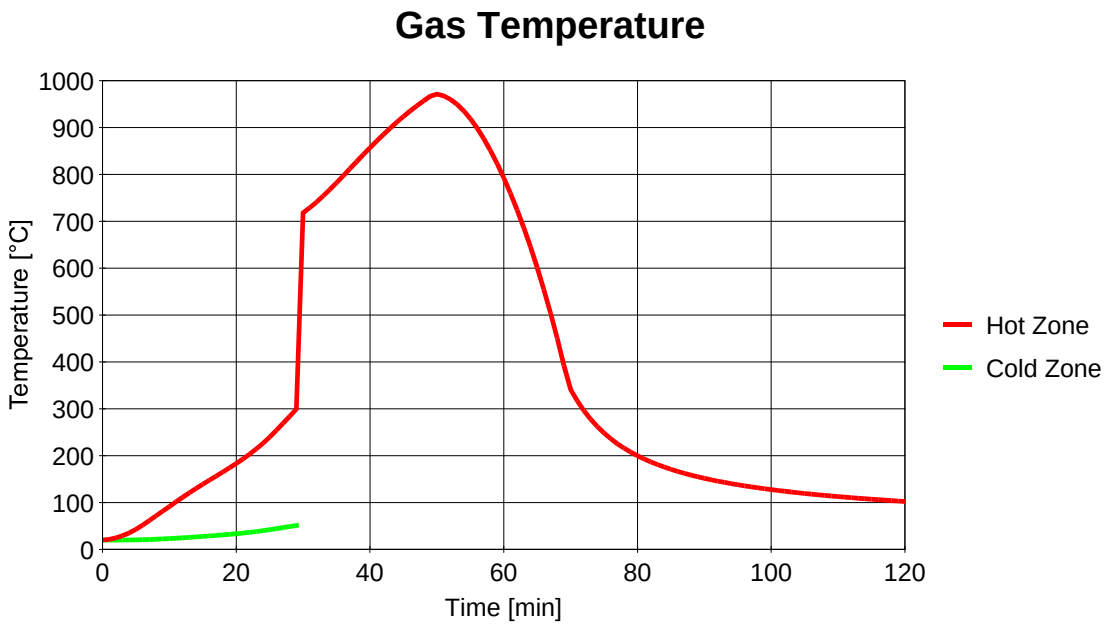
Danger of Fire Activation: $\delta_{q,\,2} = 1$

$q_{f,\,d} =$ 456,0 MJ/m²

Combustion Heat of Fuel:	17,5	MJ/kg
Combustion Efficiency Factor:	0,8	
Combustion Model:	Extended fire duration	

RESULTS

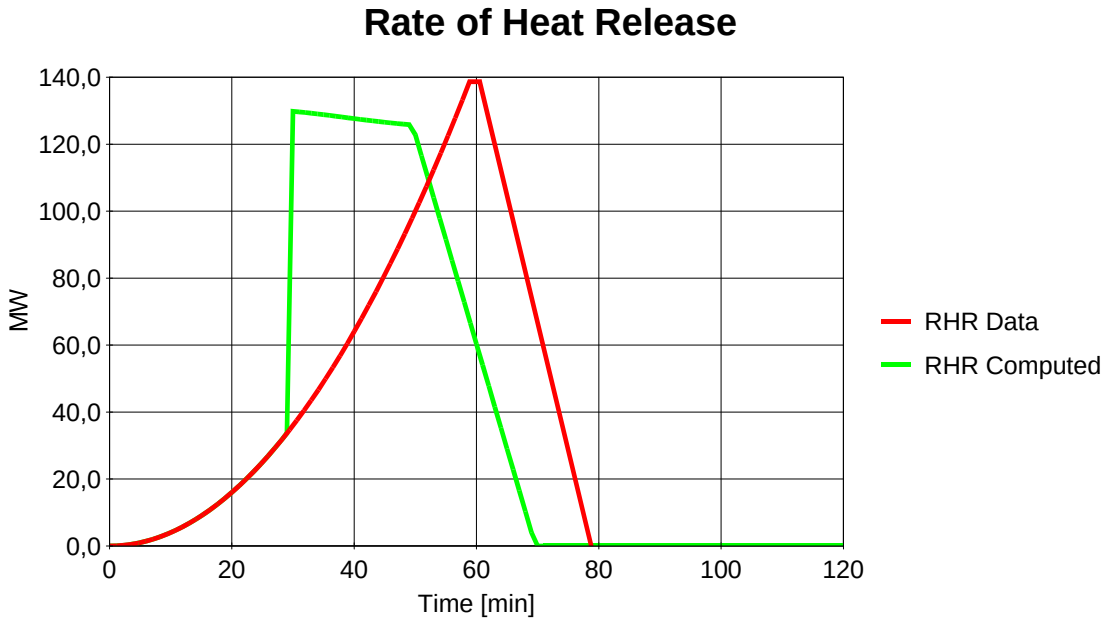
Fire Area: The maximum fire area (554.76m²) is greater than 25% of the floor area (554.76m²).
The fire load is uniformly distributed.
Switch to one zone + Fully engulfed fire: Temperature of zone in contact with fuel >300.0°C at time [s] 1744.00



Analysis Name: kantoorfunctie, thermisch zwaar

Peak: 971 °C At: 50 min

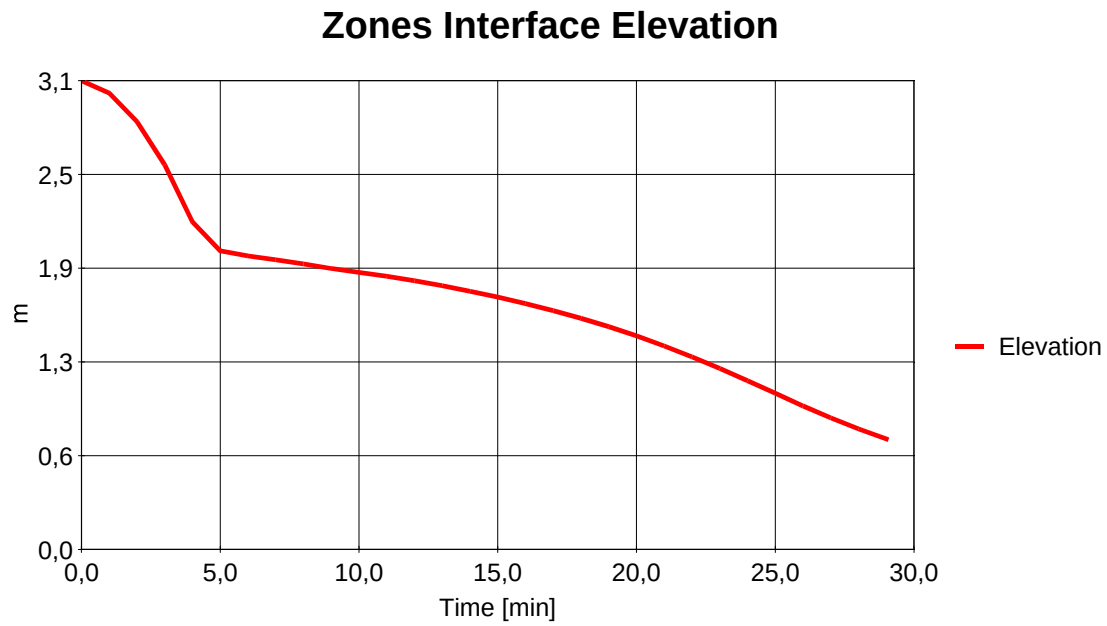
Figure 1. Hot and Cold Zone Temperature



Analysis Name: kantoorfunctie, thermisch zwaar

Peak: 138,69 MW At: 58,9 min

Figure 2. RHR Data and Computed



Analysis Name: kantoorfunctie, thermisch zwaar

h = 0,74 m At: 29,00 min

Figure 3. Zones Interface Elevation

OZone V 2.2.6 Report

Analysis Name:	**kantoorfunctie, thermisch zwaar, vertrek**
File Name:	kantoor therm-zwaar-vertrek.ozn
Created:	5-10-2010 at 2:30:43

ANALYSIS STRATEGY

Selected strategy:	Combination 2Zones - 1 Zone Model
Transition criteria from 2 Zones to 1 Zone	
Upper Layer Temperature	≥ 500°C
Combustible in Upper Layer + U.L. Temperature	≥ Combustible Ignition Temperature = 300 °C
Interface Height	≤ 0,2 Compartment Height
Fire Area	≥ 0,25 Floor Area

PARAMETERS

Openings

Radiation Through Closed Openings:	0,8
Bernoulli Coefficient:	0,7

Physical Characteristics of Compartment

Initial Temperature:	293 K
Initial Pressure:	100000 Pa

Parameters of Wall Material

Convection Coefficient at the Hot Surface:	25 W/m²K
Convection Coefficient at the Cold Surface:	9 W/m²K

Calculation Parameters

End of Calculation:	7200 sec
Time Step for Printing Results:	60 sec
Maximum Time Step for Calculation:	10 sec

Air Entrained Model:	Heskestad

COMPARTMENT

Form of Compartment:	Rectangular Floor	
Height:	3,2	m
Depth:	7,2	m
Length:	5,4	m
Roof Type:	Flat Roof	

DEFINITION OF ENCLOSURE BOUNDARIES

Floor

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Ceiling

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Wall 1

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Gypsum board [EN12524]	10	900	0,25	1000

Wall 2

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	10	2300	1,6	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Openings

	Sill Height [m]	Soffit Height [m]	Width [m]	Variation	Adiabatic
	1	2,2	5	Constant	no

Wall 3

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Gypsum board [EN12524]	10	900	0,25	1000

Wall 4

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Gypsum board [EN12524]	10	900	0,25	1000

FIRE

Fire Curve:	NFSC Design Fire	
Maximum Fire Area:	38,88	m²
Fire Elevation:	0	m
Fuel Height:	1	m

Occupancy	Fire Growth Rate	RHRf [kw/m²]	Fire Load qf,k [MJ/m²]	Danger of Fire Activation
User Defined	300	250	570	1

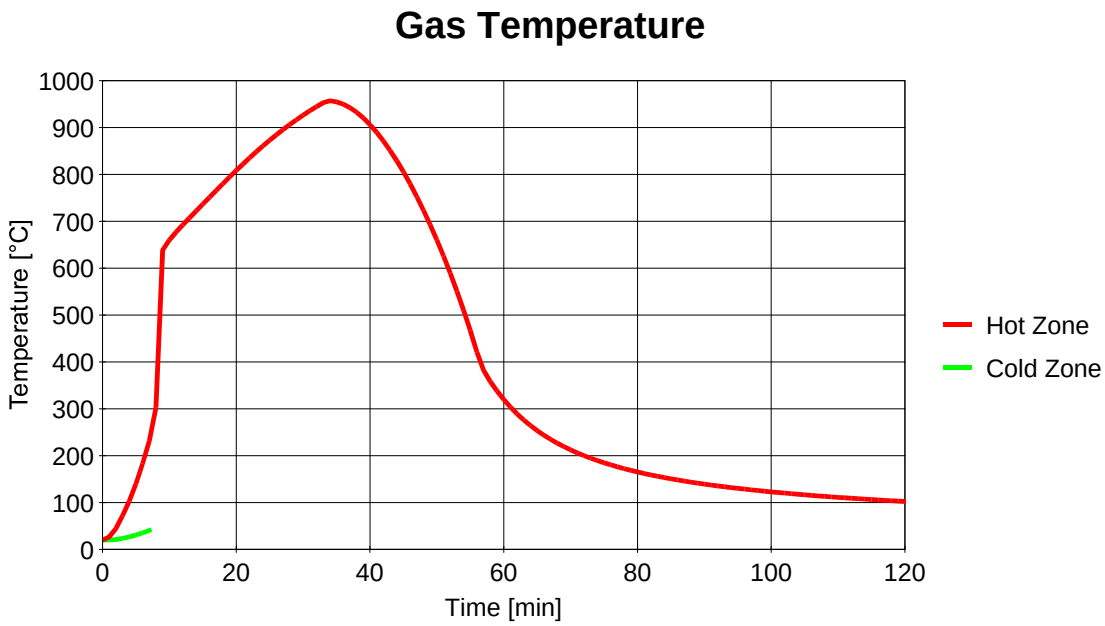
Danger of Fire Activation: $\delta_{q,\,2} = 1$

$q_{f,\,d} =$ 456,0 MJ/m²

Combustion Heat of Fuel:	17,5	MJ/kg
Combustion Efficiency Factor:	0,8	
Combustion Model:	Extended fire duration	

RESULTS

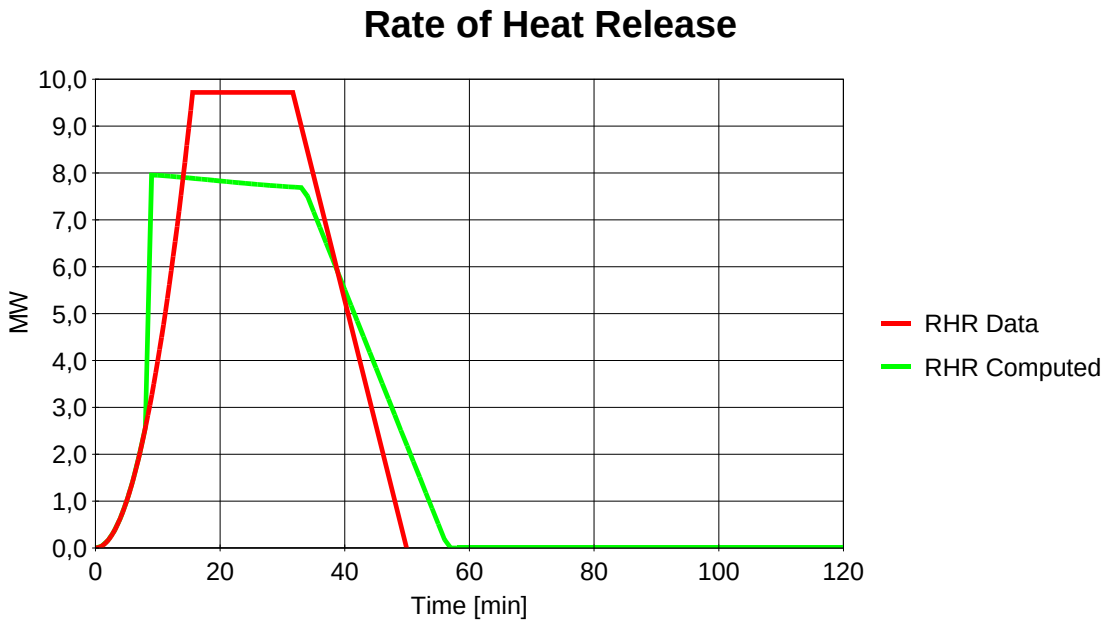
Fire Area: The maximum fire area (38.88m²) is greater than 25% of the floor area (38.88m²).
The fire load is uniformly distributed.
Switch to one zone: Lower layer Height < 20.0% ocompartment height at time [s] 435.29
Fully engulfed fire: Temperature of zone in contact with fuel >300.0°C at time [s] 480.00



Analysis Name: kantoorfunctie, thermisch zwaar, vertrek

Peak: 957 °C At: 34 min

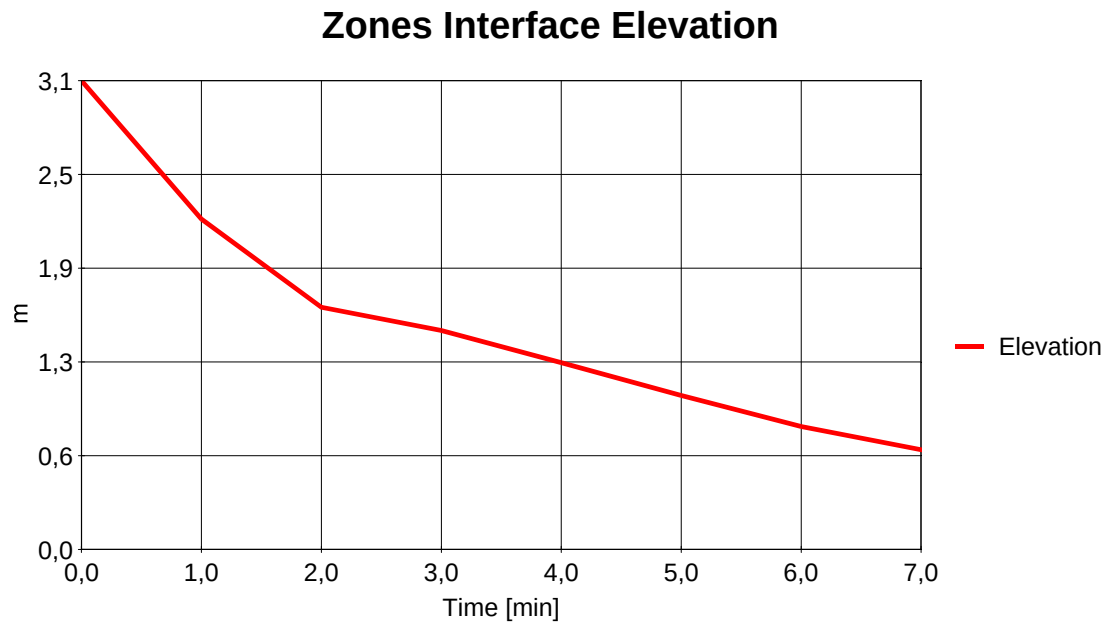
Figure 1. Hot and Cold Zone Temperature



Analysis Name: kantoorfunctie, thermisch zwaar, vertrek

Peak: 9,72 MW At: 15,6 min

Figure 2. RHR Data and Computed



Analysis Name: kantoorfunctie, thermisch zwaar, vertrek

h = 0,67 m At: 7,00 min

Figure 3. Zones Interface Elevation

OZone V 2.2.6 Report

Analysis Name:	**kantoorfunctie, thermisch licht**
File Name:	kantoor therm-licht.ozn
Created:	4-10-2010 at 17:40:54

ANALYSIS STRATEGY

Selected strategy:	Combination 2Zones - 1 Zone Model
Transition criteria from 2 Zones to 1 Zone	
Upper Layer Temperature	≥ 500°C
Combustible in Upper Layer + U.L. Temperature	≥ Combustible Ignition Temperature = 300 °C
Interface Height	≤ 0,2 Compartment Height
Fire Area	≥ 0,25 Floor Area

PARAMETERS

Openings

Radiation Through Closed Openings:	0,8
Bernoulli Coefficient:	0,7

Physical Characteristics of Compartment

Initial Temperature:	293 K
Initial Pressure:	100000 Pa

Parameters of Wall Material

Convection Coefficient at the Hot Surface:	25 W/m²K
Convection Coefficient at the Cold Surface:	9 W/m²K

Calculation Parameters

End of Calculation:	7200 sec
Time Step for Printing Results:	60 sec
Maximum Time Step for Calculation:	10 sec

Air Entrained Model:	Heskestad

COMPARTMENT

Form of Compartment:	Rectangular Floor	
Height:	3,2	m
Depth:	13,4	m
Length:	41,4	m
Roof Type:	Flat Roof	

DEFINITION OF ENCLOSURE BOUNDARIES

Floor

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Ceiling

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Wall 1

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Wall 2

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Openings

Sill Height [m]	Soffit Height [m]	Width [m]	Variation	Adiabatic
1	2,2	41	Constant	no

Wall 3

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Wall 4

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Openings

Sill Height [m]	Soffit Height [m]	Width [m]	Variation	Adiabatic
1	2,2	41	Constant	no

FIRE

Fire Curve:	NFSC Design Fire	
Maximum Fire Area:	554,76	m²
Fire Elevation:	0	m
Fuel Height:	1	m

Occupancy	Fire Growth Rate	RHRf [kw/m²]	Fire Load qf,k [MJ/m²]	Danger of Fire Activation
User Defined	300	250	570	1

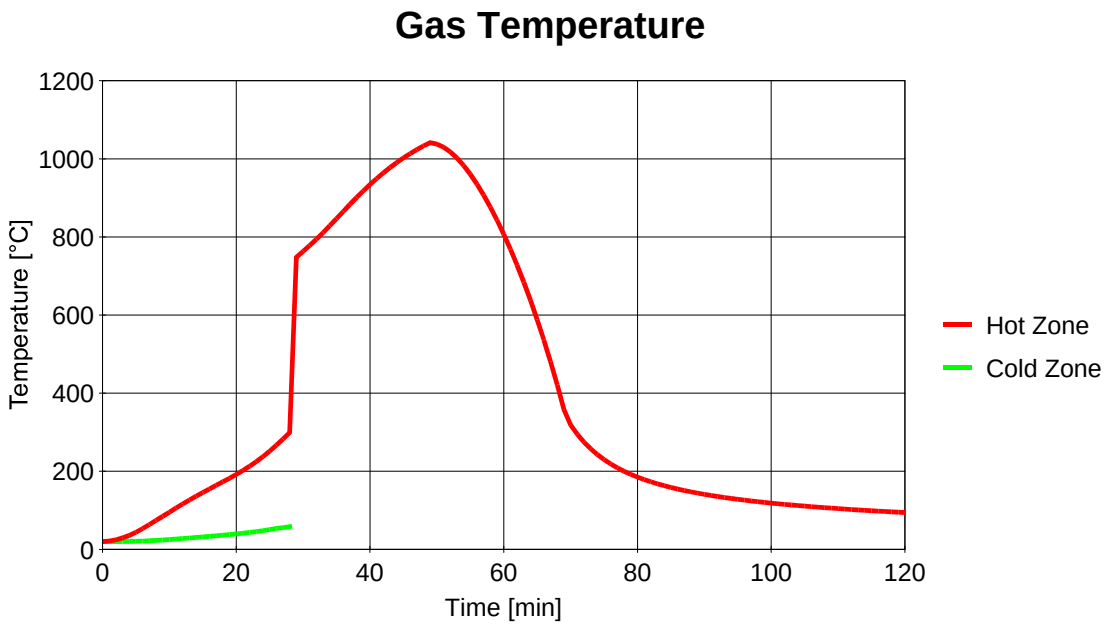
Danger of Fire Activation: $\delta_{q,\,2} = 1$

$q_{f,\,d} =$ 456,0 MJ/m²

Combustion Heat of Fuel:	17,5	MJ/kg
Combustion Efficiency Factor:	0,8	
Combustion Model:	Extended fire duration	

RESULTS

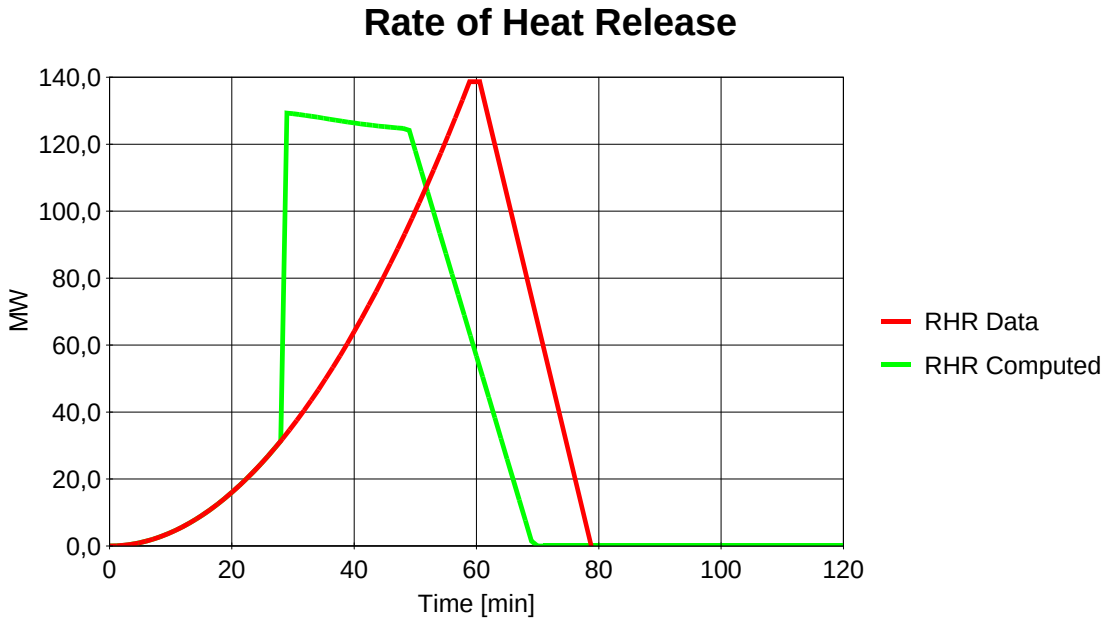
Fire Area: The maximum fire area (554.76m²) is greater than 25% of the floor area (554.76m²).
The fire load is uniformly distributed.
Switch to one zone + Fully engulfed fire: Temperature of zone in contact with fuel >300.0°C at time [s] 1684.00



Analysis Name: kantoorfunctie, thermisch licht

Peak: 1041 °C At: 49 min

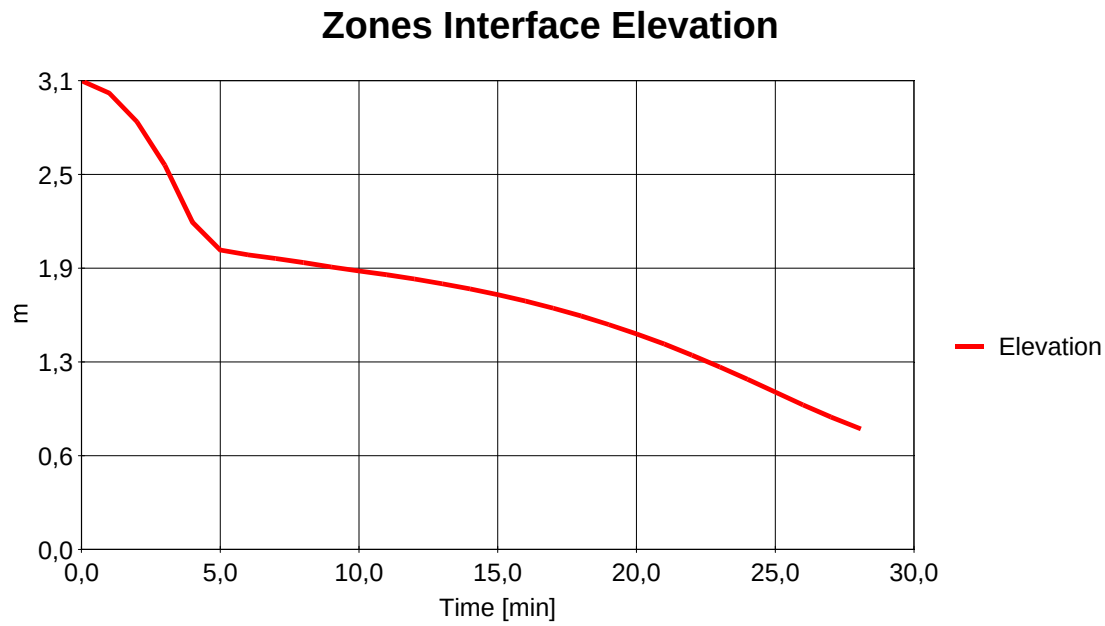
Figure 1. Hot and Cold Zone Temperature



Analysis Name: kantoorfunctie, thermisch licht

Peak: 138,69 MW At: 58,9 min

Figure 2. RHR Data and Computed



Analysis Name: kantoorfunctie, thermisch licht

h = 0,82 m At: 28,00 min

Figure 3. Zones Interface Elevation

OZone V 2.2.6 Report

Analysis Name:	**kantoorfunctie, thermisch licht, vertrek**
File Name:	kantoor therm-licht-vertrek.ozn
Created:	5-10-2010 at 2:28:44

ANALYSIS STRATEGY

Selected strategy:	Combination 2Zones - 1 Zone Model
Transition criteria from 2 Zones to 1 Zone	
Upper Layer Temperature	≥ 500°C
Combustible in Upper Layer + U.L. Temperature	≥ Combustible Ignition Temperature = 300 °C
Interface Height	≤ 0,2 Compartment Height
Fire Area	≥ 0,25 Floor Area

PARAMETERS

Openings

Radiation Through Closed Openings:	0,8
Bernoulli Coefficient:	0,7

Physical Characteristics of Compartment

Initial Temperature:	293 K
Initial Pressure:	100000 Pa

Parameters of Wall Material

Convection Coefficient at the Hot Surface:	25 W/m²K
Convection Coefficient at the Cold Surface:	9 W/m²K

Calculation Parameters

End of Calculation:	7200 sec
Time Step for Printing Results:	60 sec
Maximum Time Step for Calculation:	10 sec

Air Entrained Model:	Heskestad

COMPARTMENT

Form of Compartment:	Rectangular Floor	
Height:	3,2	m
Depth:	7,2	m
Length:	5,4	m
Roof Type:	Flat Roof	

DEFINITION OF ENCLOSURE BOUNDARIES

Floor

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Ceiling

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Normal weight Concrete [EN1994-1-2]	25	2300	1,6	1000

Wall 1

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Gypsum board [EN12524]	10	900	0,25	1000

Wall 2

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Normal Bricks	10	1600	0,7	840

Openings

	Sill Height [m]	Soffit Height [m]	Width [m]	Variation	Adiabatic
	1	2,2	5	Constant	no

Wall 3

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Gypsum board [EN12524]	10	900	0,25	1000

Wall 4

Material (from inside to outside)	Thickness [cm]	Unit Mass [kg/m³]	Conductivity [W/mK]	Specific Heat [J/kgK]
Gypsum board [EN12524]	1	900	0,25	1000
Glass wool & Rock wool	10	60	0,037	1030
Gypsum board [EN12524]	10	900	0,25	1000

FIRE

Fire Curve:	NFSC Design Fire	
Maximum Fire Area:	38,88	m²
Fire Elevation:	0	m
Fuel Height:	1	m

Occupancy	Fire Growth Rate	RHRf [kw/m²]	Fire Load qf,k [MJ/m²]	Danger of Fire Activation
User Defined	300	250	570	1

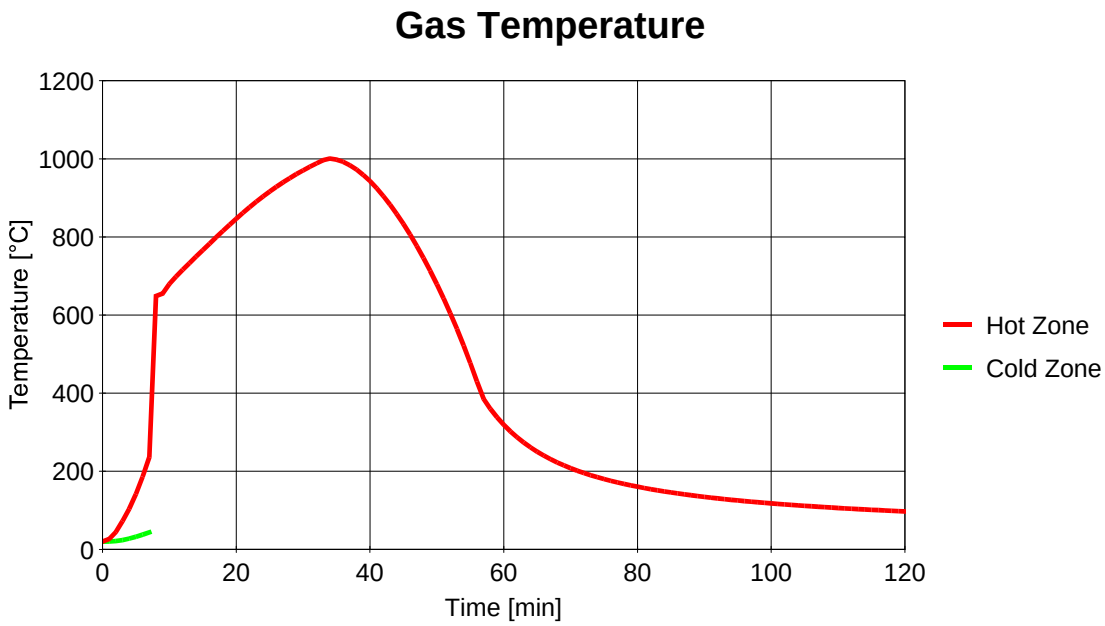
Danger of Fire Activation: $\delta_{q,\,2} = 1$

$q_{f,\,d} =$ 456,0 MJ/m²

Combustion Heat of Fuel:	17,5	MJ/kg
Combustion Efficiency Factor:	0,8	
Combustion Model:	Extended fire duration	

RESULTS

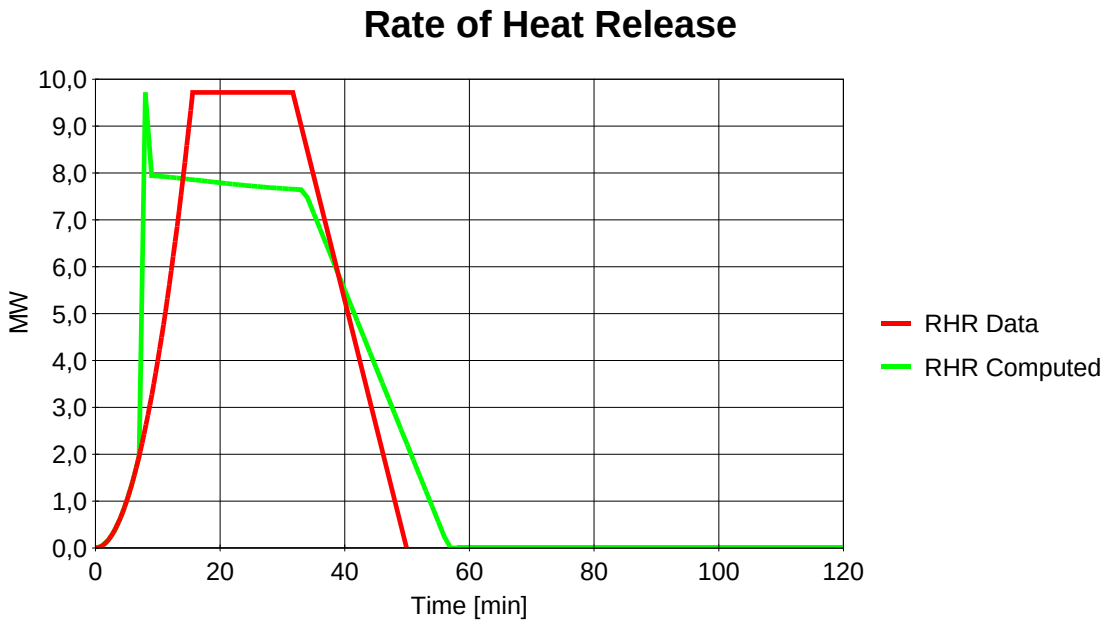
Fire Area: The maximum fire area (38.88m²) is greater than 25% of the floor area (38.88m²).
The fire load is uniformly distributed.
Switch to one zone: Lower layer Height < 20.0% ocompartment height at time [s] 436.16
Fully engulfed fire: Temperature of zone in contact with fuel >300.0°C at time [s] 472.16



Analysis Name: kantoorfunctie, thermisch licht, vertrek

Peak: 1001 °C At: 34 min

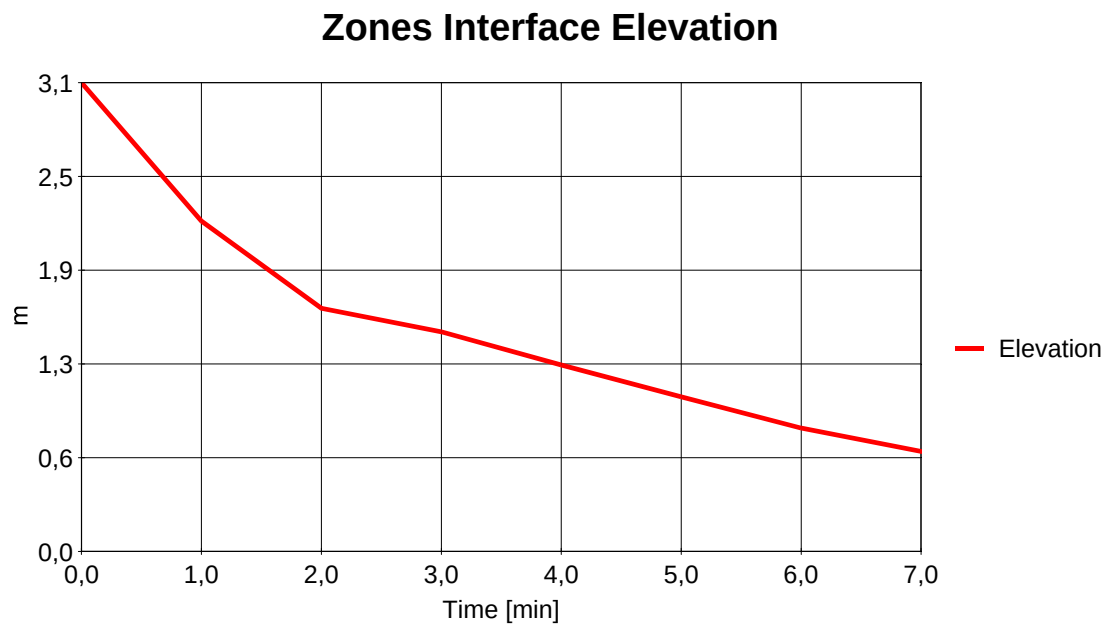
Figure 1. Hot and Cold Zone Temperature



Analysis Name: kantoorfunctie, thermisch licht, vertrek

Peak: 9,72 MW At: 15,6 min

Figure 2. RHR Data and Computed



Analysis Name: kantoorfunctie, thermisch licht, vertrek

h = 0,67 m At: 7,00 min

Figure 3. Zones Interface Elevation

Appendix 3 Thermal response after flash-over (Voltra)

Voltra calculation

Version:
- 6.3 (2006)

Discretisation grid:
- 10 mm – 25 mm

Materials:

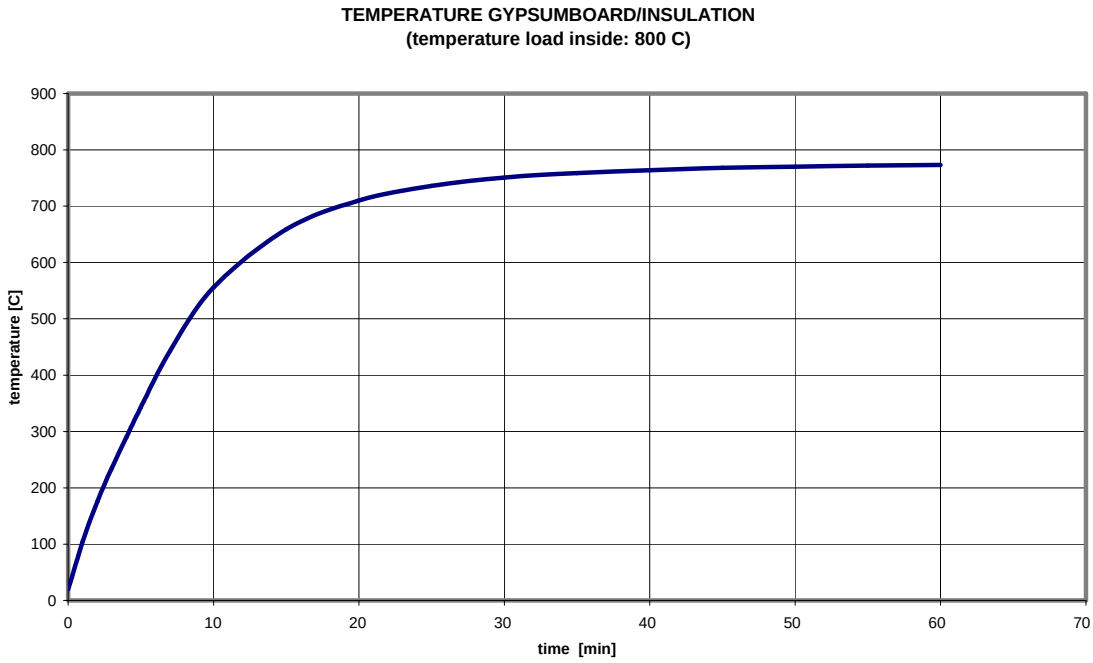
• Gypsum board:	900 kg/m3;	0,25 W/(mK);	1000 J/(kgK)
• Insulation:	50 kg/m3;	0,038 W/(mK);	1030 J/(kgK)

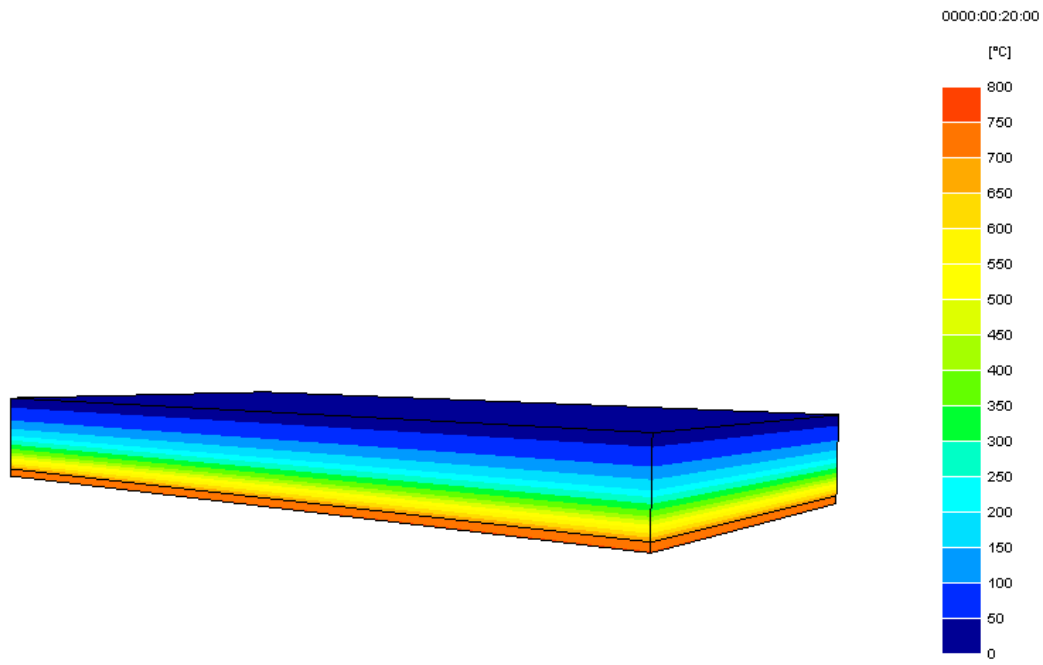
Boundary conditions:

• Inside:	h_i = 25 W/(m^2K);	T_i = 800 ^{o}C;	ε = 0,9
• Outside:	h_a = 25 W/(m^2K);	T_a = 20 ^{o}C;	ε = 0,9

Results in between layers gypsum board and insulation:

Tijdstip [min.]	Temperatuur tussen gipsplaat en steenwol [°C]
0	20
5	343
10	556
15	659
20	710
25	736
30	751
35	759
40	764
45	768
50	770
55	772
60	773





Temperatuur constructie op tijdstip 20 minuten.

ingenieursbureau voor kwaliteitszorg en bouwfysica
adviesburo NIEMAN

info@nieman.nl
www.nieman.nl

Vestiging Utrecht
Postbus 40217 - 3504 AA Utrecht
Sophialaan 1A - 3542 AR Utrecht
Tel.: 030 - 241 34 27
Fax: 030 - 241 02 66

Vestiging Zwolle
Postbus 40147 - 8004 DC Zwolle
Dr. Van Lookeren Campagneweg 16
8025 BX Zwolle
Tel.: 038 - 467 00 30
Fax: 038 - 467 00 40

Vestiging Rijswijk
Postbus 1757 - 2280 DT Rijswijk
Nassaukade 1 - 2281 ZA Rijswijk
Tel.: 070 - 340 17 20
Fax: 070 - 340 17 37

Vestiging Eindhoven
Postbus 1385 - 5602 BJ Eindhoven
Verdunplein 17 - 5627 SZ Eindhoven
Tel.: 040 - 264 58 20
Fax: 040 - 264 58 21

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