TNO-report

1998-CVB-R1045(E)

Determination of the fire resistance of a floor structure with a suspended ceiling containing light fittings provided with fire-resistant covers, manufacured by Environmental seals.

TNO Building and Construction Research

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1 SUBJECT

A floor/ceiling structure comprised of floor elements of acrated concrete, steel joists IPE 140 and a suspended ceiling, type Armstrong Trulok Prelude and Armstrong Prima Fine-Fissured ceiling panels. Four light fittings were mounted in the ceiling; the upper surfaces of these fittings were equipped with fire-resistant provisions manufactured by Environmental Seals.

2 INVESTIGATION

The fire resistance in accordance with NEN 6069:1997.

3 CLIENT

Environmental Seals Ltd
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United Kingdom.

4 THE LOCATION AND DATES OF THE INVESTIGATION

The investigation was carried out in the TNO Building and Construction Research's Centre for Fire Research laboratory at Rijswijk, the Netherlands.
The floor/ceiling structure was assembled on 9 February 1998.
The fire test was carried out on 11 February 1998.

5 DATE AND NUMBER OF REPORT

Original version, in Dutch language:
July 1998; 98-CVB-R1045.

Translation in English:
April 1999; 98-CVB-R1045(E).

6 TEST CONSTRUCTION

6.1 General

The investigation was carried out on a floor/ceiling structure with dimensions of approximately 3.2 x 4.0 m and comprised of floor elements of aerated concrete, steel joists and a suspended ceiling.
The suspended ceiling was comprised of ceiling panels manufactured by Armstrong, type Prima Fine Fissured, and an exposed suspension framework constructed of tee-section steel, manufactured by Armstrong, type Trulok Prelude. Four light fittings manufactured by Crompton lighting and Illuma, were mounted in the ceiling. The upper surfaces of the light fittings were provided with fire-resistant covers manufactured by Environmental Seals.

6.2 Materials [1]

6.2.1 *Floor and supporting construction*

The floor structure was comprised of:

- four IPE 140 steel joists, length 4600 mm, span L_1 = 4150 mm;
- six floor elements of reinforced aerated concrete, thickness 150 mm, with the following dimensions:
  - 3050 x 750 mm (4 elements);
  - 3050 x 400 mm (2 elements).

The floor was assembled in a supporting comprised of a steel test frame lined with aerated concrete elements with a wall thickness of 150 mm. The internal dimensions of the supporting construction frame were 4000 x 3200 mm.

6.2.2 *Ceiling framework*

The ceiling sections were constructed from 'stitched'[2] cold-rolled thermogalvanized steel strips, finished with a powdered epoxy-resin coating on the exposed surfaces.

- main beam (1), type Trulok Prelude, BP 314033A, principle dimensions 3600 x 38 x 24 mm, thickness 0.33 mm;
- cross tee (2), type Trulok Prelude, BP 113033A, principle dimensions 1200 x 38 x 24 mm, thickness 0.33 mm;
- wall moulding (3), type Trulok Prelude, BPT 2424H, principle dimensions 3050 x 24 x 24 mm, thickness 0.5 mm.

The structure also made use of Sealfast rapid fasteners (4), comprised of two lengths of 4 mm Ø steel wire and a connector. The positions of these fasteners are shown in Figure 1.

[1] The figures between brackets refer to the corresponding components in the parts list
[2] 'Stitched' refers to indentations pressed into the body of the tee section. According to the client this increases the rigidity of the section.

6.2.3 *Ceiling panels*

- Armstrong ceiling panels, type Prima Fine Fissured, self-supporting panels with dimensions 1200 x 600 x 15 mm (l x b x d) and with a weight of approx. 3.67 kg/panel.

6.2.4 *Light fittings (see Figure 1)*

The following light fittings were used:

a) light fitting, type Thorne Crompton with Perspex diffuser, dimensions 1200 x 600 mm;
b) light fitting, type Thorne with aluminium grid, dimensions 1200 x 600 mm;
c) and d)light fitting type D111X/C, dimensions Ø 73 mm, height 73 mm, 2 pieces.

6.2.5 *Fire-resistant covers*

- cover, type Envirograf FT2, dimensions 1225 x 610 x 115 mm (l x b x d), manufactured from glass-fibre sheet, mounted over both light fittings a) and b) as specified in 6.2.4 (see Figure 3);
- cover, type Envirograf Ref. No. 030201, dimensions Ø 150 mm, height 120 mm, manufactured from glass-fibre sheet, mounted over a light fitting d) as specified in 6.2.4 (see Figure 3);
- cover, type Envirograf Intumescent cage, dimensions 150 x 150 x 120 mm (l x b x d), manufactured from gauze incorporating a foam sheet, type Multigraf Intumescent Sheet, placed over a light fitting c) as specified in 6.2.4 (see Figure 4).

6.2.6 *Fastenings*

- UPAT Express nails, Ø 5 x 50 mm, for the attachment of the wall mouldings to the aerated-concrete framework (for further details see 6.3);
- lead anchors, for the attachment of the rapid fasteners to the aerated concrete floor elements;
- galvanized steel clips, for the attachment of the 610 x 1225 covers to the suspension framework;
- steel clips, dimensions approx. 65 x 40 mm, thickness 0.5 mm, for the attachment of the ceiling panels in the suspension framework.

6.2.7 *Seals*

Strips of rock-wool (type Rockwool 750, density 115 kg/m^3):

- to seal the joints between the floor elements, thereby ensuring that there would be no impediment to the deformation of the floor structure during the fire test;
- to seal the recesses in the aerated-concrete wall of the supporting construction at the locations in which the steel joists were placed in the wall.

6.3 Method of construction and assembly

The method used to construct and assemble the floor/ceiling structure is described below. An overview of the structure is shown in Figure 1.

- lining of the steel test frame with the aerated-concrete elements;
- positioning of the steel joists, centre-to-centre distance approx. 900 mm length-wise in the aerated-concrete frame;
- positioning of the floor elements on the steel joists;

- attachment of the wall mouldings on the inner surface of the aerated-concrete frame, at a distance of approx. 280 mm from the underside of the steel joist to the underside of the wall moulding, with UPAT nails at a centre-to-centre distance of approx. 300 mm;
- attachment of the lead anchors and the rapid fasteners, centre-to-centre distance 1200 mm, in the direction of the span of the steel joists, as shown in Figure 1;
- shortening of the main beams to lengths of approx 1.72 m and 1.48 m and the hanging of the rapid fasteners with the location of the connectors and the fire-breaks as shown in Figure 1, centre-to-centre distance between the main beams approx. 1200 mm;
- adjustment of the rapid fasteners to the correct length;
- installation the cross tees, centre-to-centre distance approx. 600 mm;
- installation of the light fittings (see Figure 1);
- attachment of the fire-resistant provisions (see Figures 2, 3 and 4);
- attachment of the other ceiling panels, using clips located centrally on each side of the ceiling panel;
- sealing of the joints between the floor elements and the recesses in the aerated-concrete framework with rock-wool.

7 THE CONSTRUCTION OF THE STRUCTURE

TNO Building and Construction Research Centre for Fire Research	:	the supporting and the floor of joists and aerated-concrete floor elements.
Armstrong BV, Breda	:	the manufacture and installation of the suspended ceiling with exposed suspension framework and ceiling panels.
Environmental Seals Ltd	:	the installation of the light fittings and the fire-resistant covers.

8 TEST METHOD

8.1 Inspection of the test piece

During construction and assembly the specifications of the materials and components were checked against the information that had been previously supplied.

8.2 Conditioning

The structure investigated in this report was located in the Centre for Fire Research's test hall in the period between the beginning of its construction until the completion of the fire test. The ambient temperature was 20 ± 5 °C and the relative humidity was 50 ± 10%.

8.3 Fire test

8.3.1 *Conditions*

The investigation was carried out in accordance with the provisions as stated in the Dutch standard NEN 6069:1997. The test specimen was heated on one side, the underside, in accordance with the standard fire curve.

8.3.2 *Measurements*

The following parameters were measured during the heating period:

- the gas temperature in the furnace, by means of seven thermocouples (TOV 1 up to and including TOV 7), and the overpressure in the furnace;
- the temperature of the underside of the flanges of the steel joists with six thermocouples (TST 1 up to and including TST 6);
- the temperature of the webs of the steel joists with six thermocouples (TST 7 up to and including TST 12);
- the temperature of the air in the plenum with six thermocouples (TST 13 up to and including TST 17);
- the temperature of the air in the plenum immediately above the fire-resistant provisions (TST 18 up to and including TST 21);
- the temperature of the unexposed surface of the floor with five thermocouples (TOPP1 up to and including TOPP5);
- the ambient temperature in the test hall;
- the velocity of the air in the test hall;
- the deflection at the centre of the floor, with one displacement transducer (VERPL. OPN1).

The location of the thermocouples and the deflection transducer are shown in figure 5.

9 OBSERVATIONS DURING THE HEATING

The heating was terminated after a period of 51 minutes; at this time one of the ceiling panels fell out of the suspension framework. Also failure to support the load as defined by NEN 6069:1997 i.e. the deflection criteria occured.

Appendix A contains a detailed description of the observations made during the heating trial.

10 MEASUREMENT RESULTS

10.1 *The determination of the density[3] and the equilibrium moisture content[4]*

Ceiling panels type Prima Fine Fissured
- density : 243 kg/m^3
- moisture content (w/w) : 1.3 %

10.2 *The fire test*

The results of the measurements are shown in Figures 6 to 14.

During the heating period the overpressure in the oven and the temperature and velocity of the air outside of the oven were in compliance with the requirements stated in NEN 6069:1997.

11 SUMMARY

The most important results from the investigation are summarized in table 1.

Table 1 Summary of the test results.

Criterion	Period from the beginning of the heating period during which the criterion was still just met
Load bearing capacity	51 min.
Intergrity	51 min.
Thermal insulation	51 min.

12 CONCLUSIONS

The Fire-resistance with respect to the separating function as well as with respect to the loadbearing capacity, as determined in accordance with NEN 6069:1997 was **51 minutes**.

[3] Determined prior to drying.
[4] Determined after drying the sample at 105°C for 24 hours.

13 DIRECT FIELD OF APPLICATION

This conclusion is applicable solely to floor/ceiling structures that are identical in every detail to the structure examined during the test, inclusive of the materials, and subject to compliance with the following conditions:

a) the total load (as a result of the dead weight and live load imposed on the joists in a fire load case is a maximum of 1.19 kN/m^1.
b) the theoretical span is a maximum of 4.15 m.
c) the joints between the floor elements and between the floor elements and the surrounding structure are sealed in a manner such that the premature integrity failure of these joints.
d) no more than two light flulings of 1200 x 600 mm and two light fittings of Ø 73 mm are installed in the ceiling.
e) the ceiling panels are attached to the sections by means of steel clips.

14 EXTENDED APPLICATION

Larger loads and/or larger spans or centre-to-centre distances between the beams are permitted only in the event that:

- steel joists are used with a section factor (U/A < 291 m^{-1});
- a calculation performed in accordance with NEN 6072:1997 has demonstrated that the temperatures of the steel joists are at most equal to the critical temperature.

  Note 1:
  Failure of the steel joists must be expected if the temperatures of the joists (Θ_a)are in excess of the critical temperature of the steel ($\Theta_{a,crit}$) as determined in accordance with NEN 6072:1997.
  For joists with a section factor <291 m^{-1} the temperatures will be less than the measured steel temperatures. The critical steel temperature depends on the load imposed on the joists and the static system[5].

  Note 2:
  The calculation of the steel temperature of the joists must be based on the heating of the joists on three sides, with ambient temperatures in accordance with the curve shown in Figure 11.

- In case of larger c.t.c. distances of the joists the suspension system (the number of suspension points) is not changed.

[5] See NEN 6072:1997

15 REMARK

After the test, the fire-resistant covers over the 1200 x 600 mm light fittings were still clearly visible (see photo 5). The covers over the other light fittings could no longer be seen.

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List of illustrations

Photographs

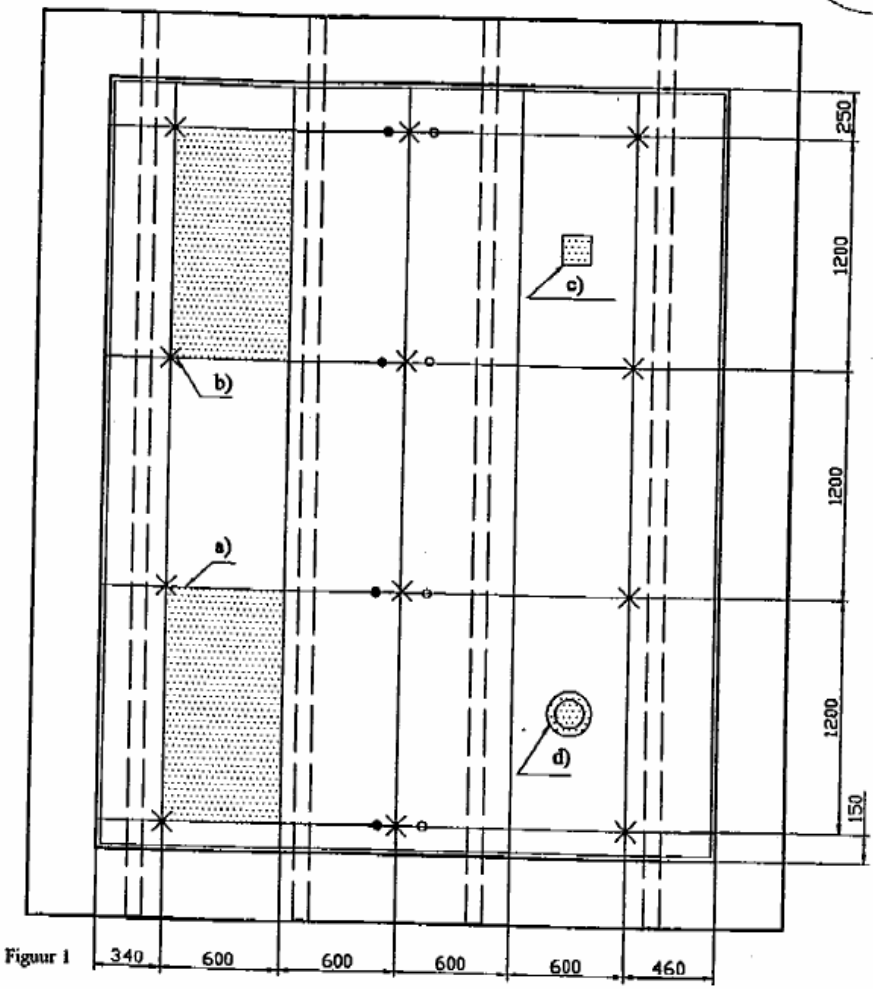
Appendix A

Observations during the heating trial

H = Observation on the side exposed to direct heat
N = Observation on the side not exposed to direct heat

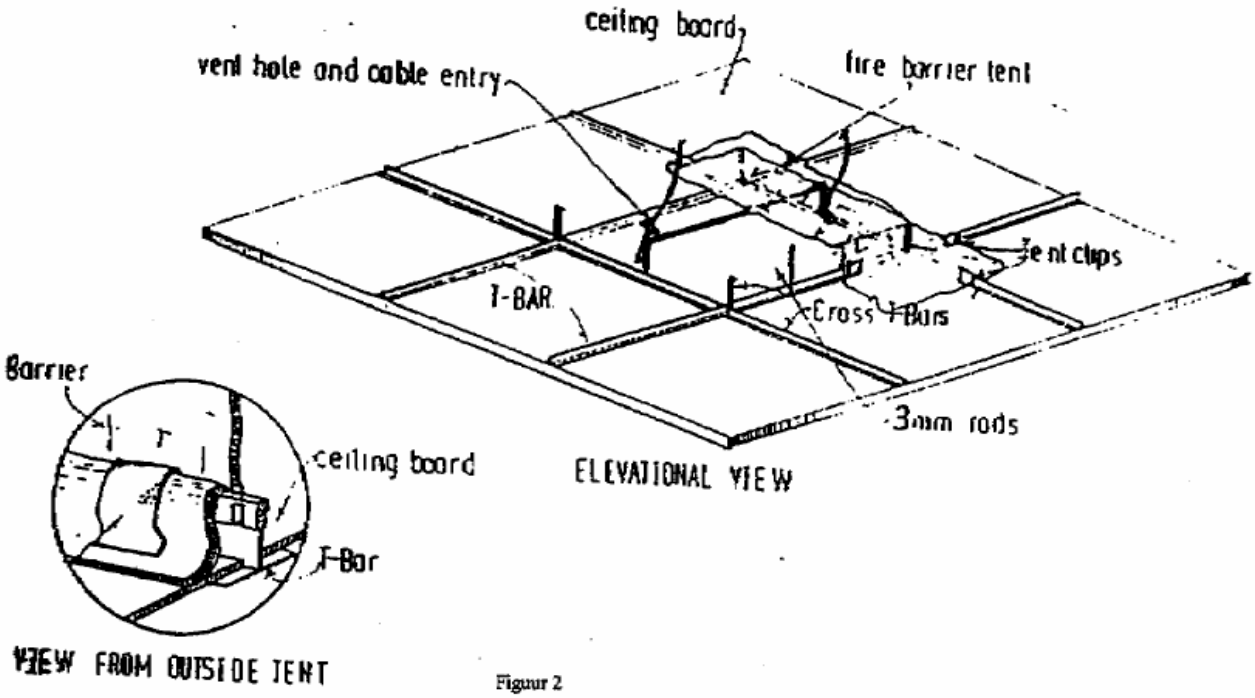
Time [min.]		Observation
0		Heating begins
2	H	Perspex panel of light fitting a) has fallen out
5	H	Fire-breaks activated
8	N	Emission of smoke above the floor
33	H	The ceiling sags slightly in the vicinity of light fittings a) and b).
40	H	An opening is visible between the edge sections and the trimmed ceiling panels adjacent to light fittings a) and b).
42	H	A small trimmed panel at the side of and between light fittings a) and b) has fallen out.
48	H	The central ceiling panel adjacent to light fittings a) and b) has fallen out.
51	N	Maximum sag attained.
		End of heating

× ophangpunt
• koppeling
○ fire-break



Figuur 1

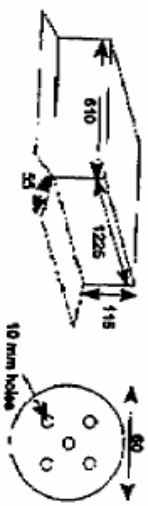
armatuur a) = lichtbak 1200 x 600 mm, type Thorne Crompton met perspex lichtkap, aan de bovenzijde voorzien van een Envirograf FT2 cover
armatuur b) = lichtbak 1200 x 600 mm, type Thorne met aluminium rooster, aan de bovenzijde voorzien van een Envirograf FT2 cover
armatuur c) = halogeenspot, type D111X/C, aan de bovenzijde voorzien van een bij verhitting opschuimend Envirograf kooitje
armatuur d) = halogeenspot, type D111X/C, aan de bovenzijde voorzien van een Envirograf nr 03201 cover

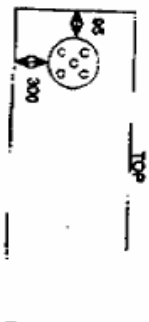


Figuur 2

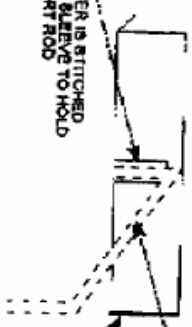
Envirograf FT2 Tent, which contains the following;

Material: 650 gram glass cloth with stitching coated with Envirograf GC Glass Cloth Coating Material.





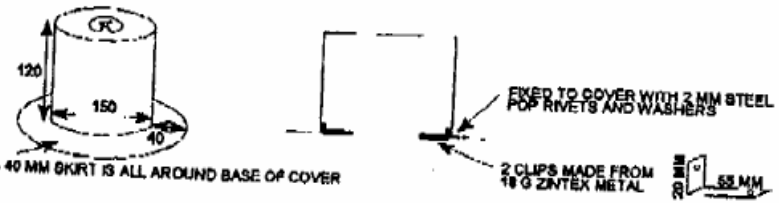
60 mm luminescent ring with fire proof card, 5 no. 10 mm holes, pop riveted to the top of the tent at one end, with 2 mm steel pop rivets and washers. The head of the pop rivet is coated and the cable entry one end only.

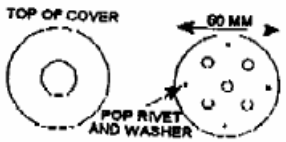


Fixing Clips made from 18 gauge steel zinc plated, go over the glass cloth and over the T bar. Total: 10 per tent.

Figuur 3

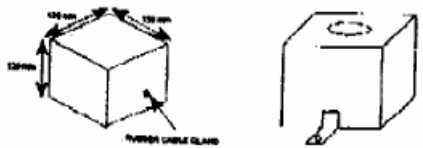
Envirograf Ref. No. 03201, size: 150 mm dia x120 mm high. Made from 400 gram glass cloth impregnated with Envirograf GC Coating.





Ring of Multigraf Intumescent with Fire Proof Card, 5 x 10 mm holes fixed to the cover with 4 pop rivets and washer, steel, 2 mm.

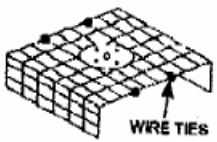
Envirograf Intumescent Cage, made from 12 mm weld mesh, 18 g wire, 150 mm x 150 mm x 120 mm high. Consisting of a mesh body, lined with Multigraf Intumescent Sheet Material with external fire faced card, white.



Stapled into mesh frame with 28/6 staples.

The frame has fitted on one side a 12 mm rubber cable gland.

On the opposite side are fitted 2 x 18 g metal brackets, 30 mm x 20 mm, welded to the cage.



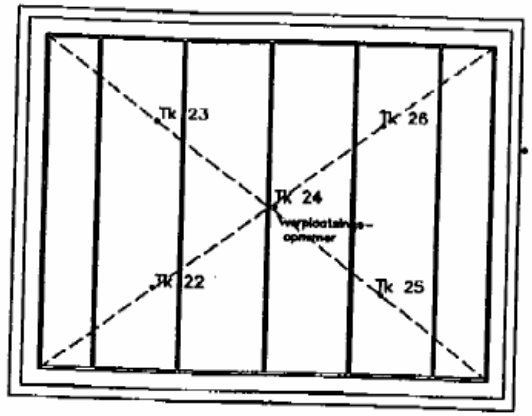
The lid consists of a 12 mm weld mesh top, 18 g wire. This is returned down at two sides by 15 mm, lined with Multigraf Intumescent Sheet Material, fixed with 28/6 staples and wired on top of the frame with 18 g wire ties.

On top of the lid is a ring of Intumescent with Fire Card, 60 mm diameter, 5 x 10 mm holes pop rivetted to the mesh with card inside and metal washers using 2 mm steel pop rivets.

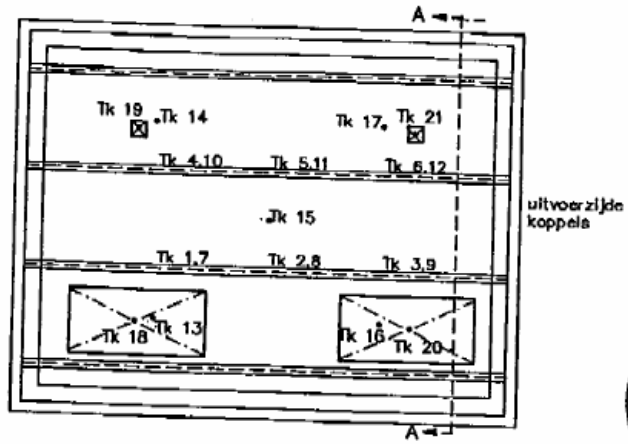
The lid is also sealed on the inside with a coating around the edges of Envirograf SIL Silicone Sealant.

The Fire Cage is adhered to the ceiling using Envirograf Sealer Adhesive under the mesh and the metal brackets.

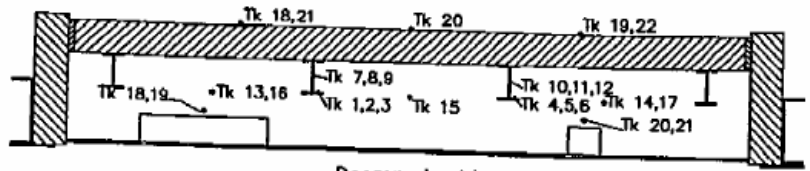
Figuur 4



Bovenaanzicht vloer

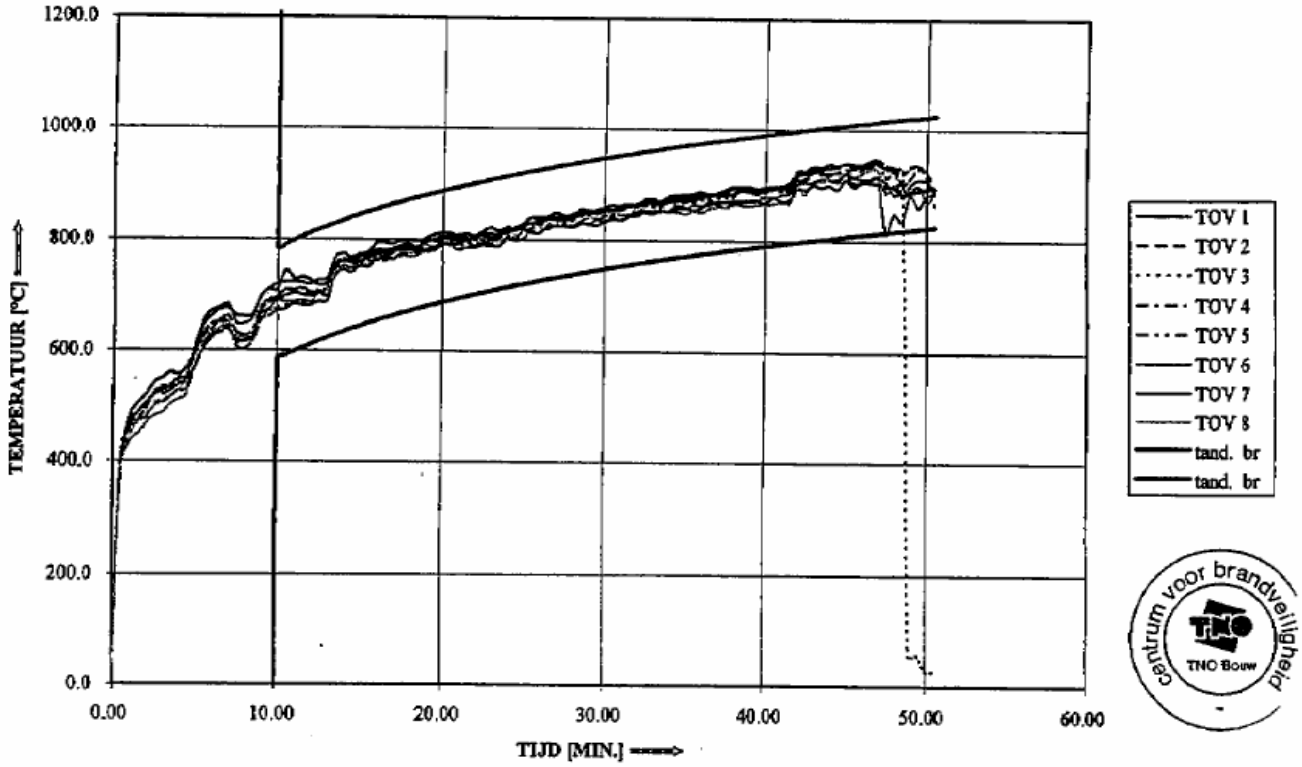


Bovenaanzicht stalen balken

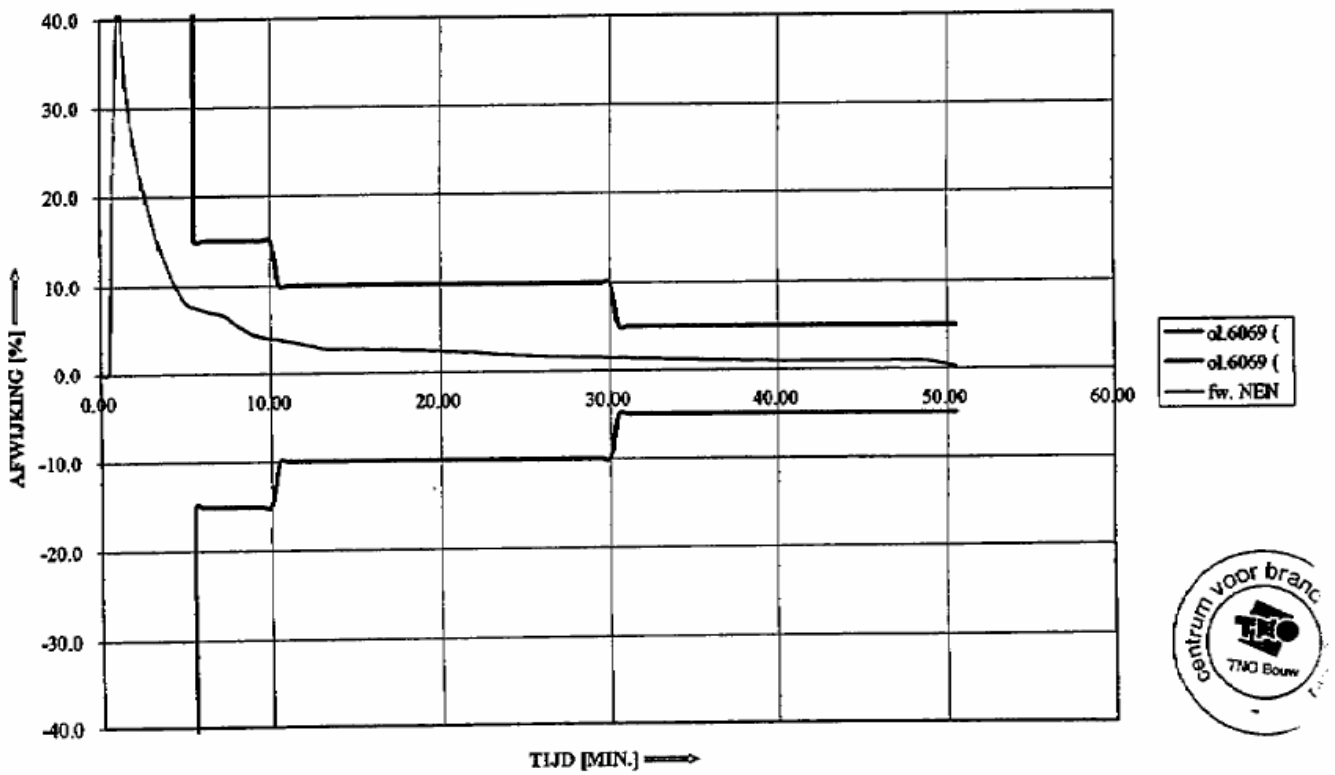


Doorsnede AA

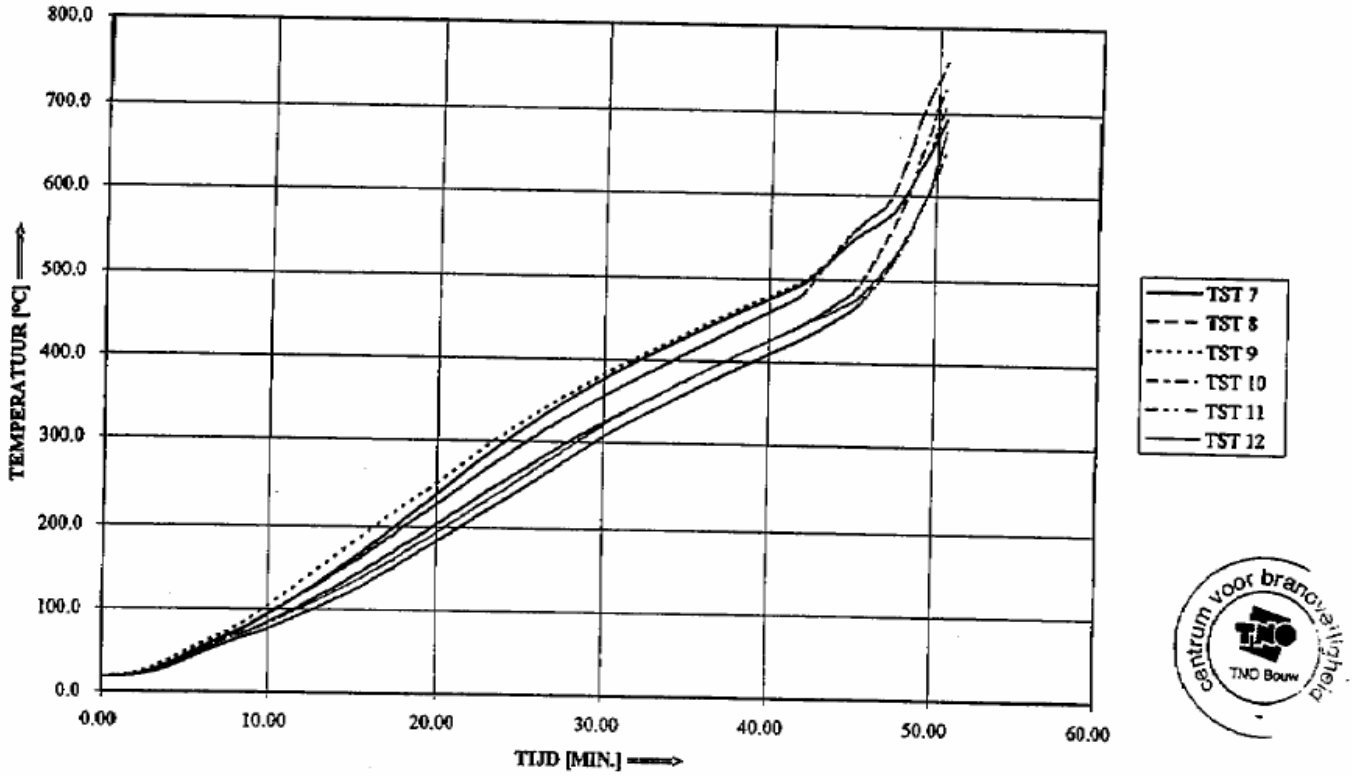
Figuur 5



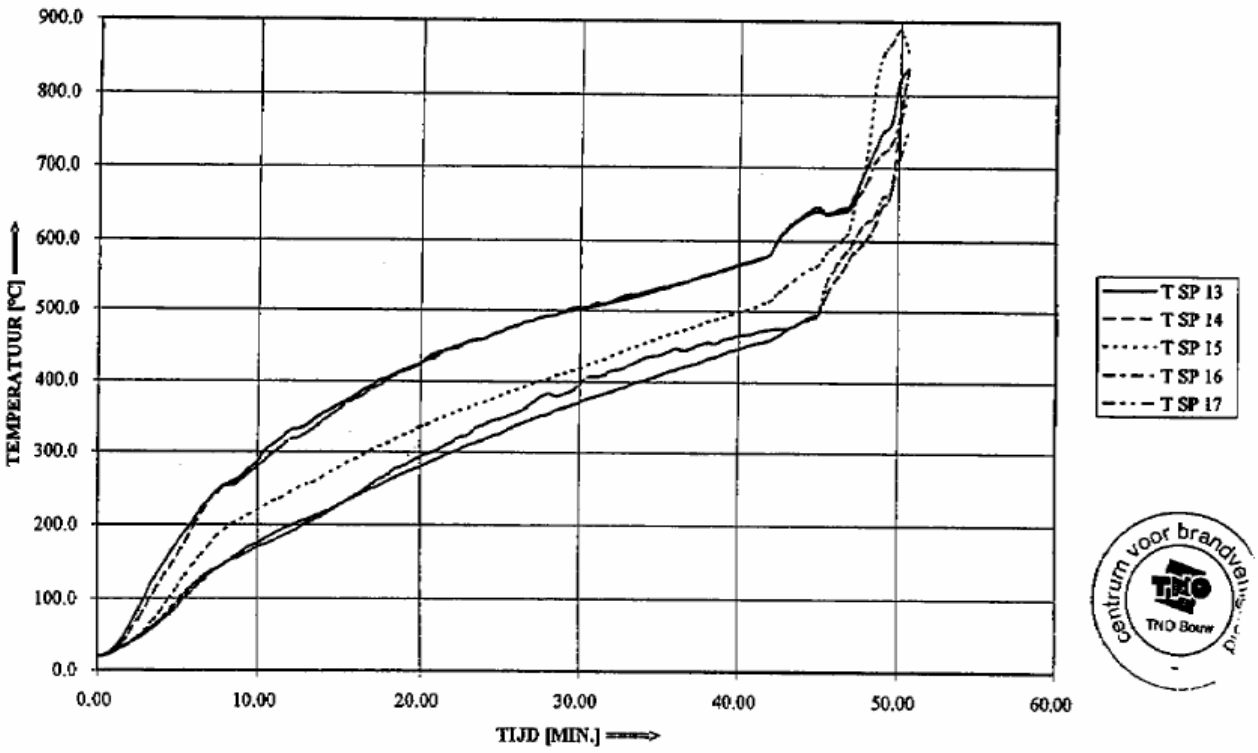
Figuur 6 : Gemeten gastemperaturen in de oven



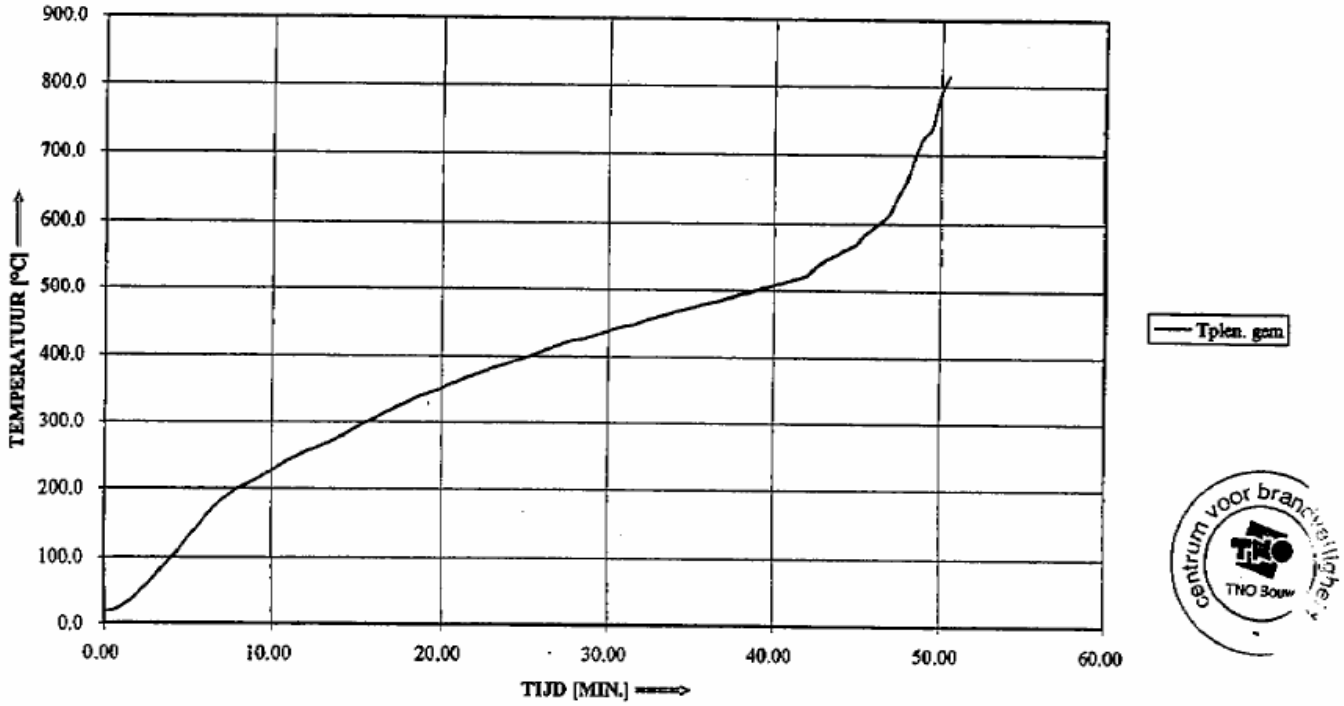
Figuur 7 : Relatieve afwijking



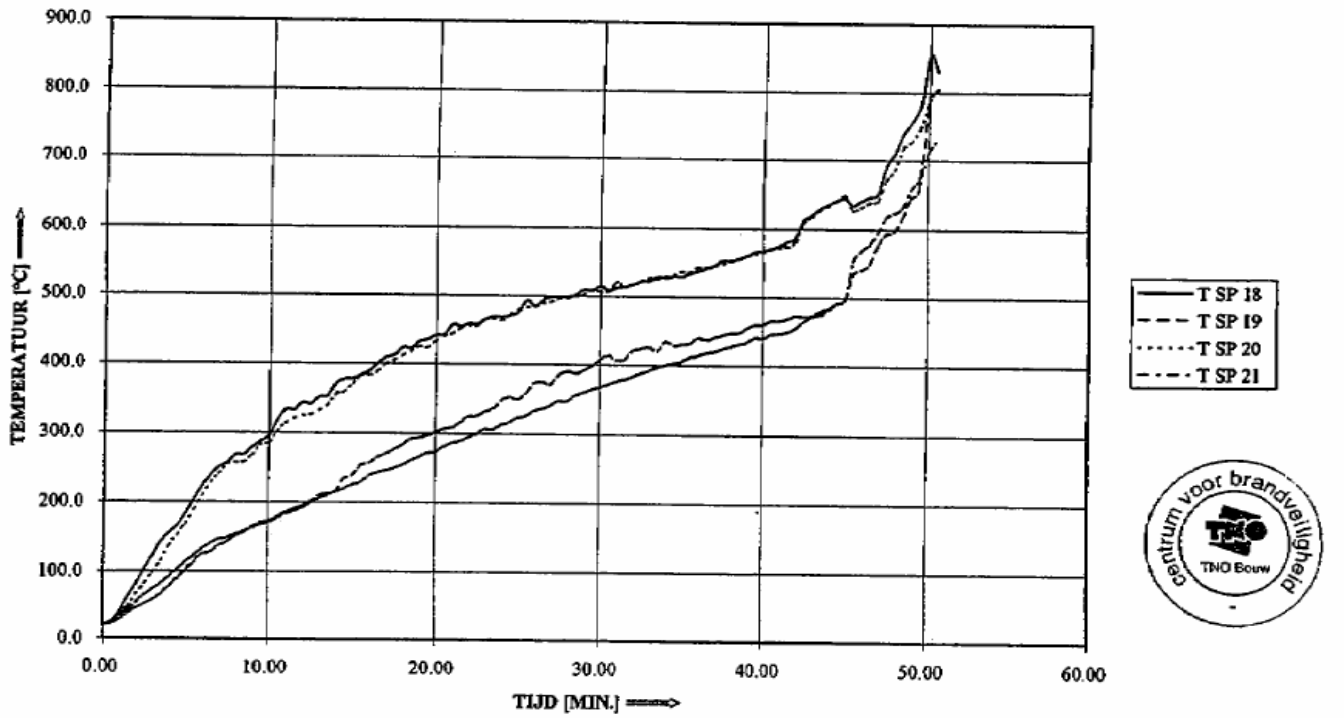
Figuur 9 temperaturen van de lijven



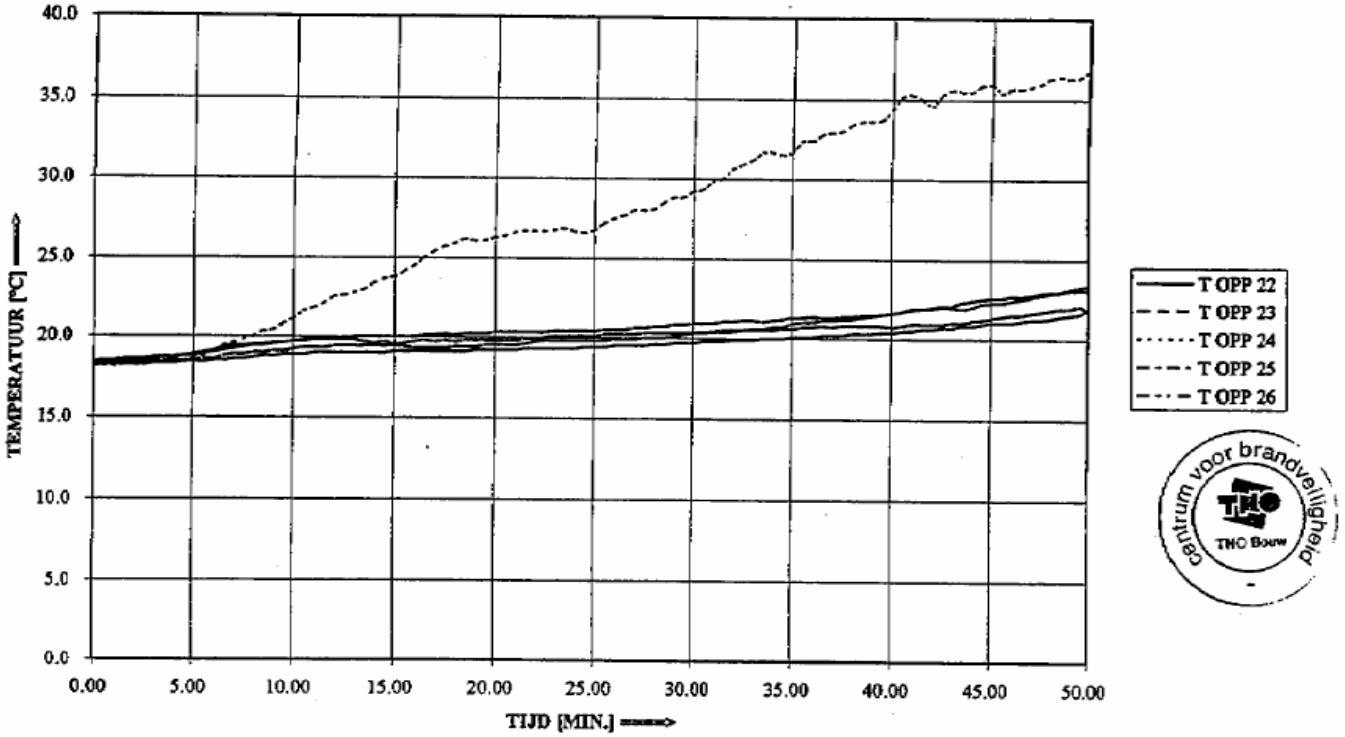
Figuur 10 : Gemeten luchttemperaturen in het plenum



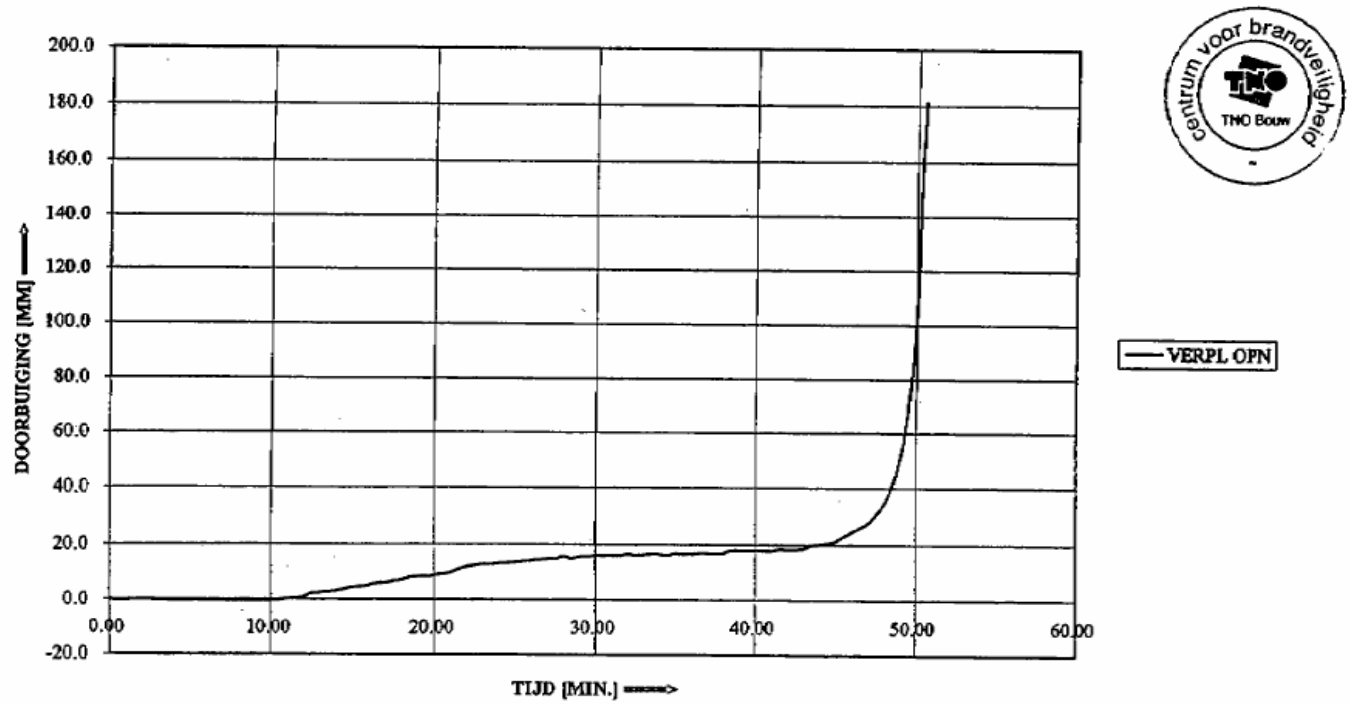
Figuur 11 Gemiddelde luchttemperaturen in het plenum



Figuur 12 : Gemeten luchttemperaturen in het plenum boven de lichtarmaturen



Figuur 13 : Gemeten oppervlakte-temperaturen van de bovenzijde van de vloer



Figuur 14 : Verticale verplaatsing (zakking) van het midden van de vloer