

Efectis Nederland BV
Centre for Fire Safety
Lange Kleiweg 5
P.O. Box 1090
2280 CB Rijswijk

Efectis Nederland report

2007-Efectis-R0667[Rev.1]

**Fire resistance of an aluminium curtain wall
structure, type CW50-FP with glazing and panels,
according to EN 1364-3: 2006, for the case "fire
from outside to inside"**

www.efectis.nl

T +31 15 276 34 80
F +31 15 276 30 25
E nederland@efectis.com

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Author(s) A.J. Lock
P.W.M. Kortekaas

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Sponsor Reynaers Aluminium NV/SA
Oude Liersebaan 266
B-2570 Duffel
Belgium

Project name Fire resistance
Project number 2007405

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1 Subject

A fire-resistant curtain wall structure, type Reynaers CW50-FP, manufactured from aluminium sections integrated with steel tubes and cooling material and provided with fire-resistant glazing and panels.

2 Examination

Determination of the fire resistance according to EN 1364-3: 2006 in the Netherlands known as the NEN-EN 1364-3: 2006, for the case “fire from outside to inside”.

3 Sponsor

Reynaers Aluminium NV/SA
Oude Liersebaan 266
B-2570 Duffel
Belgium

4 Place and data regarding the examination

The examination was performed at the laboratory of Efectis Nederland BV in Rijswijk, The Netherlands.

The supporting construction was prepared from August 20 until August 22, 2007.

The specimen was assembled from August 24 until August 28, 2007.

The fire test was performed on August 30, 2007.

5 Date and number of the report

September 2009; 2007-Efectis-R0667 [Rev.1]

The test report is modified at request of the sponsor. The changes are additional information in paragraph 6.2.2. Pressure plates and caps.

6 Test specimen

6.1 General

Experimental testing was performed on a curtain wall structure with the following main dimensions:

- Width: 4530 mm
- Height: 3700 mm

The curtain wall was subdivided by aluminium mullions and transoms into 18 bays, of which:

- 4 bays were fitted with insulating glass;
- 14 bays were fitted with insulated panels with glass face plate.

The elevation of the curtain wall is shown in figure 1.

The wall structure was erected against a special curtain wall frame with the following overall dimensions: $w \times h = 6,000 \times 5,000$ mm.

The inside dimensions of the supporting construction (the concrete floors and aerated light weight piers) were the same as the inner furnace dimensions $w \times h = 4,000 \times 3000$ mm.

The edges of the structure exhibited the following junctions:

- a) free edge;
- b) mullion junction with a partition wall;
- c) junction to the floor of a storey;
- d) junction to the ground floor.

For the dimensions and specifications of the materials and components of the examined construction, see figures 1 until 13 in chapter 12. Significant details of the construction are given in the paragraphs below. The numbers in the text between brackets correspond with the numbers of the part list.

6.2 Materials

6.2.1 Mullions and transoms

The mullions (034.0901.XX) consist of aluminium sections with an integrated tube with dimensions of 46 x 46 mm. The aluminium tube sections of the mullions are fitted with a steel tube section with dimensions of 40 x 40 x 4 mm. Refer to the cross-sections shown in figures 2 and 4. The transoms (034.0921.XX) consist of aluminium sections with dimensions of 45 x 45 mm, provided with Kerafix Coolmax cooling material, dimensions 11 x 47 mm.

The transoms of the curtain wall featured machined recesses were attached to the mullions by means of aluminium T-brackets (73.7350.--) and stainless-steel bolts. For fitting of the mullions to the concrete frame structure, anchors of type CW 60 were

fitted to the framework at the corner points. The aluminium brackets, type CW 60 are shown in figure 6.

6.2.2 *Pressure plates and caps*

Vertical aluminium pressure plates (034.2534.00) are fitted into the PVC profile (034.0075.04), (used for compartmentation) and the screw channel by means of stainless steel screws (053.5201.--) and steel plates (073.7161.--) (40 x 40 x 3 mm) with a spacing of 300 mm. The steel plates are used to secure the fixation of the glass in case of a fire.

Horizontal aluminium pressure plates (034.2535.00) are fixed with screw (050.5032.--), (M6) and steel plate (073.7161.--) in the glass support, the rest of the profile is fixed in PVC profile (034.0075.04), (used for compartmentation) and the screw channel with screws (053.5475.--). The pressure plates are covered with aluminium caps (034.0537.XX) and (034.0538.XX), with integrated Kerafix S-board.

6.2.3 *Glazing and panel sections*

For sealing against the glazing and the panels, two types of glazing seals manufactured from modified EPDM are fitted into the mullions and transoms. Glazing seal (80.9840.04) and (80.9845.04) on the inside; and the glazing seals (080.9843.04) on the outside. Between outside glazing gaskets and glazing, an aluminium sealing tape (84.9500.--) was continuously fixed vertically and horizontally, to seal off the opening between two glazing panes or panels.

6.2.4 *Support and intumescent materials*

The glass panes and panels are located on different steel glass supports. (073.7106.--), (073.7116.--) and (073.7126), see figure 13. On top of the support aluminium silicate glass support blocks (084.9017) are fitted.

Behind the caps of the pressure plates, the horizontal and vertical sections were insulated with Kerafix S-Board (87.9510.--) in cap (34.0537.XX) with dimensions of 4 x 45 mm and Kerafix S-Board (87.9511.--) in cap (34.0538.XX) with dimensions of 45 x 13 mm, see figures 2 until 5.

In the rebate around the perimeter, self adhesive intumescent material, type Kerafix Flexrem (84.9003.04) with dimensions of 55 x 1.5 mm was applied against the screw sockets of the mullions and transoms.

6.3 **Separation in mullion profiles**

In this curtain wall construction the mullions were at the top of the construction provided with a separation at the position of the top floor to create a better thermal insulation to profiles which cross the separation floor.

The mullion 34.0901.XX and the integrated steel tube were separated over a distance of +/- 35mm at position of the top floor.

The lower part of the steel tube was filled with article 087.9513.-- which is an S-board block (length: 40mm) enfolded by a Flexrem swelling gasket. In case of fire the swelling gasket will fill the cavity between S-board and steel tube.

Additionally a swelling gasket enfolded the steel tube on the outside, at the position of the Promatec sheet. In case of fire this swelling gasket will fill the cavity steel tube and Promatec sheet, see figure 6.

6.4 Glazing

Type: Glaverbel Pyrobel.
Construction: 8-12-25EG;
8 mm float glazing at the outside;
12 mm cavity;
25 mm fire resistance glazing with intumescent interlayers with 3 mm float glazing and two PVB layers on the inside.
Total thickness 49 mm
For the remaining dimensions and weights of the glass panes, refer to table 1.

Table 1: Glazing

Glass pane (see figure 1)	Dimensions (w x h) [mm]	Weight [kg]
A1	1410 x 2458	320.6
A2	1580 x 1218	178
A3	1580 x 1218	178
A4	1410 x 378	49.3

6.5 Panels

6.5.1 Panels B

Panels B (see figure 1): WPI panels, comprising:

- Hardened glass, thickness 8 mm, with tinted coat on the inside;
- Mineral wool (Conrock Q5), thickness 20 mm;
- Granamat, thickness 19 mm;
- SV Steel plate, thickness 2 mm;
- Total thickness 49 mm.

For further details, refer to table 2 and figure 5.

6.5.2 Panel C

Panels C (see figure 1): WPI panels, comprising:

- Hardened glass, thickness 8 mm, with tinted coat on the inside;
- Mineral wool (Conrock Q5), thickness 20 mm;
- Granamat, thickness 19 mm;
- Mineral wool (Conrock Q5), thickness 55 mm
- SV Steel plate, thickness 2 mm;
- Total thickness 104 mm.

For further details, dimensions and weights refer to table 2, part list and figure 4.

Table 2: Panels

Panel (see figure 1)	Dimensions (w x h) [mm]	Weight [kg/m ²]
B1	548 x 830	49
B2	548 x 1410	49
B3	548 x 1580	49
B4	548 x 580	49
B5	1218 x 580	49
B6	1218 x 580	49
B7	378 x 830	49
B8	215 x 830	49
B9	215 x 1410	49
B10	378 x 1580	49
B11	215 x 1580	49
B12	378 x 580	49
B13	215 x 580	49
C1	2458 x 830	60

6.6 Attachment of the curtain wall and sealing with the frame

The curtain wall was mounted against a special frame with two concrete floors and two aerated concrete walls. In compliance with EN 1364-3: 2006 the wall had a continuous overhang part in place of the upper simulated floor and the partition wall. This means a construction with at the top a horizontal gap seal. On the right side a partition wall with a vertical gap seal. The construction was on the left side provided with a so-called free edge, thus permitting horizontal deformation at this point.

6.6.1 Top and bottom side

The mullions of the curtain wall were mechanically attached to the floors. For this purpose, aluminium brackets were used, type CW 60. The brackets were attached to the outside edge of the floor of the furnace chamber by means of steel anchors, dimensions 130 x 10 mm.

6.6.2 Gap Seals

The sealing between the upper simulated floor and the curtain wall consisted of a strip of Promatect-H with a thickness of 25 mm, which was attached to the underside of the floor. For sealing purposes, a strip of Kerafix Flexrem (84.9003.04) with dimensions 45 x 2.5 mm was attached between the curtain wall and the Promatect-H board and sealed off with silicones (84.9012.04) see figure 6.

The cavity between the upper simulated floor and the curtain wall was filled with mineral wool (loose wool), see figures 9 and 10.

6.6.3 Junction with a fire compartment wall

One side adjoined a fire compartment partition wall. The junction consisted of a Promatect-H board with a thickness of 25 mm, which was attached to the edge of the

partition wall. The seams between the Promatect-H board and the curtain wall were sealed with Kerafix Flexrem (84.9003.04), see figure 12.

The other vertical junction with the furnace was a “free edge”. Which was filled with mineral wool, see figure 11.

6.7 Test frame with supporting construction

The test frame with internal dimensions of 6000 x 5000 mm (w x h) was provided with two concrete floor slabs with dimensions 6000 x 750 x 200 mm (l x w x t) and a density of 2000 kg/m³ to simulate the upper and lower floors.

At the left side at a distance of 4000 mm of the construction piers masonry were erected of aerated light weight concrete, with a density of 675 kg/m³. The created aperture for the curtain wall structure was 4000 x 3000 mm (w x h).

7 Sampling and manufacturing of the construction

Efectis Nederland BV
Centre for Fire Safety:

- Curtain wall test frame;
- Delivery of aerated concrete stones;
- Masonry supporting construction.

Reynaers Aluminium NV/SA

- Fabrication of curtain wall construction;
- Assemblage of the construction;
- Concrete floors.

Glaverbel
WPI

- Glass.
- Panels.

8 Mode of testing

8.1 Verification of the specimen

The materials and components used were inspected during assembly on the basis of the supplied drawings and data.

Efectis Nederland was not involved with the sampling of the curtain wall parts.

8.2 Conditioning

Between erection of the wall and testing, the test specimen was retained in the laboratory of Efectis Nederland BV with the following conditions:

- Ambient temperature: 20 ± 5°C.
- Relative humidity: 50 ± 10 %.

8.3 Density and moisture content

Material	Density [kg/m ³]	Moisture [%]
Aerated concrete	675	1,5
Rockwool	36	0,8

8.4 Fire test

8.4.1 Test conditions

The construction was non-symmetrical and tested for the case “fire from outside to inside”. The fire test was carried out according to EN 1364-3:1999 with the reduced fire curve. This also includes that during the fire test, plate thermocouples were used to measure the gas temperatures in the furnace and the overpressure targets in the furnace for 0.5 meter and 2.70 meter above floor level were 0 and 18 Pa, respectively.

8.4.2 Measurements

During the heating the following data was measured and registered:

Furnace conditions

- Temperatures in the furnace using 8 plate thermocouples (TPL1 to TPL8), equally spread over the heated construction;
- The pressure in the furnace (Press-0 and Press-2.7).

Curtain wall (not directly exposed side)

- surface temperatures on the not directly exposed side of the panels with 29 thermocouples;
- surface temperatures on the not directly exposed side of the glass panes with 11 thermocouples;
- surface temperatures of the vertical clamping strips with 6 thermocouples;
- surface temperatures of the top of the mineral wool seal between wall and floor of a storey locally with roving thermocouple.

Curtain wall and junction (inside)

- surface temperatures on the inside of the panels, 25 mm above the mineral wool sealing between wall and floor of a storey with 4 thermocouples;
- surface temperatures of the sides of the mullions, 25 mm above the brackets with 12 thermocouples;
- surface temperatures of the top of the mineral wool seal between wall and floor of a storey with roving thermocouple.

Junction with the fire compartment partition wall

- surface temperatures of the lower edge of the aluminium transom between panels A3 and B6 with 1 thermocouple;
- surface temperatures of the side of the Promatect-H plate at the not directly exposed side, between curtain wall and partition wall, with 2 thermocouples;
- surface temperature at the rear of panel C1 with 1 thermocouple.

Other measurements

- heat radiation at a distance of 1.0 m from the geometric centre of the part of the curtain wall with fire exposure and at a distance of 1.0 m from the geometric centre of the wall and glass panes A1 and C1;
- four horizontal displacements of the curtain wall at 1.50 m above the floor level of the heated mullion and the free edge.

Environment

- air temperature and air velocity in the laboratory outside the furnace.

Roving thermocouple

- surface temperature of the horizontal and vertical gap seals.

The positions of the thermocouples and deflection measurement are given in figure C1a till C1f.

9 Test results

9.1 Observations during heating

After 75 minutes thermocouple TC 37 more than 203°C: *Thermal insulation exceeded.*
The details of the observations are listed in appendix A.
Photographs of details during assembly and the construction before, during and after the test are shown in Annexe D.

9.2 Graphs of the fire test

The test results are shown as graphs in Annexe B and C.
During the heating of the specimen the ambient temperature and air velocity meet the requirements of EN 1363-1: 1999 and 1363-2:1999.

9.3 Uncertainty of measurement

Due to the nature of fire resistance testing, in which several non-linear effects are present in both the test configuration and the test specimen, which influence each other, it is at this moment not yet possible to give a stated degree of uncertainty of measurement.

10 Summary

The fire resistance is determined of a curtain wall structure, type Reynaers CW50-FP, manufactured from aluminium sections integrated with steel tubes and cooling material and provided with Glaverbel fire-resistant glazing, type Pyrobel and WPI panels. The examination is performed according to EN 1364-3:2006 for the case "fire from outside to inside".

Table 2: Summary of test results

Surface	Criterion				
	Integrity (E)			Insulation (I)	
	Cotton pad	Gap gauge	Flaming	Mean. temp.	Max. temp.
Surface 1	Not reached	Not reached	Not reached	Reached after 90 minutes	Reached after 75 minutes

Heating was terminated after 91 minutes.

11 Field of application and conditions

The results of chapter 10 are only valid for curtain wall structures which are the same in detail as the tested structure and which comply with the following conditions:

- aluminium profiles, type CW50-FP integrated with steel tubes
- transoms provided with Kerafix Coolmax cooling material;
- Glaverbel glass, type Pyrobel 8-12-25EG with maximum dimensions of 1580 x 2458 mm (w x h) and a maximum area of 3.47 m²;
- WPI panels, with maximum dimensions of 1218 x 1580 mm (w x h) and a maximum area of 0.87 m²;
- WPI panels, thickness 104 mm with maximum dimensions of 1218 x 1580 mm (w x h) and a maximum area of 1.92 m²;
- panels and glass panes distributed over the curtain wall as tested;
- the edges of the glass panes and panels provided with the specified EPDM sealing;
- profiles fixed with T-brackets, type CW 60;
- Profiles at the top provided with separation for extra thermal insulation;
- glass panes and panels supported with the specified steel supports;
- between the glass panes or panels and the steel supports aluminium silicate glass support blocks;
- in the rebate around the perimeter, self adhesive intumescent material, type Kerafix Flexrem;

horizontal and vertical sections and pressure plates insulated with Kerafix-S Board;

- design of the edge junctions as specified in the report.



A.J. Lock



Dr. Ir. G. van den Berg

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12 Figures

Part list Reynaers CW 50-FP

Figure 1: Dimensions of construction and position of cross-sections.

Figure 2: Cross-section D-D.

Figure 3: Cross-section E-E.

Figure 4: Cross-section F-F.

Figure 5: Cross-section G-G.

Figure 6: Three-dimensional detail of anchoring, cooling material and separation.

Figure 7: Detail bottom anchoring cross-section H-H.

Figure 8: Detail ceiling anchoring.

Figure 9: Detail at the left cross-section J-J.

Figure 10: Detail at the right cross-section K-K.

Figure 11: Positions of glass supports.

Figure 12: Three-dimensional overview of glass support types.

Figure 13: Assembly of glass supports.

Part list Reynaers CW 50-FP

Description of fire proof materials used for fire testing

Article number	Name	Description
034.0901.XX	Mullion 79mm	Aluminium
034.0921.XX	Transom 79mm	Aluminium
0S0.4044.--	Steel tube (metalised)	Dimensions 40x40x4
034.1534.00	Vertical pressure plate	Aluminium
034.0538.XX	Vertical face cap	Aluminium
034.1535.00	Horizontal pressure plate	Aluminium
034.0537.XX	Horizontal face cap	Aluminium
034.0075.04	Insulator	HPVC drainage profile with integrated screw channel
073.7106.--	Glass support	Stainless steel
073.7116.--	Glass support	Stainless steel
073.7126.--	Glass support	Stainless steel
073.7136.--	Glass support	Stainless steel
073.7146.--	Glass support	Stainless steel
073.7156.--	Glass support	Stainless steel
073.7161.--	Fixation plate	40x40x3 stainless steel
073.7350.--	T-bracket	T-bracket for fixation of transom to mullion
080.9840.04	Inner glazing gasket (mullion)	Gasket made of polychloroprene
080.9845.04	Inner glazing gasket (transom)	Gasket made of polychloroprene
080.9843.04	Outer glazing gasket	Gasket made of polychloroprene
084.9017.—	Glass support blocks	'Flammi 12' aluminium silicate glass support block – dimension 100 x 50 x 2
084.9500.--	Sealing tape	Aluminium 50mm x 0.38 thickness
084.9003.04	Swelling gasket – self adhesive	Graphite base water resistant (Kerafix Flextram) 1.5 x 55
087.9510.--	Cooling material – self adhesive	Kerafix S-Board water resistant 4 x45

Article number	Name	Description
087.9511.--	Cooling material – self adhesive	Kerafix S-board water resistant 13x45
087.9512.--	Cooling material	Kerafix Coolmax 10x45 for transom
080.9490.04	End gasket	EPDM gasket between transom & mullion
080.9887.04	End piece	Synthetic end piece for T-connection between transom & mullion
CW 60 anchor	Cut out profile 000.0613.00	Height 120mm
050.5389.--	Bolt M10 x 130	Fixation of mullion in anchor (fixed point)
073.5232.--	Axle Ø10 x 105	Fixation of mullion in anchor (loose point)
053.5201.--	Self drilling bimetal screw Ø5.5x110	For fixation of vertical pressure plate in glass support
050.5032.--	Screw M6x30	Fixation of 073.7161.-- in glass support
053.5475.--	Screw Ø 6.3 x 64	For fixation of horizontal pressure plate in transom
073.8202.01	Synthetic washer	For screw 053.5475.--
053.5471.--	Screw Ø 6.3 x 52	For fixation of glass support in transom
050.5142.--	Screw M6 x 80	For fixation of glass support in mullion
052.5317.--	Screw Ø4.2 x 13	For fixation of transom to mullion
052.5330.--	Screw Ø 4.8 x 13	For fixation of the T-bracket
Gluske Coollux	Cooling material – self adhesive	Coollux installed around mullion at anchor position

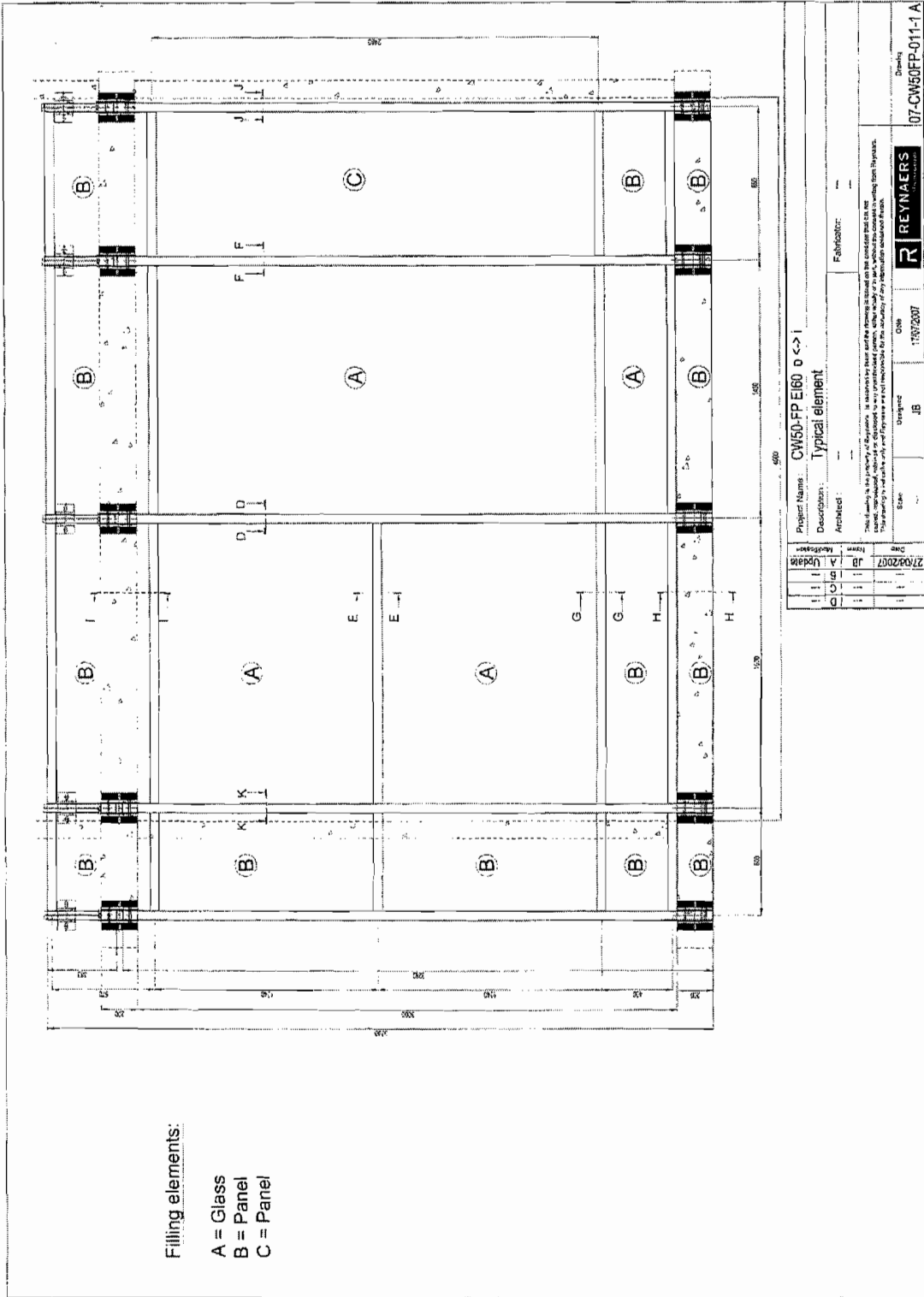


Figure 1: Dimensions of structure and position of cross-sections.

Section D-D

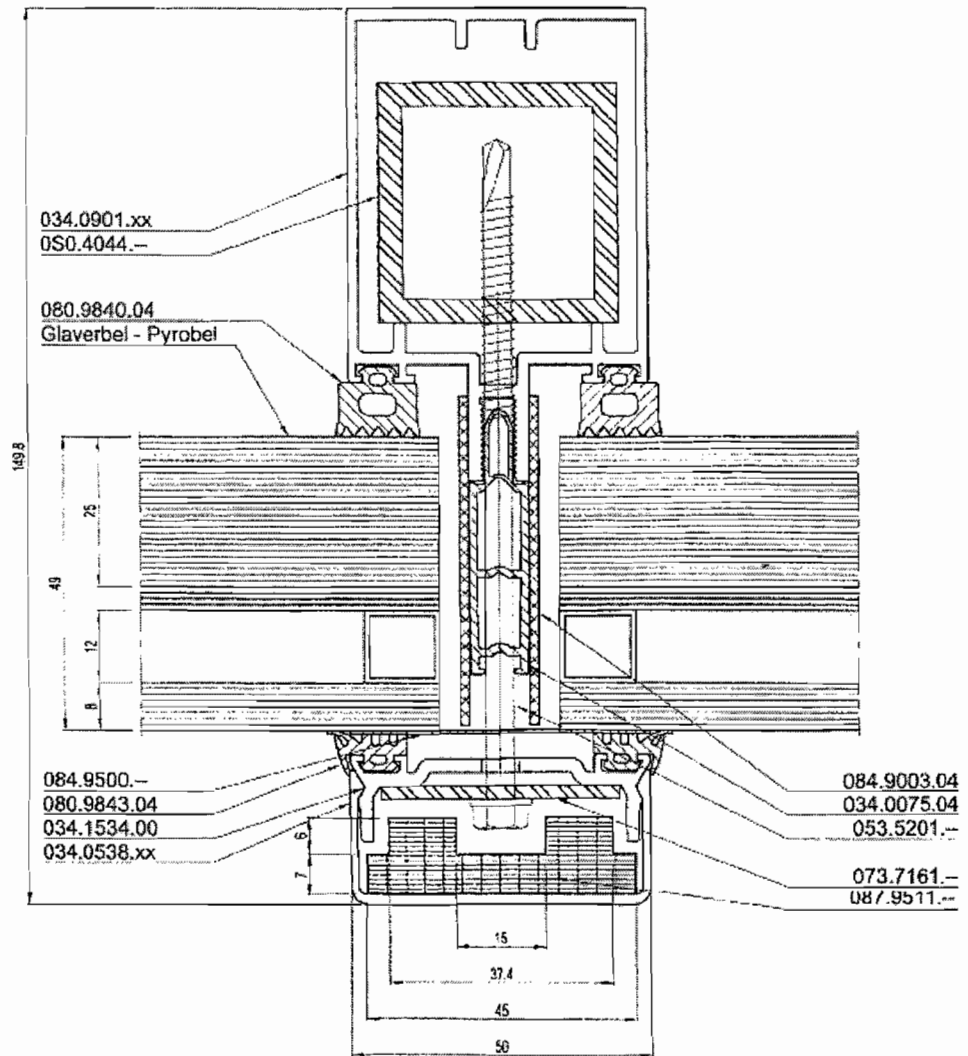


Figure 2: Cross-section D-D

Section E-E

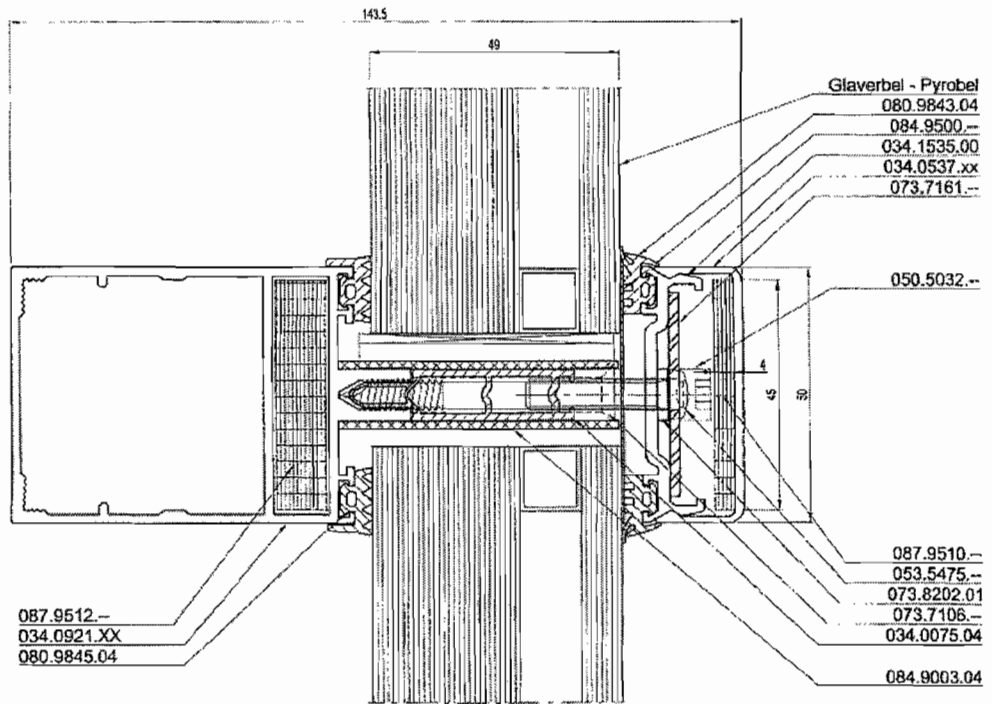


Figure 3: Cross-section E-E.

Section F-F

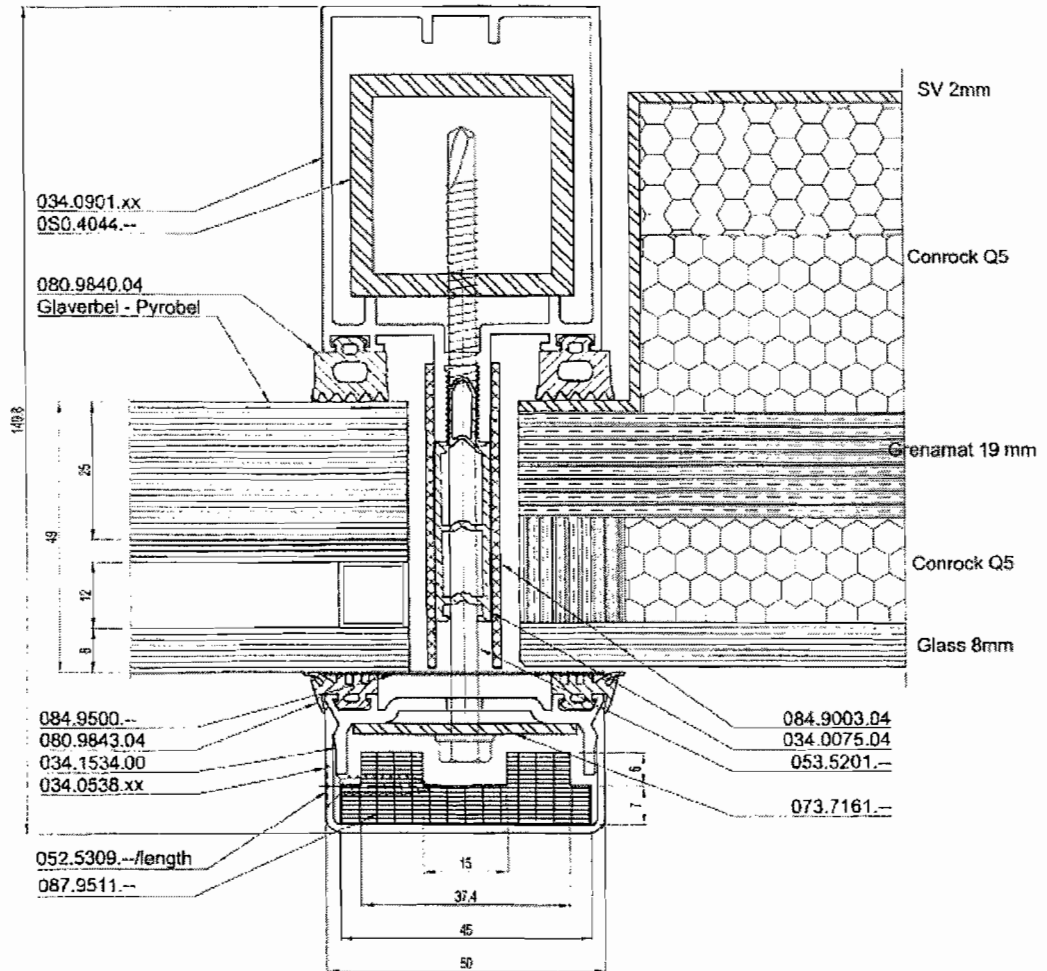


Figure 4: Cross-section F-F.

Section G-G

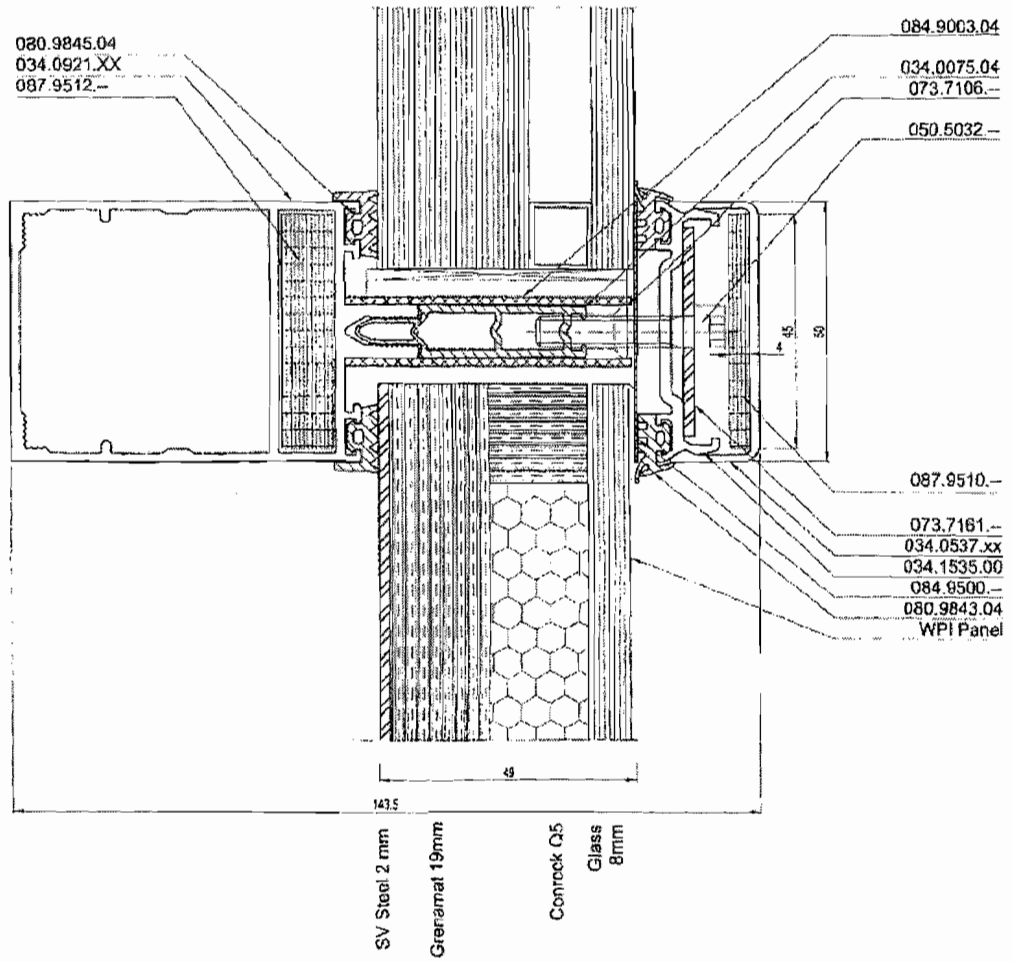


Figure 5: Cross-section G-G.

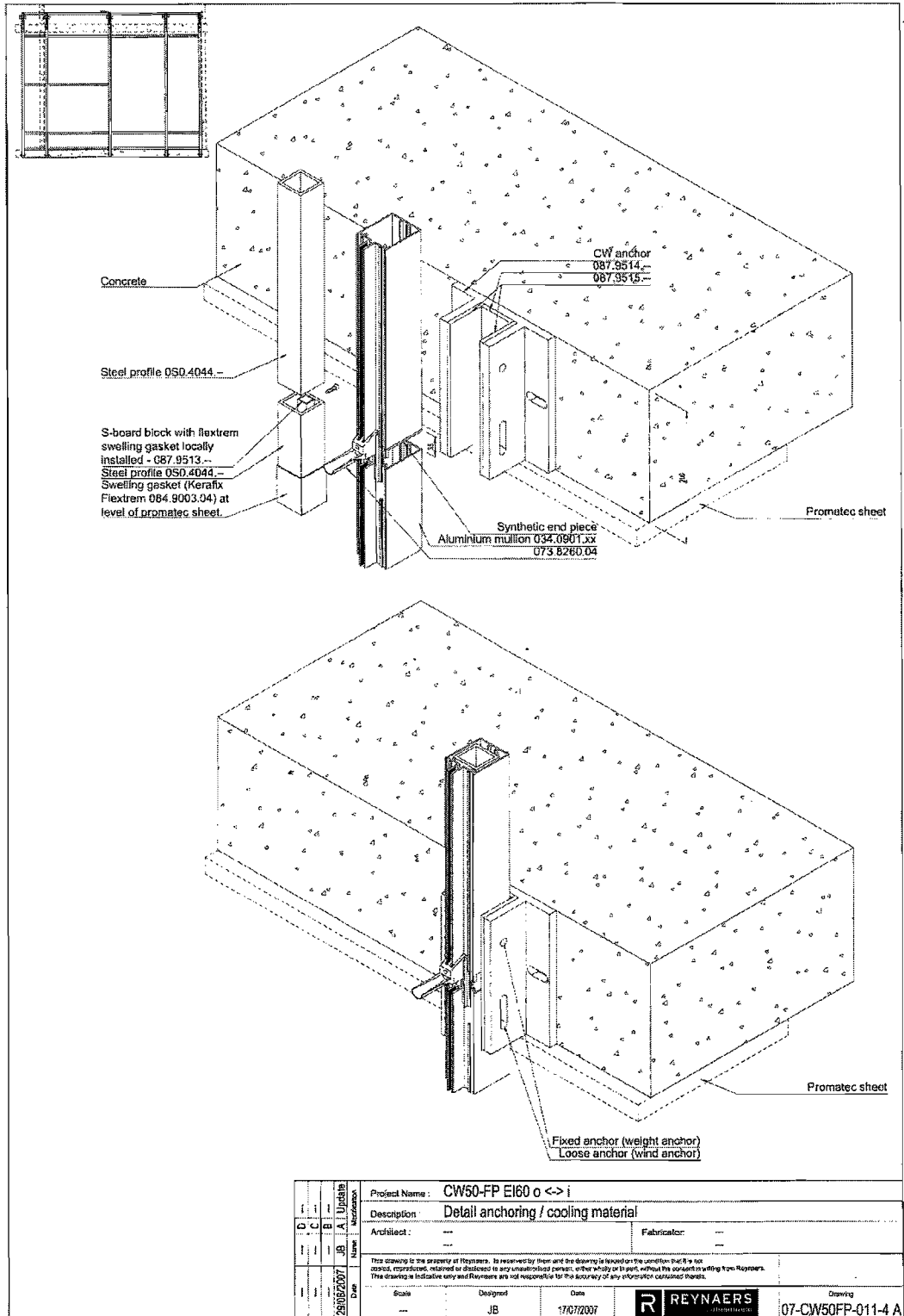


Figure 6: Three-dimensional detail of anchoring, cooling material and separation.

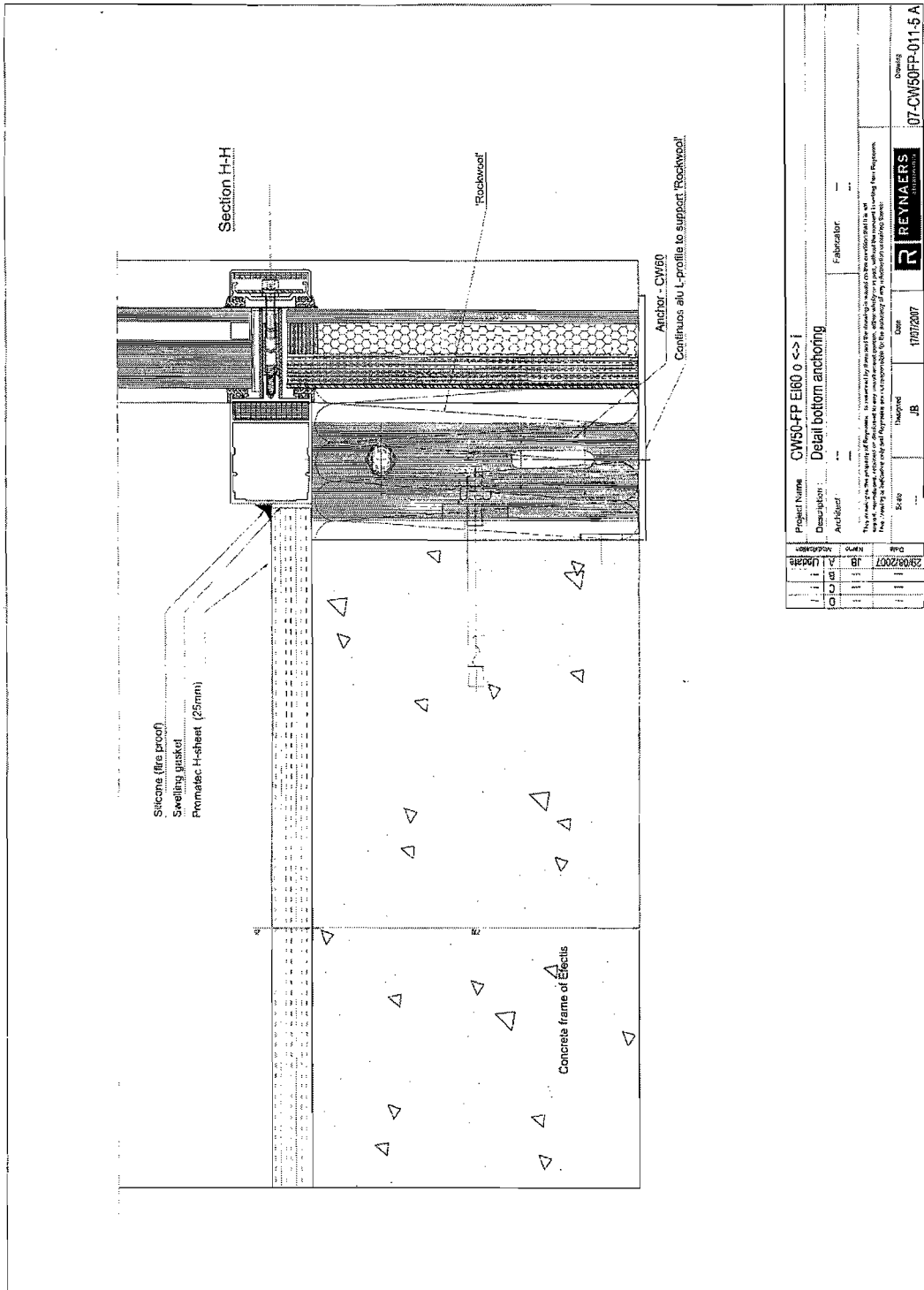


Figure 7: Detail bottom anchoring cross-section H-H.

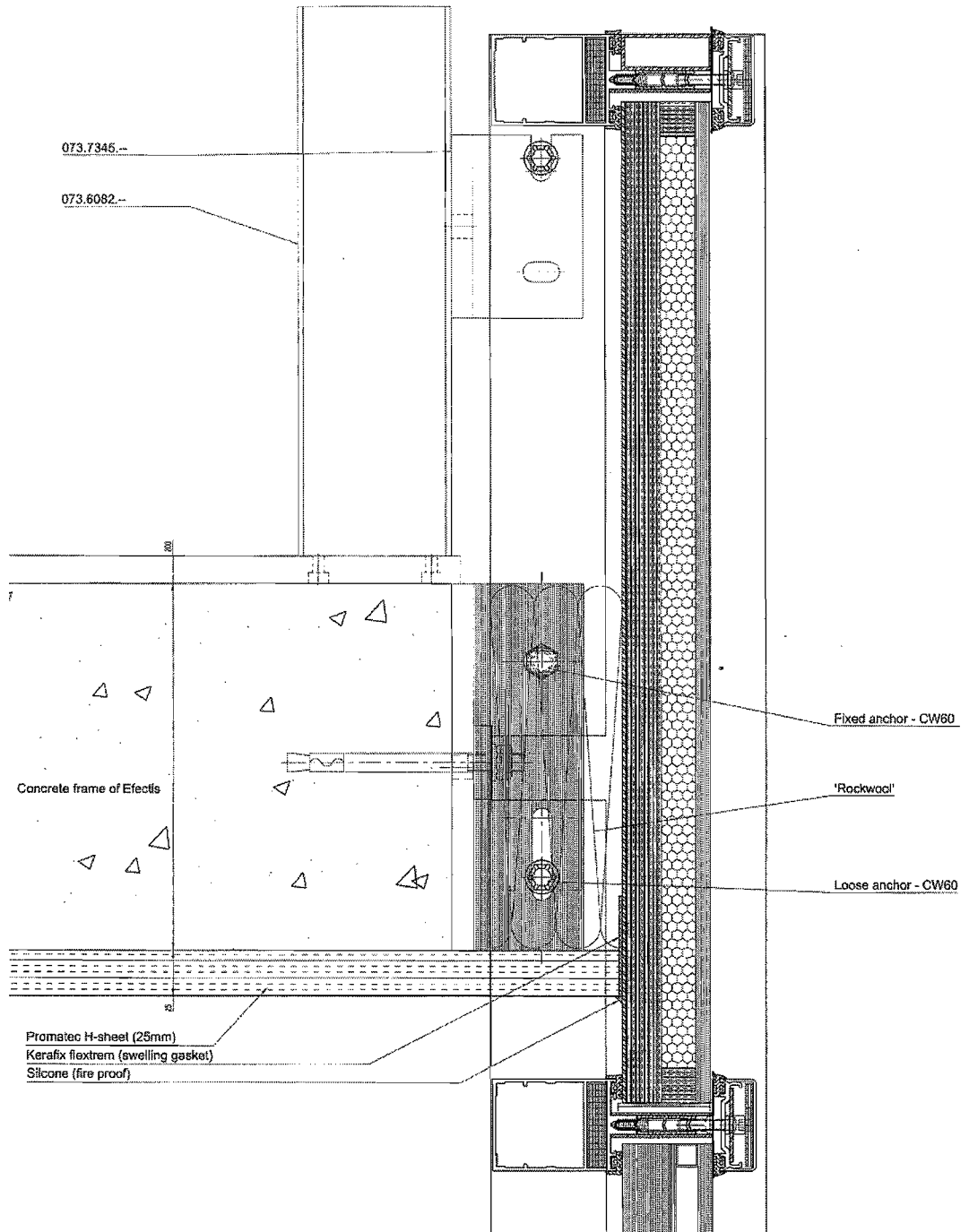


Figure 8: Detail ceiling anchoring.

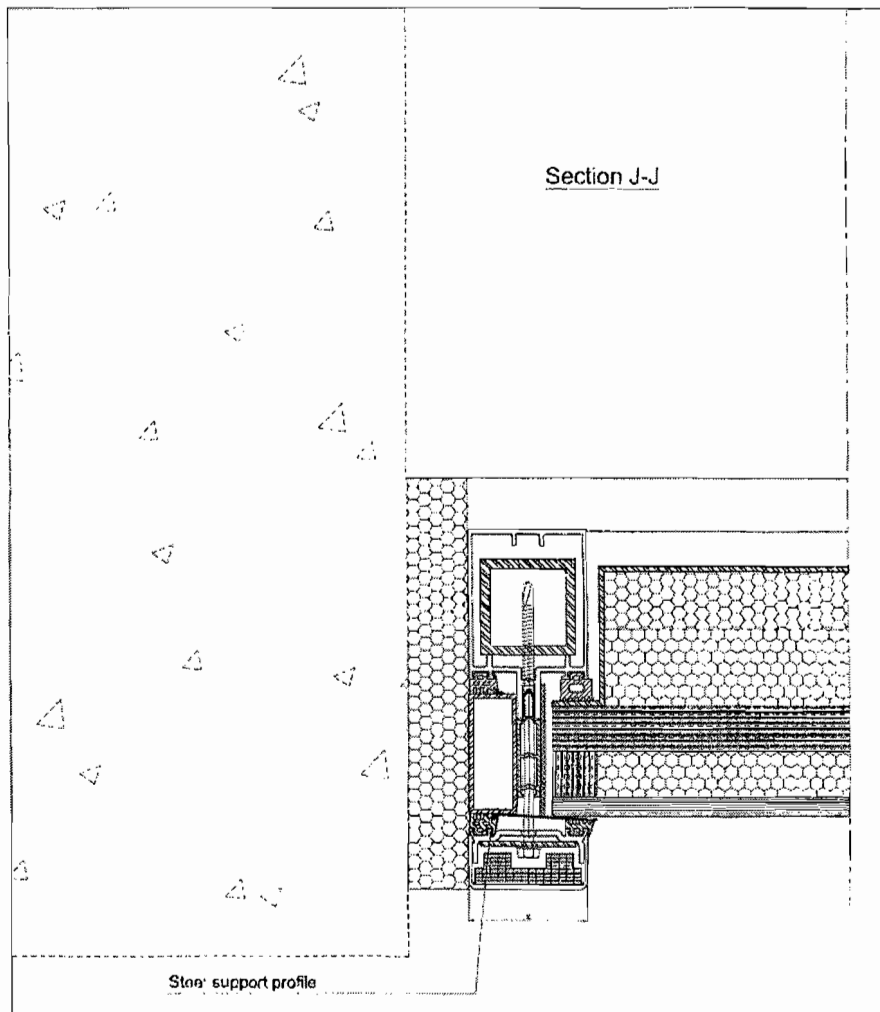


Figure 9: Detail at the left cross-section J-J.

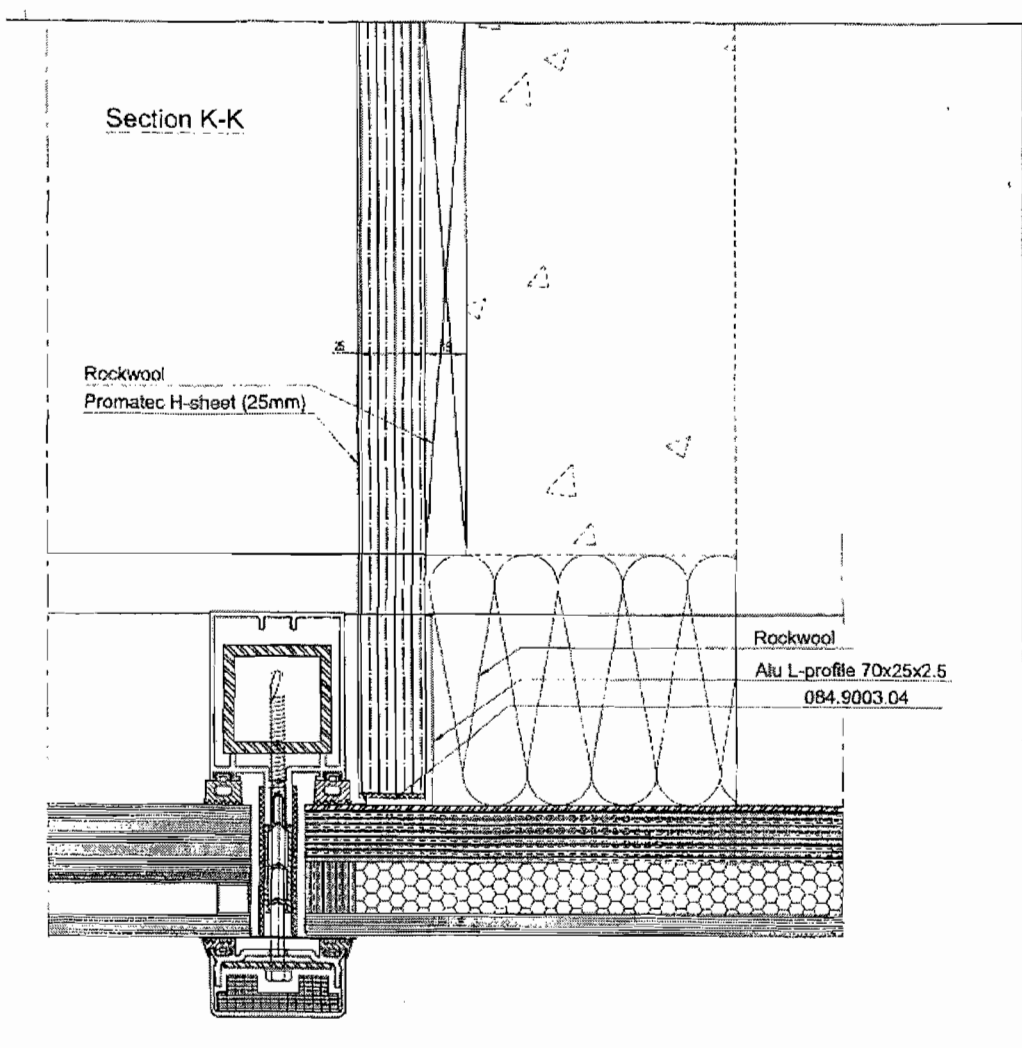



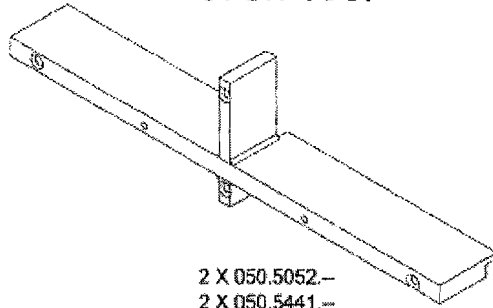


Figure 10: Detail at the right cross-section K-K.

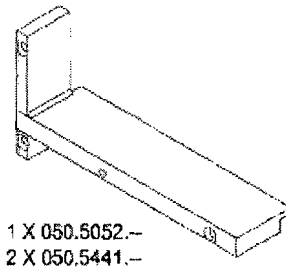
Supports Glass:

-  A = 073.7106.--
-  B = 073.7116.--
-  C = 073.7126.--

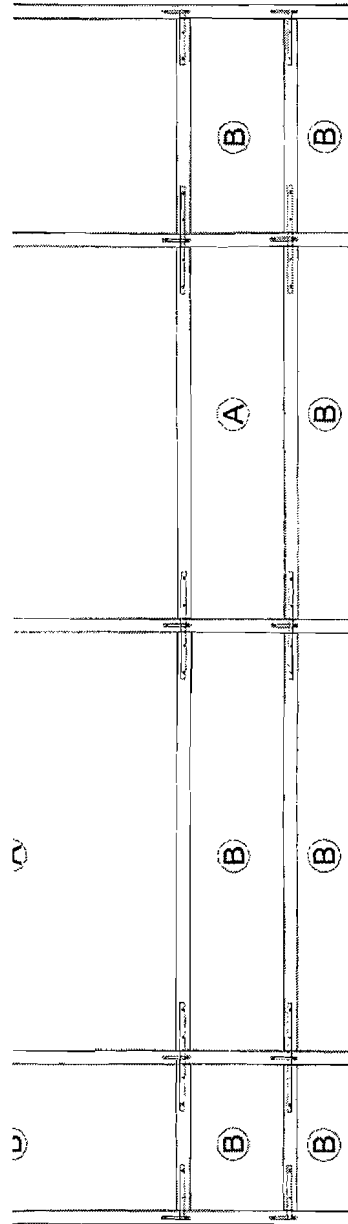
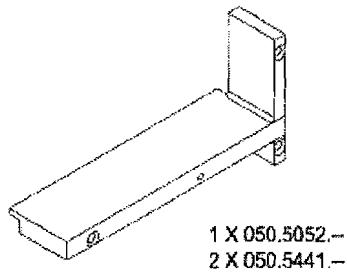
073.7106.--



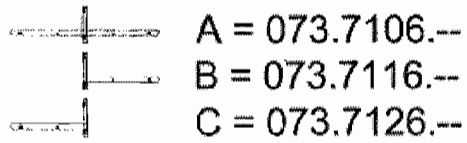
073.7116.--



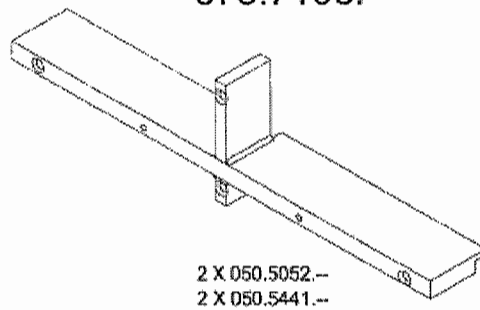
073.7126.--



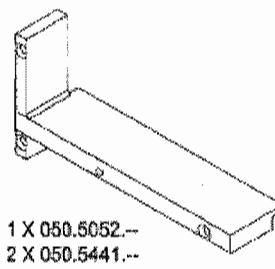
Supports Glass:



073.7106.--



073.7116.--



073.7126.--

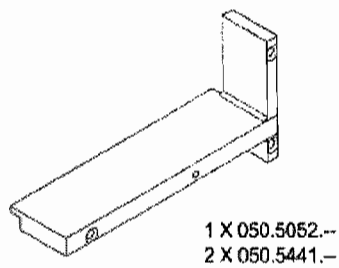
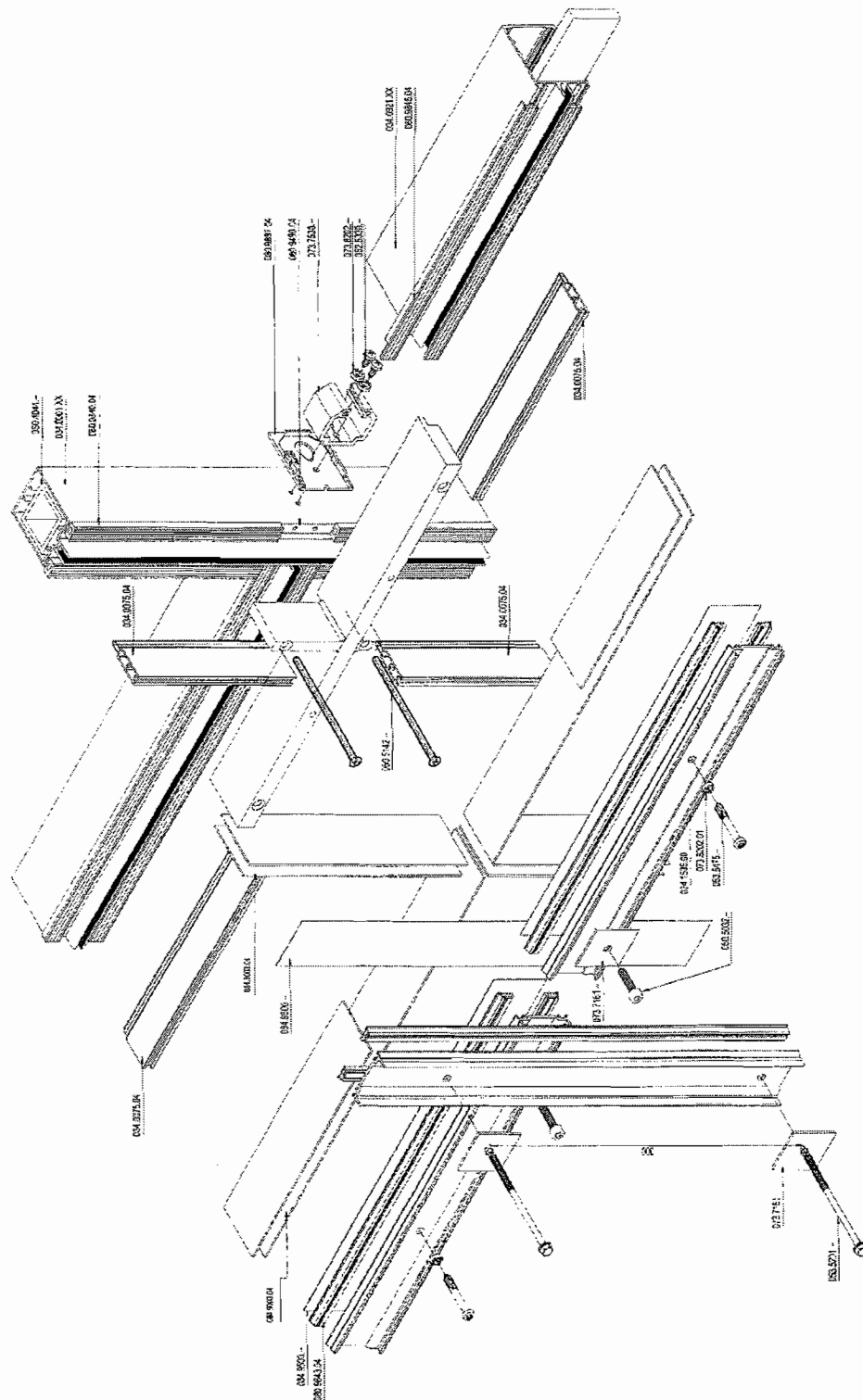


Figure 12: Three-dimensional overview of glass support types.



Figur 13: Assembly of glass supports.

A Observations

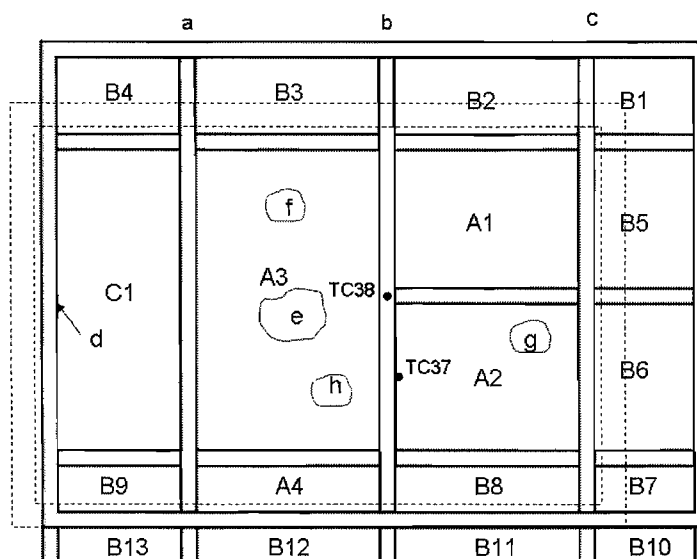
A.1 Observations during the test

F= Fire side

N = Non fire side

Time [min]	Side	Observation
0		Start heating
45'	F	First cracks in glass A3
1	N	Cracks and breaking of glass A1 and A2
8	N	Foaming of glass pane A3
10	N	Smoke coming from the profiles at the top at pos. a, b and c
15		All panes almost completely foamed except the edges (photo 10)
21	F	Breaking of glass (audible) and deforming of profile at pos. d
23	N	All panes completely foamed
24	N	More smoke coming from the profiles at the top
30	N	Piece of glass falls from construction
40	N	Glass of pane A3 came partly forward
48	N	Several cones in glass at pos. e, f, g and h (photo12)
75	N	Temperature of thermocouple TC 37 more than 203°C: <i>Thermal insulation exceeded</i>
78	N	Temperature of thermocouples TC 35 and TC 38 more than 203°C
89	N	Temperature of thermocouple TC 25 more than 203°C
90	N	Temperature of thermocouples TC 13 and TC 14 average temperature more than 164 °C
91	N	End of heating

A.2 Positions of observations during the test

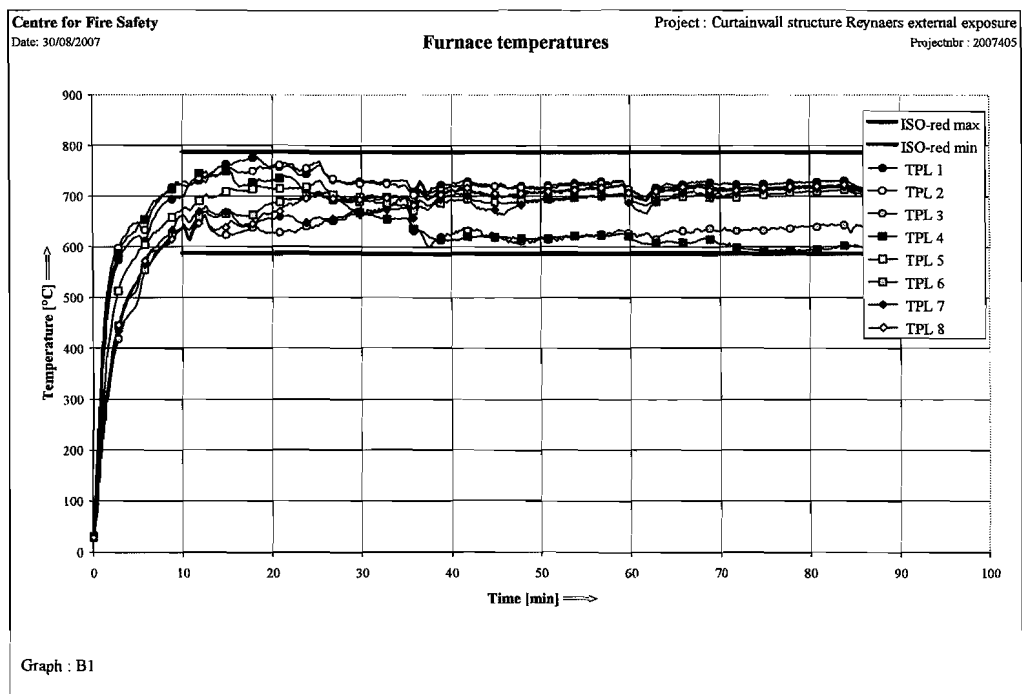


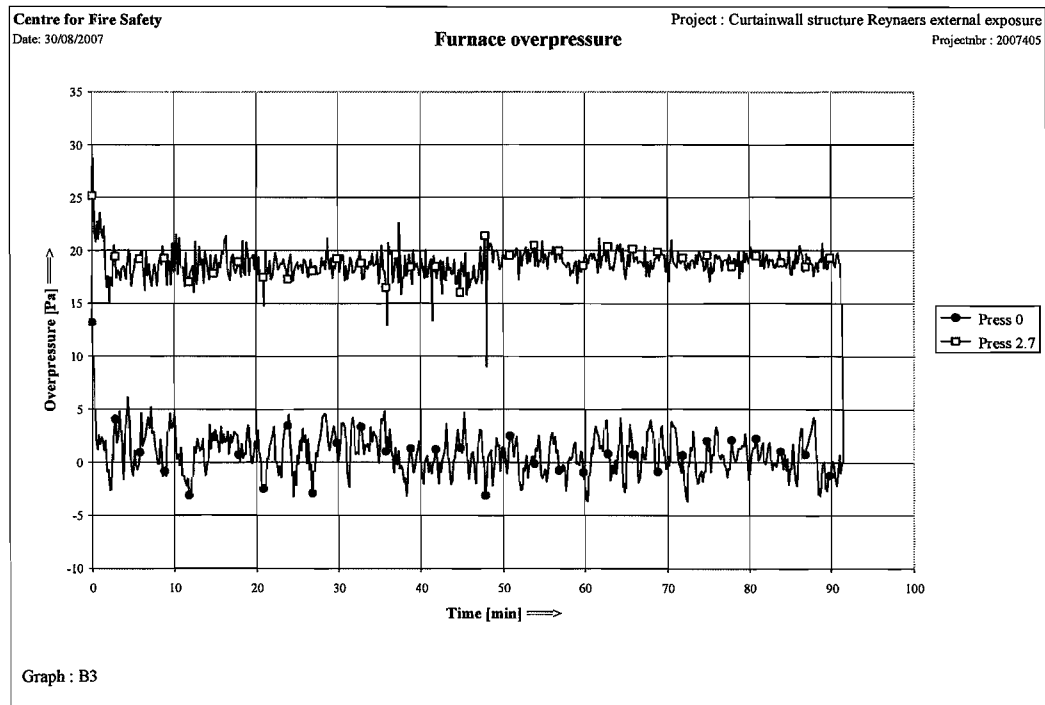
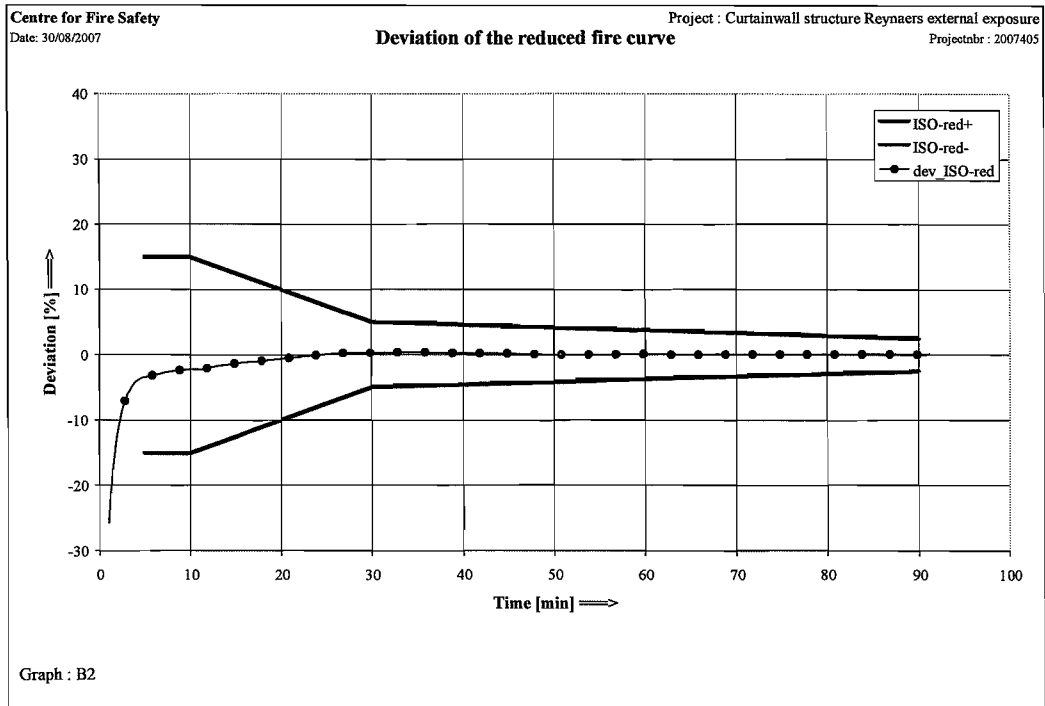
B Furnace conditions

Graph B1: Furnace temperatures

Graph B2: Deviation of the fire curve

Graph B3: Furnace overpressure





C Test results

C.1 Defined surface of the specimen

Surface 1 : front side of curtain wall panels

C.2 Overview of thermocouple positions

Figure C1a: Overview of specimen with thermocouples and deflection

Figure C1b: Positions of thermocouples on surface 1

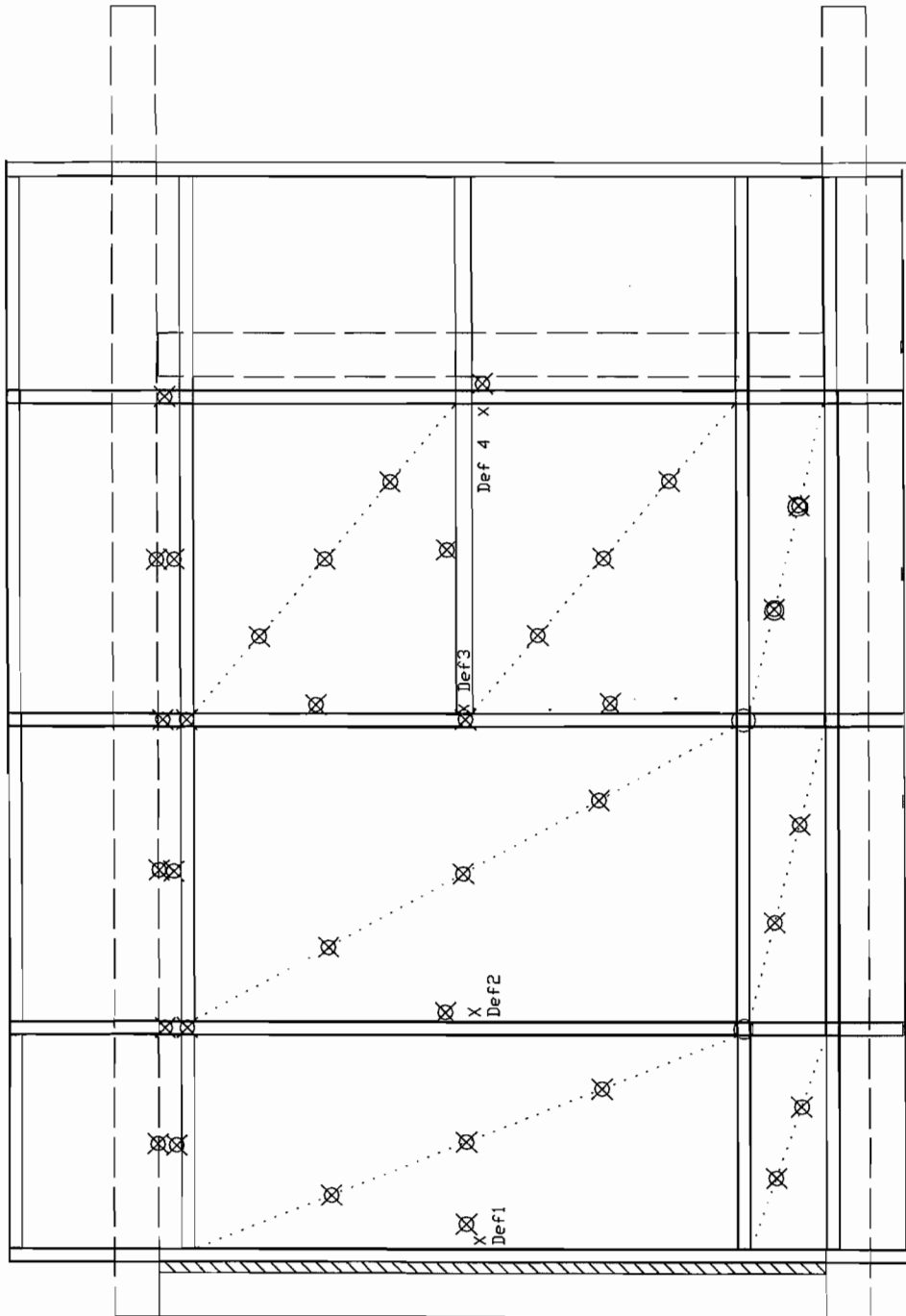


Figure C1a: Overview of specimen with thermocouples and deflection.

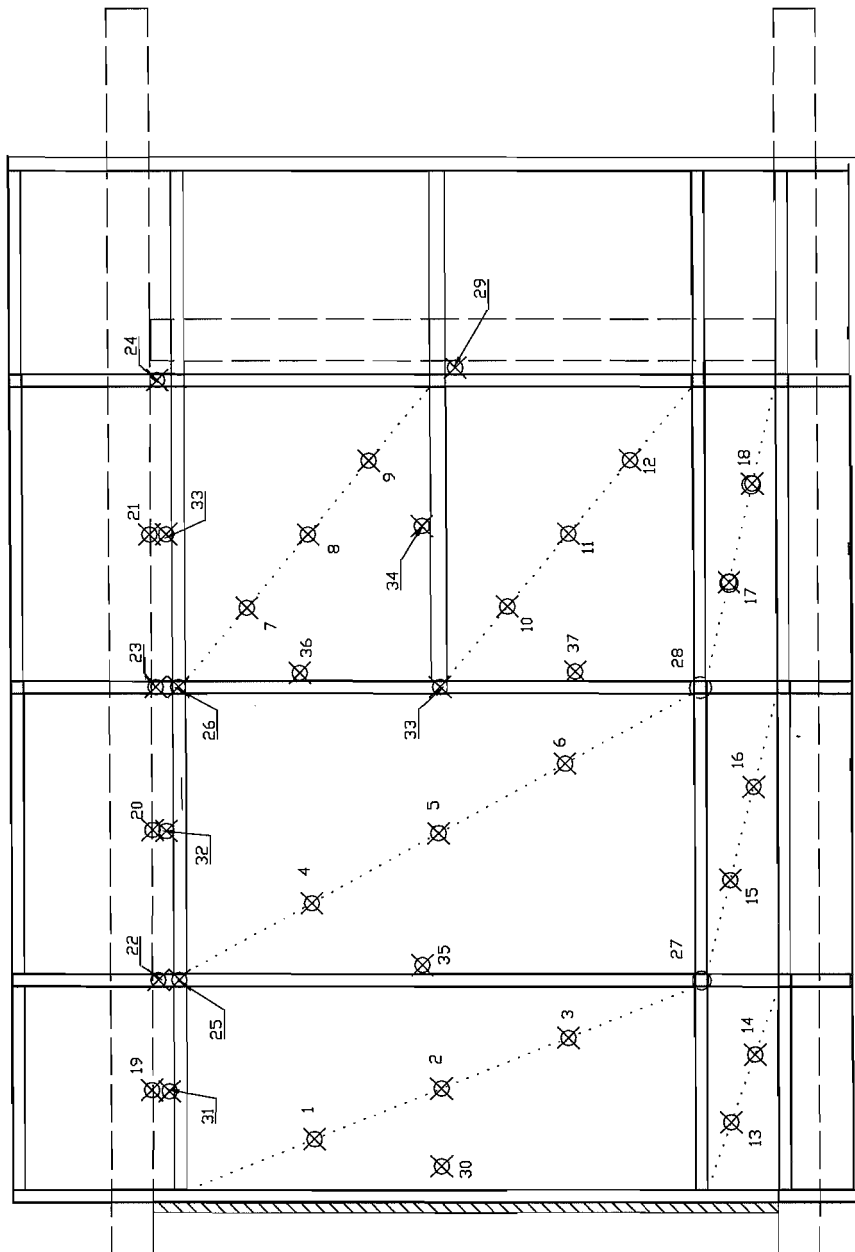


Figure C1b: Positions of thermocouples on surface 1.

C.3 Thermocouples for mean temperature

TC 1 until 18 : surface 1 front side of curtain wall;

C.4 Thermocouples for maximum temperature

Surface 1 front side curtain wall

TC 19 until 21 : (1A) level with the soffit of the upper floor at mid width;

TC 22 until 24 : (1B) level with the soffit of the upper floor in line with a mullion;

TC 25 until 28 : (1C) at the junction of a mullion and a transom;

TC 38 : (1C) at the junction of a mullion and a transom;

TC 29 : (1D) level with the soffit of the upper floor at mid width of the vertical seal;

TC 30 : (1E) at mid height from the free edge, 100 mm from the edge;

TC 31 until 34 : (1F) at mid width between two mullions, 15 mm above a horizontal joint (in the positive pressure zone);

TC 35 until 37 : (1G) at mid height between two mullions, 15 mm from a vertical joint (in the positive pressure zone);

C.5 Listing of figures with results

Graph C2: Surface temperatures of panel C1 and glass A3 (surface 1);

Graph C3: Surface temperatures of glass A1, A2 and A4 (surface 1);

Graph C4: Surface temperatures of panel B8 and B9 (surface 1);

Graph C5: Surface temperatures of glass B2, B3 and B4 below the floor (surface 1);

Graph C6: Surface temperatures of aluminium profiles below the floor (surface 1);

Graph C7: Surface temperatures of glass beside profiles (surface 1);

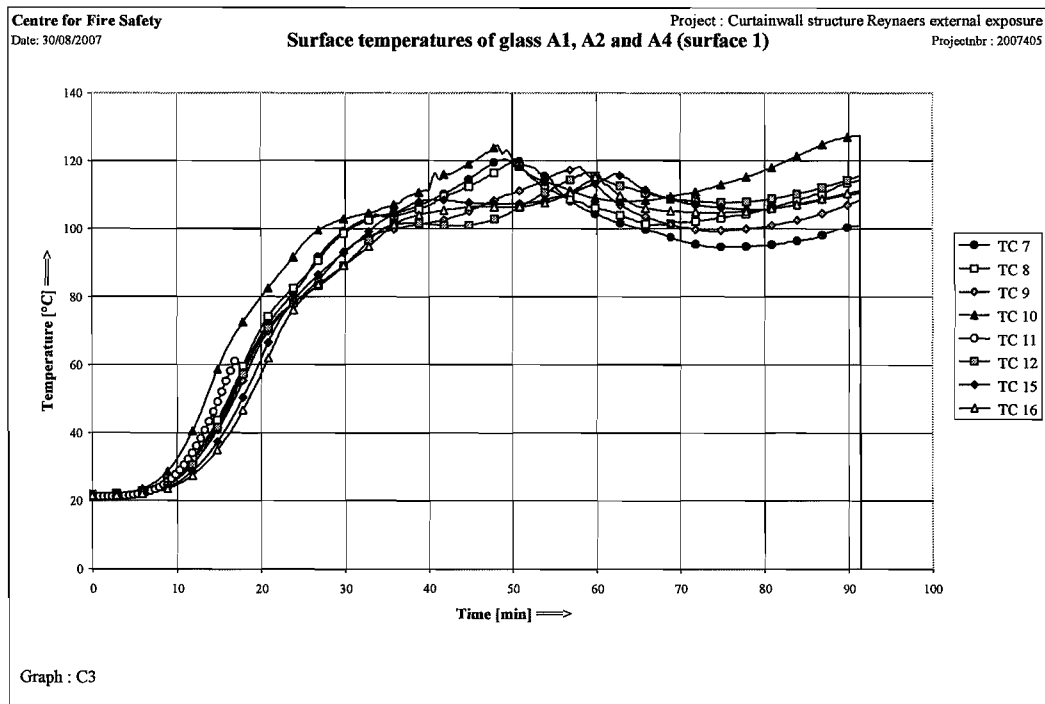
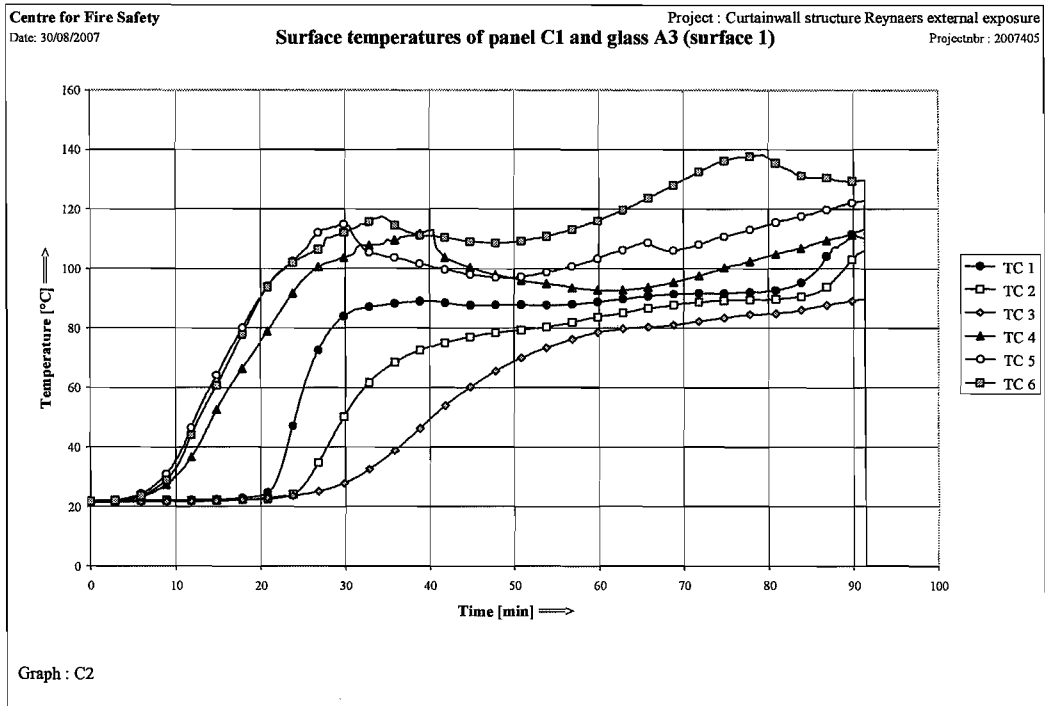
Graph C8: Surface temperatures of aluminium profiles at the junction (surface 1);

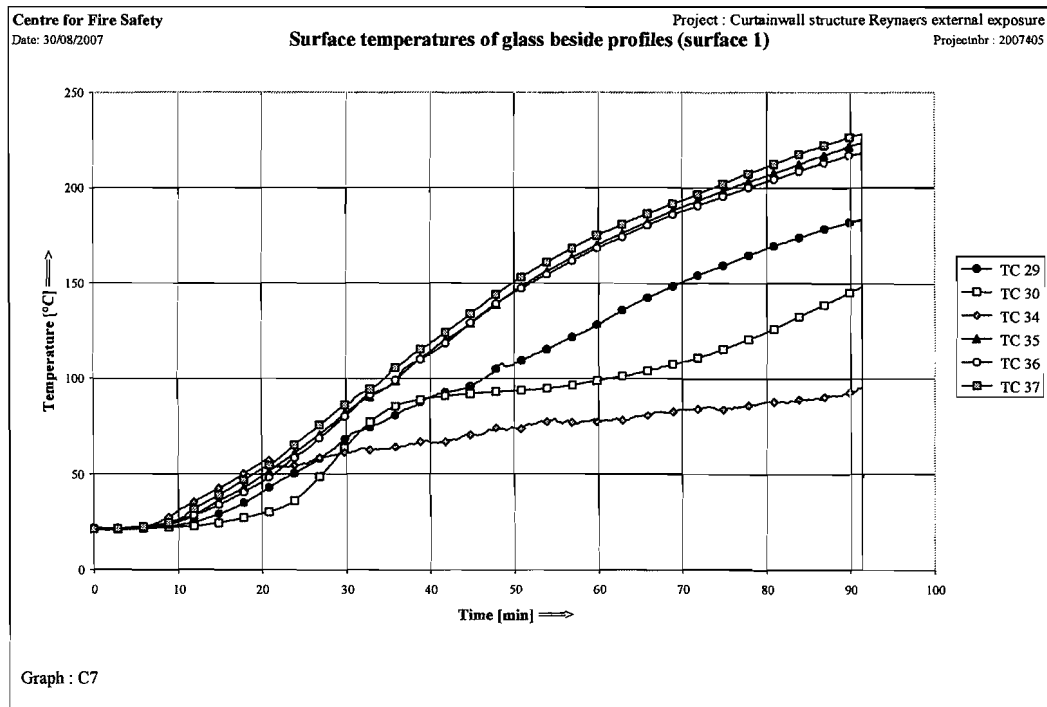
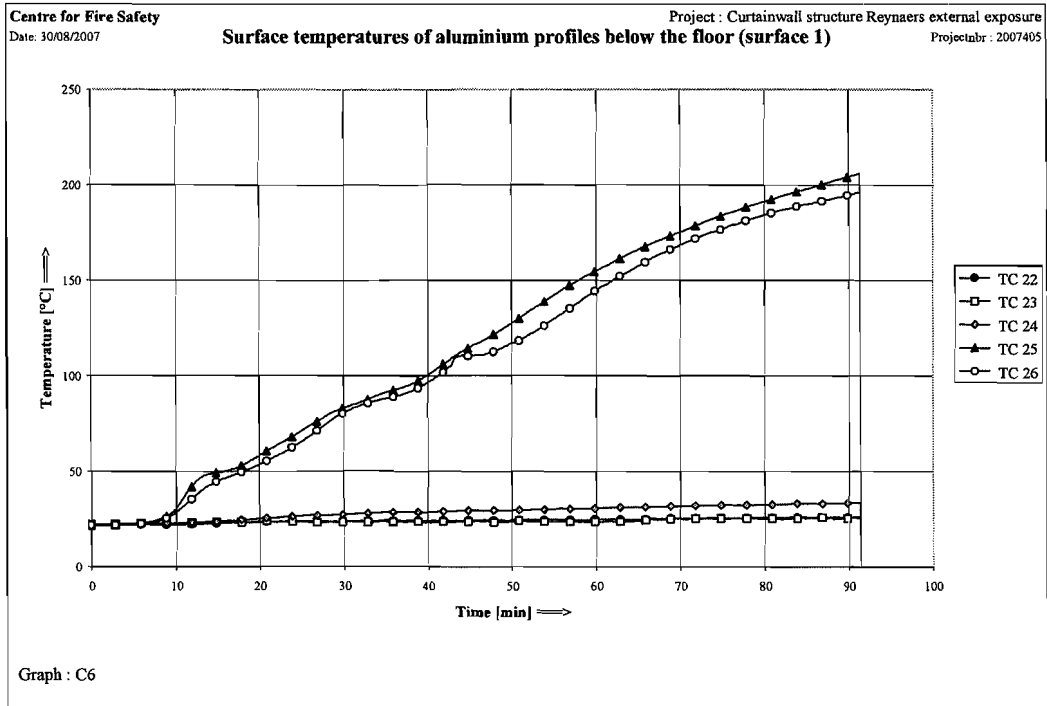
Graph C9: Radiation at 1.0 m distance from the specimen;

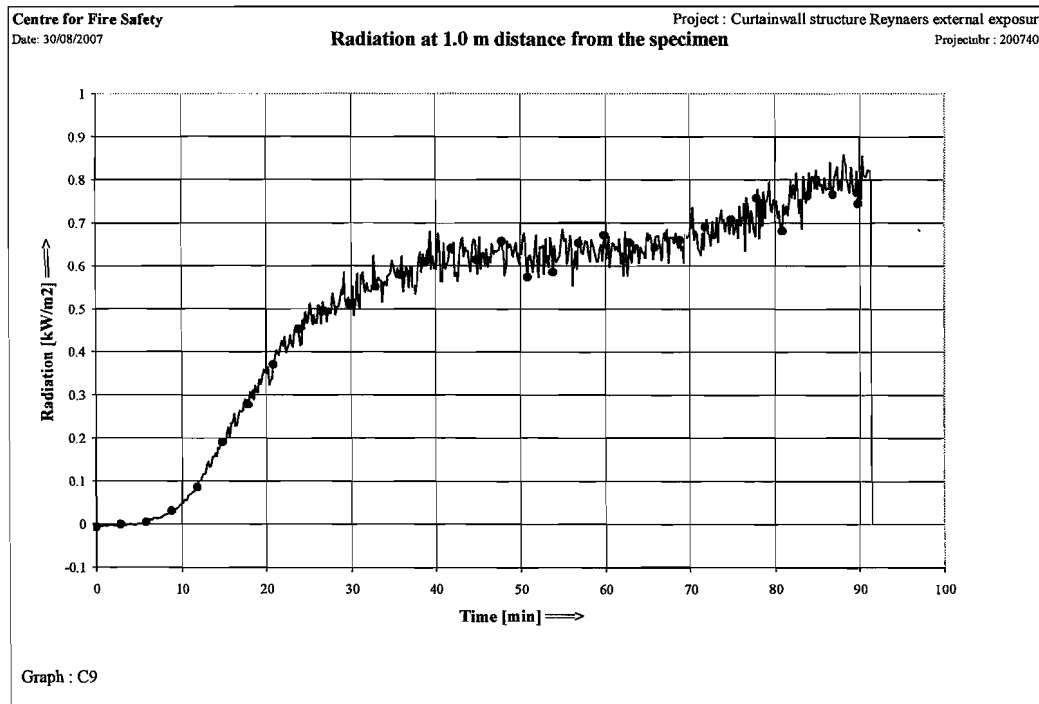
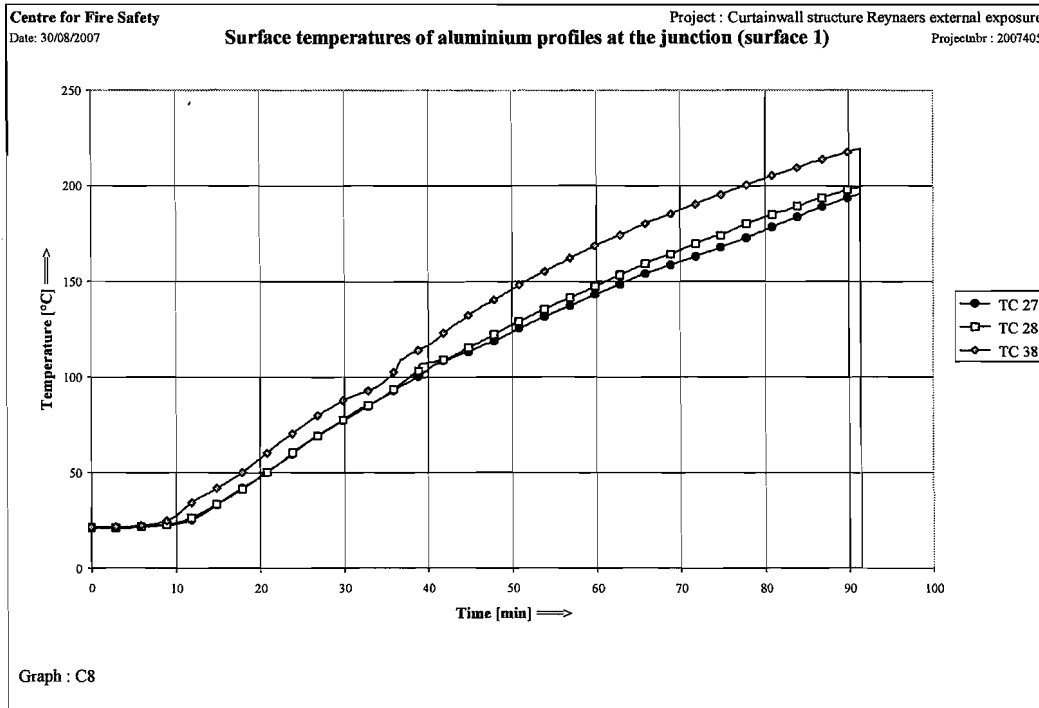
Graph C10: Deforming of construction (left part);

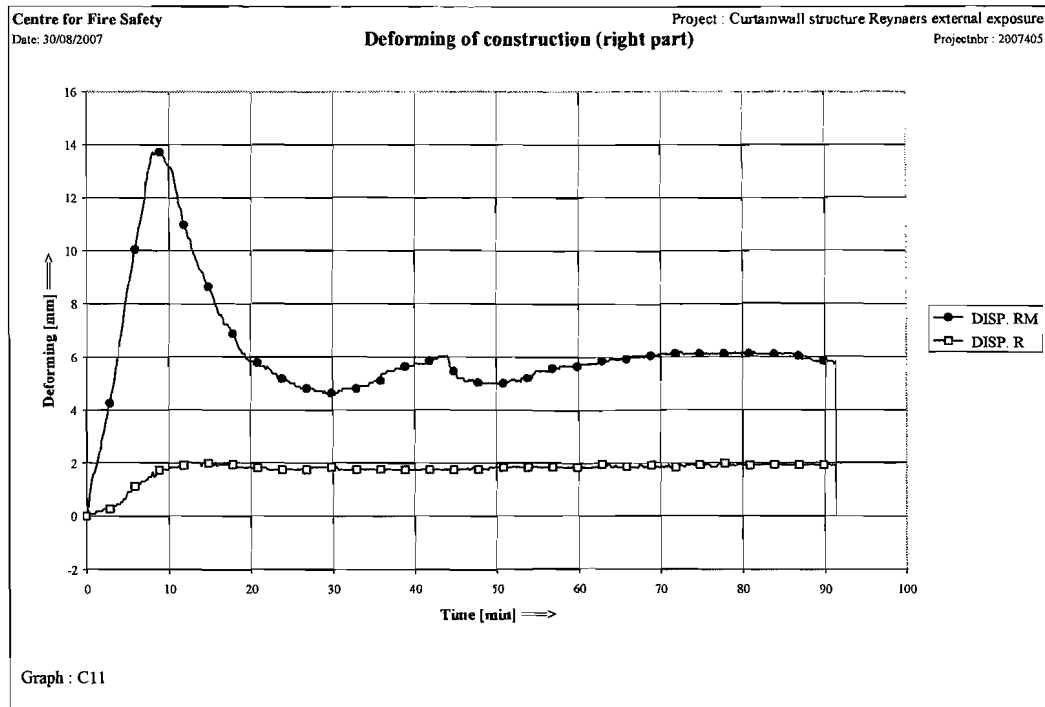
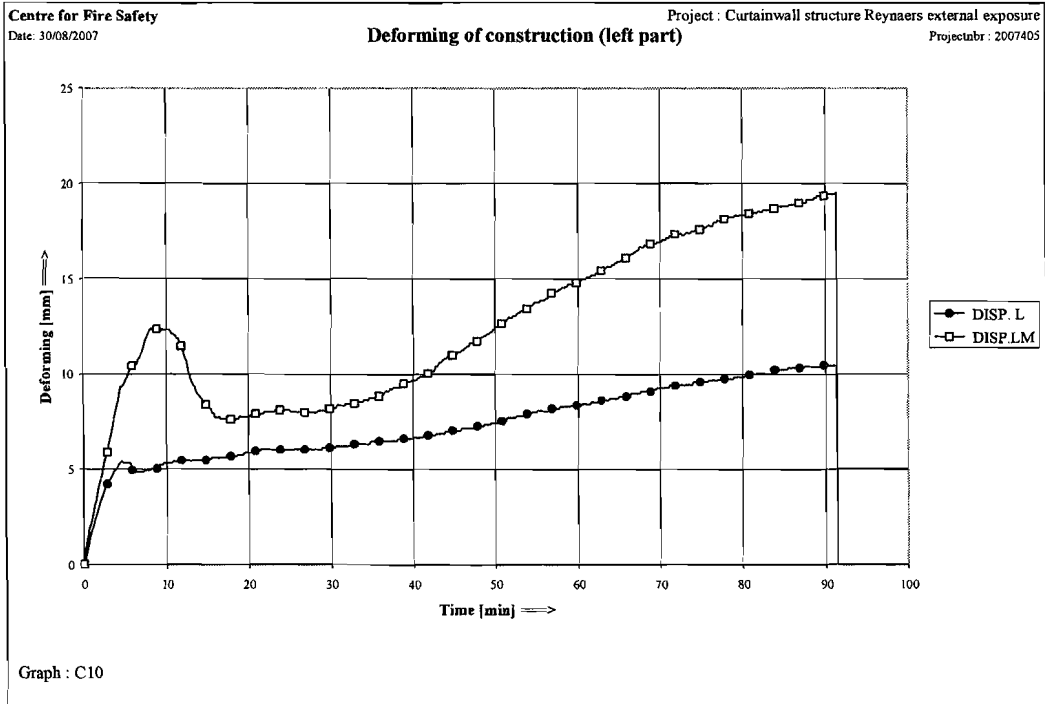
Graph C11: Deforming of construction (right part);

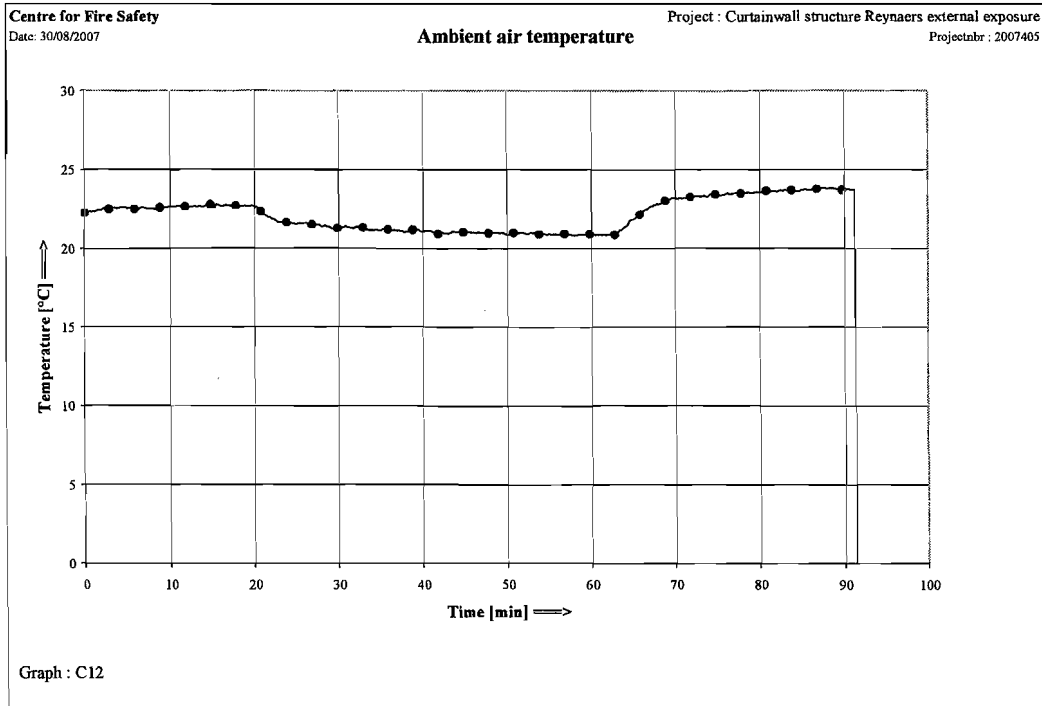
Graph C12: Ambient air temperature.











D Photographs

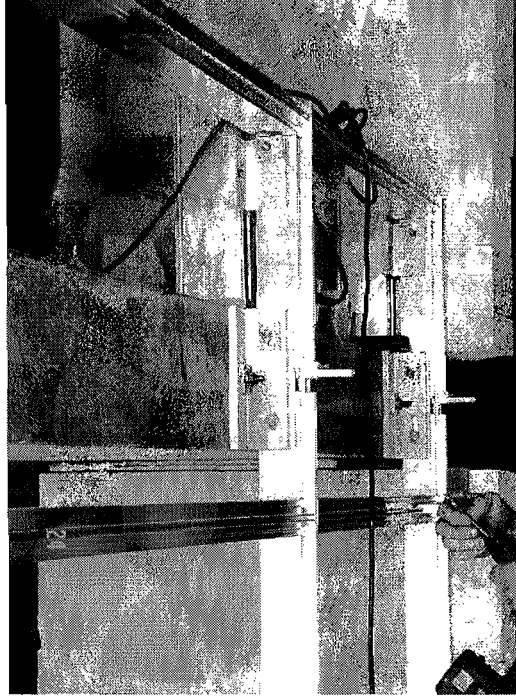


Photo 1: Aluminium profiles during assembly with separation.

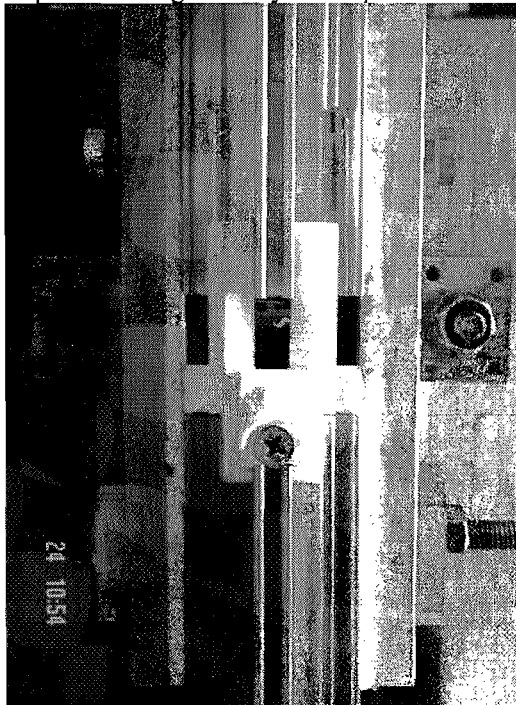


Photo 2: Profile at the top with detail of separation.



Photo 3: Junction of the structure.

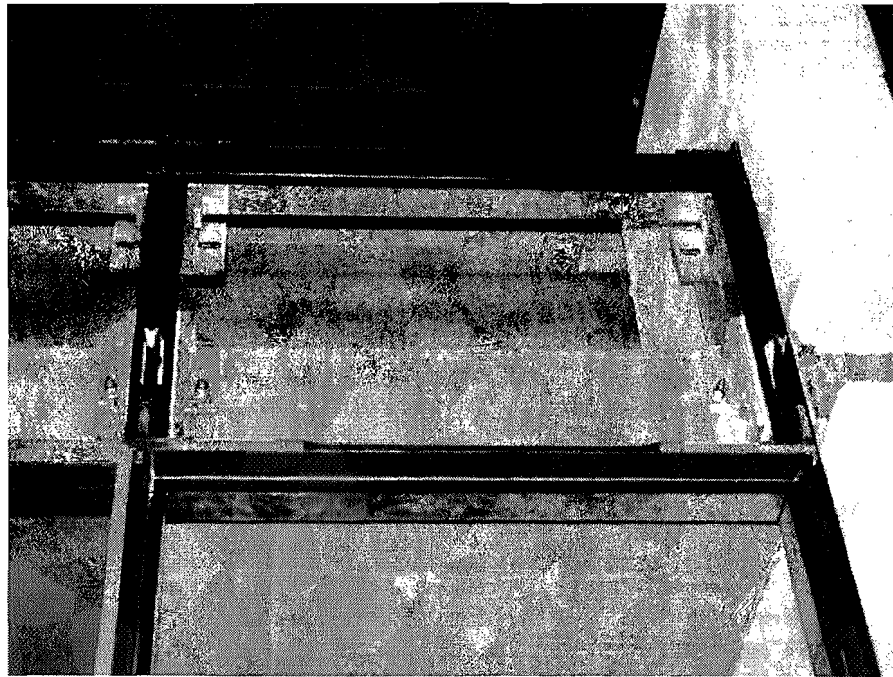


Photo 4: Top of frame construction.



Photo 5: Panels at the bottom of the construction.



Photo 6: Glass support.

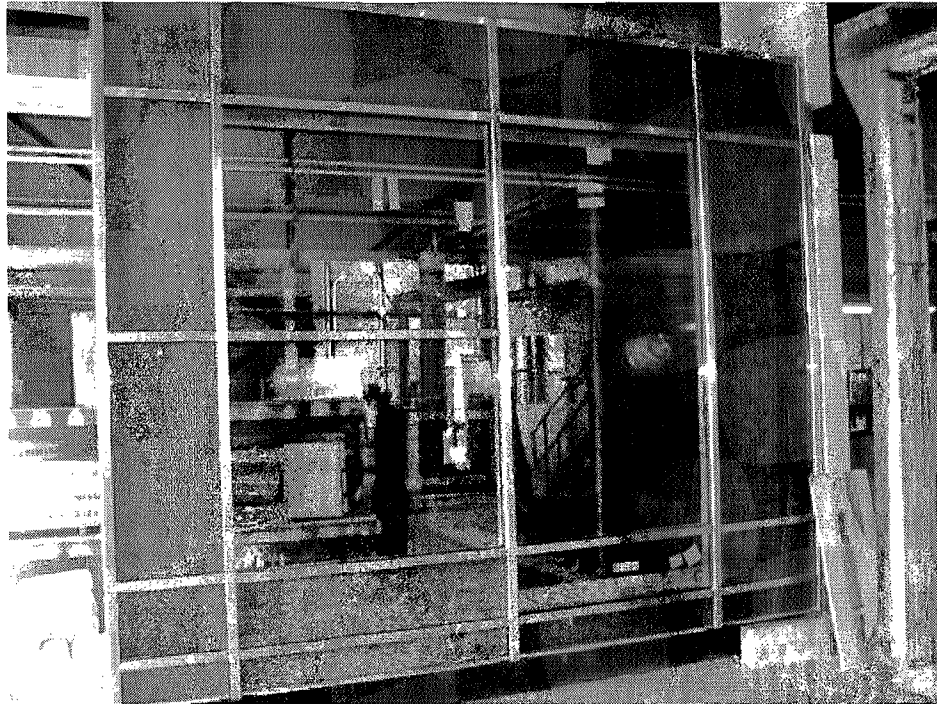


Photo 7: Curtain wall structure.



Photo 8: Curtain wall in front of furnace.



Photo 9: Foaming of pane A3.

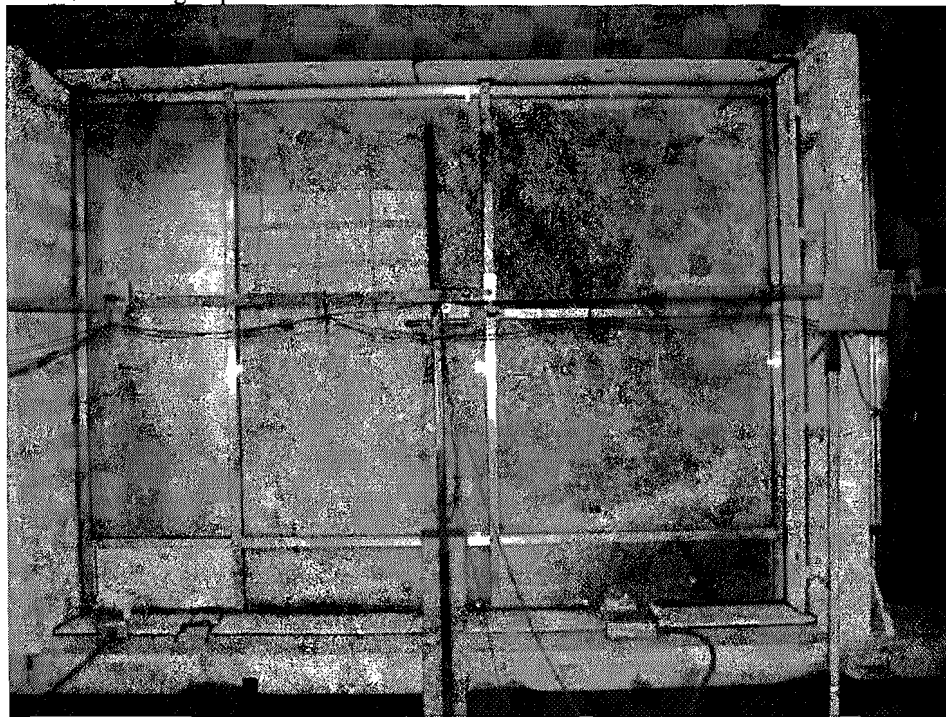


Photo 10: Windows completely foamed.



Photo 11: Kone in pane A3.



Photo 12: Curtain wall structure after the test.



Photo 13: Fire side of curtain wall after the test.

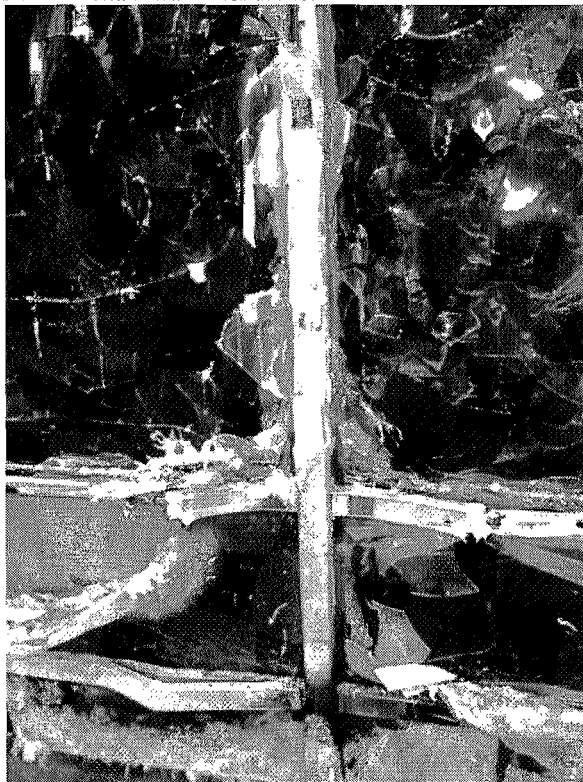


Photo 14: One of the junctions of the structure after the test.