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REPORT

Determination of the thermal behaviour of a concrete slab protected by a directly fixed Passivetec 30mm Tunnel Board exposed to the combination of the RWS and HCM fire curves during 180 minutes

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Sponsor	Passive Fire Protection (PFP) UK Ltd Hillsborough Works Langsett Road Sheffield S6 2LW United Kingdom
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1. INTRODUCTION

Tunnels of reinforced concrete must be protected against fire. To ensure that a fire protection system is able to withstand the high temperatures associated with tunnel fires, fire tests must be conducted. This investigation was undertaken to evaluate the thermal insulation performance of the Passivetec 30mm Tunnel Board.
More details of the construction can be found in chapter 6 as well as in the figures in Appendix A.
The investigation is carried out in line with the RWS/Efectis fire test procedure for concrete tunnel linings (ref: 2008-Efectis-R0695).

2. SUBJECT

Passivetec 30mm Tunnel Board for passive fire protection of tunnels.

3. INVESTIGATION

Determination of the temperature development at the surface of a concrete slab, during heating for a period of 180 minutes of the combination of the RWS and HCM fire curves. After 180 minutes of testing the furnace was controlled according to ISO 834 fire curve up to 240 minutes.

The tested specimen consisted of a C30 concrete slab of 150 x 1900 x 1600 mm^3 which was protected by the Passivetec 30mm Tunnel Board.

4. SPONSOR

Passive Fire Protection (PFP) UK Ltd
Hillsborough Works
Langsett Road
Sheffield S6 2LW
United Kingdom

5. PLACE AND TIME OF THE RESEARCH

The test was conducted at the laboratory of the Efectis Nederland BV in Rijswijk, the Netherlands.
The concrete slab, concrete strength C30, was cast by a local concrete factory in the vicinity of the site of Efectis Nederland, more than three months before the fire test.
Thermocouples were applied to the concrete surface by Efectis Nederland. The fire protection system was applied by the client on the day before the fire test. The fire test was conducted on 9-7-2013.

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6. MATERIALS

6.1 REINFORCED CONCRETE SLAB

6.1.1 Dimensions

150 x 1900 x 1600 mm^3.

6.1.2 Concrete grade

Strength class C30/37.

6.1.3 Instrumentation

Nine thermocouples were installed on the concrete surface by cutting small grooves in the surface. After placing a thermocouple wire in each groove, the grooves were filled using a fast-drying repair mortar. The locations of the thermocouples are given in figure A.1 of appendix A.

6.2 PASSIVETEC 30MM TUNNEL BOARD

The first step of the installation of the Passivetec 30mm Tunnel Board is to attach the boards to the concrete surface as shown in picture A.1 in appendix A and pictures C.1 to C.3 in appendix C.

The workflow for attaching the boards using the carbon steel HILTI anchors type HSA M6 40/30/10 (M6x85) together with the HILTI A 6.4/28 mm zinced flat washer is as follows:

1. Positioning the first board such that the design joint is exactly on thermocouple numbers 1, 4 and 7, see picture C.1 in appendix C;
2. Drilling the holes in the concrete, taken over from the holes present in panel B;
3. Hammering the anchors in the concrete, together with the 6 x 28 mm stainless steel washer, 13.9 per m^2;
4. Fastening the nuts of the anchors with a spanner;
5. Drilling the holes in the concrete, taken over from the holes present in panel A;
6. Hammering the anchors in the concrete, together with the 6 x 28 mm stainless steel washer, 6.7 per m^2;
7. Fastening the nuts of the anchors with a spanner;
8. Applying the PassiveTec XTSeal to the butt joints around the perimeter;
9. Positioning the perimeter boards which are not in the exposed area of the furnace.

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7. MEASUREMENTS

7.1 DENSITY AND MOISTURE CONTENT

According to the fire testing procedure 2008-Efectis-R0695, the moisture content shall be determined by drying a sample of the insulation material at 105°C. The objective is to drive out the free water inside the pores, but to leave any physically or chemically bound water and not deteriorate the material structure.

A sample of Passivetec 30mm Tunnel Board was dried at 105°C for 24 hrs. and weighed in order to determine the moisture content at the day of the test.

- Wet density : 1003 kg/m^3
- Moisture content : 7.7 %

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On request of the sponsor a sample of Passivetec 30mm Tunnel Board was dried at 50°C for 24 hrs. and weighed in order to determine the moisture content at the day of the test.

- Wet density : 1003 kg/m^3
- Moisture content : 1.3 %

A sample of the concrete slab was dried at 105°C for 19 days and weighed in order to determine the moisture content.

- Moisture content : 3 %

7.2 FIRE TEST

7.2.1 Conditions

The test specimen was placed on top of the small furnace of Efectis Nederland BV with the Passivetec 30mm Tunnel Board side facing down. The interior dimensions of the furnace are 1200 x 1200 mm. The furnace was heated during 180 minutes according to the combination of the RWS and HCM fire curves. After 180 minutes of testing the furnace was controlled according to ISO 834 fire curve up to 240 minutes.

7.2.2 Performance criteria

The objective of the fire test procedure (ref: 2008-Efectis-R0695) is to provide a uniform fire testing procedure for concrete tunnel structures. The actual required performance in such tests is a decision of the client. In general, performance requirements could include:

- maximum values for the concrete surface temperature
- maximum values for the steel reinforcement temperature (to be measured on the side of the steel bar which is closest to the fire exposed concrete surface)
- maximum values for the temperature at another depth in the concrete structure

RWS has specified their requirements for tunnels and other subsurface road structures in the document ROBK-6. The temperature requirements in ROBK-6 depend on the type of tunnel and the part of the structure (compression zone or tension zone). For concrete under compression in an underwater tunnel, the requirements are

- T < 250°C for the steel reinforcement
- T < 380°C on the concrete surface for underwater tunnels

For concrete under compression in other tunnels, the requirements are

- T < 250°C for the steel reinforcement
- T < 380°C for the concrete within 25 mm from a reinforcement bar

Moreover, spalling of concrete is never allowed to be more than superficial.

For each of the requirements it is advisable to specify the number of measurement points and the handling of scatter in results. For temperature measurements this means that the number of thermocouples at a certain depth should be prescribed, along with a statistical approach e.g. to use a 95% characteristic value of all measured temperatures at a given time. Also it is recommended to prescribe a minimum of thermocouples that should function correctly during the test.

7.2.3 Measurements

The following aspects were measured and recorded during heating:

- The gas temperatures inside the furnace with 4 thermocouples;
- The temperatures at the concrete and board interface with 9 thermocouples.

Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible to provide a stated degree of accuracy of the result.

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A summary of all measured temperatures is presented in appendix B.

8. RESULTS

8.1 OBSERVATIONS DURING HEATING

Time	Observation
0	Start of the test
22	Up to this time in the test thermocouple number nine was not measured due to a mistake that was corrected at this time
180	Upon the sponsors request further testing is continued according to ISO 834 time temperature curve
240	End of heating at the request of the sponsor.
	After the test the specimen was taken of the furnace. No parts of the boards or concrete slab have fallen during and after the test.

9. SUMMARY

The principal results of the test are shown in Table 9-1.

Table 9-1: Principal results of the test for the interface temperature

Thickness of the Passivetec 30mm Tunnel Board is 30 mm	
Average initial sample temperature	28 °C
Maximum measured concrete surface temperature at 60 min.	174 °C
T as a 95% characteristic calculated temperature at 60 min.	184 °C
Average measured concrete surface temperature at 60 min.	125 °C
Maximum measured concrete surface temperature at 90 min.	232 °C
T as a 95% characteristic calculated temperature at 90 min.	240 °C
Average measured concrete surface temperature at 90 min.	198 °C
Maximum concrete surface temperature at 120 min.	266 °C
T as a 95% characteristic calculated temperature at 120 min.	271 °C
Average measured concrete surface temperature at 120 min.	238 °C
Maximum concrete surface temperature at 180 min.	331 °C
T as a 95% characteristic calculated temperature at 180 min.	337 °C
Average measured concrete surface temperature at 180 min.	309 °C
Maximum concrete surface temperature at 240 min.	376 °C
T as a 95% characteristic calculated temperature at 240 min.	378 °C
Average measured concrete surface temperature at 240 min.	353 °C

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9.1 CALCULATION OF THE STEEL REINFORCEMENT TEMPERATURE

The steel reinforcement temperature after 120 minutes of heating was calculated at the request of the sponsor with a one dimensional heat calculation program. The input values are: 150 mm thick siliceous concrete slab with a concrete cover of 25 mm and a moisture content 3%, Passivetec 30mm Tunnel Board, input temperatures are the nine measured interface temperatures (95% characteristic calculated temperature). Note : it was not necessary to use the fire curve as input and the Passive Tunnel Board properties in the calculation.
The outcome of the calculation temperature after 120 minutes of heating of the steel reinforcement is approximately 188 °C. This is well below 250 °C.

9.2 CONCLUSION

9.2.1 After 180 minutes of heating to the combination of the RWS and HCM fire curves

The criterion maximum temperature on the concrete surface has been satisfied. The maximum temperature after heating for a period of 180 minutes was 331°C. The 95% characteristic calculated temperature after heating for a period of 180 was 337°C.

9.2.2 After 240 minutes of heating

After 180 minutes of heating to the combination of the RWS and HCM fire curves the furnace was controlled according to ISO 834 fire curve up to 240 minutes on the request of the sponsor.
The criterion maximum temperature on the concrete surface has been satisfied. The maximum temperature after heating for a period of 240 minutes was 376°C. The 95% characteristic calculated temperature after heating for a period of 240 was 378°C.

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APPENDIX A: DRAWINGS

Figure A.1 Overview of the specimen
Figure A.2 Overview of the thermocouples

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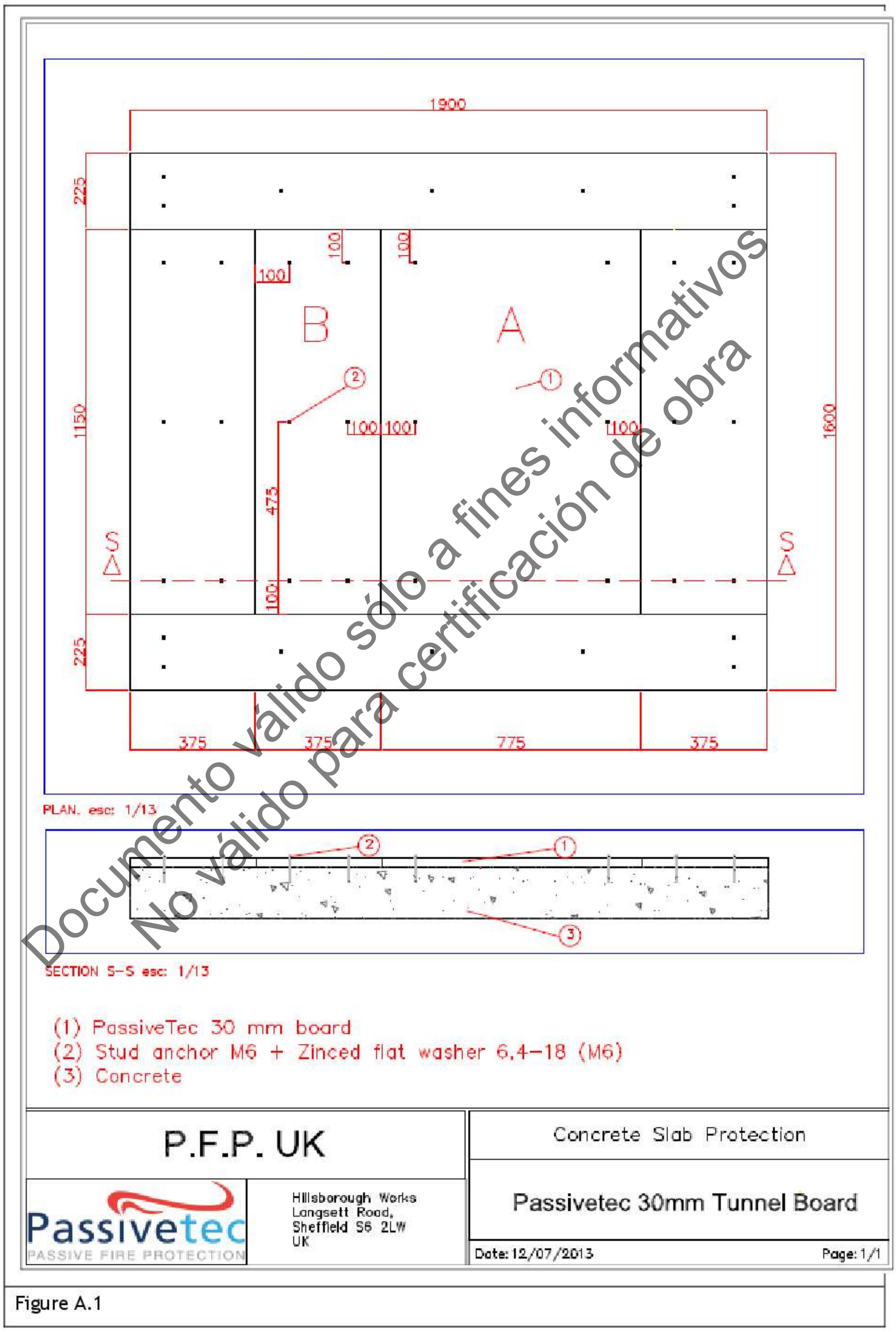


Figure A.1

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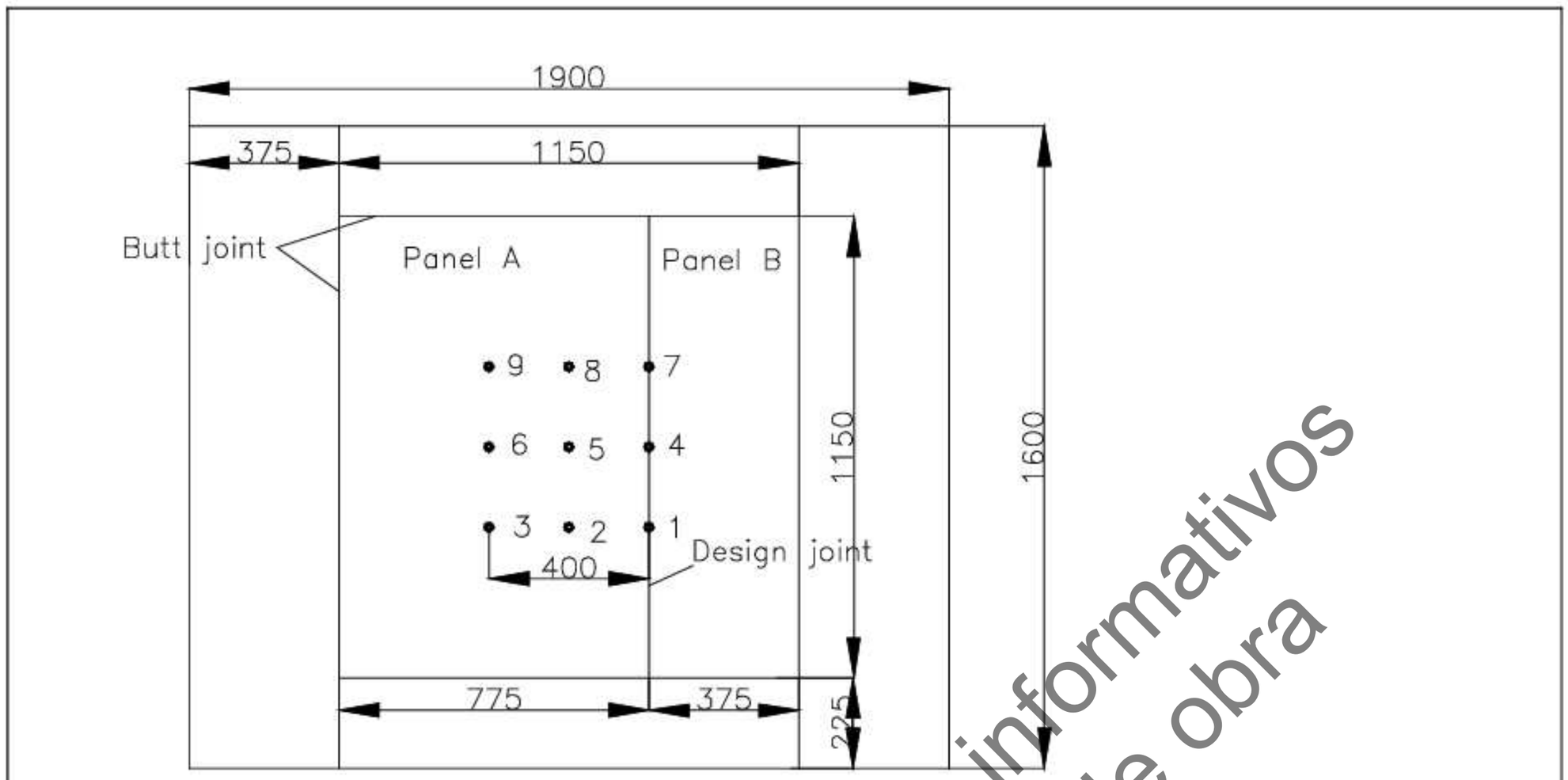


Figure A.2

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APPENDIX B: TEST RESULTS

Figure B.1 Furnace temperature
Figure B.2 Deviation of fire curve
Figure B.3 Interface temperatures
Figure B.4 Interface average, maximum and 95% characteristic temperatures

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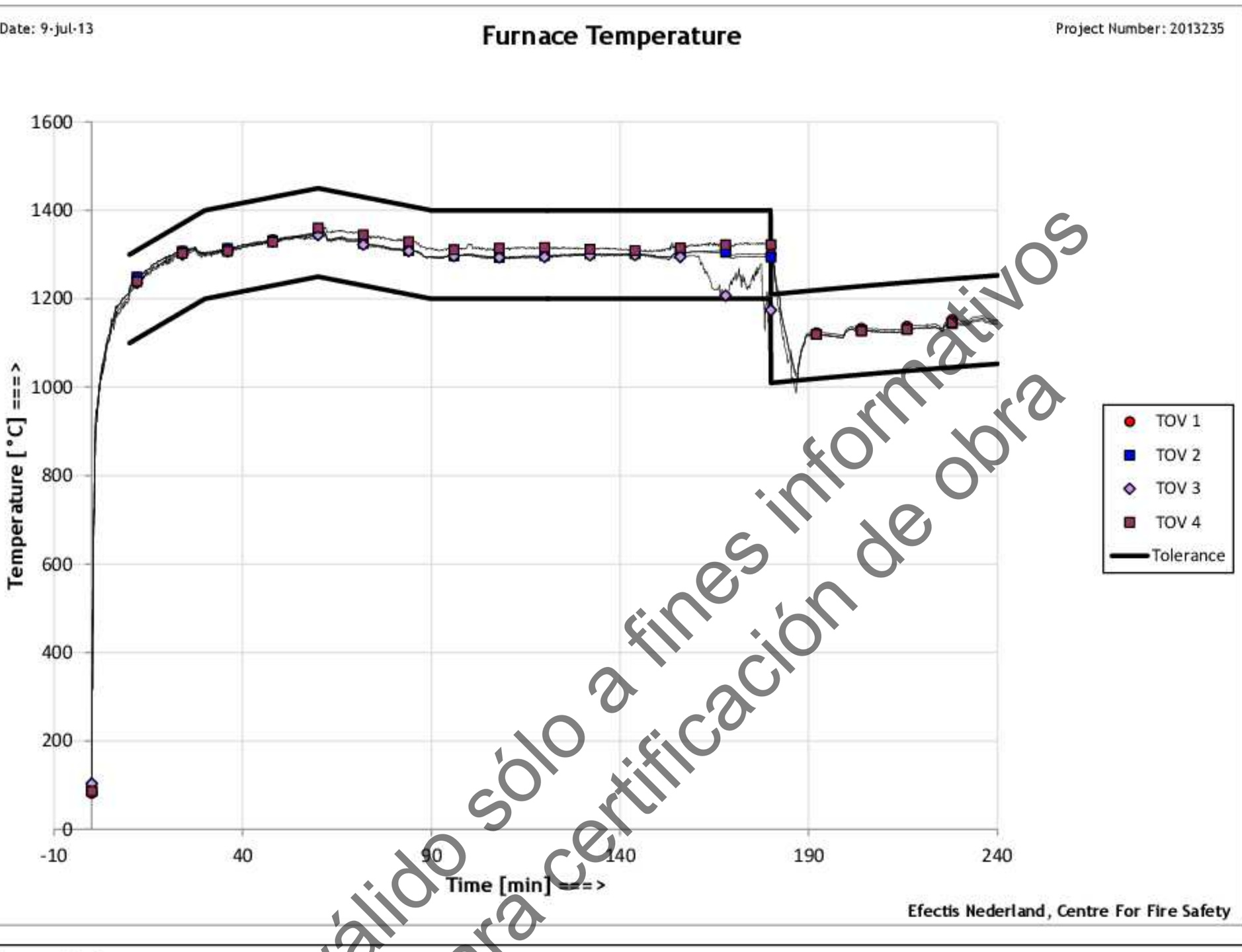


Figure B.1

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Figure B.2

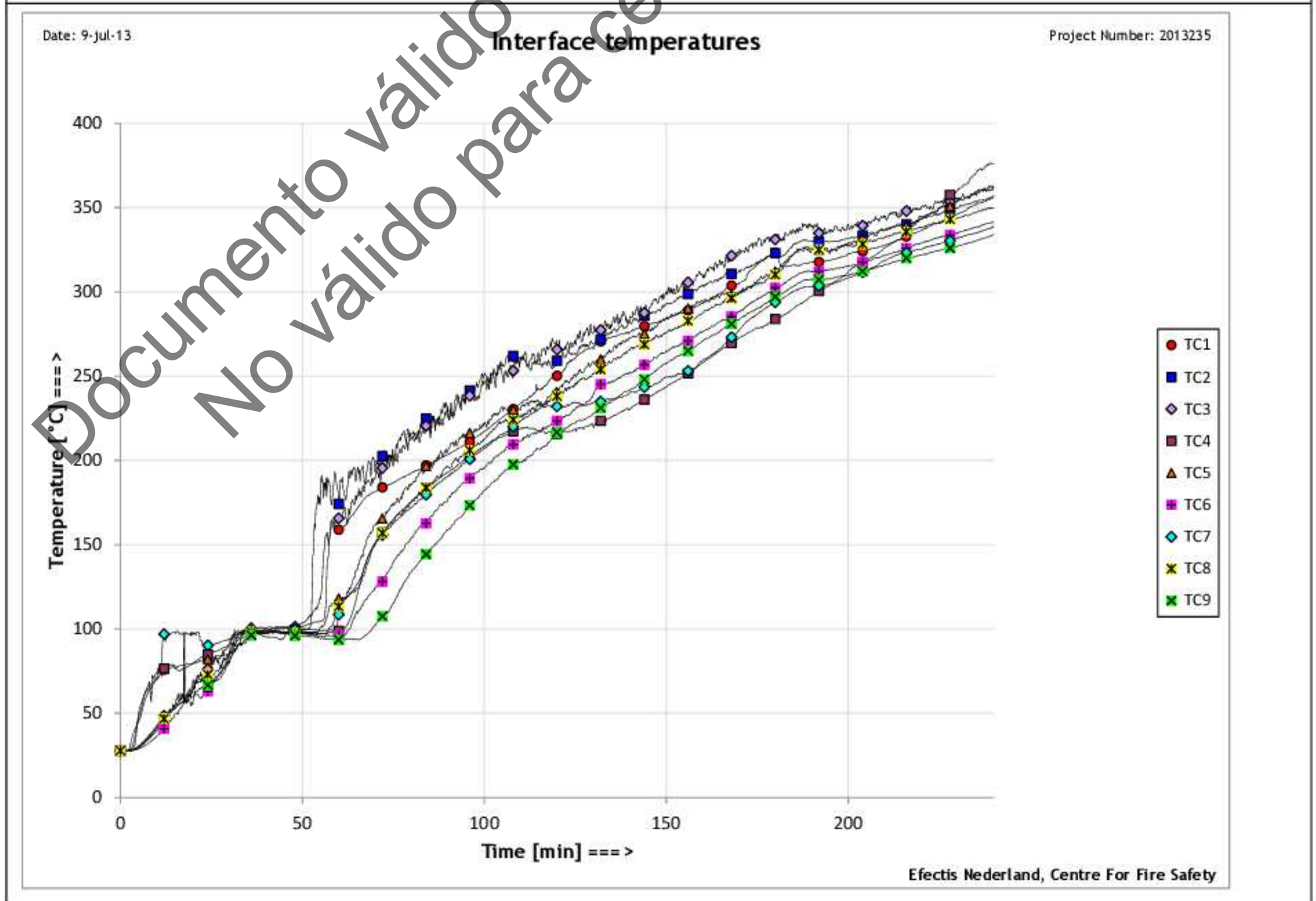


Figure B.3

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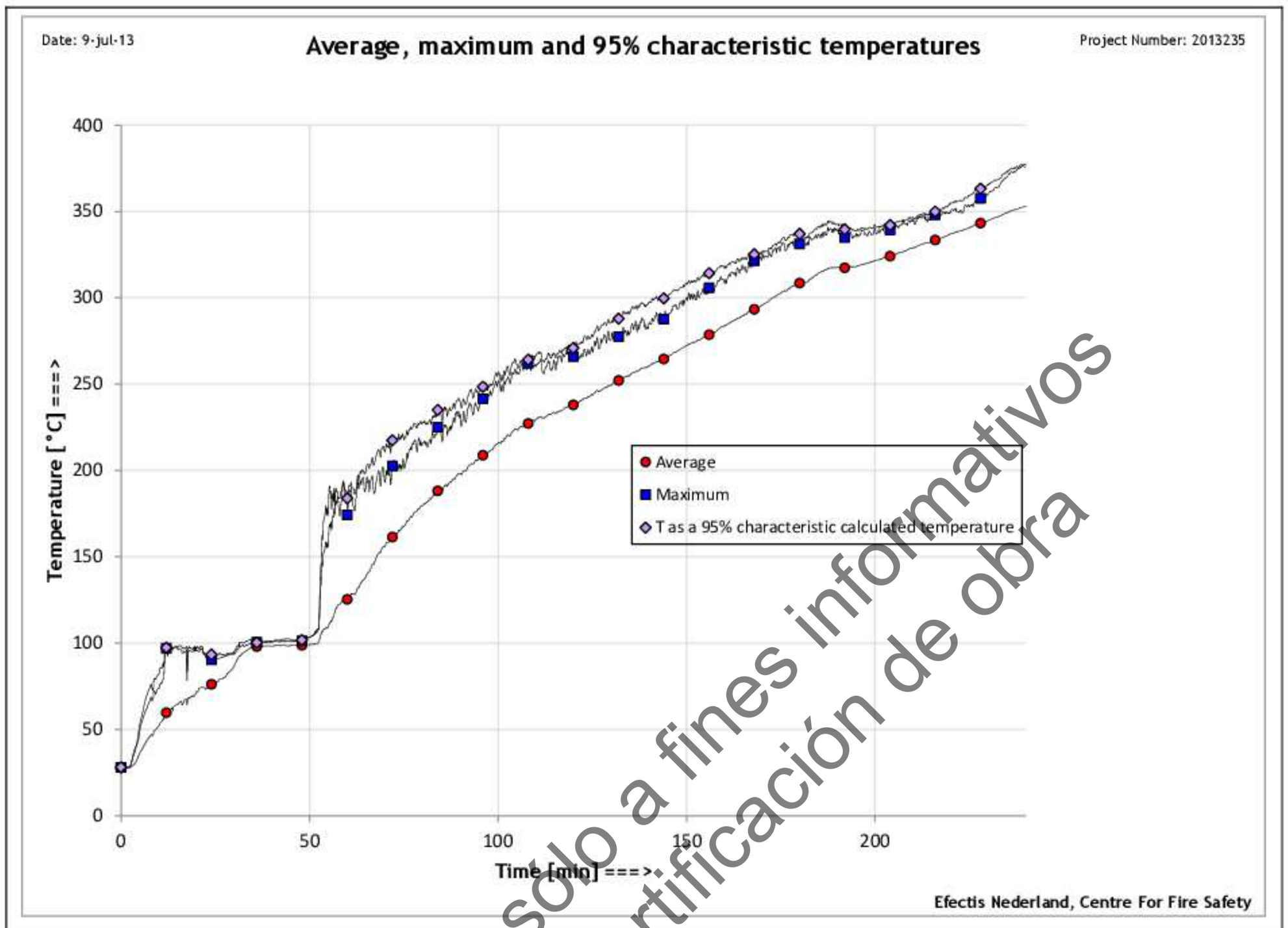


Figure B.4

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APPENDIX C: PHOTOGRAPHS

Picture C.1 Attaching the boards to the concrete slab
Picture C.2 Applying the PassiveTec XTSeal to the but joint
Picture C.3 HILTI anchors type HSA M6 40/30/10 (M6x85) together with the HILTI A 6.4/28 mm zinced flat washer
Picture C.4 Specimen direct after the fire test

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Picture C.1



Picture C.2

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Picture C.3



Picture C.4

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