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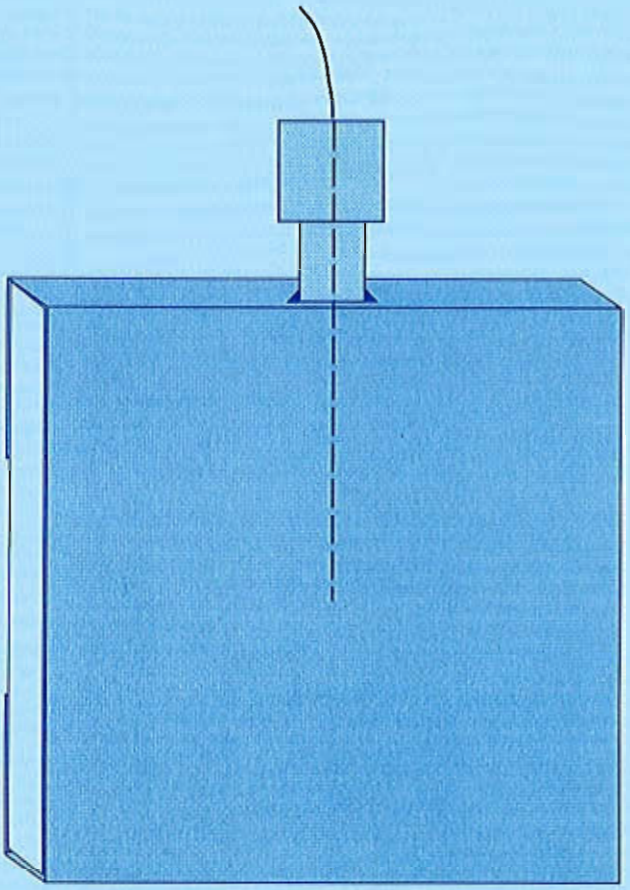
Modification of the Plate Thermometer - Proving Tests at SP and WFRC



SP
Swedish National Testing and Research Institute
Fire Technology
SP REPORT 1997:32

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1 Introduction

1.1 Introduction

The plate thermometer is an instrument that was originally designed at SP [1-4] for temperature measurements at elevated temperatures in, for example, fire resistance furnaces. The original plate thermometer (PT) consist of a folded steel plate with a 1 mm thermocouple fixed to its inside by a steel strap (spot welded or screwed) and an insulation pad. The folded steel plate and the steel strap is made of Inconel 600 steel. At use, the front side of the steel plate of the PT is facing the furnace while the insulating pad on the backside of the PT is protecting it from being influenced by the test specimen. See Figure 1.

Comprehensive investigations have recently been carried out under the auspices of CEN/TC127/AHG14 to study effects of changing from ordinary thermocouples to PT's [5-8]. In [9] further comments are given on the practical aspects using PT's.

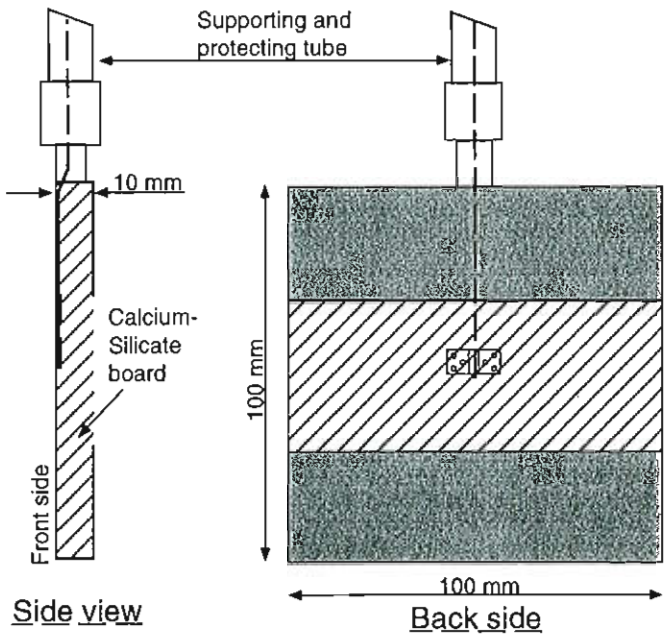


Figure 1. Design of plater thermometer.

1.2 Purpose

The purpose of the project in this report was to modify the existing PT so that it would become acceptable for all parties and members of CEN for controlling furnace temperature and thermal exposure in fire resistance furnaces.

The main task was to find a material that could replace the ceramic fibre board in the original PT with another material since ceramic fibre must not be used for health reasons according to German regulations. Other tasks were to find alternative ways of fixing the thermocouple to the steel plate and to investigate if a 3 mm thermocouple could be used instead of a 1 mm thermocouple.

1.3 Mode of procedure

Two laboratories were chosen to carry out the project, the Swedish National Testing and Research Institute (SP) and Warrington Fire Research Centre (WFRC) in England, with SP as project leader. The two laboratories were chosen by CEN TC127 on the following reason: The SP vertical furnace represents a type furnace which yields similar temperatures of the PT's as of the ordinary furnace thermocouples, while the WFRC vertical furnace yields considerably lower PT temperatures.

The project was sponsored by CEN TC127.

2 Test of modified plate thermometers

2.1 Modified plate thermometers

As a start, some pre-tests of different plate thermometer (PT) designs were carried out at prior to the main tests which are reported here. Among others, the fixing of the thermocouple (TC) to the PT was examined in SP's horizontal furnace. No temperature differences were noted between fixing by screws or by welding (the original method) as shown in figure A1 in appendix A.

Based on the above mentioned pre-tests and comments from the members of CEN/TC127/AHG14, alternative PT's were designed, manufactured and evaluated in tests at SP and WFRC. The new PT designs are all very similar to the original design. The only variable parameters are:

- the diameter of the TC: - 1 or 3 mm
- the means of fixing of the TC on to the inconel steel: - welding or screws
- type of insulation inside the PT: - ceramic insulation or - insulation X1 or - air (voids)
- the size of the PT: - 100 by 100 mm (the original PT size) or 50 by 75 mm.

The insulation here called X1 is a calcium silicate fibre board designated RATH CVS 121 with a density of approximately 280 kg/m^3. According to the manufacturer, RATH (Deutchland) GmbH, the insulation is non health hazardous.

The different plate thermometer designs are described in table 1 below.

Table 1. Different PT designs

	Sensor Type	TC	Fixing of TC	Insulation	Note
1.	PT_1mm _ce_org	1 mm	inconel steel strap fixed by spot welding	ceramic insulation	the original PT, size 100 mm by 100 mm
2.	PT_1mm_1void	1 mm	- see above -	one air void*	
3.	PT_1mm_2voids	1 mm	- see above -	two air voids**	
4.	PT_1mm_X1	1 mm	- see above -	insulation X1	
5.	PT_3mm_X1_screw	3 mm	inconel steel strap fixed by two stainless steel screws, ø 2 mm	- see above -	
6.	PT_1mm _ce_50x75	1 mm	inconel steel strap fixed by spot welding	ceramic insulation	as type 1 but size 50 mm by 75 mm

*) PT made of inconel steel only, consisting of two parallel inconel steel sheets with an air void in between as insulation. Not an air tight construction.

**) PT made of inconel steel only, consisting of three parallel inconel steel sheets with two air voids in between as insulation. Not an air tight construction.

2.2 Test conditions

The different plate thermometers tabulated in section 2.1, including the original PT, were tested together with 1 and 3 mm sheathed thermocouples in two tests, one at SP and one at WFRC.

In both tests, the test specimen consisted of a non-insulating glass pane mounted in a steel framework which in turn was mounted in an aperture in a 3,0 m x 3,0 m lightweight steel stud wall with calcium-silicate boards on the fire exposed side and plasterboards on the non exposed side.

Some of the temperature sensors were positioned in front of the non-insulating transparent glass and some in front of the insulating wall construction.

The tests were performed according those parts *of prEN 1363-3: Fire Resistance Tests - Part 1 General Requirements* which were applicable to this project.

The furnace temperatures were controlled according to the standard curve measured with the original PT's

2.2.1 Test at SP

The test set-up at SP and the designation and position of the temperature sensors are shown in figures S1 and S2 in appendix S, and in table S1 below.

Table S1. PT designs used at SP

Sensors in front of the calcium-silicate board		Sensors in front of the non-insulating glass	
Designation	Type	Designation	Type
PT1	PT_1mm _ce_org	PT5	PT_1mm _ce_org
PT2	PT_1mm_1void	PT6	PT_1mm_1void
PT3	PT_3mm_X1_screw	PT7	PT_1mm_2voids
PT4	PT_1mm_X1	PT8	PT_1mm_X1
TC1/1	1 mm sheathed TC	TC1/2	1 mm sheathed TC
TC3/1	3 mm sheathed TC	TC3/1	3 mm sheathed TC

The test was carried out on SP's vertical furnace on August 5, 1997. The test lasted 92 minutes and the furnace was controlled by two PT's of the original design, PT_1mm_ce_org, (i.e. PT1 and PT5). Propane gas was used as fuel.

2.2.2 Test at WFRC

The test set-up at WFRC and the designation and position of the temperature sensors are shown in figures W1 and W2 in appendix W, and in table W1 below.

Table W1. PT designs used at WFRC

Sensors in front of the calcium-silicate board		Sensors in front of the non-insulating glass	
Designation	Type	Designation	Type
PT1	PT_1mm _ce_org	PT5	PT_1mm _ce_org
PT2	PT_1mm_1void	PT6	PT_1mm_1void
PT3	PT_3mm_X1_screw	PT7	PT_1mm_2voids
PT4	PT_1mm_X1	PT8	PT_1mm_X1
PT9	PT_1mm_ce_50x75		
TC1/1	1 mm sheathed TC	TC1/2	1 mm sheathed TC
TC3/1	3 mm sheathed TC	TC3/1	3 mm sheathed TC

The test was carried out on WFRC's vertical furnace on August 23, 1997. The test lasted 95 minutes and the furnace was controlled by two PT's of the original design, PT_1mm_ce_org, (i.e. PT1 and PT5). Natural gas was used as fuel.

3 Results

3.1 Test results at SP

The test results from SP are presented in a number of graphs, figures S3 - S7 in appendix S. Comments to these graphs are given in table S2 below.

Table S2. Comments on temperature readings from tests at SP

Figure	Type of TC or PT	Result
S3	TC's and PT's in front of the insulating wall	Almost equal readings of PT's and TC's.
S4	TC's and PT's in front of the glazing	Only insulated PT's follows standard curve temperature. One or two voids not sufficient
S5	PT's with insulation boards of ceramic fiber and calcium silicate with 1 and 3 mm TC's	Negligible temperature differences
S5a	Differences between the above curves	PT 3mm negligibly slower than PT 1mm
S6	PT's with one or two voids in front of the glazing	Voids not sufficient as insulation
S7	1 and 3 mm TC's in front of the glazing	TC's about 50 and 60 °C respectively lower than PT after 60 minutes.

3.2 Test results at WFRC

The test results from WFRC are presented in a number of graphs, figures W2 - W8 in appendix W. Comments to these graphs are given in table W2 below.

Table W2. Comments on temperature readings from tests at WFRC

Figure	Type of TC or PT	Result
W3	TC's and PT's in front of the insulating wall	All PT's have lower temperatures than TCs.
W4	TC's and PT's in front of the glazing	PT's with void(s) get the lowest temperature. PT's with ins. closer to TC
W5	PT's with insulation boards of ceramic fiber and calcium silicate with 1 and 3 mm TC's	No difference except with 3 mm screwed TC.
W5a	Differences between the above curves	- see above -
W6	PT's with one or two voids in front of the glazing	Voids not sufficient as insulation
W7	1 and 3 mm TC's in front of the glazing	The PT in between the 1 mm and 3 mm TC's after about 60 min.
W8	PT's of different sizes 100 mm by 100 mm vs. 50 mm by 75 mm.	The smaller PT gets a higher temperature closer to TC.

4 Conclusions

From the above the following interesting and conclusive observations can be made:

- Screwing instead of spot welding of strap for fastening TC is possible without changing thermal properties of the PT.
- Changing of insulation from ceramic to calcium silicate board (RATH CVS 121) is possible. There is almost no difference between the temperature readings of the original PT's with ceramic insulation (PT1 and PT2) and the PT's with calcium silicate boards (PT5 and PT8).
- PT's with only radiation screening (i.e. without insulation pad, air void only) is not sufficient when testing glazings.
- TC's reads considerably lower temperature in front of glazings.
- PT's with insulation read in the SP furnace the same temperature in front of insulated part of specimen as in front of glazed part.
- In the WFRC furnace all temperature readings are considerably lower in front of the glazing than in front of the insulated part.
- In the WFRC furnace the difference between the TC and PT readings in front of the glazing vanishes after about 60 min.
- In the WFRC furnace a PT reduced to a size of 50 mm by 75 mm obtained higher temperature than an ordinary size PT 100 mm by 100 mm.

5 References

[1] Wickström, U., *Fire Technology* , VOL.30, No 2, pp 195,(1994).

[2] Wickström, U., "Proposal Regarding Temperature Measurements in Fire Resistance Furnaces", SP-Report 1986:17, Swedish National Testing and Research Institute, 1986.

[3] Wickström, U., "The Plate Thermometer - A Simple Instrument for Reaching Harmonised Fire Resistance Tests", SP-Report 1989:03, Swedish National Testing and Research Institute, 1989.

[4] Olsson S., "Calibration of Fire Resistance Furnaces with Plate Thermometers", BCR-report, EUR No 14555 EN, 1993, Commission of European Communities.

[5] Leur, P.H.E. van de, Twilt, L. and Wickström, U., "Proving Test Programme Fire Resistance Furnace Calibration", final report to the CEN TC127, TNO-report 95-CVB-R1275, October 1995.

[6] Leur, P.H.E. van de, Twilt, L., "Fire Resistance Furnace Calibration, Proving Test Programme; Phase 2: Tests under Plate Thermometer Furnace Control, Vertical Specimens, ISO 834 Standard Fire Curve", TNO-report 97-CVB-R0602, March 1997 (doc. CEN/TC127/N1161).

[7] Leur, P.H.E. van de, Twilt, L., "Fire Resistance Furnace Calibration, Proving Test Programme; Phase 3: Tests under Plate Thermometer Furnace Control, Vertical Specimens, Slow and Hydrocarbon Fire Curve", TNO-report 97-CVB-R0603, March 1997 (doc. CEN/TC127/N1162).

[8] Hermodsson, T., "Calibration of Horizontal Fire Resistance Furnaces - Plate Thermometer Control", Report on Nordtest and CEN/TC127/Ad hoc 14 proving tests, SP-Report 1997:xx, (to be published).

[9] Wickström, U. "The Plate Thermometer - practical aspects using and impact on test results", SP-Report 1997:28, Swedish National Testing and Research Institute, 1997.

Appendix A

Graph showing the temperature readings from a pre-test of plate thermometers with thermocouples fixed by screws vs. welding.

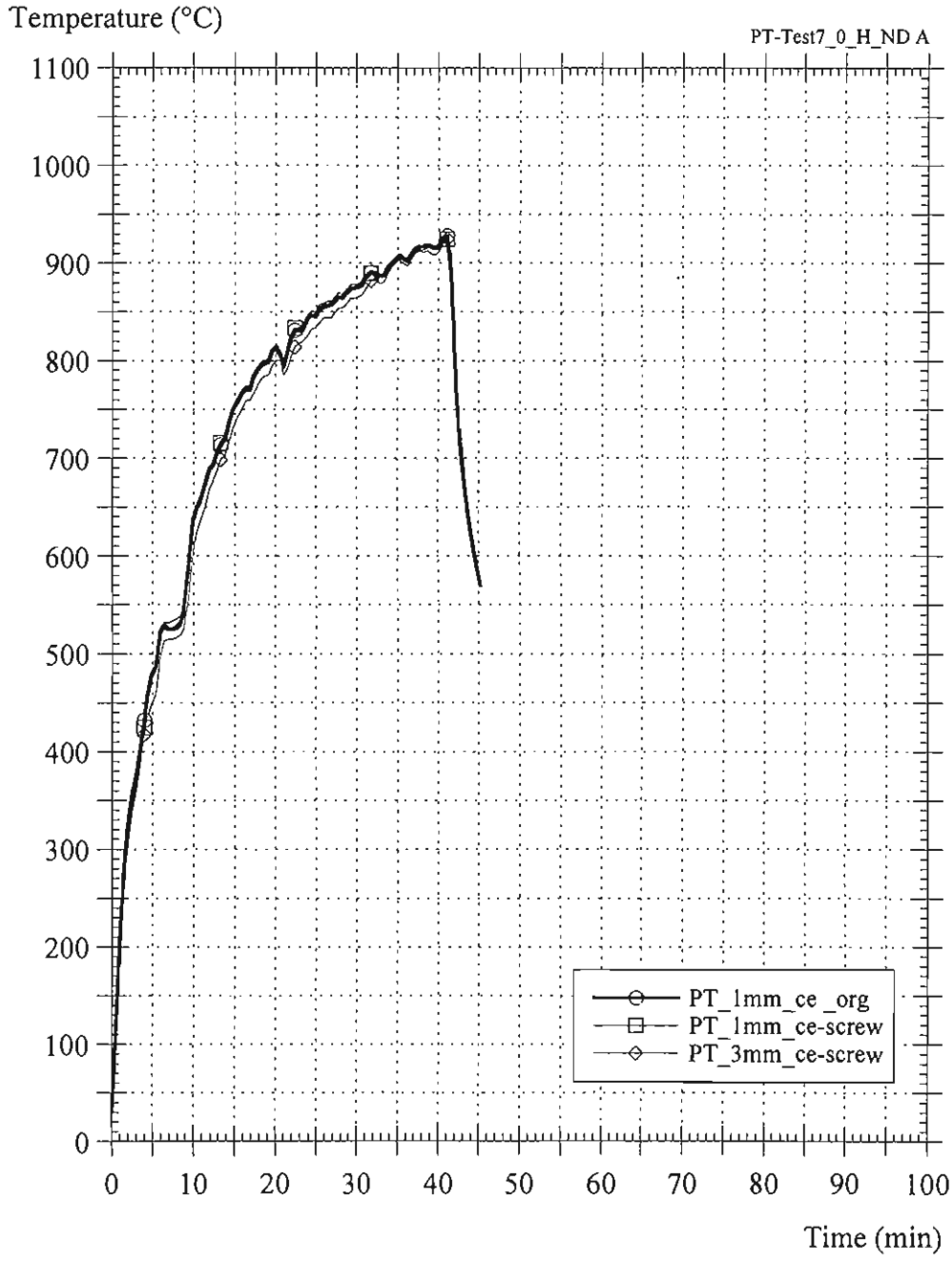


Figure A1.

Screwed TC's on the PT's. These data are from a previuos test. The PT's were mounted in the horizontal furnace in front of concrete slabs.

Appendix S

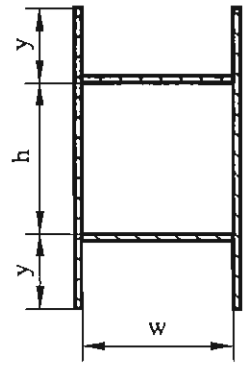
S1 - S2 : drawing and description of the test set-up at SP
S3 - S7 : graphs showing the test results from SP.

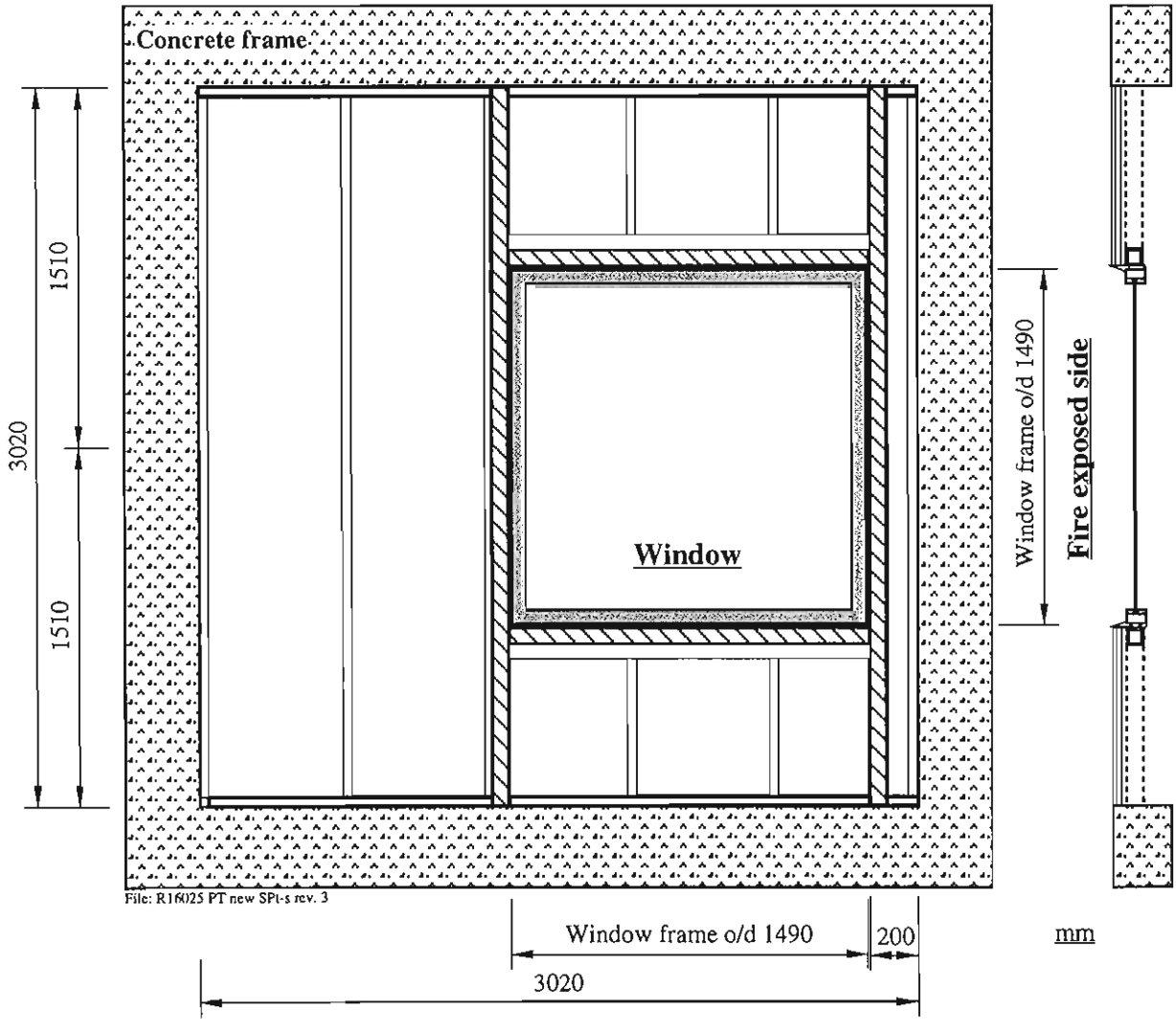
Modification of the plate thermometer - Test set-up at SP 1997-08-05

(Schematic drawing, as seen from the unexposed side)

Clear opening of the framework of RHS 70 x 70 x 5 profiles around the window

h = 1520 mm
w = 1520 mm



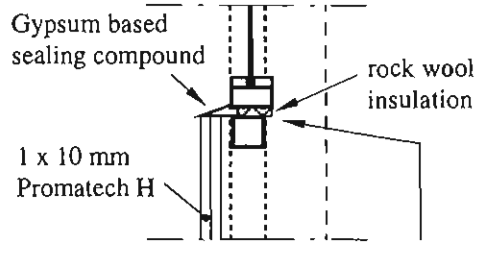


Wall construction

- 70 mm steel studs, t = 0,56 mm, c 600 mm
- steel profile, RHS 70x70x5, supporting construction for the window frame
- 2 x 15 mm plasterboard
- 1 x 10 mm calcium silicate board (Promatec H)

Window

- Frame of steel
- non-insulating glass, 6 mm Pyran S, (w x h) 1400 x 1400 mm

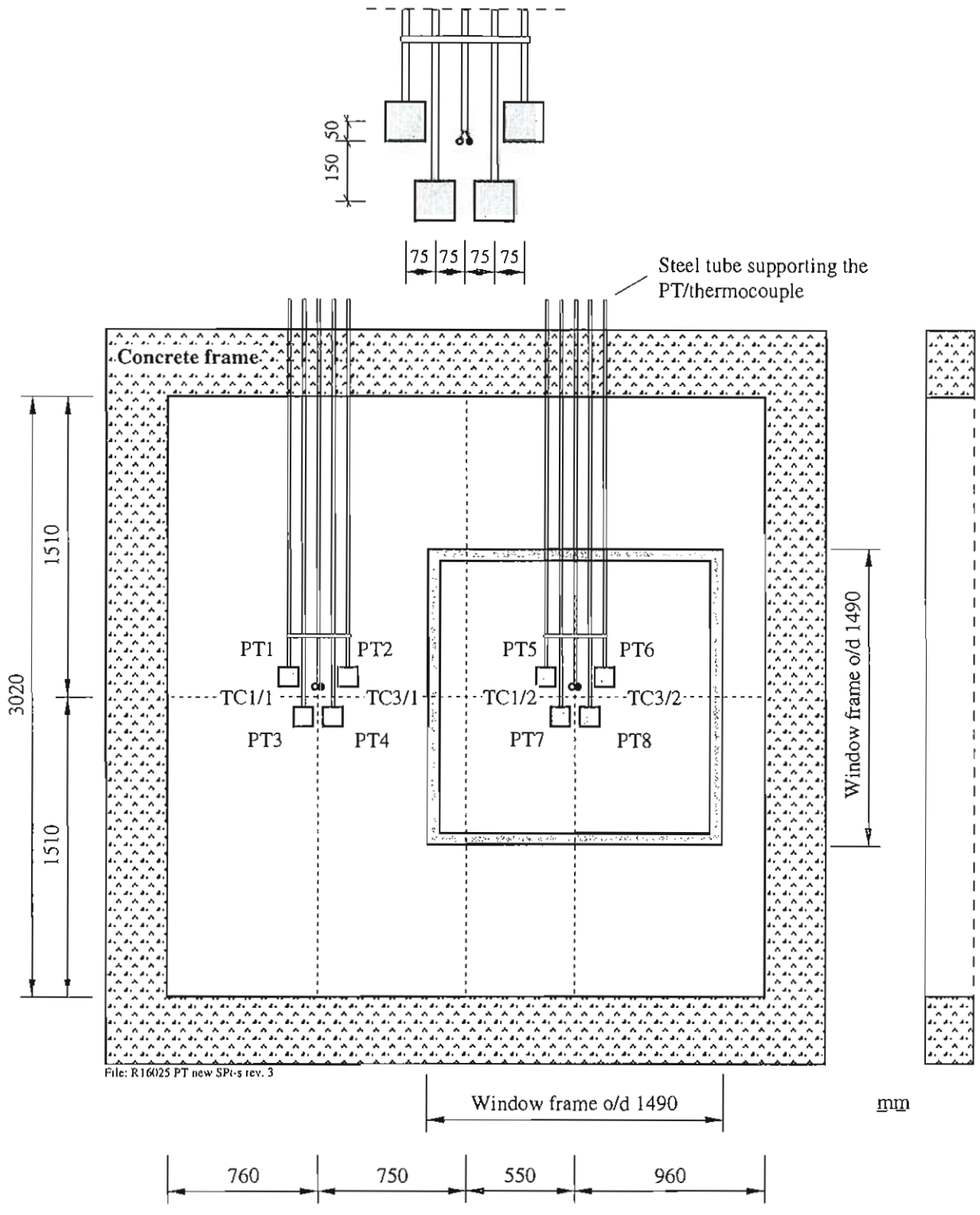


Fixing of the window frame to the supporting steel frame of RHS 70x70x5 with e.g., steel screws or with steel spacers and welding

Figure S1

Modification of the plate thermometer - Test set-up at SP 1997-08-05

(Schematic drawing, as seen from the unexposed side)



□ : PT1 - PT8 : Plate thermometers of different design

∘ : TC1/1 - TC1/2 : 1 mm TC

• : TC3/1 - TC3/2 : 3 mm TC

All sensors positioned 100 mm from the fire exposed surface of the wall/glass.

Figure S2

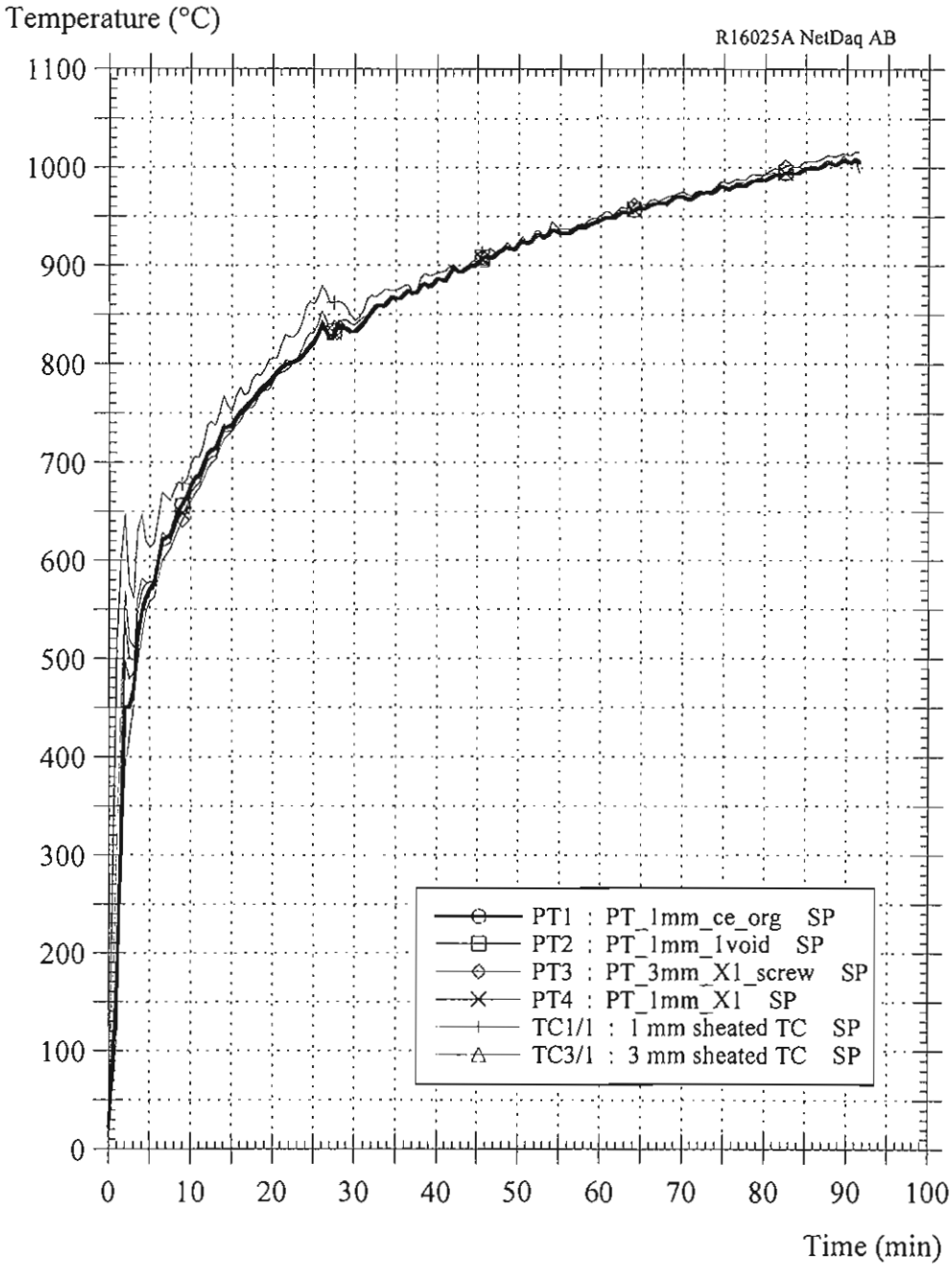


Figure S3.

TC's and PT's in front of the insulating wall (calcium silicate board).

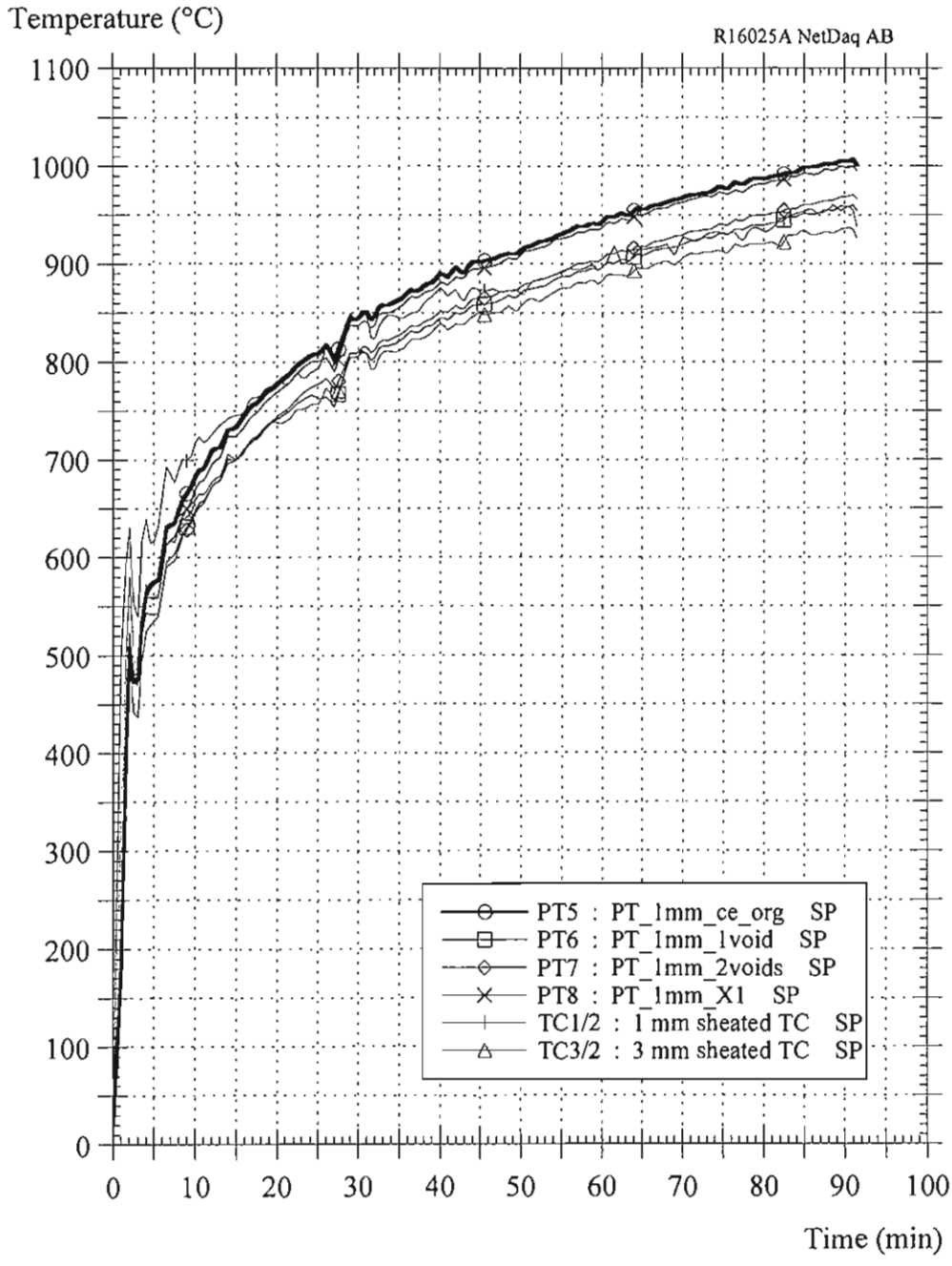


Figure S4.

TC's and PT's in front of the glazing.

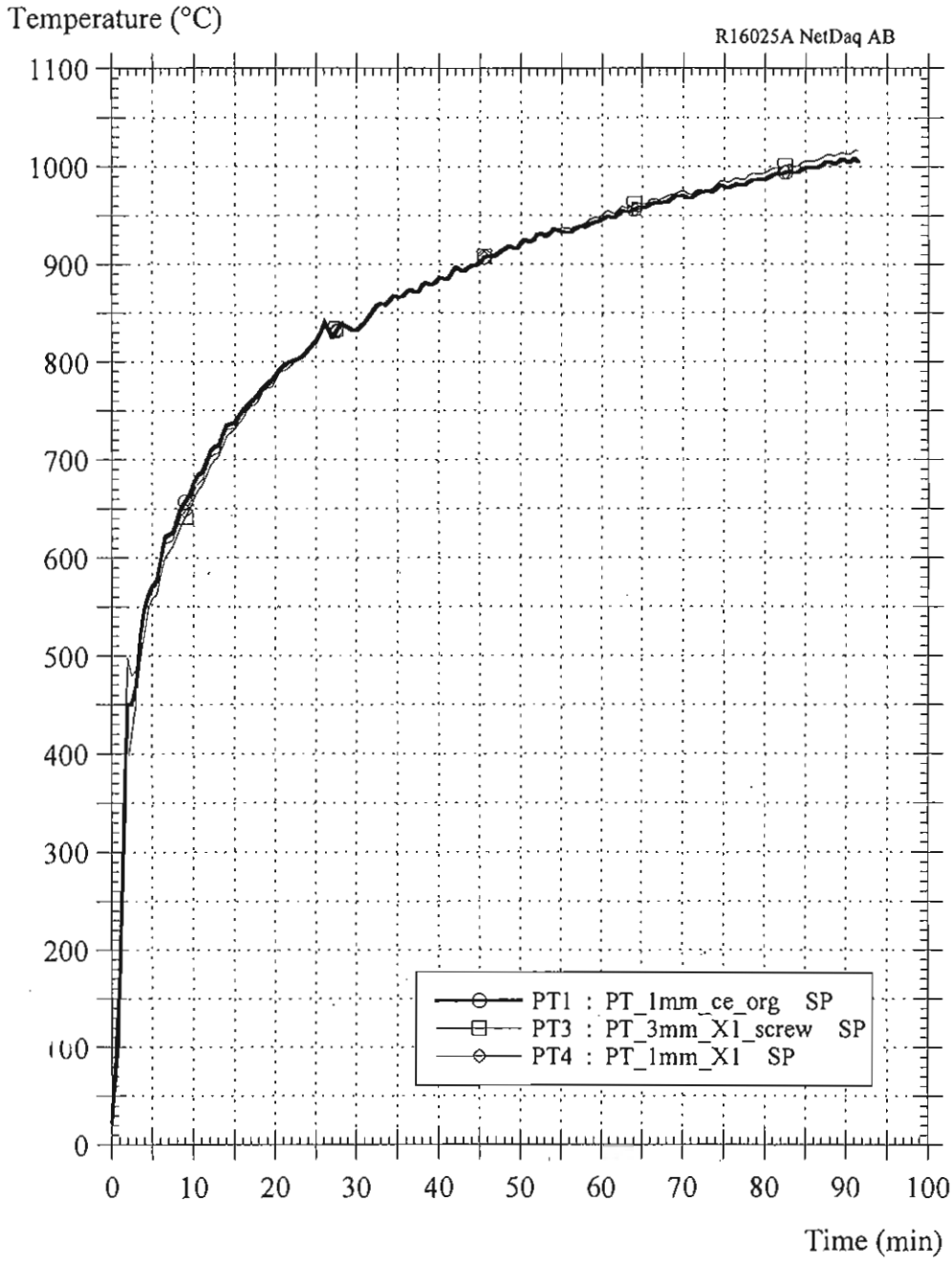


Figure S5.

PT's with 1 mm and 3 mm thermocouples in front of the insulating wall (calcium silicate board).

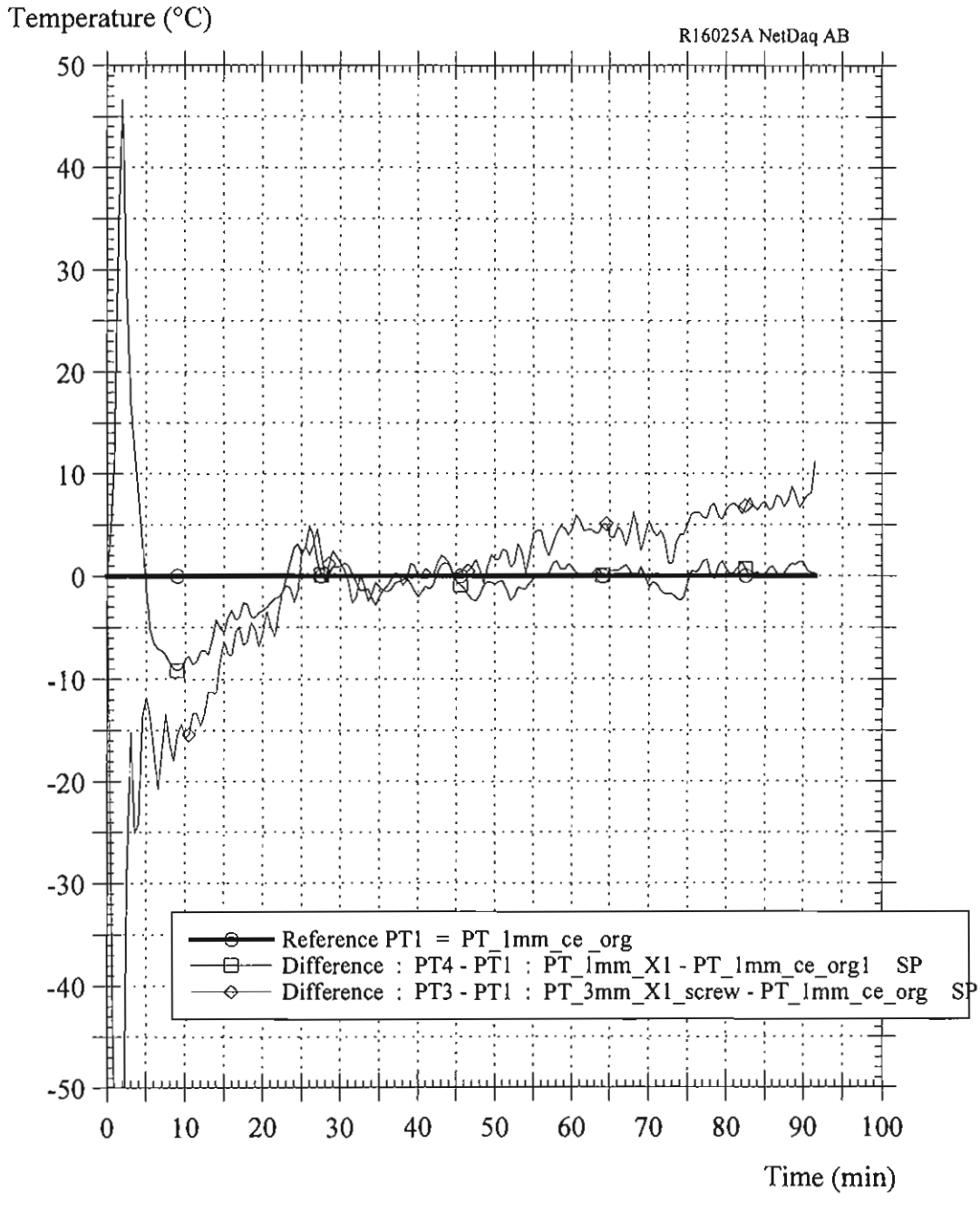


Figure S5a.

Difference between the original PT and PT's with 1 mm and 3 mm thermocouples in front of the insulating wall (calcium silicate board)

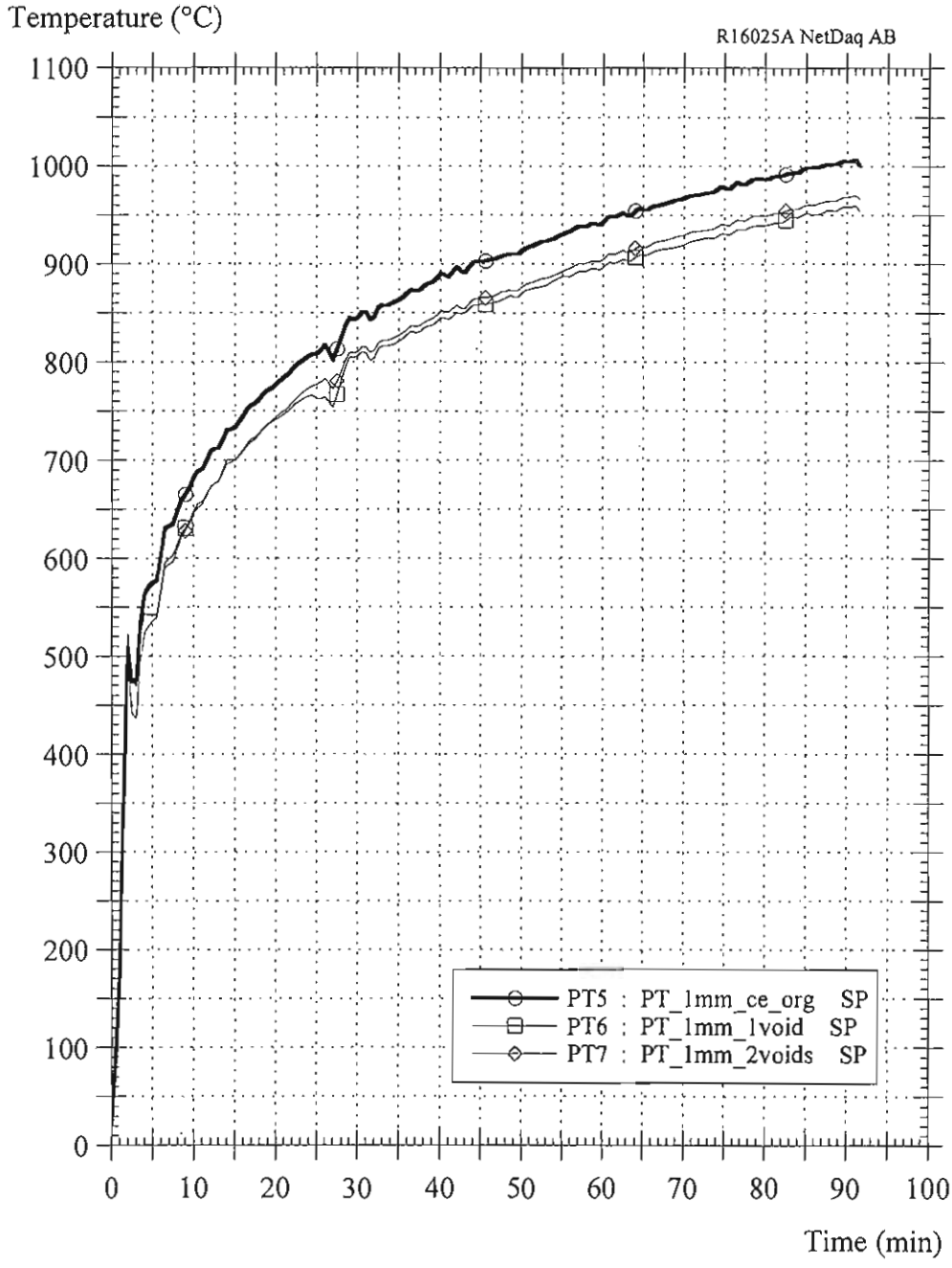


Figure S6.

PT's with one and two voids in front of the glazing.

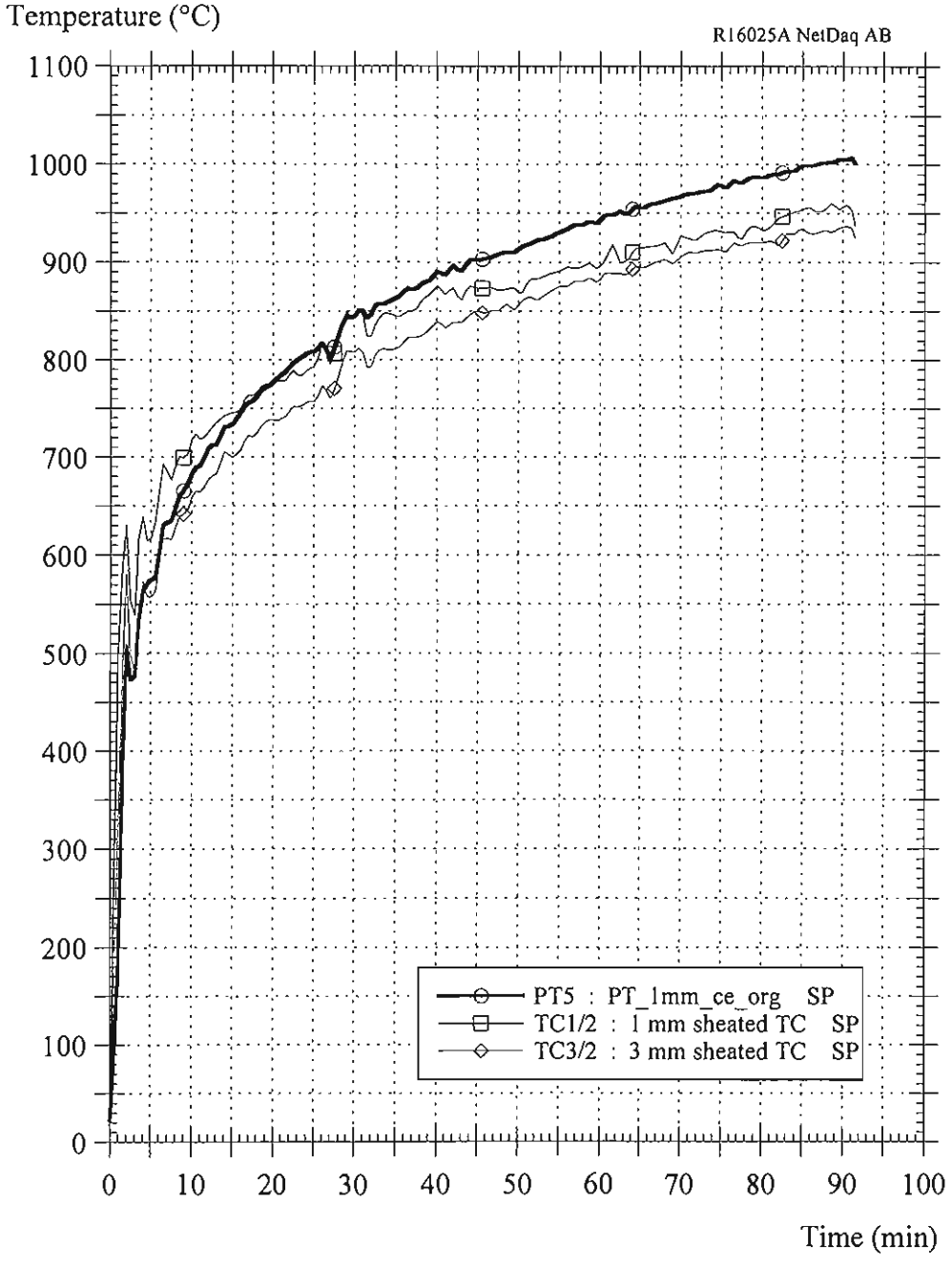


Figure S7.

TC's with 1 mm and 3 mm diameter in front of the glazing.

Appendix W

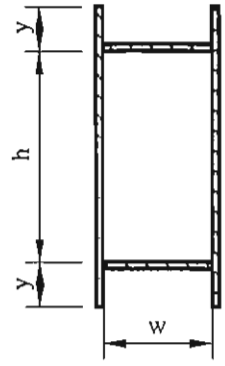
W1 - W2 : drawing and description of the test set-up at WFRC
W3 - W8 : graphs showing the test results from WFRC.

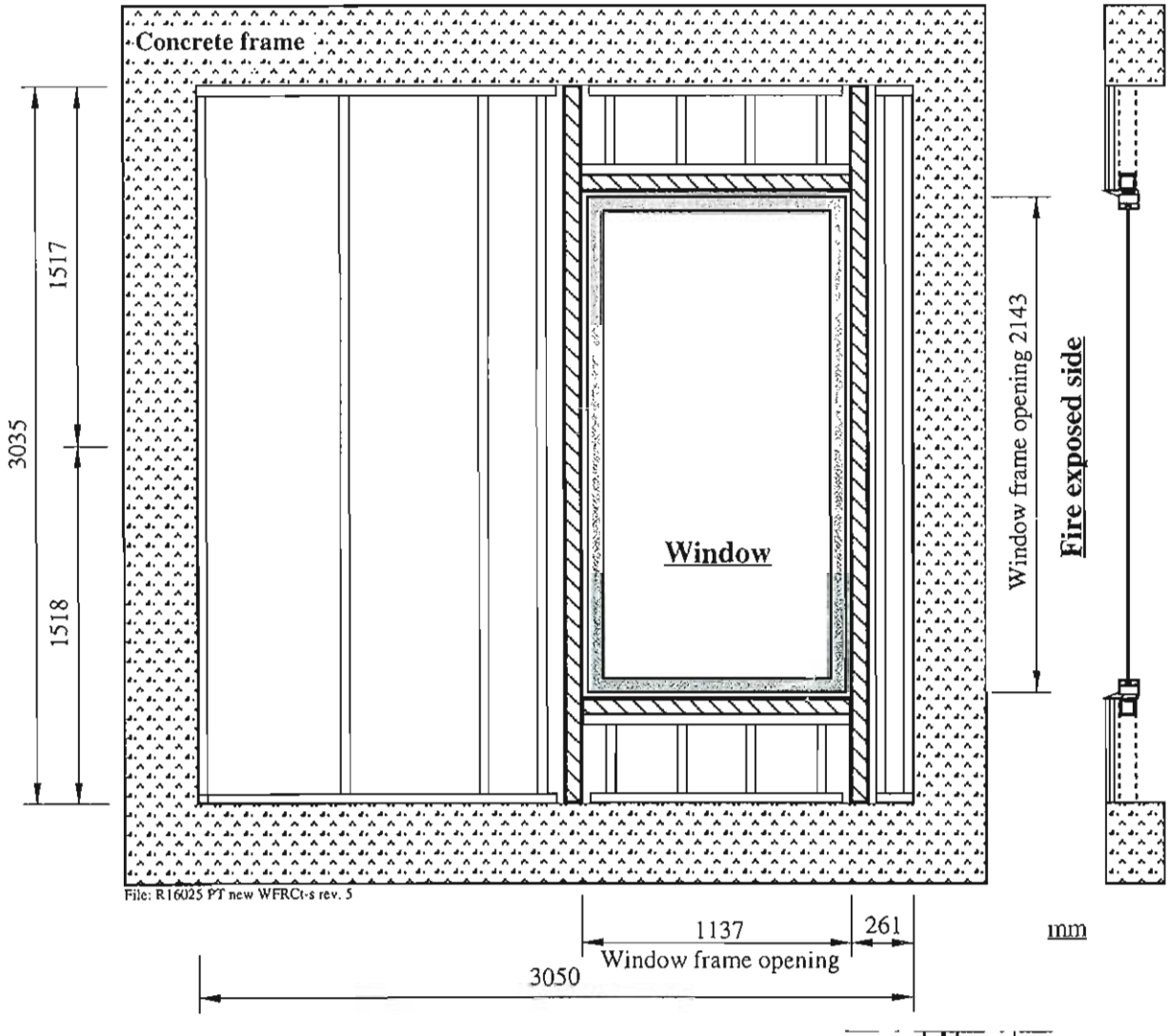
Modification of the plate thermometer - Test set-up at WFRC 1997-08-23

(Schematic drawing, as seen from the unexposed side)

Clear opening of the framework of RHS 70 x 70 x 5 profiles around the window

h = 2143 mm
w = 1137 mm



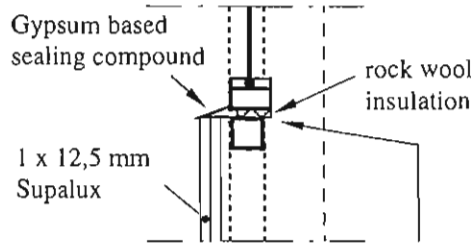


Wall construction

- 70 mm steel studs, t = 0,56 mm, c 600 mm
- steel profile, RHS 70x70x5, supporting construction for the window frame
- 2 x 15 mm plasterboard
- 1 x 12,5 mm calcium silicate board (Supalux)

Window

- Frame of steel
- non-insulating glass, 8 mm Pyran S, (w x h) 990 x 2000 mm

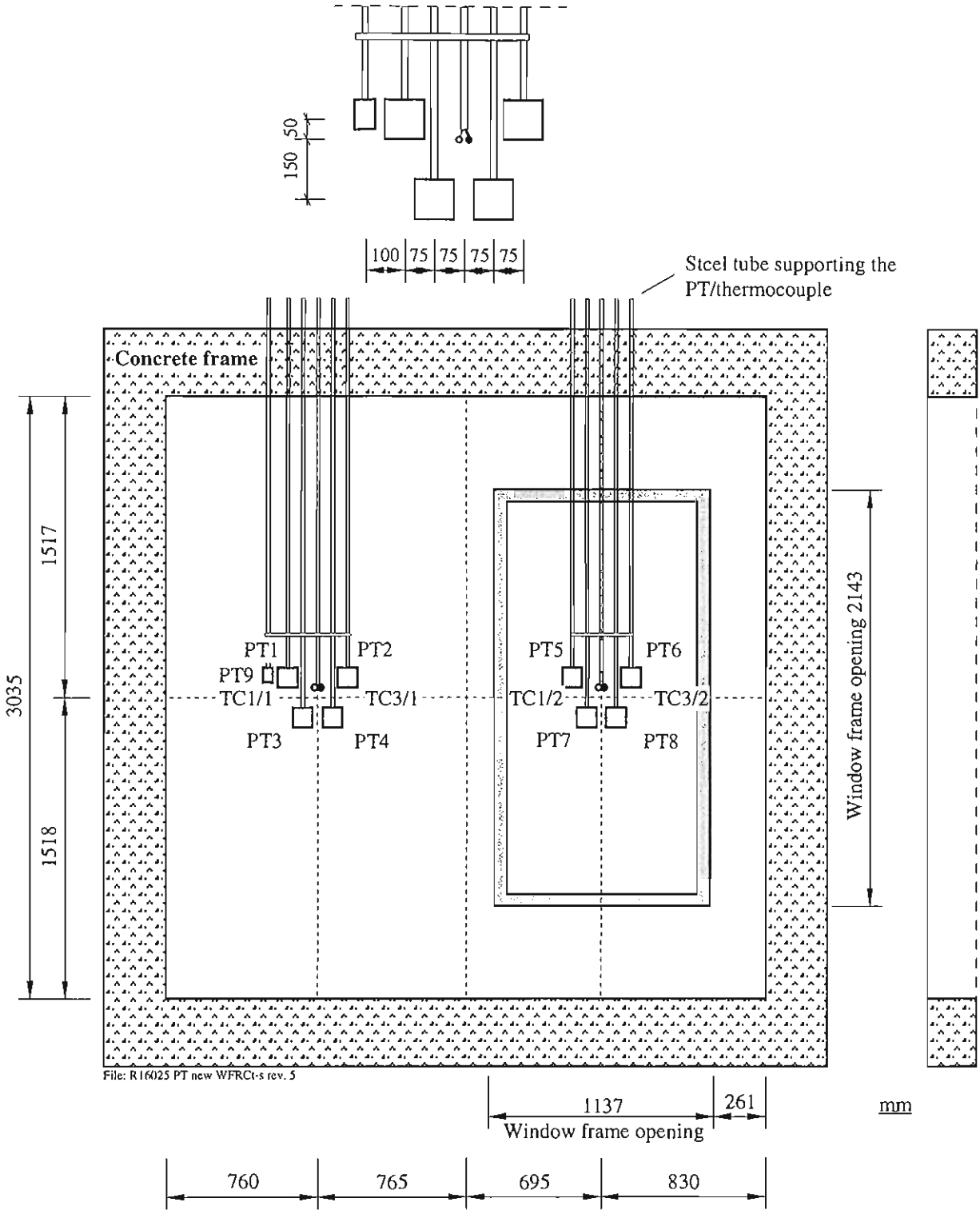


Fixing of the window frame to the supporting steel frame of RHS 70x70x5 with e.g., steel screws or with steel spacers and welding

Figure W1

Modification of the plate thermometer - Test set-up at WFRC 1997-08-23

(Schematic drawing, as seen from the unexposed side)



□ : PT1 - PT8 : Plate thermometers of different design

▯ : PT9 : Plate thermometers of smaller size

o : TC1/1 - TC1/2 : 1 mm TC

• : TC3/1 - TC3/2 : 3 mm TC

All sensors positioned 100 mm from the fire exposed surface of the wall/glass.

Figure W2

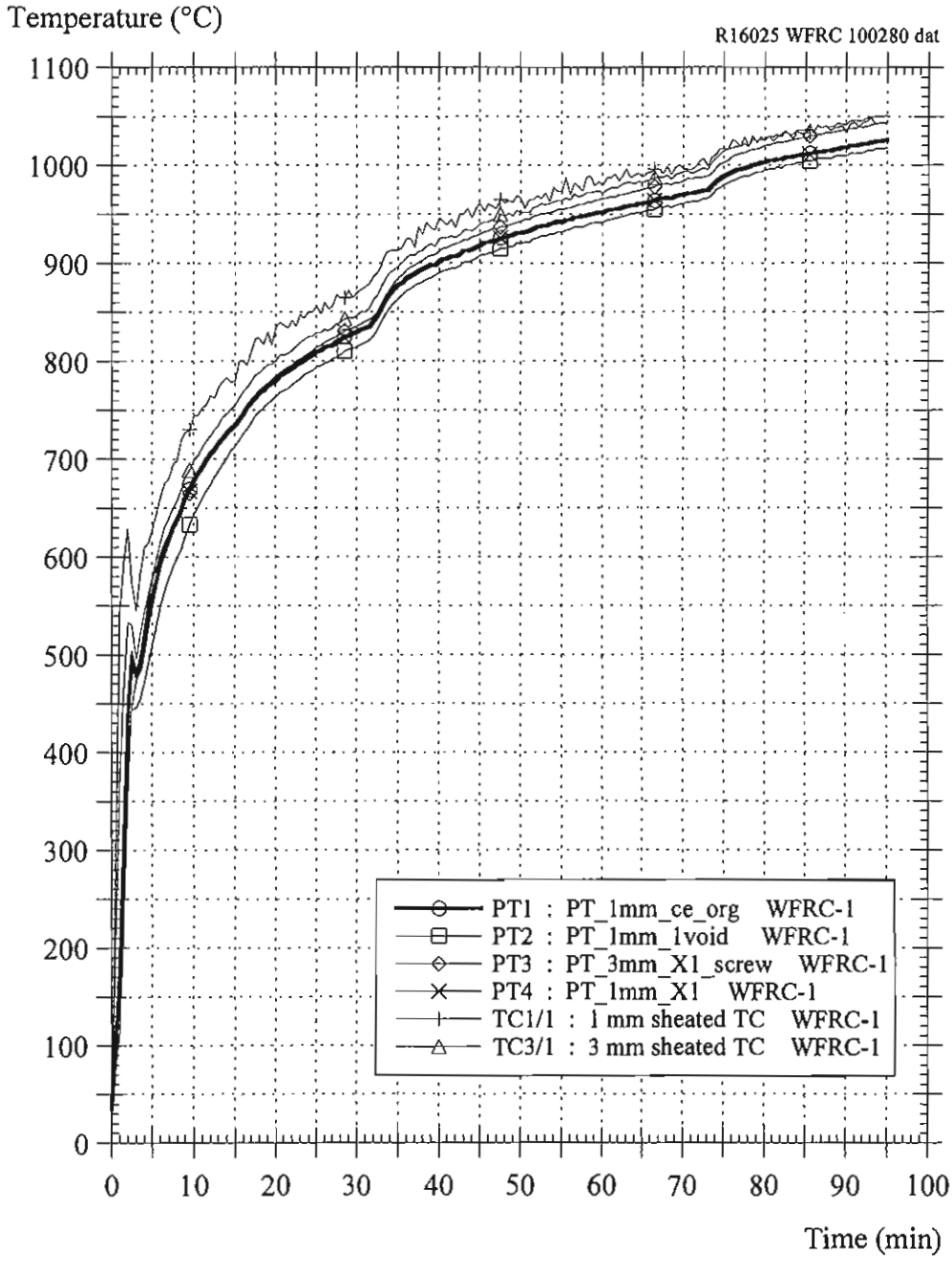


Figure W3.

TC's and PT's in front of the insulating wall (calcium silicate board).

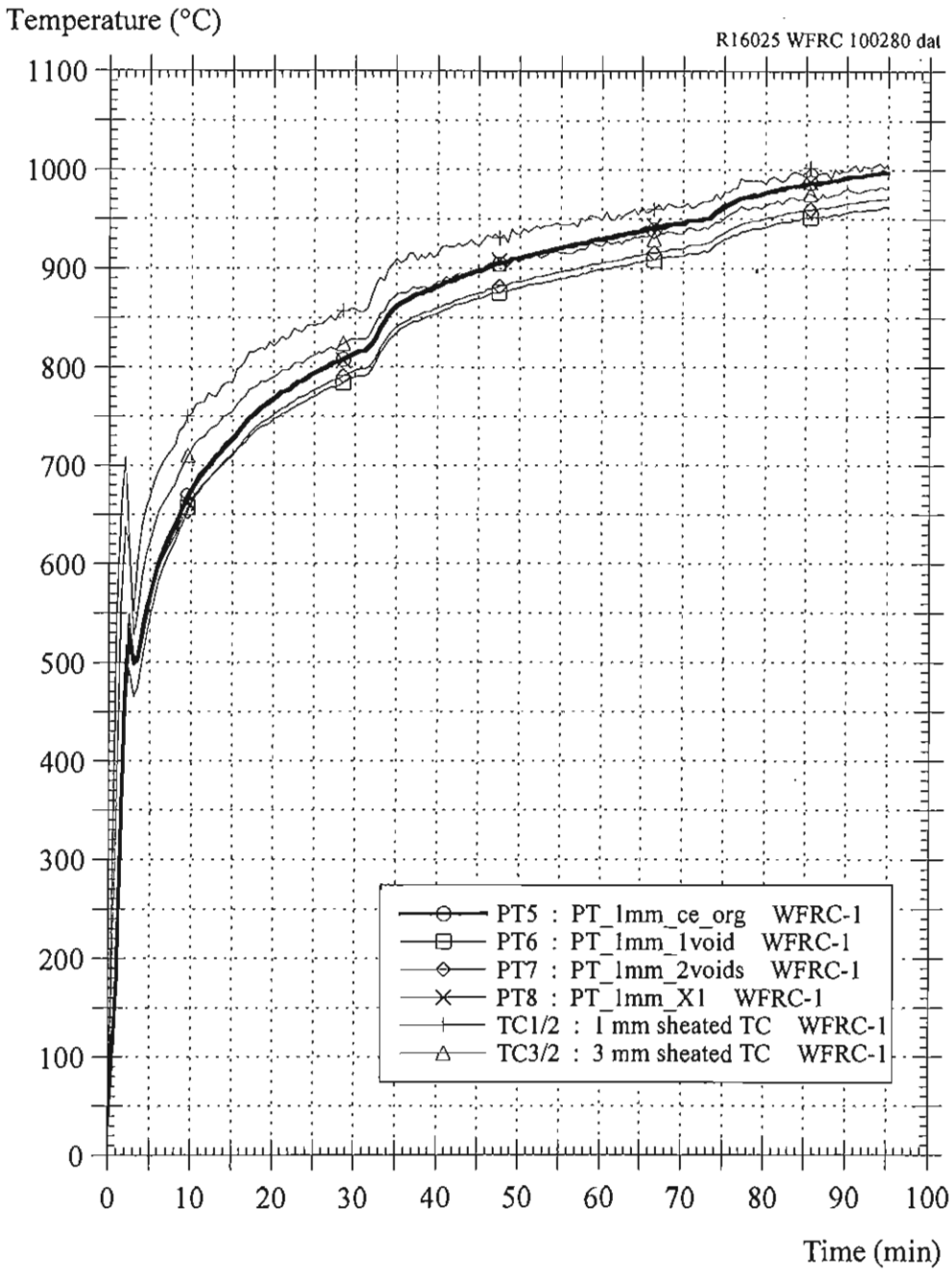


Figure W4.

TC's and PT's in front of the glazing.

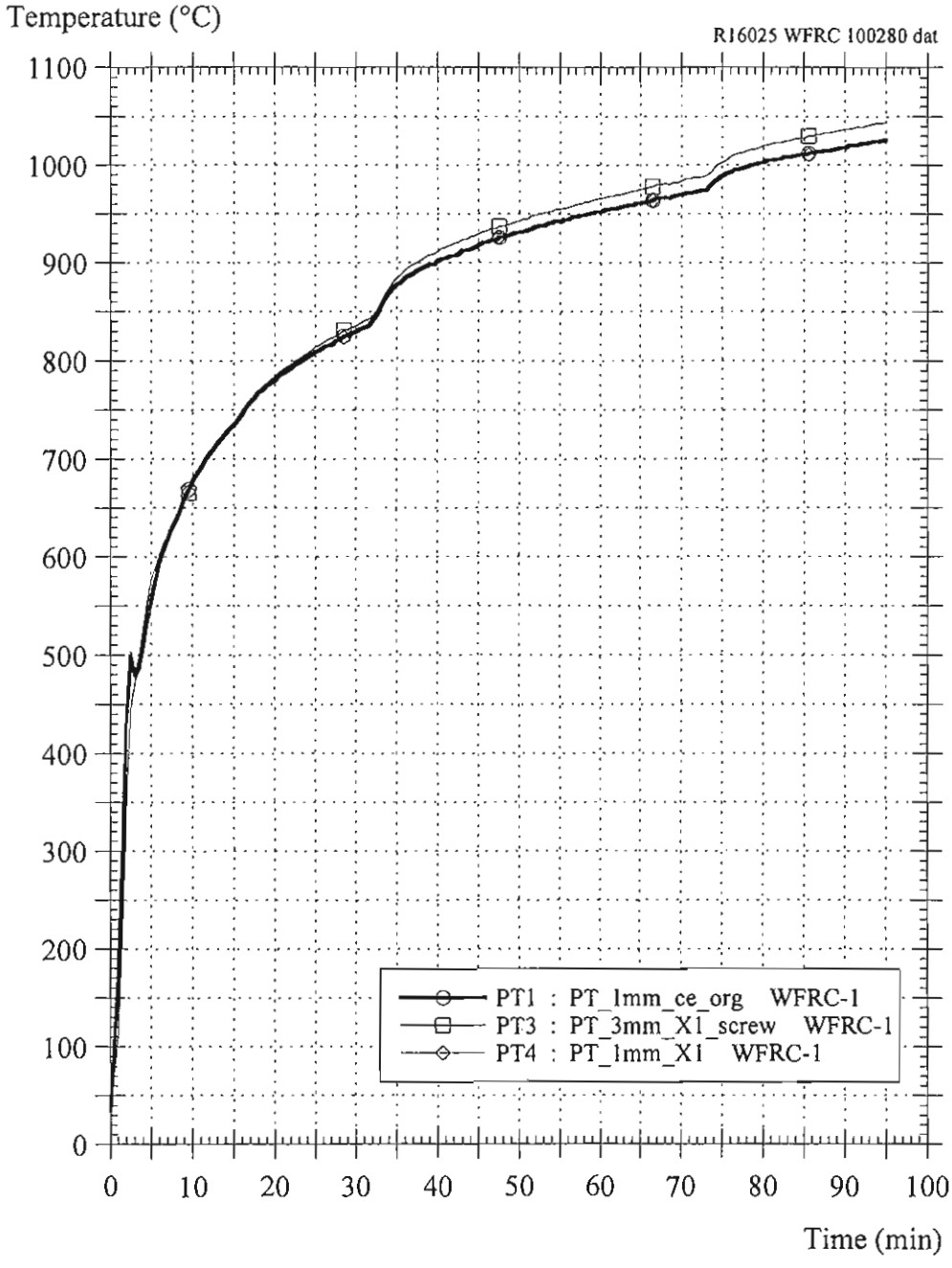


Figure W5.

PT's with 1 mm and 3 mm thermocouples in front of the insulating wall (calcium silicate board).

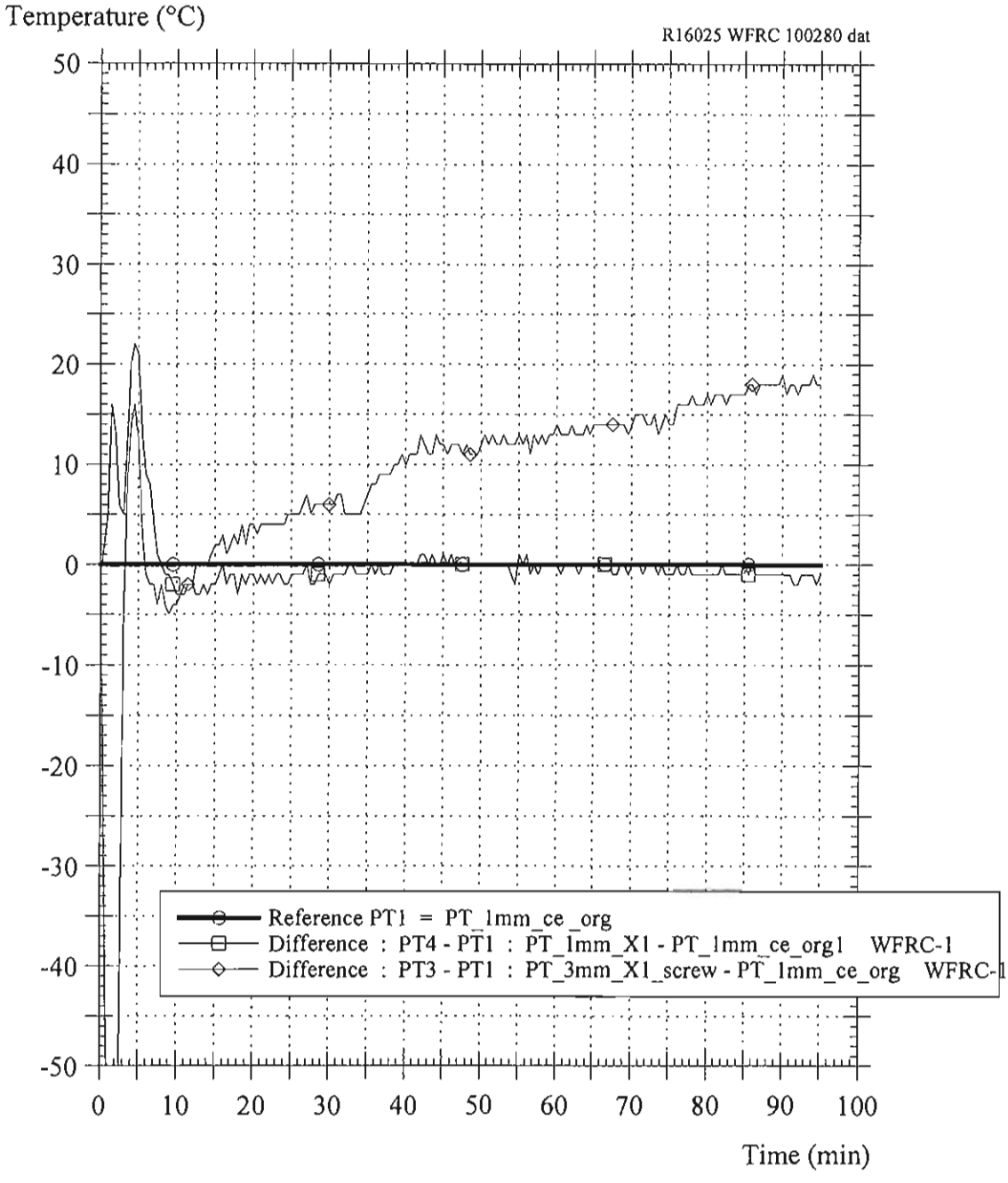


Figure W5a.

Difference between the original PT and PT's with 1 mm and 3 mm thermocouples in front of the insulating wall (calcium silicate board)

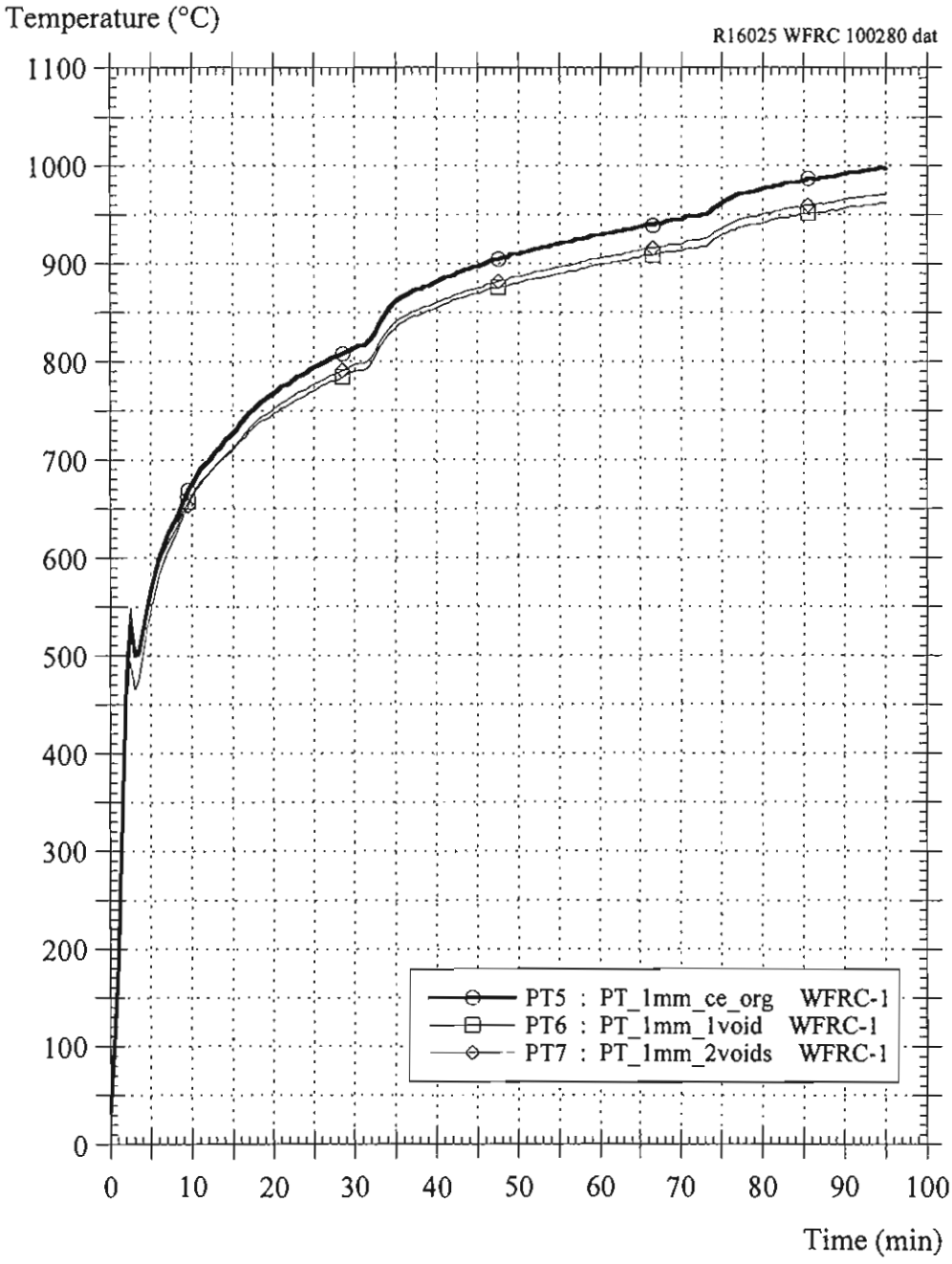


Figure W6.

PT's with one and two voids in front of the glazing.

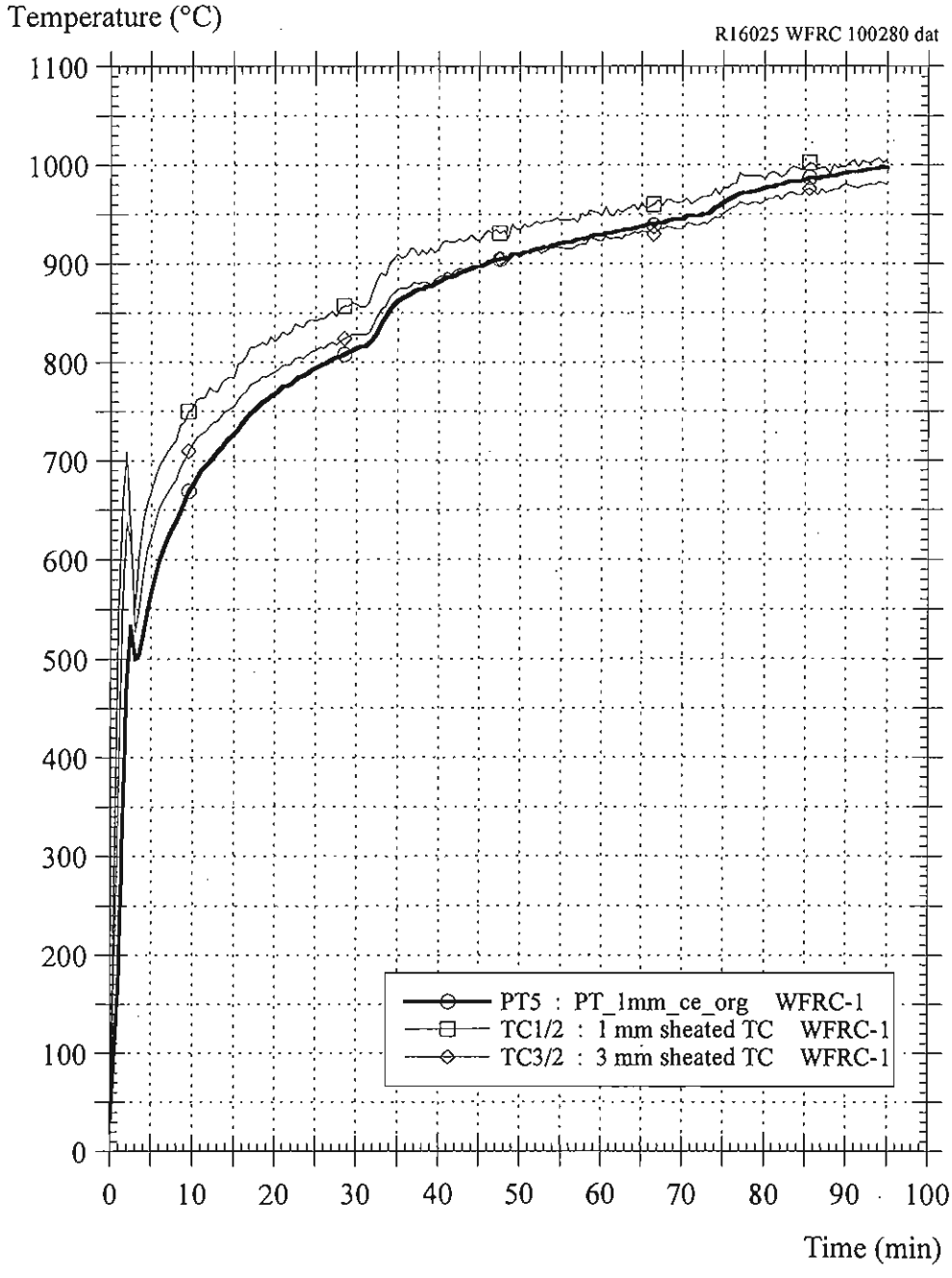


Figure W7.

TC's with 1 mm and 3 mm diameter in front of the glazing.

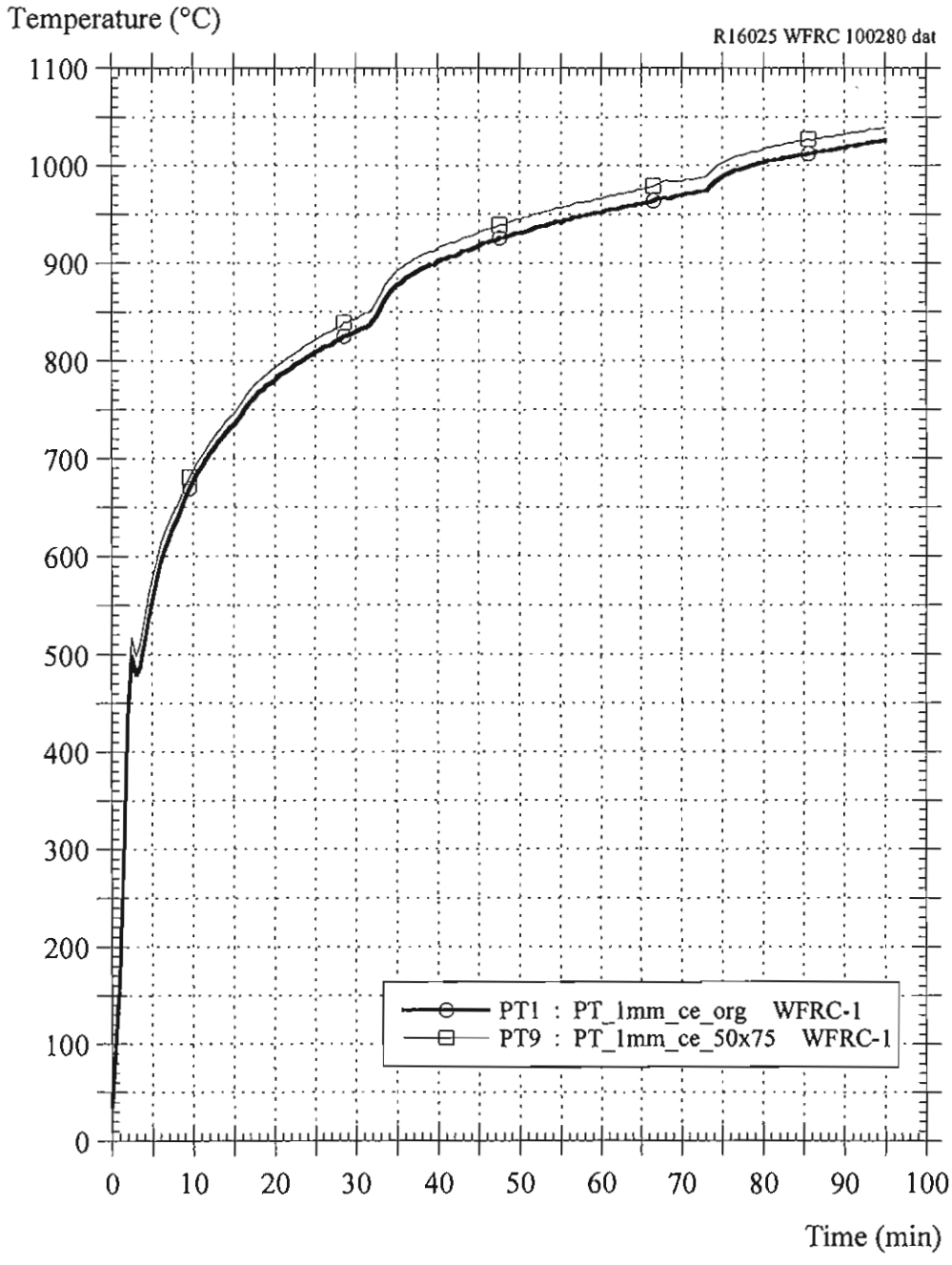


Figure W8.

PT's of different size, 100 x 100 mm vs. 50 x 75 mm.

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