Structural Applications of Ferritic Stainless Steels (SAFFS)
WP4: Structural Fire Resistance
Task 4.3 Model calibration tests (members in fire)

Beam fire tests report

Requested by: Commission of the European Communities
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Beneficiary: Technical Research Centre of Finland, VTT

Confidentiality: Confidental until May 2014

VTT EXPERT SERVICES LTD

Requested by	Commission of the European Communities Grant agreement No. RFSR-CT-2010-00026
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Fire resistance tests of ferritic stainless steel beams

Task

The task is related to research project Structural Applications of Ferritic Stainless Steels (SAFFS), Task 4.3 Model calibration tests. Two fire resistance tests were performed on ferritic stainless steel beams with RHS 40 x 80 x 2 sections.

Test specimens

Test specimens were two ferritic stainless steel beams with RHS 40 x 80 x 2 sections, section factor F/V = 430 1/m, and Grade 1.4509. The length of the beams was 1000 mm and the span 900 mm. One of the beams was uncoated and the other painted with primer Epigrip L425 and intumecent paint Firetex FX13881 manufactured by Leighs Paints. Measured mean thickness of the primer was 97.5 μm and measured mean thickness of intumecent paint 1816 μm / 1538 μm.

Information of construction and preparation of test specimens: Appendix 7

Manufacturer of the specimens: Material - Outokumpu Stainless Oy, Finland
RHS-sections - Stalatube Oy, Finland
Primer and intumecent paint - Leighs Paints, UK

Date of test specimen delivery to VTT Expert Services Ltd:
Uncoated RHS-sections 2 December 2011
Coated beam after painting 28 February 2012

Date of the mounting of the test specimen: Specimen 1 9-11 May 2012
Specimen 2 30 April - 3 May 2012

Date of the test

Test specimen 1: 11 May 2012

Test specimen 2: 3.May 2012

Test method

Applying test standard *EN 1365-3:1999 "Fire resistance tests for loadbearing elements – Part 3: Beams"*

Deviations from the test method

Size (Item 6.1 of the standard EN 1365-3:1999)

"For simply supported beams, when full size is larger than the size which can be accommodated in the furnace, then the exposed length [L exp] shall be not less than 4 m."

The effect of the deviation on the test results is significant.

Witnesses

The test was witnessed by Mr Asko Talja and Mr Petr Hradil from VTT.

Test

An identical uncoated beam as test specimen 1 has been tested before at room temperature in relation of the same research project: WP2 Structural performance of steel member, task 2.3: Model calibration tests. Therefore the fire resistance tests were performed applying the same restrained and loading conditions as used in that test.

The fire resistance tests of specimen 1 and 2 were identically carried out in the combi furnace of the testing laboratory. The test specimens were simply supported and they were free to deflect.

During the test the specimen was loaded with total load of 9.96 kN (load level 0.25) which was distributed to two point loads applied with a hydraulic jack. The load was determined on the basis of calculation (see Appendix 1).

Determination of test load Appendix 1

Test arrangements, location of measuring points for temperatures of the furnace and the test specimen, for pressure and deflection: Appendix 2

Test conditions in the furnace (furnace temperature and pressure difference between furnace and test hall): Appendices 3a and 3b

The ambient temperature in the test hall was 20 °C in the beginning of the fire resistance tests.

Specimen 1: The test was terminated 24 minutes 40 seconds after the start of the test at the client's request.

Specimen 2: The test was terminated 57 minutes 50 seconds after the start of the test at the client's request.

Test results

Test results with respect to the performance criteria imposed by the standard *EN 13501-2:2007+A1:2009* complemented with *EN 1365-2:1999* and *EN 1363-1:1999* are presented in the following table:

Table 1. Test results with respect to the criteria.

Property	Test result
Loadbearing capacity R	
Test specimen 1	
Deflection *(criterion: ≤ L^2/400d mm = 25 mm when d=80 mm)*	Not exceeded; - maximum deflection was 23 mm at test time 24 min 40 s
Rate of deflection *(criterion: ≤ L^2/9000d mm/min = 1.1 mm/min when d=80 mm and the value L/30 = 30 mm has been exceeded)*	Not exceeded; - rate of axial deflection 1.1 mm/min achieved at test time 22 min 35 s - maximum rate of axial deflection was 14.4 mm/min at test time 24 min 40 s
Test specimen 2	
Deflection *(criterion: ≤ L^2/400d mm = 25 mm when d=80 mm)*	Exceeded; - deflection was 25 mm at test time 57 min 45 s - maximum deflection was 26.9 mm at test time 57 min 50 s
Rate of deflection *(criterion: ≤ L^2/9000d mm/min = 1.1 mm/min when d=80 mm and the value L/30 = 30 mm has been exceeded)*	Not exceeded; - rate of axial deflection 1.1 mm/min achieved at test time 56 min - maximum rate of axial deflection was 8.9 mm/min at test time 57 min 50 s

The measured temperatures, deflections, observations and photographs are presented in the following appendices:

Temperatures of the test specimen	Appendix 4
Observations and deflections during the fire resistance test	Appendix 5
Photographs of the test specimen	Appendix 6

Summary

Test specimens were two ferritic stainless steel beams with RHS 40 x 80 x 2 sections (section factor F/V = 430 1/m, and Grade 1.4509) the length of which was 1000 mm and the span 900 mm. One of the beams was uncoated and the other painted with primer Epigrip L425 (thickness 97.5 µm) and intumecent paint Firetex FX13881 (thickness 1816 µm / 1538 µm). The tested beams loaded with total load of 9,96 kN distributed to two point loads met in the fire resistance test the performance criteria imposed by the standards *EN 13501-2:2007+A1:2009* complemented with *EN 1365-3:1999* and *EN 1363-1:1999* as follows:

Test specimen 1 (uncoated beam)

Loadbearing capacity R

-Deflection	24 minutes*
-Rate of deflection	24 minutes*

Test specimen 2 (fire protected beam)

Loadbearing capacity R

-Deflection	57 minutes**
-Rate of deflection	57 minutes**

***** = The test was terminated 24 min 40 s after the start of the test at the client's request.

****** = The test was terminated 57 min 50 s after the start of the test at the client's request.

This report details method of construction, test conditions and results obtained when specific element of construction described herein was tested following the procedure outlined in *EN 1365-3:1999*, and where appropriate *EN 1363-1:1999*. Any significant deviation with respect to size, constructional details, loads, stresses and edge or end conditions other than those allowed under the field of direct application in the relevant test method is not covered by this test report.

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

Field of direct application of test results

Field of direct application of the test results is presented in Appendix 8 of this test report.

Espoo, 5 July 2012

Kai Renholm
Team Leader

Tuuli Oksanen
Leading Expert

APPENDICES

Appendix 1	Determination of test load
Appendix 2	Test arrangement and measuring points
Appendix 3a and 3b	Test conditions
Appendix 4	Temperatures of the test specimen
Appendix 5	Observations during the fire resistance test
Appendix 6	Photographs of the test specimen
Appendix 7	Information of construction and materials
Appendix 8	Field of direct application of test results
Appendix 9	Comparison of calculated and measured temperatures and loads

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Determination of test load

General

The target fire resistance time within original research plan was 30 min for the uncoated beam and at least 60 min for the fire protected beam. Test load was determined performing thermal and mechanical analysis of the uncoated and coated beam at fire resistance times of 15 min, 30 min and 60 min.

Thermal analysis of the ferritic stainless steel section was performed by using two dimensional heat transfer model of FEM-program COMSOL Multiphysics /1/ in order to calculate temperature field of the section. After that failure load of the section was determined using temperature dependent mechanical material properties.

Specimen 1 (uncoated section)

Thermal analysis

Thermal analysis of section RHS 40 x 80 x 2 was performed by FEM-program COMSOL Multiphysics /1/ using thermal properties of stainless steel according to EN 1993-1-2:2005 Annex C (specific heat c [J/kgK] and thermal conductivity k [W/mK]) /2/. Thermal conductivity and specific heat were temperature dependent. Density ρ =7850 kg/m^3 and emissivity ε = 0.4 were also according to EN 1993-1-2: 2005.

The bottom surface and both vertical edges of the section were exposed to fire according to EN 1363-1:1999 /3/ and the top surface of the section was defined as thermal insulated. Heat transfer coefficient for convection was supposed to be 25 W/m^{2}K for the exposed surface as defined in the standard EN 1991-1-2:2002 /4/.

Geometry and temperature field of the uncoated beam is presented in Figure 1 at the time of 15 min. Temperature increase of the different edges of the beam in function of time is presented in Figure 2 until 30 min.

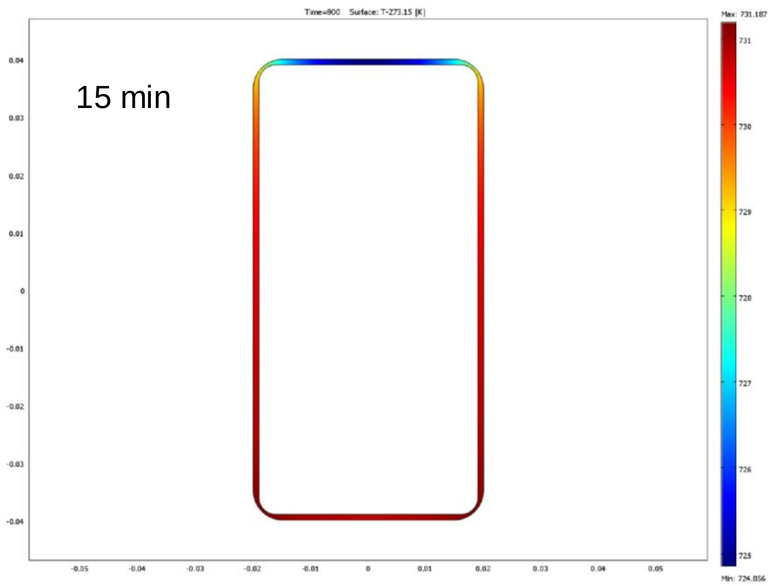


Figure 1. Geometry and temperature field of the uncoated beam.

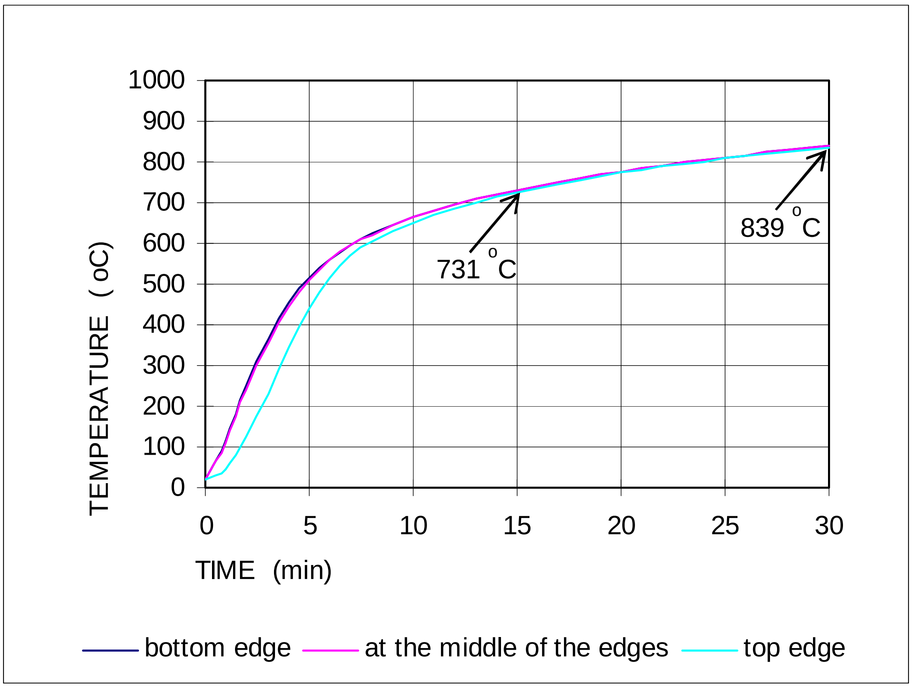


Figure 2. Temperature increase of the different edges of the beam.

Mechanical analysis

Strength reduction of stainless steel at elevated temperatures based on steady-state tests (material tests performed by Outokumpu) is presented in Figure 3. Reduction factors for proof strength $k_{p0.2,\theta} = f_{p0.2,\theta} / f_y$ are calculated into Table 1.

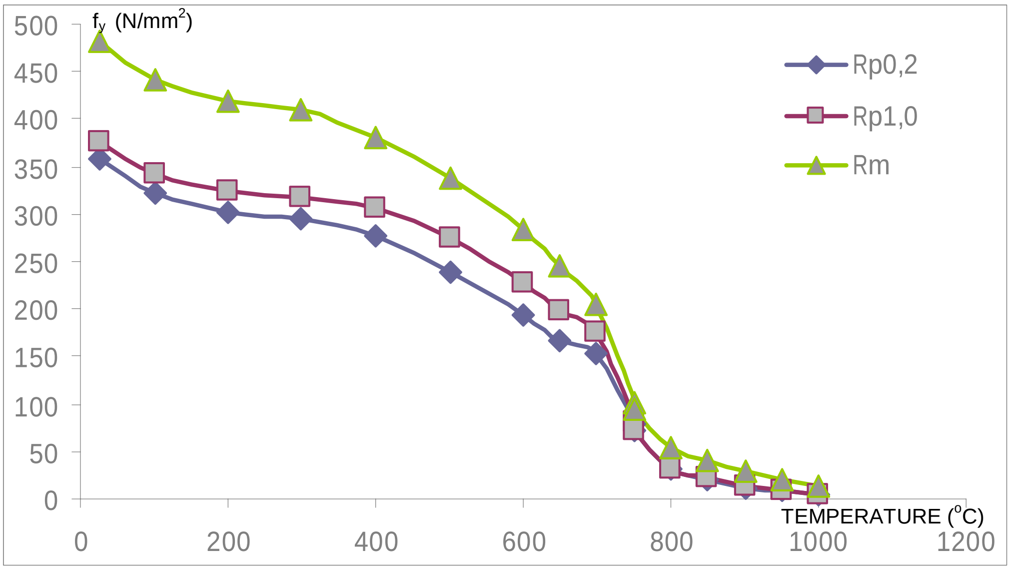


Figure 3. Strength reduction of stainless steel at elevated temperatures.

Table 1. Reduction factors $k_{p0.2,\theta}$.

Temperature (ºC)	Reduction factor $k_{p0.2,\theta}$
25	1
100	0.898
200	0.840
300	0.824
400	0.770
500	0.667
600	0.540
650	0.464
700	0.425
750	0.213
800	0.085
850	0.059
900	0.033
950	0.022
1000	0.014

Test load F [kN] distributed to two point loads are calculated on the basis of maximum bending moment M as follows:

$M = F/2*a$
$F/2 = M/a = W\ f_{y,\theta}\ /\ a$ where
$W = 9340\ mm^3$ section modulus
$f_{y,\theta} = k_{p0.2,\theta} * R_{p0.2}$ = yield stress at the temperature of θ
$k_{p0.2,\theta}$ = reduction factor for stress-strain relationship of stainless steel at elevated temperatures
$R_{p0.2}$ = yield stress = 535 N/mm^2 (stainless steel Grade 1.4509)
a = 300 mm distance from the support

Load F for 15 min when steel temperature is 731 ^oC and then $k_{p0.2,\theta=731oC}$ = 0.299 (interpolated on the basis of Table 1)

⇨ $F = 2*9340\ mm^3 * 0.299*535\ N/mm^2\ /300\ mm$ = **9.96 kN**

⇨ Load level = test load / failure load at room temperature = 0.25

failure load at room temperature = 39.74 kN

Load F = 2.16 kN for 30 min when steel temperature is 839 ^oC.

Test load of 9.96 kN was decided to use for specimen 1.

Specimen 2 (coated section)

Section factor F/V of the beam is high 430 1/m (usually max 350 1/m). The specimen was painted with intumecent paint Firetex FX13381 which has been tested according to standard EN13381-8:2010 /5/. Test results of coated beams and columns for I-section as well as coated columns for rectangular and circular hollow section are presented in test report WF No. 307504 /6/. However rectangular hollow beams were not tested. Assessment covers temperatures ranging from 350 °C to 750 °C for time periods up to 120 minutes when max F/V=350 1/m.

As no information existed of fire protection ability of intumecent paint Firetex FX13381 for rectangular hollow beams it was impossible to perform thermal and mechanical analysis of these beams. However total loads calculated using different critical temperatures of steel section are presented in table 2.

The same **test load F = 9.96 kN** as used for specimen 1 was used also for fire resistance test of specimen 2 because of comparable test results.

Summary

Summary of the calculated loads of uncoated and fire protected rectangular hollow beams are presented in Table 2.

Table 2. Summary of the calculated loads of uncoated and fire protected rectangular hollow beams.

	Uncoated section		**Fire protected section (calculated loads at different temperatures)**		
Time	15 min	30 min			
Critical temperature	**731 °C**	839 °C	500 °C	600 °C	750 °C
Total load F	**9.96 kN***	2.16 kN	22.20 kN	17.98 kN	7.08 kN
Load level	**0.25**	0.05	0.56	0.45	0.18
*Test load for both specimens					

Background

/1/ COMSOL Multiphysics 3.5a User's Guide. COMSOL AB 2009.

/2/ Standard EN 1993-1-2: 2005 Eurocode 3: Design of steel structures - Part 1.2: General rules. Structural fire design. CEN European Committee for Standardisation, Brussels, Belgium, 2002.

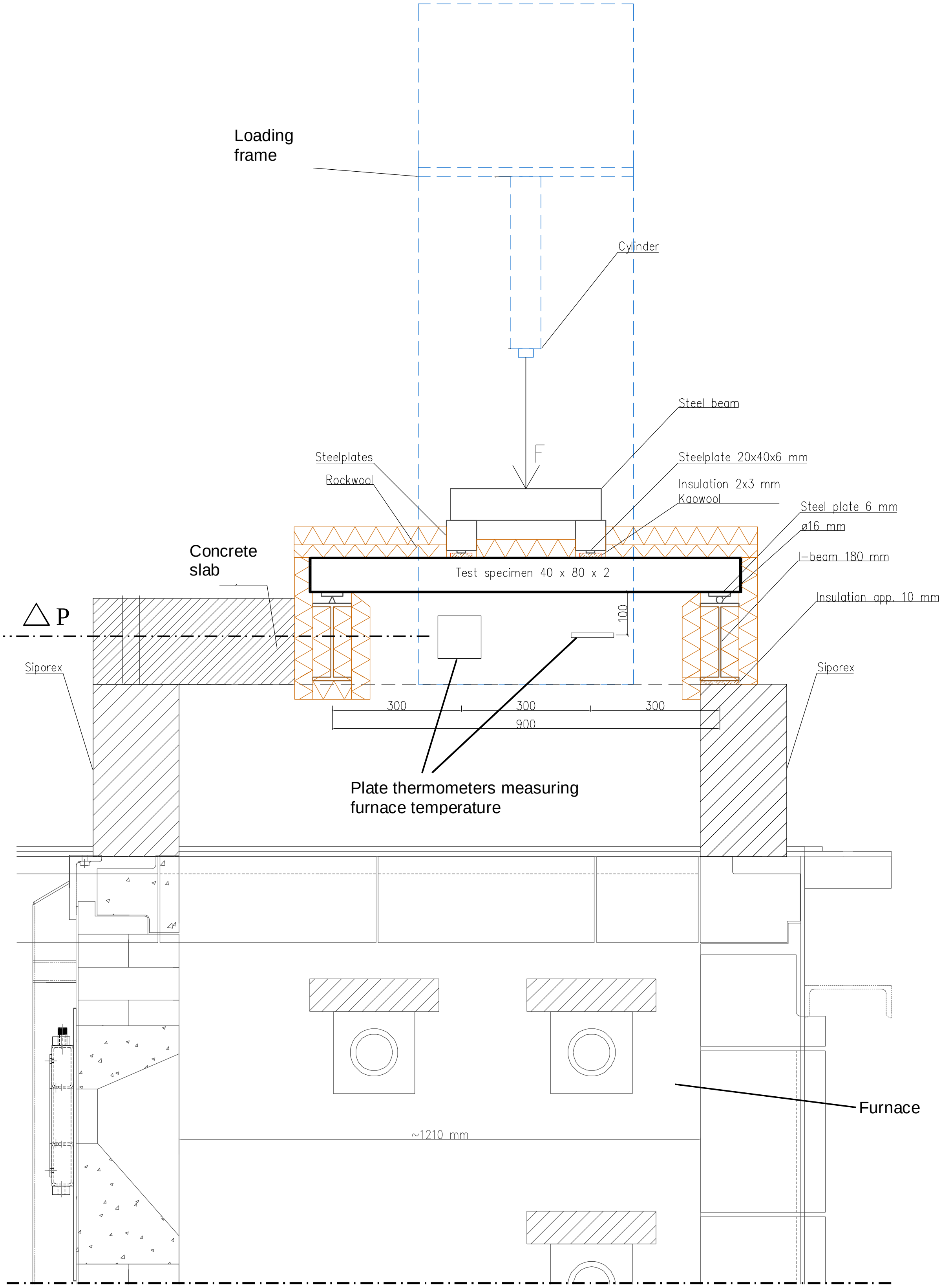
/3/ Standard EN 1363-1:1999 Fire resistance tests – Part 1: General requirements. CEN European Committee for Standardisation, Brussels, Belgium, 1999.

/4/ Standard EN 1991-1-2: 2002 Eurocode 1: Actions on structures - Part 1.2: General actions – Actions on structures exposed to fire. CEN European Committee for Standardisation, Brussels, Belgium, 2002.

/5/ Standard EN 13381-8:2010 Test methods for determining the contribution to the fire resistance of structural members - Part 8: Applied protection to steel members – reactive coatings. CEN European Committee for Standardisation, Brussels, Belgium, 2010.

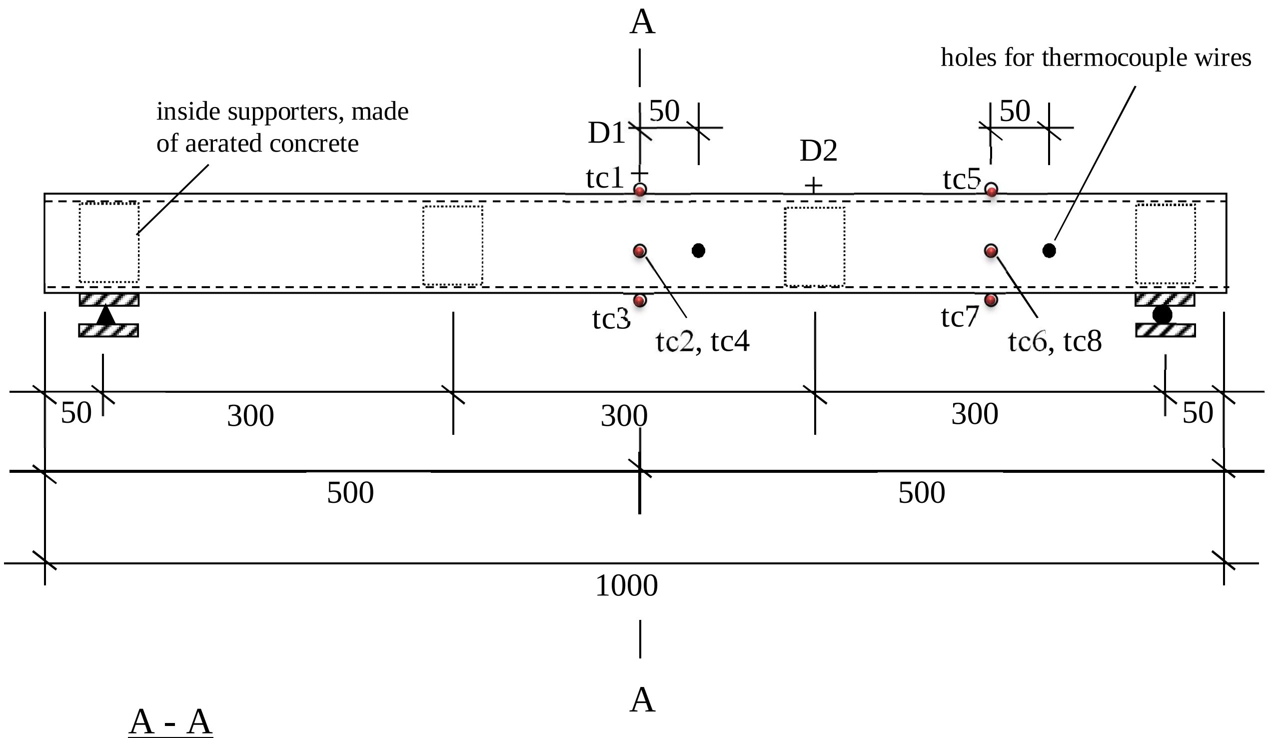
/6/ Test report WF No. 307504 by Exova Warringtonfire, dated 20 May 2011.

Test arrangement and measuring points

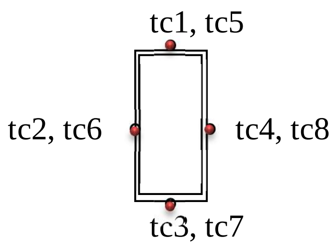


△P = pressure difference between the furnace and the test hall

Figure 1. Test specimen installed in the furnace.



A - A



Measuring points:

•	tc1 – tc8	temperature on the surface of the steel beam
+	D1 – D2	deflection of the test specimen

Figure 2. Temperature and deflection measuring points.

The test results relate only to the sample tested.

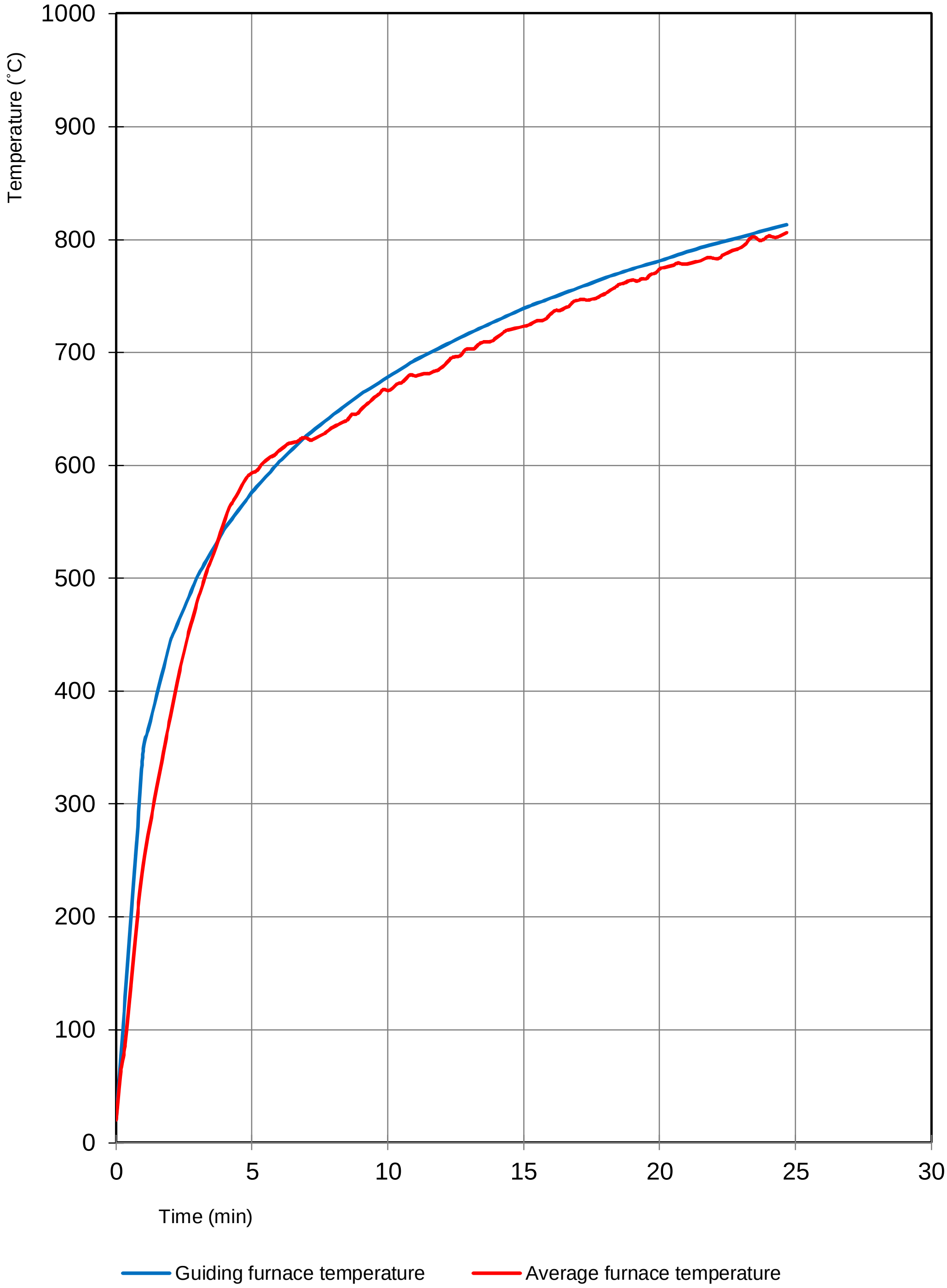


Figure 1. Furnace temperature, test 1 (11 May 2012).

Table 1. Furnace temperature, test 1 (11 May 2012).

Time	AVG Furnace temp. [˚C]	Guiding furnace temp [˚C]	Min [˚C]	Max [˚C]	A [˚C min]	As [˚C min]	d [%]	Max d [%]
0	20	20	20	20	0	0	0	15
1	246	349	228	265	797	1107	-27.9	15
2	377	445	357	397	2685	3489	-23	15
3	481	502	459	504	5283	6329	-16.5	15
4	552	544	535	570	8383	9467	-11.5	15
5	593	576	578	609	11839	12827	-7.7	15
6	613	603	595	631	15458	16364	-5.5	15
7	624	626	610	639	19177	20051	-4.4	15
8	634	645	619	649	22939	23864	-3.9	15
9	649	663	636	663	26786	27788	-3.6	15
10	666	678	652	680	30743	31811	-3.4	15
11	679	693	664	694	34786	35925	-3.2	14.5
12	687	705	673	702	38879	40119	-3.1	14
13	703	717	690	716	43057	44385	-3	13.5
14	713	728	699	728	47305	48720	-2.9	13
15	723	739	710	737	51623	53121	-2.8	12.5
16	734	748	719	749	55990	57582	-2.8	12
17	746	757	732	761	60430	62097	-2.7	11.5
18	752	766	737	767	64918	66666	-2.6	11
19	764	774	751	777	69474	71286	-2.5	10.5
20	774	781	760	789	74077	75951	-2.5	10
21	778	789	767	790	78739	80661	-2.4	9.5
22	783	796	771	796	83429	85416	-2.3	9
23	793	802	781	806	88157	90210	-2.3	8.5
24	803	809	790	816	92955	95043	-2.2	8

Where
A is area under the actual average furnace time-temperature curve
As is the area under the standard (guiding) time-temperature curve
d is deviation
Max d is highest acceptable deviation

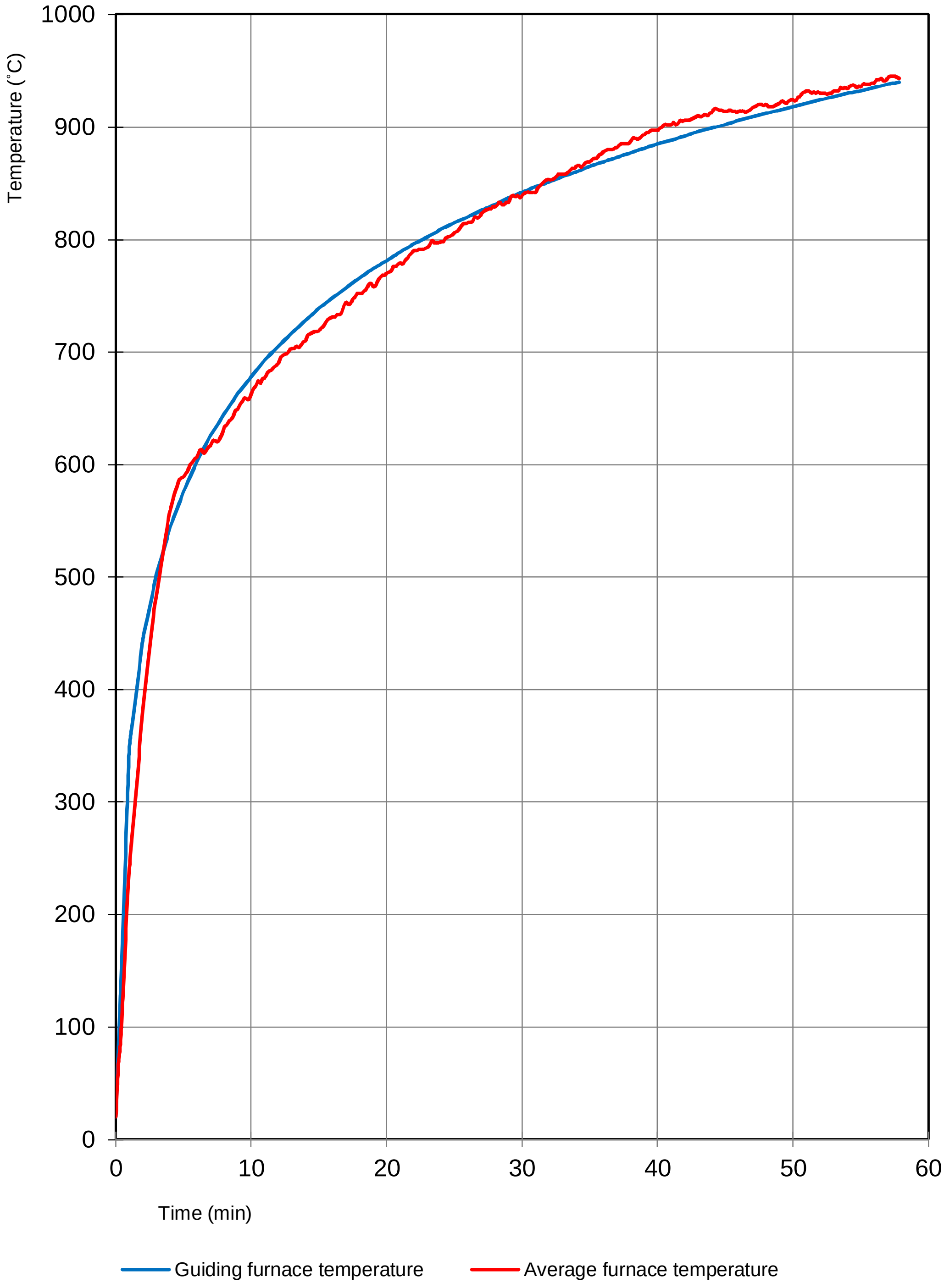


Figure 2. Furnace temperature, test 2 (3 May 2012).

Table 2. Furnace temperature, test 2 (3 May 2012).

Time	AVG Furnace temp. [˚C]	Guiding furnace temp [˚C]	Min [˚C]	Max [˚C]	A [˚C min]	As [˚C min]	d [%]	Max d [%]
0	20	20	20	20	0	0	0	15
1	241	349	221	261	777	1107	-29.8	15
2	382	445	363	401	2648	3489	-24.1	15
3	483	502	466	500	5267	6329	-16.8	15
4	558	544	541	575	8402	9467	-11.3	15
5	589	576	579	600	11870	12827	-7.5	15
6	607	603	594	621	15464	16364	-5.5	15
7	617	626	606	629	19140	20051	-4.5	15
8	633	645	621	645	22879	23864	-4.1	15
9	649	663	639	659	26724	27788	-3.8	15
10	663	678	652	674	30665	31811	-3.6	15
11	677	693	664	691	34696	35925	-3.4	14.5
12	690	705	679	702	38803	40119	-3.3	14
13	703	717	691	715	42991	44385	-3.1	13.5
14	710	728	698	723	47226	48720	-3.1	13
15	719	739	706	733	51527	53121	-3	12.5
16	731	748	720	742	55883	57582	-3	12
17	744	757	730	758	60295	62097	-2.9	11.5
18	752	766	740	765	64776	66666	-2.8	11
19	758	774	747	770	69316	71286	-2.8	10.5
20	770	781	758	782	73907	75951	-2.7	10
21	779	789	767	792	78555	80661	-2.6	9.5
22	790	796	776	804	83258	85416	-2.5	9
23	793	802	780	807	88006	90210	-2.4	8.5
24	798	809	785	812	92788	95043	-2.4	8
25	806	815	793	820	97600	99915	-2.3	7.5
26	815	820	802	828	102469	104820	-2.2	7
27	823	826	812	835	107380	109758	-2.2	6.5
28	829	831	818	840	112342	114729	-2.1	6
29	833	837	821	846	117334	119733	-2	5.5
30	839	842	829	850	122363	124770	-1.9	5
31	842	847	833	852	127415	129837	-1.9	4.9
32	853	851	844	863	132513	134931	-1.8	4.8
33	858	856	847	869	137648	140052	-1.7	4.8
34	865	860	853	878	142815	145200	-1.6	4.7
35	869	865	859	879	148017	150375	-1.6	4.6
36	878	869	869	888	153257	155577	-1.5	4.5
37	882	873	872	892	158539	160803	-1.4	4.4
38	887	877	879	896	163849	166053	-1.3	4.3

Time	AVG Furnace temp. [˚C]	Guiding furnace temp [˚C]	Min [˚C]	Max [˚C]	A [˚C min]	As [˚C min]	d [%]	Max d [%]
39	893	881	885	902	169191	171327	-1.2	4.3
40	897	885	890	904	174569	176625	-1.2	4.2
41	902	888	893	911	179975	181944	-1.1	4.1
42	906	892	897	916	185401	187284	-1	4
43	910	896	900	920	190848	192648	-0.9	3.9
44	913	899	905	922	196312	198033	-0.9	3.8
45	914	902	905	923	201803	203436	-0.8	3.8
46	914	906	906	923	207289	208860	-0.8	3.7
47	917	909	909	926	212776	214305	-0.7	3.6
48	920	912	913	927	218293	219768	-0.7	3.5
49	921	915	913	930	223808	225249	-0.6	3.4
50	924	918	916	932	229346	230748	-0.6	3.3
51	932	921	923	942	234912	236265	-0.6	3.3
52	930	924	923	937	240499	241800	-0.5	3.2
53	932	927	924	941	246081	247353	-0.5	3.1
54	934	930	927	941	251684	252924	-0.5	3
55	936	932	928	945	257302	258510	-0.5	2.9
56	939	935	932	946	262932	264111	-0.4	2.8
57	944	938	937	951	268585	269730	-0.4	2.8

Where
A is area under the actual average furnace time-temperature curve
As is the area under the standard (guiding) time-temperature curve
d is deviation
Max d is highest acceptable deviation

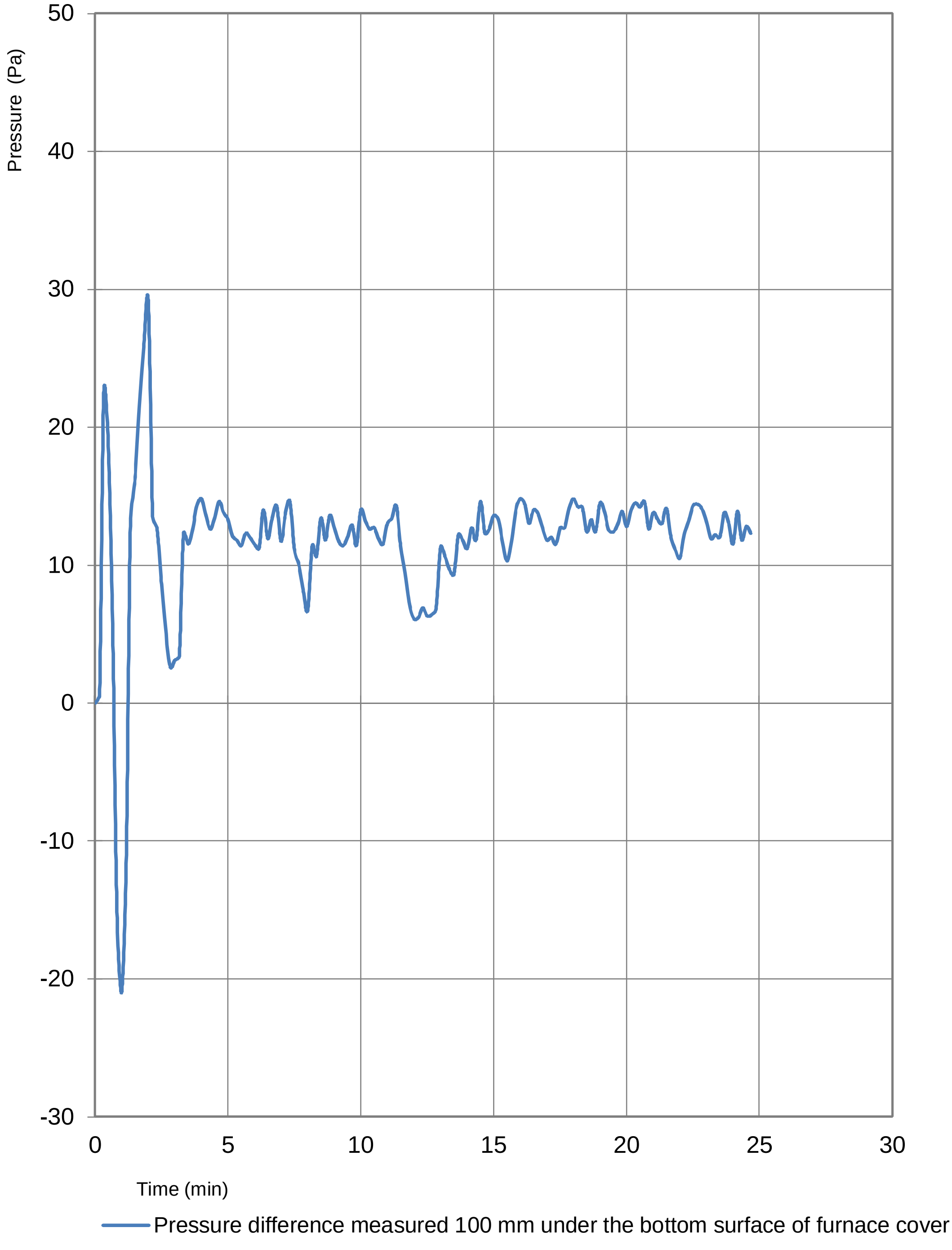


Figure 1. Pressure difference, test 1 (11 May 2012).

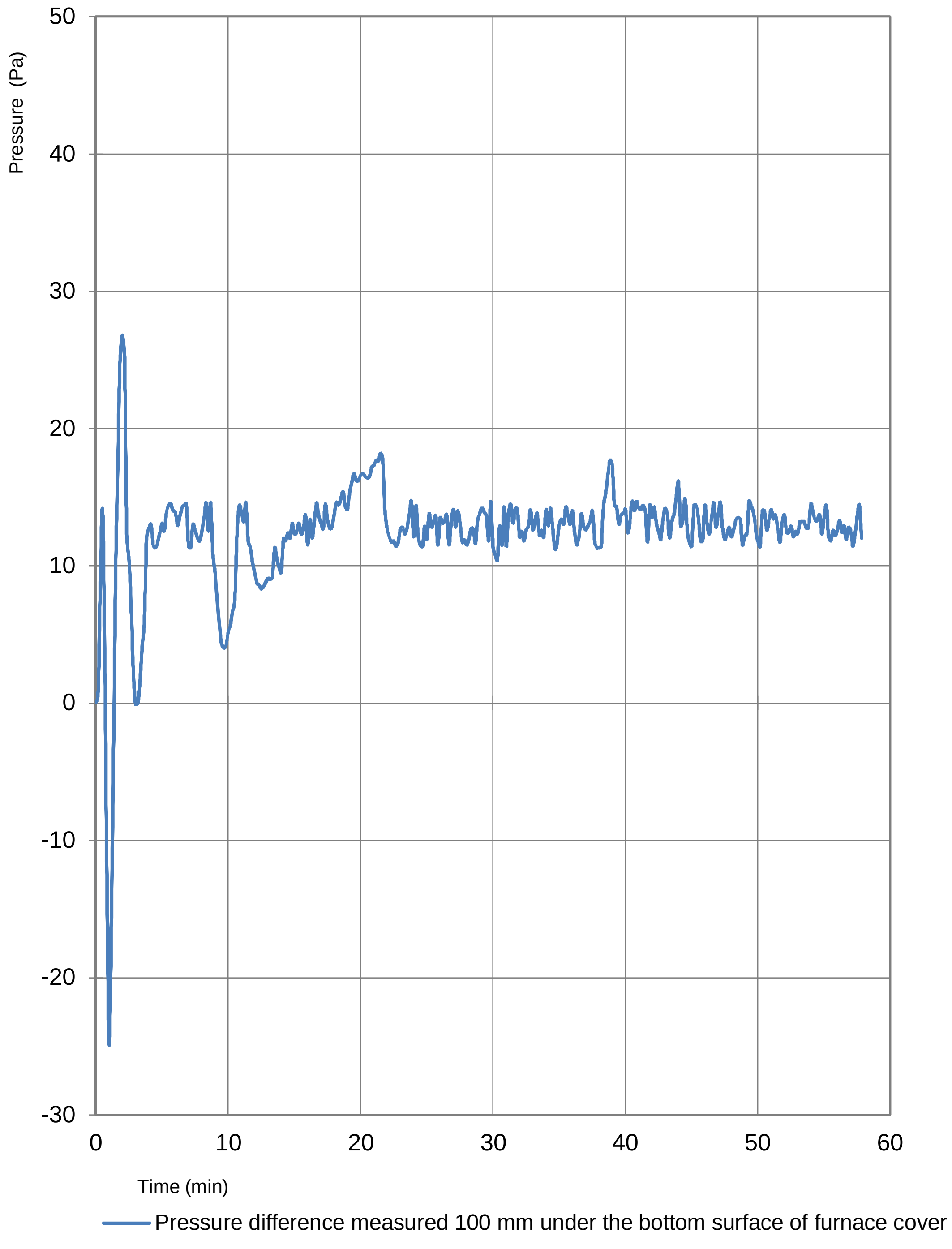


Figure 2. Pressure difference, test 2 (3 May 2012).

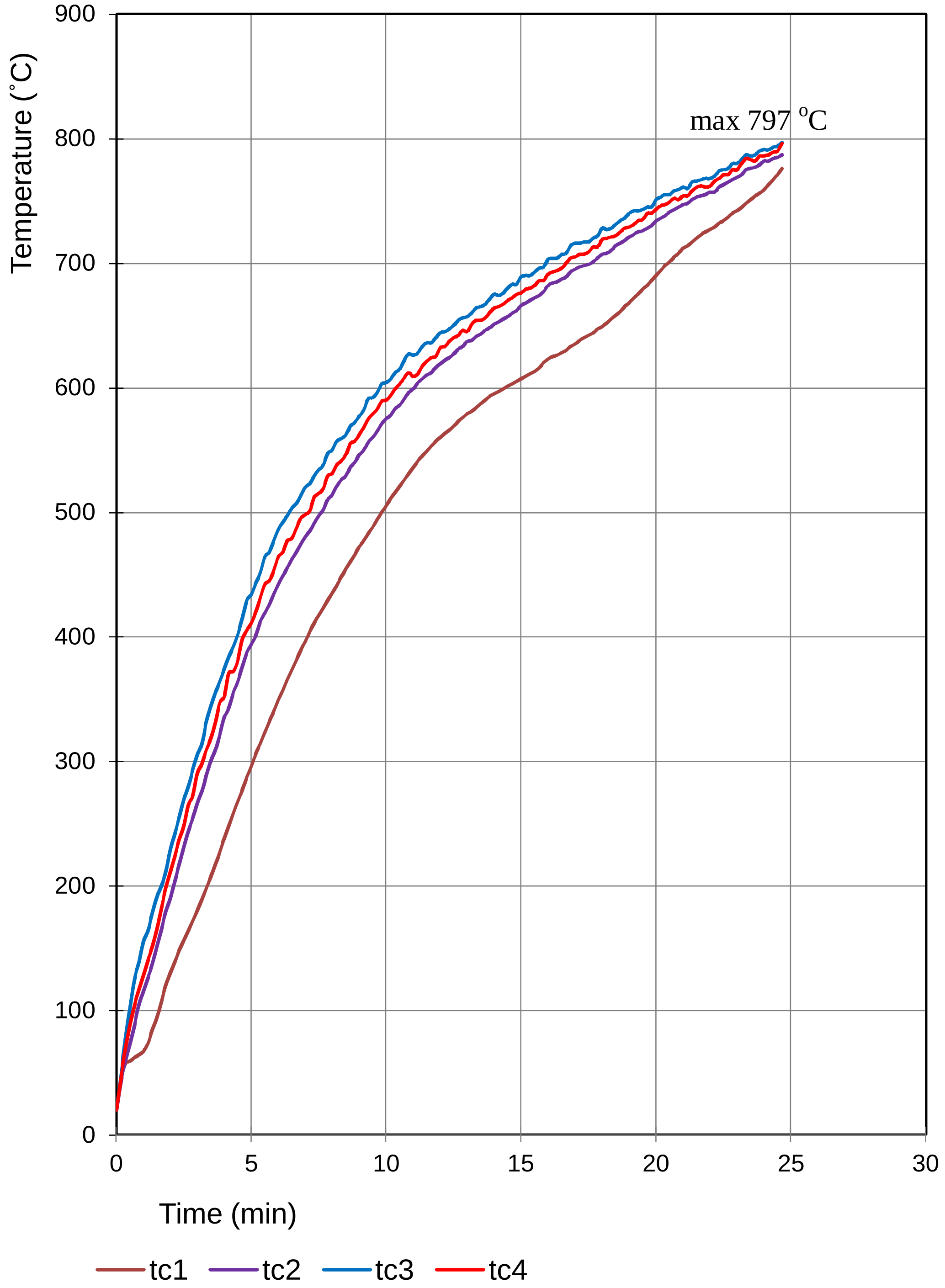


Figure 1. Measured individual specimen temperatures, test 1 (11 May 2012).

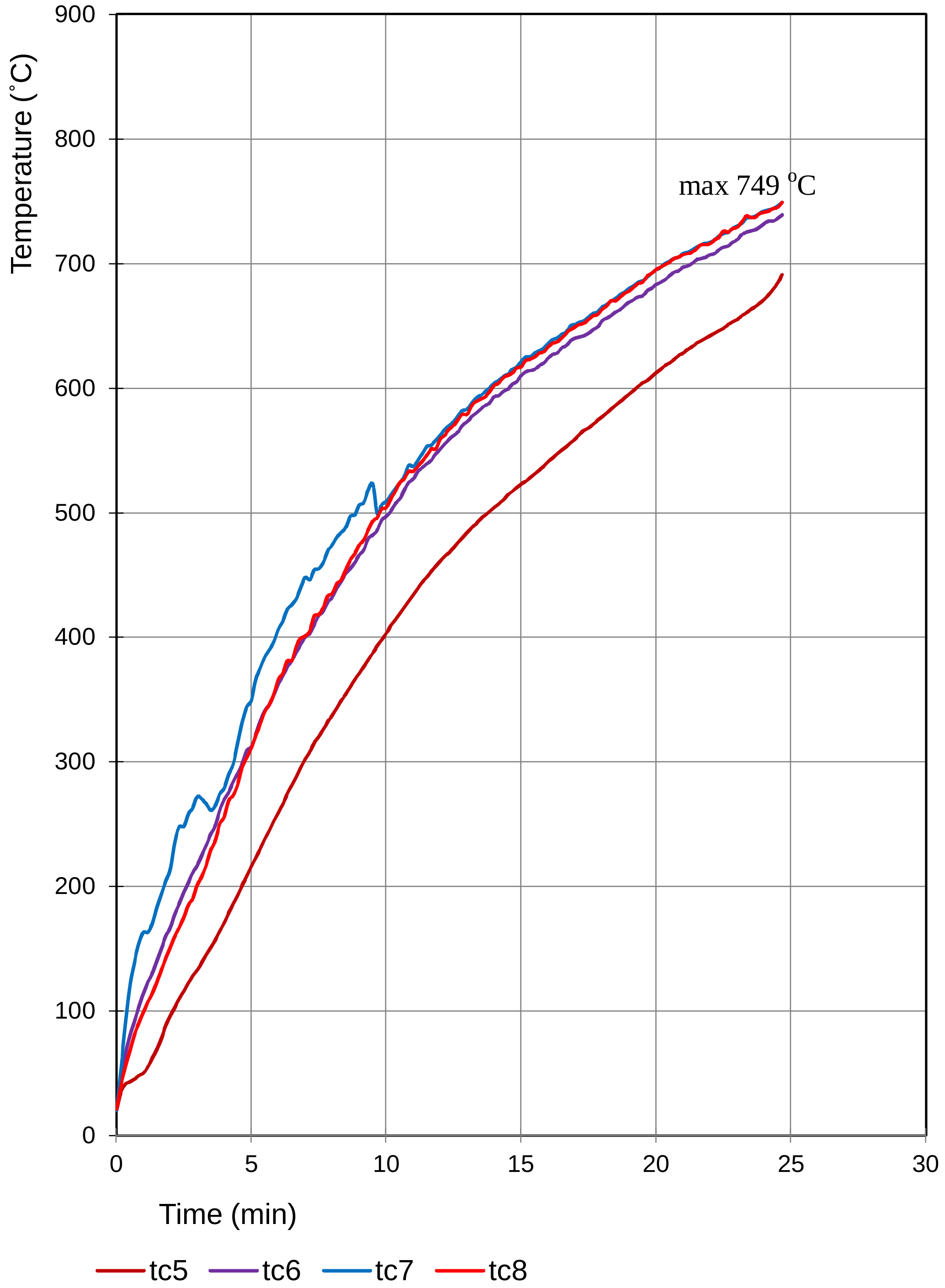


Figure 2. Measured individual specimen temperatures, test 1 (11 May 2012).

Table 1. Measured temperatures of the specimen test 1 (11 May 2012).

Time	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
0	20	20	20	20	20	20	20	21
1	67	115	155	128	50	114	163	99
2	130	190	229	211	96	167	214	151
3	180	266	305	290	133	217	272	201
4	238	335	374	352	171	270	279	256
5	296	394	434	411	216	312	349	311
6	349	442	486	464	259	362	406	366
7	396	480	520	498	302	400	448	401
8	435	514	550	531	337	432	474	435
9	472	546	577	562	371	466	506	474
10	505	575	604	590	403	497	509	504
11	536	599	626	609	434	527	537	533
12	560	619	644	632	461	551	562	559
13	579	637	657	645	484	573	583	579
14	595	651	675	664	504	593	604	602
15	607	666	689	676	523	610	621	617
16	623	682	703	691	541	624	636	633
17	635	695	716	705	559	640	651	649
18	649	707	728	719	577	654	665	663
19	668	721	740	729	595	669	680	678
20	690	734	751	743	612	683	695	695
21	712	747	761	754	628	697	708	707
22	727	757	768	762	642	707	717	716
23	742	769	780	775	655	719	730	729
24	759	782	791	786	671	732	742	741

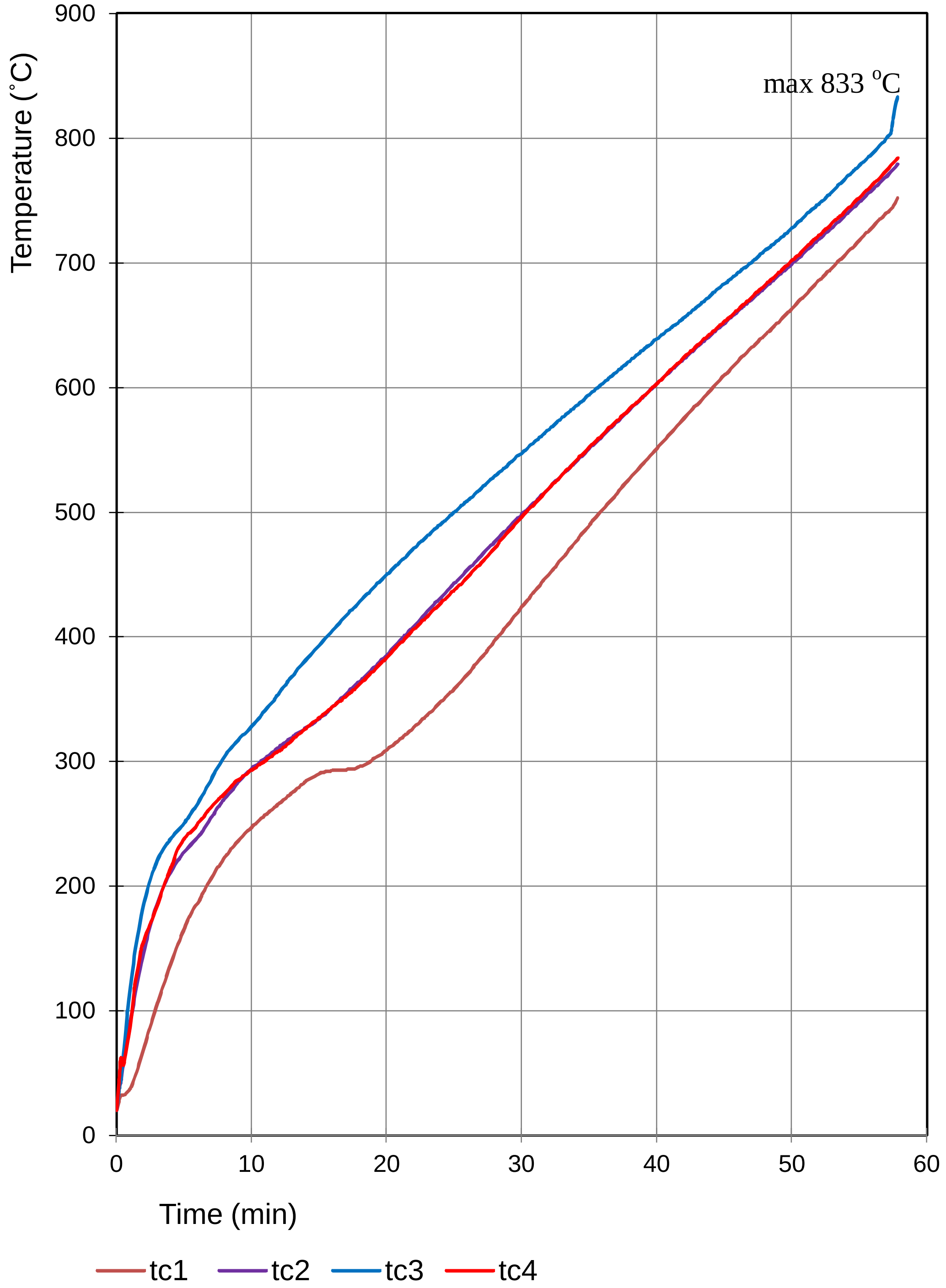


Figure 3. Measured individual specimen temperatures, test 2 (3 May 2012).

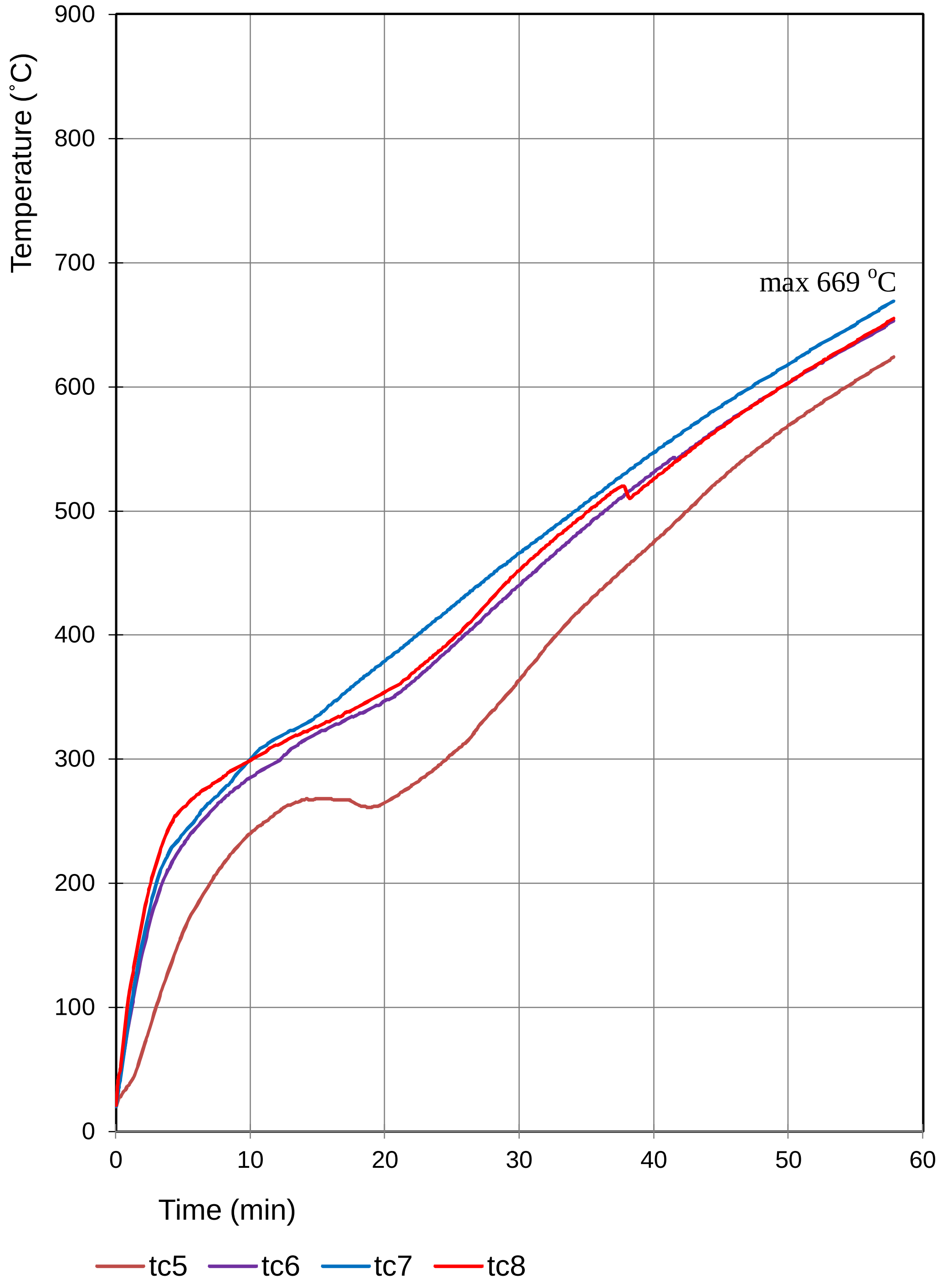


Figure 4. Measured individual specimen temperatures, test 2 (3 May 2012).

Table 2. Measured temperatures of the test specimen, test 2 (3 May 2012).

Time	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
0	20	20	20	20	20	20	20	21
1	37	91	117	87	38	90	94	113
2	69	146	185	155	66	146	154	172
3	105	185	220	184	101	186	200	216
4	137	211	238	214	132	213	226	246
5	165	227	250	238	161	231	240	261
6	186	239	266	250	182	245	253	271
7	206	255	285	263	200	257	265	278
8	223	270	304	274	216	268	276	286
9	236	283	317	285	229	277	288	293
10	247	294	328	293	240	285	300	299
11	257	302	341	300	249	292	310	305
12	266	311	354	308	257	298	317	311
13	275	319	368	317	263	308	323	317
14	284	327	381	326	267	315	328	322
15	290	334	393	335	268	321	335	326
16	293	344	405	344	268	326	344	331
17	293	354	417	352	267	331	353	337
18	296	364	428	362	263	336	362	342
19	302	375	439	372	261	341	371	348
20	309	385	450	383	265	347	379	354
21	318	397	460	395	271	353	387	360
22	327	408	471	406	279	362	396	369
23	337	420	481	416	286	371	405	378
24	348	431	490	427	295	381	414	387
25	358	443	500	437	304	391	423	396
26	370	454	509	448	313	401	432	407
27	383	465	519	459	327	410	440	418
28	397	476	529	471	339	421	449	430
29	410	487	538	484	351	430	457	442
30	424	498	547	496	364	440	466	452
31	437	508	557	507	377	450	474	462
32	450	519	566	519	391	460	482	472
33	463	530	576	530	403	469	490	481
34	476	540	585	541	415	479	499	490
35	489	551	594	552	425	488	507	499
36	502	561	603	562	436	497	515	507
37	514	572	612	573	446	506	523	516
38	527	582	621	583	456	514	531	514
39	539	592	630	593	465	523	539	517

Time	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
40	551	603	639	603	475	531	547	526
41	563	613	647	614	485	539	555	534
42	575	623	656	624	495	544	562	543
43	586	633	665	634	505	552	570	551
44	598	642	674	643	516	560	577	559
45	610	651	683	653	526	568	584	567
46	621	661	692	662	535	576	591	575
47	632	670	700	672	544	582	598	582
48	642	680	710	682	552	590	605	589
49	652	690	718	692	561	596	611	596
50	663	699	728	702	569	603	618	603
51	674	709	738	712	576	610	625	610
52	686	719	747	722	584	616	632	617
53	696	728	757	732	591	623	638	624
54	707	739	768	742	598	629	644	630
55	718	749	778	752	605	635	650	636
56	729	759	788	763	611	641	657	643
57	740	769	800	774	618	647	664	649

Observations

Specimen 1

Test time [min:s]	U/E	**Observation** (E stands for the fire exposed side and U for the unexposed side)
0:00	U/E	Test was started.
11:20	U	Smoke began to emerge in the middle of the specimen.
24:35	U	Deflection increased so rapid that loading system couldn't follow.
24:40		Test was terminated.

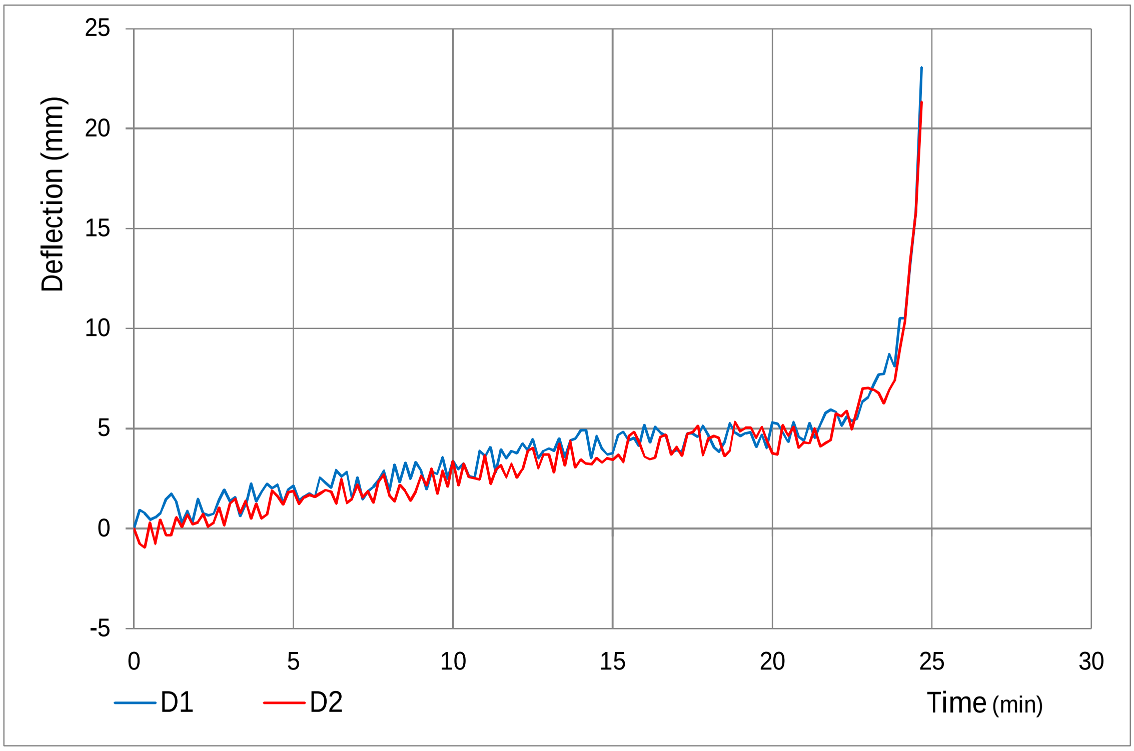


Figure 1. Deflection of the specimen, test 1 (11 May 2012).

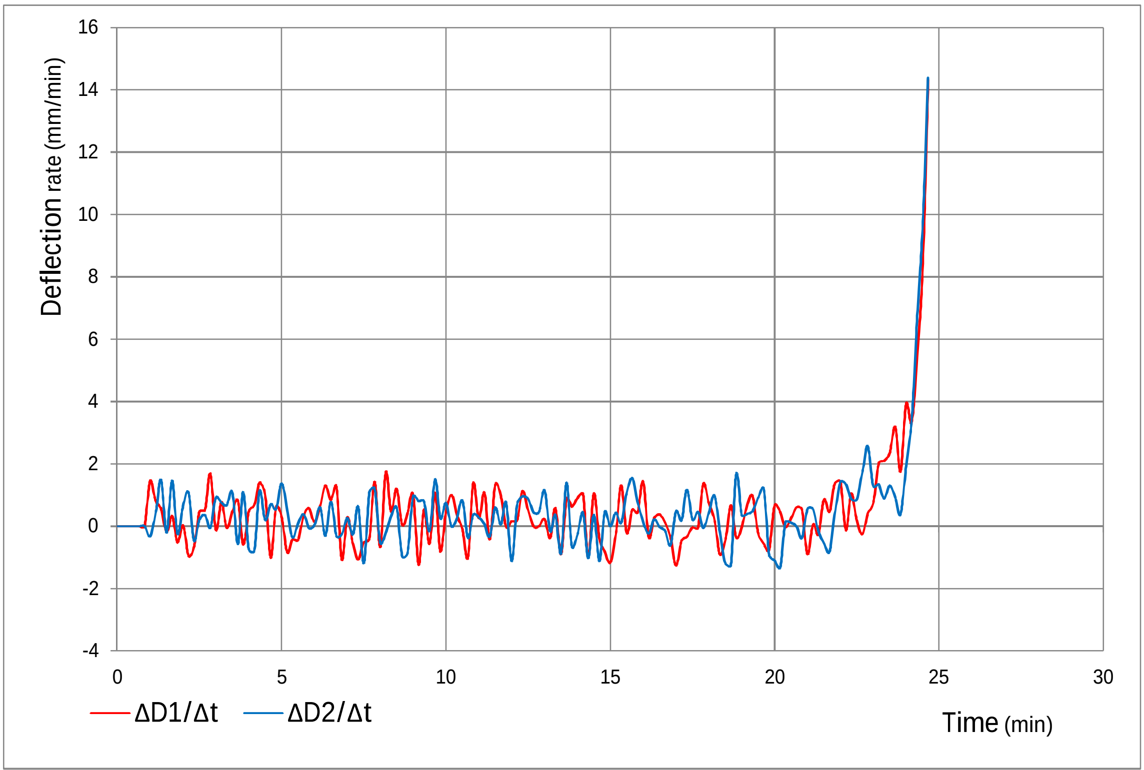


Figure 2. Deflection rate of the specimen, test 1 (11 May 2012).

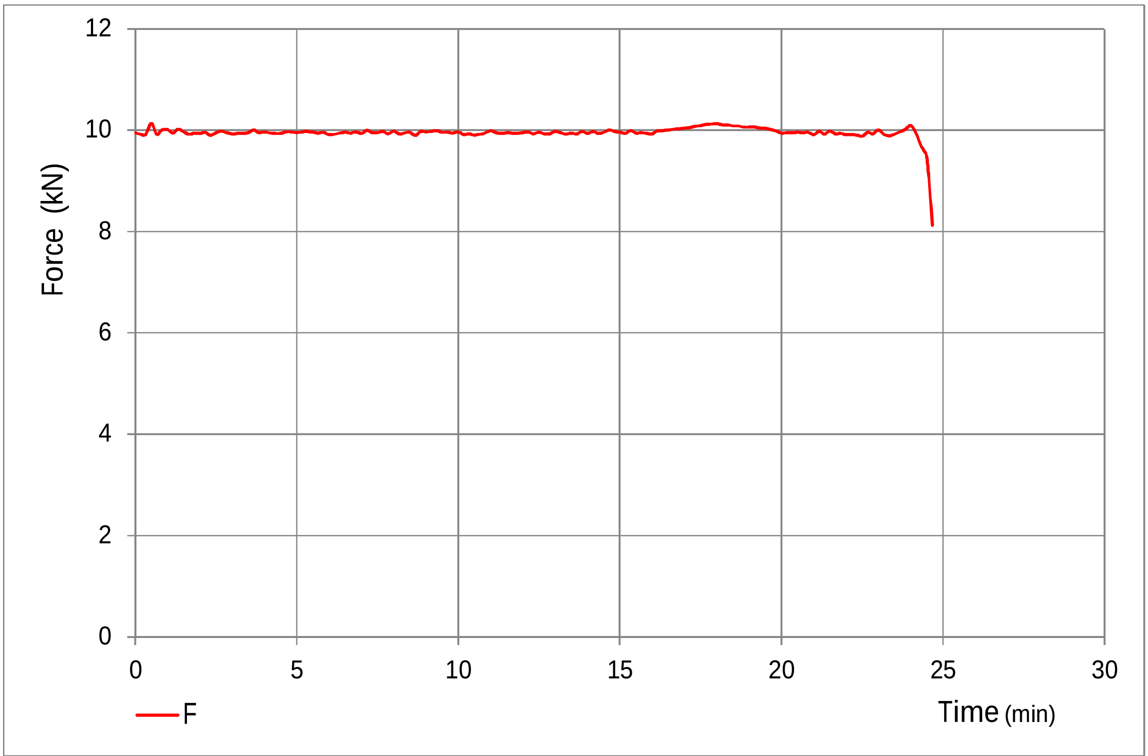


Figure 3. Load of the specimen, test 1 (11.May 2012).

Specimen 2

Test time [min:s]	U/E	**Observation** (E stands for the fire exposed side and U for the unexposed side)
0:00	U/E	Test was started.
15:45	U	Smoke began to emerge in the middle of the specimen.
57:45	U	Deflection increased so rapid that loading system couldn’t follow.
57:50		Test was terminated.

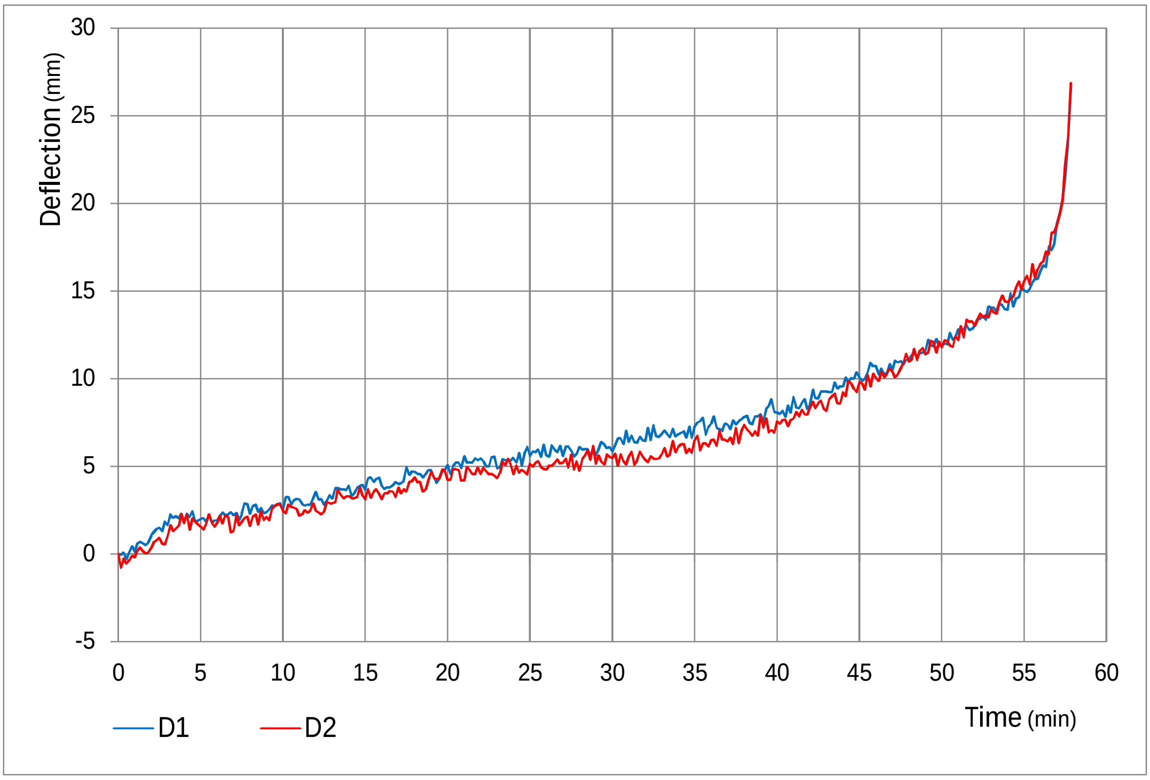


Figure 4. Deflection of the specimen, test 2 (3 May 2012).

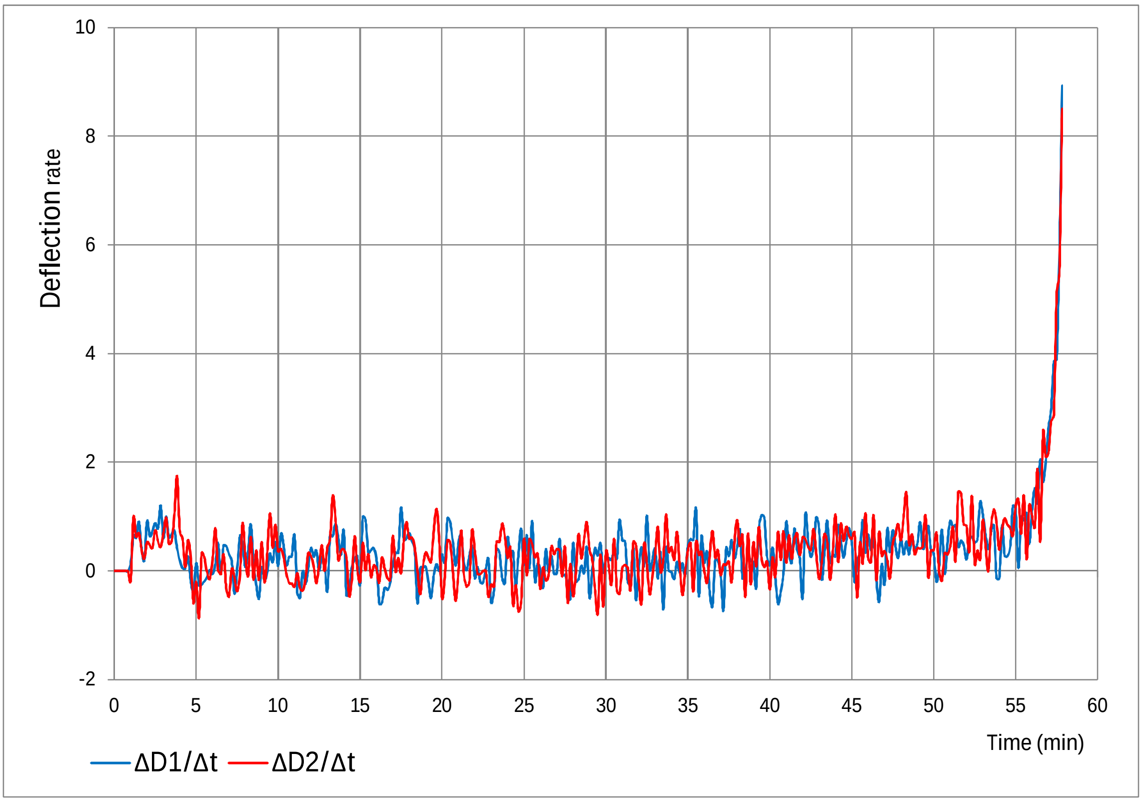


Figure 5. Deflection rate of the specimen, test 2 (3 May 2012).

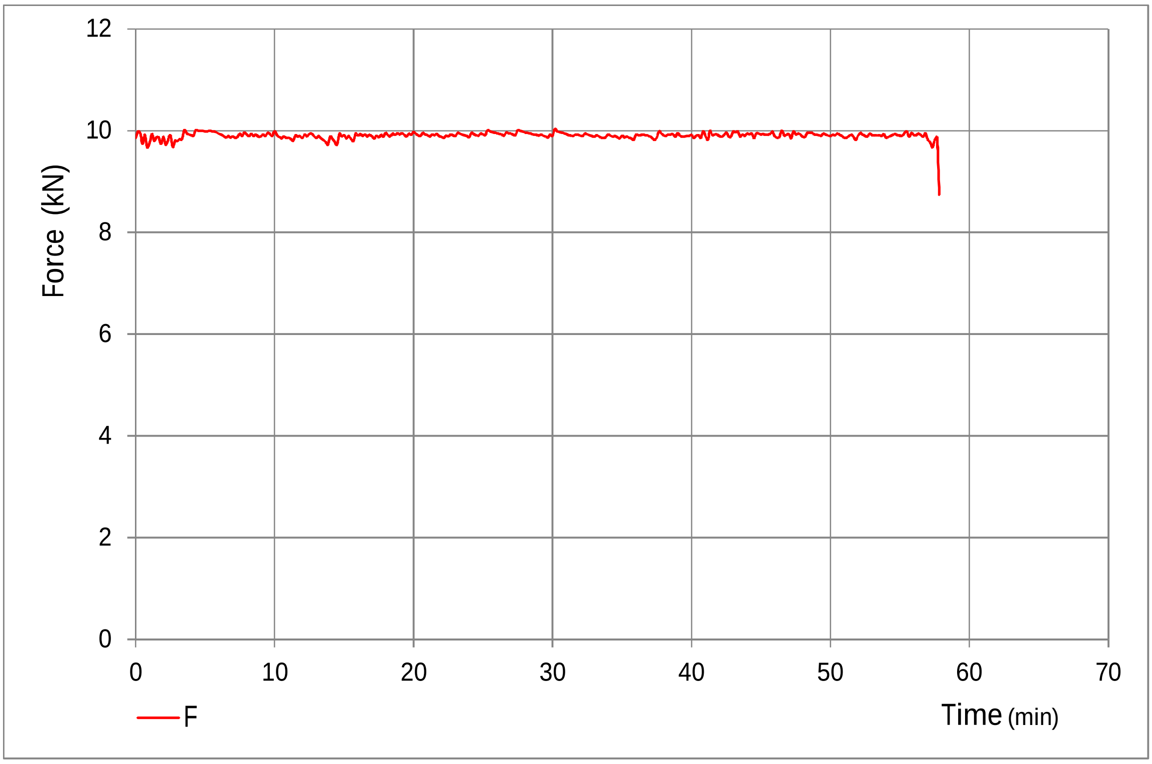


Figure 6. Load of the specimen, test 2 (3.May 2012).

Photos of test specimen 1

Figure 1. Stainless steel tube.

Figure 2. Exposed face of test specimen 1 before the test.

Figure 3. Unexposed face of test specimen 1 before the test.

Figure 4. Unexposed face of test specimen 1 before the test.

Figure 5. Unexposed face of test specimen 1 at the test time 15 min 51 s.

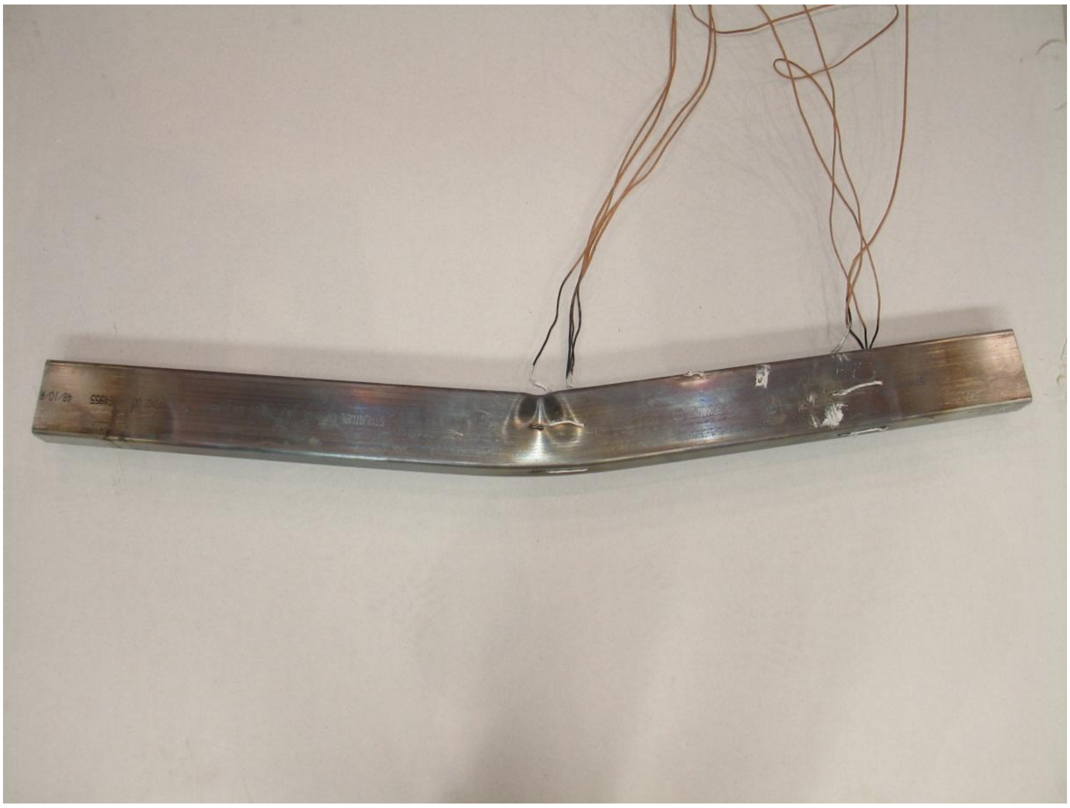


Figure 6. Test specimen 1 after the test.

Figure 7. Test specimen 1 after the test.

Photos of test specimen 2

Figure 8. Exposed face of specimen 2 before the test.

Figure 9. Unexposed face of specimen 2 before the test.

Figure 10. Test specimen 2 after the test.

Figure 11. Test specimen 2 after the test.

Construction and preparation of test specimens

Test specimens

Test specimen 1 was a ferritic stainless steel beam with RHS 40 x 80 x 2 section, Grade 1.4509. The length of the beam was 1000 mm and the span 900 mm.

Test specimen 2 was like test specimen 1 but the beam was painted with primer Epigrip L425 manufactured by Leighs Paints (see Figure 1) and intumecent paint Firetex FX13881 manufactured also by Leighs Paints (see Figure 2). All faces of the beam were fair-painted with only single layer of intumecent paint Firetex FX13881 on 31 January 2012. Painting and measurements of paint thicknesses were performed by JMP Huolto Oy. Measured mean thickness of the primer was 97.5 μm (see Figure 3) and measured mean thickness of intumecent paint 1816 μm /1538 μm (two series of measurements, see Figure 4 and 5). After drying of intumecent paint test specimen 2 was removed to the conditioning room on 28 February 2012.

Mounting of the beams

Test specimen 1 was mounted horizontally on the top of combi furnace on 9 – 11 May 2012 and test specimen 2 on 30 April – 3 May 2012. Three sides of the specimen were fire exposed and the top of the specimen was protected with ceramic fibre insulation Kaowool so that the specimen was free to deflect.

Loading

The specimens were simply supported so that the span was 900 mm. Both specimens were loaded with the load of 9.96 kN which was distributed to two point loads at the distance of 300 mm. Determination of the load is presented in Appendix 1.

The load of the specimens was increased gradually so that at least 15 minutes before the start of the test the full load was achieved.

Conditioning of the test specimen

The test specimens were conditioned in a conditioning room from 9 March 2012 until the testing day.

LEIGHS PAINTS®

EPIGRIP L425
PRODUCT TECHNICAL DATA

FULL DESCRIPTION	: EPIGRIP L425 ZINC PHOSPHATE PRIMER
MATERIAL TYPE	: A high build 2-pack epoxy zinc phosphate primer
RECOMMENDED USE	: Anti-corrosive protection of carbon steel surfaces prepared by abrasive blast cleaning : Suitable for use under appropriate coating systems for exposed or immersed conditions. : Patch primer for the repair for damaged surfaces. : Tolerant to application over manually prepared surfaces.
ENDORSEMENTS	: Complies with BS5493:1977 - Table 4K Type Kp1A : Complies with British Gas Standard PS PA9 Primer : Approved by MOD/DRA AFS No. 1903
RECOMMENDED APPLICATION METHODS	: Airless Spray Brush : Conventional Spray Roller
COLOUR AVAILABILITY	: Limited range
FLASH POINT	: Base : 24°C Additive : 26°C
% SOLIDS BY VOLUME	: 60 ± 3% (ASTM-D2697-91)
V.O.C.	: 346 gms/litre determined practically in accordance with UK Regulations PG6/23 : 376 gms/litre calculated from formulation to satisfy EC Solvent Emissions Directive : 274 gms/kilo content by weight from formulation, to satisfy EC SED
TYPICAL THICKNESS	: **Dry film thickness** 75 microns; **Wet film thickness** 125 microns; **Theoretical coverage** 8.0 m²/ltr* ** This figure makes no allowance for surface profile, uneven application, overspray or losses in containers and equipment. Film thickness will vary depending on actual use and specification.*

PRACTICAL APPLICATION RATES- microns per coat		**Airless Spray**	**Conventional Spray**	**Brush**	**Roller**
	: Dry	75*	75	50	65
	: Wet	125	125	83	108

** Maximum sag tolerance typically 175µm dry by airless spray.*

AVERAGE DRYING TIMES	**At 15°C**	**At 23°C**	**At 35°C**
To touch	: 2 hours	1½ hours	1 hour
To recoat	: 6 hours	4 hours	3 hours
To handle	: 24 hours	16 hours	12 hours

These figures are given as a guide only. Factors such as air movement and humidity must also be considered.

RECOMMENDED THINNER	: Leighs Cleanser/Thinner No. 5
RESISTANCE TO	: Moisture - Excellent; Aliphatic solvents - Excellent Acid spillage - Moderate; Abrasion - Excellent Alkali spillage - Excellent; Weather - Excellent (subject to chalking) Petroleum solvents - Excellent
RECOMMENDED TOPCOATS	: Indefinitely overcoatable with epoxy systems provided the surfaces to be coated have been suitably cleaned. Where a high degree of gloss and colour retention is required, overcoat with Resistex C137V2, Resistex C237 or Resistex K651 within 7 days at a minimum dft of 50 microns or in the case of C750V2 overcoat within 4 days. These overcoating times refer to achievement of optimum adhesion at 23°C and will vary with temperature. : For overcoating with alkyd systems, consult Leighs Customer Service Department for advice.
POT LIFE	: 8 hours at 15°C 6 hours at 23°C 3 hours at 35°C
PACKAGE	: A two component material supplied in separate containers to be mixed prior to use
Pack Size	: 20 litre and 5 litre units when mixed
Mixing Ratio	: 4 parts base to 1 part additive by volume
Weight	: 1.37 kg/litre (may vary with shade).
Shelf Life	: 2 years from date of manufacture or 'Use By' date where specified.

EPIGRIP L425 - Issue 14
Page 1 of 2

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email: enquiries@leighspaints.com website: www.leighspaints.com

Figure 1. Information of primer Epigrip L425.

SURFACE PREPARATION:
Blast clean to Sa.2½ BS EN ISO 8501-1:2001. Average surface profile in the range 50-75 microns.
Manually prepared surfaces should be prepared to a minimum standard of ST.3 BS EN ISO 8501-1:2001 at the time of coating.
Ensure surfaces to be coated are clean, dry and free from all surface contamination.
May also be applied over a wide range of pre-fabrication primers, including inorganic zinc silicate, poly-vinyl butyral and epoxy types.

APPLICATION EQUIPMENT:
Airless Spray

Nozzle Size	:	0.46mm (18 thou)
Fan Angle	:	65°
Operating Pressure	:	155kg/cm² (2200 psi)

The airless spray details given above are intended as a guide only. Details such as fluid hose length and diameter, paint temperature and job shape and size all have an effect on the spray tip and operating pressure chosen. However, the operating pressure should be the lowest possible consistent with satisfactory atomisation. As conditions will vary from job to job, it is the applicators' responsibility to ensure that the equipment in use has been set up to give the best results. If in doubt Leighs Customer Service Department should be consulted.

Conventional Spray

Nozzle Size	:	1.27mm (50 thou)
Atomising Pressure	:	2.8kg/cm² (40 psi)
Fluid Pressure	:	0.4kg/cm² (6 psi)

The details of atomising pressure, fluid pressure and nozzle size are given as a guide. It may be found that slight variations of pressure will provide optimum atomisation in some circumstances according to the set up in use. Atomising air pressure depends on the air cap in use and the fluid pressure depends on the length of line and direction of feed i.e. horizontal or vertical.

Brush and Roller: The material is suitable for brush and roller application. Application of more than one coat may be necessary to give equivalent dry film thickness to a single spray applied coat.

APPLICATION CONDITIONS AND OVERCOATING:
Epoxy paints should preferably be applied at temperatures in excess of 10ºC. In conditions of high relative humidity, ie 80-85% good ventilation conditions are essential. Substrate temperature should be at least 3ºC above the dew point and always above 0°C.
At application temperatures below 10°C, drying and curing times will be significantly extended, and spraying characteristics may be impaired.
Application at ambient air temperatures below 5°C is not recommended.
Due to the high solids content of this material, it is not normally possible to achieve optimum film formation at dry film thicknesses of less than 60 microns by spray application. Where film thicknesses down to 50 microns are specified, the material may be thinned up to 10% with Leighs Cleanser/Thinner No.5. Thinning should be carried out with thorough stirring immediately before use.
In order to achieve optimum water and chemical resistance, temperature needs to be maintained above 10ºC during curing.
If it is desired to overcoat outside the times stated on the data sheet, please seek advice of Leighs Customer Service Department.
For full notes, see data sheet entitled 'Spreading Rates and Overcoating Times'.

ADDITIONAL NOTES:
Drying times, curing times and pot life should be considered as a guide only.
The curing reaction of epoxies commences immediately the two components are mixed, and since the reaction is dependent on temperature, the curing time and pot life will be approximately halved by a 10°C increase in temperature and doubled by a 10°C decrease in temperature.

Epoxy Coatings - Colour Stability:
Variable colour stability is a feature of epoxy materials which tend to yellow and darken with age whether used on internal or external areas. Therefore any areas touched-up and repaired with the same colour at a later date may be obvious due to this colour change.
When epoxy materials are exposed to ultra-violet light a surface chalking effect will develop. This phenomenon results in loss of gloss and a fine powder coating at the surface which may give rise to colour variation depending on the aspect of the steelwork. This effect in no way detracts from the performance of the system.

Epoxy Coatings - Tropical Use
Epoxy paints at the time of mixing should not exceed a temperature of 35°C. At this temperature the pot life will be approximately halved. Use of these products outside of the pot life may result in inferior adhesion properties even if the materials appear fit for application. Thinning the mixed product will not alleviate this problem.
The maximum air and substrate temperature for application is 50°C providing conditions allow satisfactory application and film formation. If the air and substrate temperatures exceed 50°C and epoxy coatings are applied under these conditions, paint film defects such as dry spray, bubbling and pinholing etc. can occur within the coating.
Numerical values quoted for physical data may vary slightly from batch to batch.

HEALTH AND SAFETY:
Consult Product Health and Safety Data Sheet for information on safe storage, handling and application of this product.

Figure 1 continued. Information of primer Epigrip L425.

LEIGHS PAINTS

FIRETEX FX13381/1
PRODUCT TECHNICAL DATA

FULL DESCRIPTION	FIRETEX FX13381/1 INTUMESCENT COATING
MATERIAL TYPE	A single pack thin film intumescent coating
RECOMMENDED USE	FIRETEX FX13381/1 is designed for site application by airless spray, to provide fire resistance for up to 120 minutes on structural steel **For use without topcoat in dry internal areas - category Z2 as defined in ETAG 018-2.** **For use with topcoat in internal areas with high humidity, semi exposed areas and in fully exposed areas - categories Z1, X and Y as defined in ETAG 018-2.**
ENDORSMENTS	Tested and assessed to EN13381-8:2010 Tested to BS EN 13823:2002
RECOMMENDED APPLICATION METHODS	Airless Spray
COLOUR AVAILABILITY	White
FLASH POINT	27°C
% SOLIDS BY VOLUME	75 ± 4% (ASTM-D2697-03)
V.O.C.	286 gms/litre determined practically in accordance with UK Regulations PG6/23 355 gms/litre calculated from formulation to satisfy EC Solvent Emissions Directive 264 gms/kilo content by weight from formulation, to satisfy EC SED
RECOMMENDED THICKNESS	See separate sheet of FX13381/1 loading requirements.
PRACTICAL APPLICATION RATES – microns per coat	**Airless Spray** Dry 1400 Wet 1867
AVERAGE DRYING TIMES	**At 15°C** / **At 23°C**
To touch	30 minutes / 20 minutes
To recoat	4 hours / 4 hours
To handle	This will depend on the total thickness of FIRETEX FX13381/1 to be applied. *These figures are given as a guide only. Factors such as air movement and humidity must also be considered.*
RECOMMENDED THINNER	Leighs Cleanser/Thinner No. 2
RESISTANCE TO	FIRETEX FX13381/1 can resist normal weather conditions for up to 6 months without topcoat provided it has had appropriate drying prior to exposure. Once an approved topcoat has been applied as appropriate to the prevailing conditions, then durability will be substantially enhanced. **If the specific use or storage could lead to prolonged contact with water due to rainfall, condensation, or other site/transportation/storage circumstances, then a recommended topcoat must be used to prevent damage to the basecoat**
RECOMMENDED PRIMERS	Several primers have been approved for use under FIRETEX FX13381/1. Please consult Leighs Customer Service Department for detailed information
RECOMMENDED TOPCOATS	For certain dry, internal situations where the final colour/appearance is not critical, then FIRETEX FX13381/1 may remain un-topcoated **For externally exposed steelwork and severe internal environments Resistex C137V2 or Resistex C237 must be used as a topcoat.** For other internal environments where a topcoat is required then FIRETEX M71V2 or Envirogard M770 should be used. In all instances for subsequent re-decoration, use FIRETEX M71V2, Resistex C137V2 or Resistex C237 as appropriate
PACKAGE	A single component material
Pack Size	20 litre units
Weight	1.335 kg/litre
Shelf Life	2 years from date of manufacture or 'Use By' date where specified.

FIRETEX FX13381/1 – Issue 2
Page 1 of 2

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email: enquiries@leighspaints.com website: www.leighspaints.com

Figure 2. Information of intumecent paint Firetex FX13881.

SURFACE PREPARATION:

FIRETEX FX13381/1 is designed for use over a suitably prepared and primed substrate.

Ensure surfaces to be coated are clean, dry and free from all surface contamination.

Under certain circumstances it may be possible to apply FIRETEX FX13381/1 directly to steel blast cleaned to a minimum standard of Sa.2½ BS EN ISO 8501-1:2007, surface profile in the range 50-100 microns. Consult Leighs Technical Sales Department for further details.

APPLICATION EQUIPMENT:

Airless Spray

Nozzle Size	:	21 – 27 thou (0.53 – 0.69mm) depending on application requirements
Fan Angle	:	30°
Operating Pressure	:	210kg/cm² (3000 psi)

The details of airless spray tip orifice size, fan angle and pressure are given as a guide. Smaller fan angles should be used where the size of the work to be sprayed makes this appropriate. It may be found that slight variation in tip orifice size or pressure will provide optimum atomisation in some circumstances. In general, the operating pressure should be the lowest possible consistent with satisfactory atomisation.

Recommended Equipment : Use a 56:1 or 68:1 Graco King or equivalent. Use $^3/_8$" (9.53mm) ID fluid lines where lengths in excess of 3 metres are required. In-line gun or pump filters should not normally be used. Maximum length of fluid line should not exceed 60 metres.

For use on narrow web sections, the smallest tip recommended is a 21 thou (0.53mm) with a 60 mesh pump filter.

APPLICATION CONDITIONS AND OVERCOATING:

This material should preferably be applied at temperatures in excess of 5ºC. In conditions of high relative humidity, ie 80-85% good ventilation conditions are essential. Substrate temperature should be at least 3ºC above the dew point and always above 0°C.

The material must be protected from moisture during the drying period. Moisture ingress prior to drying may affect the integrity and fire protective properties of the coating.

No more than 2 coats by airless spray should be applied within any 24 hour period.

If the maximum recommended thickness per coat is exceeded or high film thicknesses are overcoated prematurely, cracking may occur.

FIRETEX FX13381/1 is capable of withstanding external exposure without topcoat providing:

- **The product is allowed to dry for at least 24 hours at 15°C in dry conditions with good air movement and ventilation. These conditions are based on a total dry film thickness of up to 800 microns. The drying time required will be increased if the film thickness is greater than 800 microns.**
- **The substrate temperature is at least 3°C above the dew point at the time of application and during the drying period.**

ADDITIONAL NOTES:

Maximum service temperature is 70°C. At temperatures greater than 40°C thermoplasticity may be observed.

Maintenance
Small areas of mechanical damage can be repaired using FIRETEX M72, FX13381/1 or FX13381/2 as preferred.

Larger areas of mechanical damage should be repaired using FIRETEX FX13381/1 or FX13381/2 as preferred, applied by brush or spray.
All repairs should then have the original topcoat reinstated by brush or spray as required.
Numerical values quoted for physical data may vary slightly from batch to batch.

HEALTH AND SAFETY:

Consult Product Health and Safety Data Sheet for information on safe storage, handling and application of this product

Figure 2 continued. Information of intumecent paint Firetex FX13881.

Readings - VTT EXPERT SERVICES OY

Reading	Time & Date	EPIGRIP L425 (µm)
1	13:44:41 31.1.2012	60
2	13:44:46 31.1.2012	80
3	13:44:50 31.1.2012	70
4	13:44:55 31.1.2012	90
5	13:44:59 31.1.2012	80
6	13:45:04 31.1.2012	80
7	13:45:08 31.1.2012	80
8	13:45:13 31.1.2012	80
9	13:45:17 31.1.2012	100
10	13:45:29 31.1.2012	100
11	13:45:33 31.1.2012	90
12	13:45:37 31.1.2012	120
13	13:45:42 31.1.2012	120
14	13:45:46 31.1.2012	140
15	13:45:49 31.1.2012	110
16	13:45:57 31.1.2012	160

Summary - VTT EXPERT SERVICES OY

Reading	Time & Date	EPIGRIP L425 (µm)
Max		160,00
Min		60,00
Mean		97,50
StdDev.		26,71

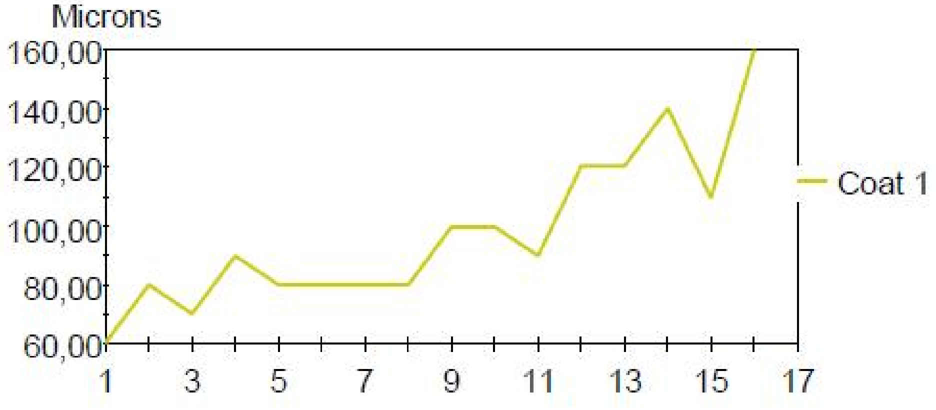
Annotations - VTT EXPERT SERVICES OY

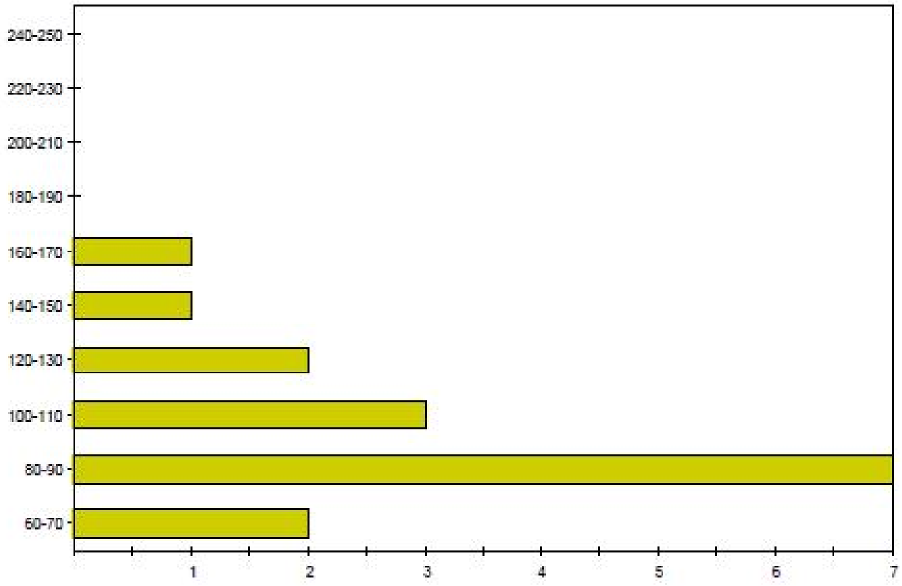
Gage Model: 6000FNTS3
Gage S/N: 620188
Probe Model: FNTS
Probe S/N: 115261
User: T. JÄRVINEN
Part:
Substrate: RAUTA
Coating 1: EPIGRIP L425
P80x80x2 ja x P80x40x2
POHJAMAALAUS
HALLIMAALAUS: JMP HUOLTO OY, VAAHTERAKAARI 3, 04150 MARTINKYLÄ

Jmp Huolto Oy www.jmp-huolto.com jmp@jmp-huolto.com

Figure 3. Thickness measurements of primer Epigrip L425.

Chart / Histogram - VTT EXPERT SERVICES OY





Jmp Huolto Oy www.jmp-huolto.com jmp@jmp-huolto.com

Figure 3 continued. Thickness measurements of primer Epigrip L425

Readings - VTT EXPERT SERVICES OY

Reading	Time & Date	FIRETEX 13381 (µm)
1	16:12:58 22.2.2012	2000
2	16:13:03 22.2.2012	2120
3	16:13:07 22.2.2012	1300
4	16:13:11 22.2.2012	1580
5	16:13:16 22.2.2012	1890
6	16:13:19 22.2.2012	1740
7	16:13:23 22.2.2012	2270
8	16:13:27 22.2.2012	1910
9	16:13:34 22.2.2012	1880
10	16:13:38 22.2.2012	2190
11	16:13:42 22.2.2012	1750
12	16:13:48 22.2.2012	1510
13	16:13:52 22.2.2012	1920
14	16:13:56 22.2.2012	1180
15	16:14:02 22.2.2012	1690
16	16:14:10 22.2.2012	2130

Summary - VTT EXPERT SERVICES OY

Reading	Time & Date	FIRETEX 13381 (µm)
Max		2270,00
Min		1180,00
Mean		1816,25
StdDev.		310,50

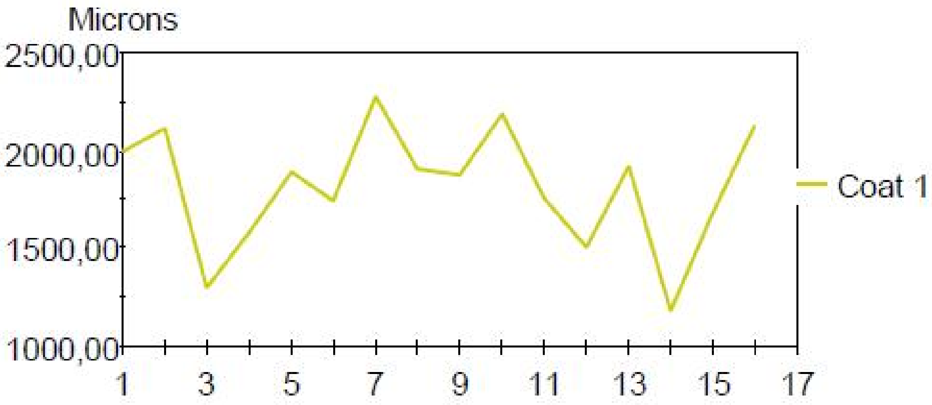
Annotations - VTT EXPERT SERVICES OY

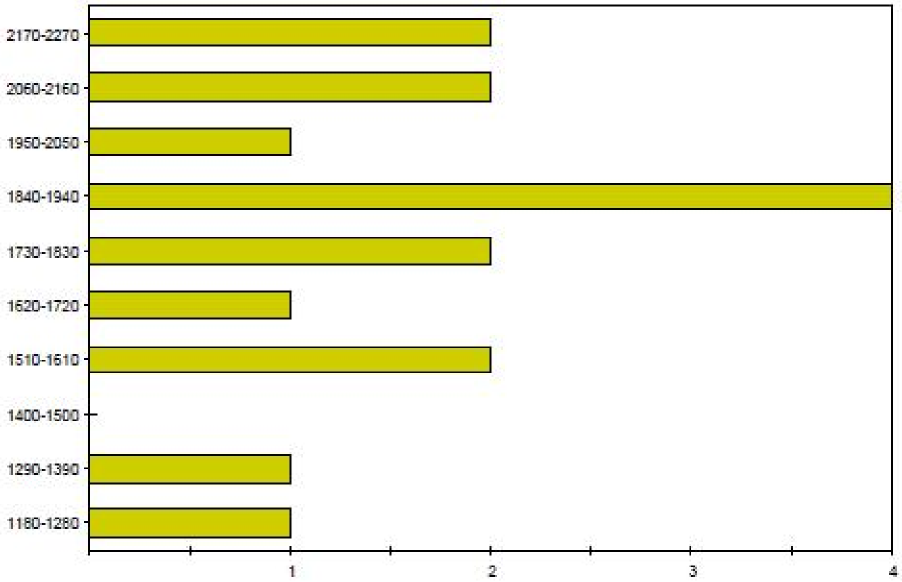
Gage Model: 6000FNTS3
Gage S/N: 620188
Probe Model: FNTS
Probe S/N: 115261
User: T. JÄRVINEN
Part:
Substrate: RAUTA
Coating 1: FIRETEX 13381
P80x80x2 PALOSUOJAMAALAUS
HALLIMAALAUS: JMP HUOLTO OY, VAAHTERAKAARI 3, 04150 MARTINKYLÄ

Jmp Huolto Oy   www.jmp-huolto.com   jmp@jmp-huolto.com

Figure 4. Thickness measurements (serie 1) of intumecent paint Firetex FX13881.

Chart / Histogram - VTT EXPERT SERVICES OY





Jmp Huolto Oy www.jmp-huolto.com jmp@jmp-huolto.com

Figure 4 continued. Thickness measurements (serie 1) of intumecent paint Firetex FX13881.

Readings - VTT EXPERT SERVICES OY

Reading	Time & Date	FIRETEX 13381 (µm)
1	16:14:59 22.2.2012	1690
2	16:15:03 22.2.2012	1110
3	16:15:07 22.2.2012	1660
4	16:15:11 22.2.2012	930
5	16:15:18 22.2.2012	1950
6	16:15:22 22.2.2012	1330
7	16:15:26 22.2.2012	1470
8	16:15:30 22.2.2012	1360
9	16:15:34 22.2.2012	2030
10	16:15:38 22.2.2012	1680
11	16:15:42 22.2.2012	1660
12	16:15:46 22.2.2012	1490
13	16:15:53 22.2.2012	1680
14	16:15:57 22.2.2012	1560
15	16:16:01 22.2.2012	1670
16	16:16:07 22.2.2012	1340

Summary - VTT EXPERT SERVICES OY

Reading	Time & Date	FIRETEX 13381 (µm)
Max		2030,00
Min		930,00
Mean		1538,13
StdDev.		282,47

Annotations - VTT EXPERT SERVICES OY
Gage Model: 6000FNTS3
Gage S/N: 620188
Probe Model: FNTS
Probe S/N: 115261
User: T. JÄRVINEN
Part:
Substrate: RAUTA
Coating 1: FIRETEX 13381
P80x40x2 PALOSUOJAMAALAUS
HALLIMAALAUS: JMP HUOLTO OY, VAAHTERAKAARI 3, 04150 MARTINKYLÄ

Jmp Huolto Oy www.jmp-huolto.com jmp@jmp-huolto.com

Figure 5. Thickness measurements (serie 2) of intumecent paint Firetex FX13881.

Chart / Histogram - VTT EXPERT SERVICES OY

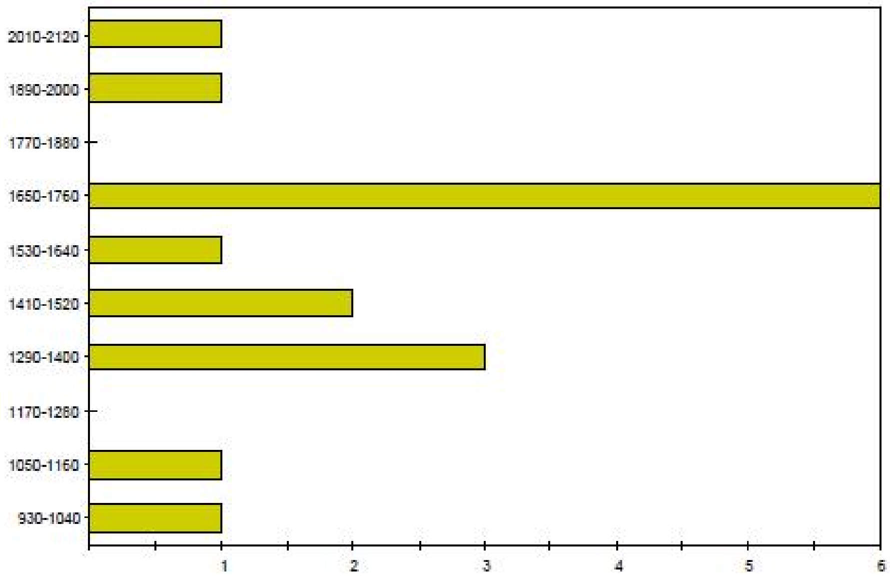


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Figure 5 continued. Thickness measurements (serie 2) of intumecent paint Firetex FX13881.

Field of direct application of test results

In the standard *EN 1365-3:1999 "Fire resistance tests for loadbearing elements - Part 1: Beams"*, section 13, the following applications are mentioned:

The test results are applicable to identical beams with maximum moments and shear forces, which when calculated on the same basis as the test load are not greater than those of the test specimen. This is only applicable provided no changes are made to any applied fire protection.

Comparison of calculated and measured temperatures and loads

Outokumpu Tornio Research Centre performed transient tests on ferritic stainless steel Grade 1.4509. Strength $R_{p0.2}$ reduction factor of stainless steel at elevated temperatures based on these tests is presented in Figure 1. Reduction factors for proof strength $k_{p0.2,\theta} = f_{p0.2,\theta} / f_y$ are calculated into Table 1.

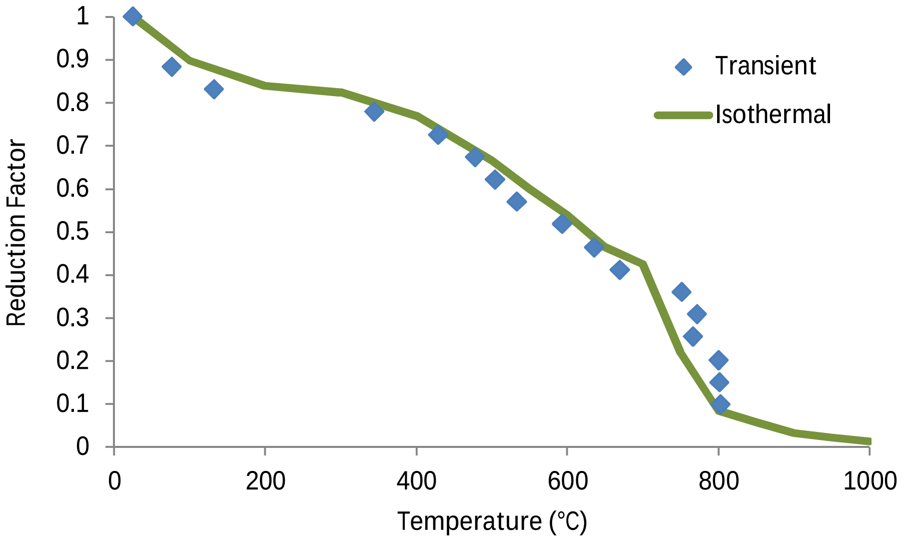

Figure 1. Strength $R_{p0.2}$ reduction factor of stainless steel at elevated temperatures (transient = based on transient tests, isothermal = based on steady-state tests).

Table 1. Reduction factors $k_{p0.2,\theta}$.

Temperature (ºC)	Reduction factor $k_{p0.2,\theta}$
25	1.000
76	0.883
132	0.831
344	0.779
429	0.725
478	0.673
504	0.621
533	0.569
593	0.518
636	0.463
669	0.411
752	0.360
772	0.308
766	0.256
800	0.202
801	0.150
803	0.098

Failure loads of the beam section are calculated using the measured temperatures of the section and the above given reduction factors $k_{p0.2,\theta}$ (see Table 2). Temperature related to test load when using above given reduction factors $k_{p0.2,\theta}$ is also calculated. For the comparison all results are gathered to Table 2.

At the load 9.96 kN (test load) calculated temperature 774 °C is closer to the measured temperatures when reduction factors $k_{p0.2,\theta}$ are based on transient test.

Table 2. Summary of the calculated and measured temperatures and loads for specimen 1 (uncoated beams) and specimen 2 (fire protected beams).

Specimen 1			
Temperature		**Load**	
		steady-state	transient
calculated	731 °C	9.96 kN*	15.33 kN
calculated	774 °C		9.96 kN*
measured max	797 °C		7.11 kN
measured average	789 °C		8.11 kN
Specimen 2			
Temperature		**Load**	
		steady-state	transient
calculated	731 °C	9.96 kN*	15.33 kN
calculated	774 °C		9.96 kN*
measured max	804 °C**		3.27 kN
measured average	780 °C		9.26 kN
*Test load **Temperature just before rapid temperature rise			

Measured temperatures of uncoated and fire protected beams are presented in Figure 2. Temperatures of fire exposed sides are within 10 °C at the time of failure with uncoated beam but with fire protected beam temperature of the bottom surface is clearly the highest. Maximum temperature of both beams is close 800 °C at the time of failure. Apparently the coating of the fire protected beam has cracked just before failure and caused the rapid increase of temperature at the bottom of the beam.

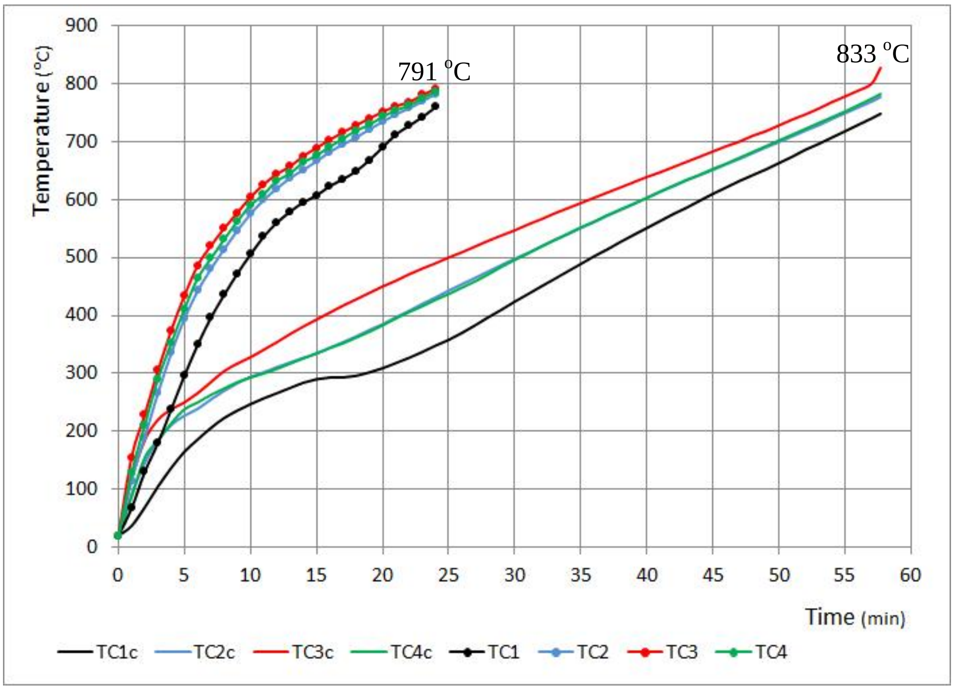

Figure 2. Comparison of the measured temperatures of uncoated and fire protected beams.