REPORT

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Fire Testing of fire protection gratings Type LHD

(Appendicies 1)

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1 Introduction

A review of national and international standards and guidelines shows that several documents address the problem of a fire in leaking transformer oil to various degrees but with no specific performance requirement [1] [2] [3] [4]. A traditional method for improving fire safety at transformer stations is to fill the transformer pit with gravel. In the Swedish standard SS 421 01 01 [5] it is written (translated to English below):

"Preferably arrangements that contribute to extinguish the fire in the leaked liquid shall be used, for example the use of a layer of stones (approximately 300 mm deep and with a grain size of about 40/60 mm) that extinguishes the burning liquid that enters the layer."

There is a lack of a technology neutral requirements concerning the performance of the arrangement described above that should contribute to extinguish the fire of leaking flammable fluid. Fire protection gratings is one technology that has been developed for these purpose. This report presents quantitative tests of a specific scenario, simulating a transformer rupture where the burning transformer oil is rapidly flowing into the transformer pit. The tests are performed in order to investigate how well PcP.s fire protection grating Type LHD is able to extinguish the fire under these specific conditions. The test scenario was developed and tested 2013 by SP as described in SP report 2013:09 [6].

2 Fire test

The scenario modeled correlates to a sudden accidental release and ignition of large oil quantities from a transformer. The maximum stipulated temperature increase inside the transformer under normal conditions is 60°C [6]. The oil temperature is not expected to exceed 90°C, thus the oil temperature was increased to 90°C in this test before ignition. The amount of oil corresponds to a depth of 3 cm in the pit. The fire test was performed two times - both times under same conditions. The test should not be regarded as representative for all possible failure scenarios.

2.1 Experimental setup

The transformer pit was 3.75 meters by 3.2 meters and 1 meter deep. The pit is built in concrete at PcPs facilities in Vildbjerg (Denmark) . During tests the oil was stored in a tippable cart with a total volume of 600 liters. Transformer oil used in the tests was the Nynas Transformer Oil – Nytro 10XN. Technical data sheet for the oil is attached in Appendix 1. Sketches and photo of transformer pit and placement of measuring instruments are presented in Figure 1 to 3. The temperature measurement was conducted with five thermocouple piles. The thermocouple piles are named A-E and their location are shown in Figure 1. Each pile contained six thermocouples at 1, 20, 50, 75, 90 and 130 cm above the ground level. Fire protection gratings ware installed at 0.80 m from the ground, i.e. the thermocouples at 90 cm and 130 cm were located above the fire protection gratings. Gas sampling for O_2 analysis was conducted at two positions, at the center of the pit and at 1 m from the back end of the pit, as shown in Figures 1 and 2. The inlet of the gas sampling pipe was located 10 cm below the fire protection gratings. The symbols in the figures represents:

- **O** are the thermocouple trees, placed at the positions A-E.
- **X** are the locations of the gas sampling pipes, placed 10 cm below the fire protection gratings.

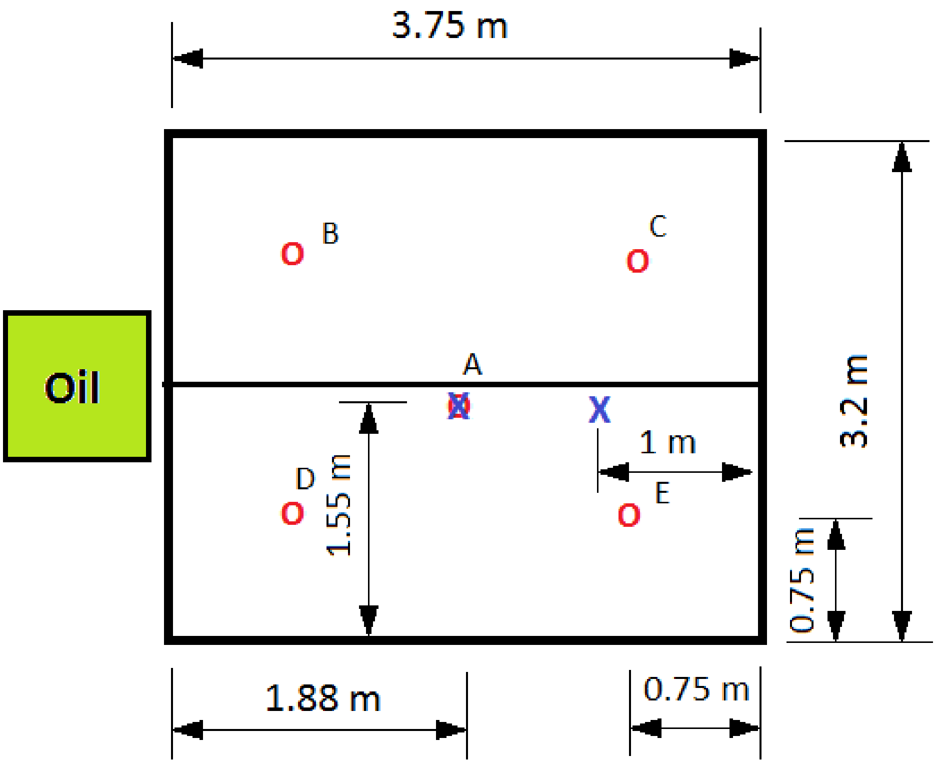

Figure 1. Top view of the experimental setup.

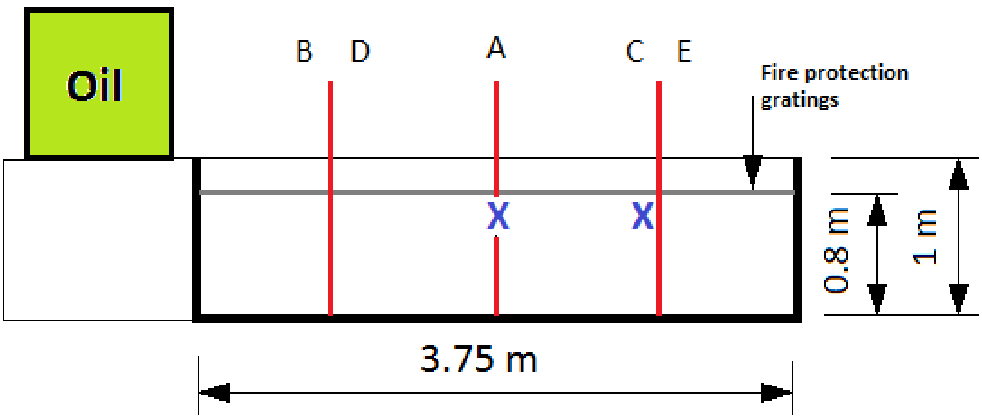

Figure 2. Side view of the experimental setup.

Figure 3. Photo of the test setup.

The fire protection gratings were placed resting 80 cm from the ground level between angle bars installed on the pit inner frame and I-beam (HEB 140) placed in the middle of the longitudinal direction of the longest side of the pit as shown in Figure 4 and Figure 5.

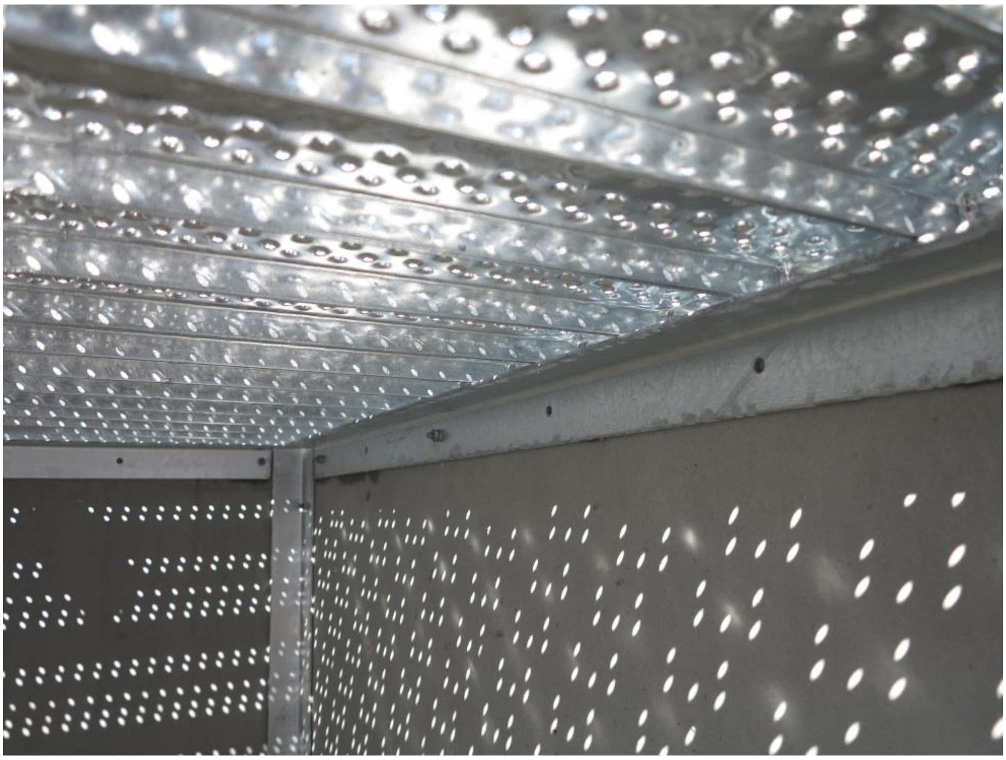

Figure 4. Fire protection gratings resting on angle bars.

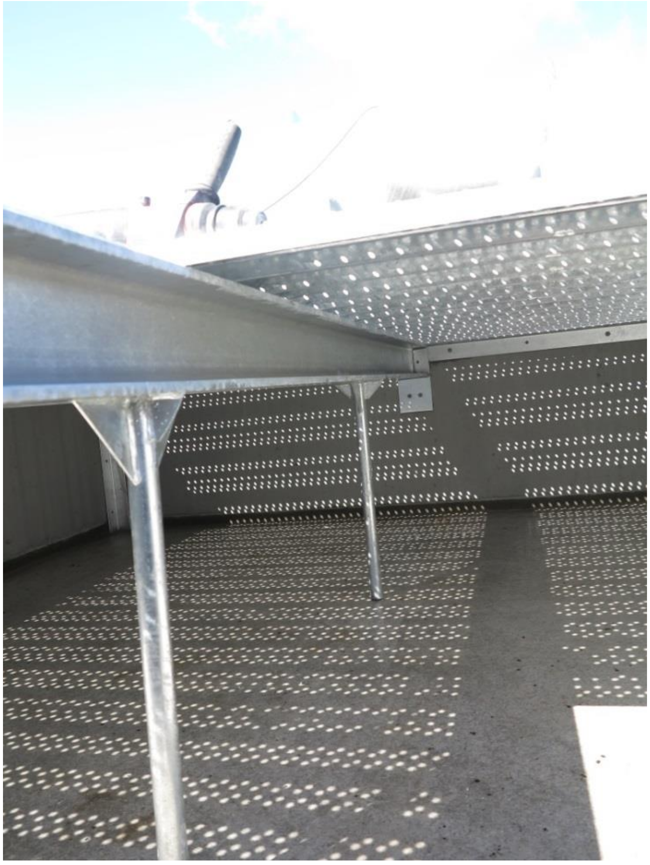

Figure 5. Fire protection gratings resting on I-beam (HEB 140) placed in the middle of the longitudinal direction of the longest side of the pit.

A shield made of metal sheet was placed on the opposite side of the tipping cart to avoid oil spillage outside the pit due to the wave caused by the rapid release of oil into the transformer pit, Figure 6.

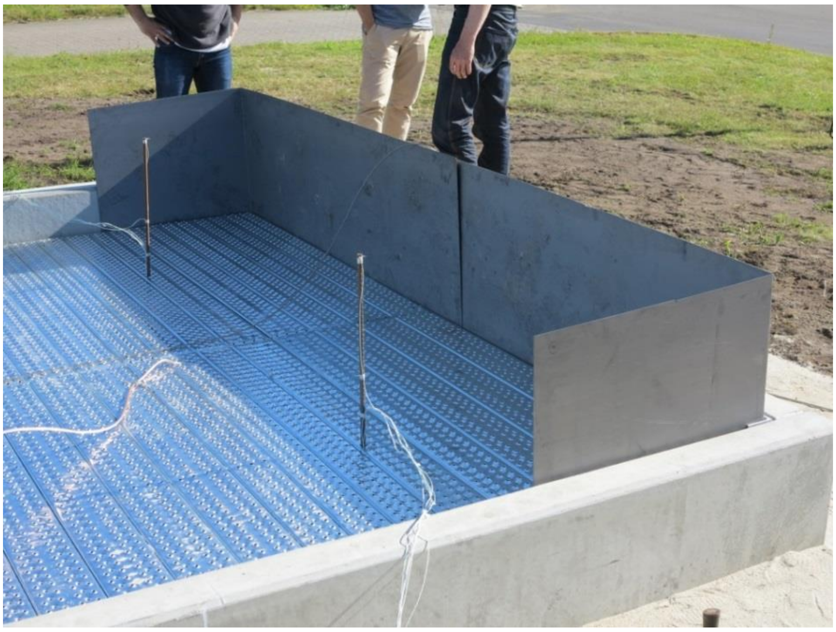

Figure 6. Shield placed on the opposite side of the tipping trailer to avoid spillage of the burning oil due to the wave front.

2.1.1 Fire protection gratings

Figure 7 shows a photo of a single grating board. It is manufactured from hot-galvanised sheet-metal. Four individual 3 mm thick sheet steel panels are welded together to form a grating board. The board has perforated surface structure. According to the manufacturer, the perforation ratio is about 4.1 % of the total surface. Each panel consists of six rows of holes, shown in Figure 7. Four of the rows are punched in the way that they form a shape of upward cone and remaining two rows are punched in the way that they form a shape of downward cone, shown in Figure 8. The holes have a diameter of 8 mm and are distributed on a centered rectangular lattice with nearest neighbor distance 25.5 mm and next nearest neighbor distance 36 mm, seen in Figure 9.

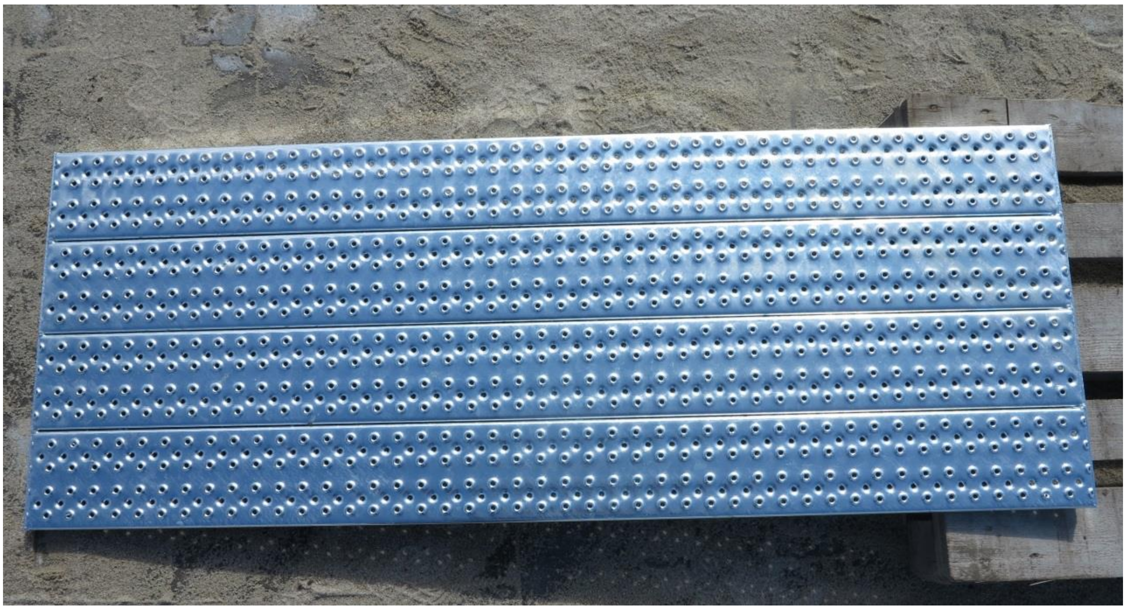

Figure 7. PcP. fire protection grating board.

Figure 8. Four of the rows are punched upwards and two rows are punched downwards.

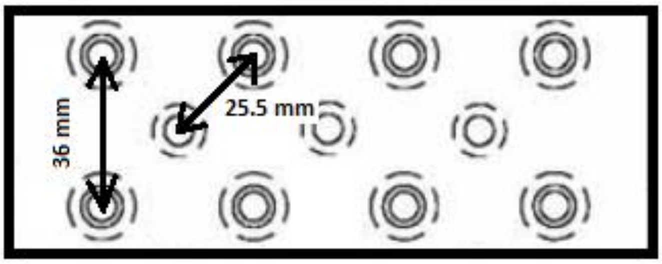

Figure 9. Perforation spacing is 25.5 mm between nearest neighbors and 36 mm between next nearest neighbors.

2.2 Experimental protocol

The test was performed two times - both times under same conditions. Each test started with filling the tippable trailer with 370 liter transformer oil, the amount that corresponds to depth of 3 cm for the pit used in the test. The oil was then heated with an electric heater combined with external gas burners. When the temperature of 90 ° C was reached, the oil was ignited with a gas burner as shown in Figure 11. After 1:30 (min:sec) pre-burn time the oil was tipped into the transformer pit. Figure 11 shows the burning oil before tipping the oil into the pit. Figure 12 shows the sequence when the oil is tipped into the transformer pit.

Important experimental parameters are listed below:

- 370 liter of oil
- Heated to 90 ° C before ignition
- 0:00 (min:sec) - Start of measurement
- 2:00 (min:sec) - Ignition of oil
- 3:30 (min:sec) - Tipping of the burning oil into the pit

Figure 10. Ignition of the oil.

Figure 11. Burning oil before tipping.

Figure 12. Tipping the burning oil into the pit.

3 Result and discussion

3.1 Visual observations

A sequence of photographs taken during the test is shown in Figures 13, 14 and 15. Figure 13 shows the high intensity of the flames when the oil was poured into the transformer pit. The intensity of the flames decreased significantly as soon as all of the oil penetrated the cavities of the fire protection gratings, as seen in Figure 14. Complete flameout, shown in Figure 15, occurred approximately 6 seconds after the start of tipping the oil into the pit. Similar visual observations were made in both tests.

Figure 13. High intensity of the flames after tipping the burning oil into the pit.

Figure 14. Flames were visibly smaller within a few seconds after tipping the burning oil into the pit.

Figure 15. All visible flames disappeared approximately 6 seconds after tipping the burning oil into the pit.

3.2 Gas temperatures

The temperature and oxygen concentration measurements from both tests correspond well. The results from second test are presented in this report. The results for the gas temperature measured by all thermocouple piles (A-E), positioned according to Figure 1, are shown in Figures 16, 17, 18, 19 and 20. For all graphs the time-axis has been shifted so that t = 0 corresponds to the moment when the oil was started to be poured into the pit. The thermocouples installed at 1 cm height from the ground are became covered by the oil layer at the bottom of the pit, meaning that these thermocouples measure the liquid temperature of the oil. The instant temperature increase after tipping the burning oil into the pit is followed by a rapid drop in temperature. Within 60 seconds the temperatures at all positions have stabilized at approximately 100 °C or lower. The temperatures below the protection gratings decay more slowly and fluctuate more than the temperatures above the protection gratings. This is due to the close proximity to the heated oil.

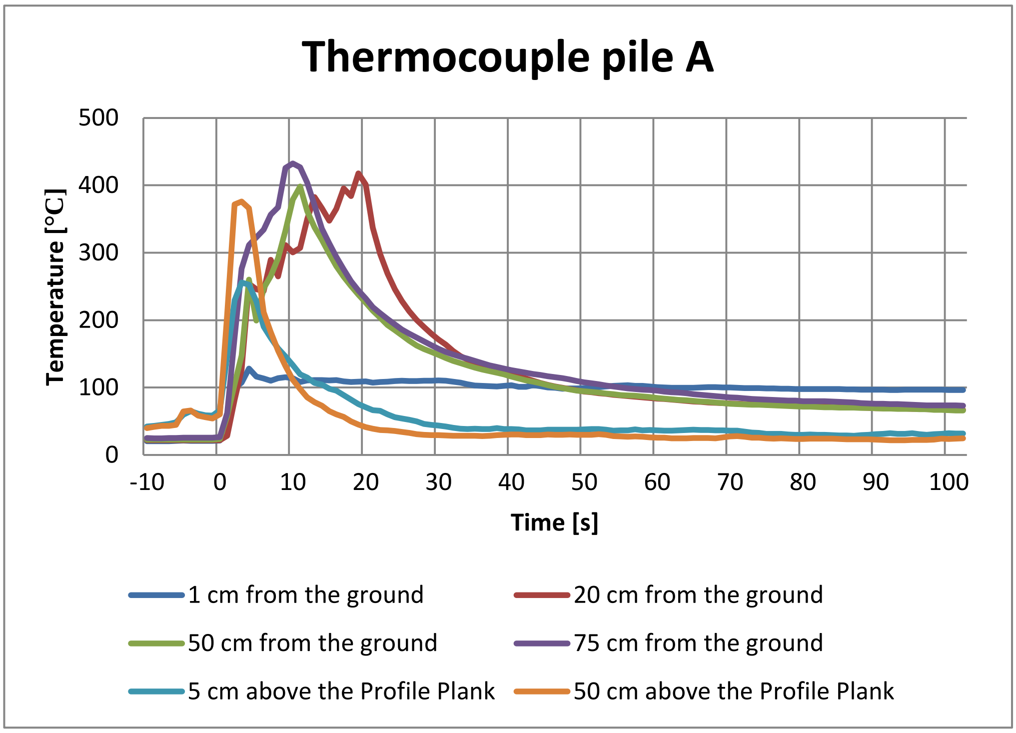

Figure 16. Gas temperature measured in the thermocouple pile A.

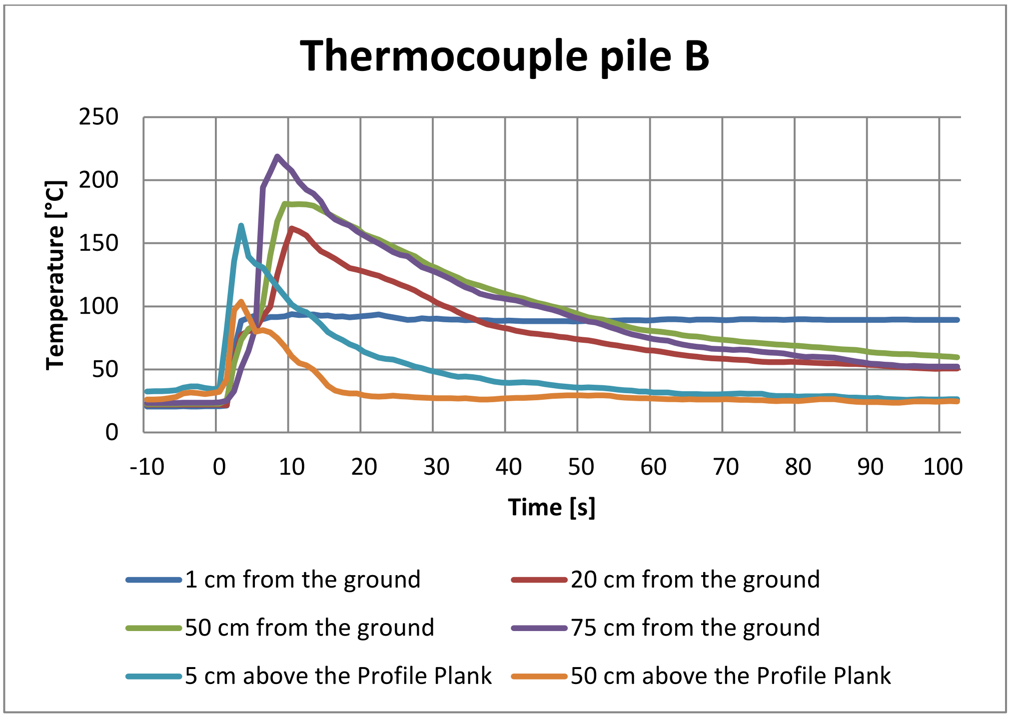

Figure 17. Gas temperature measured in the thermocouple pile B.

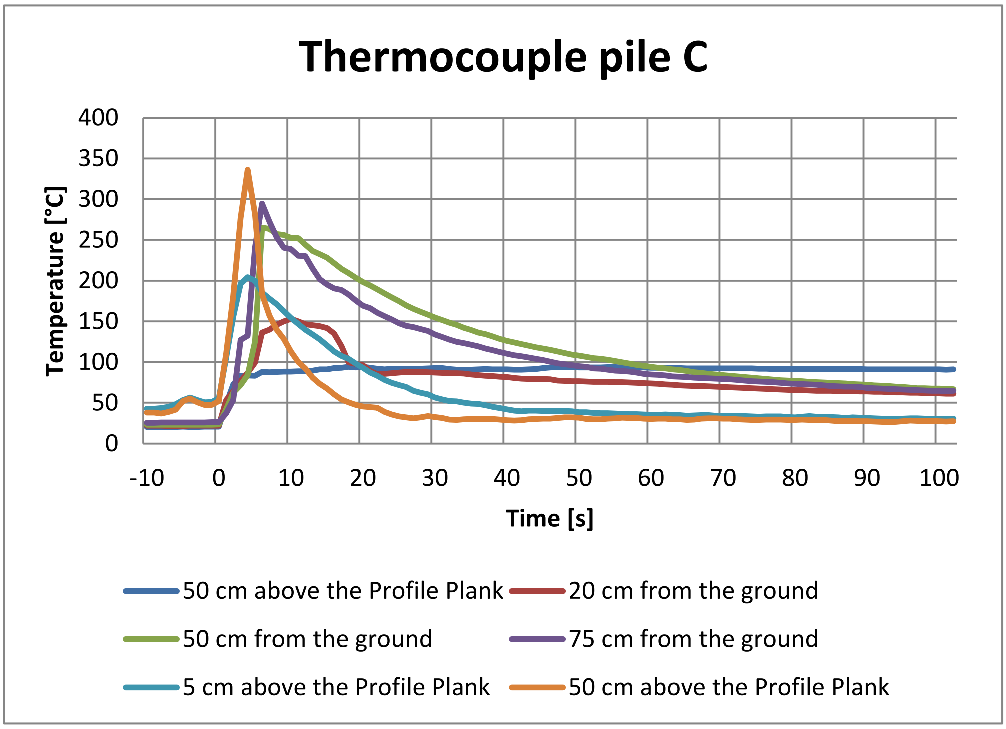

Figure 18. Gas temperature measured in the thermocouple pile C.

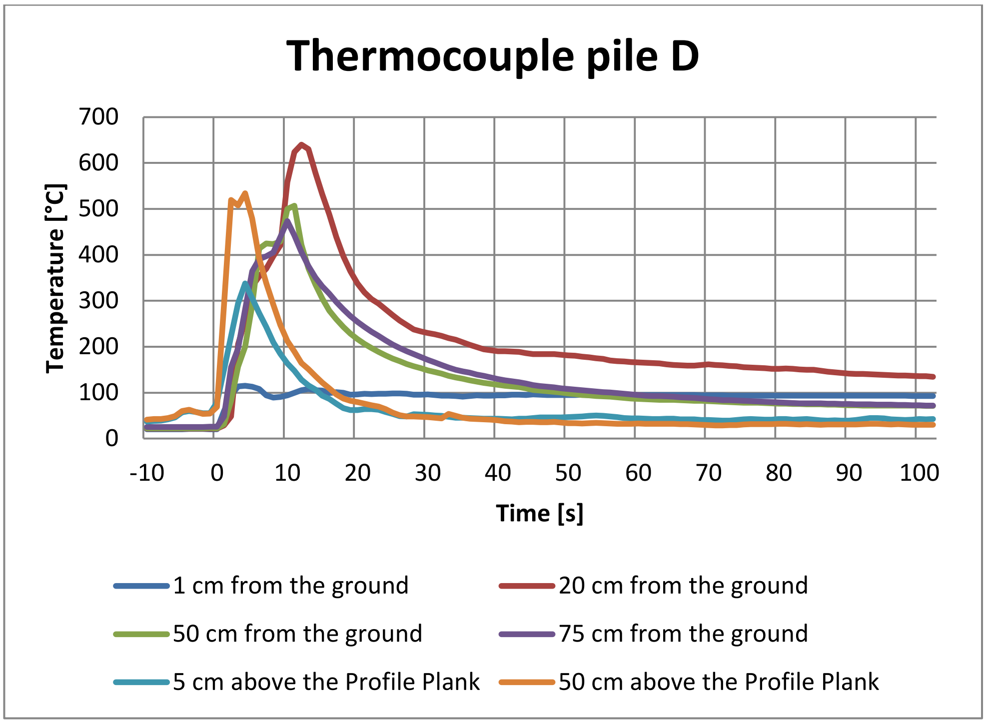

Figure 19. Gas temperature measured in the thermocouple pile D.

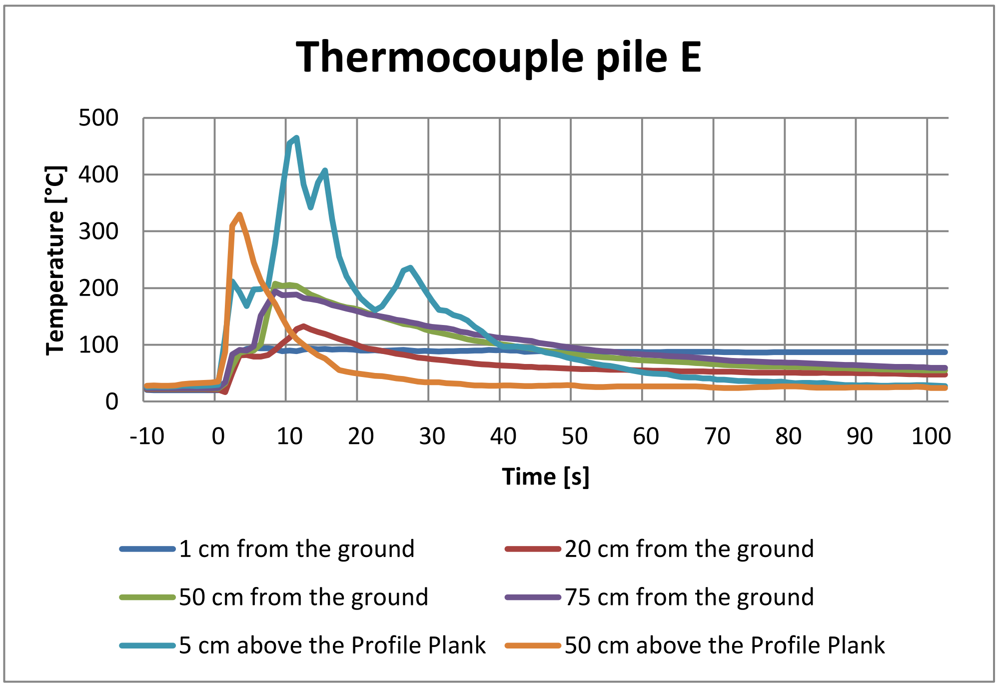

Figure 20. Gas temperature measured in the thermocouple pile E.

3.3 O_2 concentration

Gas concentrations at two positions during the test, at the center of the pit and 1 from the back end of the pit, are shown in Figure 21.

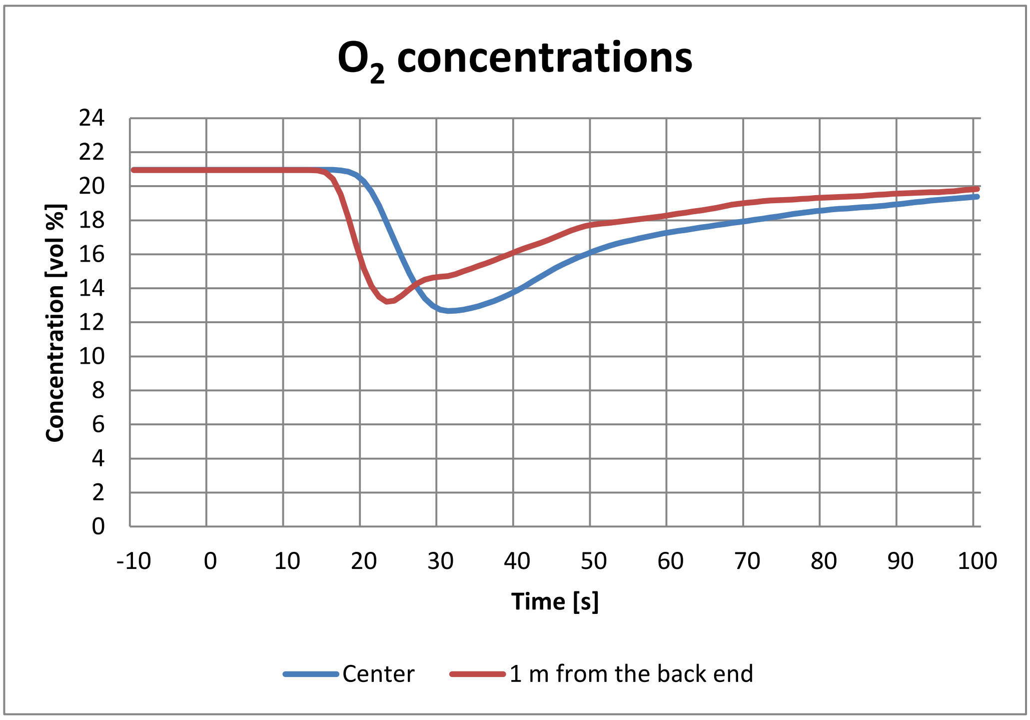

Figure 21. O_2 concentrations measured at center of the pit and 1 m from the back end of the pit.

4 Conclusion

The tests were performed in order to investigate how well the PcP.s fire protection grating Type LHD is able to extinguish an oil fire under a specific fire scenario. The scenario modeled correlates to a sudden accidental release and ignition of large oil quantities from a transformer.

The fire protection gratings Type LHD managed to successfully extinguish the fire during the performed tests. Complete flameout above the fire protection gratings occurred within 6 seconds under the conditions tested. Shortly after, the temperature and oxygen concentration measurements indicate that the fire was extinguished in the entire pit, also under the fire protection gratings.

The rapid quenching of the fire is partly due to the reduced oxygen concentration and it is therefore important that the fire grid protection is covering the complete pit and is fastened tight to the concrete wall to minimize leakage of air around the edge of the construction.

References

[1] ”980-1994 R2001 - IEEE Guide for Containment and Control of Spills in Substations,” 2001.

[2] ”NFPA 850: Recommended practice for fire protection for electric generating plants and high voltage direct current converter stations,” 2010.

[3] ”NFPA 70: National Electric Code,” 2011.

[4] ”FM Global Property Loss Prevention Data Sheets 5-4 TRANSFORMERS,” 2012.

[5] SEK Svenska Elektriska Kommissionen, ”SS 421 01 01 Starkströmanläggningar med nominell spänning överstigande 1 kV AC.,” 2004.

[6] J. Lindström och M. Försth, ”Fire test Profile Plank for transformer pit fire protection,” SP Fire Research, Borås, 2013.

[7] ”IEC 60076-2 Power Transformers - Part 2: Temperature rise,” 1993.

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PRODUCT DATA SHEET

Nytro 10XN

PROPERTY	UNIT	TEST METHOD ASTM	GUARANTEED DATA MIN	GUARANTEED DATA MAX	TYPICAL DATA
Physical					
Appearance		D 1524	Clear and bright		complies
Density, 15℃	kg/dm^3	D 1298		0.910	0.880
Viscosity, 40℃	mm^2/s	D 445		12.0	7.6
Viscosity, 100℃	mm^2/s	D 445		3.0	2.1
Viscosity, 0℃	mm^2/s	D 445		76	48
Flash Point, COC	℃	D 92	145		150
Pour Point	℃	D 97		-40	-63
Aniline Point	℃	D 611	63		77
Colour		D 1500		0.5	<0.5
Interfacial tension at 25℃	mN /m	D 971	40		50
Chemical					
Total acid No.	mg KOH/g	D 974		0.03	<0.01
Corrosive sulphur		D 1275 B	non-corrosive		non-corrosive
Antioxidant, phenols	Wt %	D 2668		0.3	<0.3
Water content	ppm	D 1533		35	<20
PCB Content	ppm	D 4059	not detectable		not detectable
Electrical					
Dielectric dissipation factor at 100℃	%	D 924		0.3	<0.1
Breakdown voltage					
- As received	kV	D877	30		55
- As received	kV	D 1816 (0.08"gap)	35		50
- As processed	kV	D 1816 (0.08"gap)	56		>70
- Impulse breakdown	kV	D 3300	145		>300
Gassing tendency	µl /min	D 2300B			+35
Oxidation Stability					
After 72 h		D 2440			
- Sludge	Wt %			0.1	<0.01
- Neutralization No.	mg KOH/g			0.3	<0.01
After 164 h					
- Sludge				0.2	<0.01
- Neutralization No.				0.4	<0.01
Rotating Bomb test	minutes	D 2112	195		370
Sludge-free life	h	DOBLE	80		>88

Nytro 10XN is an inhibited insulating oil meeting ASTM D3487 type II, excluding gassing tendency, and IEC 60296 Ed.4 (2012) special applications.

Severely Hydrotreated Insulating Oil
Issuing date: 2012-04-01

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