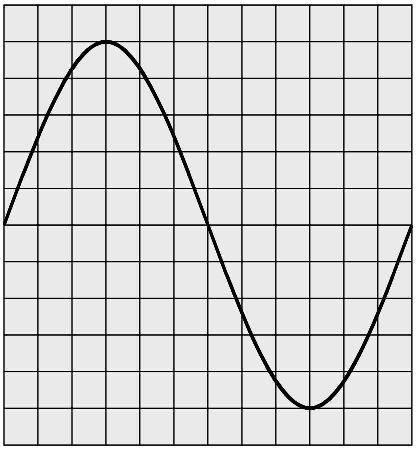

PPR-1931

Type Test Report
for
72,5 kV Heat Shrink
Outdoor Termination

Tested by: **IEH, Karlsruhe**

Date: 29.6.04

Pages: 17

Appendix: —

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Test Report No 2004-36/5

Type Test of a 72.5 kV Heat Shrink Outdoor Termination

Client: Tyco Electronics Raychem GmbH
Finsinger Feld 1
85521 Ottobrunn / Germany

Reporter: Dr.-Ing. R. Badent
Dr.-Ing. B. Hoferer

This report includes 17 numbered pages and is only valid with the original signature. Copying of extracts is subject to the written authorization of the test laboratory. The test results concern exclusively the tested objects.

1 Purpose of Test

A 72.5 kV heat shrink outdoor termination was subjected to a type test according to IEC 60840 04/2004 type test on accessories.

2 Miscellaneous Data

	Test object:	*72.5 kV - heat shrink outdoor termination*, type OHVT-72xx, Figure 1.1
	Manufacturer:	Tyco Electronics Raychem GmbH
	Type of the cable:	PEX-M-AL-LT 1 x 630 + 50
	Manufacturer:	NKT cables
Place of test:	*Institute of Electric Energy Systems and High-Voltage Technology* – University of Karlsruhe Kaiserstraße 12 – 76128 Karlsruhe	
Testing dates:	Delivery:	12.05.2004
	Mounting:	17.05. - 28.05.2004
	Test date:	28.05. - 29.06.2004
Atmospheric conditions:	Temperature:	19°C - 23°C
	Air pressure:	980 - 1020 mbar
	rel. humidity:	35% - 50%
Representatives	*Representatives responsible for the tests* Dr.-Ing. R. Badent Dr.-Ing. B. Hoferer Mr. O. Müller	

tyco
Electronics

Energy Division

72,5 kV H/S Termination

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

Unterschrift des Herstellers | Unterschrift des Prüfers

Figure 1.1: 72.5 kV - heat shrink outdoor termination

Tests: Test volume, chronological order and requirements conform to IEC 60840 04/2004 type test on accessories.

Pos. 1 Partial Discharge Test
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10 s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$ kV
no detectable discharge

Pos. 2 Heating cycle voltage test
Load cycle: 24 h
8h loading up to 95°C - 100 °C conductor temperature with at least 2h at 95°C-100°C
16h cooling
Test voltage: $\hat{u} / \sqrt{2} = 2{,}0\ U_0 = 72$ kV
Number of cycles: 20

Pos. 3 Partial Discharge Test
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10 s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$ kV
no detectable discharge

Pos. 4 Partial Discharge Test at elevated temperature
8h loading up to 95°C - 100 °C conductor temperature with at least 2h at 95°C-100°C
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10 s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$ kV
no detectable discharge

Pos.5 Lightning impulse voltage test at elevated temperature
T = 95°C-100°C, at least 2h, $\hat{u} = 325$ kV,
10 impulses each polarity

Pos.6 AC-voltage withstand test
$\hat{u} / \sqrt{2} = 2{,}5\ U_0 = 90$ kV, t = 15 min

Pos. 7 Accessory examination

3 Mounting

The cable preparation, assembling and mounting of the cable system was accomplished by technicians of Tyco Electronics Raychem GmbH in the high-voltage laboratory at IEH.

4 Test Setup

4.1 AC Voltage Withstand Test

The test voltage was generated by a 720-kVA transformer. The voltage was measured with a capacitive divider (C_H = 351 pF; ratio = 10.000:1) and a peak voltmeter reading $\hat{u} / \sqrt{2}$. The primary side of the AC-transformer was connected to a motor-generator set consisting of a variable frequency DC motor and a synchronous generator with variable excitation. The generator delivers voltages from 0 ... 500 V with currents up to 1000 A.

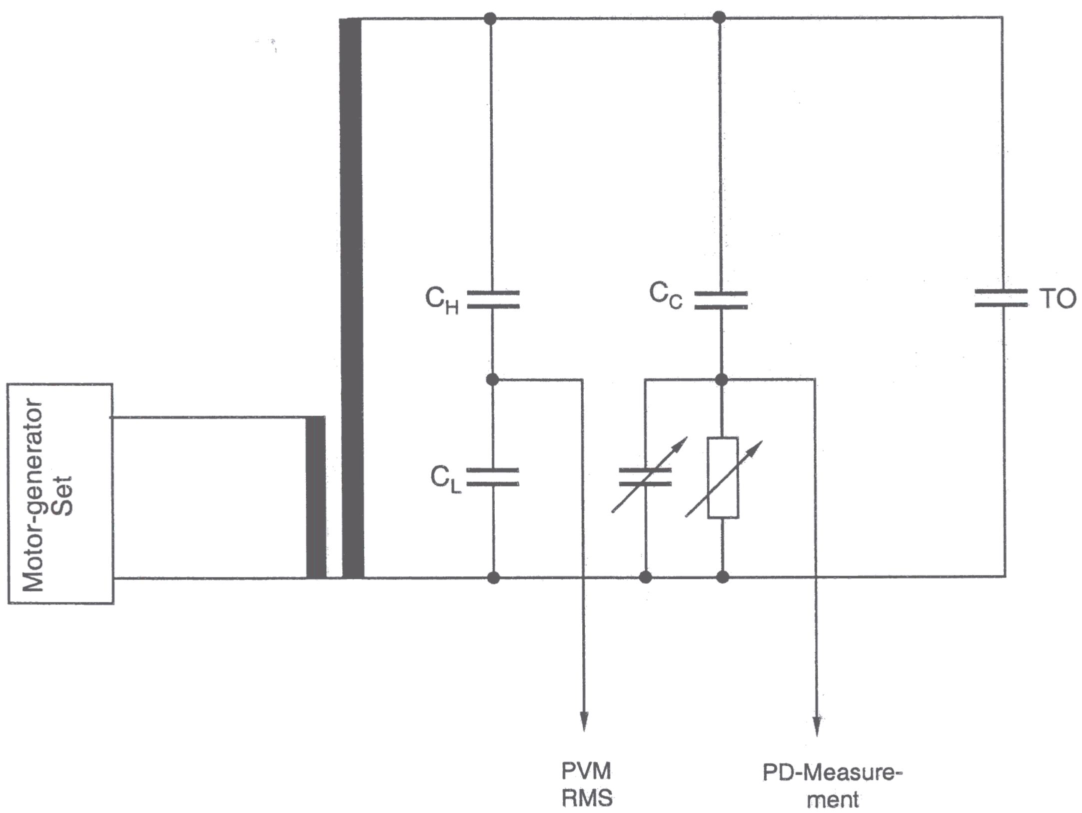

Figure 4.1: Test-setup for AC-voltage withstand test and PD measurement

AC-transformer:	500V/600kV; S_N = 720 kVA
Voltage measurement:	C_H = 351 pF; ratio 10.000:1 uncertainty 3 %
PD measurement:	C_C = 1000 pF; U_N = 800 kV_{rms} uncertainty 5 %

4.2 Partial-Discharge Test

The PD-measurement was performed with an analog bridge according to *Kreuger*, Figure 4.2. External PDs producing common mode signals at the detector are rejected by the differential amplifier. Internal PDs represent differential mode signals and are amplified. The background noise level at 54 kV_{rms} was 1,0 pC.

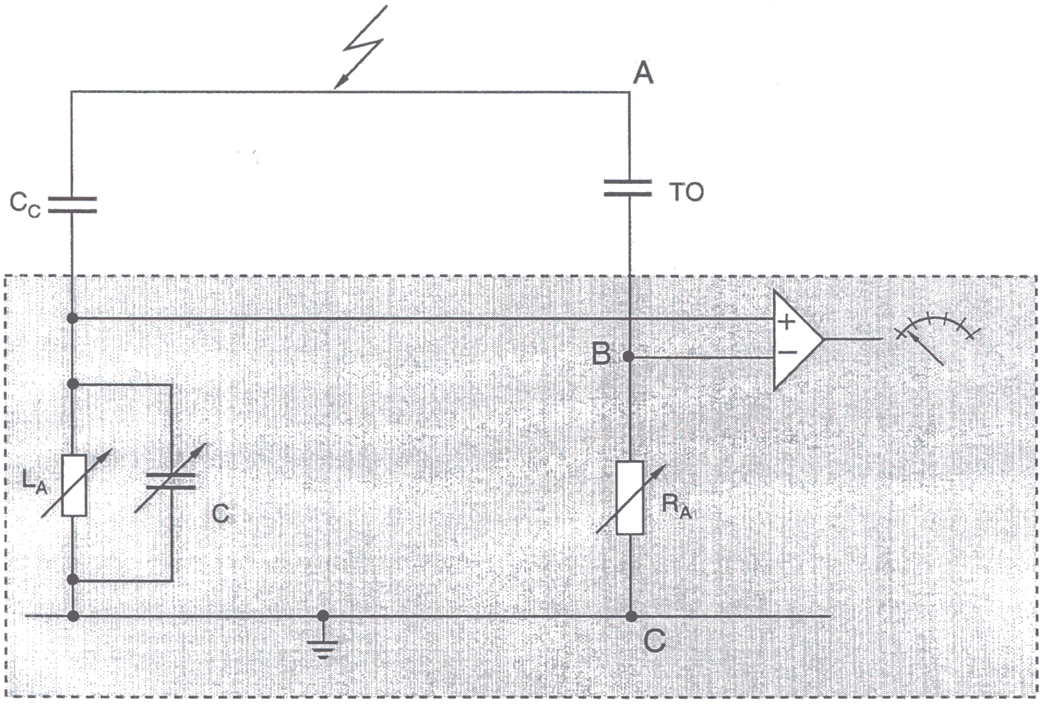

Figure 4.2: Scheme of PD test circuit
TO : Test object
C_C: Coupling Capacitor

For balancing the bridge a calibrating impulse with q_A = 10.000 pC is applied between the terminals A (high-voltage) and C (ground) and the amplifier output is minimized. A pulse between the terminals A and C corresponds to an external PD. For the calibration a PD pulse, q_A = 5 pC, is applied between A and B. Subsequently, the amplifier output of the PD measuring unit is adapted to the applied pulse.

4.3 Cyclic Current Loading

According to IEC 60840 and additional customer´s specification the test objects must be heated by a current which provides the permitted service temperature of the tested cable plus 5 K - 10 K, that means 95°C - 100°C, for XLPE-cable. The required heating current I was determined via a dummy cable. A 4 m sample of the cable used for the test, was provided with a 2 mm diameter drilling hole down to the center conductor. The temperature was measured with a thermo couple NiCr-Ni. Furthermore two additional thermocouples NiCr-Ni were placed on the outer sheath of the cable, one on the dummy and one on the test loop. Figure 4.3 illustrates the temperature rise at the conductor with a heating current of I = 1250 A, 6h and thereafter I = 1200 A, 2h. Current inception was accomplished by two transformers (U_1 = 400 V; U_2 = 20 V) which used the cable as secondary winding. The current was measured by a current transformer, 5000/5, and a digital multimeter. The measurement uncertainty was 1%.

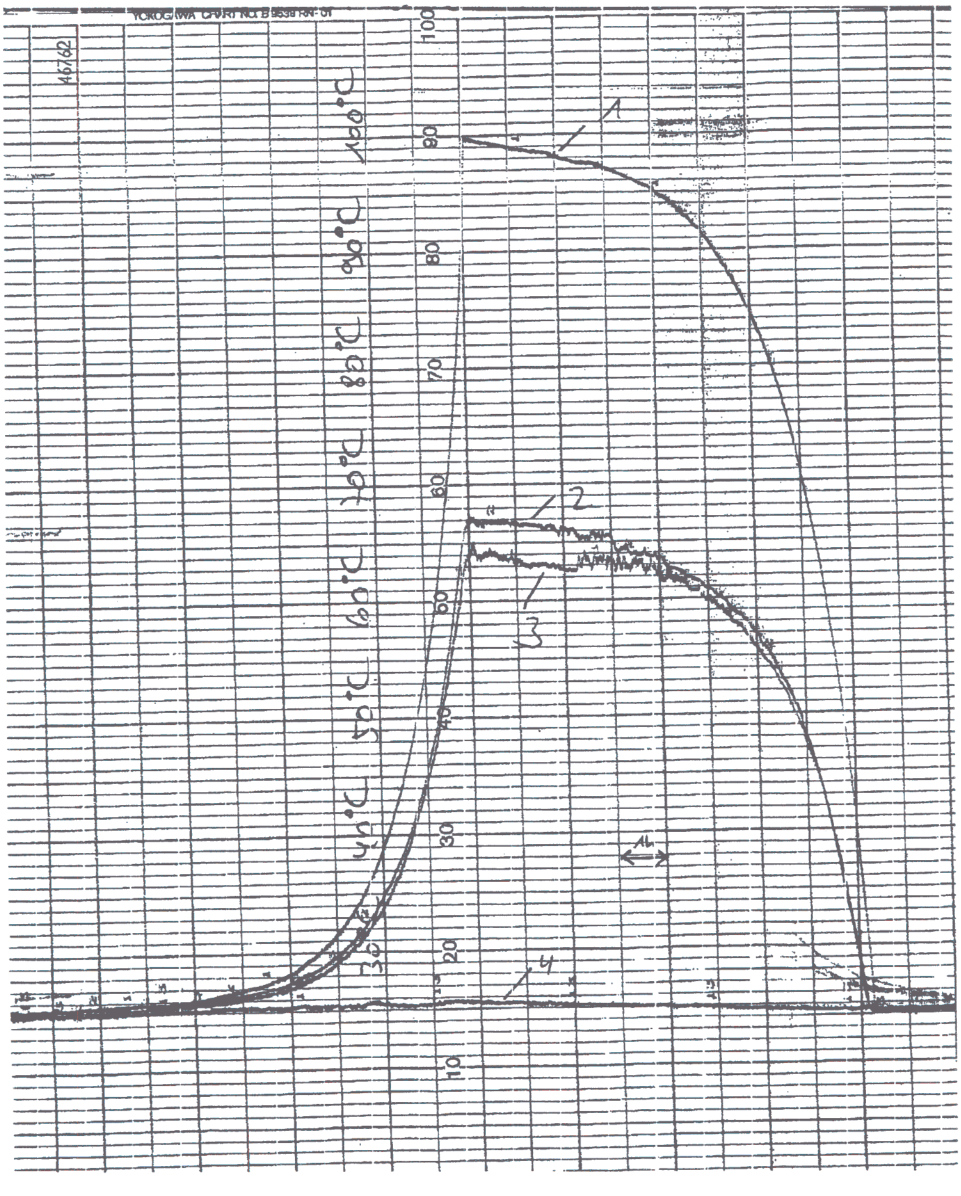

Figure 4.3: Heat cycle I = 1250 A, 6h; I = 1200 A, 2 h; I = 0A, 16 h
1: Conductor temperature; 2: Cable jacket temperature test loop;
3: Cable jacket temperature dummy; 4: Temperature HV-laboratory

4.4 Lightning Impulse Voltage Test

For lightning impulse testing 3 stages of a Marx generator (Haefely) with a maximum cumulative voltage of U = 600 kV and a maximum impulse energy of E_{max} = 30 kWs were used. The crest value of the impulse voltage was measured by a damped capacitive divider and a subsequent impulse peak voltmeter (Haefely). The front time and the time to half value were evaluated from the oscillographs.

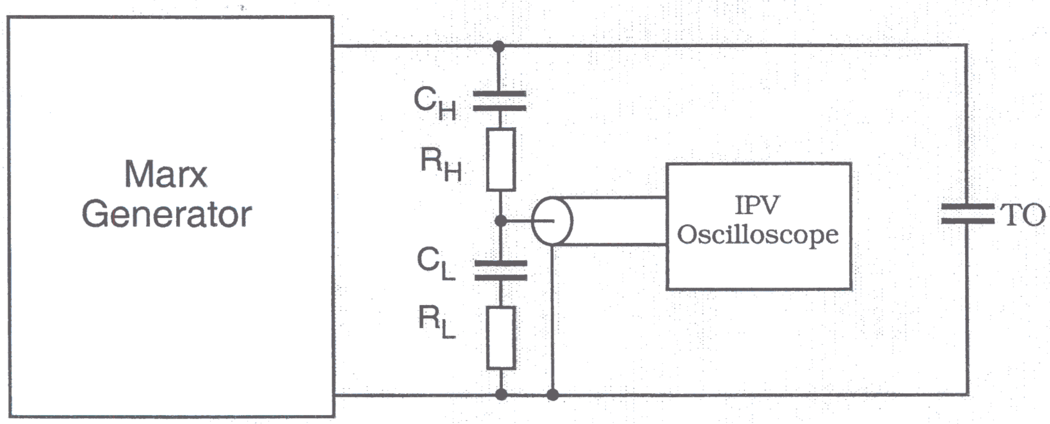

Figure 4.4: Scheme of lightning impulse voltage test circuit
C_H: 1200 pF ; R_H = 70 Ω ; ratio: 3225;
IPV: impulse-peak-voltmeter (Haefely) – measurement uncertainty 3%
Oscilloscope: Tektronix 2430 A – measurement uncertainty 2%

The waveform parameters were determined at reduced charging voltage. Figure 4.5 shows the front time, Figure 4.6 the time to half value for positive polarity each. Figure 4.7 shows the front time, Figure 4.8 the time to half value for negative polarity each.

Positive impulse:	T_1 = 4.44 µs	T_2 = 56.3µs
Negative impulse:	T_1 = 4.34 µs	T_2 = 56.0 µs

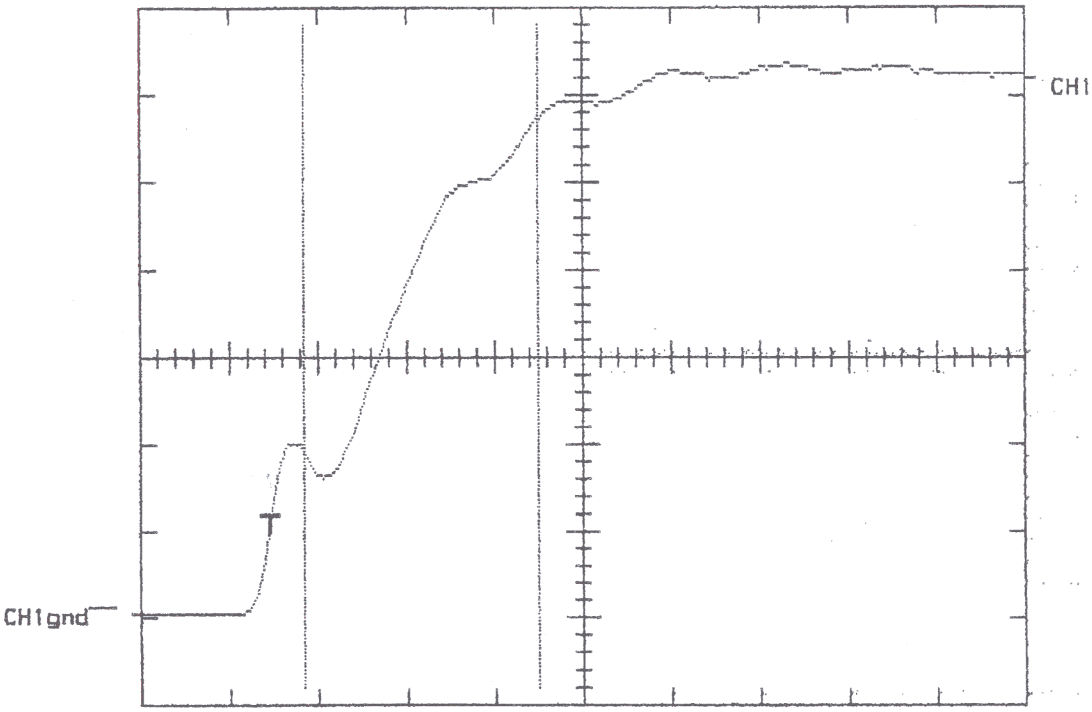

Figure 4.5: Front time, positive polarity
horiz.: 1 µs/Div; vert.: 500 mV/Div; probe 10:1; ratio 3225:1

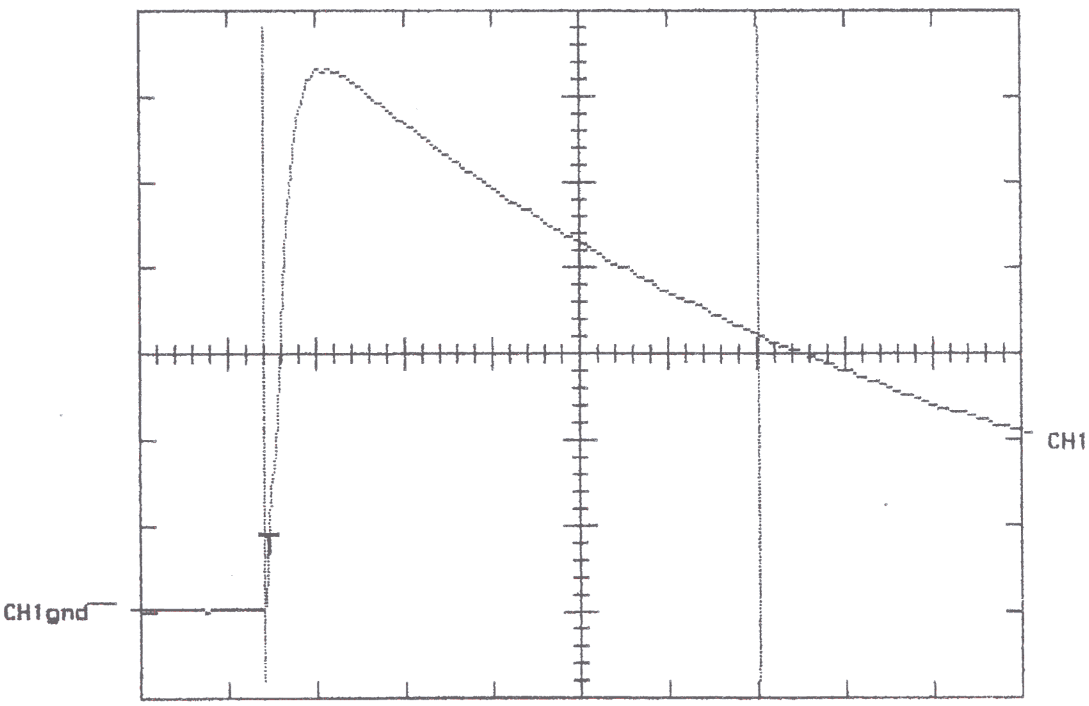

Figure 4.6: Time to half value, positive polarity
horiz.: 10 µs/Div; vert.: 500 mV/Div; probe 10:1; ratio 3225:1

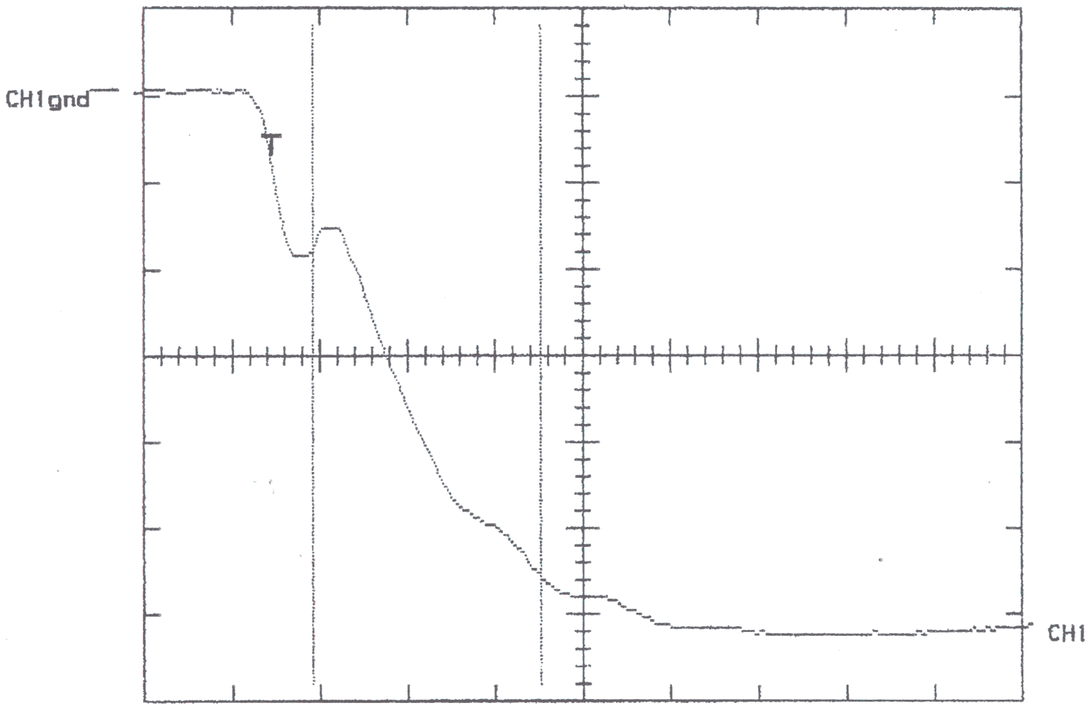

Figure 4.7: Front time, negative polarity
horiz.: 1 µs/Div; vert.: 500 mV/Div; probe 10:1; ratio 3225:1

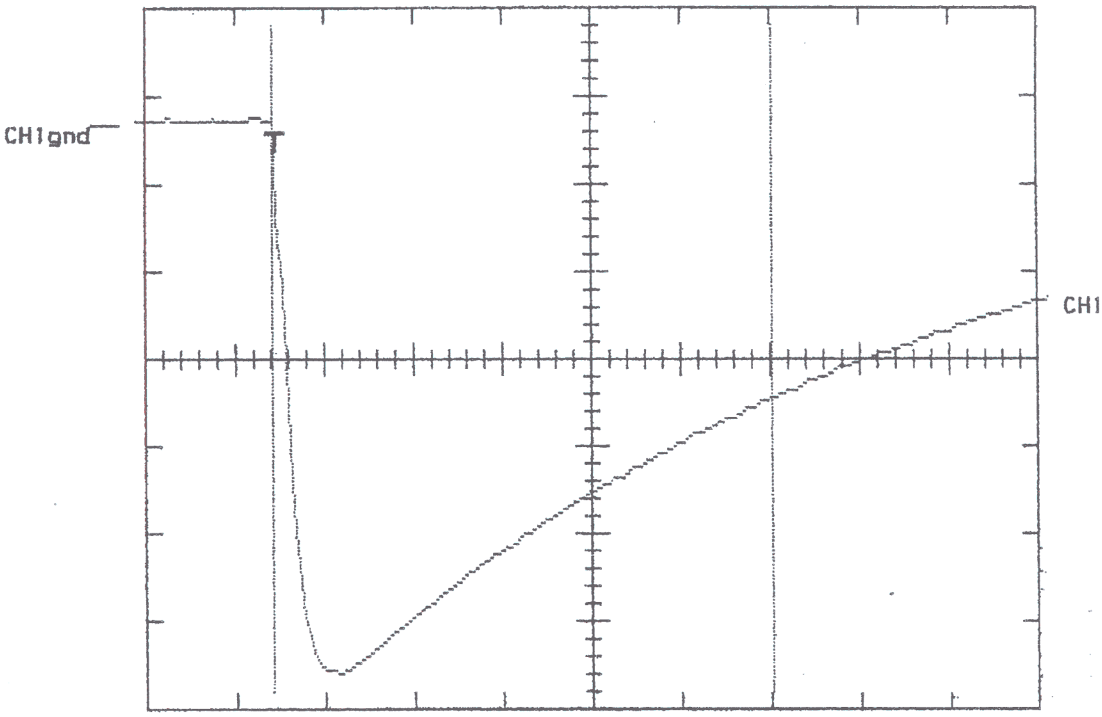

Figure 4.8: Time to half value, negative polarity
horiz.: 10 µs/Div; vert.: 500 mV/Div; probe 10:1; ratio 3225:1

5 Results

5.1 PD-Test

The test was carried out as described in 4.1 and 4.2.

Test date:	28.05.2004
Calibration pulse:	$q_{cal} = 5$ pC
Background noise level:	1.0 pC
Test voltage:	$\hat{u} / \sqrt{2} = 63$ kV; t = 10 s, thereafter
	$\hat{u} / \sqrt{2} = 54$ kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.2 Heating cycle voltage test

The test was carried out as described in 4.1 and 4.3.

Test date:	09.06. - 29.06.2004
Test voltage:	$\hat{u} / \sqrt{2} = 72$ kV
Heating current:	I = 1250 A, 6h
	I = 1200 A, 2h
	I = 0A, 16 h
Cycle:	8 h heating; 16 h cooling
Number of cycles:	20

Neither breakdown nor flashover occurred.

The test was passed successfully

5.3 PD-Test

The test was carried out as described in 4.1 and 4.2.

Test date:	29.06.2004
Calibration pulse:	$q_{cal} = 5$ pC
Background noise level:	1.0 pC
Test voltage:	$\hat{u} / \sqrt{2} = 63$ kV; t = 10 s, thereafter
	$\hat{u} / \sqrt{2} = 54$ kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.4 PD-Test at elevated temperature

The test was carried out as described in 4.1, 4.2 and 4.3.

Test date:	29.06.2004
Calibration pulse:	q_{cal} = 5 pC
Background noise level:	1.0 pC
Heating current:	I = 1250 A, 6 h
	I = 1200 A, 2 h
Temperature:	T = 96,2°C
Test voltage:	$\hat{u} / \sqrt{2}$ = 63 kV; t = 10s, thereafter
	$\hat{u} / \sqrt{2}$ = 54kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.5 Lightning Impulse Voltage Withstand Test at elevated temperature

This test was carried out as described in 4.3 and 4.4.

Test date:	29.06.2004
Test voltage:	$\hat{u}$ = 325 kV
Temperature:	T = 97,2°C
Impulse:	1-5µs / 40-60 µs
Number of tests:	10 positive polarity, 10 negative polarity

Neither flashover nor breakdown occurred at the test objects during all lightning impulse voltage tests.

The test was passed successfully

Table 1 shows the test results with positive polarity, table 2 with negative polarity.

number	charging voltage / kV	û / kV	Figure	remark
1	40,0	102,6		front time,
2	40,0	102,4		time to half value
3	63,5	164,6		50%
4	88,2	229		70%
5	113,4	297		90%
6	124,1	327	5.1	1. 100%
7	124,1	326	5.1	2. 100%
8	124,1	327	5.1	3. 100%
9	124,1	325	5.1	4. 100%
10	124,1	325	5.1	5. 100%
11	124,1	325	5.2	6. 100%
12	124,1	325	5.2	7. 100%
13	124,1	325	5.2	8. 100%
14	124,1	325	5.2	9. 100%
15	124,1	325	5.2	10. 100%

Table 1: Lightning impulse voltage withstand test, positive polarity

number	charging voltage / kV	û / kV	Figure	remark
1	- 40,0	- 101,4		front time,
2	- 40,0	- 101,3		time to half value
3	- 63,5	- 163,5		50%
4	- 88,2	- 229		70%
5	- 113,3	- 293		90%
6	- 124,1	- 325	5.3	1. 100%
7	- 124,1	- 325	5.3	2. 100%
8	- 124,1	- 325	5.3	3. 100%
9	- 124,1	- 325	5.3	4. 100%
10	- 124,1	- 322	5.3	5. 100%
11	- 124,1	- 324	5.4	6. 100%
12	- 124,1	- 324	5.4	7. 100%
13	- 124,1	- 324	5.4	8. 100%
14	- 124,1	- 325	5.4	9. 100%
15	- 124,1	- 325	5.4	10. 100%

Table 2: Lightning impulse voltage withstand test, negative polarity

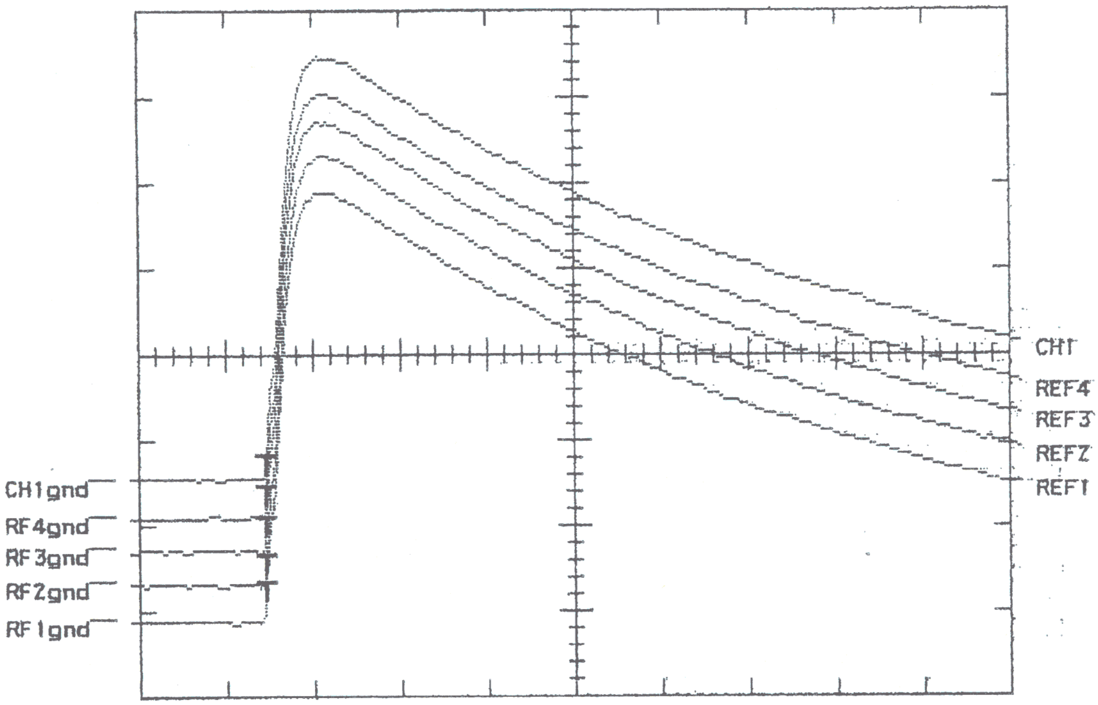

Figure 5.1: 100%-stress 1 - 5, positive polarity
Hor.: 10µs/Div; Vert.: 2V/Div; probe 10:1; ü = 3225

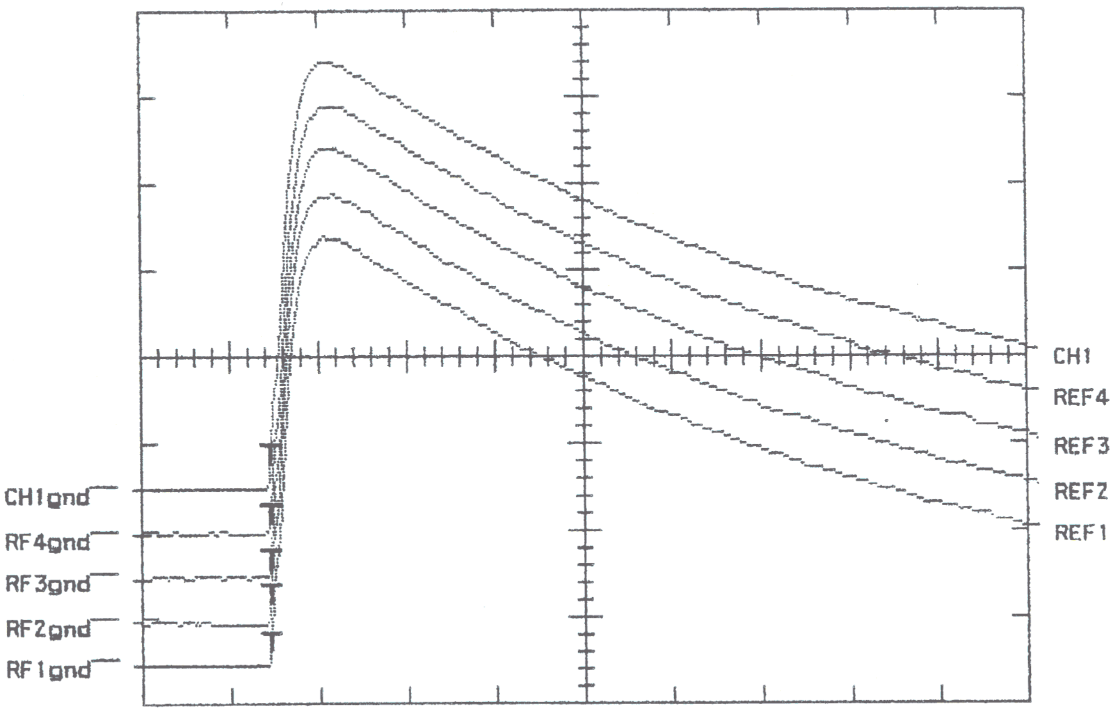

Figure 5.2: 100%-stress 6 - 10, positive polarity
Hor.: 10µs/Div; Vert.: 2V/Div; probe 10:1;ü = 3225

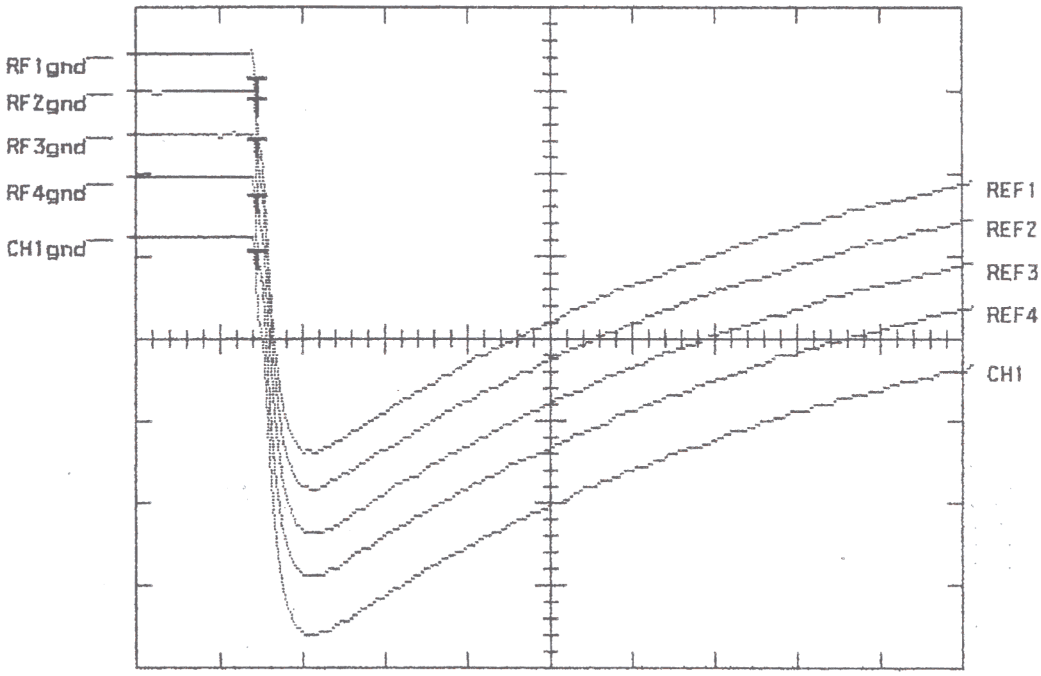

Figure 5.3: 100%-stress 1 - 5, negative polarity
Hor.: 10µs/Div; Vert.: 2V/Div; probe 10:1; ü = 3225

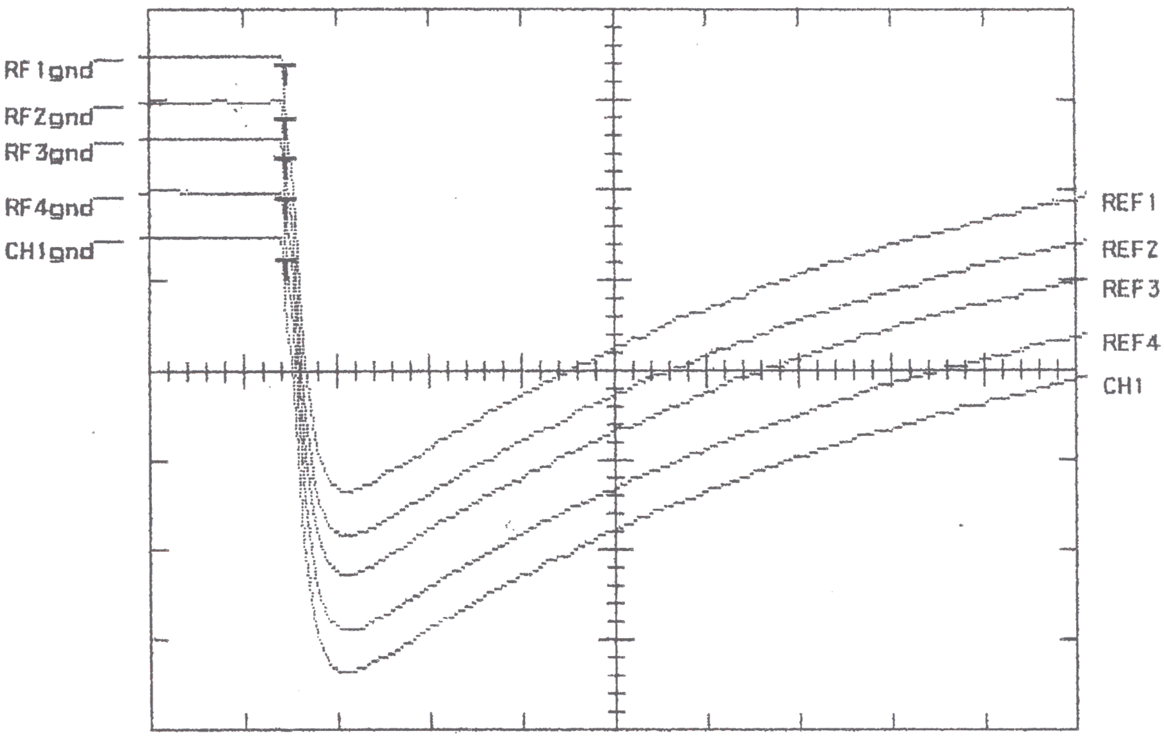

Figure 5.4: 100%-stress 6 - 10, negative polarity
Hor.: 10µs/Div; Vert.: 2V/Div; probe 10:1; ü = 3225

5.6 AC Voltage Withstand Test

The test was carried out as described in 4.1 and 4.3

Test date: 29.06.2004

Test voltage: $\hat{u} / \sqrt{2} = 90$ kV; t = 15 min

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.7 Cable and Accessory Examination

On completion of the electrical tests the accessories were examined. There was no evidence of electrical activity.

The test was passed successfully.

6 Conclusion

The 72.5 kV - heat shrink outdoor termination, type OHVT-72xx, manufacturer Tyco Electronics Raychem GmbH, passed all tests described in Chapter 2 successfully. The test object fulfilled the requirements according IEC 60840 04/2004 type test on accessories.

Karlsruhe, 13.08.2004

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Dr.-Ing. B. Hoferer
stellv. Bereichsleiter HPT