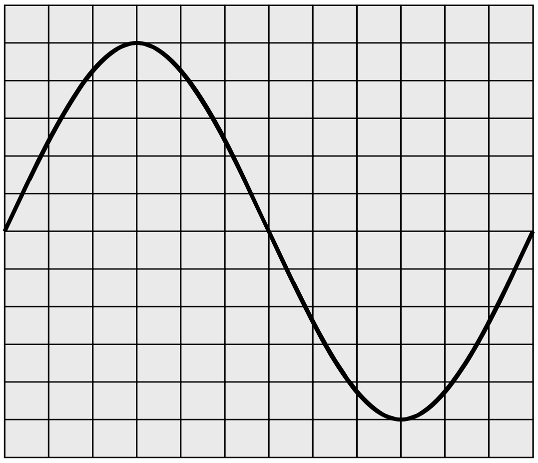

PPR-2476

Type Test Report
for
72,5 kV Heat Shrink
Shield Break Joint
according to IEC 60840

Tested by: TH Karlsruhe

Date: April 2008

Pages: 18

Appendix: —

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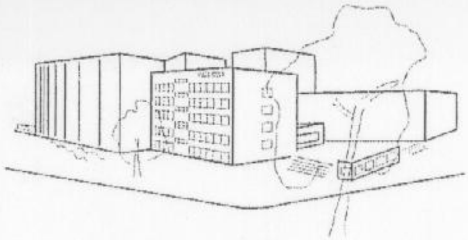
Energy Division

Tyco Electronics
Our commitment. Your advantage.

Bereich Hochspannungsprüftechnik
Institut für Elektroenergiesysteme und Hochspannungstechnik



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Test Report No 2007-179

Type Test
of a 72,5 kV- Shield Break Joint
Type EHVS-72

Client: Tyco Electronics Raychem GmbH
Finsinger Feld 1

85521 Ottobrunn

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

1 Purpose of Test

One 72,5 kV shield break joint type EHVS-72 was subjected to a type test according to IEC 60840 04/2004, " type test on accessories".

2 Miscellaneous Data

Test object:	*1 shield break joint type EHVS-72* Drawing No. EPD-204-620-00-A4-0 dated 18.01.2005, Figure 2.1 Type of the cable: single core XLPE cable with aluminium conductor 2006 ENDESA-KNE 001 PRYSMIAN 36/66 (72,5)kV-XLPE 1x1000KAL-H95-CU Cable length between accessories: 6 m
Hersteller:	Tyco Electronics Raychem GmbH Finsinger Feld 1 85521 Ottobrunn
Place of test:	*Institute of Electric Energy Systems and High-Voltage Technology* – University of Karlsruhe, Kaiserstraße 12 – 76128 Karlsruhe
Testing dates:	Delivery: 17.12.2007 Mounting: 17.12. - 20.12.2007 Test date: 20.12.2007 - 01.02.2008
Atmospheric conditions:	Temperature: 19°C - 23°C Air pressure: 980 - 1020 mbar rel. humidity: 35% - 50%
Representatives	*Client´s representatives* Dipl.-Ing. Th. Kranz, Tyco Electronics Raychem GmbH *Representatives responsible for the tests* Dr.-Ing. R. Badent ; Dr.-Ing. B. Hoferer; Mr. O. Müller

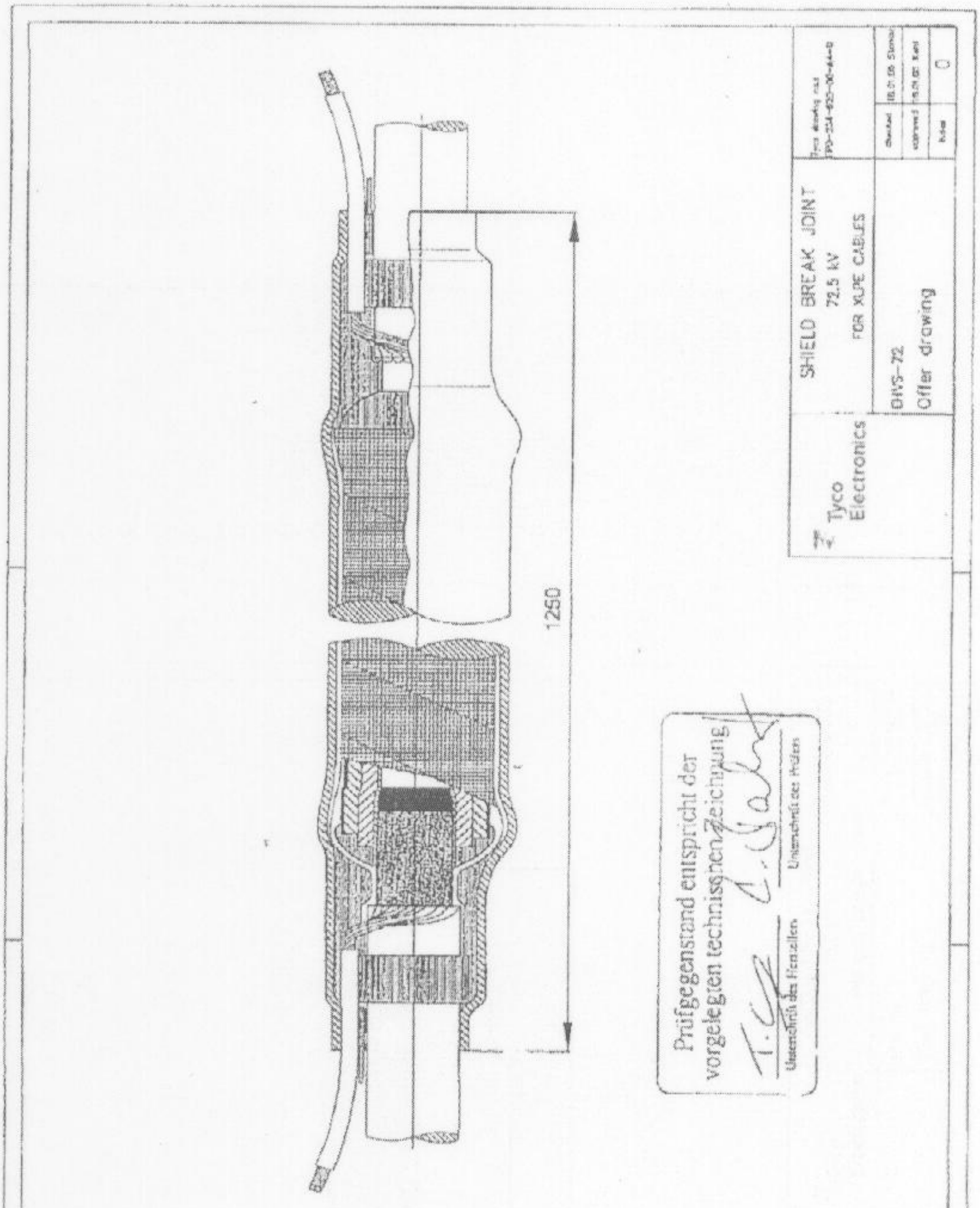

Figure 2.1: shield break joint type EHVS-72

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

Pos. 1 Check on Insulation Thickness

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

Pos. 3 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. 4 Partial Discharge Test
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$kV
no detectable discharge

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

Pos. 6 Lightning impulse voltage test at elevated temperature
T = 95°C-100°C, at least 2h, $\hat{u} = 325$ kV,
10 impulses each polarity

Pos. 7 AC-voltage withstand test during cooling period
$\hat{u} / \sqrt{2} = 2{,}5\ U_0 = 90$ kV, t = 15 min

Pos. 8 Cable and acessory examination

3 Mounting

The cable preparation, assembling and mounting of the cable system was accomplished by technicians of Tyco Electronics Raychem GmbH. The length of free cable between accessories was 6 m.

4 Test Setup

4.1 Check on Insulation Thickness

The insulation thickness was measured as described in IEC 60811-1-1, chapter 8.1. For measuring the insulation thickness a profile projector with a magnification of 10 was used which allowed a reading of 0.001 mm.

4.2 AC Voltage Withstand Test

The test voltage was generated by a 360-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.

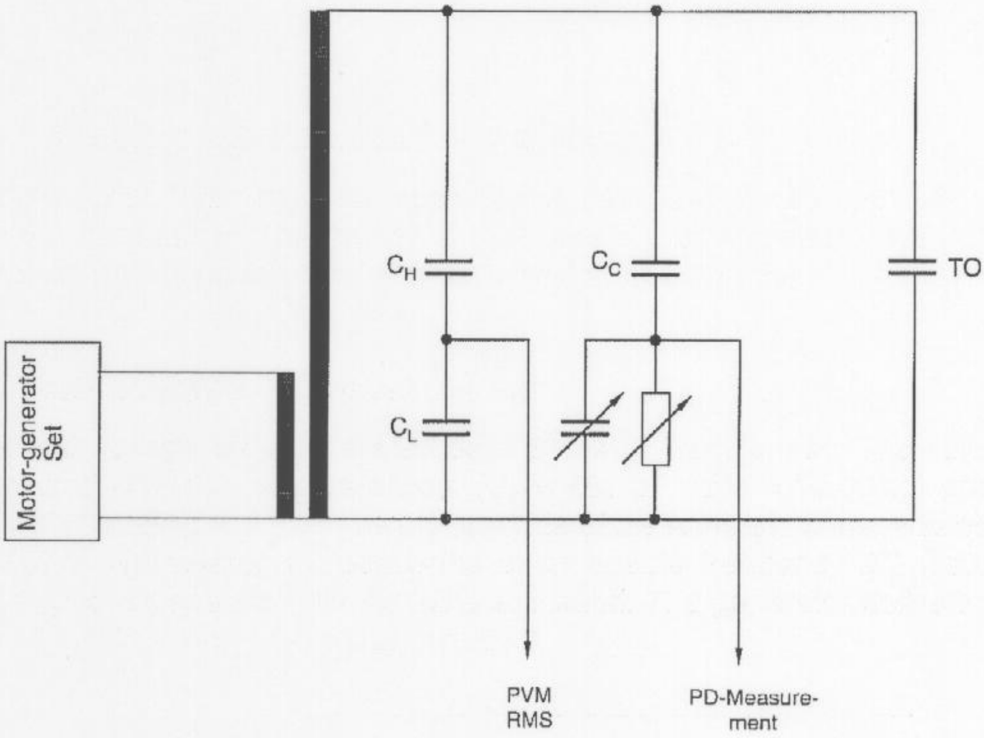

Figure 4.2: Test-setup for AC-voltage withstand test and PD measurement

AC-transformer:	500V/300kV; S_N = 360 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 %

4.3 Partial-Discharge Test

The PD-measurement was performed with an analog bridge according to *Kreuger*, Figure 4.3. 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 1.5 pC.

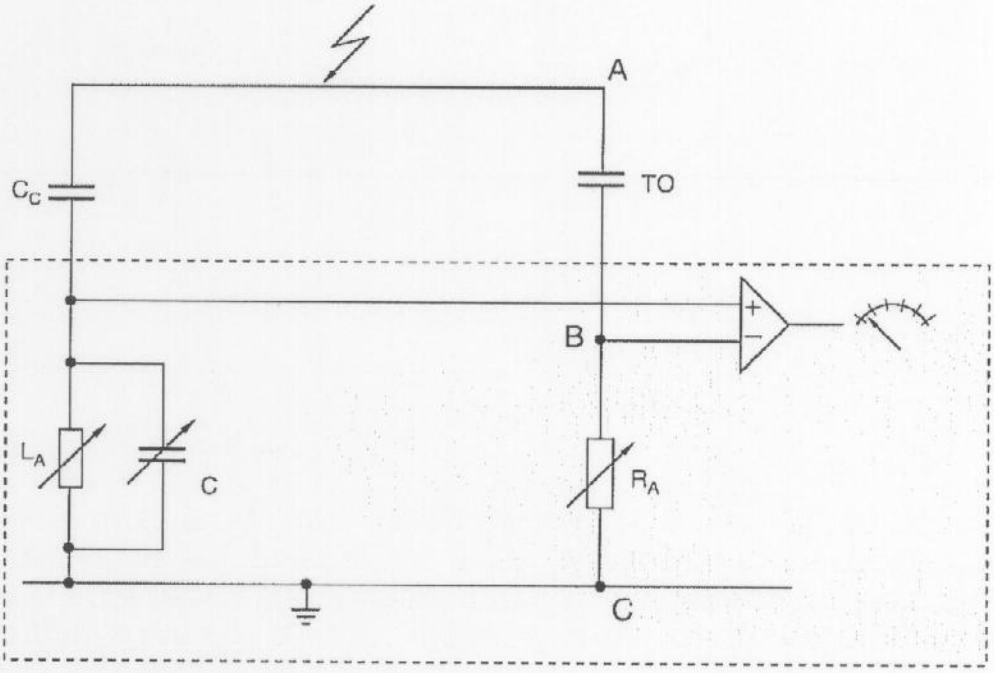

Figure 4.3: Scheme of PD test circuit
TO: Test object
C_C: Coupling Capacitor

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.

4.4 Cyclic Current Loading

According to IEC 60840 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 6 m sample of the cable used for the test, was provided with a 1 mm diameter drilling hole down to the center conductor. The temperature was measured with thermocouples NiCr-Ni. Two other thermocouples were installed on the conductor of the reference cable 0.5 m away from the middle and 1.0 m away from the middle. The difference between the three readings was less than 1°C. 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 4.4 illustrates the temperature rise at the conductor with a heating current of I = 1650 A, 8h. Current inception was accomplished by a transformer (U_1 = 400 V; U_2 = 20 V) which used the cable as secondary winding. The current was regulated by a control unit and measured by a current transformer, 3000:1, and a digital multimeter. The measurement uncertainty was 1%.

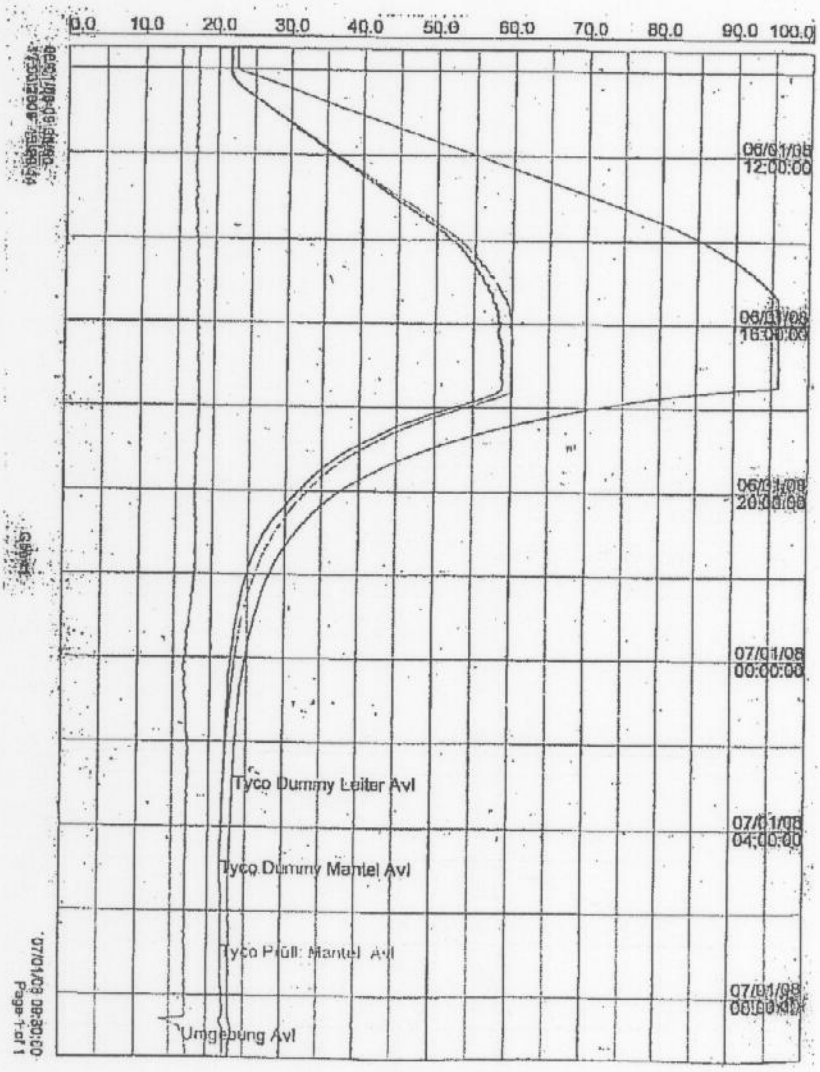

Figure 4.4: Heat cycle I = 1650 A, 8h; I = 0A, 16 h
1: Conductor temperature; 2: Cable jacket temperature test loop;
3: Cable jacket temperature dummy; 4: Temperature HV-laboratory

4.5 Lightning Impulse Voltage Test

For lightning impulse testing of the cable system 4 stages of a Marx generator (Haefely) with a maximum cumulative charging voltage of U = 800 kV and a maximum impulse energy of E_{max} = 40 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 time to crest and the time to half value were evaluated from the oscillographs.

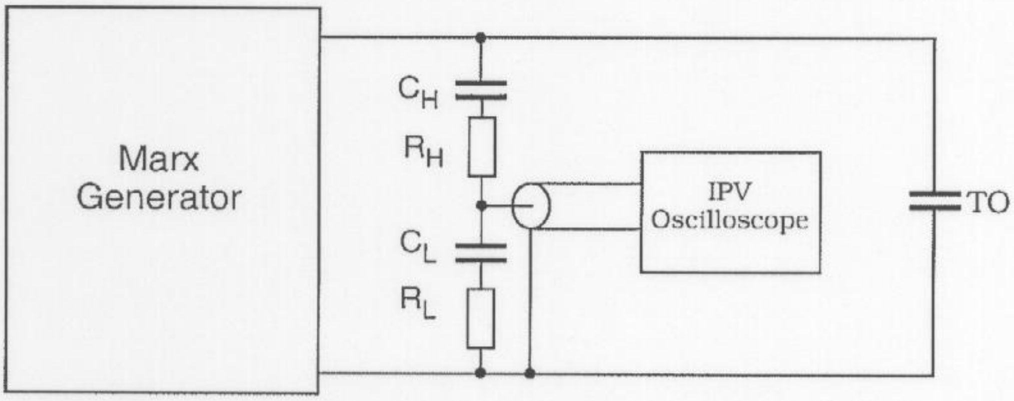

Figure 4.5.1: Scheme of switching impulse voltage test circuit
C_H: 1200 pF ; R_H = 70 Ω ; ratio: 3225;
IPV: impulse-peak-voltmeter (Haefely), measurement uncertainty 3%
Oscilloscope: Tektronix TDS 3044B – measurement uncertainty 2%

The waveform parameters were determined at reduced charging voltage. Figure 4.5.2 shows the front time, Figure 4.5.3 the time to half value for positive polarity each. Figure 4.5.4 shows the front time, Figure 4.5.5 the time to half value for negative polarity each.

Positive impulse: :	T_1 = 1.85 µs	T_2 = 49.2 µs
Negative impulse:	T_1 = 1.82 µs	T_2 = 48.0 µs

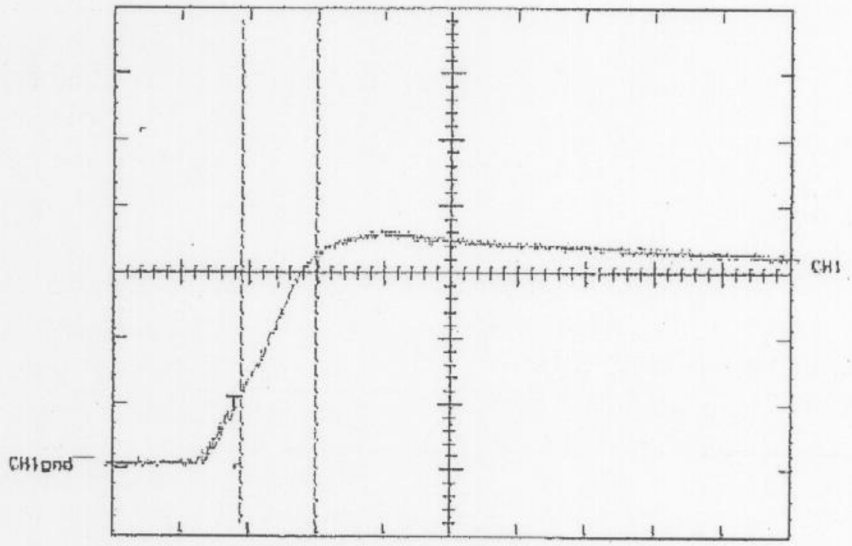

Figure 4.5.2: Front time, positive polarity
horiz.: 1 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

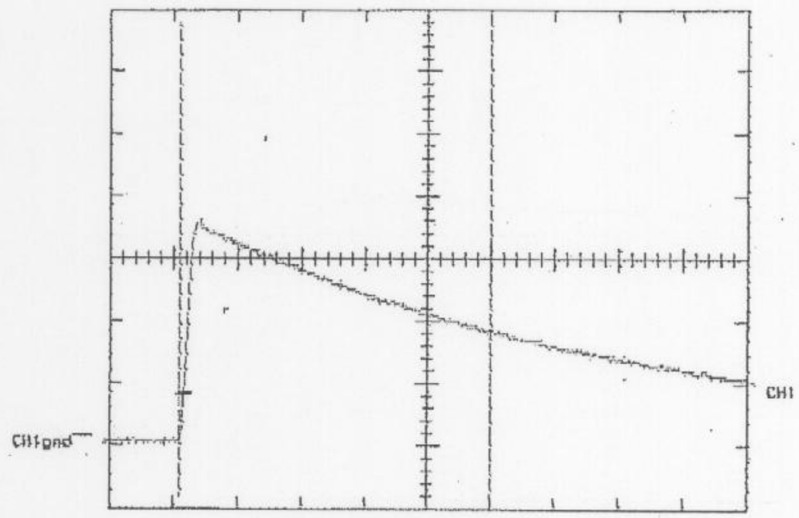

Figure 4.5.3: Time to half value, positive polarity
horiz.: 10 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

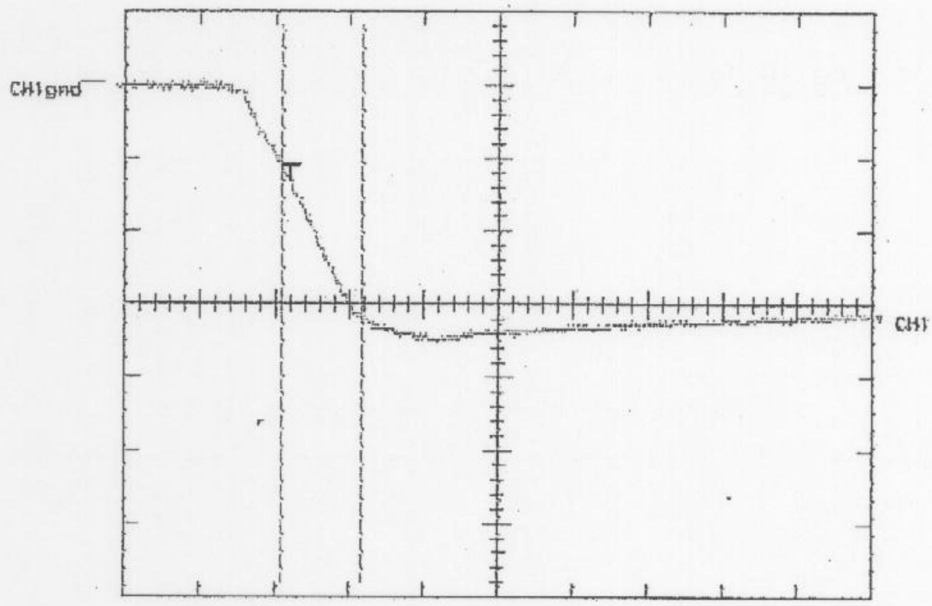

Figure 4.5.4: Front time, negative polarity
horiz.: 1 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

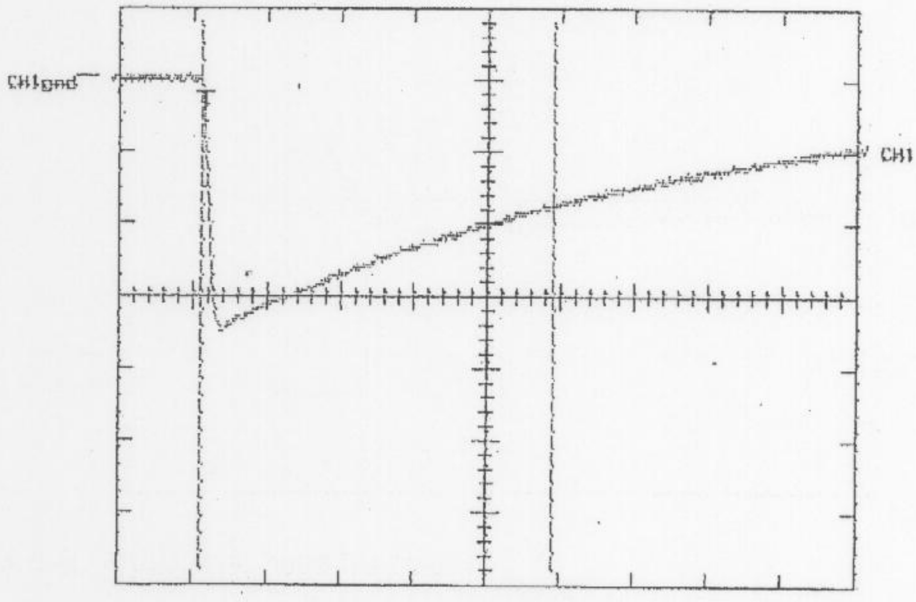

Figure 4.5.5: Time to half value, negative polarity
horiz.: 10 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

5 Results

5.1 Check on Insulation Thickness

The test was carried out as described in 4.

Test date:	19.12.2007
Measured Values:	9.15 mm
	9.35 mm
	10.02 mm
	9.81 mm
	10.17 mm
	11.31 mm
Average Value:	9.97 mm

5.2 PD-Test

The test was carried out as described in 4.

Test date:	20.12.2007
Calibration pulse:	$q_{cal} = 5$ pC
Background noise level:	1.5 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.

Test date:	22.12.2007 - 11.01.2008
Test voltage:	$\hat{u}/\sqrt{2} = 72$ kV
Heating current:	I =1650 A, 8h
	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

5.4 PD-Test

The test was carried out as described in 4.

Test date:	12.01.2008
Calibration pulse:	$q_{cal} = 5$ pC
Background noise level:	1.5 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

5.5 PD-Test at elevated temperature

The test was carried out as described in 4.

Test date:	12.01.2008
Calibration pulse:	$q_{cal} = 5$ pC
Background noise level:	1.5 pC
Heating current:	I = 1650 A, 8 h
Temperature:	T = 96,0°C
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

5.6 Lightning Impulse Voltage Withstand Test at elevated temperature

This test was carried out as described in 4.

Test date:	31.01.2008
Test voltage:	$\hat{u} = 325$kV
Temperature:	T = 96,2°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	30,0	112,2		front time,
2	30,0	112,6		time to half value
3	43,0	162,0		50%
4	60,6	227		70%
5	77,4	292		90%
6	86,1	326	5.1	1. 100%
7	86,1	325	5.1	2. 100%
8	86,1	325	5.1	3. 100%
9	86,1	325	5.1	4. 100%
10	86,1	325	5.1	5. 100%
11	86,1	326	5.2	6. 100%
12	86,1	325	5.2	7. 100%
13	86,1	325	5.2	8. 100%
14	86,1	326	5.2	9. 100%
15	86,1	326	5.2	10. 100%

Table 1: Lightning impulse voltage withstand test, positive polarity

number	charging voltage / kV	û / kV	Figure	remark
1	- 30,0	- 112,5		front time,
2	- 30,0	- 112,2		time to half value
3	- 43,0	- 161,6		50%
4	- 60,0	- 226		70%
5	- 77,4	- 292		90%
6	- 86,1	- 325	5.3	1. 100%
7	- 86,1	- 325	5.3	2. 100%
8	- 86,1	- 325	5.3	3. 100%
9	- 86,1	- 325	5.3	4. 100%
10	- 86,1	- 325	5.3	5. 100%
11	- 86,1	- 325	5.4	6. 100%
12	- 86,1	- 325	5.4	7. 100%
13	- 86,1	- 325	5.4	8. 100%
14	- 86,1	- 325	5.4	9. 100%
15	- 86,1	- 325	5.4	10. 100%

Table 2: Lightning impulse voltage withstand test, negative polarity

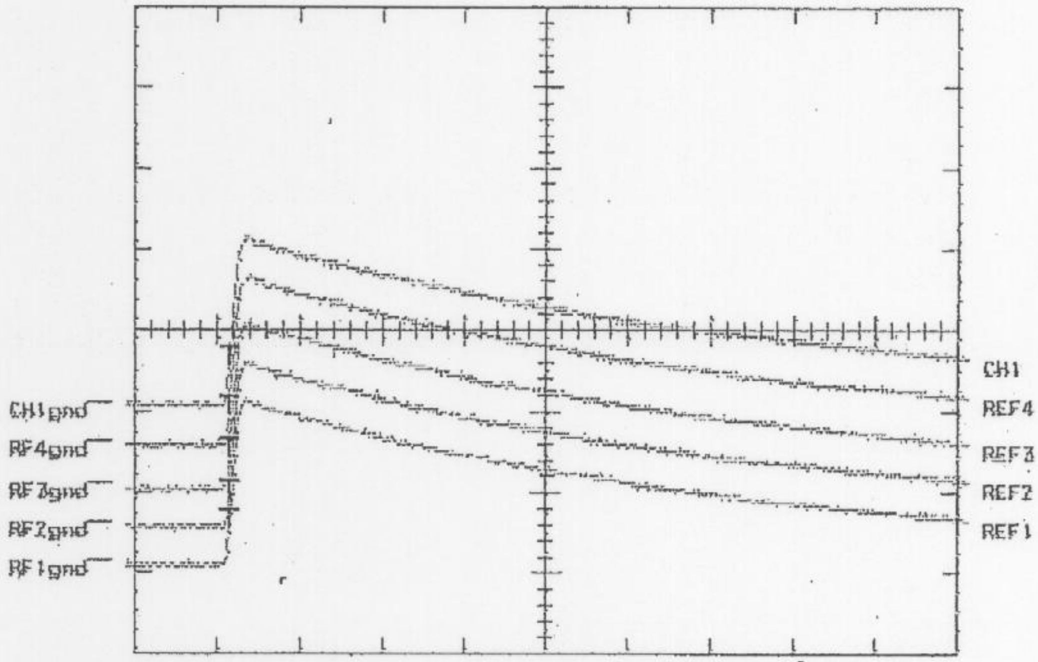

Figure 5.1: 100%-stress 1 - 5, positive polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

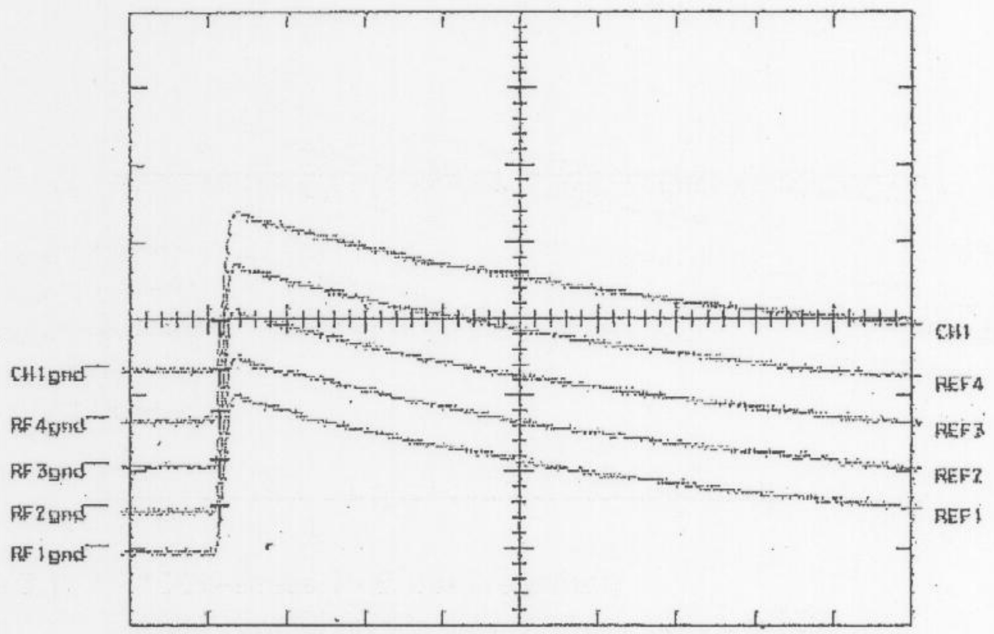

Figure 5.2: 100%-stress 6 - 10, positive polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1;ü = 3225

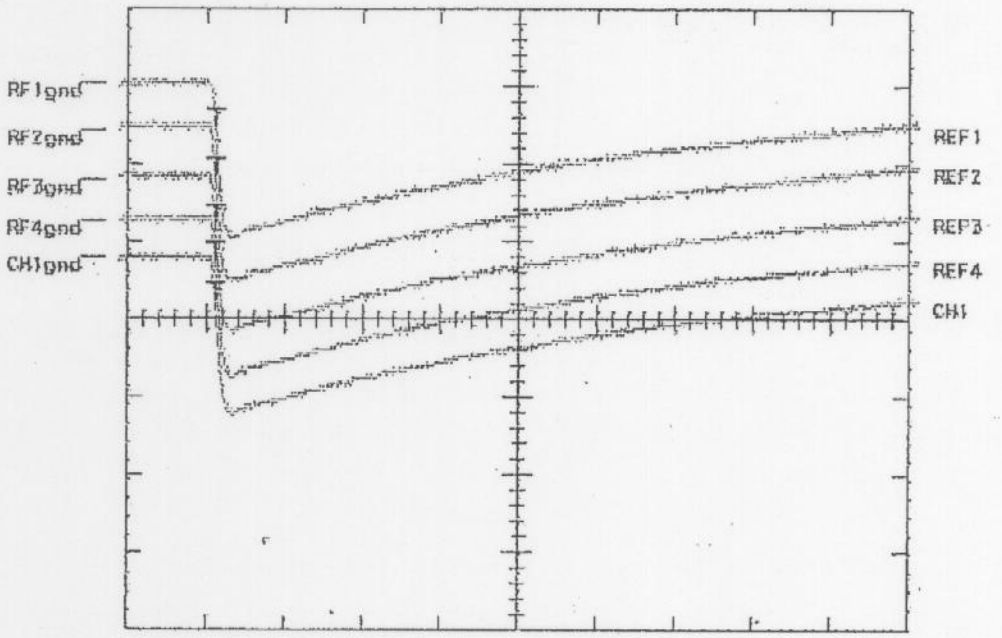

Figure 5.3: 100%-stress 1 - 5, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

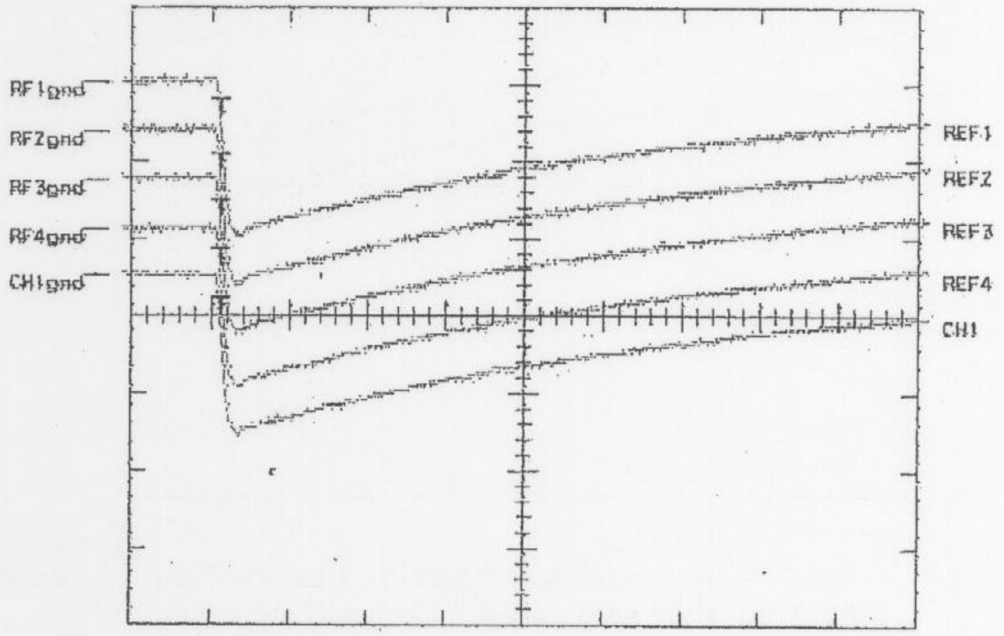

Figure 5.4: 100%-stress 6 - 10, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

5.7 AC Voltage Withstand Test during cooling period

The test was carried out as described in 4.

Test date: 01.02.2008

Temperature: $T = 27.2°C$

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

Neither breakdown nor flashover occurred.

The test was passed successfully.

6 Conclusion

The shield break joint type EHVS-72 U_m=72,5 kV, 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, 03.04.2008

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Bereichsleiter HPT

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