

Test Report No 2009-124

**Type Test
of a 72,5 kV- Molded
Rubber Termination QTEN**

Client: 3M Deutschland GmbH
Carl-Schurzstr.1
41453 Neuss

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

This report includes 28 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-Molded Rubber Termination was subjected to a type test according to IEC 60840 04/2004 type test on accessories, chapter 14.3.2 and additional customer's specification.

2 Miscellaneous Data

Test object:	<i>72,5 kV - Molded Rubber Termination for outdoor application 3 M QTEN Type 96-EP 720-2 , XE - 0091 - 3568 - 4 Installation instruction AABBCC 75657 from 02.02.2010, Figure 2.1 - 2.8 Material list AABBCC 75665 from 02.02.2010, Figure 2.9</i> - The termination was mounted on a single core XLPE insulated cable with Aluminium conductor 1000mm ² , 66 (72,5) kV, nominal insulation thickness 9 mm ² , Figure 2.10.		
Manufacturer:	3M Deutschland GmbH Carl-Schurzstr. 1 41453 Neuss		
Place of test:	<i>Institute of Electric Energy Systems and High-Voltage Technology</i> – University of Karlsruhe Kaiserstraße 12 – 76128 Karlsruhe		
Testing dates:	Delivery:	14.12.2009	
	Mounting:	14.12. – 17.12.2009	
	Test date:	18.12.2009 – 28.01.2010	
Atmospheric conditions:	Temperature:	19°C - 23°C	
	Air pressure:	980 - 1020 mbar	
	rel. humidity:	35% - 50%	
Representatives	<i>Client´s representatives</i> Dipl.-Ing. J. Weichold, 3M Germany <i>Representatives responsible for the tests</i> Dr.-Ing. R. Badent Dr.-Ing. B. Hoferer Mr. O. Müller		

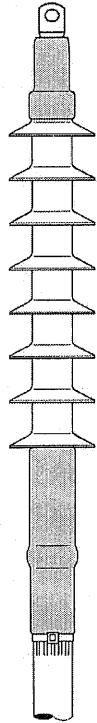
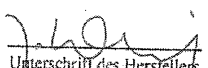
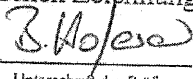
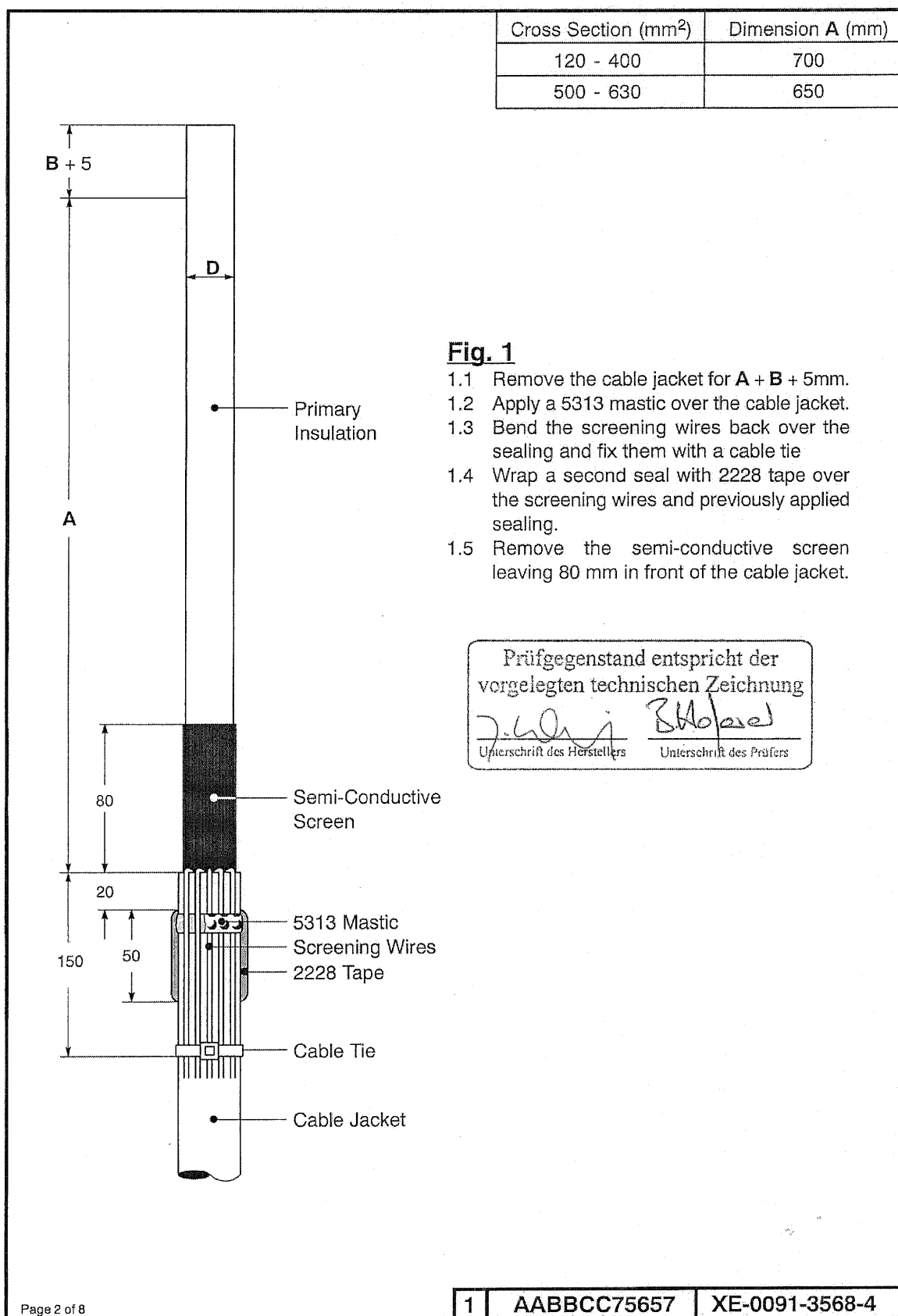
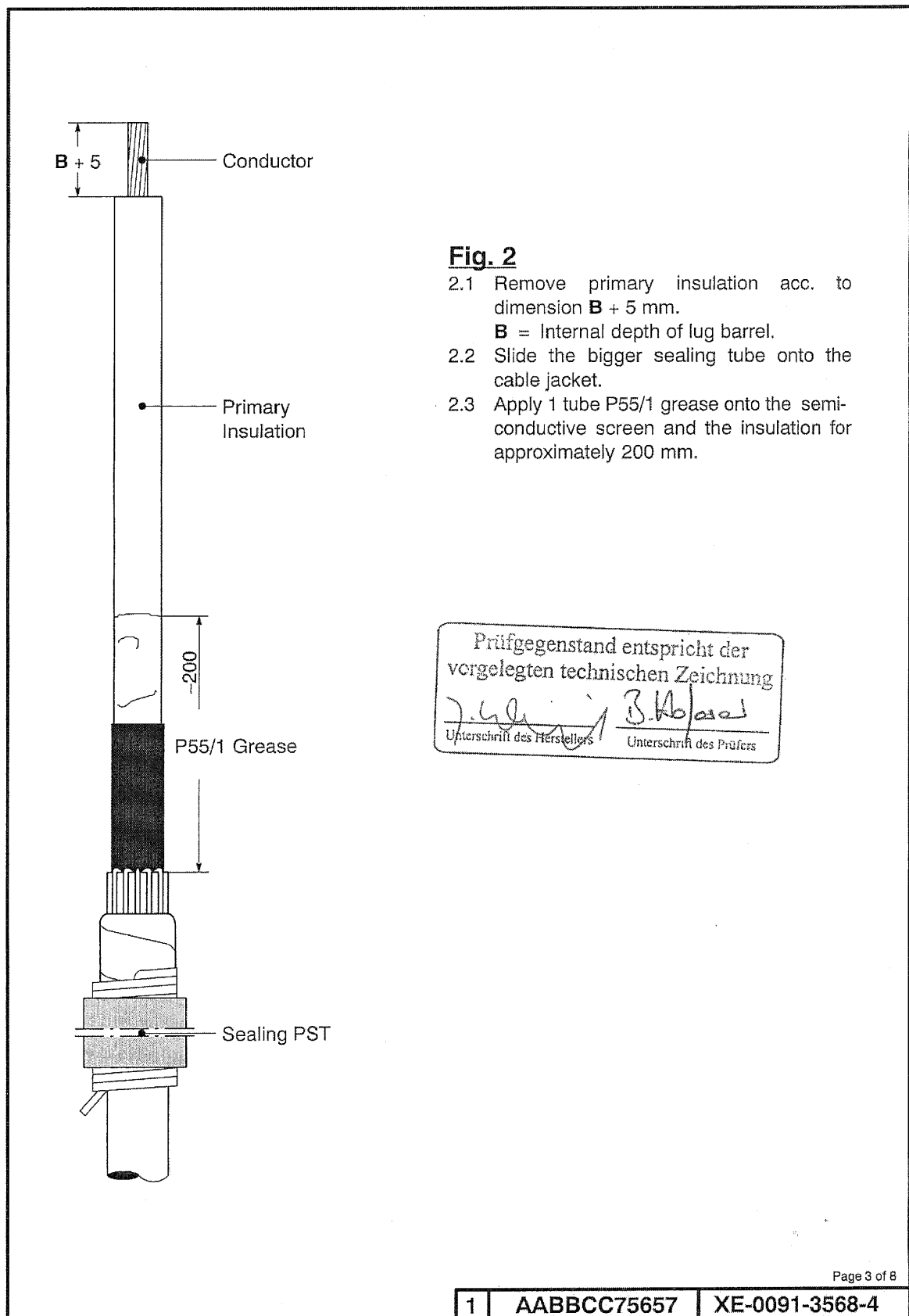
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Figure 2.1: *Molded Rubber Termination*

Figure 2.2: *Molded Rubber Termination*

Figure 2.3: *Molded Rubber Termination*

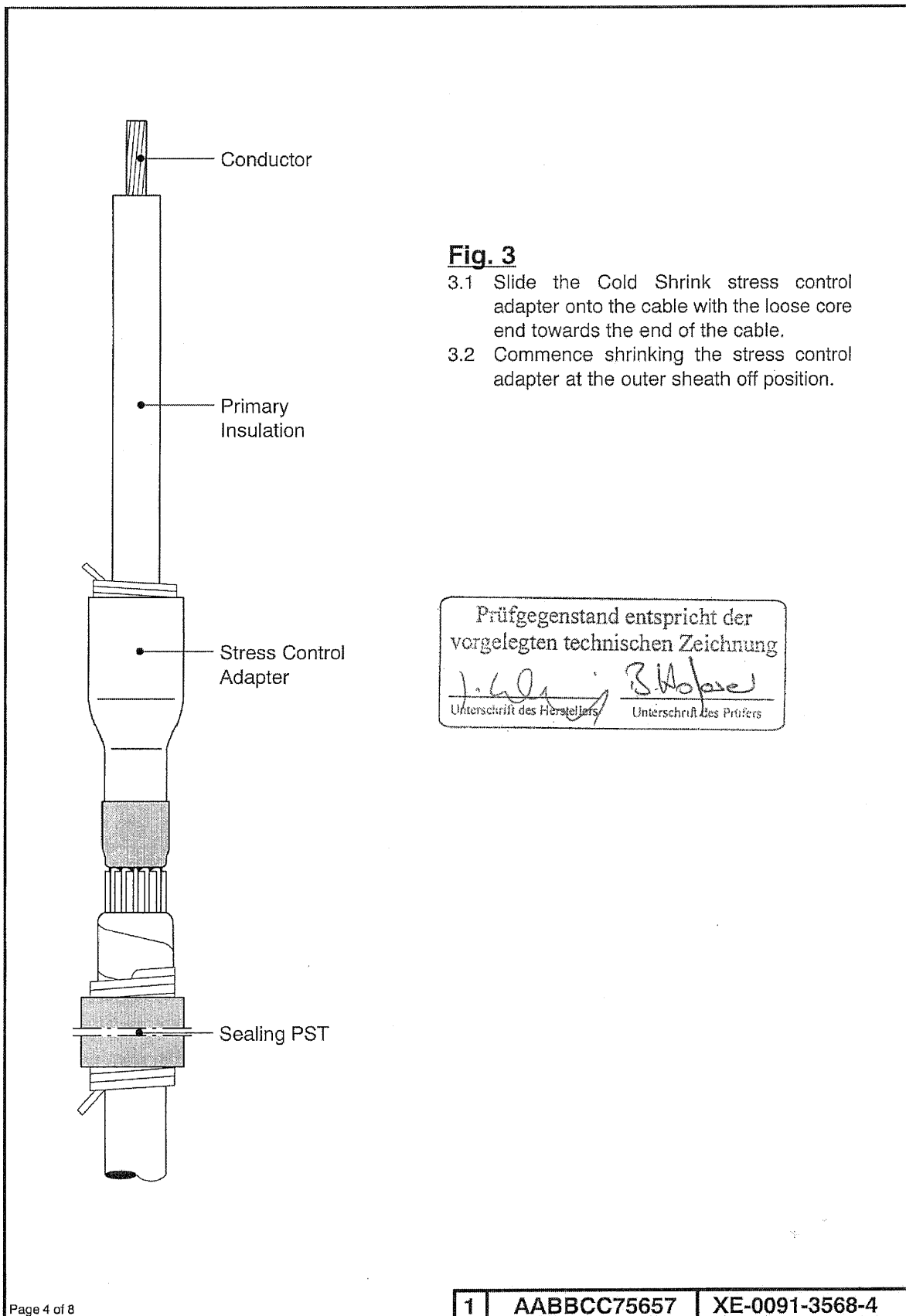


Figure 2.4: *Molded Rubber Termination*

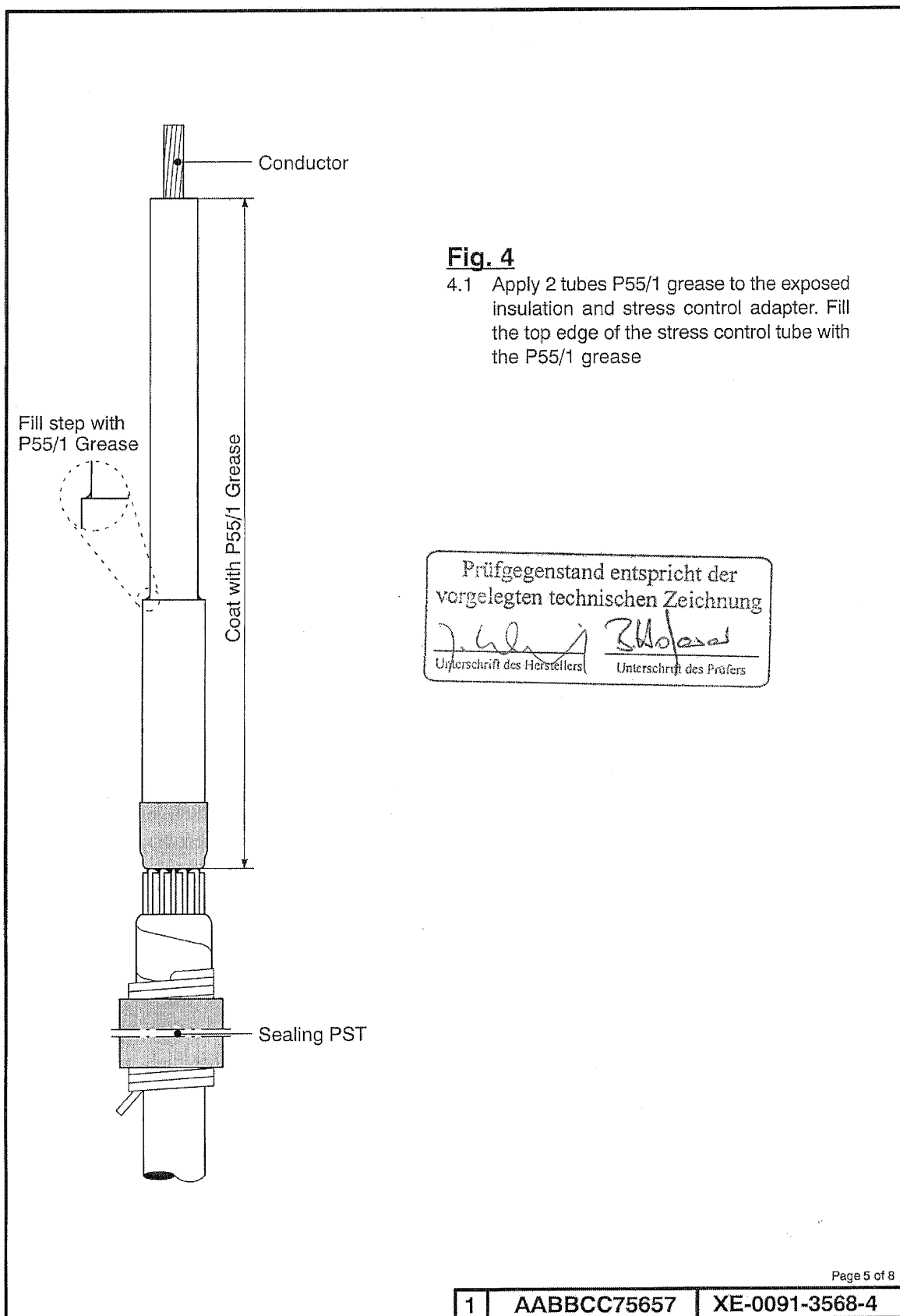
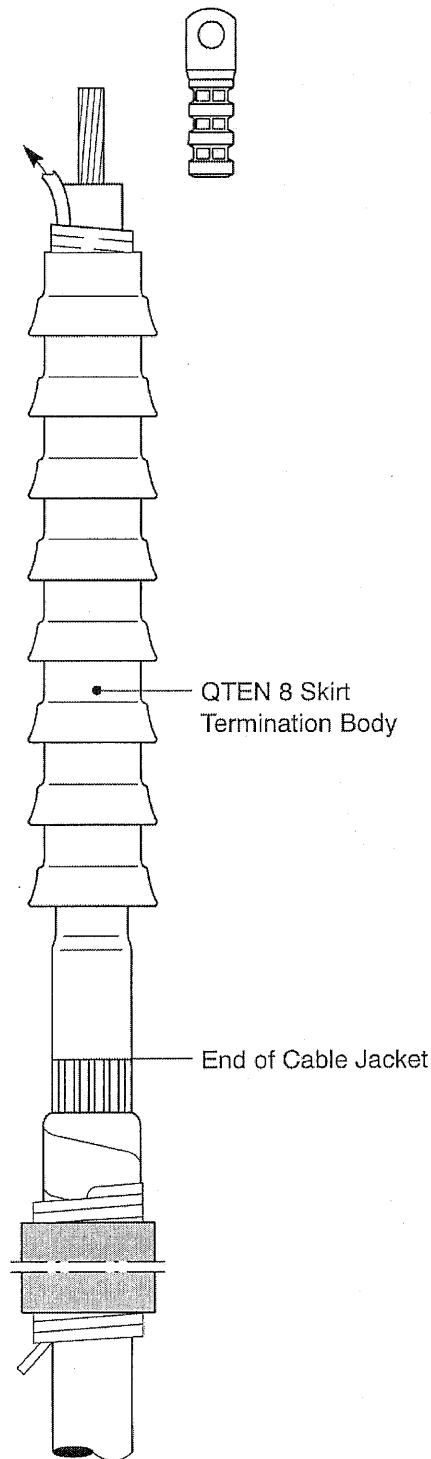


Figure 2.5: *Molded Rubber Termination*

**Fig. 5**

- 5.1 Slide the QTEN 8-skirt termination body onto the cable. Remove the collapsible zip core by unwinding it in counter clockwise direction. Start to shrink at the end of the cable jacket.
- 5.2 If necessary carefully trim the termination body in line with the cable insulation.

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Figure 2.6: *Molded Rubber Termination*

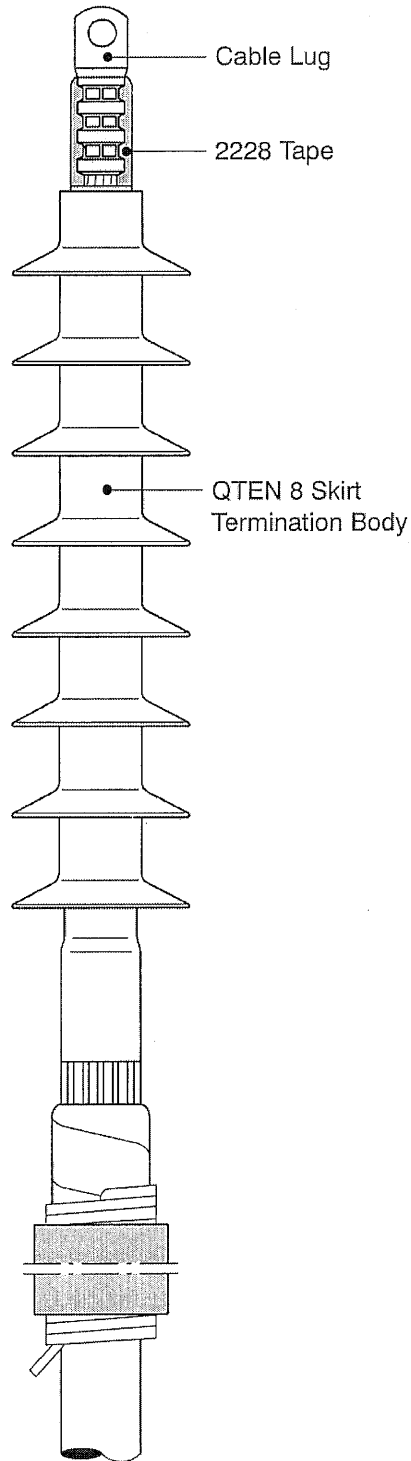


Fig. 6

- 6.1 Install the lug onto the conductor to manufacturer's instructions. Deburr, clean and smooth the lug.
- 6.2 Wrap two half-lapped layers of 2228 tape over the top lug. Fill the gap between lug and insulation.

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Page 7 of 8

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Figure 2.7: *Molded Rubber Termination*

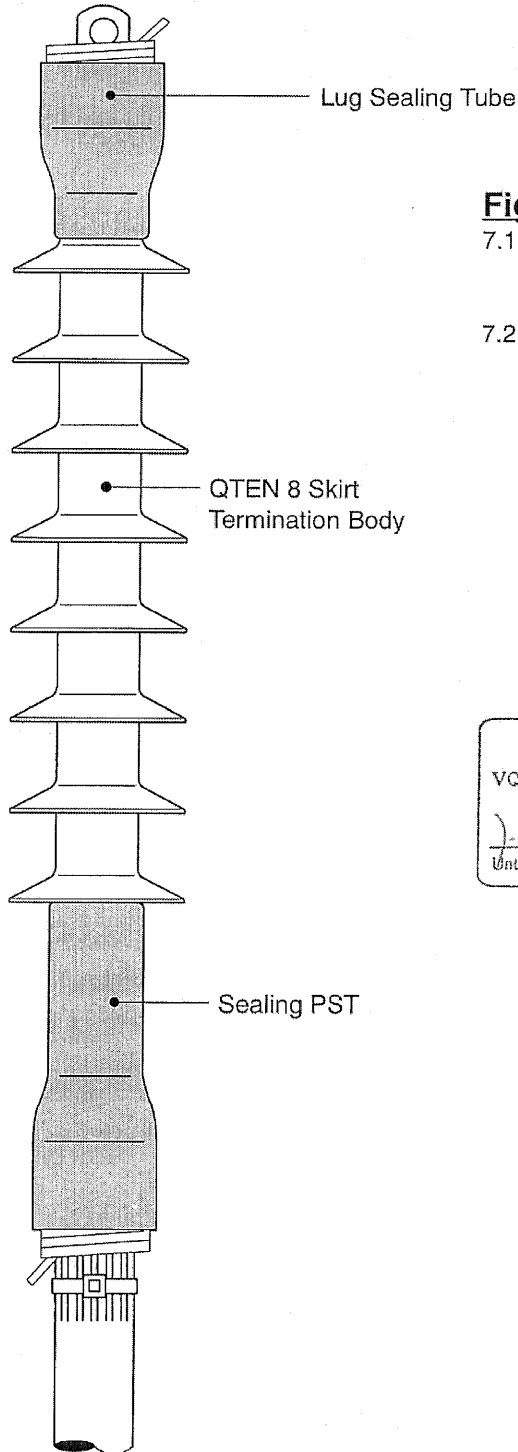


Fig. 7

- 7.1 Slide the parked sealing tube onto the termination. Start to shrink underneath the first skirt.
- 7.2 Slide the lug sealing tube onto the termination / lug. Start to shrink on top of last skirt. Carefully trim the sealing tube in line with the lug.

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Figure 2.8: *Molded Rubber Termination*

Identification of Test Cable

Rated voltage U_0/U (U_m): 36/66 (72.5) kV

Construction: ☒ 1-core ☐ 3-core

Conductors: ☒ Al ☐ Cu

☒ Stranded ☐ Solid

Cross-section: 1000 mm²

Insulation: ☒ XLPE ☐ PE ☐ EPR

Insulation screen: ☒ Bonded ☐ Strippable ☐ Graphite

Metallic screen: ☒ Wires ☐ Tape ☐ Extruded

Cross-section: 95 mm²

Armour: ☐ Wire ☐ Tape

Oversheath: ☐ PVC ☒ PE

☒ Laminated ☒ Al ☐ Cu

☒ Conductive Layer

Diameters:

Conductor	38,7	mm
Insulation	59,5	mm
Insulation screen	63,1	mm
Oversheath	75,0	mm

Cable marking: Endesa KNE 001 –General Cable 4- HERSATENE-FOC RHZ+20L(S)
36/36 (72.5)kV-XLPE-1x1000 K AL+H95 06 0F 447930

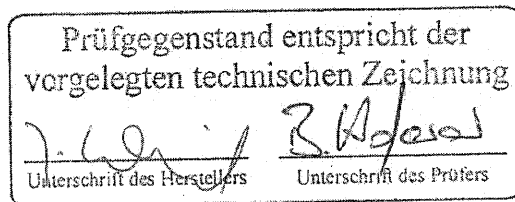


Figure 2.10: Cable Data Sheet

Tests: Test volume, chronological order and requirements conform to IEC 60840 04/2004 type test on cable accessories and additional customer's specification.

- Pos. 1 Check of insulation thickness
- Pos. 2 Partial Discharge Test
 $\hat{u} / \sqrt{2} = 1,75 U_0 = 63 \text{ kV}$ 10 s thereafter ;
 $\hat{u} / \sqrt{2} = 1,5 U_0 = 54 \text{ kV}$
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: $\hat{u} / \sqrt{2} = 2,0 U_0 = 72 \text{ kV}$
Number of cycles: 20
- Pos. 4 Partial Discharge Test
 $\hat{u} / \sqrt{2} = 1,75 U_0 = 63 \text{ kV}$ 10 s thereafter ;
 $\hat{u} / \sqrt{2} = 1,5 U_0 = 54 \text{ kV}$
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
 $\hat{u} / \sqrt{2} = 1,75 U_0 = 63 \text{ kV}$ 10 s thereafter ;
 $\hat{u} / \sqrt{2} = 1,5 U_0 = 54 \text{ kV}$
no detectable discharge
- Pos. 6 Lightning impulse voltage test at elevated temperature
T = 95°C-100°C, at least 2h, $\hat{u} = 325 \text{ kV}$,
10 impulses each polarity
- Pos. 7 AC-voltage withstand test during cooling period
 $\hat{u} / \sqrt{2} = 2,5 U_0 = 90 \text{ kV}$, t = 15 min
- Pos. 8 AC-voltage withstand test
 $\hat{u} / \sqrt{2} = 3,0 U_0 = 108 \text{ kV}$, t = 4 h
- Pos. 9 Accessory examination

3 Mounting

The cable preparation, assembling and mounting of the cable system was accomplished by technicians of 3M Deutschland GmbH.

The length of the free cable between accessories was 6 m.

4 Test Setup

4.1 Check of 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 0.01 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 ($C_H = 351 \text{ pF}$; 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.

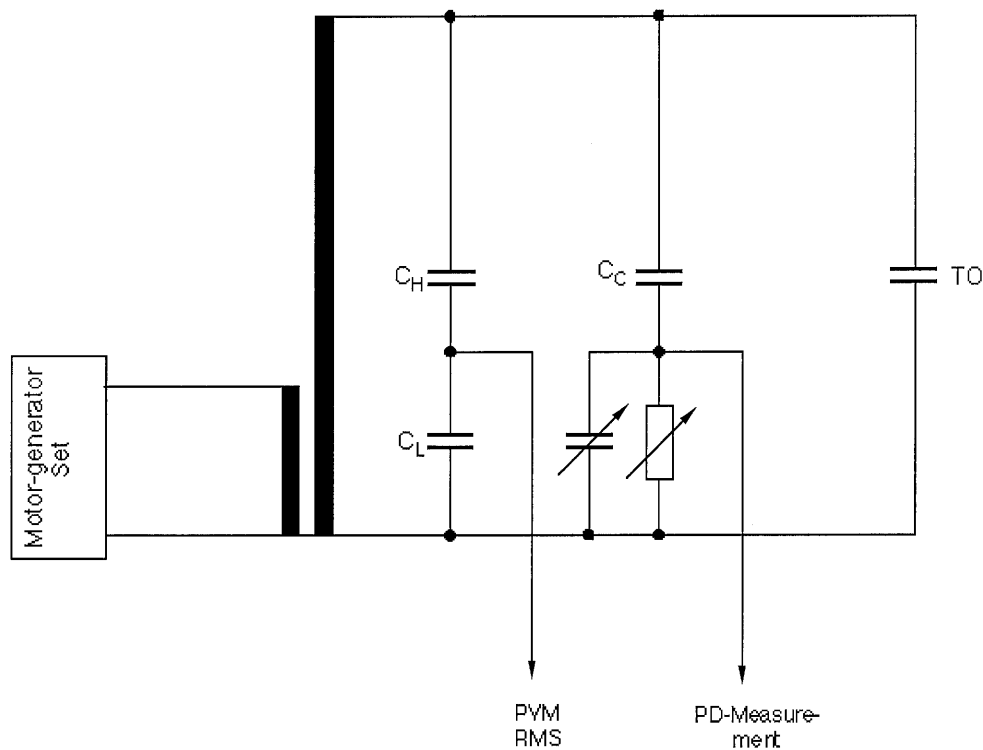


Figure 4.2: Test-setup for AC-voltage withstand test and PD measurement

AC-transformer:	500V/300kV; $S_N = 360 \text{ kVA}$
Voltage measurement:	$C_H = 351 \text{ pF}$; ratio 10.000:1 uncertainty 3 %
PD measurement:	$C_C = 1000 \text{ pF}$; $U_N = 800 \text{ kV}_{\text{rms}}$ 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 2.0 pC.

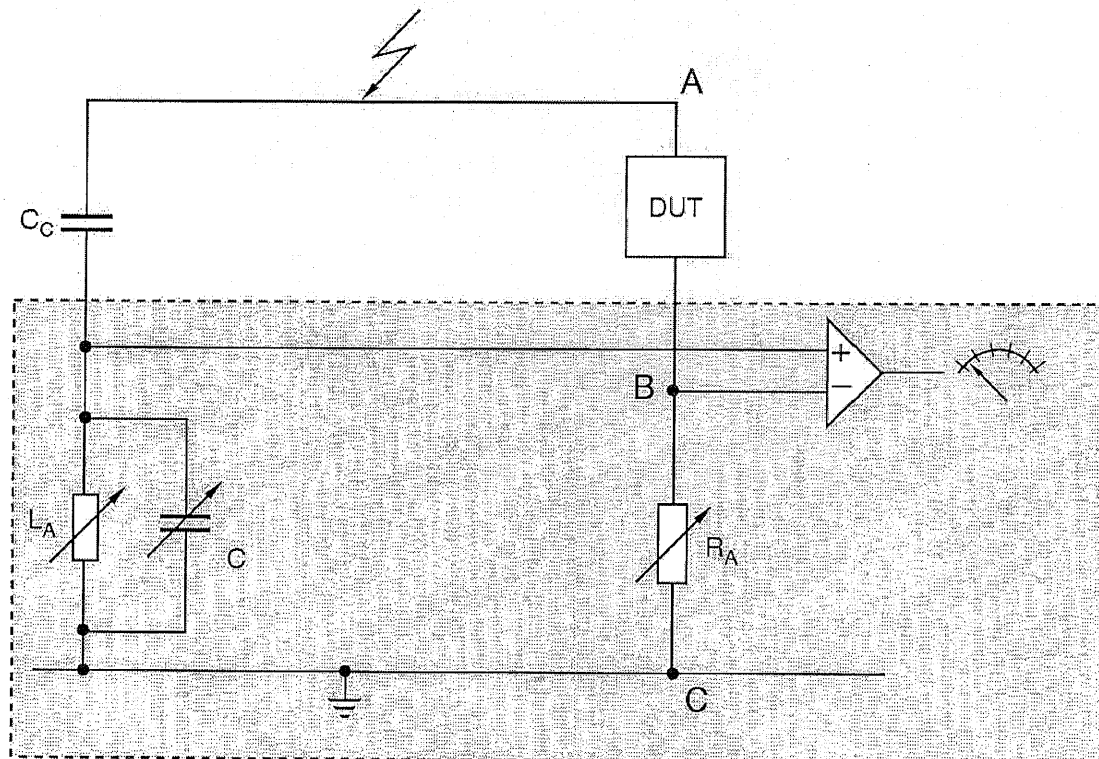


Figure 4.3: Scheme of PD test circuit
 DUT : Test object
 C_C: Coupling Capacitor

For balancing the bridge a calibrating impulse with $q_A = 10.000 \text{ pC}$ 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, $q_A = 5 \text{ pC}$, 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. The max. heating current was $I = 1600$ 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%.

4.5 Lightning Impulse Voltage Test

For lightning impulse testing of the cable 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.

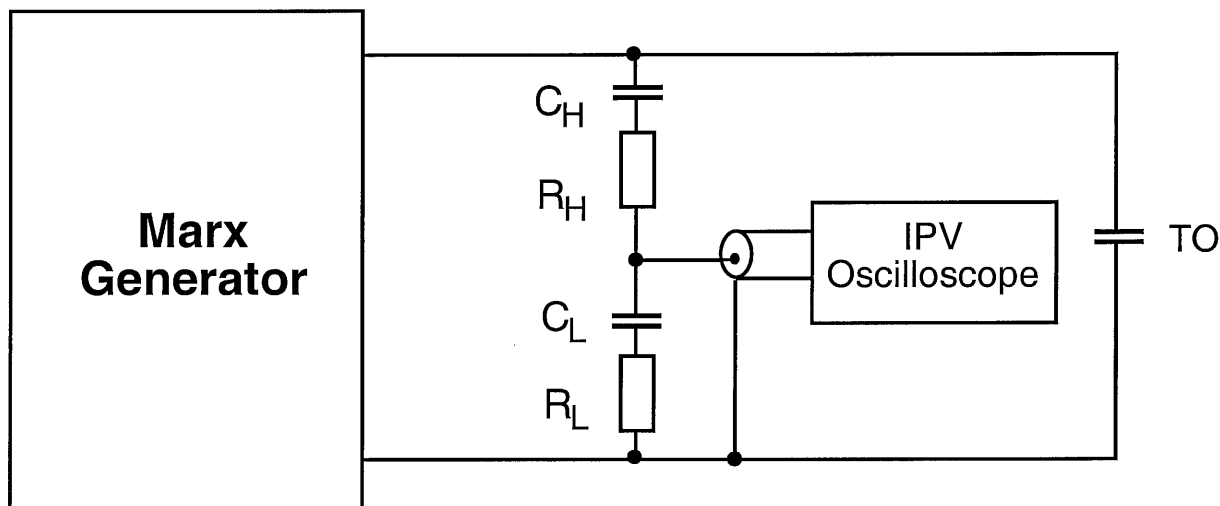


Figure 4.5.1: Scheme of lightning impulse voltage test circuit
 C_H : 1200 pF ; $R_H = 70 \Omega$; ratio: 3225;
 IPV: impulse-peak-voltmeter (Haefely) – measurement uncertainty 3%
 Oscilloscope: Tektronix TDS 3044 B – measurement uncertainty 2%

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: :	$T_1 = 1.77 \mu s$	$T_2 = 49.8 \mu s$
Negative impulse:	$T_1 = 1.67 \mu s$	$T_2 = 49.8 \mu s$

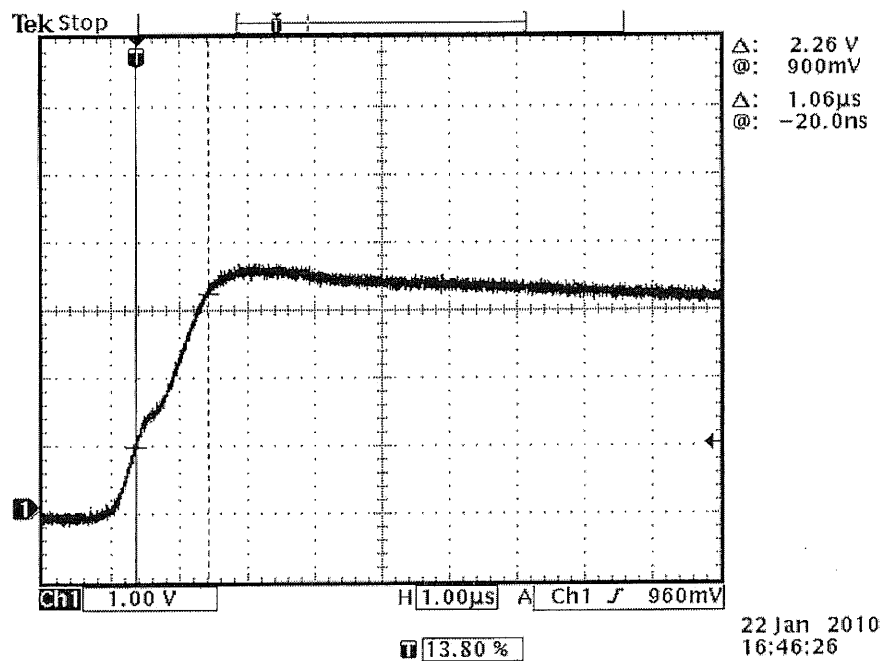


Figure 4.5.2: Front time, positive polarity
horiz.: 1 μs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

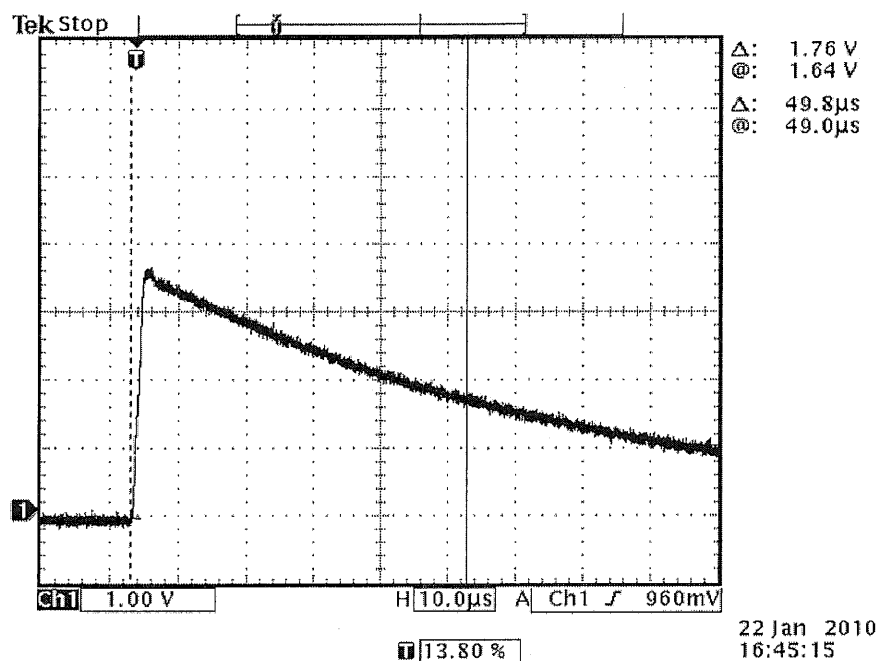


Figure 4.5.3: Time to half value, positive polarity
horiz.: 10 μs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

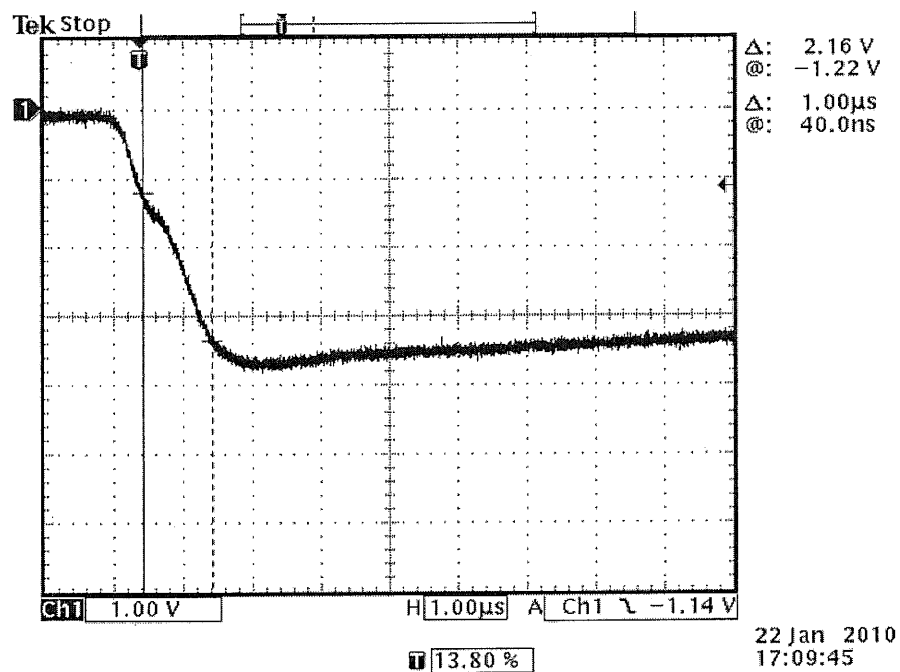


Figure 4.5.4: Front time, negative polarity
horiz.: 1 μs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

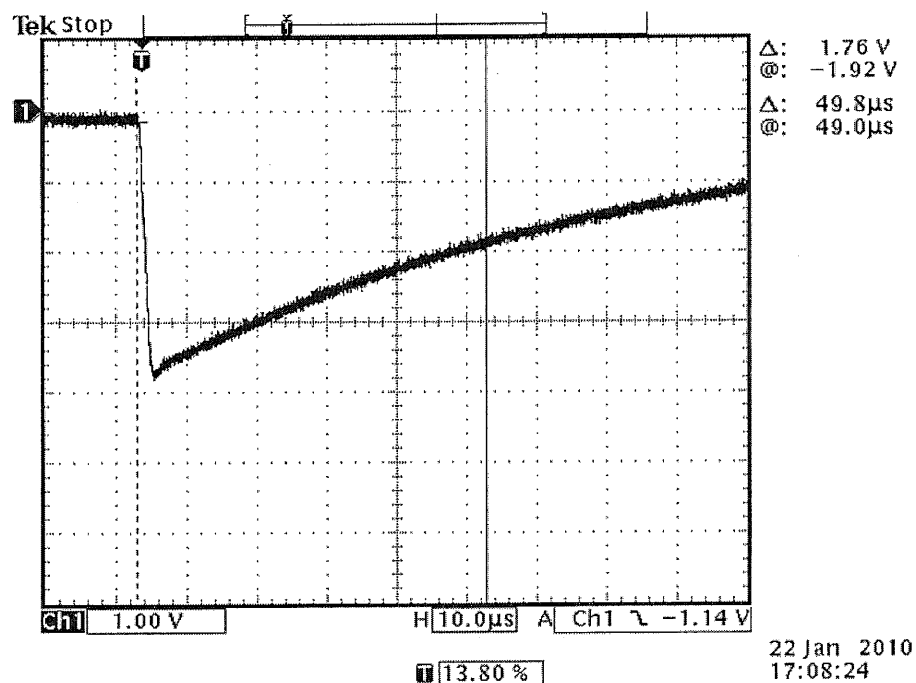


Figure 4.5.5: Time to half value, negative polarity
horiz.: 10 μs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

4.6 Measuring Devices

Table 4.6 shows all used test systems and the measurement devices including calibration dates.

Inv No.	System	Type	Ser No	Manufacturer	Last Cal date	Next Cal date	Calibrated by
AC Test System							
J 0650	Transformer	PT 60/200	83/41177	AEG			
990014	AC Measuring System	HVT 250 RCR	992.696	HILO-TEST	03/2009	03/2010	DKD-K-15901
Heating System							
960001	Heating Transformer	GENN 250/1.1	9529994	HTT			
05-026040	Current Transformer 3000:1	GSA 300 B150		Schwarz+Graf	08/2009	08/2011	IEH
05-025267	Digital Multimeter	34401A	My 45011260	Agilent	08/2009	08/2010	IEH
04-017646	Temperature Measuring Syst.	5180V	GE49322-001-001-4704x37	Eurotherm	08/2009	08/2010	IEH
Impulse Test System							
790033	Impulse Generator	SGVG 3600	180	Haefely			
790033/1	Voltage Divider	CR,3600kV SPR2	140090/91/92	Haefely	08/2009	08/2010	IEH
860074	Impulse Peak Voltmeter	64M		Haefely	08/2009	08/2010	IEH
05-025522	Digital Storage Oscilloscope	TDS 3044B	B010587	Tektronix	07/2009	07/2010	DKD-K-05352
PD Measuring System							
920075	PD Measuring Bridge	9124 WQ	139741	Tettex	08/2009	08/2010	IEH

Table 4.6: Measurement devices

5 Results

5.1 Check of Insulation Thickness

The test was carried out as described in 4.

Test date:	15.12.2009
Nominal value:	9.0 mm
Measured Values:	9.07 mm
	9.06 mm
	8.78 mm
	8.70 mm
	9.14 mm
	9.19 mm
Average Value:	8,99 mm

Result: The average value goes below the nominal value by 0.11%, so no correction was necessary

5.2 PD-Test

The test was carried out as described in 4.

Test date:	18.12.2009
Calibration pulse:	$q_{cal} = 5 \text{ pC}$
Background noise level:	0.7 pC
Test voltage:	$\hat{u} / \sqrt{2} = 63 \text{ kV}; t = 10 \text{ s, thereafter}$ $\hat{u} / \sqrt{2} = 54 \text{ kV; with pd reading}$
PD:	no detectable discharges

The test was passed successfully

5.3 Heating cycle voltage test

The test was carried out as described in 4.

Test date:	23.12.2009 – 12.01.2010
Test voltage:	$\hat{u} / \sqrt{2} = 72 \text{ kV}$
Heating current:	$I = 1500 \dots 1600 \text{ A regulated, 8 h}$ $I = 0 \text{ A, 16 h}$
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:	21.01.2010
Calibration pulse:	$q_{cal} = 5 \text{ pC}$
Background noise level:	2.0 pC
Test voltage:	$\hat{u} / \sqrt{2} = 63 \text{ kV}; t = 10 \text{ s, thereafter}$ $\hat{u} / \sqrt{2} = 54 \text{ kV; with pd reading}$
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:	22.01.2010
Calibration pulse:	$q_{cal} = 5 \text{ pC}$
Background noise level:	2.0 pC
Heating current:	$I = 1500 \dots 1600 \text{ A regulated, 8 h}$
Test voltage:	$\hat{u} / \sqrt{2} = 63 \text{ kV}; t = 10 \text{ s, thereafter}$ $\hat{u} / \sqrt{2} = 54 \text{ kV; with pd reading}$
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:	27.01.2010
Test voltage:	$\hat{u} = 325 \text{ kV}$
Heating current:	$I = 1500 \dots 1600 \text{ A regulated, 8 h}$
Impulse:	1-5 μs / 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	$\hat{u}$ / kV	Figure	remark
1	30,0	113,4		front time,
2	30,0	113,1		time to half value
3	43,0	163,1		50%
4	60,0	229		70%
5	76,6	292		90%
6	85,2	325	5.1	1. 100%
7	85,2	325	5.1	2. 100%
8	85,2	325	5.1	3. 100%
9	85,2	325	5.1	4. 100%
10	85,2	325	5.1	5. 100%
11	85,2	325	5.2	6. 100%
12	85,2	325	5.2	7. 100%
13	85,2	325	5.2	8. 100%
14	85,2	325	5.2	9. 100%
15	85,2	325	5.2	10. 100%

Table 1: Lightning impulse voltage withstand test, positive polarity

number	charging voltage / kV	$\hat{u}$ / kV	Figure	remark
1	- 30,0	- 112,6		front time,
2	- 30,0	- 113,1		time to half value
3	- 43,0	- 162,8		50%
4	- 60,0	- 228		70%
5	- 76,6	- 292		90%
6	- 85,2	- 325	5.3	1. 100%
7	- 85,2	- 325	5.3	2. 100%
8	- 85,2	- 325	5.3	3. 100%
9	- 85,2	- 325	5.3	4. 100%
10	- 85,2	- 325	5.3	5. 100%
11	- 85,2	- 325	5.4	6. 100%
12	- 85,2	- 325	5.4	7. 100%
13	- 85,2	- 325	5.4	8. 100%
14	- 85,2	- 325	5.4	9. 100%
15	- 85,2	- 325	5.4	10. 100%

Table 2: Lightning impulse voltage withstand test, negative polarity

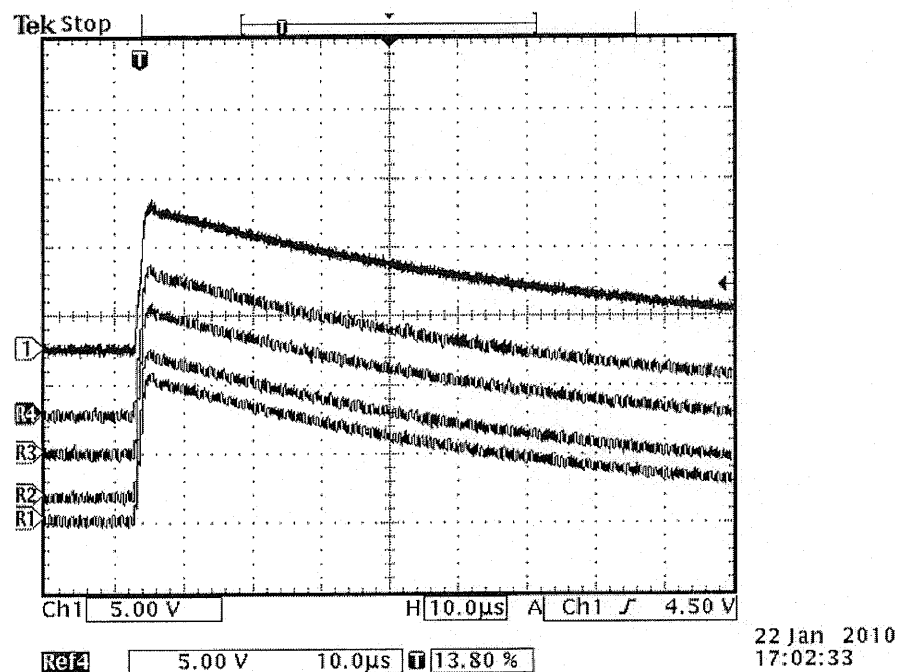


Figure 5.1: 100%-stress 1 - 5, positive polarity
Hor.: 10 μs/Div; Vert.: 5V/Div; probe 10:1; $\ddot{u} = 3225$

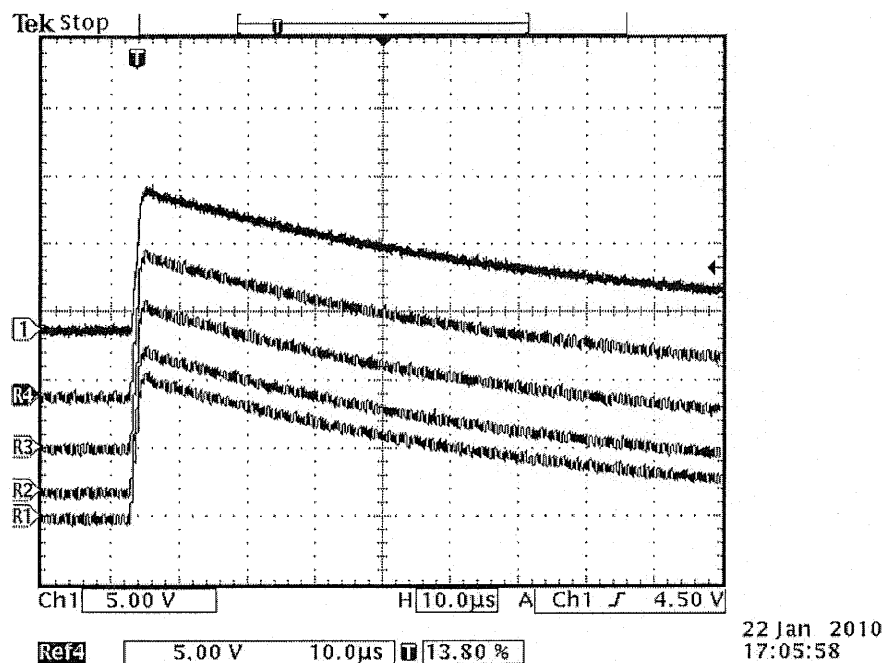
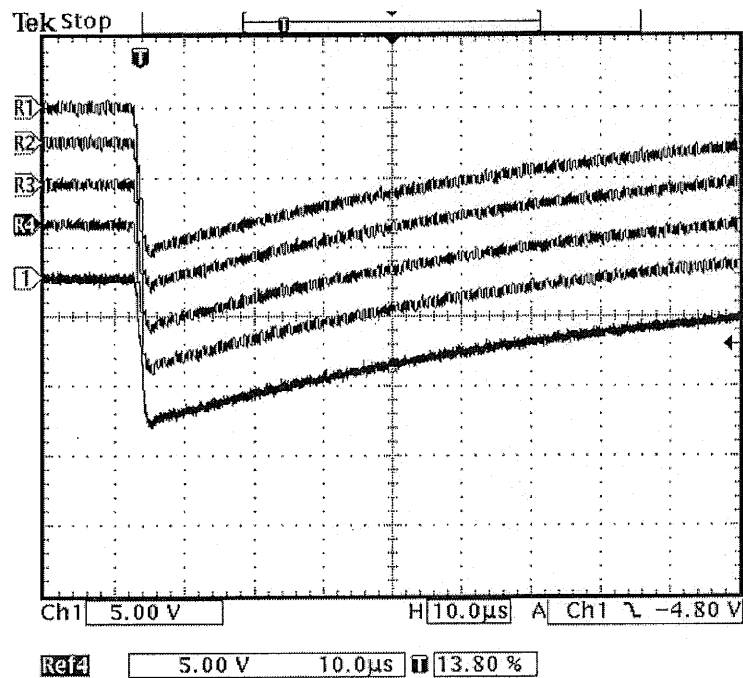
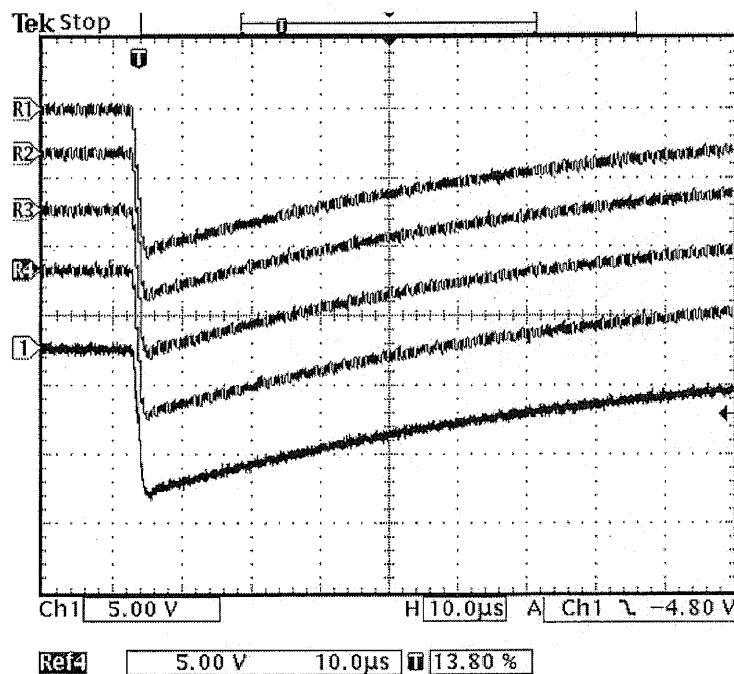


Figure 5.2: 100%-stress 6 - 10, positive polarity
Hor.: 10 μs/Div; Vert.: 5V/Div; probe 10:1; $\ddot{u} = 3225$



22 Jan 2010
17:15:31

Figure 5.3: 100%-stress 1 - 5, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; $\ddot{u} = 3225$



22 Jan 2010
17:18:59

Figure 5.4: 100%-stress 6 - 10, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; $\ddot{u} = 3225$

5.7 AC Voltage Withstand Test during cooling period

The test was carried out as described in 4.

Test date: 22.01.2010

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

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.8 AC Voltage Withstand Test

The test was carried out as described in 4.

Test date: 28.01.2010

Test voltage: $\hat{u} / \sqrt{2} = 108 \text{ kV}$; $t = 4 \text{ h}$

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.9 Accessory Examination

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

The test was passed successfully.

6 Conclusion

The 72,5 kV- Molded Rubber Termination QTEN, manufacturer 3M Deutschland GmbH, passed all tests described in Chapter 2 successfully. The test object fulfilled the requirements according to IEC 60840 04/2004 type test on accessories and additional customer's specification.

Karlsruhe, 18.03.2010



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