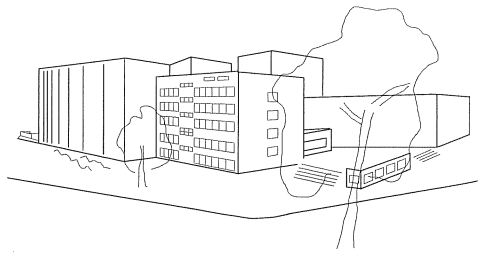
Bereich Hochspannungsprüftechnik

Institut für Elektroenergiesysteme und Hochspannungstechnik



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Test Report No 2007-18

Type Test
of a 72,5 kV- Joint Type QS- III 5488A

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

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

1 Purpose of Test

A 72,5 kV joint type QS - III 5488A was subjected to a type test according to IEC 60840 04/2004, " type test on accessories".

2 Miscellaneous Data

Test object:	*1 cold shrink silicone rubber joint type QS - III 5488A* Drawing No. 78-8131-7629-0-A, Figure 2.1 Type of the cable: single core EPR-Cable with copper conductor 1 x 300 RM 66/72,5 kV
Hersteller:	3 M Deutschland GmbH Carl-Schurz-Strasse 1 41453 Neuss
Place of test:	*Institute of Electric Energy Systems and High-Voltage Technology* – University of Karlsruhe, Kaiserstraße 12 – 76128 Karlsruhe
Testing dates:	Delivery: 15.01.2007 Mounting: 15.01. - 18.01.2007 Test date: 19.01. - 16.05.2007
Atmospheric conditions:	Temperature: 19°C - 23°C Air pressure: 980 - 1020 mbar rel. humidity: 35% - 50%
Representatives	*Client´s representatives* Dipl.-Ing. J. Weichold, 3 M Deutschland GmbH *Representatives responsible for the tests* Dr.-Ing. R. Badent ; Dr.-Ing. B. Hoferer; Mr. O. Müller

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

Unterschrift des Herstellers | Unterschrift des Prüfers

3M

Cold Shrink Silicone Rubber Splice Kit QS-III 5488A

Instructions

IEEE Std. No. 404
69kV Class 350 kV BIL
IEC 60840
72kV Class 325kV BIL

Kit Contents:

1	Silicone Rubber Splice Body
2	Jacketing Tubes
1	Shielding Sleeve, 7'
1	Pre-formed Ground Braid Assembly
7	Constant Force Springs
4	Red Compound Tubes (non-silicone grease)
1	Roll Scotch® Sealing Mastic 2229, 1" x 10'
2	Rolls Scotch® Rubber Mastic Tape 2228, 2" x 36"
1	Pad Scotch® Semi-conductive 13, 18" x 36"
1	Roll Scotch® Vinyl Electrical Tape Super 88, 1½" x 44'
4	3M™ Cable Cleaning Pads CC-3
4	Copper Foil Tape Strips 1811, 15" long
4	Rolls Armorcast™ Structural Material 4560, 3" x 15'
1	Set Screw Connector
3	Instruction Booklets

Additional Parts (included only in kit types as indicated)

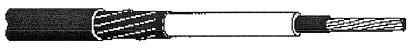
1	Silicone Rubber Tube Assembly (Standard Wall, X-Bond)
2	Silicone Rubber Tube Assembly (Reduced Wall, In-line and X-Bond)

Note: Do not use knives to open plastic bags.

Kit Selection Table

Kit Number	Primary Insulation O.D. Range	Conductor Size Range
5488A-RW	1.94–3.08" (49,3–75,4 mm)	250–1000 kcmil (125–500 mm²)

Table 1



Reduced Wall Jacketed Concentric Neutral (JCN) Cable

3M™ Cold Shrink Silicone Rubber Splice Kit QS-III
for Reduced Wall Jacketed Concentric Neutral (JCN) Cable
5488A-JCN-RW

78-8131-7629-0-A

⚠CAUTION
Working around energized systems may cause serious injury or death. Installation should be performed by personnel familiar with good safety practice in handling electrical equipment. De-energize and ground all electrical systems before installing product.

Figure 2.1: Joint type QS - III 5488A

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 10s 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 10s 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 10s 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 during cooling period
$\hat{u} / \sqrt{2} = 2{,}5\ U_0 = 90$ kV, t = 15 min

Pos. 7 Water immersion and heat cycling
Raising the water temperature up to 70-75°C with at least 5h at 70-75°C, thereafter cooling to within 10°C above ambient temperature.
Number of cycles: 20
according to IEC 60840, Annex H.3

Pos. 8 DC-voltage test in water between the metallic screen of the power cable and the earthed exterior of the joint outer protection
according to IEC 60840, Annex H.4.1

Pos. 9 Cable and acessory examination

3 Mounting

The cable preparation, assembling and mounting of the cable system was accomplished by technicians of 3 M Deutschland GmbH. The joint was mounted according to installation instruction no. 78-8131-7629-0-A. At both ends of the test loop 72,5 kV-terminations type QT-III were mounted. The length of free cable between accessories was 5m.

4 Test Setup

4.1 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.

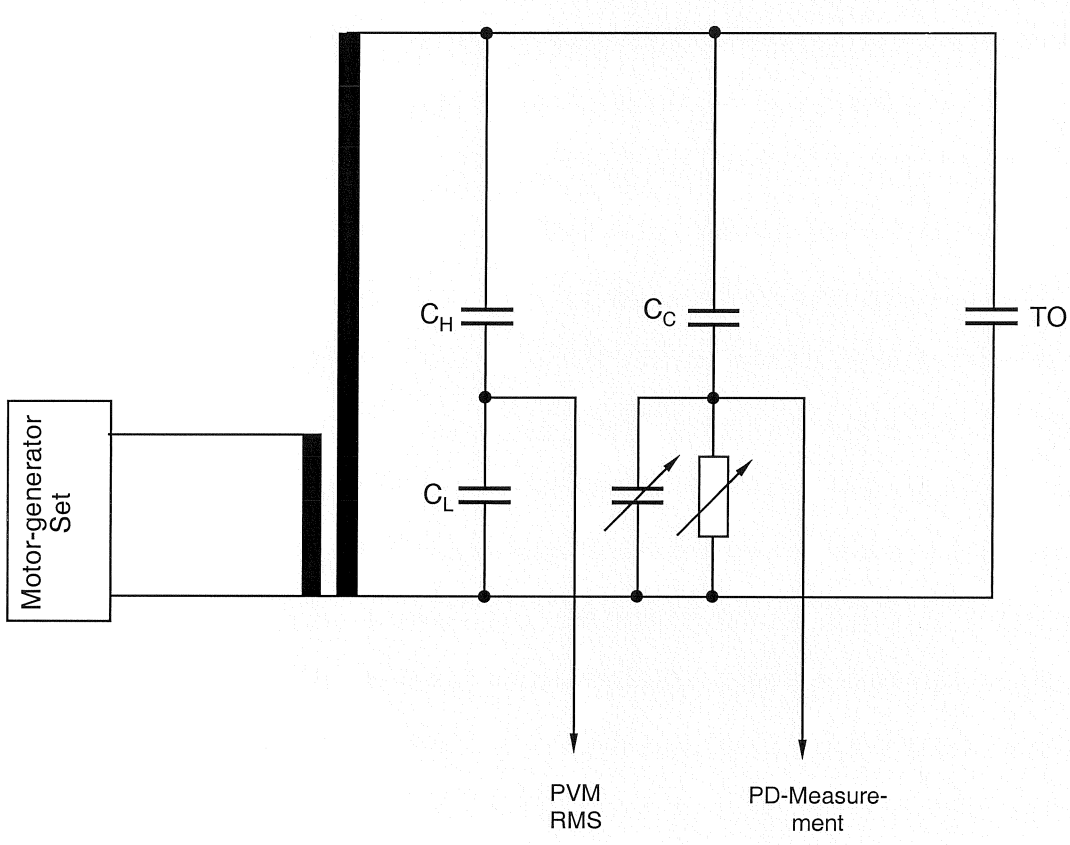


Figure 4.1: Test-setup for AC-voltage withstand test and PD measurement

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 %

4.2 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 0.8 pC.

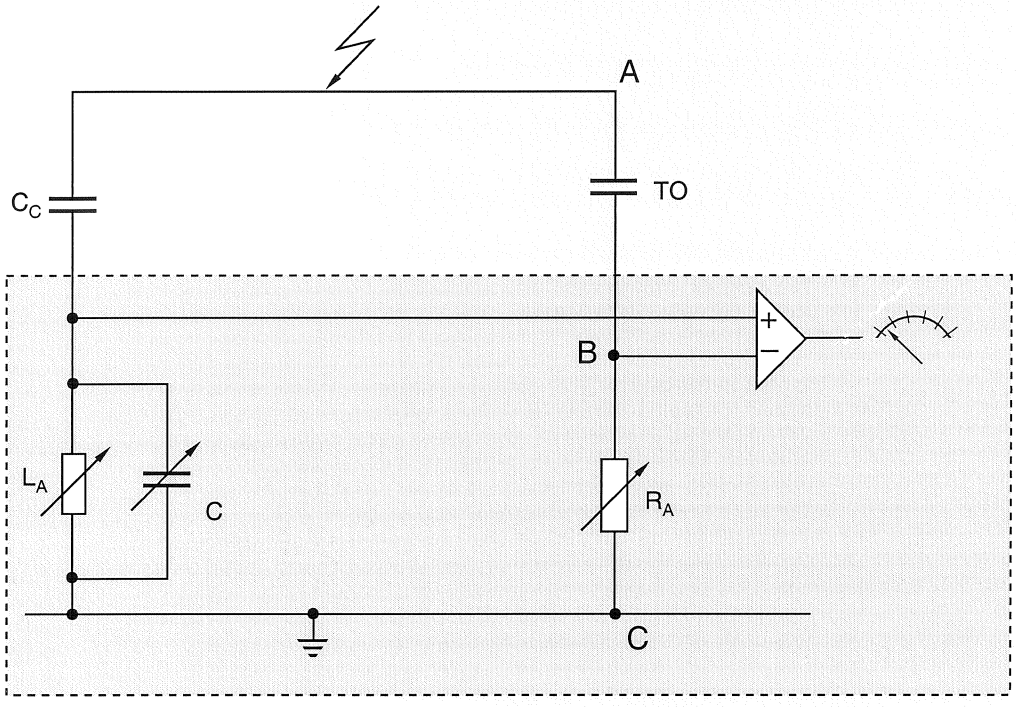


Figure 4.2: Scheme of PD test circuit
TO : Test object
C_C: Coupling Capacitor

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 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 EPR-cable. The required heating current I was determined via a dummy cable. A 5 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 4.3 illustrates the temperature rise at the conductor with a heating current of I = 980 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%.

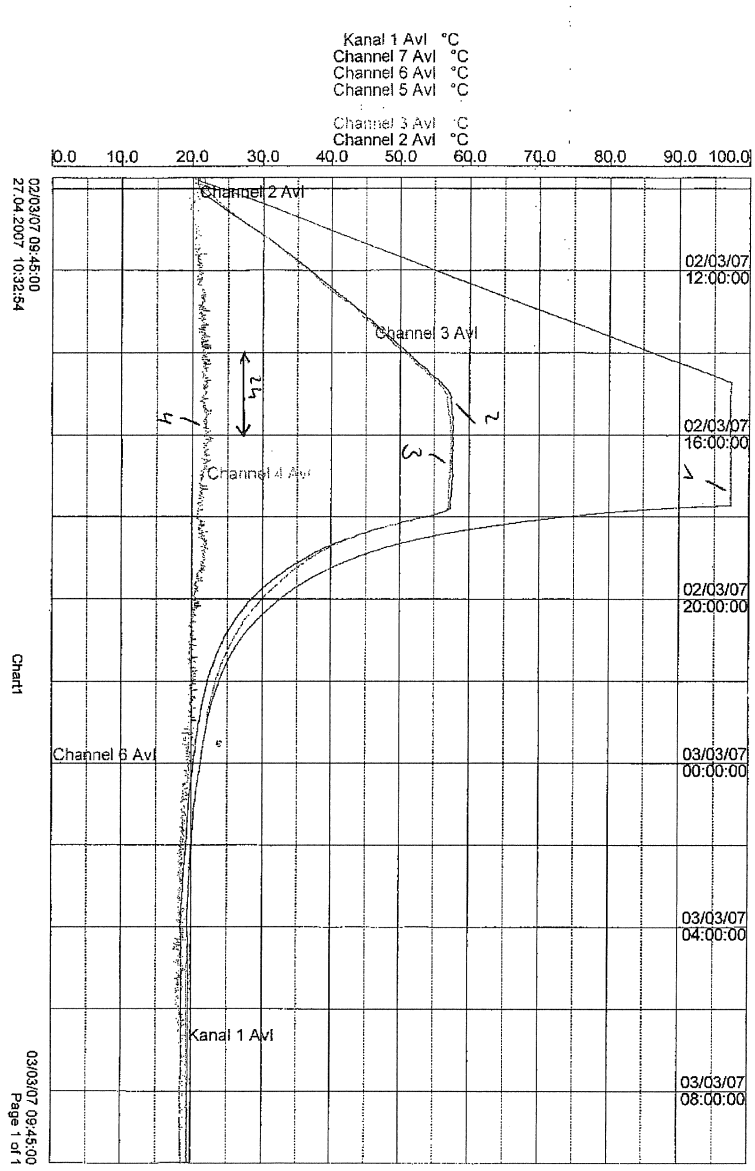


Figure 4.3: Heat cycle I = 980 A, 8h; I = 0A, 16 h
1: Conductor temperature; 2: Cable jacket temperature test loop;
3: Cable jacket temperature dummy; 4: Temperature HV-laboratory

4.4 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.

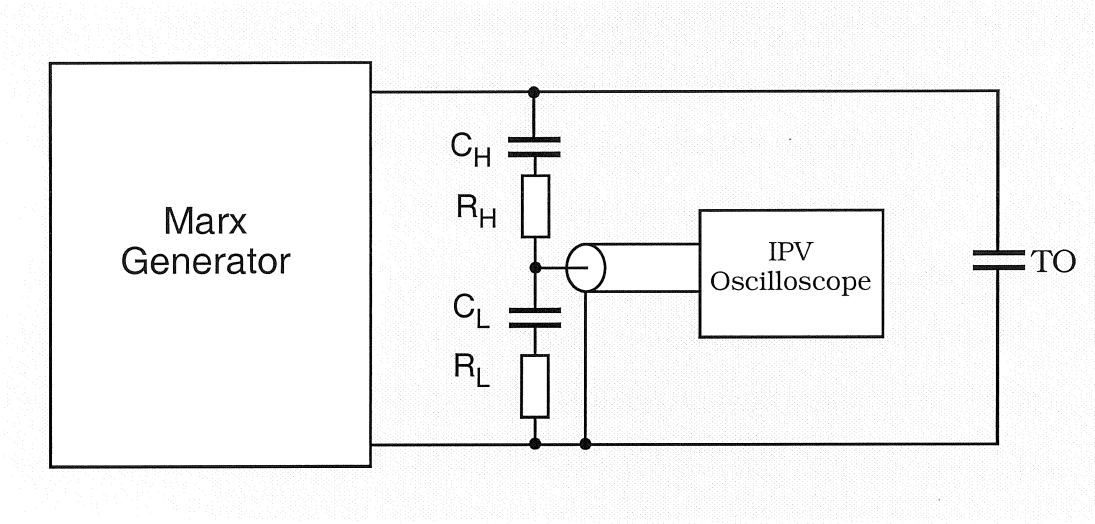


Figure 4.4.1: Scheme of switching impulse voltage test circuit
C_H: 1200 pF ; R_H = 70 Ω ; ratio: 3225;
IPV: impulse-peak-voltmeter (Haefely), measurement uncertainty 3%
Oscilloscope: Tektronix TDS 3044B – measurement uncertainty 2%

The waveform parameters were determined at reduced charging voltage. Figure 4.4.2 shows the front time, Figure 4.4.3 the time to half value for positive polarity each. Figure 4.4.4 shows the front time, Figure 4.4.5 the time to half value for negative polarity each.

Positive impulse: :	T_1 = 2.51 µs	T_2 = 51.0 µs
Negative impulse:	T_1 = 2.10 µs	T_2 = 49.4 µs

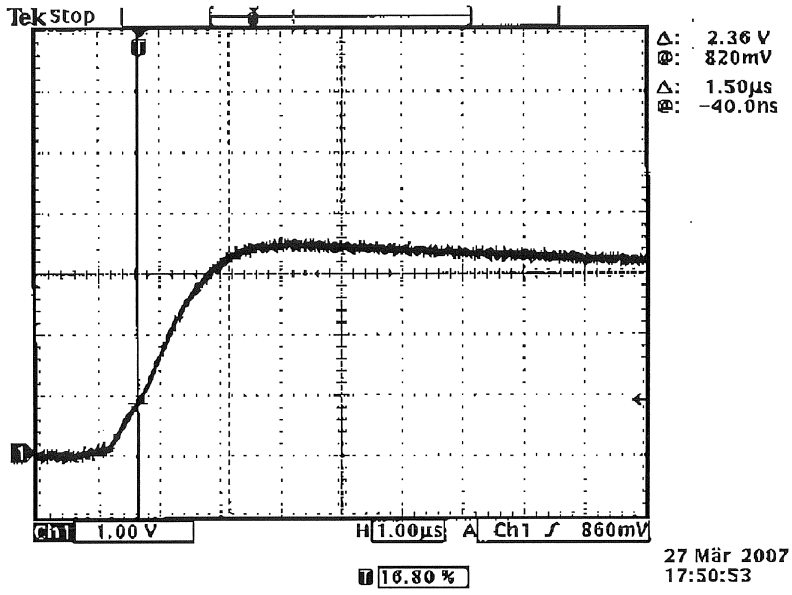


Figure 4.4.2: Front time, positive polarity
horiz.: 1 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

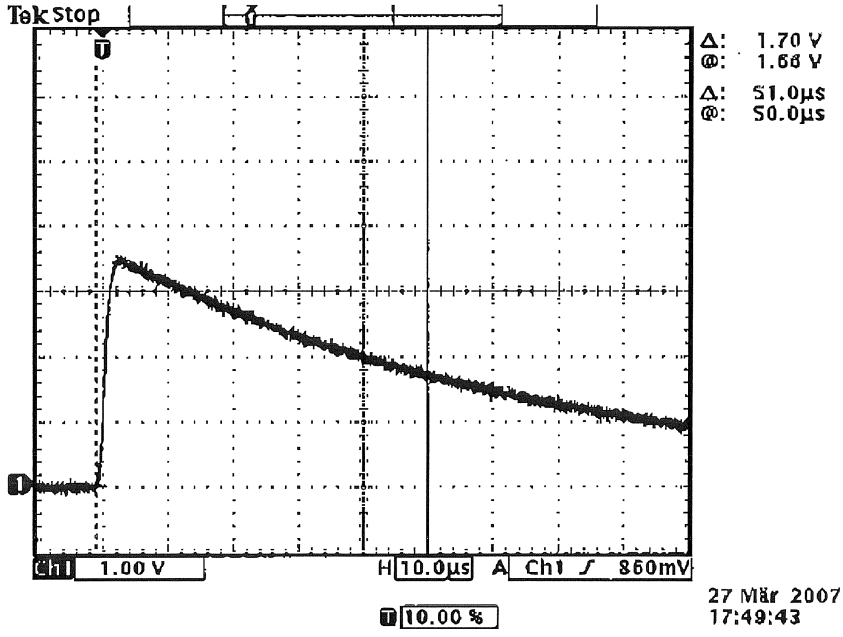


Figure 4.4.3: Time to half value, positive polarity
horiz.: 10 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

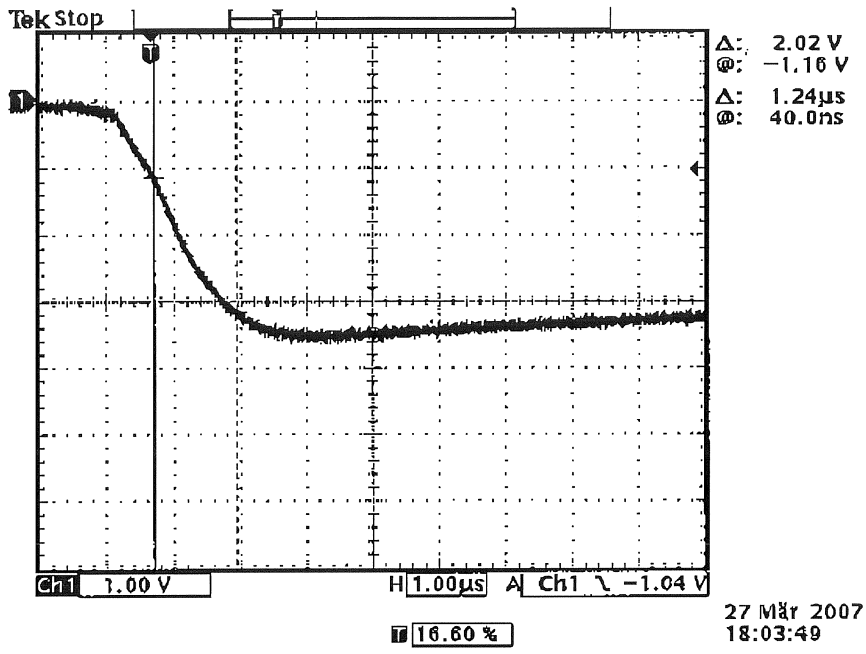


Figure 4.4.4: Front time, negative polarity
horiz.: 1 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

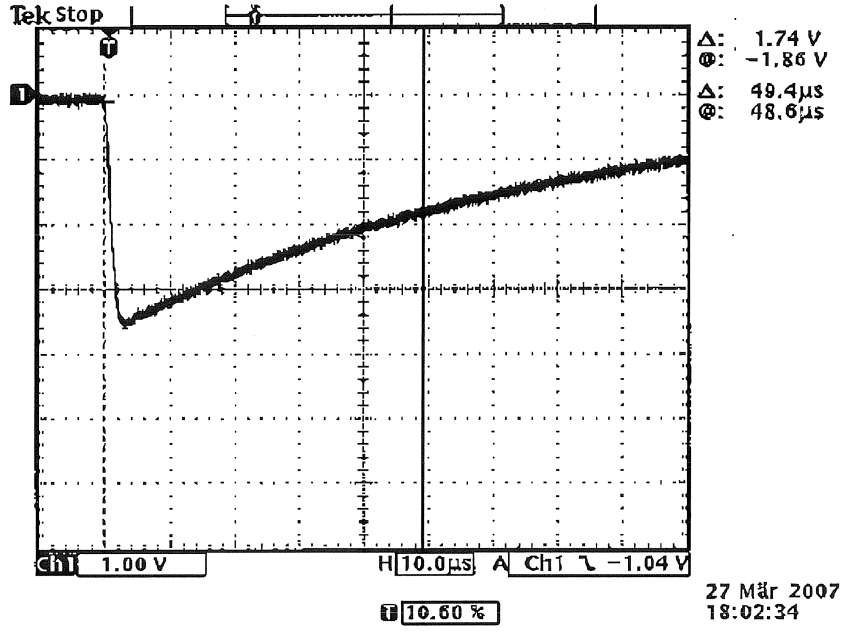


Figure 4.4.5: Time to half value, negative polarity
horiz.: 10 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

4.5 DC Voltage Withstand Test

The DC-voltage was generated by a power supply unit. The voltage measurement was carried out with an ohmic divider, ratio 2000:1. The measurement uncertainty was 1%. During the test the test object was placed in a tank filled with water. The height of the water was 1000 mm above the test object. The conductivity of the water at 20°C was 63 mS/m.

5 Results

5.1 PD-Test

The test was carried out as described in 4.

Test date:	19.01.2007
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:	26.02. - 18.03.2007
Test voltage:	$\hat{u} / \sqrt{2}$ = 72 kV
Heating current:	I = 980 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

5.3 PD-Test

The test was carried out as described in 4.

Test date:	26.03.2007
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

5.4 PD-Test at elevated temperature

The test was carried out as described in 4.

Test date:	26.03.2007
Calibration pulse:	q_{cal} = 5 pC
Background noise level:	1.5 pC
Heating current:	I = 980 A, 8 h
Temperature:	T = 98°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

5.5 Lightning Impulse Voltage Withstand Test at elevated temperature

This test was carried out as described in 4.

Test date:	27.03.2007
Test voltage:	$\hat{u}$ = 325kV
Temperature:	T = 97,5°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	110,6		front time,
2	30,0	110,7		time to half value
3	44,3	164,5		50%
4	61,4	228		70%
5	78,6	291		90%
6	87,3	325	5.1	1. 100%
7	87,3	325	5.1	2. 100%
8	87,3	325	5.1	3. 100%
9	87,3	325	5.1	4. 100%
10	87,3	325	5.1	5. 100%
11	87,3	325	5.2	6. 100%
12	87,3	325	5.2	7. 100%
13	87,3	324	5.2	8. 100%
14	87,3	324	5.2	9. 100%
15	87,3	324	5.2	10. 100%

Table 1: Lightning impulse voltage withstand test, positive polarity

number	charging voltage / kV	û / kV	Figure	remark
1	- 30,0	- 110,6		front time,
2	- 30,0	- 110,6		time to half value
3	- 44,3	- 164,4		50%
4	- 61,4	- 227		70%
5	- 78,6	- 290		90%
6	- 87,3	- 325	5.3	1. 100%
7	- 87,3	- 324	5.3	2. 100%
8	- 87,3	- 325	5.3	3. 100%
9	- 87,3	- 324	5.3	4. 100%
10	- 87,3	- 324	5.3	5. 100%
11	- 87,3	- 325	5.4	6. 100%
12	- 87,3	- 325	5.4	7. 100%
13	- 87,3	- 325	5.4	8. 100%
14	- 87,3	- 325	5.4	9. 100%
15	- 87,3	- 324	5.4	10. 100%

Table 2: Lightning impulse voltage withstand test, negative polarity

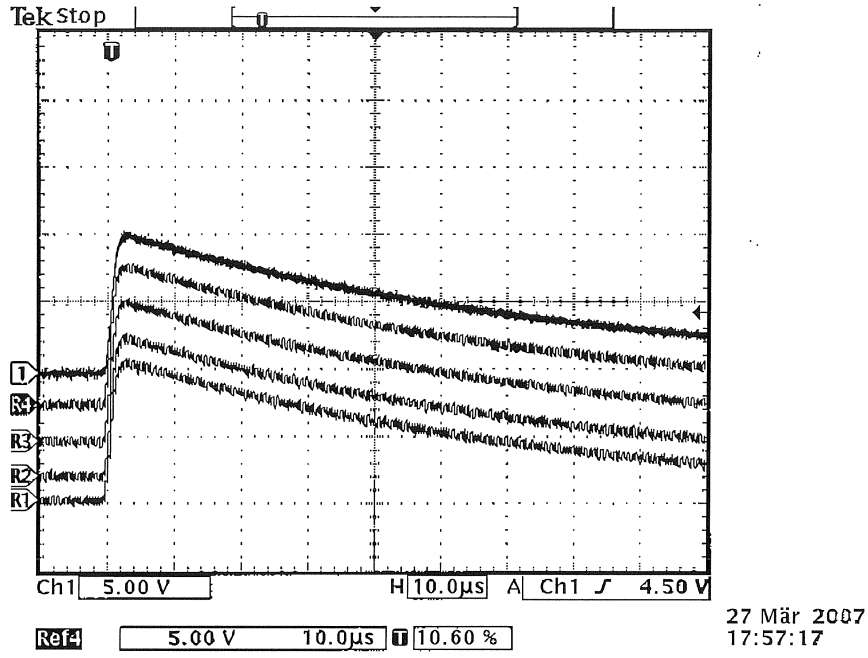


Figure 5.1: 100%-stress 1 - 5, positive polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

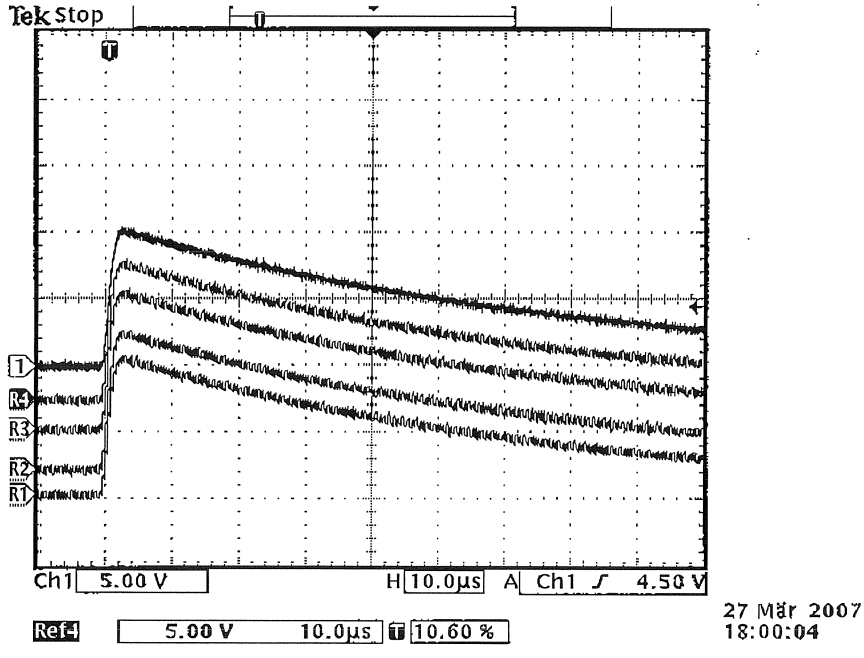


Figure 5.2: 100%-stress 6 - 10, positive polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1;ü = 3225

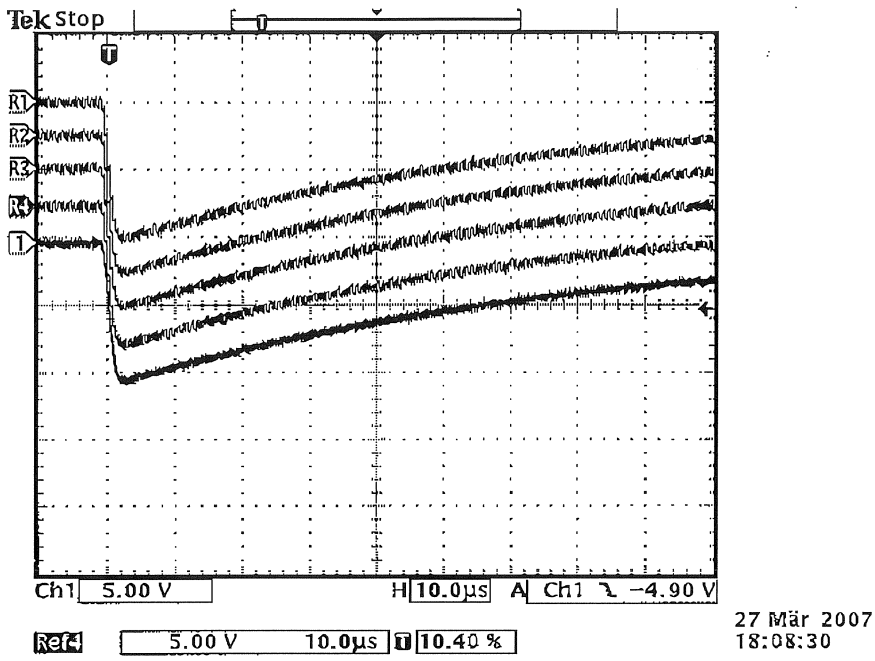


Figure 5.3: 100%-stress 1 - 5, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

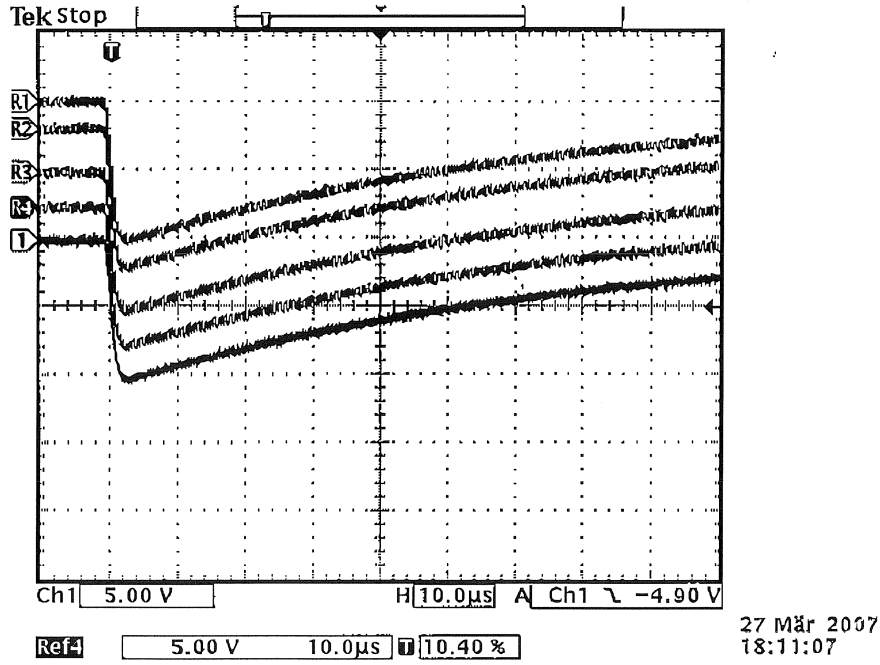


Figure 5.4: 100%-stress 6 - 10, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

5.6 AC Voltage Withstand Test during cooling period

The test was carried out as described in 4.

Test date: 27.03.2007

Temperature: T = 48,0°C

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

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.7 Water Immersion and Heat Cycling

The test was carried out as described in 4.

Test date: 13.04. - 10.05.2007

Temperature: 70-75°C, t = 5h

Number of cycles: 20

The test was passed successfully.

5.8 DC Voltage Test in Water

The test was carried out as described in 4.

Test date: 16.05.2007

Test object: screen of the cable - water

Test voltage: U = -20 kV; t = 1 min

Neither breakdown nor flashover occurred at the test object during DC voltage test.

The test was passed successfully.

5.9 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 joint type QS - III 5488A, manufacturer 3 M Deutschland 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, 09.10.2007

Dr.-Ing. R. Badent
Bereichsleiter HPT

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