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**Test Procedures for HV Transition Joints for
Rated Voltages 30kV up to 500kV**

**Working Group
B1.24**

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Test Procedures for HV Transition Joints for Rated Voltages 30kV (Um = 36kV) up to 500kV (Um = 550kV)

Working Group B1.24

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1 Introduction

1.1 Background

The use of extruded cables is increasing for transmission and distribution circuits in preference to cables with paper insulation (either kraft paper or polypropylene paper laminate). The number of manufacturers of paper cable is also decreasing, therefore the availability of such cables for repair works or re-routing will be very limited in the near future. Consequently it is becoming more common for a length of extruded cable to be introduced into a paper cable circuit requiring transition joints for the interconnection of the two cable types.

CIGRE set up WG B1.24 to review this subject and issue a report including:

- A review of existing designs of transition joints.
- A review of the existing international standards and the extent to which they cover the testing of transition joints.
- Recommendations about aligning voltage levels to those specified in IEC Standards.
- Definition of test regimes for transition joints for routine, sample, type, prequalification and after installation tests.

1.2 Scope

The purpose of these new recommendations is to give general guidance for tests on high voltage transition joints. These recommendations are valid for transition joints between paper-insulated low pressure oil filled cables and extruded insulation cables with rated voltage from 30 kV up to 500 kV. Transition joints for single core cables as well as 3-core cables are covered. The use of these recommendations in relation to other paper cable types, e.g. high pressure oil filled or gas pressure types is addressed in Appendix A.

Note: The 30kV voltage level is included in order to cover the full range of cables covered by IEC 60141

Different types of transition joints are used to connect oil-filled to extruded insulation high voltage cables, such as:

- Back-to-back transition joint
- Composite transition joint.

Tests on joints between cables with similar type of insulation are not considered in this document, even if they are used between cables with different conductors or different screens.

Although the application of high voltage transition joints for interconnection of different cable systems is likely to increase, the quantity of transition joints compared to the quantity of standard accessories required will be low. There will also be a large variety of cable constructions which have to be connected using transition joints.

The number of type tests may be limited due to the availability of suitable paper insulated cables, thus guidance is given about the range of approval.

Comments on the need for a long term prequalification test are also made.

Wherever well known and type tested components are used, for instance symmetric back-to-back transition joint designs (e.g. comprising two SF₆ terminations in a common chamber), a type test and prequalification test of the combination may be omitted.

1.3 Condition Assessment

In many cases the existing oil-filled cable on which a transition joint will be installed will have been in service for many years and hence diagnostic tests may be advisable to assess the cable condition. A full review of such procedures is given in reference [2].

In the event that the cable is found to be in as-new condition then it would generally be considered unnecessary to carry out any special diagnostic tests after installation of a transition joint.

Practices for maintenance of HV cable circuits are described in reference [3] and are not considered further in this report.

2 Normative References

The following documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- IEC 60141 *Test on oil-filled and gas-pressure cables and their accessories.*
 - Part 1: *Oil-filled, paper-insulated, metal-sheathed cables and their accessories for alternating voltages up to and including 400 kV*
 - Part 2: *Internal gas-pressure cables and their accessories for alternating voltages up to 275 kV*
 - Part 3: *External gas-pressure (gas compression) cables and their accessories for alternating voltages up to 275 kV*
 - Part 4: *Oil-impregnated paper-insulated high pressure oil-filled pipe-type cables and their accessories for alternating voltages up to and including 400 kV*
- IEC 60229 *Electric cables - Tests on extruded oversheaths with a special protective function*
- IEC 60230 *Impulse tests on cables and their accessories*
- IEC 60840 *Power cables with extruded insulation and their accessories for rated voltages above 30 kV ($U_m = 36$ kV) up to 150 kV ($U_m = 170$ kV) – Test methods and requirements.*
- IEC 60885-3 *Electrical test methods for electric cables. Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*
- IEC 62067 *Power cables with extruded insulation and their accessories for rated voltages above 150 kV ($U_m = 170$ kV) up to 500 kV ($U_m = 550$ kV) – Test methods and requirements.*
- EN 50299 *Oil-immersed cable connection assemblies for transformers and reactors having highest voltage for equipment U_m from 72,5 kV to 550 kV*

3 Definition of Tests

3.1 Development Tests

Internal tests made by the manufacturer before a new transition joint is type tested and taken into service. Details of such development tests are proprietary and shall be determined by the manufacturer.

3.2 Routine Test

Tests made by the manufacturer on each manufactured component to check that the component meets the specified requirements.

3.3 Sample Test

Tests made by the manufacturer on samples of components taken from a complete accessory, at a specified frequency, so as to verify that the finished product meets the specified requirements.

3.4 Type Test

Tests made before supplying on a general commercial basis a type of accessory covered by this recommendation, in order to demonstrate satisfactory performance characteristics to meet the intended application.

Note: Once successfully completed, these tests need not be repeated, unless changes are made in the accessory with respect to materials, manufacturing process, design or design electrical stress levels, which might adversely change the performance characteristics.

3.5 Prequalification Test

Tests made before supplying on a general commercial basis a type of accessory covered by this recommendation, in order to demonstrate satisfactory long term performance of the accessory.

Note 1: The prequalification test need only be carried out once unless there is a substantial change in the accessory with respect to material, manufacturing process, design or design electrical stress levels.

Note 2: A substantial change is defined as that which might adversely affect the performance of the accessory. The supplier should provide a detailed case, including test evidence, if modifications are introduced, which are claimed not to constitute a substantial change.

3.6 Electrical Test after Installation

Tests made to demonstrate the integrity of the cable system as installed.

4 Test Cables and Transition Joint Characteristics

For the purpose of carrying out tests described in this document and recording the results, the cables and accessory shall be identified. The relevant characteristics as given in IEC 60141-1, IEC 60840 and IEC 62067 shall be known or declared.

5 Development Tests

Development tests are carried out to prove the main electrical and non-electrical characteristics of the transition joint.

Details of such development tests shall be at the discretion of the manufacturer, examples of possible tests are given in the following clauses.

5.1 Electrical Development Tests

Electrical development tests can be adopted from the type test recommendations of this document, but may have increased test voltage levels. The duration of withstand tests as well as the number of impulses during impulse voltage test may be increased, too.

Examples for electrical development tests:

- AC voltage test
- Partial discharge test
- Lightning impulse voltage test

If new types of conductor connections are used as part of the transition joint design, the necessity for development tests of such connections should also be considered.

5.2 Non-Electrical Development Tests

Non-electrical development tests are considered to demonstrate the sufficient tightness of the external transition joint housing as well as the pressure maintaining barrier insulators between the different insulating fluids.

During operation joint housings and barrier insulators are subjected to hydraulic pressure. Barrier insulators and related sealing systems may also be subjected to vacuum during the installation process. (Vacuum processing is often used during assembly work on paper-insulated cable accessories).

Examples for non-electrical development tests:

- Pressure test
- Vacuum leak test
- Thermo-mechanical test

6 Routine Test

6.1 Extruded Cable Side of the Transition Joint

The prefabricated stress control component of a transition joint for $U > 30\text{kV}$ ($U_m > 36\text{kV}$) shall undergo partial discharge and voltage tests according to IEC 60840 or IEC 62067 using a test arrangement which may be chosen from the following:

- 1) On a transition joint installed on a cable.
- 2) By using a host accessory into which a component of a transition joint is substituted for test.
- 3) By using a simulated accessory rig (in place of a cable) in which the electrical stress environment of a main insulation component is reproduced.

In cases 2) and 3) the test voltage shall be selected to obtain electrical stresses at least the same as those on the component in a complete transition joint when subjected to the test voltages specified.

Note: The prefabricated stress control component of a transition joint consists of the components that come in direct contact with the cable insulation and are necessary to control the electric stress distribution in the accessory.

6.2 Paper Cable Side of the Transition Joint

The hydraulic tests specified in IEC 60141 shall be made on each accessory to which the relevant clauses apply.

7 Sample Test

Due to the small numbers of transition joints which are expected to be supplied under single orders, sample tests will not normally be appropriate.

Note: In special cases sample tests may be agreed between manufacturer and customer.

8 Type Test

8.1 General

The tests specified in this clause are intended to demonstrate the satisfactory performance of transition joints.

The type test may be omitted:

- As defined in the Range of Type Test Approval (see 8.2) or
- If the transition joint is a combination of existing type tested accessories.
- An example is a back-to-back transition joint .

In the case of three-core cables or three-core transition joints then if the cables and cores within the joint are fully screened then it is permitted to carry out the electrical type tests on one core only, or on a single core joint of similar electrical design.

Reference to Appendix B may be made to assist in determining the need for type tests.

A summary of type tests on transition joints is given in Appendix C.

Note 1: If suitable paper-insulated cable is unavailable, type testing will not be possible, thus approval of a transition joint design is dependant on agreement between manufacturer and customer, subject to consideration of any relevant test data.

Note 2: In the event that breakdown occurs in the paper-insulated cable or within the joint and the primary cause is attributable to the quality of the paper-insulated cable then approval of a transition joint design is dependant on agreement between manufacturer and customer, taking into account the extent of tests passed and any other relevant test data.

8.2 Range of Type Test Approval

When a type test has been successfully performed on a transition joint for connecting cables of specific conductor cross-sections, and of the same rated voltage and construction, the type approval shall be considered as valid for a transition joint within the scope of these test recommendations with other conductor cross-sections, rated voltages and with other cables provided that all the conditions of a) to c) are met:

- a) The voltage group is not higher than that of the tested transition joint.

Note: In this context, transition joints of the same rated voltage group are those of rated voltages having a common value of U_m , highest voltage for equipment, and the same test voltage levels as given in table 1.

b) The transition joint has the same or similar construction to that of the tested transition joint.

Note: Transition joints of similar construction are those of the same type and manufacturing process of stress control elements and major insulation components. Repetition of the electrical type tests is not necessary on account of the differences of the cable insulation material, of the conductor or connector type or material, or of the protective outer covering, unless these are likely to have a significant effect on the results of the test.

c) The calculated nominal electrical stresses within the main insulation parts of the transition joint and at the cable and accessory interfaces do not exceed those of the tested transition joint, or equal or higher electrical stresses at the relevant locations are well proven in other accessories.

Note: Larger conductor cross-sections than tested are allowed within this limitation.

A type test certificate signed by the representative of a competent witnessing body, or a report by the manufacturer giving the test results and signed by the appropriate qualified officer, or a type test certificate issued by an independent test laboratory, shall be acceptable as evidence of type testing.

8.3 Type Test Arrangement

The transition joint shall comply with the tests specified in 8.4.1 and 8.4.2. The minimum length of free cable between accessories shall be 5 m.

One sample of each transition joint type shall be tested.

The accessory shall be assembled on the cables in the manner specified by the manufacturer's instructions, with the grade and quantity of materials supplied, including lubricants and insulating fluids if any. There should be provision for measuring internal pressure of insulating fluid in the lapped cable compartment during the test.

In units that are intended to operate with internal oil pressure, whether such pressure is from the cable system or a separate source, the maximum pressure during the test must not exceed the minimum design operating pressure +25%. If the accessory includes an SF₆ gas filled compartment then the gas pressure must be set so that at 20°C the pressure is no greater than the minimal functional pressure for insulation specified for the accessory +0.02MPa.

Neither the cables nor the accessories shall be subjected to any form of conditioning not specified in the manufacturer's instructions which might modify the electrical, thermal or mechanical performance.

During tests a) to f) of 8.4.2, it is advisable to test joints with their outer protection fitted. If it can be shown that the outer protection does not influence the performance of the joint insulation, e.g. there are no thermo-mechanical or compatibility effects, the protection need not be fitted.

8.4 Type Test Procedure

8.4.1 Test Voltage Values

Test voltages shall be in accordance with the values given in the appropriate column of Table 1. Prior to the type tests of the transition joint, the insulation thickness of the extruded cable used shall be measured and the test voltage values adjusted, if

necessary, as stated in IEC 60840 or IEC 62067. In case of difficulty in achieving impulse and ac test voltages for paper cable the test values may be agreed upon between manufacturer and customer.

Note: If suitable oil filled cable of the required insulation thickness is not available then it is allowed to use a cable with a greater insulation thickness and to reduce the insulation thickness in the region where the joint is to be installed to the required level. As an alternative it is also allowed to adjust the test voltages in order to achieve the required electrical stress values.

8.4.2 Tests and Sequence of Tests

Transition joints shall be subjected to the following sequence:

- a) Partial discharge measurement at ambient temperature (see 8.4.3).
- b) Heating cycle voltage test (see 8.4.4).
- c) Partial discharge measurements (see 8.4.3).
 - at ambient temperature and
 - at high temperature

The measurements shall be carried out after the final cycle of item b) above or, alternatively, after the lightning impulse voltage test in item d) below.

- d) Switching impulse voltage test (required for $U_m \geq 300$ kV, see 8.4.5.1).
- e) Lightning impulse voltage test followed by a power frequency voltage test (see 8.4.5.2).
- f) Partial discharge measurements, if not previously carried out in item c) above.
- g) Tests of outer protection for buried joints (see 8.4.6).
- h) Pressure leak test: this test can be carried out on a separate sample of the transition joint. All components encapsulating the paper-insulated cable need to be assembled and a pressure and leak test performed (see 8.4.7).
- i) Examination of the transition joint after completion of the above tests (see 8.4.8).

8.4.3 Partial Discharge Measurements

The measurements shall be performed in accordance with IEC 60885-3, the sensitivity being 5 pC or better. Measured values are for information purposes only.

The test voltage shall be raised gradually to and held at $1,75 U_0$ for 10 s and then slowly reduced to $1,5 U_0$ (see Table 1).

When performed at high temperature, the test shall be carried out on the assembly which shall be heated until the cable conductors reach a steady temperature 0 K to 10 K above the maximum conductor temperature(s) in normal operation. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h.

8.4.4 Heating Cycle Voltage Test

Even though the extruded and oil filled cables may be of the same cross-section and voltage it is likely that the thermal characteristics of the cables are very different. Thus it is unlikely to be possible to heat the test assembly so that both cables achieve their required temperature, using conductor current alone. It is thus acceptable to use conductor current with the addition of heater tapes, thermal insulation or current

heating of the sheath of one or both of the cables in order to ensure that the required temperatures are reached for both cables.

- See IEC 60840 or IEC 62067 for determination of actual cable conductor temperatures.

The assembly shall be heated until the cable conductor in each case reaches a steady temperature 0 K to 10 K above the maximum conductor temperature in normal operation as specified in the relevant cable standard.

The heating shall be applied for at least 8 h. The conductor temperatures shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 16 h of natural cooling.

The extruded cable shall cool to within the temperature defined for the type test heating cycle voltage test in IEC 60840 or IEC 62067. The conductor current during the last 2 h of each heating period shall be recorded.

The cycle of heating and cooling shall be carried out 20 times.

During the whole of the test period a voltage of $2U_0$ shall be applied to the assembly.

Interruption of the test is allowed provided 20 complete heating cycles in total under voltage are completed.

Note: Heating cycles with a conductor temperature higher than 10 K above the maximum conductor temperature in normal operation are considered valid.

8.4.5 Impulse Voltage Tests

8.4.5.1 Switching Impulse Voltage Test

A switching impulse voltage test shall be carried out on transition joints of voltage $U_m \geq 300$ kV.

The assembly shall be heated as stated in section 8.4.4, until the cable conductors reach a steady temperature 0 K to 10 K above the maximum conductor temperatures in normal operation. These temperatures shall be maintained within the stated temperature limits for at least 2 h.

Note: If, for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied. The impulse voltage shall be applied according to the procedure given in IEC 60230 with standard switching impulse withstand voltage levels according to table 1. The transition joint shall withstand without failure 10 positive and 10 negative voltage impulses.

8.4.5.2 Lightning Impulse Voltage Test Followed by a Power Frequency Voltage Test

The assembly shall be heated as stated in section 8.4.4, until the cable conductors reach a steady temperature 0 K to 10 K above the maximum conductor temperatures in normal operation. These temperatures shall be maintained within the stated temperature limits for at least 2 h.

The impulse voltage shall be applied according to the procedure given in IEC 60230 with standard lightning impulse withstand voltage levels according to table 1. The transition joint shall withstand without failure 10 positive and 10 negative voltage impulses.

After the lightning impulse voltage test, the assembly shall be subjected to a power frequency voltage test at $2 U_0$ for 15 min (see table 1). At the discretion of the manufacturer, this power frequency voltage test may be carried out either during the cooling period or at ambient temperature.

No breakdown of the transition joint shall occur.

8.4.6 Tests of Outer Protection for Buried Joints

These tests shall be performed according to IEC 60840 or IEC 62067 as appropriate, unless already covered by the range of approval for these tests as specified in the relevant standard.

8.4.7 Pressure Leak Test

8.4.7.1 Leak Test

The vacuum leak test is to be performed as per manufacturer's instructions when applicable.

8.4.7.2 Pressure Test

Apply 2 times rated internal pressure for 1 h. Leakage shall be detected at the end of this period by visual examination of the test specimen and by pressure drop. This test may be performed at the end of the type tests.

No leak or rupture shall occur.

8.4.8 Examination

Examination of the transition joint, whenever possible, by dismantling, with normal or corrected vision without magnification, shall reveal no signs of deterioration which could affect the system in service operation (e.g. electrical degradation, corrosion, harmful shrinkage or leakage, in particular across any seal separating the extruded and oil filled cables).

9 Prequalification Test

9.1 General and Range of Prequalification Test Approval

The tests specified in this clause are intended to demonstrate the satisfactory long term performance of transition joints.

The prequalification test may be omitted:

- If the transition joint is a combination of existing type tested paper-insulated and prequalification tested extruded insulation accessories.
- If a transition joint of the same design has been prequalified for higher rated voltages.
- For those accessories suitable for cables with insulation screen stress less than or equal to 4,0 kV/mm covered by IEC 60840.
- If the manufacturer can demonstrate good service experience with transition joints of the same family with equal or higher calculated electrical stresses on the insulation screen of the extruded cable and in the main insulation.
- If the manufacturer has fulfilled the requirements of an equivalent long term test following a national or customer specification on similar transition joints.

It is recommended that prequalification of a new design of transition joint can be achieved by carrying out tests based on IEC 62067 prequalification test but may be installed in a

laboratory as per the recommendations made in CIGRE Technical Brochure 303 for extension of a prequalification test. The details of this test are described in sections 9.2 and 9.3.

A prequalification test certificate signed by the representative of a competent witnessing body, of a report by the manufacturer giving the test results and signed by the appropriate qualified officer, or a prequalification test certificate issued by an independent test laboratory shall be acceptable as evidence of prequalification testing.

Note 1: If the manufacturer so wishes then a transition joint can be included in a full prequalification test to IEC 60840 or IEC 62067, in which case no additional prequalification testing will be required. In this test the transition joint must be placed in a rigid installation condition as this is generally the most onerous.

Note 2: If suitable paper-insulated cable is unavailable, type testing will not be possible, thus approval of a transition joint design is dependant on agreement between manufacturer and customer, subject to consideration of any relevant test data.

Note 3: In the event that breakdown occurs in the paper-insulated cable or within the joint and the primary cause is attributable to the quality of the paper-insulated cable then approval of a transition joint design is dependant on agreement between manufacturer and customer, taking into account the extent of tests passed and any other relevant test data.

9.2 Prequalification Test Arrangement

The minimum length of free cable between accessories shall be 5 m. One sample of each transition joint type shall be tested.

The accessory shall be assembled on the cables in the manner specified by the manufacturer's instructions, with the grade and quantity of materials supplied, including lubricants and insulating fluids if any. There should be provision for measuring internal pressure of insulating fluid in the lapped cable compartment during the test.

In units that are intended to operate with internal oil pressure, whether such pressure is from the cable system or a separate source, the maximum pressure during the test must not exceed the minimum design operating pressure + 25%. If the accessory includes a gas filled compartment then the gas pressure must be set so that at 20°C the pressure is no greater than the minimal functional pressure for insulation specified for the accessory +0,02 MPa.

If the prequalification of the transition joint is to qualify the joint for use both in flexible and in rigid installations, the joint shall be installed in a rigid configuration. Otherwise the joint shall be installed in a flexible configuration.

If the joint is installed for test in a rigid configuration, the manufacturer of the joint shall consider the aspects of the design which might affect operation in a flexible installation and subject to agreement between manufacturer and customer the prequalification shall apply to both rigid and flexible installations.

Neither the cables nor the accessories shall be subjected to any form of conditioning not specified in the manufacturer's instructions which might modify the electrical, thermal or mechanical performance.

9.3 Prequalification Test Procedure

9.3.1 Test Voltage Values

Test voltages shall be in accordance with the values given in the appropriate column of Table 1. Prior to the prequalification tests of the transition joint, the insulation thickness of the extruded cable used shall be measured and the test voltage values adjusted, if necessary, as stated in IEC 60840 or IEC 62067. In case of difficulty in achieving impulse and ac test voltages for paper cable the test values may be agreed upon between manufacturer and customer.

Note: If suitable oil filled cable of the required insulation thickness is not available then it is allowed to use a cable with a greater insulation thickness and to reduce the insulation thickness in the region where the joint is to be installed to the required level.

9.3.2 Tests and Sequence of Tests

The normal sequence of the prequalification tests shall be as follows:

- a) Installation of the transition joint which is subject to the prequalification on the relevant cables.
- b) Heating cycle voltage test (see 9.3.3).
- c) Lightning impulse voltage test (see 9.3.4).
- d) Examination of the cable system with cable and accessories shall be carried out after completion of the tests above (see 9.3.5).

9.3.3 Heating Cycle Voltage Test

Even though the extruded and oil filled cables may be of the same cross-section and voltage it is likely that the thermal characteristics of the cables are very different. Thus it is unlikely to be possible to heat the test assembly so that both cables achieve their required temperature, using conductor current alone. It is thus acceptable to use conductor current with the addition of heater tapes, thermal insulation or current heating of the sheath of one or both of the cables in order to ensure that the required temperatures are reached for both cables. See IEC 60840 or IEC 62067 for determination of actual cable conductor temperatures.

The assembly shall be heated until the cable conductors reach a steady temperature 0 K to 10 K above the maximum conductor temperature(s) in normal operation.

Note: If the conductor temperature exceeds the upper limit the test is still valid.

The heating shall be applied for at least 8 h. The conductor temperatures shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 16 h of natural cooling. The conductor current during the last 2 h of each heating period shall be recorded.

The cycle of heating and cooling shall be carried out 180 times.

A voltage of $1.7 U_0$ (see table 1) shall be applied to the assembly during the whole of the test period.

Interruption of the test is allowed provided 180 complete heating cycles in total under voltage are completed.

Note 1: The test period is determined by the time required to complete thermal cycles and will be a minimum of 180 days.

Note 2: Heating cycles with a conductor temperature higher than 10 K above the maximum conductor temperature in normal operation are considered valid

Note 3: Partial discharge measurements are recommended to provide an early warning of possible degradation and to enable the possibility of a repair before failure

9.3.4 Lightning Impulse Voltage Test

The assembly shall be heated as stated in the preceding section, until the cable conductor reaches a steady temperature 0 K to 10 K above the maximum conductor temperature in normal operation.

The conductor temperature shall be maintained within the stated temperature limits for at least 2 h.

The lightning impulse voltage shall be applied according to the procedure given in IEC 60230.

The assembly shall withstand without failure or flashover 10 positive and 10 negative voltage impulses of the appropriate value given in table 1.

No breakdown of the insulation or flashover shall occur.

9.3.5 Examination

Examination of the transition joint, whenever possible, by dismantling, with normal or corrected vision without magnification, shall reveal no signs of deterioration which could affect the system in service operation (e.g. electrical degradation, corrosion, harmful shrinkage or leakage, in particular across any seal separating the extruded and oil filled cables).

10 Electrical Test after Installation

Tests on newly installed transition joints are carried out when the installation of the cable and its accessories has been completed.

If required the new cable section with extruded insulation may be tested separately according to its relevant standard before the transition joint is installed.

The test voltages recommended for general use are given in table 2, however test regimes should be evaluated on an individual basis to take into account the condition of an existing cable system.

A d.c. oversheath test according to clause 10.1 and an a.c. insulation test according to clause 10.2 are recommended.

10.1 DC Voltage Test of the Oversheath

10.1.1 New Cable Section with Extruded Insulation

The voltage level and duration specified in clause 5 of IEC 60229 shall be applied between each metal sheath or concentric wires or tapes and the ground.

10.1.2 Existing Cable Section (Paper-Insulated)

The voltage level and duration of the test should follow the local practice.

Note: Where it is required to test the oversheath of the two cable sections separately it is recommended to install a sheath sectionalised transition joint.

10.2 AC Voltage Test of the Insulation

The a.c. test voltage to be applied shall be subject to agreement between the purchaser and contractor. The waveform shall be substantially sinusoidal and the frequency shall normally be between 20 Hz and 300 Hz. However if the capacitance of the cable is such that this cannot be achieved, then subject to agreement between purchaser and contractor, the minimum frequency may be reduced to 10 Hz. A voltage according to table 2 shall be applied for 1 hour.

Note: For installations, which have been in use, lower voltages and/or shorter durations may be used. Values should be determined, taking into account the age, environment, history of breakdowns and the purpose of carrying out the tests.

Alternatively, a voltage of U_0 may be applied for 24 hours.

In addition to the a.c. voltage test, partial discharge measurements may be carried out, especially on the extruded cable part of the transition joint. The result should be recorded for information and future reference.

Table 1 - Test Voltages

1	2	3	4	5	6	7	8	9
Rated voltage	Highest voltage for equipment	Value of U_0 for determination of test voltages	Partial discharge measurement of 8.4.3	Heating cycle voltage test of 8.4.4	Heating cycle voltage test of 9.3.3	Switching impulse voltage test of 8.4.5.1	Lightning impulse voltage test of 8.4.5.2 and 9.3.4	AC Voltage test after impulse voltage test of 8.4.5.2 and 9.3.4
U	U_m	U_0	1,5 U_0	2 U_0	1,7 U_0			2 U_0
Kv	kV	kV	kV	kV	Kv	kV	kV	kV
30-33	36	18	27	36	30	-	170	36
45-47	52	26	39	52	44	-	250	65
60-69	72.5	36	54	72	61	-	325	90
110-115	123	64	96	128	109	-	550	160
132-138	145	76	114	152	129	-	650	190
150-161	170	87	131	174	148	-	750	218
220-230	245	127	190	254	216	-	1050	254
275-287	300	160	240	320	272	850	1050	320
330-345	362	190	285	380	323	950	1175	380
380-400	420	220	330	440	374	1050	1425	440
500	550	290	435	580	493	1175	1550	580

Table 2 - AC Test Voltages after Installation

Rated voltage (kV)	Value of U_0 (kV)	existing cable ≤ 5 years (kV)	existing cable > 5 years (see note) (kV)
30-33	18	36 (2 U_0)	29 (1,6 U_0)
45-47	26	52 (2 U_0)	42 (1,6 U_0)
60-69	36	72 (2 U_0)	58 (1,6 U_0)
110-115	64	128 (2 U_0)	103 (1,6 U_0)
132-138	76	132 (1,73 U_0)	106 (1,4 U_0)
150-161	87	150 (1,73 U_0)	122 (1,4 U_0)
220-230	127	180 (1,4 U_0)	152 (1,2 U_0)
275-287	160	210 (1,3 U_0)	192 (1,2 U_0)
330-345	190	250 (1,3 U_0)	228 (1,2 U_0)
380-400	220	260 (1,2 U_0)	260 (1,2 U_0)
500	290	320 (1,1 U_0)	320 (1,1 U_0)

Note: the threshold of 5 years is indicative only; test regimes should be evaluated on an individual basis to take into account the condition of an existing cable system and local practices where these exist.

APPENDIX A

Considerations for Transition Joints for Other Types of Paper Cable

The main body of this document specifically addresses transition joints connecting low pressure oil filled cables and extruded cables. The extruded cable types are those covered by IEC 60840 and IEC 62067.

However three other main types of paper cable exist and are covered by IEC 60141 parts 2, 3 and 4. Specific differences which should be taken into account when testing transition joints for use on these types of cables are given in this Appendix.

A.1 Cables to IEC 60141-2: - Internal gas-pressure cables and their accessories for alternating voltages up to 275 kV

Routine Test: - A hydraulic test as specified in the main body of this report should be carried out. In addition a gas leak test is required for the casing on the paper cable side of the joint at maximum operating pressure for 24 hours. There shall be no leakage.

AC Test Voltages For Heating Cycle Voltage Tests: - Test voltages with heating cycles are not specified in IEC 60141. The test voltages given in the main body of this report may be used. However the manufacturer should consider the values to be applied in relation to the known performance of the particular cable and adjust the AC test voltages if appropriate.

Lightning Impulse Test And AC Voltage Test After Impulse Voltage Test: - As specified in IEC 60141-2 the lightning impulse test voltage is calculated according to the formula:

- test voltage = $6U_0+40$ kV

and the AC test voltage according to:

- test voltage = $1,7U_0+10$ kV

This results in the following values reported in Table A.1.

Table A.1 – Test Voltages, case of internal gas-pressure cables

1	2	3	8	9
Rated voltage	Highest voltage for equipment	Value of U_0 for determination of test voltages	Impulse voltage test of 8.4.5.2 and 9.4.4	AC Voltage test after impulse voltage test of 8.4.5.2 and 9.4.4
U	U_m	U_0	$6U_0+40$	$1,73 U_0 +10$
kV	kV	kV	kV	kV
30-33	36	18	148	41
45-47	52	26	196	55
60-69	72,5	36	256	72
110-115	123	64	424	121
132-138	145	76	496	141
150-161	170	87	562	161
220 to 230	245	127	802	230
275 to 287	300	160	1000	287

Note: These test voltages are lower than those specified in the main body of this document.

After installation test: the test may be carried out at U_0 for 24 hours. If a one hour AC test is proposed then the condition of the cable should be taken into account in determining the voltage. Nevertheless the test voltage should not exceed the value specified in table 2 of the main document.

A.2 IEC 60141-3: - External gas-pressure (gas compression) cables and their accessories for alternating voltages up to 275 kV

Routine Test: - A hydraulic test as specified in the main body of this report should be carried out. In addition the following tests to IEC 60141-3 are required where applicable:

- A gas leak test is required for the casing on the paper cable side of the joint, if it is exposed to gas pressure in service, at maximum operating pressure for 24 hours. There shall be no leakage.
- If the accessory is subjected in normal service to small transient differences between oil pressure and gas pressure then the interface between the oil and gas regions shall be subjected to a gas pressure difference of 3bar for 1 hour. There shall be no leakage.

AC Test Voltages For Heating Cycle Voltage Tests: - Test voltages with heating cycles are not specified in IEC 60141. The test voltages given in the main body of this report may be used. However the manufacturer should consider the values to be applied in relation to the known performance of the particular cable and adjust the AC test voltages if appropriate.

Lightning Impulse Test And AC Voltage Test After Impulse Voltage Test: - As specified in IEC 60141-3 the lightning impulse test voltage is calculated according to the formula:

- test voltage = $6U_o+40$ kV

and the AC test voltage according to:

- test voltage = $1,7U_o+10$ kV

This results in the following values reported in Table A.2.

Table A.2 – Test Voltages, case of external gas-pressure (gas compression) cables

1	2	3	8	9
Rated voltage	Highest voltage for equipment	Value of U_o for determination of test voltages	Impulse voltage test of 8.4.5.2 and 9.4.4	AC Voltage test after impulse voltage test of 8.4.5.2 and 9.4.4
U	U_m	U_o	$6U_o+40$	$1,73 U_o +10$
kV	kV	kV	kV	kV
30-33	36	18	148	41
45-47	52	26	196	55
60-69	72,5	36	256	72
110-115	123	64	424	121
132-138	145	76	496	141
150-161	170	87	562	161
220 to 230	245	127	802	230
275 to 287	300	160	1000	287

Note: These test voltages are lower than those specified in the main body of this document.

After installation test: the test may be carried out at U_o for 24 hours. If a one hour AC test is proposed then the condition of the cable should be taken into account in determining the voltage. Nevertheless the test voltage should not exceed the value specified in table 2 of the main document.

A.3 IEC 60141-4: - Oil-impregnated paper-insulated high pressure oil-filled pipe-type cables and their accessories for alternating voltages up to and including 400 kV

Routine Test: - It is recommended that a hydraulic test in accordance with IEC 60141-1 is carried out on the fluid filled side of the transition joint. There shall be no leakage.

AC Test Voltages For Heating Cycle Voltage Tests: - Test voltages with heating cycles are not specified in IEC 60141. The test voltages given in the main body of this report may be used. However the manufacturer should consider the values to be applied in relation to the known performance of the particular cable and adjust the AC test voltages if appropriate.

Lightning Impulse Test And AC Voltage Test After Impulse Voltage Test: - As specified in IEC 60141-4 the lightning impulse test voltage is defined by the manufacturer of the cable. In practice the lightning impulse voltages given in table 2 of this report are those normally used. The value of test voltage given in table 2 for the AC voltage test after impulse voltage test is also recommended to be used.

These values are recommended subject to agreement and consideration of the condition of the cable used for the test.

After installation test: the test procedure as given in the main body of this document is recommended.

APPENDIX B

Design Features, Performance and Necessity for Performing Type Tests for Transition Joints

Transition joints might be either of innovative design, in which case the full scale development and type tests need to be performed or the joints might be constructed of well known and type tested components, in which case development and type tests are not necessary.

This Appendix is a general description of constructional principles of some common types of transition joint [1], with drawings and principal design features and is meant to give a general understanding and guidance to those studying this subject for the first time.

In the last section of this Appendix a methodology is described which may be employed to assess the need for testing a particular new design.

B.1 Back-to-Back Transition Joint with (2) Insulators

The transition joint as shown in Figure B-1 comprises either:

- a) Two GIS terminations in a common joint shell or
- b) two oil immersed terminations in a common joint shell.

The terminations are in back-to-back arrangement and connected with a short length of busbar. In the case of GIS terminations the joint shell is filled by insulating gas (either with SF₆ gas or mixture of SF₆ gas and nitrogen). In the case of oil immersed terminations either cable oil, transformer oil or other insulating oil is used.

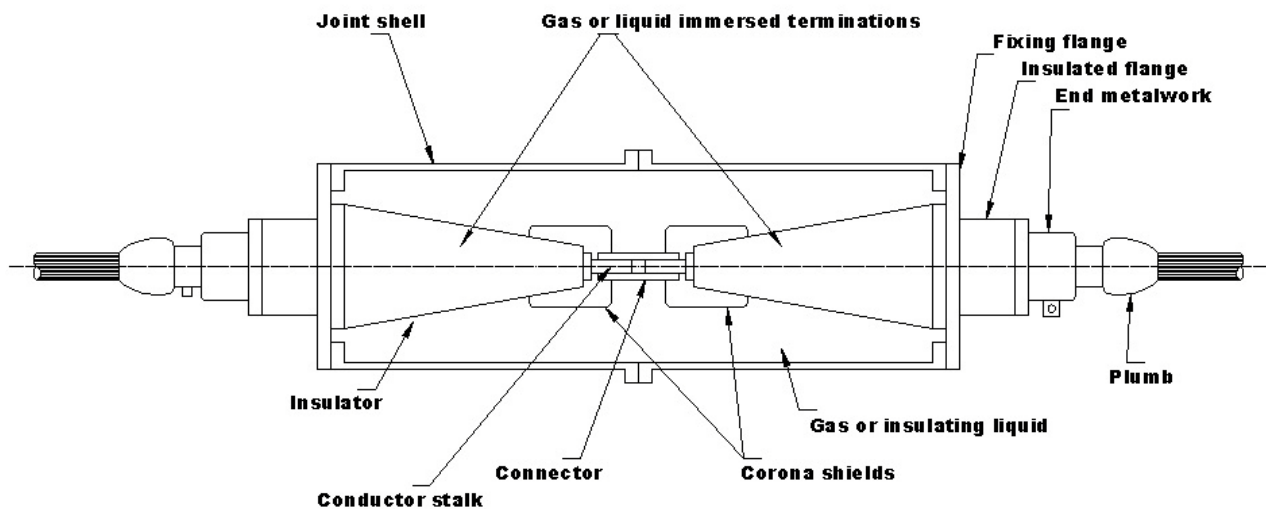


Figure B-1: Single phase back-to-back transition joint with (2) insulators

Features

Extruded and paper cable terminations are identical to terminations used in either SF₆ switchgear or transformer applications and therefore further approval testing should not be necessary.

Current carrying connection between two terminations may be specific to transition joint, in which case this may need separate evaluation.

The electrical field design in the central region may be specific to the transition joint, however this may be assessed by electric field calculations if adequate test data is available.

In the case of gas, a gas supply is required, and in case of oil the oil may be connected to the cable oil system or alternatively a header tank of some type could be used. Both systems would normally require some sort of fluid loss alarm

In the case of oil immersed terminations the chamber required may be very large, see EN 50299.

In special cases, the busbar connection can be designed so that the two cables may be disconnected allowing independent high voltage commissioning tests on the two cables.

B.2 Back-to-Back Transition Joint with One Insulator

Figure B-2 shows example of the GIS or oil immersed type termination with rigid, epoxy or porcelain, insulator on the paper-insulated cable side. The insulator anchors cable conductors and centres the corona shield within the joint shell filled with insulating fluid (SF_6 gas, mixture of SF_6 and nitrogen or insulating oil). The insulator of the GIS/transformer termination is the barrier between insulating liquid of the paper-insulated cable and the insulating oil of the joint shell.

The extruded cable end is terminated by a stress cone, which is directly immersed in the insulating fluid of the joint. It is necessary to seal the strands and sheath of the extruded cable conductor to prevent loss of insulating fluid.

The arrangement of the joint with the rigid insulator at the extruded cable side can be utilized too. In this case the joint shell is filled with insulating liquid of the paper cable and the stress cone of the paper cable is directly immersed into this liquid.

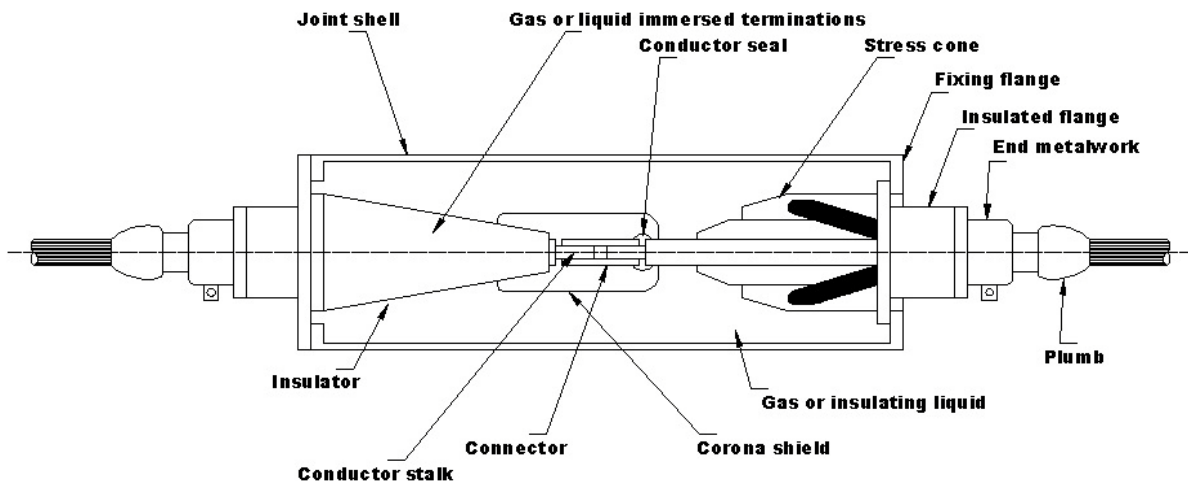


Figure B-2: Single phase back-to-back transition joint with one insulator

Features

The terminations with and without rigid insulator are identical to terminations used in either SF_6 switchgear or transformer applications.

Current carrying connection between two terminations may be specific to transition joint.

Corona shield (individual or collective) may be specific to transition joint.

An oil reservoir might be required to control thermal expansion/compression of the insulating fluid.

B.3 Composite Type Transition Joint (Three-core, Single core)

The composite type transition joint shown in Figure B-3 features central barrier, usually made of cast thermoset resin, which closely resembles the stop joint barrier employed to segregate pressure between single core liquid-filled cables. The barrier is cylindrical with an embedded metallic HV electrode, which is sealed to the conductor connection to form a seal between the two sides of the joint.

The stress control on the paper cable is made of hand applied oil-impregnated paper tapes or a combination of hand applied paper tapes and thermoset resin stress cone. In the case of single core cables there is a channel at the connector to permit insulating liquid from the cable conductor duct to be fed into the joint shell on the paper cable side. For three core cables the oil feed comes directly from the core separation position near the end of the cable sheath.

The extruded cable side of the transition joint is similar to a dry-type GIS termination, the stress cone and springs normally being identical to those used in GIS terminations. The elastomeric stress cone is sandwiched between the cable insulation and central barrier and the interface pressures are maintained by the springs.

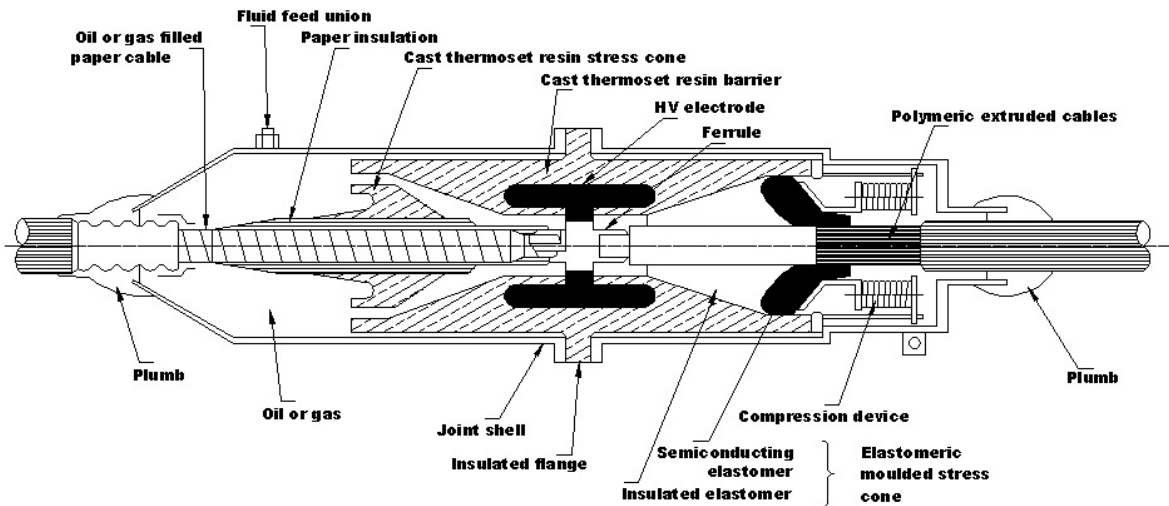


Figure B-3: Single phase composite, fed-type transition joint

Features

A common thermoset resin barrier with an embedded corona shield may be specific for use in the transition joint.

The stress cone for the extruded cable may be identical to that used in dry-type terminations.

The paper cable side may be identical to a stop joint in which case testing of the stop joint will be applicable.

In the case of the extruded cable side, testing of similar dry type accessories may be considered in conjunction with electrical stress calculations.

The current carrying connection between two cables may be specific to the transition joint.

B.4 Single-Core or Three-Core Type with Bushing

The same electrical design applies to single or three core versions of this joint.

A central barrier plate with a single bushing or multiple bushings separates lapped cable joint side from the side with extruded cable. The barrier and bushings that are usually made of premoulded thermoset resin are designed to withstand operating and test pressures required for the lapped cable.

The bushing is connected to the extruded cable in the form of extruded cable joint that can be of various designs, such as taped insulation, premoulded elastomeric body, heat shrink sleeve, etc. The joint on the paper cable side is usually insulated with either impregnated plain or crepe paper tapes.

The joint shell on the paper cable side is filled with the insulating liquid of the paper cable.

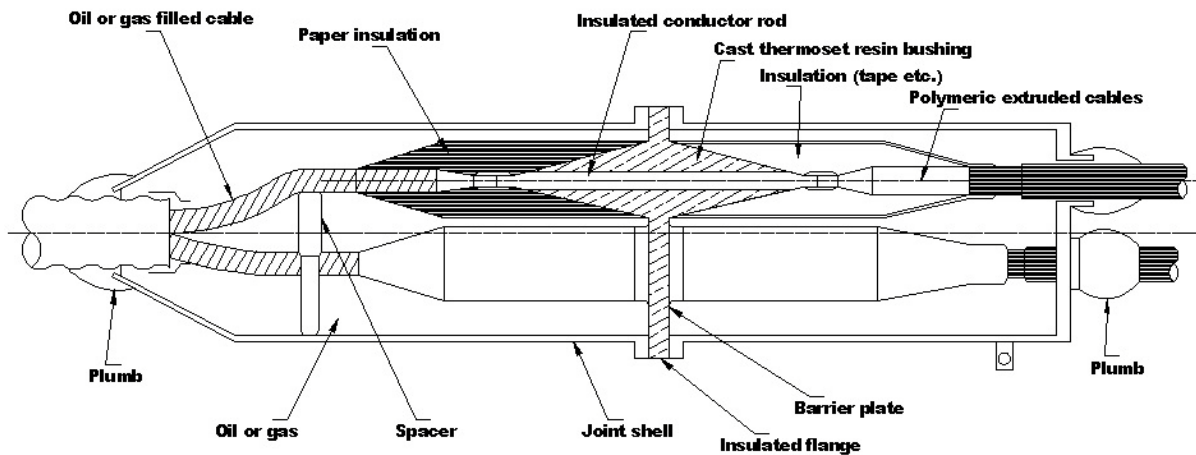


Figure B-4: Three-core transition joint with the bushing

Features

Thermoset resin bushing may be similar to one used in stop joints.

On the paper cable side the design is usually identical to a stop joint and thus previous testing of a stop joint may be applicable.

Interface of insulation with the bushing on the extruded side is specific to transition joint, however standard premoulded components or taping methods may be used.

The current carrying connection between the bushing and paper cable is usually the same as in the stop joint. Likewise, current carrying connection between bushing and extruded cable may be the same as the connection in extruded cable joint. In these cases testing of these items will already have been carried out for the standard joints.

Electrical testing of a single core can be considered valid for three core designs, only thermo-mechanical and pressure characteristics of the casings need to be considered when moving from single to three core versions.

B.5 Methodology for Assessing Test Requirements

In assessing the need for type and/or prequalification tests it is first necessary to consider the proposed design and to evaluate which parts of the accessory are similar to established accessories or parts of established accessories (for example the oil filled side of a transition joint might resemble an established stop joint). Then, based on available knowledge or lack of knowledge of performance of the particular design feature, the confidence in performance in certain test conditions should be evaluated. This can be done by considering the range of service and related test conditions which have to be met. The following table gives an example for this for a fictitious design. The need for test can then be judged based on the number of entries on the “Type Test Required” column.

Table B.1 – Example of evaluation of need for performing certain type tests of novel transition joint.

Condition (examples – others might be chosen in practice)		Confidence Level		Type Test Required?		Reason for confidence-level rank & remarks (typical comment shown as an example)
		High	Low	Yes	No	
PD initiation			x	x		Thermoset resin barrier is new
Breakdown at AC withstand voltage			x	x		
Breakdown at DC withstand voltage			x	x		
Breakdown at impulse withstand, at ambient			x	x		
Breakdown at impulse withstand, hot			x	x		
Ionization initiation in paper insulation			x	x		Electrical stress in paper insulation is influenced by the stress cone design. Test is not required if PD level is acceptable.
Load cycling	Voltage breakdown in oil (or gas) in shell		x	x		Thermoset resin barrier is new
	Voltage breakdown in termination		x	x		
	Thermal runaway of centre connector		x	x		Manufacturer to evaluate necessity of performing these tests as development tests based on past experience.
Mechanical or thermal failure during short-time current test			x		x	
Breakdown at AC withstand voltage after short-time current test			x		x	
Mechanical or thermal failure of ground connections during short-time current test		x			x	Metallic shield restoration has been individually tested
Voltage breakdown of the shield break during load cycling in water		x			x	Jacket restoration and shield-break have been individually tested
Pressure and leak test			x	x		Material and dimensions of the shell and the sealing system are critical for pressure and leak test. No test is required if previously tested on similar design

APPENDIX C

List of Type and Prequalification Tests of Cable Systems

Type tests of transition joints are covered by Clause 8

Table C.1 gives a summary and references for type testing of transition joints.

Prequalification tests of transition joints are covered by Clause 9.

Table C.2 gives a summary and references for prequalification testing of these transition joints.

Table C.1 – Type tests on transition joints

Item	Test	Clauses
a	General	8.1
b	Range of type approval	8.2
c	Type test arrangement	8.3
d	Test voltage values	8.4.1
e	Tests and sequence of tests	8.4.2
f	Partial discharge measurements	8.4.3
g	Heating cycle voltage test	8.4.4
h	Switching impulse voltage test (for $U_m \geq 300$ kV)	8.4.5.1
i	Lightning impulse voltage test followed by power frequency voltage test	8.4.5.2
j	Leak test	8.4.6.1
k	Pressure test	8.4.6.2
l	Examination	8.4.7

Table C.2 – Prequalification tests on transition joints

Item	Test	Clauses
a	General and range of prequalification test approval	9.1
b	Prequalification test arrangement	9.2
c	Test voltage values	9.3.1
d	Tests and sequence of tests	9.3.2
e	Heating cycle voltage test	9.3.3
e	Lightning impulse voltage test	9.3.4
f	Examination	9.3.5

APPENDIX D

Transition Joint Experience Data

Part of the terms of reference of WG B1-24 was to review the range of transition joints currently available. To this end the WG has carried out a survey amongst its members to investigate the types of transition joint used, their availability and number in service in the members' countries.

The results of this survey are presented in the following table:

Country	Type of Transition Joint (SC = single core; 3C = 3 core)	30-109kV		110-219kV		220-314kV		315-500kV	
		Avail- able	No. in service	Avail- able	No. in service	Avail- able	No. in service	Avail- able	No. in service
Australia	SC LPOF to SC XLPE	Yes	0	Yes	84	No	0	No	0
Belgium	SC LPOF to SC XLPE	Yes	0	Yes	0	No	0	No	0
Canada	SC LPOF to SC XLPE	Yes	0	Yes	3	Yes	0	Yes	0
China	SC LPOF to SC XLPE	Yes	0	Yes	<25	Yes	6	No	0
France	3C HPOF to SC XLPE	No	0	No	0	Yes	13	No	0
	SC LPOF to SC XLPE	Yes	0	No	0	Yes	3	Yes	6 (Back-to-back)
	3C HP Gas to SC XLPE	Yes	1	No	0	No	0	No	0
Germany	SC LPOF to SC XLPE	Yes	0	Yes	200	Yes	3 (Back-to-back)	No	0
	3C LPOF to SC XLPE	Yes	5	Yes	5	No	0	No	0
	3C IPG to 3C Pipe XLPE	No	0	Yes	7	No	0	No	0
	3C GC to 3C Pipe XLPE	No	0	Yes	2	No	0	No	0
	3C IPG Gas to SC XLPE	No	0	Yes	40	No	0	No	0
	3C GC to SC XLPE	No	0	Yes	40	No	0	No	0
Ireland	SC LPOF to SC XLPE	Yes	3	Yes	0	Yes	0	No	0
	3C LPOF to SC XLPE	Yes	30	Yes	1	No	0	No	0
	3C HP Gas to 3C Pipe XLPE	No	0	Yes	2	No	0	No	0
	3C HP Gas to SC XLPE	No	0	Yes	1	No	0	No	0
	3C MIND to SC XLPE	Yes	80	No	0	No	0	No	0
Italy	SC LPOF to SC XLPE/EPR	Yes	0	Yes	27	No	0	No	0
Japan	SC LPOF to SC XLPE	Yes	100	Yes	30	Yes	<10	No	0
	3C LPOF to SC XLPE	Yes	300	No	0	No	0	No	0
Netherlands	SC LPOF to SC XLPE	Yes	5	Yes	51	No	0	No	0
	3C LPOF to 3 SC XLPE	Yes	51	No	0	No	0	No	0
	3C MIND to 3 SC XLPE	Yes	12	No	0	No	0	No	0
Sweden	SC LPOF to SC XLPE	Yes	15	Yes	10	No	0	No	0
	3C LPOF to SC XLPE	Yes	4	No	0	No	0	No	0
UK	SC LPOF to SC XLPE	Yes	500	Yes	65	Yes	0	Yes	0
	3C LPOF to SC XLPE	Yes	250	Yes	75	No	0	No	0
	SC IPG to SC XLPE	Yes	20	Yes	30	No	0	No	0
	3C IPG to SC XLPE	Yes	0	Yes	0	No	0	No	0
USA	SC LPOF to SC XLPE	Yes	Unknown	Yes	10-20	No	0	No	0
	3C HPOF to SC XLPE	Yes	Unknown	Yes	20-30	No	0	No	0
	3C IPG to SC XLPE	Yes	Unknown	Yes	<10	No	0	No	0

Note: Data were collected between January 2007 and November 2008 and were not updated during or after WG activity: those reported should be considered as "historical" reference only

APPENDIX E

Terms of Reference for WG B1-24

Group No: WG B1.24	Name of Convener: Marco MARELLI (ITA)
TITLE of the Group: Test procedures for HV transition joints	
<p>Background: Extruded cable is increasingly being used for transmission and distribution circuits in preference to cables with lapped insulation. It is becoming more common for a length of extruded cable to be introduced into a lapped cable circuit, when the latter is repaired or diverted. International cable specifications are generally written to cover a specific insulation technology e.g. IEC 60840 applies to cables with extruded insulation and their accessories. Applications that involve cables with more than one insulation system are not usually considered. The test regimes differ between lapped paper and extruded polymeric insulation; for example an AC after laying test might be used with extruded cable and a DC test with paper cable.</p> <p>Terms of Reference:</p> <ul style="list-style-type: none">• To review the range of transition joints currently available• To review the existing international standards and the extent to which they cover the testing of transition joints• Align voltage levels to those specified in IEC Standards for extruded cable systems• To propose test regimes for transition joints and their associated cables. Type, routine, sample and after-laying tests should be considered <p>Scope of Work: The WG should take into account ac cables and accessories for rated voltages above 30kV up to 500kV. Transition joints in submarine or DC cable systems are not considered. Priority should be given to jointing paper cables with extruded cables, in particular SCFF cables and XLPE cables. All forms of testing should be considered. Priority shall be given to after-laying and type tests.</p> <p>Deliverables: The WG should provide recommendations on type, routine, sample tests for transition joints. The WG should provide a recommendation on site testing of transition joints. The WG will also provide an Electra article and a tutorial for presentation at CIGRE conferences and workshops.</p> <p>Created: 2006, Duration: 3 years</p> <p>Members: Australia, Belgium, Canada, China, Denmark, France, Germany, India, Ireland, Italy, Japan, Korea, The Netherlands, Sweden, United Kingdom, United States</p>	
Approval by TC Chairman: Klaus Frohlich Date: Nov. 12, 2006	

APPENDIX F

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