

Aerial devices with insulating boom used for live working exceeding 1 kV a.c.

The European Standard EN 61057:1993 has the status of a
British Standard

UDC 621.3.002.54:620.1:614.8

Cooperating organizations

The European Committee for Electrotechnical Standardization (CENELEC), under whose supervision this European Standard was prepared, comprises the national committees of the following countries:

Austria	Italy
Belgium	Luxembourg
Denmark	Netherlands
Finland	Norway
France	Portugal
Germany	Spain
Greece	Sweden
Iceland	Switzerland
Ireland	United Kingdom

This British Standard, having been prepared under the direction of the Power Electrical Engineering Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 March 1994

© BSI August 2006

The following BSI references relate to the work on this standard:
Committee reference PEL/88
Draft for comment 93/202884 DC

ISBN 0 580 22926 2

Amendments issued since publication

Amd. No.	Date	Comments
13865 Corrigendum No. 1	4 October 2002	Revises solvent used in 8.1.1.1 and 8.2.1 and adds a note about employer responsibility in 8.1.1.1.
16395 Corrigendum No.2	August 2006	Note added to Subclause 8.1.4

Contents

	Page
Cooperating organizations	Inside front cover
National foreword	ii
Foreword	2
Text of EN 61057	5
National annex NA (informative) Original IEC text amended by CENELEC common modifications	67
National annex NB (informative) Committees responsible	68
National annex NC (informative) Cross-references	69

National foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee and is the English language version of EN 61057:1993 *Aerial devices with insulating boom used for live working exceeding 1 kV a.c.*, including Corrigendum October 2005, published by the European Committee for Electrotechnical Standardization (CENELEC). It was derived by CENELEC from IEC 61057:1991 including Corrigendum July 1999, published by the International Electrotechnical Commission (IEC) and prepared by IEC Technical Committee No.78, Tools for live working.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by a sideline in the margin. Parts of the original IEC text that have been modified by CENELEC have been quoted in the National annex NA.

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

The graphical signs, symbols and letters used in this standard may be found in the following British Standards:

BS 3939, *Graphical symbols for electrical power, telecommunications and electronic diagrams.*

Part 1:1986, *General information, general index.*

(Related to IEC 60617-1)

Part 2:1985, *Symbol elements, qualifying symbols and other symbols having general application.*

(Identical with IEC 60617-2)

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 69 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

English version

Aerial devices with insulating boom used for live working exceeding 1 kV a.c.

(IEC 61057:1991, modified)

Equipements élévateurs à bras isolant utilisés
pour les travaux sous tension au-dessus
de 1 kV en courant alternatif
(CEI 61057:1991, modifiée)

Hubarbeitsbühnen mit isolierender
Hubeinrichtung zum Arbeiten unter Spannung
über 1 kV a.c.
(IEC 61057:1991, modifiziert)

This European Standard was approved by CENELEC on 1993-07-06. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword

The CENELEC questionnaire procedure, performed for finding out whether or not the International Standard IEC 1057:1991 could be accepted without textual changes, has shown that some common modifications were necessary for the acceptance as European Standard.

The reference document, together with the common modifications prepared by CENELEC Technical Committee TC 78, was submitted to the CENELEC members for formal vote.

The text of the draft was approved by CENELEC as EN 61057 on 1993-07-06.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-08-01
- latest date of withdrawal of conflicting national standards (dow) 1995-08-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given only for information. In this standard, Annex ZA is normative and Annex ZB is informative.

Contents

	Page
Foreword	2
Section 1. General	
1 Scope	5
2 Definitions	5
2.1 Definitions according to IEV	5
2.2 Specific definitions	6
2.3 Nomenclature	8
Section 2. Technical characteristics	
3 Special technical characteristics	11
3.1 Dimensions	11
3.2 Special devices to ensure safety	11
3.2.1 Stabilization of buckets	11
3.2.2 <i>Void</i>	11
3.2.3 Controls	11
3.2.4 Auxiliary power system	11
3.2.5 Rotation of the turntable	11
3.2.6 Communication	11
3.3 Other characteristics	12
4 Particular electrical characteristics	12
4.1 Earthing	12
4.2 Electrostatic discharge protection of metal components	12
4.3 Corona effect	12
4.3.1 Equipotential connection between conducting parts which are not insulated from each other	12
4.3.2 Guard electrode	12
4.3.3 Non-visible conductive parts	12
4.4 Bonding equipment	13
4.4.1 Bonding cable	13
4.4.2 Equipotential bonding	13
4.5 Monitoring of leakage current	13
Section 3. Type tests	
5 General	15
6 Visual inspection and dimensional check	15
6.1 Visual inspection	15
6.2 Dimensional check	15
7 Dye penetration test of insulating foam-filled structures	15
8 Electrical tests	15
8.1 Electrical tests before and after exposure to humidity for the boom, rods, hoses, optical fibre cables and hollow tubes	15
8.1.1 Boom	15

	Page		Page
8.1.2 Tubes and rods	16	10.3 Bucket creep	25
8.1.3 Hoses	16	10.4 Bucket tilt angle	25
8.1.4 Optical fibre cable	17	10.5 Precision of upper controls at the bucket	25
8.1.5 Hollow tubes	18	11 Determination of the flammability for insulating buckets and liners	25
8.2 Dielectric wet test for the boom, rods, hoses, optical fibre cables and hollow tubes	18	Section 4. Sampling and routine tests	
8.2.1 General test conditions	18	12 Sampling tests	27
8.2.2 Wet conditions	18	13 Routine tests	27
8.2.3 Test results	18	13.1 Visual inspection	27
8.3 Electrical test for oil and devices employing oil	19	13.2 Operation	27
8.4 Special requirements for hollow booms	19	13.3 Dielectric tests	27
8.4.1 Sealed hollow boom	19	13.4 Mechanical tests	27
8.4.2 Open hollow boom	19	13.5 Acoustic emission test method	27
8.5 Dielectric tests of the aerial devices	19	13.6 Determination of device stability	27
8.5.1 Dielectric tests of the complete boom	19	Section 5. Special clauses	
8.5.2 Dielectric test of a lower boom with an insulating insert	21	14 Marking	29
8.6 Dielectric test on insulating buckets and liners	21	15 Modifications	29
8.6.1 Puncture test	21	16 Acceptance tests	29
8.6.2 Surface withstand test	21	Appendix A (normative) Electrical tests before and after exposure to humidity	31
8.7 Jibs	21	Appendix B (normative) Dielectric wet test	40
9 Mechanical tests	22	Appendix C (normative) Electrical tests for aerial devices	41
9.1 Fatigue test	22	Appendix D (normative) Fatigue test of insulating hoses	44
9.1.1 Fatigue type test on upper boom and lower boom with insulating insert	22	Appendix E Overload test	46
9.1.2 Fatigue type test on insulating hoses	22	Appendix F (normative) Marking	48
9.2 Overload test	22	Appendix G (informative) Acceptance tests	49
9.2.1 Overload test on boom and jib	22	Appendix H (normative) Specific terms and nomenclature	50
9.2.2 Torsion test on boom with bucket(s)	23	Appendix J (informative) Details of typical boom current monitoring system	54
9.3 Hydrostatic tests	23	Appendix K (informative) User's guide	55
9.3.1 Bursting safety factors	23	Appendix L (informative) Acoustic emission on aerial devices with insulating booms — Test method	55
9.3.2 Hydrostatic tests on insulating hoses	23	Annex ZA (normative) Other international publications quoted in this standard with the references of the relevant European publications	64
9.3.3 Impulse test on insulating hoses	23	Annex ZB (informative) prEN 280 Mobile elevating work platforms — Design calculations — Stability criteria — Construction — Safety — Examinations and tests	65
9.3.4 Leakage test on insulating hoses	24		
9.3.5 Change in length test on insulating hoses	24		
9.3.6 Burst test on insulating hoses	24		
9.3.7 Cold bend test on insulating hoses	24		
9.4 Oil depressurization	25		
10 Mechanical factors that affect the use of a mobile unit during live working	25		
10.1 Boom deflection	25		
10.2 Horizontal bucket loading	25		

Section 1. General

1 Scope

This standard is applicable to aerial devices (mobile elevating work platforms [MEWP]), with or without the possibility of an additional jib, as a minimum with an insulating upper boom (extending structure), used for live working on the nominal voltage, which is between 1 kV r.m.s. and 800 kV r.m.s., at power frequency.

The application of some parts of this standard to d.c. systems is still under consideration.

This standard specifies:

- the specialized technical characteristics, tests and checks of the insulating parts (boom, extending structure, transmission of controls along the boom, work platform, bucket, accessories, jibs, etc.) required for live working;
- the technical characteristics, tests and checks of conducting parts, the conductive properties which are essential for positioning near to, or at, the potential of the live element (part) to be worked on;
- the special characteristics which are not necessarily subjected to test, but which are fundamental for ensuring the safety and precision essential to safe working on live parts.

Excluded from this standard, but to be observed:

- specifications applicable to all kinds of aerial devices (mobile elevated work platforms) which are covered by applicable International Standards or national regulations, for example design, calculations, stability requirements, roadway code, employment regulations, etc.;
- specifications for those parts of the aerial device (carrier, etc.) not specific to live working;
- specifications for personnel electrostatic shielding equipment (the user should provide adequate shielding equipment in accordance with national regulations).

2 Definitions

2.1 Definitions according to IEV

Flashover

An arc by-passing an insulating body (IEV 121-03-14).

Puncture

A disruptive breakdown through a solid insulant (IEV 121-03-13).

Sparkover

A disruptive discharge: passage of an arc following dielectric breakdown.

NOTE The term “sparkover” is used when a disruptive discharge occurs in a gaseous or liquid dielectric. The term “flashover” is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium. The term “puncture” is used when a disruptive discharge occurs through a solid dielectric.

Type test

A test of one or more devices made to a certain design to show that the design meets certain specifications (IEV 151-04-15).

Routine test

A test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria (IEV 151-04-16).

Sampling test

A test on a number of devices taken at random from a batch (IEV 151-04-17).

Acceptance test

A contractual test to prove to the customer that the device meets certain conditions of its specification (IEV 151-04-20).

2.2 Specific definitions

Aerial device

Any device which is primarily designed to position persons and to handle materials.

NOTE This device does not include the chassis.

Chassis

A vehicle on which the aerial device will be mounted, such as a commercial vehicle, trailer or all terrain vehicle.

NOTE The chassis (supporting vehicle) may be the base of a mobile elevating work platform (MEWP) and it may be pulled, pushed, self-propelled, vehicle-mounted, etc.

Mobile unit

A combination of an aerial device, its carrier and related equipment. See Figure H.1 of Appendix H — the letters (A), (B), etc. are referenced.

Model

Manufacturer's designation for aerial device specified.

Platform height of the mobile unit (A)

The height at maximum elevation from platform floor to ground.

Horizontal reach (B)

The maximum distance reached from the centreline of the rotating turntable to the outer edge of the platform.

Outrigger height (C)

The distance from ground level to the bottom of retracted outriggers.

Outrigger penetration (below ground level) (D)

The distance below ground level which the outriggers can reach when fully extended.

Outrigger spread (at ground level) (E)

The distance between the outer edges on fixed pads, or between pins on pivoted pads, of opposite outriggers resting on level ground.

Outrigger spread (at maximum extension) (F)

The distance between the outer edges on fixed pads, or between pins on pivoted pads, of opposite outriggers when fully extended.

Chassis height (G)

The height from ground level to the top of the chassis frame rail.

Rear axle centreline

The location of the combination moment equivalent for the centrelines of one, two, three or more rear axles (see Figure H.1A of Appendix H).

Wheel base (WB)

The distance between the front and rear axle centrelines of the chassis recommended for mounting the aerial device.

Cab-axle dimension (CA)

The distance between the back of the cab and the rear axle centreline of the chassis recommended for mounting the aerial device.

Front projection (FP)

The maximum distance of any part of the aerial device forward of the front axle centreline when stowed for travel.

Rear projection (RP)

The maximum distance of any part of the aerial device behind the rear axle centreline when stowed for travel.

Front overhang (FO)

The maximum distance of any part of the aerial device forward of the front bumper.

Rear overhang (RO)

The maximum distance of any part of the aerial device behind the rear bumper.

Overall length (OL)

The maximum distance of any part of the aerial device or the truck between the front and the back.

Aerial device centre of gravity — horizontal (K)

The horizontal component of the distance from the axis of rotation to the centre of gravity of the aerial device in the stowed position.

Aerial device centre of gravity — vertical (L)

The vertical component of the distance above the mounting surface of the aerial device to the centre of gravity of the aerial device in the stowed position.

Insulation gap (upper boom) (M)

The minimum insulated length of the upper boom and its components.

Insulation gap (lower boom) (N)

The minimum insulated length of the lower boom and its components.

Centre of rotation location (H)

The distance from the centreline of the rear axle to the axis of rotation of the turntable.

Travel height (stowed) (J)

The overall height from ground level to the highest point on the aerial device when stowed for travel.

Rated capacity (P)

The capacity is of two distinct types and in both cases shall be determined with booms extended to a position of maximum over-hanging moment attainable through the full rotation of the turntable.

Capacities in other positions shall be specified separately.

Platform capacity is the maximum load in kilograms for which the aerial device is designed to operate under the above conditions. Supplemental capacity is the maximum additional load, in kilograms, applied to the booms by jibs and for specified boom positions.

Aerial device weight (W)

Weight of the standard aerial device, less optional counterweights, accessories and auxiliary equipment.

Lower boom travel up (a)

The maximum angle reached by the lower boom measured above the horizontal axis passing through the lower boom pin.

Lower boom travel down (b)

The maximum angle reached by the lower boom measured below a horizontal axis passing through the lower boom pin.

Turntable rotation (c)

The range of turntable rotation, in either direction, expressed as continuous or non-continuous, specified in angular degrees.

Upper boom travel up (d)

The maximum angle reached by the upper boom measured above a horizontal axis passing through the elbow pin at its maximum height.

Upper boom travel down (e)

The maximum angle reached by the upper boom measured below a horizontal axis passing through the elbow pin at its maximum height.

Rated voltage of the aerial device (U_d)

The maximum use voltage between the upper boom tip and the elbow of the mobile unit at power frequency (see Appendix K and Figure H.2 of Appendix H).

NOTE This corresponds to the maximum r.m.s. line to ground voltage of a three-phase system.

2.3 Nomenclature (the numbers (1), (2), etc. are referenced — see Figure H.2 of Appendix H)

Upper controls (1)

Those controls located in or beside the platform, and designed for the movement functions of the aerial device and other functions (e.g., control of the winch).

Platform (2)

The personnel-carrying component of an aerial device, such as a bucket.

Platform or bucket pin (3)

The horizontal pin about which the platform or bucket moves relative to the upper boom.

Upper boom tip (4)

The end of the upper boom to which the platform is attached.

Upper boom (5)

The insulating structural member attached to the lower boom, or to an extendable structure, which supports the platform.

Upper boom cylinder (6)

The hydraulic cylinder which articulates the upper boom.

Upper boom drive mechanism (7)

Means, such as linkage, cables, sheaves and gears, used to produce upper boom articulation.

Elbow (8)

The structure connecting the upper boom to the lower boom, about which one articulates relative to the other.

Elbow pin (9)

The horizontal pin about which the upper boom rotates relative to the lower boom.

Lower boom (10)

The structural member attached to a turntable or base, which supports the upper boom.

Lower boom insulating insert (11)

The part of the lower boom made of high dielectric strength material (usually fibreglass reinforced plastic or equivalent).

Lower boom cylinder (12)

The hydraulic cylinder which articulates the lower boom.

Lower boom pin (13)

The horizontal pin about which the lower boom is raised and lowered relative to the turntable.

Turntable (14)

The rotating base of the aerial device that supports the booms.

Pedestal (15)

The stationary base of the aerial device that supports the turntable.

Lower controls (16)

The controls on the vehicle, turntable or pedestal, designed for the movement functions of the aerial device.

Outriggers (17)

The structural members which, when properly extended or deployed on firm ground, assist in stabilizing the mobile unit.

Outrigger controls (18)

The controls for operating the outriggers.

Stabilizers (19)

A means to assist in stabilizing the chassis such as outriggers, torsion bars and spring lock-outs.

Jib (20)

An auxiliary arm at the upper boom tip to support loads.

Liner (21)

Material so formed as to fit inside a platform, or similar support, at the upper boom tip which may modify the electrical properties of the platform.

NOTE Liners may be fully insulating or conductive.

Section 2. Technical characteristics

3 Special technical characteristics

3.1 Dimensions

The dimensions defined in 2.2 and in Figure H.1 of Appendix H shall be supplied.

3.2 Special devices to ensure safety

Aerial devices for live working shall be equipped with the following appliances.

3.2.1 *Stabilization of buckets*

Subclause 7.4.1 of prEN 280 applies (see Annex ZB).

3.2.2 *Personnel safety attachments*

Void

3.2.3 Controls

3.2.3.1 *Double action of the controls at the bucket*

In order to avoid any untimely actuating of a control at the bucket, the use of an unlocking device shall precede the use of the control itself and shall be maintained simultaneously during the use of controls.

3.2.3.2 *Emergency stop*

Subclause 9.5 of prEN 280 applies (see Annex ZB).

3.2.3.3 *Control panels*

Aerial devices for live working shall have at least two control panels, one at the bucket and another near the turntable. The lower control panel shall take priority over the upper control panel except for control of the jibs and other functions. In particular, a control at the bucket which becomes activated shall under no circumstances prevent the control panel near the turntable from functioning normally. The boom position controls and their unlocking devices shall return to their neutral position and stop movement when released by the operator. Controls shall be plainly identified as to their function and protected from damage and inadvertent activation.

NOTE 1 Based on the design and type of aerial device and the control panel arrangement employed, all controls should move in a direction that corresponds to the movement function they control.

NOTE 2 Handles of operating levers of multiple handle controls should each have a distinctive hand grip area shape. The suggested shape and order or position for the controls is shown in Figure H.3 of Appendix H.

3.2.3.4 *Control of outriggers*

Subclauses 7.2.4.1, 7.2.4.2 and 7.2.5 of prEN 280 apply (see Annex ZB).

3.2.3.5 *Autotest of electronic and numeric controls*

A permanent test process shall be provided in the case of electronic and numeric controls to verify that control and action correspond.

3.2.4 *Auxiliary power system*

Subclause 10.12 of prEN 280 applies (see Annex ZB).

In addition the auxiliary power source shall provide rotation of the turret as well as lifting and descent of the bucket.

3.2.5 *Rotation of the turntable*

Rotation requirements regarding continuous or limited angle systems shall be specified by the customer.

3.2.6 *Communication*

Communication shall be established between bucket and ground locations, including lower control panel. In the case of visual or audible communication, a clear signal shall be considered as satisfactory.

NOTE A well-defined system of communication may be used. When a transmitter-receiver system is employed, it should be so equipped that verification of proper operation is possible.

3.3 Other characteristics

Hydraulic insulating hoses shall not only comply with 9.1.2, 9.3 and 9.4 but also comply with ISO 6605.

4 Particular electrical characteristics

4.1 Earthing

All mobile units shall be equipped with earthing attachment point(s) capable of carrying induced currents.

NOTE According to the network on which the mobile unit will be employed, the earthing attachment point(s) should be capable of carrying the estimated fault current as specified by the user. Personnel (particularly those on the ground) should be instructed in the safe working procedure for access to the mobile unit under operational conditions (see Appendix K, User's guide.)

4.2 Electrostatic discharge protection of metal components

Metal parts for which insulation is not functionally necessary should not be insulated.

NOTE For an aerial device which has an insulating lower boom insert, the conductive elbow should be electrically discharged before being touched.

4.3 Corona effect

4.3.1 *Equipotential connection between conducting parts which are not insulated from each other*

All conducting parts which are not insulated from each other shall be electrically connected together, either by the nature of their assembly or by an equipotential braid.

In particular, it is essential that the ends of all hydraulic hoses shall be electrically interconnected (for an example of a layout, see Appendix J — Figure J.1). Suitable access should be provided to check the electrical connections inside the boom.

4.3.2 *Guard electrode*

No damage due to corona effects shall occur at the rated voltage of the aerial device. If necessary, guard electrodes (grading rings) shall be installed to prevent any corona effect so that no parts (hoses, rods, etc.) are damaged (see Appendix J — Figure J.2).

NOTE 1 Discharges occurring inside the boom, rods, tubes, hoses, etc. may not be visible. If damaging corona is not detected at rated voltage(s), the guard electrode (grading ring) may still be required to minimize electrical stresses on the materials involved and prevent sparkovers (flashovers) during power frequency and switching surge withstand tests, and during use. Corona discharge effects may be determined using partial discharge measurement techniques. See in particular Clause 1, and 3.2 and 4.1 of IEC 60270.

NOTE 2 The full implementation of IEC 60270 in this standard on aerial devices with insulating booms is under consideration, since it is impossible to establish acceptable corona levels due to the wide variety of organic insulating materials and systems in use.

4.3.3 *Non-visible conductive parts*

For all conductive parts fixed to or into the insulating section(s), it shall be made apparent that they are conductive. Where this is not technically possible, the outside of the insulating section shall be clearly marked to indicate that a conductive item is included. This marking should be blue.

4.4 Bonding equipment

4.4.1 *Bonding cable*

The cable used to bond the bucket to live parts should be able to withstand the aerial device power frequency charging (capacitive) current during $1\text{ h} \pm 1\text{ min}$ without heating (tolerances $30\text{ }^{\circ}\text{C}$). This current value shall be determined during the test(s) at the rated voltage and at twice the rated voltage. The values shall be furnished with the aerial device and after each complete re-test in accordance with 8.5.1.1. The cable shall, as a minimum, withstand a current equal to the current measured at twice the rated voltage.

NOTE A small bonding cable may be destroyed by a fault in the electrical insulating parts of the aerial device.

4.4.2 *Equipotential bonding*

All articulated parts and rotating parts of the aerial device shall be bonded. Example: conductive brush on bearing turntable, jumpers at elbow.

NOTE These bondings are useful to protect balls, "O" rings, etc., against the effect of leakage currents.

4.5 Monitoring of leakage current

Such a device is provided at the request of the customer. If this device is provided, it shall comply with the details given in Appendix C — Figure C.5.

NOTE 1 The current electrical circuit should be designed so that it is not damaged due to surges produced by make or break of contact.

NOTE 2 Periodic tests or work methods. Monitoring may be used for test purposes and when bare hand work is undertaken.

Section 3. Type tests

5 General

In order to show compliance with this standard, the manufacturer shall provide evidence that the following tests have been carried out successfully.

6 Visual inspection and dimensional check

6.1 Visual inspection

Each aerial device component to be tested in accordance with this section shall be visually inspected to check for manufacturing defects and correct functioning.

6.2 Dimensional check

Each aerial device component to be tested in accordance with this section shall be checked by measurement to ensure that it complies with the dimensions stated by the manufacturer.

7 Dye penetration test of insulating foam-filled structures

Five test pieces, each 100 mm long, and cut from a different foam-filled structure, shall be completely immersed in a container of 0,1 % by volume or fuchsine/distilled water solution, and this system placed in a vacuum chamber which is then evacuated to less than 6 500 Pa. The test pieces shall remain for 1 h in the dye solution after which the vacuum is released and the test pieces removed.

In order to avoid fuchsine spreading from the sample ends during cutting, it is necessary to dry the test pieces for 24 h in ambient air before cutting them.

After drying, the test pieces are cut 10 mm from each end. The new test pieces thus obtained are then split lengthways. They shall be free from any fuchsine dye penetration.

8 Electrical tests

Electrical tests specified herein are carried out at power frequency.

NOTE D.C. tests are under consideration.

8.1 Electrical tests before and after exposure to humidity for the boom, rods, hoses, optical fibre cables and hollow tubes

These tests are carried out in order to verify the ability of the products to withstand:

- electrical stress before exposure to humidity;
- electrical stress after exposure to humidity;
- electrical stress after infliction of a gash (hoses and optical cables only).

8.1.1 Boom

8.1.1.1 General test conditions

Before electrical testing, each test piece shall be prepared by cleaning with a isopropanol solution [$\text{CH}_3 - \text{CH}(\text{OH}) - \text{CH}_3$] and then dried in air for 15 min.

NOTE It is the duty of an employer to ensure that the relevant legislation and safety requirements for the use of this chemical are complied with in their entirety.

These tests are carried out on three test pieces, each 300 mm long, which are cut from the boom in such a way as to avoid the use of material within 100 mm of an end.

The ends of these test pieces shall be covered with conductive adhesive tape before each electrical test. At the time of conditioning in a humid atmosphere, this conductive tape shall be removed.

Conditioning in a humid atmosphere is carried out in accordance with IEC 60212.

The test location shall be at the standard atmospheric conditions given in Table 1 of IEC 60212, i.e. with a temperature range from 18 °C to 28 °C.

The test arrangement is shown in Figure A.1 through Figure A.5 of Appendix A. The measuring equipment shall be at least 2 m from the high voltage (HV) electrode. The measuring leads, shunt and optional protective gap shall be shielded and earthed. The test piece shall be mounted approximately 1 m above the ground on an insulating support. A voltage of 100 kV r.m.s. at power frequency is applied between the electrodes, in accordance with IEC 60060 and the current passing through the test piece is measured (the guard electrode, on the earth (ground) side, is directly connected to earth).

The specified acceptable current values are given in r.m.s. values. The phase difference between current and voltage is measured as follows:

- current (earth end) by passing it through a known impedance (lower than 10 000 Ω);
- voltage (line end) by means of an appropriate divider.

During the tests there shall be no sign of flashover or puncture of any of the test pieces.

8.1.1.2 Test before exposure to humidity

After at least 24 h in the ambient atmosphere of the test area, the current I_1 is measured at an a.c. voltage of 100 kV r.m.s. at power frequency applied between the electrodes for 1 min. The maximum current and the phase angle ϕ_1 between current and voltage are recorded.

8.1.1.3 Test after exposure to humidity

The specimens are placed in a chamber and subjected to the following conditioning:

168 h/23 $\times$ C/93 % r.h. according to Table I of IEC 60212.

At the end of this period, the test pieces shall remain in an atmosphere of 93 % relative humidity and be tested upon return to the ambient temperature of the test area. After the test pieces have been lightly wiped with a dry cotton cloth, the current I_2 and phase angle ϕ_2 are measured under the same conditions as I_1 and ϕ_1 .

The test piece shall be located in the same position in relation to earth; the high-potential end of the test piece shall be the same for both tests.

8.1.1.4 Test results

The current I_1 measured shall not exceed 5 nA/mm² (for this ratio, the whole surface of the measuring electrode shall be taken). See Figure A.2 of Appendix A.

The phase angle ϕ_1 shall be higher than 80°. After exposure to humidity, the current I_2 shall be lower than twice I_1 and the phase angle ϕ_2 higher than 50°.

8.1.2 Tubes and rods

Foam-filled or solid tubes or rods shall comply with IEC 60855.

Hollow tubes shall comply with the future IEC publication concerning insulating hollow tubes for electrical purposes.

8.1.3 Hoses

Hoses, as applicable, include all flexible components that are of composite or laminated construction.

Hoses in the insulating portion of the boom shall not be wrapped, even with insulating material, because moisture may ingress between the hose and this covering.

Hoses shall comply with Appendix M and with the additional tests specified in 8.1.3.1 and 8.1.3.2 of this standard.

8.1.3.1 Tests before and after exposure to humidity

8.1.3.1.1 General test conditions

Tests before and after exposure to humidity are the same as those specified in 8.1.1.1, 8.1.1.2 and 8.1.1.3 (in which the word “boom” will be replaced by the word “hoses”). The hoses on test shall be filled with insulating oil recommended by the manufacturer for the aerial device. After the hose has been cut (500 mm minimum length) its ends shall be plugged and sealed (these plugs shall not be removed during conditioning). The test arrangement is shown in Figure A.1, Figure A.3, Figure A.6 and Figure A.7 of Appendix A.

8.1.3.1.2 Test results

The current I_1 measured shall not exceed 10 4A. The phase angle ϕ_1 shall be higher than 80° . After exposure to humidity, the current I_2 shall be lower than twice I_1 .

If I_2 is greater than twice I_1 but lower than $I_1 + 40$ 4A, the specimen also passes if the phase angle between voltage and the current I_2 is greater than 40° .

In no case shall I_2 be greater than $I_1 + 40$ 4A.

8.1.3.2 Test after the infliction of a gash on hoses

This test shall be carried out on three test pieces.

NOTE A gash of the external surface only may affect its electrical withstand. If the gash were more severe, the hose would burst.

8.1.3.2.1 Preparation of the test pieces

The test piece shall be fitted with end fittings, filled with oil at atmospheric pressure and capped. A gash is then inflicted on the surface of the test piece. It consists in cutting the surface until reaching the meshed fibres. The dimensions of the gash shall be:

— length: 20 mm — width: 0,1 mm

For hoses without fibre reinforcement or construction, the gash shall consist of a cut made with a knife, and having a length of 20 mm and a depth equal to 50 % of the wall thickness.

The gash shall be inflicted at a minimum distance of 30 mm from one of the electrodes (see Appendix A, Figure A.8).

8.1.3.2.2 Test procedure

The test pieces shall be immersed during 24 h under 20 cm of water (conditioning according to IEC 60212: 24 h/23 $\times$ C/water). The water resistivity shall be 100 Ω ·m. The test piece shall be kept horizontal. Then the test specified in 8.1.3 shall be carried out again, but without exposure to humidity.

8.1.3.2.3 Test results

No puncture or flashover shall occur. The current is not measured.

8.1.4 Optical fibre cable

The optical fibre cable included in the thickness of the boom, tube or rods, shall be tested as indicated in 8.1.1 and 8.1.2.

The optical fibre cable in the insulating portion of the boom shall not be wrapped, even with insulating material, because moisture may ingress between the optical fibre and its covering.

If the optical fibre cables are in the form of an independent optical cable, the following tests shall be applied.

NOTE Multilayer optical fiber cables in the form of a single and independent optical cable are not considered as wrapped.

8.1.4.1 Test before and after exposure to humidity

8.1.4.1.1 General test conditions and test before and after exposure to humidity

These general test conditions are the same as defined in 8.1.1.1, 8.1.1.2 and 8.1.1.3, in which the word “boom” will be replaced by the word “optical cable”.

8.1.4.1.2 Test results

The current I_1 measured shall not exceed 10 4A. The phase angle ϕ_1 shall be greater than 80° . After exposure to humidity, the current I_2 shall be lower than twice I_1 .

If I_2 is greater than twice I_1 but lower than $I_1 + 40$ 4A, the specimen also passes if the phase angle between voltage and current ϕ_2 is greater than 40° .

In no case shall I_2 be greater than $I_1 + 40$ 4A. No puncture or flashover shall occur.

8.1.4.2 Test after the infliction of a gash

This test shall be carried out on three samples.

NOTE A gash of the external surface only may affect its electrical withstand. If the gash were more severe, the optical fibre would not function properly.

8.1.4.2.1 *Preparation of the test pieces*

A gash is inflicted on the surface of the test piece. It consists in cutting the surface until reaching the fibre itself. The dimensions of the gash shall be:

- length: 20 mm – width: 0,1 mm

The gash shall be inflicted at a minimum distance of 300 mm from the ends of the optical fibre (see Appendix A, Figure A.8).

8.1.4.2.2 *Test procedure*

The test pieces shall be immersed during 24 h under 20 cm of water (conditioning according to IEC 60212: 24 h/23 °C/water). The water resistivity shall be 100 $\Omega\cdot\text{m}$. The test piece shall be kept horizontal. Then the test specified in 8.1.5.1 and 8.1.5.2 shall be carried out again, but without exposure to humidity.

8.1.4.2.3 *Test results*

No puncture, sparkover or flashover shall occur. Current is not measured.

8.1.5 *Hollow tubes*

Laminated hollow tubes shall not be used. Wet winding fibre reinforced plastic tubes shall not be considered as laminated. Hollow tubes shall not be covered with independent or separate, even insulating, material because moisture could ingress between the tube and this covering.

Hollow tubes shall comply with the future IEC publication concerning insulating hollow tubes for electrical purposes.

8.2 *Dielectric wet test for the boom, rods, hoses, optical fibre cables and hollow tubes*

8.2.1 *General test conditions*

Before dielectric testing, each test piece shall be prepared by cleaning with isopropanol [$\text{CH}_3 - \text{CH}(\text{OH}) - \text{CH}_3$] and then dried in air for 15 min.

These tests are carried out on three test pieces, each 1,2 m long, which are cut from booms, tubes, rods, hoses, optical fibre cables and hollow tubes; they shall not use material within 0,1 m of the end.

The electrodes, made with three or four turns of copper or aluminium wire from 2 mm to 4 mm in diameter, shall be $1\,000 \pm 5$ mm apart.

The test location shall be at the standard ambient conditions of IEC 60212, with a temperature range of 23 ± 5 °C.

The test arrangement is shown in Figure B.1 and Figure B.2 of Appendix B. The test piece shall be inclined at an angle of 45°. The voltage of 80 kV r.m.s. at power frequency shall be applied between the electrodes, in accordance with IEC 60060, for a period of 1 h.

8.2.2 *Wet conditions*

The wet test is carried out in accordance with the revised wet test procedure described in IEC 60060-1 and corresponding to the following revisions:

- average precipitation rate: 1.0 to 1.5 mm/min;
- water resistivity: 100 ± 15 $\Omega\cdot\text{m}$.

However, contrary to the requirements of the above-mentioned publication, the test piece shall not be pre-wetted before voltage application; spray and voltage shall be applied simultaneously for 1 h.

8.2.3 *Test results*

The test duration is 1 h and the test is successful if there is:

- no flashover, sparkover or puncture;
- no tracking or erosion on the surface observed without a magnifying glass.

8.3 Electrical test for oil and devices employing oil

This test shall be applied to aerial devices that use oil between earth and bucket(s) (controls, tool outlets, etc.).

The method for the determination of the electric strength of insulating oil is described in IEC 60156.

Methods for obtaining samples and related specifications are included in IEC 60247, IEC 60296 and IEC 60475.

The values selected shall be in accordance with the requirements of the specific materials employed in the aerial devices and design ratings.

Each individual breakdown voltage obtained during the test shall not be lower than 10 kV. The average of the results shall be greater than 20 kV.

8.4 Special requirements for hollow booms

8.4.1 *Sealed hollow boom*

Sealed booms shall be equipped with a reliable system to ensure that the inside is dust and moisture-free.

NOTE The boom may be filled with inert gas. If so the difference in pressure between the gas and the atmosphere is measured continuously to ensure the efficiency of the sealing. The boom may be fitted with a silica-gel-chemical material ensuring, when blue, that the partial pressure of water is correct. (Usually, the percentage of water is lower than one part per million.)

8.4.2 *Open hollow boom*

If the boom is open, it shall be manufactured in such a way that cleaning, drying and inspection of the inside are possible.

NOTE An endoscope or any other camera system may be used to permit the internal survey of the boom.

8.5 Dielectric tests of the aerial devices

These tests shall be conducted after mechanical tests. The test voltage levels employed depend upon the rated voltage of the aerial device. The aerial device shall be free of damaging corona at its rated voltage.

NOTE 1 The metallic parts of the booms located between the two insulating parts should be earthed before contact by personnel to prevent electrostatic discharge.

NOTE 2 Corona discharge effects may be determined using partial discharge measurement. See IEC 60270, particularly Clause 1, and 3.2.1 and 4.1.

The full implementation of IEC 60270 in this standard is beyond its scope, as the level of discharge that may occur, or is permitted, varies among materials and designs which are not specified in detail in this standard.

8.5.1 *Dielectric tests of the complete boom*

The tests shall consist of rated voltage, double-rated voltage and either 10 s withstand or switching surge voltage, as specified in Table 1. Applied voltages shall be applied in accordance with IEC 60060. If the insulating length of the boom is greater than or equal to 1,0 m, a dielectric surface leakage test of the complete boom shall be conducted.

NOTE When performed at high voltages, these tests can result in degradation or damage to the boom components, particularly those made from organic insulation.