

Behaviour of cables under fire



BEHAVIOUR OF CABLES UNDER FIRE

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IEC 60332

Tests on insulated wires and cables under fire conditions

Great, considerable damage at person and real value may occur through the combustion of thermoplastic cables. Professional installation of standard cables are operationally safe and doesn't cause a fire. A fire may spread more or less along cables or the cables may lighted more or less depending on kind of cable type, used insulation and sheathing materials, and installation conditions, caused by appearing of an additional source of fire. As soon as a fire is developed, it is very important, that the flame propagation shall be, reduced or avoided.

Those following standards shall be served to tested the flame propagation and flame retardancy of insulated wires and cables.

IEC 60332-2 (acc. to DIN VDE 0472-804, test procedure A)

This standard specifies a method of testing a small insulated wire under fire conditions.

IEC 60332-1 (acc. to DIN VDE 0472-804, test procedure B)

This standard specifies a method of testing a single, vertical insulated wire or cable under fire conditions. If the test sample melts during the application of the flame, the IEC 332-2 shall be used.

IEC 60332-3 (gen. to with DIN VDE 0472-804, test procedure C)

This standard specifies a method to define the ability of bunched wires or cables to restrain flame propagation. Practical example have shown, that the test acc. to IEC 60332-1 and -2 may not guarantee a sufficient safety against spreading of fire. In this reason the IEC 60332-3 tests the spreading of fire or flame propagation at groupings of cables, which is more practical.

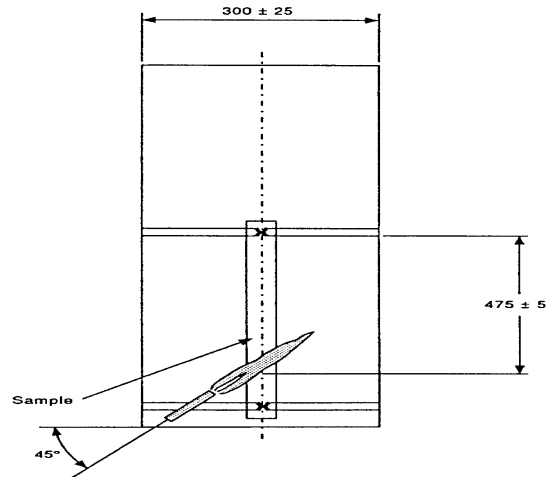
IEC 60332-1

(3. Edition 1993-04)

Test on insulated wires or cables under fire conditions

- Test on single vertical insulated wires or cables -

The test piece shall measure (600 ± 25) mm from the produced wire or cable and clamped in a vertical position in a metal chamber with open frontside. A propangasburner shall be positioned so that the tip of the inner blue cone impinges on the surface of the test piece. The distance between the flame and the upper horizontal support shall measure (475 ± 5) mm and the angle between burner and the vertical axis of the sample is 45° .



The flame application time shall be applied as follows:

<i>Outer diameter of the sample</i>	<i>Time for flame application</i>
50(s)	
$D \leq 25$	60
$25 < D \leq 50$	120
$50 < D \leq 75$	240
$D > 75$	480

The test is passed, if the sample didn't burn, or the flames are self-extinguished and the distance between the source of the fire and the lower edge of the top support and the onset of charring is greater than 50 mm. Traces of fire, e.g. soot, changing of colours will be ignored.

IEC 60332-2

50 *Edition 1989-03*)

Test on insulated wires or cables under fire conditions

- Test on single small vertical insulated wires or cables -

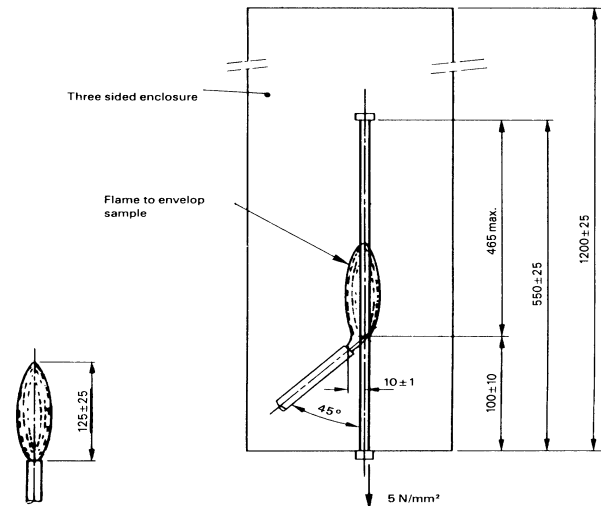
Three test sample with (600 ± 25) mm length from the produced wire or from the cable shall be cut out of the produced length.

The sample shall be straightened and clamped in an metal chamber (H x B x T: $(1200 \times 300 \times 450)$ mm). The distance between the upper and lower attachments measures (550 ± 25) mm. In addition shall be the sample below the clamp with an load of 5 N/mm^2 per mm^2 copper cross-section. During the test, draught is unavoidable.

The gas- and airflow from the propangas burner shall be adjusted so that the total length of the luminous flame is (125 ± 25) mm. The pressure of the gas is reduced to 1 bar.

The burner shall be arranged at an angle of 45° to the sample and the distance of (10 ± 1) mm between burner and sample. Further (100 ± 1) mm above the lower attachment.

The flame shall be applied to the first sample for a maximum duration of (20 ± 1) s. If the conductor of the first sample is melting during the defined time, so repeat the test with a second sample for a duration of $(T - 2)$ s.



The test is passed, if the test sample didn't burn or the flames were self-extinguished and the distance between the source of the fire and the lower edge of the top support and the onset of charring is greater than 50 mm.

Traces of fire, e.g. soot, changing of colours, will be ignored.

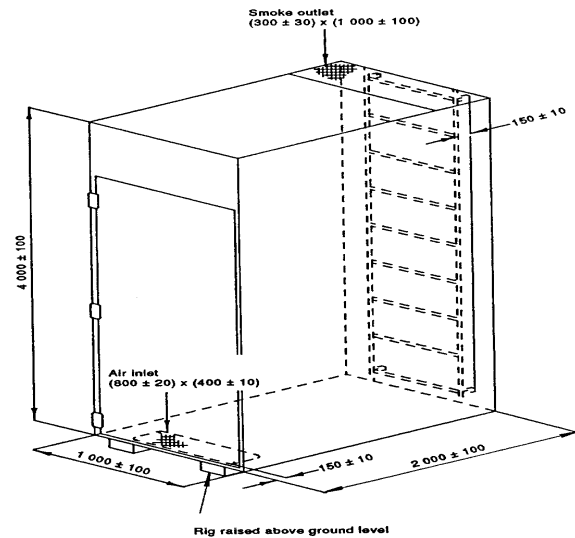
IEC 60332-3

(2. Edition 1992-03)

Test on insulated wires or cables under fire conditions

- Test on bunched wires or cables -

The test samples with an minimum length of 3.5 m shall be fixed on a ladder. The samples are taken from a new produced cable. The total number of samples is defined by conductor area and the overall diameter. An air flow should be adjusted to a rate of 5 m³/min through an inlet in the floor of the rig, to cause a chimney effect. The distance between the burner and the front surface of the cables is measured by 75 mm. The total number of the 3.5 m long samples is defined by the following categories:



Category A

The number of test pieces required to provide a nominal total volume of non-metallic material of 7 litres per metre. The minimum duration of test is 40 min.

Category B

The number of test pieces required to provide a nominal total volume of non-metallic material of 3.5 litres per metre.

Category C

The number of test pieces required to provide a nominal total volume of non-metallic material of 1.5 litres per metre. The minimum duration of test is 20 min.

The test is passed, if the flames are self-extinguished and the maximum extent of the charred portion measured on the test sample should not have reached a height exceeding 2.5 m above the bottom edge of the burner. Traces of fire, e.g. soot, changing of colour, brittles (crumbling) surface, damages by the armour wires, will be ignored.

IEC 60331

Tests for electric cables under fire conditions - Circuit integrity -

Great, considerable damage at person and real value may occur through the combustion of thermoplastic cables. Professional installations of standard cables are operationally safe and doesn't cause a fire. A fire may spread more or less along cables or the cables may lighted more or less depending on kind of cable type, used insulation and sheathing materials, and installation conditions, caused by appearing of an additional source of fire. Depending on the extent and temperature of the fire the electrical function of a cable (short circuit) and of the connected electrical equipment can not be guaranteed.

Important functions like emergency lighting, lift, air conditioning etc. in public buildings have to be kept during a fire. During a fire in industrial plants the manufacturing processes may be finished checkable to avoid large industrial accidents.

For testing of insulated wires and cables concerning the fire resistance, the following tests are available:

IEC 60331-11: Apparatus – Fire alone at a flame temperature of at least 750 °C

IEC 60331-21: Procedures and requirements – Cables of rated voltage up to and including 0.6/1 kV

IEC 60331-22: Procedures and requirements – Cables of rated voltage above 0.6/1 kV

IEC 60331-23: Procedures and requirements – Electric data cables

IEC 60331-22: Procedures and requirements – Optical fibre cables

General construction notes of cables \geq 0.6/1 kV with fire resisting characteristics

To guarantee the fire resistance and also the function of the cables, the conductors should be insulated with a material, which at the same time withstands the heat of a fire and keeps the insulation effect. About this mineral materials (mineral insulated cables), mica tapes, or materials which form a fire protection sheath during the combustion are outstandingly.

If MICA-tapes are used to fulfill the fire resistance, an additional electrical insulation has to be extruded over the MICA-tape wrapped conductors. This insulation is also used as mechanical protection to prevent damages at the MICA-tapes. In the reason of conductable acids zero halogen insulation materials have to be used. Because the acids will come through the MICA-tapes and conduct the current between the conductors (short circuit).

Sheaths (unarmoured cables) or beddings (armoured cables) directly applied over the cable core have to be zero halogen, too.

IEC 60331-21

(1.Edition 1999-04)

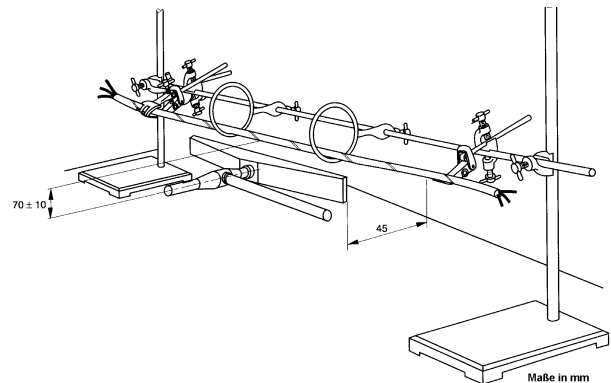
Test on insulated wires and cables under fire conditions

- Procedures and requirements – Cables of rated voltage $\leq 0.6/1$ kV -

A sample of the completed cable 1200 mm long shall have 100 mm of sheath or outer coverings removed from each end. At both ends of the cable, the conductors shall be suitably prepared for electrical connections, and at the other end, the exposed cores shall be spread apart to avoid contact with each other.

The cable shall be held horizontally by means of suitable clamps at each end of the sheathed or protected portion. The source of heat shall be a 500 mm long flat type gas burner which produces a line of closely spaced flames. The gas ($(5 \pm 0,25)$ l/min) and air ((80 ± 5) l/min) supply shall then be adjusted until a temperature of $750 \text{ }^\circ\text{C}$ is registered by the thermocouples. The thermocouples shall be inserted into the flames with the couple parallel to the burner and situated 45 mm from the burner and (70 ± 10) mm above it.

The sample shall be installed, so the flames of the burner touches the lower surface end of the sample. A transformer shall be connected to the cable through a 2 A fuse in each phase. The neutral circuit and any other metal parts of the supporting apparatus must be earthed too.



The electrical supply shall be switched on and the voltage adjusted so that the rated voltage of the cable shall be applied continuously during the test for a period of 90 min. The flames shall be protected against draught.

After the flame shall be extinguished the cable shall remain energized for a further period of 15 min. So the total test duration shall be the flame application time together with the 15 min cooling period.

After this test procedure the conductor shall be checked by continuity test. The test is passed, if there didn't apply fuse fails during the whole test period and afterwards the conductor didn't rupture.

IEC 60754

Test on gases evolved during combustion of insulated wires and cables

Large amount of corrosive and toxic gases, resulted through the combustion of thermoplastic cables of e. g. PVC, PE, etc. cause considerable damages for persons (respiratory tract, poisoning) and at material assets. Additional corrosive acids resulted by fire extinguish water, will also cause large damages. The caused costs by the corrosiveness of combustion gas are often higher than the costs from primary fire damage.

IEC 60754-1

This part of IEC 60754 describes a method for the determination of the amount of halogen acid gas, evolved during the combustion of materials from insulated wire and cables. Halogenated acids contain the elements from the VII. main group of periodic system as fluorine, chlorine, bromine, iodine and astatine. For materials containing less than 5 mg/g or 0.5 % halogenated acid, it is recommended to use the test method specified in IEC 60754-2.

IEC 60754-2

This part of IEC 60754 describes a method for the determination of the degree of acidity of gases, evolved during the combustion of materials from insulated wires and cables. The determination of small amount is measured by pH and the conductivity of the distilled or demineralized water solution.

IEC 60754-1

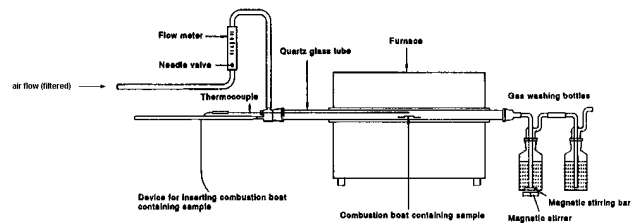
(2. Edition 1994-01)

Test on gases evolved during combustion of insulated wires and cables - Determination of the amount of halogen acid gas -

A sample shall consist of 500 mg - 1000 mg of the test material from the insulated wire or cable and shall be stored for at least 16 h at a temperature of $(23 \pm 2) \text{ }^\circ\text{C}$ and a relative humidity of $(50 \pm 5) \%$. The sample, which shall be weighed after conditioning to an accuracy of 0.1 mg, shall be put into a combustion boat.

The combustion boat shall be inserted into the quartz glass tube from the combustion furnace. The boat flowed with filtered air, the flow rate of air shall be adjusted by a needle valve at $(0.0155 \times D^2) \text{ l/h} \pm 10\%$ (D = inner diameter of the quartz glass tube) and shall be kept constant during the test.

The temperature of the sample shall then be raised at a uniform heating rate over a time of (40 ± 5) min. The heating rate maintained at $(800 \pm 10) \text{ }^\circ\text{C}$ for 20 min.. The air flow washed round the sample and the occurred combustion gases shall be washed in filled gas wash bottles with demineralized or distilled water.



The bottles shall be disconnected from the test apparatus and the both solution together made up to 1000 ml with distilled water.

After cooling to ambient temperature, 200 ml of the solution shall be taken and shaken with special acid and benzene in defined conglomerations.

The whole test method shall be carried out without a sample or without the tested material as duplicate test.

Through the mathematical comparison of the both solutions the amount of halogenated acid obtains.

IEC 60754-2

(1. Edition 1991-07 + Amendment 1997-04)

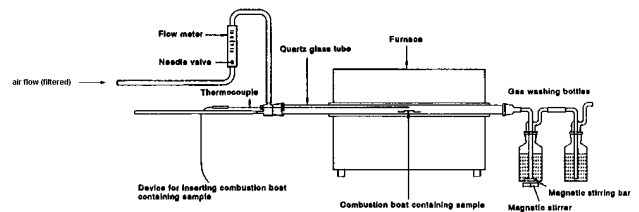
Test on gases evolved during combustion of insulated wires and cables

- Determination of degree of acidity of gases by measuring pH and conductivity -

A test piece shall consist of (1000 ± 5) mg of the materials from insulated wires or cables to be tested. It shall be stored for at least 16 h at a temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) %. The sample, which shall be weighed after conditioning to an accuracy of 0.1 mg, shall be put into a combustion boat.

The combustion boat shall be inserted into the quartz glass tube from the combustion furnace. The boat flowed round with filtered air, the flow rate of air shall be adjusted by a needle valve at $(0,0155 \times D^2)$ l/h $\pm 10\%$ (D = inner diameter of the quartz glass tube) and shall be kept constant during the test.

The combustion boat with the sample shall be placed in a distance of 300 mm from the heating zone. The temperature of the combustion furnace shall be not less than 935 °C. The temperature at a position 300 mm from the boat in the direction of the air flow shall be not less than 900 °C. The air flow washed round the sample and the occurred combustion gases shall be washed in filled gas wash bottles with demineralized or distilled water.



The combustion procedure under the air flow condition shall be continued for 30 min. in the furnace.

After the test, the bottles shall be disconnected from the test apparatus and together the both solution made up to 1000 ml with distilled water.

After cooling the solution, the pH and the conductivity shall be determined. The followed values shall be kept:

pH $\geq 4,3$

Conductivity $\leq 10 \mu\text{S}/\text{mm}$

IEC 61034

Measurement of smoke density of cables burning under defined conditions

Through the combustion of thermoplastic cables, e.g. PVC, PE, the visibility get worse resulted by very large amount of black and thick smoke. Fire fighting and rescue operations shall be restricted at places with a lot of public. The persons in this part of the building get restricted to leave over the emergency exit because of poor visibility. A test chamber with a photometric measurement is developed to determinate the smoke density of the cables under defined conditons.

IEC 61034-1

This part describe details of the test apparatus to be used for measuring the smoke density, as test chamber, the photometric system and the fan to ensure uniform distribution of the smoke. Further the method for calibrating the test equipment is described.

IEC 61034-2

This part of IEC 61034 describe the test procedure for measuring the smoke density. Test pieces (overall diameter $\geq 2\text{mm}$) shall be installed horizontal above a alcohol tray. The fan ensures uniform distribution of the smoke and the alcohol has to be ligthed. During the combustion the remaining light transmission through the smoke will be measured by the photometric system.

IEC 61034-1

(2. Edition 1997-08)

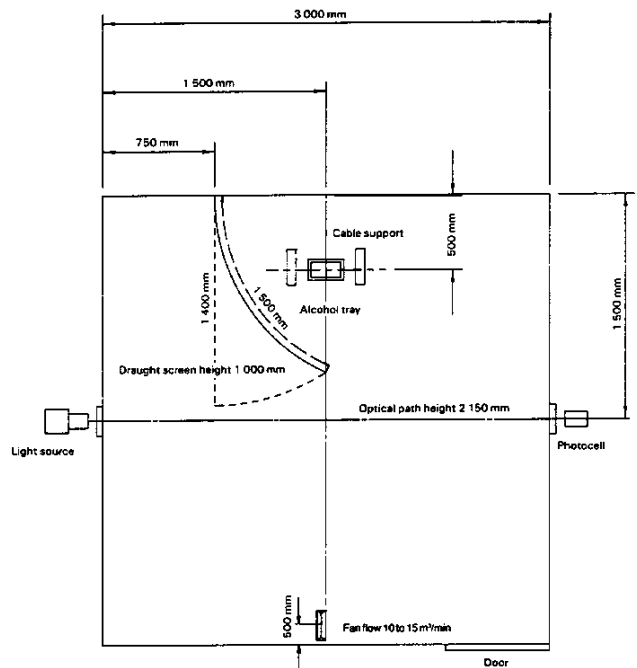
Measurement of smoke density of cables burning under defined conditions

- Test apparatus -

The equipment shall comprise a cubic test chamber with inside dimensions of (3000 ± 30) mm. One side shall have a door, with a glass window. Transparent sealed windows with an minimum size of (1000 ± 100) mm shall be provided on two opposite sides to permit the transmission of a beam of light from the horizontal photometric system. The distance from the floor to the centre of these windows shall be (2150 ± 100) mm. The photometric system existing of a halogen lamp with 100 W nominal power and a selenium- or silicon photocell.

For the preparation of heating of the test chamber to (25 ± 5) °C shall be burned one litre alcohol (90 % ethanol, 4 % methanol, 6 % water). For an uniform distribution of the smoke a fan shall be placed on the floor of the cube as fume distribution. Air shall be blown horizontally by the fan during the test, but the ignition source (alcohol tray) shall be protected by a windshield.

For calibrating the measurement equipment shall a compound of toluene and alcohol in proportions 4 : 96 and 10 : 90 be burned.



The measured absorbance by combustion will be calculated in a standard absorbance. The calculated value has to meet specified limits.

IEC 61034-2

(2. Edition 1997-09)

Measurement of smoke density of cables burning under defined conditions - Test procedure and requirements -

The test pieces consist of straight, insulated wires and cables of (1 ± 0.05) m length which shall be conditioned for at least 16 h at (23 ± 5) °C. The numbers of samples determined by following table:

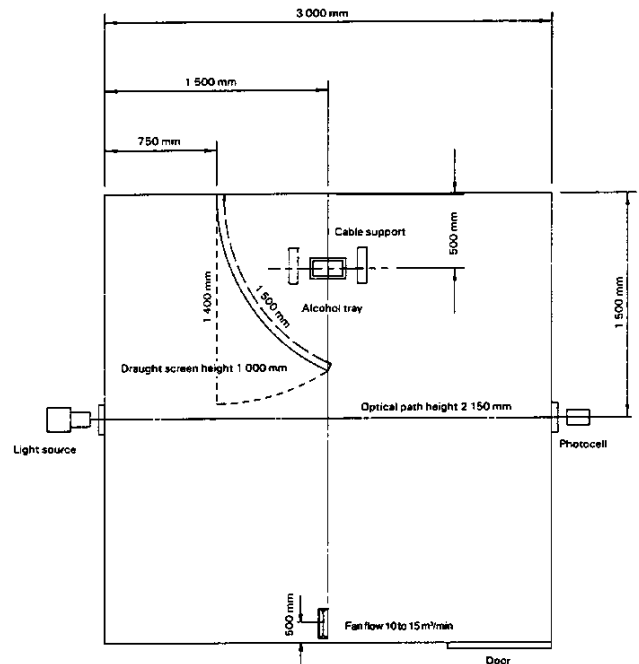
Overall diameter (mm)	Number of test pieces	
	Cable or wires	Bundles
$D > 40$	1	---
$20 < D \leq 40$	2	---
$10 < D \leq 20$	3	---
$5 < D \leq 10$	45/D	---
$2 < D \leq 5$	---	15/D

The cables shall be laid in touching arrangement.

The cables or bundles are bound with two turns of approximately 0.5 mm diameter wire in the centre and at every 100 mm each side from the centre.

The test pieces (cables, wires or bundles) shall be laid in a horizontal position and centred above the alcohol tray. The distance between the underneath of the test pieces and the alcohol tray must be (150 ± 5) mm.

Before starting the test, the ambient temperature in the test chamber shall be keep at (20 ± 10) °C. The temperature within the chamber shall be in the range of (25 ± 5) °C. By combustion of 1 litre alcohol shall be preheat the chamber has to be preheated and afterwards the photometric system calibrated.



The samples centred above the alcohol tray, the fan shall be switched on and the alcohol shall be lighted. The test is considered as ended when there is no decrease in light transmittance for 5 min. after the fire source has extinguished or when the test duration reaches 40 min.

If no value is given in the relevant specifications of cables and wires, the test is passed, if the light transmittance exceeded a value of 60 % during the test.

This means a smoke density of max. 40 %.

COMPARISON

EN, IEC, DIN VDE (old) und DIN VDE (latest)

Flame retardancy

EN	part	clause	Titel	IEC	DIN VDE (old)	DIN VDE (latest)
50265			Test for resistance to vertical flame propagation for a <i>single</i> insulated conductor or cable	60332 part ...	0472 part ...	0482 part ...
	2	1	Procedures: 1 kW-pre-mixed flame	1	804, method B	265-2-1
	2	2	Procedures: Diffusion flame	2	804, method A	265-2-2

EN	part	clause	Titel	IEC	DIN VDE (old)	DIN VDE (latest)
prEN 50266 (draft)			Test for resistance to vertical flame propagation for <i>bunched</i> insulated conductor or cable	60332-3	0472 part ...	0482 part... (draft)
	2	1	category A F/R			266-2-1
	2	2	category A			266-2-2
	2	3	category B			266-2-3
	2	4	category C		804, method C	266-2-4
	2	5	category D			266-2-5

Zero Halogen / Corrosiviness of combustion gases

EN	part	clause	Titel	IEC	DIN VDE (old)	DIN VDE (latest)
50267			Tests on gases evolved during combustion of materials from cables	60754 part ...	0472 part ...	0482 part...
	2	1	Procedures: Determination of the amount of halogen acid gas	1		267-2-1
	2	2	Procedures: Determination of degree of acidity of gases for materials by measuring pH and conductivity	2 (Amdm. 1)		267-2-2
	2	3	Procedures: Determination of degree of acidity of gases for cables by determination of the weighed average of pH and conductivity	2	813	267-2-3

COMPARISON

EN, IEC, DIN VDE (old) und DIN VDE (latest)

Smoke density

EN	part	clause	Titel	IEC	DIN VDE (old)	DIN VDE (latest)
50268			Measurement of smoke density of cables burning under defined conditions	61034 part ...	0472 part ...	0482 part...
	2	—	Procdure	2	816	268-2