INTERNATIONAL STANDARD

IEC 60092-354

Second edition
2003-06

Electrical installations in ships –

Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)

Installations électriques à bord des navires –

Partie 354: Câbles d'énergie unipolaires et tripolaires à isolant massif extrudé pour tensions assignées 6 kV (U_m = 7,2 kV) à 30 kV (U_m = 36 kV)

Reference number
IEC 60092-354:2003(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

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PRICE CODE R

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60092-354 has been prepared by subcommittee 18A: Cables and cable installations, of IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This second edition cancels and replaces the first edition published in 1994 and constitutes a technical revision.

The text of this standard is based on the following documents:

FDIS	Report on voting
18A/243/FDIS	18A/245/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This standard forms a part of IEC 60092 *Electrical installations in ships.*

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)

1 Scope and object

This part of IEC 60092 is applicable to shipboard and offshore power cables with extruded solid insulation, conductor and core screening, having a voltage rating of 3,6/6 (7,2) kV, 6/10 (12) kV, 8,7/15 (17,5) kV, 12/20 (24) kV, 18/30 (36) kV (see Clause 4) and intended for fixed installations. The voltage rating for shipboard use is limited to 8,7/15(17,5) kV.

The various types of power cables are given in Clause 8. The constructional requirements and test methods are expected to comply with those indicated in IEC 60092-350, unless otherwise specified in this standard.

The object of this standard is:

– to standardize cables whose safety and reliability is ensured when they are installed in accordance with the requirements of IEC 60092-352 for shipboard use
– to lay down standard manufacturing requirements and characteristics of such cables directly or indirectly bearing on safety;
– to specify test methods for checking conformity with those requirements.

NOTE 1 Only radial field cables are covered.

NOTE 2 IEC 61892-4, *Mobile and fixed offshore units – Electrical installations – Part 4: Cables* is under consideration by TC18.

2 Normative references

The following referenced 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 60038, *IEC standard voltages*

IEC 60092-350, *Electrical installations in ships – Part 350: Shipboard power cables – General construction and test requirements*

IEC 60092-351, *Electrical installations in ships – Part 351: Insulating materials for shipboard and mobile and fixed offshore units power, telecommunication, and control data cables*

IEC 60092-352, *Electrical installations in ships – Part 352: Choice and installation of cables for low-voltage power systems*

IEC 60092-359, *Electrical installations in ships – Part 359: Sheathing materials for shipboard power and telecommunication cables*

IEC 60228, *Conductors of insulated cables*

IEC 60230, *Impulse tests on cables and their accessories*

IEC 60332-3-22, *Tests on electric cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*

IEC 60811 (all parts), *Common test methods for insulating and sheathing materials of electric cables and optical cables*

IEC 60885-2, *Electrical test methods for electric cables – Part 2: Partial discharge tests*

3 Definitions

For the purposes of this document, the definitions given in IEC 60092-350 apply.

4 Rated voltage

The standard rated voltages U_o/U (U_m) of the cables considered in this standard are as follows:

U_o/U (U_m) = 3,6/6 (7,2) – 6/10 (12) – 8,7/15 (17,5) – 12/20 (24) – 18/30 (36) kV r.m.s.

In the voltage designation of cables given above,

U_o is the rated power-frequency voltage between conductor and earth or metallic screen, for which the cable is designed;

U is the rated power-frequency voltage between conductors for which the cable is designed;

U_m is the maximum value of the “highest system voltage” for which the equipment may be used (see IEC 60038).

Refer also to IEC 60092-352.

NOTE Refer also to IEC 61892-4, under consideration by TC18.

5 Types of insulating compounds

The insulating compounds shall be those designated as EPR, HF EPR, HEPR, HF HEPR, XLPE and HF XLPE in IEC 60092-351.

6 Types of sheathing compounds

The sheathing compounds and their designations shall be those given in IEC 60092-359.

7 Markings

7.1 Indication of origin

Cables shall be provided with a continuous indication of origin (manufacturer's name or trade mark), rated voltage (U_0/U) and construction (number of cores and cross sectional area of power conductors) to be printed or embossed on the sheath. In addition, it is permitted to include an identification thread or printed tape. In the case of braid armour applied over the outer-sheath, identification by thread or printed tapes inserted under the braid is obligatory.

EXAMPLE

"name or trade mark" 6/10 kV 3×70

7.2 Continuity

The marking of the manufacturer's name or trade mark is deemed to be continuous if the distance between the end of any marking and the beginning of the next does not exceed:

550 mm if the indication is on the outer sheath, or

275 mm in all other cases.

7.3 Durability

Printed marking shall be durable. Compliance with this requirement is checked by the test of 17.1.

7.4 Legibility

The marking of the manufacturer's name or trade mark shall be legible.

7.5 Core identification for three-core cables

Cores of cables shall be provided with a suitable method of identification. Each core shall be easily distinguishable from the other cores in the cable.

8 General description

The cables shall be single- or three-core radial field cables constituted as follows: copper conductor, conductor semi-conducting screen, insulation, insulation semi-conducting and metallic screen, laid up (for three-core cables). The following types and combinations of protective coverings and layers are permitted:

a) a single sheath of one of the materials listed in IEC 60092-359;

b) an inner sheath and an outer sheath of one of the materials listed in IEC 60092-359;

c) a single sheath of one of the materials listed in IEC 60092-359 with an outer metal braid;

d) an inner sheath, a metal armour, and an outer sheath of one of the materials listed in IEC 60092-359.

e) a copper braid over an extruded inner covering with an outer single sheath of one of the materials listed in IEC 60092-359.

A thermoplastic inner sheath is not recommended where the outer sheath consists of a vulcanized material.

NOTE Cables for installation in spaces where corrosion may occur, e.g. weather decks, wet locations, battery compartments, refrigeration spaces, etc., shall have an outer sheath over the braid, if any, unless the braid itself is corrosion resistant.

9 Conductors

Material, metal coating and class of the conductors shall be in accordance with IEC 60092-350.

The form of the conductor shall be round circular stranded, non-compacted or compacted, in accordance with Class 2 of IEC 60228.

To aid installation a conductor of Class 5 may be used. Cables with such Class 5 conductors should not be regarded as suitable for repeated flexing in service.

NOTE When using cables with Class 5 conductors, users should carefully check the applicable current rating, which may be lower than that for cables with the same cross-sectional area of Class 2 conductors.

The minimum cross-sectional area shall be 10 mm^2 for 3,6/6 (7,2) kV cables, 16 mm^2 for 6/10 (12) kV cables, 25 mm^2 for 8,7/15 (17,5) kV cables, 35 mm^2 for 12/20 (24) kV cables and 50 mm^2 for 18/30 (36) kV cables.

10 Insulation

10.1 Material

Insulation shall be extruded solid dielectric of one of the types indicated in Clause 5.

10.2 Electrical and non-electrical characteristics of insulation

These shall be as specified in IEC 60092-351.

10.3 Thickness of insulation

a) The average thickness shall be not less than the value specified for each rated voltage and cross-section of conductor in Table 1.

b) The thickness at any point may be less than the specified value provided the difference does not exceed 0,1 mm + 10 % of the specified value.

c) The thickness of the semi-conducting screen on the conductor, or over the insulation shall not be included in the thickness of insulation.

Table 1 – Nominal thickness of insulation

Nominal cross-sectional area of conductor mm^2	Nominal thickness of insulation at rated voltage U_0/U (U_m)				
	3,6/6 (7,2) kV	6/10 (12) kV	8,7/15 (17,5) kV	12/20 (24) kV	18/30 (36) kV
	mm	mm	mm	mm	mm
10	2,5	–	–	–	–
16	2,5	3,4	–	–	–
25	2,5	3,4	4,5	–	–
35	2,5	3,4	4,5	5,5	–
50 to 185	2,5	3,4	4,5	5,5	8,0
240	2,6	3,4	4,5	5,5	8,0
300	2,8	3,4	4,5	5,5	8,0
400	3,0	3,4	4,5	5,5	8,0
500 to 1000	3,2	3,4	4,5	5,5	8,0

NOTE Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor shall be increased by a conductor screen (see 11.1), or the insulation thickness shall be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

11 Screening of cores

11.1 General

Screening of individual cores in single- or three-core cables, shall consist of a conductor screen and an insulation screen.

11.2 Conductor screening

The conductor screen shall be non-metallic and shall consist of an extruded semi-conducting compound, which may be applied on top of a semi-conducting tape. The extruded semi-conducting compound shall be firmly bonded to the insulation.

11.3 Insulation screening

a) The insulation screen shall consist of a non-metallic semi-conducting layer in combination with a metallic layer.

b) The non-metallic layer shall be extruded directly upon the insulation of each core and consist of either a bonded or strippable semi-conducting compound.

NOTE A layer of semi-conducting tape or compound may then be applied over the individual cores or the core assembly.

c) The metallic layer shall be applied over the individual cores and shall comply with the requirements of Clause 12.

12 Metallic screen

12.1 Construction

The metallic screen shall consist of one or more tapes, or a braid, or a concentric layer of wires, or a combination of tape(s) and wires.

12.2 Requirements

The dimensional, physical and electrical requirements of the metallic screen shall be determined taking into account any other requirements (e.g. national or approval authority regulations and standards), including the value of the current to be carried in case of fault.

13 Cabling and filling

Cores of a three-core cable shall be laid up, and interstices filled with fillers or inner covering according to IEC 60092-350.

14 Inner covering

14.1 General

The inner covering shall be extruded. The relevant material and characteristics shall be in accordance with IEC 60092-350.

Compliance with this requirement is checked by the test specified in item e) of 18.4.

14.2 Thickness of inner covering

The approximate values of the thickness of extruded coverings are given in Table 2:

Table 2 – Thickness of inner coverings

Fictitious diameter over laid-up cores		Thickness of extruded inner covering (approximate value)
Above mm	Up to and including mm	mm
–	25	1,0
25	35	1,2
35	45	1,4
45	60	1,6
60	80	1,8
80	–	2,0
NOTE For the calculation of fictitious diameter, see Annex A and B of IEC 60092-350.		

15 Non-metallic sheath

15.1 Electrical and non-electrical characteristics of the sheathing material

The sheath shall be extruded from one of the materials specified in IEC 60092-359.

15.2 Thickness of sheath(s)

The thicknesses of outer sheath and inner sheath, if any, are given as a function of the internal diameter of the sheath under consideration, this fictitious diameter being calculated by the method of Annexes A and B of IEC 60092-350.

The formulae are:

a) **for armoured or unarmoured single-sheathed cables**:

t_1 = 0,04 D + 0,8 mm, with a minimum thickness of 1,0 mm

(D = fictitious diameter under the sheath)

b) **for unarmoured double-sheathed cables**:

– inner sheath t_1 = 0,025 D + 0,6 mm, with a minimum thickness of 0,8 mm

– outer sheath t_2 = 0,025 D + 0,9 mm, with a minimum thickness of 1,0 mm

c) **for armoured double-sheathed cables**:

– inner sheath t_1 = 0,04 D + 0,8 mm, with a minimum thickness of 1,0 mm

– outer sheath t_2 = 0,025 D + 0,6 mm, with a minimum thickness of 0,8 mm

The mean value of the thickness, and the thickness at any point, shall satisfy the prescriptions given in IEC 60092-350.

15.3 Colour of outer sheath

The sheath shall be coloured red, unless otherwise specified by the purchaser at the time of ordering.

16 Metallic armour

16.1 Types of metallic armours

The armour types covered by this standard are:

a) braid armour;

b) round or flat-wire armour;

c) double-tape armour.

16.2 Materials and construction

The materials and the constructional requirements of the armours shall be those given in IEC 60092-350.

When choosing the material of the armour, special consideration shall be given to the possibility of corrosion.

The armour of single-core cables for use on a.c. circuits shall consist of non-magnetic material. In special cases, for instance when the cables are used on d.c. circuits, magnetic materials can also be used.

16.3 Application of the armour

The armour shall be applied in such a way that it shall not adhere to the inner sheath, nor to the outer sheath.

16.4 Dimension of armour wires and armour tapes

The nominal diameters of round armour wires, and the nominal thicknesses of the armour tapes and flat wires shall be not less than the values given in the following paragraphs and tables:

a) **Braid wire diameter**

Irrespective of the metal used, the nominal diameter of the braid wire shall be:

0,3 mm, for fictitious cable diameter ≤30 mm under the braid

0,4 mm, as a minimum, for fictitious cable diameter >30 mm under the braid.

b) **Round armour wires**

Table 3 – Diameter of armour wire

Fictitious diameter under the armour		Diameter of armour wire
Above mm	Up to and including mm	mm
–	10	0,8
10	15	1,25
15	25	1,6
25	35	2,0
35	60	2,5
60	–	3,15

c) **Armour tapes**

Table 4 – Thickness of armour tape

Fictitious diameter under the armour		Thickness of tape	
Above mm	**Up to and including** mm	**Galvanized steel** mm	**Aluminium alloy** mm
–	30	0,2	0,5
30	70	0,5	0,5
70	–	0,8	0,8

d) **Flat armour wires**

The nominal thickness of the flat steel wire shall be 0,8 mm.

16.5 Round or flat wire armour

a) The wire armour shall be closed, i.e. with a minimum gap between adjacent wires. An open helix, consisting of galvanized steel tape of minimum nominal thickness 0,3 mm, may be provided over flat steel wire armour and over round steel wire armour if necessary.

Tolerances on this steel tape shall comply with IEC 60092-350.

b) Cables with a diameter under armour less than 15 mm shall not be armoured with flat wires.

16.6 Tape armour

The tape armour shall be applied helically in two layers, so that the outer tape is approximately central over the gap of the inner tape. The gap between adjacent turns of each tape shall not exceed 50 % of the width of the tape.

16.7 Braid wire armour

a) The coverage density of the braid shall be in accordance with IEC 60092-350.

b) The fictitious diameter under the braid is calculated by the method given in IEC 60092-350, Annex A.

17 Particular tests

17.1 Durability of marking

Compliance with the requirements of 7.3 is checked by trying to remove the marking of the manufacturer's name or trade mark, and the colour of the cores, by rubbing them lightly 10 times with a piece of cotton wool or cloth soaked in water.

18 Tests on completed cables

For these tests, reference is made to the relevant Clauses of IEC 60092-350.

For test methods for insulations and sheaths, reference should be made to the appropriate part of IEC 60811.

18.1 Routine tests

a) Measurement of electrical resistance of conductors (see IEC 60092-350).

b) Partial discharge test.

The partial discharge test shall be carried out in accordance with IEC 60885-2.

The magnitude of the discharge at 1,73 U_0 shall not exceed 5 pC.

c) High-voltage test (see IEC 60092-350).

The values of the power-frequency test voltage are given in Table 5:

Table 5 – Power frequency test voltage

Rated voltage U_0	3,6	6,0	8,7	12	18
Test voltage r.m.s.	12,5	21	30,5	42	63

18.2 Special tests

a) Conductor examination (see IEC 60092-350).

b) Check of cable dimensions (see IEC 60092-350).

c) Hot set test for cross-linked/thermoset compounds (see IEC 60092-350).

d) Tests at low temperature for thermoplastic compounds (see IEC 60092-350).

e) Coverage density of the braid (see IEC 60092-350).

f) Electrical test:

The test shall be carried out on a sample of completed cable at least 5 m in length between the test terminations.

A power-frequency voltage of 4 U_0 shall be applied for 4 h at room temperature between each conductor and metallic screen(s).

The test voltage shall be increased gradually to the specified value, and maintained for 4 h. No breakdown of the insulation shall occur.

18.3 Type tests, electrical

The electrical type tests listed in 18.3.1 shall be performed on a sample of completed cable 10 m to 15 m in length between the test accessories.

With the exception of the provisions in 18.3.2, all the tests listed in 18.3.1 shall be applied successively to the same sample.

In the three-core cables, each test or measurement shall be carried out on all the cores.

18.3.1 Sequence of tests

The normal sequence of tests shall be:

a) Partial discharge test (see 18.3.3).

b) Bending test, plus partial discharge test. The magnitude of the discharge at 1,73 U_0 shall be recorded (see 18.3.4)

c) Tan δ measurement as a function of the voltage (see 18.3.5).

d) Tan δ measurement as a function of the temperature (see 18.3.6).

e) Heating cycle test plus partial discharge test. The magnitude of the discharge at 1,73 U_0 shall be recorded (see 18.3.7).

f) Impulse withstand test, followed by a power-frequency voltage test (see 18.3.8).

g) Voltage test for 4 h (see 18.2 and Table 5).

18.3.2 Special provisions

Tests c) and d) may be carried out on a different sample from the sample used for the normal sequence of tests listed in 18.3.1.

18.3.3 Partial discharge test

The partial discharge test shall be carried out as described in IEC 60885-2.

The magnitude of discharge at 1,73 U_0 shall be measured and recorded. This value shall not be higher than 5 pC.

18.3.4 Bending test

a) The sample shall be bent around a test cylinder (for example the hub of a drum) at room temperature for at least one complete turn. It shall then be unwound, and the process repeated, except that the bending of the sample shall be in the reverse direction.

   This cycle of operations shall be carried out three times.

b) The diameter of the cylinder shall be:

   – for single-core cables : 20 ($d + D$) ± 5 %;

   – for three-core cables: 15 ($d + D$) ± 5 %;

   where:

   D is the actual external diameter of the cable sample, in millimetres;

   d is the actual diameter of the conductor, in millimetres.

c) On completion of this test, the sample shall be subjected to a partial discharge measurement and shall comply with the requirements given in 18.3.3 above.

18.3.5 Tan δ measurement as a function of the voltage

a) The power factor of the sample mechanically conditioned, as described in a) and b) of 18.3.4 above, shall be measured at ambient temperature with alternating voltage at power frequency of 0,5 U_0, U_0 and 2 U_0.

b) The measurement value shall not exceed those given in Table 6.

Table 6 – Tan δ versus voltage

	EPR, HF EPR, HEPR, and HF HEPR	XLPE and HF XLPE
Maximum tan δ at U_0 (× 10^{-4})	200	40
Maximum increment of tan δ between 0,5 U_0 and 2 U_0 (× 10^{-4})	25	20

18.3.6 Tan δ measurement as a function of the temperature

a) The sample of completed cables shall be heated by one of the methods described below; in each method the temperature of the conductor shall be determined either by measuring the conductor resistance, or by a thermometer in the bath or oven or on the surface of the screen.

   The sample shall be placed either in a tank of liquid or in an oven, or heating current shall be passed through the metallic insulation screen.

The temperature shall be raised gradually, until the conductor has reached the highest rated temperature given in IEC 60092-351.

b) The power factor shall be measured with an alternating voltage of 2 kV at power-frequency at the temperature specified above.

c) The measured values shall comply with the requirements given in Table 7.

Table 7 – Tan δ versus temperature

	EPR, HF EPR, HEPR, and HF HEPR	XLPE and HF XLPE
Maximum tan δ at ambient temperature ($\times 10^{-4}$)	200	40
Maximum tan δ at rated temperature (85 °C) ($\times 10^{-4}$)	400	80

18.3.7 Heating cycle test plus partial discharge test

a) The sample, which has been subjected to the previous tests, shall be laid out on the floor of the test room, and heated by passing alternating current through the conductor, until the conductor reaches a steady temperature 10 °C above the maximum rated temperature of the insulation in normal operation.

For multicore cables, the heating current shall be passed through all conductors.

This heating current shall be applied for at least 2 h, followed by at least 4 h of natural cooling in air.

This cycle shall be repeated twice more.

b) After the third cycle, the sample shall be subjected to the partial discharge measurement described in 18.3.3 and shall comply with the requirements of that subclause.

18.3.8 Impulse withstand test, followed by a power-frequency voltage test

a) This test shall be performed on the sample at a conductor temperature 5 °C above the maximum rated operating temperature of the insulation.

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

b) The cable shall withstand without failure 10 positive and 10 negative voltage impulses, of the appropriate value given in Table 8.

Table 8 – Impulse withstand voltages

Rated voltage U_0	kV	3,6	6,0	8,7	12	18
Test voltage	kVp	60	75	95	125	170

c) After the test given in items a) and b), the cable sample shall be subjected, at room temperature, to a power-frequency voltage test for 15 min (on each core).

The values of the test voltage shall be those specified in item c) of 18.1.

No breakdown of the insulation shall occur.

18.4 Type test non-electrical

a) Measurement of thickness of insulation

b) Measurement of thickness of sheath

c) Non-electrical characteristics of insulation

d) Non-electrical characteristics of sheaths

e) Additional ageing test on pieces of completed cables.

NOTE For a) through e) above, see IEC 60092-350.

f) Flame spread test (see IEC 60332-3-22). Unless otherwise given in the individual product standards, the cables shall be tested in a touching configuration.

Bibliography

IEC 60092-353, *Electrical installations in ships – Part 353: Single and multicore non-radial field power cables with extruded solid insulation for rated voltages 1 kV and 3 kV*

IEC 60502-2, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) – Part 2: Cables for rated voltage from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

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Q2 Please tell us in what capacity(ies) you bought the standard *(tick all that apply).* I am the/a:

purchasing agent ❑
librarian ❑
researcher ❑
design engineer ❑
safety engineer ❑
testing engineer ❑
marketing specialist ❑
other.....

Q3 I work for/in/as a: *(tick all that apply)*

manufacturing ❑
consultant ❑
government ❑
test/certification facility ❑
public utility ❑
education ❑
military ❑
other.....

Q4 This standard will be used for: *(tick all that apply)*

general reference ❑
product research ❑
product design/development ❑
specifications ❑
tenders ❑
quality assessment ❑
certification ❑
technical documentation ❑
thesis ❑
manufacturing ❑
other.....

Q5 This standard meets my needs: *(tick one)*

not at all ❑
nearly ❑
fairly well ❑
exactly ❑

Q6 If you ticked NOT AT ALL in Question 5 the reason is: *(tick all that apply)*

standard is out of date ❑
standard is incomplete ❑
standard is too academic ❑
standard is too superficial ❑
title is misleading ❑
I made the wrong choice ❑
other .....

Q7 Please assess the standard in the following categories, using the numbers:
(1) unacceptable,
(2) below average,
(3) average,
(4) above average,
(5) exceptional,
(6) not applicable

timeliness.....
quality of writing.....
technical contents.....
logic of arrangement of contents .....
tables, charts, graphs, figures.....
other .....

Q8 I read/use the: *(tick one)*

French text only ❑
English text only ❑
both English and French texts ❑

Q9 Please share any comment on any aspect of the IEC that you would like us to know:

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ISBN 2-8318-7065-8

ICS 29.060.20; 47.020.60

Typeset and printed by the IEC Central Office
GENEVA, SWITZERLAND