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(affiliée à l'Organisation Internationale de Normalisation — ISO)

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Electrical installations in ships

Part 3: Cables (construction, testing and installations)

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
3) In order to promote this international unification, the IEC expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the IEC recommendations as the fundamental basis for these rules in so far as national conditions will permit.
4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.
5) The IEC has not laid down any procedure concerning marking as an indication of approval and has no responsibility when an item of equipment is declared to comply with one of its recommendations.

PREFACE

The first edition of IEC Publication 92 was published in 1957 and included the same subjects as those which will be covered by the second edition. It was realized at that time that intensive study of these subjects must be continuous in order to take account of new developments and the rapid trend towards the use of alternating current.

Accordingly Technical Committee No. 18 immediately commenced work on the second edition and from 1955 to 1962 met annually for this purpose. It was decided at the outset that to facilitate future revisions without incurring the expense of reprinting the whole document, it should be divided and published in six Parts, viz.:

Part 1: General Requirements.
Part 2: Graphical Symbols.
Part 3: Cables (construction, testing and installations).
Part 4: Switchgear, Electrical Protection, Distribution and Controlgear.
Part 5: Transformers for Power and Lighting, Semi-conductor Rectifiers, Generators (with associated prime-movers) and Motors, Electric Propulsion and Tankers.
Part 6: Accessories, Lighting, Accumulator (Storage) Batteries, Heating and Cooking appliances, Internal Communications, Lightning Conductors.

The present booklet contains Part 3. Parts 1, 2, 4, 5 and 6 will be issued as IEC Publications 92-1, 92-2, 92-4, 92-5 and 92-6 respectively.

Part 3 was completed at Stockholm in 1961 and the draft was circulated to the National Committees for approval under the Six Months' Rule in May 1962.

The following countries voted explicitly in favour of publication of Part 3:

Belgium	Netherlands
Canada	Norway
Czechoslovakia	Portugal
Denmark	Sweden
France	Turkey
Germany	United Kingdom
Italy	United States of America
Japan	

The requirements of the following chapters contained in Part 1 of this Publication also apply:

Chapter 1 — General definitions.
Chapter 2 — General requirements and conditions.
Chapter 3 — Earthing of non-current-carrying parts.
Chapter 4 — Application of diversity (demand) factors.
Chapter 5 — D.C. ship's service system of supply.
Chapter 6 — A.C. ship's service system of supply.
Chapter 7 — Abatement of radio interference.
Chapter 8 — Test of completed installation.

INTRODUCTION

The operating conditions in ships sailing the seven seas as far as they affect electrical appliances are the same regardless of where the ship is built. Except for variations in quality, the materials used in the construction of electrical appliances are similar and are subject to the same natural laws. The characteristics of electric circuits and the behaviour of appliances are likewise predeterminable and follow the same fundamental laws irrespective of the country of origin.

It is accordingly feasible to establish international standards to secure that degree of performance, reliability and safety which are essential for the well-being of crews and passengers alike and for the safe carriage of valuable cargoes.

It is for the fulfilment of these ends that the present Recommendations have been formulated. Shipbuilders, electrical contractors and manufacturers engaged in the building of ships for the international market are faced at present with several codes of rules and regulations with which to comply although, as already stated, the conditions of service are identical.

It is recognized that apparatus manufactured in various countries will inevitably differ in appearance and conception, but for the same duties similar apparatus and materials will necessarily have to meet the same service conditions. This code has therefore been drafted in the form of "Recommendations" thus allowing the fullest possible scope for the manufacturer to use initiative in the design and development of his product and to use existing tools and patterns so far as they are suitable.

Complete and progressive co-operation between the naval architect, the shipbuilder, the owner and the designer and installer of the electrical installation are essential from the earliest stages right through to completion to ensure not only that all services required of the electrical appliances are met, but that proper and suitable space and accommodation is provided for electric cables and appliances.

It is not intended to exclude new materials, appliances and methods or to discourage invention.

It cannot be too strongly emphasized that good technical design, the correct choice of apparatus, good and suitable materials and, above all, good workmanship are essential for a sound installation. The Recommendations are not intended to take the place of a detailed specification or to instruct untrained persons.

These Recommendations make reference, in several of their chapters, to other IEC Publications. It should be understood that the editions of these Publications in force on the date of issue of these Recommendations, are the only valid ones, in so far as they are not in contradiction with them.

Moreover, Technical Committee No. 18 may be led to amend and supplement these Recommendations, either because of the issue of new IEC Publications or due to amendments made by other Committees to existing IEC Publications, to the extent in which the corresponding Recommendations concern the work of Technical Committee No. 18.

The present Recommendations are not to be regarded as a substitute for, or as additional Rules to, the Classification Rules and National Standards. Where a shipowner requests the observance of these Recommendations when ordering his vessel, he should not give this request the character of a stipulation. Where there are deviations, the Rules of the Classification Societies and the National Standards have preference over the Recommendations.

Notes 1.) — All dimensions in these Recommendations are, in the first place, given in metric units; figures in brackets in British and American units are not exact numerical equivalents of the metric quantities, but are the nearest dimensions in practical use in the respective countries.

2.) — The Chapters in Part 1 apply to all installations and to the equipment dealt with in all other Parts of these Recommendations, i.e. Part 2 to Part 6.

ELECTRICAL INSTALLATIONS IN SHIPS

Part 3: Cables (construction, testing and installations)

CHAPTER X — CABLES, CONSTRUCTION AND TESTS

DEFINITIONS

For the purpose of this publication, the following definitions shall apply:

a) *Cable*

A length of insulated single conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

b) *Core (of a cable)*

The conductor with its insulation but not including any mechanical protective covering.

c) *Flexible cable or cord*

A cable or cord intended to connect movable or portable equipment in a construction containing one or more cores, having conductors formed of a group of wires, the diameters of the cores and wires being sufficiently small to afford flexibility.

d) *Length of lay*

The axial length of one complete turn of the helix formed by the core, in the case of a cable, or of the wire, in the case of a stranded conductor.

e) For the definitions of general terms used in these Recommendations, reference should be made to the International Electrotechnical Vocabulary (IEC Publication 50).

SECTION ONE — SPECIFIED CHARACTERISTICS

CONDUCTORS

10.01 **Material**

High conductivity copper only is considered as standard material for conductors in these Recommendations.

10.02 **Tinning or alloy coating**

Copper wires should be tinned or alloy coated when used for rubber insulated conductors; for otherwise insulated conductors, tinning or coating may be omitted.

Tinning or coating should be considered satisfactorily if, at a visual inspection (see Clause 10.35), the wire surface appears bright and the insulation is not adherent to the conductor. If a chemical test is specified, Clause 10.61 and Appendix H should be applied.

10.03 **Cross-sectional area**

For the purpose of these Recommendations, the *effective* cross-sectional area of each conductor should be specified. Tables may further specify the *nominal* cross-sectional area of each conductor but for designation purposes only.

The effective cross-sectional area of each conductor should be checked by measuring its electrical resistance (see Clauses 10.05 and 10.42).

10.04 **Strand composition and shape**

Conductor composition and stranding should be so selected that sufficient flexibility is assured for the cable (see Clauses 10.50 and 10.51). Compact stranding, both for round and shaped conductors, may be permitted. Conductor shape should be regular, free from sharp projections and other defects liable to damage the insulation. Compliance should be checked by visual inspection (see Clause 10.35) and mechanical tests (see Clauses 10.48 and 10.49).

10.05 **Electrical resistance**

The d.c. electrical resistance of each copper conductor in a completed cable, corrected to 20° C, should not exceed the value calculated in the following way:

$$R = \frac{17.241 \cdot k_1 \cdot k_2 \cdot k_3}{N \cdot 0.7854 \cdot d^2} = \frac{17.241 \cdot k_1 \cdot k_3}{A}$$

where:

R = the maximum electrical resistance to be guaranteed, in ohms/km, at 20° C;

17.241 = standard resistivity of the annealed copper, in ohm.mm²/km, at 20° C;

N = specified number of strands of which the conductor is made up;

d = specified diameter of the strands, in mm;

A = the effective cross-sectional area of the conductor, in mm², and is equal to the area of a solid conductor of the same length, composed of material of standard resistivity and having the same resistance.

k_1 = the correction factor which allows for variations in diameter and conductivity of individual wires;

k_2 = the correction factor which allows for the laying up of the strands in the conductor;

k_3 = the correction factor which allows for the laying up of the cores in a twin or multi-core cable.

The values of factors k_1, k_2 and k_3 are given in the following Table I.

Notes 1.) — The first part of the above formula is applicable to circular conductors consisting of cylindrical wires all of the same diameter.

2.) — The second part of the formula applies also to shaped and/or compacted conductors, provided the area "A" used is the effective area.

TABLE I

Correction factors for Conductor Resistance

1	2	3	4
Nominal diameter of the strands in the conductor in mm*)	above 0.10 up to 0.30	above 0.30 up to 0.90	above 0.90 up to 3.60
Values of k_1 for coated (tinned) wires For single-wire (solid) conductors For stranded conductors	 — 1.07	 1.05 1.04	 1.04 1.03
Values of k_1 for plain wires For single-wire (solid) conductors For stranded conductors	 — 1.04	 1.03 1.02	 1.03 1.02
k_2 = 1.00 for single-wire (solid) conductors; k_2 = 1.02 for stranded conductors with strands exceeding 0.6 mm in diameter; k_2 = 1.04 for stranded conductors with strands not exceeding 0.6 mm in diameter.			
k_3 = 1.02 for all cables except the following: k_3 = 1.00 for single-core, flat twin and flat three-core cables; k_3 = 1.05 for flexible cables and cords having two or more conductors; k_3 = 1.03 for multi-pair telephone cables.			

*) For compacted conductors, the nominal diameter of the component wires shall be understood "before crushing".

INSULATION

10.06 **Material**

Eleven categories of insulating materials are considered for standardization purposes in these Recommendations; they are listed in the following Table II and referred to by designation numbers.

Other types of insulating materials may, however, be permitted (for instance: silicone rubber, silicone treated glass tapes, impregnated paper, asbestos and polyvinylchloride, etc.); in that case, the characteristics of each preferred material should be fully specified similarly to what is specified in the present Chapter.

TABLE II

Designation number	Standard types of insulating materials	Rated operating temperature*)	Notes
60A	Natural rubber compound — General purpose	60°C (140°F)	1) 2)
60B	Synthetic rubber compound — General purpose	60°C (140°F)	1) 2)
60C	Polyvinylchloride compound — General purpose	60°C (140°F)	1) 2)
60D	Rubber-polychloroprene composite insulation	60°C (140°F)	1) 2)
75A	Natural rubber compound — heat-resistance quality	75°C (167°F)	1) 2)
75B	Synthetic rubber compound — heat-resistance quality	75°C (167°F)	1) 2)
75C	Polyvinylchloride compound — heat-resistance quality	75°C (167°F)	1) 2)
80A	Butyl rubber compound — special heat resistance quality	80°C (176°F)	1) 2) 3)
80B	Varnished cambric insulation	80°C (176°F)	4) 5)
85A	Asbestos-varnished-cambric insulation	85°C (185°F)	6) 7)
95A	Mineral insulation	95°C (203°F)	8)

1) Specified characteristics: see Clause 10.07 and Table V.
2) Insulating materials complying with the test specified under Sub-clause 10.50 *e)* are considered as "flame-retardant materials".
3) Silicone rubber is not considered under this quality.
4) Specified characteristics: see Clause 10.10.
5) 85°C instead of 80°C may be permitted in certain carefully considered situations.
6) Specified characteristics: see Clause 10.12.
7) 95°C instead of 85°C may be permitted in certain carefully considered situations.
8) Specified characteristics: see Clause 10.13.

*) The temperature of the conductor assumed for the calculation of current ratings (current carrying capacities) of cables for continuous service (see Clauses 11.04 and 11.05).

10.07 **Rubberlike insulating compounds**

Eight "qualities" of rubber and polyvinylchloride insulating compounds (see Clause 10.06) are considered suitable for ship cables, each quality with some particular advantages and limitations.

Their properties should comply with the values specified in Table V and with the test specified in Section Two of this Chapter (particularly with those referred to in the same Table V).

The rated operating temperature (maximum operating conductor temperatures) indicated in Tables II and V for each compound should not be exceeded (see Chapter XI).

10.08 **Application of the rubber insulation**

The insulation should consist of one or more layers of rubber compounds equal or different in quality (including polychloroprene compound but not pure rubber). The use of a single layer should be permitted only when it is applied by extrusion. The layers should be bonded together and the insulating wall should be close-fitting but not adherent to the copper conductor.

The manufacturer should be allowed, but not obliged, to apply a tape or film on the rubber insulation and/or a similar separator between insulation and conductor.

10.09 **Application of the polyvinylchloride insulation**

The polyvinylchloride insulating wall should be applied by extrusion in one or more layers, which should be close-fitting but not adherent to the conductor.

10.10 **Varnished cambric insulation**

The varnished cambric should consist of a closely woven cotton cloth, which should be uniformly coated on both sides with an insulating varnish consisting of drying oils and bitumen. Textile materials other than cotton may be permitted.

The average thickness of the finished varnished cloth (cotton) should be neither less than 0.13 mm (5 mils) nor more than 0.33 mm (13 mils). The properties of v.c. insulation should comply with the tests specified in Clause 10.60.

With reference to Clause 10.44, the insulation resistance constant K_i at 20°C should not be lower than 400 megohm.km. (or 1 300 megohm . 1 000 ft or 435 megohm . 1 000 yards).

Its rated operating temperature should be 80°C (see Chapter XI). A rated temperature as high as 85°C may, however, be permitted for particular cable constructions and in certain carefully considered situations.

10.11 **Application of the varnished cambric insulation**

The insulating wall should consist of several layers of varnished cambric tapes. The tapes should be applied helically and smoothly, with or without overlapping, each tape covering the gap (if any) of the adjacent tape.

An insulating and suitable lubricating compound should be applied between the layers of varnished cloth so as to exclude as far as practicable air and moisture.

The manufacturer should be allowed, but not obliged, to insert a separator (for instance a film or a woven tape) between conductor and insulation, and to apply a binder on the insulating wall. If the binder or the identification tape is made of an insulating material, it may be considered as a part of the insulating wall.

10.12 **Asbestos-varnished cambric insulation**

The insulating wall of each conductor should consist of a layer of impregnated felted asbestos, plus some layers of varnished cambric tapes complying with Clauses 10.10 and 10.11, plus a layer of impregnated felted asbestos. The felted asbestos should be made of long fibre chrysolite asbestos, dried and then saturated with a heat and moisture resisting compound. The manufacturer should be allowed to use, in place of each felted asbestos layer, a layer of asbestos roving or glass roving, or of asbestos or glass tapes, which in any case should be dried and impregnated as above indicated.

The asbestos-varnished cambric insulation should comply with the tests specified for the varnished cambric insulation and further with the requirement specified under Clause 10.44 (last sentence).

Its rated operating temperature should be 85°C. A rated operating temperature as high as 95°C may, however, be permitted for particular cable constructions and in certain carefully considered situations.

10.13 **Mineral insulation**

The mineral insulation should consist of a powdered mineral material (for instance magnesium oxide) highly compressed between conductors and copper sheath. The insulation should be temperature stable and non-corrosive to copper. It should comply with the test specified in Section Two of this Chapter for mineral insulated cables. With reference to Clause 10.44 the insulation constant K_i at 20° C should be not lower than 5 000 megohm.km. ($\frac{5\,000}{0.305}$ megohm. 1 000 ft or $\frac{5\,000}{0.915}$ megohm. 1 000 yards).

The rated operating temperature, in continuous service, of this insulation should be 95° C, giving consideration to the temperature capabilities of materials used in terminating the cable.

10.14 **Thickness of the insulated wall**

In the case of rubber-like insulations, when a thickness value is specified, it should be understood as "minimum average thickness" so that the average of the actually measured values should be not less than the specified value. The thickness measurements should be carried out with the method specified in Sub-clause 10.37 *b)*. The "minimum thickness at any point" should comply with the tolerances specified in the same sub-clause.

In the case of taped insulations, when a thickness value is specified, it should be understood as a value complying with the test specified in Sub-clause 10.37 *c)*.

PROTECTIVE COVERINGS

10.15 **Constituent elements of protective coverings**

The protective covering of any cable consists of one or more "constituent elements" which shall be specified case by case. The following types of "constituent elements" are considered in these Recommendations:

a) Metallic elements (Clauses 10.16 to 10.22):
1 — lead or lead-alloy sheath,
2 — copper sheath,
3 — metal braid armour,
4 — metal wire armour,
5 — metal tape armour.

b) Non-metallic elements (Clauses 10.23 to 10.26):
1 — rubber or rubberlike sheath (including polyvinylchloride),
2 — impregnated fibrous braid,
3 — bedding for metal armour,
4 — paint for metal armour.

10.16 **Lead or lead-alloy sheath**

Any of the lead-alloys indicated in Table VI should be considered suitable for sheathing ship cables; except for special cases, the choice should be left to the manufacturer. Lead (as defined in the same Table) should be permitted only when the lead sheath is protected by a non-metallic impervious sheath (see Clause 10.23). Lead containing from 0.04 to 0.08% of copper may be used in the same conditions as lead.

10.17 **Copper sheath**

A copper sheath is only considered for mineral insulated cables, which are manufactured by a special process.

10.18 **Thickness of metal sheaths**

For the purpose of these Recommendations, when a thickness value is specified, it should be understood as a "minimum average thickness", so that the average of the actually measured values should be not less than the specified value. For the measurement method and tolerances, see Sub-clause 10.38 *c)*.

10.19 **Metal braid armour**

The standard type of braid armour should be made of zinc-coated (galvanized) steel wires. On special request, the braid may be formed of copper, copper-alloy or aluminium-alloy wires.

The "coverage density" of the braid should be such that the weight of the braid is at least 90% of the weight of a tube consisting of the same metal, having an internal diameter equal to the internal diameter of the braid and a thickness equal to the diameter of one of the wires forming the braid. (Test method, see Sub-clause 10.39 *b)*.)

10.20 **Metal wire armour**

The standard type of metal wire armour should consist of annealed steel, having an elongation at break of at least 12% and complying with the galvanizing test specified in Clause 10.65 and Appendix J.

On special request, wires may be of a non-magnetic metal instead of steel and may have a flat instead of a circular cross-section.

The wires should be applied over the bedding so as to form a uniform and substantially uninterrupted cylindrical layer, and so as to assure a sufficient flexibility for the finished cable (see bending test under Clause 10.48).

10.21 **Metal tape armour**

The standard type of metal tape armour should be made of annealed steel tapes which, on special request, may be galvanized. Tapes of non-magnetic metals (for instance copper or aluminium-alloys) may be used, on special request, in place of steel tapes.

The armour should, in general, be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than one half of the tape width and the second layer covers this gap with an overlap.

Particular types of metal tape armours (for instance consisting of one tape) may be permitted, provided their mechanical characteristics are specified.

For cables whose diameter under the bedding is less than 10 mm (0.4 in) the use of a metal tape armour is not recommended.

10.22 **Dimensions of the metal armours**

For the purposes of these Recommendations, when wire diameters, tape thicknesses, and other similar armouring dimensions are specified, they should be understood as "average values", complying with Sub-clause 10.39 *a)*.

10.23 **Non-metallic impervious sheath**

Six "qualities" of compounds, as listed in the following Table III are considered in these Recommendations for manufacturing impervious sheaths.

Their properties should comply with the values specified in Table VII and with the tests specified in Section Two of this Chapter (particularly with those referred to in Table VII).

Other kinds of compounds may be permitted provided their properties are fully specified.

TABLE III

Designation number	Type of non-metallic impervious sheath	Maximum rated conductor temperature	Suitable for
SP 1	Polychloroprene compound	60° C (140° F)	cables for fixed installation only
SP 2	Polychloroprene compound	80° C (176° F)	
SV 1	Polyvinylchloride compound	60° C (140° F)	
SV 2	Polyvinylchloride compound	80° C (176° F)	
SP 3	Polychloroprene compound	60° C (140° F)	also for flexible cables
SP 4	Polychloroprene compound	80° C (176° F)	

Specified characteristics: see Table VII and Clause 10.23.

10.24 **Thickness of non-metallic sheath**

For the purpose of these Recommendations, when a thickness value is specified, it should be understood as a "minimum average value" as indicated under Clause 10.14. For measurements methods and tolerances, see Sub-clause 10.38 *b)*.

10.25 **Impregnated fibrous braid**

The textile braid, if permitted, should be of cotton, hemp, asbestos, glass or other equivalent textile fibre, and should be of a strength suitable for the size of the cable. It should be effectively impregnated with a compound which is resistant to moisture, flame-retardant and free from deleterious action upon the various materials constituting the cable.

10.26 **Bedding for armour**

When tapes are used as a bedding, they should be wound in such a manner that each tape covers the gap (if any) between the edges of the adjacent tape. Woven tapes (for instance cotton or glass tapes) should be saturated or coated with a moisture resisting and, if specified, flame-retardant compound.

When fibrous rovings are used (for instance jute or asbestos or glass rovings), they should be wound in close spirals and should be saturated and filled with moisture resisting and, if specified, flame-retardant compound.

When a fibrous braid is used as a bedding, it should comply with Clause 10.25.

When a non-metallic sheath is used as a bedding, it should comply with Clause 10.23. On the other hand, its specified thickness should not be understood as "minimum average thickness" (as stated under Clause 10.24).

CABLING

10.27 **General**

Whichever be the insulating material, both the "belted" and the "non-belted" constructions are considered acceptable by these Recommendations for 2, 3 and multi-conductor cables, provided the insulation thicknesses are suitably determined and specified. The choice of either type should be specified case by case, for instance in Tables of Standard Dimensions.

10.28 **Cables without common belt of insulation**

When a "non-belted cable" is specified, two or more insulated cores, each with the addition of a tape or binder (at the option of the manufacturer, see Clauses 10.08 and 10.11) and a distinctive marking (see Clause 10.31) should be cabled together with a long and regular lay. The spaces among the cores should be filled with fibrous or rubberlike fillers (see Clause 10.30) and the cylindrical assembly should be sheathed with the specified protective covering. A binder (for instance a tape) may be applied (at manufacturer's option) between the cable assembly and the protective covering.

Fillers may be omitted in multi-core cables having conductor sections not exceeding 4.5 mm^2 (0.007 in^2).

10.29 **Cables with common belt of insulation**

When a "belted cable" is specified, its construction should be as indicated under Clause 10.28, except that an additional insulating wall should be applied on the cabled cores before applying the protective covering and the (optional) binder. For rubber and polyvinylchloride insulated cables, the common insulating belt should consist of a rubber or polyvinylchloride compound (not necessarily of the same "quality" as the core insulation), which may or may not (at manufacturer's option) form one body with the fillers.

The specified thickness of the insulating belt should be understood as indicated in Clause 10.14.

In the case of rubberlike belts, for the measurement method and tolerances, see Sub-clause 10.38 *b)*, last sentence; in the case of taped belts, see Sub-clause 10.37 *c)*.

10.30 **Fillers**

When "fibrous fillers" are permitted, they should consist of jute or similar roving (including asbestos, glass, etc.) and, when necessary, should be fully impregnated with a moisture retardant compound.

When "rubberlike fillers" are specified, they should consist of rubber (including regenerated and/or un-vulcanized rubber) compounds or plastic compounds, and should be impervious to moisture. For non-metallic sheathed cables, the fillers may (at manufacturer's option) either form one body with the sheath or be separated therefrom.

When a "watertight cable" is specified, the spaces among cores and sheath and the interstices in the conductor strands should both be filled so as to obtain a continuous sealing all along the cable, which should in particular comply with the watertightness test and the bending test specified in Clauses 10.51 and 10.48.

In any case, the fillers should be of such a composition and hardness as not to give rise, with time, to leakages between cables and glands.

10.31 **Identification of insulated cores**

Identification may be effected by colouring or printing (for instance with code numbers) the insulation or the outer tape or separator (if any). Any other identification method may be allowed, provided the various cores are identifiable, not only in new cables, but also in those which have been in service for some time.

For multi-core cables in which the cores are cabled in several concentric layers, it is recommended that in each layer at least two adjacent cores be coloured differently from all the others.

SECTION TWO — TESTING SPECIFICATIONS

GENERAL RECOMMENDATIONS FOR TESTS

10.32 **Object and place of tests**

Tests to be carried out on finished cables only are considered in these Recommendations, namely tests applicable to:

a) full cable lengths ready for dispatch (see Clauses 10.41—10.44);

b) pieces of completed cables, taken from *a)* (see Clauses 10.35 to 10.40; and 10.45 to 10.54);

c) pieces of constituent parts of cables, taken from *a)*; for instance insulating walls, metallic sheaths, etc. (see Clauses 10.55 to 10.62).

For the purpose of these Recommendations, pieces *b)* and *c)* are referred to as "samples".

Tests applicable to unfinished cables, for instance on insulated cores before they are cabled, are not recommended.

In general, the tests should be carried out at the manufacturer's works and the manufacturer should make available the necessary equipment.

10.33 Test categories

For the purpose of these Recommendations, the tests are divided into four categories:

RT: Routine tests — Tests to be carried out on full cable lengths ready for dispatch;

OST: Obligatory sample tests — Tests to be carried out on a specified number of samples, for instance one sample from each group of 10 cable lengths;

AST: Agreed sample tests — Tests to be carried out only when specifically agreed between purchaser and manufacturer, who will also agree the extent of sampling;

TT: Type tests — Tests not to be carried out for every contract but once for each particular design of cable to be supplied against an order. A cable shall be deemed an approved type if one of the same construction, but not necessarily of the same size, complies with the test requirements and the manufacturer may submit a certificate to this effect.

10.34 Repetition of tests

In the case of tests on samples (see Sub-clauses 10.32 *b)* and *c)*), if the result of a test is not satisfactory, the same test should be repeated on twice the number of samples tested the first time, the new samples being taken from cable lengths not previously sampled. If the results from these new samples are not all satisfactory, all the cable lengths represented by the said samples may be declared unsatisfactory.

Inspection for regular manufacturing and check of dimensions

10.35 General examination (OST)

A visual inspection for the conformity of cables with the manufacturing requirements specified in the order and with a good manufacturing practice should be carried out on cable pieces. These should be taken from the ends of some manufacturing lengths after having discarded, if necessary, a portion of cable (of at least 60 cm or 2 ft) which might have suffered damage.

10.36 Conductor dimensions (RT)

The cross-sectional area should be checked by measuring the electrical resistance (see Clauses 10.42 and 10.05). No measurements of wire diameters should be required in checking the conductors.

10.37 Insulation thicknesses (OST)

a) General

The insulation thickness should be checked on a number of manufacturing lengths, as specified (see Clause 10.33 — OST). Each selected length should be represented by two cable pieces, taken one from each end after having discarded (if necessary) a portion which might have suffered damage. If one of the pieces fails to meet the requirements of Clause 10.37, two other pieces should be checked and only if both comply should the length be accepted.

b) Rubberlike insulations (rubber and polyvinylchloride)

The insulation thickness should be measured with the method described in Appendix A, using a measuring microscope. The use of a micrometer or other means may be permitted, but in case of dispute a microscope at 10 magnifications should be used.

The average of the 12 measurements carried out on the 2 specimens (see Sub-clause 10.37 *a)*) should not be less than the insulation thickness specified for the length considered. In addition, the smallest of the 12 measured values should not fall below the specified thickness by more than 0.10 mm (4 mils) + 10% of the specified thickness.

c) Taped insulations (varnished cambric and asbestos varnished cambric)

One of the following two methods may be used, the choice being agreed between manufacturer and purchaser. In either case, both the results found on the two specimens representing each selected length (see Sub-clause 10.37 *a)*) should be not lower than the insulation thickness specified for that length.

In the case of "belted cables", the thickness of each core insulation and of the belt should be measured separately.

When a layer of asbestos or equivalent material is included in the insulating wall, its thickness should be measured with the first method.

c1) First method

Using a micrometer having flat contacts at least 5 mm (0.2 in) in diameter, the diameter in the insulating wall is measured in two directions, at right angles to another. The insulation is then removed and the diameter under the insulating wall is similarly measured in the same directions. Separators, binders and identification tapes (see Clause 10.11), if any, are not to be included in the insulating wall, unless they consist of an insulating material. The insulation thickness is finally calculated as half the mean of the two diameter differences. Instead of a micrometer, a measuring tape may be used for determining the diameters from the circumferential lengths, both in the case of round and sector shaped conductors.

c2) Second method

(Not applicable when the tapes are wound with an overlap.)

The tapes of the specimen should be unwound and then bunched together (without removing the lubricant) and the total thickness should be measured with a micrometer having the characteristics defined below. All the tapes which make up the insulation should be included in the measurement, whereas the separators and binders (if any) shall not be included unless they are made of insulating materials.

The faces of the micrometer shall be cleaned between each successive measurement.

The apparatus may be any form of precision dead weight micrometer capable of measuring up to a total thickness of 6.3 mm (0.25 in) with an instrument error not exceeding ± 0.005 mm (± 0.2 mil).

The movable face of the pressure foot should be circular, and have a diameter not less than 5.0 mm (0.2 in). The area of the fixed face should be equal to or greater than the area of the pressure foot. The faces should be concentric and parallel to within 0.0025 mm (0.0001 in) over the range of travel.

The pressure foot should exert a steady pressure of 3.5 ± 0.2 kgf/cm^2 (or 50 ± 2.5 lbf/in^2).

10.38 **Sheath thickness** (OST)

a) General

The sheath thickness should be checked on a number of manufacturing lengths, as specified (see Clause 10.33 — OST).

Each selected length should be represented by two cable pieces, taken one from each end after having discarded (if necessary) a portion which might have suffered damage. If one of the pieces fails to meet the requirements of Clause 10.37, two other pieces should be checked and only if both comply should the length be accepted.

b) Non-metallic impervious sheath

The sheath thickness should be measured, using the means and method described in Appendix A, radially in the directions where the sheath is thinnest (i.e. corresponding to the points where the cores were embedded in the sheath), subject to a maximum of six measurements on each specimen. In particular, in case of a sheath applied on a cylindrical assembly (for instance on a metal sheath), the six measurements should be made.

The average of the values found on the two specimens taken from each cable length (see Sub-clause 10.38 *a)*) should not be lower than the sheath thickness specified for that length.

In addition, the smallest measured value should not fall below the specified thickness by more than 0.10 mm (0.004 in) + 15% of the specified thickness.

The method indicated above is also valid for measuring the thickness of the insulating belt. When this embodies the fillers, a tolerance of 0.3 mm (0.012 in) + 15% should be permitted.

c) Metallic sheaths

From each of the two pieces of cable (see Sub-clause 10.38 *a)*) one specimen should be cut and removed, without damaging it, in the form of a sleeve having a length approximately equal to its diameter (but at least 20 mm or 0.8 in). Using a micrometer, five measurements should be taken on each specimen, regularly spaced around the circumference and at least 10 mm (0.4 in) distant from the edges of the specimens.

If the specimen is left in the form of a ring, the measurement should be made with a micrometer having either a flat nose and a ball nose or a flat nose and a flat rectangular nose 0.8 mm (0.032 in) wide and 2.4 mm (0.095 in) long. The ball nose or the flat rectangular nose should be applied inside the ring.

If the specimen is flattened, the measurement may be made with a micrometer having flat noses.

The average of the ten values found on the two specimens taken from the considered cable length should be not lower than the sheath thickness specified for that length. In addition, the smallest value should not fall below the specified thickness by more than 0.10 mm (0.004 in) + 10% of the specified thickness.

10.39 **Dimensions of armourings** (OST)

a) A number of micrometer measurements should be made on some specimens selected at random, in order to check that metal wire diameters and metal tape thicknesses comply with the nominal values (see Clause 10.22). Compliance should be understood as follows:

All individual measured values to be not smaller than 90% of the nominal value minus 0.03 mm (0.0012 in) and not greater than 110% of the average value plus 0.03 mm (0.0012 in).

b) Checking of the coverage density of a metal braid armour should be carried out by weighing a braid specimen at least 25 cm (10 in) long; the weight should be not less than 90% of the calculated weight of an equivalent tube as specified under Clause 10.19.

10.40 **Cable diameters** (OST)

The overall diameter of any cable should be measured in at least three points spaced 1 m (3 ft) or more from one another. Either a measuring tape (suitable only for diameters greater than 20 mm or 0.8 in) or a micrometer may be used, in the first case the diameter being calculated from the measured circumference length and in the second case as the mean of two diameters measured at right angles. The average of the three values so obtained should differ from the specified mean diameter by not more than:

0.5 mm (0.02 in) + 4% of the specified diameter, for unarmoured cables,

1.0 mm (0.04 in) + 4% of the specified diameter for armoured cables.

If the maximum instead of the mean overall diameter is specified, none of the three measured values should be greater than the specified value.

ELECTRICAL TESTS ON FULL CABLE LENGTHS

10.41 **General**

The electrical tests specified under Clauses 10.42 to 10.44 should be carried out on all complete lengths of finished cables (except in the following case).

In the case of p.v.c. insulated cables only, it may be accepted that the measurement of the insulation resistance on full cable lengths (Clause 10.44) is omitted, the test being instead carried out on short lengths, in hot water, as specified under Clause 10.45.

10.42 **Conductor resistance** (RT)

The cable shall be in the test room, which should be at reasonably constant temperature, for sufficient time to ensure that the cable temperature is equal to the ambient temperature.

The electrical resistance of each conductor should be measured with direct current (knowing the exact length and temperature) and corrected to 20° C by the following formula:

$$R_{20} = R_t \frac{254.45}{234.45 + t}$$

where R_t is the electrical resistance found at a temperature t° C (ambient temperature). The value R_{20} should be not higher than the conductor resistance either specified or calculated as stated in Clause 10.05.

10.43 **High-voltage test** (RT)

a) This test should be carried out at ambient temperature using a single-phase a.c. voltage of practically sinusoidal waveform or, alternatively, a practically flatform d.c. voltage. The power available in the test equipment shall be sufficient to maintain constantly in the cable the specified value of the test voltage and the corresponding charging current.

b) Whichever the insulation type, each insulated core should sustain for 15 minutes, without breakdown occuring, the following values of the test voltage:

TABLE IV

Rated voltage[1]) of cable volts (a.c. or d.c.)		Test voltage for 15 minutes		
Above	Up to and including	Alternating current volts (a.c.)		Direct current volts (d.c.)
—	80	1 000[2])		2 000[2])
80	250	1 500		3 000
250	750[3])	2 500		5 000
750	1 100	3 500		7 000
1 100	3 300	7 500[4])	10 000	20 000
3 300	6 600	14 000[4])	16 000	32 000

[1]) The rated voltage is to be understood for systems with neutral (or central point) not earthed.
[2]) For 5 minutes only.
[3]) For mineral insulated cables having a rated voltage above 250 V up to and including 440 V, the test voltage may be 2 000 V a.c. and 4 000 V d.c.
[4]) For rubber or p.v.c. insulated cables only.

c) The voltage should be applied gradually so as to arrive at the specified value in about one minute. The connection procedures in applying the test voltages to the different types of cables should be as follows:

For single-core, metal sheathed or metal armoured cables, the test voltage should be applied between conductor and sheath or armour.

For single-core cables having an impervious non-metallic sheath and no further covering, the test voltage should be applied between the conductor and the water in which the cable should be immersed at least one hour before the test.

For single-core cables having a non-metallic covering liable to be impaired if immersed in water, the test voltage should be made on samples at least 1 m (40 in) long, after having covered their surface with a metal foil.

For cables having from 2 to 5 conductors, with or without metal sheath or armour, the voltage test should be applied in turn between each conductor and all other conductors connected together and to the metal covering, if any.

For cables having more than 5 conductors, the voltage test should be applied: first between all conductors of uneven number in all layers and all conductors of even number in all layers; second, between all conductors of even layers and all conductors of uneven layers; third, if necessary, between the first and the last conductor of each layer having an uneven number of conductors.

10.44 **Insulation resistance** (RT)

a) The insulation resistance should be measured after the high-voltage test has been carried out. A d.c. voltage of at least 300 V should be used, with the connection procedures specified in Sub-clause 10.43 *c)*. The measurement should in general be effected one minute after application of the d.c. voltage; in certain cases, however, in order to reach a substantial steady state condition, the electrification time may be prolonged up to a maximum of 5 minutes.

The insulation resistance values measured at a temperature T (which should preferably be not higher than 30° C and not lower than 10° C) should then be corrected to 20° C using an appropriate temperature correction factor based on experimental results obtained on the insulation material concerned.

The corrected values should be not lower than the value calculated, with the insulation constant K_i specified in Table V and in Clauses 10.10 and 10.13 for the insulating material concerned.

b) For the calculation of the insulation resistance the following formula should be used:

$$R_i = K_i \log_{10} \frac{D}{d} \text{ in megohm.km}$$

where

K_i (in megohm.km) is the insulation resistance constant specified for the material concerned (see Table V and Clauses 10.10 and 10.13);

d is the calculated diameter of the conductor (including separator, if any)[1]);

D is the calculated diameter of the insulation (namely $D = d + 2t$, where t is the specified insulation thickness).

Both D and d shall be expressed in the same unit. To calculate the insulation resistance per 1 000 ft or per 1 000 yards of cable the value of R_i obtained from this formula shall be multiplied by factors as follows:

For Megohm . 1 000 ft	× 3.28
For Megohm . 1 000 yards	× 1.09

Unless otherwise agreed, the above calculation may be applied not only in the case of single-core cables but also in the case of twin and multicore (for belted cables t being the sum of the specified thicknesses of core insulation plus belt insulation).

For asbestos-varnished-cambric insulated cables, the minimum specified insulation resistance should be one-fourth of the minimum values specified for the varnished-cambric insulated cables of same cross-section and same rated voltage.

ELECTRICAL TESTS ON CABLE SAMPLES

10.45 **Insulation resistance** (for polyvinylchloride insulated cables only)

This test may be required either as a substitute for test of Clause 10.44 or in addition thereto. In the first case it is an AST; in the second case a TT (see Clause 10.33).

a) Each cable sample, having a length of at least 5 m (16 ft), should be dismantled so as to obtain one insulated core without any covering (i.e. without belt, tape, etc.). This specimen should be immersed (with the ends protruding) in water at room temperature and after 2 to 3 hours immersion subjected to a voltage test, applying the voltage value specified in Clause 10.43 for 5 minutes between conductor and water.

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[1]) *Note.* — For practical purposes the diameter d of a sector shaped conductor may be calculated dividing by 3.14 the length of the conductor circumference as measured by means of a measuring tape.

b) The insulated core should be then immersed in hot water, a length of about 25 cm (10 in) at each end of the specimen being kept above the water level, whilst at least 4 m (13 ft) shall be in water. The temperature of the water should be maintained at a value equal to the rated operating temperature of the considered compound (see Tables II and V) with a tolerance of ± 2°C.

After 2 to 3 hours immersion, a d.c. voltage of at least 300 V should be applied between the conductor and the water. The insulation resistance should be measured one minute after the application of the voltage; in certain cases, however, in order to reach a substantial steady-state condition the electrification time may be prolonged up to a maximum of 5 minutes.

The measurement result shall be not less than the value calculated, as shown in Sub-clause 10.44 *b)*, with the K_i specified in Table V for the insulating compound concerned. If necessary, guard rings shall be applied at the ends of the specimen.

10.46 **Resistance of the insulation to direct current** (TT)

This test should be required only for polyvinylchloride insulated cables having no metallic sheath.

One core specimen which has been subjected to the high-voltage test specified in Sub-clause 10.45 *a)* should be maintained in a water bath at 60 ± 5°C continuously for 10 × 24 hours, approximately 10 g/l of sodium chloride being dissolved in the water. The negative pole of a 220 V d.c. supply (but 100 V for specimens from cables whose rated voltage is 110 V) should be connected to the conductor and the positive pole to a copper electrode, which is immersed in the salt water and has no galvanic connection with the metallic tank. Breakdown should not occur within the period specified, after which the exterior of the insulation should show no damage (discolouration of the insulation is neglected).

10.47 **Water absorption test** (TT)

One core specimen which has been subjected to the high-voltage test specified in Sub-clause 10.45 *a)* should be accommodated in a water tank so that its middle portion for a length of 3 m (10 ft) is immersed whilst the ends are above the water level, each for a length of 0.75 m (30 in). Distilled water should be used, whose temperature is maintained between 20° C and 25° C for 14 days.

The capacitance of the specimen should be measured with a.c. low voltage, preferably at a frequency of 800 to 1 000 Hz (c/s), after one, seven and fourteen days continuous immersion, with the water at the same temperature for all measurements. The capacitance values so found should comply with the conditions specified under Item F in Table V for the insulating compound concerned.

Note. — This clause is under further consideration.

PHYSICAL TESTS ON CABLE SAMPLES

10.48 **Bending test for cables for fixed installation** (AST)

This test should not be required for rubber or p.v.c. insulated cables. It should be carried out at a temperature of 10°C to 35°C, after having brought the cable sample and the bending cylinder to the same temperature.

The cable sample, whose length is 3 to 4 times the bending diameter (see below), should be bent, in 20 to 40 seconds, on a cylindrical barrel so as to form one complete turn. It should then be straightened, turned 180° round its axis, bent in the same manner on the cylinder and again straightened. This cycle is performed twice, making a total of 4 bends (2 in each direction). During the bending operation the cable should be held in such a way that it cannot revolve around its axis, and the sample ends should not be sealed.

The barrel diameters D shall be as follows:

$$D = n\, d$$

where:

n = 12 for varnished-cambric and asbestos-varnished-cambric insulated cables with or without metallic sheath;

n = 12 for mineral insulated cables;

d = is the overall diameter of the cable (including armour, etc., if any).

Immediately following the bending operations and without straightening the sample after the last operation, the bent cable should be immersed for 2 to 3 hours in water at room temperature and then a high-voltage test carried out, applying the a.c. test voltage specified in Clause 10.43 for 5 minutes in turn between each conductor and the remaining conductors (if any) connected to the water. No breakdown shall occur.

However, for mineral insulated cables the test voltage should be:

1 000 V for rated voltages up to 440 V,

1 500 V for rated voltages above 440 V to 750 V.

10.49 **Mechanical test for flexible cable** (AST)

Note. — A test method will be specified in a later issue of the Recommendations.

10.50 **Flammability test** (OST)

a) General

Except for the special asbestos-varnished-cambric insulated cables intended to be operated at 95°C (for which Appendix B applies), the flammability test should be carried out on vertical specimens with the apparatus and testing procedure specified in Sub-Clauses *b), c)* and *d).*

b) Apparatus

A three-sided metal enclosure approximately 1.2 m (48 in) high, 0.30 m (12 in) wide and 0.38 m (15 in) deep, with open front and top, having clamping facilities to keep the cable sample straight vertically in the middle. A gas burner with a nominal bore of 10 mm ($^3/_8$ in), fed with ordinary illuminating gas at normal pressure and regulated so as to give a flame approximately 125 mm (5 in) long with an inner blue cone approximately 40 mm (1½ in) high. The cable specimen should be 1.2 m (48 in) long and clamped in the enclosure with the lower end touching the supporting plate.

A bare copper wire 0.7 mm (0.028 in) in diameter, having a free length of not less than 100 mm (4 in) should be inserted horizontally in the flame, 50 mm (2 in) above the top of the burner, so that the free end of the wire is vertically above the edge of the burner on the side remote from the supported end of the wire. If the wire takes more than 6 seconds to melt, it is an indication that the flame is not hot enough for the purpose of this test.

c) Procedure

Keeping the burner at an angle of 45° to the vertical, the flame should be narrowed to the cable specimen so that the tip of the internal cone touches its surface at approximately 0.3 m (12 in) from its lower end. The flame should be so maintained for the specified duration, then the gas turned off and the time measured during which the cable continues to burn. The time of flame application shall be (in seconds) $t = 10 + W/50$, where W is the total weight of the cable specimen (in grams). The application should not be continuous but in steps of 10 seconds with interruptions of 10 seconds (the last step being less than 10 seconds if t is not an integral multiple of 10 seconds).

d) Observations

Based on the test results, cables are classified in three groups, as follows:

i) flame extending when the flame travels along the whole length of the specimen;

ii) flame retardant when the flame stops before reaching the top of the specimen;

iii) fire resisting when in addition to *b)* the specimen is able to withstand (after cooling) for one minute an a.c. voltage test of twice its rated (service) voltage. Voltage testing procedure as described in Sub-clause 10.43 *c)*.

In order to carry out this voltage test in the case of single-core non-metal covered cables, the specimen should consist of two pieces of cable twisted together; the voltage should then be applied between the two conductors and its value should be four times the rated voltage.

e) Special test for flame retardant insulations

If an insulating material is referred to as "flame retardant" the following additional test should be passed by a sample of an insulated core from which all external coverings have been removed. The core should be tested as described in *b)* and *c)*, except that the flame should be allowed to impinge on the sample for only one period of 60 seconds. After removal of the flame, the dielectric should not continue to burn for longer than 60 seconds and the total length burned or charred should not exceed 150 mm (or 6 in).

10.51 **Watertightness test** (either AST or OST)

When a cable is required to be "watertight" this test should be carried out as an OST; in other cases it may be carried out as an AST.

a) General

If a cable is required to be "watertight", the volume of water lost by a cable specimen, when tested in the conditions specified in Sub-Clauses *b)*, *c)* and *d)* below, should be not greater than the value V calculated from the formula:

$$V = 10\,N\,(A + 2), \text{ in cm}^3$$

where:

N is the number of conductors in the cable, and

A is the cross-section of each conductor, in mm^2 [1]).

In any case, the lost volume should be not more than 2 000 cm^3 (125 in^3).

[1]) $V = 400\,N\,(A' + 0.003)$ in in^3, where A' is in in^2, or: $V = 0.32\,N\,(A'' + 4)$, in in^3, where A'' is in MCM.

b) Specimens

The specimen should be a piece of finished cable, 1.5 m (5 ft) long, which has not been subjected to prior flexing or heating or any other test. The metal armour may be removed from the ends, without disturbing the cable, to facilitate making a watertight gland.

c) Apparatus

A small water tank, fitted with watertight stuffing tubes, should be connected with a device permitting the application of a controlled pressure, which is measured by a gauge, and with a device permitting detection of leakages, if any. The fittings used for securing specimens to the tank should neither constrict nor widen the ends of the said specimens and should not give rise to leakage.

d) Procedure

One end of each specimen should be secured to the tank, then the water pressure raised in about one minute to 1.0 kgf/cm^2 (i.e. 14 lbf/in^2) and maintained at this value for 3 hours. Any water coming from the other end or from the surface of the specimen should be gathered and measured.

10.52 **Flattening test for mineral insulated cables** (AST)

Two specimens of suitable length should be removed from two places at least 30 cm (1 ft) apart in the cable sample and flattened between anvils until the thickness of the flattened portions is two-thirds of the nominal diameter. Each of the anvils should have a flat surface not less than 75 mm × 25 mm (3 in × 1 in) and the longer dimension should be parallel to the axis of the cable sample during the test. The edges of the anvils should be rounded to a radius not less than 12.5 mm (½ in).

The metal sheath should show no split, crack or flaw.

The flattened samples should be bent sufficiently to allow them to be immersed in water with their ends clear of the water and should be so immersed for not less than one hour. Both samples should then withstand for 2 minutes, without failure of the insulation, the appropriate test voltage given below. The voltage should be applied between conductors and between each conductor and the sheath.

The r.m.s. value of the test voltage should be:

— for 440 V cables	1 000 V
— for 660 and 750 V cables	1 500 V

10.53 **Dripping test** (AST)

a) For cables having some part of the protective coverings consisting of impregnated fibrous materials. The cable sample, which should be at least 0.30 m (1 ft) long, should be suspended vertically in an oven and continuously maintained for 16 hours at 10 ± 1°C below the rated temperature of the insulating material used for the cable concerned. No material should drip from the sample.

b) For cables of any construction and particularly for varnished-cambric and asbestos-varnished-cambric insulated cables. The cable sample, which is at least 0.30 m (1 ft) long, after having had all protective coverings removed except metallic or non-metallic sheath (which, if any, is left in place) should be maintained, as stated above, for 16 hours at the maximum rated conductor temperature. No material should drip from the sample.

10.54 **Ozone resistance test** (AST)

Any rubber or rubberlike insulated cable having a rated voltage in excess of 1100 V should withstand an ozone resistance test, which should be carried out as described in Appendix C.

TESTS ON MATERIALS

10.55 **Mechanical characteristics of rubberlike insulations**
(rubber and polyvinylchloride (AST))

The tests for the mechanical characteristics specified in Table V should be carried out with the methods described in Appendix D.

The ageing tests specified in Table V should be carried out as described in Appendix E.

An additional ageing test should be carried out when a cable has rubber insulated cores surrounded by p.v.c. fillers or sheaths, or when a cable has p.v.c. insulated cores surrounded by rubber fillers or sheaths, with a direct contact between the different types of compounds. The test methods and requirements should be as specified under Appendix D, Clause D. 7, Contamination test.

10.56 **Mechanical characteristics of rubberlike sheaths** (AST)

The tests for tensile strength, elongation at rupture, etc. specified in Table VII should be carried out with the methods described in Appendix F.

If the sheath consists of two layers, equal or different in quality, only the outer layer should comply with Table VII.

10.57 **Mechanical characteristics of rubberlike insulating belts** (AST)

In the case of cables having an insulating belt on the cabled cores, the compound used for the belt should be tested without ageing and after ageing in an air oven at 80°C for 168 hours, with the procedure described in Appendix F. Whatever the "quality" of the compound used for the cores, the compound used for the belt should comply — both aged and unaged — with the following figures:

— tensile strength, minimum 42 kgf/cm^2 or 600 lbf/in^2
— elongation at rupture, minimum 100%

In addition, the values obtained after ageing should be not lower than 60% of the values obtained without ageing.

10.58 **Resistance to oil immersion** (AST)

When an oil immersion test is specified in Table VII (polychloroprene sheaths), the test should be carried out on a group of three specimens taken from the cable samples and prepared as specified in Appendix F. After having been measured (for determining their cross-section), the specimens should be maintained completely immersed in oil at the temperature and for the period specified in the Table.

In case of doubt about the quality of the oil to be used for the test, an oil having the following characteristics should be used:

Aniline point	93 ± 3°C
Viscosity (Saybolt Universal)	100 ± 5 seconds at 100°C
Flash point	245 ± 6°C.

At the end of the immersion period the specimens should be removed from the excess of oil, blotted lightly to remove excess of oil and suspended in air at room temperature for at least 16 hours, after which they should be tested for tensile strength and elongation (see Appendix F).

The calculations for tensile strength should be based on the cross-sectional area of the specimen determined before immersion in the oil. The median of the three specimens shall comply with the percentage specified in Table VII for the material concerned, when compared with the unaged median value resulting from test 10.56. The median is obtained by disregarding the highest and the lowest test results and taking the intermediate result.

10.59 **Thermoplastic characteristics of polyvinylchloride insulations and sheaths** (AST)

The tests for the characteristics specified under paragraph E of Tables V and VII should be carried out with the methods described in Appendix G.

10.60 **Physical characteristics of varnished-cambric tapes** (AST)

a) Several pieces of v.c. tape should be taken from different points of a cable sample approximately 0.60 m (2 ft) long and wiped with absorbent paper in order to take off the lubricant. They should then be left for at least 10 hours in an atmosphere having approximately 65% relative humidity at room temperature before beginning the test, which should be made in the same atmosphere.

Each of the following tests should be made on five different specimens and not more than one result in each test should be unsatisfactory.

b) *Tensile strength*

After having measured the tape thickness, the specimen, with gauge lines marked 20 mm (0.80 in) apart, should be stretched at a speed of approximately 5 mm/sec. (0.02 in/sec.) in a dynamometric machine, in order to check the tensile strength of the v.c. tape in a longitudinal direction. The tensile strength in longitudinal direction, measured on strips approximately 20 mm (0.79 in) wide should be not lower than 1.7 kgf/mm^2 (2.400 lbf/in^2).

c) *Flexibility*

The specimen should be placed on a plane surface and bent on itself in transversal direction; a metal plate 30 mm (1.2 in) wide and 2 mm (0.08 in) thick, long enough to cover completely the width of the v.c. tape, should be placed on the fold and loaded with a weight of about 50 g (0.112 lb) for a fold about 2 cm (0.8) in long. After 5 minutes the plate should be removed, and the tape straightened and examined with normal sight; the varnish should not be cracked.

d) *Heat resistance*

The specimens should be heated in an air oven at a temperature of 120 ± 5°C for a period of 150 hours, and then left for 2 hours at room temperature with about 65% relative humidity. Each specimen should be then bent through 180° around a mandrel having a diameter of 3.2 mm (0.125 in). The varnish film of the specimen examined with normal sight should not appear cracked.

10.61 **Tinning (coating) test on copper wires** (AST)

For the visual inspection, see Clauses 10.02 and 10.35.

If a chemical test is required, it should be carried out with the method and requirements specified in Appendix H (colorimetric method).

10.62 **Galvanizing test** (AST)

When a galvanizing test is required for checking the resistance of steel wires against rusting, the immersion test specified in Appendix I should be carried out on wire specimens taken from the cable sample. If a paint (see Sub-clause 10.15 *b)*) is applied on the armour, this test should be made on specimens taken from wires not yet applied on the cable.

TABLE V

Recommended characteristics of rubberlike insulating compounds

1		2	3	4	5	6	7	8	9
Basic material of the compound		Natural rubber		Synthetic rubber			Polyvinyl-chloride (p.v.c.)		Rubber poly-chloroprene
				(Styrene)		(Butyl)			
Designation of the insulating compound		60 A	75 A	60 B	75 B	80 A	60 C	75 C	60 D
Maximum rated operating temperature	°C	60	75	60	75	80	60	75	60
A. *Mechanical characteristics without ageing* (Test methods: See Appendix D)									
1. *Tensile strength,* minimum:									
1 *a)* in case of one vulcanization[1])	kgf/cm²	70	105	49	49	42	127	150	70
	lbf/in²	1 000	1 500	700	700	600	1 800	2 300	1 000
1 *b)* in case of two vulcanizations[1])	kgf/cm²	60	84	42	42	42	—	—	—
	lbf/in²	860	1 200	600	600	600	—	—	—
2. *Elongation at rupture,* minimum:									
2 *a)* in case of one vulcanization[1])	%	250	400	300	300	300	125	125	300
2 *b)* in case of two vulcanizations[1])	%	250	300	250	250	300	—	—	—
3. *Tensile set* (permanent elongation) maximum[2])	%	under consideration							
B. *Mechanical characteristics after ageing in air oven* (see Appendices D and E)									
Duration and temperature of treatment	hours	168	—	—	—	168	168	240	168
	°C	80	—	—	—	100	80	100	80
1. *Tensile strength:* percentage of value found on the unaged specimens									
1 *a)* minimum	%	70	—	—	—	60	80	80	75
1 *b)* maximum	%	130	—	—	—	—	120	120	—
2. *Elongation at rupture:*									
percentage of value found 2 *a)* minimum	%	70	—	—	—	60	80	80	65
2 *b)* maximum	%	130	—	—	—	—	120	120	—
C. *Mechanical characteristics after ageing in oxygen bomb at 21 kgf/cm²* (see Appendices D and E)									
Duration and temperature of treatment	hours	96	168	96	168	—	—	—	—
	°C	70	80	70	80	—	—	—	—

TABLE V (continued)

1	2	3	4	5	6	7	8	9
Basic material of the compound	Natural rubber		Synthetic rubber			Polyvinyl-chloride (p.v.c.)		Rubber poly-chloro-prene
			(Styrene)		(Butyl)			
Designation of the insulating compound	60A	75A	60B	75B	80A	60C	75C	60D
Maximum rated operating temperature °C	60	75	60	75	80	60	75	60
1. *Tensile strength:* minimum percentage of value found on the unaged specimens:								
1 *a)* in case of one vulcanization[1]) %	70	75	75	50	—	—	—	—
1 *b)* in case of two vulcanizations[1]) %	70	65	75	50	—	—	—	—
2. *Elongation at rupture:* minimum percentage of the value found on the unaged specimens:								
2 *b)* in case of one vulcanization[1]) %	70	75	65	50	—	—	—	—
2 *b)* in case of two vulcanizations[1]) %	70	65	65	50	—	—	—	—
D. *Mechanical characteristics after ageing in air bomb at 5.6 kgf/cm²* (see Appendices D and E)								
Duration and temperature of treatment hours	—	20	—	20	20	—	—	—
Duration and temperature of treatment °C	—	127	—	127	127	—	—	—
1. *Tensile strength:* minimum percentage of the value found on the unaged specimens (in case of both one and two vulcanizations)[1]) %	—	50	—	50	60	—	—	—
2. *Elongation at rupture:* minimum percentage of the value found on the unaged specimens (in case of both one and two vulcanizations)[1]) %	—	50	—	50	60	—	—	—
E. *Thermoplastic characteristics* (Test methods — See Appendix G)								
1. *Hot deformation test* (on unaged specimens)								
Duration of pre-heating hours	—	—	—	—	—	1	1	—
Duration under load hours	—	—	—	—	—	1	1	—
Temperature in air oven °C	—	—	—	—	—	120	120	—
Weight of the indenter grams	—	—	—	—	—	350	500	—
Maximum permissible deformation %	—	—	—	—	—	40	40	—
2. *Cold bending test* (on aged specimens)								
a) ageing treatment in air oven hours	—	—	—	—	—	168	168	—
a) ageing treatment in air oven °C	—	—	—	—	—	80	90	—
b) cold treatment before bending, duration and temperature hours	—	—	—	—	—	4	4	—
b) cold treatment before bending, duration and temperature °C	—	—	—	—	—	−20	−20	—
3. *Heat shock test:* Temperature in air oven °C	—	—	—	—	—	150	150	—
F. *Electrical characteristics* (Test methods — see Clauses 10.44 and 10.45)								
1. *Insulation resistance constant:* $K_i = R_i/\log_{10} D/d$ [3])								
1 *a)* at 20°C, minimum Megohm.km	1 500	1 500	420	420	2 400	200	750	125
1 *b)* at the max. operating temperature (see heading of this table) Megohm.km	—	—	—	—	—	0.2	0.5	—
2. *Increase in a.c. capacity* after immersion in distilled water at 20° to 25°C								
2 *a)* between the end of the first and the end of the 14th day, maximum				under consideration				
2 *b)* between the end of the 7th and the end of the 14th day, maximum				under consideration				

TABLE V (continued)

1	2	3	4	5	6	7	8	9
Basic material of the compound	Natural rubber		Synthetic rubber (Styrene)		Synthetic rubber (Butyl)	Polyvinyl-chloride (p.v.c.)		Rubber poly-chloroprene
Designation of the insulating compound	60 A	75 A	60 B	75 B	80 A	60 C	75 C	60 D
Maximum rated operating temperature °C	60	75	60	75	80	60	75	60
G. *Additional ageing test for p.v.c. compounds*								
Test method, only tentative, see Appendix E, Clause E. 5								
Temperature of the air °C	—	—	—	—	—	80	100	—
Duration hours	—	—	—	—	—	120	120	—
Max. loss of weight (provisional value) mg/cm²	—	—	—	—	—	2.0	2.0	—

Notes 1.) — With reference to paragraphs A and C, when a rubber compound has been subjected to a second vulcanization, such as is required for the application of a p.c.p. sheath, the values specified under the items "two vulcanizations" are admitted instead of those specified under "one vulcanization".

2.) — Test methods for the tensile set (see Appendix D, 5*c*):
First procedure for compounds 60A, 75A, 80A,
Second procedure for compound 60D.

3.) — The "specific dielectric resistance", expressed in ohm.cm, may be calculated multiplying K_i (from the table) by $0.273 \cdot 10^{12}$

TABLE VI

Recommended lead alloys for cable sheathing

Type of Alloy	Tin min.	Tin max.	Antimony min.	Antimony max.	Cadmium min.	Cadmium max.	Tellurium min.	Tellurium max.	Lead
No. 1	1.8	2.2	—	—	—	—	—	—	The remainder
No. 2	—	—	0.7	0.95	—	—	—	—	
No. 3	0.35	0.45	0.15	0.25	—	—	—	—	
No. 4	0.35	0.45	—	—	0.12	0.18	—	—	
No. 5	—	—	—	—	—	—	0.035	0.09	
No. 6	0.16	0.24	—	—	0.05	0.10	—	—	

(Composition: percentages by weight)

Notes 1.) — "Lead" should be understood as lead containing not less than 0.02% and not more than 0.05% impurities, of which not more than 0.005% As — 0.005% Fe — 0.005% Zn — 0.005% Sn — 0.006% Ag — 0.008% Cu — 0.015% Bi — 0.015% Sb — 0.02% other impurities.

2.) — An additional copper content up to 0.05% may be permitted in alloys Nos. 1 to 4, except for alloy No. 2 which may have up to 0.09% copper.

3.) — For the use of lead and lead alloys, see Clause 10.16.

TABLE VII

Recommended characteristics of rubberlike sheathing compounds

1	2	3	4	5	6	7
Basic material of the compound	Polychloroprene (p.c.p.)				Polyvinylchloride (p.v.c.)	
Designation of sheathing compound	SP1	SP2	SP3	SP4	SV1	SV2
Maximum operating temperature in the conductor of sheathed cable[1]) °C	60	80	60	80	60	80
A. *Mechanical characteristics without ageing* (Test method: see Appendix F)						
1. *Tensile strength,* minimum kgf/cm²	84	84	127	127	105	150
lbf/in²	1 200	1 200	1 800	1 800	1 500	2 150
2. *Elongation at rupture,* minimum %	250	250	300	300	100	125
3. *Tensile set* (permanent elongation) maximum[2]) %			under consideration			
B. *Mechanical characteristics after ageing in air oven* (see Appendices E and F)						
Duration and temperature of treatment hours	168	168	168	168	120	240
°C	80	100	80	100	100	100
1. *Tensile strength:* percentage of value found on the unaged specimens (minimum) %	70	70	70	70	85	80
percentage of value found on the unaged specimens (maximum) %	—	—	—	—	—	120
2. *Elongation at rupture:* percentage of value found on the unaged specimens (minimum) %	70	60	70	60	60	80
percentage of value found on the unaged specimens (maximum) %	—	—	—	—	—	120
C. *Mechanical characteristics after ageing in oxygen bomb at 21 kgf/cm²* (see Appendices E and F)						
Duration and temperature of treatment hours	96	96	96	96	—	—
°C	70	80	70	80	—	—
1. *Tensile strength:* percentage of value found on the unaged specimens, minimum %	70	70	70	70	—	—
2. *Elongation at rupture:* percentage of value found on the unaged specimens, minimum %	70	70	70	70	—	—
D. *Mechanical characteristics after immersion in hot oil* (see Clause 10.58)						
Duration and oil temperature hours	24	24	24	24	—	—
°C	100	100	100	100	—	—
Minimum percentage of value found on the not immersed specimens:						
1. *Tensile strength,* minimum %	60	60	60	60	—	—
2. *Elongation at rupture,* minimum %	60	60	60	60	—	—
E. *Thermoplastical characteristics* (Test methods: see Appendix G)						
1. *Hot deformation test* (on unaged specimens) Duration of pre-heating hours	—	—	—	—	1	1
Duration under load hours	—	—	—	—	1	1
Temperature of air oven °C	—	—	—	—	120	120
Weight of the indenter grams	—	—	—	—	350	400
Maximum permissible deformation %	—	—	—	—	40	40

TABLE VII (continued)

1	2	3	4	5	6	7
Basic material of the compound	Polychloroprene (p.c.p.)				Polyvinylchloride (p.v.c.)	
Designation of sheathing compound	SP1	SP2	SP3	SP4	SV1	SV2
Maximum operating temperature in the conductor of sheathed cable 1) °C	60	80	60	80	60	80
2. *Cold bending test* (on aged specimens):						
a) ageing treatment in air oven — hours	—	—	—	—	168	168
— °C	—	—	—	—	80	90
b) cold treatment before bending: duration and temperature — hours	—	—	—	—	4	4
— °C	—	—	—	—	−20	−20
3. *Heat shock test:* temperature in air oven °C	—	—	—	—	120 ± 2	120 ± 2
F. *Additional ageing test for p.v.c. compounds* (Test method, only tentative, see Appendix E, Clause E. 5)						
Temperature of the air °C	—	—	—	—	80	100
Duration hours	—	—	—	—	120	120
Maximum loss of weight (provisional value) mg/cm²	—	—	—	—	2.0	2.0

Notes 1.) — All compounds may be used for cables for fixed installations, compound SP3 may be also used for portable cables for heavy service.

2.) — First procedure (see Appendix D, Sub-clause D. 5*c*).

APPENDIX A

THICKNESS MEASUREMENTS OF RUBBERLIKE INSULATIONS AND SHEATHS

A. 1 General

The purpose of measuring the insulation and sheath thicknesses may be either to check the correct manufacture of cables or to determine the mechanical characteristics of rubberlike compounds. In the first case, the number of specimens to be measured and the places from which they should be taken are specified in Clauses 10.37 and 10.38. In the second case, numbers and taking procedures are specified in Appendices D and F.

A. 2 Procedure

Each specimen should consist of a thin slice of insulating or sheathing wall, from which all coverings and internal parts have been carefully removed. The slice shall be cut, with a sharp knife, along a plane perpendicular to the axis of the conductor (in the case of insulations) or of the cable (in the case of sheaths).

The specimen shall be placed under a 10× microscope, in such a way that the plane which has been cut forms a right angle with the optical axis.

When the inner profile of the specimen is a circle, six measurements are to be carried out radially at angles of 60°. When the inner profile has the impressions of a stranded conductor or of a multicore assembly, several measurements are to be made radially in the directions where thickness is thinnest (between the ridges), the measuring places being as far as possible equally distributed over the circumference, subject to a maximum of six directions.

In each case, the first measurement shall be taken at the place where the insulation or sheath is thinnest. The influence of any unevenness in the outer profile, originating from a tape or the like, if any, shall be eliminated by placing the cross-wire of the microscope as indicated in Figure 1. For the evaluation of the results, see Clauses 10.37, 10.38 and Appendices D and F.

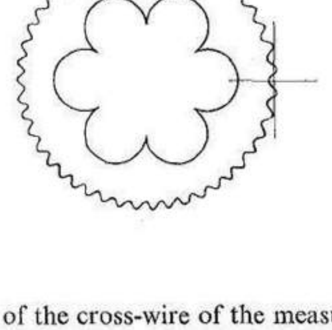


FIG. 1. — Placing of the cross-wire of the measuring microscope.

APPENDIX B

FLAMMABILITY TEST FOR SPECIAL ASBESTOS-VARNISHED-CAMBRIC INSULATED CABLES

B. 1 Specimens

Specimens should consist of straight sections of completed wire or cable approximately 450 mm (18 in) in length.

B. 2 Apparatus

An enclosure of sufficient size to contain the specimen, supports, heater coil, sparking plugs, flame travel gauge and their associated accessories should be arranged to eliminate air draughts and permit a clear view of the interior through shatterproof, glass windows. Vent holes, distributed round the sides adjacent to the base, should be provided to admit fresh air when an exhaust fan connected to the top of the enclosure is operated at a minimum suction, just sufficient to carry off smoke and gases. Supports should be suitable for holding the specimens in a vertical position with an unsupported span not less than 350 mm (14 in) in length. The lower end of the specimen should be wrapped with varnished cambric in such a manner that gases released through this end are diverted towards the sparking plug.

Heater coils should consist of 7 turns of 2.6 mm (0.102 in) diameter resistance wire having a resistivity of 1.06 ± 0.03 ohm.mm²/m space wound to 6.4 mm (0.25 in) between centres. The inside diameter of the coil should exceed the overall diameter of the specimen by not less than 12.5 mm (0.5 in) and by not more than 15.3 mm (0.6 in). The lower end of the heater coil should be located 38 mm (1.5 in) above the top of the lower specimen support.

Two sparking plugs, with extended electrodes spaced 3.2 mm ($^1/_8$ in) from the surface of the specimen and located on diametrically opposite sides of the specimen, should be placed with their longitudinal centre lines in a horizontal plane 12.5 mm (½ in) above the top of the heater coil, to ignite the gases emitted from the heated specimen. A suitable electric circuit should be provided to maintain continuous sparking at the electrodes during the specified time. The sparking plugs should be mounted in such a manner that they may be moved away from the specimen after ignition takes place so as not to impede the travel of the flame and to prevent their electrodes from becoming fouled by soot.

A suitable flame travel gauge should be positioned near the specimen to judge the distance of flame travel without appreciably impeding the progress of the flame.

B. 3 Procedure

Flame tests are specified for heat and flame-resisting type cables and the required performance is as follows:

Minimum ignition time (seconds)	Maximum burning time (seconds)	Maximum flame travel mm	in
60	60	51	2

B. 4 **Time of ignition**

With the enclosure closed and ventilated, the specimen centred in the heater coil, and the sparking plugs and flame gauge properly located, a stop watch should be started simultaneously with the energizing of the heater coil and sparking plugs. A constant current as specified in the table below should be supplied from a suitable transformer source to the heater coil. Ignition should be considered as occuring when the flame transfers from the escaping gases to the surface of the specimen and continues there, disregarding the flashes which may occur in the gassing space prior to the sustained flame. The time required to ignite the specimen should be recorded.

TABLE VIII

Current in heating coil

Nominal diameter of cable		Current (amperes) a.c. r.m.s.
inch	mm	
0.050 to 0.099	1.27 to 2.51	45
0.100 to 0.19	2.54 to 4.82	46
0.20 to 0.29	5.08 to 7.36	47
0.30 to 0.39	7.62 to 9.90	48
0.40 to 0.49	10.16 to 12.44	49
0.50 to 0.59	12.70 to 14.98	50
0.60 to 0.69	15.24 to 17.52	51
0.70 to 0.79	17.78 to 20.06	52
0.80 to 0.89	20.32 to 22.60	53
0.90 to 0.99	22.86 to 25.14	54
1.00 to 1.09	25.40 to 27.68	55
1.10 to 1.39	29.94 to 35.30	56
1.40 to 1.79	35.56 to 45.46	57
1.80 to 2.29	45.72 to 58.16	58
2.30 to 3.00	58.42 to 76.20	59

B. 5 **Time of heating**

For all armoured cables, tested with or without armour, the heating current should be switched off 30 seconds after ignition occurs. For all unarmoured cables, where the ignition time is not greater than 60 seconds, the heating current should be switched off 60 seconds after being switched on; where the ignition is greater than 60 seconds, the heating current should be switched off when ignition occurs.

B. 6 **Distance of flame travel**

Immediately after ignition occurs, the electric supply to the sparking plugs should be cut off and the plugs shifted away from the flame. The maximum distance to which the flame travels along the surface of the specimen, measured from the top of the heater coil, before extinction, should be noted and recorded.

B. 7 **Time required for flame extinction**

The number of seconds that the specimen continues to burn, until the cessation of all flaming, after the current in the heating coil has been cut off, should be recorded as the time required for flame extinction.

B. 8 **Observations**

The amount and colour of the smoke and the amount and size of the soot particles shall be observed and recorded.

APPENDIX C

OZONE RESISTANCE TEST FOR RUBBER AND RUBBERLIKE INSULATED CABLES

C. 1 Purpose

The purpose of this method is to test the resistance of rubber insulation to ozone attack which may be encountered in connection with the operation of high-voltage cables.

C. 2 Apparatus

The apparatus should consist of the following:

a) a device for generating a controlled amount of ozone,

b) a means for circulating ozonized air under controlled conditions of humidity and temperature through a chamber containing the specimens to be tested, and,

c) a means for determining the percentage of ozone concentration.

C. 3 Test specimens

a) Two specimens for the ozone test should be selected beyond a point not less than 1.5 m (5 ft) from the end of the reel or coil to be tested. Where protective coverings are applied, such coverings should be removed when non-adherent to the insulation. However, where tapes or sheaths are applied directly to the insulation prior to vulcanization and left in place during vulcanization, and are consequently adherent to the insulation in the completed cable, such covering shall not be removed.

b) Each specimen should be examined to make sure it is free from mechanical defects such as cuts, dents, tears, loose threads, etc. One specimen should be bent in the direction and plane of the existing curvature of the cable around a mandrel and through the specified angle in accordance with paragraphs *c)* and *d)*. The other specimen should be bent similarly, but in the reverse direction.

c) Specimens should be bent without twisting at room temperature but at not less than 20°C, around the mandrels. The mandrel diameters should be as follows:

Cable outside diameter	*Mandrel diameter*
Less than 12.7 mm (or 0.5 in)	4 × cable OD
12.7 mm (or 0.5 in) but less than 19 mm (or 0.75 in)	5 × cable OD
19 mm (or 0.75 in) but less than 31.75 mm (or 1.25 in)	6 × cable OD
31.75 mm (or 1.25 in) but less than 44.5 mm (or 1.75 in)	8 × cable OD
44.5 mm (or 1.75 in) and above	10 × cable OD

d) The specimens should be bent around a brass, aluminium, or suitably treated wooden mandrel of the specified diameter, binding it with twine or tape where the ends cross. If the cable is too rigid to permit crossing of the ends, it may be bent in the form of a U and tied so that at least a 180° bend of the proper diameter is obtained.

e) The surface of the insulation on each specimen should be wiped with a clean cloth to remove dirt or sweat. The bent specimens on their mandrels should then be placed in a desiccator for 30 to 45 minutes after bending to remove surface moisture and until placed in the ozone chamber.

C. 4 Procedure

a) Circulate the air through the test apparatus at a constant rate of flow for at least 15 minutes prior to bending of the specimens. The flow shall be between 300 l and 600 l (10 ft^3 and 20 ft^3) per hour as indicated on the flow meter. The manometer should indicate a pressure of approximately 12.7 mm (or 0.5 in) of water above atmospheric in the test chamber. This pressure may be controlled by the degree of closure of the discharge cock. After the ozone has been generated for at least 15 minutes a check should be made on the percentage of ozone concentration. Then regulate the voltage of the ozone generator or the rate of flow of air should be regulated so as to give a concentration of ozone as specified in the product specification. The temperature of the air in the test chamber should be regulated to 25 $\pm$ 2° C. When constant test conditions are obtained, and after the ozone chamber has been in equilibrium operation for at least 45 minutes, the specimens should be placed in the test chamber. Care should be taken not to handle the insulation. The specimens should be supported in an approximately vertical plane midway between the top and bottom, with the free ends down to, but not touching, the bottom.

b) The ozone concentration should be maintained between 0.025 and 0.03% by volume. After exposing the specimens for 3 hours, they should be taken out of the chamber, all coverings removed from the specimens, and the specimens examined by the un-aided eye for cracks in the bent portion. Cracks occuring on the 180° sector including the tie (where the specimen is not curved to conform to the mandrel) shall not be considered failures.

C. 5 Ozone resistance test

The ozone concentration should be determined with one of the methods described in Sections 43 to 47 of the A.S.T.M. Specification D 470 — 59 T, Tentative methods of testing rubber and thermoplastic insulated wires and cables (included as Annex 1 to Appendix C).

Annex 1 to appendix C

Sections 42 to 47 of the ASTM Specification D 470-59 T

Determination of ozone concentration

42 Purpose

These methods for the determination of ozone concentration are for use in connection with the Ozone Resistance Test, Sections 37 to 41.

Chemical analysis

43 Reagents

a) Starch Indicator Solution

Stir 1 g of soluble starch into 40 ml cold water, heat to boiling, while stirring constantly, until starch is thoroughly dissolved, dilute with cold water to about 200 ml, and add 2 g of crystallized zinc chloride. Let the solution settle for some time and then pour off the supernatant liquid for use. Renew every two or three days. A fresh solution of 1 g of soluble starch in 100 ml of boiling water may also be used. When using these starch solutions as an indicator, add a few drops of acetic acid (10%) to the solution being titrated.

b) Standard Iodine Solution

Place in a weighing tube 2 g of KI and 10 ml of water, and weigh the tube and solution. Add iodine directly to the solution in the weighing tube on the balance pan until the total iodine in solution is about 0.1 g. Accurately weigh the solution with the added iodine. Determine the amount of iodine added to the solution. Remove the weighing tube, pour the solution into a beaker, wash the weighing tube held over the beaker with distilled water, pour the solution from the beaker into a volumetric flask, rince the beaker into a 1 000 ml volumetric flask with distilled water, and dilute the solution in the flask to 1 litre. This solution is fairly stable if kept in a cool, dark place in a well-stoppered, brown bottle.

c) Sodium Thiosulphate Solution

Prepare a $Na_2S_2O_3$ solution of approximately the same strength as the standard iodine solution by placing about 0.24 g of $Na_2S_2O_3 . 5H_2O$ in a 1 000 ml volumetric flask, and dilute to 1 litre. Since this solution gradually loses its strength, standardize it against the standard iodine solution on the day tests are run. The method for calculating the strength of the $Na_2S_2O_3$ solution is described in Section 46 *a)*.

d) Potassium Iodine Solution

Dissolve about 20 g of pure KI in 2 litres of water.

e) Acetic Acid (10%)

44 Collection of sample

Place a 100 ml portion of KI solution (1 %), slightly acidulated by a few drops of acetic acid, in the sampling bottle and connect the latter to the sampling cock and gas burette (as shown in Figure 2: Apparatus for Ozone Resistance Test).

Then open the two-way stopcock on the burette to the air and fill the burette to the mark with water by lifting the aspirator bottle. Close the stopcock to the air and open it to the sampling bottle, and then open the sampling cock on the test chamber.

Lower the aspirator bottle until the burette is emptied. When this point is reached, 500 ml of gas will have bubbled through the KI solution.

Then close the stopcocks and withdraw the bottle for titration.

45 Analysis of sample

Add to the solution in the bottle a few drops of freshly prepared starch solution as an indicator, and then titrate with the standardized $Na_2S_2O_3$ solution.

46 Calculations

a) Sodium Thiosulphate Solution

Calculate the strength of the $Na_2S_2O_3$ solution as follows:

$$E = \frac{F \times C}{S}$$

where:

E = iodine equivalence of $Na_2S_2O_3$ expressed as milligrams of iodine per millilitre of $Na_2S_2O_3$,
F = number of millilitres of the iodine solution,
C = concentration of iodine in milligrams per millilitre, and
S = number of millilitres of $Na_2S_2O_3$ used to titrate the solution.

b) Ozone

Since 1 mg of iodine is equivalent to 0.1 ml of ozone at room temperature and pressure (within the accuracy of this method of analysis at average room temperature and pressure), the ozone may be calculated as follows:

$$O = E \times 0.1$$

where:

O = number of millilitres of ozone at room temperature and pressure equivalent to 1 ml of $Na_2S_2O_3$ solution used, and
E = iodine equivalent of $Na_2S_2O_3$ expressed as milligrams of iodine per millilitre of $Na_2S_2O_3$,

then: $\text{Percentage of ozone} = \frac{S \times O}{M} \times 100$

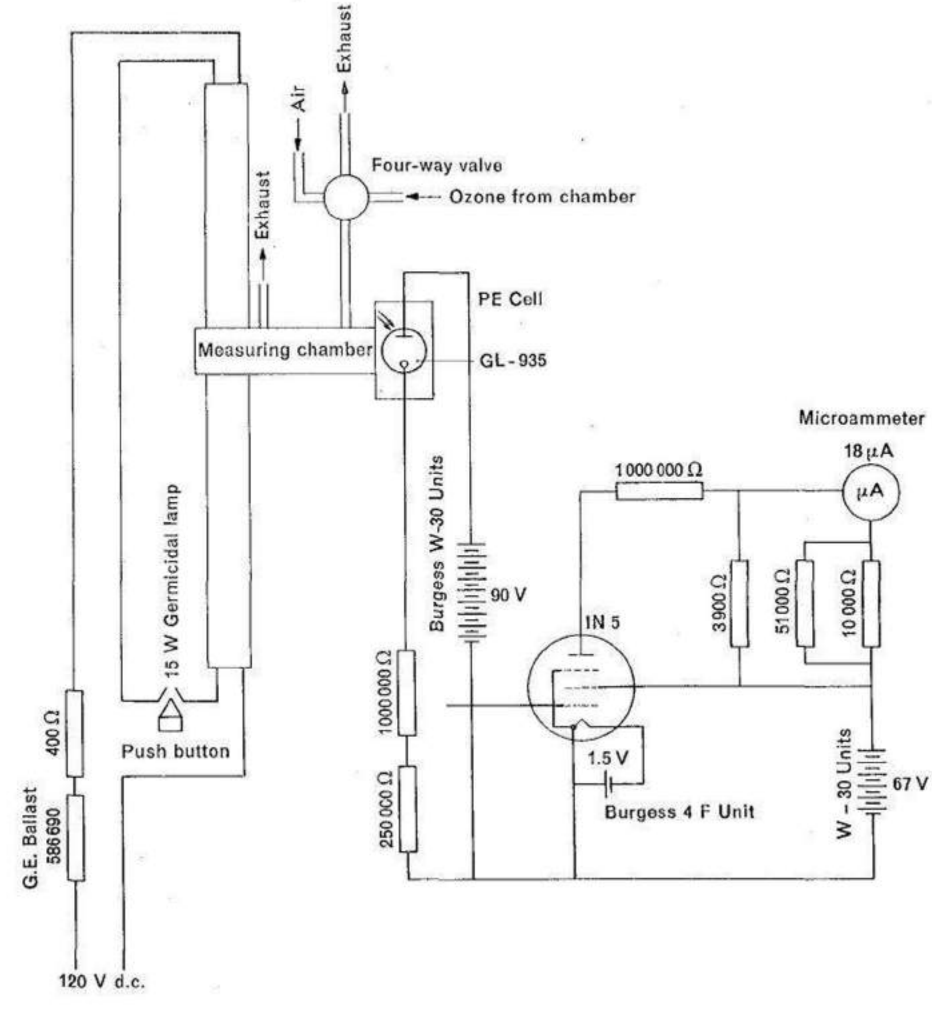
where:

S = number of millilitres of $Na_2S_2O_3$ used to titrate the solution,
O = number of millilitres of ozone at room temperature and pressure equivalent to 1 ml of $Na_2S_2O_3$ solution used, and
M = number of millilitres of the sample collected.

DIRECT MEASUREMENT WITH AN OZONOMETER

47 Procedure

This method is based on the absorption of 2 537 A radiation by ozone. The equipment is composed of a source of 2 537 A radiation and a photoelectric cell located on the opposite sides of a measuring cell through which the ozone atmosphere to be measured is passed. The amount of 2 537 A radiation that is available for activating the photoelectric cell is dependent on the concentration of ozone in the measuring chamber.



Note. — Resistor values in microammeter shunt will vary with the meter used and with the concentration scale desired.

Electronic Ozonometer

The current generated in the photoelectric cell is amplified sufficiently to be read directly on a sensitive microammeter. The above figure shows a suggested schematic arrangement of this apparatus. The microammeter can be marked to read directly in percentage ozone. The calibration of this instrument should be made by comparison with results obtained with the chemical method (Sections 43 to 45). The advantage in using this method is that after a calibration is obtained the ozone concentration is continuously readable on the microammeter without drawing a sample from the test chamber and thus upsetting equilibrium.

APPENDIX D

TEST OF THE MECHANICAL AND CONTAMINATION CHARACTERISTICS OF RUBBERLIKE INSULATIONS (RUBBER AND P.V.C. COMPOUNDS)

D. 1 General

a) The tests described in this Appendix consist in determining the tensile strength and the elongation at rupture of the insulating material taken from pieces of cable:

i) as received (i. e. without any ageing treatment);

ii) after an accelerated ageing treatment;

iii) after another ageing treatment, different from *ii)*, if required,

and comparing the obtained results, which should comply with the requirements specified in Table V, Items A, B, C and D.

Tests are also included for determining contamination when rubber and p.v.c. compounds are in contact within the cable.

Note. — All the set of tests described in this Appendix should be considered as being made on *one* sample. It is, on the other hand, outside the scope of the Appendix to specify how many samples should be tested in relation to the types and sizes and quantities of cables which may be manufactured under one or more contracts (see definition of "type tests" in Clause 10.33).

b) Three pieces of finished cable should be used for the tests, each piece being taken at least 1 metre away from the others.

Each cable piece should be cut into six small pieces, two of which should be used for each of the tests *i), ii)* and *iii)*, so that six small pieces of insulated core*) are provided for each tests *i), ii)* and *iii)*.

If additional tests are specified in special cases (see for instance Sub-clause D. 7 *b)*, Clause E. 5 and Sub-clause D. 5 *c)*), additional small pieces should be prepared from the three pieces taken as above.

c) The following deviations may be permitted, but in case of dispute Sub-clause D. 1 *b)* only should be considered valid:

c 1) Two pieces of finished cable (instead of three) may be used and cut each into six small pieces, so that four (instead of six) small pieces are provided for each test *i), ii)* and *iii)*.

c 2) When, as specified under Sub-clause D. 2 *a)*, dumb-bell strips are used for the test, three instead of six small pieces may be retained for each test *i), ii)* and *iii)*.

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*) In case of multicore cables, two differently coloured cores should be tested as if they were two different single-core cables (two whatever be the number of cores in the cable).

D. 2 Preparation of the test specimens

a) Two types of test specimens should be considered for the tensile tests; the first, having the form of a tube, consists of a piece of the whole insulating wall without longitudinal cutting; the second consists of a dumb-bell strip having the dimensions represented in Figure 2 and is punched from a piece of the insulating wall which has previously been flattened by grinding, care being taken that the insulating material is not unduly heated.

Test specimens of the first type should be used whenever the cross section of the conductors does not exceed 25 mm² (0.04 in²) and the expected breaking strength of the tube does not exceed 65 kgf (145 lbf); specimens of the second type should be used when the conductor section exceeds 25 mm² (0.04 in²) or the breaking strength of the whole insulating wall exceeds 65 kgf (145 lbf) (this value being considered the standard capacity of the drawing machine).

b) In order to prepare the test specimens, the pieces of insulated core, having been taken as described in Clause D. 1, shall have the outer surface of the insulating wall made bare by carefully removing the coverings, tape, etc., if any.

The conductor should also be removed (except in the case specified at the end of Sub-clause D. 3 *b)*), taking care not to damage the insulation.

The insulating tubes, so prepared in lengths of at least 100 mm (4 in), are ready to be used as test specimens of the first type.

c) Specimens of the second type are prepared, when necessary, by cutting longitudinally the tubes described under *b)* and grinding strips so obtained in order to obtain two flat and parallel surfaces. The dumb-bell specimens corresponding to Figure 2 are then punched in the direction of the conductor's axis.

D. 3 Ageing treatments

a) The specimens destined to the tests *ii)* and *iii)* mentioned in Sub-clause D. 1 *a)* should be subjected to the accelerated ageing procedures described in Appendix E and with the conditions specified in Table V, Items B, C and D.

The ageing treatment shall be carried out on the test specimens prepared as specified in Clause D. 2, excepting the case mentioned in Sub-clause D. 3 *b)*.

After completion of the ageing process, the aged specimens should be left for at least 16 hours, and in case of p.v.c. not more than 24 hours, at ambient temperature and not exposed to light.

b) In the case of rubber insulated cores from which the specimens of the first type have to be prepared for the tests *ii)* and *iii)*, two procedures may be chosen: either the general one as described above, or by carrying out the ageing treatment before removing the copper conductor from the insulating wall.

The first procedure is to be applied if the good tinning of the copper wires is checked by the chemical test specified in Appendix H. If, instead, this test is omitted (see Clause 10.02) the copper conductor should be removed from the insulation after completion of the ageing tests.

D. 4 Determination of the area of the specimens

a) For specimens of the first type either one or the other of the following methods may be used:

a 1) The cross-sectional area Q (in mm²) of the tube is calculated by the formula:

$$Q = \pi (d + t) t$$

where t (in mm) is the mean value of the insulation thickness from six measurements made in accordance with Appendix A (the slice to be put under the measuring microscope being cut from an end of the specimen concerned),

and d (in mm) is the internal diameter of the insulating tube (i.e. the internal diameter of the slice put under the microscope), excluding the ridges, if any.

a 2) The cross-sectional area Q (in mm²) of the tube is calculated by the following formula:

$$Q = 1\,000\ W/w \cdot l$$

where W (in g) is the weight of the specimen,
w (in g/cm³) is the density of the compound,
l (in mm) is the length of the specimen.
W and l should be measured directly on each specimen;
w should be determined on a piece of compound using an accepted method.

b) For specimens of the second type (Figure 2), the cross-sectional area is calculated from the width and the thickness of the middle portion of the specimen concerned (between the gauge lines), each being the mean of three measurements made by a micrometer or similar instrument producing a contact pressure not exceeding 700 gf/cm² (10 lbf/in²).

c) In any case, for the specimens which are subjected to an ageing test, the determination of the area should be calculated after the completion of the ageing and storing period (see Sub-clause D. 3 *a)*).

D. 5 Mechanical testing procedure

a) The tensile tests should be carried out at an ambient temperature of 20 ± 5° C, after having conditioned the aged and unaged specimens for at least 10 hours at a temperature of 20 ± 5° C in case of rubber and of 20 ± 1° C in case of p.v.c. compounds.

In the latter case the test should be completed within 5 minutes after each specimen has been taken out of the conditioning room.

The conditioning period may be (and in case of p.v.c. should be) included in the storing period mentioned under Sub-clauses D. 3 *a)* and D. 4 *c)*.

A conditioning and testing temperature slightly different from 20° C (for instance 23° C), and with slightly different tolerances, may be permitted, but in case of dispute the values specified in the first paragraph of this Sub-clause should be complied with.

b) A suitable dynamometric machine should be used, having grips of the self-tightening type. Non self-tightening grips may, however, be used when testing specimens of the first type. Any specimen breaking at or near the grips should be ignored.

Each specimen (on which a gauge length of approximately 20 mm (0.79 in) is marked by two lines) should be secured in the machine so that the free length between the grips is about 75 mm (3 in) in case of tubes and 50 mm (2 in) in case of dumb-bell strips.

The above figures are given only as an indication; in any case the rate of separation of the grips should be such that the rate of elongation of the spe cimen between the line marks is 500% per minute.

c) When the determination of the permanent elongation is required (see Tables V and VII), one of the following procedures should be applied:

First procedure

The specimen is stretched until the distance between the gauge lines becomes three times its initial value (200% elongation); it is maintained so stretched for 5 seconds, then abruptly released; 1 minute after the release the distance between the gauge lines is measured.

Second procedure

Elongation 150% for 4 hours; measurement 2 hours after the release.

D. 6 Evaluation of the tests results

a) The median of the tensile strength values obtained on the unaged specimens should comply with the requirements specified under Item A. 1 of Table V for the type of compound with which the cable has been declared to be insulated. (The median is obtained by disregarding the highest and the lowest test results and taking the mean of the remaining results.)

b) Similarly, the median of the tensile strength values obtained on the specimens aged in the air oven should comply with the requirements specified under Item B. 1 *a)* of the same table, and also under Item B. 1 *b)*. In calculating the percentages mentioned under these items, the median of the values obtained after ageing is to be divided by the median of the values obtained without ageing and the result is to be multiplied by 100.

c) A similar procedure should be followed for the evaluation of the other mechanical characteristics before and after ageing.

D. 7 Additional test on the insulating materials when rubber and p.v.c. compounds are in contact within the cable (contamination test)

a) With reference to Sub-clause D. 1 *b)*, three pieces of cable should be prepared, having the external coverings (if any) removed but the sheath left in place. Subject to agreement, two instead of three pieces may be used as specified in Sub-clause D. 1 *c)*.

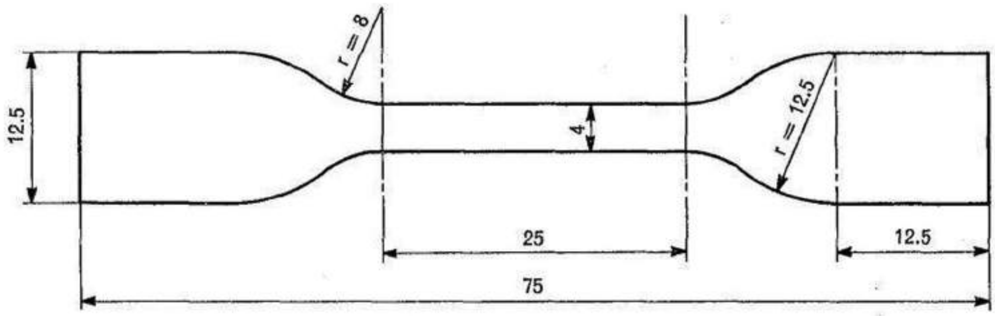
They should be heated in air oven (see Appendix E) for 168 hours at a temperature 20°C higher than the rated operating temperature of the insulating compound (see on top of Table V).

b) At least 16 hours after completion of the ageing process, six specimens of the insulating wall should be prepared as described in Clause D. 2, then measured and tested as described in Clauses D. 4 and D. 5. Four (or three) specimens, instead of six, may be used if paragraph D. 1 *c 1)* or D. 1 *c 2)* is agreed.

c) In the case of insulating compounds for which test requirements are given under Item B of Table V, the same test requirements should be complied with when the test is carried out as described under *a)* and *b)* above.

In the case of insulating compounds for which test requirements are not given under Item B of Table V, the following requirements should apply:

The mean of the tensile strength values obtained on these specimens should not be lower than 65 % of the mean value obtained on the unaged specimens. Similarly, the mean value of the elongation at rupture should not be lower than 65 % of the mean value found on the unaged specimens.



Dimensions in millimetres

FIG. 2

APPENDIX E

ACCELERATED AGEING TESTS

E. 1 General

Except the one in Clause E. 5, the tests described in Appendix E should be associated with mechanical tests — such as tensile tests and cold bending test — so that this Appendix should be read in conjunction with Appendices D, F and G.

E. 2 Ageing in air oven

The specimens should be suspended freely and not in contact with each other in a heating cabinet, in which the air is renewed by natural draught, so that the atmosphere existing in the enclosure has practically the same composition and pressure as the ordinary ambient air.

The temperature and the duration of the heat conditioning are specified in Tables V and VII for each material considered. The heating should be continuous and the temperature variation should not exceed $\pm$ 2°C. In case of doubt, a tolerance not larger than $\pm$ 1°C should be assured.

E. 3 Ageing in oxygen bomb

The specimens should be suspended freely and not in contact with each other in a thermostatic tank, which is then filled with oxygen under pressure.

If several groups of specimens are placed in the bomb, they should be of the same quality and origin, so that one group is not influenced by emanations from another group during the heating. The total volume occupied by the specimens should be not more than one tenth of the effective capacity of the bomb.

The oxygen should have a pureness of not less than 97% and its pressure in the bomb shall be maintained at 21 $\pm$ 0.7 kgf/cm^2 (300 $\pm$ 10 lbf/in^2) during all the ageing period.

The duration and the temperature of the heat treatment are specified in Tables V and VII for each material considered. The heating should be continuous and the temperature variation should not exceed $\pm$ 1°C.

After the completion of the ageing period, the pressure should be released gradually, reaching the atmospheric pressure in at least 5 minutes, in order to avoid formation of porosity in the specimens.

E. 4 Ageing in air bomb

What is indicated in Clause E. 3 should here be repeated, with the difference, however, that the bomb is filled with air and maintained at a pressure of 5.6 $\pm$ 0.20 kgf/cm^2 (80 $\pm$ 3 lbf/in^2).

The temperature inside the bomb should reach the test temperature within 15 minutes after inserting the test specimens. The air should be substantially free from oil and moisture.

E. 5 **Additional ageing test for p.v.c. compounds**

a) This additional test is applicable to p.v.c. insulated and/or p.v.c. sheathed cables only, and consists in determining the loss of weight caused on pieces of p.v.c. compounds by a hot air stream during a period of time.

Notes 1.) — This test is considered as an obligatory one, but for the time being the method and requirements have a tentative character, so that failure to comply with the provisional values given in Tables V and VII may be tolerated.

2.) — All the sets of tests described in this Clause should be considered as being made on *one* sample, as stated in the Note to Sub-clause D. 1 *a)*.

b) For the test on insulants, the specimens should consist of pieces of insulated core having all coverings removed but with the conductor left *in situ*. For the test on sheaths, the specimens should consist of pieces of sheath from which all coverings (if any) and all cores and fillers (if any) have been removed In the latter case, both ends of each specimen should be tightly plugged so that only the outer surface remains exposed to the air, for a length of 150 mm (6 in).

The number of specimens to be used in each test is as follows:

External diameter of the specimens (mm)	above / up to	— / 5	5 / 12.7	12.7 / 25.4	25.4 / —
Number of specimens in each test		6	4	2	1

Two tests shall be made for each compound and both results should comply with Sub-clause E. 5 *d)*.

c) The specimens should be weighed and then suspended in a tube about 100 mm (4 in) in diameter and about 300 mm (12 in) in length. Each specimen should be at least 19 mm (0.75 in) from any other specimen and from the wall of the tube. No other test samples of different compound shall be exposed in the tube at the same time.

The tube should be inserted vertically in a suitable oven automatically controlled to maintain the specimens at the specified test temperature (see Tables V and VII) with a tolerance of $\pm$ 0.5°C.

Air, pre-heated to approximately the same temperature, should be supplied to the tube at a rate of 3.8 l per minute (8 ft^3 per hour), entering at the bottom and flowing upwards and out at the top of the tube. Air turbulence in the tube should be maintained by any suitable means, e.g. a paddle placed at the bottom rotating at about 60 rev/min.

The specimens should be maintained under these conditions for the time specified in Tables V and VII and should then be allowed to cool to room temperature after which they should be reweighed.

Note. — The apparatus and procedure described in the preceding three paragraphs should not be considered as exclusive; different devices may be used, provided the following conditions are assured:

i) Fresh air should be fed into the container so that the direction of the air stream is in the direction of the samples; the mean speed of the air stream should be 50 $\pm$ 5 cm per minute, this speed being regarded as the ratio between the air flow in cm^3 per minute and the cross-sectional area of the vessel (preferably a tube) containing the sample in cm^2; sufficient turbulence should be introduced into the air stream to ensure uniform conditions in all parts of the vessel.

ii) The exposed surface of the specimens should be not less than 150 cm^2 and not more than 250 cm^2.

iii) The maximum tolerance of the temperature in the container should be $\pm$ 1°C.

iv) Contamination of one sample by another should be prevented.

d) The total loss of weight of all the specimens used in each test (see Sub-clause E. 5 *b)*) should be divided by the total exposed area of the same specimens and expressed in grams per cm^2. The resulting values should not exceed the limits specified in Tables V and VII for the type of p.v.c. compound considered.

APPENDIX F

TEST OF THE MECHANICAL CHARACTERISTICS OF RUBBERLIKE SHEATHS (RUBBER, P.C.P. AND P.V.C. COMPOUNDS)

F. 1 General

a) The contents of Sub-clause D. 1 *a)* are here applicable, substituting "sheathing material" for "insulating material" and "Table VII, Items A, B and C" for "Table V, Items A to D".

b) Three pieces of finished cable should be used for the tests, each piece being taken at least 1 metre (3 ft) away from the others.

Each cable piece should be cut into six small pieces, two of which should be used for each of the tests *i), ii)* and *iii)*.

c) Deviations in accordance with the contents of Sub-clause D. 1 *c)* may be permitted, but in case of dispute Sub-clause F. 1 *b)* without deviations should be applied.

F. 2 Preparation of the test specimens

a) Two types of test specimens should be considered for the tensile tests on sheaths: the first consists of a piece of the whole sheath without longitudinal cutting; the second consists of a dumb-belled strip having the dimensions represented in Figure 2 punched from a piece of sheath which has previously been flattened by grinding.

Test specimens of the first type should be used when the external diameter of the sheath does not exceed 10 mm (0.4 in); in case of larger sizes, specimens of the second type only should be used.

b) In order to prepare the test specimens, the pieces of cable, having been taken as described in Clause D. 1, should have the outer coverings (if any) removed and the internal core or cores and fillers (if any) taken out, so that the external and internal surfaces of the piece of sheath are made bare.

The sheath tubes, so prepared in lengths of at least 100 mm (4 in), then are ready to be used as test specimens of the first type.

c) Specimens of the second type are prepared as described in Sub-clause D. 2 *c)*, punching the strips in the direction of the axis of the cable.

F. 3 Ageing treatments

The specimens destined for the tests *ii)* and *iii)* mentioned in Sub-clause F. 1 *a)* should be subjected to the accelerated ageing procedures described in Appendix E and with the conditions specified in Table VII, Items B and C. After completion of the ageing process, the aged specimens should be left for at least 16 hours, and in case of p.v.c. not more than 24 hours, at ambient temperature and not exposed to light.

F. 4 **Determination of the area of the specimens**

a) For the specimens of the first type, the cross-section should be calculated, as specified in Sub-clause D. 4 *a 2)*, by dividing the volume by the length of the tube. The volume should be calculated by dividing the weight of the specimen by the density of the compound. This density should be determined separately by an accepted method.

b) For the specimens of the second type (Figure 2), the cross-sectional area should be determined as described in Sub-clause D. 4 *b)*.

c) In any case, for the specimens which have been subjected to an ageing test, the determination of the area should be effected after the completion of the ageing and storing period (see Sub-clause F. 3 *a)*).

F. 5 **Mechanical testing procedure**

See Clause D. 5.

F. 6 **Evaluation of the test results**

See Clause D. 6, except that Table VII should be referred to instead of Table V.

APPENDIX G

TEST OF THE THERMOPLASTIC CHARACTERISTICS OF P.V.C. COMPOUNDS

G. 1 General

The tests described in this Appendix are applicable both to p.v.c. insulating and p.v.c. sheathing compounds, with the appropriate requirements specified in Tables V and VII.

Note. — All the set of tests described in this Appendix should be considered as being made on *one* sample. It is, on the other hand, outside the scope of the Appendix to specify how many samples should be tested in relation to the types and sizes and quantities of cables which may be manufactured.

G. 2 Hot deformation test

a) Preparation of test specimens

The test specimens should be prepared from a piece of finished cable. Two test specimens should be prepared for each type of p.v.c. compound. The insulating wall or sheath should be cut in small pieces, which should be moulded at a suitable temperature (in general, 175 ± 5°C). Each test specimen should consist of a sheet 1.20 (0.047 in) to 1.50 mm (0.059 in) thick and at least 12.0 (0.0186 in) to15.0 mm (0.0232 in) square or 12.0 to 15.0 mm in diameter.

The moulding cycle should consist of a pre-heating period of 5 minutes in the press at full moulding temperature under light pressure, followed by the application of a pressure not less than 35 kgf/cm^2 (500 lbf/in^2) calculated on the area of the moulding. Cooling should begin within 2 minutes of the application of full pressure. The compound should be cooled as rapidly as possible consistent with producing a smooth surface on the sheet, full moulding pressure being maintained during cooling.

The use of test specimens not exactly complying with the conditions recommended in the preceding two paragraphs may be permitted, but in case of dispute these conditions only should be valid. The specimens may, for instance, be prepared by cutting and buffing pieces of the insulating wall or the sheath instead of by moulding pieces of same.

b) Apparatus

The apparatus should be substantially as shown in Figure 3. Its parts are:

(A) — A flat horizontal support on which the test piece is laid.

(B) — A vertical cylindrical indenter, 3.18 ± 0.025 mm (0.125 ± 0.001 in) in diameter, flat at the lower end, rigidly supported in frame (C).

(C) — A frame carrying a weight (D).

(D) — A weight such that the total load on the indenter complies with the appropriate values specified in Tables V and VII.

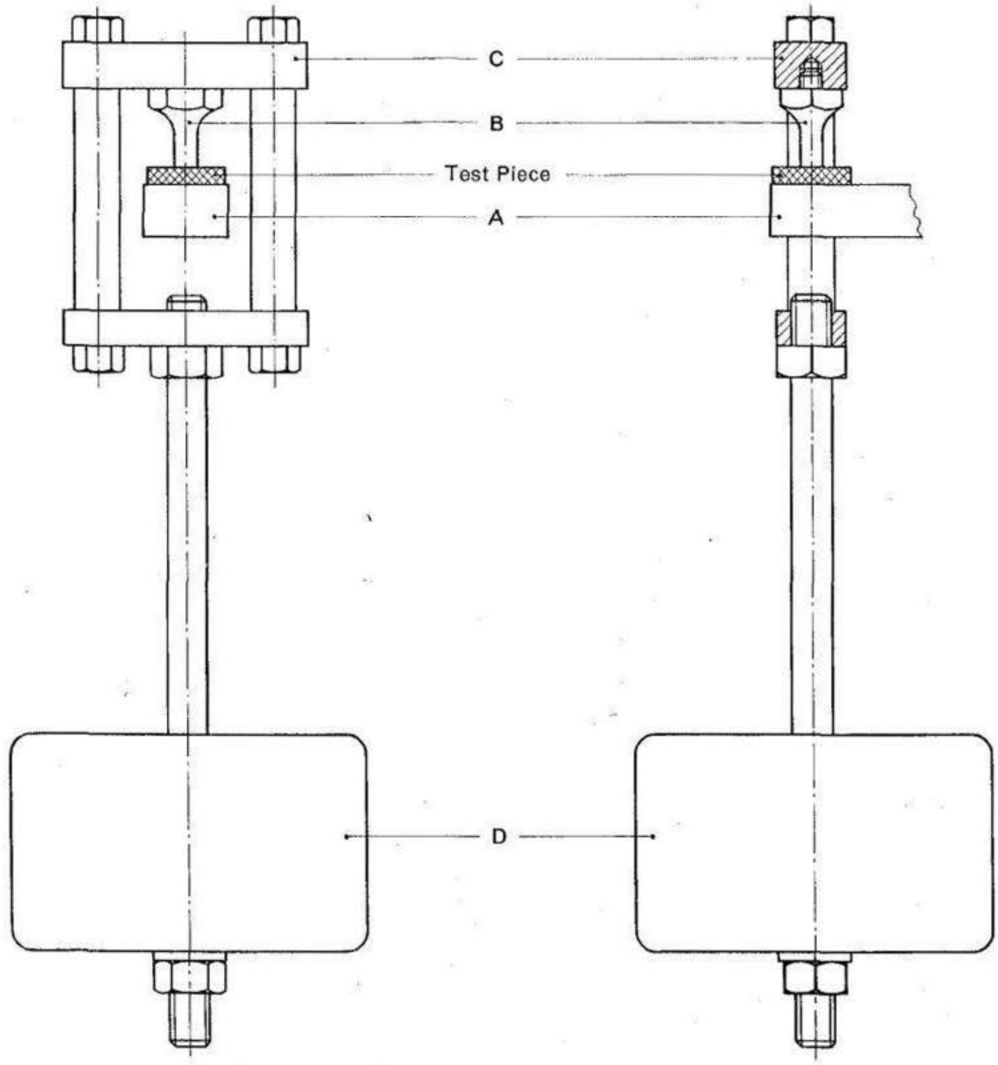


FIG. 3. — Apparatus for hot deformation test.

The assembly of indenter, frame and weight should be so arranged that the centre of gravity is well below the lower end of the indenter. The assembly should be such that, when the lower end of the indenter rests on the centre of the test specimen, it has no other contact with the remainder of the apparatus, except that guides may be provided to prevent swinging. Any guides should be such as to introduce no friction.

The use of apparatus different from the above description may be permitted, if agreed by the interested parties. In any case the specific pressure (kgf/cm^2) exerted by the indenter on the specimen should correspond to the values mentioned in (B) and (D).

c) *Procedure*

The thickness of the test specimen should be measured within the area over which pressure is to be applied. This measurement should be made at room temperature, using a micrometer such that a contact pressure not exceeding 200 gf/cm^2 (2.9 lbf/in^2).

The test specimen should be placed in position on the support without applying the load on it. The whole apparatus should be put in an oven at the temperature specified in Item E. 1 of Tables V or VII and kept at that temperature for 1 hour. The indenter with load should then be applied to the centre of the specimen and the assembly further maintained at the same temperature for the period of time specified in the said Tables.

The oven should be in a position free from vibration or mounted on an anti-vibration support and no apparatus likely to cause vibration, such as an air-stirring mechanism, should be directly attached to the oven.

At the end of the specified period, the apparatus should be removed from the oven and allowed to cool for 1 hour under room conditions ($20 \pm 5°C$) with the load still applied. The load should be removed and the thickness of the deformed portion of the test specimen measured immediately by means of the instrument used at the beginning of the test.

The following deviations in the measuring procedure may be permitted if a suitable apparatus is used (for instance a plastometer, whose dial index is controlled by the indenter):

The first thickness measurement is effected as specified in the first paragraph of this Sub-clause.

The final thickness measurement is effected at the end of the heating period when the load is still applied on the specimen at the specified temperature.

d) *Results and requirements*

The hot deformation for any one test should be expressed by the difference between the initial and final thickness calculated as a percentage of the initial thickness.

The mean of the two results (see Sub-clause G. 2 *a)*) should be taken as the hot deformation of the type of compound considered and should not exceed the appropriate value specified in Tables V and VII.

If the higher result exceeds the lower by more than 20 % of the mean value, the results shall be disregarded and the complete test repeated.

G. 3 **Cold bending test**

a) Preparation of the test specimens

The test specimens should be taken from a piece of finished cable. Two specimens should be prepared for each type of p.v.c. compound to be tested. Two types of specimens are considered, both having a sufficient length for being used with the apparatus described below: when the external diameter of an insulated core (or of a p.v.c. sheath) is not greater than 12.5 mm (0.5 in), then each specimen should consist of a piece of core (or of cable) from which any external covering have been removed but the conductor (or the cores and fillers, if any) have been left *in situ.*

When instead, the external diameter of the insulated core (or of the p.v.c. sheath) is greater than 12.5 mm (0.5 in), then each specimen should consist of a strip whose width is about 1.5 times its thickness but not less than 4 mm (0.16 in); the strip is cut in the direction of the axis of the conductor (or of the cable) and need not be ground.

b) Apparatus

The apparatus should be a two-mandrel machine as shown in Figure 4 (page 107). A refrigerated compartment is also necessary whose temperature is controlled within deviations not exceeding $\pm$ 2° C.

The diameters of the turning mandrel should be:

— not less than 2.7 and not more than 3.0 times the external diameter of the specimen when testing specimens of the first type;

— not less than 3.6 and not more than 4.0 times the thickness of the specimen when testing specimens of the second type.

c) Accelerated ageing

Both test specimens should be subjected to an accelerated ageing treatment before being bend tested. The duration and the temperature in the air oven are specified in Tables V and VII, Item E. 2 *a)*, for each class of p.v.c. compound considered.

After completion of the ageing process, the aged specimens should be left for at least 16 hours and not more than 24 hours, at ambient temperature and not exposed to light.

d) Procedure

Each of the two test specimens shall be mounted in the apparatus, in the manner shown in Figure 4, with at least three close turns on one mandrel and at least one in the other.

The apparatus with the specimen should be placed in the refrigerated room and maintained there at the temperature and for the time specified in Tables V and VII, Item E, for the class of p.v.c. compound considered.

At the end of that time, and still at the same temperature, the bending test should be carried out in such way that at least two complete turns of the specimen are wound off one mandrel and wound on the other, each turn in about 15 seconds.

The specimen should finally be allowed to attain the ambient temperature (20 $\pm$ 5° C) and should then be examined without unwinding; there should not be cracks visible to the naked eye. In case of specimens (in form of strips) having ridges on one side, cracks in the ridges shall be disregarded provided they affect the thickness of the ridges only.

If one specimen fails, the test should be repeated on two other specimens, both of which should comply with the foregoing requirements.

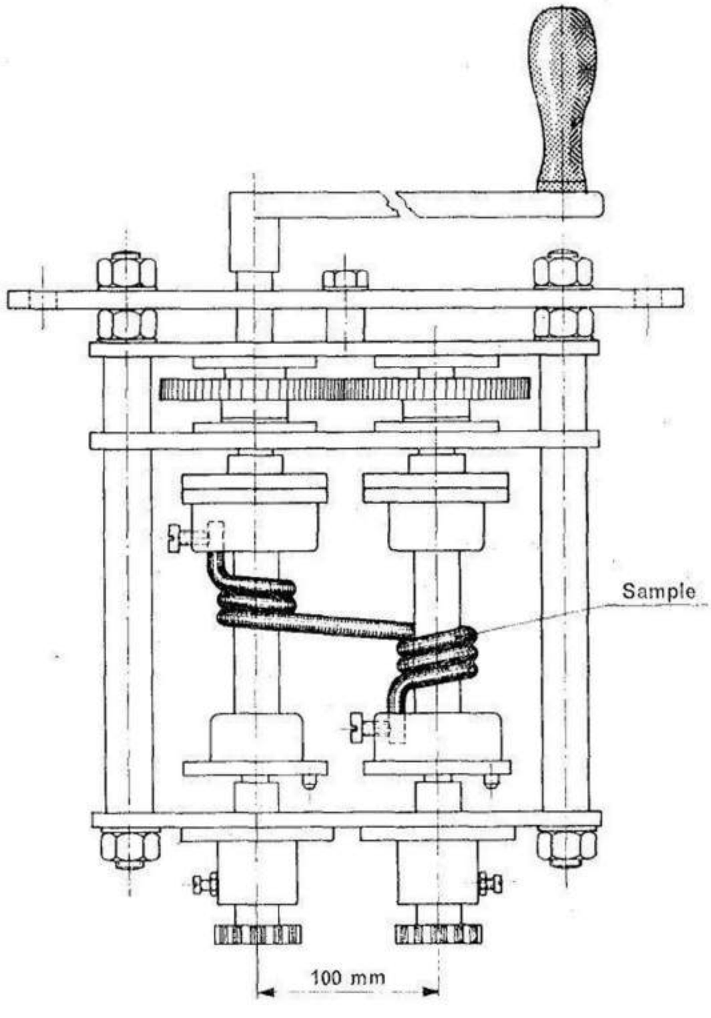


FIG. 4 — Cold bend test apparatus.

G. 4 **Heat shock test**

a) For the preparation of the test specimens, see Sub-clause G. 3 *a)*. Two test specimens should be prepared and not subjected to the accelerated ageing.

b) Each specimen should be wound, in at least three close turns, on a mandrel having a diameter approximately equal to three times the external diameter of the specimen, or four times the thickness of the flat strip.

c) The specimens should be introduced into an oven having a temperature of $150 \pm 2°C$ in case of insulants and $120 \pm 2°C$ in case of sheaths and left at that temperature for 1 hour. They should then be taken out, allowed to attain the ambient temperature and examined without unwinding.

d) There should not be cracks visible to the naked eye. If one specimen fails, the test should be repeated on two other specimens, both of which should comply with the above requirements.

APPENDIX H

TINNING (COATING) TEST FOR COPPER WIRES

H. 1 Preparation of specimens

The cable sample, which is about 0.30 m (1 ft) long, should be dismantled so as to make the copper conductors bare, avoiding causing injury to the wire coating. Several wire pieces should be taken from the outer layer of each conductor and should be cut in shorter sections which will permit complete immersion for the persulphate solution.

The wires whould then be thoroughly cleaned with a suitable solvent (for instance, benzine or petroleum ether) and wiped dry with a clean soft cloth. The ends of each wire portion should be completely coated with wax to protect the exposed copper.

Two specimens should be so prepared from the cable sample. The total length of each specimen should be calculated with the formula $L = 300/d$ where d is the nominal wire diameter, both L and d being expressed in mm (or $L = 0.465/d$ both L and d being expressed in inches). The wax coated ends should not be included in determining the length L.

H. 2 Special solutions

a) Test solution (ammonium persulphate)

Dissolve 10 grams of ammonium persulphate ($(NH_4)_2S_2O_8$ crystals containing not less than 95 % of ammonium persulphate) in 500 millilitres of distilled water. Add 75 millilitres of chemically pure solution of ammonia (density 0.90) and dilute to 1 litre with distilled water.

The ammonium persulphate solution should be freshly prepared each day tests are to be conducted and should not be subjected to temperature above 35° C.

b) Reference colour standard (copper sulphate — ammonium hydroxide)

Dissolve 0.156 grams of copper sulphate ($CuSO_4$. $5H_2O$)*) in distilled water, add 75 millilitres of a chemically pure solution of ammonia (density 0.90), and dilute to 1 litre.

H. 3 Test procedure

Each specimen of the required length L should be immersed in 100 millilitres of the test solution, using as container a test tube of appropriate dimensions. The specimen should be left immersed in the test solution at a temperature of 20 ± 1° C for a period of 15 minutes. The specimen should then be removed, and the test solution compared with an equal depth of the reference colour standard contained in a similar test tube. The colour comparison should be made by viewing the solutions lengthwise through the test tubes.

The colour of the test solution after immersion of the test specimen should not be darker than that of the reference colour standard solution. Both specimens should comply with this requirement.

*) 0.156 g $CuSO_4$. $5H_2O$ contains 0.100 g $CuSO_4$.

APPENDIX J

GALVANIZING TEST FOR STEEL WIRES

Five specimens, 200 mm (8 in) long, should be cleaned with a piece of wadding soaked in benzine and dried.

The specimens should be immersed one by one in a glass vessel with a height of 160 mm (or 6 in) and a diameter of 35 mm (or 1.5 in), about four-fifths full of a solution of copper sulphate. The liquid should not be stirred. After 1 minute the specimen should be removed from the liquid and immediately cleaned in running water with the aid of a piece of wadding to remove spongy precipitation of copper.

This operation should be repeated with the same liquid until a coherent precipitation of copper occurs, which cannot be removed with the wadding. The part of the specimen within 30 mm (or 1.2 in) from the submerged end is not considered.

For each specimen a fresh solution should be used. This solution should contain one part of copper sulphate ($CuSO_4 \cdot 5H_2O$) in five parts of water (187 g/l) and should be kept at a temperature of $18 \pm 0.5°$ C.

The average number of immersions for the five specimens should not be less than the number indicated in the following Table IX before non-removable red copper appears on the specimen, as stated above.

TABLE IX

Number of immersions for the Galvanizing test

Nominal diameter of round wires or thickness of shaped wires				Minimum number of immersions (of 1 minute)
Exceeding		Not exceeding		
mm	mils	mm	mils	
0.8	32	1.3	51	1
1.3	51	2.0	80	2
2.0	80	2.5	100	3
2.5	100	5.1	200	4

Notes 1.) — Wires having a diameter not exceeding 0.8 mm (32 mils) should withstand at least one dip of ½ minute.

2.) — It sometimes happens that copper is deposited on the zinc coating itself, giving a false appearance of failure. Such a deposit may be tested for adherence after the completion of the final dip, either by peeling, light rubbing, or by immersion in a solution of hydrochloridric acid (1/10) for 15 seconds, followed by immediate rinsing in clean running water with vigorous scrubbing. If the copper has been removed, and zinc appears underneath, the sample should not be deemed to have failed.

CHAPTER XI — CHOICE AND INSTALLATION OF CABLES

DEFINITION

Bunched Cables

Cables are said to be bunched when two or more are contained within a single conduit, duct or groove, or, if not enclosed, are not separated from each other.

SECTION ONE — CHOICE OF THE CABLES

11.01 **Choice of the insulation**

a) The rated voltage of any cable (see Chapter X) should not be lower than the nominal voltage of the circuit for which it is used.

Special consideration should be given to the type and voltage rating of cables which are to be used on highly inductive circuits (e.g. contactor control circuits).

b) The rated operating temperature of the insulating material (see Chapter X) should be at least 10°C higher than the maximum ambient temperature likely to exist, or to be produced, in the space where the cable is installed.

11.02 **Choice of protective coverings**

a) Cables fitted on decks exposed to the weather, in damp and wet situations (e.g. bathrooms), in cargo holds, in refrigerated spaces, in machinery compartments and in general where water condensation or harmful vapours (including oil vapour) may be present, should have either a watertight metallic sheath (for instance a lead alloy sheath) or an impervious non-metallic sheath (see Table VII in Chapter X). In permanently wet situations the use of metallic sheaths should be considered for cables not having a moisture resistant insulation.

b) In choosing among the different types of protective coverings (see Chapter X), due consideration should be given to the mechanical actions to which each cable may be subjected during installation and in service. In case the mechanical strength of the protective covering is considered insufficient, the cables should be fitted in pipes or conduits, or be otherwise protected (see Clause 11.13).

c) All cables should be of the "flame-retardant" or "fire-resisting" types, as defined in Chapter X; except that "flame-extending" cables may be used, for final circuit only, in the following two cases:

— in the case of cables installed in all-metallic conduits having an internal diameter not exceeding 25 mm (1.0 in) and provided the conduits are mechanically and electrically continuous;

— in the case of flexible cords having conductor sections not exceeding 4.5 mm^2 (0.007 in^2) and being used for portable apparatus.

d) For cables to be used with alternating current, see (in addition to the above) Clause 11.25.

11.03 Cables for fire extinguishing services

For those services "fire-resisting" cables should be taken in consideration.

11.04 Determination of the cross-sectional areas of conductors

The cross-sectional area of each conductor should be large enough for the following conditions to be complied with:

a) The "corrected current rating" of each cable should be not lower than the highest current likely to be carried by the cable concerned.

The "corrected current rating" is calculated by applying the relevant correction factors (see 11.06 to 11.08) to the "current ratings for continuous service" given by Graph No. 1 (see 11.05).

The highest load liable to be carried by the cable should be calculated from the load demands and diversity factors of circuits, machinery, etc., supplied by the cable (see Part I, Chapter IV and Clause 11.10).

b) The voltage drop in the circuit, when carrying the highest load, should not exceed the limits specified for the circuit concerned (see in particular Clause 11.09).

c) After having been determined by the foregoing calculations, the cross-sectional area should be checked, taking into consideration the temperature rises liable to be caused by overloads, short circuits and motor starting currents (see Clause 11.08).

d) The mechanical strength of conductors should be sufficient for the installation and working conditions.

e) The cross-sections of the earth conductors should comply with Part I, Chapter III.

Note. — The diagrams and tables incorporated in these Recommendations for the current ratings and correction factors give only average values, which are not exactly applicable to all cable constructions and all installation conditions existing in practice. They are nevertheless recommended for general application, considering that the errors (a few degrees Celsius in the estimated operating temperature) are of little importance against the advantages of having a single international standard for the evaluation of the current ratings. In particular cases, however, a more precise evaluation should be permitted, based on experimental or calculated data acceptable to all interested parties.

11.05 Current ratings for continuous service

a) "Continuous service" for a cable should be considered, for the purposes of Chapter XI, as a current consuming service (with constant load) having a duration longer than three times the "thermal time constant" of the cable, i.e. longer than the "critical duration" given by curves (T_a) or (T_b) in Graph No. 2.

b) The current ratings for continuous service recommended for single-core cables are given in Graph No. 1. For the use of that Graph, see Table X.

The curves are applicable, with fair approximation, whatever is the type of covering (e.g. both for armoured and unarmoured cables).

Note. — All curves have been calculated assuming an ambient temperature of 45°C and assuming that a conductor temperature approximately equal to the maximum rated temperature of the insulation (see Chapter X) is reached and maintained continuously in the case of a group of four cables bunched together and laid in free air. For different conditions, see following clauses.

c) For 2, 3 and 4 conductor cables, the current values given by the curves should be multiplied by the following (approximated) correction factors:

0.85 for 2-core cables;
0.70 for 3- and 4-core cables.

TABLE X

Guide to the use of Graph No. 1

Curve No.	Insulation	Maximum Conductor temperature
1	Rubber or polyvinylchloride, general purpose quality	60° C
2	Rubber or polyvinylchloride, heat-resisting quality	75° C
3	Varnished-cambric or butyl rubber (compound 80 A)	80° C
4	Mineral insulation	95° C

Notes. — *i)* For the asbestos-varnished-cambric insulation (Type 85 A) multiply by 1.07 the ampere values from curve No. 3, except that in special cases, i.e. when 95° C maximum conductor temperature is permitted, the correction factor is 1.18 instead of 1.07.

ii) When the sheath of a mineral insulated cable is liable to be touched, the current ratings given by curve No. 4 should be multiplied by the correction factor 0.80 in order that the sheath temperature does not exceed 70° C. For the same reason, the correction factors 1.07 and 1.18 mentioned in note *i)* above should not be applied.

iii) In using the graphs the effective (not the nominal) cross-sectional areas should be taken for the abscissae.

11.06 Correction factors for different cooling air temperatures

The ambient temperature of 45° C, on which the current ratings in Graph No. 1 are based, is considered as a standard value for the cooling-air temperature, generally applicable for any kind of ship and for navigation in any climates.

When, however, ships for particular uses are considered (for instance: coasters, ferries, harbour craft) so that the ambient temperature is known to be permanently lower than 45° C, the current values from Graph No. 1 may be increased (but in no case should the ambient temperature be considered to be lower than 35° C).

When, on the other hand, it is to be expected that the air temperature around the cables is generally higher than 45° C (for instance when some part of a cable length is placed in spaces or compartments where much heat is produced), the current ratings from Graph No. 1 must be reduced.

The correction factors for these cases are given in the following table:

TABLE XI

Correction factors for various cooling-air conditions

1	2	3	4	5	6	7
Type of cable insulation	Maximum conductor temperature	Correction factors for cooling-air temperatures of				
		35°C	40°C	45°C	50°C	55°C
Rubber or polyvinylchloride, general purpose quality	60°C	1.29	1.15	1.00	0.82	—
Rubber or polyvinylchloride, heat-resisting quality	75°C	1.15	1.08	1.00	0.91	0.82
Varnished cambric or butyl heat-resisting rubber	80°C	1.13	1.07	1.00	0.93	0.85
Asbestos varnished cambric	85°C	1.12	1.06	1.00	0.94	0.87
Mineral insulation	95°C	1.10	1.05	1.00	0.95	0.89

11.07 Correction factors for cable grouping

a) Except in the case mentioned under Sub-clause *b)*, the current rating values given in Graph No. 1 (and those derived therefrom) should be considered applicable, without correction factors:

— for not more than six cables bunched or laid close together in flat formation;

— for not more than two cable layers with the following disposition:

000 000 000 000
000 000 000 000

— and irrespective of whether the cables are laid in "open" or partially "enclosed" raceways.

b) When more than six cables belonging to the same circuit (and then operating with the same load) are bunched or laid close together in such a way that there is an absence of free air circulation around them, a correction factor of 0.85 should be applied to the current ratings obtained from Graph No. 1.

11.08 Correction factors for non-continuous services

a) If a cable is intended to supply a motor or equipment operating for periods of *half an hour* or *one hour*, its current rating, as given by Graph No. 1, may be increased using the relevant correction factors given by Graph No. 2.

In general, the half an hour service is applicable to: steering gears, capstans, windlasses, heavy cargo winches.

The correction factors in Graph No. 2 are applicable only if the intermediate periods of rests are longer than the "critical durations" (T_a) and (T_b) indicated in the same Graph No. 2.

Note. — It is to be noted that the correction factors given in Graph No. 2 are roughly approximate and are mainly dependent upon the quantity of metal contained in the cables.

Further they have been calculated admitting that the conductor temperature at the end of each load period (half an hour or one hour) are approximately 62 — 78.5 — 84 — 101°C respectively, instead of 60 — 75 — 80 — 95°C (see for comparison Table X).

b) For cables supplying a single motor intended to operate in an *intermittent service,* as is generally the case for cargo winches (except heavy cargo winches) engine room cranes and similar devices, the current ratings as given by Graph No. 1 may be increased by applying the correction factors given by Graph No. 3.

The correction factors given on Graph No. 3 have been roughly calculated for periods of 10 minutes, of which 4 minutes are with a constant load and 6 minutes without load.

11.09 Voltage drop

The cross-sectional areas of conductors should be so determined that the drop in voltage from the main switchboard bus-bars to any and every point on the installation when the conductors are carrying the maximum current under normal conditions of service, does not exceed for lighting circuits 5% of the nominal voltage and for heating and power circuits 7% of the nominal voltage.

These values are applicable under normal steady conditions. Under special conditions of short duration the voltage drop may be 8% and 11% respectively. Special consideration may be necessary, in certain cases, in order to ensure satisfactory starting of motors.

11.10 Estimation of lighting loads

In the assessment of the current rating of lighting points for the purpose of determining sizes of conductors, every lampholder should be deemed to require a current equivalent to the maximum load likely to be connected to it, and this should be assumed to be at least 60 W; except that, where the lighting fitting is so constructed as to take only a lamp rated at less than 60 W, the current rating may be assessed accordingly.

SECTION TWO — INSTALLATION OF CABLES

11.11 Cable runs

a) Cable runs should be selected so as to be as far as possible straight and accessible.

b) They should be selected so as to avoid action from condensed moisture or drip. Cables should, as far as possible, be remote from sources of heat such as hot pipes, resistors, etc., and protected from avoidable risks of mechanical damage. Where installation of cables near sources of heat cannot be avoided, and where there is consequently a risk of damage to the cables by heat, suitable shields should be installed.

c) Unless absolutely unavoidable, cables should not be installed across expansion joints. In that case, a loop of cable having a length proportional to the expansion of the joint should be provided. The minimum internal radius of the loop should be 12 times the external diameter of the cable.

d) In the construction of cable runs, account should be taken of the need for protection against rats.

e) For cable runs in the vicinity of a radio-receiving room, etc., the recommendations of Clause 11.12 should be carefully observed.

f) In the case of a service which is required to have a duplicate supply, the two supply lines should follow different paths, which should be separated as far as practicable.

g) Cables having insulating materials with different maximum rated conductor temperatures (see Table II in Chapter X) should not be bunched in a common clip, gland, conduit or duct.

When this is impracticable, the cables should be so selected that no cable reaches a temperature higher than that permissible for the lowest temperature rated cable in the bunch.

h) Cables having a protective covering which may damage the covering of more vulnerable cables should not be bunched in a common clip, gland, conduit or duct.

j) Cables having a copper sheath should be installed in such a way that galvanic corrosion by contact with other metals is prevented.

11.12 **Cables in the vicinity of radio equipment**

a) All permanently installed cables within 9 m (30 ft) of any aerial system, radio cabin or direction finder, unless a metal deck or bulkhead intervenes, should be metal-sheathed, metal-braided or otherwise adequately screened. In such situations flexible cables should be screened wherever practicable.

b) It is important that cables other than those feeding services in a radio room should not be installed therein. Cables which must pass through a screened radio room should be run throughout the length within the cabin in a continuous metal conduit or trunking which shall be bonded to the screening of the cabin at the points of entry and exit.

Note. — It has been found both advantageous and practicable to group cables supplying services to rooms adjacent to radio receiving installations in a minimum number of well-defined runs.

c) When the power converting plant is placed outside the radio room, the cables connecting convertor and radio room should preferably be installed separately from other cables not associated with the radio installation. Similar action may be necessary for certain other cables liable to pick-up interference, e.g. auto alarm bells, D/F signal lighting and bridge telephones, unless suitable suppression can be provided.

d) Where it is necessary to use single-core cable, the lead and return conductors should be fixed as close to one another as possible and should be so run as to avoid loops or partial loops.

e) Particular care should be taken to segregate cables carrying pulses of high amplitude and power cables supplying units in which such pulses are present. The use of screened cable alone is often inadequate in such cases and it may be necessary to use screened cable run in heavy-gauge conduit.

f) When the radio room is of wholly metallic construction, some advantage may be gained by the fitting of suppressors to cables at their point of entry into the room.

11.13 **Mechanical protection**

a) Cables exposed to risk of mechanical damage should be enclosed in steel conduits (see, however, the preamble of Clause 11.18) or be protected by metal casing, unless the protective covering (for instance armour or sheath) is sufficient to withstand the probable damage.

b) Cables exposed to exceptional risk of mechanical damage, for example in holds, storage-spaces, cargo-spaces, etc., should be protected by suitable casing or conduits, even when armoured, if the steel construction does not afford sufficient protection for the cables.

c) Metal casing used for mechanical protection of cables should be efficiently protected against corrosion.

11.14 **Earthing of metal coverings of cables and of mechanical protection**

a) All metal coverings of cables (lead sheath, armour, etc.) should be electrically connected to the metal hull of the ship at both ends except in final sub-circuits, where they may be connected only at the supply end.

For single-core a.c. cables, see Clause 11.25.

b) Earthing connections should be carried out with conductors having cross-sectional areas related to the current ratings of the cables (see also Part I, Chapter III), or with metal clamps gripping the metal sheath of the cable and connected to the metal hull of the ship. The sheaths and armours of cables may be earthed by means of glands intended for the purpose and so designed as to ensure an effective earth connection. The glands should be firmly attached to, and in effective electrical contact with, a metal structure earthed in accordance with these Recommendations.

c) The electrical continuity of all metal coverings throughout the length of the cables, particularly at joints and tappings, should be ensured.

d) In no case should the lead of lead-sheathed cables be used as the sole means of earthing non-current-carrying parts (see Part I, Chapter IV).

e) Metal casings, pipes and conduits should be effectively earthed and when fitted with joints, should be mechanically and electrically continuous and effectively earthed.

11.15 **Radius of bend**

The internal radius of bend for the installation of cables should comply with the following Table XII.

TABLE XII

Bending radii

Cable construction		Overall diameter of cable D	Minimum internal bending radius (times overall diameter D)
Insulation (1)	Outer covering (2)	(3)	(4)
Rubber or Polyvinyl-chloride	Lead-alloy sheathed and armoured	Any	6
	Other finishes	Not exceeding 9.5 mm ($^3/_8$ in)	3
		Exceeding 9.5 mm ($^3/_8$ in) but not exceeding 25.4 mm (1 in)	4
		Exceeding 25.4 mm (1 in)	6
Varnished Cambric	Any	Any	8
Mineral	Hard metal sheathed	Not exceeding 7 mm (0.28 in)	2
		Exceeding 7 mm but not exceeding 12.7 mm (½ in)	3
		Exceeding 12.7 mm (½ in)	4

11.16 **Fixing**

a) With the exception of cables for portable appliances and of those installed in conduits or wood casings, cables should be fixed by means of cleats, clips or saddles made of metal or other suitable preferably flame-retardant material, if necessary suitably treated, having a large surface area and smooth edges and so rounded that the cables remain tight without their coverings being damaged.

b) The distances between supports should be suitably chosen according to the type of cable and the probability of vibration and should not exceed the values given in Table XIII.

TABLE XIII

Spacing of cable supports

External diameter of cable				Non-armoured cables		Armoured cables		Mineral insulated cables	
Exceeding		Not exceeding							
mm	in	mm	in	cm	in	cm	in	cm	in
—	—	7.6	0.3	20	8	25	10	30	12
7.6	0.3	12.7	0.5	25	10	30	12	37	15
12.7	0.5	20	0.8	30	12	35	14	45	18
20	0.8	30	1.2	35	14	40	16	45	18
30	1.2	—	—	40	16	45	18	45	18

The distances given in this Table are applicable for cables laid in horizontal runs; in case of vertical runs, they may be increased by 25%.

c) The supports and the corresponding accessories, should be robust and should be of corrosion-resistant material or suitably treated before erection to resist corrosion.

11.17 **Cables penetrating bulkheads and decks**

a) Penetration of watertight decks and bulkheads should be effected in a watertight manner. Either individual stuffed glands or boxes containing several cables and filled with a flame-retardant packing may be used for this purpose. Whichever is the type of cable, the glands or boxes and the packing should be such that the assembly complies with the gland-watertightness test described in Appendix K which is to be considered as a Type Test (see Clause 10.33).

b) Cables passing through decks should be protected to a suitable height above the deck (at least 200 mm (8 in)).

c) If unarmoured cables have to pass through non-watertight bulkheads and generally through holes drilled in sheets of structural steel, these holes should be fitted (if necessary in order to avoid damage to cables) with glands or bushings of soft metal or hard wood or of any suitable material. Such a precaution is also recommended for armoured cables.

The choice of the materials used for glands and bushings should be such that there is no risk of corrosion.

Cables penetrating bulkheads and decks on passenger ships

Where, on passenger ships, fire-resisting bulkheads or decks are pierced for the passage of electric cables, arrangements should be made to ensure that the fire resistance is not impaired.

Where fire-retarding bulkheads are pierced for the passage of electric cables, arrangements should be made so that the fire-retarding properties are not impaired.

On passenger ships, vertical trunks for electric cables should be so constructed as not to afford passage of fire from one between-deck or compartment to another.

Note. — "Fire-resisting" and "fire-retarding" as defined in Regulation 35, Chapter II, Part D of Convention for Safety of Life at Sea, 1960.

11.18 Installation in metallic pipes or conduits

Installations of cables in metal tubes or metal conduits* should be avoided as far as possible. However, when this method is necessary, the following precautions should be observed (see also Sub-clauses 11.11 *g)* and 11.11 *h)* for bunching of cables).

a) The pipes should be perfectly smooth on the interior and not subject to deterioration from the effects of moisture.

b) The pipes or conduits should have their ends shaped or bushed in such a way as not to damage the cable covering.

c) The pipes or conduits should have such internal dimensions and radius of bend as will permit the easy drawing in and out of the cables which they are to contain; the internal radius of bend should be not less than those permitted for cables (see Clause 11.15) and for pipes exceeding 63 mm (2.5 in) external diameter, not less than twice the external diameter of the pipe.

d) Pipes and conduits should be mechanically and electrically continuous and effectively earthed.

e) Pipes and conduits should be so arranged that water cannot accumulate inside them (account being taken of possible condensation).

f) Terminating boxes should be mechanically and electrically connected to the pipes and conduits.

g) The drawing-in factor (ratio of the sum of the cross-sectional areas corresponding to the external diameters of the cables to the internal cross-sectional area of the pipe or conduit) should not be greater than 0.4.

h) If necessary, ventilating openings should be provided, preferably at the highest and lowest points, so as to permit air circulation and to obviate the possibility of water accumulating at any part of the pipe or conduit run. This may be done only if the fire-risk will not be increased thereby.

i) Drawing of lead-sheathed cables without any covering into tubes or conduits is deprecated.

j) If there is reason to fear that a tube may break because of its length, appropriate expansion joints should be provided.

11.19 Inspection and draw-boxes

If the conduits are of metal, inspection and draw-boxes should be of metal and should be in electrical and mechanical connection with the conduits. For steel conduits this connection should be obtained by screwing into the box or into a device clamping both sides of the wall of the box. For copper conduits this connection should be obtained by brazing or soldering a suitable ferrule on the conduit, the ferrule being secured to the box by screwing or by clamping to the wall of the box.

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*) Non-metallic tubes or conduits should be used only with special authorization.

11.20 **Installation in non-metallic ducting or capping and casing**

Cables may be enclosed in non-metallic casings either on surface or concealed behind ceilings or panelling, provided the following precautions are observed:

a) All cables should be "flame-retardant" in accordance with Chapter X.

b) The cables for circuits having a nominal voltage in excess of 250 V should have a metallic covering.

c) Non-metallic ducting or casing and capping should be used only in dry situations (e.g. in cabins, saloons and accommodation alley-ways) and where not exposed to drip due to condensation or other causes.

d) If the fixing of capping is by means of screws they should be of brass or other non-rusting material arranged so as not to damage the cables.

The capping should be readily accessible and in full view.

e) When the casing is concealed, the capping may be omitted, and the cables retained in place by flat strips of a suitable material, which for non-sheathed braided and compounded cables should be non-metallic. The strips should be secured in accordance with Paragraph *d)* of this clause and should be spaced in accordance with Table XIII; in the case of non-sheathed cables the spacings given in column 3 of the Table should be applied. The cables should be accessible throughout the entire length of concealment.

f) The casing and capping should be made of flame-retardant material or should be made flame-retardant in accordance with Part I, Chapter II.

g) The cables should be visible when the capping is removed from the casing.

h) Cables in ducting should be fixed if necessary with clips as described in Clause 11.16.

i) Cables belonging to different phases or polarities, or to different electric systems (including communication systems) should not be bunched in the same groove, unless the nominal voltage is less than 60 V or the cables are of the sheathed type (either metallic or impervious non-metallic sheathed).

j) Where cables in different grooves cross one another, they should be separated by insulating material, unless the conditions indicated under paragraph *i)* are complied with.

k) The precautions recommended in Sub-clauses 11.11 *g)* and *h)* should be observed also for the installation in non-metallic casing.

11.21 **Protection of cables in store rooms containing low-flash-point hydro-carbon products**

When it is necessary to install cables in such spaces, for example when the lighting cannot be effected from outside, the cables passing inside these spaces shall be protected by one of the following methods:

a) They should be enclosed in pipes, including joints if necessary, which shall be capable of resisting an internal pressure of at least 20 kgf/cm² and should comply with the requirements of flameproof enclosures (see IEC Publication 79, Recommendations for the Construction of Flameproof Enclosures of Electrical Apparatus).

b) They should be of the mineral-insulated type.

c) They should be of the lead-covered type, armoured with galvanized steel wire or galvanized steel tape.

d) Lead sheathed cables having a steel braid armour may be permitted, provided that in the installation a protection is applied giving the same degree of mechanical security as in cases *a), b)* or *c)* and that the braid is effectively protected against chemical corrosion.

Note. — For tankers see the clause on "wiring" in Chapter XX.

11.22 **Installation in refrigeration spaces**

a) Cables to be installed in refrigeration spaces should include a watertight or impervious sheath and should be protected against mechanical damage.

In case of p.v.c. sheathed cables, special attention is called to Sub-clause 11.13 *a)*.

If an armour is applied on the sheath, the armour should be protected against corrosion by a further moisture-resisting covering.

b) Cables installed in refrigeration spaces should not be covered by thermal insulation. They should be secured to perforated tray plates (made for instance of galvanized steel), which should be so placed as to leave a space between the back of the plates and the face of the refrigeration chamber. If an armoured cable has an outer impervious and anti-corrosion sheath, it may be placed directly on the face of the refrigeration chamber. The casual use of the cables as a means of suspension should be obviated by the provision of guards surrounding the cables.

c) If the cables must pass through the thermal insulation of the compartments, they should do so at right angles, in tubes provided with entries of material protected against oxidation.

11.23 **Tensile stress**

Cables should be so installed that the tensile stress applied to them either by reason of their own weight or for any other reason, is minimized.

These precautions are particularly important for cables of small cross-section and for cables on vertical runs, which should be suitably fixed.

11.24 **Electrodynamic forces**

In order to guard against the effects of electrodynamic forces developing on the occurrence of a short circuit, single-core cables must be firmly fixed, using supports of adequate strength to withstand forces corresponding to the anticipated values of the short-circuit currents.

11.25 **Special precautions for a.c. wiring**

A.C. wiring should be carried out as far as possible in twin or multicore cables. When, however, it is necessary to use single-core cables for circuits rated in excess of 20 A, the following precautions should be observed:

a) The cables should either be non-armoured or they should be armoured with a non-magnetic material.

b) Conductors belonging to the same circuit should be contained within the same pipe or conduit, or the clamps which fix them must include all the phases, unless they be made of non-magnetic material.

c) In the installing of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits, or three-phase and neutral circuits, the cables should as far as possible be in contact with one another. In every case, the distance measured between the external covering of two adjacent cables should not be greater than one diameter.

d) When single-core cables having a current rating greater than 250 A must be installed near a steel bulkhead, the distance between the cables and the bulkhead should be at least 50 mm (2 in).

e) Magnetic material should not be used between single-core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit should pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material should be not less than 75 mm (3 in).

f) In ascertaining the cross-sectional area of cables, it is necessary for account to be taken of induced currents in the sheaths and of the effect of bulkheads, when cable runs pass along metal plates or through bulkheads of magnetic metal.

g) In order to equalize to some degree the impedances of three-phase circuits of considerable length consisting of single-core cables of a conductor cross-section of 200 mm^2 (0.31 in^2) or over, a transposition of the phases should be effected at intervals not exceeding 15 m (50 ft). Alternatively, the cables may be installed in trefoil formation. The above precautions are, however, not necessary when the length of the run is less than 30 m (100 ft).

h) In case of circuits involving several single-core cables in parallel per phase, all cables should have the same length and the same cross-sectional area. Further, the cables pertaining to the same phase should be as far as practicable alternated with those of the other phases so that unequal division of the current is avoided. For instance, in case of two cables per phase, correct dispositions are:

RSTTSR or RST and not RRSSTT or RST
TSR RST

11.26 **Cable ends**

a) Where mechanical clamps are not used, the ends of all cable conductors having a cross-sectional area greater than 4 mm^2 (0.0065 in^2) should be fitted with soldering sockets or compression-type sockets of sufficient size to contain all the strands of the conductor. Where soldering is adopted, corrosive solid or liquid fluxes should not be used.

b) All protective coverings should be removed for at least 13 mm (½ in) from the end of the insulation, except in case of mineral insulated cables for which see Sub-clause *h)*.

c) When necessary, the watertightness of the cable ends should be ensured by appropriate means at the time of installation, unless cables of watertight construction are used (see Clause 10.30).

d) Cable sockets and connecting terminals should be of such design and dimensions that the maximum current likely to flow through them will not produce heat which would be injurious to the insulation. In general, the temperature should not exceed that allowed for the cable in relation to the insulation.

e) In the case of cables with a supplementary insulating belt beneath the protective sheath, at the ends where the belt has been removed, an additional insulation must be added at the points where the insulation of each core enters, or may enter, into contact with earthed metal.

f) The fixing of conductors in terminals, at joints and at tappings should withstand the thermal and dynamic effects of short-circuit currents.

g) When required, cable ends should be marked for identification.

h) The ends of mineral insulated cables should be prepared in accordance with the instructions issued by the manufacturers of these cables.

i) Cables not having a moisture-resistant insulation (e.g. varnished cambric, mineral insulation, etc.) should have their ends effectively sealed against ingress of moisture.

11.27 **Joints and branch circuits**

a) Cable runs should not include joints. If, in the case of repair, a joint is absolutely necessary, it should be carried out in a suitable box of such design that the conductors remain properly insulated and protected from atmospheric action, and fitted with terminals or bus-bars of dimensions proportionate to the current rating. The box should be clearly marked in order to identify the cable.

Note. — In certain exceptional cases, and only under skilled supervision, it may be permissible to use joints in conductors and to reconstitute the insulation and the protective coverings of the cable.

b) Tappings should be made in suitable boxes, of such design that the conductors remain suitably insulated and protected from atmospheric action, and fitted with terminals or bus-bars of dimensions appropriate to the current rating.

c) For both cable joints and tappings, the cable-ends should be connected as described in Clause 11.26. Cables not having a moisture-resistant insulation (e.g. varnished cambric, mineral insulation, etc.) should have their ends effectively sealed against ingress of moisture.

d) All joint boxes or wiring devices should be so constructed as to prevent the spread of fire from the box or device.

11.28 **Joint boxes**

Live parts should be mounted on durable flame-retardant moisture resistant material, of permanently high dielectric strength and insulation resistance. The live parts should be so arranged by suitable spacing or shielding with flame-retardant insulating materials, that conductors of opposite polarity or between conductors and earthed metal cannot readily be short-circuited.

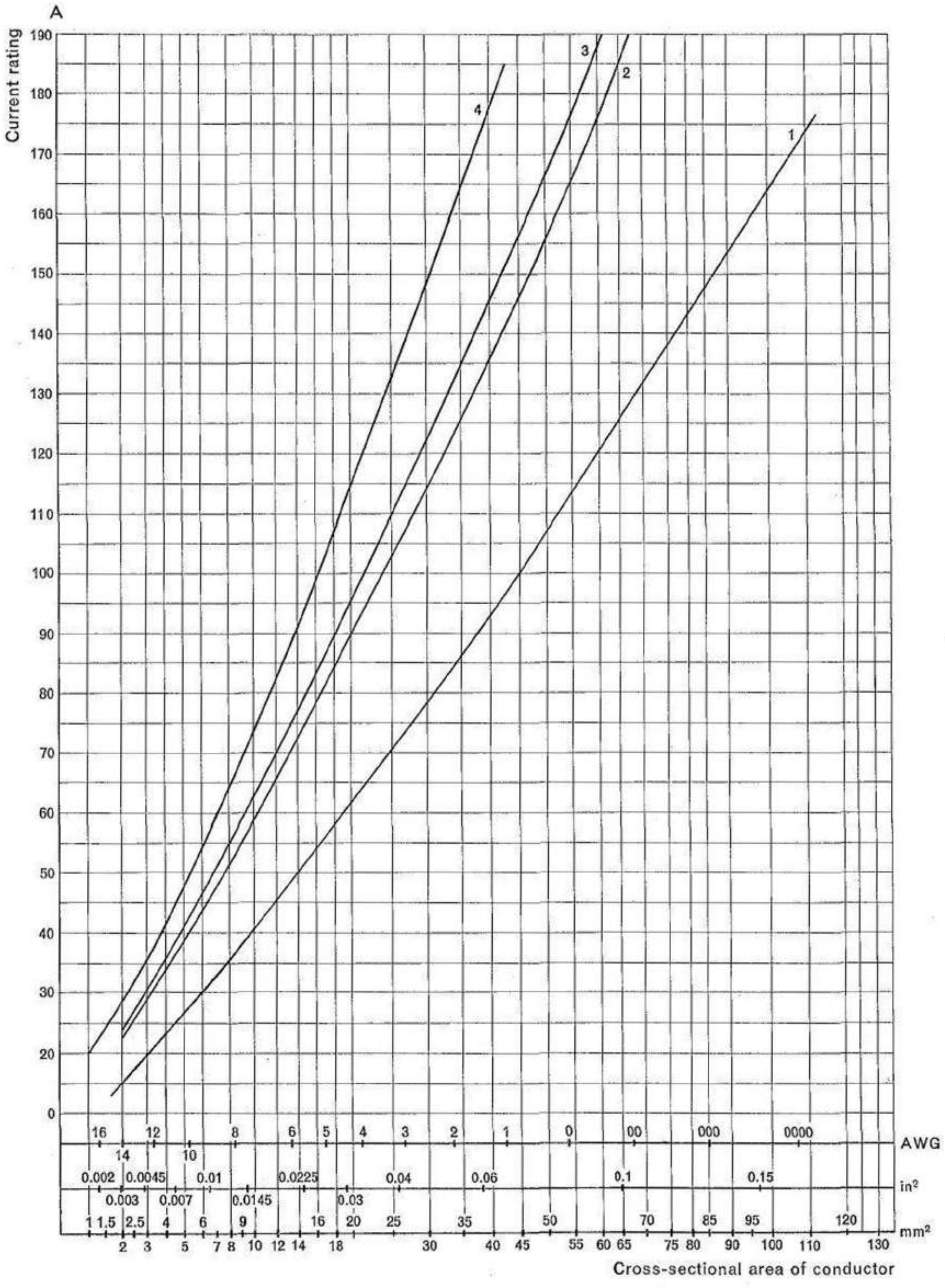
APPENDIX K

GLAND WATERTIGHTNESS TEST

The apparatus should be a closed tank having two holes on opposite sides. The cable sample should pass through the tank and be sealed by the desired glands, in such a way that the cable ends are outside the tank. The tank should be filled with water at one atmosphere gauge pressure and this pressure maintained for 1 hour, in order to check that watertightness is secured as in an ordinary ship installation.

The cable sample should then be subjected (with no water in the tank) to 20 thermal cycles, each cycle consisting of 8 hours heating followed by 16 hours natural cooling (the whole test should last 4 weeks, working 5 days per week). The final temperature during the heating period should be 5° C higher than the declared rated temperature of the type of cable under test.

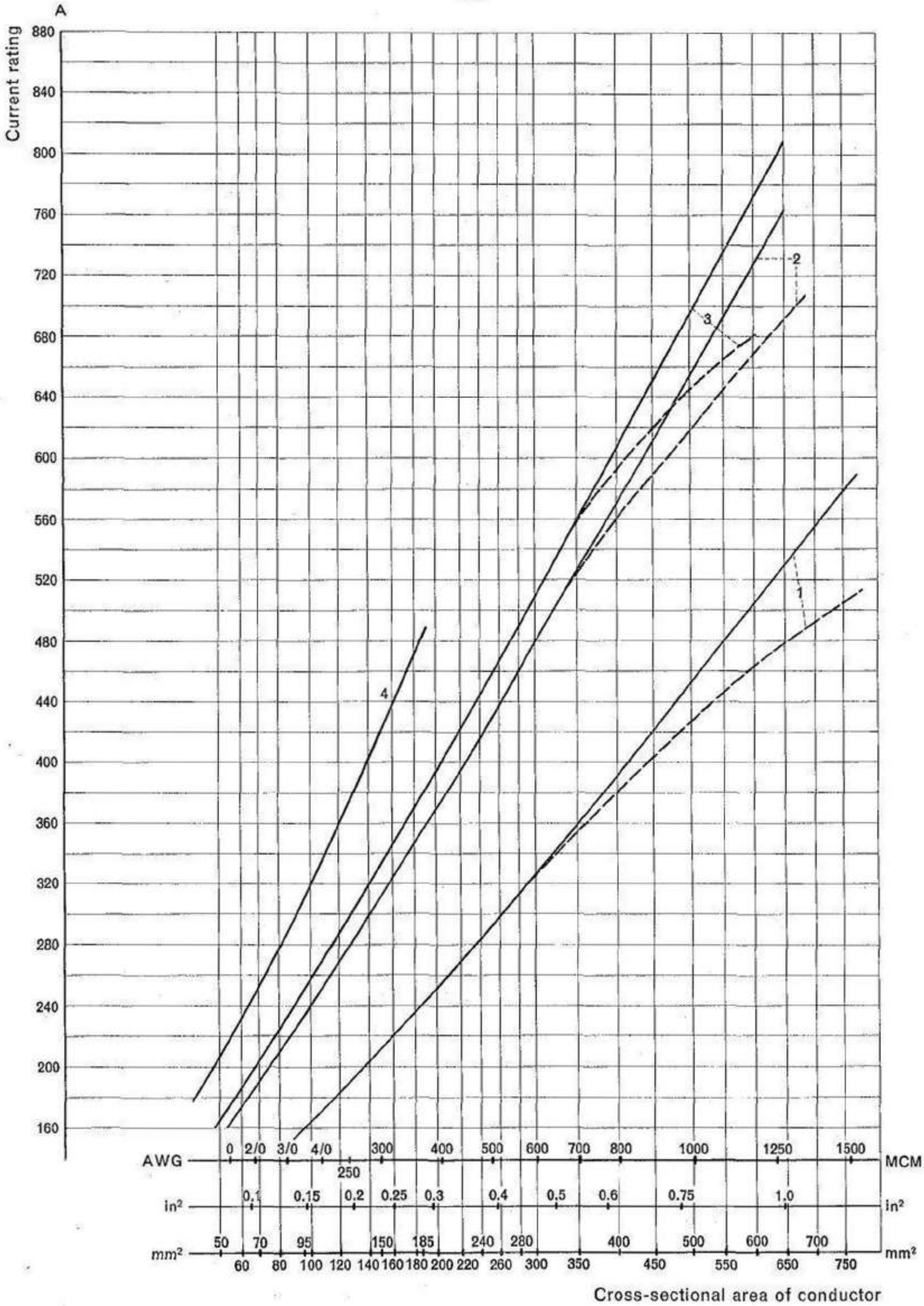
At the end of the last cycle, the tank should be again filled with water at one atmosphere gauge pressure, there should be no leakage during 1 hour.



GRAPH No. 1. — SHEET 1: Current ratings in continuous service of single-core cables — Ambient temperature 45°C.

MAXIMUM CONDUCTOR TEMPERATURES

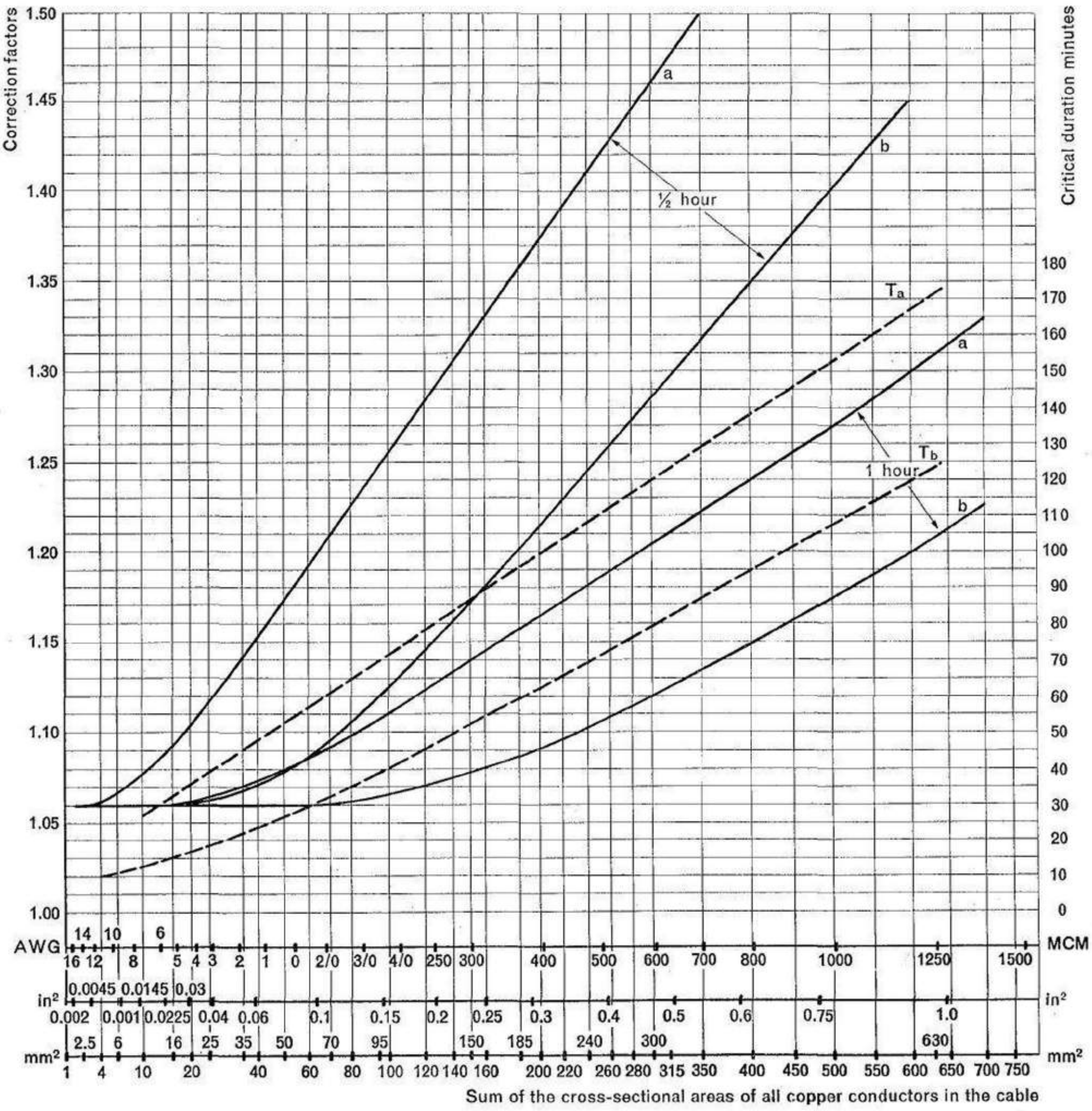
Curve No. 1: 60°C (rubber or thermoplastic insulation, standard quality).
Curve No. 2: 75°C (rubber or thermoplastic insulation, heat-resisting quality).
Curve No. 3: 80°C (varnished cambric and special rubber insulation).
Curve No. 4: 95°C (mineral insulation).



GRAPH No. 1. — SHEET 2: Current ratings in continuous service of single-core cables — Ambient temperature 45°C.

MAXIMUM CONDUCTOR TEMPERATURES

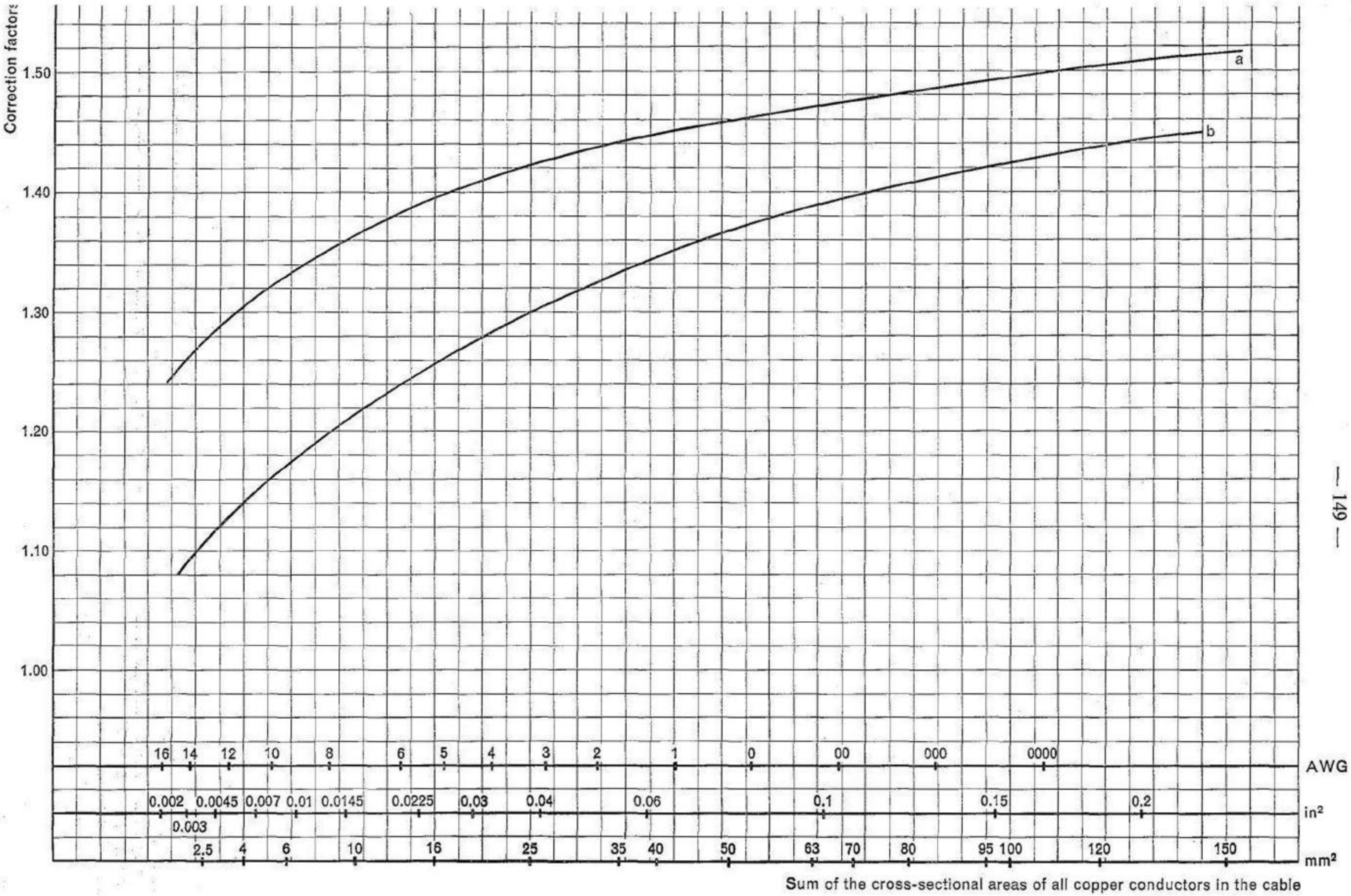
Curve No. 1: 60°C (rubber or thermoplastic insulation, standard quality).
Curve No. 2: 75°C (rubber or thermoplastic insulation, heat-resisting quality).
Curve No. 3: 80°C (varnished cambric and special rubber insulation).
Curve No. 4: 95°C (mineral insulation).



GRAPH No. 2. — Correction factors for half-hour and one-hour service:

a) for lead sheathed and armoured cables,
b) for non-metallic sheathed and unarmoured cables.

Notes: These correction factors are applicable, with rough approximation, whichever be the insulation type of the cables. For lead sheathed unarmoured and for non-metallic sheathed armoured cables, interpolated factors should be used. Curves T_a and T_b represent the "critical durations" as specified in Clauses 11.05 and 11.08.



GRAPH No. 3. — Correction factors for intermittent service:

a) for lead sheathed and armoured cables,
b) for non-metallic sheathed and unarmoured cables.

Intermittance period: 10 min. Intermittance ratio: 40%

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