C.D.U./U.D.C.: 621.315.2/.3:621.315.616.96:678.743.22.001.4.(047):620.1(047)

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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

RAPPORT DE LA CEI

INTERNATIONAL ELECTROTECHNICAL COMMISSION

(affiliated to the International Organization for Standardization — ISO)

IEC REPORT

Publication 330

Première édition — First edition

1970

Méthodes d'essai des enveloppes isolantes et gaines de p.c.v. pour les câbles électriques

Methods of test for p.v.c. insulation and sheath of electric cables

Bureau Central de la Commission Electrotechnique Internationale

1, rue de Varembé

Genève, Suisse

Prix Fr. s.
Price S. Fr. **40.–**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METHODS OF TEST FOR P.V.C. INSULATION AND SHEATH OF ELECTRIC CABLES

FOREWORD

1) The formal decisions or agreements of the I E C 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 I E C expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the I E C 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.

PREFACE

This Report has been prepared by IEC Technical Committee No. 20, Electric Cables.

A first draft was discussed at the meeting held in Ankara in 1967, as a result of which a new draft was submitted to National Committees for approval under the Six Months' Rule in January 1969.

The following countries voted explicitly in favour of the publication:

Australia	Netherlands
Austria	Poland
Belgium	Romania
Czechoslovakia	Sweden
Denmark	Switzerland
Finland	Turkey
Germany	Union of Soviet Socialist Republics
Israel	United Kingdom
Italy	United States of America
Japan	Yugoslavia

Since sufficient agreement could not be reached, IEC Technical Committee No. 20 decided that this Publication should be published as a Report instead of as a Recommendation.

This Report is incomplete. The test for determining the weight loss measurement and the accelerated ageing test, together with tests for resistance to cracking and methods of test and behaviour at low and high temperatures are being reconsidered, taking into account the latest knowledge on this subject. Electrical tests have been omitted and are under consideration for inclusion in the form of fundamental electrical tests for this material. A second edition will be published later.

METHODS OF TEST FOR P.V.C. INSULATION AND SHEATH OF ELECTRIC CABLES

1. Scope

This Report is a catalogue, incomplete in this first edition, of test methods which are recommended to be used for testing polyvinyl chloride insulation and sheath of electric cables, wires and cords used for power distribution or telecommunications.

Full test requirements, giving all the limiting values for test results, are not specified in this Report: it is intended that these should be specified in the Recommendations for the various types of cable. Any test requirements which are given in this Report should be considered as examples only and may be modified to suit the needs of a particular type of cable.

Conditioning values and testing parameters are specified for the most common types of p.v.c. compounds and of cables, wires and cords. It is intended that the values of these parameters should be modified for use in various applications, particularly for p.v.c. compounds for operation at temperatures higher than 70 °C.

Notes 1. — The term "polyvinyl chloride" is used to denote compounds of polyvinyl chloride or suitable co-polymers based on vinyl chloride or of mixtures of p.v.c. and such co-polymers.

2. — This Report is intended as a guide to IEC Technical Committees in drafting Recommendations for electric cables and to the National Committees in drafting specifications for use in their own countries. These Committees should select from this general Report the tests appropriate to the particular application with which they are concerned, and reproduce these tests in their cable specifications after adding the limiting values for test results.

This Report is not intended to be used as a guide in drafting purchasing specifications, which should be based on the relevant national specifications for electric cables or, where these do not exist, on the relevant IEC Recommendations for electric cables.

2. General notes on tests

2.1 The tests described in this Report are type tests.

Note. — The definition of a type test is given in IEC Publication 189-1, Low-frequency Cables and Wires with p.v.c. Insulation and p.v.c. Sheath, Part 1: General Test and Measuring Methods.

2.2 If the methods of sampling are not given in the following tests, these should be specified in the relevant cable Recommendation.

2.3 Unless otherwise specified, tests shall be made at an ambient temperature of 20 ± 5 °C.

2.4 Unless otherwise specified, test voltages shall be a.c. 40 Hz to 62 Hz of approximately sine-wave form, the ratio peak value/r.m.s. value being within the limits $\sqrt{2} \pm 7\%$. The values quoted are r.m.s. values.

2.5 If a marking is stamped into the insulation or sheath, thus giving rise to a local thickness smaller than the specified thickness, the samples used for the tests shall be taken so as to include such marking.

2.6 Where the term "median value" is used in this Report, it means either the middle value, if an odd number of values is obtained, or the mean of both the middle values if an even number of values is obtained, after the values have been arranged in order of increasing value.

3. Tests for determining mechanical properties of insulation before and after ageing

The tests shall determine the tensile strength and elongation at break of the insulating material taken from pieces of cable in the following conditions:

a) as received (i.e. without any ageing treatment);
b) after an accelerated ageing treatment;
c) after another ageing treatment, different from *b)*, if required.

3.1 *Sampling*

Three samples of each core to be tested shall be taken, each not less than 1 m from the other two. The cores of flat cords are not separated. Each sample shall be at least 60 cm long, and shall be cut into six small pieces, two of which shall be used for each of the tests *a)*, *b)* and *c)*, so that six small pieces of insulated core are provided for each of these tests.

If it is possible to take two test pieces from the circumference of the core, the sample shall be 40 cm long and shall be cut into four small pieces.

Note. — In general, this type of sample is applicable to a conductor of cross-sectional area of 50 mm² and above.

If the samples of core are taken from the three places x, y and z, they shall be marked consecutively:

x_0, x_1, x_2, x_3, x_4, x_5;
y_0, y_1, y_2, y_3, y_4, y_5;
z_0, z_1, z_2, z_3, z_4, z_5.

When two test pieces are taken from the circumference of the core, the numbering shall be:

<table>
<tr><td rowspan="2">x_0</td><td>x_1</td><td>x_4</td><td rowspan="2">x_5</td></tr>
<tr><td>x_2</td><td>x_3</td></tr>
</table>

The procedure shall be the same for test pieces y and z. The numbering of the samples shall correspond to their original places in the sample of the core.

Those numbered:

1 and 3 shall be subjected to the preparation and determination of the cross-sectional area, as specified in Sub-clauses 3.2 and 3.3 respectively, and to the test specified in Sub-clauses 3.4 and 3.5 without an ageing treatment.

2 and 4 to the test after an ageing treatment, as specified in Sub-clause 3.7.

0 and 5 to the test after another ageing treatment, if required.

The tensile test on the unaged pieces shall be made at the same time as the test on the aged pieces.

3.2 *Preparation of test pieces*

Test pieces may be of two types, tubular and dumb-bell.

3.2.1 *Tubular test pieces*

This type shall be used for cores with a conductor having a nominal cross-sectional area not exceeding 25 mm², except when the expected breaking load of the test specimen exceeds 650 N in which case a dumb-bell must be used, if possible.

A tube not less than 100 mm long is obtained by removal of all outer coverings and the conductor, care being taken not to damage the insulation.

If withdrawal of the conductor is difficult, it should be stretched by any suitable means.

A length of 20 mm shall be marked by two lines, centrally on each piece, immediately before the tensile test.

3.2.2 *Dumb-bell test pieces*

This type of test piece shall be used for cores with a conductor having a nominal cross-sectional area exceeding 25 mm² or, if possible, when the expected breaking load of a tubular test piece is more than 650 N. The small dumb-bell may be used for cores having a nominal cross-sectional area not exceeding 25 mm², as an alternative to a tubular test piece.

The insulation shall be cut open in the direction of the axis and the conductor removed.

The insulation shall be ground so as to obtain two parallel surfaces, care being taken to avoid undue heating. After grinding, the thickness of the dumb-bell, measured as described in Appendix A, shall not be less than 0.8 mm and not more than 2.0 mm.

Note. — Other methods of cutting are allowed.

After this preparation, one dumb-bell according to either Figure 1, page 46, or Figure 2, page 46, shall be punched; if possible, two dumb-bells shall be punched side by side.

Immediately before the tensile test, a length of 20 mm shall be marked by two lines, centrally on each dumb-bell according to Figure 1; a length of 10 mm shall be similarly marked on each dumb-bell according to Figure 2.

3.3 *Determination of cross-sectional area of insulation*

3.3.1 *Cross-sectional area of the test piece described in Sub-clause 3.2.1*

The cross-sectional area Q, in square millimetres, of the insulation of each of the samples of core shall be determined by one of the following methods:

a) From the dimensions of the section, according to the formula:

$$Q = \pi (D-i)i$$

Where:

i = the mean value of the thickness of the insulation, in millimetres to two decimal figures, determined as described in Appendix A

D = the mean value of the outer diameter of the core, in millimetres to two decimal figures, determined as described in Appendix A *b)* From the density, the mass and the length, according to the formula:

$$Q = \frac{100\,m}{\varrho\ l}$$

Where:

m = the mass of the piece of insulation, in grammes to three decimal figures

l = the length, in centimetres to two decimal figures

ϱ = the density obtained from an additional sample of the same insulation, in grammes per cubic centimetre to three decimal figures, determined as described in Appendix B

The density shall be measured on material before ageing. In case of dispute, method *b)* shall be used.

3.3.2 *Cross-sectional area of the test piece described in Sub-clause 3.2.2*

The cross-sectional area of each of the dumb-bell pieces shall be calculated from the width and the least thickness of the middle portion of the dumb-bell (between the gauge lines), each being the mean value of three measurements. The measurements shall be made by a micrometer or similar instrument producing a contact pressure not exceeding 7 N/cm² and shall be expressed in millimetres to two decimal figures.

3.4 *Conditioning of test pieces*

All test pieces shall be kept at a temperature of 20 ± 1 °C for at least 3 h before the tensile test.

3.5 *Tensile test procedure*

The test shall be carried out not less than 16 h after the extrusion of the core, at a temperature of 20 ± 5 °C; each test shall be completed within 5 min of the removal of the test piece from the conditioning chamber.

In case of dispute, the test shall be repeated at 20 ± 1 °C.

The grips of the tensile machine may be either of a self-tightening type or a non self-tightening type for both dumb-bell and tubular test pieces.

The free length between the grips may be about:

34 mm in the case of dumb-bells according to Figure 2, page 46;
50 mm in the case of dumb-bells according to Figure 1, page 46;
50 mm in the case of tubes, if tested with self-tightening grips;
85 mm in the case of tubes, if tested with non self-tightening grips.

The rate of separation of the jaws of the tensile machine shall be:

20 ± 2 cm/min for dumb-bell test pieces if the length between the grips is 34 mm;
20 ± 2 cm/min for dumb-bell test pieces if the length between the grips is 50 mm;
30 ± 3 cm/min for tubular test pieces if the length between the grips is 50 mm;
50 ± 5 cm/min for tubular test pieces if the length between the grips is 85 mm.

The elongation shall be determined by measuring the distance between the two marker lines at rupture.

If a test piece breaks due to damage by the grips, it shall be ignored; in such a case at least four valid results are required in order to calculate the tensile strength and elongation at break, otherwise the test must be repeated.

3.6 *Expression of results*

All breaking loads shall be referred to the cross-sectional area of the unstretched test piece for calculation of tensile strength. The median of the values of tensile strength shall be recorded as the tensile strength; the median of the values of elongation at break shall be recorded as the elongation at break.

3.7 *Weight loss measurement*

Test pieces for this test shall be prepared as described in Sub-clause 3.2. The surface of evaporation shall be calculated from the original dimensions of the test pieces; for a tubular test piece (ignoring the cut ends) from the mean outer diameter, measured as described in Appendix A, and the length; for dumb-bells from the following formulae:

For a dumb-bell according to Figure 1, page 46:

$$Q = \frac{1\,256 + (180 \times t)}{100} \text{ cm}^2$$

For a dumb-bell according to Figure 2, page 46:

$$Q = \frac{624 + (118 \times t)}{100} \text{ cm}^2$$

Where:

t = the mean thickness of the dumb-bell, in millimetres, measured as described in Appendix A

In flat cords, the cores shall not be separated, since the surface of evaporation shall be taken as the sum of the surfaces of each core, which shall be calculated from the length and the mean outer diameter, measured as described in Appendix A, ignoring the cut ends and the surface over which the cores cohere.

The open ends of the tubular test pieces shall be closed by the following methods:

a) for thin insulation by fusing the ends together;

b) for insulation of large dimensions by plugging, for example, with cotton wool; materials which might absorb plasticizer, like rubber and plastics shall not be used.

The test pieces shall be weighed accurately without plugging materials, if any, after a conditioning period of at least 20 h at ambient temperature in a dessicator.

The test pieces shall be stored in an oven, in air at atmospheric pressure, for 7 × 24 h at 80 ± 2 °C, under the following conditions.

Compounds of different compositions shall not be in the oven at the same time.

Test pieces shall be hung substantially in the middle of the oven and at least 20 mm apart.

Test pieces shall not take up more than 2% of the volume of the oven. Air shall enter the oven in such a manner that it shall flow over the surface of the test piece and shall leave the oven at or near the top.

There shall be no obstruction to the air flow over the surface of the test pieces.

The rate of air flow shall be such as to give not less than eight changes per hour.

Immediately afterwards, the test pieces shall be taken out of the oven and left at ambient temperature, avoiding direct light for at least 20 h in a dessicator. After this period, the test pieces shall be re-weighed without plugging materials, if any.

The loss in weight shall be calculated and expressed as milligrammes per square centimetre of surface of evaporation.

The median of the values of loss in weight shall be recorded as "weight loss".

Two methods for measuring the rate of air flow through an oven are given in Appendix C. In case of dispute, Method 2 (the flowmeter method) shall be used.

3.8 *Accelerated ageing test*

After being tested for weight loss and conditioned by the method described in Sub-clause 3.7, a tensile test shall be carried out with the same test pieces. The test pieces shall be subjected to the determination of cross-sectional area, as specified in Sub-clause 3.3, and to the tensile test and conditioning as specified in Sub-clauses 3.4 and 3.5. The result shall be expressed as described in Sub-clause 3.6.

4. Tests for determining mechanical properties of sheaths before and after ageing

The tests shall determine the tensile strength and elongation at break of sheathing material taken from pieces of cable in the following conditions:

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

b) after an accelerated ageing treatment;

c) after another ageing treatment, different from *b)*, if required.

4.1 *Sampling*

Three samples of cable or cord to be tested shall be taken, each not less than 1 m from the other two. Each sample shall be at least 60 cm long, and shall be cut into six small pieces, two of which shall be used for each of the tests *a)*, *b)* and *c)*, so that six small pieces of cable or cord are provided for each of these tests.

If it is possible to take two test pieces from the circumference of the sheath, the sample shall be 40 cm long and shall be cut into four small pieces.

Note. — In general, this sample is applicable to cables or cords with a diameter over the sheath exceeding 12.5 mm.

If the samples of cable or cord are taken from the three places x, y and z, they shall be marked consecutively:

$x_0, x_1, x_2, x_3, x_4, x_5$;
$y_0, y_1, y_2, y_3, y_4, y_5$;
$z_0, z_1, z_2, z_3, z_4, z_5$.

When two test pieces are taken from the circumference of the sheath, the numbering shall be:

x_0	x_1	x_4	x_5
	x_2	x_3	

The procedure shall be the same for test pieces y and z. The numbering of the samples shall correspond to their original places in the sample of the cable or cord.

Those numbered:

1 and 3 shall be subjected to the preparation and determination of the cross-sectional area, as specified in Sub-clauses 4.2 and 4.3 respectively, and to the test specified in Sub-clause 4.4 without an ageing treatment.

2 and 4 to the test after an ageing treatment, as specified in Sub-clause 4.5.

0 and 5 to the test after another ageing treatment, if required.

The tensile tests on unaged pieces shall be made at the same time as the tests on the aged pieces.

4.2 *Preparation of test pieces*

Test pieces may be of two types, tubular and dumb-bell.

4.2.1 *Tubular test pieces*

This type shall be used for cables and cords with a specified upper limit of average diameter of sheath not exceeding 12.5 mm, except when the expected breaking load of the test specimen exceeds 650 N, in which case a dumb-bell must be used, if possible.

A tube not less than 10 cm long is obtained by removal of all outer coverings, core(s) and fillers (if any), care being taken not to damage the sheath.

A length of 20 mm is marked by two lines, centrally on each piece, immediately before the tensile test.

4.2.2 *Dumb-bell test pieces*

This type of test piece shall be used for cables and cords with a specified upper limit of average diameter of sheath exceeding 12.5 mm or, if possible, when the expected breaking load of a tubular test piece is more than 650 N. The small dumb-bell may be used as an alternative to a tubular test piece, for cables and cords with a specified upper limit of average diameter of sheath not exceeding 12.5 mm when the expected breaking load of the test piece exceeds 650 N.

After removing all outer coverings, the sheath shall be cut open in the direction of the axis of the cable or cord or, if there are ridges caused by the cores, in the direction of the ridges; the core(s) and fillers (if any) are then removed. Sheaths with ridges shall be ground, care being taken to avoid undue heating. Grinding is also permissible for sheaths without ridges. After grinding, two parallel surfaces shall be obtained, the thickness of the dumb-bells shall not be less than 0.8 mm and not more than 2.0 mm.

Note. — Other methods of cutting are allowed.

After this preparation, one dumb-bell according to either Figure 1, page 46, or Figure 2, page 46, shall be punched or, if possible, two dumb-bells shall be punched side by side.

Immediately before the tensile test, a length of 20 mm is marked by two lines, centrally on each dumb-bell according to Figure 1; a length of 10 mm shall be similarly marked on each dumb-bell according to Figure 2.

4.3 *Determination of cross-sectional area of the sheath*

4.3.1 *Cross-sectional area of the test piece described in Sub-clause 4.2.1*

The cross-sectional area Q, in square millimetres, of a sheath without ridges on any of the samples shall be determined by one of the following methods:

a) From the dimensions of the section, according to the formula:

$$Q = \pi (D-i)i$$

Where:

i = the mean value of the thickness of the sheath, in millimetres to two decimal figures, determined as described in Appendix A

D = the mean value of the outer diameter of the sheath, in millimetres to two decimal figures, determined as described in Appendix A

b) From the density, the mass and the length, according to the formula:

$$Q = \frac{100\, m}{\varrho\, l}$$

Where:

m = the mass of the piece of sheath, in grammes to three decimal figures

l = the length, in centimetres to two decimal figures

ϱ = the density obtained from an additional sample of the same sheath, in grammes per cubic centimetre to three decimal figures, determined as described in Appendix B

The density must be measured on material before ageing. In case of dispute, method *b)* shall be used.

The cross-sectional area, Q, in square millimetres, of a sheath with ridges on each of the samples is determined by method *b)*.

4.3.2 *Cross-sectional area of the test piece described in Sub-clause 4.2.2*

The cross-sectional area of each of the dumb-bell test pieces shall be calculated from the width and the least thickness of the middle portion of the dumb-bell (between the gauge lines), each being the mean value of three measurements. The measurements shall be made by a micrometer or similar instrument producing a contact pressure not exceeding 7 N/cm^2 and shall be expressed in millimetres to two decimal figures.

4.4 *Conditioning of test pieces, test procedure, and expression of results*

Conditioning of test pieces, test procedure, and expression of results shall be made as specified in Sub-clauses 3.4, 3.5 and 3.6 respectively.

4.5 *Weight loss measurement*

After preparation of the test pieces as described in Sub-clause 4.2, the weight loss measurement shall be made as specified in Sub-clause 3.7.

4.6 *Accelerated ageing test*

This test shall be carried out after the weight loss test with the same test pieces. The test pieces are subjected to the determination of cross-sectional area, as specified in Sub-clause 4.3, and to the test with conditioning as specified in Sub-clauses 3.4 and 3.5. The results shall be expressed as described in Sub-clause 3.6.

5. Electrical tests

Under consideration.

6. Tests for resistance of insulation and sheath to cracking

6.1 *Preparation of the specimens*

6.1.1 Both for testing of insulation and sheath, one sample of cable or cord of suitable length shall be taken from two places, separated by at least 1 m. Two types of specimens shall be considered.

6.1.2 For cores and sheaths with an over-all diameter not exceeding 12.5 mm, each specimen shall consist of a piece of core, cable or cord, except for polyethylene insulated p.v.c. sheathed cables or cords. External coverings, if any, shall be removed from the insulation and sheath.

6.1.3 For cores and sheaths with an over-all diameter exceeding 12.5 mm, and for sheaths of polyethylene insulated cables or cords, each specimen shall consist of a strip, taken from the insulation or the sheath, whose width shall be 1.5 times its thickness but not less than 4 mm; the strip shall be cut in the direction of the axis of the conductor, cable or cord.

6.2 *Procedure*

6.2.1 *For cores and sheaths with an over-all diameter not exceeding 12.5 mm*

Each specimen of core, cable or cord as described in Sub-clause 6.1.2 shall be wound on a mandrel to form a close helix. The diameter of the mandrel and the number of turns are given in Table I.

For flat cords, the mandrel diameter shall be based on the minor dimension of the cord, which is wound on with its minor axis perpendicular to the mandrel.

TABLE I

Over-all diameter of core, cable and cord mm	Mandrel diameter mm	Number of turns
Up to and including 2.5	5	6
Over 2.5 up to and including 4.5	9	6
Over 4.5 up to and including 6.5	13	6
Over 6.5 up to and including 9.5	19	4
Over 9.5 up to and including 12.5	40	2

Each specimen, on its mandrel, shall be kept for 1 h in a heating cabinet at a temperature of 150 ± 2 °C.

After the samples have been allowed to attain approximately room temperature, they shall be examined while still on the mandrel. The samples shall show no crack visible to the naked eye.

6.2.2 *For cores and sheaths with an over-all diameter exceeding 12.5 mm*

Each specimen as described in Sub-clause 6.1.3 shall be wound on a mandrel to form a close helix having six turns, with the inside of the insulation or sheath on the mandrel.

The diameter of the mandrel is given in Table II.

TABLE II

Nominal thickness of insulation and sheath mm	Mandrel diameter mm
Up to and including 1 mm	2
Over 1 up to and including 2 mm	4
Over 2 up to and including 3 mm	6
Over 3 up to and including 4 mm	8
Over 4 up to and including 5 mm	10

The test shall then be carried out as described in Sub-clause 6.2.1.

7. Methods of test for insulation and sheath at low temperatures

7.1 *Impact test*

7.1.1 *Sampling of insulation and sheath*

For testing the insulation and the sheath, ten samples of core, cable or cord, at least 15 cm long shall be taken; for flat cords without sheath, ten complete samples shall be taken. In each case, two samples shall be taken from five places separated by at least 1 m.

7.1.2 *Preparation and test procedure for insulation and sheath*

The samples shall be subjected to an impact test not less than 16 h after extrusion by means of the apparatus shown in Figure 6, page 50. The mass of the hammer for testing the insulation shall be:

100 g for fittings cables and flexible cords without sheath;

200 g for single core cables without sheath having an over-all diameter up to and including 12.5 mm;

500 g for single core cables without sheath having an over-all diameter from 12.5 mm up to and including 15.0 mm;

750 g for single core cables without sheath having an over-all diameter exceeding 15.0 mm.

Note. — The insulation of cables and flexible cords with sheath is not subjected directly to the impact test, as its behaviour is adequately checked during the impact test of the sheath.

The mass of the hammer for testing the sheath shall be:

100 g for flexible cables and cords;

500 g for other cables for which an upper limit of average over-all diameter not exceeding 15.0 mm is specified;

750 g for other cables for which an upper limit of average over-all diameter exceeding 15.0 mm is specified.

The test shall be made after any covering has been removed from the insulation or the sheath.

The apparatus on a pad of sponge rubber, 4 cm thick, shall be placed together with the samples in a refrigerator at a temperature of -15 ± 2 °C, for at least 16 h. At the end of this period, each sample in turn shall be placed in position as shown in Figure 6 and the hammer shall be allowed to fall from a height of 10 cm.

Flat cords shall be tested with their minor axis perpendicular to the steel base.

Note. — The cooling period of 16 h includes the time necessary for cooling down the apparatus. If the apparatus has been pre-cooled, a shorter period is permissible, but not less than 4 h, provided that the samples have attained the prescribed test temperature.

Before examining the insulation, the samples shall be allowed to attain approximately room temperature after the test.

The insulation shall then be examined and shall show no crack visible to the naked eye after the samples have been twisted, while held straight, through an angle equal to 360° for each 10 cm of length.

If, however, it is not possible to twist the samples in this way, they should be examined as specified for the sheath.

Before examining the sheath, the samples shall be immersed in hot water after the test; the sheath shall then be cut open in the direction of the axis of the cable or cord.

The inside and outside of the sheath and the insulation shall then be examined, and shall show no crack visible to the naked eye.

The insulation of cables and cords with sheath shall be examined on the outside only.

7.2 *Bending test*

7.2.1 *General*

This test is intended for cores, cords and cables with an over-all diameter up to and including 12.5 mm. Samples having a larger diameter may be also subjected to this test as far as practicable; otherwise, they must be subjected to the elongation test described in Sub-clause 7.3.

7.2.2 *Sampling*

One sample of core, cord or cable, of suitable length shall be taken from two places separated by at least 1 m.

7.2.3 *Preparation and test procedure*

Before commencing the test, all covering (if any) shall be removed from the insulation or sheath.

The test shall be carried out not less than 16 h after extrusion.

The samples shall be cooled in air to a temperature of -25 ± 2 °C for at least 4 h.

A mandrel, the diameter of which shall be four times that of the sample, shall also be cooled at the same temperature and for the same time as the samples. For flat cords and cables, the mandrel diameter shall be based on the minor dimension of the sample, which shall be wound with its minor axis perpendicular to the mandrel.

Each sample shall be bent tautly round the mandrel in a close helix at a rate of one turn in approximately 5 s, while at the temperature specified above. The number of turns is given in the following table:

Over-all diameter of the sample mm	Number of turns
Up to and including 2.5	10
Over 2.5 up to and including 4.5	6
Over 4.5 up to and including 6.5	4
Over 6.5 up to and including 8.5	3
Over 8.5 up to and including 12.5	2

After bending at low temperature, the samples shall be allowed to attain approximately room temperature.

The samples shall then be examined while still on the mandrel. Neither the insulation nor the sheath shall show any crack visible to the naked eye.

Note. — This bending test may be effected with the apparatus shown in Figure 7, page 51, with explanations. In that case, the apparatus with the sample in position is kept for at least 16 h at a temperature of −25 ± 2 °C. If the apparatus has been pre-cooled, a shorter period is permissible, but not less than 4 h, provided the sample has attained the specified test temperature.

7.3 *Elongation test*

7.3.1 *General*

This test is intended for cores, cords and cables having an over-all diameter exceeding 12.5 mm and for sector-shaped cores.

7.3.2 *Sampling of insulation and sheath*

One sample of core, cord or cable, of suitable length shall be taken from two places separated by at least 1 m.

7.3.3 *Preparation and test procedure for insulation and sheath*

After removing all covering, if any, the insulation or sheath shall be cut open in the direction of the axis after which the conductor or the cores and fillers (if any) shall be removed.

The insulation and the sheath shall not be ground if their mean specified thickness does not exceed 4.0 mm. Samples having a thickness exceeding this limit shall be ground on the outside only, obtaining a regular thickness of the sample, care being taken to avoid undue heating. After grinding, the thickness shall not be less than 3.0 mm.

After this preparation, three dumb-bells of each sample according to Figure 1, page 46, shall be punched in the direction of the axis; if possible, two dumb-bells are punched side by side.

For sector-shaped cores, the dumb-bells shall be punched out of the back of the core (see Figure 8, page 52).

The test shall be carried out not less than 16 h after extrusion, at a temperature of −25 ± 1 °C.

The test may be carried out on a normal tensile machine provided with a cooling device or on a tensile machine installed in a cooling chamber. Using a liquid as refrigerant, the conditioning time shall not be less than 10 min at specified temperature; when cooling in air, the conditioning period shall be at least 4 h; this period may be reduced to 2 h if the apparatus has been pre-cooled.

If a liquid mixture is used for cooling, it must not impair the insulating or sheathing material.

The grips of the tensile apparatus shall be of a non self-tightening type. In both grips, the dumb-bell shall be clamped over the same length; the free length between the jaws shall be 30 ± 0.5 mm. The speed of separation of the jaws of the tensile machine shall be 50 ± 5 mm/min.

The elongation shall be determined by measuring the distance between the jaws at rupture.

For calculating the elongation, the increase of the distance between the jaws shall be related to the length of 30 mm.

If it is not possible to observe the sample during the elongation test, the test pieces must be examined after the test; if they have slipped out of the grips, the result shall be ignored. At least five valid values are required for calculating the elongation, otherwise the test must be repeated. None of these values shall be less than 20%.

Note. — A suitable refrigerant for testing p.v.c. is a mixture of methylated spirit with solid CO_2; another mixture is petrol with solid CO_2.

8. Behaviour of insulation and sheath at high temperatures

8.1 *Pressure test at high temperatures*

8.1.1 *General*

This test is intended for cords and cables with a maximum rated operating temperature of 70 °C.

The serving of a cable shall be tested in the same way as the sheath.

8.1.2 *Sampling of the insulation and the sheath*

Three complete pieces of cord and cable, each about 4 cm long, shall be taken from both ends of a sample which is about 1.25 m long.

8.1.3 *Preparation and test procedure for the insulation*

Any covering shall be removed from the insulation. The insulation of round cores and flat cords without sheath shall be tested on complete pieces of core and cord, whereas the insulation of sector-shaped cores shall be tested on strips.

These strips, which must be as wide as possible, shall be cut from the back of the insulation in the direction of the axis of the core (see Figure 8, page 52).

The test shall be made in water or air, at least 16 h after extrusion, by means of an apparatus having a rectangular blade with an edge, 0.7 mm wide, which can be pressed against the test piece, as shown in Figure 9, page 52.

Flat cords without sheath shall be laid on their flat side. The strips, cut from sector-shaped cores, are supported by a metal pin or tube which may be halved in the direction of its axis to make a more stable support.

The radius of the pin or tube is approximately equal to the radius of the inner side of the insulation on the back of the sectoral core.

Each test piece shall be placed in position as shown in Figure 9, the force shall be applied in a direction perpendicular to the axis of the core or the pin (tube), and the blade shall also be perpendicular to the axis of the core or the pin (tube).

When the insulation of cores with a conductor having a nominal cross-sectional area exceeding 35 mm² is tested in air, the apparatus, pin or tube (if any) and the weight should be pre-heated till they have reached the test temperature. The force P, in newtons, exerted by the blade upon the test piece (of the sample of round and sector-shaped cores) is given by the formula:

$$P = 0.8 \sqrt{2\,Di - i^2}$$

Where:

i = the mean value, in millimetres, of the thickness of the insulation of the sample
D = the mean value, in millimetres, of the outer diameter of the sample for round cores

For sector-shaped cores, D is the mean value, in millimetres, of the diameter of the stranded sector-shaped cores, determined from one measurement of the circumference made at three different places of the sample of cable.

The force applied upon the test piece of flat cords without sheath is twice the value given by the above formula, where:

D = the mean value, in millimetres, of the minor dimension of the sample
i = the mean value, in millimetres, of the thickness of the insulation of the sample

The calculated force may be rounded off downwards by not more than 3%. When testing in water, the upward pressure upon the blade and the weight hanging on the blade should be taken into account.

The loaded, not pre-heated, test-piece shall be kept in the test position for 3 h in water or for 4 h in air at a temperature of:

70 ± 0.5 °C for flexible cables and cords;
80 ± 0.5 °C for other cables.

The test piece shall then be chilled under load. In the heating cabinet, this operation may be carried out by spraying the test piece with cold water on the spot where the blade is pressing.

When testing in a water bath, the test piece shall either be brought just above the water surface or the water surface shall be lowered till just below the test piece, after which the test piece shall be chilled with cold water.

During the cooling procedure, after testing in water, the load shall remain below the water level.

The test piece shall be removed from the apparatus when it has cooled to a temperature where the recovery of the insulation is substantially complete; the test piece shall be cooled further by immersion in cold water.

Immediately after cooling, the test piece shall be prepared for determining the depth of indentation.

A narrow strip shall be cut from the insulation in the direction of the axis of the core, perpendicular to the indentation as shown in Figure 10, page 53.

The strip shall be laid flat under a measuring microscope and the cross wire shall be adjusted to the bottom of the groove and the outside of the insulation as shown in Figure 11, page 53.

The insulation of small cores shall be halved in the direction of the axis of the core, perpendicular to the indentation as shown in Figure 12, page 54. The median value of the indentation measurements of the test pieces shall be not more than 50% of the mean value of the thickness of the insulation of the sample.

Note. — The capacity of the heating elements in the water bath should be sufficient for testing heavy cores.

8.1.4 *Preparation of and test procedure for the sheath*

Any covering shall be removed from the sheath. A strip, enclosing about a third part of the circumference shall be cut in the direction of the axis of the cable or cord from a sheath without ridges, and from a sheath with ridges caused by more than five cores. These ridges shall be removed by grinding.

If a sheath shows ridges caused by five or less cores, the strip shall be cut in the direction of the ridges so that it contains at least one groove, which lies approximately in the middle of the strip throughout its length.

The test shall be made by means of the apparatus described in Sub-clause 8.1.3. The strips are supported by a metal pin or tube in the same way as the insulation of sector-shaped cores.

If the prepared test piece shows ridges, the pin (tube) radius shall be approximately equal to half the core diameter; if the prepared test piece contains no ridges, the pin (tube) radius shall be approximately equal to half the inner diameter of the sheath.

The apparatus, the strip and the supporting pin (tube) shall be arranged so that the pin supports the strip, the pin lying in the groove, if any, of the test piece, and the blade pressed against the outer surface of the sheath.

When a sheath with a mean thickness exceeding 1.5 mm is tested in air, the apparatus, pin or tube and the weight shall be pre-heated till they have reached the test temperature.

The force shall be applied in a direction perpendicular to the axis of the pin, and the blade shall also be perpendicular to the axis of the pin. The force P, in newtons, exerted by the blade upon each test piece of the sample of the sheath is given by the formula:

$$P = 0.8 \sqrt{2Di - i^2}$$

Where:

i = the mean value, in millimetres, of the thickness of the sheath of the sample
D = the mean value, in millimetres, of the outer diameter of the sheath of the sample

For flat samples, D is the mean value, in millimetres, of the minor outer dimension of the sheath of the sample.

The force applied upon a prepared test piece, taken from a round cord or cable which contains one or more grooves, is 0.9 times the calculated value, P.

The calculated force may be rounded off downwards by not more than 3%. When testing in water, the upward pressure upon the blade and the weight hanging on the blade shall be taken into account.

The test shall then be completed as described in Sub-clause 8.1.3 for cores, to determine the depth of the indentation.

The median value of the indentation measurements of the test pieces shall be not more than 50% of the mean value of the thickness of the sheath of the sample.

APPENDIX A

MEASUREMENTS OF THICKNESS AND OUTER DIAMETER OF INSULATION AND SHEATH

Procedure

Each specimen should consist of a thin slice of insulation or sheath, from which all coverings and internal parts have been carefully removed. The slice should 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 should be placed under a measuring microscope with the plane of the cut perpendicular to the optical axis. The microscope allows a reading of 0.001 mm.

When the outer profile shows unevenness, the cross-wire of the microscope should be adjusted as indicated in Figure 3, page 47.

When the inner profile of the specimen (insulation or sheath) is a circle, six measurements should be carried out radially, as far as possible equally spaced around the circumference.

When the insulation is taken from a stranded conductor, six measurements should be made radially in the directions where the insulation is thin, i.e. between the ridges caused by strands.

In all cases, the first measurement should be made at the place where the insulation is thinnest.

After adjusting the microscope, both thickness and outer diameter should be measured.

The readings should be made to three decimal figures.

The values for the diameter and the thickness derived from the measurements should be rounded off to two decimal figures; if the third decimal figure is 5 or more, the second decimal figure should be raised to the next number.

The averages of the six values found in this way for diameter and thickness are the mean diameter and the mean thickness of the test piece respectively.

APPENDIX B

METHOD FOR DETERMINING THE DENSITY OF P.V.C. INSULATION AND SHEATH

PYCNOMETER METHOD

1. Apparatus

The apparatus for this method consists of:

- a balance with a precision of 0.1 mg;
- a pan straddle or other stationary support;
- a pycnometer of 50 ml capacity;
- a liquid bath provided with a thermostatic control.

2. Specimen

The specimen should be taken from the bare insulation or sheath. The mass of the specimen should be not less than 1 g and not greater than 5 g. The specimen should be made by cutting the sample of insulation or sheath into a number of small pieces; small tubes of insulation and sheath should be cut longitudinally into two or more parts to prevent the enclosure of air bubbles.

3. Conditioning

The specimen should be at an ambient temperature of 20 ± 5 °C.

4. Procedure

Weigh the pycnometer empty and dry, then weigh a suitable quantity of the specimen in the pycnometer. Cover the test specimen with immersion liquid (alcohol 96%) and remove all air from the specimen, for example by applying a vacuum to the pycnometer standing in a desiccator. Break the vacuum (if applied) and fill the pycnometer with the immersion liquid. Bring it to a temperature of 20 ± 0.5 °C in the bath, and then complete filling exactly to the limits of the capacity of the pycnometer. Wipe dry and weigh the pycnometer with its contents. Empty and fill with the immersion liquid, removing air and determine the weight of the contents and pycnometer at 20 ± 0.5 °C.

5. Calculation

Calculate the density of the p.v.c. insulation and sheath from the following relation:

$$\text{density at } 20\ ^\circ\text{C} = \frac{m \times \varrho_1}{m_1 - m_2}$$

Where:

m = mass of specimen, in grammes
m_1 = mass of liquid required to fill the pycnometer, in grammes
m_2 = mass of liquid required to fill the pycnometer, when containing the specimen, in grammes
ϱ_1 = density of immersion liquid at 20 °C, alcohol 96%:

$$\varrho \text{ at } 20\ ^\circ\text{C} = 0.8013\ \text{g/cm}^3$$

APPENDIX C

METHODS OF MEASURING AIR FLOW IN OVENS

1. Method 1 – Indirect or power consumption method

In this method, the additional power required to maintain the oven at a given temperature with its ports open, over that required to maintain the oven at the same temperature with its ports closed, is used as a measure of the quantity of air passing through the oven when the ports are open. The average power (x watts) required to maintain the oven temperature at 80 ± 2 °C above the room temperature when the ports are open is determined over a period of 30 min or longer. The ventilation ports (and, if necessary, the thermometer aperture) are now closed and the average power (y watts) to maintain the same temperature over a similar period is determined. It is essential that the difference between the oven temperature and the room temperature should be the same for the two tests to within 0.2 °C. The room temperature should be measured at a point 183 cm (6 ft) from the oven, approximately level with its base, and at least 61 cm (2 ft) from any solid objects.

The amount of air passing through the oven when the ports are open is given by the formulae:

$$w = \frac{x - y}{Cp\ (t_2 - t_1)} \quad (1)$$

$$V = \frac{3\,600\ w}{d} \quad (2)$$

Where:

Cp = the specific heat of air at constant pressure (1.003 J/g)
t_1 = the room temperature
t_2 = the oven temperature
$x - y$ = the difference in power consumption, as defined in the first paragraph
w = the mass of air, in grammes per second
V = the volume of air, in litres per hour
d = the density of air in the laboratory at the time of test, in grammes per litre

Note. — The density of air at 760 mmHg and 20 °C is 1.205 g/l.

Hence:

$$V = \frac{3600\ (x - y)}{1.003\ d\ (t_2 - t_1)} \quad \text{or} \quad V = \frac{3\,590\ (x - y)}{d\ (t_2 - t_1)}$$

This formula assumes that, when the ports are closed, no air passes through the oven. Therefore, there must be no leakages; the door joint should be sealed with adhesive tape and all apertures, including the inlet port, should be effectively closed.

If the power consumption is measured with a wattmeter, the total length of time in seconds for which the oven heaters are "on" is measured with a stopclock and the reading of the wattmeter is taken once during each "on" period. The average of the wattage readings multiplied by the total time registered by the stopclock and divided by the duration of the test in seconds is taken as the power, in watts, required to maintain constant temperature.

If a watt-hour or kilowatt-hour meter is used, the reading of the total energy consumption registered by the meter is divided by the duration of the test measured as a fraction of an hour. If a domestic kilowatt-hour meter is used, the dial units are too large to enable a sufficient accuracy to be obtained over a reasonably short test, and the rotating disc with which these meters are provided is therefore used as the power consumption indicator. The meter is put into operation until the index mark on the disc is opposite the centre of the window; it is then disconnected until the start of the test.

To reduce the possible error, a long enough period of test is taken to give about 100 disc revolutions, and the test is preferably ended when the mark on the disc is visible. If, however, the mark is out of sight at the end of the test, an estimated fraction of a revolution is added. The test is started and stopped at corresponding points of the "on-off" heating cycle (e.g. at the moment when the heaters are switched on by the thermostat).

2. Method 2 – Direct and continuous method

This method, as an alternative to Method 1, allows a direct and continuous control of the air supply.

2.1 *Description of the equipment*

Starting from the air source at high pressure, i.e. from a pipe system of air cylinders:

a) Air-pressure regulator

A device to reduce the air pressure from the many atmospheres of the supply mains to the quite low pressure values needed for feeding the oven.

It is equipped with an adjustable valve which guarantees a constant pressure downstream.

b) Flowmeter

An instrument with which the rate of air flow can be measured. It is illustrated by Figure 4, page 48, and operates on a manometric principle, with:

1) A capillary calibrated tube, with an internal calibrated diameter of about 2 mm and a calibrated length of about 70 mm. Figure 5, page 49, shows a typical calibration diagram, made by a recognized Italian institution and from which it appears that such a tube enables the control of air flow up to 500 l/h to 600 l/h;

2) A manometric tube with a double graduation of pressure difference ranging between 0 and ± 300 mm of water. Distilled water is in the manometric liquid.

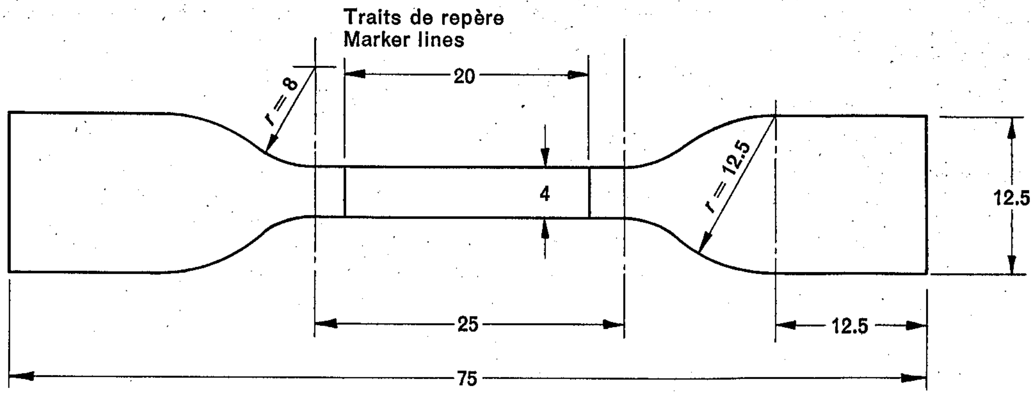
c) Air oven

An ordinary air oven to be operated accurately sealed, including sealing round the inlet tube, which should preferably enter the oven through the bottom. The outflow hole which should be at the top of the oven is the only port to be open.

Note. — The following two features of the reliability of the method and the equipment are pointed out:

a) The flowmeter described above can be considered as fully reliable, easy to manufacture and to calibrate, as well as suitable for the range of air rates here involved.

b) As shown by tests, the adoption of "forced" ventilation does not alter, in practice, the uniformity of the temperature at the various points in the ovens.



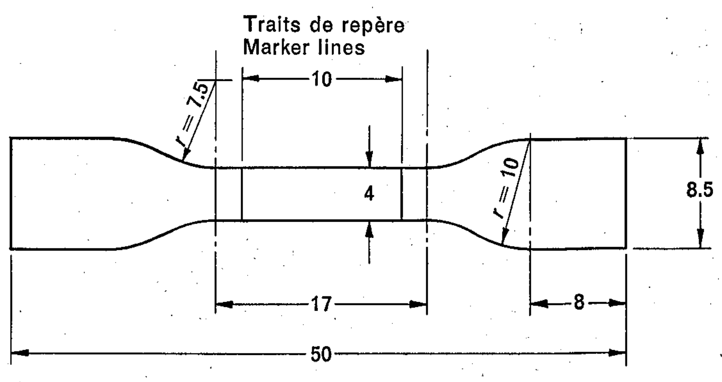
Dimensions en millimètres

Les traits de repère ne s'appliquent pas à l'essai d'allongement à basse température

Dimensions in millimetres

The marker lines are irrelevant to the elongation test at low temperature

FIG. 1. — Eprouvette en forme d'haltère.
Dumb-bell test piece.



Dimensions en millimètres

Dimensions in millimetres

FIG. 2. — Petite éprouvette en forme d'haltère.
Small dumb-bell test piece.

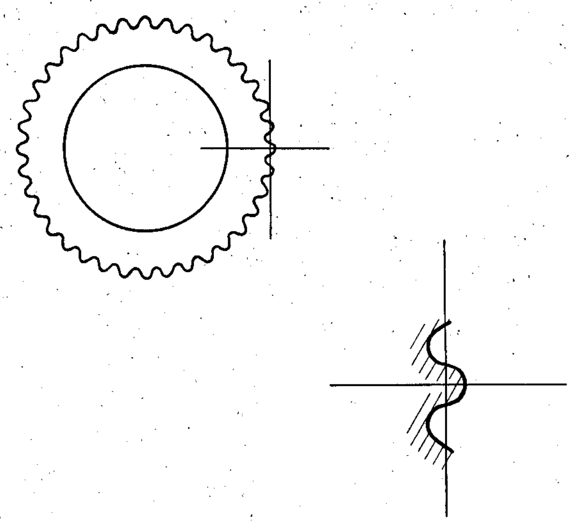


FIG. 3. — Mise en place du réticule du microscope de mesure.
Placing of the cross-wire of the measuring microscope.

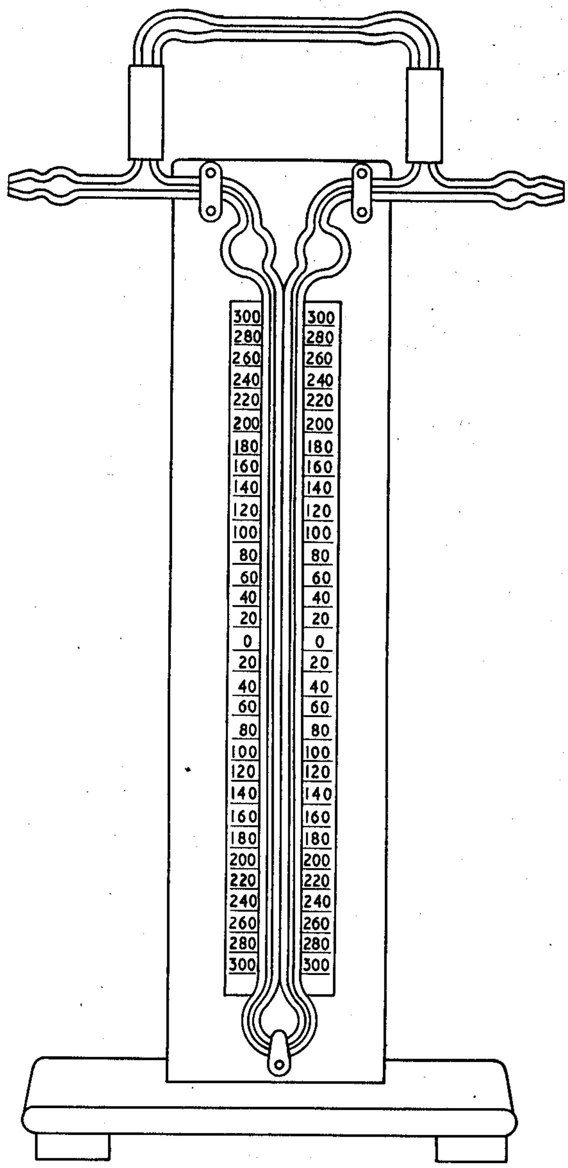


FIG. 4. — Débitmètre pour le contrôle du débit d'air dans les étuves pour la méthode 2.
Flowmeter for air flow control in air ovens for Method 2.

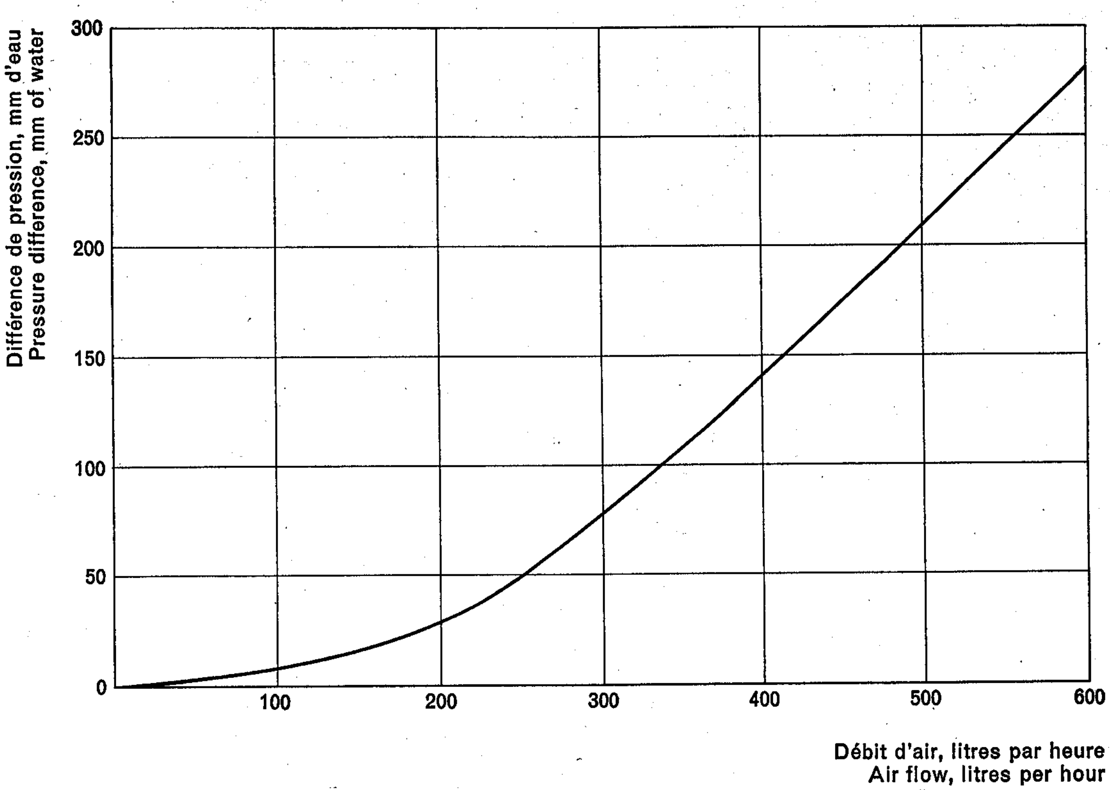
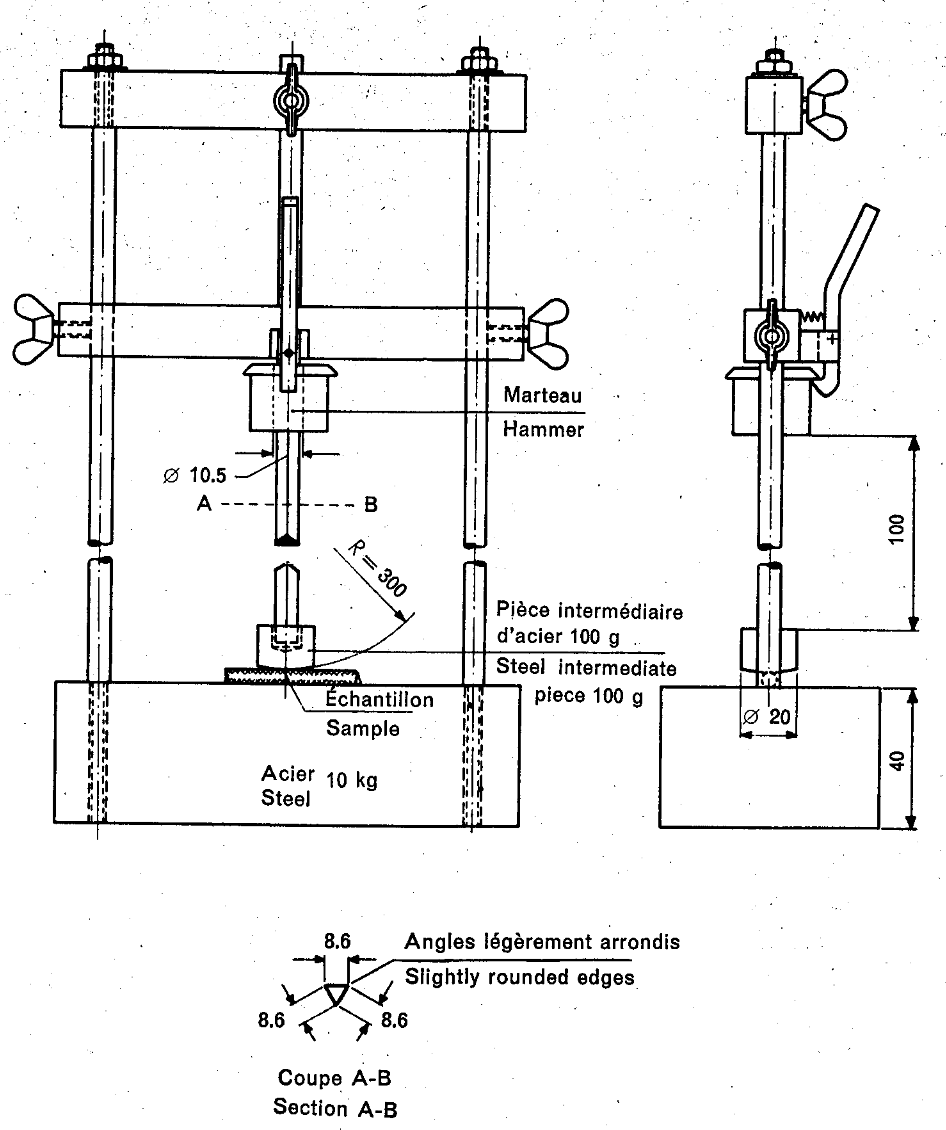


FIG. 5. — Diagramme d'étalonnage du tube capillaire (d = 2,0 mm, l = 70 mm) du débitmètre pour le contrôle du débit d'air dans les étuves par la méthode 2.

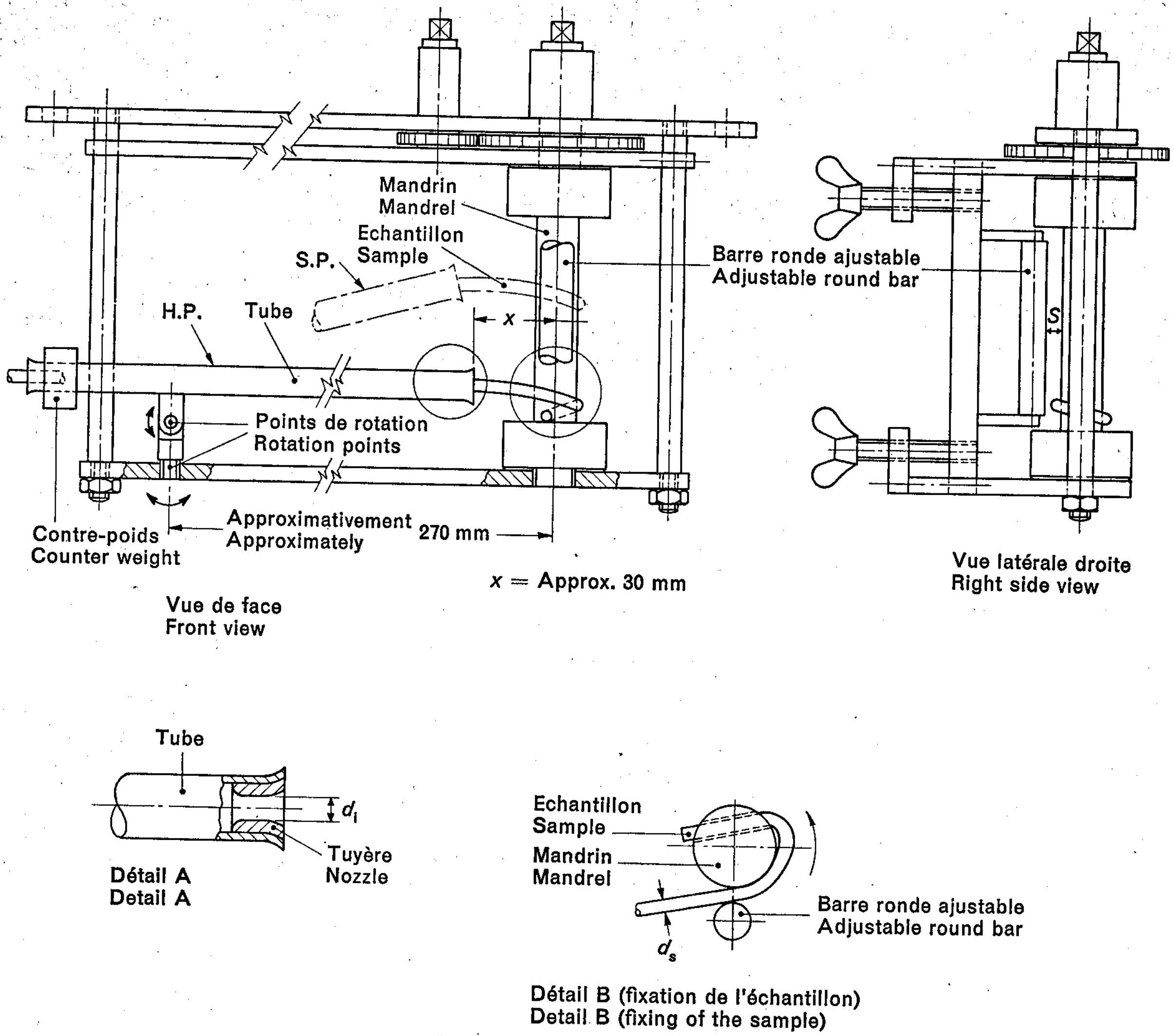
Calibration diagram of the capillary tube (d = 2.0 mm, l = 70 mm) of the flowmeter for air flow control in air ovens for Method 2.



Dimensions en millimètres

Dimensions in millimetres

FIG. 6. — Appareil d'essai de choc.
Impact-test apparatus.



Notes 1.— $d_s < S < 1,5\, d_s$

2.— $d_i = 1,2$ à $1,5 \times d_s$

3.— En position horizontale, le tube ne doit pas trop appuyer l'échantillon vers le bas.

4.— En position en pente, le tube ne doit pas trop appuyer l'échantillon vers le haut.

Notes 1.— $d_s < S < 1.5\, d_s$

2.— $d_i = 1.2$ to $1.5 \times d_s$

3.— In horizontal position (H. P.), the tube should not press the sample down too much.

4.— In slope position (S. P.), the tube should not press the sample upwards too much.

FIG. 7. — Appareil pour l'essai de pliage à froid.
Cold-bend test apparatus.

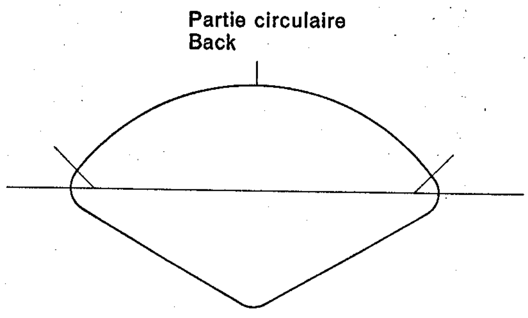


FIG. 8. — Conducteur sectoral.
Sector-shaped core.

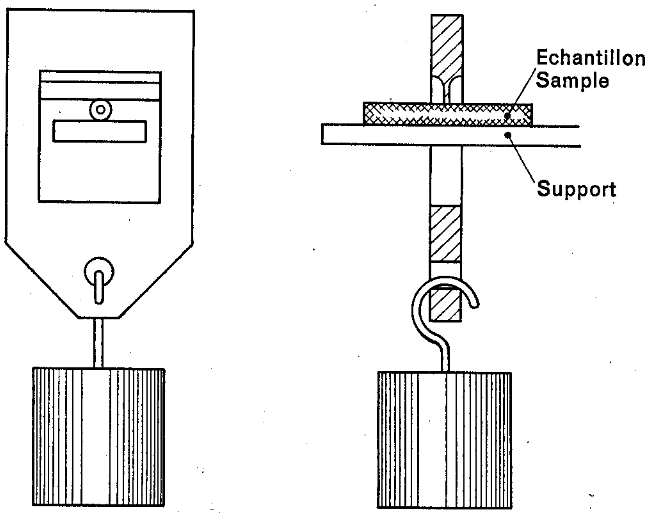


FIG. 9. — Appareil pour l'essai de pression à haute température.
Apparatus for pressure test at high temperature.

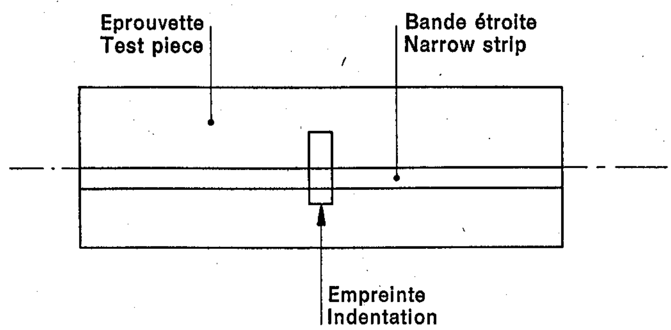


FIG. 10. — Bande étroite pour la mesure de l'empreinte.
Narrow strip for measurement of indentation.

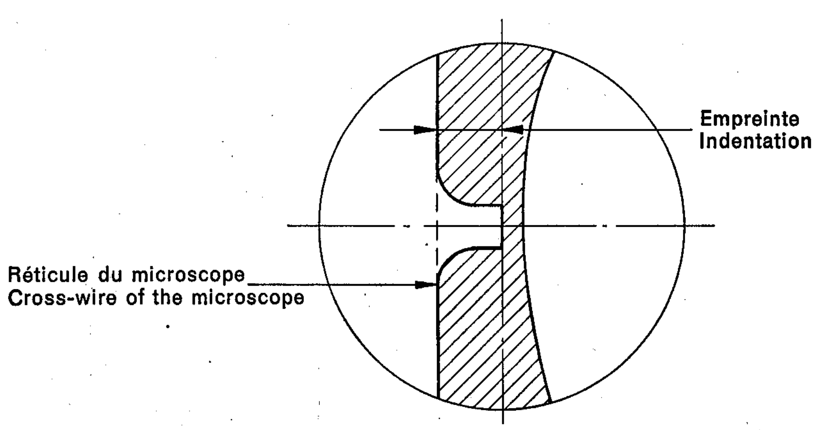


FIG. 11. — Image dans le microscope de mesure.
Picture in measuring microscope.

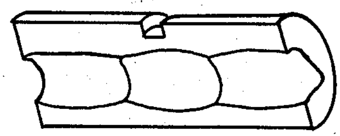


FIG. 12. — Enveloppe isolante coupée en deux.
Halved insulation.