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Rubber — General procedures for preparing and conditioning test pieces for physical test methods

Caoutchouc — Procédures générales pour la préparation et le conditionnement des éprouvettes pour les méthodes d'essais physiques

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 23529 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analyses*.

It cancels and replaces ISO 471:1995, ISO 3383:1985, ISO 4648:1991 and ISO 4661-1:1993, of which it constitutes a technical revision.

Rubber — General procedures for preparing and conditioning test pieces for physical test methods

WARNING — Persons using this International Standard should be familiar with normal laboratory practice. This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any national regulatory conditions.

1 Scope

This International Standard specifies general procedures for the preparation, measurement, marking, storage and conditioning of rubber test pieces for use in physical tests specified in other International Standards, and the preferred conditions to be used during the tests. Special conditions applicable to a particular test or material or simulating a particular climatic environment are not included, nor are special requirements for testing whole products.

This International Standard also specifies the requirements for the time-interval to be observed between forming and testing of rubber test pieces and products. Such requirements are necessary to obtain reproducible test results and to minimize disagreements between customer and supplier.

2 Identification and record keeping

Records shall be kept of the identity of each test piece so that it is identifiable with the sample supplied and such that all the relevant details of preparation, storage, conditioning and measurement are traceable to each individual test piece.

Each sample or test piece shall be individually identifiable by marking or segregation at each stage of its preparation and testing. Where marking is used as the method of identification, the markings shall be sufficiently durable to ensure that the test piece or sample remains identifiable until discarded. Where grain effects may be significant, the direction of the grain shall be identified on each sample or test piece.

The method of marking shall not affect the properties or the sample or test piece and shall avoid significant surfaces, i.e. surfaces which are to be directly tested (as in e.g. abrasion tests) or surfaces at which a fracture will terminate during the test (as in e.g. tear or tensile tests).

3 Standard laboratory conditions

3.1 Standard laboratory temperature

The standard laboratory temperature shall be either (23 ± 2) °C or (27 ± 2) °C in accordance with national practice.

If a closer tolerance is required, it shall be ± 1 °C.

NOTE The temperature 23 °C is normally the standard laboratory temperature in temperate countries and 27 °C is normally the standard laboratory temperature in tropical and sub-tropical countries.

3.2 *Standard laboratory humidity*

If control of both temperature and humidity is necessary, they should preferably be selected from Table 1.

Table 1 — Preferred relative humidity

Temperature °C	Relative humidity %	Tolerance on humidity %
23	50	± 10[a]
27	65	

[a] If a tighter tolerance is needed, ± 5 % can be specified.

3.3 Other conditions

When control of temperature and humidity is not necessary, the prevailing ambient temperature and humidity shall be used.

4 Storage of sample and test pieces

4.1 Samples awaiting the preparation of test pieces and test pieces prior to conditioning shall be stored under conditions which minimize the possibility of degradation by ambient conditions, such as heat or light, or of contamination, for example cross-contamination from other samples.

4.2 For all tests, the minimum time between forming the material and testing shall be 16 h. When test pieces are cut from products or where whole products, e.g. bridge bearings, are tested, considerably more than 16 h may be necessary. In these cases, the minimum time shall be as given in the product specification and/or relevant test method.

4.3 For non-product tests, the maximum time between forming the material and testing shall be 4 weeks and, for evaluations intended to be comparable, the tests shall be carried out, as far as possible, after the same time interval.

4.4 For product tests, whenever possible, the time between forming the product and testing shall not exceed 3 months. In other cases, tests shall be made within 2 months of the date of receipt of the product by the customer.

4.5 These requirements relate only to initial rubber material tests and to product tests at both the initial and delivery stage. Special tests for other purposes may be carried out at any time, e.g. for the purposes of process control or to evaluate the influence of abnormal storage conditions on a product. Such reasons shall be clearly stated in the test report.

4.6 *In the case of unvulcanized compound, batches shall be conditioned for between 2 h and 24 h at one of* the standard laboratory temperatures specified in 3.1, preferably in a closed container to prevent absorption of moisture from the air, or in a room in which the relative humidity is controlled at (50 ± 5) %.

5 Preparation of test pieces

5.1 Test piece thickness

The test piece thickness shall be as specified in the relevant test method. However, it is recommended that the test piece thicknesses given in Table 2 be used for specially moulded test sheets for all tests unless, for technical reasons, other thicknesses are necessary.

Table 2 — Preferred test piece thicknesses

Test piece thickness mm	Tolerance mm
1	± 0,1
2	± 0,2
4	± 0,2
6,3	± 0,3
12,5	± 0,5

5.2 Thickness adjustment

5.2.1 General

Material requiring testing, particularly products, may not be available in the thickness specified in 5.1, in which case procedures will be required to adjust the thickness to within the prescribed limits. Recommended procedures are given in 5.2.2. In most cases, the thickness adjustments should be made on the material before the cutting of the test pieces.

5.2.2 Techniques

5.2.2.1 Removal of textiles combined with the rubber

The separation should preferably avoid the use of a liquid, which causes swelling. If this is not possible, a non-toxic liquid of low boiling point, such as isooctane, may be used to wet the contacting surfaces. Care shall be taken to avoid excessive stretching of the rubber during the separation by separating a little at a time while the rubber is gripped near the point of separation. If a liquid is used, the rubber shall be placed so as to permit free evaporation of the liquid, and time shall be allowed for the complete evaporation of the liquid, preferably at least 16 h, before the test pieces are cut and tested.

5.2.2.2 Cutting techniques

When it is necessary to remove a considerable thickness of rubber or to produce a number of slices from a thick piece of rubber, cutting equipment such as that described in 5.2.3.1 and 5.2.3.2 shall be used.

5.2.2.3 Abrading techniques

When it is necessary to remove surface unevenness, such as fabric impressions or corrugations caused by contact with fabric components or with cloth wrappings used for vulcanization, or unevenness caused by cutting, this shall be done using the equipment described in 5.2.3.3 or that described in 5.2.3.4.

5.2.3 Equipment for test piece preparation

5.2.3.1 Rotating-blade equipment

This equipment is based on commercial slicing machines. The machine consists of a motor- or hand-driven disc cutter of suitable diameter with a movable cutting table which transports the sample to the cutting edge. An adjustable slow-feed mechanism fitted to the cutting table feeds the rubber forward to the line of cut, and controls the thickness of the slice. Clamping devices shall be available to secure the rubber. The blade should preferably be lubricated with a dilute aqueous detergent solution to ease the cutting operation.

5.2.3.2 Skiving machines

This equipment is based on commercial leather-slitting machinery, and convenient types are available for cutting strips about 50 mm wide with thicknesses up to about 12 mm. Adjustment shall be possible to vary the thickness of cut, and feed rollers shall be provided to transport the material past the knife. Provision shall be made for maintaining the cutting edge in a sharp condition. Attachments are available for splitting and cutting sections from cable sheathing.

5.2.3.3 Abrasive wheels

The abrading apparatus shall consist of an abrader with a motor-driven abrasive wheel. It is important that the wheel runs true without vibration, and that the abrasive surface, of aluminium oxide or silicon carbide, is true and sharp. The abrader may be equipped with a slow-feed mechanism so that very light cuts may be made to avoid over-heating of the rubber. Suitable means shall be provided for securing the rubber to prevent excessive deformation and for controlled traversing of the rubber against the abrasive wheel.

NOTE Wheels of diameter 150 mm operating at a surface speed in the range 10 m/s to 12 m/s, designated C-30-P-4-V for roughing and designated C-60-P-4-V for finishing (see ISO 525), have been found suitable.

The depth of cut produced in the first pass shall not exceed 0,2 mm. Successive cuts shall be progressively less deep to avoid overheating. Buffing shall not be carried out beyond the point where unevenness in the thickness has been eliminated. For removal of greater thicknesses of rubber, cutting equipment as described in 5.2.3.1 or 5.2.3.2 shall be used.

5.2.3.4 Flexible abrasive belts

The apparatus shall consist either of a motor-driven drum on which a helical strip of the abrasive belt is secured, or of two pulleys, one motor-driven and the other adjustable, to tension and align the belt. The abrasive belt shall be of textile or paper or a combination of the two, with the abrasive, of aluminium oxide or silicon carbide, bonded to the surface with a resin which is unaffected by water. Equipment shall be provided for slow feeding of the material to the abrasive belt and for securing the material without excessive deformation.

NOTE A surface speed of the band in the range of 20 m/s ± 5 m/s has been found suitable.

With this apparatus, cuts removing several tenths of a millimetre of rubber are practicable as much less heat is produced than with the equipment described in 5.2.3.3. Abrasion may be carried out against the drum, against one of the pulleys or against the taut belt between the pulleys.

5.3 Test piece cutters

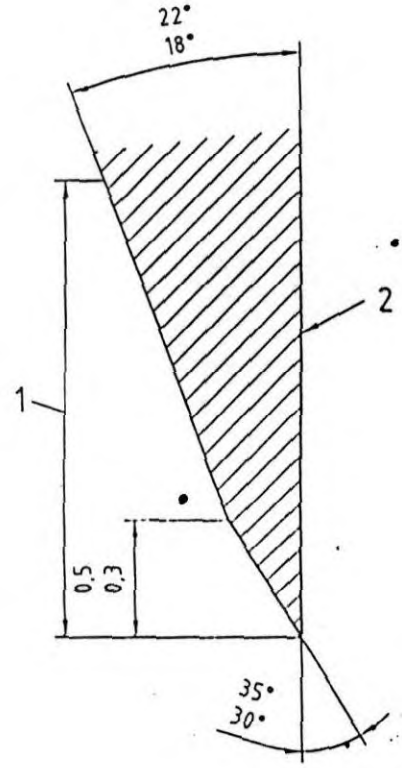
5.3.1 Design of cutters

The design and type of cutter or die employed will depend on the thickness and hardness of the material under test. In the case of thin materials, punching or rotary cutting techniques shall be used as described in 5.3.2, 5.3.3 or 5.3.4. For thicker materials, usually above 4 mm, a rotary cutting technique as described in 5.3.4 is desirable to reduce the degree of dishing of the cut edge resulting from compression of the rubber during cutting. For cutters which do not have replaceable blades, a suitable design of cutting edge is shown in Figure 1.

5.3.2 Fixed-blade cutters

These shall be made from high-quality tool steel and may be of either one-piece (solid metal) or two-piece construction. They may be designed to punch out single or multiple test pieces. It is essential that the design ensures sufficient rigidity to prevent distortion of the cutting shape, and the cutter should preferably be fitted with an ejection system to release the test piece. If fitted, such a system shall be designed to accommodate material up to the maximum thickness to be cut, normally 4,2 mm. If an ejection system is not fitted, access shall be available from the rear to permit release of the test piece by the operator without damaging the cutting edge. The cutting edge shall be kept sharp and free from nicks, as described in 5.4, to prevent the formation of ragged edges on the test pieces.

Dimensions in millimetres



Key

1 ground area approximately 6 mm wide

2 inside surface of cutter

Figure 1 — Suitable cutting edge

5.3.3 Replaceable-blade cutters

These shall use sharpened, high-carbon-steel strips, such as single-edged razor blades, which are sufficiently flexible to conform to the shape of the cut required. The cutting edge shall be securely clamped between shaped metal spacers and shaped blocks which conform to the specified cut shape. The spacers and shaped blocks shall be of sufficient thickness to support the cutting blade so that under normal circumstances not more than 2,5 mm of the blade protrudes from the surface. The back of the cutting blade shall bed firmly on a solid metal base. The cutter should preferably be fitted with an ejection system to release the test piece. If fitted, such a system shall be designed to accommodate material up to the maximum thickness to be cut, normally 2,2 mm. If an ejection system is not fitted, access shall be available from the rear to permit release of the test piece by the operator without damaging the cutting edge. Checks shall be made to ensure that the blade is not significantly deformed during the cutting operation, particularly with rubbers of high hardness.

5.3.4 Rotary cutters

Either annular or arc-shaped knives or razor blades, held in a suitable adapter permitting them to be fitted in a drilling machine, shall be used. Means shall be provided for holding the rubber in place during the cutting operation. This can consist of a combination of a plunger with a presser foot incorporated in the adapter to secure the central portion of the rubber and a metal pressure plate having a central hole larger than the size of the test piece to be cut out, or it can consist of a vacuum-type holder which applies suction to the lower surface of the rubber. Means may be provided for lubricating the surface of the rubber during the cutting operation. To assist in obtaining a perpendicular cut, a second annular blade of larger diameter, working at the same time as the test piece cutting blade, has been found effective. The size of the blades and the movement of the drill head shall be sufficient to accommodate the thickness of rubber to be cut. The leading edge of an arc-shaped blade shall be angled and sharpened to facilitate entry into the rubber. It is important that the cutting area be adequately guarded with a transparent shield permitting examination of the cutting operation. Other techniques in which the rubber is rotated against a stationary knife or razor blade may also be used.

5.4 Maintenance of cutters

Care shall be exercised at all times to protect and maintain the cutting edges of cutting equipment, as any dulling, nicking or bending of the cutting edge can lead to defective test pieces which will give atypical results. During storage, cutters shall be either placed in such a way that the cutting edge is resting on a soft surface such as foamed rubber or, preferably, placed so that the cutting edge does not contact any surface.

5.5 Preparation of test pieces by moulding

5.5.1 Test sheets

When test sheets are prepared by mould cure (see Note to 5.5.2), vulcanize them to reproduce as closely as possible the state of vulcanization of the product. First press-cure the sheets to the thickness specified in the relevant test method, then cut out test pieces using cutters.

5.5.2 Test discs

When test discs are prepared by mould cure, vulcanize them to reproduce as closely as possible the state of vulcanization of the product.

NOTE Suitable procedures for moulding test sheets and test discs are described in ISO 2393.

5.5.3 Thermoplastic materials

Samples of thermoplastic materials shall be moulded in accordance with the manufacturer's instructions for the material, application and type and size of moulding.

6 Conditioning

6.1 General

When both temperature and humidity are specified, the conditioning time shall be a period of not less than 16 h immediately before testing.

When a standard laboratory temperature is specified without the need to control the humidity, the conditioning time shall be a period of not less than 3 h immediately before testing.

When a temperature other than a standard laboratory temperature is specified without the need to control the humidity, the conditioning time shall be a period sufficient for the rubber to reach temperature equilibrium with the environment or the period required by the specification covering the material or product being tested.

Test pieces prepared from buffed samples shall be conditioned before testing.

6.2 Conditioning times for subnormal or elevated temperatures

Annex A gives calculated times for the centre of a test piece to reach a temperature within 1 °C of a set conditioning temperature, starting from an initial temperature of 20 °C. The time depends on the geometry, the material and the type of heat-transfer medium used.

7 Measurement of the dimensions of test pieces

NOTE For the measurement of the dimensions of products for control purposes, the reader is referred to ISO 3302-1.

7.1 Method A — For dimensions less than 30 mm

This method is applicable where the dimension to be measured is less than 30 mm, with the test piece lying between two flat parallel surfaces, and where the other dimensions are such that the application of pressure does not cause any appreciable buckling.

The apparatus used shall consist of a flat rigid baseplate, on which the test piece or product rests, and a gauge having a flat circular foot of diameter between 2 mm and 10 mm that is applied to the test piece or product, exerting a specified pressure.

The gauge shall be capable of measuring the thickness with an error of not more than 1 % or 0,01 mm, whichever is the smaller.

The circular foot shall not extend over the edge of the test piece or product and shall exert a pressure of 22 kPa ± 5 kPa for solid rubber of hardness equal to or greater than 35 IRHD or a pressure of 10 kPa ± 2 kPa if the hardness is less than 35 IRHD. The normal masses required to give the specified pressures of 10 kPa ± 2 kPa and 22 kPa ± 5 kPa are given, for different foot diameters, for reference purposes in Table 3.

NOTE This type of apparatus may also be used for other types of test piece not having a flat parallel surface, provided that the measurement conditions are given in the relevant standard.

At least three measurements shall be made of each dimension to be determined, and the median value of each dimension reported.

Table 3 — Surface pressure as a function of foot diameter

Foot diameter	Mass, in grams, required to give a pressure of	
mm	10 kPa ± 2 kPa	22 kPa ± 5 kPa
2	3	7
3	7	16
4	13	28
5	20	44
6	29	63
8	51	113
10	80	176

7.2 Method B — For dimensions of 30 mm and up to and including 100 mm

The measurement shall be made by means of a vernier calliper capable of measuring the dimension with an error of not more than 1 %. Each measurement shall be made along a line perpendicular to the opposite faces of the test piece or product defining the dimension to be measured. The measurement shall be made with the test piece or product supported, so that the dimension measured is not affected by strain in the test piece or product.

The calliper shall be adjusted so that the faces which contact the surfaces of the test piece or product do not compress them.

At least three measurements shall be made of each dimension to be determined, and the median value of each dimension reported.

7.3 Method C — For dimensions over 100 mm

The measurement shall be made by means of a graduated ruler or tape with an error of not more than 1 mm. Each measurement shall be made along a line perpendicular to the opposite faces of the test piece or product defining the dimension to be measured.

At least three measurements shall be made of each dimension to be determined, and the median value of each dimension reported.

7.4 Method D — Non-contact method

This method, which does not involve any contact with the rubber, may be required when the test piece or product has a special shape (for example O-rings or test pieces taken from hoses). Various types of optical apparatus may be used, for example a travelling microscope, projection microscope or shadowgraph.

The gauge shall be capable of measuring the thickness with an error of not more than 1 % or 0,01 mm, whichever is the smaller.

At least three measurements shall be made of each dimension to be determined, and the median value of each dimension reported.

8 Conditions of test

8.1 Duration of test

The period required to obtain any given degree of change in a test piece (for example during ageing) depends largely upon the type of rubber, its composition and state of cure, and the nature and severity of the test environment. When an extensive investigation is required, changes are usually monitored by testing at set time-intervals. For control purposes, such a procedure is not usually necessary and a single test period may suffice. In both cases, it is recommended that the test period(s) be selected from Table 4.

Table 4 — Preferred test periods

Test period h	Tolerance h
8	± 0,25
16	
24	$^{0}_{-2}$
48	
72	
168	± 2
Multiples of 168	

In cases where, for technical reasons, closer tolerances are necessary, they shall be as specified in the test method.

8.2 Temperature and humidity

8.2.1 Standard laboratory temperature and humidity

The standard conditions of temperature and humidity are those defined in Clause 3.

8.2.2 Other test temperatures

When a subnormal or an elevated temperature is necessary, this temperature shall be selected from the values in Table 5 unless otherwise necessary for technical reasons.

NOTE Closer tolerances may be specified where they have been shown to be necessary in order to obtain reproducible test results.

Table 5 — Test temperatures

Test temperature °C	Tolerance °C
− 85 − 70 − 55 − 40 − 25 − 10 0	± 2
40 55 70 85 100	± 1
125 150 175 200 225 250 275 300	± 2

9 Test chambers

9.1 General requirements for temperature-controlled chambers

The immersion medium in the chamber shall have no significant effects on the properties of the rubber test pieces. The temperature of the part of the chamber in which the test pieces are placed shall be controlled to within the tolerances specified by the relevant method of test. The immersion medium shall be circulated thoroughly throughout the chamber. Automatic temperature control is preferred. Recovery to the set temperature after the introduction of test pieces or test apparatus shall be as rapid as possible consistent with minimal overshoot or undershoot, but in any case shall not exceed 15 min, particular care being required with gaseous media.

The chamber shall be thermally insulated to prevent condensation on exterior surfaces when testing at subnormal temperatures and to prevent discomfort to the touch when testing at elevated temperatures. If a window is needed to observe the test equipment, e.g. to read meters, it shall be constructed so as to ensure adequate thermal insulation and to prevent condensation.

The construction of the chamber depends on the type of immersion medium. For gaseous media, a side entrance for introducing test pieces is convenient, and is necessary where the test equipment is operated from the side. The interior walls of the chamber shall be made of a good thermal conductor, preferably aluminium or tin-plated copper, to ensure uniform temperature and minimize radiant effects. When manual operation of equipment (except for mounting and removal of test pieces) inside the chamber is necessary, hand-holes equipped with gloves and insulated sleeves shall be installed in the walls of the chamber.

For liquid media, the temperature may be controlled by elements immersed in the medium or by circulating the medium though a heat-exchange system outside the chamber.

9.2 Chambers operating at elevated temperatures

9.2.1 Chambers with gaseous heat-transfer media

The gaseous medium shall be heated by means of suitable electric heating elements, a fan or blower being provided to ensure adequate circulation of the gas. The heating elements shall be shielded to avoid thermal radiation falling directly on the test pieces.

To obtain the necessary precision of temperature control, the heating system shall:

a) use a recirculating gas system;

b) be designed so that most of the heat required is supplied continuously and the remainder intermittently for temperature control or with proportionating devices in the heat supply that prevent large cyclic variations in temperature.

9.2.2 Chambers with liquid heat-transfer media

Such chambers should preferably follow the same principles as in 9.2.1, using an immersion heater instead of the heating elements used in 9.2.1 and a stirrer or pump instead of the fan or blower.

9.2.3 Fluidized beds

Such chambers should preferably utilize a bed of inert material which may be "fluidized" by passing a suitable gas through the bed at a suitable speed.

9.3 Chambers operating at subnormal temperatures

9.3.1 Mechanically refrigerated units

In general, mechanically refrigerated low-temperature chambers have a multi-stage compressor and suitable cooling coils which surround the test chamber.

9.3.2 Solid carbon dioxide units (direct-cooling type)

In the direct-cooling type of solid carbon dioxide cooled low-temperature chamber, a suitable fan or blower, located in the solid carbon dioxide compartment, circulates the carbon dioxide vapour from the solid carbon dioxide compartment into the test piece compartment and back.

9.3.3 Solid carbon dioxide units (indirect-cooling type)

In the indirect-cooling type of solid carbon dioxide cooled low-temperature chamber, air is used as the heat-transfer medium and no carbon dioxide vapour comes into contact with the test pieces.

9.3.4 Packaged refrigeration units

It is frequently desirable to house the test equipment in the test chamber and circulate temperature-regulated cold air or carbon dioxide vapour from a separate refrigeration unit to the test chamber and back through insulated ducts or pipes.

9.3.5 Liquid nitrogen

Liquid nitrogen may be injected into the chamber as required to control the temperature or, alternatively, a sufficient volume of the gas in the chamber to give the required temperature may be circulated through a liquid-nitrogen vessel outside the chamber. When liquid nitrogen is injected, it shall be completely vaporized and the nitrogen gas shall have reached the test temperature before it contacts the test equipment or test pieces.

10 Test report

The test report shall include the following information:

a) the moulding conditions and the date of moulding (if applicable);

b) the methods used for sample and test piece preparation;

c) details of test piece conditioning;

d) the method(s) used to measure the test piece dimensions and the results of the measurements;

e) the test temperature and humidity, where appropriate.

Annex A
(normative)

Conditioning times for rubber test pieces

Tables A.1 to A.3 give calculated times for the centre of a test piece to reach a temperature within 1 °C of a set conditioning temperature, starting from an initial temperature of 20 °C. The time depends on the geometry, the material and the type of heat-transfer medium used.

To make individual calculations for every test piece in current use would be impractical. Fortunately, nearly all test pieces fall into three geometrical categories: discs, flat sheets and flat strips. Dumb-bell test pieces used in tensile tests may be considered as flat strips.

The conditioning time depends on the thermal properties of the sample material. For rubber, the thermal diffusivity may be taken as 0,1 mm^2/s and the thermal conductivity as 0,2 W/(m·K).

The majority of temperature-controlled chambers use either air or a liquid as the heat-transfer medium. To generate the tables, a heat-transfer coefficient for air of 20 W/(m^2·K) was assumed. Different liquids have different heat-transfer coefficients, but for most purposes a value of 750 W/(m^2·K) can be assumed.

The conditioning time is not critical to the nearest minute, although it is essential that the test piece be given sufficient time to reach equilibrium. All times in the tables have been rounded up to the next highest multiple of 5 min.

Table A.1 — Discs

Medium	Temp. °C	Time to 1 °C off equilibrium, minutes											
		Diameter, mm											
		64	40	37	32	29	29	25	25	25	13	13	9,5
		Height, mm											
		38	30	10,2	16,5	25	12,5	20	10	6,3	12,6	6,3	9,5
Air	− 50	130	75	35	45	50	35	40	25	20	20	15	15
	0	95	55	25	35	40	25	30	20	15	15	10	10
	50	105	60	30	35	45	30	35	20	20	20	15	15
	100	130	75	35	45	55	35	45	25	20	20	15	15
	150	145	85	40	50	60	40	45	30	25	25	20	20
	200	155	90	40	55	65	45	50	30	25	25	20	20
	250	160	95	45	55	65	45	50	30	25	25	25	20
Liquid	− 50	75	35	10	15	20	10	15	5	5	5	5	5
	0	60	30	10	15	15	10	15	5	5	5	5	5
	50	65	30	10	15	20	10	15	5	5	5	5	5
	100	80	35	10	20	25	15	15	5	5	5	5	5
	150	85	40	10	20	25	15	20	10	5	10	5	5
	200	90	45	10	20	25	15	20	10	5	10	5	5
	250	90	45	15	20	25	15	20	10	5	10	5	5

Table A.2 — Flat sheets

Medium	Temp. °C	Time to 1 °C off equilibrium, *minutes* — Thickness, mm 25	15	10	8	5	3	2	1	0,2
Air	− 50	135	70	45	35	20	15	10	5	5
	0	95	50	30	25	15	10	10	5	5
	50	110	60	35	30	20	10	10	5	5
	100	140	75	45	35	20	15	10	5	5
	150	155	80	50	40	25	15	10	5	5
	200	160	85	55	40	25	15	10	5	5
	250	170	90	55	45	25	15	10	5	5
Liquid	− 50	90	35	15	10	5	5	5	5	5
	0	75	30	15	10	5	5	5	5	5
	50	80	30	15	10	5	5	5	5	5
	100	90	35	20	10	5	5	5	5	5
	150	95	40	20	10	5	5	5	5	5
	200	100	40	20	15	5	5	5	5	5
	250	105	40	20	15	5	5	5	5	5

Table A.3 — Flat strips

Medium	Temp. °C	Time to 1 °C off equilibrium, minutes																	
		Width, mm: 25,4								15,0	12,7								
		Thickness, mm: 12,7	10,0	9,5	6,5	5,0	3,0	2,0	1,0	15,0	12,7	10,0	9,5	6,5	5,0	3,2	3,0	2,0	1,0
Air	− 50	45	35	35	25	20	15	10	5	35	30	25	25	20	15	15	10	10	5
	0	30	25	25	20	15	10	10	5	30	25	20	20	15	15	10	10	5	5
	50	35	30	30	20	15	10	10	5	30	25	20	20	15	15	10	10	10	5
	100	45	35	35	25	20	15	10	5	40	30	30	25	20	20	15	10	10	5
	150	50	40	40	30	20	15	10	5	40	35	30	30	25	20	15	15	10	5
	200	50	40	40	30	20	15	10	5	45	35	30	30	25	20	15	15	10	5
	250	55	45	40	30	25	15	10	5	45	40	35	35	25	20	15	15	10	5
Liquid	− 50	15	10	10	5	5	5	5	5	10	10	10	10	5	5	5	5	5	5
	0	10	10	10	5	5	5	5	5	10	10	5	5	5	5	5	5	5	5
	50	15	10	10	5	5	5	5	5	10	10	5	5	5	5	5	5	5	5
	100	15	10	10	5	5	5	5	5	10	10	10	10	5	5	5	5	5	5
	150	15	10	10	5	5	5	5	5	15	10	10	10	5	5	5	5	5	5
	200	15	10	10	5	5	5	5	5	15	10	10	10	5	5	5	5	5	5
	250	15	10	10	5	5	5	5	5	15	10	10	10	5	5	5	5	5	5

Table A.3 (*continued*) — Flat strips

Medium	Temp. °C	Time to 1 °C off equilibrium, minutes — Width, mm: 6,35 — Thickness, mm: 12,7	10,0	6,5	5,0	3,0	2,0	1,5	1,0	Width 4,0 — Thickness, mm: 12,7	10,0	6,5	5,0	3,0	2,0	1,0
Air	− 50	20	20	15	15	10	10	5	5	15	15	10	10	10	5	5
	0	15	15	10	10	10	5	5	5	10	10	10	10	5	5	5
	50	15	15	15	10	10	5	5	5	10	10	10	10	10	5	5
	100	20	20	15	15	10	10	5	5	15	15	10	10	10	10	5
	150	25	20	15	15	10	10	10	5	15	15	15	10	10	10	5
	200	25	20	20	15	10	10	10	5	15	15	15	15	10	10	5
	250	25	25	20	15	10	10	10	5	20	15	15	15	10	10	5
Liquid	− 50	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	50	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	100	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	150	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	200	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	250	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

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