International Standard ISO 6942

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Clothing for protection against heat and fire — Method of evaluation of thermal behaviour of materials and material assemblies when exposed to a source of radiant heat

Vêtements de protection contre la chaleur et le feu — Méthode d'évaluation du comportement thermique de matériaux simples et d'assemblages de matériaux exposés à une source de chaleur radiante

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6942 was developed by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, and was circulated to the member bodies in May 1980.

It has been approved by the member bodies of the following countries :

Australia	Germany, F.R.	Romania
Austria	Hungary	South Africa, Rep. of
Belgium	Ireland	Spain
Canada	Israel	Sweden
Czechoslovakia	Italy	Switzerland
Egypt, Arab rep. of	New Zealand	
France	Poland	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Japan
United Kingdom

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Clothing for protection against heat and fire — Method of evaluation of thermal behaviour of materials and material assemblies when exposed to a source of radiant heat

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1 Scope and field of application

This International Standard specifies two complementary methods of evaluation of the thermal radiation behaviour of materials used for clothing for protection against radiant heat. These methods allow :

a) observation of the possible changes in the appearance of the material, and

b) determination of the heat transmission factor in the conditions specified in this International Standard.

The test conditions are conventional and, though the heat transmission factor reflects the efficiency of the materials, the sole aim of the tests described in this International Standard is to classify the materials. The results obtained are not necessarily applicable directly to practical working conditions.

The tests generally apply to a representative specimen of the layer(s) of fabric, or other materials making up the protective garment. They may also be applicable to specimens which constitute the whole of the garments worn (for example protective garments worn over workwear and underwear).

The methods involve the testing of materials exposed to high radiation while the air temperature remains close to ambient temperature. They are not applicable to testing materials at higher air temperatures.

2 Reference

ISO 139, *Textiles — Standard atmospheres for conditioning and testing.*

3 Definitions

3.1 heat transmission factor (*TF*) : A measure of the percentage of heat transmitted through a specimen exposed to a source of radiant heat. It is numerically equal to the ratio of the transmitted to the incident heat flux density.

3.2 specimen : Specimen consisting of one or several layers of fabric or other materials.

3.3 change in appearance of the specimen : All changes in the appearance of the material (shrinkage, formation of char, discoloration, scorching, glowing, melting, etc.).

4 Principle

4.1 Method A

A test sample is fixed to a supporting frame and exposed to a specific radiation level. Changes in the appearance of the sample are recorded.

4.2 Method B

The heat transmission factor (*TF*) of the test sample is measured under specified test conditions by measuring the incident and transmitted heat flux densities by means of a calorimeter of known characteristics on which the sample is mounted.

5 Apparatus

The test apparatus shall comprise :

Method A :

a) a metal supporting frame for the specimen (5.1);

b) a source of radiant heat (5.2);

c) a test frame (5.5).

Method B :

a) a source of radiant heat (5.2);

b) a receiving calorimeter (5.3);

c) a measuring device (5.4);

d) a test frame (5.5).

5.1 Metal supporting frame, for specimens for use in method A.

Dimensions in millimetres

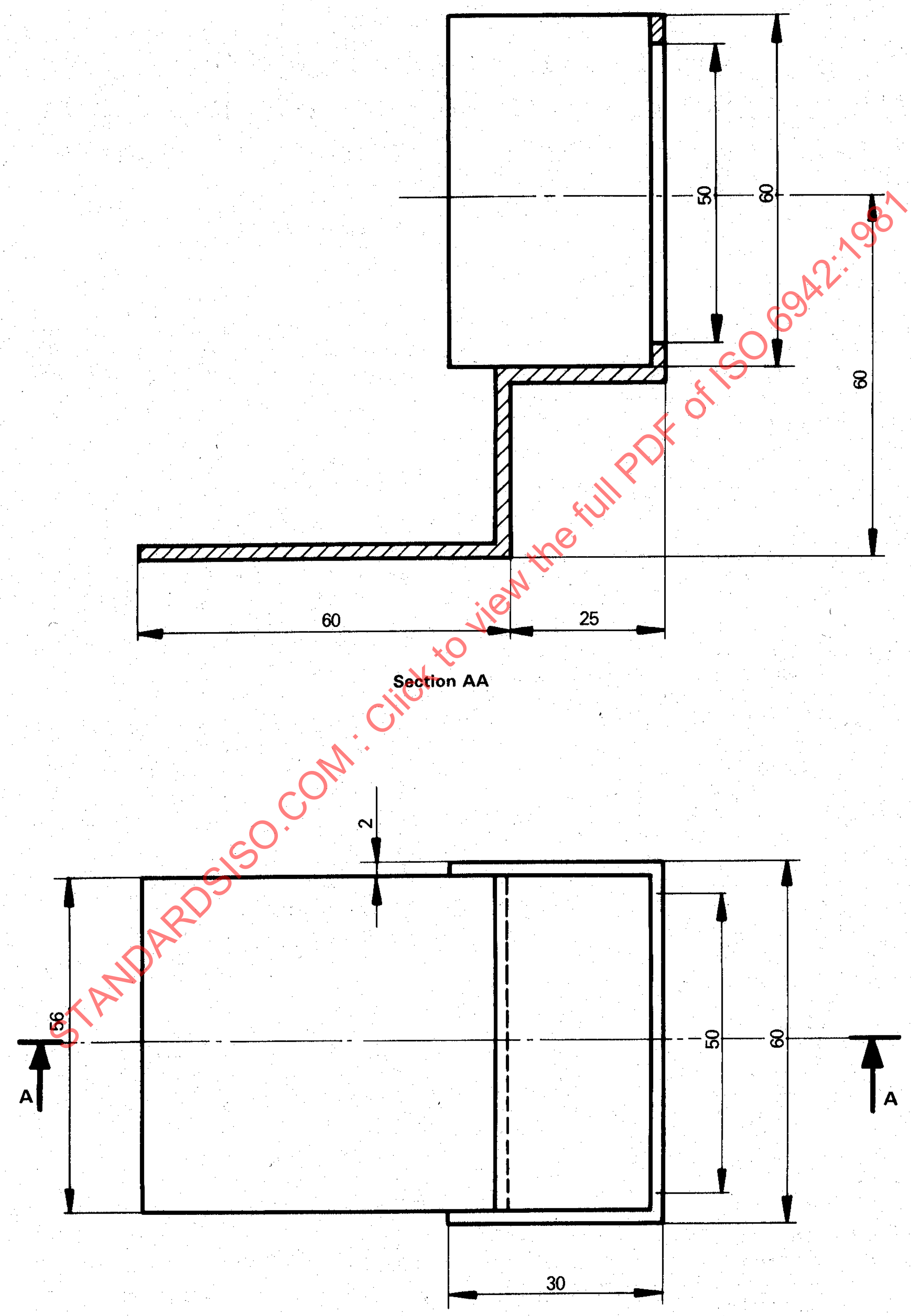

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Figure 1 — Metal supporting frame for the specimen (Method A)

5.2 Source of radiant heat comprising six silicon carbide heating rods, the technical specifications of which are as follows :

- total length : 356 mm;
- length of heating part : 178 mm;
- diameter : 7,9 mm;
- electrical resistance : 3,62 Ω ± 10 % at 1 071 °C.

These rods are placed in a support made of insulating, flame resistant material so that they are arranged horizontally and in the same vertical plane. Figure 2 shows the constructional details of the support and the arrangement of the heating rods, which shall be mounted very freely in the grooves of the support in order to avoid mechanical stress.

A diagram of the electricity supply for the heat source is shown in figure 3.

The six rods are arranged into two groups of three rods placed in series. The groups can either be connected in parallel or in series. The electrical connections of the heating rods shall be made carefully by means of aluminium strips. Precautions shall be taken to avoid short circuits between the rods.

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Dimensions in millimetres

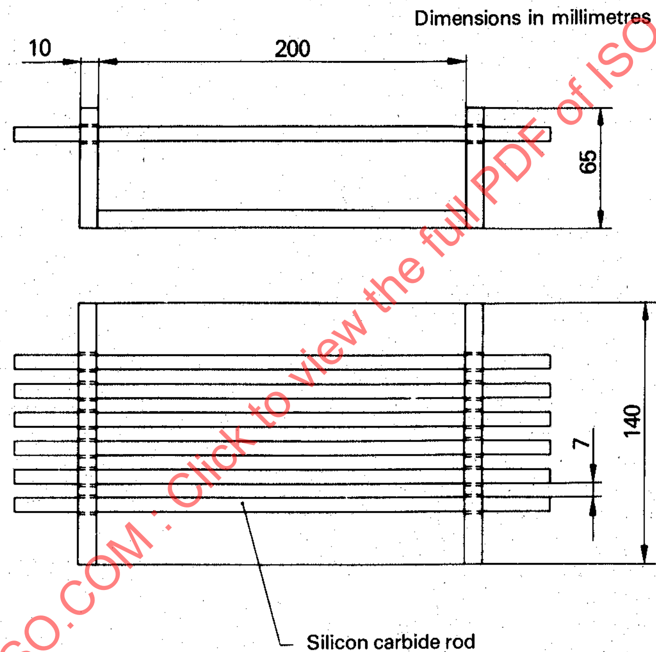

Figure 2 — Support for heating rods

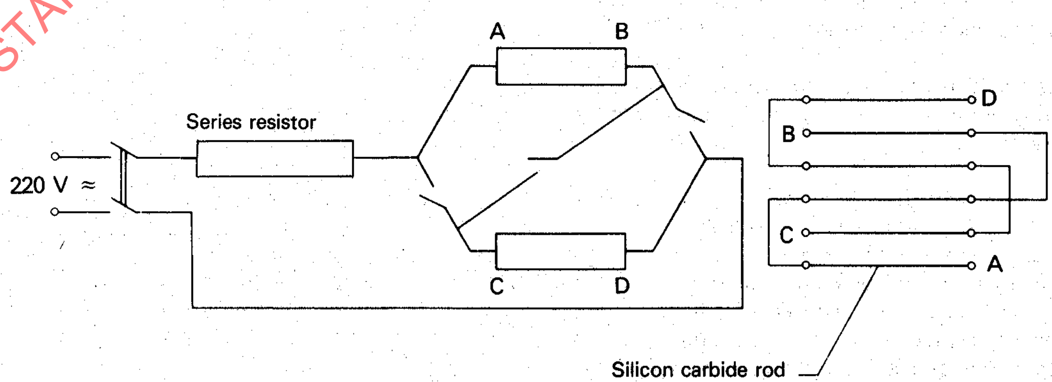

Figure 3 — Circuit diagram for heat source

An additional resistance, intended to limit the voltage supply to the heating rods is placed in series with the heat source. It is composed of two heating rods of silicon carbide in parallel, having the following technical specifications :

- total length : 270 mm;
- length of heating part : 96 mm;
- diameter of heating part : 7,9 mm;
- diameter of the ends : 13 mm;
- resistance : 2,4 Ω ± 10 % at 1 400 °C.

5.3 Receiving calorimeter comprising a block of pure aluminium of dimensions as given in figure 4.

In the aluminium block are set :

- two platinum resistance thermometers complying with the requirements of annex C;
- a heating coil consisting of a constantan resistance wire wound round an aluminium cylinder.

The dimensions of the heating coil are given in figure 5. The resistance of the constantan wire, of approximately 700 Ω, shall be measured to the nearest ± 1 %.

The thermometric probe and heating coil are sealed in the calorimeter (for example by means of ceramic glue) and the mass of the cylinder shall then be determined. The bore for the thermometric resistor probe, adapted to suit the required dimensions, shall be located as shown in figure 4. After connecting up the heating coil, the front surface of the calorimeter is machined to a radius of 130 mm and sanded.

The receiving calorimeter is insulated, except for the front surface, using flexible expanded polyurethane of density 40 kg/m^3 and thickness 20 mm. To prevent burning of the front side of the insulator, the expanded polyurethane shall be replaced over a length of 20 mm by insulating mineral fibre material of density 120 kg/m^3 as shown in figure 4.

The calorimeter and its insulating lagging are placed in a stand made of brass of thickness 1 mm as shown in figure 6.

The stand has two screws whose ends provide a stop for the rear surface of the calorimeter and prevent compression of the back of the insulator.

The stand is fixed on a base that slides between two slide bars fixed to the frame, so that the receiving calorimeter lies in the axis of the opening of the front shield of the frame. The longitudinal axis of the calorimeter shall be horizontal and perpendicular to the radiant source. During the test the calorimeter is kept in position by means of a stop. Figure 6 shows the arrangement of the various items. A device that does not adversely affect the insulating properties of the lagging shall be used for strict positioning of the calorimeter with respect to the frame. The position of the calorimeter shall be the same for all tests.

If the calorimeter is made exclusively of aluminium and its thermal losses are zero, the relation between the amount of heat absorbed, Q_a, expressed in joules, and the rise in temperature is as follows :

$$Q_a = mC_{Al}\Delta T$$

where

m is the mass of calorimeter, in kilograms;

C_{Al} is the heat capacity of aluminium in joules per kilogram kelvin;

ΔT is the rise in temperature of the calorimeter, in kelvins.

Dimensions in millimetres

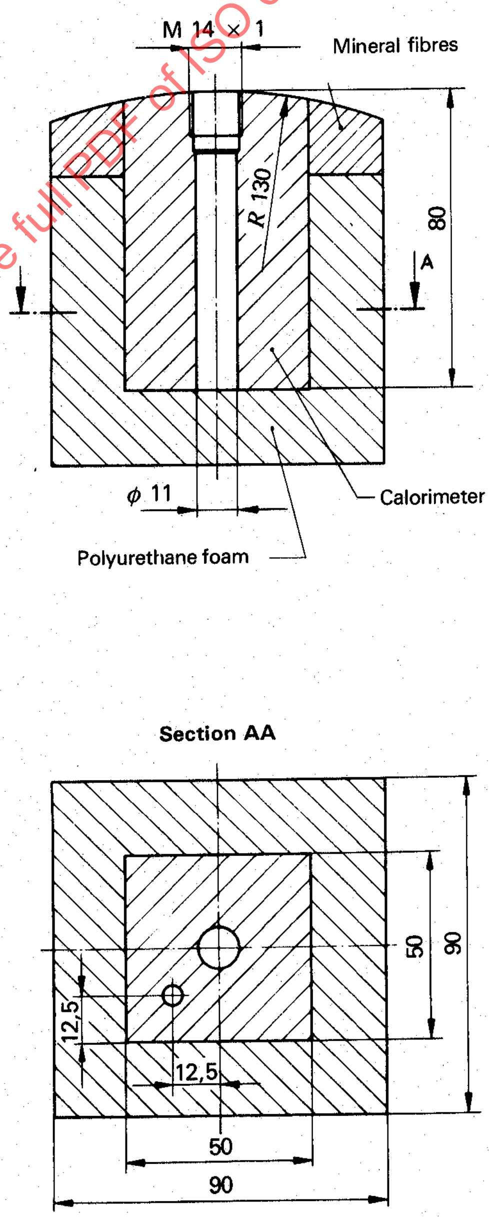

Figure 4 — Receiving calorimeter

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Dimensions in millimetres

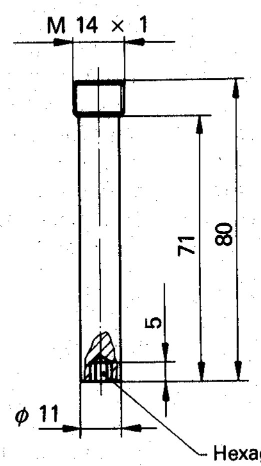

Figure 5 — Heating coil

Dimensions in millimetres

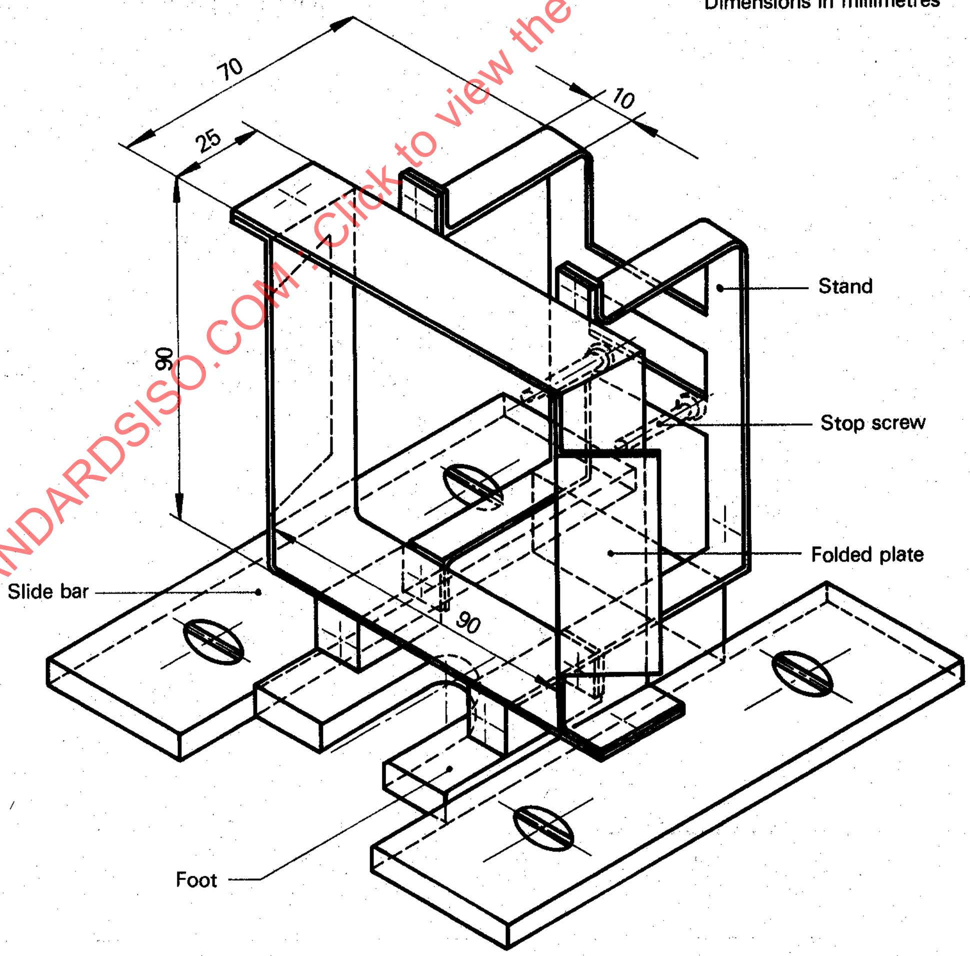

Figure 6 — Calorimeter stand

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The presence in the calorimeter of elements other than aluminium and the inevitable thermal losses make it necessary to introduce a correction factor K, approximately equal to unity, in the above formula.

The front surface of the calorimeter shall be insulated beforehand in the same way as the other surfaces. The calorimeter is then heated by means of its heating coil which is supplied with a constant current of about 150 mA until a temperature rise of about 10 K is obtained. The time of heating is measured. The quantity of heat dissipated in the calorimeter, Q_e, is given, in joules, by the formula

$$Q_e = RI^2t$$

where

R is the resistance of the heating coil, in ohms;

I is the supply current of the heating coil, in amperes;

t is the duration of heating, in seconds.

This amount of heat Q_e is compared with the amount of heat measured, $Q_a = mC_{Al}\Delta T$.

i.e. $K \stackrel{\text{def}}{=} \dfrac{Q_e}{Q_a}$.

To calculate Q_a, the rise in temperature ΔT is measured as follows.

The temperature variation curve when measuring Q_e is shown in figure 7 as the solid line. After heating has finished, the heat losses bring about a slow cooling of the calorimeter. It is necessary to prolong the straight lines for the initial and final temperatures, i.e. A to the right and E to the left. A perpendicular is dropped to the line prolonged from A, giving the two triangles ABC and CDE, of equal areas. The segment BD represents the rise in temperature ΔT to be introduced in the formula Q_a.

5.4 Measuring equipment, comprising :

5.4.1 A stabilized supply, capable of delivering a continuous current of 0,1 A at about 12 V.

5.4.2 A measuring bridge, allowing the conversion of the resistance of the thermometric probe into continuous voltage measured by a recorder. Annex B gives, for information, an example of a suitable measuring bridge.

5.4.3 A recording potentiometer, with 10 mV full scale deflection.

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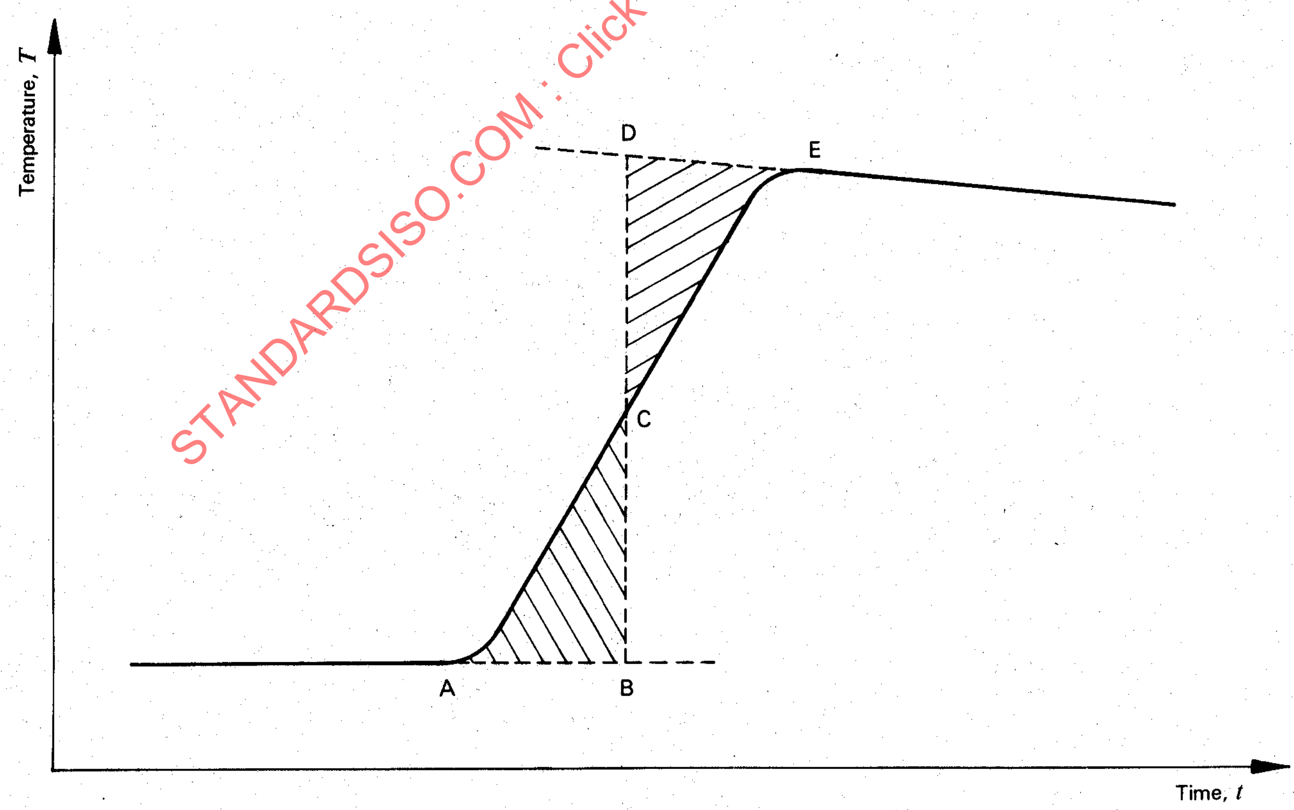

Figure 7 — Temperature variation curve

5.5 Frame, intended to support the calorimeter and the heat source and to shield the calorimeter from radiation during exposure periods.

The frame basically consists of two sheets of non-combustible board assembled as shown in figure 8.

The vertical surface of the frame is partially covered by a copper plate of thickness 2 mm, in which a square opening of sides 60 mm is made. This plate contains two vertical slide bars allowing the sliding of a movable screen made of copper. Copper pipes are welded on the vertical plate and the movable screen to ensure cooling by water circulation (see figure 9).

The screen is used to shield the calorimeter from the source of radiation before the test starts.

To reduce the heat absorbed by the movable screen, a sheet of aluminium foil is stuck onto the surface of the screen facing the heat source.

The heat source is supported and held at the appropriate distance by means of three threaded rods fixed to the front plate of the frame. When the heat source is at a distance from the frame, the strain shall be taken off the threaded rods by a supplementary device supporting the sources such as blocks placed beneath the rods. The slide bars for positioning the calorimeter and the device for tensioning the specimens are positioned on the horizontal part of the frame, as shown in figure 10.

The device for tensioning the specimen consists of two supports into each of which a spindle is slid. These spindles support and guide the wire connecting the specimen clamp and its 200 g tensioning mass (see figure 10). Each layer making up the sample is tensioned by means of an individual tensioning thread.

The opening made in the vertical plate shall be sufficiently large so that the calorimeter, its insulating lagging and the specimen cannot, when in a normal position, come into contact with the plate.

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Dimensions in millimetres

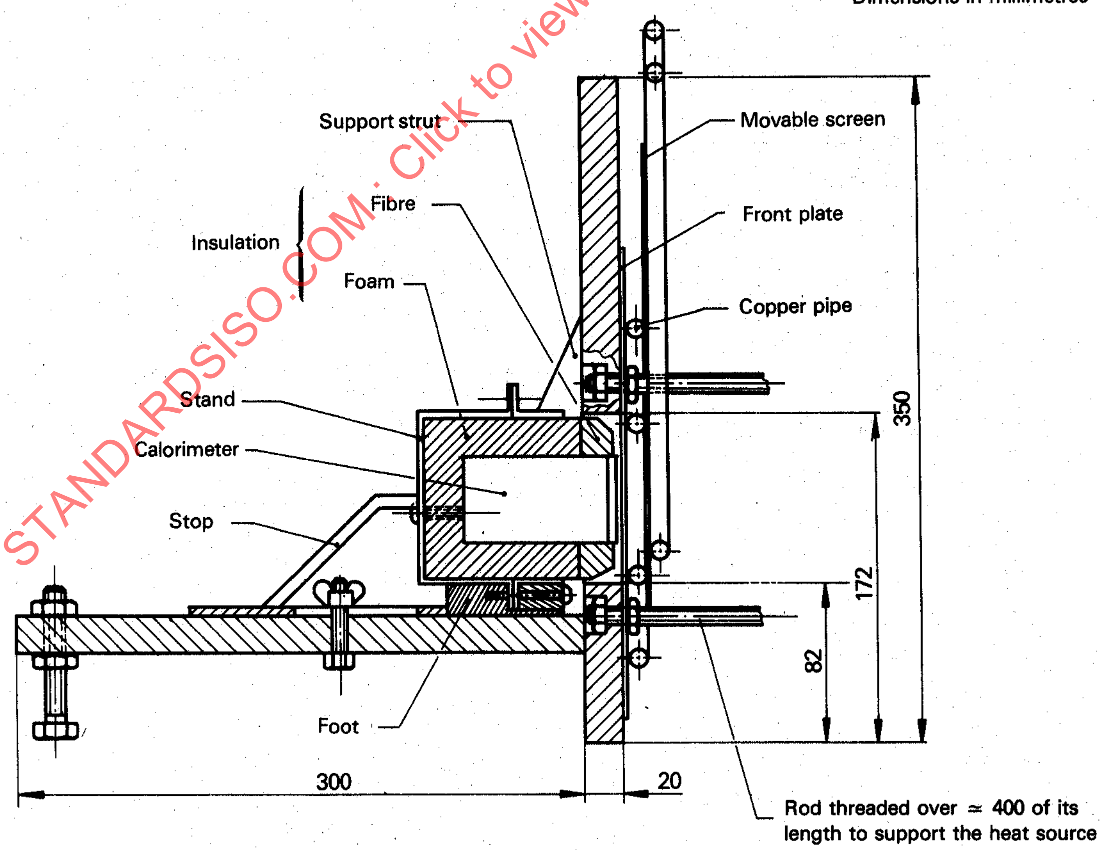

Figure 8 — Supporting frame for calorimeter and heat source (Methods A and B)

Dimensions in millimetres

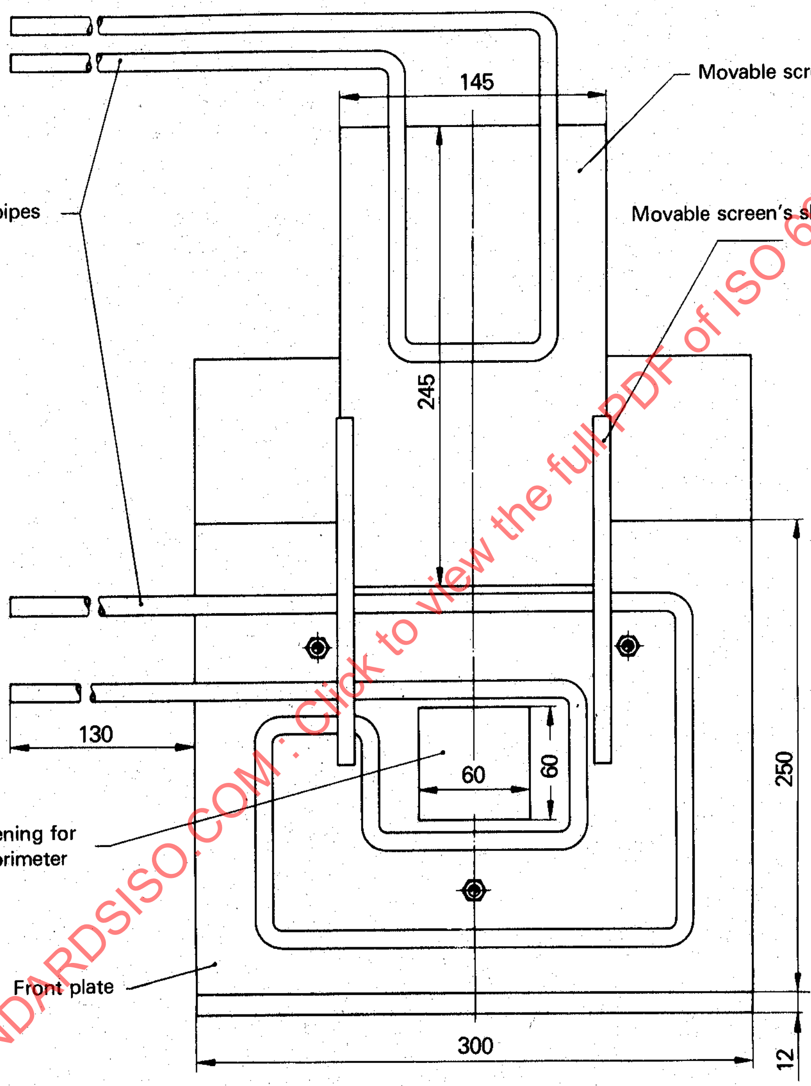

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Figure 9 — Cooling system

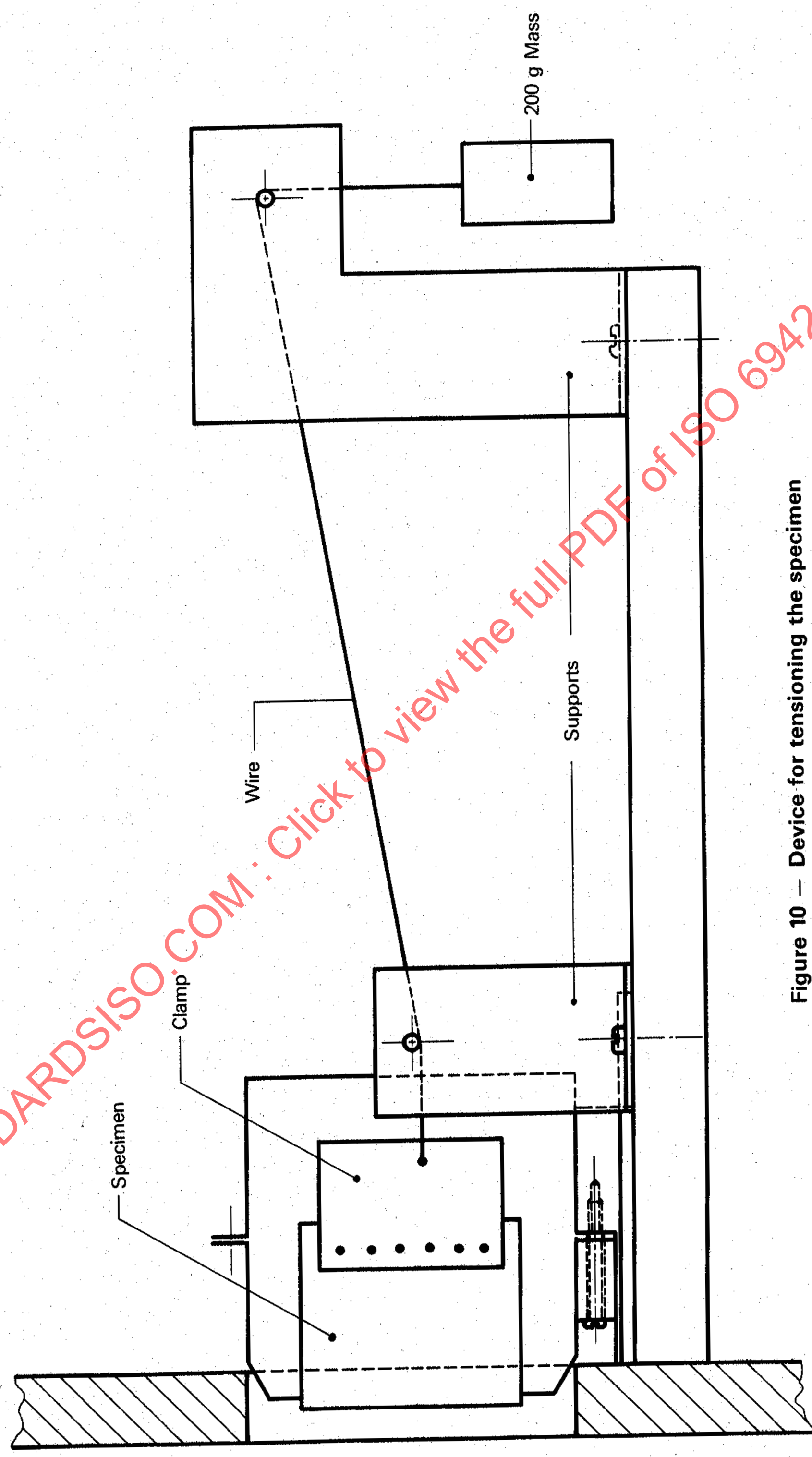

Figure 10 — Device for tensioning the specimen

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6 Specimens

It is recommended that each test (method A and method B) is performed using five specimens per heat flux level, three being the minimum number.

The specimens shall have the dimensions 230 mm × 70 mm and shall be taken from points more than 20 mm from the edge of the piece of material, in an area free from defects. Composite specimens shall reproduce the arrangement in which the layers are used in practice.

Should the supplier of the material fail to indicate which is the external surface of the material and it is impossible to distinguish external from the internal surface, the test shall be performed on each side.

7 Conditioning and testing atmospheres

7.1 Conditioning atmosphere

Before testing, the specimens shall be conditioned for at least 24 h at a temperature of 20 ± 2 °C and a relative humidity of 65 ± 2 % (see ISO 139).

7.2 Testing atmosphere

The tests shall be carried out in a room free of air currents and protected from any system that is capable of producing stray heat radiation that could be recorded by the calorimeter.

When tests are carried out with an incident heat flux density equal to or less than 5 kW/m^2, the temperature in the test room shall be between 18 and 22 °C.

When tests are carried out with an incident heat flux density greater than 5 kW/m^2, the temperature in the test room shall be between 15 and 25 °C.

8 Test conditions

The levels of incident heat flux density are chosen from :

5-10-20-40 and 80 kW/m^2.

Tests with methods A and B are carried out independently of each other but it is recommended that the test with method A is carried out first.

9 Test methods

9.1 Method A

Place the radiant source (5.2) at a distance corresponding to the chosen incident heat flux (see 9.2.2) and wait until a steady state is attained.

Stretch the specimen onto the metal frame (5.1) as shown in figure 10 and place this in the opening of the front plate of the frame described in 5.5. Withdraw the movable screen and expose the specimen to the chosen incident flow for 3 min (see note 1).

Examine the surface of the specimen. All changes in appearance of the material (shrinkage, formation of char, discoloration, scorching, glowing, melting, etc.) shall be given in the test report (see note 2).

This test is not to be replaced by the observations of changes in appearance of the specimens observed during the test with method B.

NOTES

1 This standardized test of exposure for 3 min is compulsory for all materials tested.

However, independent of these 3 min of exposure, the supplier and the user may agree to carry out additional tests for either a longer or a shorter time of exposure, depending on the proposed use of the protective clothing. The description and results of these additional tests shall be given in the test report.

2 A change in appearance of the specimen does not necessarily indicate that the thermal resistance of the material is insufficient but perhaps that the change is due to a particular treatment or structure of the material for increasing its thermal resistance.

9.2 Method B

9.2.1 Preliminary measures

Arrange the radiant source (5.2) so that the radiation is emitted horizontally. Place the movable screen in the slide bars of the frame (5.5) and ensure that it cannot come into contact with the source or the calorimeter. Place the calorimeter (5.3) on the frame after blackening the front non-insulated surface with paint having a known absorption coefficient.[1)]

Connect the parts of the measuring equipment (5.4) and check the balancing of the measuring bridge. Supply the radiant source with current.

Ensure that the radiant source has reached its steady state. Check if necessary with a voltmeter. Check the cooling of the frame's front plate and movable screen. This is satisfactory if, with the movable screen and the blackened calorimeter on the frame, the temperature of the calorimeter does not rise by more than 1 K in 10 min.

NOTE — The blackening on the front surface of the calorimeter should be renewed after at least every 20 tests or as soon as a deposit of char is visible. This blackening should be done after removing the previous layer of paint with a suitable solvent.

9.2.2 Regulation of incident heat flux density

After carrying out the preliminary measures, select the rate of travel of the temperature recorder. Then withdraw the movable screen and, after a period of exposure exceeding 60 s, return it

1) Paint of this kind is obtainable commercially. Details may be obtained from the Secretariat of ISO/TC 94 or from the ISO Central Secretariat.

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to its position. As a function of time the temperature recorder shows a curve similar to that in figure 7. Note the slope $\Delta T/\Delta t$ of the straight part of the curve. Calculate the incident heat flux density q_0, in watts per square metre, from the following equation :

$$q_0 = \frac{m\ C_{Al}\ K}{S\ \alpha_{cal}} \times \frac{\Delta T}{\Delta t}$$

where

m is the mass of the calorimeter in kilograms;

C_{Al} is the heat capacity of the aluminium, i.e. 0,9 J/(kg·K);

K is the calorimeter correction factor;

S is the projection, in a plane perpendicular to the radiation, of the front surface of the calorimeter, i.e. $2{,}5 \times 10^{-3}$ m²;

α_{cal} is the coefficient of absorption of the front surface of the calorimeter (for example : 0,93);

$\frac{\Delta T}{\Delta t}$ is the slope of the straight part of the calorimeter temperature rise curve as a function of time, expressed in kelvins per second.

Delays caused by the slowness of response of the thermometric resistor and the thermal inertia of the material of the calorimeter are such that the slope of the straight part of the curve in figure 7 is only accurate after the 40th second of exposure. Therefore, so that the slope is measured over a sufficiently long part of the curve it is necessary for the period of exposure to be greater than 60 s.

By varying the distance between the radiant source and the calorimeter (reducing it if q_0 is less than, and increasing it if q_0 is more than the incident heat flux density desired), the incident heat flux density can be adjusted to the required level.

Allow the calorimeter to cool to 20 ± 5 °C.

NOTE — It is recommended to check the stability of the supply of voltage of the radiant source. If the supply voltage is fluctuating, the incident heat flux density shall be measured before each measurement of the heat flow transmitted.

9.2.3 Measurement of transmitted heat flux density

Carry out this measurement immediately after measuring the incident heat flux and cooling the calorimeter.

Fix one end of the specimen at the position provided on the calorimeter stand by means of a clip. With the movable screen in place, place the calorimeter on the frame.

The thickness of multi-layer specimens may be considerable. In order to maintain the required distance between the heat source and the external surface of the specimen, the calorimeter shall be moved back by a distance equal to the thickness of the specimen.

Fasten the free end of each layer of the specimen.

The tension of the specimen is fixed at 2 N. In the case of multilayer materials the tension is applied to each layer.

Select the rate of travel of the recording device; withdraw the movable screen and record the temperature rise as a function of time. The period of exposure shall be greater than 60 s.

Note the slope $\Delta T/\Delta t$ of the straight part of the curve, counting from the 40th second of exposure.

Calculate the transmitted heat flux density, q_c, in watts per square meter from the formula

$$q_c = \frac{m\ C_{Al}\ K}{S} \times \frac{\Delta T}{\Delta t}$$

where m, C_{Al}, K, S, ΔT and Δt are as shown in 9.2.2.

Allow the calorimeter to cool to 20 ± 5 °C before any further tests.

9.2.4 Observation of the behaviour of the specimen

Observe for any change in the specimen's appearance (shrinkage, formation of char, scorching, glowing, melting) and note down in the test report.

9.2.5 Expression of results

The heat transmission factor, TF_x, for each level of incident heat flow is given by the formula

$$TF_x = \frac{q_c}{q_0}$$

where

TF_x denotes the transmission factor for an incident flux density of x kW/m²;

q_c is the transmitted heat flux density for an incident heat flux density of q_0.

10 Test report

The test report shall contain the following particulars :

a) a statement as follows :

"These results have been obtained by a test method aimed solely to classify the material and are not necessarily applicable directly to practical working conditions."

b) reference to this International Standard;

c) a description of the test material and, if possible, its generic name(s);

d) identification reference of the material;

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e) the temperature and humidity of the testing atmosphere;

f) the number of specimens tested for each level of incident heat flux;

g) the value of incident and transmitted heat flux for each specimen tested;

h) the value of heat transmission factor (*TF*), and the incident flux for which it was determined, for each specimen which shall be immediately followed by the letter "C" if any of the specimens has shown any change in appearance during the test method A;

j) the average value of the heat transmission factor (*TF*), and the incident flux for which it was determined, of each material or assembly of materials which shall be followed immediately by the letter "C" if any of the specimens has shown any change in appearance during the test with method A;

k) the value of the standard deviation of the heat transmission factor (*TF*);

m) the description of any change in appearance of the specimens during the test with method A;

n) the description of any change in appearance of the specimens during the test with method B;

p) all incidents observed during the tests likely to cause any hazard;

q) the date of testing.

The following additional information may also be given in the test report :

r) the total increase in temperature of the calorimeter measured from the beginning of the specimen exposure;

s) the total exposure time of the specimen to the radiation;

t) the range of times and temperatures used for calculating q_0 and q_c;

u) the distance between the front face of the calorimeter and the axial plane of the heating element;

v) other quantitative tests which have been carried out to show the effect on other properties, any changes being represented by the letter "C".

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Annex A

Measuring the additional temperature rise of the block-calorimeter

Measurement of the additional temperature rise of the calorimeter, after exposure to radiant flow, may give an approximate idea of the thermal inertia of the material tested.

The additional temperature rise reflects the thermal inertia of the calorimeter and the materials tested. Consequently, it only allows a comparison of materials but should not be used for determining the response time of the materials.

When measuring the density of flow transmitted (9.2.3), the additional temperature rise of the calorimeter is measured as follows :

— mark on the recording the temperature of the receiver at the moment of closing of the movable screen;

— record the maximum temperature attained when stabilizing the temperature of the receiver;

— the additional temperature rise is equal to the difference between these two temperatures.

For each level of density of incident heat flux density, the test report shall mention :

a) the individual values found for each of the specimens;

b) the average of the individual values.

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Annex B

Temperature measuring bridge

This annex gives an example of the temperature measuring bridge which can be used in the test described in this International Standard.

The measuring bridge is intended to convert the resistance of the thermometric probe to direct current measurable by the potentiometric recording device. Figure 11 shows the diagram of the electrical measuring bridge.

The resistance of 215,6 Ω, which corresponds to that of a thermometric probe with two measuring resistors raised to 20 °C is coiled. The 10 Ω and 5 kΩ potentiometers are precision potentiometers. The supply voltage applied to the terminals E and F shall be approximately 12 V (d.c). The recording device is connected to the diagonal of the bridge (terminals G and H). Figure 12 shows the arrangement for connection of the parts of the measuring device.

Balancing of the bridge should preferably be done before the thermometric probe is mounted in the calorimeter. The supply voltage used for balancing shall be kept for all the tests. If not the bridge shall be rebalanced.

To carry out balancing, the parts of the measuring device are connected as shown in figure 12 and the thermometric probe is raised to a temperature of 20 ± 0,1 °C. The output voltage of the measuring bridge is reduced to zero by the 10 Ω potentiometer. The thermometric probe is then raised to a temperature of 40 ± 0,1 °C. The output voltage of the measuring bridge is adjusted to 10 mV by means of the 5 kΩ potentiometer. A variation in voltage of 0,5 mV/°C is thus obtained within the temperature range 20 to 40 °C.

It is advisable to check the balancing of the measuring bridge prior to each test. To do this, the resistance of the thermometric probe, which is raised to 20 °C and 40 °C, can be simulated by means of a resistance box.

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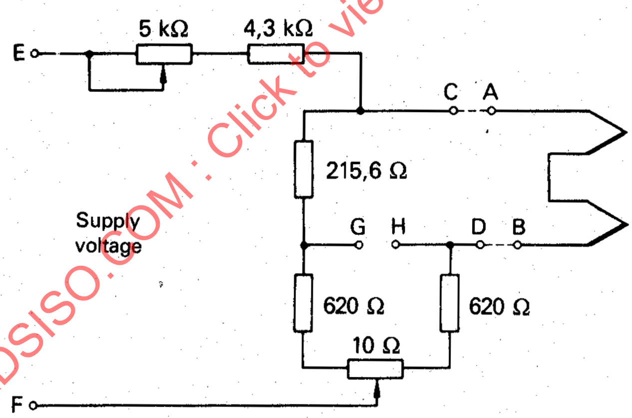

Figure 11 — Diagram of the electrical measuring bridge

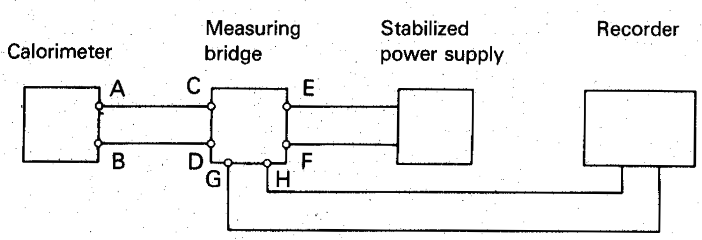

Figure 12 — Arrangement for connection of the parts of the measuring device