
**Refractory materials — Determination of
thermal conductivity —**

Part 1:
**Hot-wire methods (cross-array and
resistance thermometer)**

*Matériaux réfractaires — Détermination de la conductivité thermique —
Partie 1: Méthodes du fil chaud («croisillon» et «thermomètre à
résistance»)*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 8894-1 was prepared by Technical Committee ISO/TC 33, *Refractories*.

This second edition cancels and replaces the first edition (ISO 8894-1:1987), which has been revised to include a hot-wire “resistance thermometer” method, as well as the hot-wire “cross-array” method and to harmonize the text with that of EN 993-14:1998, *Methods of testing dense shaped refractory products — Part 14: Determination of thermal conductivity by the hot-wire (cross-array) method*, prepared by CEN/TC 187.

ISO 8894 consists of the following parts, under the general title *Refractory materials — Determination of thermal conductivity*:

- *Part 1: Hot-wire methods (cross-array and resistance thermometer)*
- *Part 2: Hot-wire method (parallel)*

Refractory materials — Determination of thermal conductivity —

Part 1: Hot-wire methods (cross-array and resistance thermometer)

1 Scope

This part of ISO 8894 describes the hot-wire methods (“cross-array” and “resistance thermometer”) for the determination of the thermal conductivity of non-carbonaceous, dielectric refractory products and materials.

This methods are applicable to dense and insulating refractories (shaped products, refractory castables, plastic refractories, ramming mixes, powdered or granular materials) with thermal conductivity values less than 1,5 W/m·K (“cross-array”) and less than 15 W/m·K (“resistance thermometer”) and thermal diffusivity values less than 5×10^{-6} m²/s.

Thermal conductivity values can be determined at a room temperature up to 1 250 °C. The maximum temperature (1 250 °C) can be reduced by the maximum service limit temperature of the refractory, or by the temperature at which the refractory is no longer dielectric.

NOTE 1 In general, it is difficult to make accurate measurements on anisotropic materials and the use of this method for such materials can be agreed between the parties concerned.

NOTE 2 The thermal conductivity of products with a hydraulic or chemical bond can be affected by the appreciable amount of water that is retained after hardening or setting and is released on firing. These materials might therefore require pre-treatment; the nature and extent of such pre-treatment and the period for which the test piece is held at the measurement temperature as a preliminary to carrying out the test, are details that are outside the scope of this part of ISO 8894 and are agreed between the parties concerned.

NOTE 3 The measurement of thermal conductivity is not sufficiently uncomplicated for an engineer to expect to achieve correct results without having particular work experience and if the work is based exclusively on this standard. Sufficient experience of measuring temperatures and laboratory skills are imperative.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1 thermal conductivity

λ

density of heat flow rate divided by the temperature gradient

NOTE Thermal conductivity is expressed in watts per metre kelvin (W/m·K).

2.2 thermal diffusivity

a

thermal conductivity divided by the bulk density times the specific heat capacity

NOTE 1 $a = \lambda / \rho \cdot c_p$

where:

- λ is the thermal conductivity;
- ρ is the bulk density;
- c_p is the specific heat capacity at constant pressure per weight.

NOTE 2 Thermal diffusivity is expressed in units of square metres per second (m^2s^{-1}).

2.3 power

P
rate of energy transfer

NOTE Power is expressed in watts (W).

3 Principle

Both the hot-wire “cross-array” and “resistance thermometer” methods are dynamic measuring procedures based on the determination of the temperature increase against time of a linear heat source (hot wire) embedded between two test pieces which make up the test assembly.

The test assembly is heated in a furnace to a specified temperature and maintained at that temperature. Further local heating is provided by a linear electrical conductor (the hot wire) that is symmetrically embedded in the test assembly and carries an electrical current of known power that is constant in time and along the length of the test pieces.

The increase in temperature as a function of time follows a logarithmic law, and is measured and recorded from the moment the local heating current is switched on. The thermal conductivity of the test pieces is calculated using the rate of temperature increase and the power input.

For the “cross-array” method, the temperature increase is measured using a thermocouple that is welded to the hot wire at its centre. The thermocouple leads are perpendicular to the hot wire.

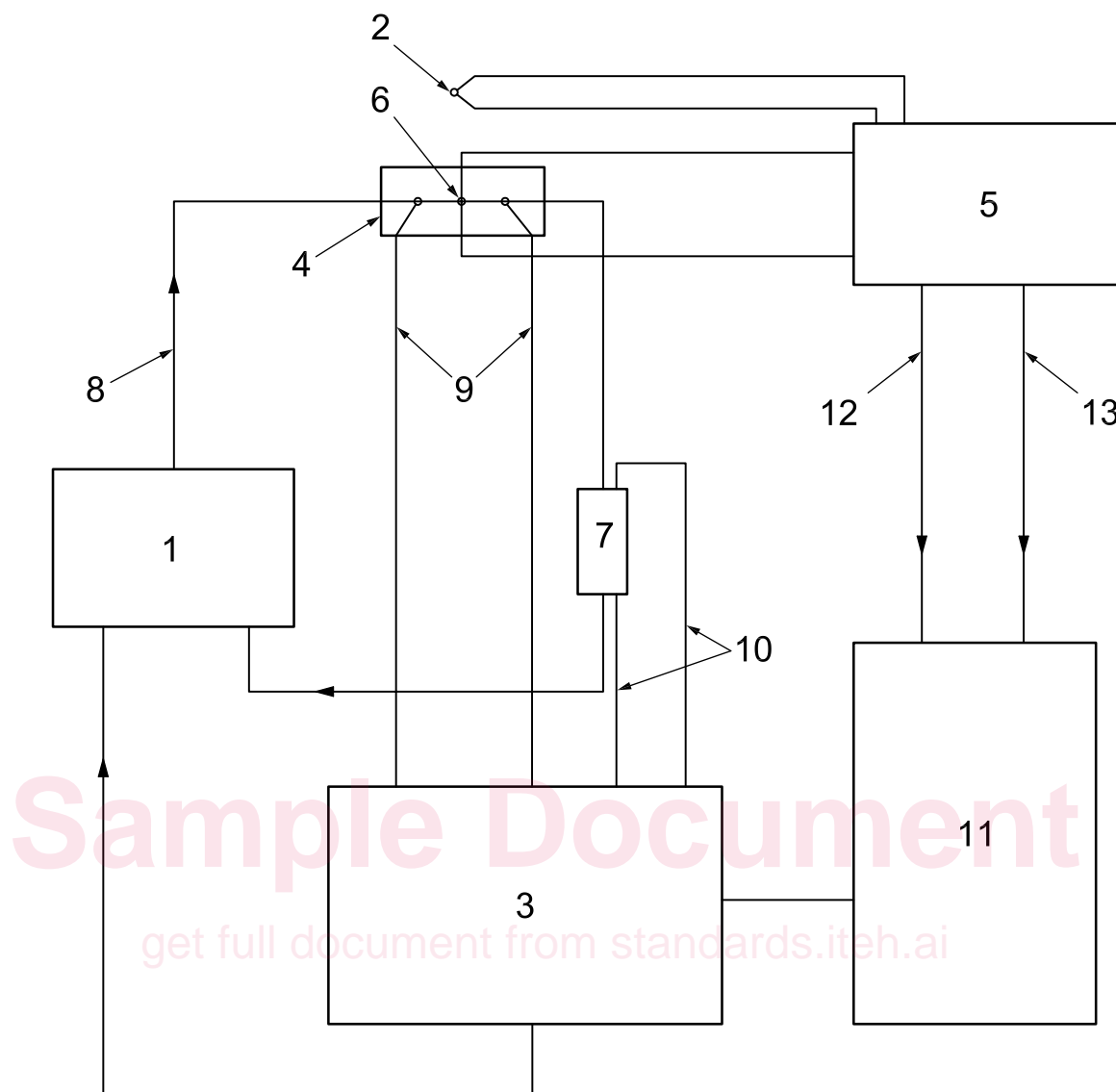
For the “resistance thermometer” method, the temperature increase is measured by using the hot wire itself as both heat source and temperature sensor. An integral temperature measurement of the hot wire is carried out over the length between the voltage taps. The change in resistance of this part of the hot wire is determined. From these data, its temperature increase is calculated. The mathematical procedure is described in Annex A.

4 Apparatus

NOTE A block diagram of a suggested test apparatus for the “cross-array” method is shown in Figure 1 and for the “resistance thermometer” method in Figure 2.

4.1 Furnace, electrically heated, capable of taking one or more test assemblies (see 5.1) up to the required maximum test temperature. The temperature at any two points in the region occupied by the test pieces shall not differ by more than 10 K. The temperature measured on the outside of the test assembly during a test (of duration about 15 min) shall not vary by more than $\pm 0,5$ K, and shall be known with an accuracy of ± 10 K.

4.2 Hot wire, preferably of platinum or platinum-rhodium, with a minimum length equivalent to that of the test piece and a diameter not more than 0,5 mm. Both ends of the hot wire are attached to the power supply (4.4). Leads outside the assembly shall consist of two or more tightly twisted wires of 0,5 mm diameter. The current lead connections external to the furnace shall be made of heavy gauge cable.

**Key**

- | | |
|--|---|
| 1 hot-wire power supply; a.c. source 1 kHz | 8 heating circuit |
| 2 reference thermocouple T_r | 9 voltage taps |
| 3 hot-wire power control unit | 10 current measurement |
| 4 test assembly | 11 data acquisition system and computer |
| 5 cold junction of thermocouples | 12 absolute signal (T_i) |
| 6 measurement thermocouple T_i | 13 difference signal ($T_i - T_r$) |
| 7 shunt | |

Figure 1 — Block diagram of apparatus for “cross-array” method