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Metallic and other inorganic coatings — Determination of thermal conductivity of thermal barrier coatings

*Revêtements métalliques et autres revêtements inorganiques —
Détermination de la conductivité thermique des revêtements
barrières thermiques*

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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.

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 107, *Metallic and other inorganic coatings*.

Introduction

Thermal barrier coatings are highly advanced material systems. They are generally applied to surfaces of hot-section components made of nickel or to cobalt-based superalloys, such as combustors, blades, vanes of power-generation gas turbines in thermal power plants and aero-engines operated at elevated temperatures.

The function of these coatings is to protect metallic components for extended periods at elevated temperatures by employing thermally insulating materials which can sustain an appreciable temperature difference between load bearing alloys and coating surfaces. These coatings permit the high-temperature operation by shielding these components, thereby extending their lives.

Although thermal conductivity is one of the most important properties of thermal barrier coatings, the existing ISO standard (ISO 18755:2005) includes only the method for determining the thermal diffusivity of monolithic ceramics, regarding the heat conduction in thermal barrier coating.

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Metallic and other inorganic coatings — Determination of thermal conductivity of thermal barrier coatings

1 Scope

This International Standard specifies the method for determining the thermal conductivities of thermal barrier coatings consisting of metallic bond coats and ceramic top coats, in a direction normal to the coating surface, at room temperature.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

ISO 18755:2005, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of thermal diffusivity of monolithic ceramics by laser flash method*

EN 821-3, *Advanced technical ceramics — Monolithic ceramics. Thermophysical properties — Part 3: Determination of specific heat capacity*

ASTM E1269-11, *Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry*

3 Terms and definitions

For the purpose of this standard, the terms and definitions given in ISO 18755:2005 and the following apply.

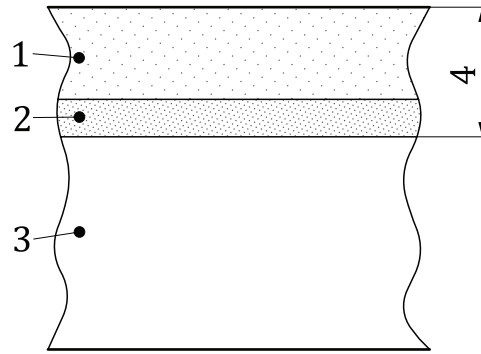
3.1

thermal barrier coating

TBC

two-layer coating consisting of a metallic bond coat (BC) and a ceramic top coat (TC), in order to reduce heat transfer from outside of the top coat through the coating to the substrate

Note 1 to entry: See [Figure 1](#).



Key

- 1 top coat (TC)
- 2 bond coat (BC)
- 3 substrate
- 4 thermal barrier coating (TBC)

Figure 1 — Diagrammatic view of a section of TBC

[SOURCE: ISO 14188:2012, definition 3.1, modified]

**3.2
apparent thermal diffusivity**

thermal diffusivity of the specimens [substrate with bond coat (BC) and substrate with thermal barrier coating (TBC)] in a direction normal to the coating surface

**3.3
normalized temperature rise**

$$T(t)/\Delta T$$

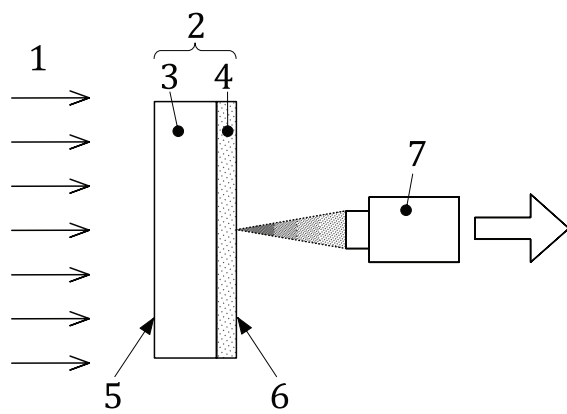
value which is determined by dividing the difference between the temperature of the specimen rear surface after the pulse heating and the temperature of the specimen rear surface before the pulse heating by the difference between the maximum temperature of the specimen rear surface and the temperature of the specimen rear surface before the pulse heating

$$\frac{T(t)}{\Delta T} = \frac{T_1(t) - T_0}{T_{\max} - T_0}$$

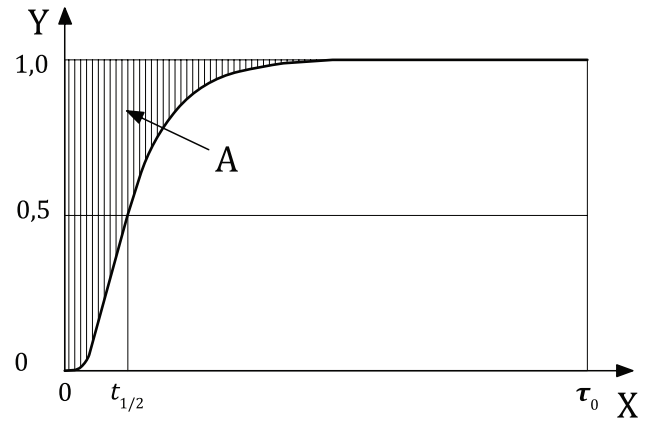
where

- $T_1(t)$ is temperature of specimen rear surface after pulse heating by a flash method;
- t is time;
- T_0 is temperature of the specimen rear surface before pulse heating;
- T_{\max} is maximum temperature of specimen rear surface.

Note 1 to entry: See [Figure 2](#).



a) Flash method



b) Temperature-rise curve under ideal conditions

Key

1	pulse heating	X	time (s)
2	specimen	Y	normalized temperature rise $T(t) / \Delta T$
3	substrate	A	areal heat diffusion time (s)
4	TBC		
5	front surface		
6	rear surface		
7	infrared radiometer		

Figure 2 — Flash method and temperature-rise curve under ideal conditions**3.4 temperature-rise curve**

curve which shows the variation in the normalized temperature rise of the specimen rear surface with time

Note 1 to entry: See the thick solid line in [Figure 2b](#).

3.5 half rise-time

$t_{1/2}$

time required for the normalized temperature rise to reach 0,5 in the temperature-rise curve

Note 1 to entry: See [Figure 2b](#).

3.6 areal heat diffusion time

A

area with time-dimension which is bordered by the horizontal line at the height of the maximum temperature-rise and by the temperature-rise curve

Note 1 to entry: See [Figure 2b](#).

3.7 heat diffusion time

τ_0

time period beginning with pulse heating of the specimen front surface until time at which the specimen temperature becomes uniform

$$\tau_0 = \frac{d^2}{\alpha}$$

where

- τ_0 is heat diffusion time (s);
- d is thickness of specimen (m);
- α is thermal diffusivity (m²/s).

Note 1 to entry: See [Figure 2b](#).

4 Principle

Thermal conductivities of the substrate, BC, and TC are determined according to calculations using the thermal diffusivities, specific heat capacities and bulk densities. The fundamental procedures are shown in [Figure 3](#).

The fundamental procedures for determining the thermal diffusivities of the substrate, BC, and TC consist of the measurement of temperature-rise curves of three types of specimens (substrate, substrate with BC, and substrate with TBC) by a flash method, and of calculations. The thermal diffusivities of the BC and TC are obtained by applying a multi-layer analytical model to the temperature-rise curves.

The specific heat capacities and bulk densities of the substrate, BC, and TC are measured separately.

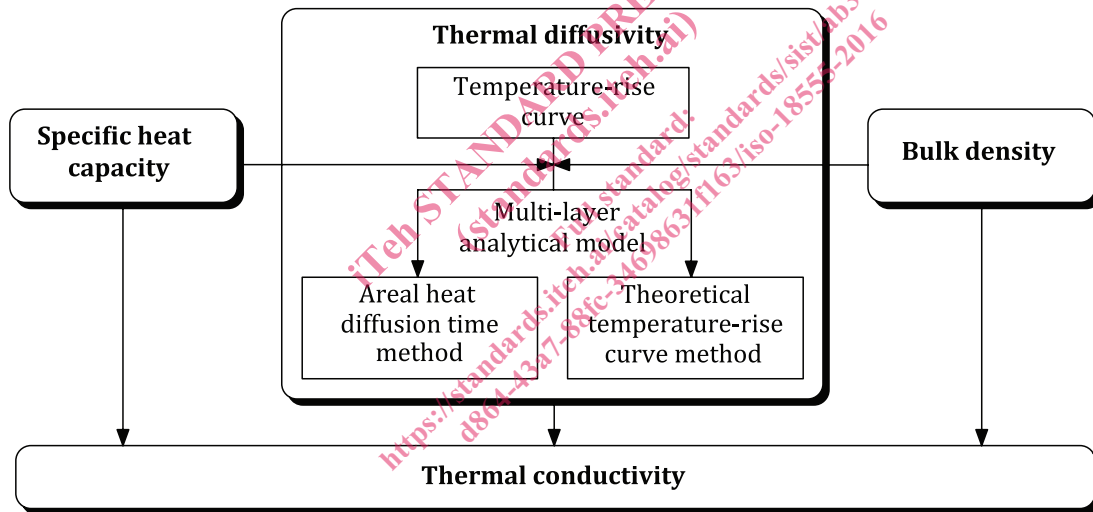


Figure 3 — Fundamental procedures for determining thermal conductivity

5 Apparatus for measuring thermal diffusivity

An example of the apparatus for measuring the thermal diffusivity is schematically shown in [Figure 4](#).

The apparatus consists of the following.

- 5.1 Pulse heating light source.
- 5.2 Data recorder.
- 5.3 Measurement circuit.
- 5.4 Infrared radiometer.