

Methods of testing Refractory materials —

Part 10: Investment casting shell mould systems —

Section 10.2: Determination of permeability and standard air flow capacity at elevated temperatures

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Committees responsible for this British Standard

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- British Ceramic Research Ltd.
- British Industrial Ceramic Manufacturers' Association
- British Steel Industry
- Refractories Association of Great Britain
- Refractory Contractors' Association
- Society of Glass Technology

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Investment Casting Trade Association
- Department of Trade and Industry (National Engineering Laboratory)
- Institute of British Foundrymen

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Foreword

This Section of BS 1902-10 has been prepared under the direction of the Refractory Products Standards Policy Committee. It is one of two Sections covering the testing of investment casting shell mould systems, as follows.

- *Section 10.1: Determination of resistance to deformation at elevated temperatures;*
- *Section 10.2: Determination of permeability and standard air flow capacity at elevated temperatures.*

To ensure the quality of castings manufactured by the investment casting process, the moulds used should have sufficient air flow capacity to obtain complete mould fill during casting. As the metal is poured into the mould, entrapped air will be expelled through the mould walls to be replaced by the molten metal. Low air flow capacity will restrict this action and may result in incomplete filling of the mould.

The significance of the values of standard air flow capacity (which is dependent on mould thickness) and permeability (which is independent of mould thickness) on the quality of the final casting will vary depending on, for example, the geometry of the mould, the temperature of the metal, the metalostatic head and the alloy to be cast. Generally speaking, the higher the standard air flow capacity and permeability the better, as long as other mould properties such as resistance to deformation are not adversely affected.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 14, an inside back cover and a back cover.

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1 Scope

This Section of BS 1902-10 describes a method for determining the standard air flow capacity of investment casting shell moulds, and the inherent permeability of the shell material, at elevated temperatures.

2 Definitions

For the purposes of this Section of BS 1902-10 the following definitions apply.

2.1

permeability

a measure of the ability of a material to allow air to pass through it which is the ratio of volumetric flowrate to the pressure gradient causing flow, at a given temperature

NOTE 1 The value calculated is corrected for the viscosity of air and the geometry of the test piece.

NOTE 2 This definition of permeability covers any fluid, but it is assumed that, in the context of investment casting, this fluid will predominantly be air.

2.2

air flow capacity

a measure of the volumetric flowrate of air passing through a given shell mould at a given temperature

2.3

standard air flow capacity (SAF)

a measure of the volumetric flowrate of air passing through a standard shell mould at a fixed gauge pressure of 10 kN/m² (1.45 psig) at a given temperature

3 Principle

The apparatus records the flow of air through a shell mould sample of known dimensions under a known pressure difference and at a given temperature. This information is used to calculate the permeability and the standard air flow capacity of the shell mould in question.

4 Apparatus

4.1 *Test equipment*, as shown in outline in Figure 1.

NOTE If the pressure drop across the flow sensor is very low the pressure regulator may be mounted before the flow sensor. This reconfiguration is acceptable because it does not have a significant effect on the regulation of air pressure at the test piece.

4.2 *Air supply*, which shall be clean and dry. The length of the pipework between the pressure regulator and the test piece shall be no more than 1 m, and the pipework shall have a bore of no less than 4 mm.

NOTE This will minimize any drop in the regulated pressure up to the test piece.

4.3 *Pressure regulator*, capable of supplying regulated pressures in the range of 6.9 kN/m² to 34.5 kN/m². The regulator shall be capable of maintaining a selected pressure to ± 3.5 kN/m² throughout the period of the test.

NOTE Pressure regulators are normally supplied in the UK with measuring scales graduated in pounds per square inch (psi). 1 psi = 6.9 kN/m².

4.4 *Thermal mass flow sensor*, covering the range 0 ml/min to 2 000 ml/min. The sensor shall be accurate to ± 1 % of full scale deflection but shall not be used in any part of the range where the accuracy is less than ± 5 % of the true reading (this may prohibit the use of the sensor near the bottom of its range).

NOTE 1 Certain materials of low air flow capacity may require the use of a thermal mass flow sensor with a range of 0 ml/min to 1 000 ml/min as this may give better accuracy.

NOTE 2 Flow rates of higher than 2 000 ml/min are not suitable for this type of test as chilling of the test piece can occur.

4.5 *Pressure sensor*, capable of covering the range 6.9 kN/m² to 34.5 kN/m² with an accuracy of ± 1 % of full scale deflection but shall not be used in any part of the range where the accuracy is less than ± 5 % of the true reading (this may rule out using the sensor near the bottom of its range).

NOTE The pressure sensor should be connected close to the test piece to minimize any pressure drop between the test piece and the sensor.

4.6 Test piece temperature indication, comprising the combined test piece thermocouple and indicator required to record the test piece temperature which shall be accurate to $\pm 5^\circ\text{C}$. It shall be insulated in a sheath of nominal diameter 3.0 mm. The thermocouple and sheathing shall be sealed at the cold end to ensure there are no leaks from the system via the bore of the thermocouple sheathing.

NOTE A suggested method of inserting the thermocouple into the sample without causing any leakage from the equipment is shown in Figure 2 and Figure 3.

4.7 Programmable control furnace, capable of accurate temperature control as the time a test piece spends at elevated temperature is critical to the test results. The following conditions shall be met.

- The furnace thermocouple, which is separate from the test piece thermocouple, and the temperature indicator shall have a combined accuracy of $\pm 5^\circ\text{C}$. The thermocouple shall be located as close as possible to the middle of the outer surface of the shell mould.
- The furnace shall be capable of applying a controlled heating rate of $20^\circ\text{C}/\text{min}$ up to the given test temperature. When ramping up to the test temperature, above 500°C the furnace control shall be such that the furnace set point and indicated furnace temperature shall not differ by more than 5°C .
- On reaching a temperature dwell phase the indicated furnace temperature shall not overshoot the set point temperature by more than 5°C , after which the two values shall not differ by more than an indicated $\pm 2^\circ\text{C}$.

The test piece shall be located in the furnace such that a minimum of 150 mm of the test piece (measured from the middle of the mould upwards) shall be exposed to the furnace elements (see Figure 4).

