

Viscosity and viscometric fixed points of glass —

Part 4: Method for the determination of viscosity by beam bending

[ISO title: Glass — Viscosity and viscometric fixed points —
Part 4: Determination of viscosity by beam bending]

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Committees responsible for this British Standard

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- British Glass Industry Research Association
- Glass Manufacturers' Federation
- Society of Glass Technology

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National foreword

This Part of BS 7034 has been prepared under the direction of the Laboratory Apparatus Standards Committee. It is identical with ISO 7884-4:1987 “Glass — Viscosity and viscometric fixed points — Part 4: Determination of viscosity by beam bending”, prepared by Subcommittee 5 of ISO/TC 48, Laboratory glassware and related apparatus, of the International Organization for Standardization (ISO), with the active participation and approval of the United Kingdom.

The other Parts of BS 7034 are as follows.

- *Part 1:1988 Recommendations for use in the determination of viscosity and viscometric fixed points*; (identical with ISO 7884-1:1987)
- *Part 2:1988 Method for the determination of viscosity by rotation viscometers*; (identical with ISO 7884-2:1987)
- *Part 3:1988 Method for the determination of viscosity by fibre elongation viscometer*; (identical with ISO 7884-3:1987)
- *Part 5:1988 Method for the determination of working point by sinking bar viscometer*; (identical with ISO 7884-5:1987)
- *Part 6:1988 Method for the determination of softening point*; (identical with ISO 7884-6:1987)
- *Part 7:1988 Method for the determination of annealing point and strain point by beam bending*; (identical with ISO 7884-7:1987)
- *Part 8:1988 Method for the determination of (dilatometric) transformation temperature*. (identical with ISO 7884-8:1987)

Terminology and conventions. The text of the International Standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

The comma has been used as a decimal marker. In British Standards it is current practice to use a full point on the baseline as the decimal marker.

Wherever the words “part of ISO 7884” appear, referring to this standard, they should be read as “Part of BS 7034”.

Cross-reference.¹⁾ The Technical Committee has reviewed the provisions of IEC 584-1, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard. The references in 4.2 to IEC 584-1 are only informative references, but thermocouples complying with the following Parts of BS 4937 “*International thermocouple reference tables*” are suitable.

- *Part 1:1973 Platinum — 10 % rhodium/platinum thermocouples. Type S*;
- *Part 4:1973 Nickel — chromium/nickel — aluminium thermocouples. Type K*.

Manufacturing tolerances for type S and K thermocouples are given in BS 4937-20:1983 “*Specification for thermocouple tolerances*”.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ See also the second paragraph.

0 Introduction

International Standard ISO 7884, *Glass — Viscosity and viscometric fixed points*, consists of the following separate parts:

- *Part 1: Principles for determining viscosity and viscometric fixed points;*
- *Part 2: Determination of viscosity by rotation viscometers;*
- *Part 3: Determination of viscosity by fibre elongation viscometer;*
- *Part 4: Determination of viscosity by beam bending;*
- *Part 5: Determination of working point by sinking bar viscometer;*
- *Part 6: Determination of softening point;*
- *Part 7: Determination of annealing point and strain point by beam bending;*
- *Part 8: Determination of (dilatometric) transformation temperature.*

1 Scope and field of application

This part of ISO 7884 specifies a method of determining the dynamic viscosity of glass on a rod-shaped test specimen (called a beam) supported at its ends. The viscous deflection rate of the beam is measured under a given load at the midpoint between the supports. In addition the viscosity-temperature relationship and the dependence of the viscosity on the thermal history of the sample can be determined.

The viscosity range covered by this method extends from 10^9 to 10^{15} dPa s²⁾, corresponding to measuring temperatures between about 900 and 400 °C for all glasses of normal bulk-production compositions.

The procedures are limited to small deflections and to small deflection rates (see 3.6).

NOTE During beam bending, elongation flows of both signs occur (zero passage within the neutral plane). The determination of shear viscosity is possible only with Newtonian or linear-viscoelastic behaviour of the glass. The procedures are sensitive to interference by devitrification of the sample. With viscosities above 10^{12} dPa s the adjustment of the structure equilibrium within the glass is perceptibly delayed with respect to the temperature setting. For tests within this range it should be agreed whether it is necessary to wait for the final equilibrium viscosity at a given temperature or to take the viscosity value corresponding to a conventional temperature-time programme (see 6.3).

2 Reference

IEC Publication 584-1, *Thermocouples — Part 1: Reference tables*.

3 Principle

3.1 Beams

For this test procedure, rod-shaped test specimens, called beams, are prepared from the sample. Along their length l they have a constant cross-sectional area (see Figure 1) which may be

- a) rectangular, of thickness h , and width b ;
- b) circular, of diameter d .

3.2 Supports, span

The beam is placed horizontally on two supports; the beam axis and the supports are perpendicular.

For rectangular cross-section beams the supports are horizontal and have straight edges.

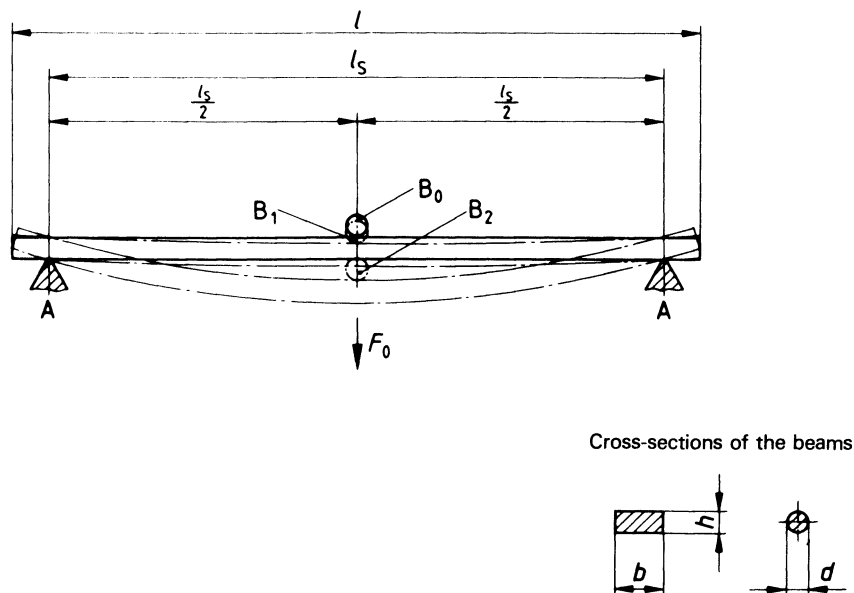
For circular cross-section beams the support edges may be semi-circles or notches.

The distance l_s between the supports is called the span. The beam juts out only little beyond the supports, satisfying equation (1):

$$1,1 < \frac{l}{l_s} < 1,15 \quad \dots (1)$$

²⁾ $1 \text{ dPa s} = 1 \frac{\text{dN} \cdot \text{s}}{\text{m}^2} = 1 \text{ P}$

(P is the symbol for poise)



- A supports
 B₀ bending edge, unloaded
 B₁ bending edge, loaded (elastically deformed beam)
 B₂ bending edge, sagged position Δf after measuring time Δt (Δf is the interval between B₁ and B₂)
 l beam length
 l_s span; position of bending edge at l_s/2
 F₀ force of the load
 b beam width
 h beam thickness
 d beam diameter (circular cross-section)
- (rectangular cross-section)

Figure 1 — Principle of viscosity determination by beam bending

3.3 Load, loading pieces, bending edge

The load consists of all parts of the measuring device on which gravity acts to produce a force on the beam by means of the bending edge, i.e. the loading pieces (variable) and the loading rod together with yoke and bending edge (given for the individual measuring device). The load exerts a vertically downward directed force F_0 upon the central cross-sectional area of the beam (distance $l_s/2$ from both supports). The bending edge is horizontal and parallel to the supports.

3.4 Dead-weight

The dead-weight stems from the beam; it can be taken into account by calculation — see equations (13) to (15). Within the span, the force of the dead-weight acts in the same sense as that of the load. The dead-weight of the overhanging parts of the beam produces a force component opposed to the force of the load; this part of the dead-weight can be neglected if equation (1) is respected.

3.5 Flow

When the force of the load (disregarding the dead-weight) acts upon a beam free from defects and showing Newtonian or linear-viscoelastic behaviour, and all elastic deformations after applying the load have faded out and thereupon the sag is sufficiently small, the flow is described by equation (2) as follows:

$$\frac{df}{dt} = \frac{l_s^3 F_0}{144 I_c \eta} \quad \dots (2)$$

where

df/dt is the midpoint deflection rate, with which the bending edge moves downward (see Figure 1);

I_c is the cross-sectional moment of inertia of the beam;