Calibration materials for viscosity measurements on glass melts

PTB offers three glasses with different viscosity-temperature behaviour (VT behaviour). The VT behaviour of these glasses was determined using a specially designed rotational viscometer. The rotational viscometer was traced back to the national standard of viscosity by means of calibration liquids. In addition, the viscosity measurement was monitored using a fibre-elongation device as well designed at PTB with a contact-free recording of the elongational speed.

The **soda-lime glass G1** is certified in the temperature range from 525°C up to 1400°C. There is a restriction that measurements above 1200°C can only be performed if all measurements at lower temperatures are completed. This behaviour is typical for a soda-lime glass and is, for example, also valid for the standard glass of the Deutsche Glastechnische Gesellschaft, which can be purchased from this institution. The **lead-oxide containing glass G2** is certified in the range from 900°C up to 1400°C and the **hard glass G3** in the temperature range from 1000°C to 1400°C. The fix points (no thermodynamic fix points) defined in the standard ISO 7884 (12.87) were measured as far as they were within the certification range. For each calibration glass, a fitting curve as suited as possible was determined for the VT behaviour; the calibration certificate additionally comprises a VT table in 25-K steps and indications on the measurement uncertainty.

Indication on the measurement uncertainty: In each case, the expanded measurement uncertainty is given, which is obtained from the standard measurement uncertainty multiplied with the coverage factor $k = 2$. It was determined according to the “Guide to the Expression of Uncertainty in Measurement" (ISO, 1995). The value of the measurand is normally within the assigned value interval with an probability of approx. 95%.

Data for the soda-lime glass G1:

Temperature °C	Dynamic viscosity dPa·s	Decimal logarithm of the dyn. viscosity	Temperature coefficient of the viscosity in 10^{-2} K^{-1}
525	$2.3293 \cdot 10^{13}$	13.3672	10.07
600	$3.1685 \cdot 10^{10}$	10.5008	7.43
700	$8.5417 \cdot 10^{7}$	7.9315	4.65
800	1897700	6.2782	3.11
900	135970	5.1334	2.23
1000	19403	4.2878	1.69
1100	4294.5	3.6329	1.34
1200	1282.9	3.1081	1.08
1300	475.8	2.6773	0.90
1400	207.6	2.3171	0.76

528.9; u_T=1.2	$1.585 \cdot 10^{13}$	13.2	Upper cooling point
717.0; u_T=1.0	$3.981 \cdot 10^{7}$	7.6	Littleton point
1041.0; u_T=1.2	$1.000 \cdot 10^{4}$	4.0	Working point

The values stated above were calculated from a Vogel equation with three constants and a five-term correction polynomial according to Meerlender. The combined equation with the corresponding constants is:

$$\lg \eta = A + \frac{B}{\vartheta - C} - \frac{B}{(\vartheta - C)^2} \sum_{i=1}^{5} \left\{ b_i \left(\frac{1000}{\vartheta + 273.15} \right)^{i-1} \right\} \qquad \vartheta \text{ in °C and } \eta \text{ in dPa} \cdot \text{s}$$

With A = -1.485703
B = 4472.106
C = 225.1503

b_1 = 604.2458
b_2 = -2807.975
b_3 = 4780.683
b_4 = -3537.12
b_5 = 960.6668.

The measurement uncertainty of the viscosity-temperature function expressed as uncertainty of the temperature indication u_r is:

In the temperature range from 525°C to < 1100°C: 1.5 K
In the temperature range from 1100°C to < 1200°C: 2.7 K
In the temperature range from 1200°C to 1400°C: 4.9 K.

Data for the lead-oxide containing glass G2:

Temperature °C	Dynamic viscosity dPa·s	Decimal logarithm of the dyn. viscosity	Temperature coefficient of the viscosity in 10^{-2} K^{-1}
900	35840	4.5543	1.72
1000	7700.8	3.8865	1.37
1100	2226.7	3.3476	1.12
1200	800.2	2.9031	0.93
1300	338.8	2.5299	0.79
1400	162.9	2.2119	0.67
981.3; u_T=1.5	10000	4.0	Working point

The values stated above were calculated using an equation according to Sturm with three constants. The equation with the corresponding constants is:

$$\lg\eta = A - B \cdot \lg\left(1 - \frac{C}{T}\right) \qquad T \text{ in } K \text{ and } \eta \text{ in dPa} \cdot \text{s}$$

With A = -1.831803

B = 24.27971

C = 532.931.

The measurement uncertainty of the viscosity-temperature function expressed as uncertainty of the temperature indications amounts to:

In the temperature range from 900°C to < 1100°C: 1.8 K

In the temperature range from 1100°C to 1400°C: 3.6 K

Data for the Suprax hard glass G3:

Temperature °C	Dynamic viscosity dPa·s	Decimal logarithm of the dyn. viscosity	Temperature coefficient of the viscosity in 10^{-2} K^{-1}
1000	284380	5.4539	1.85
1100	54195	4.7339	1.47
1200	14239	4.1535	1.20
1300	4728.1	3.6746	1.00
1400	1872.8	3.2725	0.85
1230.1; u_T=2.4	10000	4.0	Working point

The values stated above were calculated using an equation according to Sturm with three constants. The equation with the corresponding constants is:

$$\lg\eta = A - B \cdot \lg\left(1 - \frac{C}{T}\right) \qquad T \text{ in } K \text{ and } \eta \text{ in } \mathrm{dPa \cdot s}$$

With A = -1.479891

B = 21.538

C = 666.4888.

The measurement uncertainty of the viscosity-temperature function expressed as uncertainty of the temperature indications amounts to:

In the temperature range from 1000°C to < 1100°C: 1.5 K
In the temperature range from 1100°C to 1400°C: 2.8 K

Note: In the temperature range between 800°C and below 1000°C, the viscosity of the Suprax hard glass G3 increases with time if it is kept in this range over many hours or longer. In a time period of up to approx. 5 hours, no changes in viscosity were observed in this temperature range. As cause for this behaviour, devitrification could be detected. This process can be reversed by heating the melt up to 1300°C or higher.

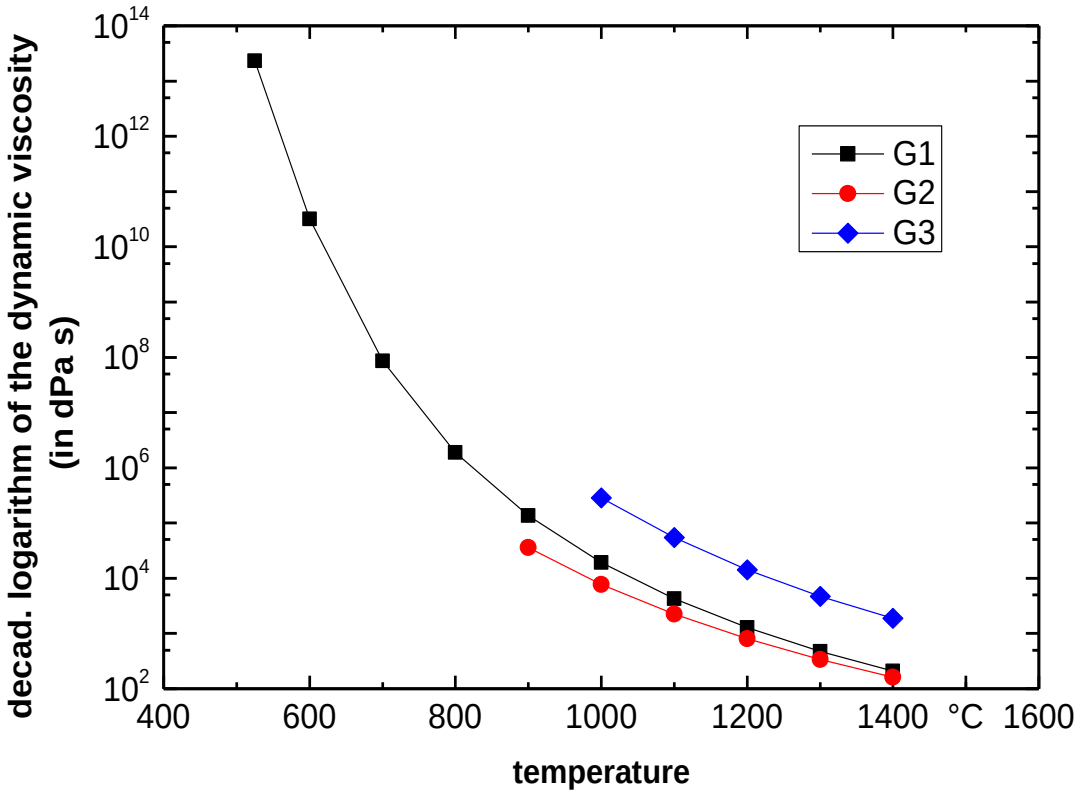

Fig. 1: Temperature dependence of the dynamic viscosity of the three calibration-materials G1, G2, and G3.

Further information can be found in

Norbert Böse, Günther Klingenberg, Gustav Meerlender

Viscosity measurements of glass melts – Certification of calibration material

Glastech. Ber. Glass Sci. Technol. **74** (2001) 115 - 126

The calibration glasses are supplied in pieces of approx. 500 g (450 g to 550 g), the costs are approximately 462,50 € each.

These costs are charged according to the Regulations governing charges for services rendered by PTB and calculated according to the average work done, which is necessary for the dissemination, viscosity determination and supply of the calibration glasses.

Additionally, a transport flat rate is charged, which is €15.00 for the first calibration glass when dispatched within Germany; €37.50 within the EU; otherwise €60.00; for each additional glass the flat rate increases by €7.50.

Inquiries can be made to:

Physikalisch-Technische Bundesanstalt
Working Group 3.32 ”Properties of Liquids“
Postfach 33 45
38023 Braunschweig
Germany

Phone: +49 531 592-3141 (Dr. Jürgen Rauch)
Fax: +49 531 592-693320
E-Mail: kundeninfo332@PTB.DE