STUDY OF THE REAL METROLOGICAL CHARACTERISTICS OF THE VALUES OF THE VISCOMETER MODEL SVM 3000

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Abstract. *In this article, a study was made of the actual metrological characteristics of the viscometer values by calibration (according to the calibration procedure for automatic viscometers UzNIM-PC-06, November 20, 2019) in accordance with the requirement of ISO 17025.*

Keywords: *liquid, viscosities, dynamic viscosity, kinematic viscosity, viscometer, SVM 3000, calibration, verification, sample.*

Viscosity is one of the important indicators that determine the quality of liquid materials. To measure the level and control the viscosity of various liquids, a specific device called a Viscometer is used.

The determination of viscosity with a viscometer is used in various branches of science and production:

- pharmacology (production of drugs in the form of thick substances);
- medicine (blood viscosity measurement);
- food research (honey, milk, juices);
- oil and fuel production (engine oil, gasoline, paraffin, etc.);
- paint and varnish and chemical industry (paints, varnishes, resins).

Rotational viscometers make it possible to carry out fast and accurate measurements of the viscosity of substances according to the method, which is an advantage for using this SVM 3000 viscometer model in an applied project on the topic "Creating a set of equipment for reproducing a unit of kinematic viscosity of a liquid" No. FZ-202102088.

Rotational viscometers have a number of advantages over others, especially when testing materials with high viscosity, they are reliable in operation and can be used both for rapid measurements and for continuous measurement of viscosity for process control purposes.

To obtain reliable data, it is necessary that the viscometer has a high degree of reliability in operation. A mandatory requirement for rotational viscometers, especially those of individual manufacture, is the metrological assurance of verification and calibration of device characteristics.

The viscometer consists of a cell for measuring the viscosity of a liquid, a cell for measuring the density of a liquid, an electronic thermostat, a block for processing measurement information, a liquid crystal display and control keys, structurally combined in one housing.

The instrument has a standard viscosity index calculation mode according to ASTM D 2270 “Practice for Calculating Viscosity Index From Kinematic Viscosity at 40° and 100°C”.

This model was calibrated according to the method and procedure UzNIM-PC-06 Calibration procedure for automatic viscometers.

Application area

The calibration procedure applies to automatic, rotational viscometers (hereinafter referred to as the viscometer) with a measurement range:

- dynamic viscosity, from 0.2 to 20,000 mPa*s
- kinematic viscosity, from 0.2 to 20,000 mm^2/s
- liquid density, from 0.65 to 3.0 kg/m^3
- temperature, from 15 to 105°C

The set of operations performed on a measuring system so that it provides prescribed readings corresponding to specified values of the measurand. Calibration covers the entire range of instrument operation carried out in laboratory conditions before installation.

Calibration conditions and preparation for calibration

Viscometers are calibrated under the following conditions:

- ambient temperature………………………………………....from 15 to 25 °C;
- relative humidity ……………………..………………………from 20 to 80 %;
- atmosphere pressure ………………………………………….from 84 to 104 kPa;

The environmental conditions during calibration must be recorded using a data logger and stored in a database.

When calibrating viscometers, safety requirements during operation must be observed.

Viscometers should be installed so that there is enough space for heat dissipation and air circulation, away from air conditioning or central heating at a distance of at least 1.5 m.

Calibration of viscometers with power supply from the network should be carried out no earlier than 30 min after connecting to the network.

During calibration, the viscometer must not be subjected to vibration, shock or shock, as well as external electric and magnetic fields that may affect its operation.

Before starting the calibration, the viscometer must be rinsed with ethanol or acetone to clean the inner tube to remove residual material that has adhered to the tube wall of the previous measurement, and then dry it with dry air.

Before calibration, maintenance is performed in accordance with the operational documentation.

Prepare the calibration tools for use in accordance with the instructions for their use.

To start calibration, turn on the viscometer and wait at least 30 min. and set the desired temperature (planned calibration temperature).

Set the following measurement parameters on the viscometers:

- measurement mode - units mm^2/s (cSt); mPa*s (cP); kg/m^3.
- measured value - calibration points according to the customer's request;

Viscometers are calibrated using the direct measurement method using standard solutions.

Table 1.

Values of measured standard samples

SS for N2 kin calibration	2,907	mm^2/s
SS for N2 din calibration	2,348	mPa·s

SS for N2 plot calibration	0,8076	g/sm^3
SS for N2 T °C calibration	20	t °C

Table 2.

Technical characteristics of SI

Reproducibility ±	0,35	%
Acc. measuring instrument U cer	0,12	%
Measurement repeatability ±	0,1	%
Density measurement accuracy	0,0008076	g/sm^3
Acc. temperature measurement	0,005	°C
Digital instrument resolution	0,0001	

Table 3.

Results of measurements at 20 °C

	mm²/s	**mPa·s**	**g/sm³**	**t °C**
1	2,9043	2,3614	0,8070	19,999
2	2,9030	2,3611	0,8070	19,999
3	2,9033	2,3614	0,8069	20,001
4	2,9018	2,3616	0,8069	19,998
5	2,8984	2,3592	0,8066	19,997
a/r	2,9022	2,36094	0,806862	19,9988

Measurement model

$$y = x_{cp} - \Delta_{\text{rep}} - \Delta_{\text{repe}} - \Delta_{\text{para}} - \delta_{\partial} - \delta_t$$

1. The relative measurement error of dynamic viscosity for each standard sample is determined, (%).

$$\Delta\eta = \frac{\eta_j - \eta_{Cert}}{\eta_{Cert}} \cdot 100\% = 0{,}551107325 \quad (1)$$

2. The relative measurement error of the kinematic viscosity for each standard sample is determined, (%).

$$\Delta_{\nu} = \frac{\nu_j - \nu_{Cert}}{\nu_{Cert}} \cdot 100\% = 0{,}166494668 \quad (2)$$

3. The absolute error of density measurement for each standard sample is determined, g/sm3.

$$\Delta\rho = \rho_j - \rho_{Cert} = \text{-}0{,}000738 \quad (3)$$

4. The absolute error of temperature measurement is determined by

$$\Delta_t = t_{jt} - t_{ref} = \text{-}0{,}0012 \quad (4)$$

5. Type A uncertainty

$$U_A(y_{cp}) = \frac{t_p(V)}{k_p}\sqrt{\frac{\sum_{j=1}^{n}(y_i - y_{cp})^2}{n(n-1)}} = 0{,}0010211 \quad (5)$$

6. The uncertainty due to reproducibility error is calculated as the standard deviation from the mean of the reading.

$$u_B(\Delta_c) = \frac{\Delta_{\text{rep}} \cdot \frac{\sum_1^n y_1}{n}}{100\sqrt{3}} = 0{,}0175934 \qquad (6)$$

7. Uncertainty due to viscometer repeatability error.

$$u_B(\Delta_{\text{repe}}) = \frac{\Delta_{\text{repe}} \cdot \frac{\sum_1^n y_1}{n}}{100\sqrt{3}} = 0{,}0050267 \qquad (7)$$

8. Uncertainty difference due to variation error in viscometer measurements

$$u_B(\Delta_{\text{para}}) = \frac{D}{2\sqrt{3}} = 0{,}001277387 \qquad (8)$$

9. Uncertainty due to error Discreteness of measurement results

$$u_B(\delta_{dis}) = \frac{d}{2\sqrt{3}} = 0{,}000433013 \qquad (9)$$

10. Uncertainty due to temperature instability (from datasheet)

$$u_B(\delta_t) = \frac{\delta_t}{\sqrt{3}} = 0{,}288675135 \qquad (10)$$

11. Determination of the total standard uncertainty

$$u(y) = \sqrt{u_A^2(y_{cp}) + u_B^2(\Delta_c) + u_B^2(\Delta_{repe}) + u_B^2(\Delta_{para}) + u_B^2(\delta_{dis}) + u_B^2(\delta_t)} = 0{,}167341982 \qquad (11)$$

12. Expanded uncertainty.

$$U = k \cdot u_c(Y) = 0{,}334683963 \qquad (12)$$

Table 4.

Results of measurements and calculations

Input Value, x_{cp}	**Input value, x_{cp}**	**Unit**	**Probability distribution**	**Type of uncertainty**	**standard uncertainty $u(x_{cp})$**	**Sensitivity factor, c_i**	**Uncertainty contribution $U(y_i)=c_i u(x_i)$**
X_{cp}	2,9022	%	normal	A	0,00102	1	0,00102108
Δ_c	0	%	rectangular	B	0,01759	1	0,01759341
Δ_{repe}	0	%	rectangular	B	0,00503	1	0,00502669
Δ_{para}	0	%		B	0,00128	1	

			rectangular				0,00127739
δ_{dis}	0	%	rectangular	B	0,00043	1	0,00043301
δ_{t}	0	%	rectangular	B	0,28868	1	0,28867513
$u(y)$	2,9022	%	rectangular	B	0,16734	1	0,16734198
0,33							

Table 5.

Calibration Conditions

Ambient temperature change from	20,3	to	22,4 °C
Change in relative humidity from	31,6	to	35 %
Change in atmospheric pressure from	965,8	to	975,3 hPa

Calibration is done with:

- Density reference material: S6, N7.5, N350, D5000 with metrological traceability to the NPL of the UK National Physical Laboratory.
- Thermometer millikelvin MKT -50 № 82779658.
- Electronic thermohygrograph (Dataloger) type «OPUS 20 THIP» ep. №038.0819.0802.034.

Table 6.

Calibration results including uncertainty.

№	**Calibration liquid**	**The temperature of the liquid being calibrated, °C**	**The actual value of the liquid, mm²/s²**	**viscometer reading during calibration, mm²/s²**	**U (k=2), %**
1	CRM N2	20	2,907	2,902	0,33
2	CRM S3	25	8,872	8,873	0,35
3	CRM N1000	37,78	1172	1172,11	0,39
4	CRM D5000	40	2100	2100,10	0,49

The expanded uncertainty is obtained by multiplying the standard uncertainty by a coverage factor k = 2, corresponding to a confidence level of approximately 95%, assuming a normal distribution.

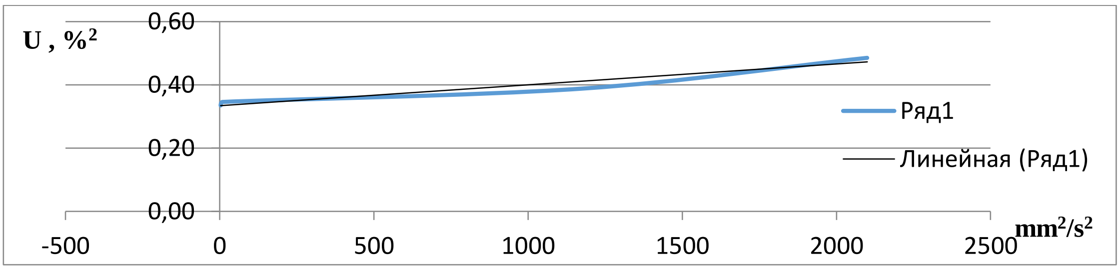

Fig.1. Calibration chart including uncertainty.

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