On Capillary Viscosity Measurements: How Far do Surface Tension Effects go?

Maria C. M. Sequeira, Fernando J. P. Caetano, Hermínio A. P. Diogo, João M. N. A. Fareleira, Fernando J.V. Santos, Ana P. Serro

Groups V, IX and X

CQE Days 2023

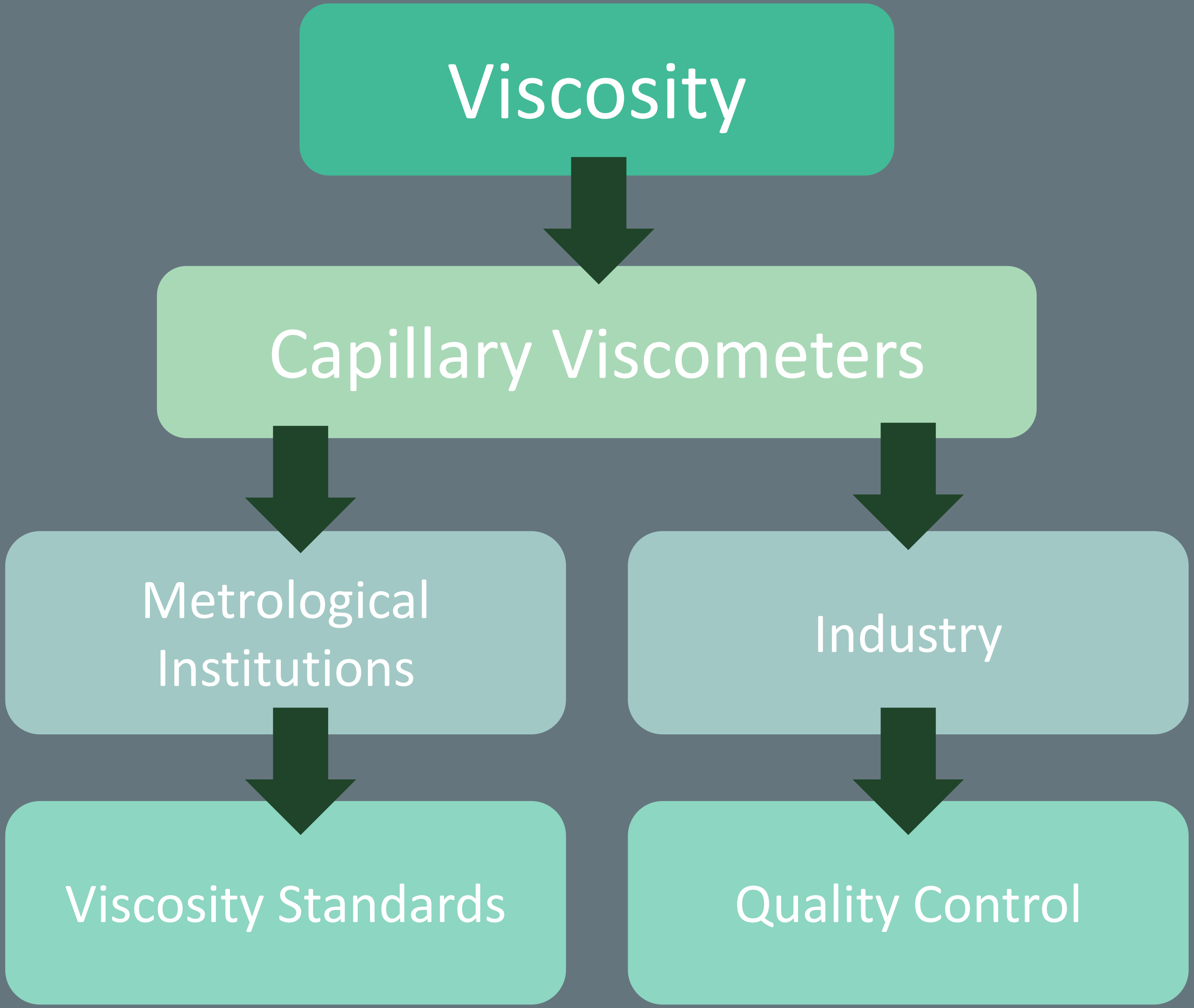
Index

1. Background and Purpose

2. Experimental Work

3. Conclusions

1. Background and Purpose


Viscosity
Capillary Viscometers
Metrological Institutions
Industry
Viscosity Standards
Quality Control

Capillary Viscosity Measurements

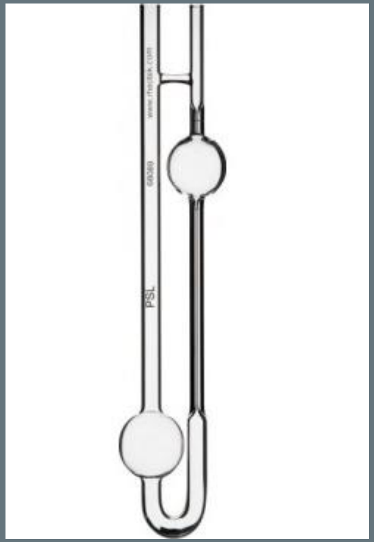
Haggen – Poiseuille Equation:

$$\Delta \mathbf{p} = \frac{8\pi\mu LQ}{A^2}$$

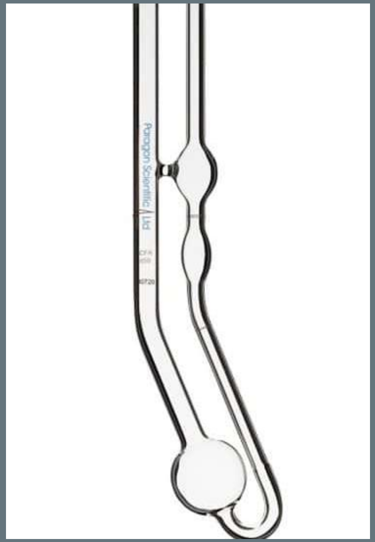
$$\upsilon = \boxed{\frac{\pi R^4 g h_m}{8VL}} \cdot t \quad \Longleftrightarrow \quad \upsilon = \boxed{K} \cdot t$$

- **Characteristic for each capillary**
- **Kinetic Energy effects are not considered**
- **Archimedes' Principle is not considered**

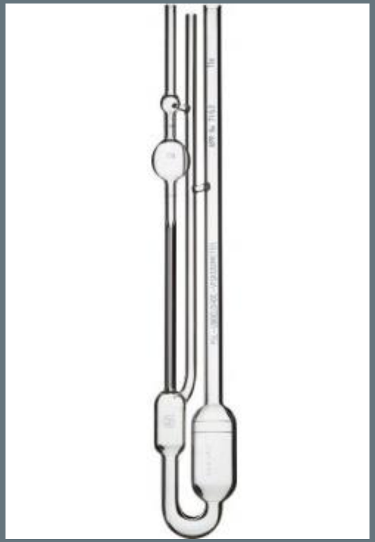
Types of Capillary Viscometers



Ostwald/U-tube Viscometer



Canon-Fenske Viscometer



Ubbelohde Viscometer

Restrictions to the Hagen-Poiseuille Equation

Kinetic Energy Effects

The Hage-Poiseuille equation is based on the following assumptions:

- Constant velocity along the tube of the capillary
- Parabolic distribution of the flow velocity through the cross section

Surface Tension Effects

- Ubbelohde Capillary Viscometers are designed to compensate the effect of the surface tension in the measuring bulb by means of the appropriate curvature of the suspended level
- Water as the primary viscosity standard

Purpose

Obtain the lowest uncertainty for the Ubbelhode capillary viscometer 541 01/IA

Understand the need for the corrections that must be considered when using capillary viscometers and how they should be applied

2. Experimental Work

Results

Capillary Viscometer Calibration

According to German Standard DIN 51562 – 4 with 3 viscosity standards

New value for K:
$K = 0.006088\ mm^2/s^2$
(u_k = ±1.0% 95%confidence level)

Old K (Schott Geräte):
$K = 0.004998\ mm^2/s^2$
(u_k = ±1.2% 95%confidence level)

Deviation of 21.8%

The glass conditions change over time!

Results

Kinetic Energy Effects Assessement

For *n*-Tetradecane at 293.95 K

According to the supplier Schott Geräte → Kinetic Energy Correction vs flow time → Kinetic Energy Correction for *n*-C_{14} at 293.95 K

↓

Correction of 0.03%

Results

Surface Tension Effects Assessement[1]

For *n*-Tetradecane at 293.95 K

$$\nu_{corr} = K \cdot t \cdot \left[1 - \chi\left(\frac{\sigma_0}{\rho_0} - \frac{\sigma_i}{\rho_i}\right)\right]$$

→

$$\chi = \frac{1 - \left(\frac{\upsilon_A}{K_0 t_A}\right)}{\left(\frac{\sigma_0}{\rho_0}\right) - \left(\frac{\sigma_A}{\rho_A}\right)}$$

$$\Delta_{ST} = \left[\chi\left(\frac{\sigma_i}{\rho_i} - \frac{\sigma_0}{\rho_0}\right)\right]$$

→ Correction of 2.1%

0, A – Viscosity Standards
i – fluid sample

[1] Diogo et al. 2014 (doi: 10.1007/s10765-013-1487-y)

Discussion

Table 1 – Comparison of the experimental results for *n*-tetradecane at 293.95 K.

$\eta_{capillary}$ /mPa.s (before calibration)	$\eta_{capillary}$ /mPa.s (after calibration)	η_{VW} /mPa.s (Vibrating wire)[2]	η_{K} /mPa.s (Calibration + Kinetic Energy)	η_{ST} /mPa.s (Calibration + Surface Tension)
2.440 (8.44%)	2.262 (0.53%)	2.250	2.261 (0.48%)	2.311 (2.71%)

[2]Santos et al. 2017 (doi: 10.1016/j.fluid.2017.08.025)

3. Conclusions

The calibration showed that the current state of the capillary is very different from the initial one

The assessement of the kinetic energy and surface tension effects was performed

The viscosity value corrected for kinetic energy effects approximates the virating-wire viscosity value (not affected by any of the mentioned effects)

It is not accurate to calculate the surface tension effect for a fluid that is very similar to the one used to calibrate the viscometer

Understand the need for the corrections that must be considered when using capillary viscometers and how they should be applied

Aknowledgements

Centro de Química Estrutural is a Research Unit funded by Fundação para a Ciência e Tecnologia through projects UIDB/00100/2020 and UIDP/00100/2020.

Institute of Molecular Sciences is an Associate Laboratory funded by FCT through project LA/P/0056/2020.

M.C.M. Sequeira acknowledges the PhD grant funded by FCT ref. UI/BD/152239/2021.