# Towards a Traceable Calibration for Trans-epidermal Water Loss

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[2] The TEWL Calibration Project is sponsored by the UK Department of Trade and Industry. Project partners are:- EnviroDerm Services (project manager) (C L Packham and H E Packham), London South Bank University (R E Imhof, H E Packham and P Xiao), UK National Physical Laboratory (S A Bell, R M Gee and M Stevens), Biox Systems Ltd (E P Berg, R E Imhof and P Xiao), Dstl Porton Down (R P Chilcott & C H Dalton), and Gillette UK (A Stevens & N Weston).

# Introduction

The aim of this project is to develop an accurate and reproducible calibration method for TEWL instruments. The deliverables are:-

(a) A protocol for the calibration of TEWL instruments that provides traceability to recognised standards.

(b) Components, accessories and materials for calibrating TEWL instruments in accordance with the above protocol.

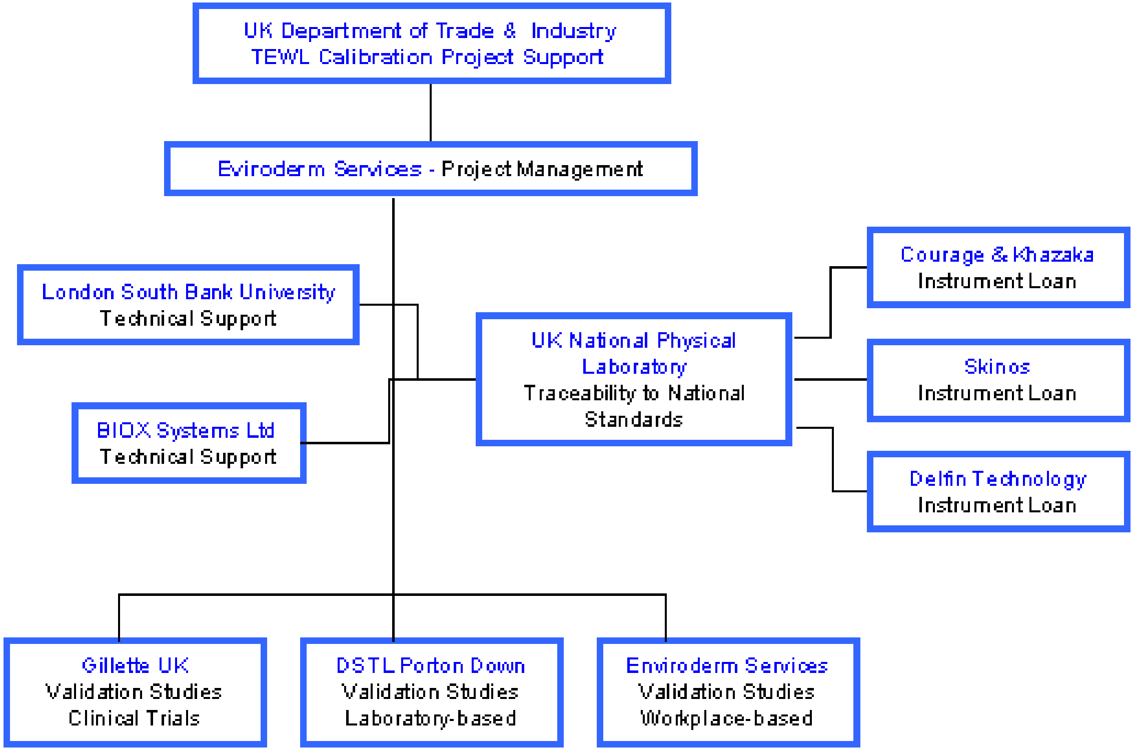
(c) Results from field tests providing evidence of comparability of TEWL measurements performed using different instruments and measurement methods.

(d) Publication of theoretical background and practical implementation of the new calibration.

**NB**

The TEWL calibration project is focused on the traceable calibration of water vapour flux density. The correct and traceable calibration of individual humidity and temperature sensors used for the measurement of flux density is a necessary pre-condition for a correct calibration of flux density.

# Project Partners & Organisation




**Sponsor:**
UK Department of Trade

**Project Management:**
Enviroderm Services

**Standards Lab:**
UK National Physical Laboratory

**Technical Support:**
Biox Systems Ltd
London South Bank University

**Validation:**
Dstl Porton Down
Enviroderm Services
Gillette UK

**Associates:**
Courage & Khazaka
Delfin Technology
Skinos Ltd

# Flux Density Calibration Methods

Two main calibration methods were studied, as follows:-

## 1. The Membrane Method

Such methods have been widely used to calibrate an compare TEWL instruments [1-4]. Our mathematical and numerical modelling has now revealed that this approach is fundamentally flawed.

## 2. The Water Droplet Method

This is a new approach, adopted when it became clear that the membrane method would not be suitable.


[1] G. E. Nilsson, *Measurement of Water Exchange through Skin*, Med. Biol. Comput., **15**, 209-18, 1977.

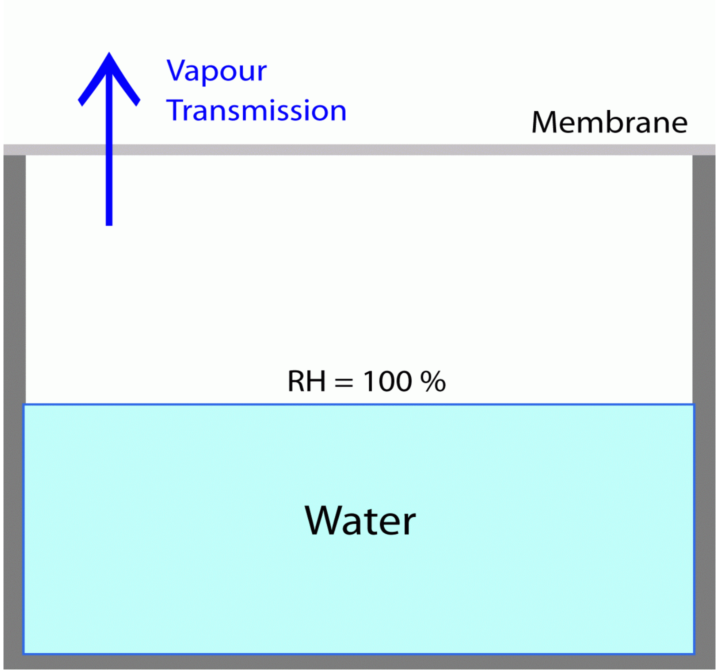
[2] J Pinnagoda, R A Tupker, T Agner, and J Serup, *Guidelines for Transepidermal Water Loss (TEWL) Measurement*, Contact Dermat, **22**, 164-78, 1990.

[3] G L Grove, M J Grove, C Zerweck and E Pierce, *Comparative Metrology of the Evaporimeter and the DermaLab Probe*, Skin Res & Technol, **5**, 1-8, 1999.

[4] J. Nuutinen, E. Alanen, P. Autio, M-R. Lahtinen, I. Harvima & T. Lahtinen, *A Closed Unventilated Chamber for the Measurement of Transepidermal Water Loss*, Skin Res. & Technol., **9**, 85-9, 2003.

# 1. The Membrane Method

This is based on the standard ASTM-96 *Wet Cup* method for measuring Water Vapour Transmission of Materials [1]. The mean flux of water vapour escaping through the membrane can be determined from measurements of cup weight loss. The TEWL instrument is calibrated by placing its measurement chamber in contact with the membrane and adjusting its reading to agree with the gravimetrically determined mean flux.

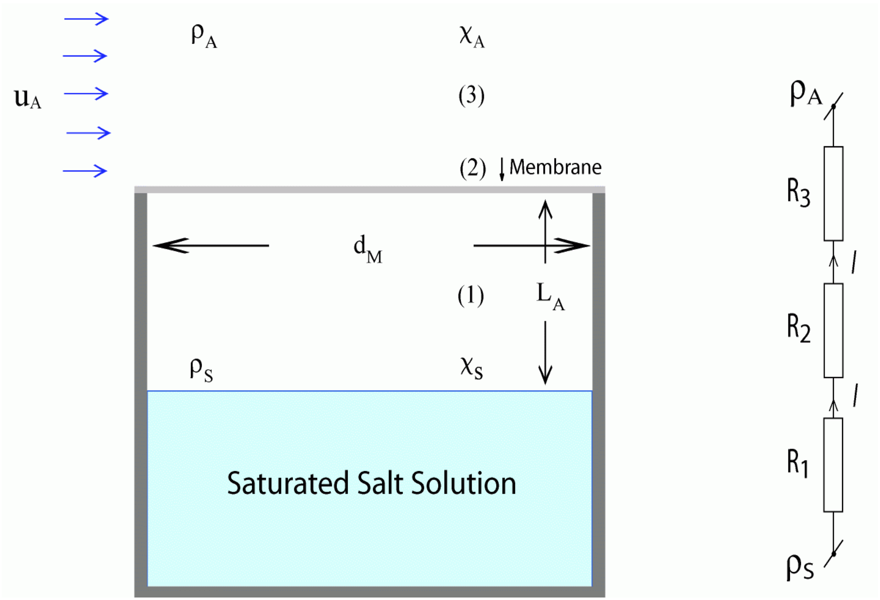



**Main conditions stipulated in ASTM-96:-**

| | |
|---|---|
| Ambient temperature | 21-32 °C |
| Ambient RH | 50±2 % |
| Ambient air speed | 0.02-0.3 $ms^{-1}$ |
| Membrane diameter | >61 mm |
| Membrane-liquid separation | 13-25 mm |

[1] ASTM E 96-00: *Standard Test Methods for Water Vapour Transmission of Materials.*

# Model Calculation of ASTM-96 Flux Density

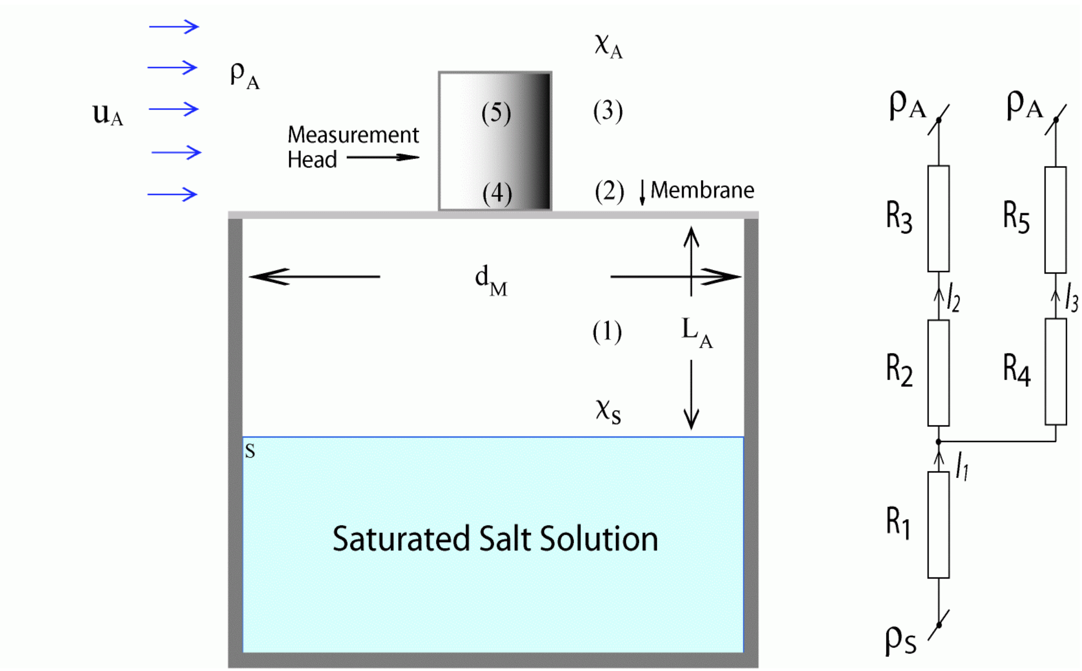



Use Fick's law to calculate water vapour flux density in the space between the liquid surface and the membrane (Region 1) and within the membrane itself (Region 2). Use fluid dynamics to calculate the effect of the air flow above the membrane (Region 3).

The analysis permits the convenient representation of the vapour transport as current flow in an electrical circuit [1] as illustrated in the figure. In this case, the three regions are represented as resistances in series. The potential difference across them is the difference in vapour density between the source at the surface of the saturated salt solution and the sink in the ambient atmosphere.


[1] A E Wheldon & J L Monteith, *Performance of a Skin Evaporimeter*, Med Biol Comput, **18**, 201-5, 1980.

# Model Calculation of Membrane Calibration Method

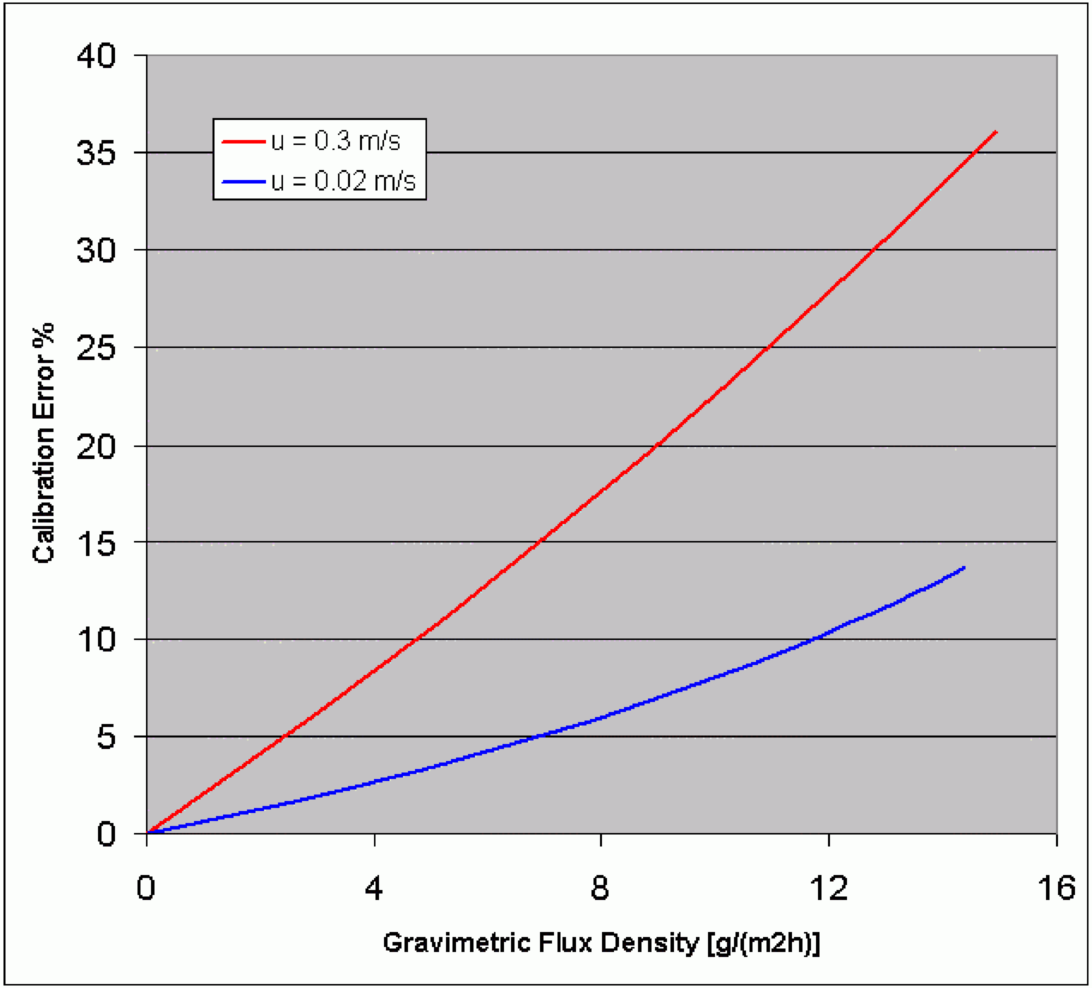



The model can be extended to calculate flux densities when a TEWL measurement head is placed into contact with the membrane. In this case, the flux divides, with some flux entering the measurement head and some flux by-passing it.

The equivalent electrical circuit illustrated in the figure now has two branches. The case illustrated is that of an open measurement chamber, where the vapour sink is the ambient atmosphere.

The main point is that the currents in the two branches will generally be different, depending on the relative magnitudes of the diffusion resistances of the measurement head and the uncovered membrane.

# Sample Calculation of TEWL Calibration Error with the Membrane Method




The figure shows the range of calibration errors resulting from the assumption that the gravimetrically determined flux density is equal to the measurement head flux density. The measurement head is assumed to be of the open-chamber type, with a cylinder length of 20mm and a diameter of 10mm. The membrane diameter is assumed to be 10cm.

The parameter **u** is the flow speed of the ambient air. The two values used cover the range stipulated by the ASTM-96 standard. Ambient temperature and humidity are 21°C and 50% respectively.

# Membrane Calibration Summary

1. The ASTM-96 wet cup is not a constant water evaporation device.

2. The flux density through the measurement head is not equal to the gravimetric flux density.

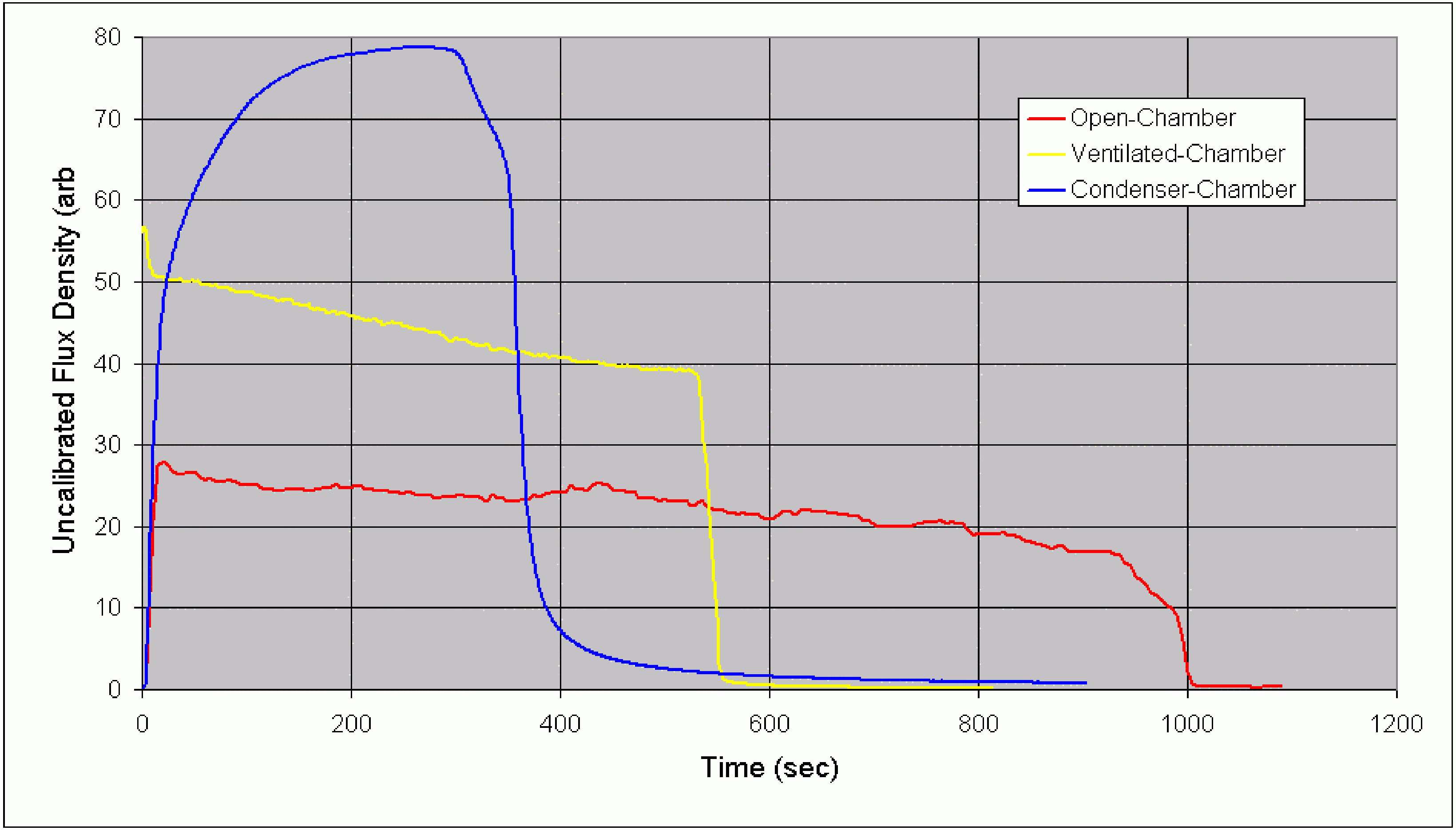
Therefore, the ASTM-96 standard is not a good starting point for a traceable calibration.

# 2. The Droplet Method

This is an alternative approach to calibration. You measure out a small quantity of water, typically 1µL, into a well fitted to the base of a TEWL measurement chamber. You then record the instrument's flux density readings continuously, until the drop has evaporated. The calibration constant can be worked out from the relationship between the quantity of water dispensed and the area under the flux density time-series curve. Traceability is provided via a calibrated micro-syringe such as the one shown below.

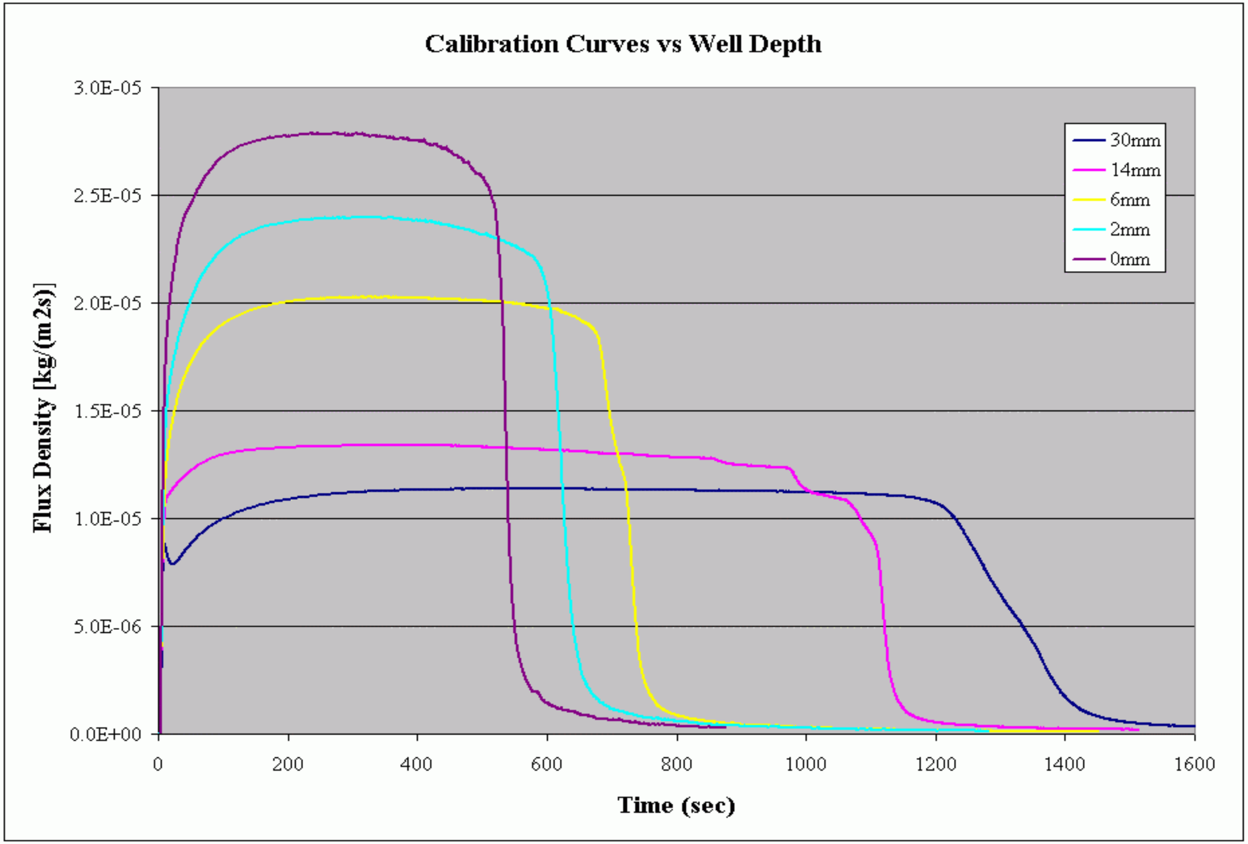
# Typical Calibration Curves

Shown below are examples of calibration curves measured using an open-chamber, a ventilated-chamber and a condenser-chamber instrument.



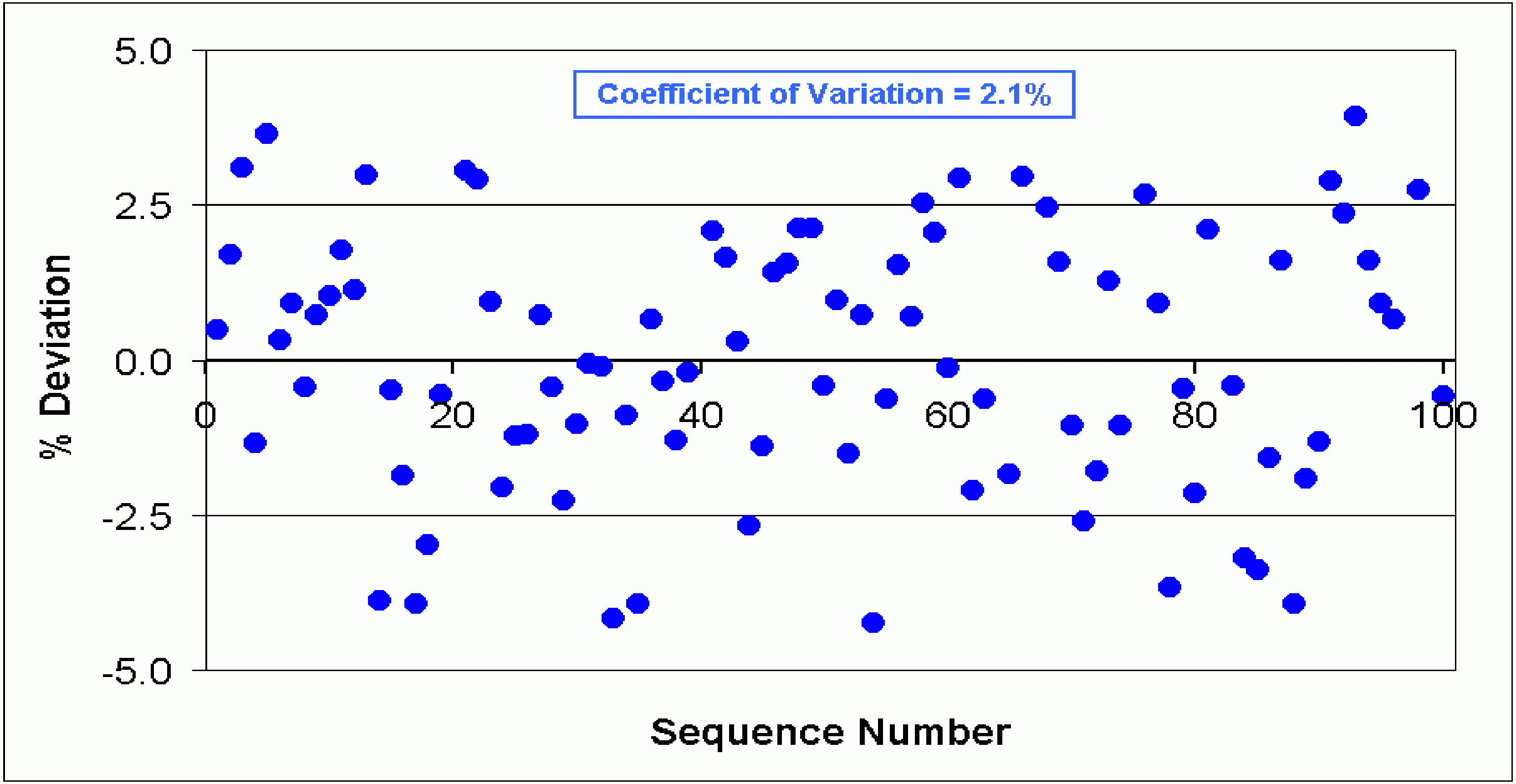
# Mean Flux Density during Calibration

The mean flux density during calibration can be controlled through the use of calibration wells of different depths. This is illustrated below for the range of depths 0-30mm below the normal sample position. According to our numerical modelling work, the separation between the droplet and the nearest sensor needs to be at least one chamber diameter in order to ensure radial flux uniformity.



# Calibration Repeatability

This repeatability test used a closed-chamber condenser instrument in a measurement sequence of 100 calibrations. A smaller than usual dispensed volume of 0.5μL was used, partly to speed up the work and partly to amplify any measurement errors. Shown below is a residuals plot for the individual measurements, which are all contained within a ±5% band of deviation. This scatter is expected to decrease with increasing dispensed volume.



# Droplet Calibration Summary

1. The Droplet method can be used with all TEWL instruments capable of measuring flux time-series.

2. Calibration traceability is achieved via a calibrated micro-syringe.

3. A high degree of repeatability can be demonstrated for the method.

Work is in progress to:-

Develop calibration protocols for individual instrument types.

Develop calibration accessories for individual instrument types.

Compile an error budget for the method.

Verify the calibration via practical trials.