Poster Title: A Practical Guide to Computerized Evaporimetry
Poster Abstract: G. Grove, J. Damia & C. Zerweck

Our group has nearly 30 years of experience with a variety of devices that allows one to measure evaporative water loss from human skin non-invasively. These include both closed-chamber and open chamber devices that were either laboratory constructed prototypes or commercially available instruments such as the ServoMed Evaporimeter and the DermaLab TEWL Probe. Many of our studies have monitored the response of the stratum corneum barrier to a variety of mechanical, physical and chemical insults by measuring TEWL rates under steady-state conditions at appropriate times after the insult has been delivered and the test products administered either prophylactically or therapeutically. Other studies such as the Post Occlusive Stress Test and evaluating the absorbance of diapers have required these assessments to be made under dynamic conditions. As a result of our considerable experience, we have a good appreciation of the various problems and pitfalls that one can encounter in these types of investigation. In this poster we will discuss different design considerations, various calibration procedures, performance tests and other quality assurance concerns related to evaporative water loss rate measurements.

Conflict of Interest Disclosure Statement

Dr. Gary Grove and his group at cyberDERM, inc. in Media, PA are the North American agents for Cortex Technology, Hadsund, Denmark who are the manufacturers of the DermaLab TEWL Probe. cyberDERM, inc. also custom builds computerized systems for measuring EWL based on either closed chamber or open chamber designs. These include the cyberDERM RG-1 and CCM-1 model Evaporimeters. cyberDERM, inc. also provides world-wide technical and service support including calibration for these types of devices.
INTRODUCTION

Our group has nearly 30 years of experience in measuring evaporative water loss from human skin. While with Al Kligman's group at Penn, we utilized various closed chamber systems that were rather crude in that they used gravimetric assessments of the amount water pick up over various times. Even with the advent of electronic humidity sensors, we realized that closed chamber systems should only be considered as being a "quick and dirty" measurement device. Although we had better success with ventilated chamber systems, it was very difficult to establish what flow rates would provide the most reliable values. It was only when we began to use the Servo-Med Evaporimeter based on Gert Nilsson's Vapor Pressure Gradient Estimation Method [1] that we began to feel comfortable with these types of assessments. We soon learned that we could greatly increase the reproducibility and reliability of EWL measurements by developing a computerized system. Computerized evaporimetry not only made it much easier to determine when steady-state conditions were reached but also allowed measurements to be taken in real time under dynamic conditions needed to evaluate the performance of baby diapers [2]. Some of our design elements were incorporated into later versions of the ServoMed Evaporimeter and more recently into the DermaLab TEWL probe manufactured by Cortex Technology [3,4]. Our latest effort is the cyberDERM RG-1 Evaporimeter which is a research grade instrument that utilizes the same TEWL probes as the DermaLab but with advanced electronics in a smaller footprint box that is USB interfaced to a laptop.

As a result of our considerable experience in offering technical and service support for both the ServoMed and DermaLab instruments, we have become very familiar with the typical problems and pitfalls that our customers have encountered over the years. We have also learned quite a bit about evaporative water loss while developing our SSS bioassay which is based on shed snake skin specimens exposed to various toxic agents [5,6].

In this poster, we hope to provide some guidelines on how to maximize the performance of any open chambered device based on Nilsson's Vapor Pressure Gradient Estimation Method.
THE OPEN CHAMBER EVAPORIMETER

The key to understanding the open chamber devices based on Nilsson's Vapor Pressure Gradient Estimation Method is the paired sensors that are located at fixed distances above the surface from which the water is evaporating as diagrammatically shown below:

In order to achieve maximum performance, three major questions need to be answered. They are ...

- Are the sensors properly calibrated for both temperature and relative humidity?
- Are the sensors, properly positioned?
- Do the sensors have a rapid and equal response when either temperature and/or RH changes?

How to best answer these 3 questions will be discussed in this poster.
Are the sensors properly calibrated for both temperature and relative humidity?

For sure this is the first question and in fact mistakenly often the only question that the user may consider worth addressing. To make matters worse, the Factory Calibration Certificates generally only deal with whether or not the sensors provide the proper temperature and relative humidity readings when the unit left the factory.

For both temperature and RH one should always use reference standards that are traceable to NIST. In the case of RH this involves a series of saturated salt solutions that are known to generate different RH levels in the head space just above the liquid level. There was some debate when the DermaLab was first introduced over whether a 2 point or 3 point calibration check was best but it is now generally agreed that a 2 point approach based on saturated solutions of Lithium Chloride and Sodium Chloride is sufficient. Although kits do exist for calibrating in the field, we believe it best that the factory calibrate the probes since they have not only more experience but also much more sophisticated electronic equipment and truly traceable references standards that are required for these critical adjustments.
Routine Performance Check

Although we don’t recommend that the user attempt to adjust the calibration of their unit, we do strongly urge them to run Routine Performance Checks immediately before and after a measurement session. This simple test will reveal how well the upper and lower sensors are matched.

It just requires placing the EWL probe on its side on top of a dry surface. In this position, both the upper and lower sensors are being licked by the same air.

This means that the temperature and relative humidity readings of the upper and lower sensors should be nearly identical and correspond to that of the ambient room conditions. This can easily be checked with the cyberDERM diagnostic software as shown below:

<table>
<thead>
<tr>
<th>Sensor Readings</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper RH</td>
<td>Upper Temperature</td>
</tr>
<tr>
<td>37.55</td>
<td>21.00</td>
</tr>
<tr>
<td>Lower RH</td>
<td>Lower Temperature</td>
</tr>
<tr>
<td>37.35</td>
<td>21.10</td>
</tr>
<tr>
<td>Net RH</td>
<td>Net Temperature</td>
</tr>
<tr>
<td>-0.20</td>
<td>0.10</td>
</tr>
</tbody>
</table>

If the temperature and the relative humidity of the ambient air are known as would be the case for an environmental chamber, then one can easily establish tolerance limits for assessing the calibration status of that EWL probe. Indeed, it is a simple matter to create a source document that would allow the Routine Performance Checks to be logged and documented for QA purposes. Discrepancies mean that either the EWL probe and / or the environmental room conditions are out of spec.
Are the paired sensors, properly positioned?

It is generally assumed that if the Open Chamber Evaporimeter passes the Routine Performance Check that the device is in perfect working order. However, this only establishes that the paired sensors are properly calibrated as to temperature and RH. What is often forgotten is that the EWL calculations are based on those 2 sensors being located at fixed distances not only from one another but also relative to the surface being measured. If this geometry should accidentally change, then the sensors would no longer be sampling the vapor pressure gradient at the proper points and the calculated EWL would certainly be in error.

In order to verify that the sensors are indeed properly positioned, we run another test based on a model system in which the relative evaporative water loss rates are known and held constant over time. This is not a new concept and in fact was discussed in some detail in the original studies by Gert Nilsson [1].

A simplified but temporary version based on covering a dish of water with a Op-site membrane was proposed by the Standardization Group of the European Society of Contact Dermatitis [7]. In our comparative metrology study [5], we used a reference substrate based on an open foam material which was fully loaded with a standard amount of water and covered with polymeric films that differed in water vapor transmission rates. A similar system is utilized in the SSS-bioassay except that the shed snake skin specimens [5,6] take the place of the polymeric films.
The Wet Substrate Test

Regardless of which artificial wet surface is chosen, the underlying principle of this test is that if the paired sensors are properly positioned and the test conditions remain constant over time, then the calculated EWL will also remain constant. Not only that but the paired sensor outputs for both RH and temperature although no longer equivalent will show values that should vary little from day to day. Again it is a simple matter to create a source document that would allow results from the Wet Substrate Test to be logged and documented for QA purposes. We also include the results from this type of test when we calibrate a probe to cyberDERM specs.

### DermaLab TEWL 372 Certification Report

#### Diagnostic test on sensors with Ambient Air & EWL = 0

<table>
<thead>
<tr>
<th>RUN</th>
<th>Relative Humidity</th>
<th>Temperature</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>1</td>
<td>54.43</td>
<td>55.10</td>
<td>20.60</td>
</tr>
<tr>
<td>2</td>
<td>64.02</td>
<td>64.90</td>
<td>20.60</td>
</tr>
<tr>
<td>3</td>
<td>54.00</td>
<td>54.90</td>
<td>20.60</td>
</tr>
<tr>
<td>Mean</td>
<td>54.15</td>
<td>54.80</td>
<td>20.60</td>
</tr>
<tr>
<td>SD</td>
<td>0.24</td>
<td>0.27</td>
<td>0.05</td>
</tr>
</tbody>
</table>

#### Diagnostic test on sensors using Wet Substrate

<table>
<thead>
<tr>
<th>RUN</th>
<th>Relative Humidity</th>
<th>Temperature</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>1</td>
<td>74.95</td>
<td>89.65</td>
<td>20.70</td>
</tr>
<tr>
<td>2</td>
<td>75.00</td>
<td>89.10</td>
<td>20.80</td>
</tr>
<tr>
<td>3</td>
<td>79.28</td>
<td>90.42</td>
<td>20.80</td>
</tr>
<tr>
<td>Mean</td>
<td>75.61</td>
<td>90.68</td>
<td>20.77</td>
</tr>
<tr>
<td>SD</td>
<td>0.67</td>
<td>0.32</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Upper and Lower Sensors RH Values are within .75 of one another and within 2% of NIST Value. Upper and Lower sensors T values are within 0.2 C of one another and within 0.5 C of NIST value. NIST values from RENSE ThermoHygrometer Model DM509 as certified by Ohmic Instruments. Steady-state values within 2.5 units of reference rate based on WVTR of standard substrate. Both upper and lower sensors show rapid and equivalent response in dynamic test.

Performed by D. Gary Grove in cyberDerm Calibration Lab on JAN 31, 2002. With proper care probes should maintain these specs for approximately 1 year. Annual Recertification needs to be run no later than JAN 31, 2003.
Do the sensors have a rapid and equal response when either temperature and/or RH changes?

With dynamic assessments such as a Post Occlusion Stress Test or for evaluating the performance of diapers immediately after removal, it is extremely important that both sensors respond rapidly and equally to these changes. In such critical studies, we also recommend that a dual probe instrument be used and their outputs pooled to compensate for variations in probe performance. You can see how well matched they are by simultaneously placing both on a wet substrate and plotting the EWL over time as shown below:

![Graph showing EWL over time with two sensor readings](image)

For steady-state measurements such as determining the integrity of the stratum corneum barrier, how fast the sensors respond is less critical. The only real consequence is that a probe with a slow responding sensor will take longer to achieve steady-state but the value finally obtained will be a reliable indicator of EWL rates. For this reason, we generally advocate using interactive programs where the operator determines when steady-state conditions are met rather than having the program run for a fixed duration and then automatically stops.
cyberDERM Training Course

Quality Assurance Concerns

- Highly Trained Operators
- Properly Maintained Instruments
  - Calibration Certificates / NIST Traceable
  - Routine Performance Checks
- Standard Operating Procedures
  - Standardized Measurement Conditions
  - Validated Methods & Analysis
  - Documentation / Audit Trails
- Catastrophic Recovery Plan

In this poster we have tried to stress various Quality Assurance Concerns related to the use of Open Chamber Devices for measuring Evaporative Water Loss based on Gert Nilsson’s Vapor Pressure Gradient Estimation Method. As you can see at the top of our list shown above is **highly trained operators**. As part of our Certified Operator Program, cyberDERM has created a CD with a series of training courses in the form of PowerPoint presentations with voice overlays that are available for free upon request.

**EWL Measurements**

**cyberDERM Training Course**

Training includes practical tips of how to take the measurements and yes we have found it necessary to show some operators which side of the probe should be placed on the skin, hence the pointer arrows.
References:


