AquaLab

Water Activity Meter

Operator's Manual
For Series 4, 4TE, 4TEV, DUO, and TEV DUO

METER Group, Inc.

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Contents

1 Introduction

Welcome to METER's AquaLab Series 4, 4TE, 4TEV, and DUO, the standard industry devices for measuring water activity (a_w). AquaLab is the quickest, most accurate, and most reliable instrument available for measuring water activity. Whether you are researching or working on the production line, AquaLab suits your needs. It is easy to use and provides accurate and timely results.

1.1 Customer Support

If you ever need assistance with your AquaLab, have any questions or feedback, there are several ways to contact us. METER has Customer Service Representatives available to speak with you Monday through Friday, between 7 am and 5 pm Pacific time.

Note: If you purchased your AquaLab through a distributor, please contact them for assistance.

Email:
support.food@metergroup.com or **sales.food@metergroup.com**

Phone:
1-509-332-5601

Fax:
1-509-332-5158

If contacting us by email or fax, please include as part of your message your instrument serial number, your name, address, phone, fax number, and a description of your problem or question.

1.2 About This Manual

This manual includes instructions for setting up your AquaLab, verifying the calibration of the instrument, preparing samples, and maintaining and caring for your instrument. Please read these instructions

before operating AquaLab to ensure that the instrument performs to its full potential.

1.3 Warranty

AquaLab has a 30-day satisfaction guarantee and a one year warranty on parts and labor. Your warranty is automatically validated upon receipt of the instrument. We contact our customers within the first 90 days of your purchase to see how the AquaLab is working for you.

1.4 Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from the date of receipt of equipment.

Note: We do not consider the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause as defects.

The Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts Freight On Board the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes the buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

1.5 General Safety Information

Please read through this documentation carefully before putting the instrument into operation. The documentation contains information and warnings which the user must follow in order to ensure safe operation. This instrument may only be operated in accordance with the specifications in this documentation.

This instrument has left the factory in a flawless state in terms of technical and electrical safety. To maintain this state and ensure non-hazardous operation of the instrument, the following instructions must be observed carefully.

1. Only personnel qualified by METER are authorized to carry out service work on the electrical components. When work is required a Certificate of Calibration will be issued upon completion of the work.
2. Never remove the housing of the instrument. The instrument could be damaged by this. There is also a risk of serious injury if the live components are touched. There are no parts inside the housing which can be serviced or replaced by the user.
3. An incorrect main power voltage can damage the instrument. Only operate this instrument with a main power voltage specified for it (see rear label).
4. This product is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground.
5. Should a fuse need to be replaced. Use only the fuse type and rating specified for this instrument.
6. If the instrument is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

2 About AquaLab

AquaLab is the fastest and most accurate instrument for measuring water activity, giving readings in five minutes or less. Its readings are reliable, providing ± 0.003 a_w accuracy. The instrument is easy to clean and checking calibration is simple.

2.1 AquaLab 4 Instrument Specifications

Water Activity Range: 0.030 to 1.000 a_w

Water Activity Accuracy: ± 0.003 (4TE Dew Point Mode) and ± 0.015 (4TEV Capacitance Mode)

Water Activity Resolution: 0.0001 a_w

Read Time[1]: $\leq$ 5 min.

Sample Temperature Range: 15 to 50 °C

Sample Temperature Accuracy: ± 0.2 °C

Sample Temperature Resolution: 0.01 °C

Sample Temperature Adjustment Increment: 1 °C

Sample Dish Capacity: 15 mL full

Operating Environment: 4 to 50 °C; 0 to 90% Humidity non-condensing

Case Dimensions: 26.7 x 17.8 x 12.7 cm

Weight: 3.1 kg

Case Material: POLYLAC PA-765 (ABS) with fire retardant

Display: 64 x 128 Graphical

Data Communications: USB & RS 232 A serial, 9600 to 115200 baud

Power: 110 to 220 VAC, 50/60 Hz

[1] On samples with no significant impedance to vapor loss.

Warranty: One year parts and labor

2.2 AquaLab 4 DUO Specifications

Moisture Content Repeatability: 0.02%

Accuracy to Moisture Content Ref.: 0.1% to 0.5%

2.3 AquaLab Model and Options

Series 4: Uses a chilled-mirror dew point sensor, but lacks the temperature control features found in our premium models.

Series 4TE: User-selectable internal temperature control model, uses thermoelectric (Peltier) components to maintain internal temperature.

Series 4TEV: Uses both a chilled-mirror dew point sensor and a capacitance sensor for measuring non-volatile and volatile substances, respectively. Either sensor is easily selected using the instrument menu system.

Series 4TE DUO: Uses a chilled-mirror dew point sensor and programmed models obtained from isotherm data to give the user both water activity and moisture content simultaneously in five minutes or less.

Series 4TEV DUO: Uses both a chilled-mirror dew point sensor or capacitance sensor as well as programmed models obtained from isotherm data to give the user both water activity and moisture content simultaneously for samples containing both non-volatile and volatile substances.

AquaLab and Water Activity

Water activity (a_w) is a measurement of the energy status of the water in a system. The value indicates how tightly water is "bound," structurally or chemically, within a substance. Water activity is the relative humidity of air in equilibrium with a sample in a sealed chamber. The concept of water activity is of particular importance in determining product quality and safety. Water activity influences color, odor, flavor, texture and shelf-life of many products. It predicts safety and stability with respect to microbial growth, chemical and biochemical reaction rates, and physical properties. For a more detailed description of water activity as it pertains to products, please refer to Section 3 of this manual, titled "Water Activity Theory."

2.4 How AquaLab Works

AquaLab uses the chilled-mirror dew point technique to measure the water activity of a sample. In an instrument that uses the dew point technique, the sample is equilibrated with the head-space of a sealed chamber that contains a mirror and a means of detecting condensation on the mirror. At equilibrium, the relative humidity of the air in the chamber is the same as the water activity of the sample. In the AquaLab, the mirror temperature is precisely controlled by a thermoelectric (Peltier) cooler. Detection of the exact point at which condensation first appears on the mirror is observed with a photoelectric cell. A beam of light is directed onto the mirror and reflected into a photo detector cell. The photo detector senses the change in reflectance when condensation occurs on the mirror. A thermocouple attached to the mirror then records the temperature at which condensation occurs. AquaLab then signals you by beeping and displays the final water activity and temperature.

In addition to the technique described above, AquaLab uses an internal fan that circulates the air within the sample chamber to reduce equilibrium time. Since AquaLab measures both dew point and sample surface temperatures simultaneously, it eliminates the need for complete thermal equilibrium, thereby reducing measurement times to less than five minutes for most samples. The AquaLab 4TEV and

4TEV DUO both use a capacitance humidity sensor to measure the water activity of a sample. The sensor is suspended in the headspace of the chamber and uses a special polymide material sandwiched between two electrodes to sense humidity changes. The sensor converts the humidity value into a specific capacitance, which is then measured electronically by the circuit. This signal is then translated by the software and displayed as water activity on the instrument screen. At equilibrium, the relative humidity of the air in the chamber is the same as the water activity of the sample.

2.5 AquaLab and Temperature

Samples not read at room temperature during the read cycle equilibrate with the AquaLab temperature before the water activity displays. Large temperature differences cause longer reading times, since the Series 4 does not make a complete and accurate reading until the sample and the instrument equilibrate to ±4 °C of each other. There are several advantages in having a temperature-controlled water activity meter. A few major reasons are:

1. **Research purposes.** Researchers can use temperature control to study the effects of temperature on the water activity of a sample, make a comparison of the water activity of different samples independent of temperature, and conduct accelerated shelf-life studies or other water activity studies where temperature control is critical. There are many shelf-life, packaging, and isotherm studies in which temperature control would be very beneficial. (see Section 14 for further resources)

2. **Compliance with government or internal regulations** for specific products. Though the water activity of most products varies by less than ±0.002 per °C, some regulations require measurement at a specific temperature. The most common specification is 25 °C, though 20 °C is sometimes indicated.

3. **Minimization of extreme ambient temperature fluctuations.** If the environmental and AquaLab temperatures fluctuate by as much as ±5 °C daily, water activity readings vary by ±0.01 a_w. Temperature control eliminates variations due to

changes in ambient conditions.

Series 4TE/4TEV/4TE-DUO

The AquaLab Series 4TE models have thermoelectric components installed to allow the instrument to maintain a set chamber temperature. Customers can set the temperature using the Configuration tab of any of the Series 4TE models.

2.6 Chilled Mirror Dew Point Limitations

AquaLab limitation is its ability to accurately measure samples with high concentrations (typically $> 1\%$) of certain volatiles such as ethanol or propylene glycol, which can condense on the surface of the chilled mirror. The extent of the effect is determined by how readily the material volatilizes, which is both concentration and matrix dependent. Therefore, even if your sample contains materials that could volatilize, it may still be possible to make accurate readings using the chilled mirror dew point sensor.

AquaLab Series 4TEV which incorporates both a chilled mirror sensor and a capacitance sensor for measuring volatile substances is METER's solution for products containing volatile materials. If you are unsure if you need the TEV model, please call and discuss your product with a METER representative. Refer to the Section 8 section titled "Volatile Samples" or contact METER for more details.

3 Water Activity Theory

Water is a major component of foods, pharmaceuticals, and cosmetics. Water influences the texture, appearance, taste and spoilage of these products. There are two basic types of water analysis: moisture content and water activity.

3.1 Moisture Content

The meaning of the term moisture content is familiar to most people. It implies a quantitative analysis to determine the total amount of water present in a sample. There are two primary methods for determining moisture content: loss on drying and Karl Fisher titration, but you can also use secondary methods such as infrared and NMR. Moisture content determination is essential in meeting product nutritional labeling regulations, specifying recipes and monitoring processes. However, moisture content alone is not a reliable indicator for predicting microbial responses and chemical reactions in materials. The limitations of moisture content measurement are attributed to differences in the intensity with which water associates with other components.

3.2 Water Activity

Water activity is a measure of the energy status of the water in a system, and thus is a far better indicator of perishability than water content. Figure 1 shows how the relative activity of microorganisms, lipids and enzymes relate to water activity. While other factors, such as nutrient availability and temperature, can affect the relationships, water activity is the best single measure of how water affects these processes. Researchers measure the water activity of a system by equilibrating the liquid phase water in the sample with the vapor phase water in the headspace and measuring the relative humidity of the head-space. In the AquaLab, you place a sample in a sample cup that seals inside the sample chamber. Inside the sample chamber is a fan, a dew point sensor, a temperature sensor, and an infrared thermometer. The dew point sensor measures the dew point

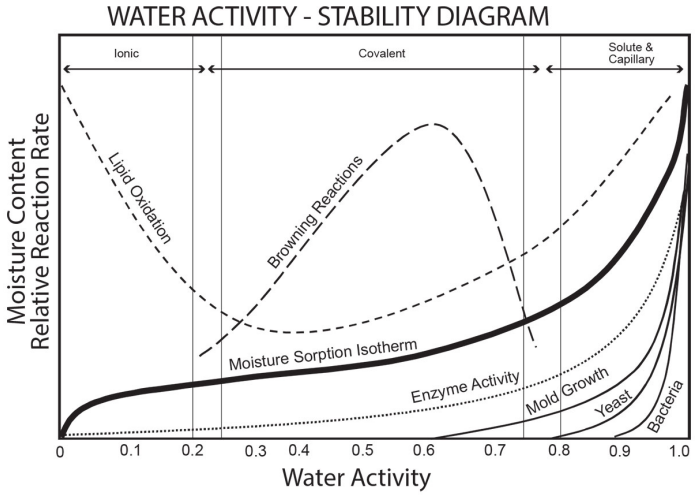


Figure 1: Water Activity Diagram adapted from Labuza

temperature of the air in the chamber, and the infrared thermometer measures the sample temperature. From these measurements, the relative humidity of the head-space is computed as the ratio of dew point temperature saturation vapor pressure to saturation vapor pressure at the sample temperature. When the water activity of the sample and the relative humidity of the air are in equilibrium, the measurement of the head-space humidity gives the water activity of the sample. The purpose of the fan is to speed equilibrium and to control the boundary layer conductance of the dew point sensor.

In addition to equilibrium between the liquid phase water in the sample and the vapor phase, the internal equilibrium of the sample is important. If a system is not at internal equilibrium, one might measure a steady vapor pressure (over the period of measurement) which is not the true water activity of the system. An example of this might be a baked good or a multi-component food. Initially out of the oven, a baked good is not at internal equilibrium; the outer surface is at a lower water activity than the center of the baked good. One must wait a period of time in order for the water to migrate and the system to come to internal equilibrium. It is important to remember the restriction of the definition of water activity to equilibrium.

Temperature Effects

Temperature plays a critical role in water activity determination. Most critical is the measurement of the difference between sample and dew point temperature. If this temperature difference were in error by 1 °C, an error of up to 0.06 a_w could result. In order for water activity measurements to be accurate to 0.001, temperature difference measurements need to be accurate to 0.017 °C. The AquaLab infrared thermometer measures the difference in temperature between the sample and the block. It is carefully calibrated to minimize temperature errors, but achieving 0.017 °C accuracy is difficult when temperature differences are large. Best accuracy is therefore obtained when the sample is near chamber temperature.

Another effect of temperature on water activity occurs when samples are near saturation. A sample that is close to 1.0 a_w and is only slightly warmer than the sensor block condenses water within the block. This causes errors in the measurement, and in subsequent measurements until the condensation disappears. A sample at 0.75 a_w needs to be approximately 4 °C above the chamber temperature to cause condensation. The AquaLab warns the user if a sample is more than 4 °C above the chamber temperature, but for high water activity samples the operator needs to be aware that condensation can occur if a sample that is warmer than the block is put in the AquaLab.

3.3 Water Potential

Some additional information may be useful for understanding what water activity is and why it is such a useful measure of moisture status in products. Water activity is closely related to a thermodynamic property called the water potential, or chemical potential (μ) of water, which is the change in Gibbs free energy (ΔG) when water concentration changes. Equilibrium occurs in a system when (μ) is the same everywhere in the system. Equilibrium between the liquid and the vapor phases implies that (μ) is the same in both phases. It is this fact that allows us to measure the water potential of the va-

por phase and use that to determine the water potential of the liquid phase. Gradients in (μ) are driving forces for moisture movement. Thus, in an isothermal system, water tends to move from regions of high water potential (high a_w) to regions of low water potential (low a_w). Water content is not a driving force for water movement, and therefore can not be used to predict the direction of water movement, except in homogeneous materials.

Factors In Determining Water Activity

The water activity of the water in a system is influenced by factors that effect the binding of water. They include osmotic, matric, and pressure effects. Typically water activity is measured at atmospheric pressure, so only the osmotic and matric effects are important.

Osmotic Effects: Osmotic effects are well known from biology and physical chemistry. Water is diluted when a solute is added. If this diluted water is separated from pure water by a semi-permeable membrane, water tends to move from the pure water side through the membrane to the side with the added solute. If sufficient pressure is applied to the solute-water mixture to just stop the flow, this pressure is a measure of the osmotic potential of the solution. Addition of one mole of an ideal solute to a kilogram of water produces an osmotic pressure of 22.4 atm. This lowers the water activity of the solution from 1.0 to 0.98 a_w. For a given amount of solute, increasing the water content of the systems dilutes the solute, decreasing the osmotic pressure, and increasing the water activity. Since microbial cells are high concentrations of solute surrounded by semi-permeable membranes, the osmotic effect on the free energy of the water is important for determining microbial water relations and therefore their activity.

Matric Effects: The sample matrix affects water activity by physically binding water within its structure through adhesive and cohesive forces that hold water in pores and capillaries, and to particle surfaces. If cellulose or protein were added to water, the energy status of the water would be reduced. Work would need to be done to extract the water from this matrix. This reduction in energy status

of the water is not osmotic, because the cellulose or protein concentrations are far too low to produce any significant dilution of water. The reduction in energy is the result of direct physical binding of water to the cellulose or protein matrix by hydrogen bonding and van der Waal forces. At higher water activity levels, capillary forces and surface tension can also play a role.

3.4 Sorption Isotherms

Relating Water Activity to Water Content

Changes in water content affect both the osmotic and matric binding of water in a product. Thus a relationship exists between the water activity and water content of a product. This relationship is called the sorption isotherm, and is unique for each product. Besides being unique to each product, the isotherm changes depending on whether it was obtained by drying or wetting the sample. These factors need to be kept in mind if one tries to use water content to infer the stability or safety of a product. Typically, large safety margins are built into water content specifications to allow for these uncertainties.

While the sorption isotherm is often used to infer water activity from water content, one could easily go the other direction and use the water activity to infer the water content. This is particularly attractive because water activity is much more quickly measured than water content. This method gives particularly good precision in the center of the isotherm. In order to infer water content from water activity, one needs an isotherm for the particular product. METER sells an Isotherm Generator called the AquaLab Vapor Sorption Analyzer (VSA) or you can also have METER run the isotherm for a fee.

For example, if you were using the AquaLab to monitor the water content of dried potato flakes, you would measure the water activity and water content of potato flakes dried to varying degrees using the standard drying process for those flakes. You could then use that data to construct an isotherm and infer the water content using the measured water activity of samples and that isotherm. METER has an upgrade available to Series 4TE users that would allow you to

determine moisture content and water activity simultaneously. This instrument is called the Series 4TE DUO.

We cannot overemphasize the importance of the concept of water activity for foods, pharmaceuticals, and cosmetics. Water activity is a measure of the energy status of the water in a system. More importantly, the usefulness of water activity in relation to microbial growth, chemical reactivity, and stability over water content has been shown.

4 Getting Started

4.1 Components of your AquaLab

Your AquaLab should have been shipped with the following items:

- AquaLab water activity meter
- Calibration certificate
- Power cord
- USB interface cable
- 50 disposable sample cups
- Operator's Manual
- Quick Start Guide
- Cleaning kit
- Two vials each of the following verification solutions:

  0.760 a_w 6.00 mol/kg NaCl
  0.500 a_w 8.57 mol/kg LiCl
  0.250 a_w 13.41 mol/kg LiCl

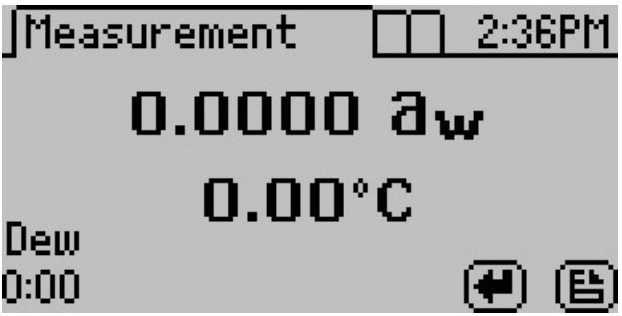
4.2 Choosing a Location

To ensure that your AquaLab operates correctly and consistently, place it on a level surface. This reduces the chance of spilling sample material and contaminating the sample chamber. Also select a location where the temperature remains fairly stable to avoid temperature changes that can affect accuracy. This location should be well away from air conditioner and heater vents, open windows, etc. Place the AquaLab in a location where cleanliness can be maintained to prevent contamination of the sample chamber.

4.3 Preparing AquaLab for Operation

After finding a good location for your AquaLab, plug the power cord into the back of the unit. The ON/OFF switch is located on the lower left corner of the AquaLab back panel. When the AquaLab is turned on, you should see a model name/number screen and then the main Measurement screen.

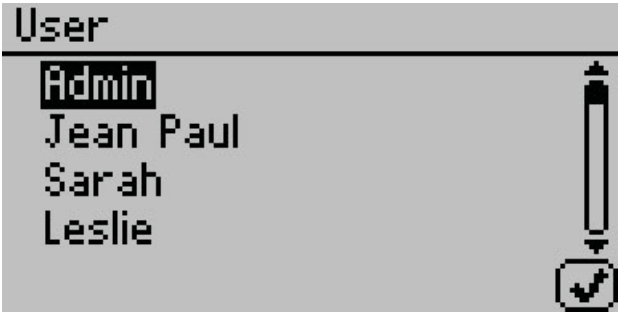
Warning: Only use the supplied power cord or one rated for your AquaLab 4 and certified for the country of use. The cord must be minimum of 18 AWG and have a rating for 10 Amps or greater.



The main screen shows the water activity (a_w) in the middle of the screen and above the sample temperature. On the Series 4TEV model you also see either DEW or CAP indicating whether you are using the dew point or capacitance sensor respectively.

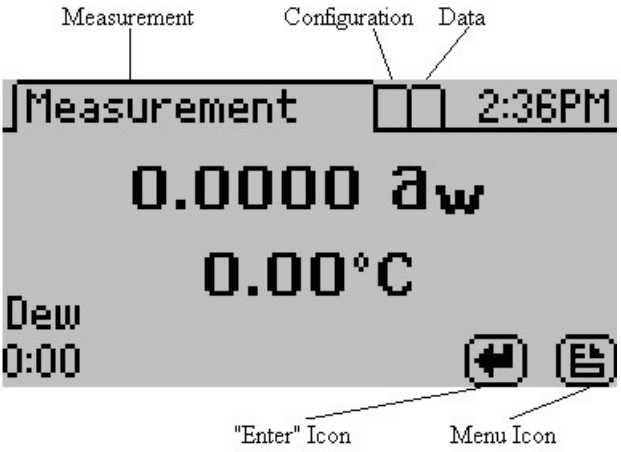
Note: Allow your AquaLab a 15 minute warm-up period to ensure the most accurate readings.

If you have users set up, the User screen appears instead of the main screen. (see Section 5 for more information on administrative settings and user setup.) Select the appropriate user to begin.


User
Admin
Jean Paul
Sarah
Leslie

5 Menus

At the top of the display screen there are three tabs: Measurement, Configuration, and Data. These tabs indicate the three menus you can access. To change between the tabs press the right most button below the Menu icon.

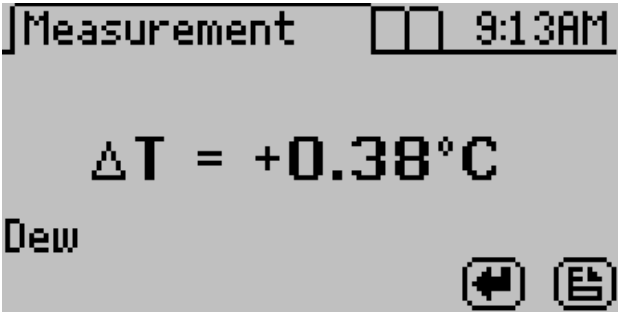


The enter icon is the Read or Enter button. Once the latch is set to the Read position, the Menu icon switches to an "X" icon, which allows the user to stop the current reading. During a reading, pressing Enter again restarts the reading.

5.1 Measurement Tab

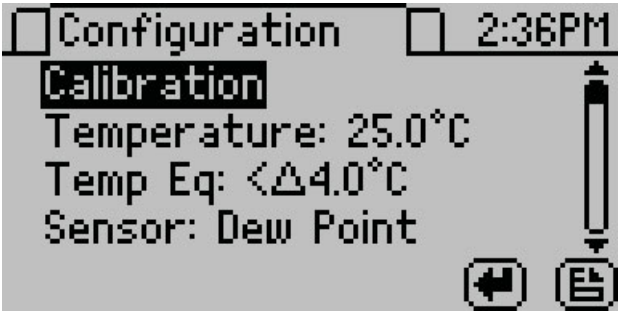
The Measurement tab, as seen above, is the main screen which displays each time you turn on your AquaLab. If this screen does not appear, refer to Section 12 for troubleshooting instructions. As mentioned earlier, the water activity and sample temperature are displayed on the screen.

Pushing the right or left arrow keys changes the display to a temperature equilibration screen. This screen shows the temperature difference between the sample temperature and the lid temperature.



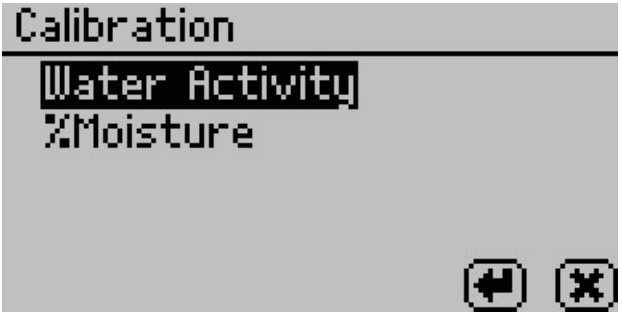
5.2 Configuration Tab

When at the configuration screen, pressing the up and down arrow keys moves the cursor through the various configuration options. Press the left and right arrows to page through the options. The Enter button allows you to change the highlighted setting.



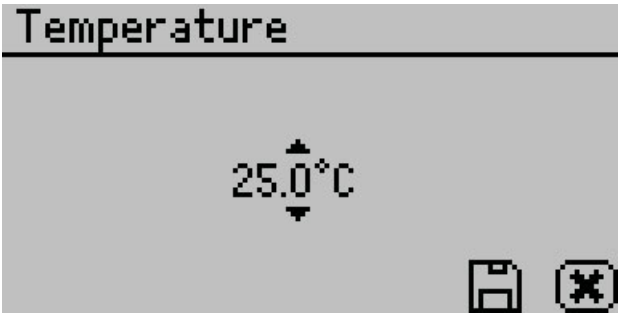
Calibration

Pressing the Enter button with Calibration highlighted starts the calibration process. For more details on the water activity verification and calibration procedures refer to Section 7. Refer to Section 10 for moisture content verification information (DUO model only). You may also reset the calibration to the factory defaults by highlighting the Defaults option and pressing Enter. This resets all options to the way they were when the instrument arrived at your location.



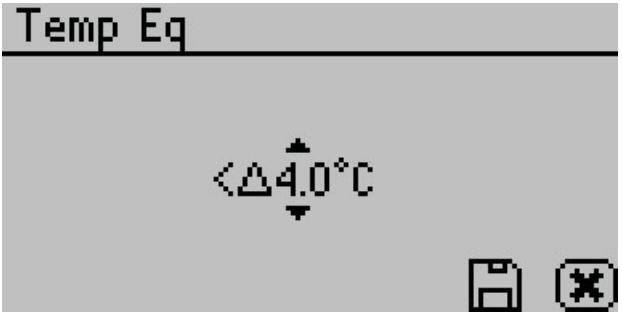
Temperature

The default temperature is 25 °C. Press the Enter button to change the temperature setting. The AquaLab Series 4TE models may be set between 15 and 50 °C by 0.1 °C intervals. Using the up and down arrows, set the AquaLab to your desired temperature and press the save button.



Temp Eq

The Temperature Equilibration option allows you to set the level of temperature equilibration desired before the water activity measurement begins. The range is 0.5 to 4.0 °C. A setting of 4.0 °C begins the measurement immediately (assuming the sample is not $>$ 4.0 °C above or below the block temperature). A setting of 0.5 °C causes the instrument to wait until the sample temperature is within $<$ 0.5 °C of the block temperature before starting the water activity measurement.



Sensor

In the AquaLab Series 4TEV model only, this option indicates the selected sensor type, either dew point or capacitance (The Series 4 and 4TE models are always dew point). Pressing Enter when the Sensor option is highlighted allows you to change between a capacitance sensor or chilled mirror dew point sensor for sampling with or without volatiles, respectively.

Mode

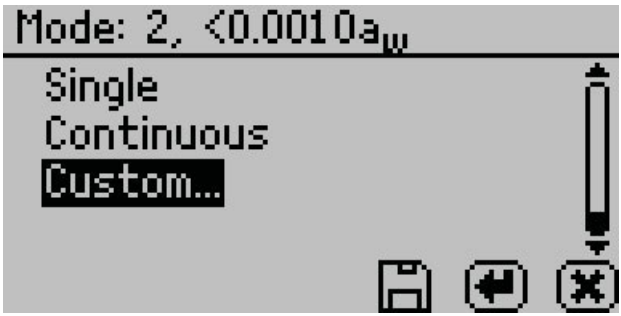
Users may choose between single, continuous, or custom mode by pushing the save button.

Single Mode: Single mode reads the sample once, after which the instrument notifies you that it is finished and the water activity and temperature display on the screen.

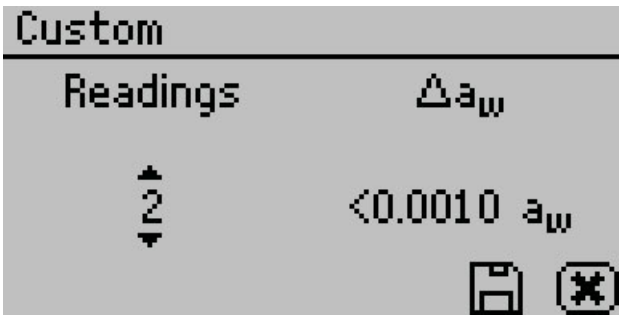
Continuous Mode: Continuous mode reads your sample until you open the chamber lid or stop the test using the stop button. The AquaLab reads the sample, displays the water activity and temperature, then begins another read cycle without further input from the user. Between samples, the machine signals you with beeps. This mode eliminates the possibility of moisture exchange with the environment outside the chamber in between readings. A time on the bottom left of the screen tracks the cumulative read time. All readings taken during continuous mode are saved on the instrument memory if the autosave feature is selected (see Auto Save below).

Custom Mode: Custom mode allows a sample to be read multiple times until a desired level of stability is achieved. The user determines how many consecutive tests they want to be within a given water activity stability setting. For instance, the customer can choose to have four consecutive tests be within ± 0.001 a_w. The instrument continues to run tests until it records four consecutive tests that are within ± 0.001 a_w and then stop and report the value of the final test. If autosave is turned on, all test readings save to the instrument memory, but only the final reading appears on the main measurement screen.

On the Mode screen at the top of the page, the current mode settings appear with the number of tests appearing first, followed by the stability value (Δa_w). Pressing enter with the custom mode highlighted allows you to change the number of tests and stability settings.



To change the number of readings, use the right/left arrow buttons to highlight the number under Readings, and then use the up and down buttons to change to any value between 2 and 9.



To change the stability setting, use the right/left arrow buttons to highlight the number under (Δa_w), and then use the up and down buttons to change to any value between 0.0005 and 0.0200. To save the settings and finish, press the save button (to exit without updating, press the cancel button). The Mode screen now appears with the updated custom settings appearing at the top of the screen. Press the save button to return to the configuration screen and begin using the custom mode (To exit without updating, press the cancel button).

Date

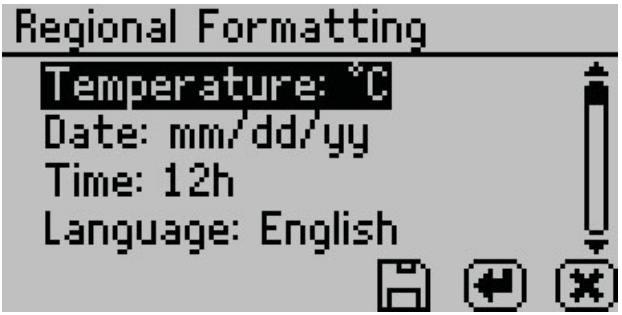
AquaLab Series 4 models now have an internal calendar and clock. The time and date are recorded with each water activity reading. Pressing Enter when the Date option is highlighted allows you to set the date in the instrument. Press the left and right arrows to change between the month, day and year. Press the up or down arrows to change any of the individual values.

Time

Pressing Enter with the Time option highlighted allows you to set the current local time. Press the up or down arrows to change any of the individual values. Press the left or right buttons to change between hour and minutes. The hour setting automatically changes between AM and PM.

Regional Formatting

Allows you to configure how all Series 4 models display information. You may choose the temperature scale (Celsius vs Fahrenheit), the date display (mm/dd/yy vs dd/mm/yy), the hour format (12 vs 24 hour) and the language.



5.3 Admin Settings

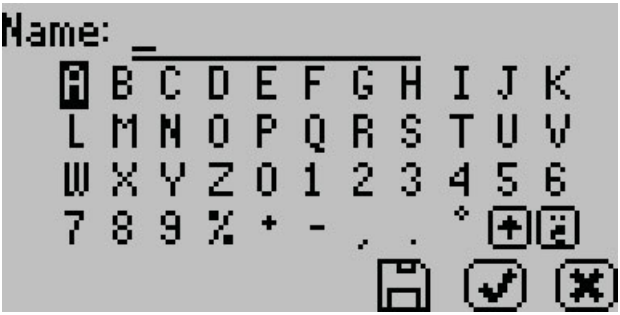
Allows you to create an administrator password as well as create, edit, and delete additional users.

The admin settings allow the administrator to grant or block access to some or all of the configuration options in all Series 4 models. For example: If the administrator wanted to make sure that all samples were read at 25 °C the administrator would set their temperature to 25 °C and then lock all other users out of that configuration screen. Administrators may lock out users by entering the Access function and selecting the desired option to toggle it on and off. You can also lock and unlock all of them at once. (For example, if you do not want an individual changing the instrument measurement temperature, the administrator can lock that function for only certain individuals.) The areas that you can lock are calibration, temperature, temperature equilibration, sensor selection, mode, date/time, region, password, auto-save, number of beeps, , and delete functions.

User Setup

Administrators can add, edit, or delete users from this screen. An alphabet screen appears where you can enter a name using lower

case, upper case and accents.



Note: User setup is not required for instrument operation. It is in place for users wanting to be compliant with 21 CFR Part 11 or who want to maintain the settings they have selected.

Auto Save

AquaLab Series 4 models have the ability to store water activity readings within the instrument. By selecting Auto Save On, the instrument automatically stores every water activity reading in the internal memory. AquaLab Series 4 can store up to 8,000 records before the memory is full. If you turn Auto Save Off then the instrument does not automatically store data, although you may store any individual reading manually right after completing the test and before beginning the next test.

To manually store a water activity or append an annotation to the active reading that has been autosaved, press the save icon button after the water activity measurement is completed. Pressing the icon opens a Name screen. You may give this reading a name by pressing the arrow buttons to highlight the letter and then pressing the Check icon button. Press the save icon to save this data record with the name you have specified.

Note: Pressing the Save icon button without giving it a name saves the reading without name. If the save icon is not pressed after a

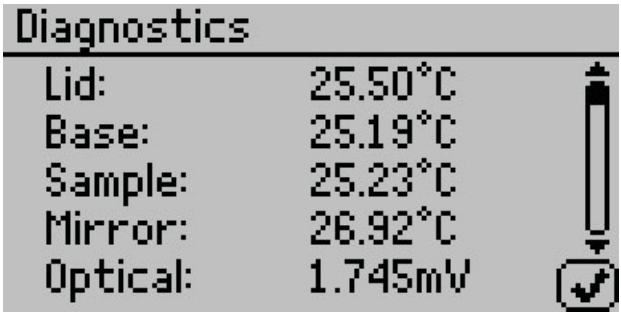
reading, and the reading is autosaved, it is not possible to give an annotation later.

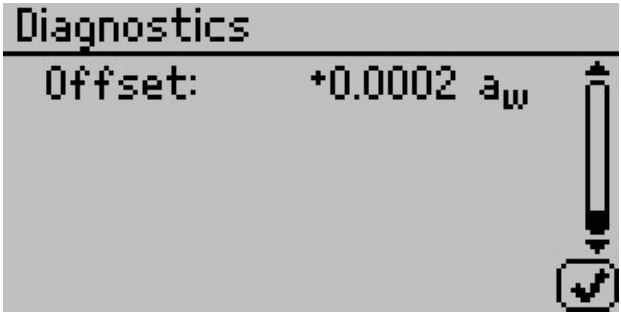
Beeps

Allows you to set the reading finished notification from 4 beeps to continuous beeps. You may also turn the audible notification off.

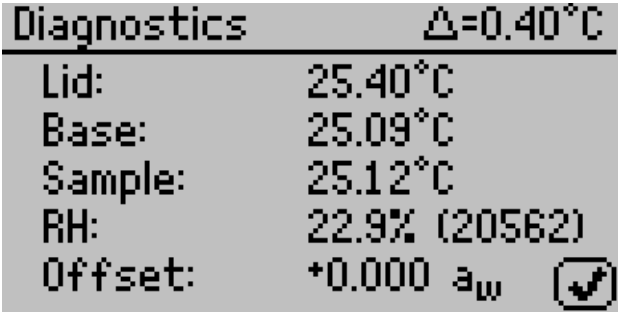
Diagnostics

For the chilled-mirror dew point sensor, Diagnostics provides you with a lid, base, sample and mirror temperatures, optical voltage, and the user calibration.





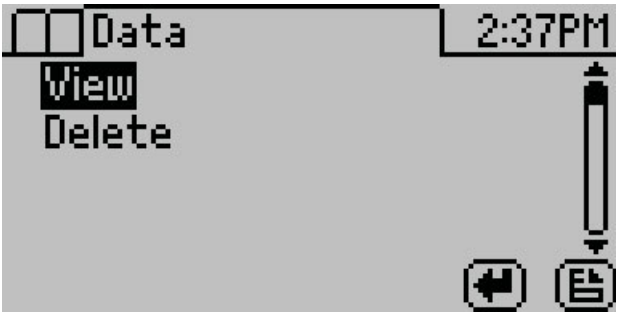
For the capacitance sensor (TEV Models only) Diagnostics provides you lid, base, and sample temperatures, relative humidity, and the capacitive sensor calibration.



About

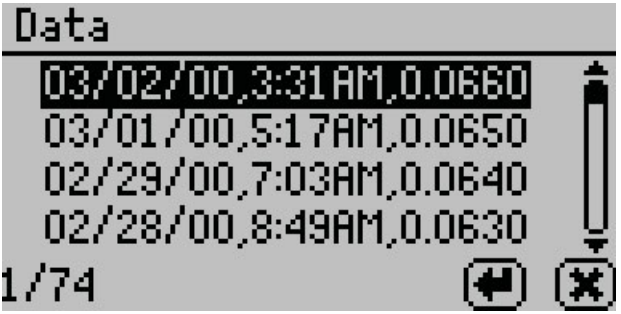
This screen provides important information including the serial number and code version of your instrument.

5.4 Data Tab

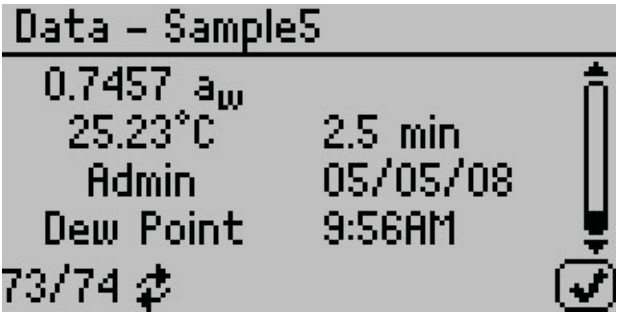


View

This selection allows you to view your stored measurements. The up/down arrows move you through the stored data with the most recent measurements at the top of the table. You may also press the left and right arrows to page quickly through the data. See Section 11: Computer Interface for information about downloading these readings to a computer.



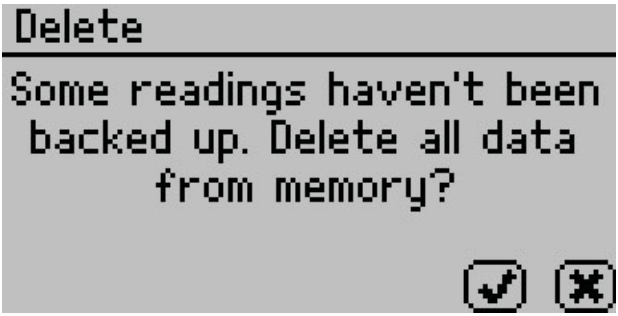
When you are viewing the summary screen, you may press the Enter button on a highlighted reading to get detailed information on the reading as the Data - Sample screen shows.



The information shown is the water activity of the sample, the temperature, the test time, the user who ran the test (if setup), the date of the reading, the sensor used (4TEV only), the time the reading was taken, and the sequence number of the stored reading. Use the up and down arrows to scroll through readings.

Delete

Selecting this option deletes all of the information currently stored in the instrument. If you have not backed up this information with AquaLink 4, the Delete window issues a reminder.



Note: You cannot recover deleted data.

6 Cleaning and Maintenance

Keeping your AquaLab clean is vital to maintaining the accuracy of your instrument. Dust and sampling debris can contaminate the sampling chamber, so you must regularly clean your instrument. To clean your instrument, carefully follow these instructions and refer to the labeled diagram in Figure 2. METER recommends you send your AquaLab in for annual factory calibration.

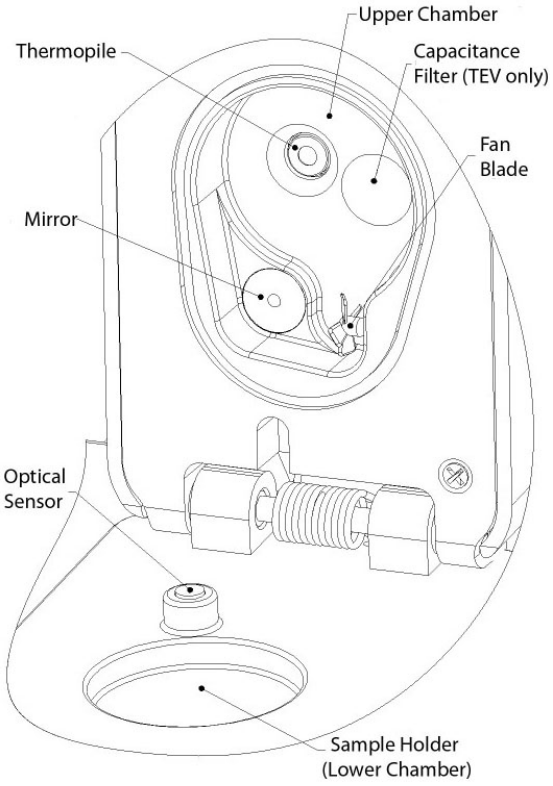


Figure 2: AquaLab Instrument Diagram

Purpose

The purpose for the cleaning procedure is to remove grease, dirt and other soluble substances which can absorb or release water during verification, calibration, and/or sample testing. For a smooth

and even dew formation, it requires the mirror to be perfectly clean. If there are any contaminants (e.g. fingerprints) on the mirror, the dew forms unevenly and can affect the accuracy of the reading.

When to Clean

The instrument should be cleaned if visual inspection indicates the chamber is dirty or as instructed in Figure 3 on page 40.

Cleaning Supplies

Your new instrument comes with the AquaLab Cleaning Kit. The AquaLab Cleaning Kit comes with all the materials needed to clean the instrument for about a year. Every time you send in your instrument for the annual calibration service, you receive a new cleaning kit. The following supplies are included in the cleaning kit:

- Spatula (a thin plastic rod)
- Deionized Water for cleaning
- Cleaning Solution
- Kimwipes®

Note: Wash your hands with soap and water and use clean lab gloves before starting the cleaning procedure. This prevents oils from contaminating the cleaning materials, the sample chamber and/or the sensors.

Note: You can substitute Isopropyl Alcohol for the Cleaning Solution

6.1 Cleaning the Block Sensors

Accessing the Sample Chamber

Turn the power off on your AquaLab. If latched, move the lever over to the open position. Lift the chamber cover to expose the sample chamber and sensors. The sample chamber consists of all surfaces inside the red o-ring when the lid is closed.

6.2 Cleaning a Series 4TEV

When cleaning an AquaLab Series 4TEV, follow the cleaning procedures listed below being careful not to get cleaning solution on the capacitance sensor filter (see Figure 2). If you run out of cleaning solution, you can use isopropyl alcohol (IPA) instead. Repeated exposure of cleaning materials or contaminants to the filter may cause inaccurate readings. If the filter appears to be contaminated, it may need to be replaced. (To replace the capacitance sensor filter, use a tweezer or small knife blade to pry up the edge of the filter, being careful not to disturb the sensor beneath. Discard the soiled filter, then with clean hands, gently press a new filter into place.)

6.3 Cleaning Procedure:

Cleaning your AquaLab is a multi-step procedure which involves washing, rinsing, and drying for each specific area as outlined below. (Refer to Figure 2 at the beginning of this section to identify component locations for cleaning.)

1. **Cleaning the Sample Chamber**

   Note: Be extremely careful not to damage the fan blades (see illustration) when cleaning the chamber.

   (a) Remove any debris that may have collected within or around the sample chamber.
   (b) Wrap a NEW Kimwipe around the end of the spatula (thin plastic rod) and moisten it with cleaning solution.

   Note: Do NOT dip a used Kimwipe into your cleaning solution (the cleaning solution becomes contaminated).

   (c) WASH — Clean upper chamber, o-ring, and all surfaces of the block within the o-ring. You may need to replace the Kimwipe if it becomes too dirty during this process.

(d) Clean lower block with a fresh Kimwipe. Be sure to clean the entire block surface.
(e) RINSE — Repeat steps b through d using new Kimwipes with deionized water.
(f) DRY — Repeat steps b through d using new, dry Kimwipes to help remove any moisture remaining from the cleaning.

Note: Do not reuse Kimwipes.

2. **Clean the Mirror**

(a) Wrap a NEW Kimwipe around the end of the spatula and moisten it with cleaning solution.
(b) WASH — Swipe the moistened Kimwipe across the mirror once. (A single swipe is usually sufficient to remove contaminants.)
(c) RINSE — Repeat steps a through b using new Kimwipes moistened with deionized water instead of cleaning solution.
(d) DRY — Repeat steps a through b using new and dry Kimwipes to help remove any moisture remaining from the cleaning.
(e) Visually inspect the mirror for cleanliness. Clean again if necessary.

3. **Clean the Thermopile and Optical Sensor**

(a) Wrap a new Kimwipe around the end of the spatula and moisten it with cleaning solution.
(b) WASH — Swipe the moistened Kimwipe across thermopile and optical sensor. (A single swipe across the sensor is usually sufficient to remove contaminants.)
(c) RINSE — Repeat steps a through b using new fs moistened with deionized water instead of cleaning solution.
(d) DRY — Repeat steps a through b but use a new, dry Kimwipe to help remove any moisture remaining from the cleaning.
(e) Visually inspect the thermopile and optical sensor for clean-

liness. Clean again if necessary.

4. **Additional Drying Time**

   (a) Visually inspect the sample chamber and sensors for contaminants, including moisture. If necessary, repeat the cleaning process using new Kimwipes.
   (b) Let stand for five minutes to ensure the sample chamber is dry.

6.4 Verification of Calibration

After you have cleaned the chamber and other parts of your AquaLab, it is important to check the instrument performance in order to correct for any linear offset that may have occurred during the cleaning process.

Before you check the instrument we recommend that you run a sample of the activated charcoal pellets provided in your AquaLab Cleaning Kit. This cleans the air inside the chamber, helping it come back to a stable sampling environment.

Verify the linear offset against known verification standards according to the procedure described in the next section. If a linear offset has occurred, refer to adjust for linear offset section in Section 7 for directions on how to correct for linear offset. If, after adjusting for linear offset, your instrument is still not reading samples correctly, it may be time for an annual factory calibration. Contact AquaLab at support.food@metergroup.com or 509-332-5601 for annual calibration.

7 Verification and Calibration

It is important to verify the AquaLab water activity calibration against known standards to guarantee optimal performance and accuracy. METER recommends verification daily, once per shift or before each use. METER also recommends annual factory calibration to maintain optimal performance.

7.1 Water Activity Verification

The AquaLab uses the chilled-mirror dew point technique to determine water activity. Because this is a primary measurement of relative humidity, no calibration is necessary; but we recommend periodic calibration to verify for linear offset. The components used by the instrument to measure water activity are subject to contamination which may affect the AquaLab performance. When this occurs, it changes the accuracy of the instrument. This is what is called a linear offset. Therefore, frequent verification assures you that your AquaLab is performing correctly. Linear offset is checked by using two different verification standards.

Verification Standards

Verification standards are specially prepared unsaturated salt solutions having a specific molality and water activity value which are accurately measurable. The verification standards that were sent with your initial shipment are very accurate and readily available from METER. Using verification standards to verify accuracy can greatly reduce preparation errors. For these reasons, we recommend using standards available through METER for the most accurate verification of your AquaLab performance. Performance Verification Standards come in seven water activity levels: 1.000, 0.984, 0.920, 0.760, 0.500, 0.250, and 0.150 a_w. The standards are produced under a strict quality assurance regime. Please contact METER to order additional standards via sales.food@metergroup.com or 509-332-5985.

Table 1: Verification Standards

Verification Standard @ 25 °C	Dew Point A_w	Capacitive A_w
17.18 mol/kg LiCl	0.150 ±0.005	0.150 ±0.015
13.41 mol/kg LiCl	0.250 ±0.003	0.250 ±0.015
8.57 mol/kg LiCl	0.500 ±0.003	0.500 ±0.015
6.00 mol/kg NaCl	0.760 ±0.003	0.760 ±0.015
2.33 mol/kg NaCl	0.920 ±0.003	0.920 ±0.015
0.50 mol/kg KCl	0.984 ±0.003	0.984 ±0.015
USP Purified Water	1.000 ±0.003	1.000 ±0.015

Note: If you need to obtain a Safety Data Sheet (SDS) for any of these standards, a printable version is available on our website at http://sds.metergroup.com/.

To use a verification standard, remove the twist top and pour the contents into an AquaLab sample cup. Information about the standard value and molality can be found printed on the outside of the plastic vial. If for some reason you cannot obtain METER's verification standards and need to make a saturated salt solution for verification, refer to Appendix A.

In TEV models, the capacitance sensor can hold a memory of high water activity samples such as USP (United States Pharmacopia Specifications) Purified Water or the 0.984 a_w standard. If you verify calibration with one of these high water activity standards, you must wait an hour to allow the capacitance sensor and filter to dry before testing samples of lower water activity or the results may be slightly high.

Note: To avoid inaccurate water activity readings, verification standards should be used once immediately after opening and not stored in sample cups for repeated use.

7.2 Verification of Calibration

When to Verify for Linear Offset

Linear offset should be checked against two known verification standards daily, either once per shift or before each use. Linear offset should never be verified solely against USP Purified Water, since it does not give an accurate representation of the linear offset. For batch processing, the instrument should be checked regularly against a known standard of similar water activity. It is also a good idea to check the offset with a standard of similar water activity when the general water activity range of your sample is changing. Checking the water activity of a standard solution alerts you to the possibility of unit contamination or shifts in the linear offset from other causes.

Follow steps 1 through 8 to verify for linear offset of your AquaLab. (Refer to Figure 3: the Verification Standard Flowchart for a quick overview.)

1. Choose a verification standard that is close to the water activity of the sample you are measuring.

   Note: The AquaLab needs to warm up for approximately 15 minutes to make accurate readings.

2. Empty a vial of solution into a sample cup and place it in the AquaLab testing chamber. Make sure that your standard is as close to the instrument temperature as possible. See Section 8 for detailed instructions.

   Note: Make sure the rim and outside of the sample cup are clean.

3. Carefully close the lid and move the lever to the Read position.

4. Take two readings. The water activity readings should be within ± 0.003 a_w of the given value for the dew point and ± 0.015 for capacitance when testing the verification standard. See Appendix B for the correct water activity value of ME-

TER's standards at temperatures other than 25 °C.

5. If your AquaLab reads within ±0.003 a_w of the verification standard for dew point and ±0.015 for capacitance, choose a second verification standard that would border the range of water activity you plan to test. For example, if you plan to test for water activity readings ranging between 0.713 and 0.621 you should use the 8.57 mol/kg LiCl (0.50 a_w) standard for your first verification and the 6.00 mol/kg, NaCl (0.76 a_w) for the second verification.

6. Prepare a sample cup of the second verification standard and make two readings. The second water activity reading for the second verification standard should be within ±0.003 a_w for the dew point and ±0.015 for the capacitance sensors.

7. If either of the verification standards is not correct, it is probably due to contamination of the sensor chamber. For cleaning instructions, see Section 6. After cleaning, repeat verification from step two.

8. If you are consistently getting readings outside the water activity of your first verification standard by more than ±0.003 a_w for dew point and ±0.015 for capacitance, a linear offset has probably occurred. In this case, adjust the reading to match the correct verification standard value as outlined in the next section.

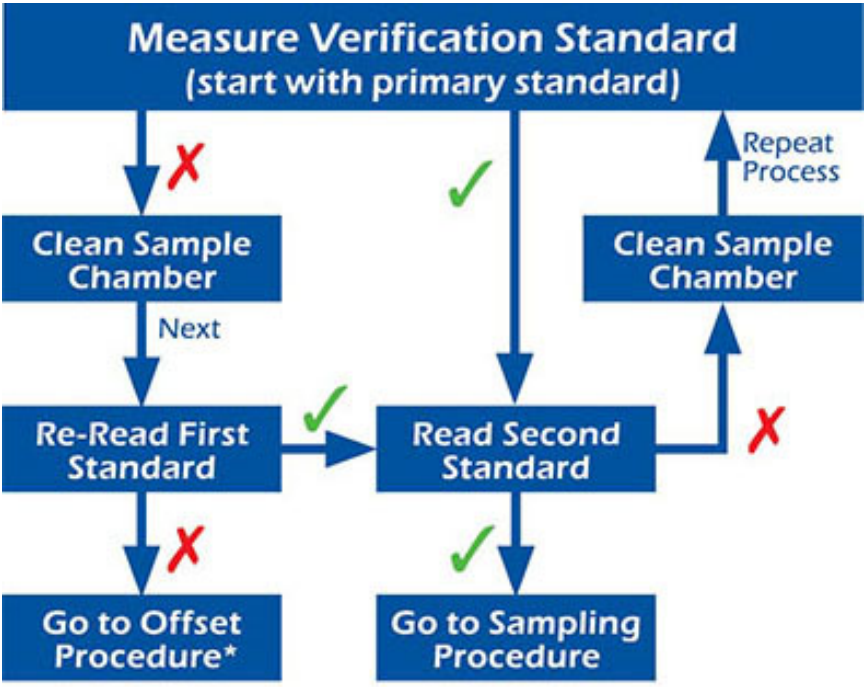
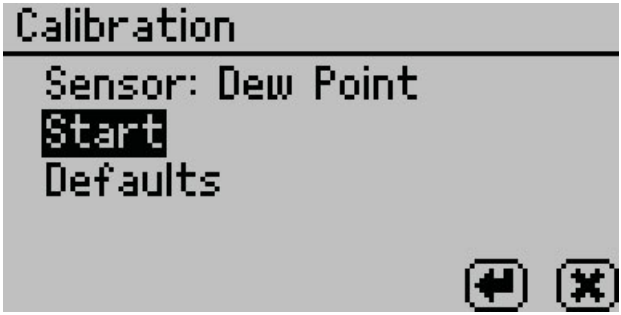


Figure 3: Verification Standard Flowchart

Note: The Measure Verification Standard flowchart is a graphical representation of the Verification of Calibration directions.

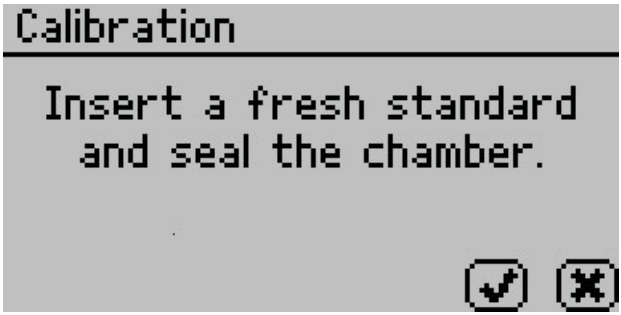
Adjust for Linear Offset

1. Once you are certain a linear offset has occurred, toggle to the Configuration tab by pressing the Menu icon button. Calibration is the first option highlighted in the Configuration tab. Press the Enter icon button to begin the verification process. The on screen commands guides you through the linear offset routine. The Calibration screen prompts you to start.



Note: The DUO model shows both water activity and moisture content on this screen. For TEV Models, make sure to select the correct sensor before beginning the offset.

2. Press the Enter button to start the linear offset process. To return to the Configuration tab, press the Cancel button. After pressing the Enter button, the Calibration screen prompts you to insert a fresh standard and seal the chamber.



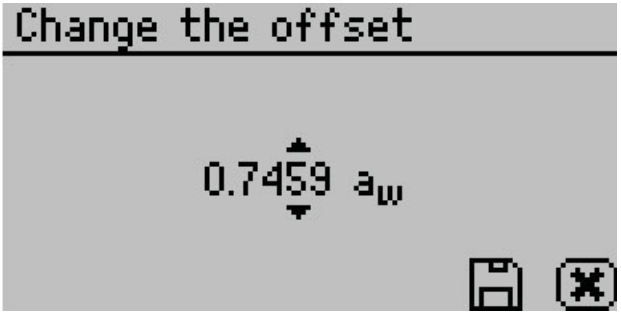
3. Empty the whole vial of solution into a sample cup. We recommend using the 6.00 NaCl (0.76 a_w). Do not adjust for the offset using USP Purified water. Ensure the rim and outside of the cup are clean. Place the sample cup in the AquaLab sample chamber.

   Note: You may use the same verification standard to verify and adjust the linear offset.

4. Carefully close the lid and move the lever to the Read position. Press the Check icon button to begin testing.

Note: If you decide at this point not to continue with the multi-point calibration, just return the lever to the Open position or press the Cancel button to return to the previous screen.

5. After your AquaLab has finished measuring the verification standard, it displays a Change the Offset screen.



6. Press the up and down arrows to adjust the water activity reading to its proper value for the particular verification standard you are measuring. When the correct value displays, press the Save icon button to store this new value. To cancel and return to the main menu, press the cancel button to make no changes.
7. Re-measure the verification standard again in normal sampling mode. It should read the proper value (within ±0.003 a_w dew point or ±0.015 capacitance) at a given temperature for your particular standard (see Appendix B for temperatures other than 25 °C).

Measure the water activity of a second verification standard according to the verification procedure described above. If both verification readings are within ± 0.003 a_w for dew point and ±0.015 for capacitance then the instrument is ready to begin testing. If you still have incorrect verification standard readings after cleaning the chamber and adjusting for linear offset, contact METER by email at support.food@metergroup.com or by phone at 509-332-5601 for further instructions. If you purchased your METER instrument from one of our international distributors, please contact them for local service

and support.

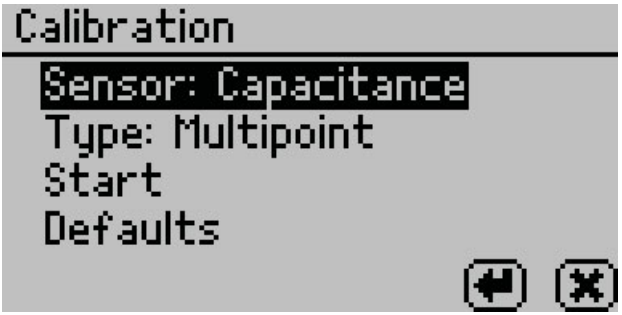
7.3 Multi-Point Calibration

(TEV Models, capacitance sensor only)

1. The capacitance sensor used for measuring the water activity of materials with volatiles (AquaLab 4TEV models only) is a secondary method for measuring water activity and consequently may require a slope change to the calibration in addition to a linear offset. This is the case when the offset in capacitance mode is different at high water activities than low water activities.

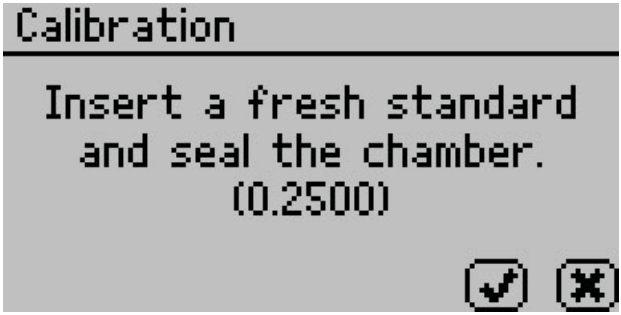
2. You need the 0.25 a_w, 0.50 a_w, 0.76 a_w and 0.92 a_w unsaturated salt standards from METER to proceed with multi-point calibration.

3. To perform a multi-point calibration, with the sensor type set to Capacitance, select Calibration from the Configuration tab. The Calibration screen prompts you with options.



4. Highlight Type and select Enter to toggle to multi-point. The AquaLab guides you through the multi-point calibration routine through on screen commands.

5. Toggle to the Start button and press Enter to begin the multi-point calibration. Once you press Enter, the Calibration screen prompts you to insert a fresh standard and seal the chamber.



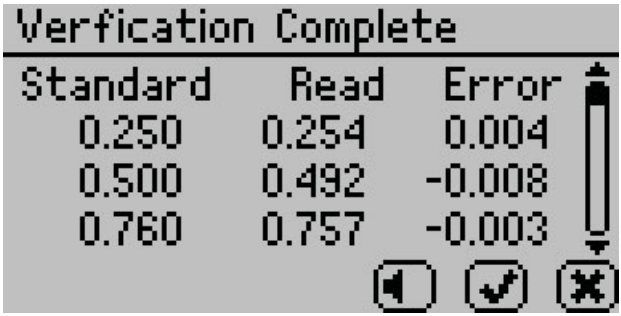
6. Empty the whole vial of 0.25 a_w standard solution into a sample cup. Ensure the rim and outside of the cup are clean. Place the sample cup in the AquaLab sample chamber.

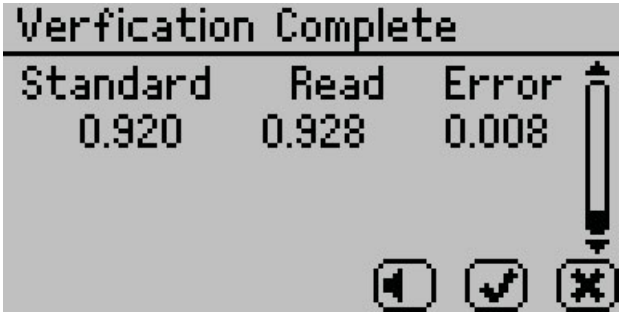
7. Carefully close the lid and move the lever to the Read position. Press the Check icon button to begin testing.

8. After your AquaLab has finished measuring the verification standard, a new screen appears requesting that a 0.50 a_w standard be placed in the chamber. Repeat steps 6 through 7 for 0.50, 0.76, and 0.92 a_w standards.

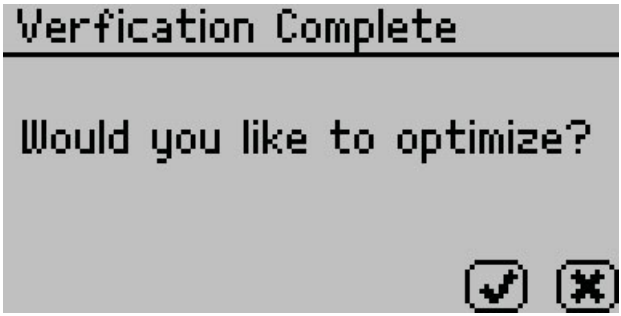
   Note: If you decide at this point not to continue with the multi-point calibration program, just return the lever to the Open position or press the cancel button and return to the previous screen.

9. When measurements are complete on all four standards, a verification complete window appears showing the testing results for each standard.



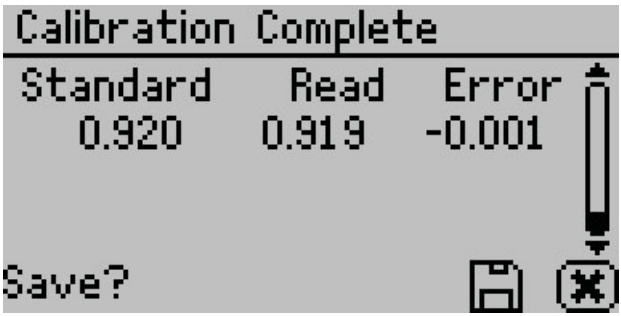


10. Press the Cancel button to cancel the calibration process while selecting the Check Mark brings up the optimize prompt. You can toggle the audio icon to turn beeping on and off.



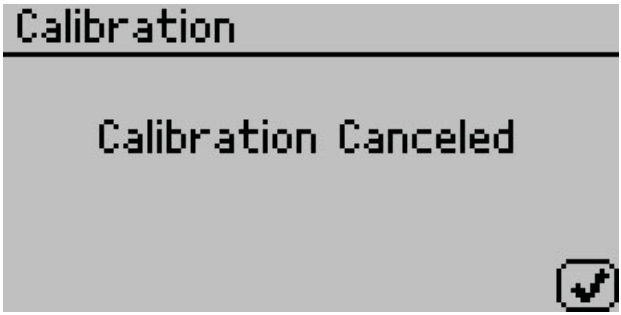
11. To make adjustments to the calibration, select the check mark. Select the Cancel button to cancel without adjusting the calibration.

12. After optimizing the new calibration, the Calibration Complete screen appears.



13. To save the new calibration changes, select the Save icon and the Calibration screen to verify that the AquaLab saved your new multi-point calibration.

14. To discard the calibration changes and exit without saving, press the Cancel button and the system returns a calibration canceled message.



15. Let the chamber air out for at least an hour, then re-measure a 0.76 a_w verification standard again in normal sampling mode (with sensor type still capacitance). It should read the proper value (within ± 0.015 a_w) at a given temperature of a second verification standard (0.25 or 0.50 a_w) according to the verification procedure described above. (Appendix B) If both verification readings are within ± 0.015 a_w then the instrument is ready to begin testing.

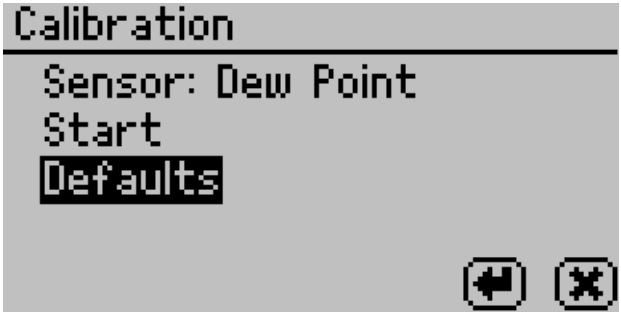
16. Chose a second verification standard and run a test. If you still have incorrect verification standard readings for the ca-

pacitance sensor after cleaning the chamber, adjusting for linear offset, and applying a multi-point calibration, contact METER by email at support.food@metergroup.com or by phone at 509-332-5601 for further instructions. If you purchased your METER instrument from one of our international distributors, please contact them for local service and support.

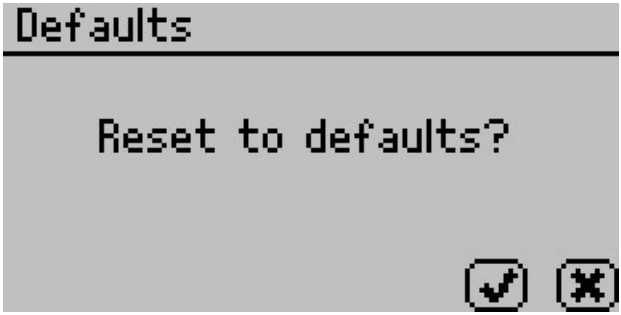
7.4 How to Restore Factory Defaults

To restore original calibration settings, do the following:

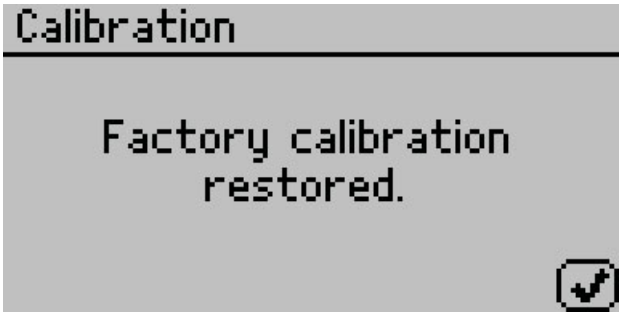
1. Toggle to the Configuration tab by pressing the Menu icon button. Select Calibration and press the Enter button (Select water activity for DUO models.)



2. Scroll down to Defaults and press the Enter icon button to access the Restore Factory Defaults routine. To cancel and return to the main menu, press the cancel button. After pushing the Enter icon button, the Default screen prompts you to reset defaults.
   Note: For TEV models make sure you have the correct sensor selected.



3. To restore the factory calibration values, select the Check icon. To cancel and return to the main menu, choose the Cancel button. After pressing the Check icon, the Calibration screen verifies that you have restored the factory calibration.



4. To return to the Configuration Tab, select the check icon, then the Cancel icon until the configuration tab appears.

8 Sample Preparation

Proper sample preparation is an important step in keeping your AquaLab clean and achieving repeatable results. Careful preparation and loading of samples lengthen time between cleanings and help you avoid downtime.

8.1 Preparing the Sample

1. **Make sure the sample to be measured is homogeneous.** Multicomponent samples (e.g., muffins with raisins) or samples that have outside coatings (like deep-fried, breaded foods) can be measured, but may take longer to equilibrate. For samples like these, the AquaLab may take more than five minutes to give an accurate reading, or may require multiple readings of the same sample. We discuss measuring the water activity of these types of products in detail later in this section (see Samples Needing Special Preparation).
2. **Place the sample in a disposable sample cup, completely covering the bottom of the cup, if possible.** The AquaLab is able to accurately measure a sample that does not (or cannot) cover the bottom of the cup. For example, raisins only need to be placed in the cup and not flattened to cover the bottom. A larger sample surface area increases instrument efficiency by providing more stable infrared sample temperatures. It also speeds up the reading by shortening the time needed to reach vapor equilibrium.
3. **Do not fill the sample cup more than half full. Overfilled cups contaminates the sensors in the sensor chamber.** Filling the sample cup does not make the readings faster or more accurate. There only needs to be enough sample in the cup to allow the water in the sample to equilibrate with the water in the vapor phase and not change the moisture content of the sample. Covering the bottom of the sample cup provides enough sample to get an accurate reading.

4. **Make sure the rim and outside of the sample cup are clean.** Wipe any excess sample material from the rim of the cup with a clean Kimwipe. Material left on the rim or the outside of the cup can contaminate the sensor chamber and be transferred to subsequent samples.

5. **If a sample reads at some other time, put the disposable sample cup lid on the cup to restrict water transfer.** For longterm storage, seal the lid by placing tape or Parafilm® completely around the cup to lid junction.

6. **Be consistent in sample preparation practices.** If you crush, grind, or slice your sample, be consistent in the method you use in order to obtain reproducible results.

8.2 Samples Needing Special Preparation

The AquaLab reads most materials in five minutes or less. However, the nature of some samples necessitates longer reading times. These materials need additional preparation to ensure quick, accurate readings. To find out whether special sample preparation is necessary, take several readings to see if readings (a_w and time) stabilize. If continued readings take longer than six minutes, remove the sample and take a reading of a verification standard. This ensures the sample itself is causing the long read time, and that there is not a problem with your instrument. If the verification standard also takes longer than six minutes to test, the chamber may be dirty. Refer to Section 6 for cleaning procedures.

Coated and Dried Samples

Samples with high sugar or fat coatings often require multiple readings, because it takes longer for them to equilibrate. If this is the case for your samples, it is not a problem with your instrument; it simply means that your particular sample takes longer than most to equilibrate.

To reduce the time needed to take a water activity reading for coated or dried samples, you can crush or slice the sample before sampling.

This increases the surface area of the sample, thus decreasing reading times. However, keep in mind that modifying some samples may alter their water activity readings.

For example, a candy may have a soft chocolate center and a hard outer coating. The water activity reading for the center and the outer coating are different, so one would need to evaluate which part of the sample needed to be measured before crushing it. When the candy is crushed, the water activity represents the average water activity of the entire sample; whereas leaving the candy whole gives a reading for the coating, which may act as a barrier to the center.

8.3 Slow Water-Emitting Samples

Some extremely dry, dehydrated, highly viscous water-in-oil (butter), high fat, or glassy compositions may require multiple tests due to their slow water-emitting properties. This is because the slow emission of water decreases the change in water activity sufficiently that the instrument determines the test to be complete, even though changes in water activity are still occurring. The most effective way to test these types of samples is to run them in the AquaLab using the continuous or custom mode and wait for the water activity readings to stabilize.

For faster reading, it is important to have the water activity of the chamber at or below the water activity of these type of samples. This causes the sample to release water to the vapor phase and equilibrate with the chamber. If the water activity of the head-space is greater than this type of sample, the sample requires a long period of time to reach equilibrium and this delay may affect the water activity of the sample.

8.4 Volatile Samples

The AquaLab gives accurate readings on most samples. However, samples with certain volatiles in high enough concentrations may give inaccurate water activity values. This is because the volatiles

condense on the mirror during the reading process, but do not evaporate from the mirror as water does. As a result, the reading on samples with volatiles may not be accurate. The concentration of volatiles that causes interference is variable and matrix dependent. The most effective method to determine if volatiles are a problem is to compare dew point readings to capacitance readings. If the dew point readings are more than 0.018 higher than the capacitance readings, volatiles are likely a problem.

METER designed the Series 4TEV for measuring volatiles such as propylene glycol and ethanol. The Series 4TEV contains both a chilled mirror dew point and a capacitance sensor. Simply choose the sensor you want to use from the menu, as described in Section 5. The only difference in operation is a lower accuracy of ± 0.015 a_w for the capacitance sensor. After measuring volatiles with the Capacitance sensor, it is a good idea to clean the chamber and run charcoal before switching to the dew point sensor.

8.5 Low Water Activity

When a sample water activity value is below the cooling capacity of the Series 4, the AquaLab displays an error message indicating the lowest reading it attained on that particular sample. See the troubleshooting problem number five in Section 12 for possible solutions. If your sample is not below 0.03 a_w, but is still getting the error message, refer to Section 12 for other possible explanations.

8.6 Samples Not at Room Temperature

Samples that are 4 °C colder or warmer than the instrument chamber temperature need to equilibrate to instrument temperature before you can make a fast and accurate reading. Rapid changes in temperature over short periods of time causes the water activity readings to rise or fall until the temperature stabilizes. When the temperature stabilizes within an optimal one or two degrees of the chamber temperature, you can proceed with normal measurements.

High-water activity samples that are warmer than the chamber temperature can cause condensation inside the measuring chamber, which adversely affect subsequent readings. A warning message appears (Sample too hot) if the sample temperature is more than 4 °C above chamber temperature. If this message appears, immediately remove the sample from the instrument, place a lid on the cup, and allow the sample to cool to within 4 °C of the instrument before measuring.

Samples that are lower than 4 °C of the instrument temperature causes long read times. The sample temperature must be within one or two degrees of the chamber temperature before you can take fast and accurate readings.

Note: The device fan can blow powdery substances, so be sure not to overfill the sample cup and verify the cleanliness of the sample chamber before reading a new sample.

9 Taking a Reading

9.1 Measurement Steps

Once you have verified for cleanliness, calibration, and prepared your sample, you are ready to take readings. Follow steps 1 through 4.

1. Move the chamber lever to the Open position and lift the chamber lid.
2. Check the top lip and outside of the sample cup to make sure they are free from sample residue and that the sample cup is not overfilled.

   Note: Over-filling the sample cup may contaminate the chamber sensors.
3. Place your prepared sample cup in the chamber. The sample cup lid must be removed while in the testing chamber for correct functionality.
4. Close the chamber lid and move the lever to the Read position. This seals the chamber and start the reading.

In one to two minutes, the first water activity measurement displays on the LCD (this is an intermediate reading and not the final water activity). Length of read times may vary depending on temperature differences between the chamber and your sample, and other properties of your sample.

9.2 How AquaLab Takes Readings

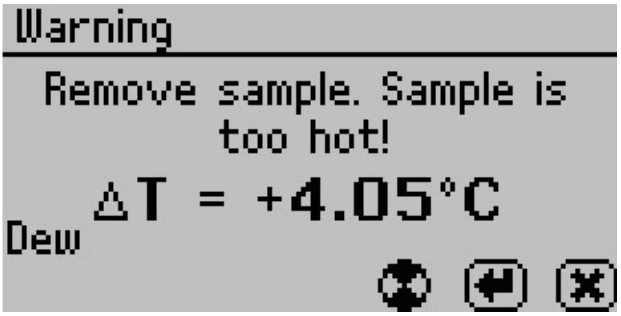
The AquaLab reading cycle continues until the rate of change of three consecutive readings are less than 0.0005 a_w of each other. The instrument crosses the dew threshold numerous times to ensure equilibrium and the accuracy of readings. When the instrument has finished its read cycle, the water activity and read time displays, the Store icon replaces the spinning measurement icon, and, if enabled,

you hear a series of beeps.

Cautions

- **Never leave a sample in your AquaLab after a reading has been taken. The sample may spill and contaminate the instrument chamber if the instrument is accidentally moved or jolted.**
- **Never try to move your instrument after a sample has been loaded. Movement may cause the sample material to spill and contaminate the sample chamber.**
- **If a sample has a temperature that is 4 °C higher (or more) than the AquaLab chamber, the instrument beeps and display a warning that the sample is too hot. Remove the sample until it is at room temperature.**

Note: To check the differences in temperature between the sample and the chamber prior to beginning a read, set the sample in the chamber, close the lid without latching it, and press the right arrow button.

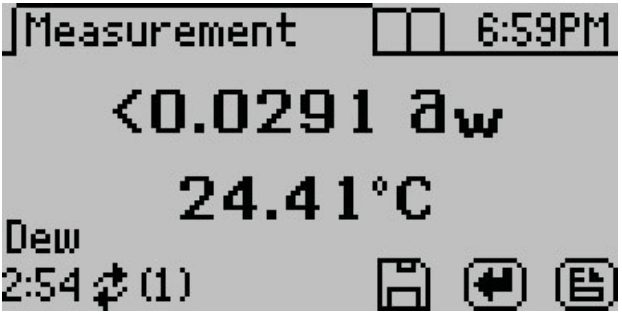


Although the instrument measures warmer samples, the readings may be inaccurate. Warm samples can cause condensation in the chamber if they have a high water activity. It is best to remove the sample from the instrument, place a lid on the cup and allow the sample to cool before reading.

The physical temperature of the instrument should be between 15

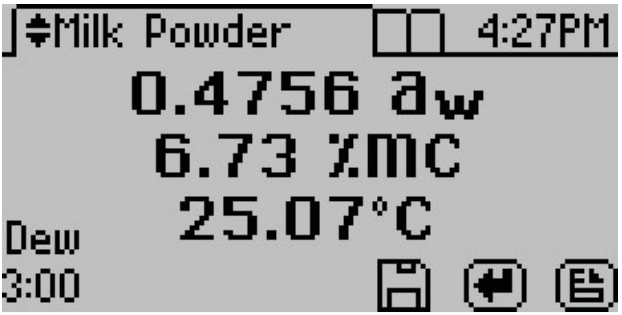
and 50 °C. Between these ambient temperatures, the AquaLab measures samples of similar temperature quickly and accurately. The AquaLab Series 4TE and 4TEV have temperature control capabilities that enable them to read samples at temperatures different from ambient temperature, but no higher than 50 °C.

If a sample has a water activity lower than about 0.03, the AquaLab displays the < symbol in the Measurement window to notify you that your sample is too dry to be accurately measured by the AquaLab.



If you know that your sample water activity is above what the screen is telling you, your instrument sensors may have been contaminated and needs to be cleaned (Section 6) or serviced (Section 13).

10 DUO Operation (Optional)



Previously, measuring moisture content and water activity required different instruments. Now it is possible to determine both moisture content and water activity with one machine. The Series 4TE and 4TEV can be upgraded to Series 4TE DUO and 4TEV to a 4TEV DUO, both of which display moisture content simultaneously with water activity.

To calculate moisture content using water activity requires an understanding of the relationship between the two parameters. This relationship, referred to as the moisture sorption isotherm, is complex and unique to each product type. Customers can use the product isotherm to calculate moisture content based on a water activity measurement. This is most easily accomplished using a model that characterizes the isotherm. For additional information about sorption isotherms and models, please refer to Section 3.

The DUO generates water activity values just as a Series 4TE or 4TEV, but then it uses preloaded product specific isotherm models to calculate moisture content and present it on the screen with the water activity.

For information about upgrading your Series 4TE/4TEV to a Series 4TE DUO or 4TEV DUO, please contact METER.

10.1 Obtaining Product Isotherm Models

Since the isotherm relationship for each product is unique, each product isotherm model must be determined experimentally. This only needs to be done once, but must be done prior to testing moisture content with the DUO.

There are several strategies that can be used to generate models. Please contact METER for information on model development.

10.2 Loading and Organizing Product Models

A Product model must be loaded into the Series 4TE DUO before it can calculate moisture content. Each product must have its own model and the model can either be loaded at the factory by METER or by using the AquaLink 4 software program. This software is included with all Series 4 instruments. Product model files generated by METER are sent to customers via e-mail and can then be loaded into the instrument by connecting to the instrument using the AquaLink 4 software.

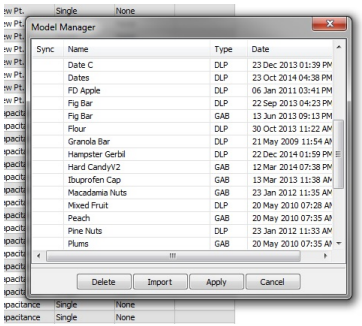


Figure 4: AquaLink 4 Model Loading Tool

The software uses a model loading tool to add and remove product models from the Series 4TE DUO, allowing the user to control and organize their product models.(Figure 4) Up to 100 models can be

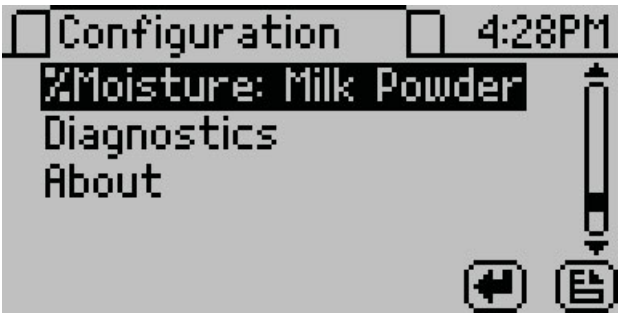
stored on the instrument. The AquaLink 4 software can also download data (including moisture content) from the instrument, present the data in table form, filter the data, and print reports.

10.3 Measuring Moisture Content

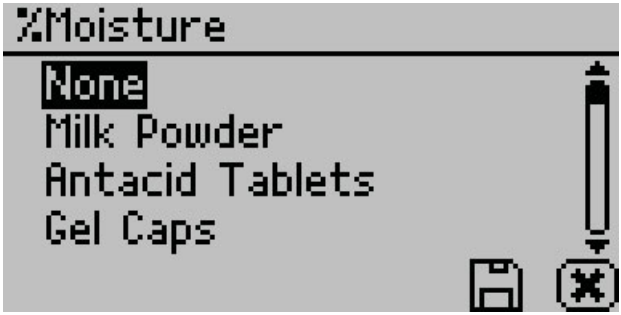
With the product models loaded into the instrument, the Series 4TE DUO can generate moisture content and water activity simultaneously.

Selecting a Product for Analysis

1. With the AquaLab turned on, use the up and down arrows in the Measurement tab to scroll through models or toggle to the configuration tab, select %Moisture, and select the model of choice.
2. At the configuration screen, scroll down and select moisture content. Access this quickly by scrolling from the Measurement screen.



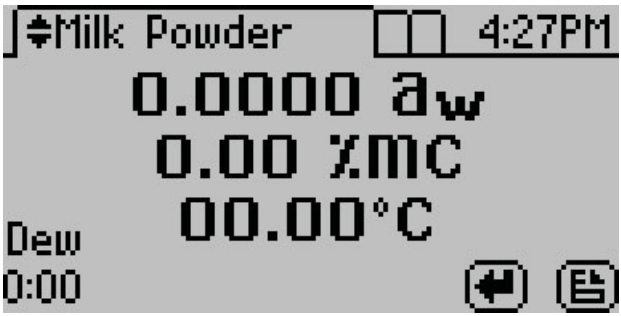
3. A list of available models appears organized by name.



4. Select the model for the product to be analyzed. Select None to not select any model.

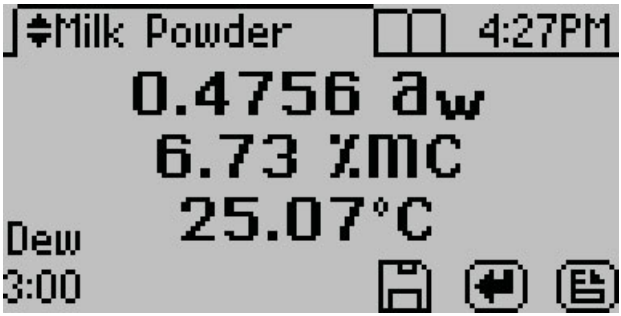
Taking a Reading

1. Readings are taken with the DUO the same as outlined in Section 9. First, return to the main screen.
2. The product chosen for analysis shows in the tab at the top of the screen. To choose a different product for analysis scroll through all of the available product models on the screen by pressing the up and down buttons. This eliminates the need to return to the configuration screen to change products.

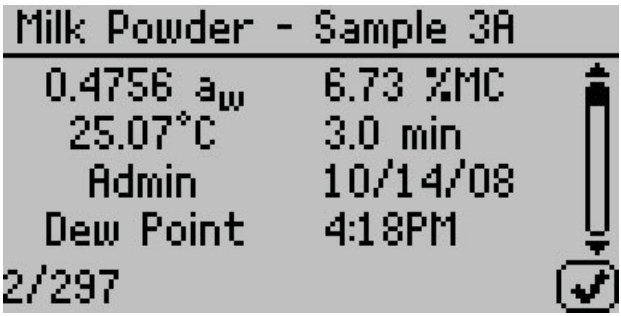


3. When the tab at the top shows Measurement, no model is selected and only water activity displays on the screen.
4. Place a sample in the chamber and begin testing by sliding the lever left to the Read position. For information about sample preparation, see Section 8 and for additional information about running a test, see Section 9.

5. When the test is complete, the screen displays the water activity and moisture content for the product selected. If you have the wrong model selected, use the up and down buttons to toggle to the correct model. The moisture content value adjusts based on the selected model. However, autosave only saves the moisture content value of the model selected at the end of the test. The autosave can be overwritten after selecting the correct model and pressing the button under the Save icon. (see Section 5)



6. Select the Save icon to save the test to the instrument memory. You may add an annotation, if you selected autosave the data saves without any annotation.



Operators can view the results by moving to the data screen (press the right most button, which is below the Menu icon, to toggle between tabs) as shown in Section 5, the Moisture Content now appears in the upper right. The only difference are that moisture content data

now appears in the upper right column on the detailed information screen.

10.4 Moisture Content Adjustment

The AquaLab DUO calculate moisture content values based on water activity readings by utilizing models stored within the instrument. Because moisture content results vary between reference methods, it is important to ensure that the model in the instrument correlates well with your reference method moisture contents (i.e. Karl Fischer titration, oven loss on drying, etc.). Moisture content differences among various methods are usually linear and can be easily corrected with a linear offset. Therefore, if moisture contents calculated with the AquaLab DUO instrument are not agreeing with your reference method, the problem can likely be addressed by adjusting a linear offset.

When to Adjust for Linear Offset

Reference methods can differ between labs, so it is a good idea to check for a linear offset upon receipt of a new isotherm model from METER. In addition, the linear offset should be adjusted if moisture contents being calculated by the AquaLab DUO instrument are consistently higher or lower for a product than your reference method values over several samples.

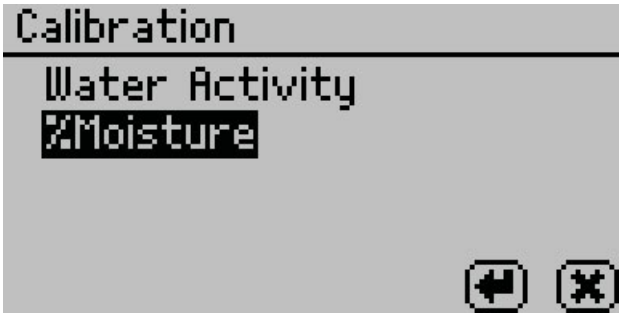
10.5 How to Adjust for Linear Offset or Create a New Model Based Off an Old Model

1. For the product whose model is to be offset, collect three subsamples for analysis.

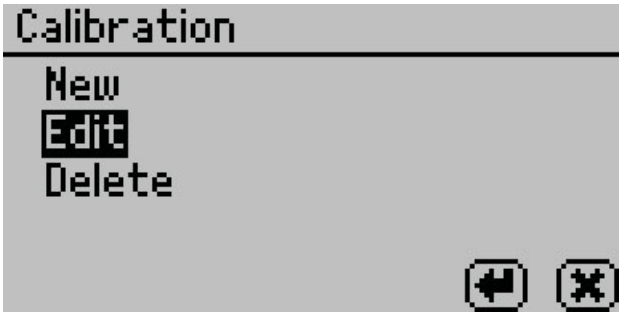
2. Use two of the subsamples to determine duplicate reference method moisture contents and then combine to determine the average moisture content.

3. Once you have obtained a reference moisture content, navigate to the Calibration screen in the Configuration tab of the

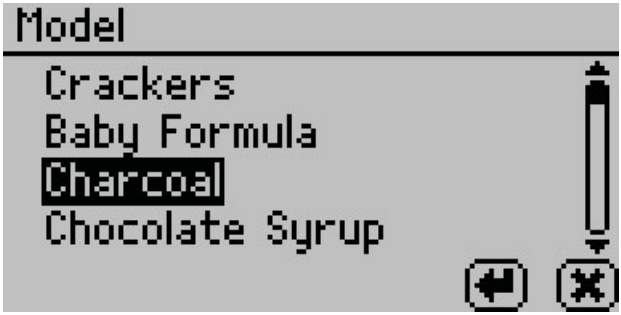
AquaLab DUO and select %Moisture from the list of calibration types.



4. Select Edit to edit and replace an existing model. Select New if you would like to create a new offset model with this calibration instead of replacing the existing model. Pressing Enter opens a model screen listing all models currently loaded on the instrument.



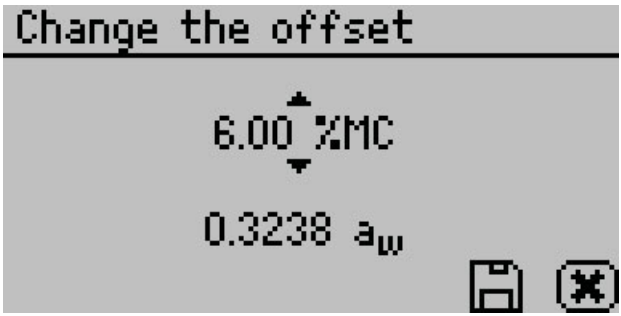
5. Scroll down to find the model for the product to be offset and press Enter. If you selected New, choose a reference model to use as a basis for your new model.



6. The screen instructs you to place a sample of the product in the testing chamber. Place the third subsample from step 1 in a sample cup, then put the sample cup in the testing chamber of the AquaLab DUO instrument and close the lid.

7. Press Enter to begin a reading.

8. Once the reading is complete, a screen displays the water activity measured as well as the moisture content based on the target model. Adjust the moisture content reading using the up and down arrows until it matches the moisture content value obtained from your reference method and click Save.



Note: If you chose to edit an existing model, pressing save updates the model but keeps the same name. If you chose to create a new model, pressing save brings up an annotation screen where you enter the new name for the model. Pressing the cancel button returns you to the Configuration tab and cancel the moisture content adjustment.

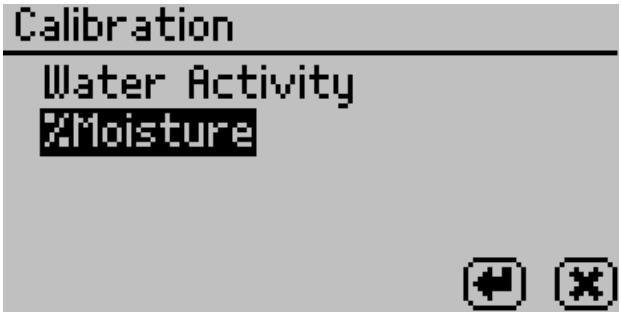
9. Let the chamber air out for at least an hour and then measure the sample again in normal sampling mode. It should now read the corrected moisture content value you provided in the previous step.

If your moisture content readings are still inconsistent, contact METER by email at support.food@metergroup.com or by phone at 509-332-5601 for further instructions. If you purchased your AquaLab Instrument from one of our international distributors, please contact them for local service and support.

10.6 Restore Moisture Content Settings

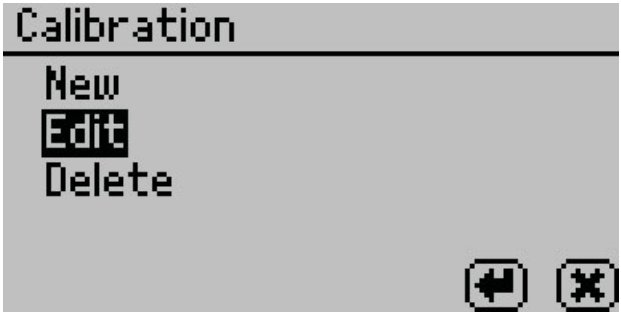
To restore the original model settings, do the following:

1. Navigate to the calibration screen in the Configuration tab of the AquaLab DUO and select %Moisture from the list of calibration types.

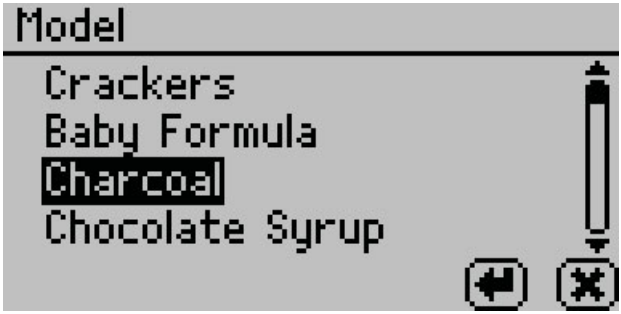


Note: If you do not see %Moisture as an option you may not have a DUO model or you may not have any models installed.

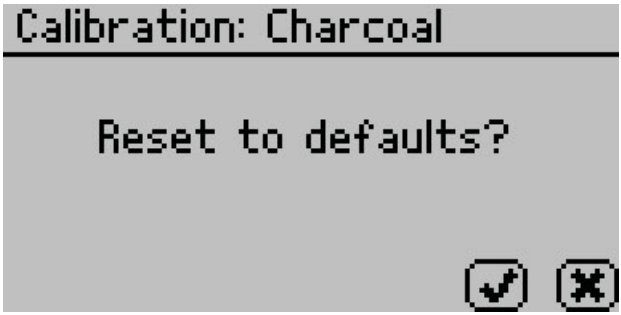
2. Scroll down to Edit and press the Enter button.



3. Select the model that you would like to reset to its original setting and press the Enter button.

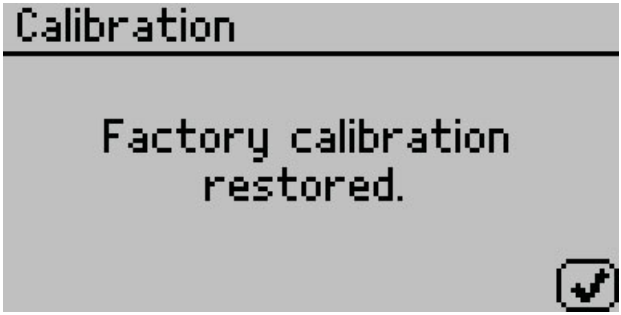


4. Scroll down to Defaults and press the Enter icon button to restore to defaults. To cancel and return to the Calibration tab, select the Cancel icon. After selecting the Enter button, the system prompts you to reset the defaults.



5. To restore the original model settings, press the Check icon. To cancel and return to the main menu, press the Cancel button.

After pressing the Check icon, a Calibration screen confirms the restoration of your factory calibration.



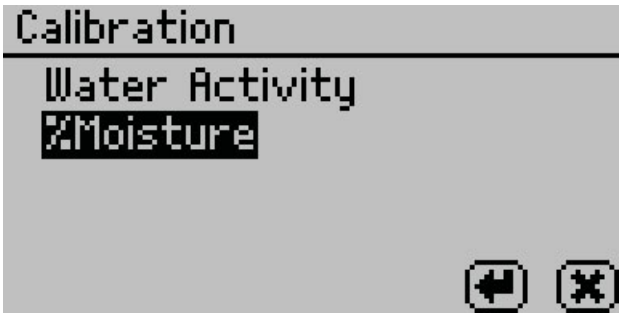
6. Select the Check icon to return to the Configuration tab.

10.7 How to Delete Models

If you find that a model is no longer needed, you have the option of deleting the model directly from the instrument. If you delete the model other users are no longer be able to use it.

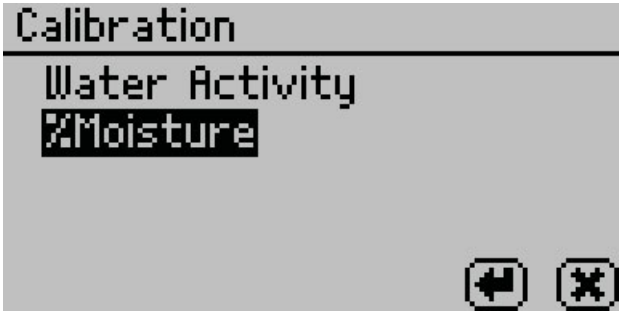
Note: If you do not back up the model with AquaLink 4, you cannot recover the model at a later time.

1. Navigate to the calibration screen in the Configuration tab of the AquaLab DUO and select %Moisture from the list of calibration types.

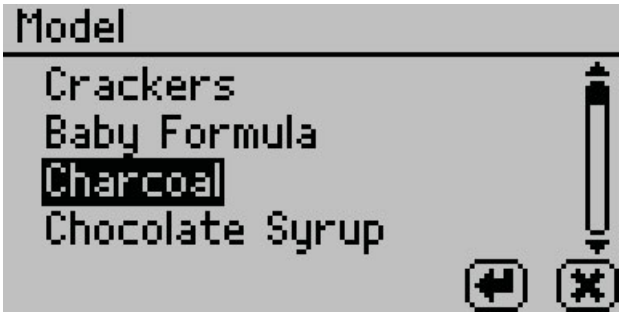


Note: If you do not see %Moisture as an option you may not have a DUO model or you may not have any models installed.

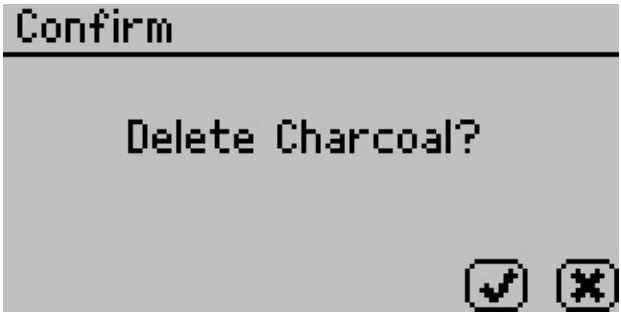
2. Scroll down to Delete and press the Enter button.



3. Select the model you would like to delete and press the Enter icon button to continue or the X button to cancel.



4. Upon pressing Enter, the following screen should appear indicating the model to be deleted. Press the Check icon to delete the model or press the Cancel icon to cancel the deletion.



11 Computer Interface

Your AquaLab can connect to your computer using USB (included) or RS232. Using this cable, you can send water activity data to a computer for further analysis and storage. The interface is run through a terminal communication program.

Note: You must install the USB driver before connecting the USB Cable to your computer. You can find it on the METER website.

11.1 AquaLink 4 Software

An optional software program, AquaLink 4, is available for use with your AquaLab. AquaLink 4 is a Windows based program designed for data collection and customized report generation for all AquaLab models. AquaLink 4 logs water activity, temperature, time of measurement, and date stamps along with other information. AquaLink 4 also has sample identification and comment fields that you can use to help annotate the data your AquaLab is gathering. Figure 5 shows a screen shot of the AquaLink 4 program.

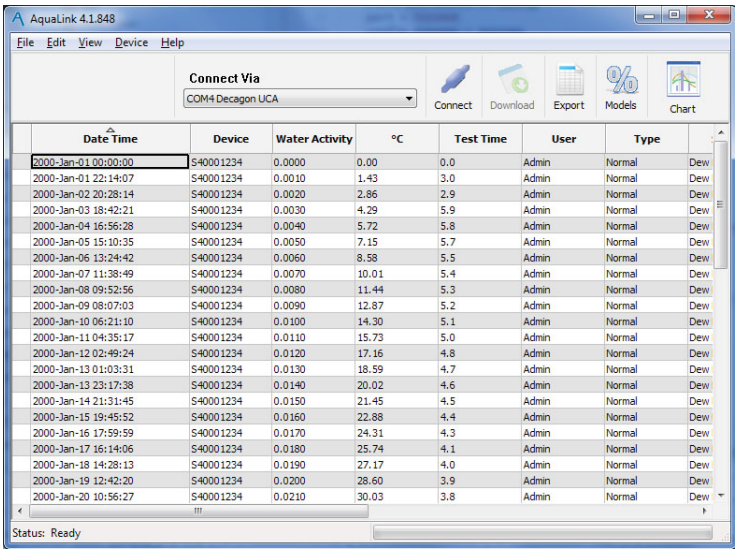


Figure 5: AquaLink 4 Screen Shot

11.2 Using a Communication Program

There are several terminal program options. METER has its own terminal program (DecaTerm) which can be downloaded from http://software.metergroup.com/DecaTerm.zip. Two other options are TeraTerm, which is a free program that can be found on the Internet and Hyperterminal which came standard with Microsoft Windows prior to Windows 7.

To use any of these terminal programs with your AquaLab, follow the instructions for the program with the following settings. Be sure to power on the AquaLab prior to connecting the USB interface cable to your computer.

- Choose correct Com port
- Set/Verify Com Properties

  ✓ Bits per second 9600
  ✓ 8 Databits
  ✓ No parity
  ✓ 1 stop bit
  ✓ Flow control set to none

After successfully connecting the AquaLab to your computer and upon completion of a water activity reading, the data displays in the terminal program in the format as follows: measurement time (minutes), sample temperature, and water activity. Table 2 shows an example data return.

Table 2: Terminal Data

Time since chamber was closed	Temperature (°C)	a_w
3.1,	24.3,	0.862

12 Troubleshooting

The AquaLab is a high performance, low maintenance instrument, designed to have few problems if used with care. Unfortunately, sometimes even the best operators using the best instruments encounter technical difficulties. Below is quick reference guide that directs you to detailed solutions of some problems that may occur. If these remedies still do not resolve your problem, then please contact METER for help (see Section 1).

Note: If you purchased your METER instrument from one of our international distributors, please contact them for local service and support.

Table 3: Troubleshooting Quick Guide

If this problem occurs:	**Refer to:**
AquaLab does not turn on	Problem #1
Readings are slow or inconsistent	Problem #2
A_w readings on solutions are too high/low to adjust	Problem #3
Screen displays "Sample too hot"	Problem #4
Screen displays "$a_w < 0.0$"	Problem #5
Dew point sensor failure	Problem #6
Verification is not correct	Problem #7
Screen displays "Crystal failure"	Problem #8
Screen displays "Contaminated Mirror"	Problem #9
Screen displays "Firmware is corrupted"	Problem #10
DUO Model–Test was run with wrong model	Problem #11
DUO Model–%Moisture Content displayed is not correct	Problem #12
DUO Model–%Moisture Content is not shown on screen	Problem #13
DUO Model–%Moisture Content displaying "...%MC"	Problem #14

1. PROBLEM:
AquaLab does not turn on.

SOLUTIONS:

1. Check to make sure your power cord is securely attached to the back of the instrument and it is plugged into the power outlet.
2. A power surge may have caused a fuse to blow. To change the fuses, follow instructions a through d.
   (a) Unplug the power cord.
   (b) Locate the panel where the power cord plugs in. The fuse box is on the right side of that panel. Press in on the release tab and pull the fuse-holder out. Pull the broken fuse(s) out and replace with a 1.25 Amp 250 V fuse.

   Caution: Do not use any other kind of fuse or you risk damaging your instrument as well as voiding your warranty.

   (c) Replace the fuse-holder and push it into the fuse-well until the release tab snaps in place.
   (d) Connect the power cord and turn your instrument on. If the fuse blows again, a failed component may be causing the problem. Contact METER to make arrangements for repairs.

2. PROBLEM:
Readings are slow or inconsistent.

SOLUTIONS:

1. The sample chamber may be dirty. Refer to Section 6 for directions on cleaning the sample chamber.
2. The temperature difference between the sample and the block chamber may be too great. The sample needs to equilibrate to instrument temperature before a fast, accurate reading can be made. (Refer to Section 8, Samples Not at Room Temperature.)

3. Some products absorb or desorb moisture very slowly, causing measurements to take longer than usual, and nothing can be done to speed up the process. Refer to Section 8 for further explanation.

4. Your sample may contain volatiles. Volatiles are known to cause unstable readings, because they condense on the surface of the chilled mirror and alter readings. Please refer to the volatiles section in Section 8 for suggestions on reducing difficulties with measuring samples with propylene glycol. If you have further questions regarding the measurement of volatiles contact METER.

5. A fan blade in the block chamber may be broken or bent. If even salt standards take a long time to read, and the sample chamber is clean, you may have a broken chamber fan blade. This is especially likely if you have just cleaned the chamber. If you suspect this may have happened, contact METER for details on replacement.

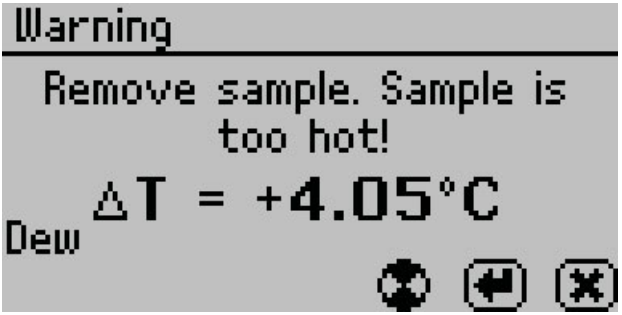
3. PROBLEM:
Water activity readings on verification standards are too high/low and a linear offset adjustment cannot be made any higher/lower.

SOLUTIONS:

1. The thermopile in your chamber, which measures sample temperature, may have become contaminated. Refer to Section 6 for directions on cleaning.

2. The chamber mirror may be dirty. Refer to Section 6 for directions on cleaning.

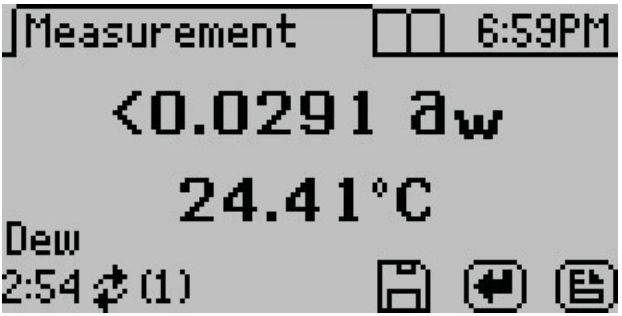
4. PROBLEM:
Message on screen displays a warning that the sample is too hot:



SOLUTION:

Your sample temperature is too high for the instrument to equilibrate with it in a reasonable amount of time. The instrument and sample need to be in temperature equilibrium before accurate measurements can be made. Therefore, cold samples take a long time to measure for the same reason. To avoid this problem, make sure to only measure samples that are at the same temperature as the instrument.

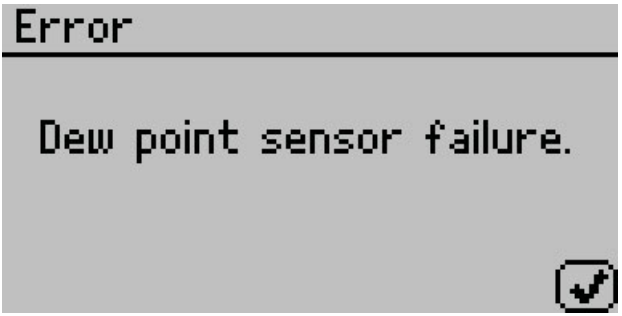
5. PROBLEM:
Message on screen displays a_w below instrument detection limits.



SOLUTIONS:

1. The sample is too dry for the instrument to read accurately. If your sample has a water activity that is less than the detection limits of the instrument, this message appears. Essentially, it means that there is not enough sample moisture to condense on the mirror and provide a reading.
2. The mirror may be dirty. Try cleaning the mirror and chamber and measuring the sample again.

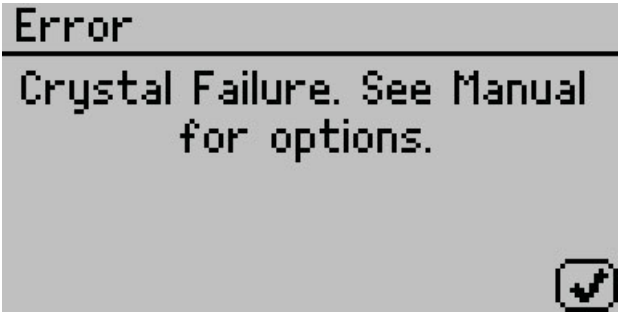
6. PROBLEM:
Message on screen displaying dew point sensor failure.



SOLUTION:

The Cooler is damaged and needs to be serviced by METER. See Section 13 for detailed instructions.

7. PROBLEM:
Message on screen displays the following:



SOLUTION:

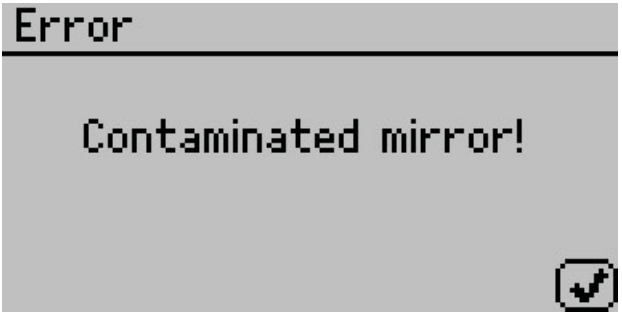
The crystal that runs the firmware is having trouble starting. Occasionally, cycling the power solves the problem. If this message continues to appear, the instrument needs to be serviced by METER. See Section 13 for detailed instructions.

8. PROBLEM:
Verification is not correct.

SOLUTION:

1. The sample chamber and mirror need to be cleaned. See Section 6 for detailed cleaning instructions. If verification is still not correct, then linear offset has occurred.
2. Verify and Adjust for Linear offset. After you have cleaned the sample chamber and mirror (Section 6) use a Verification Standard to verify and adjust for Linear offset as described in Section 7.

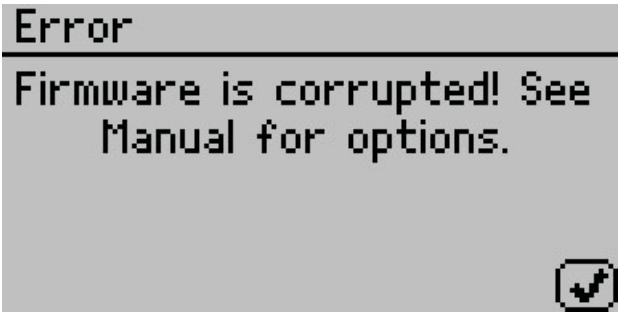
9. PROBLEM:
Message on screen displays “Contaminated mirror.”



SOLUTION:

The mirror used for dew point measurements requires cleaning. Follow the instructions outlined in Section 6: Cleaning and Maintenance before trying to run your sample again. If this message continues to appear, contact METER for further options.

10. PROBLEM:
Message on screen displays the error "Firmware is corrupted."



SOLUTION:

The firmware on the instrument is corrupted and needs to be reloaded. To download new firmware to the Series 4 models, the instrument must be serviced by METER.

11. PROBLEM:
Ran test with wrong model.

SOLUTION:

1. On the measurement screen, toggle to the correct model using the up and down arrow keys. The moisture content value updates to correspond with the model selected.
2. If the correct model is not available, the model may not be loaded on the instrument.
   (a) To determine which models are loaded on the instrument, cycle to the menu tab, select Moisture Content and then the loaded models appear.
3. If the correct model is not available, load the appropriate model using AquaLink 4 Software. The AquaLab DUO can hold a total of 100 models at any one time. You may need to remove a model using the Software or use the delete option in the %Moisture Calibration menu before you can add a new one. AquaLink 4 saves any model that you remove with the software and allows you to reload again later.

12. DUO PROBLEM:
Moisture Content displayed is not correct.

SOLUTION:

1. Model selected may not be correct for the product being tested.
   (a) Toggle through the available models to find a more appropriate model.
   (b) If the model is correct but not giving correct moisture content values it may be necessary to generate a new model for the product or update an existing model. For information about generating a model, contact METER for updating a model, refer to Section 10: DUO Operation.

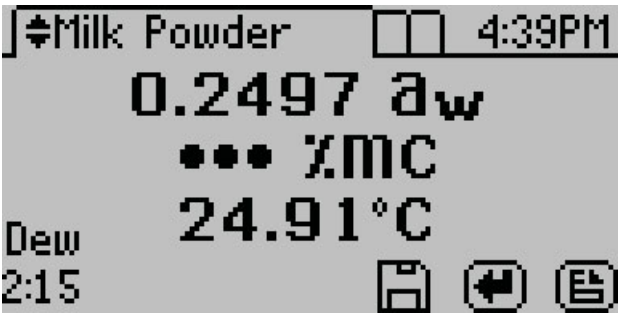
13. DUO PROBLEM:
Moisture content does not show up on the screen.

SOLUTION:

Moisture content has not been activated.

1. Toggle to menu tab, select moisture content, and select the appropriate model.
   (a) If no models appear in moisture content screen, reload models using AquaLink 4.
   (b) If moisture content is not an active selection, the DUO feature may not be active. Content METER to learn how to activate the DUO feature.

14. DUO PROBLEM:
Message on the screen displays no moisture content reading.



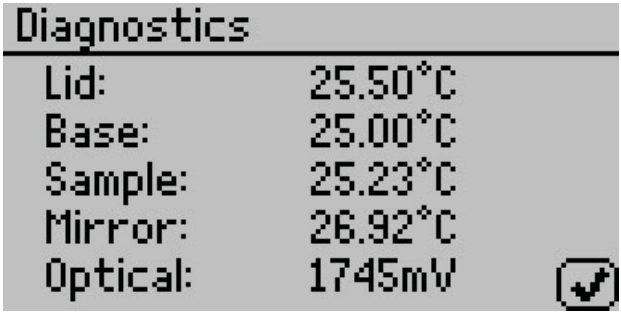
SOLUTION:

1. When a moisture content reading is not shown, the water activity or temperature for that reading is beyond the scope of the moisture sorption isotherm. This can happen under the conditions a or b.
   (a) The isotherm equation calculates a moisture content that is less than 0% or greater than 100% with the given water activity.

(b) The control temperature is significantly different than the isotherm temperature. Make sure that the sample water activity and the instrument controlling temperature are within the scope of the selected moisture sorption isotherm model.

Diagnostic Screen

If, after cleaning your instrument and reading the other troubleshooting hints, you have reason to believe that one of the components of your AquaLab may be causing measurement error, you may access a screen that displays values for component performance. Operators can access this Diagnostics screen by navigating to the Configuration tab and then by scrolling down to Diagnostics. Press Enter to generate a list of components and their values.



This screen shows typical values for the dew point method. Lid, base and sample temperatures may fluctuate but should not change more than 0.03 degrees. Typical ranges for the lid, base and sample temperatures is between 24.5 and 25.5 °C.

If the mirror temperature is at lid temperature, the cooler has failed and must be replaced. If the mirror is below the lid temperature or appears to be random, the thermocouple wire is broken and must be repaired. A typical optical range is between 300 mV and 2900 mV. For capacitance mode, not shown here, the RH percentage should always be between 0 and 100%.

13 Support and Repair

Note: If you purchased your AquaLab from one of our international distributors, please contact them. They can provide you with local support and service.

When encountering problems with your AquaLab (that you are unable to resolve with the help of this manual), please contact METER Customer Support at support.food@metergroup.com, 509-332-5601 or fax us at 509-332-5158. Please have the serial number and model of the instrument ready.

AquaLab annual calibration is available. For details on sending your AquaLab to METER or your distributor in for calibration, contact us by phone or email at support.food@metergroup.com.

All AquaLabs returning to METER for servicing must be accompanied with a Return Material Authorization (RMA) number. Prior to shipping the instrument, please contact a METER customer support representative to obtain an RMA number.

Shipping Directions

The following steps should help to ensure the safe shipping and processing of your AquaLab.

1. Ship your AquaLab in its original cardboard box with suspension packaging. If this is not possible, use a box that has at least four inches of space between your instrument and each wall of the box.
2. Place the AquaLab in a plastic bag to avoid disfiguring marks from the packaging.
3. Do not ship the power cord or serial cable.
4. If the original packaging is not available, pack the box moderately tight with packing material (e.g. styrofoam peanuts or bubble wrap), ensuring the instrument is suspended in the packing material.

5. On the RMA form, please verify the ship to and bill to information, contact name, and problem description. If anything is incorrect please contact a METER representative.
6. Tape the box in both directions for added support.
7. Include the RMA number in the attention line on the shipping label.

   Ship to:
   METER Group, Inc.
   ATTN: RMA (insert your RMA #)
   2365 NE Hopkins Court
   Pullman, WA 99163

13.1 Repair Costs

METER repairs manufacturer defects and instruments within the one year warranty at no charge. We charge you for non-warranty repairs based on cost of parts, labor and shipping. An extra fee may be charged for rush work. METER can provide an estimated repair cost upon request.

13.2 Loaner Service

METER has loaner instruments to keep you measuring water activity while your instrument is being serviced. If your AquaLab is still under calibration warranty there is no charge for the loaner service.

14 Further Reading

14.1 Water Activity Theory & Measurement

Bousquet-Ricard, M., G. Qualyle, T. Pharm, and J. C. Cheftel. 1980. Comparative study of three methods of determining water activity in intermediate moisture foods. Lebensm Wiss Technol 13:169-173.

Cazier, J.B., and V. Gekas. 2001. Water activity and its prediction: a review. International Journal of Food properties 4(1):35-43.

Chirife, J., G. Favetto, C. Ferro-Fontn, and S.L.Resnik. 1983. The water activity of standard saturated salt solutions in the range of intermediate moisture foods. Lebensm Wiss Technol 16:36-38.

Duckworth, R. 1975. Water relations of foods. Academic Press, New York.

Gmez, R., and J. Fernandez-Salguero. 1992. Water activity and chemical composition of some food emulsions. Food Chem 45:91-93.

Greenspan, L. 1977. Humidity fixed points of binary saturated aqueous solutions. J Res Nat Bur Stand - A Phys Chem 81A:89-96.

Karmas, E. 1981. Measurement of moisture content. Cereal Foods World 26:332-334.

Kitic, D., D.C. Pereira-Jardim, G.J. Favetto, S.L. Resnik, and J. Chirife. 1986. Theoretical prediction of the water activity of standard saturated salt solutions at various temperatures. Journal of Food Science 51:1037-1042.

Labuza, T.P., and R. Contreras-Medellin. 1981. Prediction of moisture protection requirements for foods. Cereal Foods World 26:335-343.

Labuza, T.P., K. Acott, S.R.Tatini, R.Y. Lee, J. Flink, and W. McCall. 1976. Water activity determination: A collaborative study of

different methods. Journal of Food Science 41:910-917.

Marcolli, C., and Th . Peter. 2005. Water activity in polyol/water systems: new UNIFAC parameterization. Atmospheric Chemistry and Physics 5:1545-1555.

Ninni, L., M.S. Camargo, and A.J.A. Meirelles. 2000. Water activity in polyol systems. Journal of Chemical and Engineering Data 45:654-660.

Prior, B.A. 1979. Measurement of water activity in foods: A review. Journal of Food Protection 42:668-674.

Rahman, M.S. and S.S. Sablani. 2001. Measurement of water activity by electronic sensors. P. A2.5.1-A2.5.4 In R.E.Wrolstad (ed.) Current Protocols In Food Analytical Chemistry. John Wiley & Sons, Inc., New York.

Rahman, M.S., S.S. Sablani, N. Guizani, T.P. Labuza, and P.P. Lewicki. 2001. Direct manometic determination of vapor pressure. P. A2.4.1-A2.4.6. In R.E. Wrolstad (ed.) Current Protocols In Food Analytical Chemistry. John Wiley & Sons, Inc., New York.

Reid, D.S., A.J. Fontana, M.S. Rahman, S.S. Sablani, T.P. Labuza, N. Guizani, and P.P. Lewicki. 2001. Vapor pressure measurements of water p. A2.1.1-A2.5.4. In R.E. Wrolstad (ed.) Current Protocols In Food Analytical Chemistry. John Wiley & Sons, Inc., New York.

Reid, D.S. 1976. Water activity concepts in intermediate moisture foods. p. 54-65. In R.Davies, G.G.Birch, and K.J.Parker (ed.) Intermediate Moisture Foods. Applied Science Publishers, London.

Richard, J., and T.P. Labuza. 1990. Rapid determination of the water activity of some reference solutions, culture media and cheese using a dew point method. Sci. des Aliments 10:57-64.

Roa,V., and M.S.Tapia de Daza. 1991. Evaluation of water activity measurements with a dew point electronic humidity meter. Lebensm

Wiss Technol 24:208-213.

Rodel, W. 2001. Water activity and its measurement in food. P. 453-483. In E. Kress-Rogers, and C.B. Brimelow (ed.) Instrumentation and sensors for the food industry. CRC Press LLC, Boca Raton, FL.

Roos, K.D. 1975. Estimation of water activity in intermediate moisture foods. Food Tech 29:26-30.

Scott, V.N., and D.T. Bernard. 1983. Influence of temperature on the measurement of water activity of food and salt systems. Journal of Food Science 48:552-554.

Snavely, M.J., J.C. Price, and H.W. Jun. 1990. A comparison of three equilibrium relative humidity measuring devices. Drug Dev. Ind. Pharm. 16:1399-1409.

Stamp, J.A., S. Linscott, C. Lomauro, and T.P. Labuza. 1984. Measurement of water activity of salt solutions and foods by several electronic methods as compared to direct vapor pressure measurement. Journal of Food Science 49:1139-1142.

Stoloff, L. 1978. Calibration of water activity measuring instruments and devices: Collaborative study. Journal of the Association of Official Analytical Chemists 61:1166-1178.

Troller, J.A. 1983. Methods to measure water activity. Journal of Food Protection 46:129-134.

Troller, J.A., and J.H.B Christian. 1978. Water Activity and Food. Academic Press, New York.

Troller, J.A., and V.N. Scott. 1992. Measurement of water activity(a_w) and acidity. p. 135-151. In C. Vanderzant, and D.F. Splittstoesser (ed.) Compendium of Methods for the Microbiological Examination of Foods. American Public Health Association, Washington, D.C.

Van den Berg, C. 1986. Water activity. p. 11-36. In D. MacCarthy (ed.) Concentration and drying of foods. Elsevier Applied Science Publishers, London.

Van den Berg, C. 1991. Food-water relations: Progress and integration, comments and thoughts. In H. Levine, and L. Slade (ed.) Water Relationships in Foods. Plenum Press, New York.

Van den Berg, C., and S. Bruin. 1981. Water activity and its estimation in food systems: Theoretical aspects. p. 1-61. In L.B. Rockland, and G.F. Stewart (ed.) Water Activity: Influences on Food Quality. Academic Press, New York.

Vega-Mercado, H., andG.V. Barbosa-Canovas. 1994. Prediction of water activity in food systems: A review on theoretical models. Revista Espanola De Ciencia Y Tecnologia De Alimentos 34:368-388.

Vega-Mercado, H., B. Romanach, and G.V. Barbosa-Canovas. 1994. Prediction of water activity in food systems: A computer program for predicting water activity in multicomponent foods. Revista Espanola De Ciencia Y Tecnologia De Alimentos 34:427-440.

Vos, P.T., and T.P. Labuza. 1974. Technique for measurements of water activity in the high a_w range. J. Agric. Food Chem. 22:326-327.

Voysey, P. 1993. An evaluation of the AquaLab CX-2 system for measuring water activity. F. M. B. R. A. Digest No. 124 24-25.

Food Safety and Microbiology

Bei, Z.H., and R.-M.J. Nout. 2000. Effects of temperature, water activity and gas atmosphere on mycelial growth of tempe fungi Rhizopus microsporus var. microcporus and R. microsporus var. oligosporus. World Journal of Microbiology and Biotechnology 16:853-858.

Beuchat, L.R. 1981. Microbial stability as affected by water activity.

Cereal Foods World 26:345-349.

Brandt, L. 1996. Bound for success. Controlling water activity gives technologists the edge in developing safe, shelf-stable foods. Food Formulating 2:41-48.

Chirife, J., and M.P. Buera. 1994. Water activity, glass transition and microbial stability in concentrated/semimoist food systems. Journal of Food Science 59:921-927.

Chirife, J., and M.P. Buera. 1995. A critical review of some nonequilibrium situations and glass transitions on water activity values of foods in the microbiological growth range. Journal of Food Engineering 25:531-552.

Chirife, J., and M.P. Buera. 1996. Water activity, water glass dynamics, and the control of microbiological growth in foods. Critical Rev. in Food Sci. Nutr. 36:465-513.

Farberm, J.M., F. Coates, and E. Daley. 1992. Minimum water activity requirements for the growth of Listeria monocytogenes. Lett Appl Microbiol 15:103-105.

Franks, F. 1991. Water activity: a credible measure of food safety and quality? Trends Food Sci Technol March:68-72.

Garcia de Fernando, G.D., O. Diaz, M. Fernandez, and J.A. Ordonez. 1992. Changes in water activity of selected solid culture media throughout incubation. Food Microbiology 9:77-82.

Gibson, A.M., J. Baranyi, J.I. Pitt, M.J. Eyles, and T.A. Roberts. 1994. Predicting fungal growth: The effect of water activity on Aspergillus flavus and related species. International Journal of Food Microbiology 23:419-431.

Goaleni, N., J.E. Smith, J. Lacey, and G. Gettinby. 1997. Effects of temperature, water activity, and incubation time on production of aflatoxins and cyclopiazonic acid by an isolate of Aspergillus flavus

in surface agar culture. Appl Environ Microbiol 63:1048-1053.

Hardman, T.M. 1988. Water and food quality. Elseiver Press, London.

Hocking, A.D., and B.F. Miscamble. 1995. Water relations of some Zygomycetes isolated from food. Mycological Research 99:1113-1118.

Hocking, A.D., B.F. Miscamble, and J.I. Pitt. 1994. Water relations of Alternaria alternata, Cladosporium cladosporioides, Cladosporium sphaerospermum, Curvulario lunata and Curvulario pallescens. Mycological Research 98:91-94.

Houtsma, P.C., A. Heuvelink, J. Dufrenne, and S. Notermans. 1994. Effect of sodium lactate on toxin production, spore germination and heat resistance of proteolytic Clostridium botulinum strains. Journal of Food Protection 57:327-330.

Kress-Rogers, E. 1993. Food quality measurement. Food Industry News September:23-26.

Kuntz, L.A. 1992. Keeping microorganisms in control. Food Product Design August:44-51.

Levine, H., and L. Slade. 1991. Water Relationships in Foods. Plenum Press, New York.

Li, K.Y., and J.A. Torres. 1993. Water activity relationships for selected mesophiles and psychrotrophs at refrigeration temperature Journal of Food Protection 56:612-615.

Lopez-Malo, A., S. Guerrero, and S.M. Alzamora. 2000. Probabilistic modeling of Saccharomyces cerevisiae inhibition under the effects of water activity, pH, and potassium sorbate concentration. Journal of Food Protection 63:91-95.

Mannheim,C.H., J.X. Liu, and S.G. Gilbert. 1994. Control of water in foods during storage. Journal of Food Engineering 22:509-532.

Marauska, M., A. Vigants, A. Klincare, D. Upite, E. Kaminska, and M. Bekers. 1996. Influence of water activity and medium osmolality on the growth and acid production of Lactobacillus casei var. alactosus. Proceedings of the Latvian Academy of Sciences Section B Natural Exact and Applied Sciences 50:144-146.

Masana, M.O., and J. Baranyi. 2000. Growth/no growth interface of Brochothrix thermosphacta as a function of pH and water activity. Food Microbiology 17:485-858.

Mattick, K. L., F. Jorgensen, J.D. Legan, M.B. Cole, J. Porter, H.M. Lappin-Scott, and T.J. Humphrey. 2000. Survival and filamentation of Salmonella enterica serovar Enteritidis PT4 and Salmonella enterica serovar Typhimurium DT104 at low water activity. Appl Environ Microbiol 66:1274-1279.

Mattick, K.L., F. Jorgensen, J.D. Legan, H.M. Lappin-Scott, and T.J. Humphrey. 2000. Habituation of Salmonella spp. at reduced water activity and its effect on heat tolerance. Appl Environ Microbiol 66:4921-4925.

Mattick, K.L., F. Jorgensen, J.D. Legan, H.M. Lappin-Scott, and T.J. Humphrey. 2001. Improving recovery of Salmonella enterica Serovar Typhimurium DT104 cells injured by heating at different water activity values. Journal of Food Protection 64:1472-1476.

McMeekin, T.A., and T. Ross. 1996. Shelf life prediction: Status and future possibilities. International Journal of Food Microbiology 33:65-83.

Miller, A.J. 1992. Combined water activity and solute effects on growth and survival of Listeria monocytogenes. Journal of Food Protection 55:414-418.

Nakajo, M., and Y. Moriyama. 1993. Effect of pH and water activity on heat resistance of spores of Bacillus coagulans. Journal of the Japanese Society for Food Science and Technology 40:268-271.

Nelson, K.A., and T.P. Labuza. 1994. Water activity and food polymer science: Implications of state on arrhenius and WLF models in predicting shelf life. Journal of Food Engineering 22:271-289.

Nesci, A., M. Rodrigues, and M. Etcheverry. 2003. Control of Aspergillus growth and aflatoxin production using antioxidants at different conditions of water activity and pH. Journal of Applied Microbiology 95:279-287.

Nolan, D.A., D.C .Chamblin, and J.A. Troller. 1992. Minimal water activity levels for growth and survival of Listeria monocytogenes and Listeria innocua. International Journal of Food Microbiology 16:323-335.

Noorlidah, A., A. Nawawi, and I. Othman. 2000. Fungal spoilage of starch-based foods in relation to its water activity (aw). Journal of Stored Products Research 36:47-54.

Park, C.M., and L.R.Beuchat. 2000. Survival of Escherichia coli O157:H7 in potato starch as affected by water activity, pH and temperature. Lett Appl Microbiol 31(5):364-367.

Petersson, S., and J. Schnuerer. 1995. Biocontrol of mold growth in high-moisture wheat stored under airtight conditions by Pichia anomala, Pichia guilliermondii, and Saccharomyces cerevisiae. Appl Environ Microbiol 61:1027-1032.

Pitt, J.I., and B.F. Miscamble. 1995. Water relations of Aspergillus flavus and closely related species. Journal of Food Protection 58:86-90.

Plaza, P., J. Usall, N. Teixido, and I. Vinas. 2003 Effect of water activity and temperature on germination and growth of Penicillium digitatum, P. italicum and Geoteichum candidum. Journal of Applied Microbiology 94:549-554.

Quintavalla, S., and G. Parolari. 1993. Effects of temperature, water

activity and pH on the growth of Bacillus cells and spore: A response surface methodology study. International Journal of Food Microbiology 19:207-216.

Rockland, L.B., and G.F. Stewart. 1981. Water activity: Influences on food quality. Academic Press, New York.

Rockland, L.B., and S.K. Nishi. 1980. Influence of water activity on food product quality and stability. Food Tech 34:42-59.

Saad, R.R. 1992. Effect of water activity on growth and lipids of xerophilic fungi, Aspergillus repens and Aspergillus amstelodami. Zentralblatt Fuer Mikrobiologie 147:61-64.

Salter, M.A., D.A. Ratkowsky, T. Ross, and T.A. McMeekin. 2000. Modelling the combined temperature and salt (NaCl) limits for growth of a pathogenic Escherichia coli strain using nonlinear logistic regression. International Journal of Food Microbiology 61:159-167.

Santos, J., T.M.Lopez-Diaz, M.C.Garcia-Lopez, M.C.Garcia-Fernandez, and A.Otero. 1994. Minimum water activity for the growth of Aeromonas hydrophila as affected by strain, temperature and humectant. Lett Appl Microbiol 19:76-78.

Sautour, M., A. Rouget, P. Dantigny, C. Divies, and M. Bennsoussan. 2001. Prediction of conidial germination of Penicillium chrysogenum as influenced by temperature, water activity and pH. Lett Appl Microbiol 32:131-134.

Seow, C.C., T.T. Teng, and C.H. Quah. 1988. Food preservation by moisture control. Elsevier, New York.

Shebuski, J.R., O. Vilhelmsson, and K.J. Miller. 2000. Effects of growth at low water activity on the thermal tolerance of Staphylococcus aureus. Journal of Food Protection 63:1277-1281.

Taoukis, P., W. Breene, and T.P. Labuza. 1988. Intermediate moisture foods. Adv Cereal Sci Technol 9:91-128.

Tapia de Daza, M.S., Y. Villegas, and A. Martinez. 1991. Minimal water activity for growth of Listeria monocytogenes as affected by solute and temperature. International Journal of Food Microbiology 14:333-337.

Tokuoka, K., and T. Ishitani. 1991. Minimum water activities for the growth of yeasts isolated from high-sugar foods. Journal of General and Appied Microbiology 37:111-119.

Torres, R., J. Usall, N. Teixido, M. Abadias, and I. Vinas. 2003. Liquid formulation of the biocontrol agent Candida sake by modifying water activity or adding protectants. Journal of Applied Microbiology 94:330-339.

Ucar, F., and I. Guneri. 1996. The effect of water activity, pH and temperature on the growth of osmophilic yeasts. Turkish Journal of Biology 20:37-46.

Wijtzes, T., P.J. Mcclure, M.H. Zwietering, and T.A. Roberts. 1993. Modelling bacterial growth of Listeria monocytogenes as a function of water activity, pH and temperature. International Journal of Food Microbiology 18:139-149.

Zwietering, M.H., T. Wijtzes, J.C. de Wit, and K.Van'T Riet. 1992. A decision support system for prediction of the microbial spoilage in foods. Journal of Food Protection 55:973-979.

Meat and Seafood

Allen, K., D. Cornforth, D. Whittier, M. Vasavada, and B. Nummer. 2007. Evaluation of high humidity and wet marinade methods for pasteurization of jerky. Journal of Food Science. 72:C351-C355.

Chen, H.C. 1995. Seafood microorganisms and seafood safety. Journal of Food and Drug Analysis 3:133-144.

Clavero, M.R.S., and L.R.Beuchat. 1996. Survival of Escherichia

coli O157:H7 in broth and processed salami as influenced by pH, water activity, and temperature and suitability of media for its recovery. Appl Environ Microbiol 62:2735-2740.

Duffy, L.L., P.B. Vanderlinde, and F.H. Grau. 1994. Growth of Listeria monocytogenes on vacuum-packed cooked meats: Effects of pH, a_w, nitrite and ascorbate. International Journal of Food Microbiology 23:377-390.

Elgasim, E.A., and M.S. Al Wesali. 2000. Water activity and Hunter colour values of beef patties extended with samh (Mesembryanthemum forsskalei Hochst) flour. Food Chem 69(2):181-185.

Gmez, R., and J. Fernandez-Salguero. 1993. Note: Water activity of Spanish intermediate moisture fish products. Revista Espanola De Ciencia Y Tecnologia De Alimentos 33:651-656.

Hand, L. 1994. Controlling water activity and pH in snack sticks. Meat Marketing and Technology May:55-56.

Lee, M.B., and S. Styliadis. 1996. A survey of pH and water activity levels in processed salamis and sausages in Metro Toronto. Journal of Food Protection 59:1007-1010.

Luecke, F.K. 1994. Fermented meat products. Food Res Intl 27:299-307. Minegishi, Y., Y. Tsukamasa, K. Miake, T. Shimasaki, C. Imai, M.

Sugiyama, and H. Shinano. 1995. Water activity and microflora in commercial vacuum-packed smoked salmons. Journal of the Food Hygienic Society of Japan 36:442-446.

Nunez, F., M.C. Diaz, M. Rodriguez, E. Aranda, A. Martin, and M.A. Asensio. 2000. Effects of substrate, water activity, and temperature on growth and verrucosidin production by Penicillium polonicum isolated from dry-cured ham. Journal of Food Protection 63:231-236.

Placido, M. and M.P. Aleman. 2002. Rapid hygrometric method for

determing water activity. Ciencia y Tecnologia Alimentaria 3(4):229-235.

Rocha-Garza, A.E., and J.F. Zayas. 1996. Quality of broiled beef patties supplemented with wheat germ protein flour. Journal of Food Science 61:418-421

Sabadini, E., M.D. Hubinger, P.-J.d.Sobral, and B.C. Carvalho, Jr. 2001. Change of water activity and meat colour in the elaboration process of dehydrated salted meat. Ciencia e Tecnologia de Alimentos 21(1):14-19.

Shimasaki, T., K. Miake, Y. Tsukamasa, M.A. Sugiyama, Y. Minegishi, and H. Shinano. 1994. Effect of water activity and storage temperature on the quality and microflora of smoked salmon. Nippon Suisan Gakkaishi 60:569-576.

Untermann, F., and C. Muller. 1992. Influence of a_w value and storage temperature on the multiplication and enterotoxin formation of staphylococci in dry-cured raw hams. International Journal of Food Microbiology 16:109-115.

Williams, S.K., G.E. Rodrick, and R.L. West. 1995. Sodium lactate affects shelf life and consumer acceptance of fresh Catfish (Ictalurus nebulosus, marmoratus) fillets under simulated retail conditions. Journal of Food Science 60:636-639.

Dairy Products

Clavero, M.R.S., and L.R. Beuchat. 1996. Survival of Escherichia coli O157:H7 in broth and processed salami as influenced by pH, water activity, and temperature and suitability of media for its recovery. Appl Environ Microbiol 62:2735-2740.

Correia, R., M. Magalhaes, M. Pedrini, A. da Cruz, and I. Clementino. 2008. Ice cream made from cow and goat milk: chemical composition and melting point characteristics. Revista Ciencia Agronomica 39:251-256.

Duffy, L.L., P.B.Vanderlinde, and F.H. Grau. 1994. Growth of Listeria monocytogenes on vacuum-packed cooked meats: Effects of pH, a_w, nitrite and ascorbate. International Journal of Food Microbiology 23:377-390.

Gmez, R., and J. Fernandez-Salguero. 1993. Note: Water activity of Spanish intermediate moisture fish products. Revista Espanola De Ciencia Y Tecnologia De Alimentos 33:651-656.

Hand, L. 1994. Controlling water activity and pH in snack sticks. Meat Marketing and Technology May:55-56.

Hardy, J., J. Scher, and S. Banon. 2002. Water activity and hydration of dairy powders. Lait 82:441-442.

Lee, M.B., and S. Styliadis. 1996. A survey of pH and water activity levels in processed salamis and sausages in Metro Toronto. Journal of Food Protection 59:1007-1010.

Luecke, F.K. 1994. Fermented meat products. Food Res Intl 27:299-307.

Malec, L.S., A.S. Pereyra-Gonzales, G.B. Naranjo, and M.S. Vigo. 2002. Influence of water activity and storage temperature on lysine availability of a milk like system. Food Res Intl 35(9):849-853.

Minegishi, Y., Y. Tsukamasa, K. Miake, T. Shimasaki, C. Imai, M. Sugiyama, and H. Shinano. 1995. Water activity and microflora in commercial vacuum-packed smoked salmons. Journal of the Food Hygienic Society of Japan 36:442-446.

Rocha-Garza, A.E., and J.F. Zayas. 1996. Quality of broiled beef patties supplemented with wheat germ protein flour. Journal of Food Science 61:418-421.

Shah, N.P., and R.R. Ravula. 2000. Influence of water activity on fermentation, organic acids production and viability of yoghurt and

probiotic bacteria. Australian Journal of Dairy Technology 55(3):127-131.

Shimasaki, T., K. Miake, Y. Tsukamasa, M.A. Sugiyama, Y. Minegishi, and H. Shinano. 1994. Effect of water activity and storage temperature on the quality and microflora of smoked salmon. Nippon Suisan Gakkaishi 60:569-576.

Untermann, F., and C. Muller. 1992. Influence of a_w value and storage temperature on the multiplication and enterotoxin formation of staphylococci in dry-cured raw hams. International Journal of Food Microbiology 16:109-115.

Williams, S.K., G.E. Rodrick, and R.L. West. 1995. Sodium lactate affects shelf life and consumer acceptance of fresh Catfish (Ictalurus nebulosus, marmoratus) fillets under simulated retail conditions. Journal of Food Science 60:636-639.

Fruits and Vegetables

Ayub, M., R. Khan, S. Wahab, A. Zeb, and J. Muhammad. 1995. Effect of crystalline sweeteners on the water activity and shelf stability of osmotically dehydrated guava. Sarhad Journal of Agriculture 11:755-761.

Beveridge, T., and S.E. Weintraub. 1995. Effect of blanching pretreatment on color and texture of apple slices at various water activities. Food Res Intl 28:83-86.

Clavero, M.R.S., R.E. Brackett, L.R. Beuchat, and M.P. Doyle. 2000. Influence of water activity and storage conditions on survival and growth of proteolytic Clostridium botulinum in peanut spread. Food Microbiology 17(1):53-61.

Fouskaki, M., K. Karametsi, and N.A. Chaniotakis. 2003. Method for the determination of water content in sultana raisins using a water activity probe. Food Chem 82:133-1337.

Gogus, F., C. Cuzdemir, and S. Eren. 2000. Effects of some hydrocolloids and water activity on nonenzymic browning of concentrated orange juice. Nahrung 44(6):438-442.

Hubinger, M., F.C. Menegalli, R.J. Aguerre, and C. Suarez. 1992. Water vapor adsorption isotherms of guava, mango and pineapple. Journal of Food Science 57:1405-1407.

Jimenez, M., M. Manez, and E. Hernandez. 1996. Influence of water activity and temperature on the production of zearalenone in corn by three Fusarium species. International Journal of Food Microbiology 29:417-421.

Khalloufi, S., J. Giasson, and C. Ratti. 2000. Water activity of freeze dried mushrooms and berries. Canadian Agricultural Engineering 42(1):51-56.

Kiranoudis, C.T., Z.B. Maroulis, E. Tsami, and D. Marinos-Kouris. 1993. Equilibrium moisture content and heat of desorption of some vegetables. Journal of Food Engineering 20:55-74.

Lopez-Malo, A., and E. Palou. 2000. Modeling the growth/nogrowth interface of Zygosaccharomyces bailii in Mango puree. Journal of Food Science: 65:516-520.

Makower, B., and S. Myers. 1943. A new method for the determination of moisture in dehydrated vegetables. Proceedings of Institute of Food Technologists, 4th Conference 156.

Maltini, E., D. Torreggiani, B.R. Brovetto, and G. Bertolo. 1993. Functional properties of reduced moisture fruits as ingredients in food systems. Food Res Intl 26:413-419.

Marin, S., N. Magan, M. Abellana, R. Canela, A.J. Ramos, and V. Sanchis. 2000. Selective effect of propionates and water activity on maize mycoflora and impact on fumonisin B1 accumulation. Journal of Stored Products Research 36:203-214.

Marin, S., V. Sanchis, I. Vinas, R. Canela, and N. Magan. 1995. Effect of water activity and temperature on growth and fumonisin B-1 and B-2 production by Fusarium proliferatum and F. moniliforme on maize grain. Lett Appl Microbiol 21:298-301.

Monsalve-Gonzalez, A., G.V. Barbosa-Canovas, and R.P. Cavalieri. 1993. Mass transfer and textural changes during processing of apples by combined methods. Journal of Food Science 58:1118-1124.

Pinsirodom, P., and K.L. Parkin. 2000. Selectivity of Celite-immobilized patatin (lipid acyl hydrolase) from potato (Solanum tuberosum L.) tubers in esterification reactions as influenced by water activity and glycerol analogues as alcohol acceptors. J. Agric. Food Chem. 48(2):155-160.

Tapia de Daza, M.S., C.E. Aguilar, V. Roa, and R.V. Diaz de Tablante. 1995. Combined stress effects on growth of Zygosaccharomyces rouxii from an intermediate moisture papaya product. Journal of Food Science 60:356-359.

Zeb, A., R. Khan, A. Khan, M. Saeed, and S.A. Manan. 1994. Influence of crystalline sucrose and chemical preservatives on the water activity and shelf stability of intermediate banana chips. Sarhad Journal of Agriculture 10:721-726.

Zhang, X.W., X. Liu, D.X. Gu, W. Zhou, R.L. Wang, and P. Liu. 1996. Desorption isotherms of some vegetables. Journal of the Science of Food and Agriculture 70:303-306.

Baked Goods and Cereals

Abellana, M., A.J. Ramos, V. Sanchis, and P.V. Nielsen. 2000. Effect of modified atmosphere packaging and water activity on growth of Eurotium amstelodami, E. chevalieri and E. herbariorum on a sponge cake analogue. Journal of Applied Microbiology 88:606-616.

Aramouni, F.M., K.K. Kone, J.A. Craig, and D.Y.C. Fung. 1994. Growth of Clostridium sporogenes PA 3679 in home-style canned

quick breads. Journal of Food Protection 57:882-886.

Cahagnier, B., L. Lesage, and D. Richard-Molard. 1993. Mould growth and conidiation in cereal grains as affected by water activity and temperature. Lett Appl Microbiol 17:7-13.

Clawson, A.R., and A.J.Taylor. 1993. Chemical changes during cooking of wheat. Food Chem 47:337-343.

Fleurat-Lessard, F. 2002. Qualitative reasoning and integrated management of the quality of stored grain: a promising new approach. Journal of Stored Products Research 38:191-218.

Gmez, R., J. Fernandez-Salguero, M.A. Carmona, and D. Sanchez. 1993. Water activity in foods with intermediate moisture levels: Bakery and confectionery products: Miscellany. Alimentaria 30:55-57.

Guynot, M.E., A.J. Ramos, L. Seto, P. Purroy, V. Sanchis, and S. Marin. 2003. Antifungal activity of volatile compounds generated by essential oils against fungi commonly causing deterioration of bakery products.

Harris, M., and M. Peleg. 1996. Patterns of textural changes in brittle cellular cereal foods caused by moisture sorption. Cereal Chem 73:225-231.

Hope, R., and N. Magan. 2003. Two-dimensional environmental profiles of growth, deoxynivalenol and nivalenol production by Fusarium culmorum on wheat-based substrate. Lett Appl Microbiol 37:70-74.

Michniewicz, J., C.G. Biliaderis, and W. Bushuk. 1992. Effect of added pentosans on some properties of wheat bread. Food Chem 43:251-257.

Moreno-Contreras, M.D., A.J. Martinez-Yepez, and R.R. Martinez. 2000. Determination of deoxynivalenol (DON) in wheat, barley and corn and its relationship with the levels of total molds, Fusarium spp., infestation percentage, and water activity. Archivos Latinoameri-

canos de Mutricion. 50(2):183-186.

Phoungchandang, S., and J.L. Woods. 2000. Moisture diffusion and desorption isotherms for banana. Journal of Food Science 65:651-657.

Ramanathan, S., and S. Cenkowski. 1995. Sorption isotherms of flour and flow behaviour of dough as influenced by flour compaction. Canadian Agricultural Engineering 37:119-124.

Roessler, P.F., and M.C. Ballenger. 1996. Contamination of an unpreserved semisoft baked cookie with a Xerophilic Aspergillus species. Journal of Food Protection 59:1055-1060.

Schebor, C., and J. Chirife. 2000. A survey of water activity and pH values in fresh pasta packed under modified atmosphere manufactured in Argentina and Uruguay. Journal of Food Protection 63:965-969.

Seiler, D.A.L. 1979. The mould-free shelf life of bakery products. FMBRA Bulletin April:71-74.

Sumner, S.S., J.A. Albrecht, and D.L. Peters. 1993. Occurrence of enterotoxigenic strains of Staphylococcus aureus and enterotoxin production in bakery products. Journal of Food Protection 56:722-724.

Tesch, R., M.D. Normand, and M. Peleg. 1996. Comparison of the acoustic and mechanical signatures of two cellular crunchy cereal foods at various water activity levels. Journal of the Science of Food and Agriculture 70:347-354.

Weegels, P.L., J.A. Verhoek, A.M.G. de Groot, and R.J. Hamer. 1994. Effects of gluten of heating at different moisture contents: I. Changes in functional properties. Journal of Cereal Science 19:31-38.

Beverages/Soups/Sauces/Preserves

Cardelli, C., and T.P. Labuza. 2001. Application of Weibull Hazard

Analysis to the determination of shelf life of roasted and ground coffee. Lebensm Wiss Technol 34:273-278.

Carson, K.J., J.L. Collins, and M.P. Penfield. 1994. Unrefined, dried apple pomace as a potential food ingredient. Journal of Food Science 59:1213-1215.

Cavia, M.M., M.A. Fernandez-Muio, J.F. Huidobro, and M.T. Sancho. 2004. Correlation between Moisture and Water Activity of Honeys Harvested in Different Years. Journal of Food Science 69:C-368-370.

Durrani, M.J., R. Khan, M. Saeed, and A. Khan. 1992. Development of concentrated beverages from Anna apples with or without added preservatives by controlling activity of water for shelf stability. Sarhad Journal of Agriculture 8:23-28.

Ferragut, V., J.A. Salazar, and A. Chiralt. 1993. Stability in the conservation of emulsified sauces low in oil content. Alimentaria 30:67-69.

Gleiter, R.A., H. Horn, and H.-D. Isengard. 2006. Influence of type and state of crystallization on the water activity of honey. Food Chem 96:441-445.

Hajmeer, M.N., F.M. Aramouni, and E.A.E.Boyle. 2000. Shelf-life of lite syrup after opening and storage at room or refrigerated temperature. Journal of Food Quality 23:529-540.

Ibarz, A., J. Pagan, and R. Miguelsanz. 1992. Rheology of clarified fruit juices: II. Blackcurrant juices. Journal of Food Engineering 15:63-74.

Khalloufi, S., Y. El-Maslouhi, and C. Ratti. 2000. Mathematical model for prediction of glass transition temperature of fruit powders. Journal of Food Science 65:842-848.

Kusumegi, K., T.Takahashi, and M.Miyagi. 1996. Effects of ad-

dition of sodium citrate on the pasteurizing conditions in "Tuyu," Japanese noodle soup. Journal of the Japanese Society for Food Science and Technology 43:740-747.

Perera, C.O. 2005. Selected quality attributes of dried foods. Drying Technology 23:717-730.

Sa, M.M., and A.M. Sereno. 1993. Effect of temperature on sorption isotherms and heats of sorption of quince jam. International Journal of Food Science & Technology 28:241-248.

Shafi ur-Rahman, M. 2005. Dried food properties: challenges ahead. Drying Technology 23:695-715.

Pharmaceuticals/Cosmetics

Ahlneck, C., and G. Zografi . 1990. The Molecular basis of moisture effects on the physical and chemical stabilty of drugs in the solid state. International Journal of Pharmaceutics 62:87-95.

Bell, L.N., and K.L. White. 2000. Thiamin Stability in Solids as Affected by the Glass Transition. Journal of Food Science 65:498-501.

Cochet, N., and A.L. Demain. 1996. Effect of water activity on production of beta-lactam antibiolics by Streptomyces clavuligerus in submerged culture. Journal of Applied Bacteriology 80:333-337.

Constantino, H.R., R. Langer, and A.M. Klibanov. 1994. Solid-Phase Aggregation of Proteins under Pharmaceutically Relevant Conditions. Journal of Pharmaceutical Science 83:1662-1669.

Enigl, D.C. 2001. Pharmaceutical stability testing using water activity. European Pharmaceutical Review 6:46-49.

Enigl, D.C., and K.M.Sorrel. 1997. Water Activity and Self-Preserving Formulas. p. 45-73. In J.J. Kabara, and D.S. Orth (ed.) Preservative-Free and Self-Preserving Cosmetics and Drugs: Principles and Prac-

tice. Marcel Dekker.

Hageman, M.J. 1988. The Role of Moisture in Protein Stability. Drug Dev. Ind. Pharm. 14:2047-2070.

Heidemann, D.R., and P.J. Jarosz. 1991. Preformulation Studies Involving Moisture Uptake in Solid Dosage Forms. Pharmaceutical Research 8:292-297.

Kontny, M.J. 1988. Distribution of Water in Solid Pharmaceutical Systems. Drug Dev. Ind. Pharm. 14:1991-2027.

Sablani, S.S., K. Al-Belushi, I. Al-Marhubi, and R. Al-Belushi. 2007. Evaluating Stability of Vitamin C in Fortified Formula Using Water Activity and Glass Transition. International Journal of Food Properties 10:61-71.

Zografi, G. 1988. States of Water Associated with Solids. Drug Dev. Ind. Pharm. 14:1905-1926.

Zografi, G., and M.J. Kontny. 1986. The interactions of water with cellulose and starch-derived pharmaceutical excipients. Pharmaceutical Research 3:187-193.

Miscellaneous

Bell, L.N. 1995. Kinetics of non-enzymatic browning in amorphous solid systems: Distinguishing the effects of water activity and the glass transition. Food Res Intl 28:591-597.

Bell, L.N., and T.P. Labuza. 1992. Compositional influence on the pH of reduced-moisture solutions. Journal of Food Science 57:732-734.

Bell, L.N., and T.P. Labuza. 1994. Influence of the low-moisture state on pH and its implication for reaction kinetics. Journal of Food Engineering 22:291-312.

Bhandari, B., and I. Bareyre, 2003. Estimarion of crystalline phase present in glucose crystal-solution mixture by water activity measurement. Lebensm Wiss Technol 36:729-733(5).

Brake, N.C., and O.R. Fennema. 1993. Edible coatings to inhibit lipid migration in a confectionery product. Journal of Food Science 58:1422-1425.

Dole, M., and L. Faller. 1950. Water sorption by synthetic high polymers. Journal of the American Chemical Society 12:414-419.

Fernandez-Salguero, J., R. Gmez, and M.A. Carmona. 1993. Water activity in selected high-moisture foods. Journal of Food Composition and Analysis 6:364-369.

Juhan, K., and G.K. Byung. 2000. Lipase-catalyzed synthesis of lysophosphatidylcholine using organic cosolvent for in situ water activity control. Journal of American Oil Chemists' Society 77(7):701-797.

Lima, J.R., S.D.S. Campos, and L.-A.G. Goncalves. 2000. Relationship between water activity and texture of roasted and salted cashew kernel. Journal of Food Science and Technology 37(5):512-513.

Lomauro, C.J., A.S. Bakshi, and T.P.Labuza. 1985a. Evaluation of food moisture sorption isotherm equations. Part II: Milk, coffee, tea, nuts, oilseeds, spices and starchy foods. Lebensm Wiss Technol 18:118-124.

Lomauro, C.J., A.S. Bakshi, and T.P. Labuza. 1985b. Evaluation of food moisture sorption isotherm equations. Part I: Fruit, vegetable and meat products. Lebensm Wiss Technol 18:111-117.

15 Appendix A

15.1 Preparing Salt Solutions

If you choose to mix a saturated salt solution for use as a verification standard, we recommend that you use the approved AOAC method.

Steps 1 through 4 detail the AOAC method.

1. Select a reagent-grade salt and place it in a test container to a depth of about 4 cm for more soluble salts (lower a_w), to a depth of about 1.5 cm for less soluble salts (high a_w), and to an intermediate depth for intermediate salts.

2. Add steam distilled water in increments of about 2 mL, stirring constantly.

3. Add water until the salt can absorb no more water, evidenced by the presence of free liquid. Keep the amount of free liquid to the minimum needed to keep the solution saturated with water. If you plan on using this solution over a long term period, seal the solution well to prevent losses from evaporation. Table 4 shows saturated salt solutions and their respective water activities at various temperatures. Please note that these values are based on averaged published data, and the standard errors shown reflect Greenspan's standard error for each salt solution, not the AquaLab accuracy in measuring the salt. The AquaLab measures all samples with an accuracy of ± 0.003 a_w using the dew point sensor and $\pm$ 0.015 a_w using the capacitance sensor.

Table 4: Water Activity of Selected Salt Solutions

Saturated Solution	a_w at 20°C	a_w at 25°C
Lithium Chloride	0.113 ±0.003	0.113 ±0.003
Magnesium Chloride	0.331 ±0.002	0.328 ±0.002
Potassium Carbonate	0.432 ±0.003	0.432 ±0.004
Magnesium Nitrate	0.544 ±0.002	0.529 ±0.002
Sodium Chloride	0.755 ±0.001	0.753 ±0.001
Potassium Chloride	0.851 ±0.003	0.843 ±0.003
Potassium Sulfate	0.976 ±0.005	0.973 ±0.005

Note: Table 4 adapted from Greenspan (1977). Rounded to nearest thousandth.

4. Saturated salt solutions are very temperature-sensitive and their values are not as accurate as the verification standards offered by METER.

16 Appendix B

Temperature Correction of METER's Verification Standards

Table 5: Water Activity of Selected Salt Solutions

Temp. (°C)	H_2O	0.50 mol/kg KCL	2.33 mol/kg NaCL	6.00 mol/kg NaCL	8.57 mol/kg LiCl	13.41 mol/kg LiCl	17.18 mol/kg LiCl
15.0	1.000	0.984	0.923	0.761	0.492	0.238	0.140
20.0	1.000	0.984	0.922	0.760	0.496	0.245	0.145
25.0	1.000	0.984	0.920	0.760	0.500	0.250	0.150
30.0	1.000	0.984	0.920	0.760	0.504	0.255	0.155
35.0	1.000	0.984	0.920	0.760	0.508	0.261	0.160
40.0	1.000	0.984	0.921	0.760	0.512	0.266	0.165
50.0	1.000	0.984	0.894	0.740	0.517	0.275	0.172

Note: The AquaLab measures these verification standards to ± 0.003 a_w *with the dew point sensor and* ± 0.015 a_w *with the capacitance sensor.*

17 Appendix C

AquaLab Verification Standards
Application Note

Using AquaLab is easier then ever. Pre-packaged standard salt solutions are immediately available for performance verification, saving you time and money. Validation and documentation for GMP and GLP has also become easier. Operate your instrument with certainty and insure the quality of your food product by using low cost precision salt solutions.

- No need to purchase and store reagent grade salts.
- No additional laboratory equipment necessary.
- Avoid solution handling and mixing errors.
- Save technician time.

The AquaLab should be verified against a known salt standard daily. For high use or batch processing, the instrument should be checked regularly against a known salt standard of similar water activity. Checking the water activity of a standard solution alerts the operator to the possibility of contamination of the unit or shifts in the linear offset from other causes.

Now, you can verify AquaLab performance with confidence. Performance Verification Standards in six water activity levels: 0.984, 0.920, 0.760, 0.500, 0.250, and 0.150 a_w. Order your calibration salt standard of similar water activity today.

Uncertainties Using Saturated Salt Solutions

The water activity values listed in our operator's manual for saturated salts were reprinted from Greenspan (1977). His method for determining water activity was to combine all of the available data from tests by other researchers. He did not set up any experiments of his own. The uncertainty he published is due to variation among the results from the different methods. There are, therefore, limitations to the accuracy of these values. The instrumentation available for

making water activity measurements is much better now than it was in 1977, so improved standards are needed.

Saturated salt solutions can be prepared by several methods. The AOAC method involves starting with salt and adding water in small increments, stirring well with a spatula after each addition, until salt can absorb no more water as evidenced by free liquid (where it takes on the shape of the container but does not easily pour). This method gives the most accurate readings, but only for a short time unless great care is taken to prevent water gain or loss. When a salt standard is prepared so that it consists mostly of liquid with a few crystals in the bottom, it can result in a layer of less than saturated solution at the surface which produces a higher reading than anticipated. Conversely, solid crystals protruding above the surface of the liquid can lower the readings. To comply with Good Laboratory Practices (GLP), a saturated salt solution must read within reasonable analytical error of the accepted published value for a given temperature.

Why AquaLab Verification Standards are Superior

Our research indicates that unsaturated salt solutions make much better standards than saturated salts. Robinson and Stokes (1965) give activity coefficient for various salt solutions. Customers can use these activity coefficients to the water potential, or partial specific Gibbs free energy, of the water in the solution using;

$$\Psi = -\phi\gamma cRT \tag{1}$$

where Ψ is the water potential, ϕ is the number of active particles per molecule of solute (i.e. 2 for NaCl), γ is the activity coefficient, c is the concentration of the solute (mol kg^{-1}), R is the gas constant (8.314 J mol^{-1} K^{-1}), T is the Kelvin temperature. Water potential is related to water activity by the equation;

$$a_w = \exp\left(\frac{\Psi M_w}{RT}\right) \tag{2}$$

where M_w is the molecular weight of water (0.018 kg mol^{-1}). When equations 1 and 2 are combined a simplified equation for water ac-

tivity is obtained;

$$a_w = \exp(-\phi\gamma c M_w) \tag{3}$$

For example, equation 3 gives the a_w in a 6 mol kg^{-1} NaCl solution, ($M_w = 0.018$ kg mol^{-1}, $\phi = 2$, and $\gamma = 1.271$; from tables in Robinson and Stokes, 1965) as

$$a_w = \exp(-2 \times 1.271 \times 6 \times 0.018) = 0.760 \tag{4}$$

It is important to note that equation 3 has no explicit temperature dependence. Available data on temperature dependence of γ indicates variation is less than $\pm 2\%$ over the range 0 to 50 °C for NaCl (Lang, 1967) and KCl (Campbell and Gardner, 1971) and no other terms have any temperature dependence.

A further advantage of unsaturated salts is that there is no solid phase present to affect the water activity of the solution. Salt in saturated solutions can exist in different states and result in uncertainty in the water activity values.

Instructions for Using METER's Verification Standards

Simply empty one vial of standard solution into a sample dish and place the dish immediately into the AquaLab for measurement. Each vial should fill a sample dish to just less than half full. Table 6 shows the expected values.

Note: If you need to obtain a Safety Data Sheet (SDS) for any of these standards, a printable version is available on our website at http://sds.metergroup.com/.

Table 6: Verification Standard Expected Values

Verification Standard Water Activity	Dew Point	Capacitance
USP Purified Water	1.000 ±0.003	1.000 ±0.015
0.50 mol/kg KCl	0.984 ±0.003	0.984 ±0.015
2.33 mol/kg NaCl	0.920 ±0.003	0.920 ±0.015
6 mol/kg NaCl	0.760 ±0.003	0.760 ±0.015
8.5 mol/kg LiCl	0.500 ±0.003	0.500 ±0.015
13.4 mol/kg LiCl	0.250 ±0.003	0.250 ±0.015
17.18 mol/kg LiCl	0.150 ±0.003	0.150 ±0.015

Verify the AquaLab is functioning properly with any two of these solutions. We recommended that you choose a standard from the range in which you are measuring and steam distilled water (or another solution from the table).

1. Place the verification standard (do not start with water) in AquaLab for measuring. When you reach a final reading, check it against the values in Table 6. If it is within ±0.003, place your second solution in the drawer for testing. It should read the value ±0.003 listed in the table above. If the readings are within the expected values your verification is complete.

2. If the first solution does not read within ±0.003 of the expected value, then you need to adjust the linear offset so that the solution reads correctly (see Section 7). When you are finished measuring both standards, the readings should be within ±0.003 of the predicted values.

References

AOAC, Method 978.18D Preparation of Reference Salt Slushes. 1995. Official Methods of Analysis of AOAC International. 16th Ed. AOAC International, Arlington VA.

Campbell, G.S. and W.H. Gardner. 1971. Psychrometric measurement of soil water potential: temperature and bulk density effects. Soil Sci. Soc. Am. Proc. 35:8-12.

Greenspan, L. 1977. Humidity fixed points of binary saturated aque-

ous solutions. J. Res. National Bureau of Stds. A. Physics and Chem. 81A:89-96.

Lang, A.R.G. 1967. Osmotic coefficients and water potentials of sodium chloride solutions from 0 to 40 °C. Aust. J. Chem. 20:2017-2023.

Robinson, R.A. and R.H. Stokes. 1965. Electrolyte Solutions. Butterworths, London.

18 Declaration of Conformity

Application of Council Directive:	2004/108/EC and 2011/65/EU
Standards to which conformity is declared:	EN 61326-1:2013 and EN 50581:2012
Manufacturer's Name:	METER Group, Inc. 2365 NE Hopkins Ct. Pullman, WA 99163 USA
Type of Equipment:	AquaLab Water Activity Meter.
Model Number:	Series 4, Series 4TE, Series 4TEV, Series 4TE DUO, and Series 4TEV DUO
Year of First Manufacture:	2008

The undersigned hereby declares on behalf of METER Group, Inc. that the above referenced products, to which this declaration relates, fully conform to the provisions of the Council Directives and standards referenced above.

Michael Wadsworth
Engineering Director
7-9-2015

19 Certificate of Traceability

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METER Group, Inc. manufactures all AquaLab water activity meters according to accepted international temperature standards with traceable calibration.

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