جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

EGEL
Energy GeoEngineering Laboratory

Soil Water Characteristic Curve (SWCC) Using the WP4C

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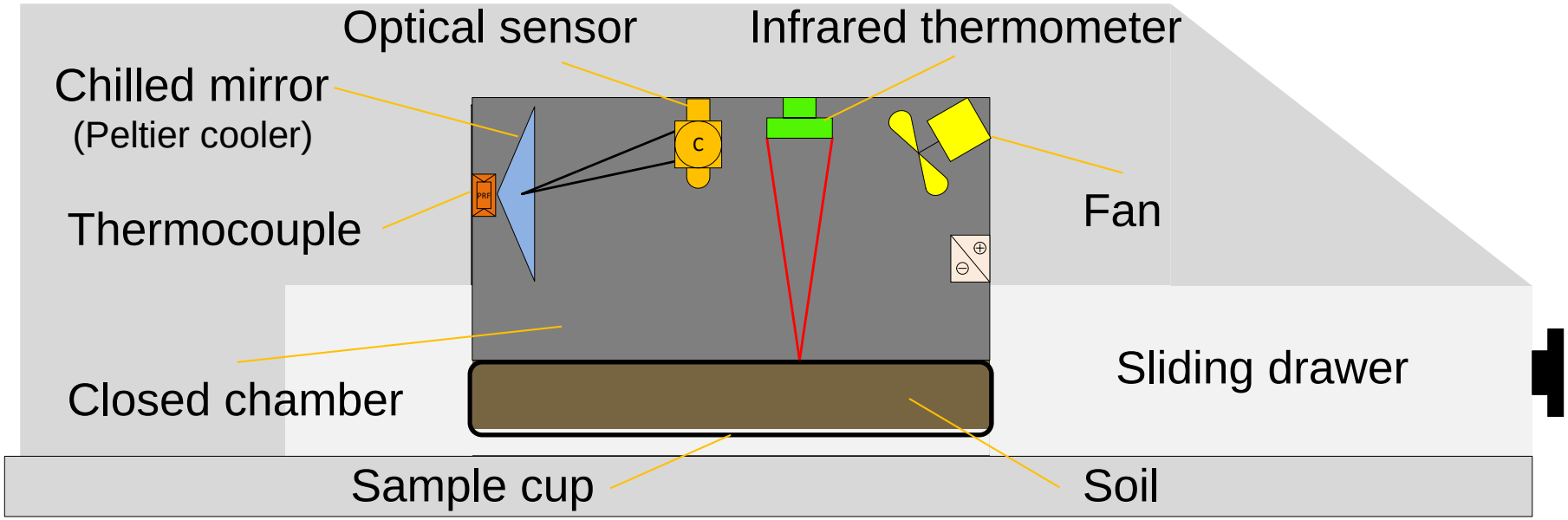
Note: *This pictorial manual is not intended to replace the official Decagon WP4C manual. The purpose of this document is to be an illustrated, quick reference guide which includes lab images and concise instructions. For detailed information please refer to the WP4C manual.*

WP4C features:

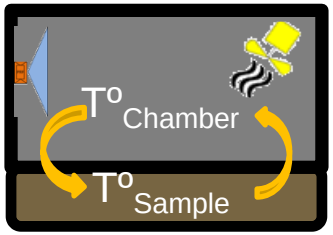


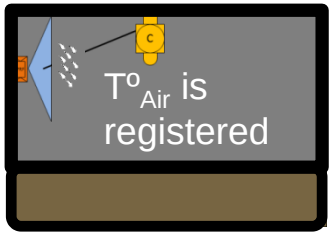
Specifications

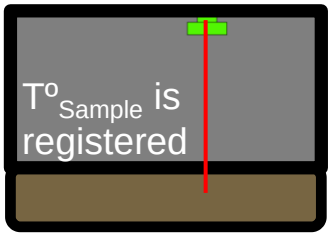
Total suction measurement technique: Dew point (uses psychrometric law)
Sensor types: A chilled-mirror dew point and an infrared temperature sensor
Range: 0 to -300 MPa
Accuracy: ± 0.05 MPa from 0 to -5 MPa & 1% from -5 MPa to -300 MPa
Temperature control: 15ºC to 40ºC (± 0.2 ºC)
Sample cup capacity: 7 mL maximum

Water potential meter based on the chilled-mirror dew point technique

How it works:







p_v^{air}

p_v^{sat}

RH

T° Sample < T° Chamber

Thermodynamic equilibrium

Dew Point

$$\Psi_{total} = -\frac{RT}{M_w} ln(RH)$$

Selecting the READ position on the device triggers the sealing of the internal chamber and consequently, the thermodynamic equilibrium is reached in relation to the internal temperature and relative humidity. A fan accelerates the internal equilibrium. The three events below occur simultaneously:

1. A cooled thermoelectric Peltier maintains the mirrors temperature. A photodetector directs a beam of light onto the mirror and detects the change in reflectance at the exact moment when the condensation occurs on the mirror.
2. A thermocouple attached to the mirror records the temperature when the dew point occurs.
3. An infrared thermometer measures the sample temperature at the surface.

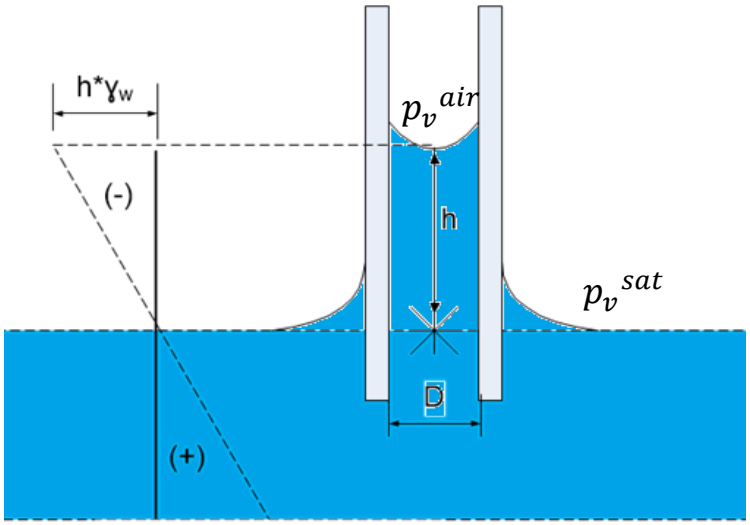
Theory: Psychrometric law

$$\Psi = -\frac{RT}{M_w}\ln(\mathrm{RH})$$

Eqs.: **(1)** $dp_v = -\rho_v * g * dy$

(2) $p_v = \rho_v * T * \frac{R}{M_w}$

(3) $\Psi = h * \rho_l * g$



From (2) & (1)

$$dy = -\frac{dp_v}{\rho_v * g} = -\frac{dp_v}{p_v} * \frac{R * T}{M_w * g}$$

$$\int_0^h dy = -\frac{R * T}{M_w * g} * \int_{p_v{}^{sat}}^{p_v{}^{air}} \frac{dp_v}{p_v}$$

Eq. (4) $\rightarrow h = -\frac{R*T}{M_w*g} * \ln\left(\frac{p_v{}^{air}}{p_v{}^{sat}}\right)$

From (3) & (4)

$$\frac{\Psi}{\rho_l * g} = -\frac{R * T}{M_w * g} * \ln\left(\frac{p_v{}^{air}}{p_v{}^{sat}}\right)$$

$$\Psi = -\frac{RT}{M_w}\ln\left(\frac{p_v{}^{air}}{p_v{}^{sat}}\right) = -\frac{RT}{M_w}\ln(\mathrm{RH})$$

T is temperature(ºK), *R* is the ideal gas constant and M_w is molecular mass of water. The value of R/M is 461 kPa/°K

General recommendations

- The WP4C requires a level surface away from any air conditioning vents and refrigerator exhausts, etc. that may cause rapid temperature fluctuations.
- Wear disposable gloves throughout the test.
- Wait 30 minutes between switching the machine on and taking the initial reading. Waiting stabilizes the chambers internal temperature.
- The sample temperature must be (slightly) less than the chambers temperature prior to commencing calibration or readings.
- Never place a hot or warm sample in the drawer. Condensation will form inside the chamber, contaminating the device and will cause measurement errors.
- The cup capacity is 15 mL. Do not overfill.
- Ensure that the rim and external surfaces of the sample cup are always clean before placing them into the drawer.
- Clean the sample cups with deionized water after the test.
- Measurement times are dependent on the selected reading mode.

Start-up

1. Turn on the WP4C by pressing the switch at the back.
2. Wait 30 minutes.

Start up [Step 1]

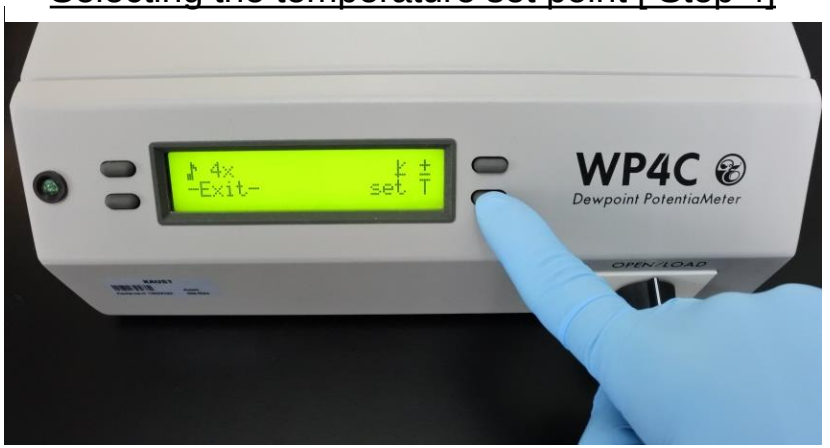
3. Press the lower left button to select the System Configuration Menu.

Selecting the System Configuration Menu [Step 3]

Start up (continued)

4. Press the lower right button on the Configuration Screen (set T).

Selecting the temperature set point [Step 4]



5. Adjust the chamber temperature using the +/- buttons. *The recommended value is the laboratory temperature.*
6. Press the lower left button (-Exit-) to store the selected value.

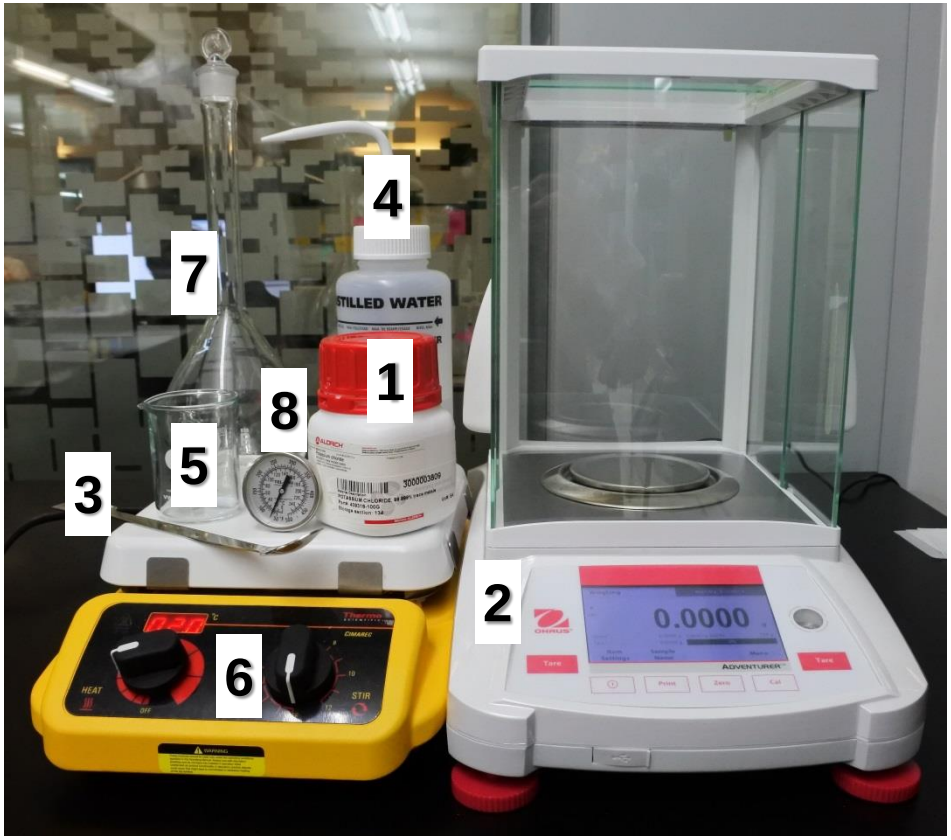
Temperature Set Point screen [Step 5 & 6]

Note: A complete and accurate reading will not occur until the difference between the sample temperature and the chamber temperature is less than 1.0 ºC. Therefore, a large difference between the sample and the chamber temperatures will cause longer reading times.

WP4C Calibration materials

Solution preparation materials:

1. Potassium chloride (KCl)
2. Spoon
3. Precision scale
4. Deionized water
5. Beaker
6. Magnetic stirrer
7. Volumetric flask
8. Thermometer



Note: Check the calibration with the KCl solution before daily use. For batch processing check the calibration regularly.

These instructions use the following calibration solution: **0.5 mol/kg (KCl / H_2O)**

The quantities shown produce 0.5Lt calibration solution:

- 18.6378 gr KCl
- 500 ml of H_2O heated to 20ºC

Refer to manual for other concentrations, associated suction and temperature values.

WP4C Calibration (1)

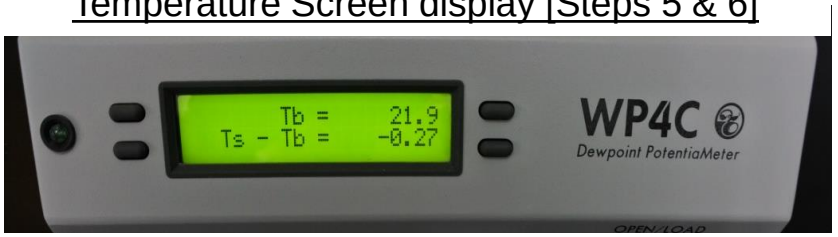
1. Ensure that the calibration solution is approximately 20ºC.
2. Choose the most appropriate type of disposable cup (stainless steel or plastic) for the test.
3. Fill the cup to a maximum of 7mL, approximately ½ cup.
4. Check that the cup rim and external surfaces are clean.

Selecting the Temperature Screen from the Main Menu [Step 5]

5. Press the lower right button to select the Temperature Screen.

Temperature Screen display [Steps 5 & 6]

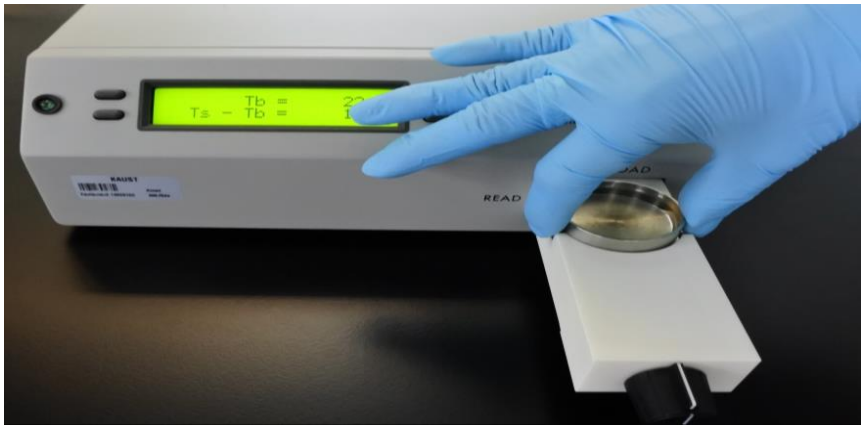
6. When the Temperature Screen is displayed, slide open the sample drawer.



WP4C Calibration (2)

7. Place the filled calibration cup in the drawer and slide in.

Placing the cup in the drawer [Step 7]



8. Check Ts and Tb Values

- If Ts – Tb = (-) Value → ✓

Continue the calibration process

- If Ts – Tb = (+) Value → ✗

Remove the sample from the WP4C and allow it to cool until the sample temperature is lower than the chamber temperature. *Repeat Steps 6 to 8.*

Checking the Temperature [Step 8]

Ts: Sample temp. & **Tb**: Chamber temp.

WP4C Calibration (3)

9. Press the lower left button (x2) until the System Configuration Menu Screen is displayed.

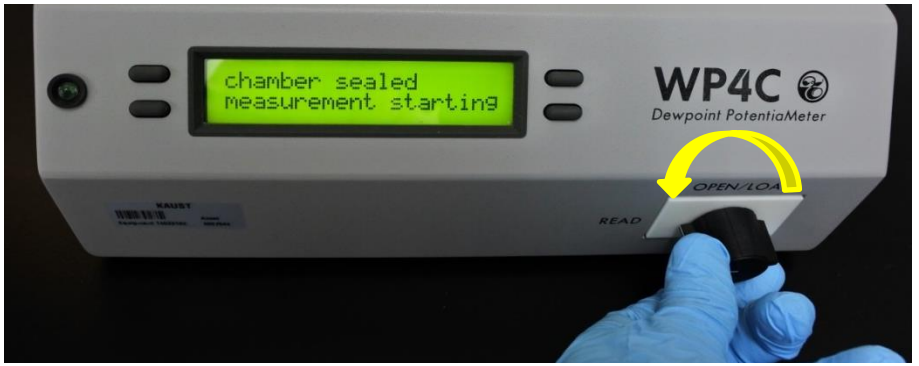
Selecting the System Configuration Menu [Step 9]

10. Press the upper right button to select Calibration Mode.

System Configuration Menu Screen [Step 10]

11. Turn the drawer knob to READ (one beep & a green LED).
12. Wait until the readings have been completed (two beeps & a green LED).

Sealing the chamber [Step 11]



WP4C Calibration (4)

13. Adjust the Ψ calibration value if needed using the ↕ buttons on the right side. See table below for values:

Suction values for 0.5 mol/kg KCl solution

Temperature (ºC)	Suction (MPa)
20	2.19
25	2.22

14. Press the lower left button (-Exit-) to store the selected value.
15. Turn the knob to OPEN/LOAD and remove the sample cup.
16. Place the same cup back in the drawer without changing the calibration solution and turn the knob to READ. This verifies the calibration.
17. Wait until the calibration has been verified (four beeps & a green LED).
18. Repeat Step 15 to finish calibration.

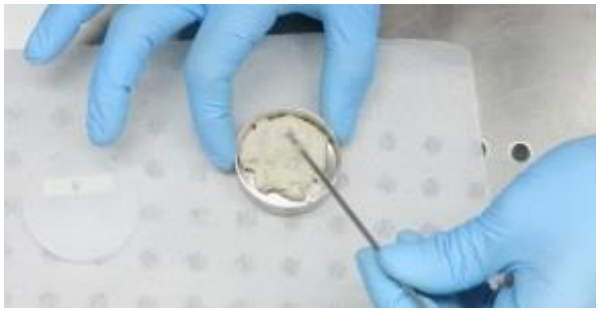
Calibration Completion Screen [Steps 13 & 14]

Verifying the calibration [Step 17]

Note: The reading obtained should be within **± 0.05** MPa of the value selected in Step 13. *If the value is not within this range, repeat the calibration process from Steps 1 to 18. If the error continues after repeated calibration attempts please check the Problems and Solution section of the Decagon manual.*

Sample preparation for SWCC

1. Choose the same cup type that was used for calibration.
2. Half fill the cup with the sample ensuring that the sample completely covers the bottom surface of the cup.
3. Clean any excess soil from the rim and external cup surfaces.
4. Select the appropriate procedure below to obtain the SWCC, depending on individual requirements.

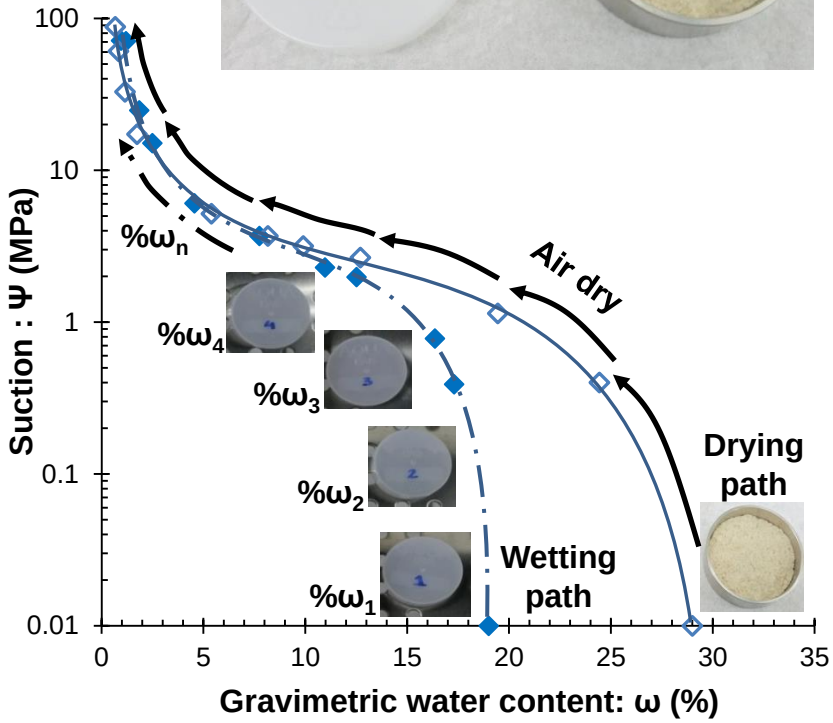


Procedure to obtain a SWCC with a drying path:

- Use a single sample
- Fill the cup as described in Steps 1 to 3 above
- Allow the sample to air dry
- Sample will require 24 hours to reach equilibrium prior to additional measurements.

Procedure to obtain a SWCC with a wetting path:

- Use a series of specimens
- Prepare samples with different water contents
- Fill the cup as described in Steps 1 to 3 above.



Procedure: Measurements (1)

1. Refer to the table below to determine the appropriate Reading Mode.

Reading Mode suggestions

Reading Mode	**P**recise	**C**ontinuous	**F**ast
Read time (min)	10 - 15	Long term	3 - 5
Useful in samples with (Ψ)	> - 40 MPa	> - 0.5 MPa	< - 40 MPa

2. Select the Reading Mode by pressing the upper left button on the Main Screen (see the very small letter on the top left).

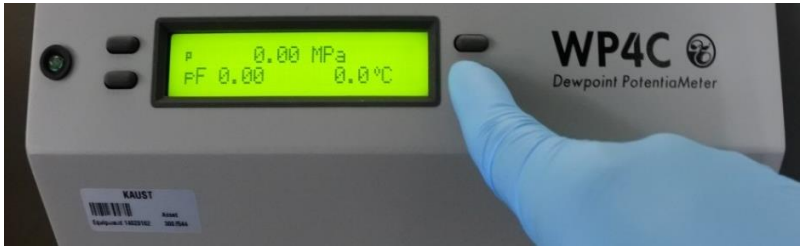
3. Press the lower right button to select the Temperature Screen.

4. When the Temperature Screen is displayed, slide open the sample drawer.

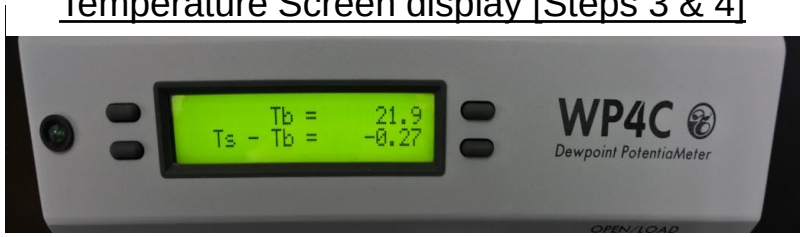
Selecting the Reading Mode [Step 2]

P: precise **C**: continuous **F**: fast

Selecting the Temperature Screen from the Main Menu [Step 3]



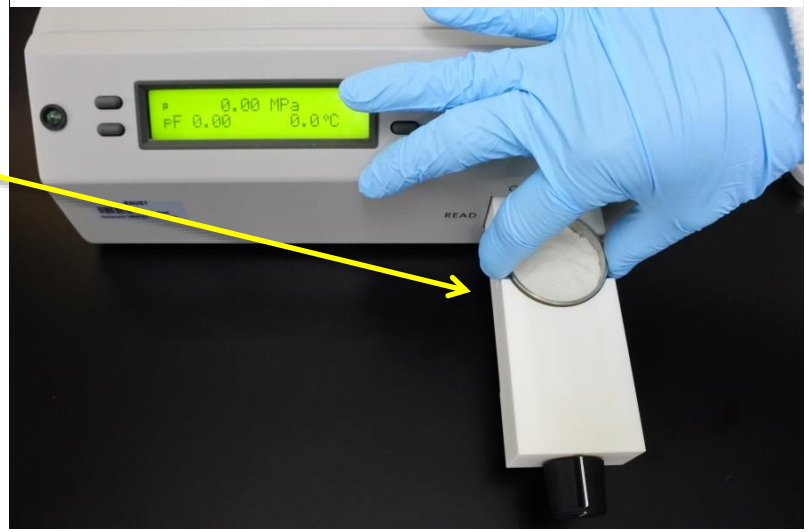
Temperature Screen display [Steps 3 & 4]



Procedure: Measurements (2)

5. Place the sample cup in the drawer (holding the cup as shown in the photo).
6. Slide the drawer into the device.

Placing the cup in the drawer [Step 5]



7. Check Ts and Tb Values

- If Ts – Tb = (-) Value → ✓
  Continue the calibration process.
- If Ts – Tb = (+) Value → ✗
  Remove the sample from the WP4C and allow it to cool until the sample temperature is lower than the chamber temperature. *Repeat Steps 6 to 8.*

Checking the Temperature [Step 7]

Ts: Sample temp. & **Tb**: Chamber temp.

Procedure: Measurements (3)

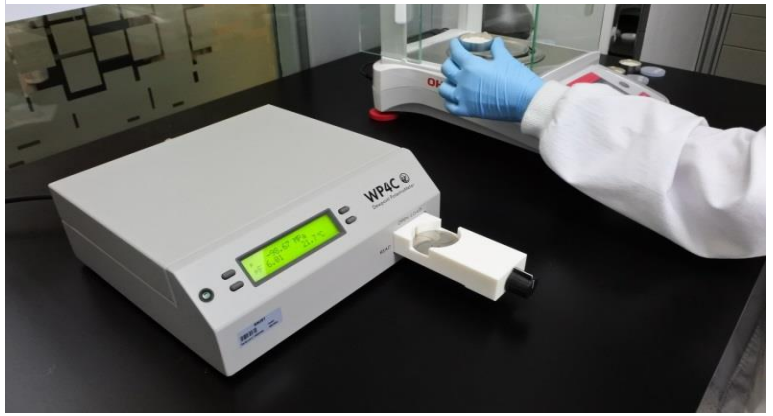
8. Turn knob to READ (one beep & green LED).
9. Wait until the readings have been completed (four beeps & green LED).

Sealing the chamber [Step 8]

10. Record the obtained suction Ψ value and write it down for later use in the SWCC.
11. Turn the knob to OPEN/LOAD and remove the sample cup from the device.
12. Record the sample weight using lab scales.
13. Determine the gravimetric water content using standard guidelines.
14. Repeat *the Procedure Measurements with Steps 1 to 13 as required to complete the SWCC*.

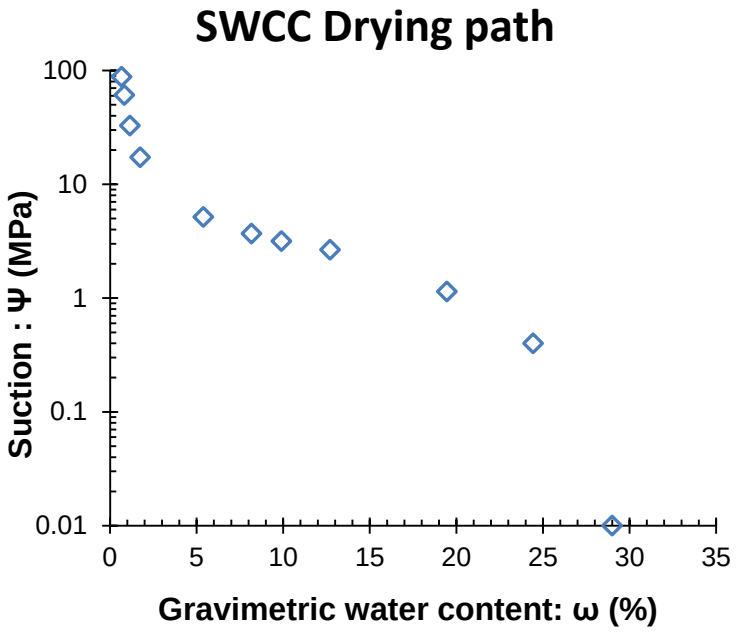
Obtaining the suction value [Step 9]

Determining the sample weight [Step 12]

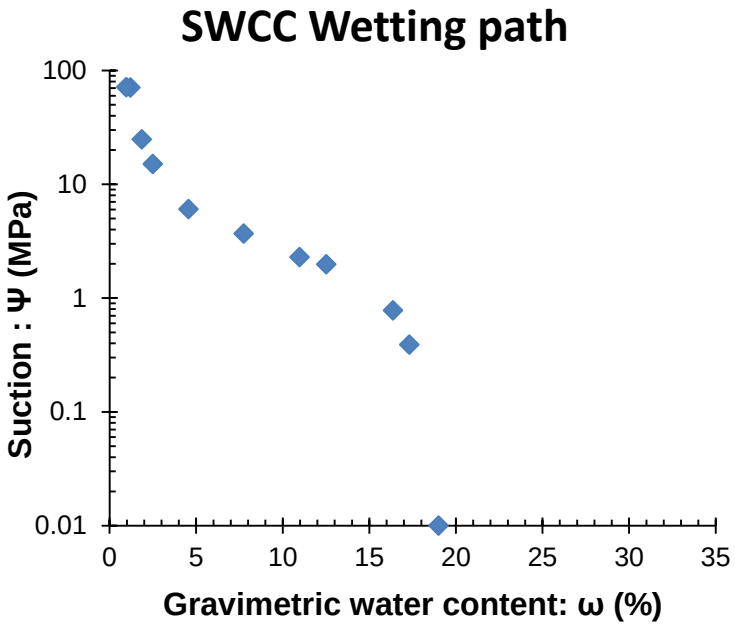


Results: SWCC (1)

Single specimen measurements



Measurements from a series of specimens



$$\omega_i = \omega_0 + \frac{M_i - M_0}{M_s}$$

ω_0: Gravimetric water content using oven drying for the 1st suction measurement

M_i: Sample dry mass for the i_{th} suction measurement

M_0: Sample mass for the 1st suction measurement

M_s: Sample dry mass

Results: SWCC (2)

Suggested equation to transform the gravimetric water content to the degree of saturation if the sample volume remains constant:

$$S = \frac{\rho_s * (\omega_i * M_s)}{\rho_w * (V_{Ti} * \rho_s - M_s)}$$

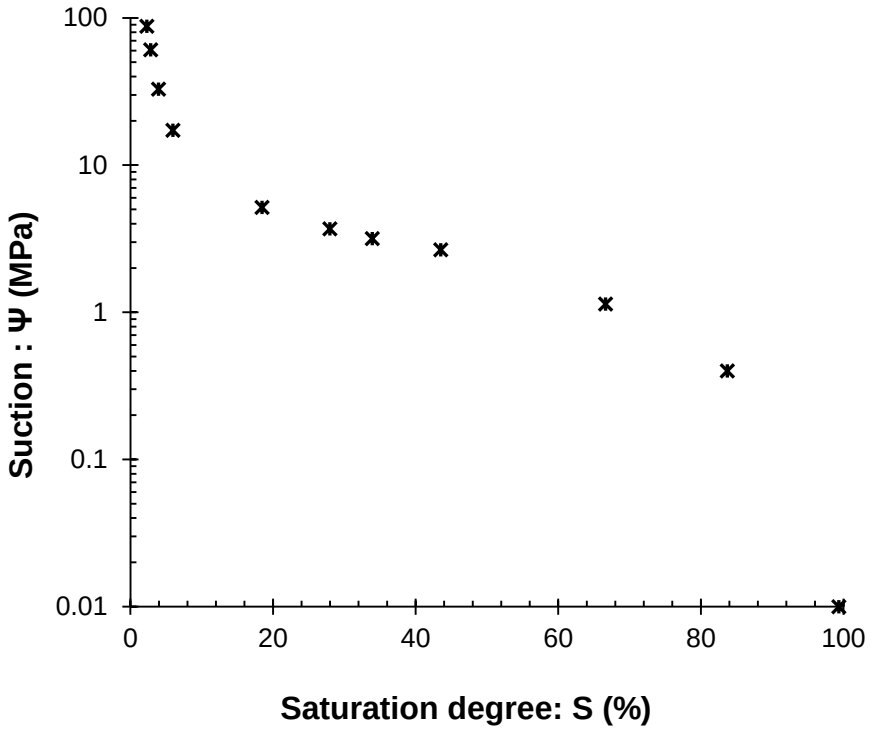
ω_i: Gravimetric water content determined using oven drying for the i_{th} suction measurement

V_{Ti}: the bulk volume for the i_{th} suction measurement

M_s: the dry mass of the specimen

ρ_s: the density of soil solids

ρ_w: the density of water



References

ASTM D6836-02(2008)e2 Standard Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using a Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, and/or Centrifuge, ASTM International, West Conshohocken, PA, 2008, http://dx.doi.org/10.1520/D6836-02R08E02