

MEASUREMENT OF SOIL SUCTION

Rifat Bulut, Ph.D.

Postdoctoral Research Associate
Texas Transportation Institute
Texas A&M University
College Station, TX 77843-3135
r-bulut@tamu.edu

Prof. Dr. Robert L. Lytton

Professor of Civil Engineering
Texas A&M University
College Station, TX 77843-3135
r-lytton@tamu.edu

TOTAL AND MATRIC SUCTION MEASUREMENTS WITH THE FILTER PAPER METHOD

Rifat Bulut, Ph.D.

FUGRO SOUTH, INC.

2880 Virgo Lane

Dallas, Texas 75229

Phone : 972-484-8301

Fax : 972-620-7328



- A General View of Lab Material Needed for the Filter Paper Method

- ✓ Filter Papers
- ✓ Sensitive Balance
- ✓ Constant Temperature Container
- ✓ Oven



- ✓ Moisture Tins
- ✓ Glass Jars
- ✓ Tweezers
- ✓ Gloves
- ✓ PVC-Rings
- ✓ Electrical Tape
- ✓ Aluminum Block

THEORY OF CALIBRATION BASED ON WATER VAPOR MEASUREMENTS

$$h_t = \frac{RT}{V} \ln \left(\frac{P}{P_o} \right)$$

$$h_\pi = -\nu RT m \phi$$

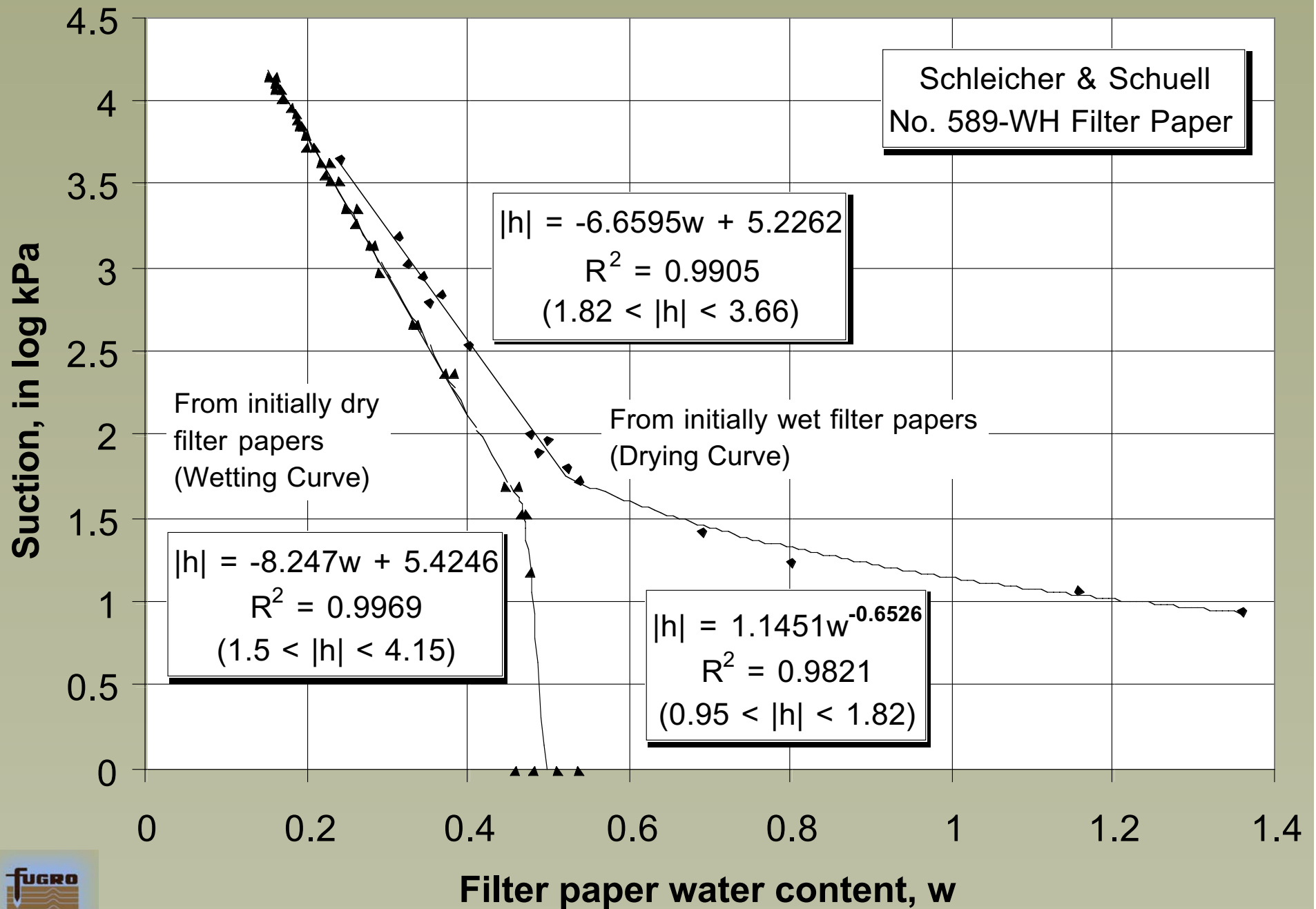


- If initially dry filter papers are used for soil suction measurements then one of the wetting filter paper calibration curves given in the next two slides can be adopted.
- A more detailed information about the calibration curves and soil suction measurements can be found in the publications:

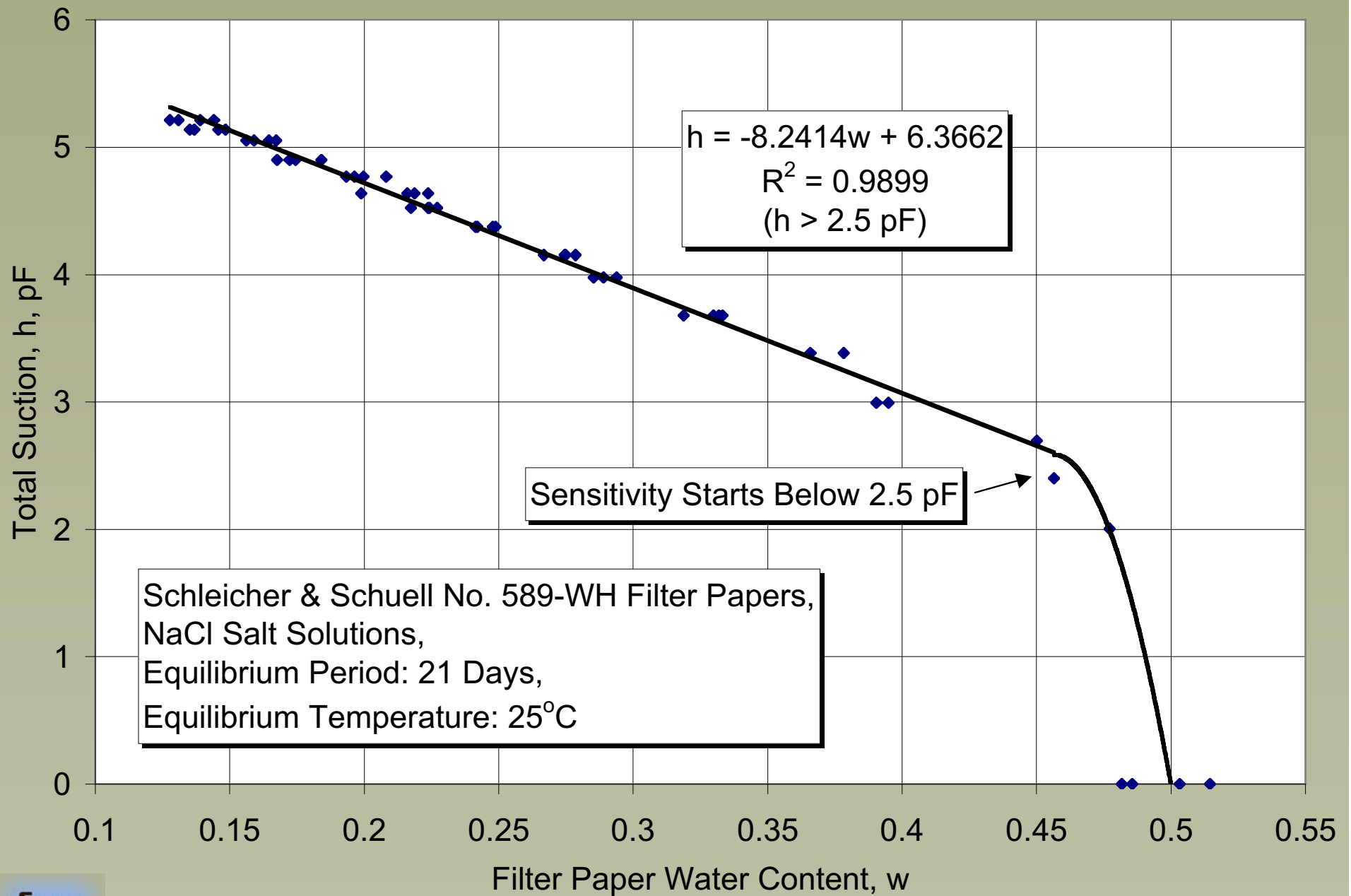
□ Bulut, R., Lytton, R. L., and Wray, W. K. (2001). “Suction Measurements by Filter Paper,” *Expansive Clay Soils and Vegetative Influence on Shallow Foundations*, ASCE Geotechnical Special Publication No. 115 (eds. C. Vipulanandan, M. B. Addison, and M. Hasen), ASCE, Reston, Virginia, pp. 243-261.

□ Bulut, R., Hineidi, S. M., and Bailey, B. (2002). “Suction Measurements – Filter Paper and Chilled Mirror Psychrometer,” The Proceedings, Texas Section ASCE, Fall Meeting, Waco, Texas.

CALIBRATION CURVE [Bulut, R., Lytton, R. L., and Wray, W. K. (2001)]



CALIBRATION CURVE [Bulut, R., Hineidi, S. M., and Bailey, B. (2002)]



BEFORE COMMENCING THE TESTING,
MAKE SURE THAT ALL ITEMS
RELATED TO FILTER PAPER METHOD
ARE CLEAN, MOISTURE, OIL, AND
DUST FREE!

NOTE:

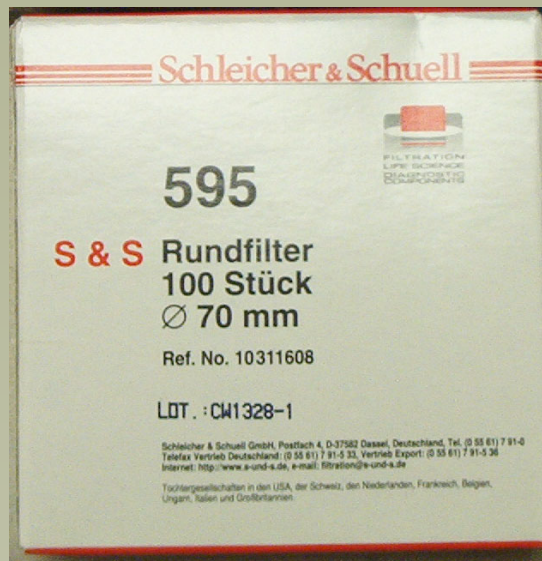
- *Make sure that tweezers are used to handle filter papers*
- *Make sure that moisture tins, O-rings are handled with gloves*

- Use a container that a Shelby-tube soil sample can be fit into easily without the disturbance of the soil sample.
- Cut the soil sample into two halves for matric suction measurements.
- Make sure that the surfaces of the soil samples are smooth and flat for establishing an intimate contact between the soil sample and the filter paper for matric suction measurements.



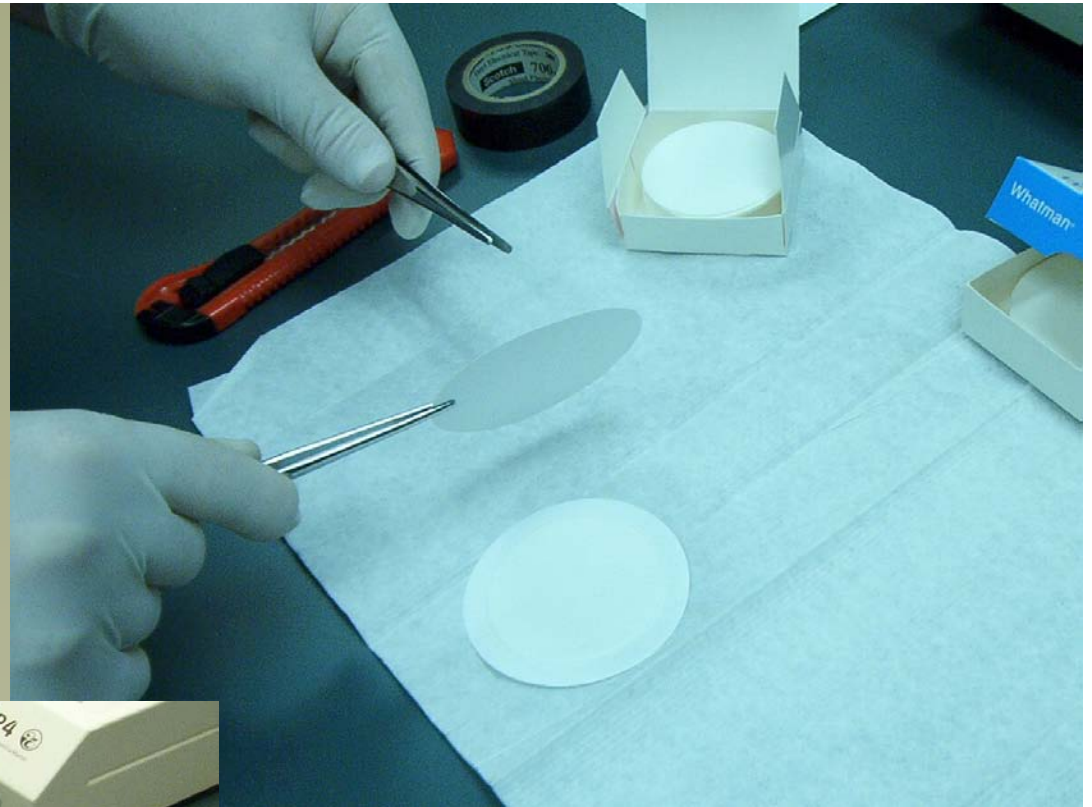
NOTE: When preparing the soil samples make sure that sample disturbance is minimal.

- Remove a *Schleicher & Schuell* No. 589-WH filter paper from the box using tweezers (5.5 cm in diameter)



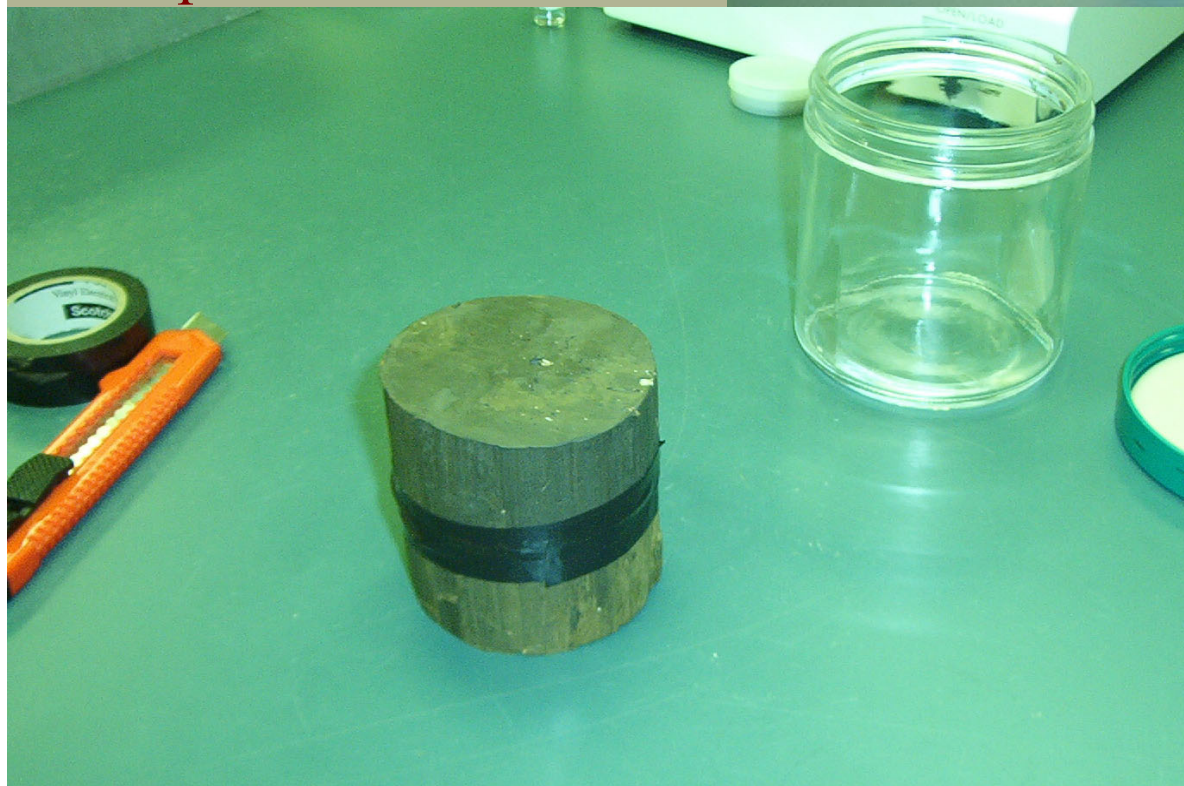
Almost any brand of high permeability and larger diameter filter paper can be used as protective filter papers for matric suction measurements (as shown in the lower left box and in the picture, about 70 mm in diameter)

- For matrix suction measurements, insert a single Schleicher & Schuell No. 589-WH filter paper in between two larger in diameter protective filter papers as shown on the right



- Using tweezers put the sandwiched filter papers on top of the soil sample as shown on the left

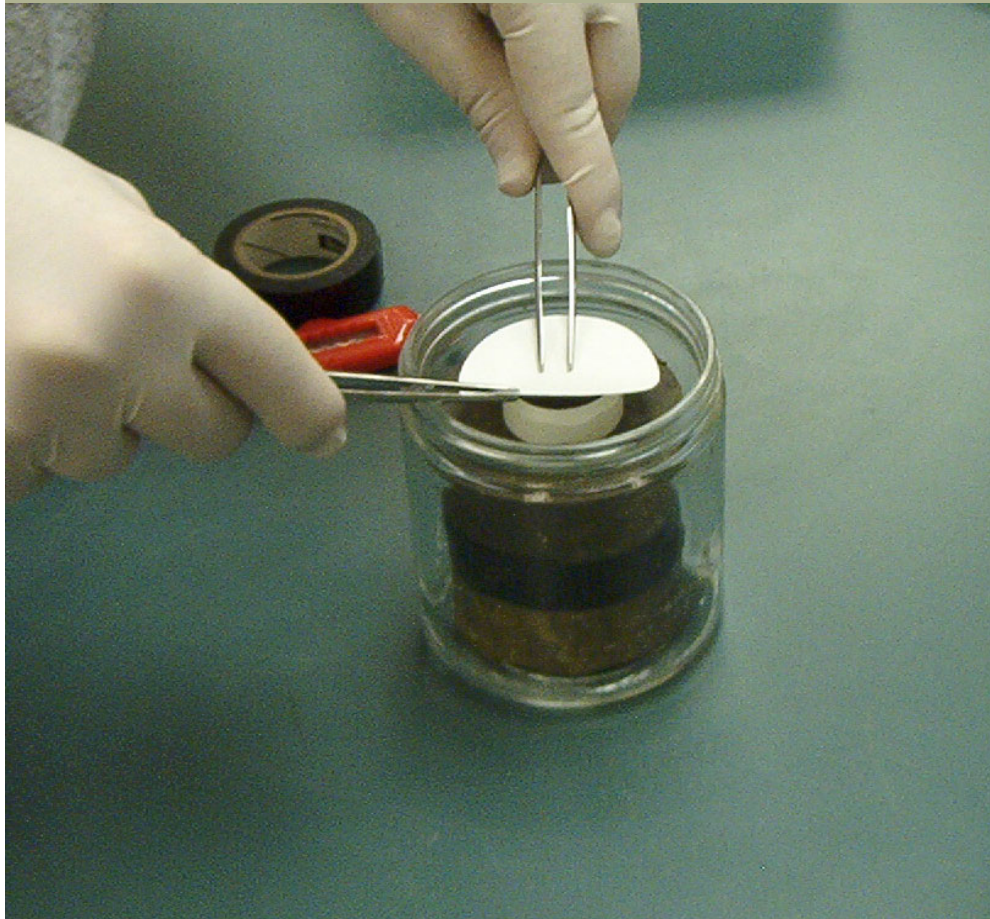
- Put the other half of the soil sample on top, keeping the sandwiched filter papers in between and in intimate contact with the soil samples



- Tape the two pieces of the soil sample together

NOTE: Electrical tape works nicely for this purpose

- Insert a clean PVC O-ring, with the sharp edge facing up, on top of the soil sample for total suction measurements



- Place two *Schleicher & Schuell* No. 589-*WH* filter papers on top of the ring as shown on the left

NOTE: Bend the edge of the top filter paper up a little so that it will be easy to remove them later!



- Put the lid on and tape it tight to prevent any moisture exchange between the air inside and the air outside of the jar
- Label the jar as necessary



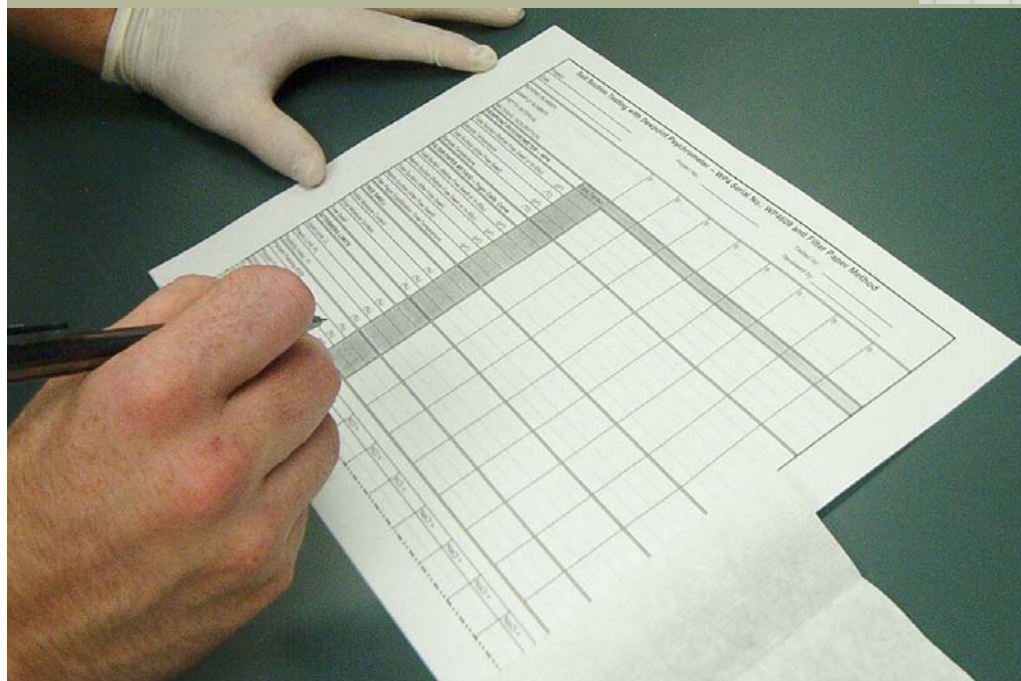
- Insert the glass jar into a well-insulated container for suction equilibrium

NOTE: Temperature control is critically important

- ✓ Soil suction measurement set up, as described in the previous slides, will be kept in a temperature-controlled environment for at least one week
- ✓ Temperature fluctuations should be kept as low as possible, preferably below $\pm 1^{\circ}\text{C}$
- ✓ Refer to the publications that were cited before for detailed information about the equilibration periods and temperature control

AT THE END OF AT LEAST ONE WEEK OF EQUILIBRIUM PERIOD:

- Before opening the lid of the temperature-controlled container, take the dry, cold weight of the moisture tins



- Record all the weights with their corresponding tin numbers

NOTE: Use a balance at least to the nearest 0.0001 g. accuracy

- Remove a glass jar from the temperature-controlled container
- Time is critical at this stage and thus it is suggested that two people share the work
- The time that the filter papers are exposed to the lab environment should be minimal, preferably less than a few seconds



Note that while one person is opening the glass jar the other person is ready to pick up the filter papers

- Open the glass jar and quickly carry the filter paper to the moisture tin using tweezers, in less than a few seconds



- Immediately close the lid of the moisture tin with the wet filter paper inside

- After closing the lid of the moisture tin, immediately weigh the tin with the wet filter paper inside



- Record the weight as cold tare plus wet filter paper mass

Note that this is a total suction measurement



- Continue with the matric suction measurement by removing the tape that was holding the soil samples together



- Remove the filter paper that was sandwiched between the two protective filter papers
- Immediately carry the filter paper to the moisture tin

- Immediately close the lid of the moisture tin and weigh the tin with the wet filter paper inside



- Record the weight as cold tare plus wet filter paper mass

Note that this is a matric suction measurement



- After opening all the glass jars and recording the weight of the moisture tins with the wet filter papers inside, carry them to a hot oven with the lids half open
- Leave them in the oven for at least 10 hours



- Before taking them out from the oven, close their lids for equilibrium and leave them in the oven for about 5 minutes

- Remove a hot tin from the oven and put on a large aluminum block

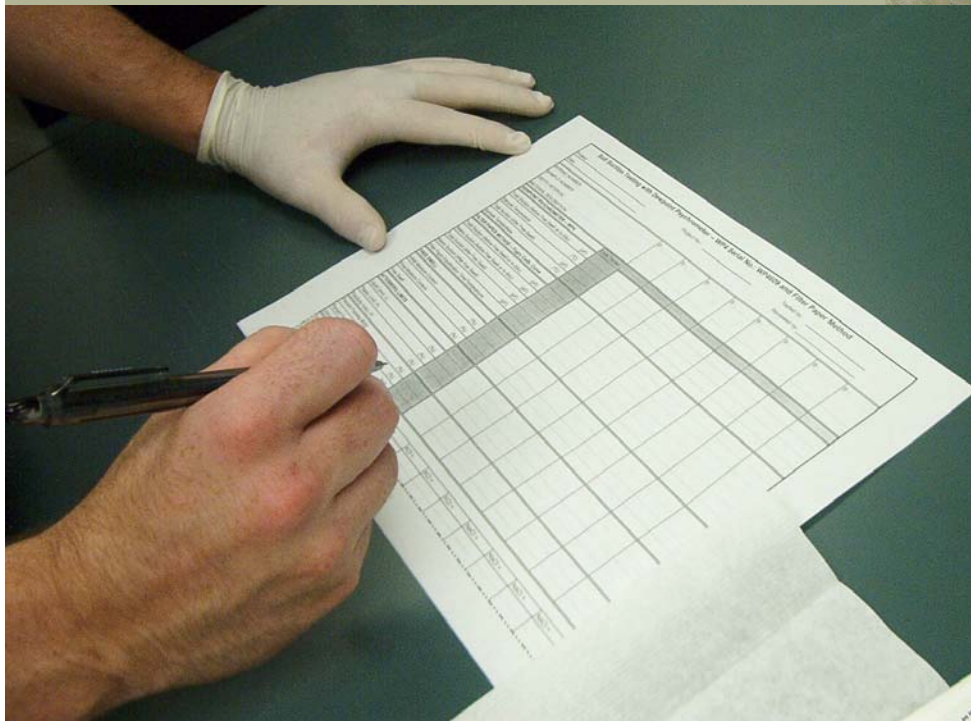
NOTE: The aluminum block will expedite the process of the cooling



- Leave the tin on the block for about 20 seconds
- Weigh the hot tin with the dry filter paper inside
- Record the weight as hot tare plus dry filter paper mass



- Finally, take the dry filter paper out of the tin
- Weigh the empty hot tin



- Record the weight as hot tare mass
- Repeat the above process for other tins in the oven

- Calculate the moisture content of each filter paper for both total and matric suction measurements. A calculation work sheet as given in the next slide can be used
- Obtain the suction value from an appropriate calibration curve that was provided above

MEASUREMENT OF SOIL SUCTION USING FILTER PAPER

BORING NO.: _____

DATE TESTED: _____

DATE SAMPLED: _____

TESTED BY: _____

SAMPLE NO.: _____

Depth							
Moisture Tin No.							
Top Filter Paper/Bottom Filter Paper (circle)		<u>Top/Bot.</u>	<u>Top/Bot.</u>	<u>Top/Bot.</u>	<u>Top/Bot.</u>	<u>Top/Bot.</u>	<u>Top/Bot.</u>
Cold Tare Mass, g	Tc						
Mass of Wet Filter Paper + Cold Tare Mass, g	M1						
Mass of Dry Filter Paper + Hot Tare Mass, g	M2						
Hot Tare Mass, g	Th						
Mass of Dry Filter Paper, g (M2-Th)	Mf						
Mass of Water in Filter Paper, g (M1-M2-Tc+Th)	Mw						
Water Content of Filter Paper, g (Mw / Mf)	Wf						
Suction, cm of water	h						
Suction, pF or log kPa	h						



***A GOOD LABORATORY PROTOCOL IS
ESSENTIAL IN THE FILTER PAPER
SOIL SUCTION MEASUREMENTS***

-- Rifat Bulut, Ph.D.

TRANSISTOR PSYCHROMETER

(Total Suction Measurement)

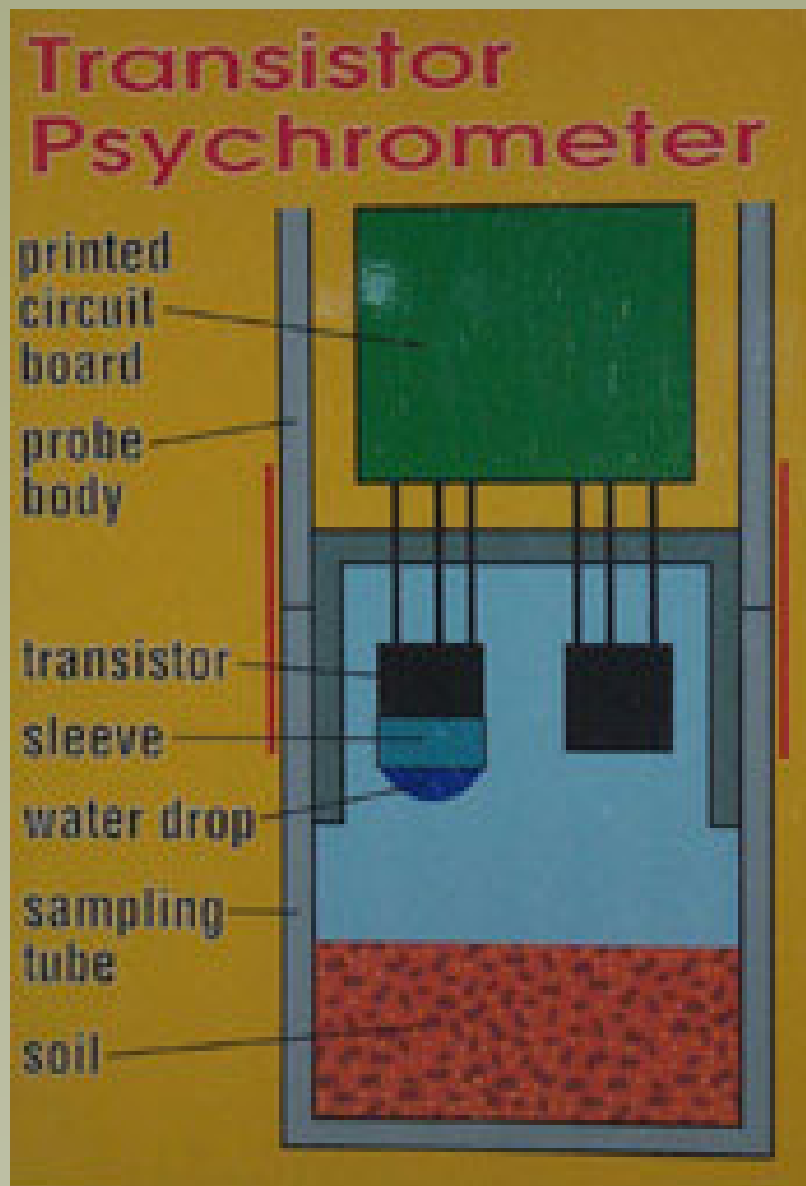
TWELVE-PROBE TRANSISTOR PSYCHROMETER



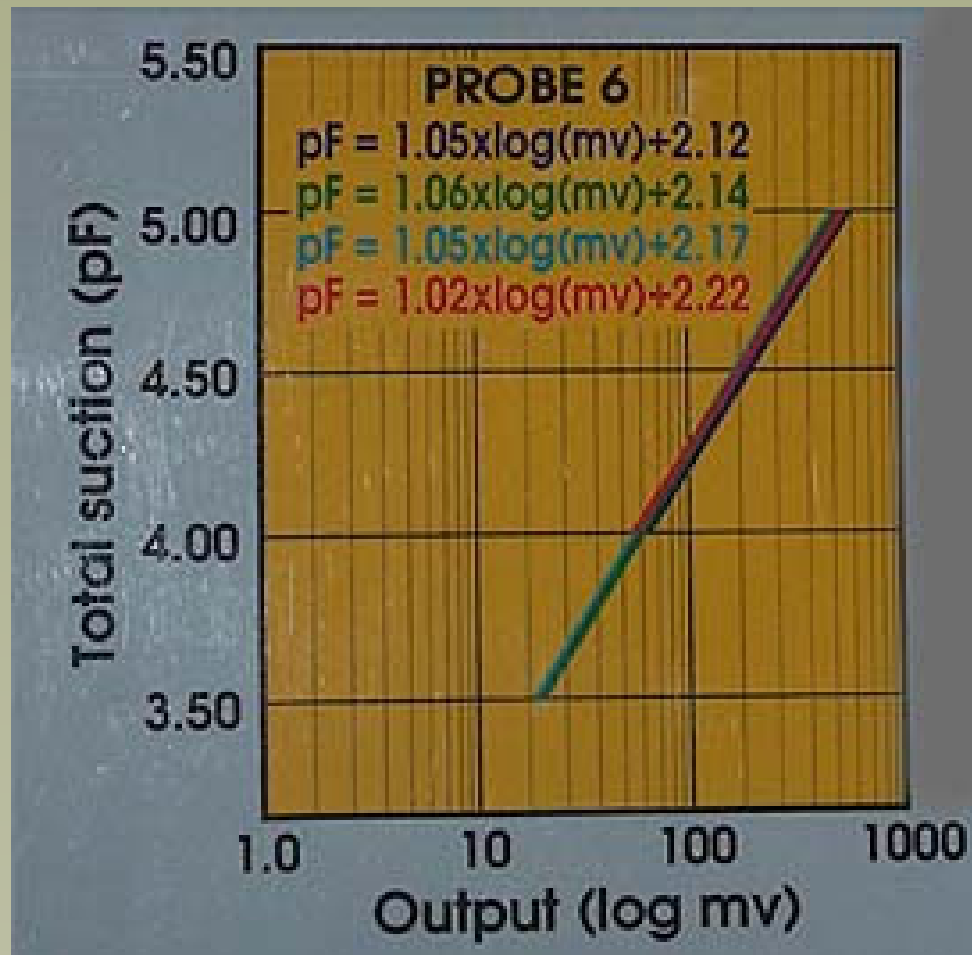
DATA LOGGER



THE PROBE TIP OF THE PSYCHROMETER



CALIBRATION CURVE



SALT SOLUTION CAPS AND TRAY





APPLYING WATER DROP



SEAL THE PROBE



SOIL SUCTION MEASUREMENTS



DISC OF SOIL SAMPLE



PLACE PLUG IN BOTTOM AND STOPPER IN TOP



SEAL THE PROBE



EIGHT PROBE MODEL INCLUDING DATA LOGGER



Transistor Psychrometer
available at
<http://www.smi-unsat.com>

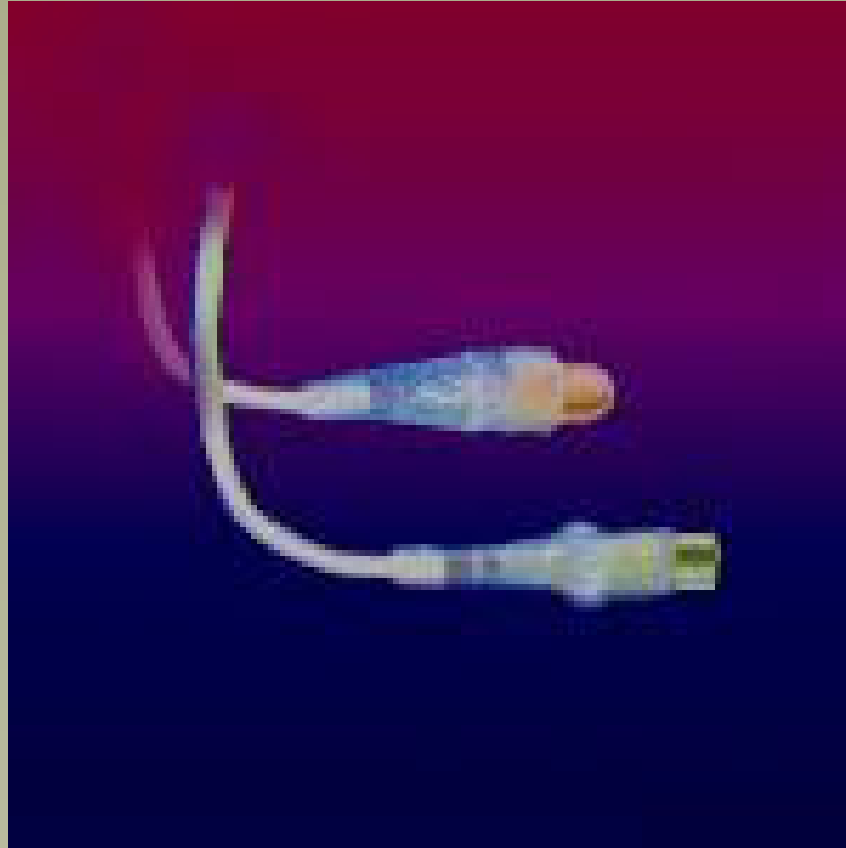
THERMOCOUPLE PSYCHROMETER

(Total Suction Measurement)

HR 33T DEW POINT MICROVOLTMETER



THERMOCOUPLE PSYCHROMETERS



Thermocouple Psychrometer
available at
<http://www.wescor.com>