Unsaturated Soil Mechanics
Lesson 3

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Unsaturated Soil Mechanics

- **Basic Concepts**
  - **Effective stress principle**
  - **Mohr-Coulomb and Tresca failure criteria**
- **Meteorological aspects and soil water balance**
  - **Rain and evaporation**
  - **Infiltration**
  - **Retention**
- **Soil as a particulate media**
  - **Mass and volume relations**
  - **Pore size distribution**
- **Capillary and suction concepts**
  - **Matrix suction**
  - **Osmotic suction**
  - **Total suction**

- **Soil suction measurement**

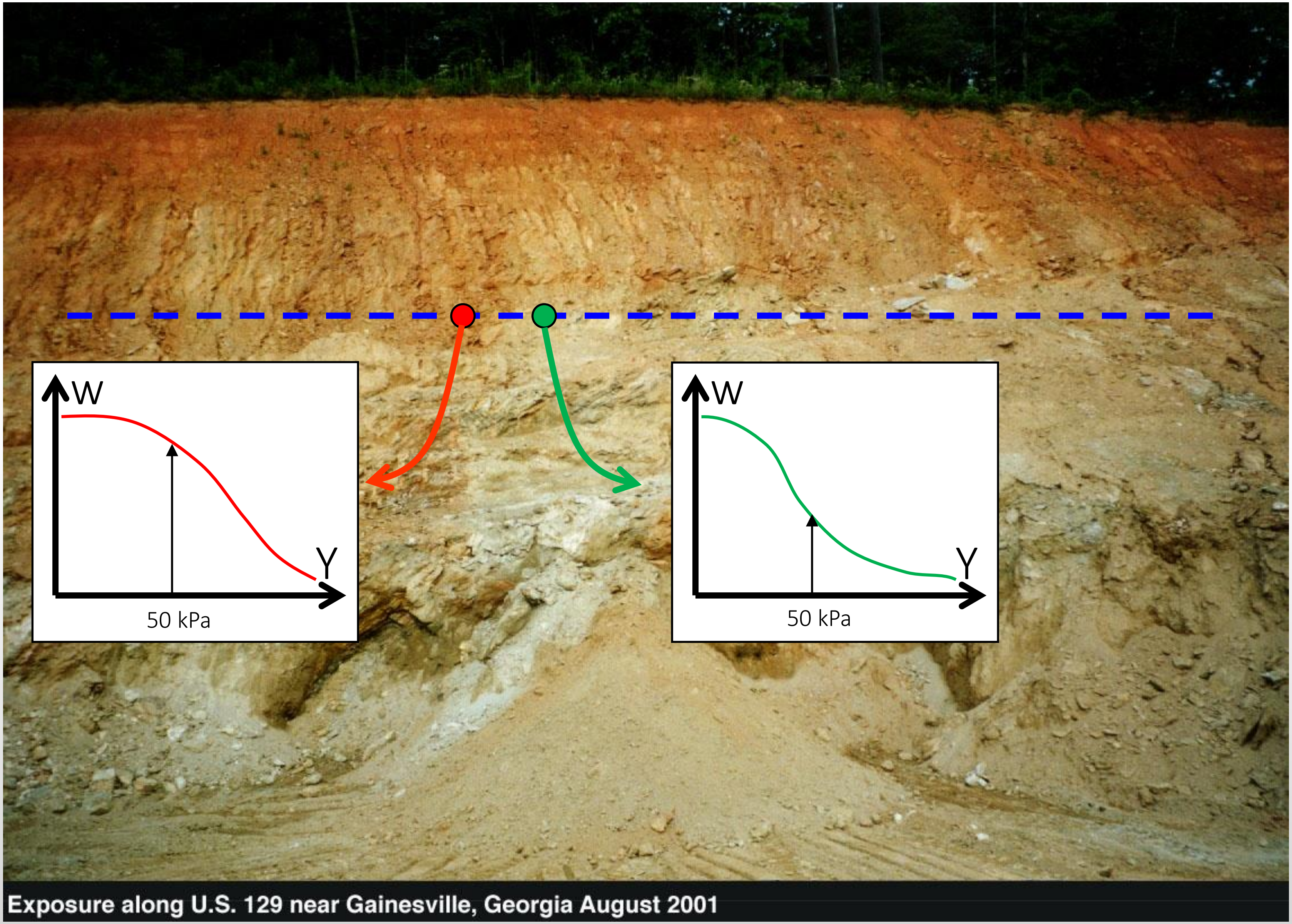
- **The Soil Water Retention Curve - SWRC**
  - **Interpretation of the SWRC**
  - **Fitting models for the SWRC**
- **Shear strength for unsaturated soils**
  - **Shear strength parameters**
    - **Laboratory tests**
  - **Bishop´s concepts**
  - **Fredlund´s concepts**
  - **Models using the SWRC**
- **Applications**
  - **Slopes**
  - **Dams**
  - **Mining**

- **Soil suction measurement**

"When one starts already with a complicated, expensive apparatus, HE IS SLAVE OF HIS INSTRUMENT"

Terzaghi

Suction or Water Content, what is more difficulty to measure?



www.gly.uga.edu

What does the sensors measure?

Table 1.2. Surrogate measures used by different θ_v sensors

Method	Surrogate Measurement	Explanation
Neutron moisture meter	Count of slow neutrons around a source of fast neutrons	A radioactive source emits fast neutrons (5 MeV), which lose energy as they collide with other atoms, in particular hydrogen. The surrogate is the concentration of slow neutrons. Since the only rapidly changing source of hydrogen in the soil is water, θ_v can be calibrated vs. the count of slow neutrons.
Thermal sensors	Heat conductivity or heat capacity of the soil	A pulse of heat is generated and the subsequent rise or fall in temperature of adjacent soil is measured over time. Soil is a poor conductor of heat, and water a good one, so the amount of heat or rate of heat transmission is closely related to θ_v.
Time domain reflectometer (TDR)	Travel time of an electromagnetic pulse	A fast rise time electromagnetic pulse is injected into a waveguide inserted into or buried in the soil. The time required for the pulse to travel along the metal rods of the waveguide is determined by the bulk electrical permittivity of the soil. The θ_v is a major factor influencing the bulk permittivity (BEC). True TDR involves capture of a waveform and analysis to find the travel time of the highest frequency part of the pulse.
Campbell FDR	Repetition time for a fast rise time electromagnetic pulse	See TDR sensors; same, except reliance on reflected pulse reaching a set voltage rather than waveform analysis causes the method to be more influenced by BEC and temperature.
Capacitive sensors	Frequency of an oscillating circuit	An oscillating current is induced in a circuit, part of which is a capacitor that is arranged so that the soil becomes part of the dielectric medium affected by the electromagnetic field between the capacitor's electrodes. The θ_v influences the electrical permittivity of the soil, which in turn affects the capacitance, causing the frequency of oscillation to shift.
Conductivity sensors (e.g., granular matrix sensors and gypsum blocks)	Electrical conductivity of a porous medium in contact with the soil	An alternating current voltage is placed on two electrodes in a porous material in contact with the soil, and the amount of current is a measure of the conductivity and amount of water in the porous material between the electrodes. These are used for estimation of soil water tension (suction), not θ_v.
Tensiometers	Matric and gravitational soil water potential components	Capillary forces retaining water in the soil pores are connected through the soil water to water in a porous cup connected to a tube filled with water. This generates a negative pressure within the tube, which can be measured with a vacuum gauge. These are used for estimation of soil water tension (suction), not θ_v.

In this cases suction is measured

IAEA (2008)

What interferes with measurements of each sensor?

Table 1.4. Characteristics of some types of soil water sensor

Technology	Sensed volume	Interferences
NMM	3×10^4 cm^3 (wet soil) 28×10^4 cm^3 (dry soil)	Cl, B, Fe, C
TDR	Soil volume along length of probe rods, and ~10 mm above and below the plane of the rods, and 10 mm to the side of the plane of the rods (e.g., ~320 cm^3 for a 20 cm probe with 3 rods and 3 cm rod-to-rod spacing).	Salt, electrical conductivity of soil and temperature, magnetic minerals (uncommon)
Capacitive, FDR	Highly variable — usually 90% of reading comes from within 20 mm of the sensitive face of the sensor, but sometimes the sensed volume is smaller than the height of the sensors. Typically ~200– 400 cm^3.	Salt, electrical conductivity of soil (including clay type, content, and water content) and temperature
Heat dissipation	Highly variable — 20 mm zone around sensor, which is small.	Metallic soil components
Conductivity sensors (e.g. gypsum blocks)	Will equilibrate with a volume of soil that is determined by the soil hydraulic conductivity. Typically 500 cm^3 in wet soil, but much smaller in dry soil.	Temperature, salts other than the $CaSO_4$ used in the sensor

IAEA (2008)

Table 4.2 Devices for Measuring Soil Suction and Its Components

Name of Device	Suction Component Measured	Range, kPa	Comments
Psychrometers (Peltier type)	Total	100[a] to ~8000	Constant-temperature environment required
Filter paper	Total	Entire range	May measure matric suction when in good contact with moist soil
Tensiometers	Negative pore-water pressures or matric suction when pore-air pressure is atmospheric	0–90	Difficulties with cavitation and air diffusion through ceramic cup
Null-type pressure plate (axis translation)	Matric	0–1500	Range of measurement is a function of the air-entry value of ceramic disk
Thermal conductivity sensors	Matric	10 to ~1500	Indirect measurement using variable-pore-size ceramic sensor
Pore fluid squeezer	Osmotic	Entire range	Used in conjunction with psychrometer or electrical conductivity measurement

[a]Controlled temperature environment to $\pm 0.001^{\circ}$C.

Fredlund et al (2012)

Table 2.3 Methods for measuring soil suction (after Ridley and Wray, 1995)

Device	*Measurement mode*	*Range (kPa)*	*Approximate equilibrium time*
Thermocouple psychrometer	Total	100 to 7,500	Minutes
Thermisor/Transistor psychrometer	Total	100 to 71,000	Minutes
Filter paper (in-contact)	Matric	30 to 30,000	7 days
Filter paper (no-contact)	Total	400 to 30,000	7–14 days
Porous block	Matric	30 to 3,000	Weeks
Thermal conductivity probe	Matric	0 to 300	Weeks
Pressure plate	Matric	0 to 1,500	Hours
Standard tensiometer	Matric	0 to −100	Minutes
Tensiometer suction probe	Matric	0 to −1,800	Minutes

Ng and Manzies (2007)

Table 2.1 Approximate measurement ranges and times for equilibration in measurement and control of soil suction.

Instrument	Suction component measured	Typical measurement range (kPa)	Equilibration time
		Suction measurement	
Pressure plate	Matric	0–1,500	Several hours to days
Tensiometers and suction probes	Matric	0–1,500	Several minutes
Thermal conductivity sensors	Matric	1–1,500	Several hours to days
Electrical conductivity sensors	Matric	50–1,500	Several hours to weeks
Filter paper contact	Matric	0–10,000 or greater	2–57 days
Thermocouple psychrometers	Total	100–8,000	Several minutes to several hours
Transistor psychrometers	Total	100–70,000	About 1 hour
Chilled mirror psychrometer	Total	1–60,000	3–10 minutes
Filter paper non-contact	Total	1,000–10,000 or greater	2–14 days
Electrical conductivity of pore water extracted using pore fluid squeezer	Osmotic	entire range	—
		Suction control	
Negative (or Hanging) water column technique	Matric	0–30 or greater with multiple columns or vacuum control	Several hours to days
Axis translation technique	Matric	0–1,500	Several hours to days
Osmotic technique	Matric	0–10,000	up to 2 months
Vapour equilibrium technique	Total	4,000–600,000	1–2 months

Murray and Sivakumar (2010)

Measurements made with different sensors at the same location in the same time interval.

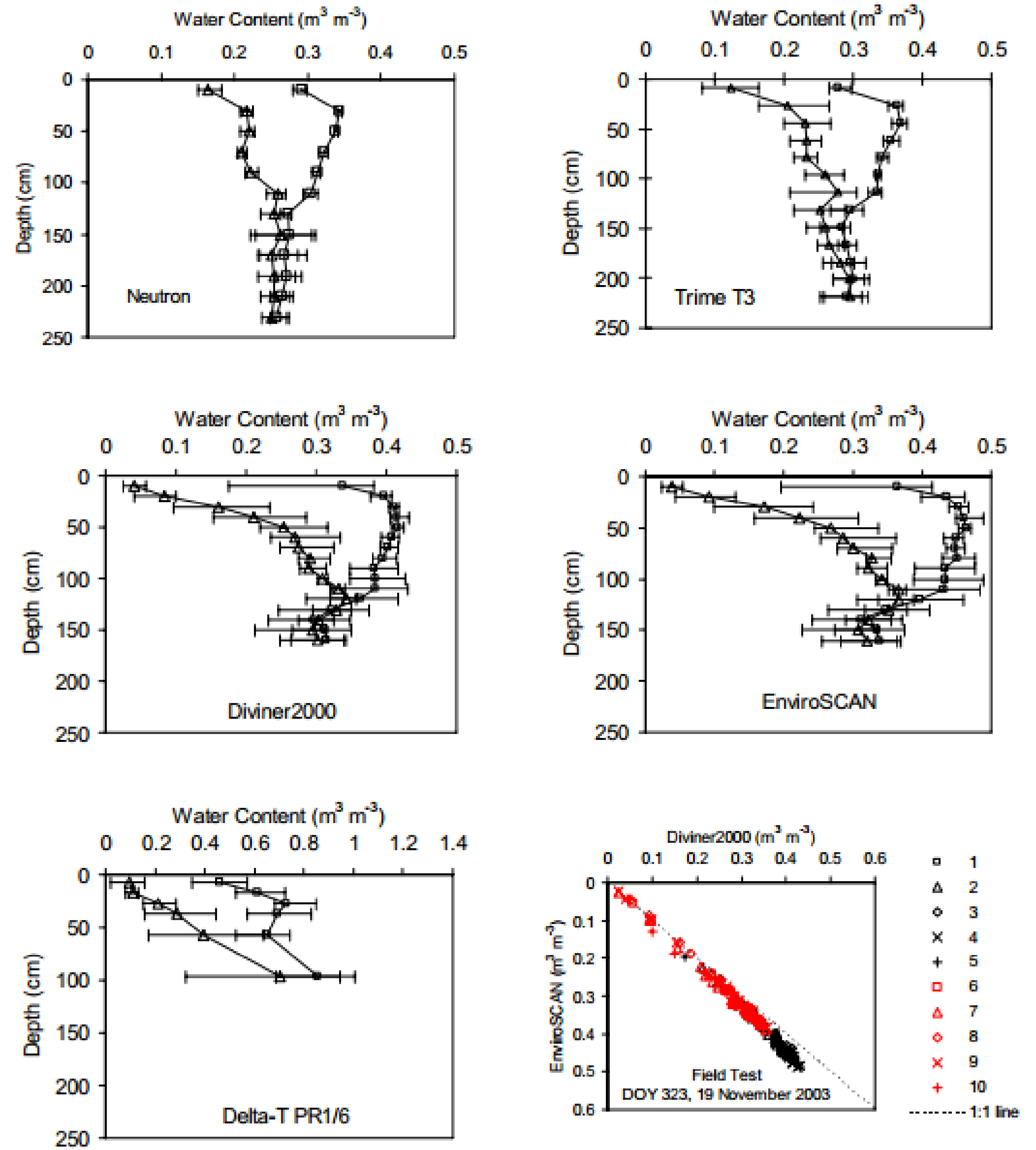


Figure 1.1. Soil water contents reported by five different sensors in access tubes in two plots irrigated weekly to 100% replenishment of soil water to field capacity (squares) and to 33% of the 100% amount (triangles indicate this deficit irrigation). Ten access tubes for each sensor were in the 100% plot and ten each in the 33% plot. Bars indicate the maximum and minimum values of θ_v for each plot and depth, and solid lines indicate the mean value of θ_v.

IAEA (2008)

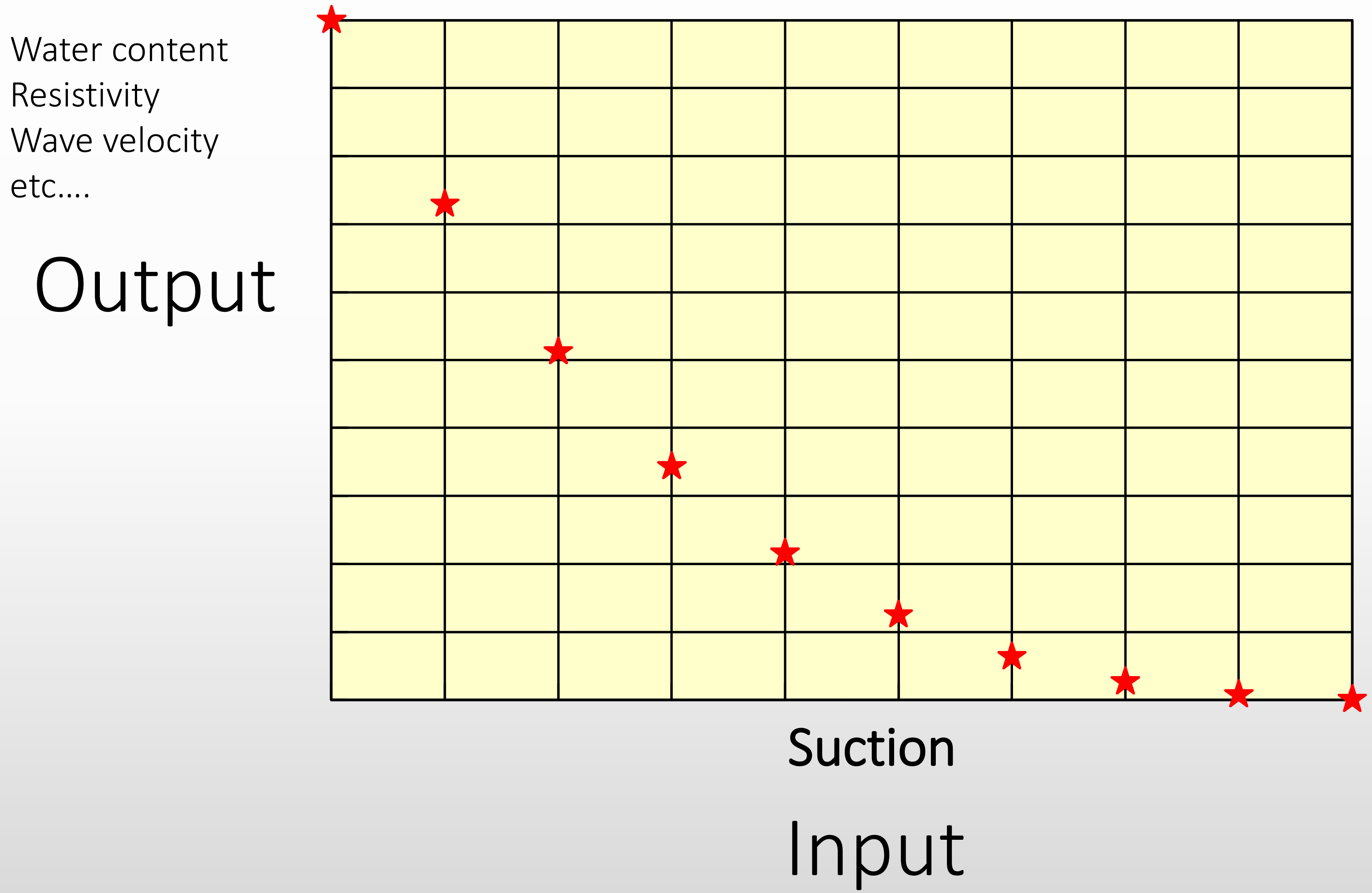
Suction Measurement and Control Technique

- Ordinary tensiometer
- High capacity tensiometer
- Filter Paper
- Suction Plate (control)
- Axis translation (control and measurement)

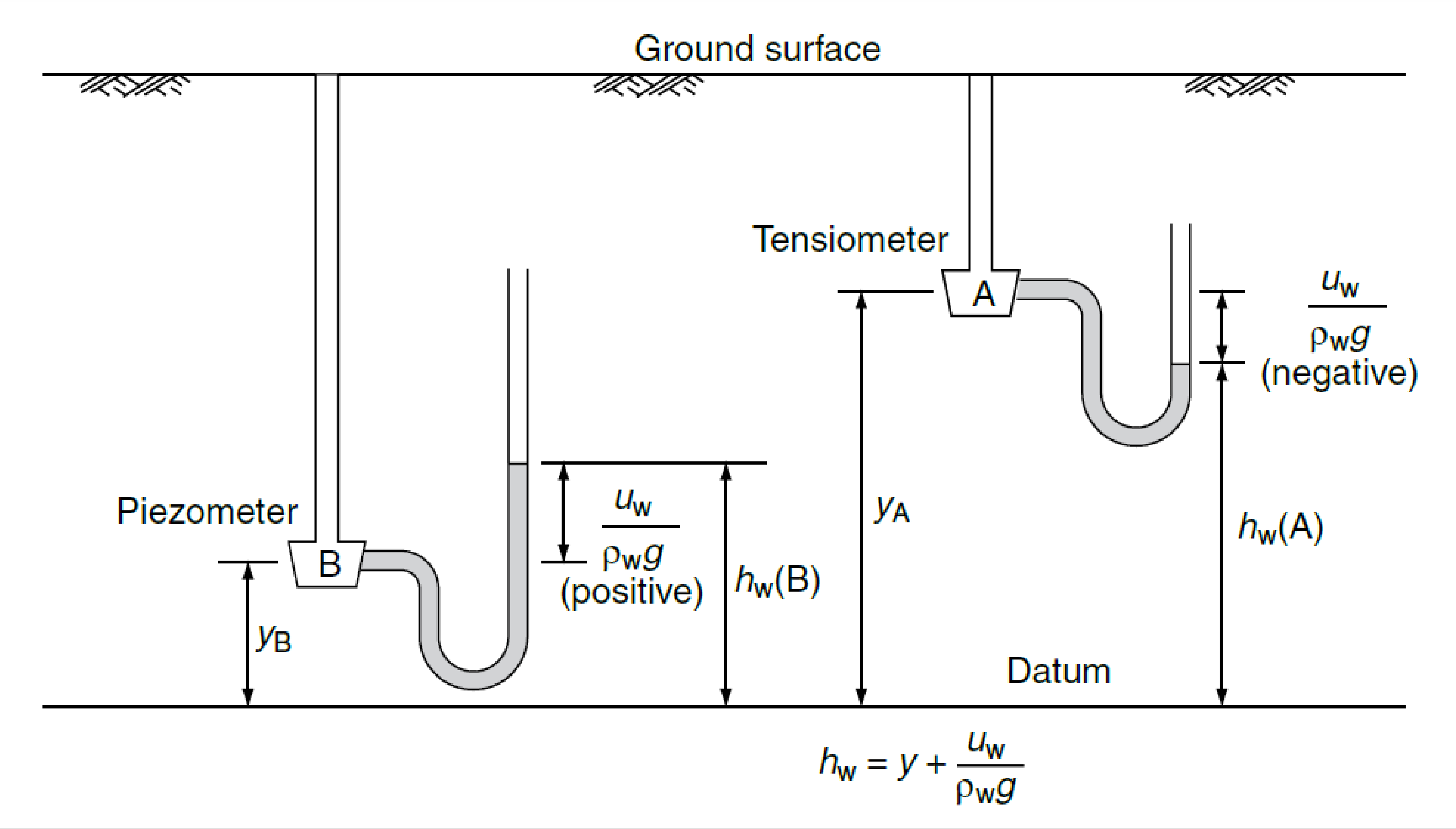
What is a sensor?

A Sensor is a device, which responds to an input quantity by generating a known output.

What is a sensor?

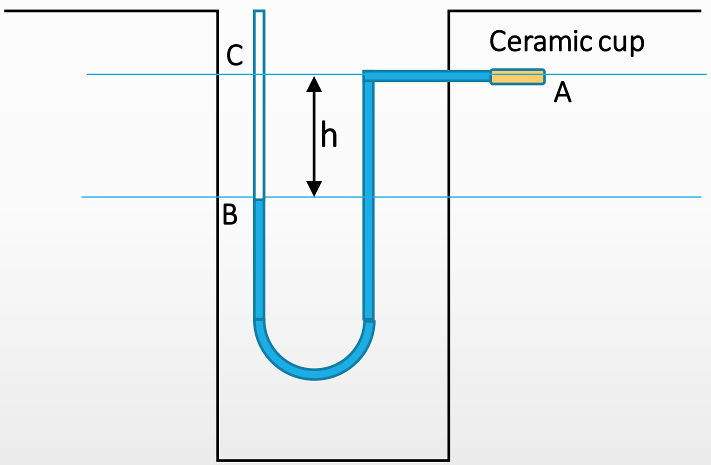


Concept of potential and head for saturated soils

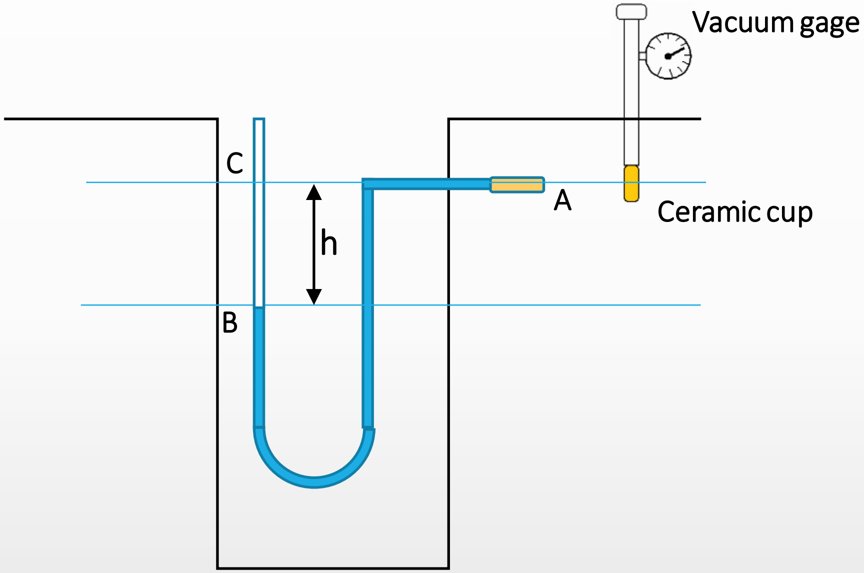


Fredlund and Rahardjo (1993)

Working Principle of a Tensiometer

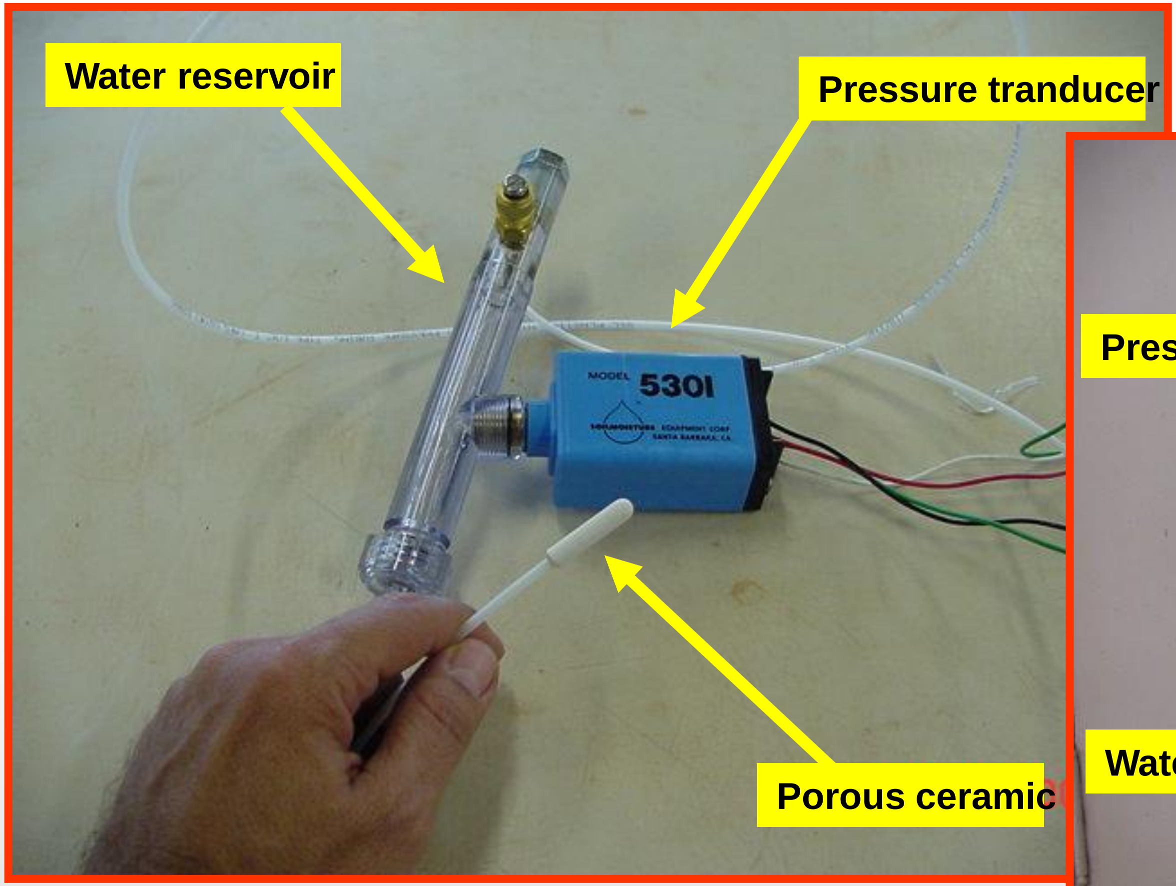


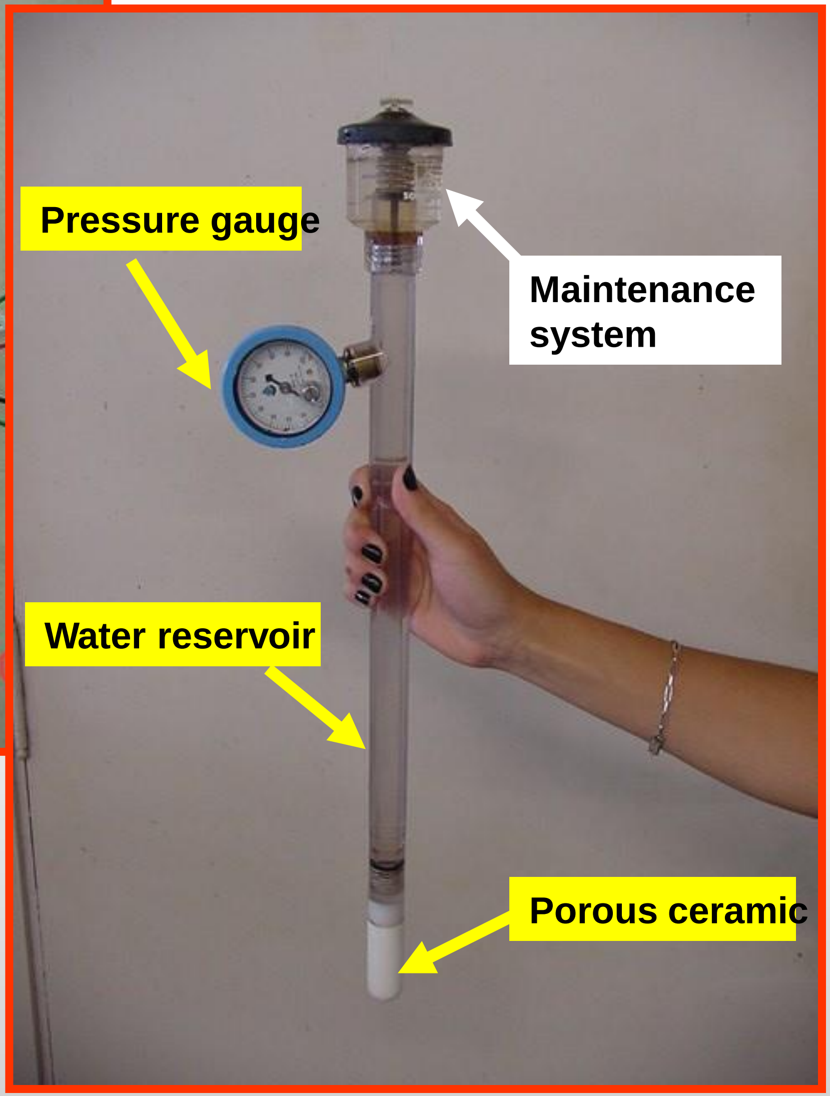
$$Pressure = -h * \gamma_w$$
$$Suction = h * \gamma_w$$



$$Pressure = -h * \gamma_w$$
$$Suction = h * \gamma_w$$

Ordinary Tensiometer





Working Principle of a High Capacity Tensiometer

Capillarity

Soil

↓

Voids

↓

Capillary phenomena

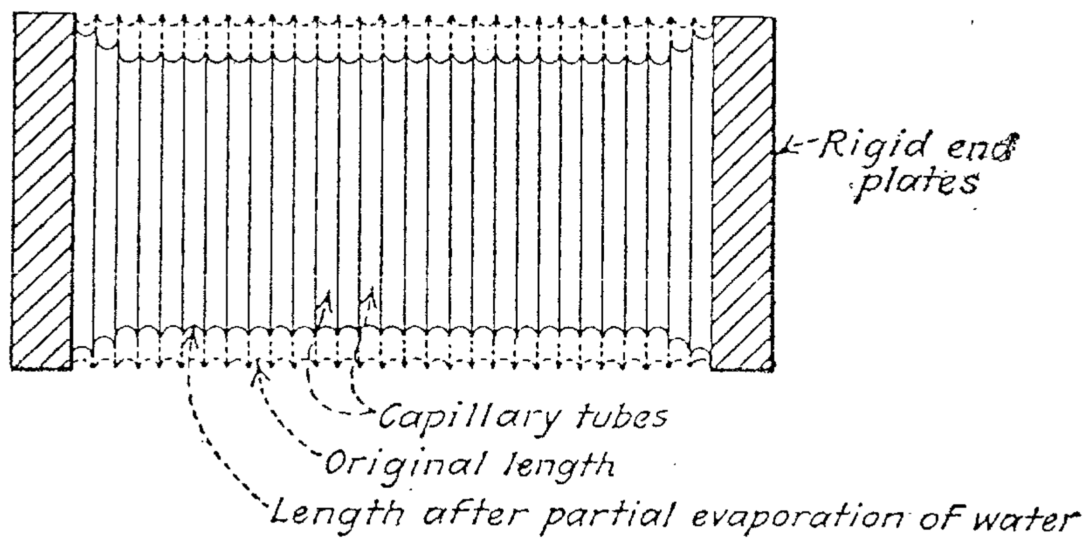
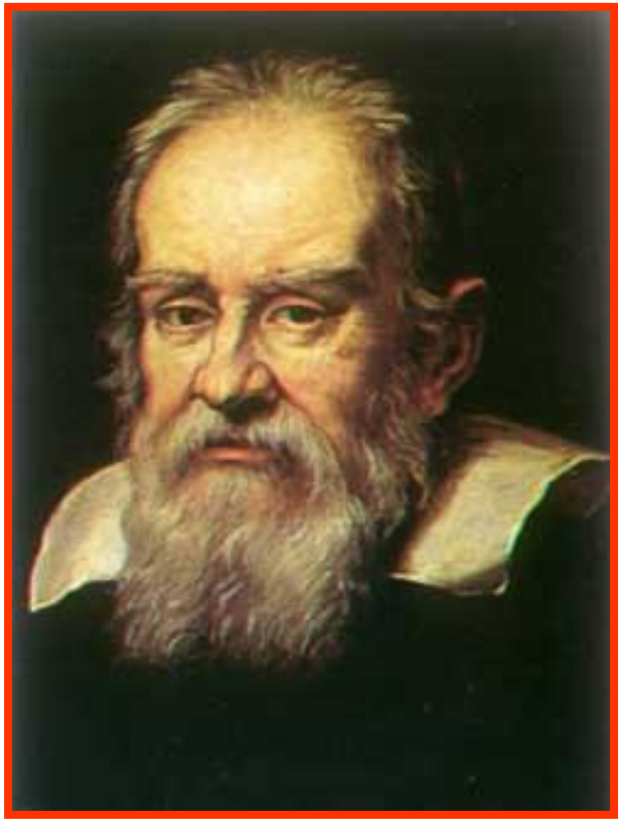


FIG. 4—BUNDLE OF CAPILLARY TUBES COMPRESSED BY EVAPORATION OF CONTAINED WATER

Terzaghi (1925)

Galileo-Galilei

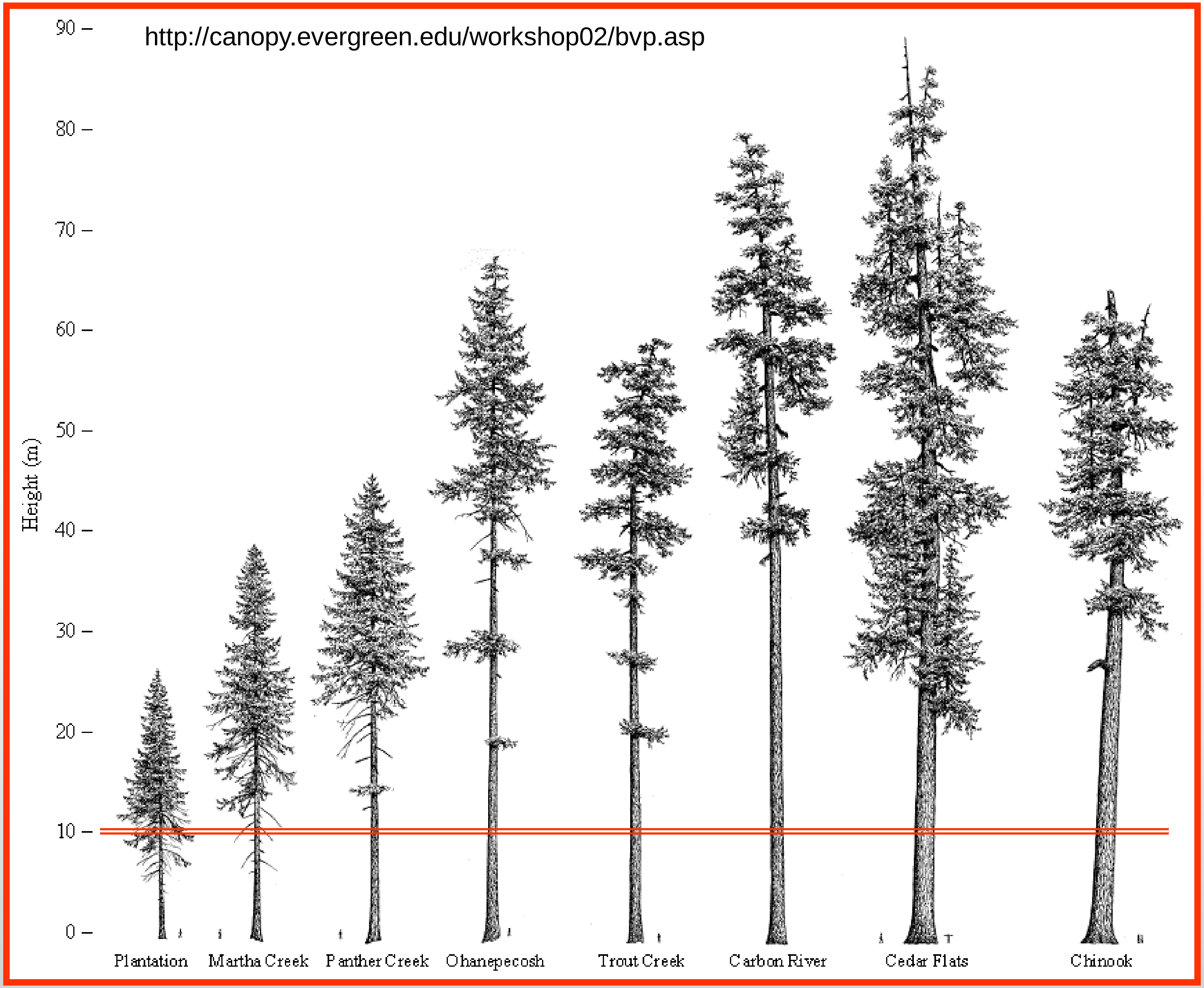


The first observation that water cannot rise indefinitely has been attributed to Galileo Galilei.

He found that 10m was the limit to which the water could rise in a suction pump.

This limit is determined by the pheomena of cavitation

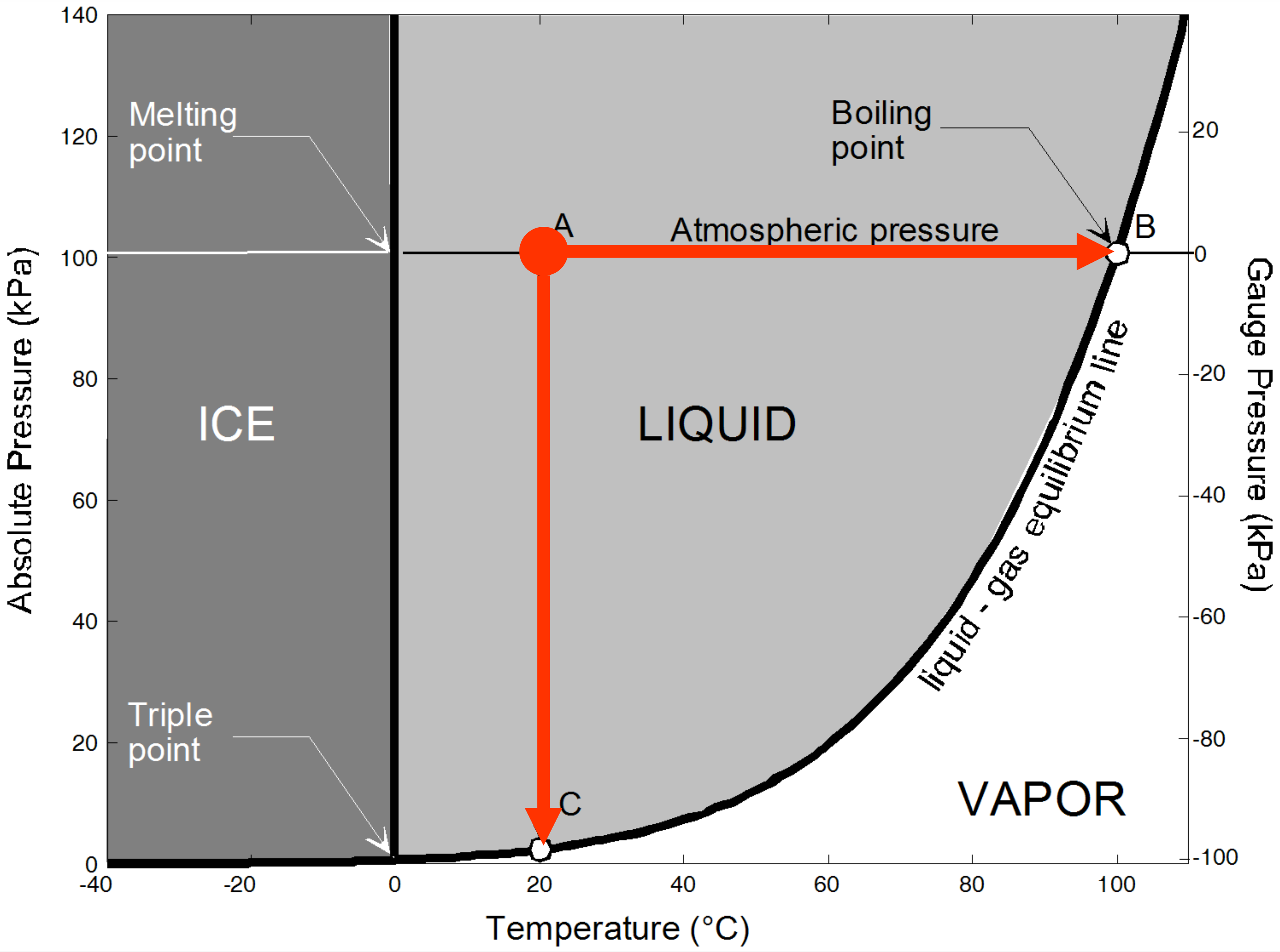
Water rise



http://canopy.evergreen.edu/workshop02/bvp.asp
90
80
70
60
50
40
30
20
10
0
Height (m)
Plantation
Martha Creek
Panther Creek
Ohanepecosh
Trout Creek
Carbon River
Cedar Flats
Chinook

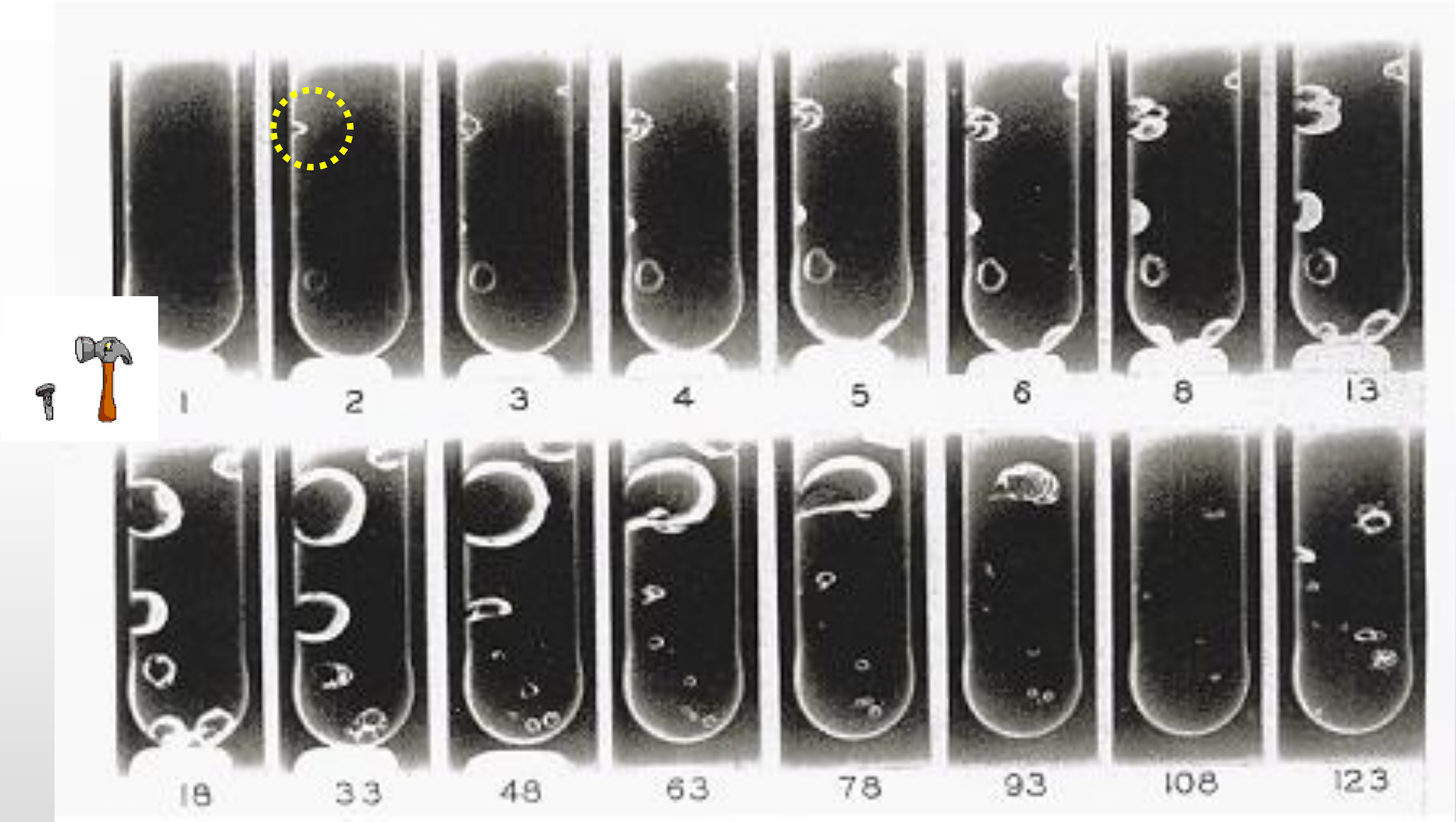
http://www.plantphys.net/printer.php?ch=4&id=100
Stratosphere Giant
112.34 m

Cavitation



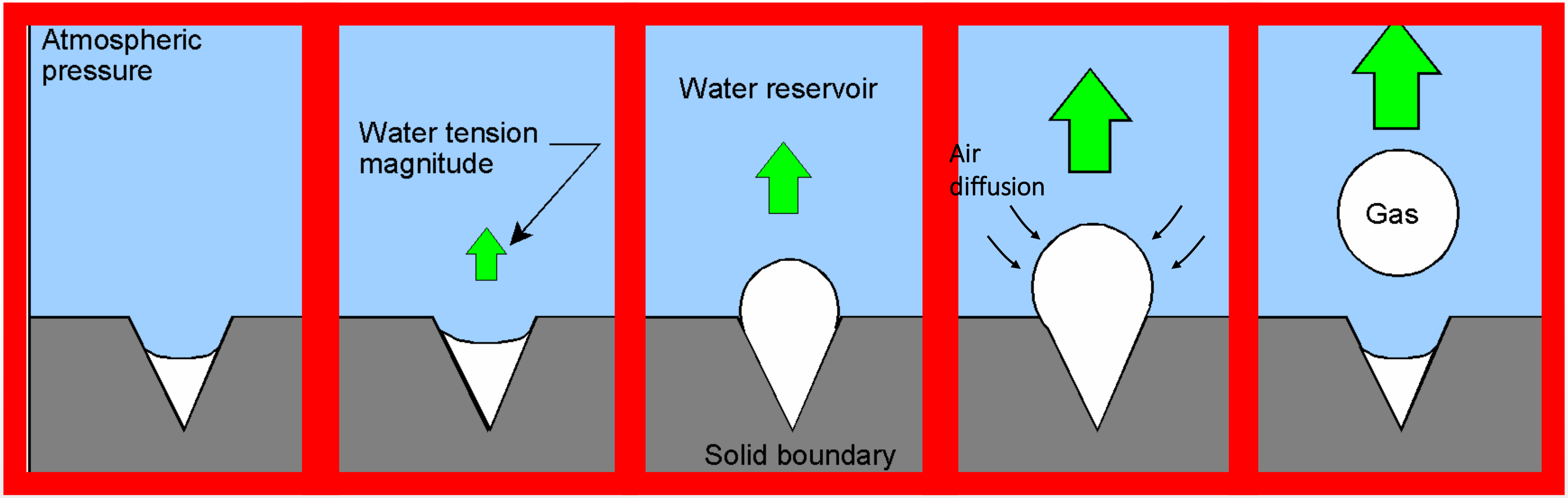
Melting point
Boiling point
Atmospheric pressure
A
B
C
ICE
LIQUID
VAPOR
Triple point
liquid - gas equilibrium line
Absolute Pressure (kPa)
Gauge Pressure (kPa)
Temperature (°C)
140
120
100
80
60
40
20
0
-40
-20
0
20
40
60
80
100
20
0
-20
-40
-60
-80
-100

Cavitation



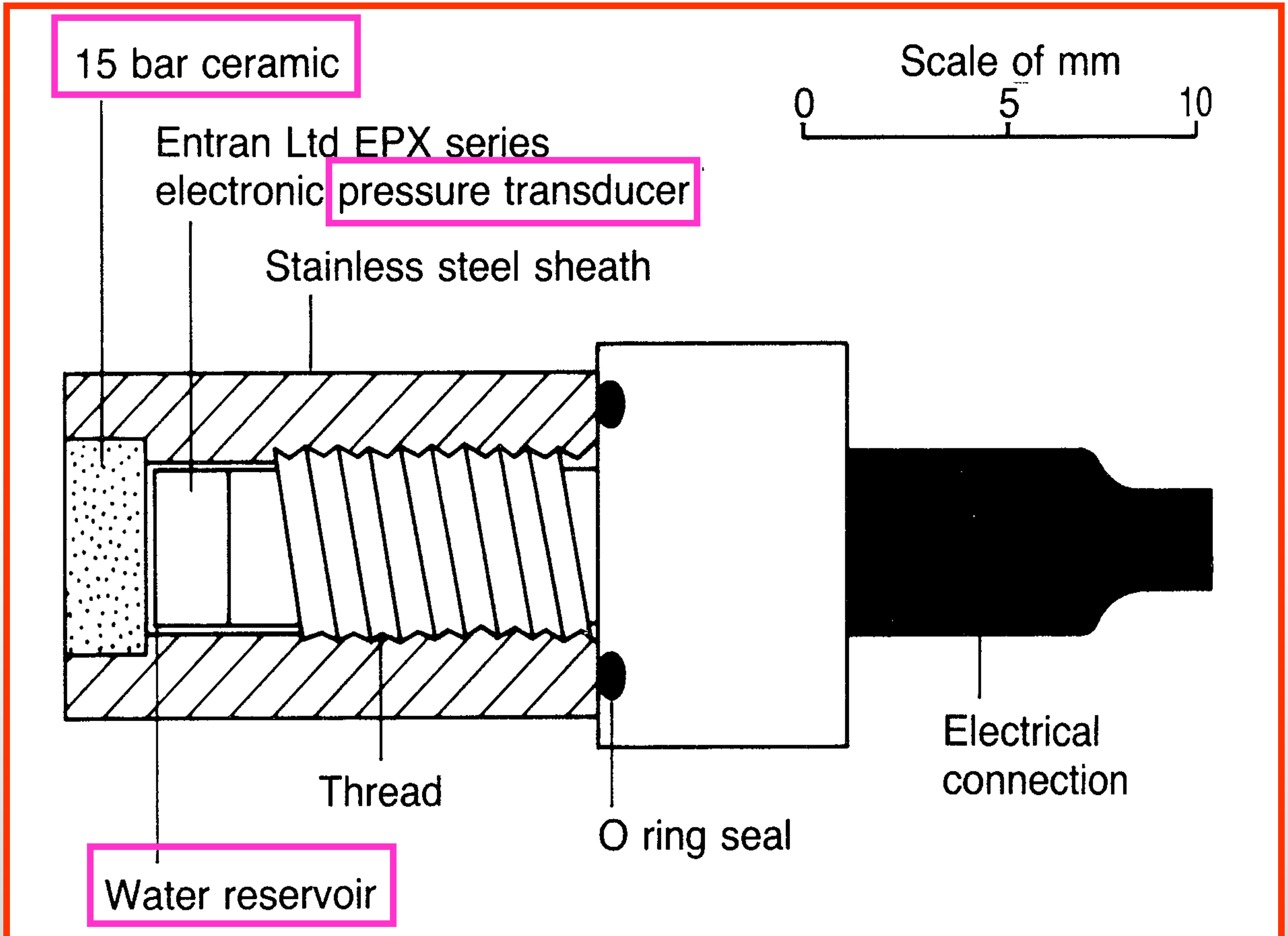
Air bubbles arising in a glass tube. (Harvey et al., 1944)

A Cavitation Mechanism (Harvey et al, 1944)



Does this mean that tensiometers are limited to - 1atm?

The design of a HCT



Ridley & Burland (1993)

High Capacity Tensiometer

The Tensiometer: Saturation

<u>Initial Saturation:</u>

- Evacuation of tensiometer reservoir / ceramic
- Importance of initially dry ceramic (e.g. Take & Bolton, 2003)
- Rotational technique (low air entry value ceramics)
- Two chamber technique (higher air entry value ceramics)

<u>Pre-pressurisation (Conditioning):</u>

- Application of a large positive water pressure
- Cycles of cavitation and pressurisation (Tarantino & Mongiovì, 2001)

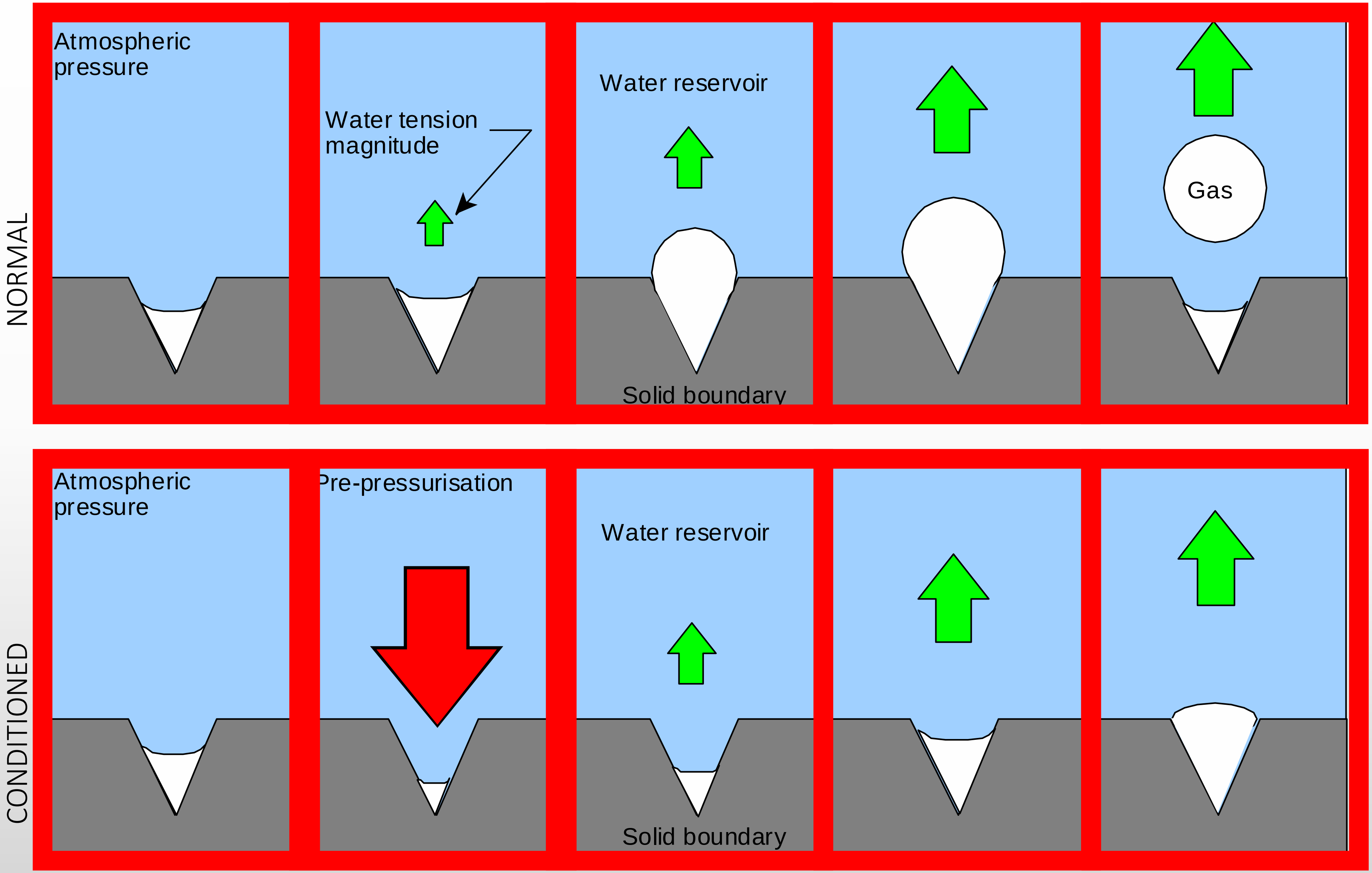
<u>Difficulty of Saturation</u>

- Increases with air-entry value (AEV)
- Required conditioning pressure increase with AEV

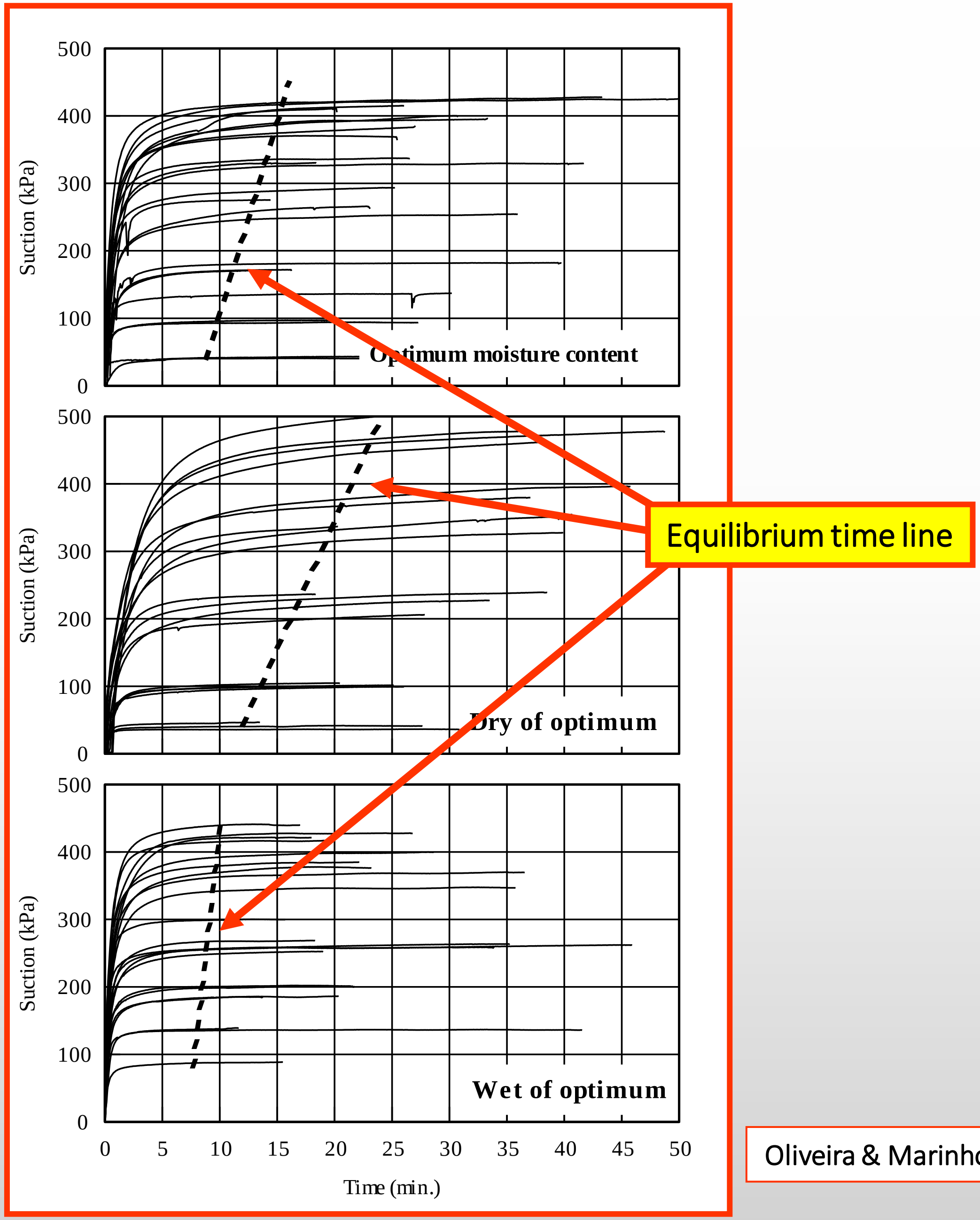
<u>Chemical Treatment</u>

- May help in the reduction of number of cavitation nuclei?

The Tensiometer: Saturation

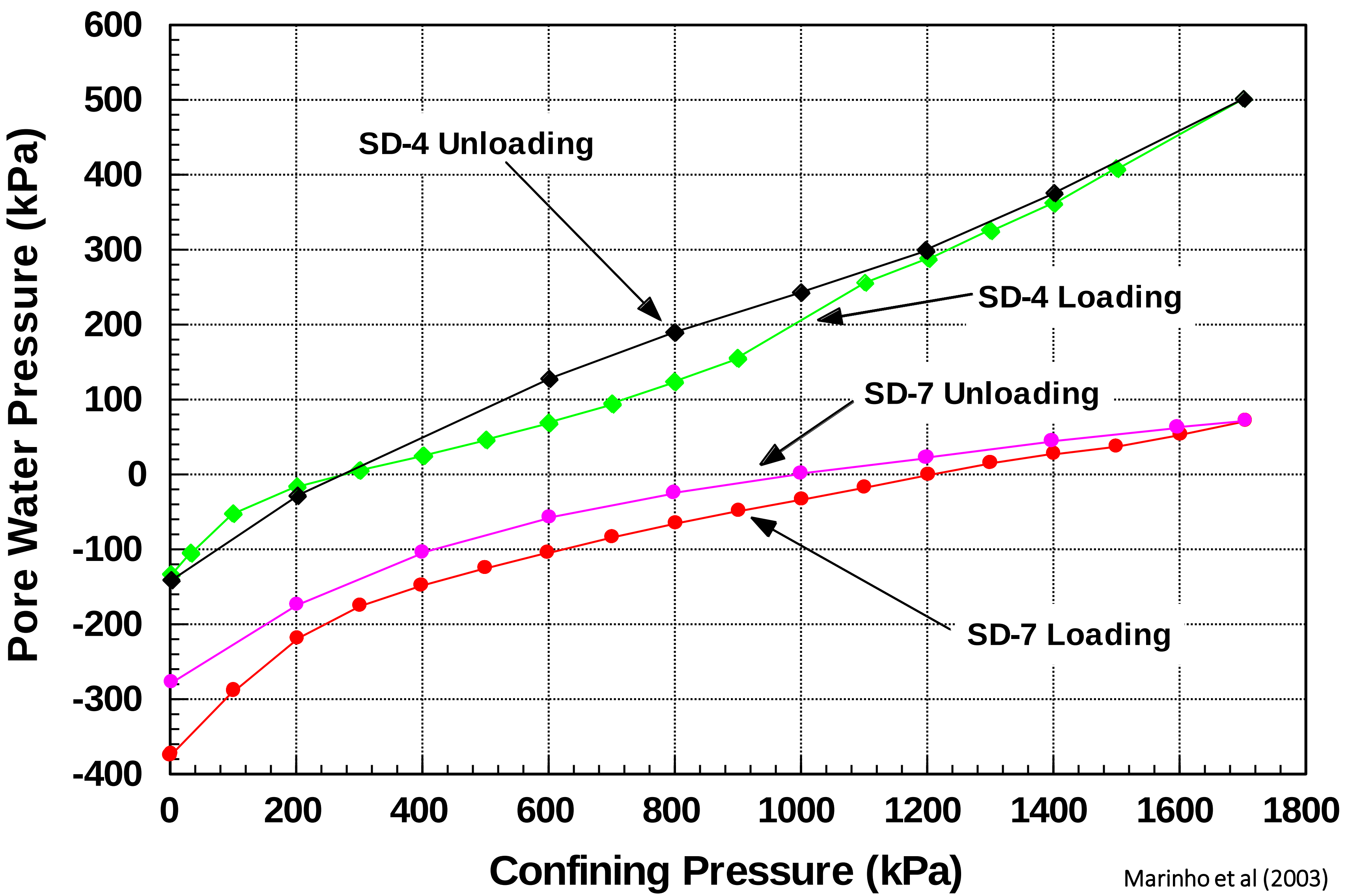


The HCT: Applications



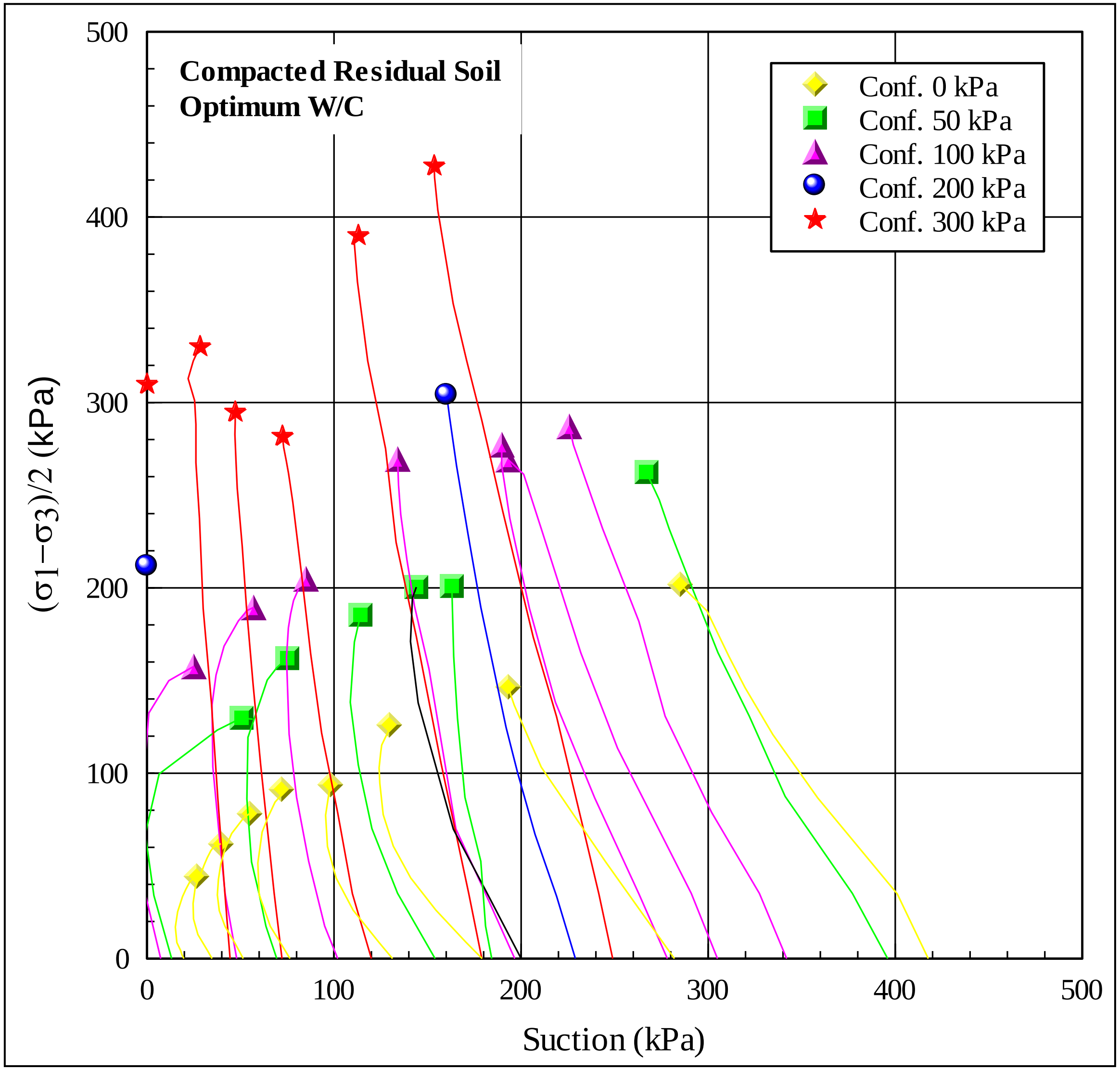
Oliveira & Marinho (2005)

The Tensiometer: Applications



The effect of loading and unloading on suction (compacted residual soil)

The HCT: Applications



Oliveira (2004)

Suction path during triaxial test on compacted residual soil

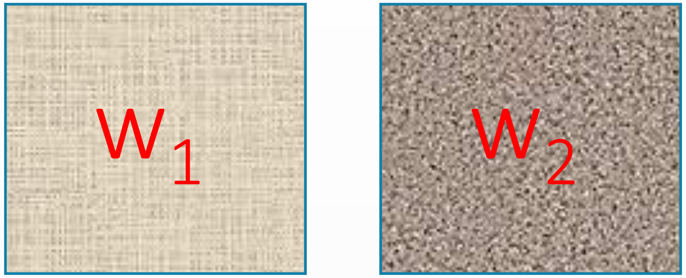
High Capacity Tensiometer
0 – 200kPa

Filter Paper Technique

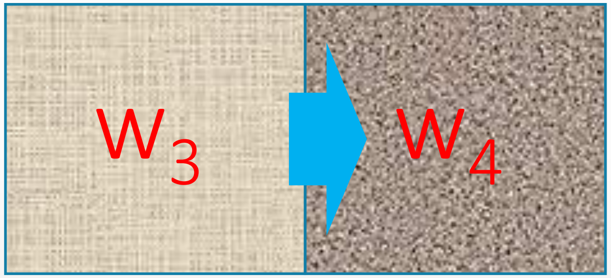
The Filter Paper Technique

Absortion

Two materials
two water contents and two suctions



Initial flow (Absorption)
Moving to equilibrium of suction

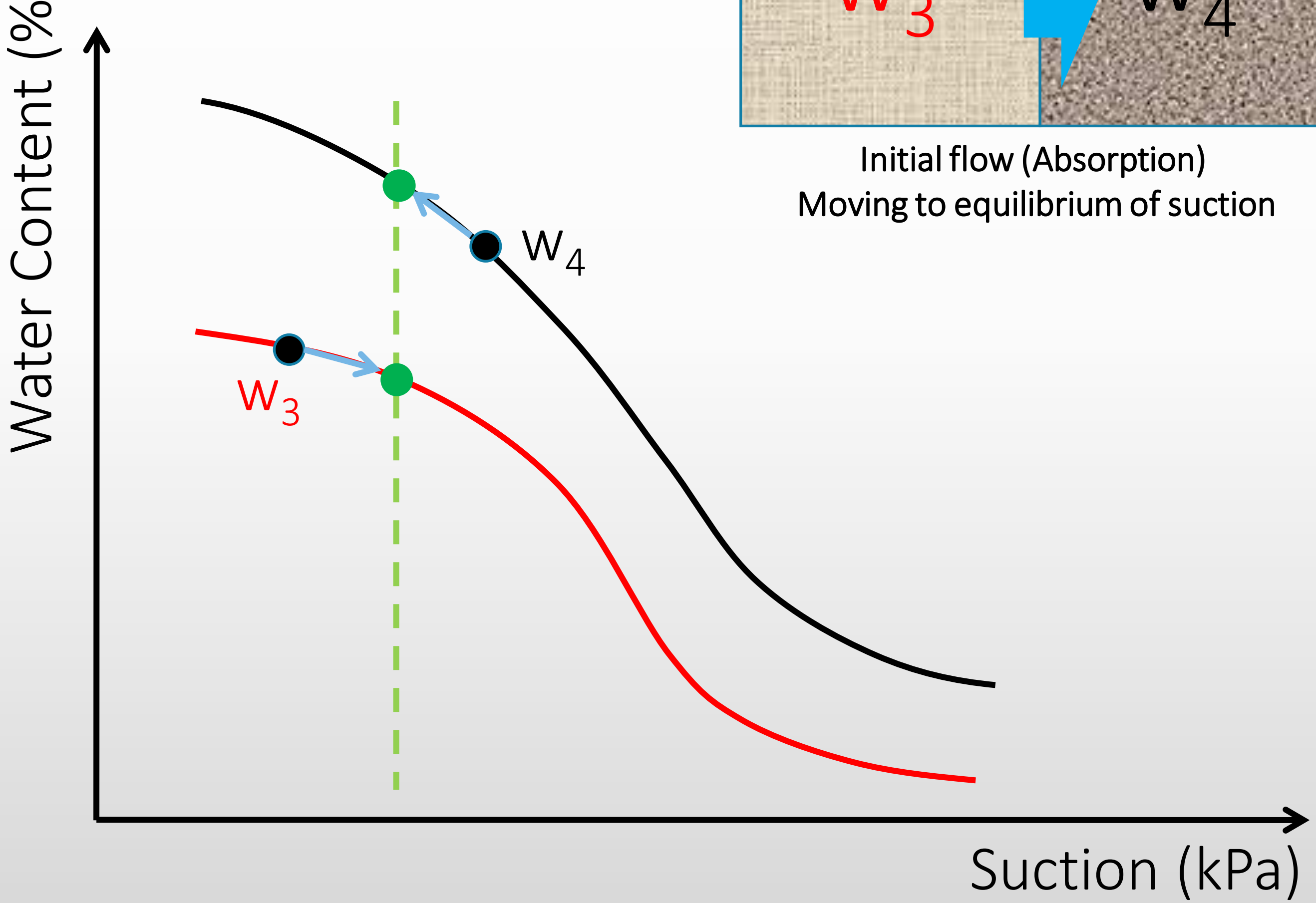


Equilibrium (no flow)
two water contents and same suction

The Filter Paper Technique

Absorption

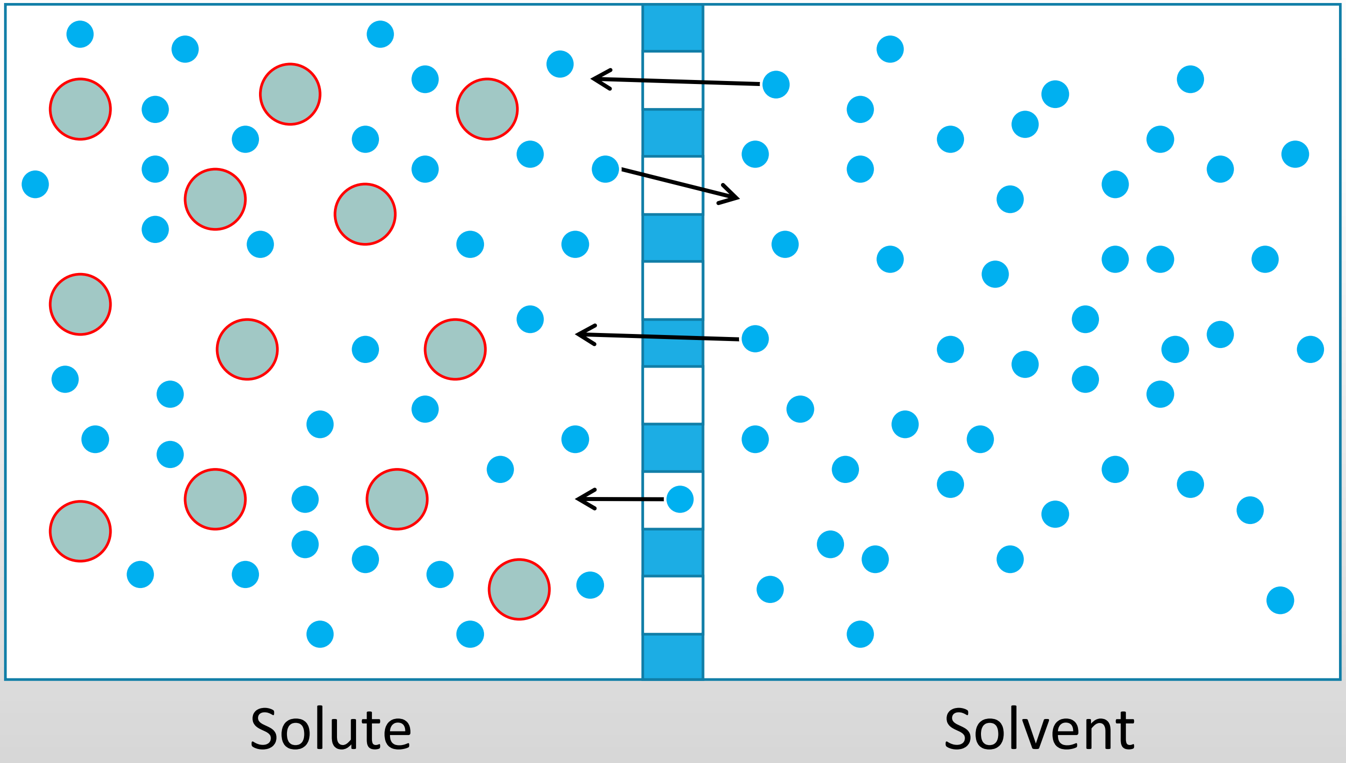
Initial flow (Absorption)
Moving to equilibrium of suction



The Filter Paper Technique

Absorption / Osmotic effect

There is a net flow of small molecules through a semi-permeable membrane. The flow is stopped if a pressure is applied against the direction of the flow. This is the osmotic pressure



The Filter Paper Technique

Absorption / Osmotic effect

Shull (1916)

Semi-permeable membrane

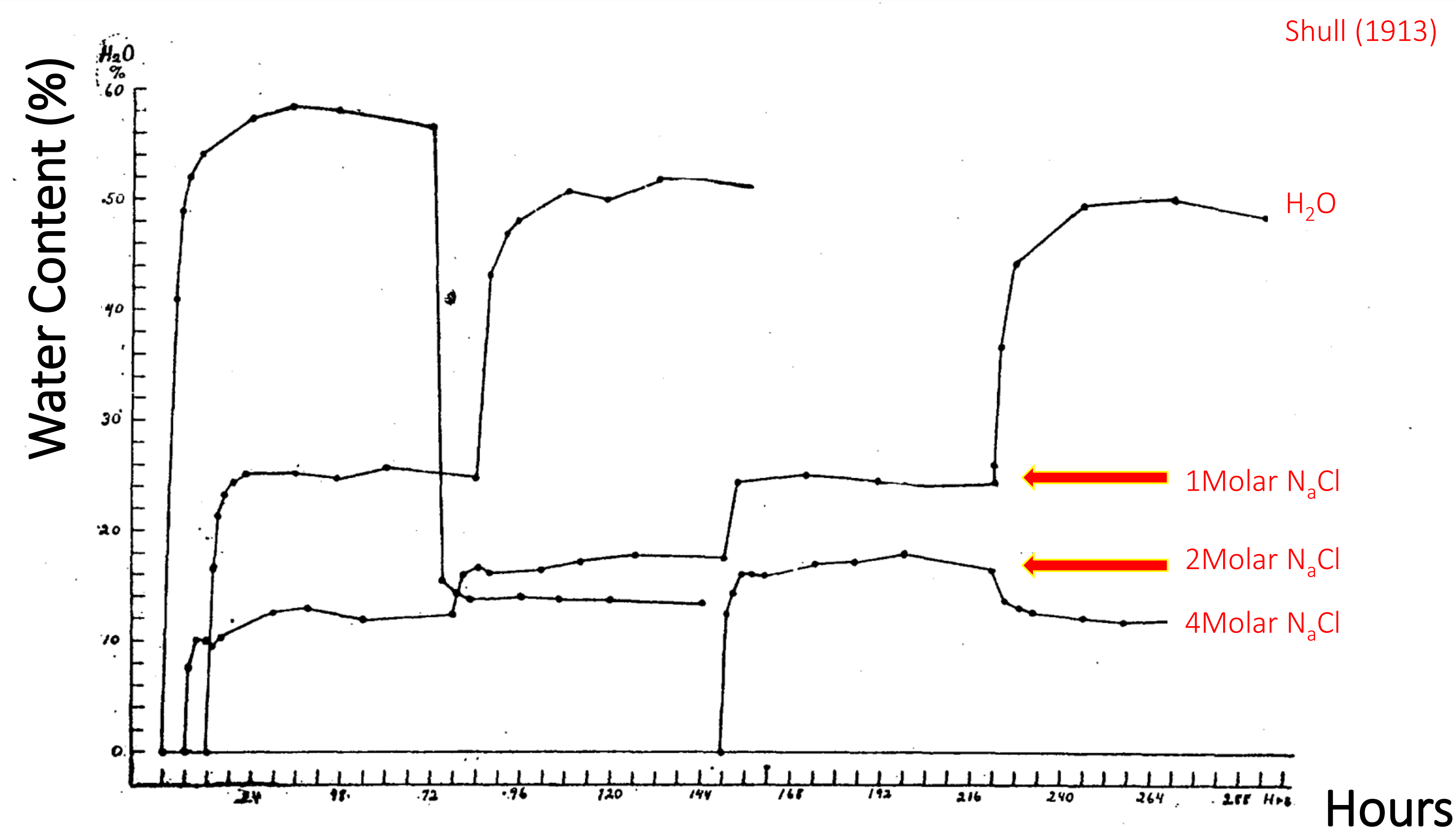
Soil

Solution

The Filter Paper Technique

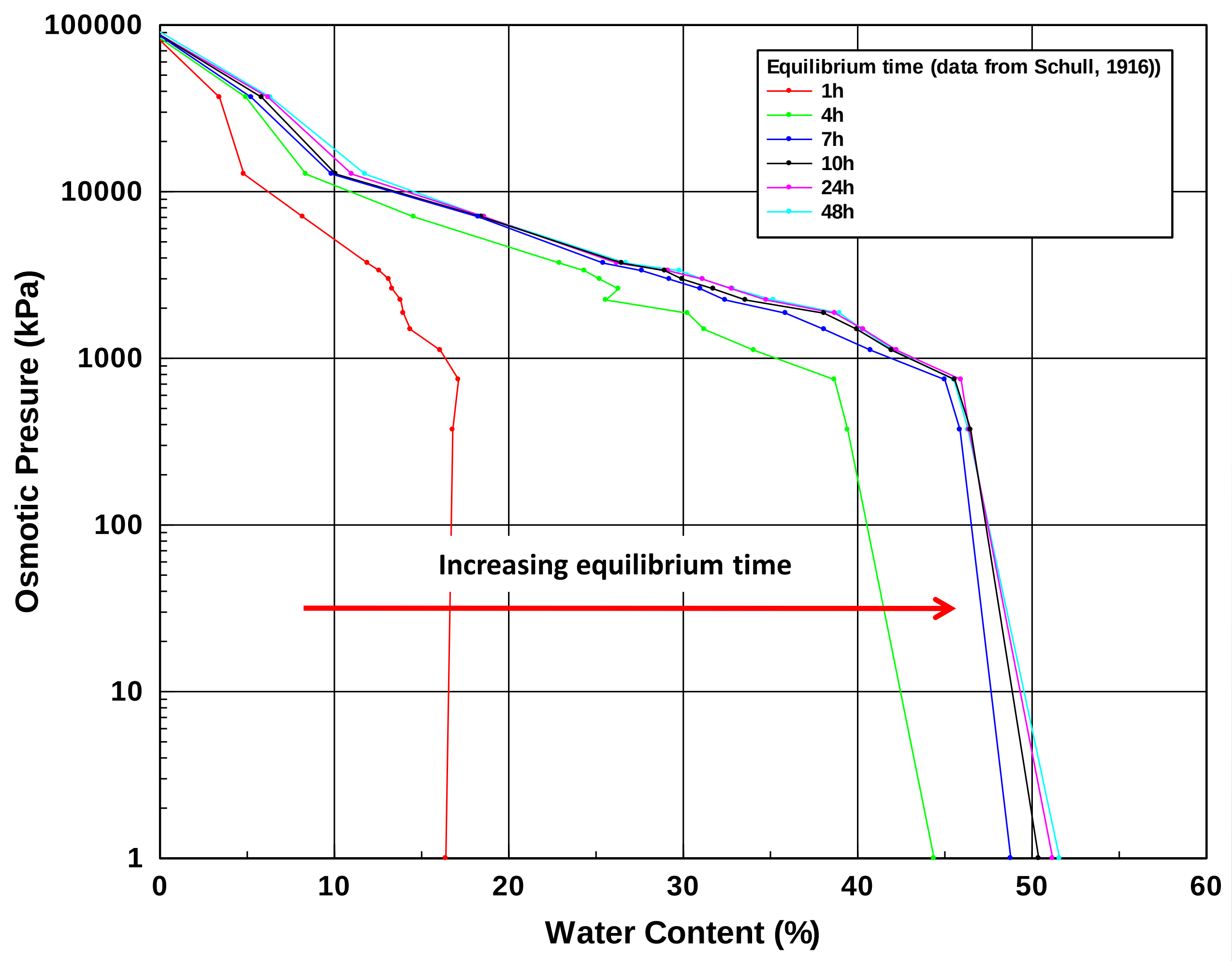
Absorption / Osmotic effect

Response time of seeds placed within solutions



The Filter Paper Technique

Variation of the seeds water content with osmotic pressure for different equilibrium times

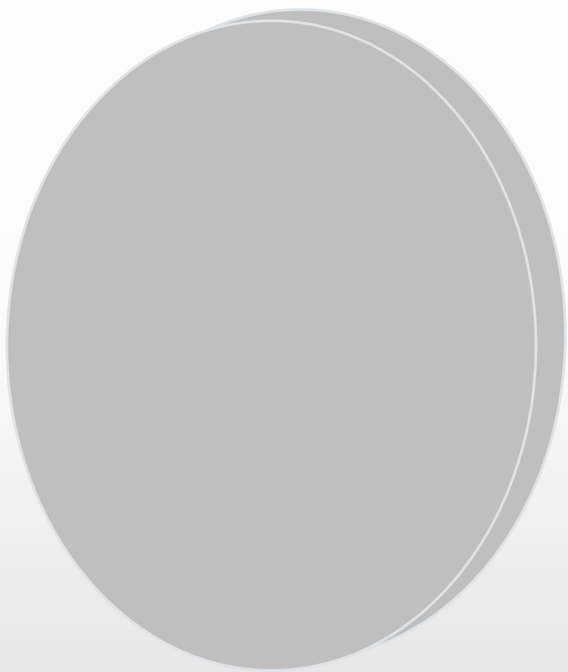


Shull (1916)

The Filter Paper Technique

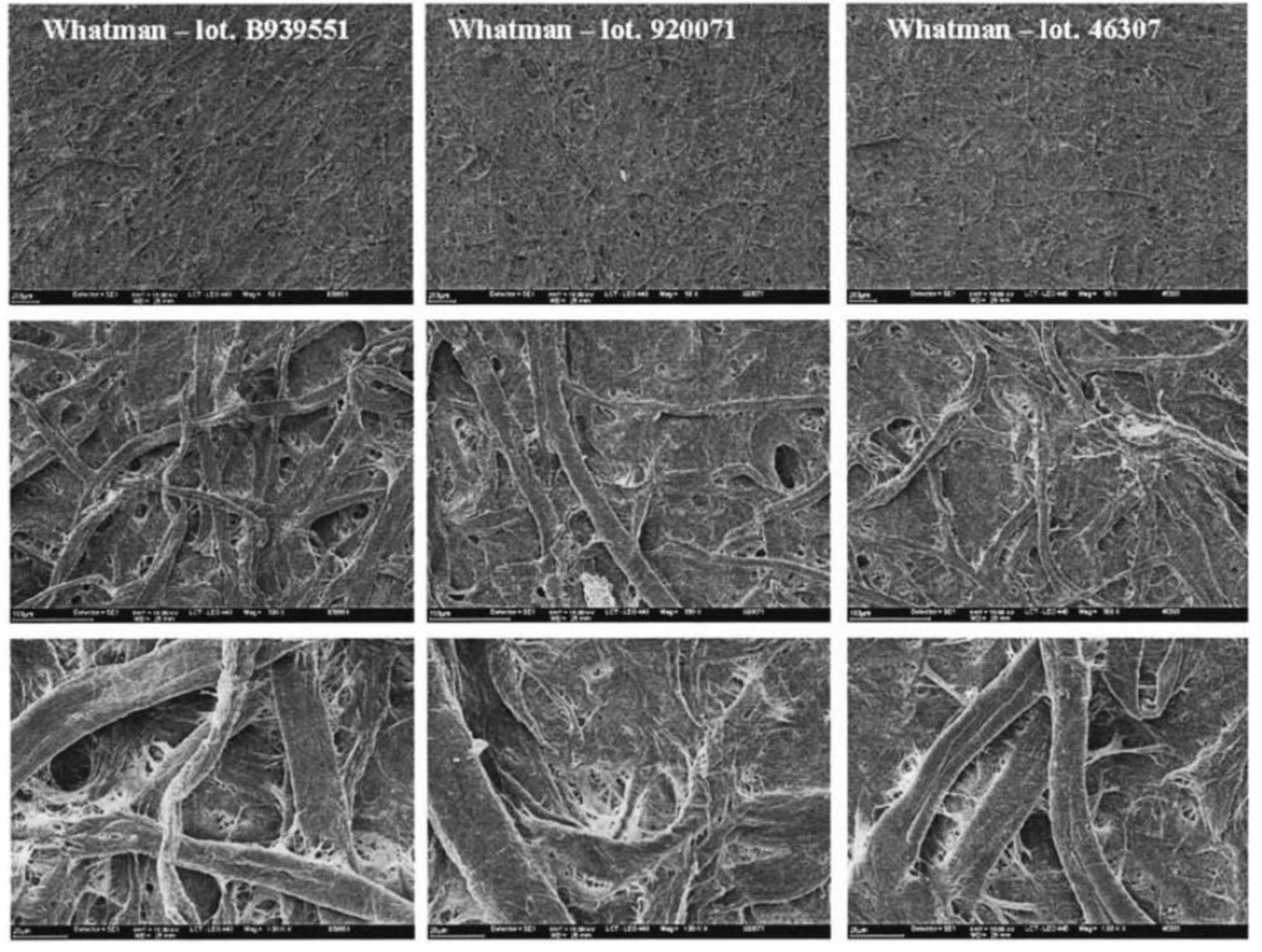
The Filter Paper Technique

Quantitative filter paper



Ordinary paper

The Filter Paper

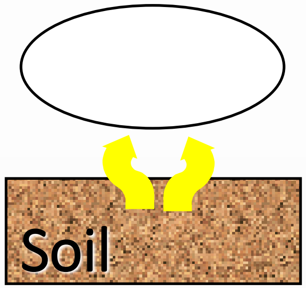


Marinho & Oliveira (2006)

The Filter Paper Technique

Vapour flow

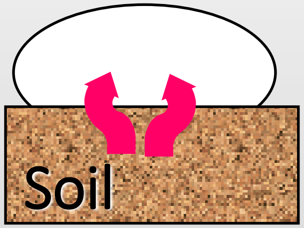
Total Suction



or

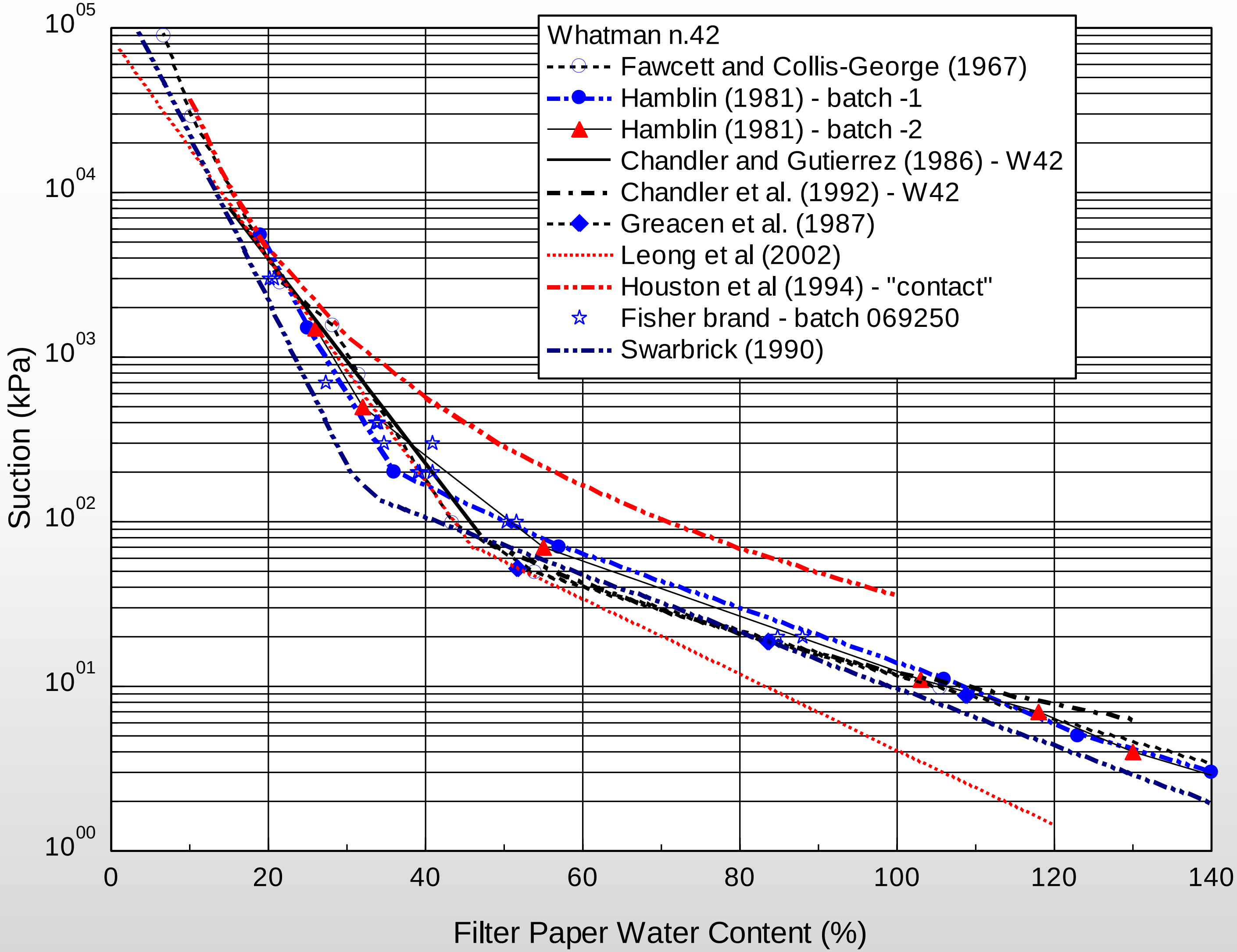
Capilary flow

Matrix Suction



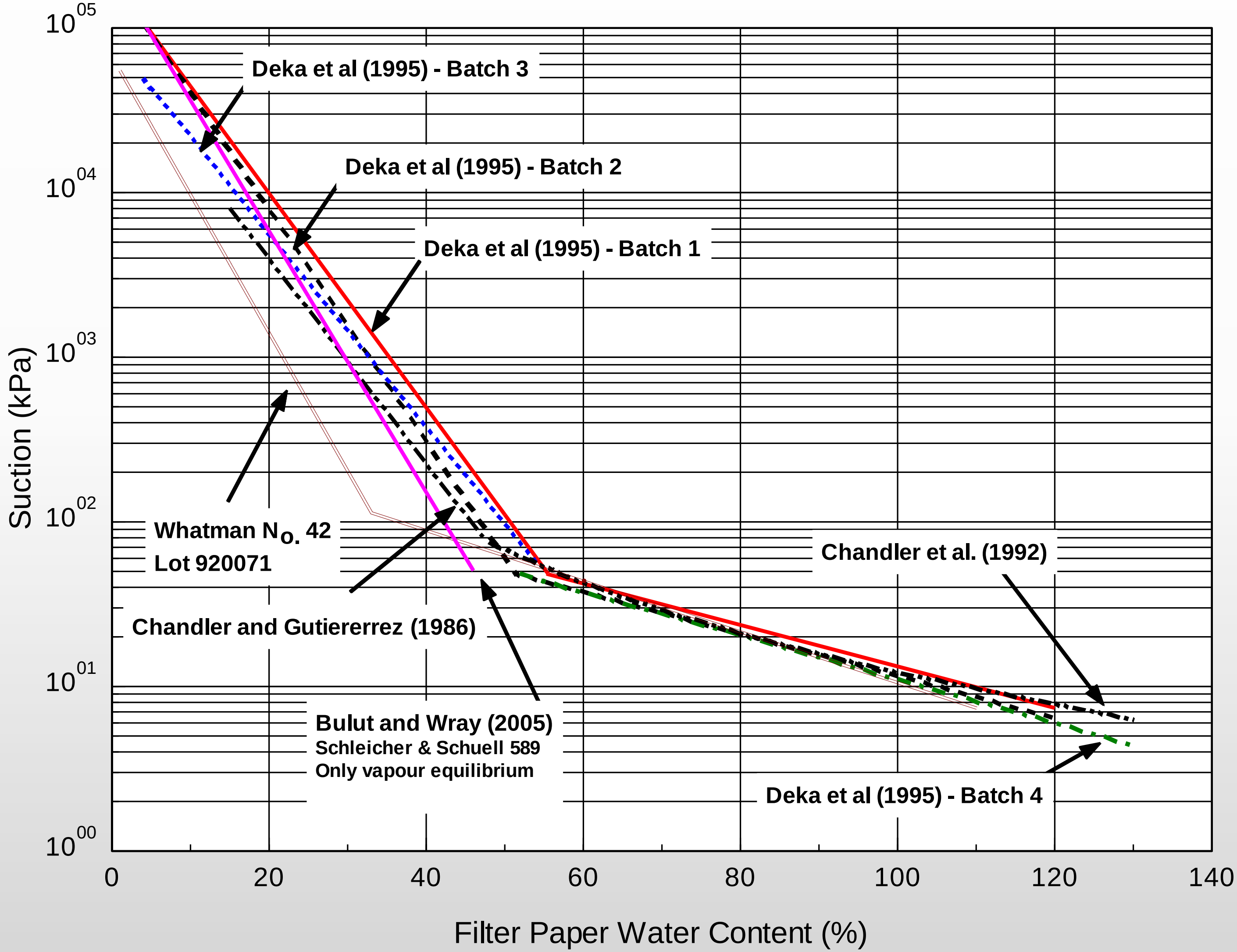
The Filter Paper Technique

Calibration Curve



The Filter Paper Technique

Calibration Curve



The Filter Paper Technique

Calibration Curve

Chandler and Gutierrez (1986)
Chandler et al.(1992)

For filter paper w/c $> 47\%$

$$Suction(kPa) = 10^{(6.05 - 2.48\log w)}$$

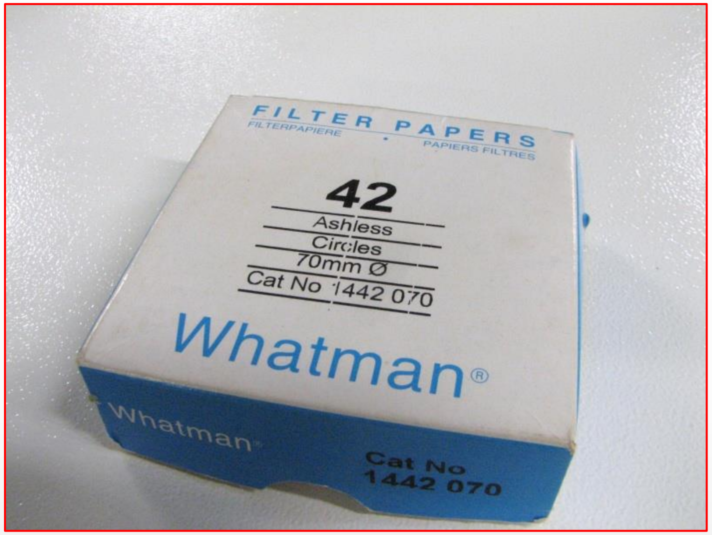
For filter paper w/c $\leq 47\%$

$$Suction(kPa) = 10^{(4.84 - 0.0622w)}$$

The Filter Paper Technique

Procedure

Filter paper at “natural” water content

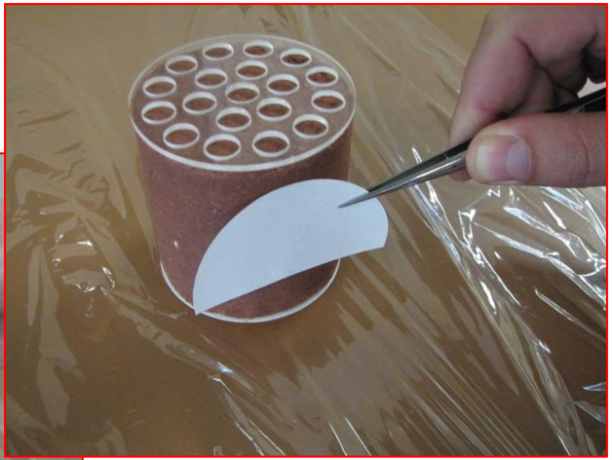


Twizers to manipulate the filter paper

The Filter Paper Technique

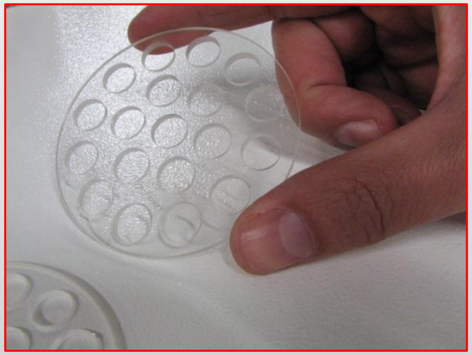
Procedure

Filter paper placed in contact with the soil



Filter paper place without contact with the soil

Perforate disk used for total suction measurement



The Filter Paper Technique

Procedure

Wrapping (firmly) the sample using cling film

Wrapping the sample using aluminium foil

Placing the samples within the isolated box.

The Filter Paper Technique

Procedure

Removing the filter paper after equilibration time is reached

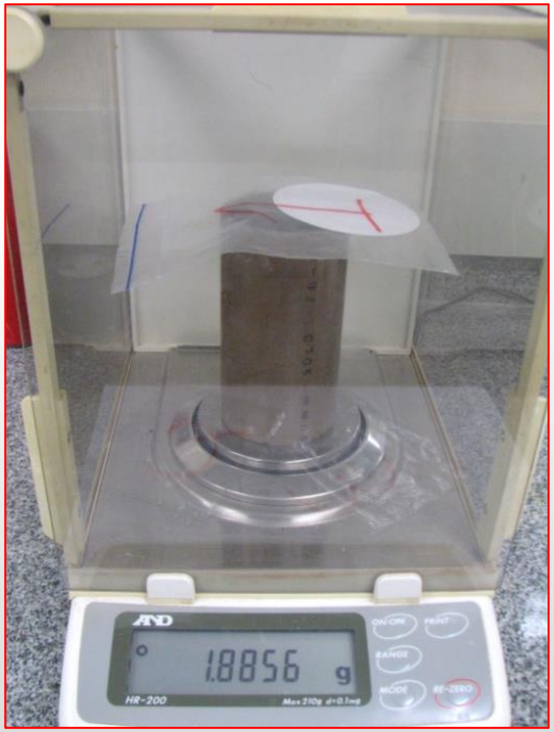
Placing the F.P inside the zip lock plastic bag

The Filter Paper Technique

Procedure

Weighting the plastic bag without filter paper

Weighting the filter paper within the plastic bag

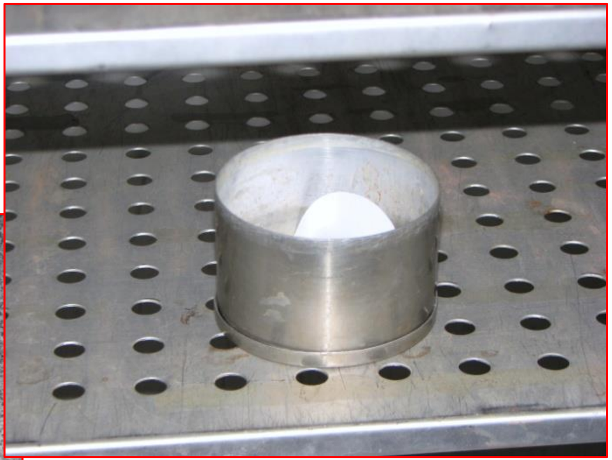


Tube used to avoid static effect from the plastic in the balance

The Filter Paper Technique

Procedure

Placing the F.P in the oven at 105° C for at least two hours



Removing the filter paper from the oven

The Filter Paper Technique

Procedure

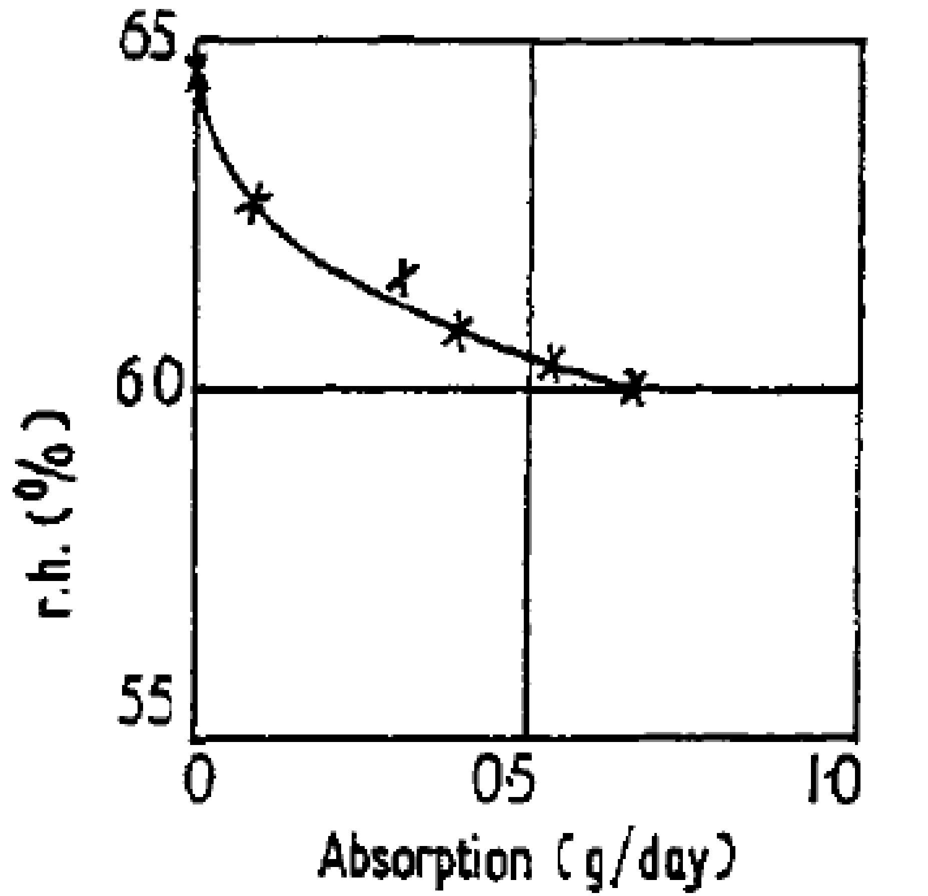
The Filter Paper Technique

Why There is Only One Calibration Curve for Matrix and Total Suction

The Filter Paper Technique

One Calibration Curve

Effect of the presence of an absorbent material on the relative humidity



Martin (1962)

The Filter Paper Technique

The equilibrium concept

What is the equilibrium relative humidity?

It is the relative humidity when the movement of moisture from a material to the environment (and vice versa) have equalized.

This Equilibrium Relative Humidity balance is achieved when vapor pressures (within the material and the environment) have equalized.

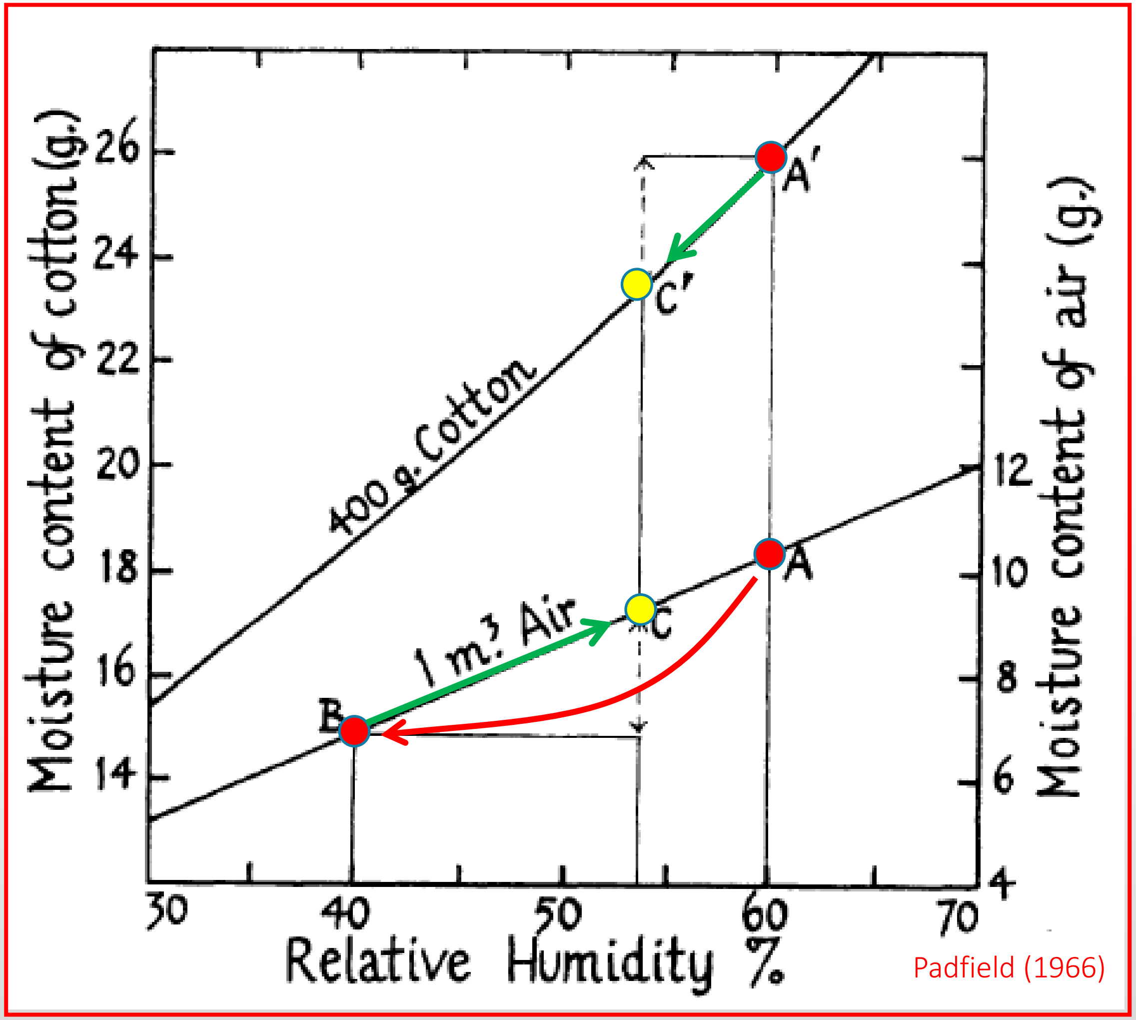
At this point the moisture level of a material can be expressed in terms of equilibrium relative humidity.

At equilibrium the free energy of all components of the system are the same.

The Filter Paper Technique

The equilibrium concept

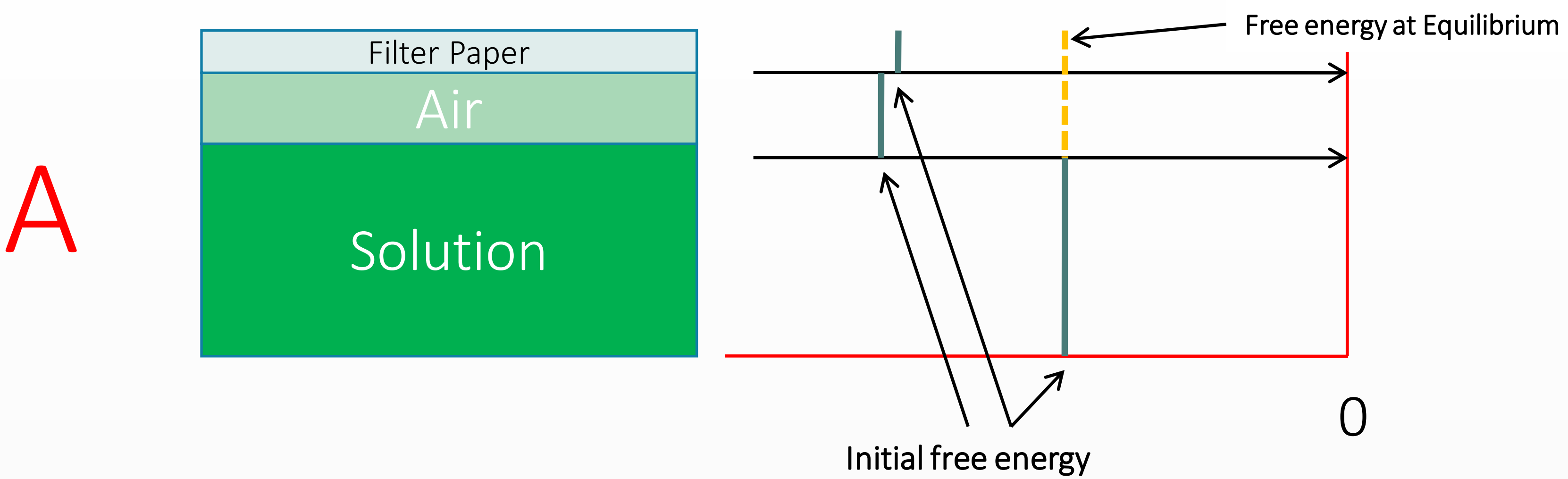
Museums showcase

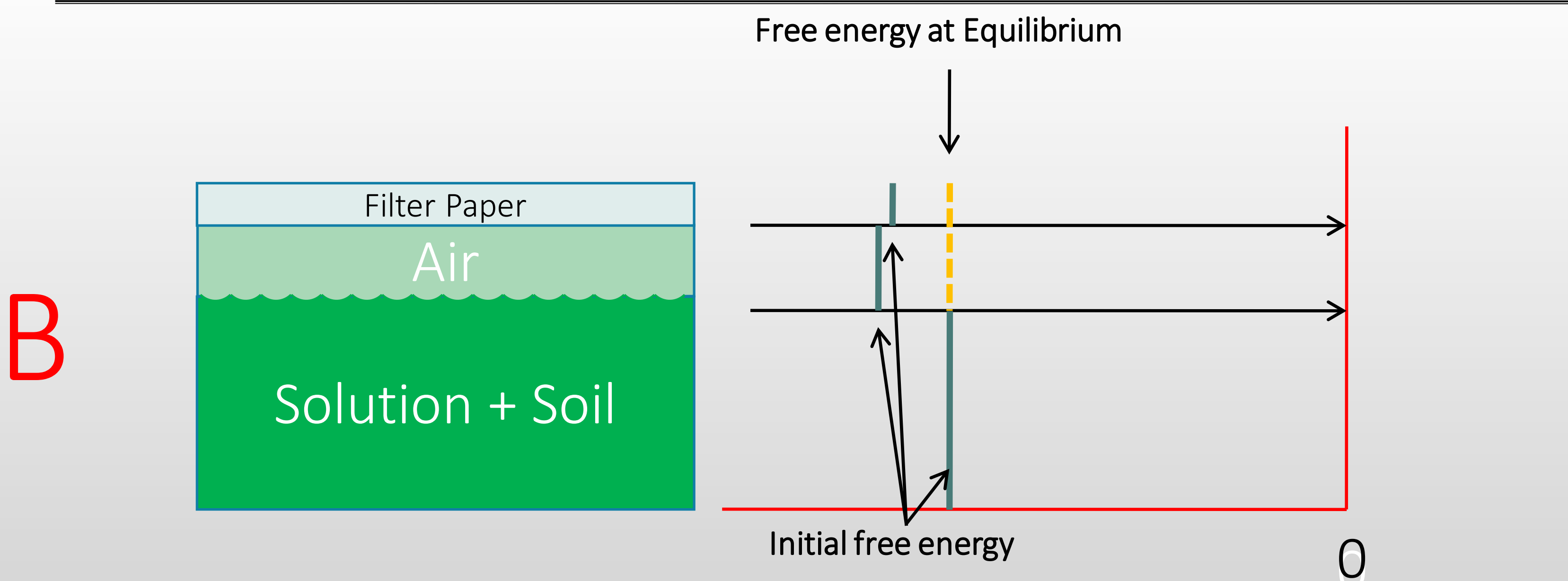


Padfield (1966)

The Filter Paper Technique

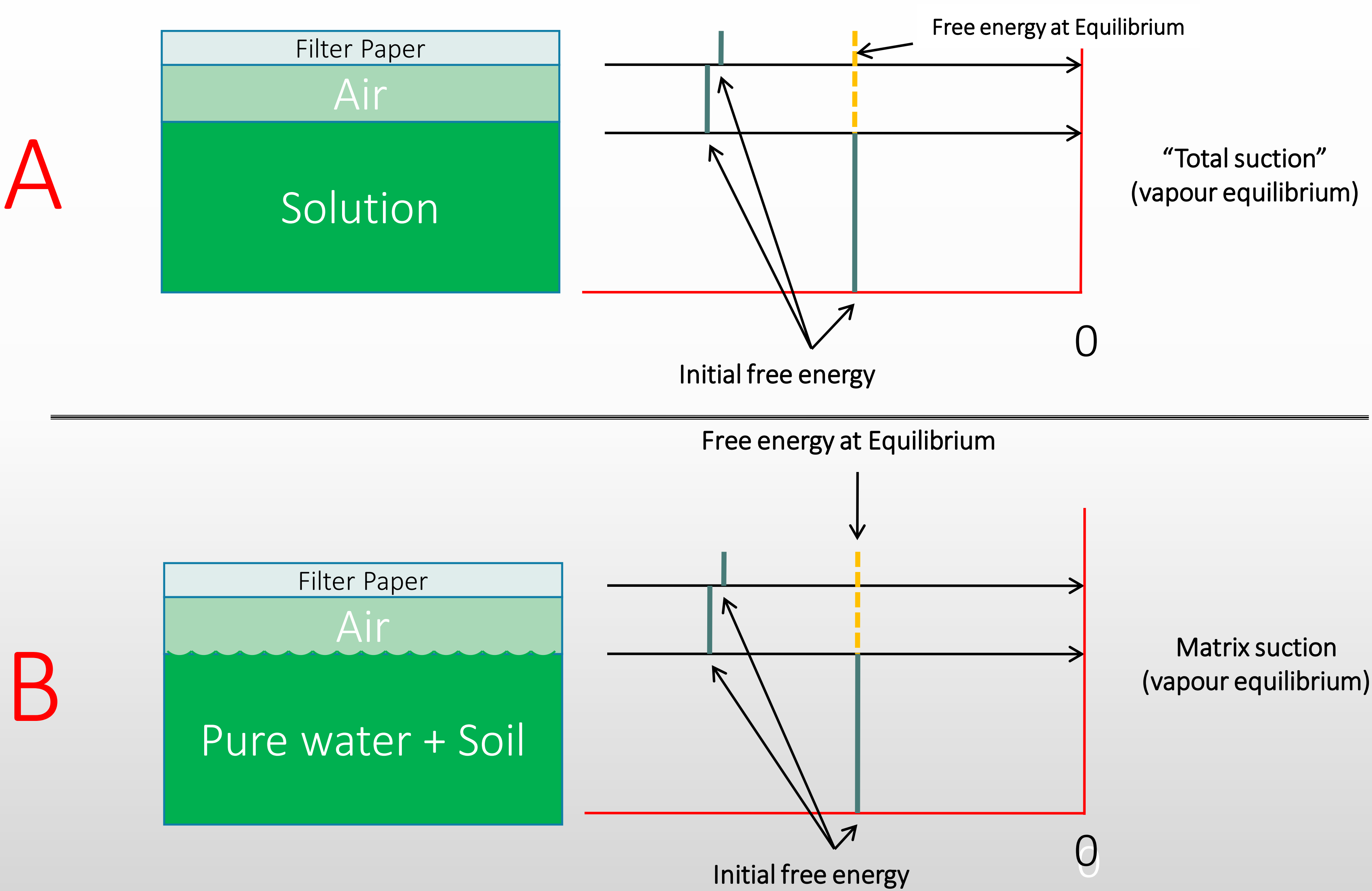
The equilibrium concept





The Filter Paper Technique

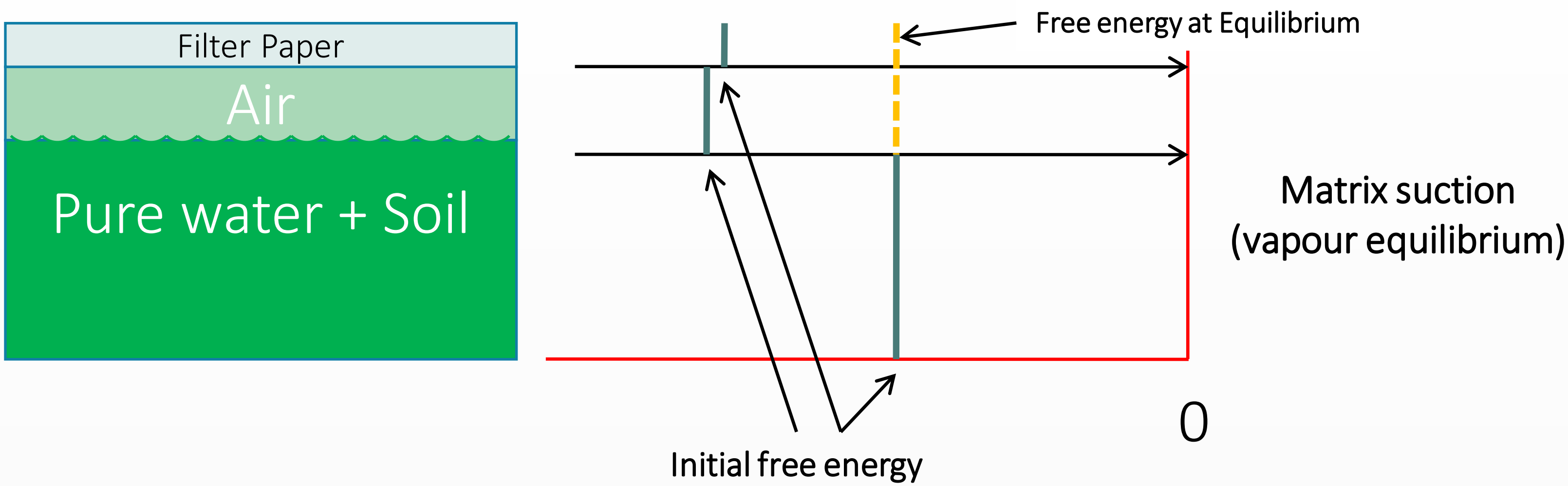
The equilibrium concept



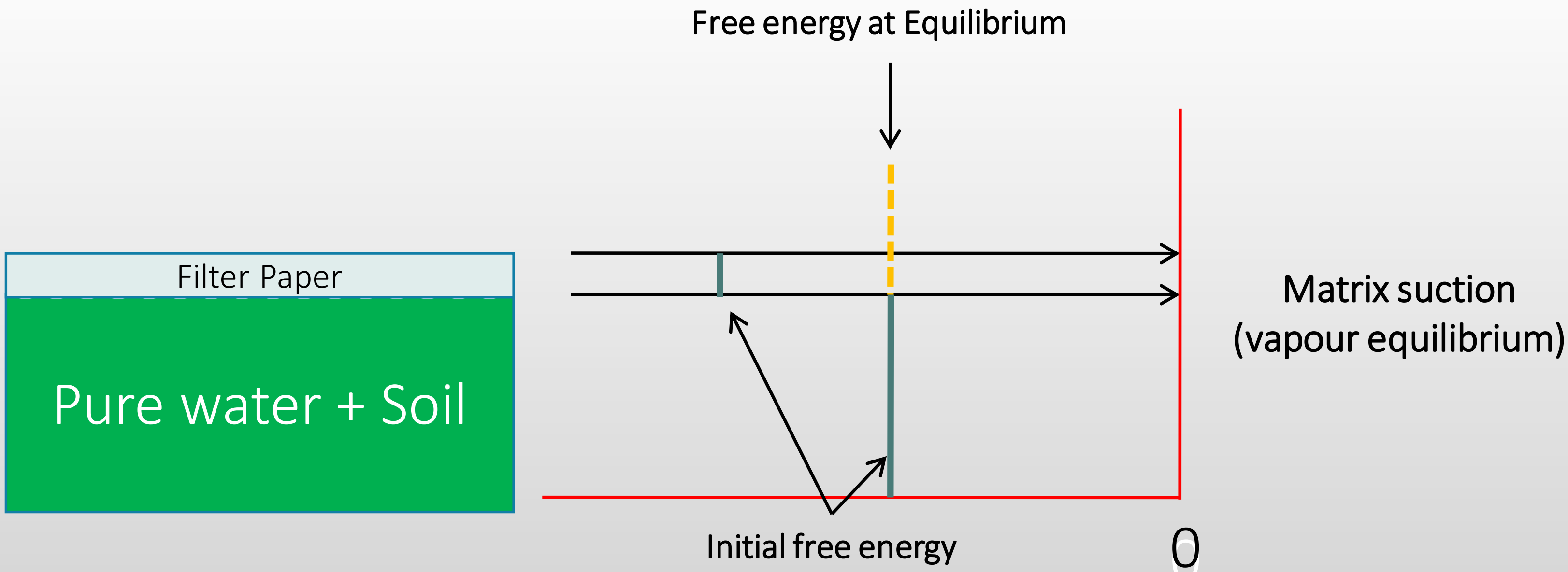
The Filter Paper Technique

The equilibrium concept

A

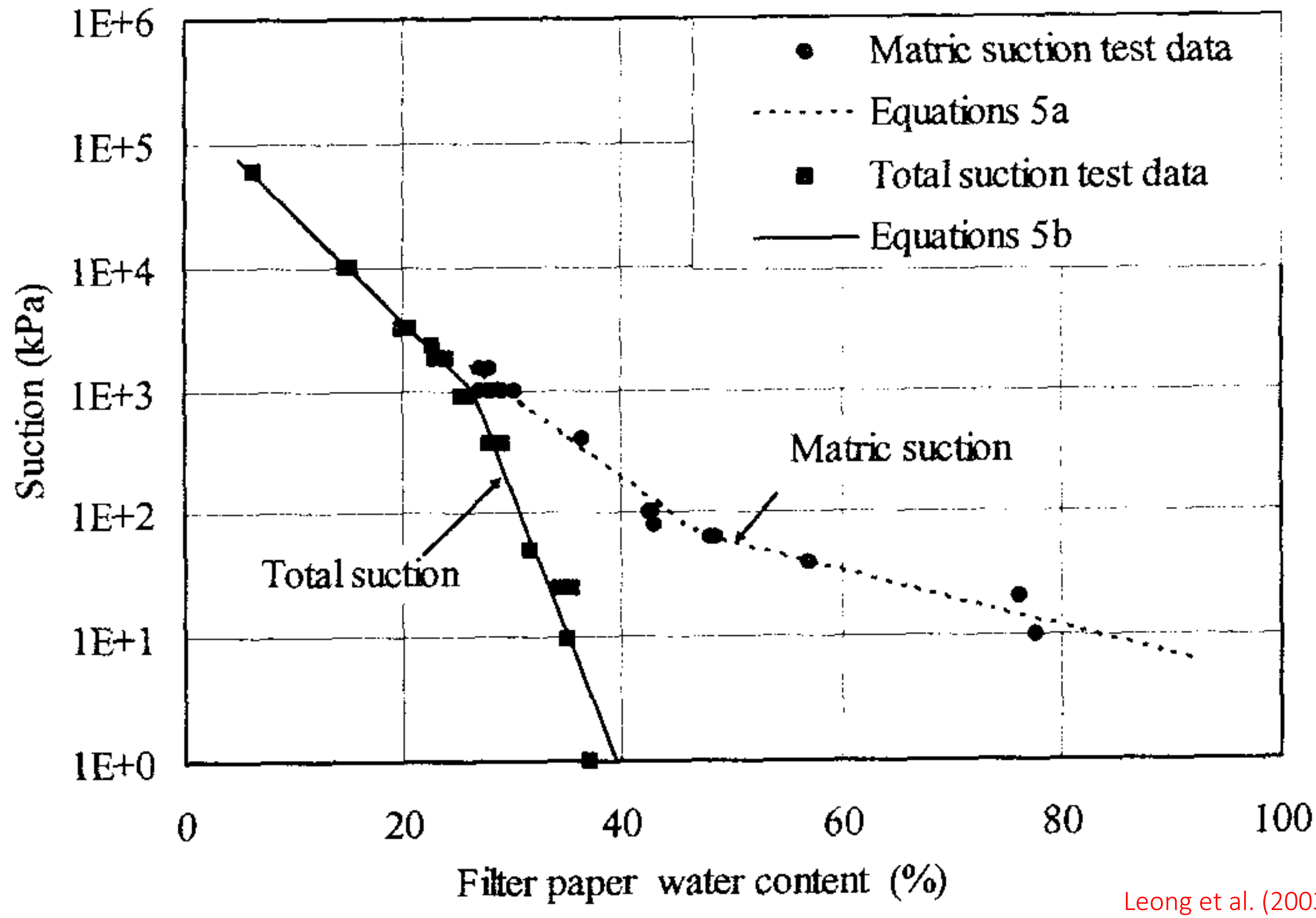


B



The Filter Paper Technique

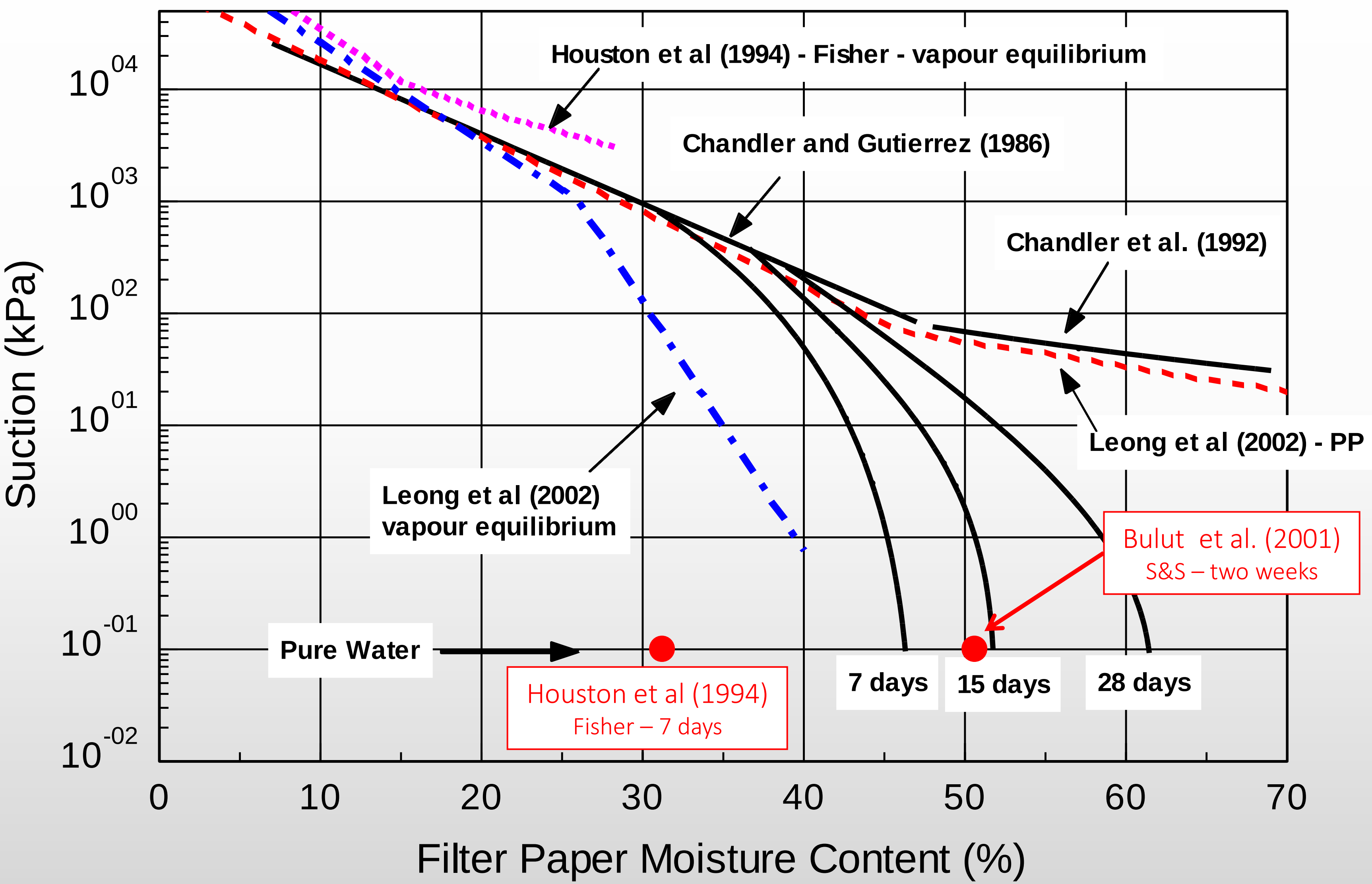
One Calibration Curve



Leong et al. (2003)

The Filter Paper Technique

One Calibration Curve

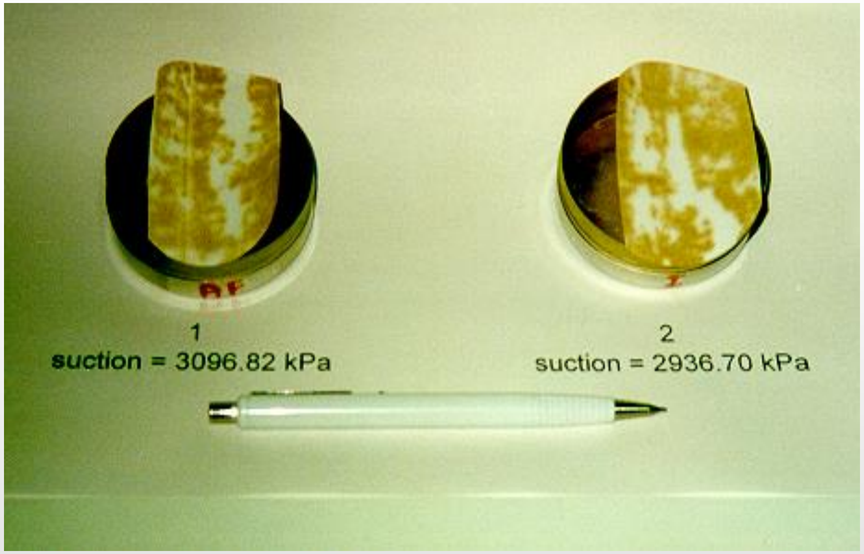


The Filter Paper Technique

The effect of contact

Shroud of Turin

Filter Paper



The Filter Paper Technique

The effect of contact

Type of Contact

Ideal Situation

Full Contact

The water from the soil sample flows by capillary to the filter paper.

Actual Situation

Partial Contact

The water from the soil sample flows by capillary and vapour at the same time at different rates.

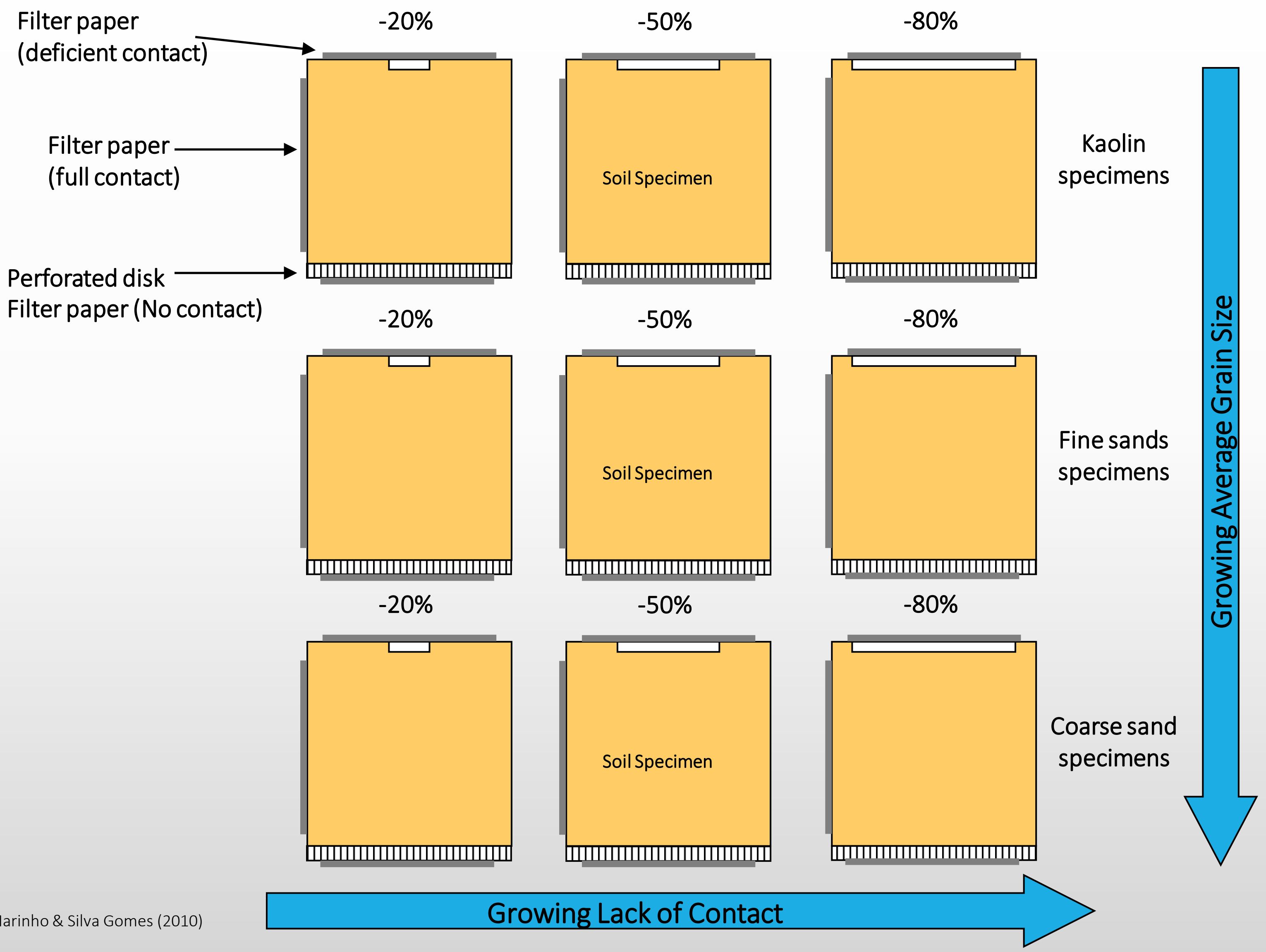
Ideal Situation

Out of Contact

The water from the soil flows by vapour to the filter paper.

The Filter Paper Technique

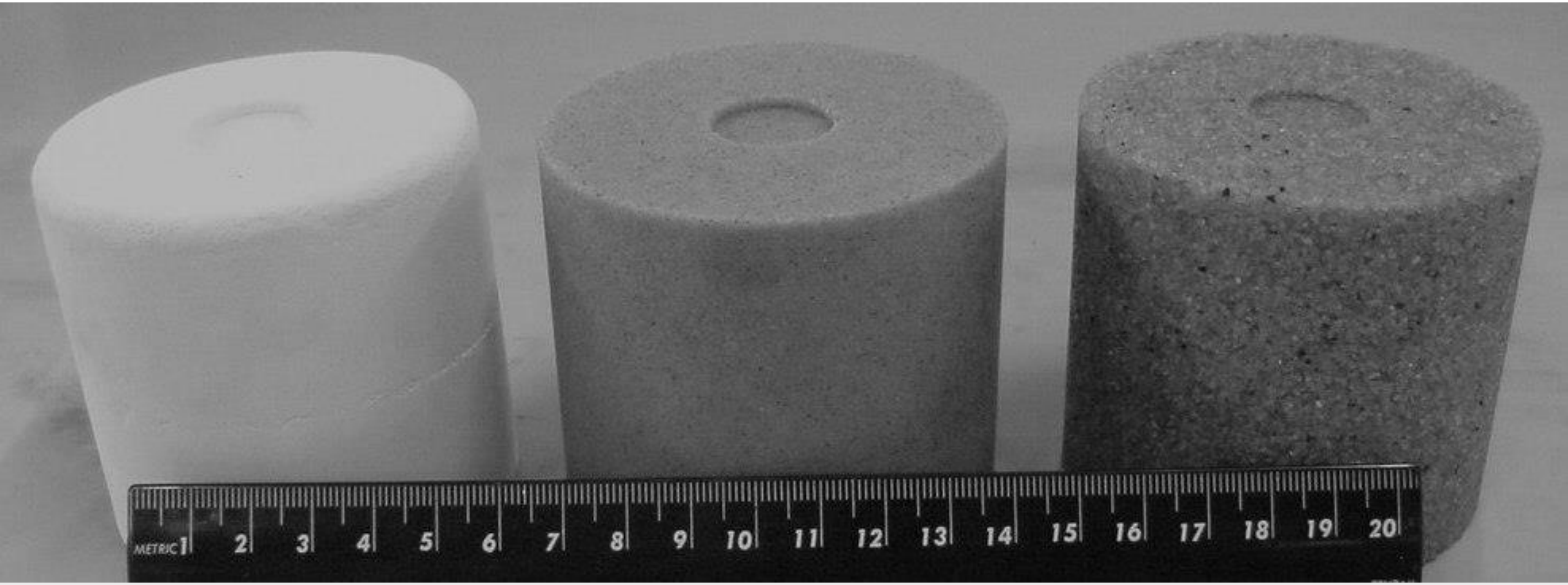
The effect of contact



Marinho & Silva Gomes (2010)

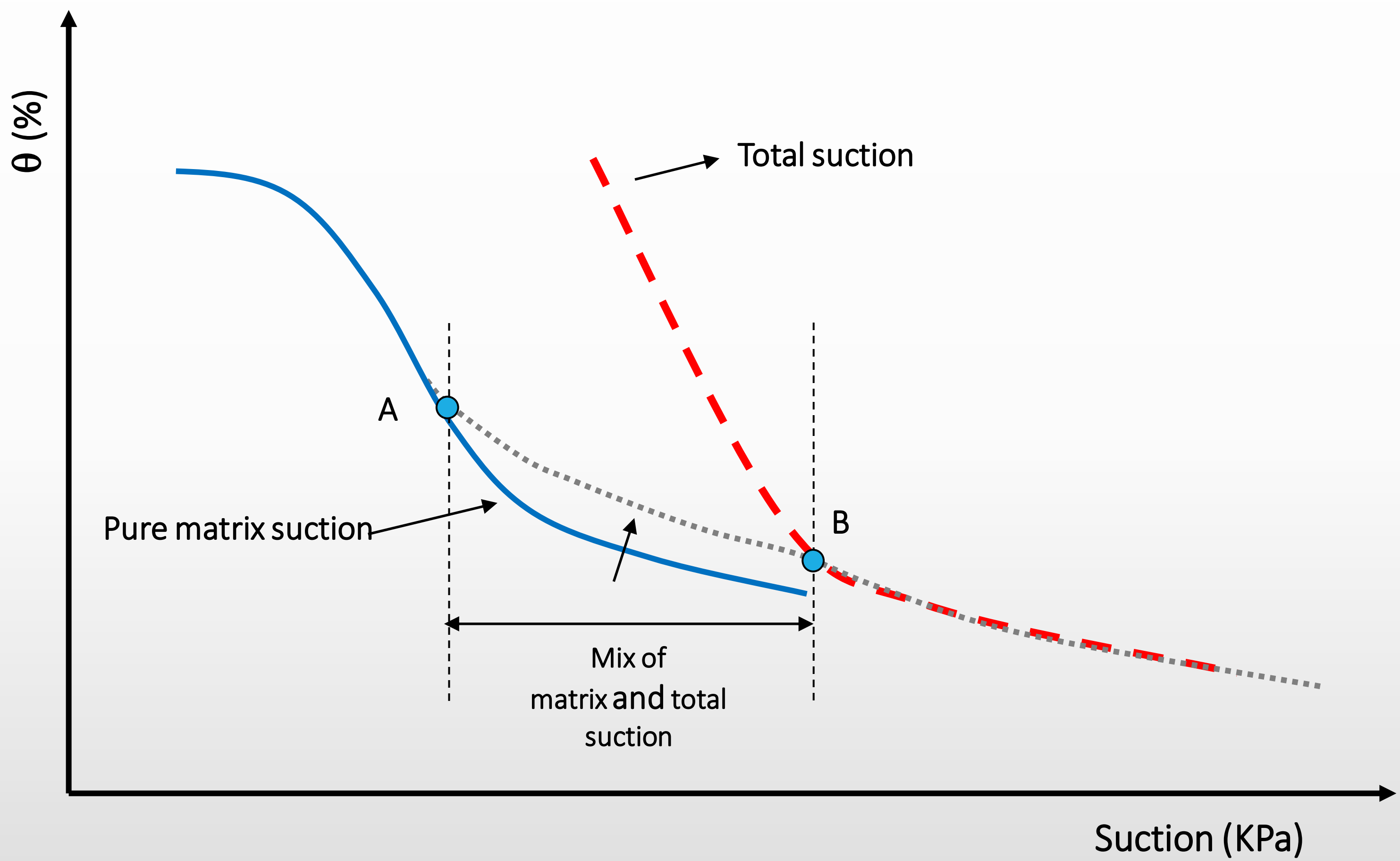
The Filter Paper Technique

The effect of contact



The Filter Paper Technique

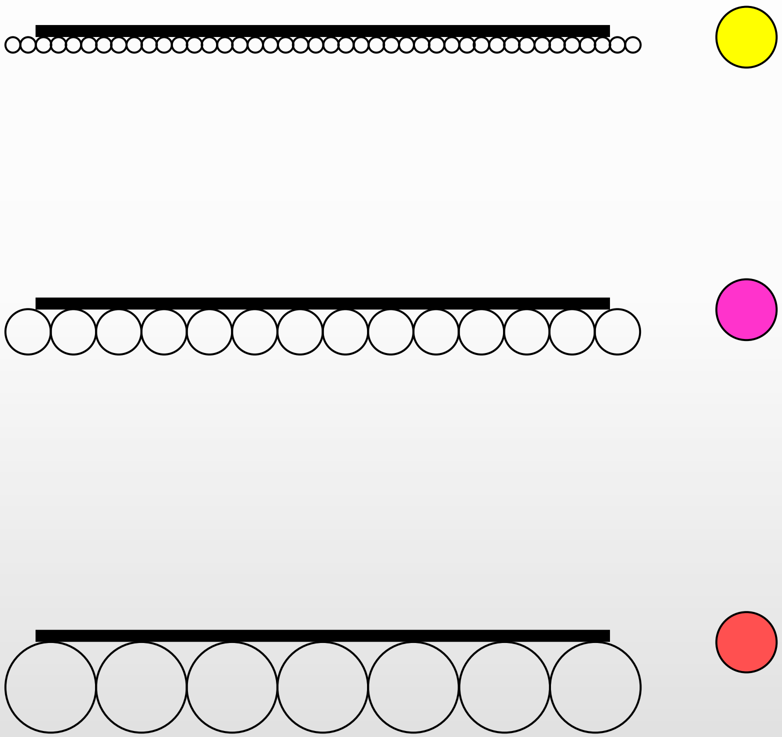
The effect of contact

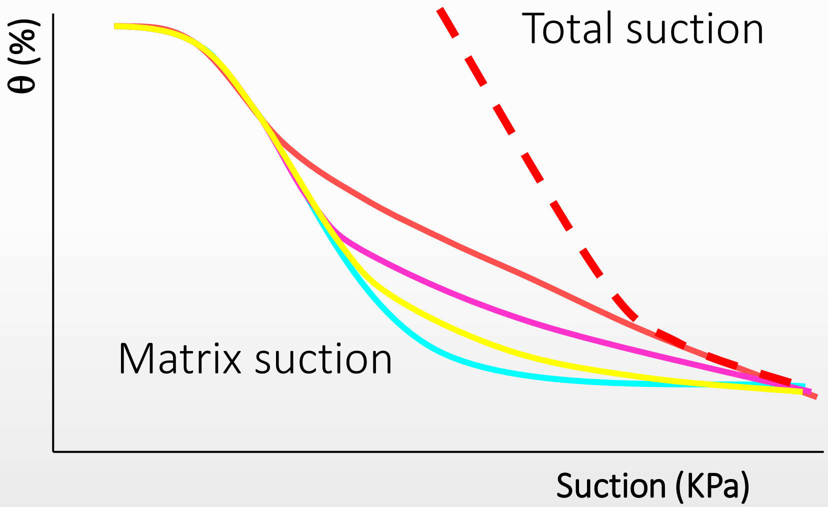


Marinho & Silva Gomes (2010)

The Filter Paper Technique

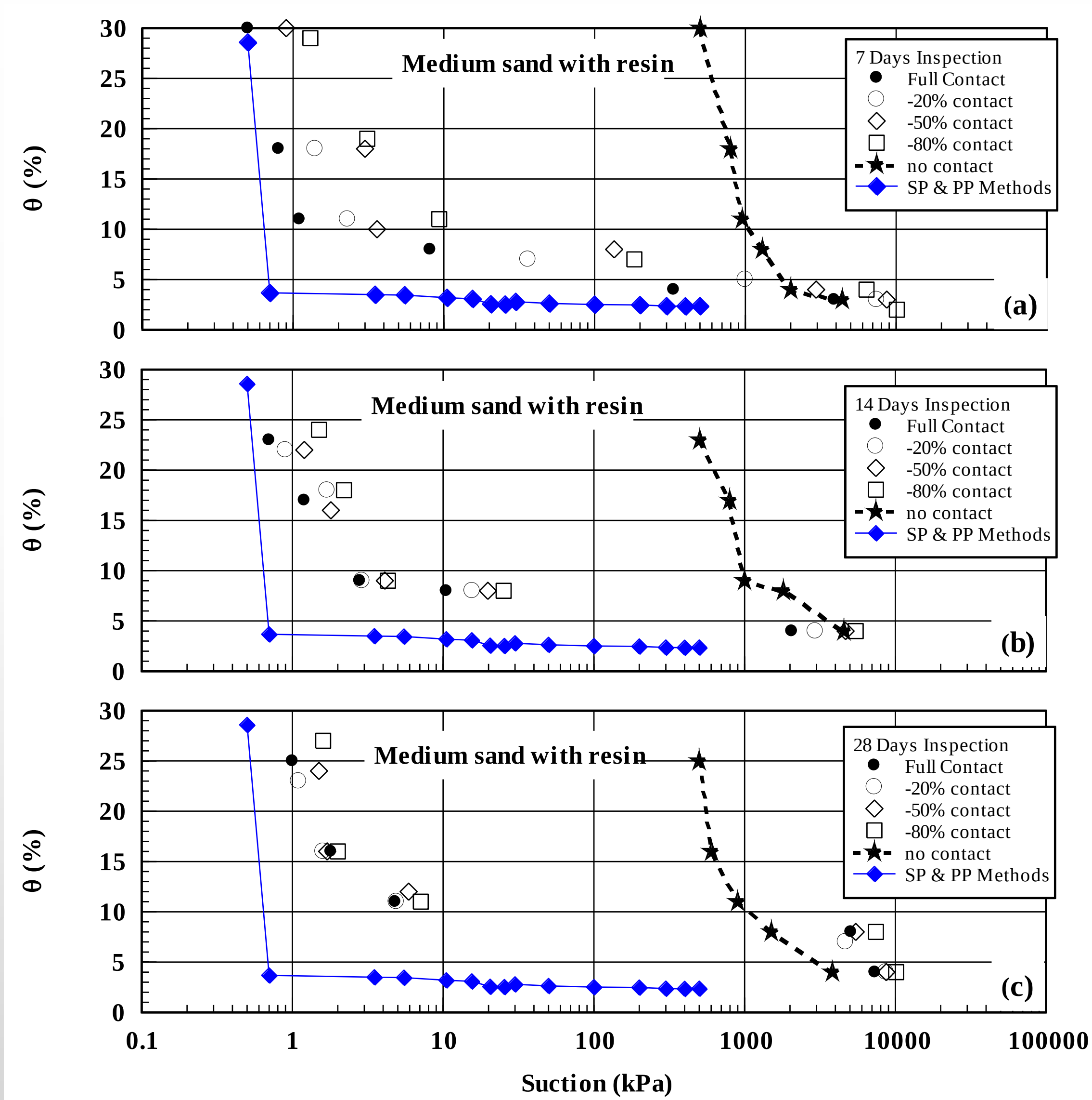
The effect of contact





The Filter Paper Technique

The effect of contact



7 Days

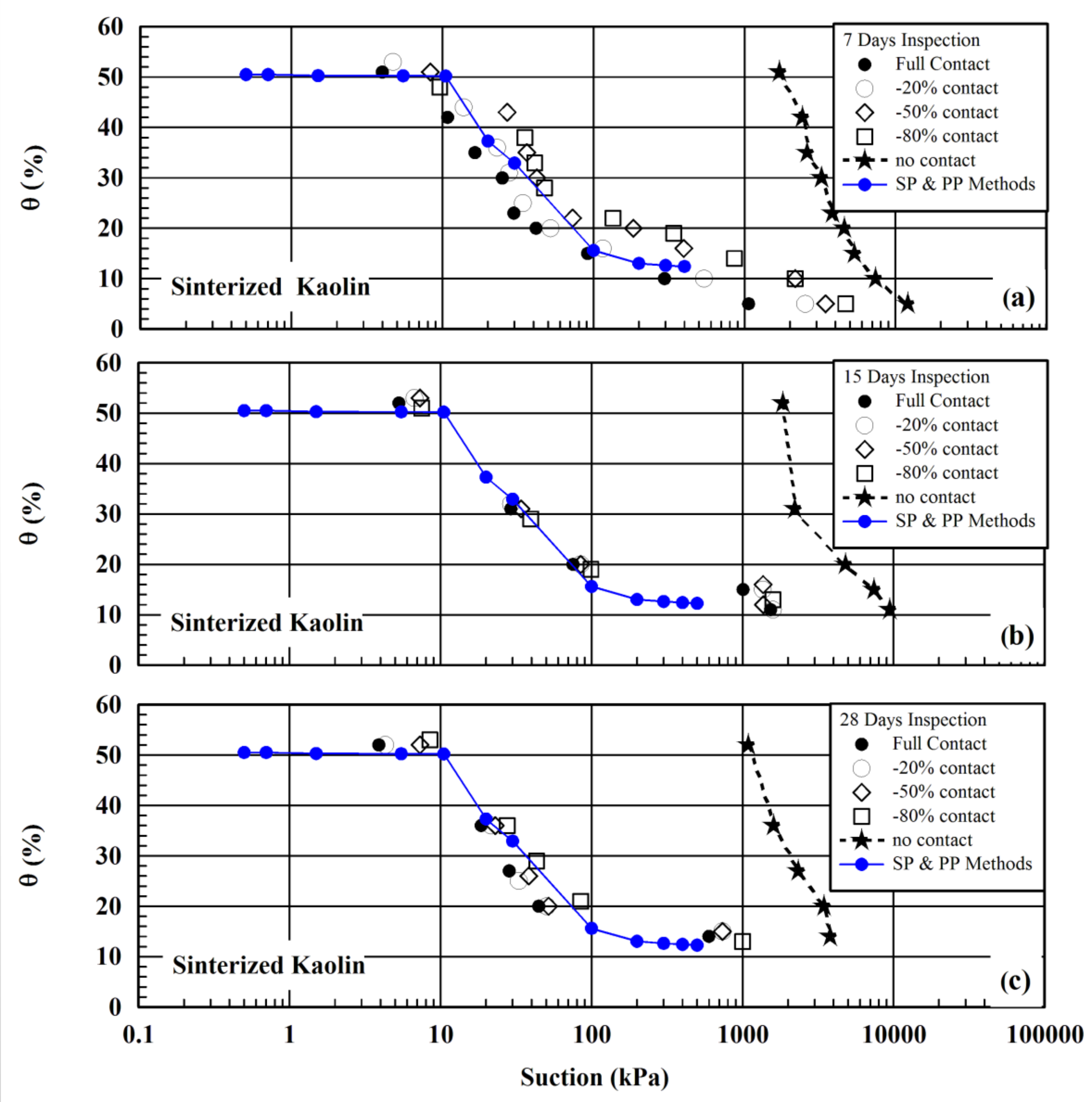
14 Days

28 Days

Marinho & Silva Gomes (2010)

The Filter Paper Technique

The effect of contact



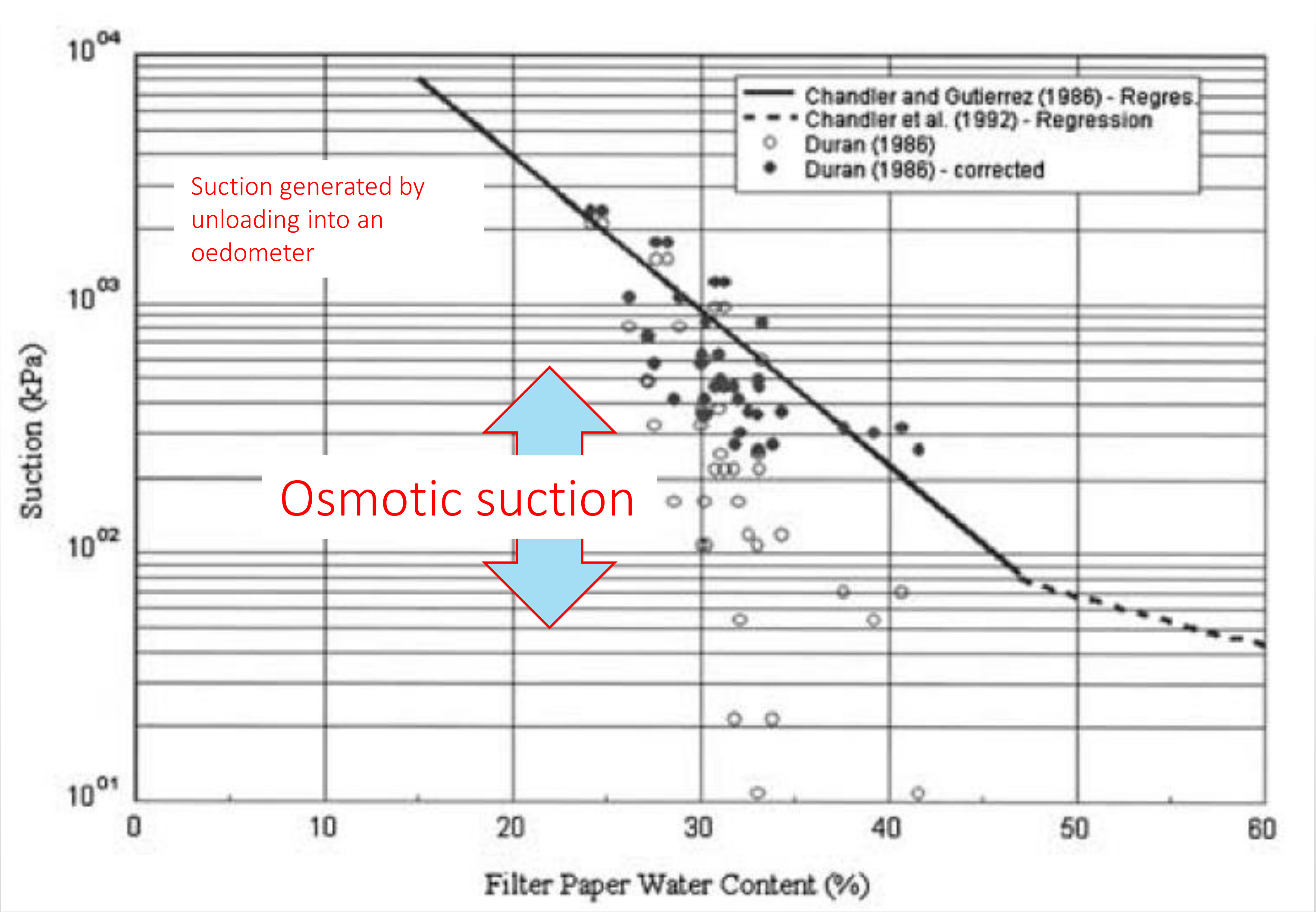
7 Days

14 Days

28 Days

The Filter Paper Technique

Interpretation



Marinho & Oliveira (2006)

The Filter Paper Technique

Equilibrium time

Suggested equilibrium time according to the suction level

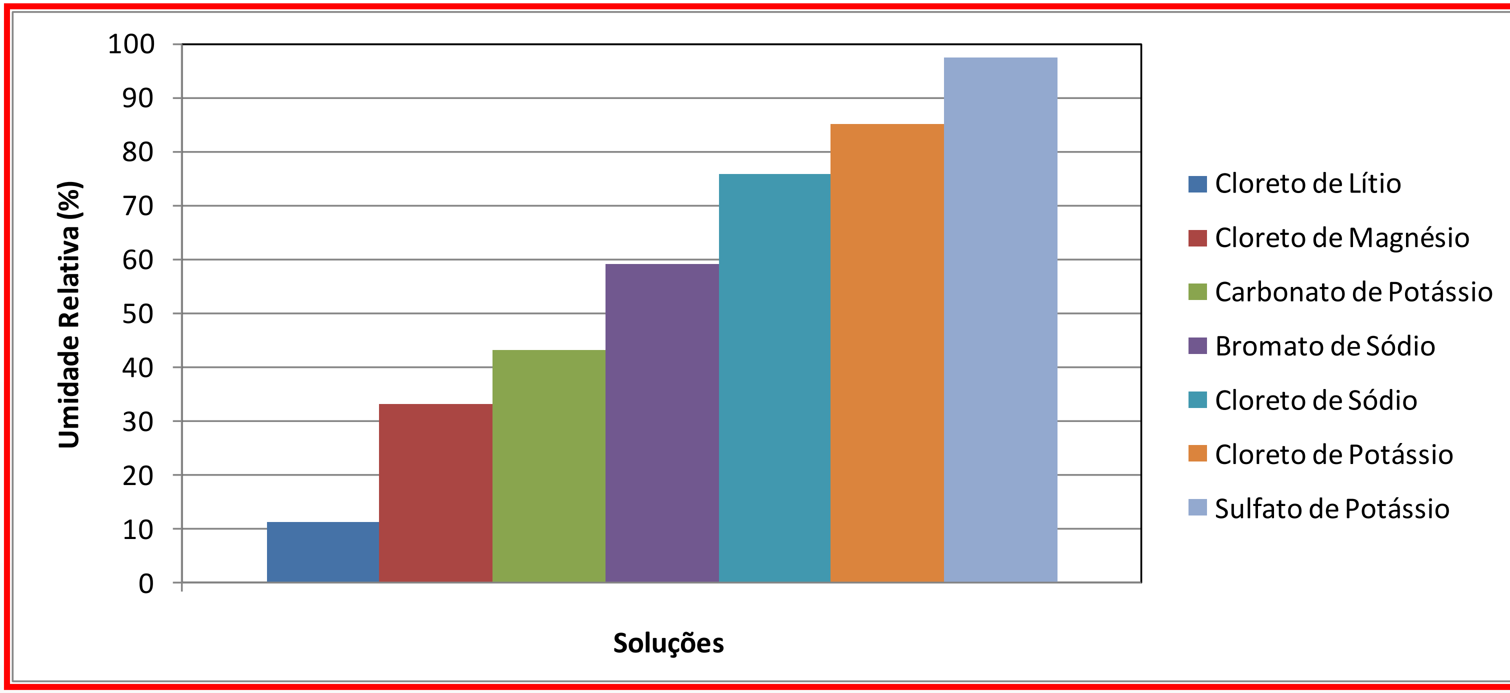
Total Suction Range (kPa)	Equilibration Time Suggested
0–100	Not determined, but certainly more than 30 days
100–250	30 days
250–1000	15 days
1000–30000	7 days

Marinho & Oliveira (2006)

To remember

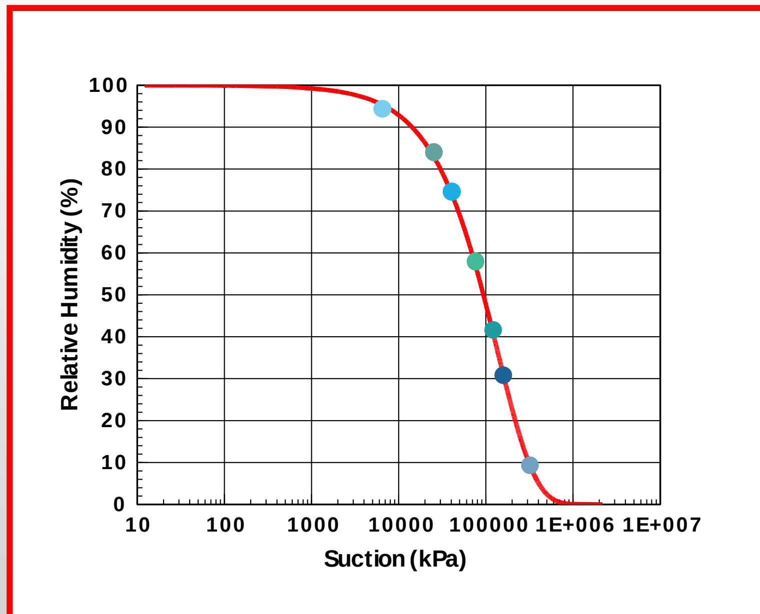
$$\psi = -\frac{RT}{M_V}\ln(RH) = -135055\ln(RH)$$

Conceitos de Termodinâmica



Cloreto de Lítio	$LiCl$	11.3
Cloreto de Magnésio	$MgCl$	33.1
Carbonato de Potássio	K_2CO_3	43.2
Bromato de Sódio	$NaBrO_3$	59.1
Cloreto de Sódio	$NaCl$	75.7
Cloreto de Potássio	KCl	85.1
Sulfato de Potássio	K_2SO_4	97.6

Dados: Department of Biology – University of Colorado



To remember 

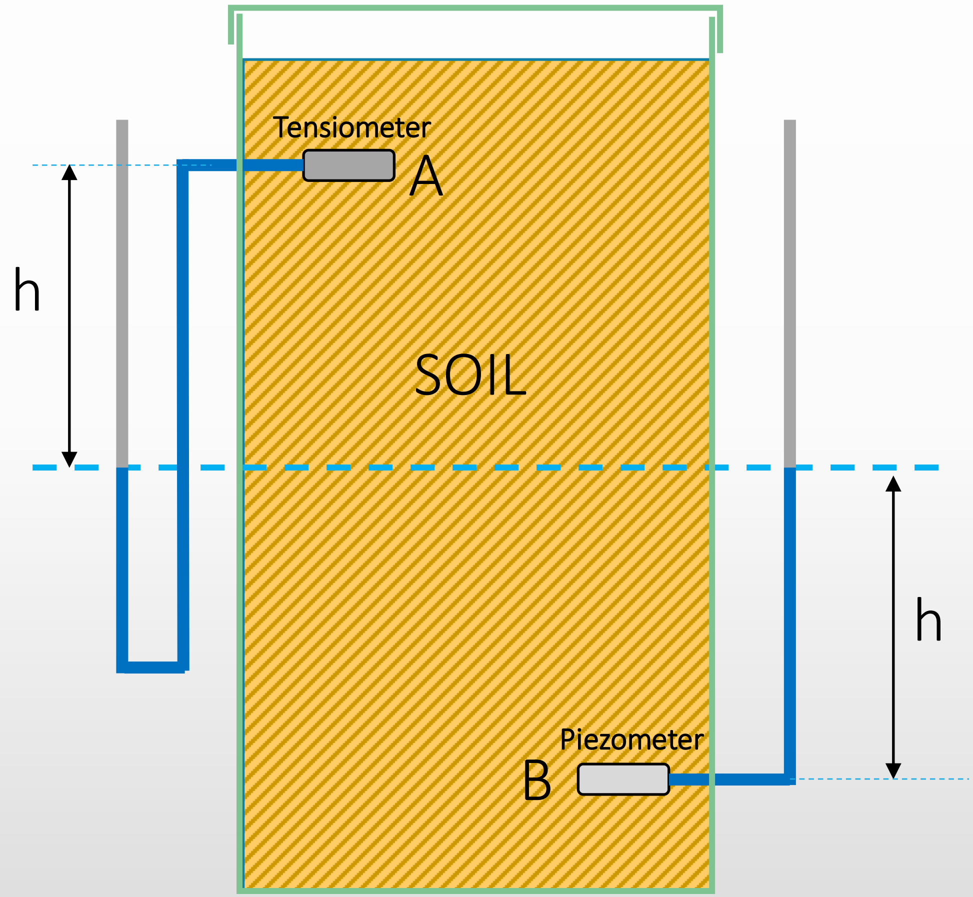
Placa de Sucção

Hydraulic Potentials

Pressure head

$p_A = -\rho g h$

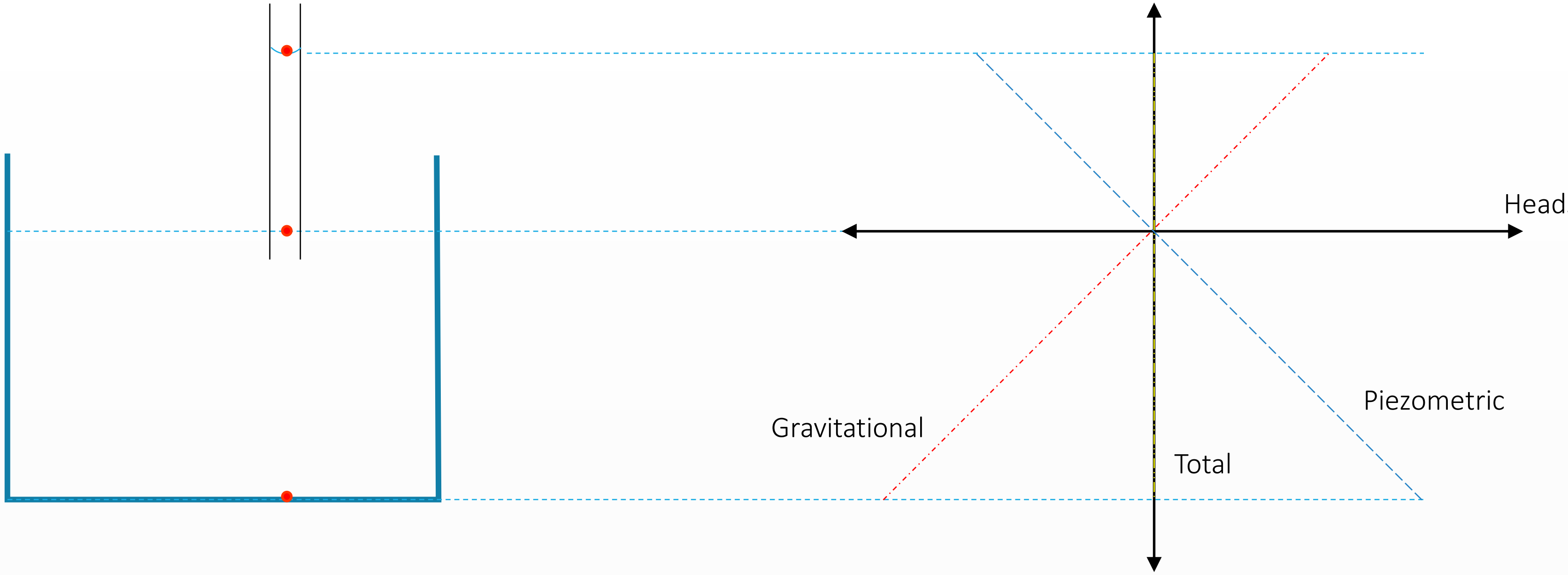
$Matrix\ suction_A = \rho g h$

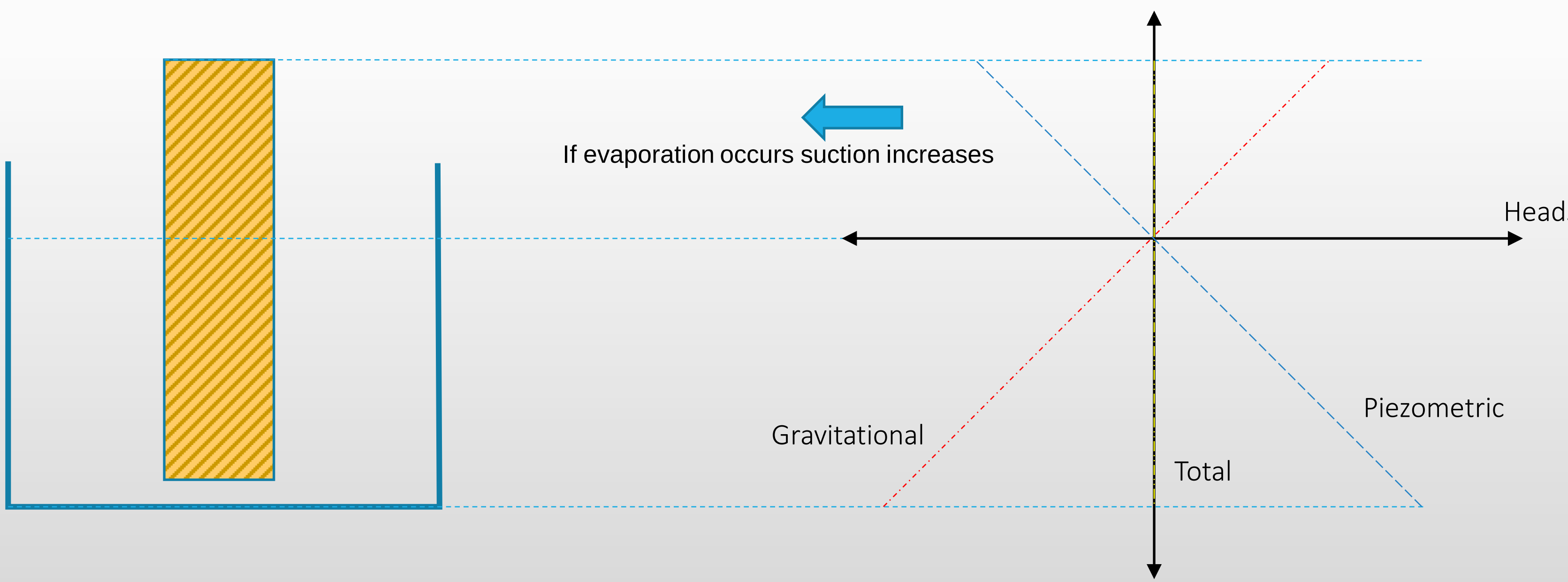


$p_B = \rho g h$

Pressure head

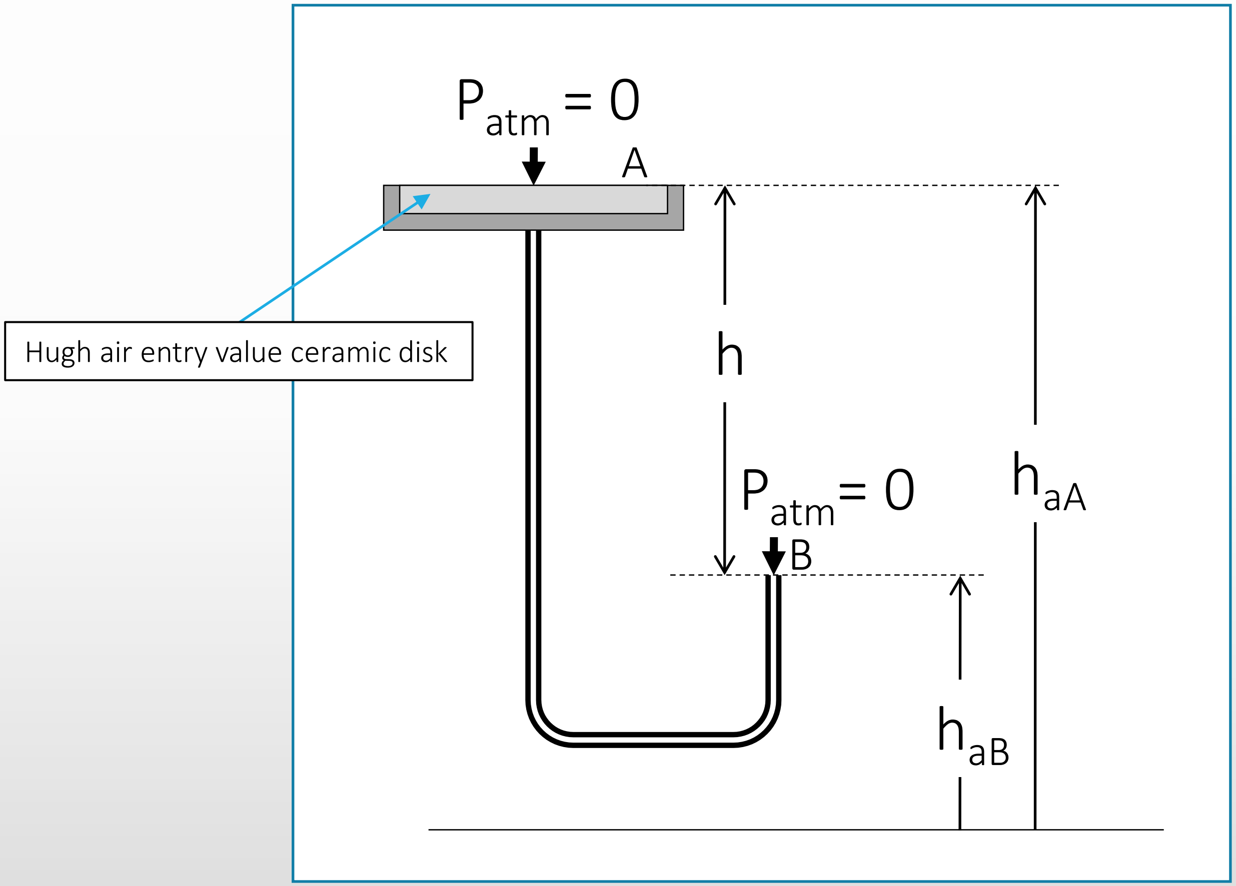
Modified from Holmes & Rose (1996)


Heads
Piezometric
Gravitational
Total


If evaporation occurs suction increases
Heads
Piezometric
Gravitational
Total

Suction Plate

Working principle

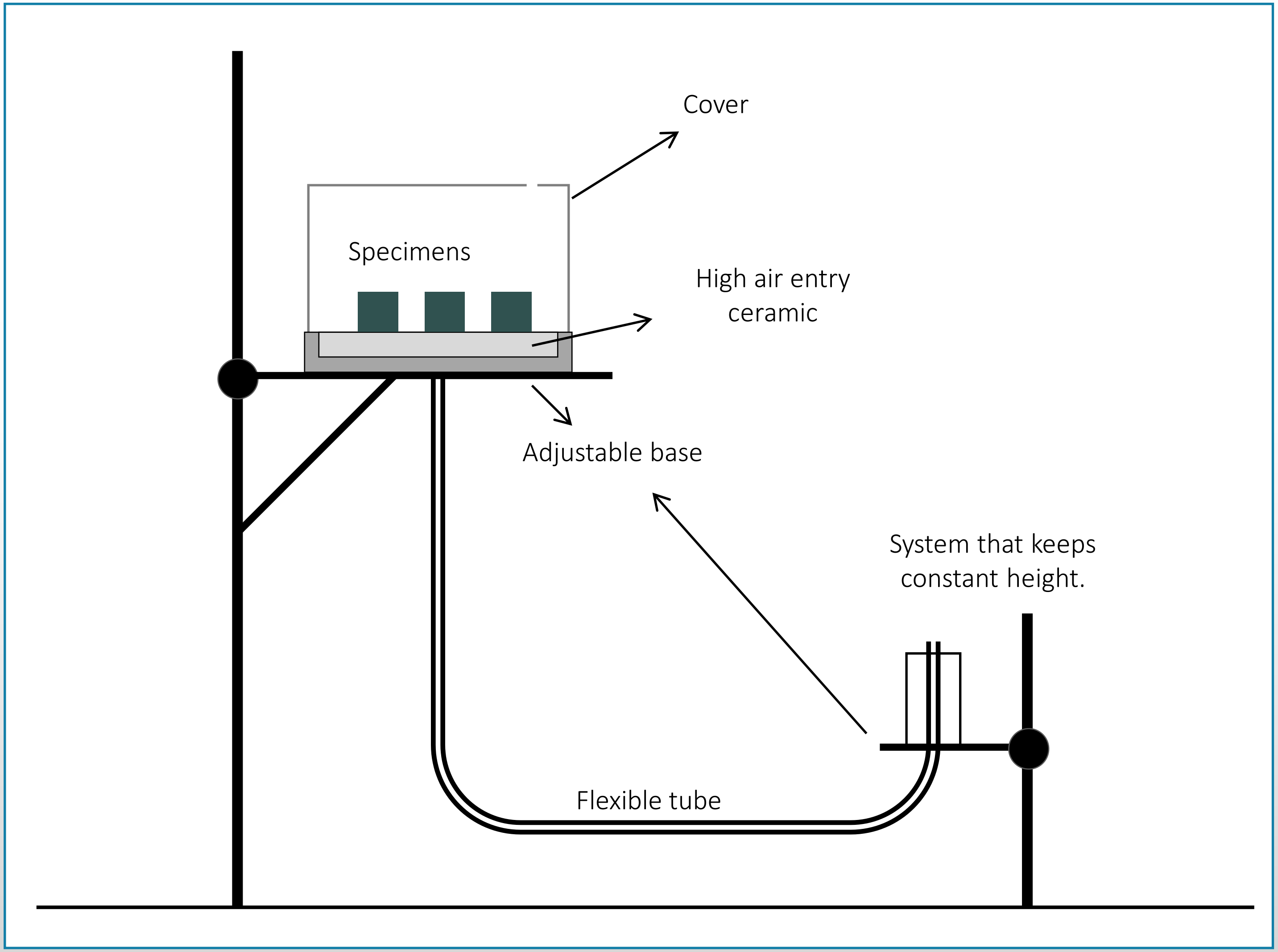


$$suction = h * \gamma_w$$

The suction applied by the difference in height (h) is not enough to desaturate the ceramic.

Suction Plate

Working principle



Suction Plate

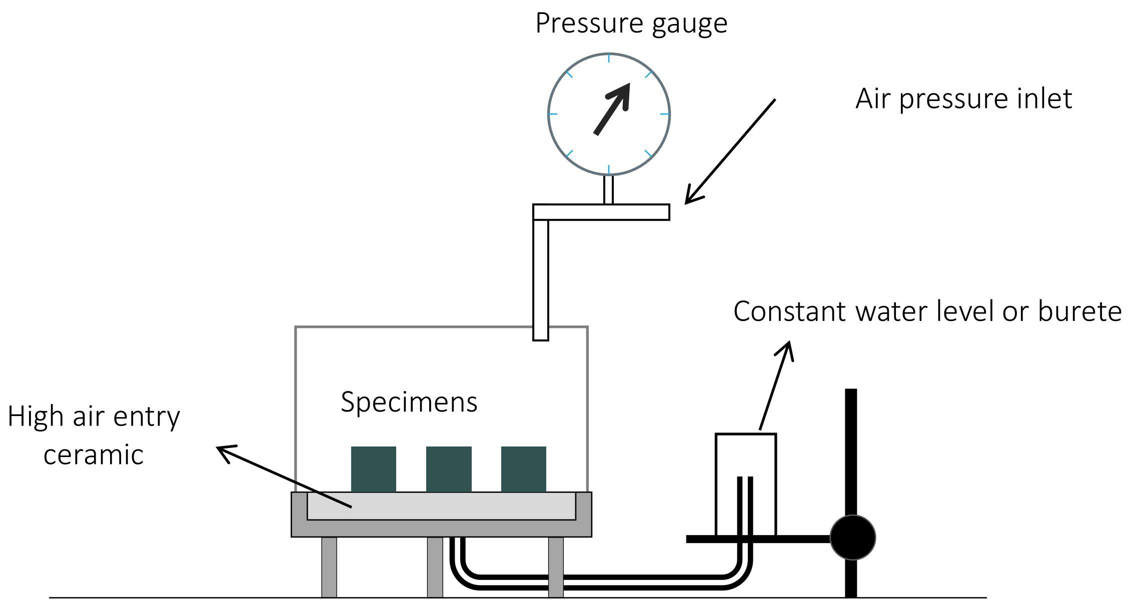
Procedures

- The system should be saturated to eliminate any visible bubble.
- The ceramic should be saturated over night under pure water using a high vacuum pump.
- The use of hot water (above 35º) improve the saturation.
- The specimens can be undisturbed, compacted or remoulded.
- Volume of the specimen should be determined in order to be able to calculate volume based parameters
- Specimen is placed on the top of the ceramic taking care to have a intimate contact between soil water and ceramic water.
- In case the contact is not good a filter paper or silica should be used to improve the contact.
- The middle of the specimen and the output level of the system should be placed at the same level.
- After the specimen is placed water can added in the surrounding of the mould. Eventually water can be added from the top.
- The initial saturation procedure may take few days.
- After the saturation equilibrium the specimen is weighted and its volume determined.
- After that the differential height is increased.
- The choice of heights (suctions) depends on the soil type.
- The procedure is repeated for each increase in height.
- If the soil is not going to be used for another test (e.g. pressure plate or filter paper), the sample should be placed in the over after weighting and determining its volume.
- With the dry weight of the specimen water content and any volume based parameter can be obtained.

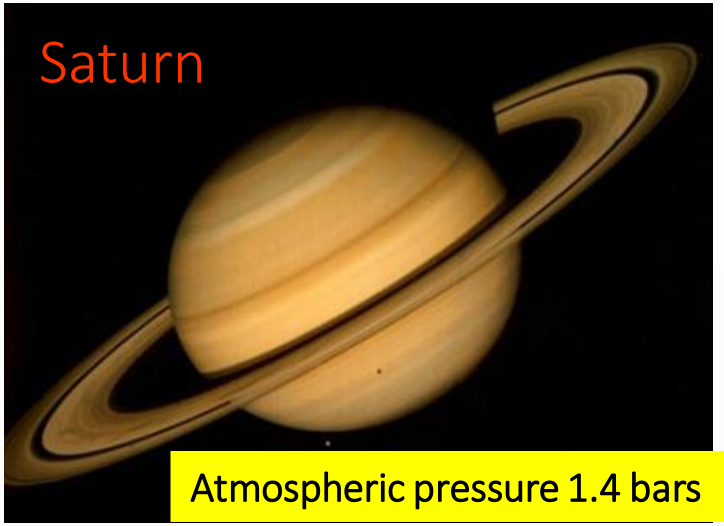
Pressure Plate

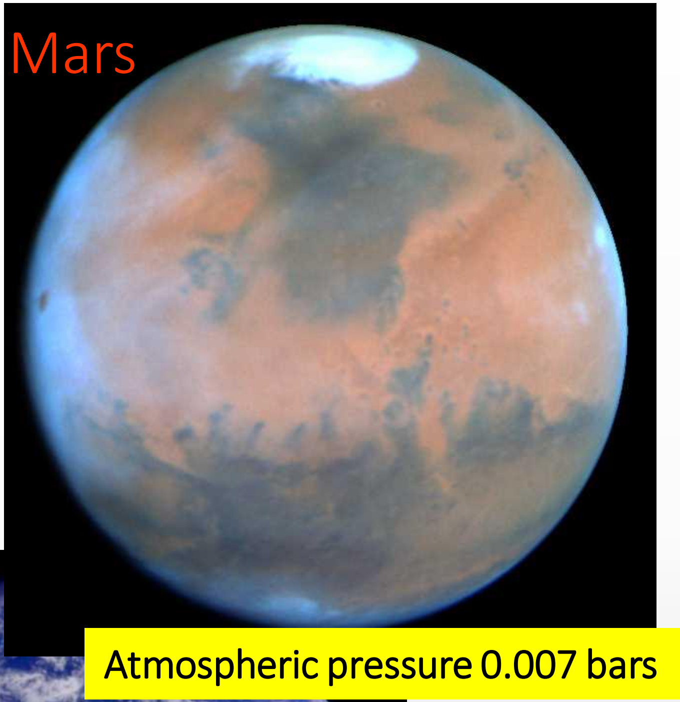
Axis translation technique

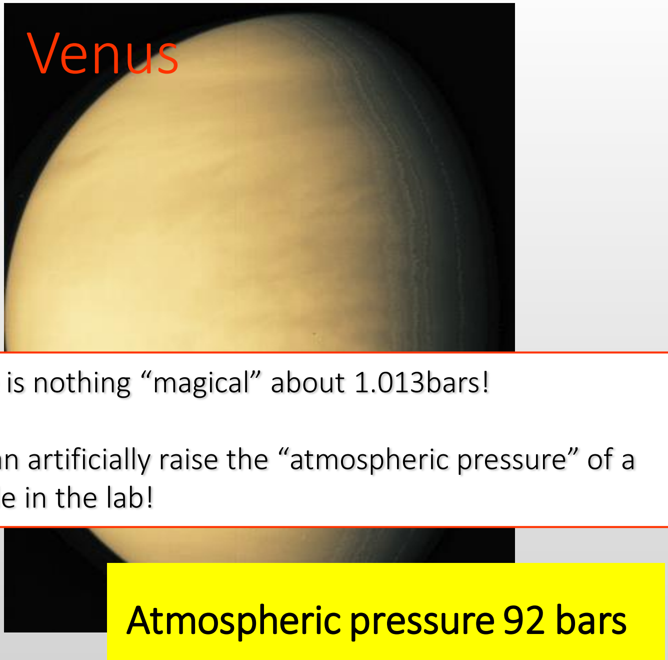
Pressure Plate



The Axis-Translation Technique

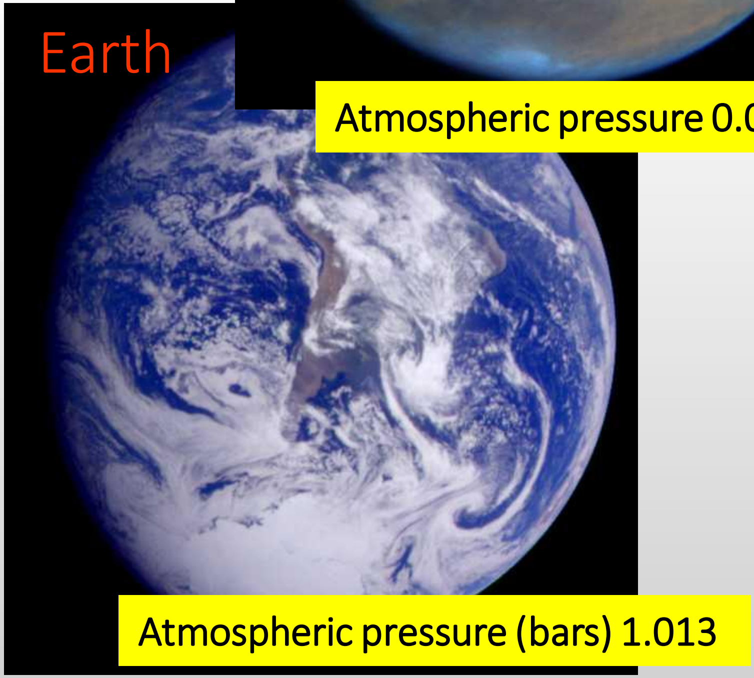




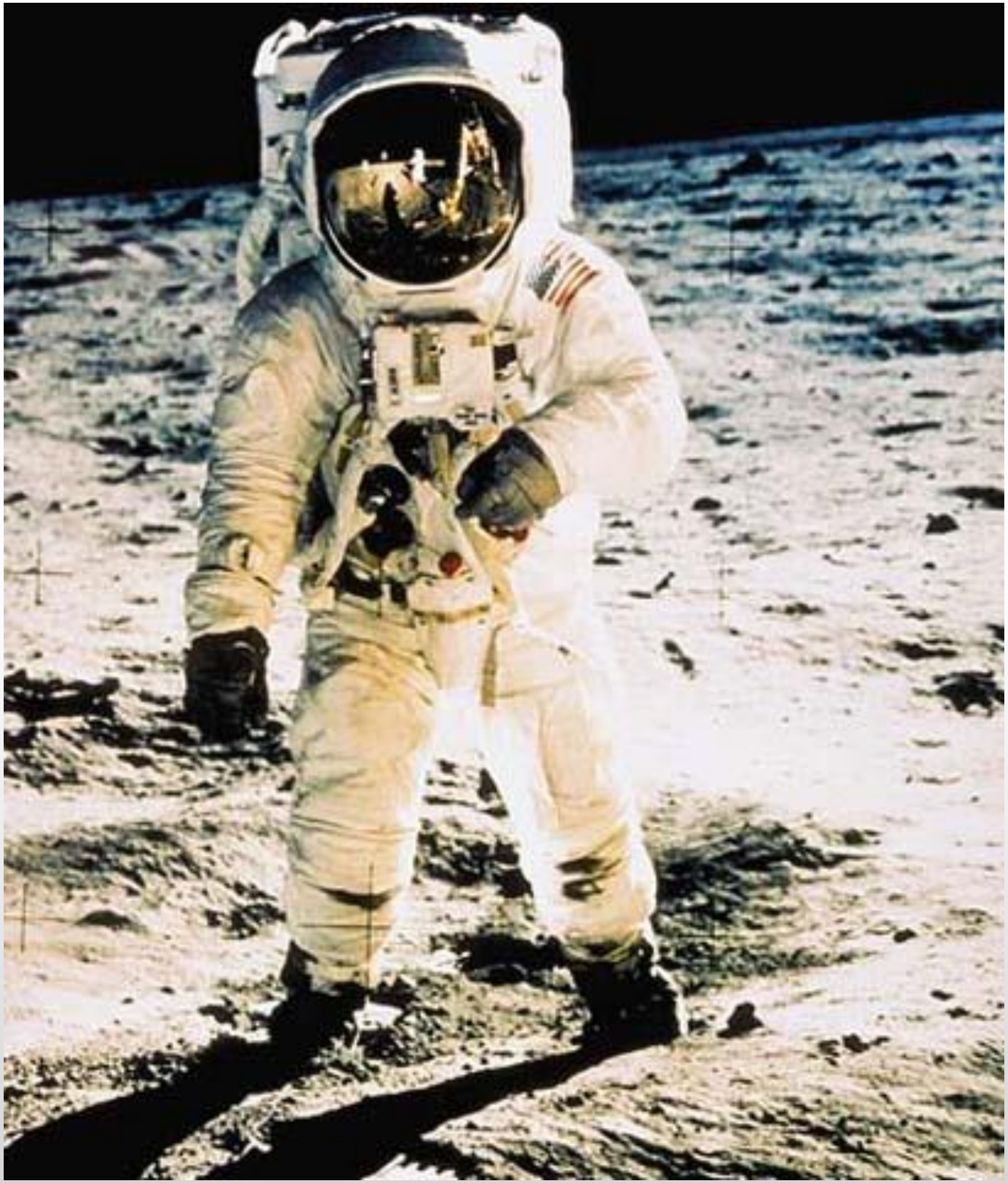


There is nothing “magical” about 1.013bars!

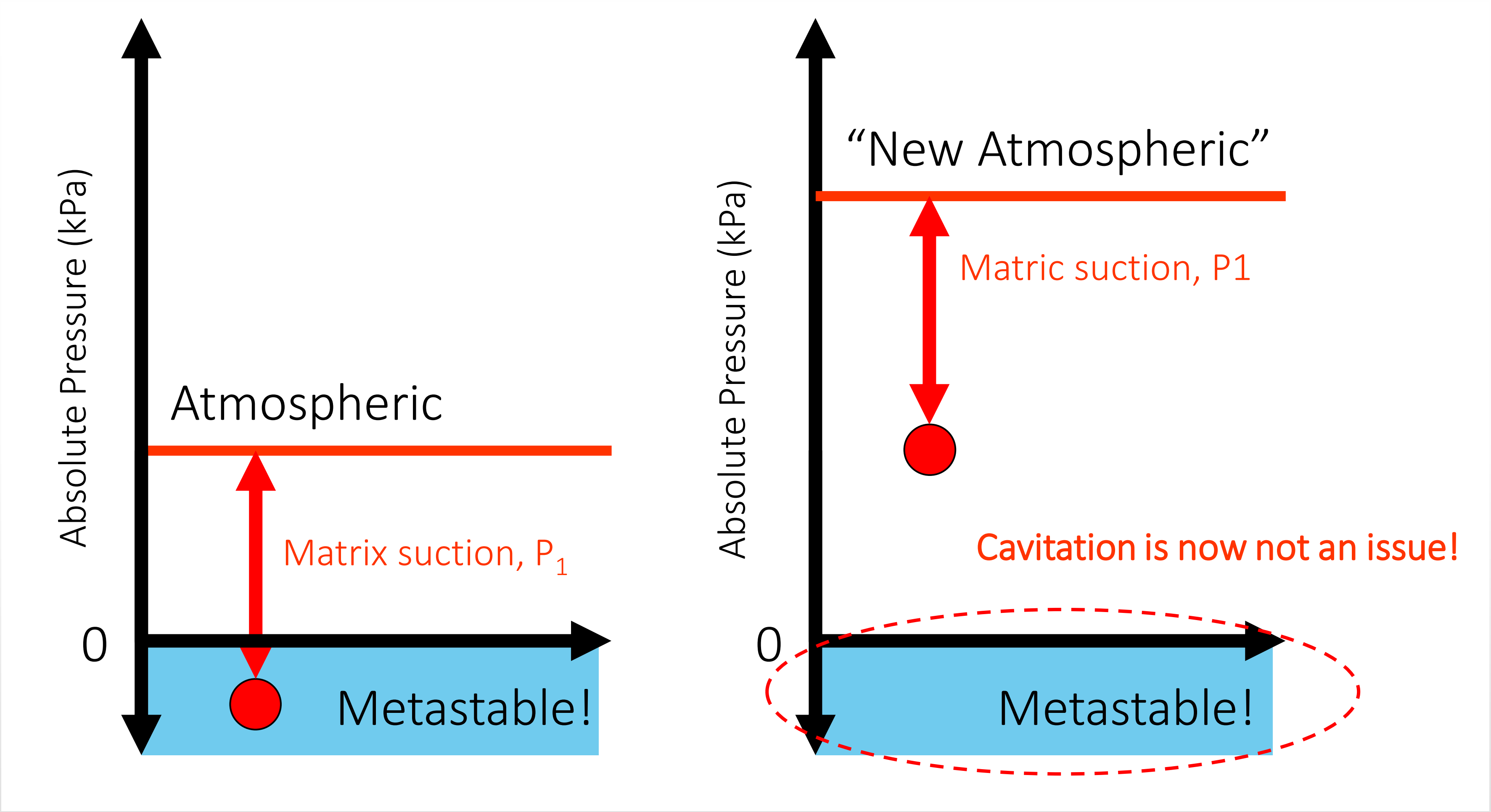
We can artificially raise the “atmospheric pressure” of a sample in the lab!



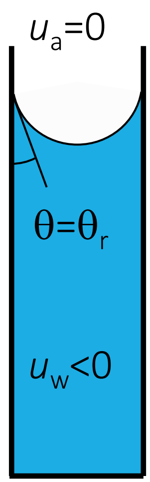
http://www.solarviews.com/



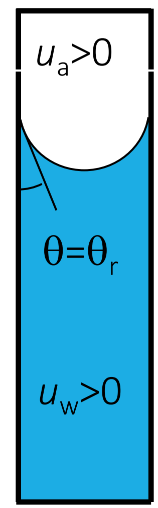
The Axis-Translation Technique



Conceptual justification



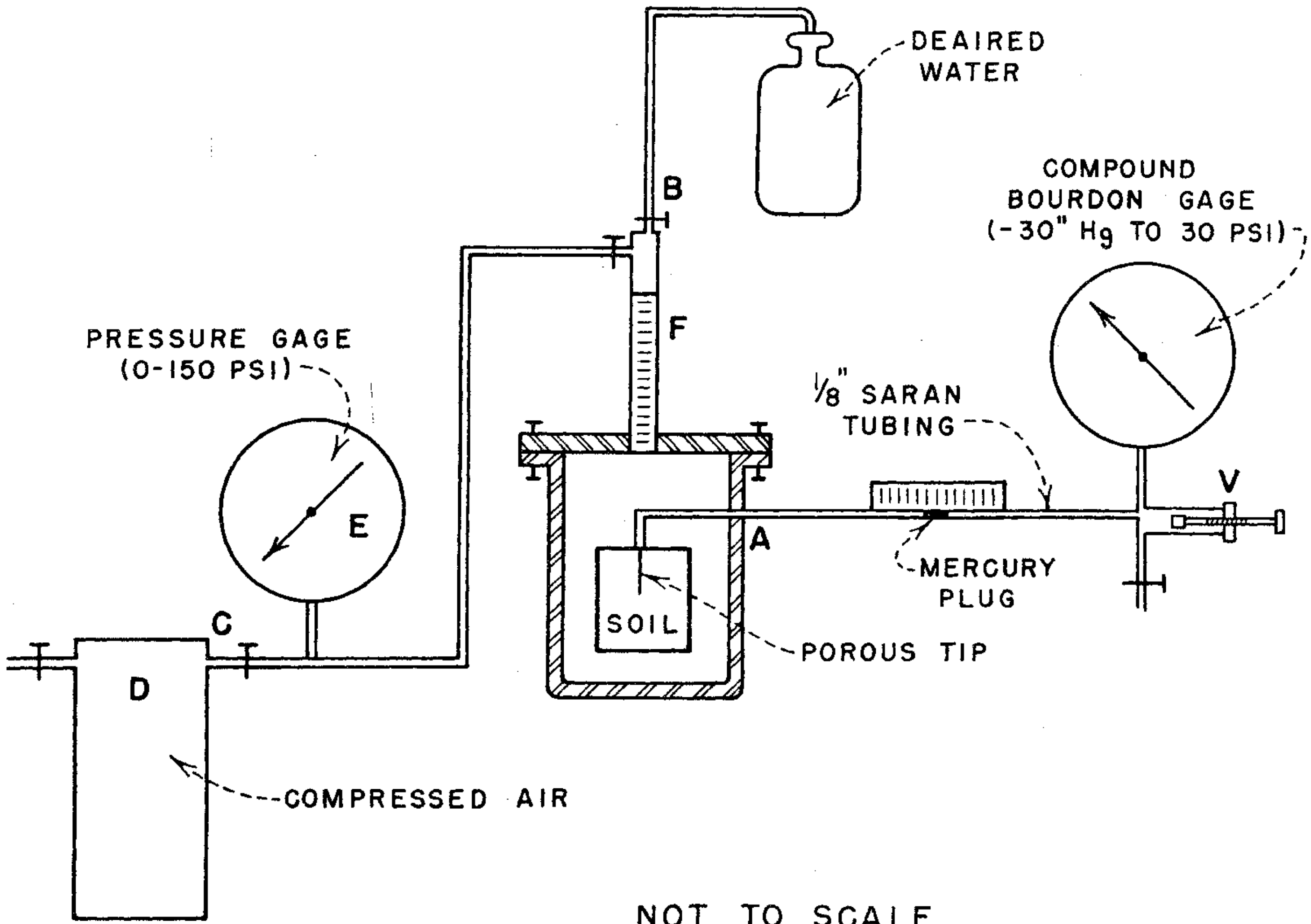
u_w-u_a= -2T $cos\theta_r$ /r



u_w-u_a= -2T $cos\theta_r$ /r

For incompressible liquid, an increase in air pressure does not alter the meniscus curvature and, hence, the difference u_w-u_a

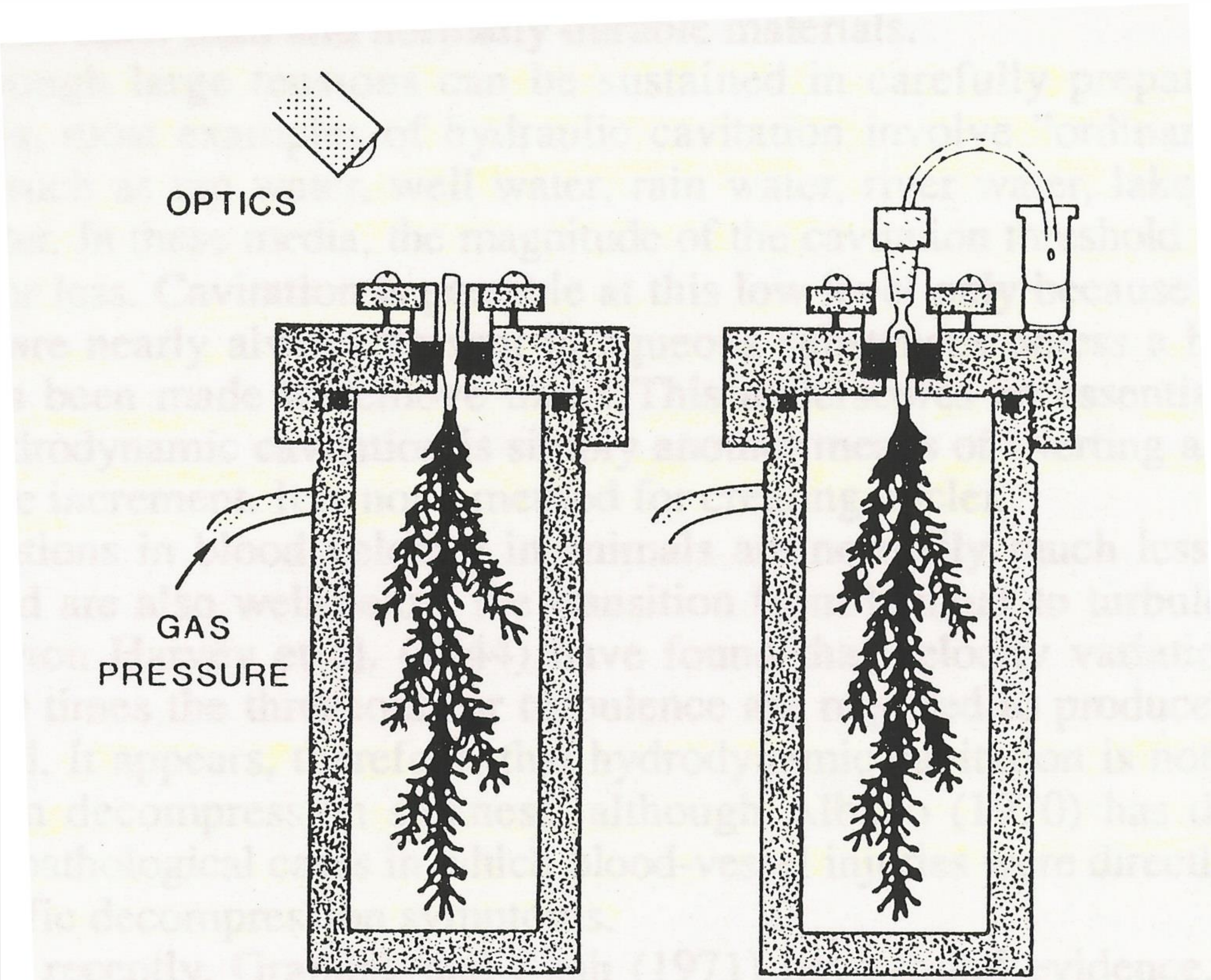
The Axis-Translation Technique



Hilf (1956)

Layout of apparatus for triaxial compression test with pore pressure measurement

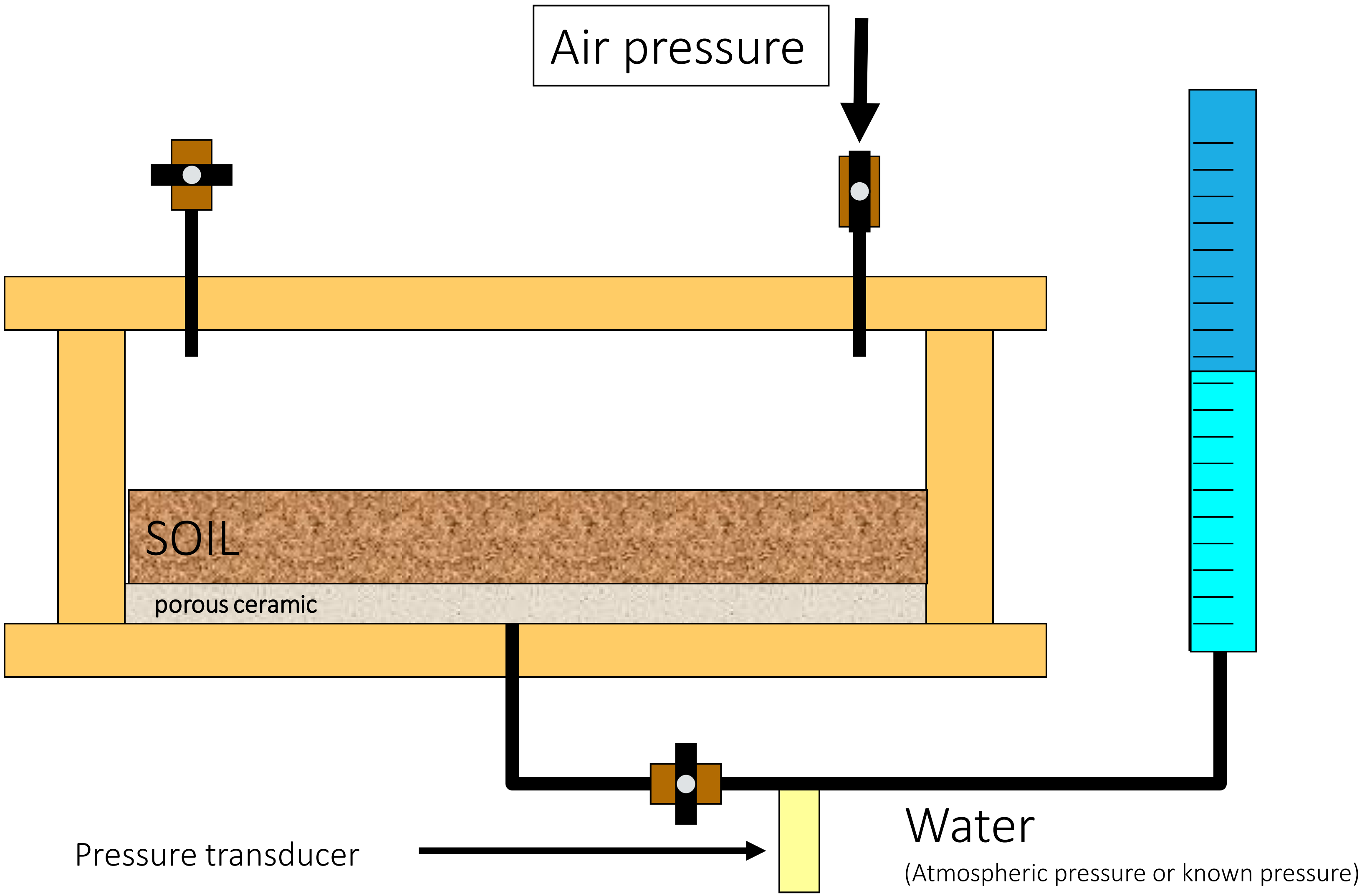
The Axis-Translation Technique



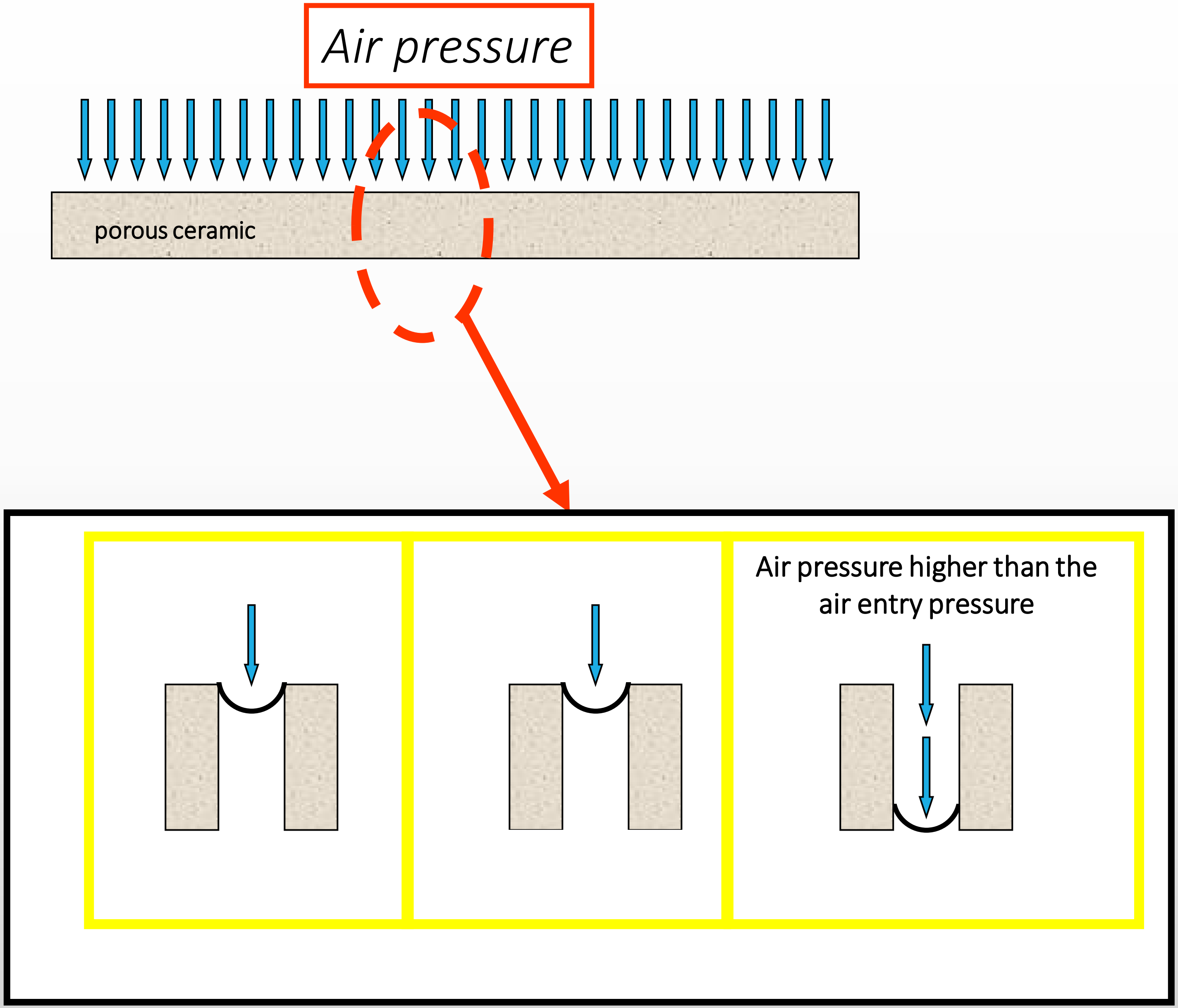
Scholander et al (1965)

Apparatus used to measure the internal tensile pressure in a twig severed from its stalk

The Axis-Translation Technique



The Axis-Translation Technique



Tensiometer versus Axis-Translation

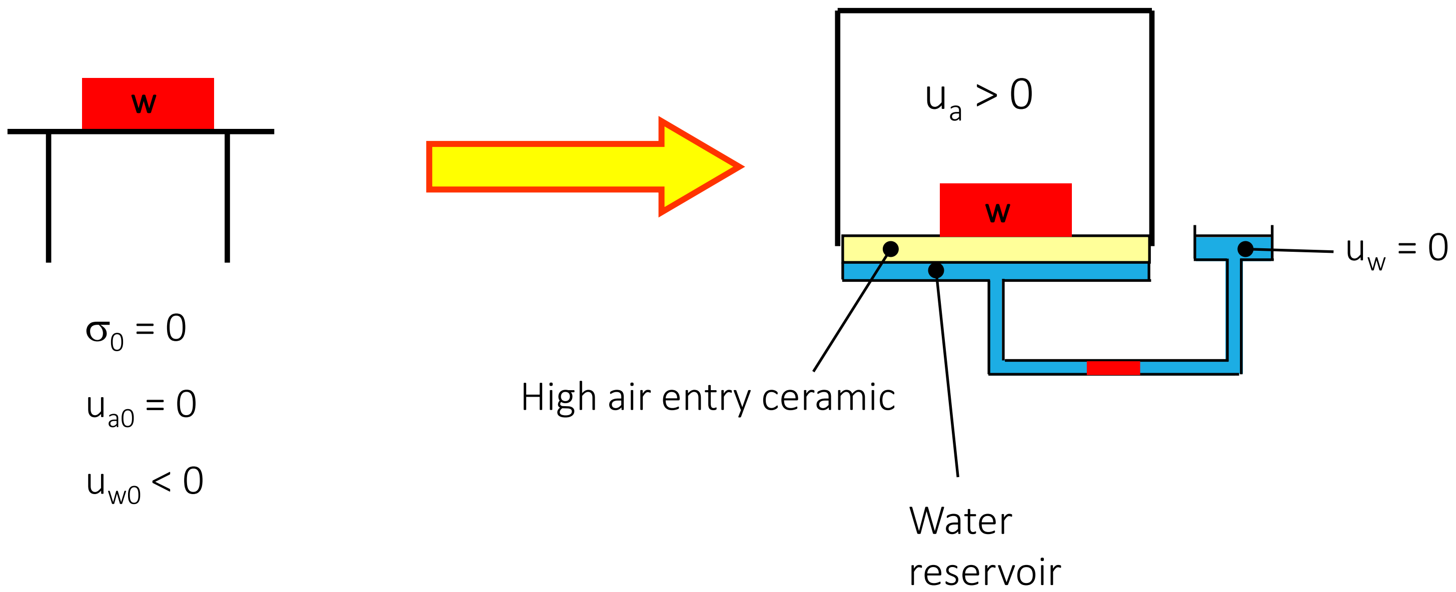
<u>Similarities</u>

- A pressure differential is measured across a high air entry ceramic
- Expansion of air cavities in the ceramic may also take place in axis-translation technique, but this problem is (probably?) negligible if the ceramic is adequately saturated
- Water pressure in the water reservoir may differ from pore-water pressure if the ceramic is not adequately saturated

<u>Differences</u>

- Water in axis-translation is NOT in a metastable state
- In axis-translation, relatively large air cavities in the ceramic may slowly expand (because of air diffusion) but there is not rapid expansion of cavitation nuclei.

Validity of Axis-Translation Technique



At the same water content, can we state that

$$u_{a0} - u_{w0} = u_a - u_w$$

and hence chamber air pressure u_a equals negative pressure $-u_{w0}$?

Validation of the Axis-Translation

Medium degree of saturation (S_r < 0.85-0.9)

- Bishop & Donald (1961)
- Bocking & Fredlund (1980)
- Tarantino, Mongiovi, and Bosco (2000)

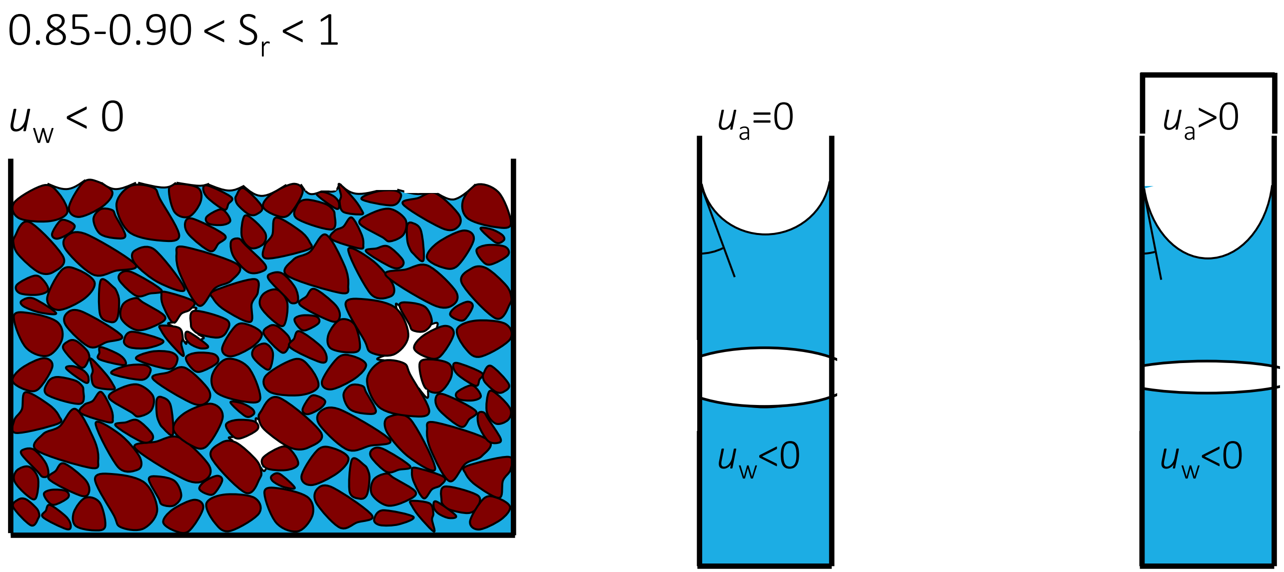
High degree of saturation (Sr > 0.85-0.9)

- Fredlund & Morgenstern (1977) (data not really consistent)
- Tarantino and Mongiovi (2005) (one single test)

Is axis translation reliable at high degrees of saturation ?

Do we have clear and convincing experimental evidence ?

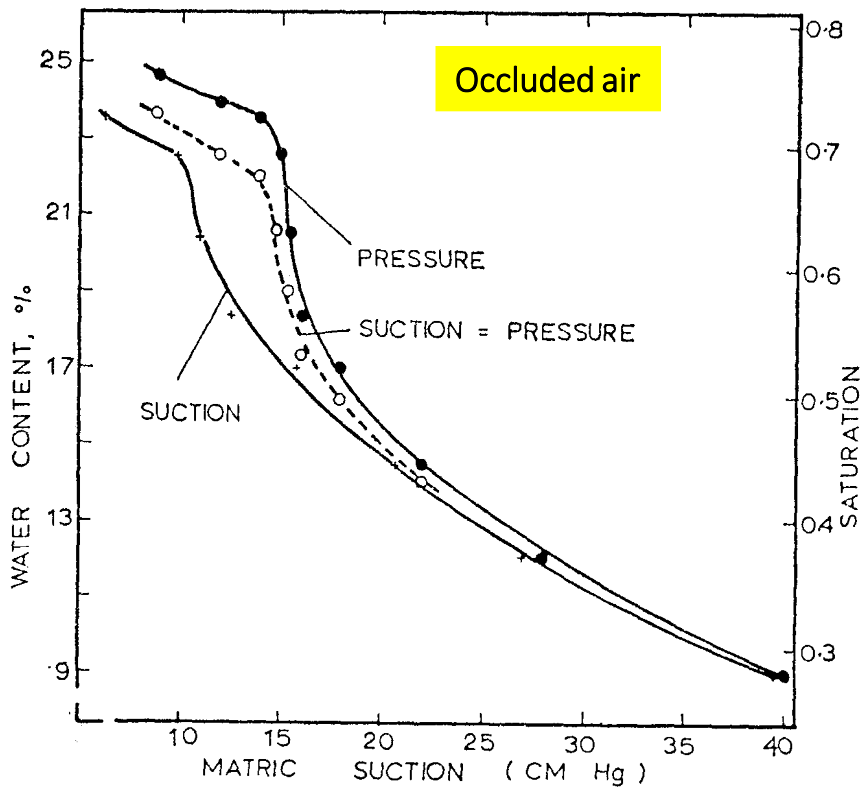
Conceptual limitation of Axis-Translation



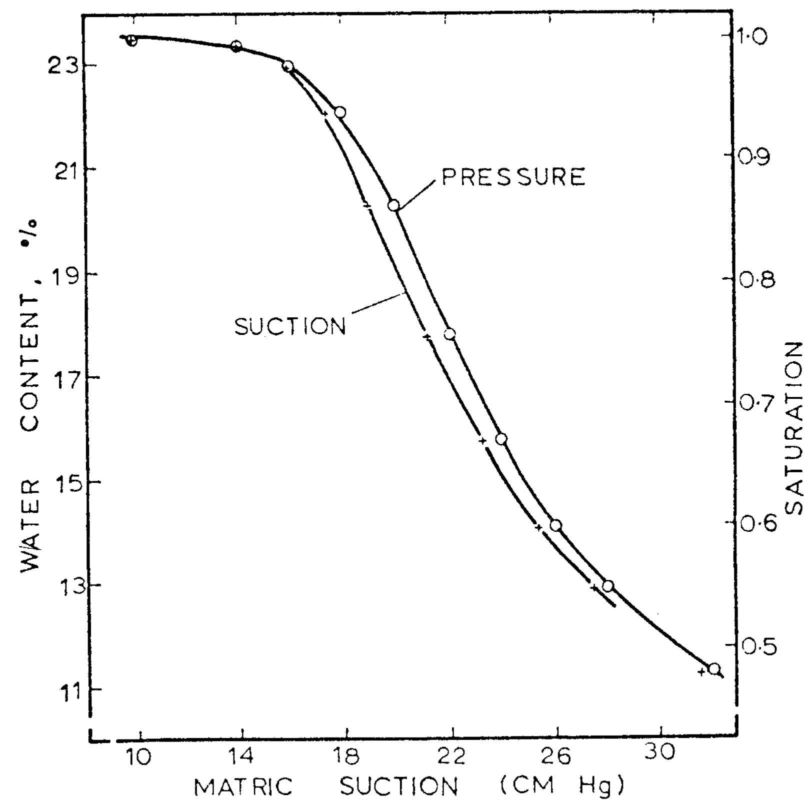
At high degree of saturation, we have to figure out a capillary tube with compressible liquid. The increase in air pressure increase the boundary meniscus curvature and, hence, the difference u_w-u_a

Axis translation might overestimate suction at high degrees of saturation

The Axis-Translation Technique



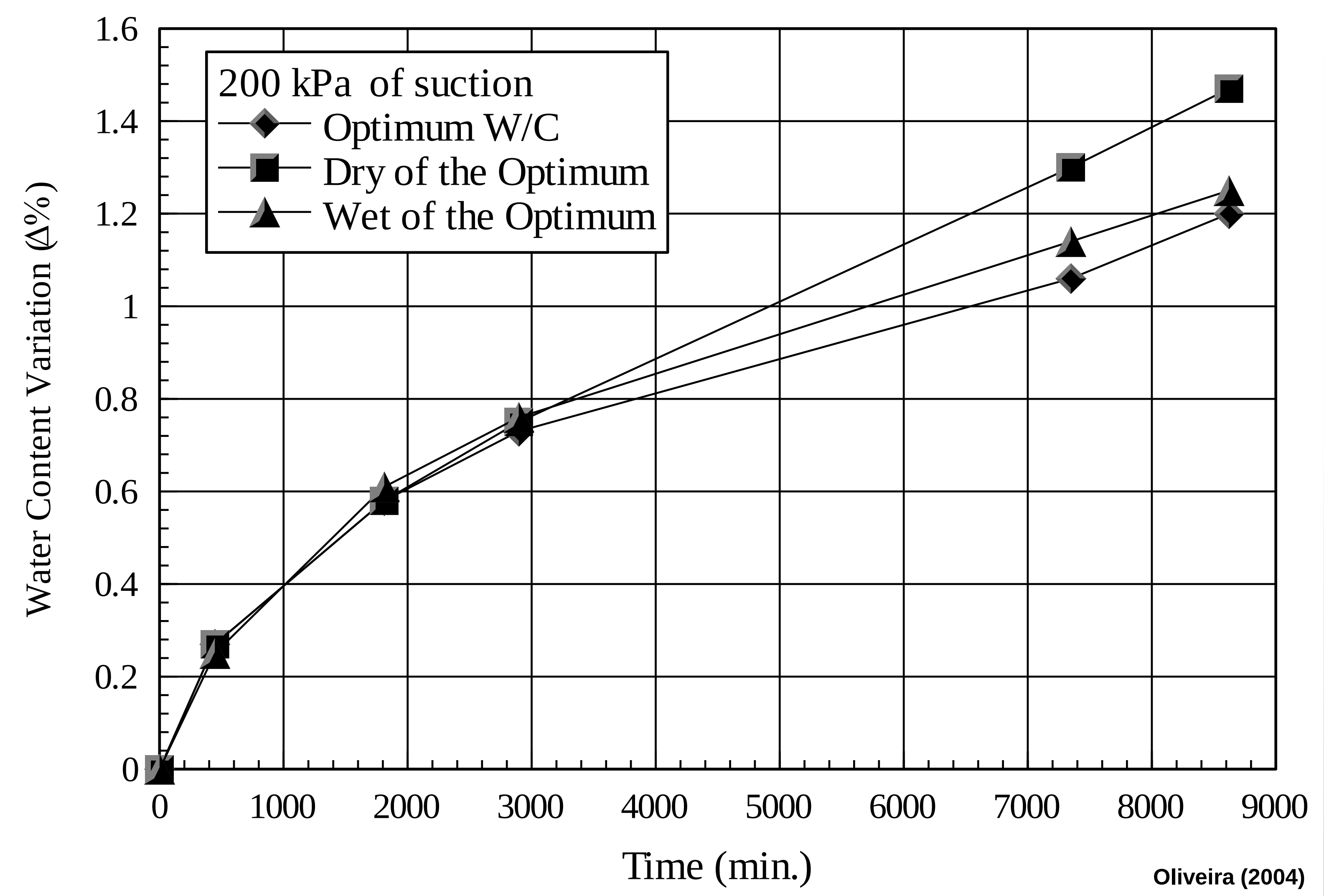
Soil-water retention curve for initially unsaturated coarse silt.



Soil-water retention curve for initially saturated coarse silt

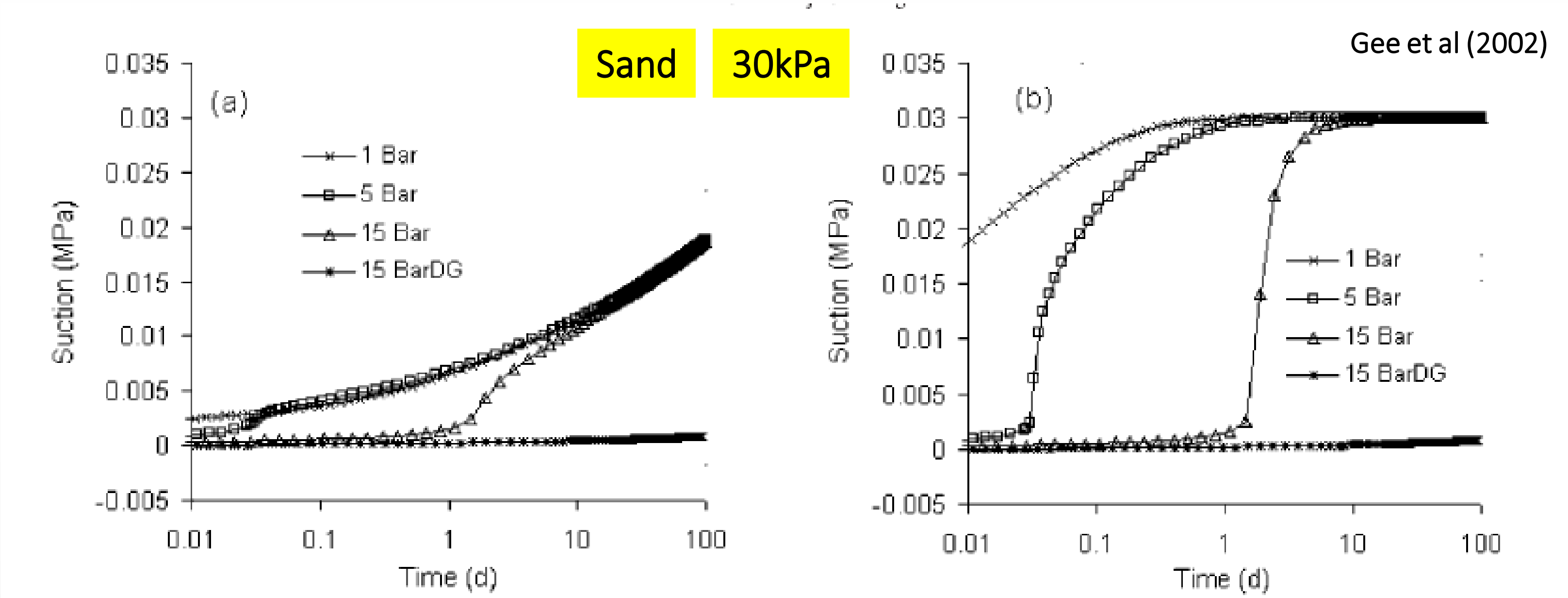
Chahal and Yong, 1965

The Axis-Translation Technique



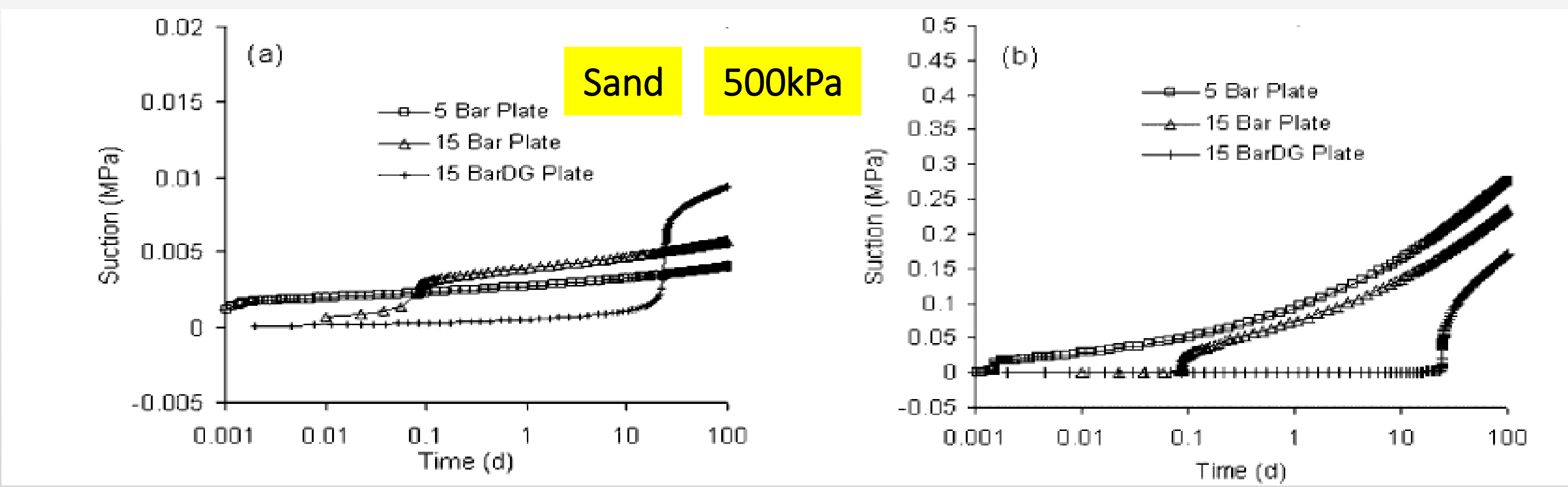
Soil water content change during axis translation

The Axis-Translation Technique



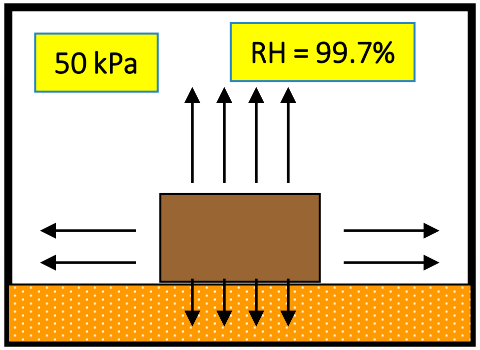
The 5 mm height (sample midpoint)

The soil-plate interface

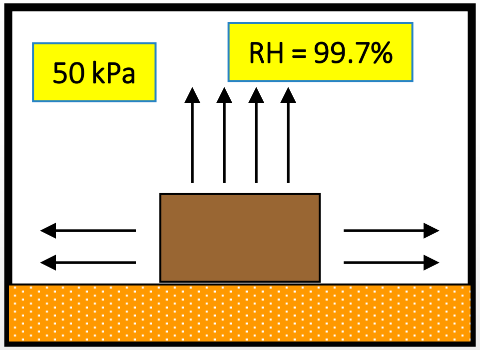


The Axis-Translation Technique

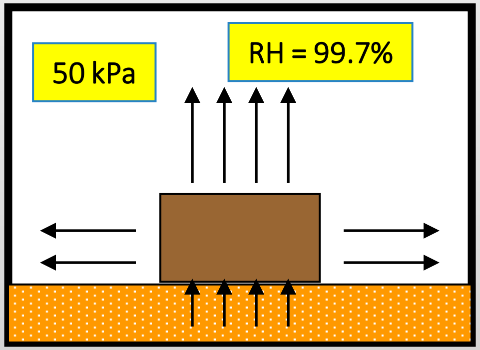
(a)

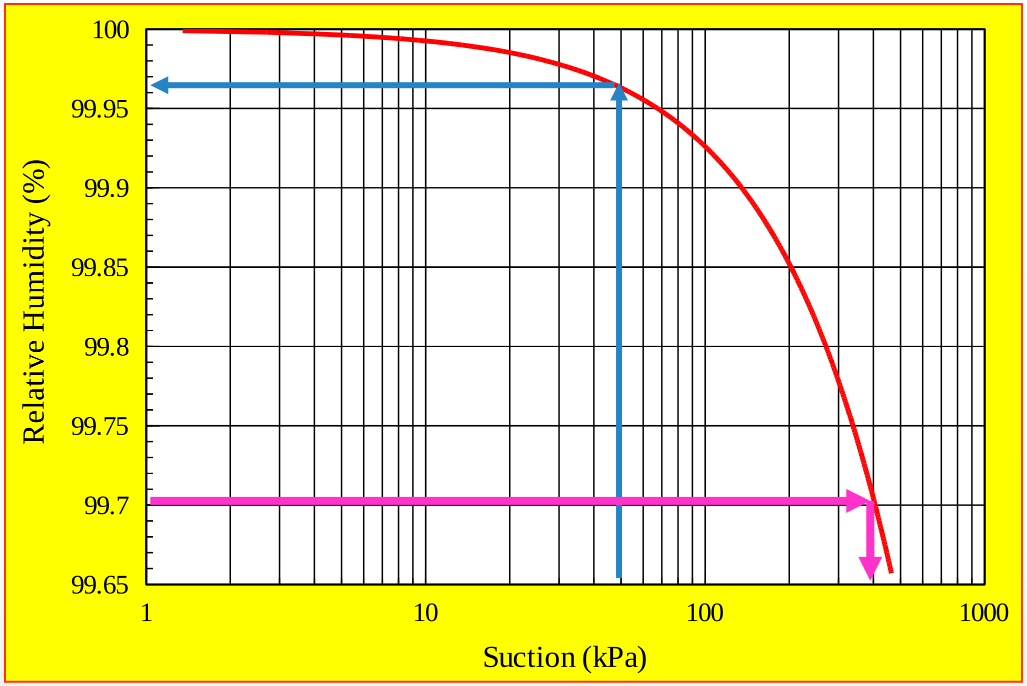


(b)



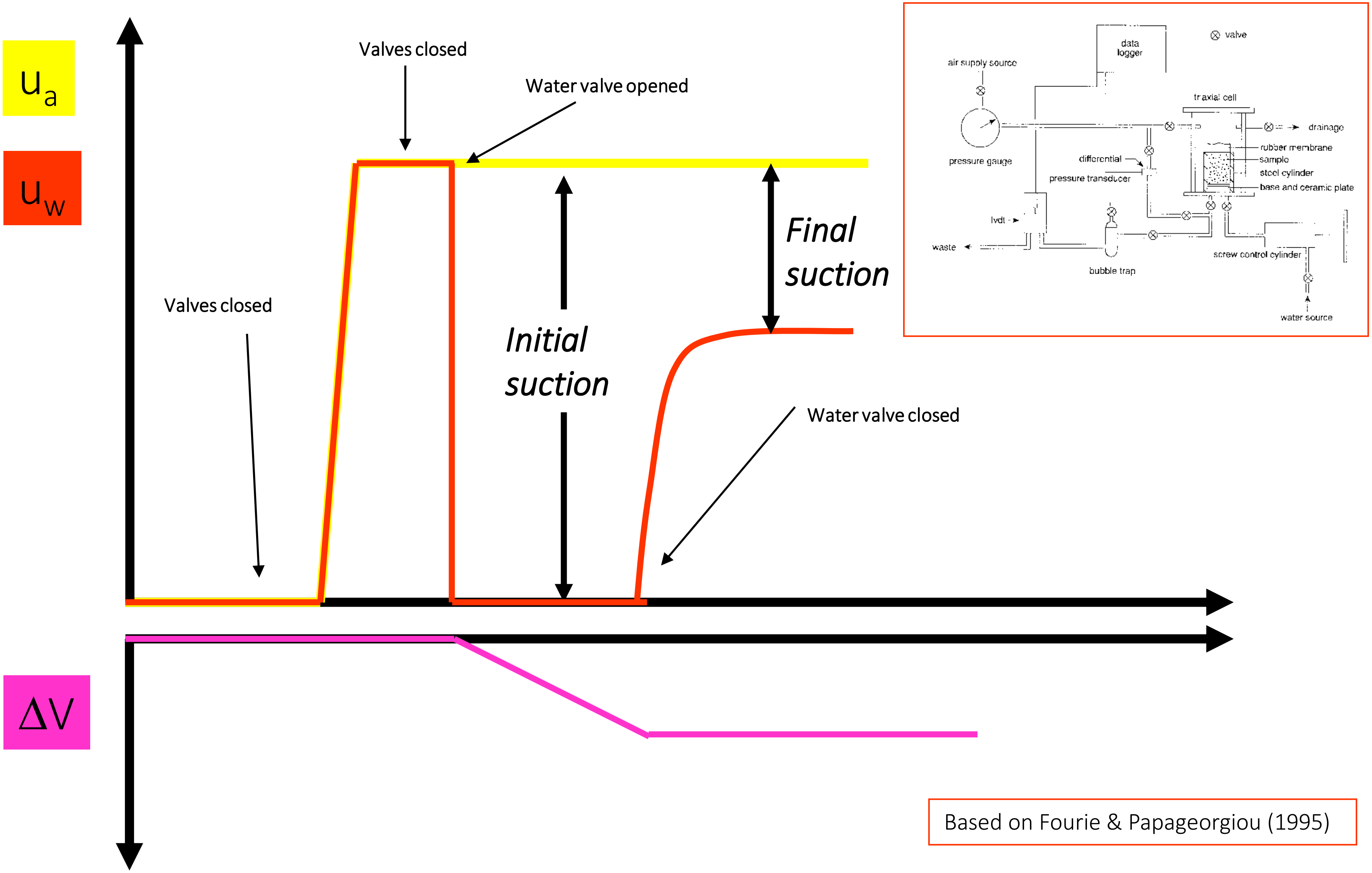
(c)





Relative humidity inside the chamber

The Axis-Translation Technique



Based on Fourie & Papageorgiou (1995)

Technique to reduce the equilibrium time

WATERMARK Sensors

TEROS 21


WP4C
Dewpoint PotentioMeter
OPEN/LOAD

Pre
Water Activity Analyzer
OPEN/LOAD
READ

Exercises

1. *In which situation the osmotic suction can affect the actual measurement of matrix suction?*
2. *Why an ordinary tensiometer can measure higher values of suction if the measurement is made in Santos in relation to São Paulo city?*
3. *What is the importance of the ceramic for a tensiometer and why it should have a high air entry value?*
4. *What level of suction you consider important for engineering purpose?*
5. *What kind of suction is induced when you place a soil sample out of contact with a salt solution in a closed environment?*
6. *Consider that a salt solution generate a RH that induces a suction of 700 kPa. If a filter paper is placed in contact with a specimen (with no salt in it) and another is placed out of contact, what value of suction you should expect from both filter papers?*
7. *When using a suction plate or a pressure plate the specimen is in contact with air. What is the influence of the RH of that air on the equilibrium of the system?*
8. *How can you generate suction for calibration of all sensors and equipment presented here?*