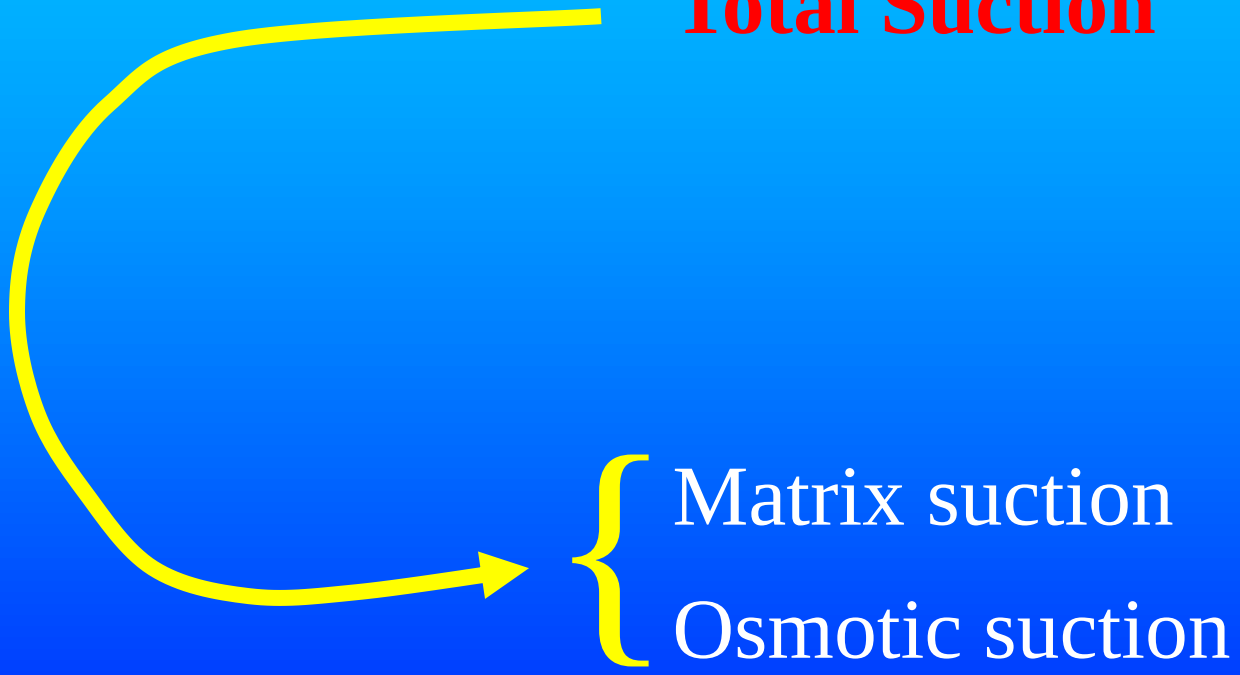
Medição da Sucção

Fernando A. M. Marinho
2017

Soil Suction Components



Métodos de Medição de Sucção

- ✓ **Psicrômetro**
- ✓ **Papel Filtro**
- ✓ **Tensiômetro**
- ✓ **Sensor de condutividade térmica**
- ✓ **Translação de eixos**
- ✓ **Condutividade elétrica**
- ✓ **TDR**

PSICRÔMETRO

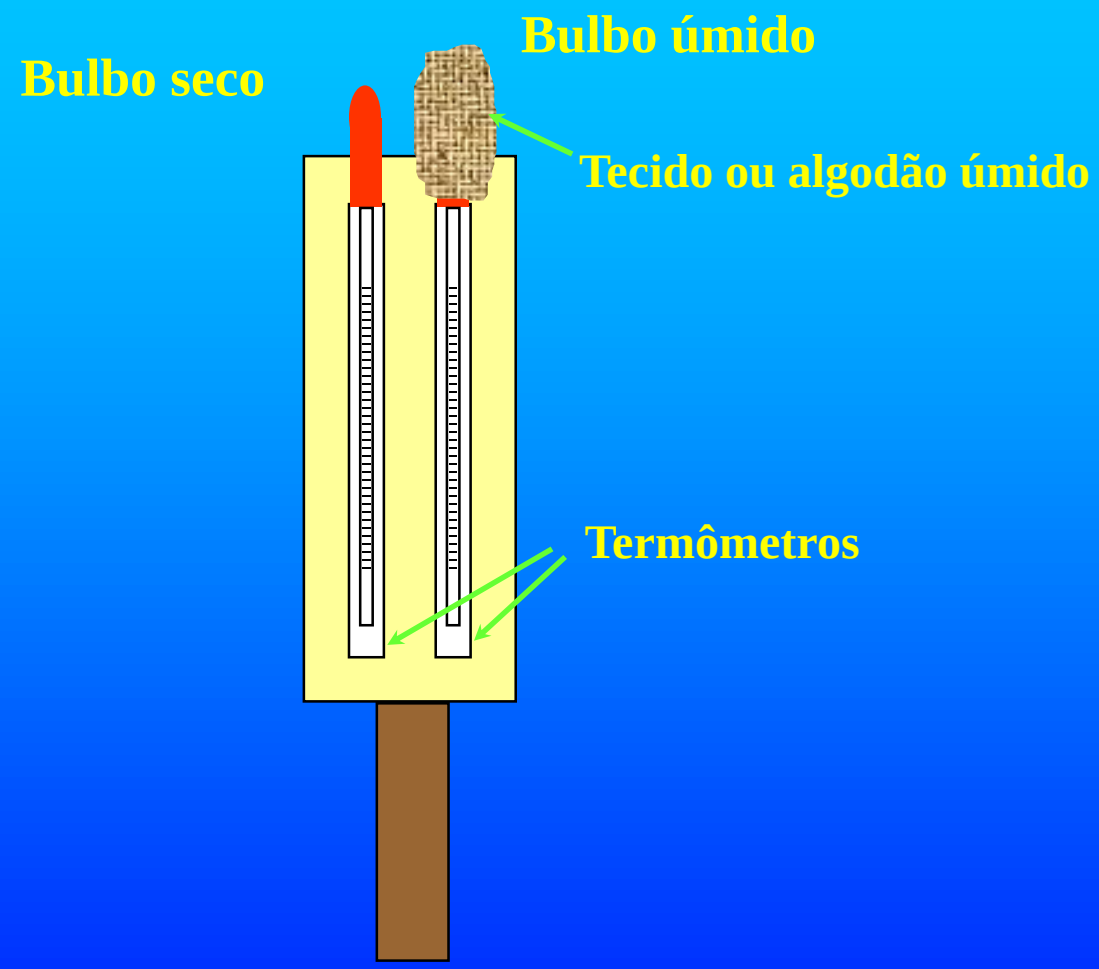
Seebeck Effect

Dry Bulb

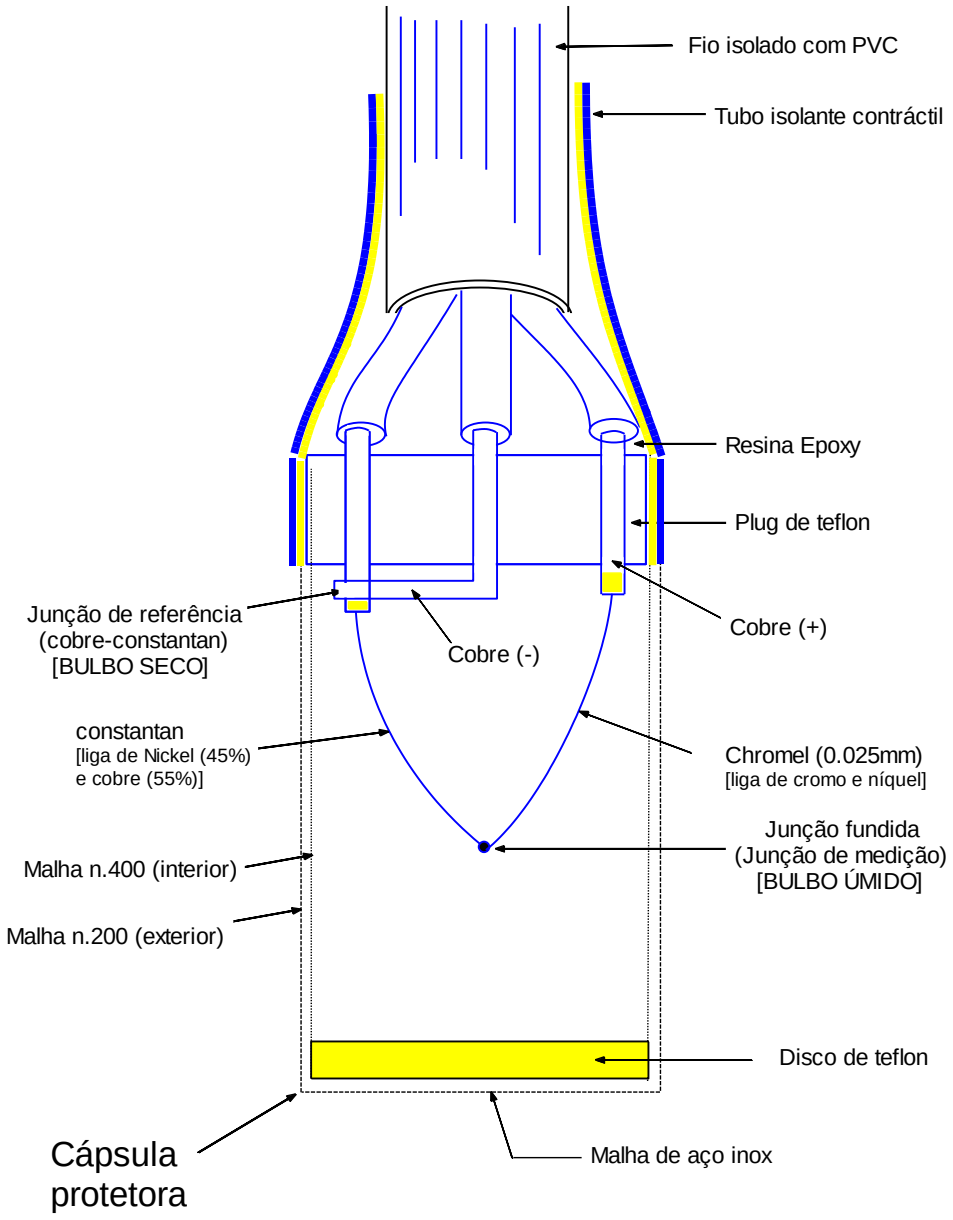
Wet Bulb

Peltier effect

Psicrômetro Caseiro




85.5
DP 50.1F
Humi 43.5%


Fio isolado com PVC
Tubo isolante contráctil
Resina Epoxy
Plug de teflon
Junção de referência
(cobre-constantan)
[BULBO SECO]
Cobre (-)
Cobre (+)
constantan
[liga de Nickel (45%)
e cobre (55%)]
Chromel (0.025mm)
[liga de cromo e níquel]
Junção fundida
(Junção de medição)
[BULBO ÚMIDO]
Malha n.400 (interior)
Malha n.200 (exterior)
Disco de teflon
Cápsula
protetora
Malha de aço inox

Umidade Relativa do Ar

$$RH = \frac{\text{Pressão parcial de vapor}}{\text{Pressão de vapor de saturação}}$$

Pressão de Vapor

$$P = 6.11 * 10^{\left[\frac{7.5T}{(237.7+T)}\right]}$$

Relative Humidity Table (in percent)

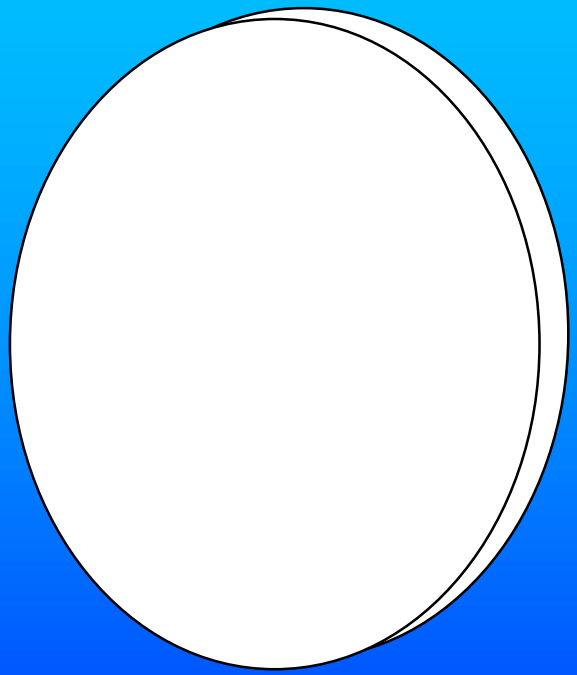
Dry Bulb	Dry Bulb Minus Wet Bulb (degrees celsius)									
°C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
10	88	77	66	55	44	34	24	15	6	
11	89	78	67	56	46	36	27	18	9	
12	89	78	68	58	48	39	29	21	12	
13	89	79	69	59	50	41	32	22	15	7
14	90	79	70	60	51	42	34	25	18	10
15	90	81	71	61	53	44	36	27	20	13
16	90	81	71	63	54	46	38	30	23	15
17	90	81	72	64	55	47	40	32	25	18
18	91	82	73	65	57	49	41	34	27	20
19	91	82	74	65	58	50	43	36	29	22
20	91	83	74	67	59	53	46	39	32	26
21	91	83	75	67	60	53	46	39	32	26
22	91	83	76	68	61	54	47	40	34	28
23	92	84	76	69	62	55	48	42	36	30
24	92	84	77	69	62	56	49	43	37	31
25	92	84	77	70	63	57	50	44	39	33

Limitações do Psicrômetro

- Elevado custo
- Sensível a variações de temperatura
- Elevado tempo de resposta

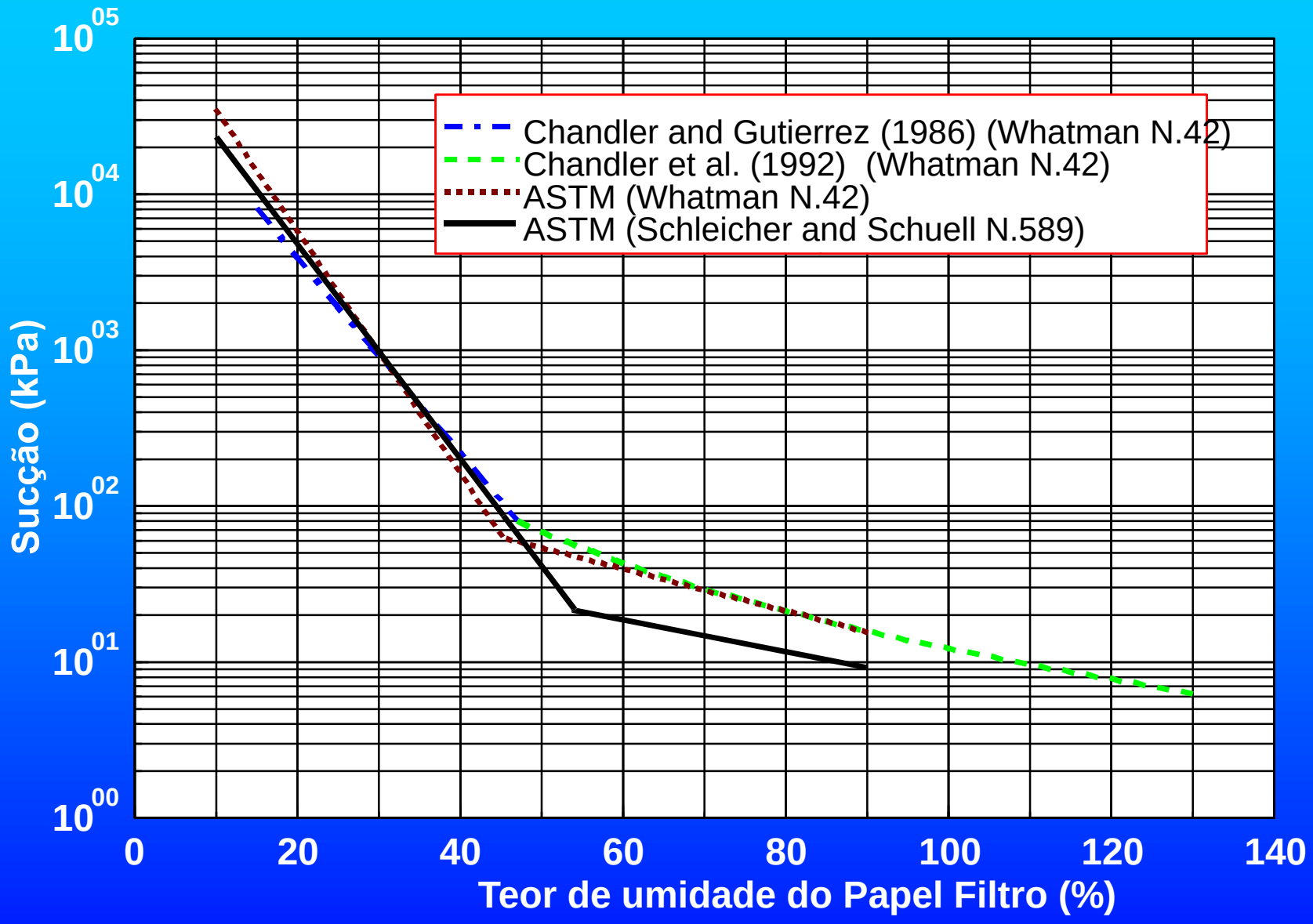
Técnica do Papel Filtro

Papel Filtro Quantitativo



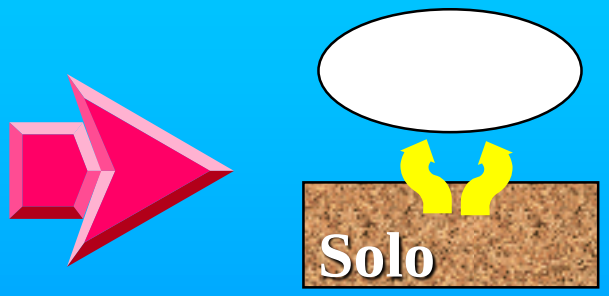
Papel comum

Curvas de Calibração de Papeis Filtro



Sucção Total

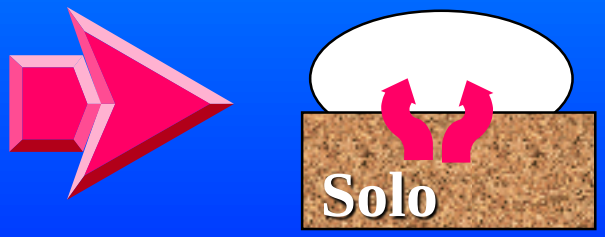
Fluxo de vapor



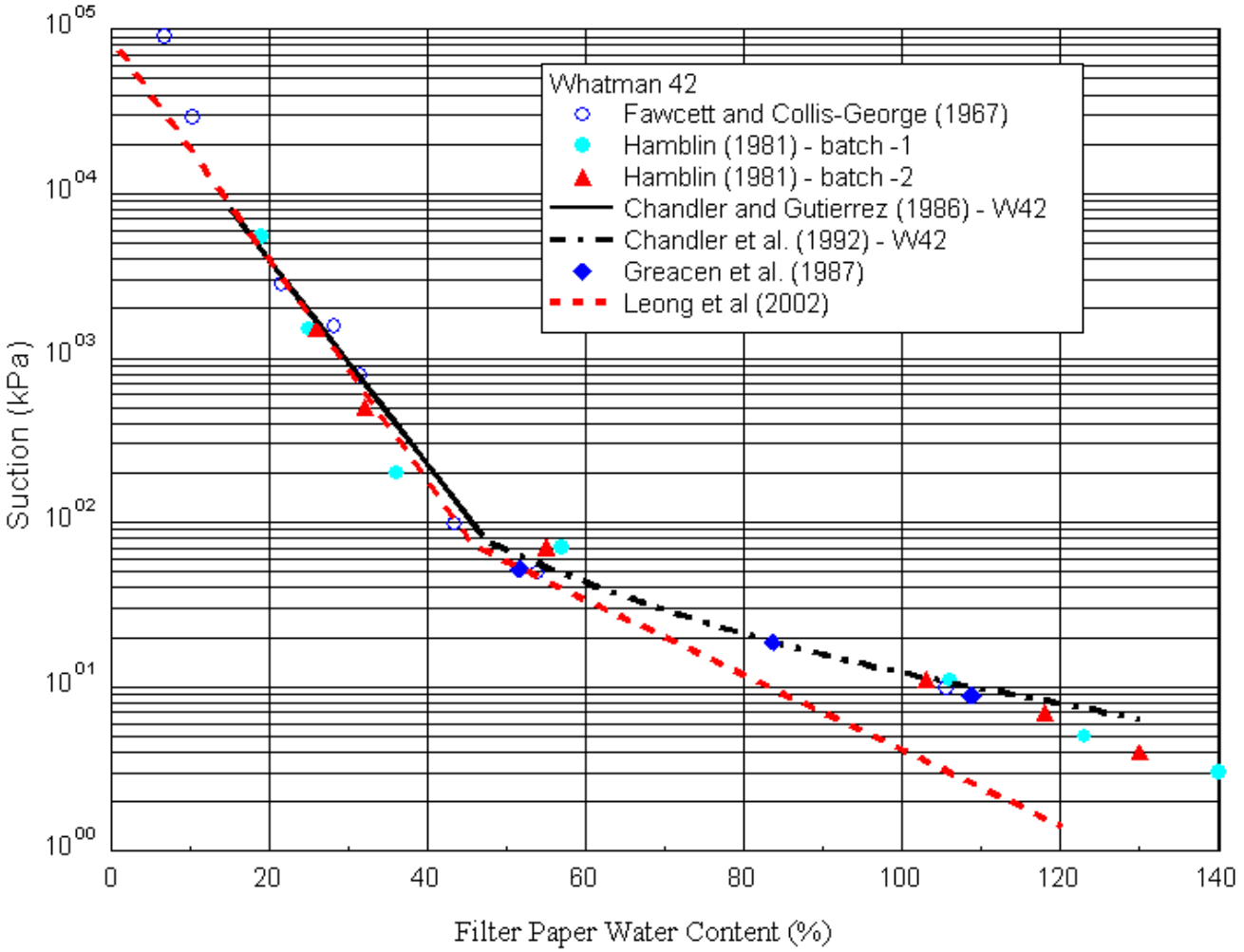
ou

Sucção Matricial

Fluxo capilar

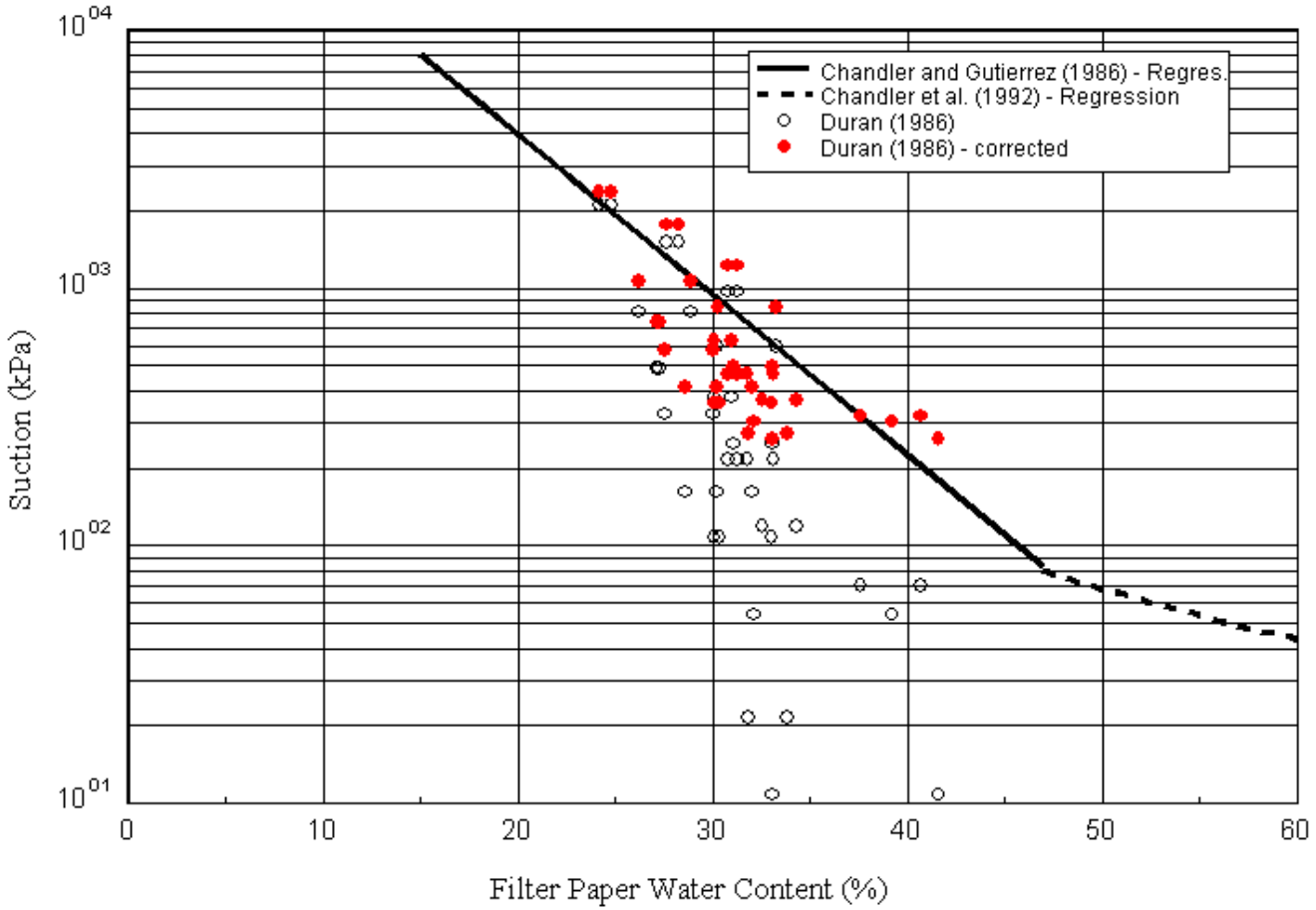


Curvas de Calibração do Whatman 42



Marinho & Oliveira (2006)

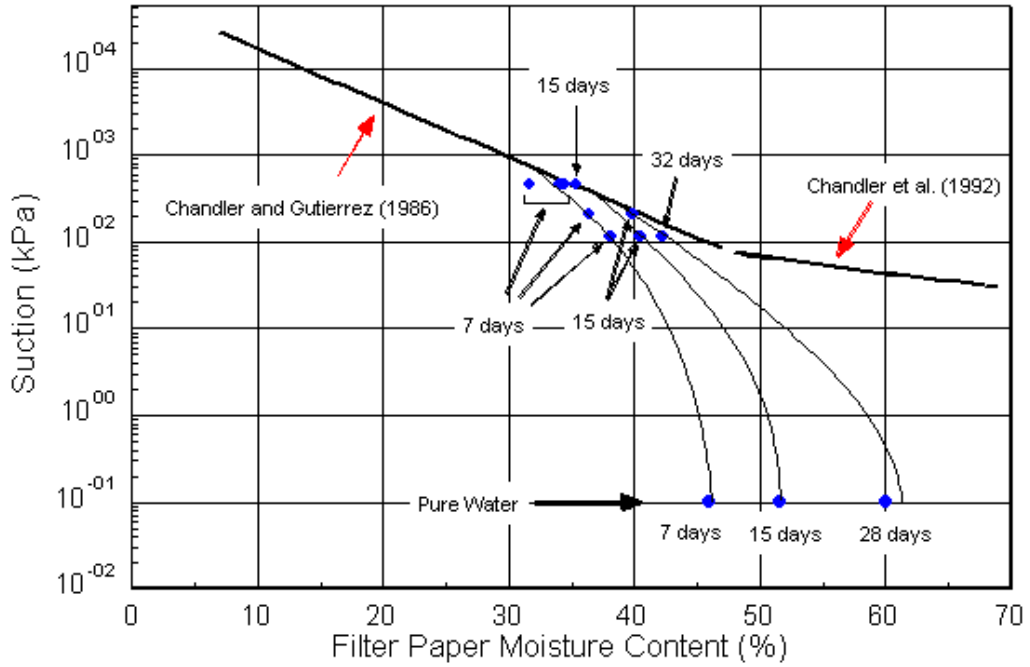
Interpretação de dados para calibração do papel filtro
Efeito osmótico no processo de calibração



Marinho & Oliveira (2006)

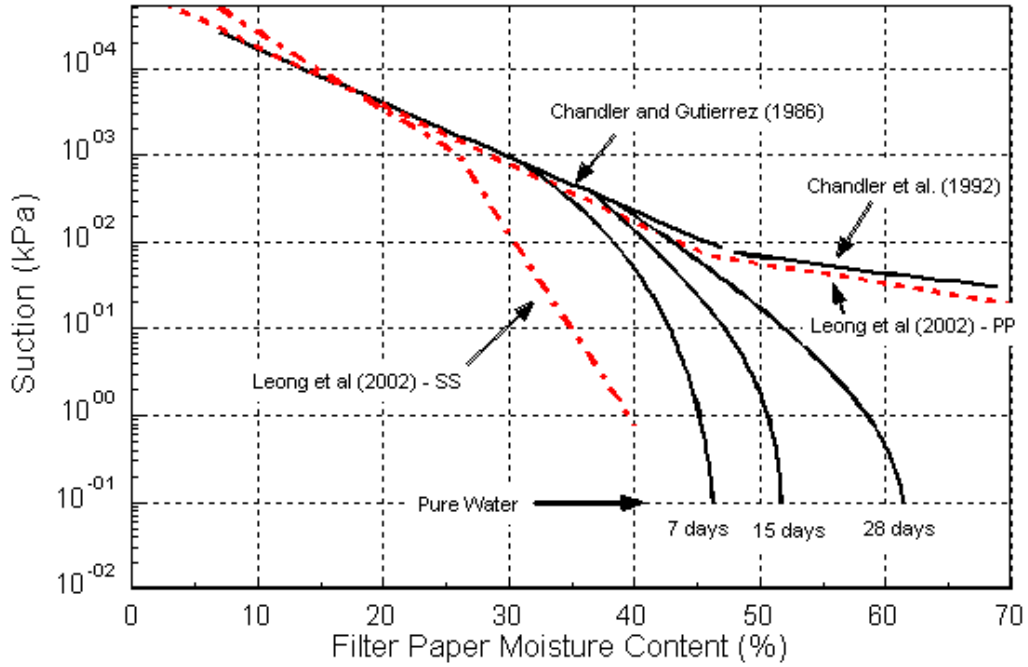
Tempo de Equilíbrio

(Papel Filtro)



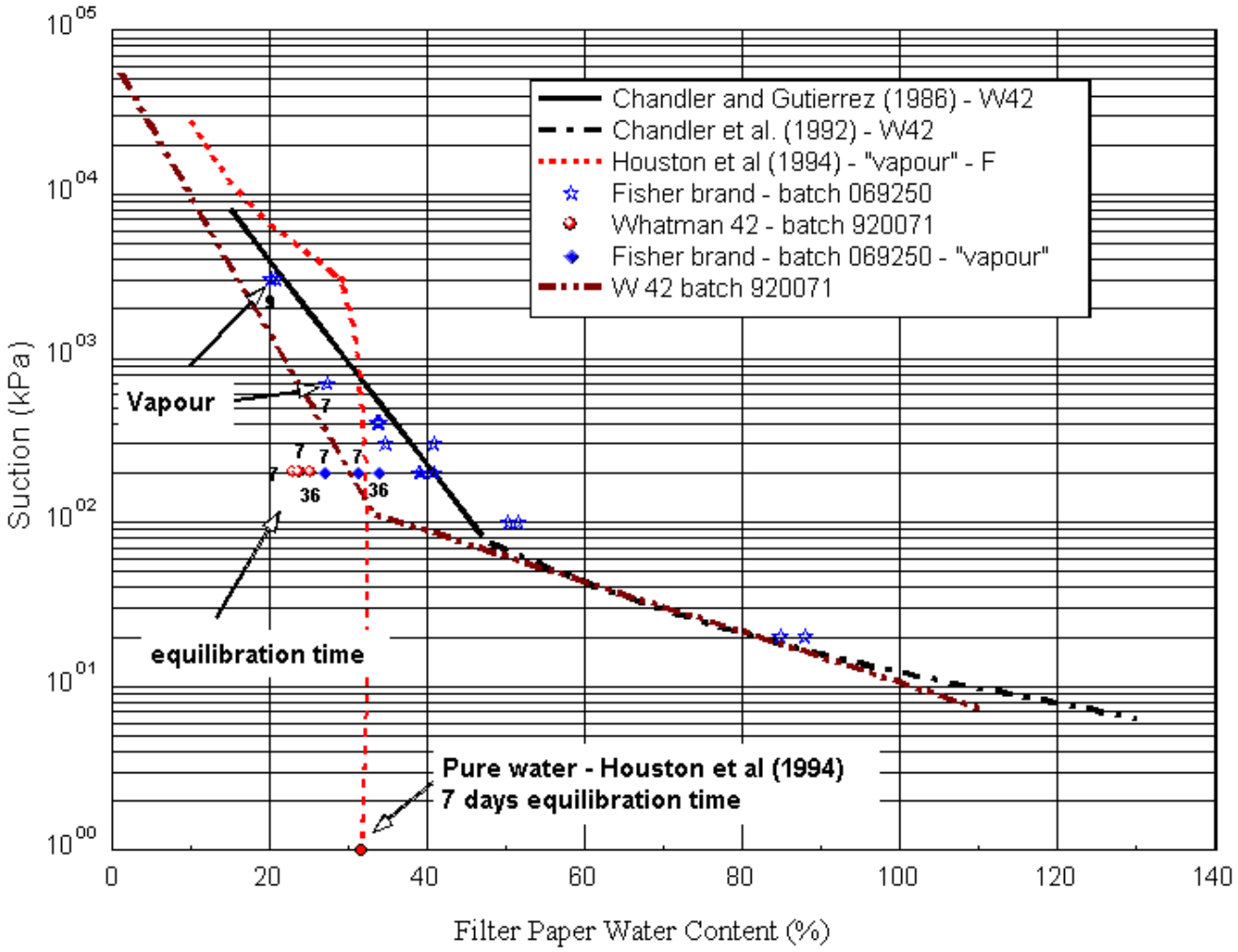
Marinho & Oliveira (2006)

Efeito do tempo nas Calibrações



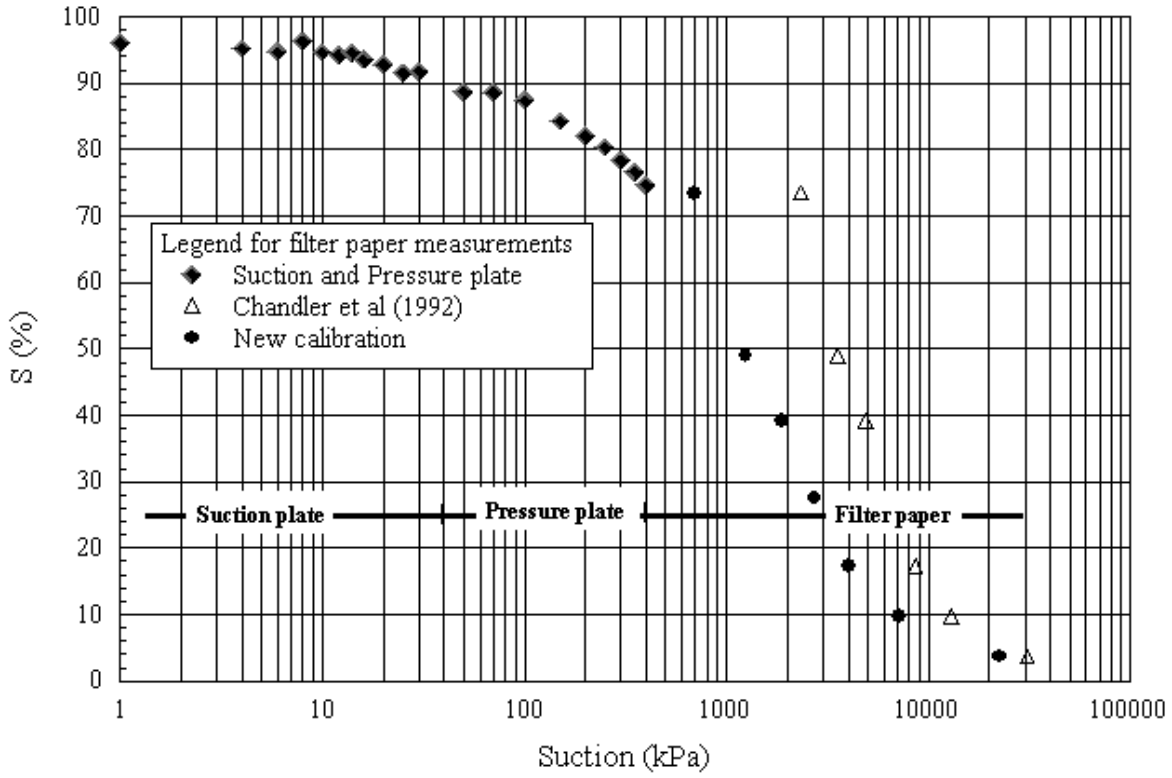
Marinho & Oliveira (2006)

Curva de Calibração usando método de vapor



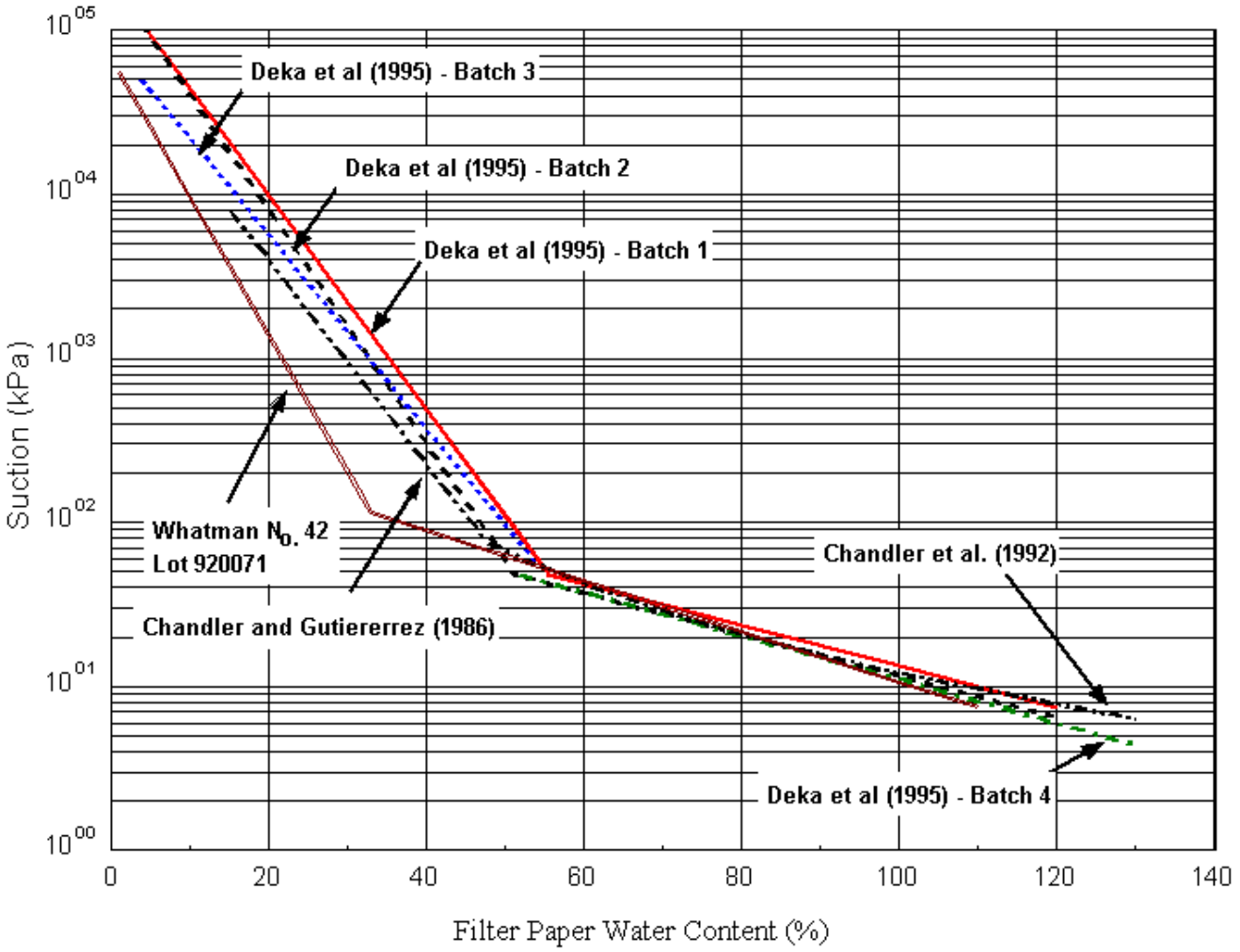
Marinho & Oliveira (2006)

Curva de retenção obtida por diferentes métodos



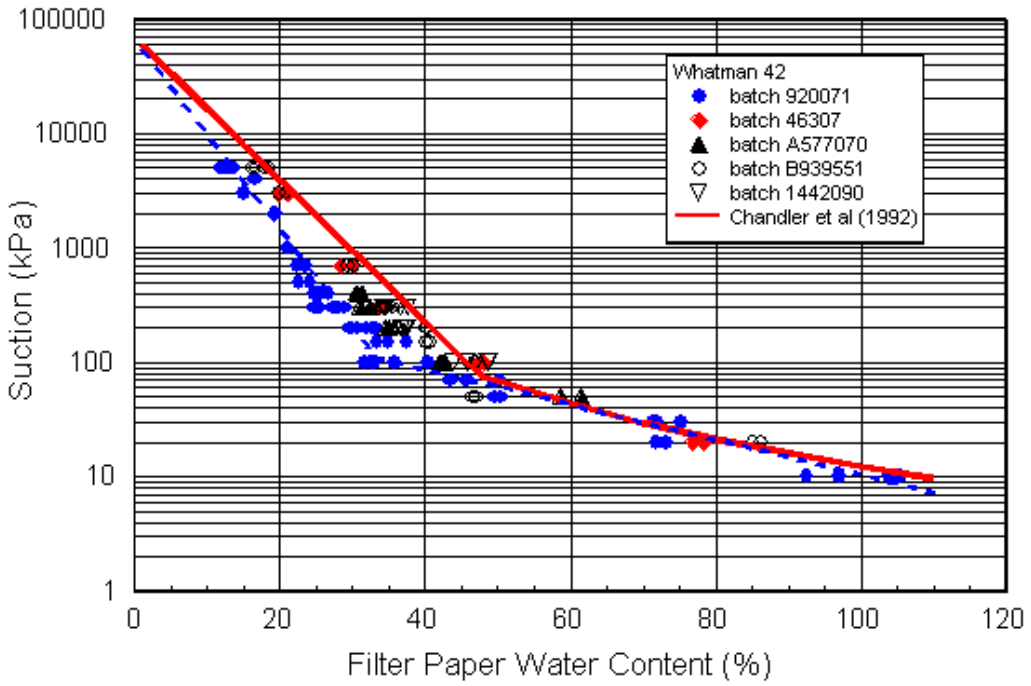
Marinho & Oliveira (2006)

Comparação entre calibrações de diferentes lotes



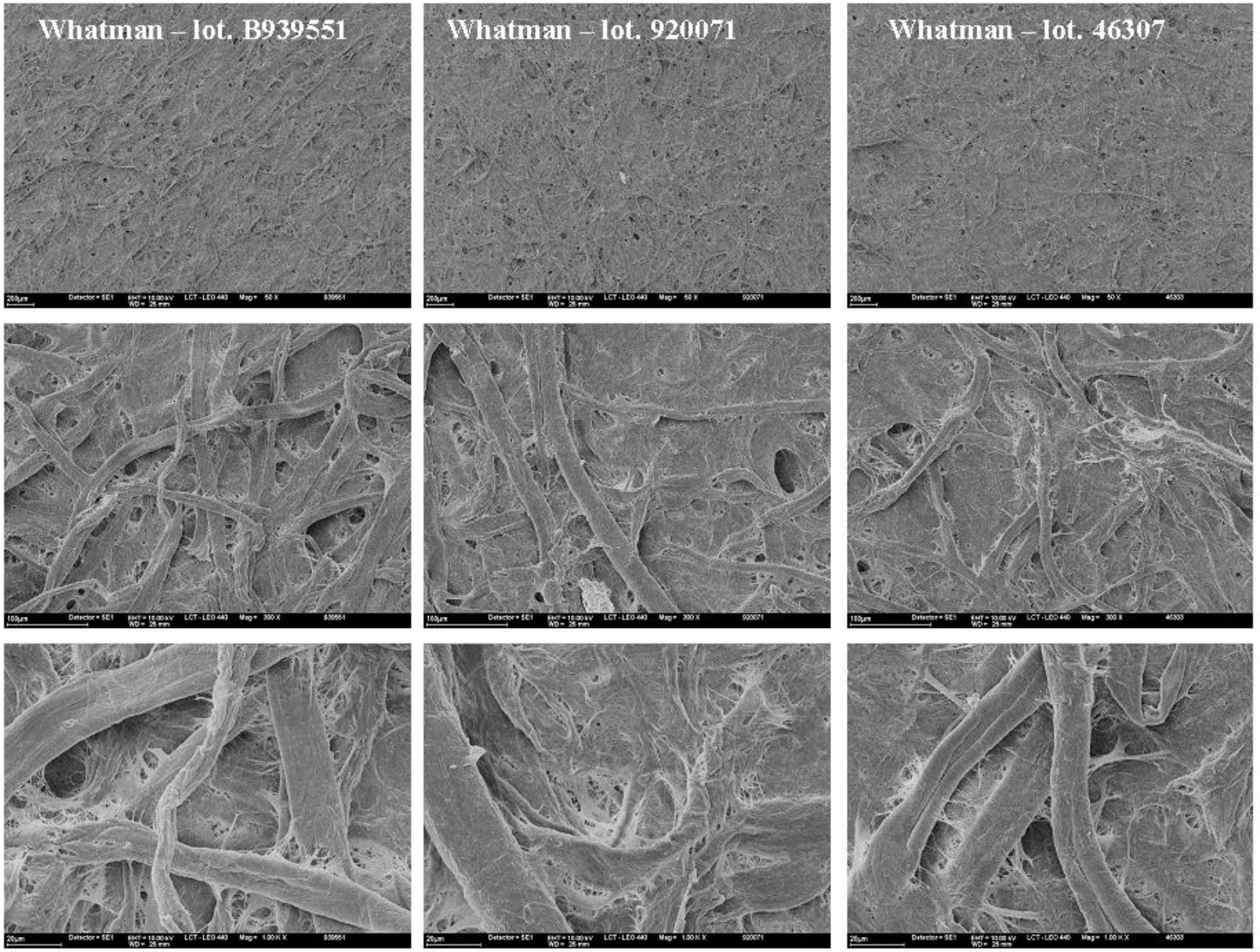
Marinho & Oliveira (2006)

Dados experimentais de calibrações de diferentes lotes



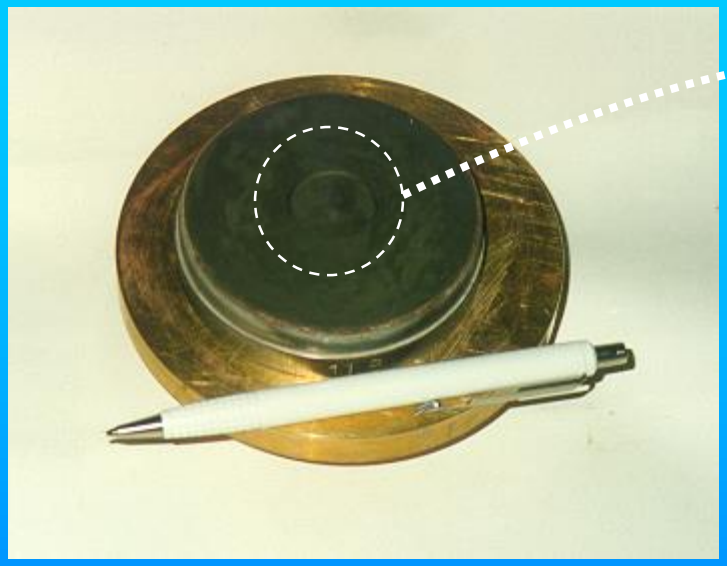
Marinho & Oliveira (2006)

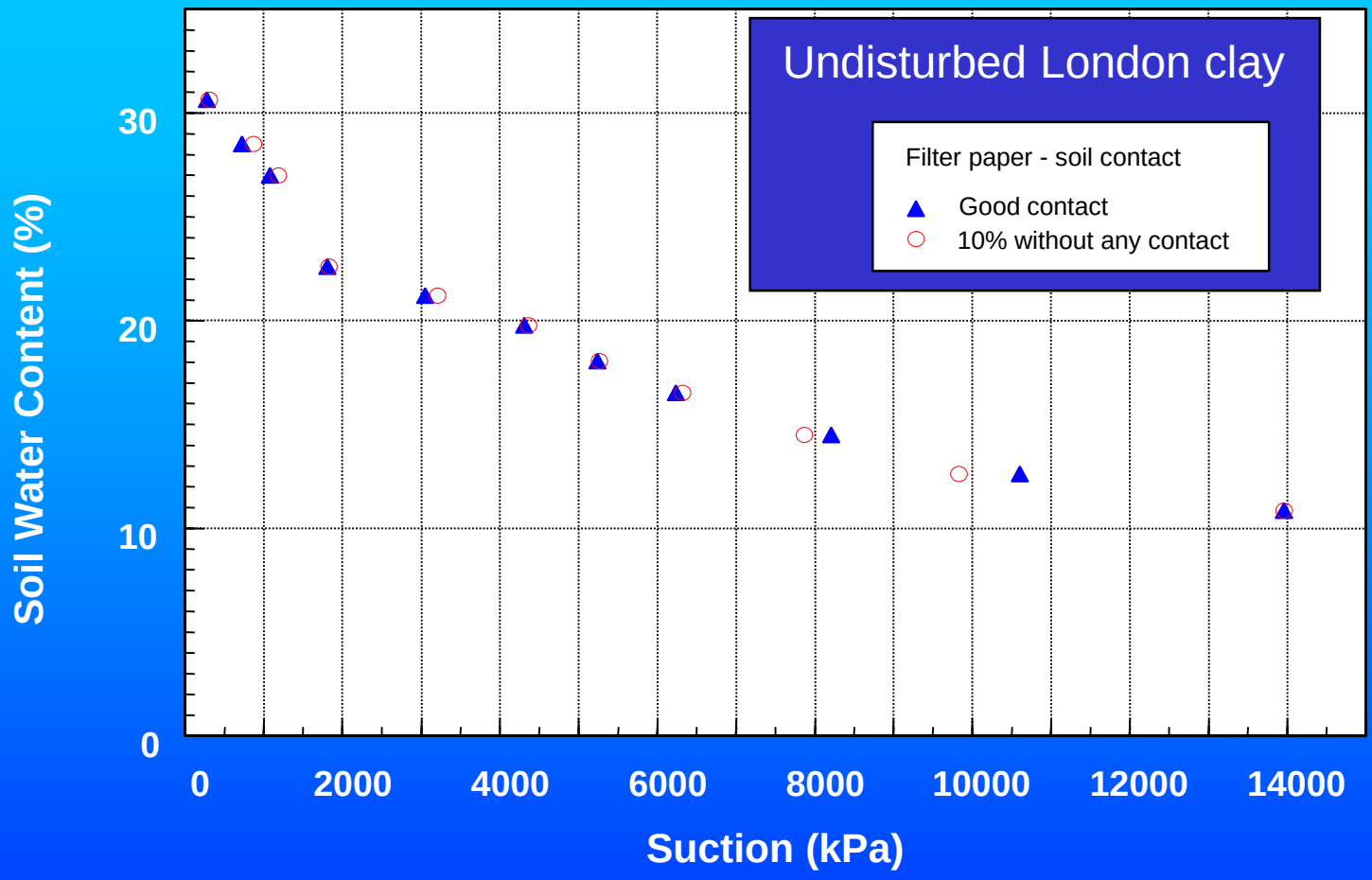
Imagens de microscopia eletrônica de três lotes



Interacão entre o Papel Filtro e o Solo

Falta de contato

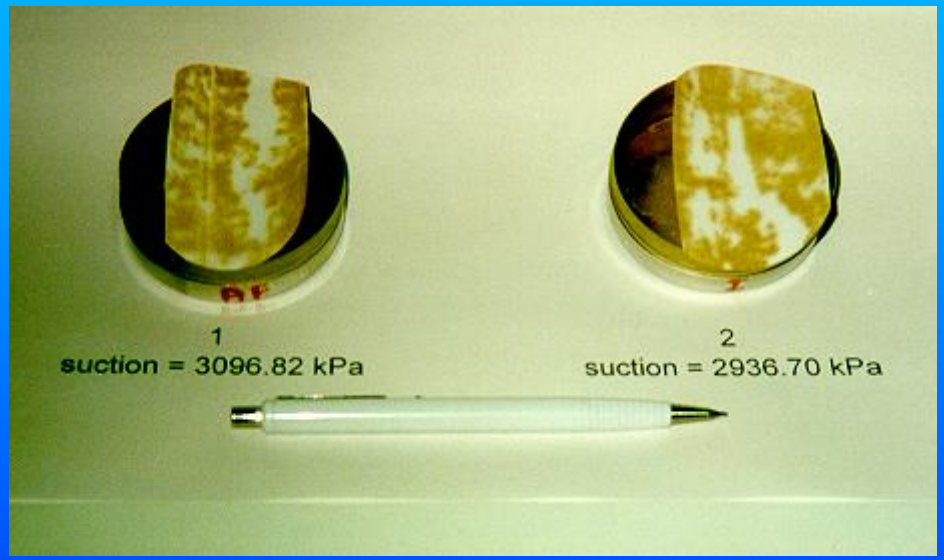



Undisturbed London clay
Filter paper - soil contact
Good contact
10% without any contact
Soil Water Content (%)
0
10
20
30
0
2000
4000
6000
8000
10000
12000
14000
Suction (kPa)

Santo sudário

(Shroud of Turin)

Papel Filtro

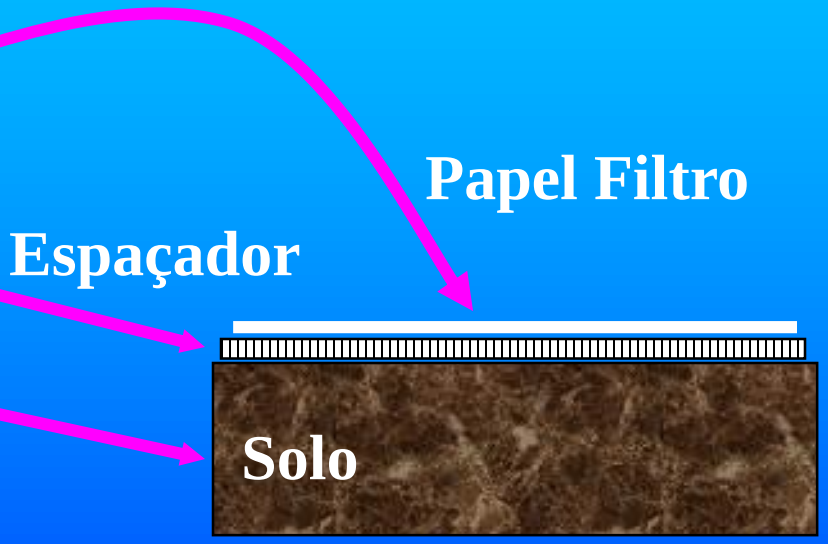


Medição de sucção Utilizando o Papel Filtro

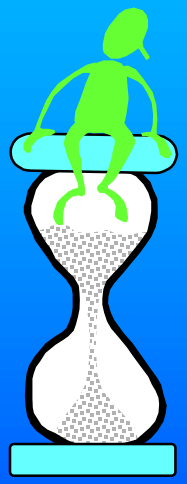
Filme plástico

Papel filtro e amostra indeformada

Medição de Sucção Total

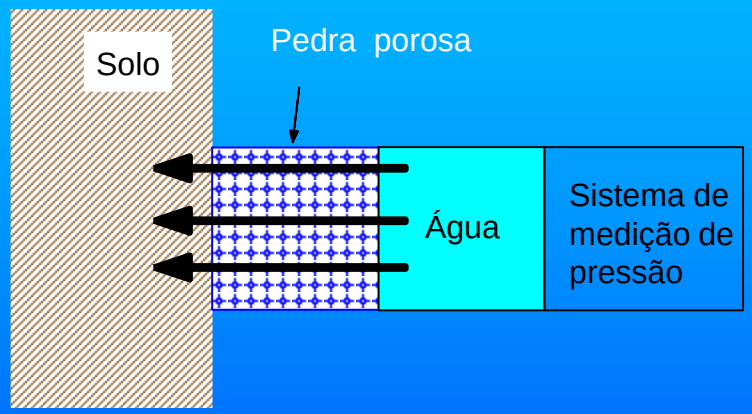


Limitações da Técnica do Papel Filtro



- Não é possível se fazer medições contínuas
- O tempo para medição é longo
- Não pode ser usado no campo
- Não mede sucções totais menores que 100kPa

Tensiômetros


Solo
Pedra porosa
Água
Sistema de medição de pressão

Lucien Vidie

Inventor do manômetro

Tensiômetros

Vantagens

Medição direta

Permite fazer leituras contínuas quando associado a tranduitortes de pressão

Permite leituras com alta frequência

Em princípio não é afetado pela salinidade do solo (Cuidado!!!)

Baixo custo

Desvantagens

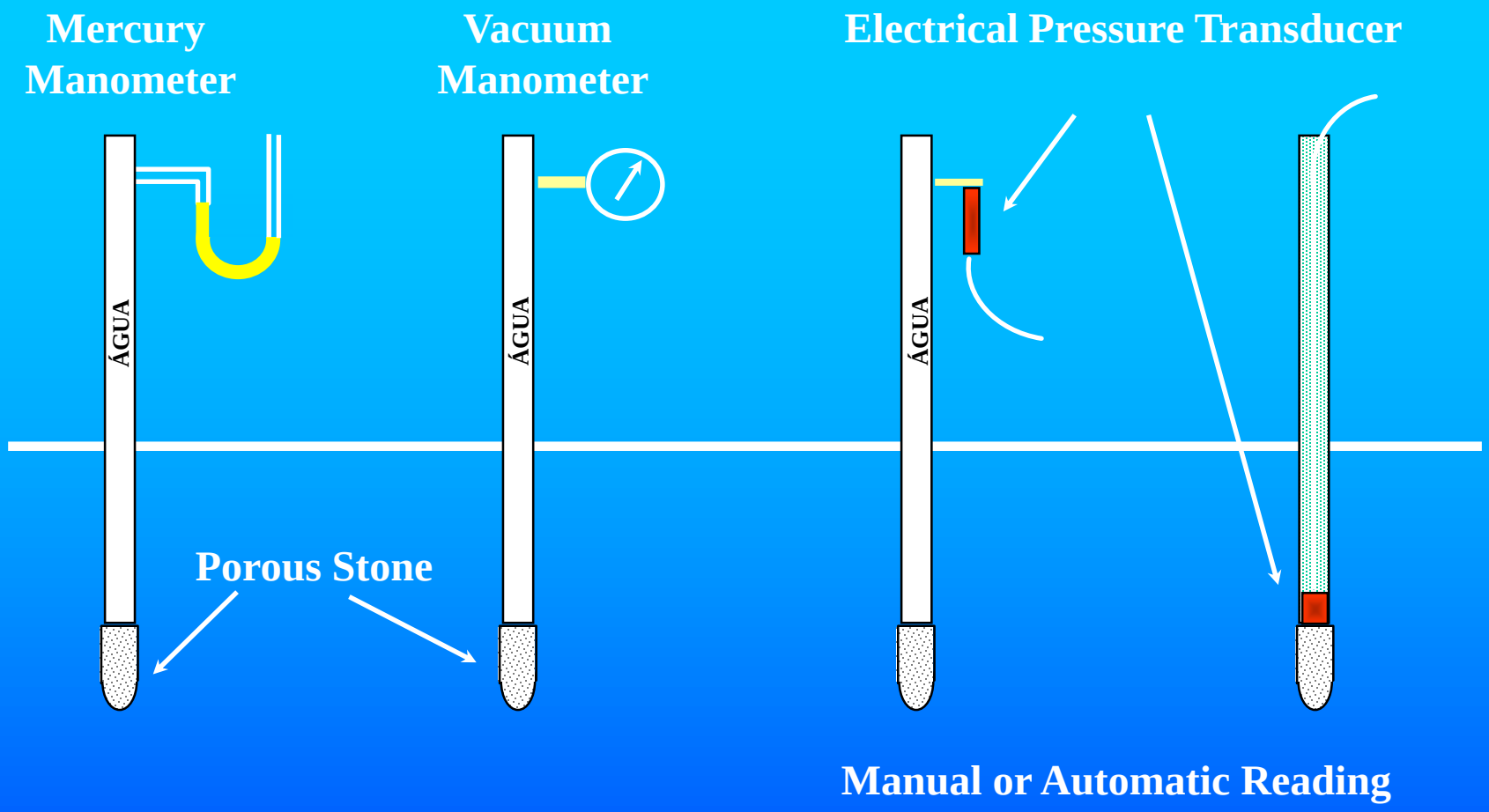
O uso no campo está limitado a sucções de até 100kPa

Em laboratório pode ir até 1MPa.

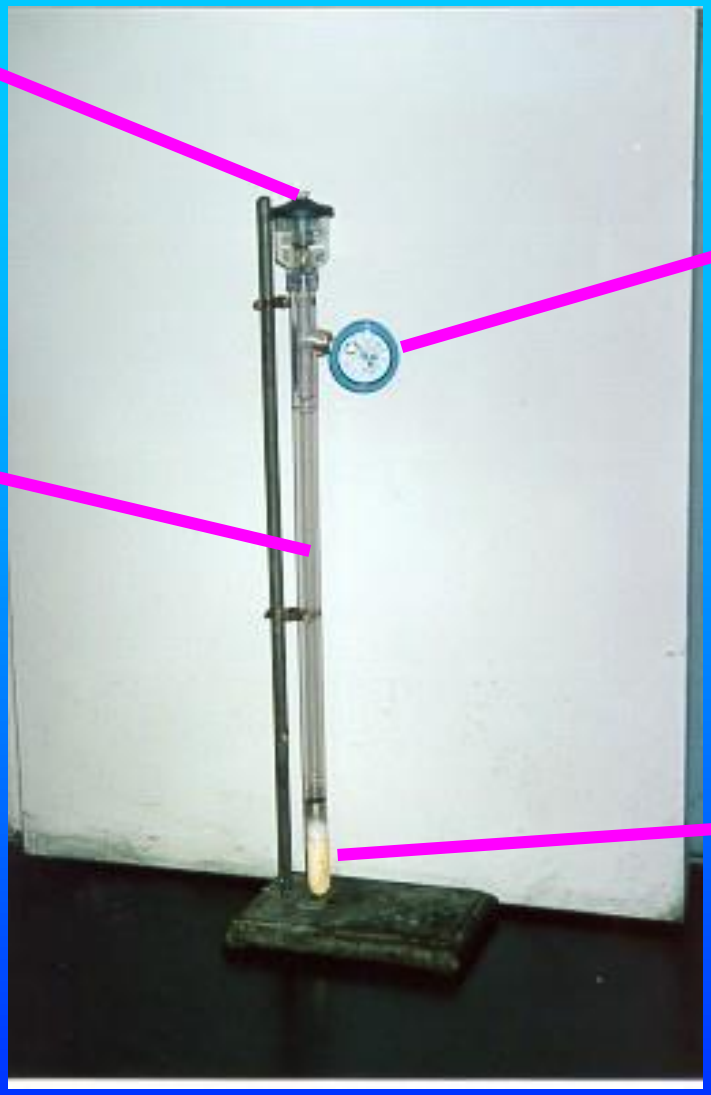
Necessita bom contato entre a água do tensiômetro e a água do solo

Se o solo varia de volume o contato pode ser perdido

Necessita manutenção permanente devido a difusão de ar para dentrro do tensiômetro


Mercury Manometer
Vacuum Manometer
Electrical Pressure Transducer
ÁGUA
ÁGUA
ÁGUA
Porous Stone
Manual or Automatic Reading
Manual Reading
Manual Reading

“Jet-Fill” System



Vacuum Manometer

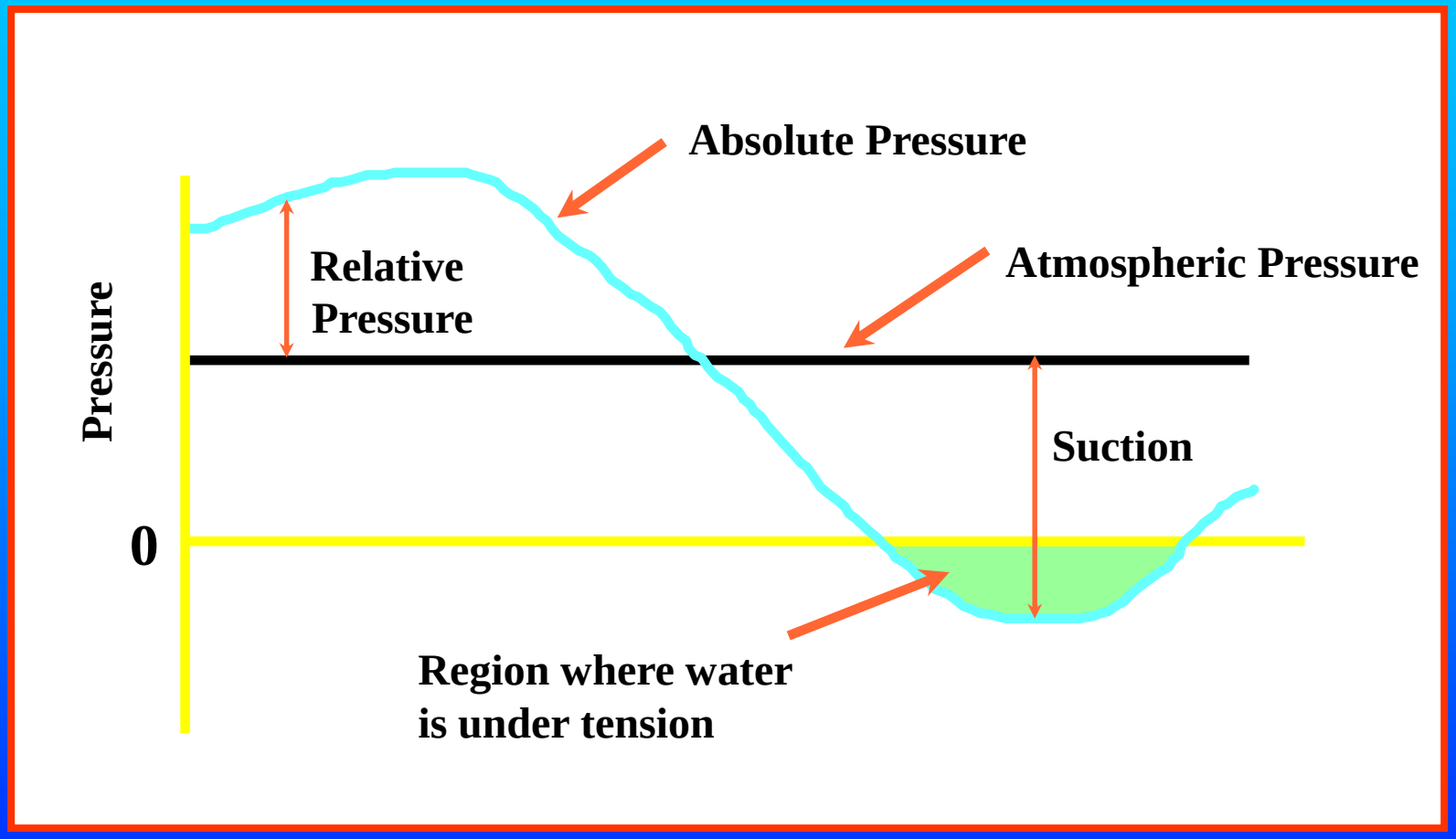
Water

Porous Stone

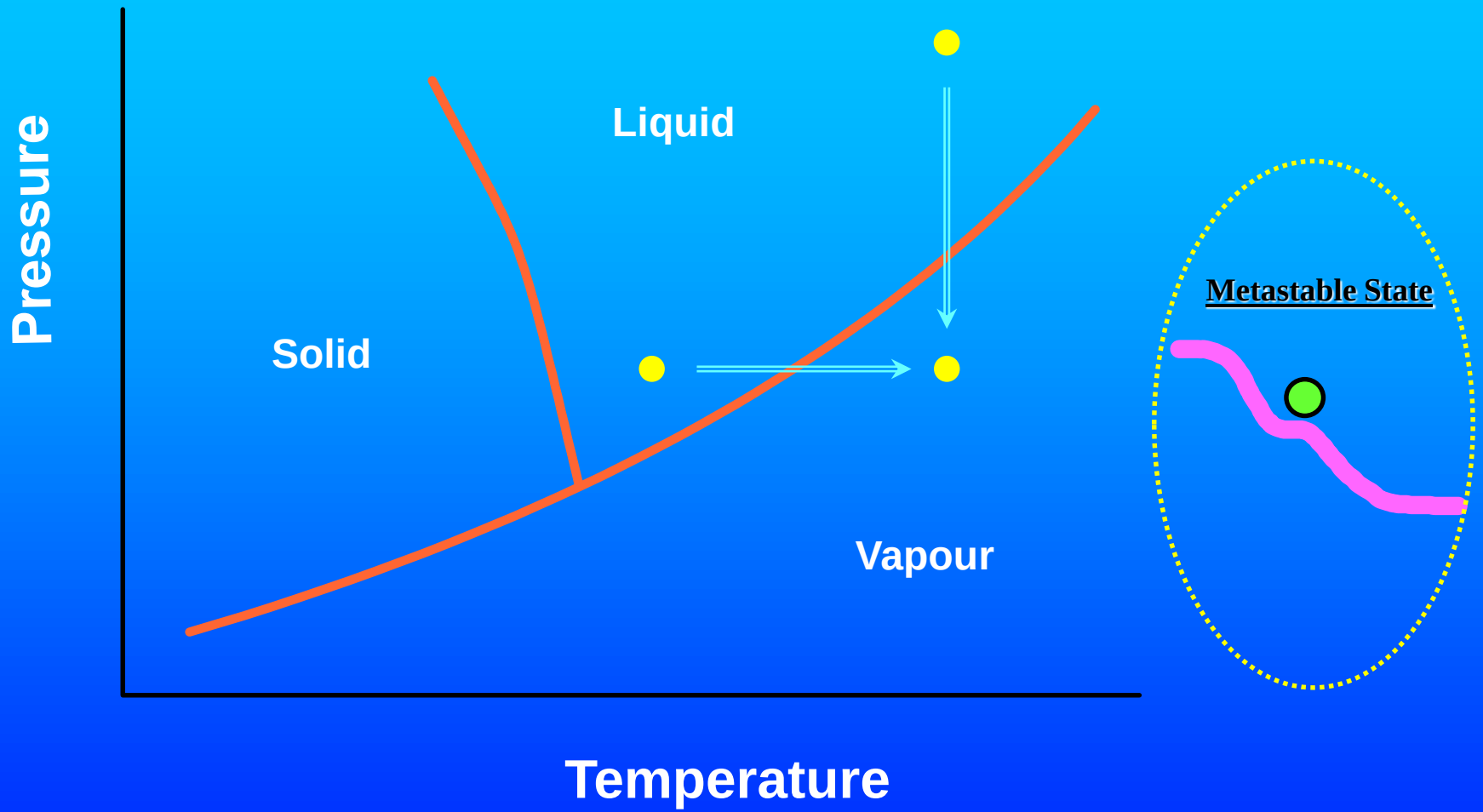
Limitations of the Tensiometer

- Maximum suction up to approx. 90kPa.

Concepts

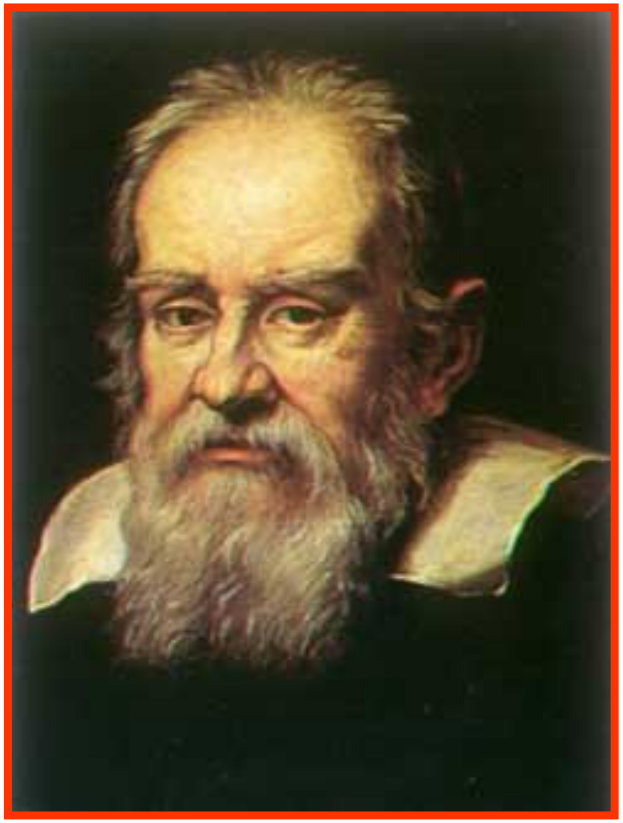

Absolute Pressure
Relative Pressure
Atmospheric Pressure
Pressure
Suction
0
Region where water is under tension

Phase Diagram



Basic Concepts: Cavitation

Galileo-Galilei



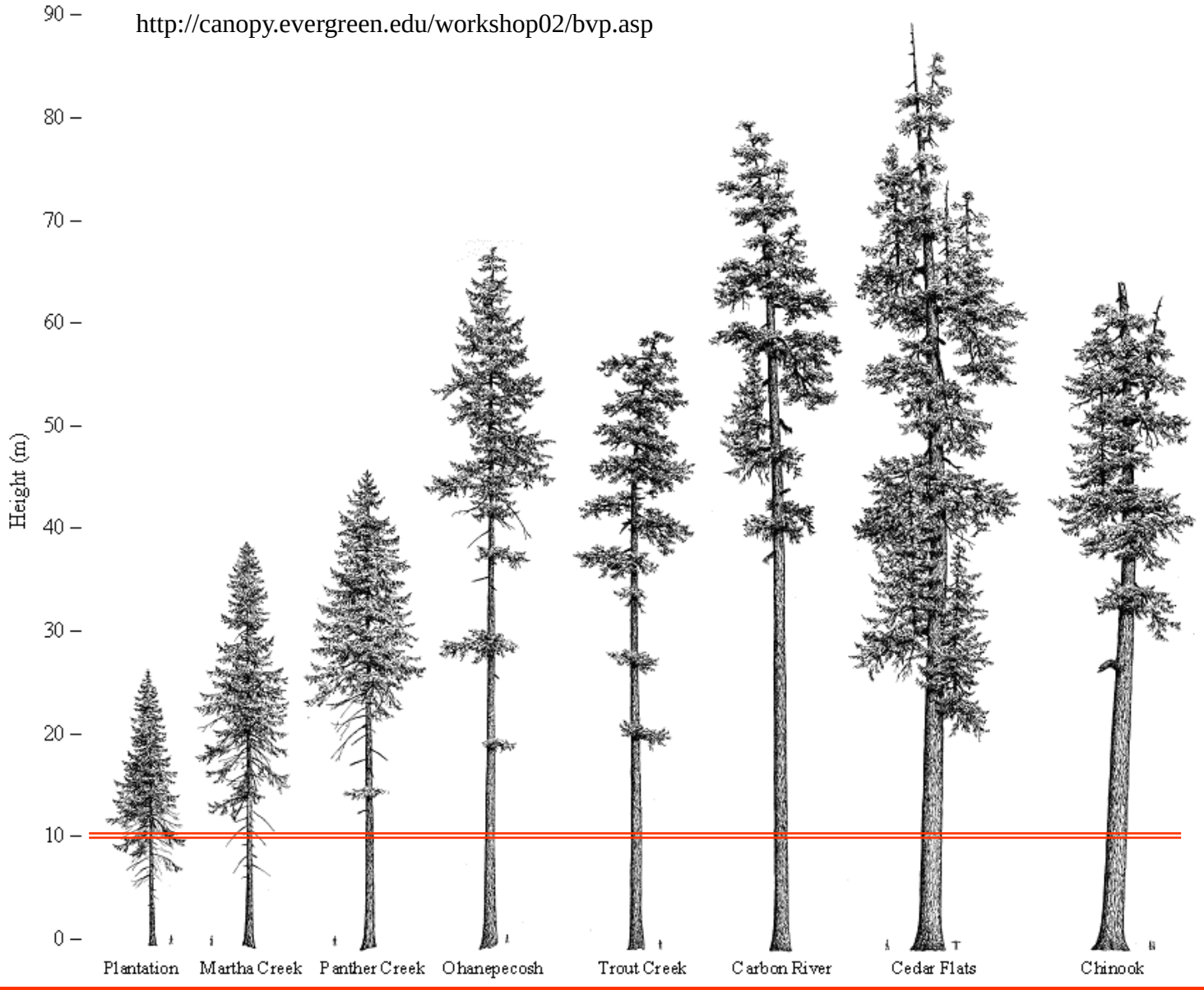
The first observation that water cannot rise indefinitely has been attributed to Galileo Galilei.

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

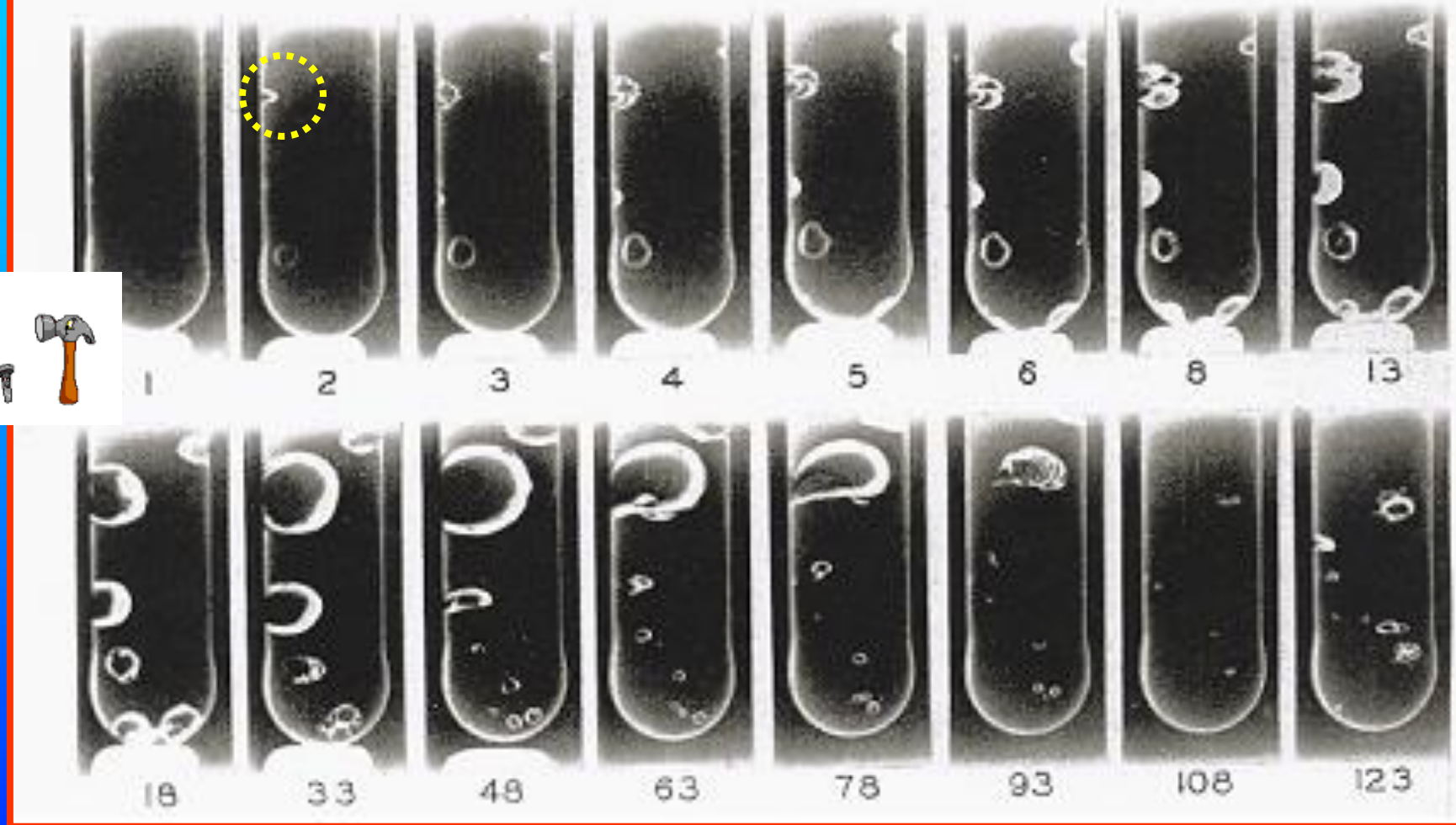
This limit is determined by the pheomena of cavitation

Basic Concepts: Cavitation

http://canopy.evergreen.edu/workshop02/bvp.asp



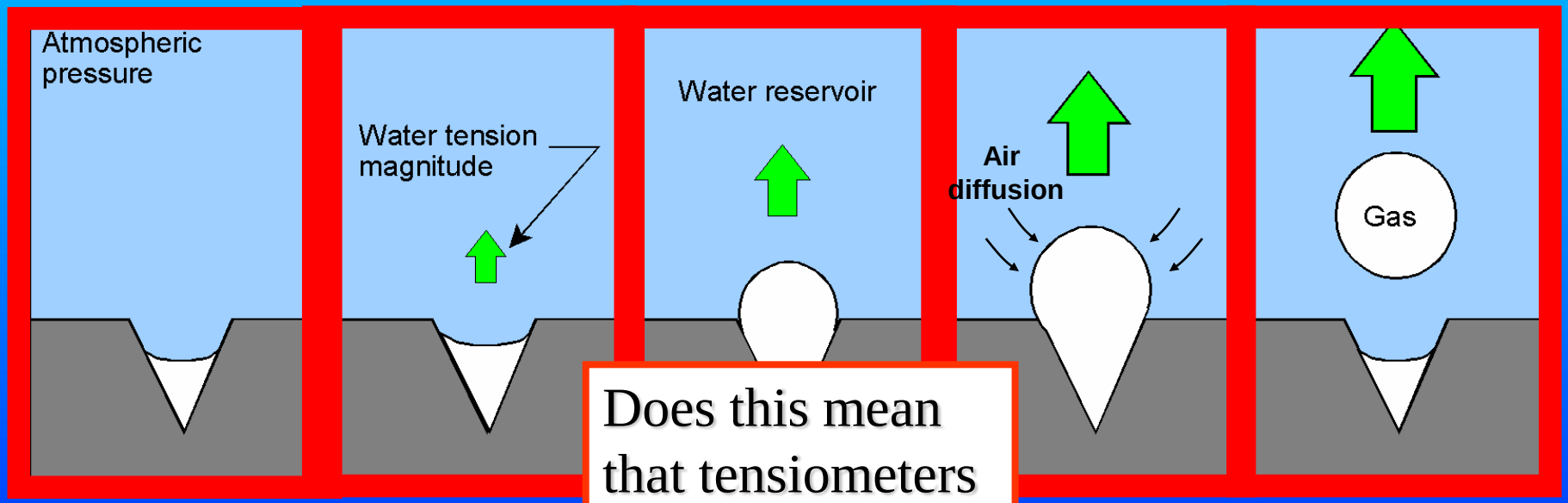
Basic Concepts: Cavitation



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

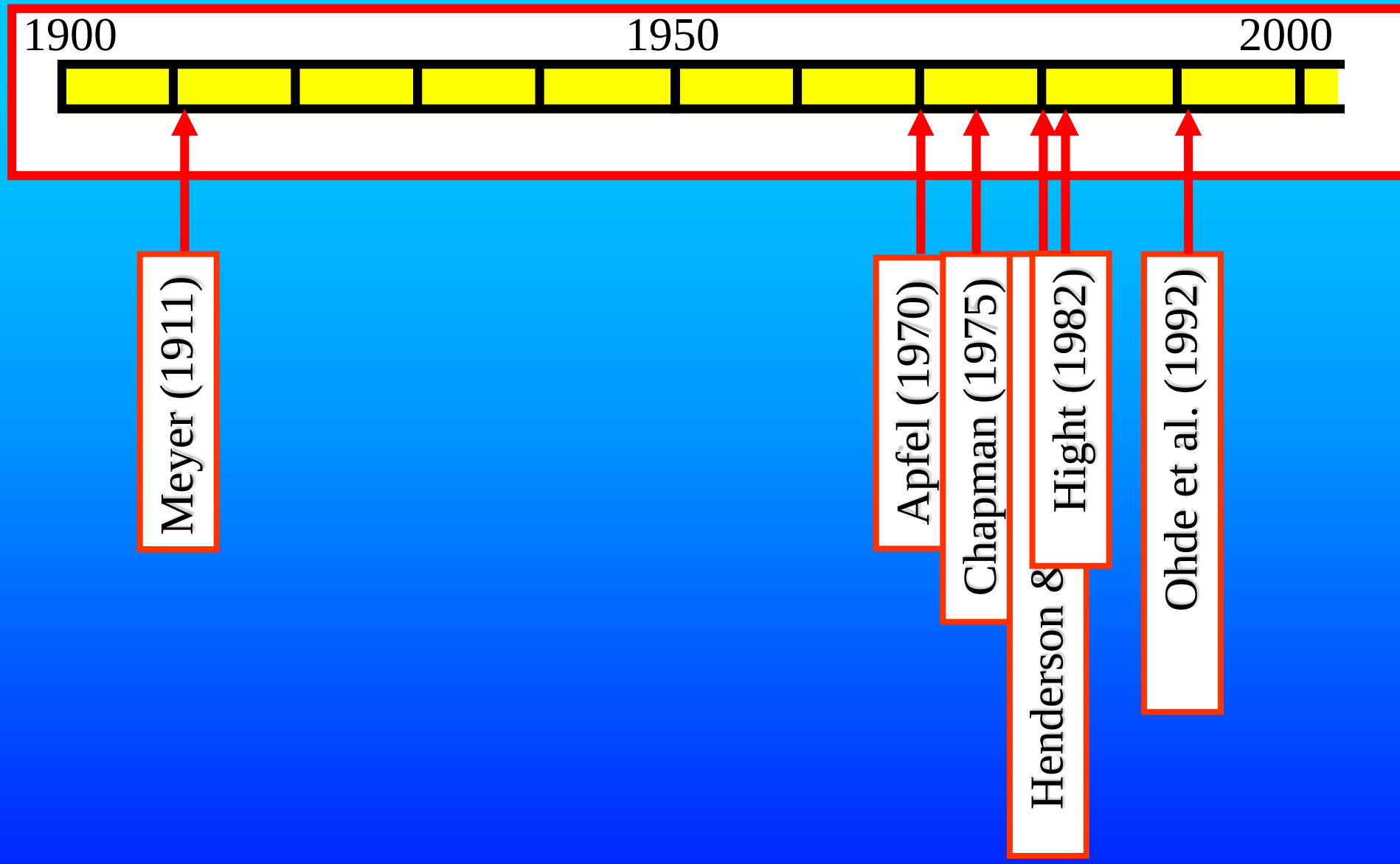
Basic Concepts: Cavitation

A Cavitation Mechanism (Harvey et al, 1944)

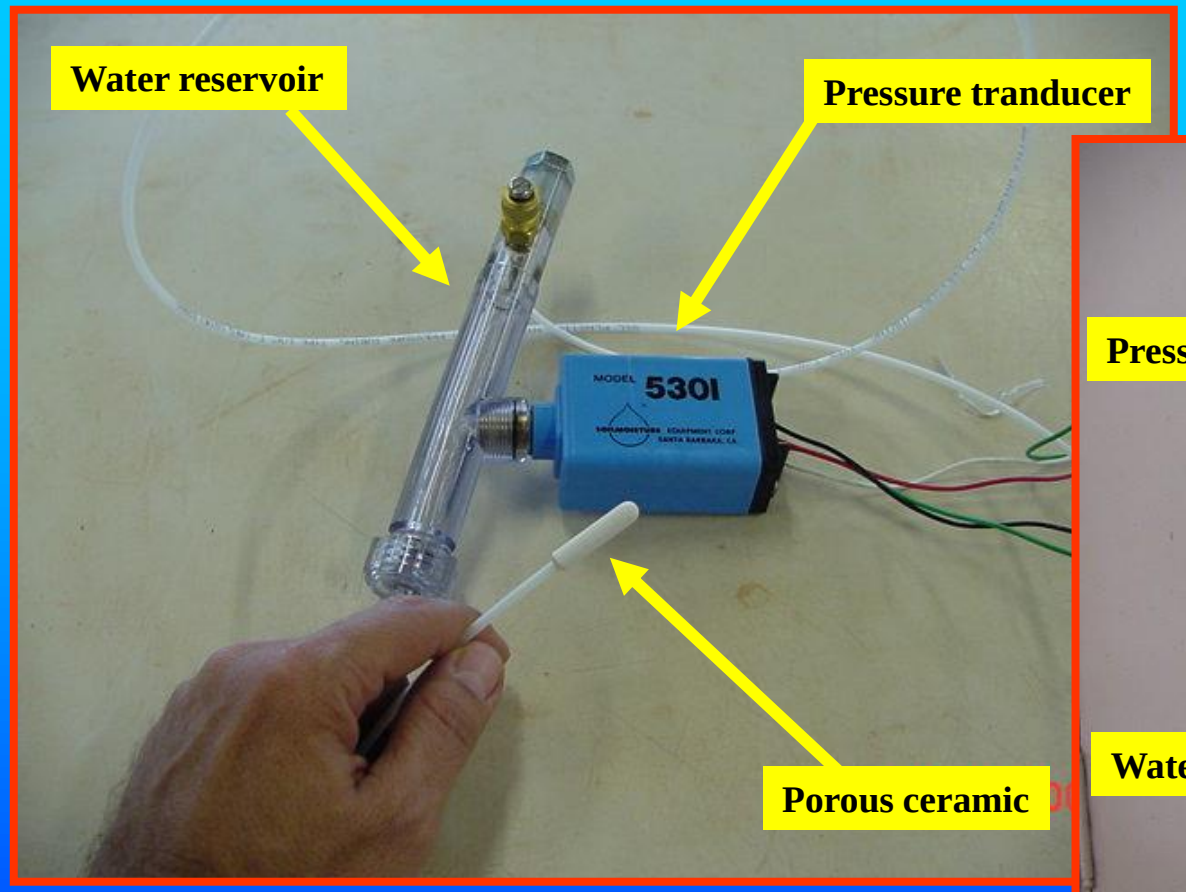


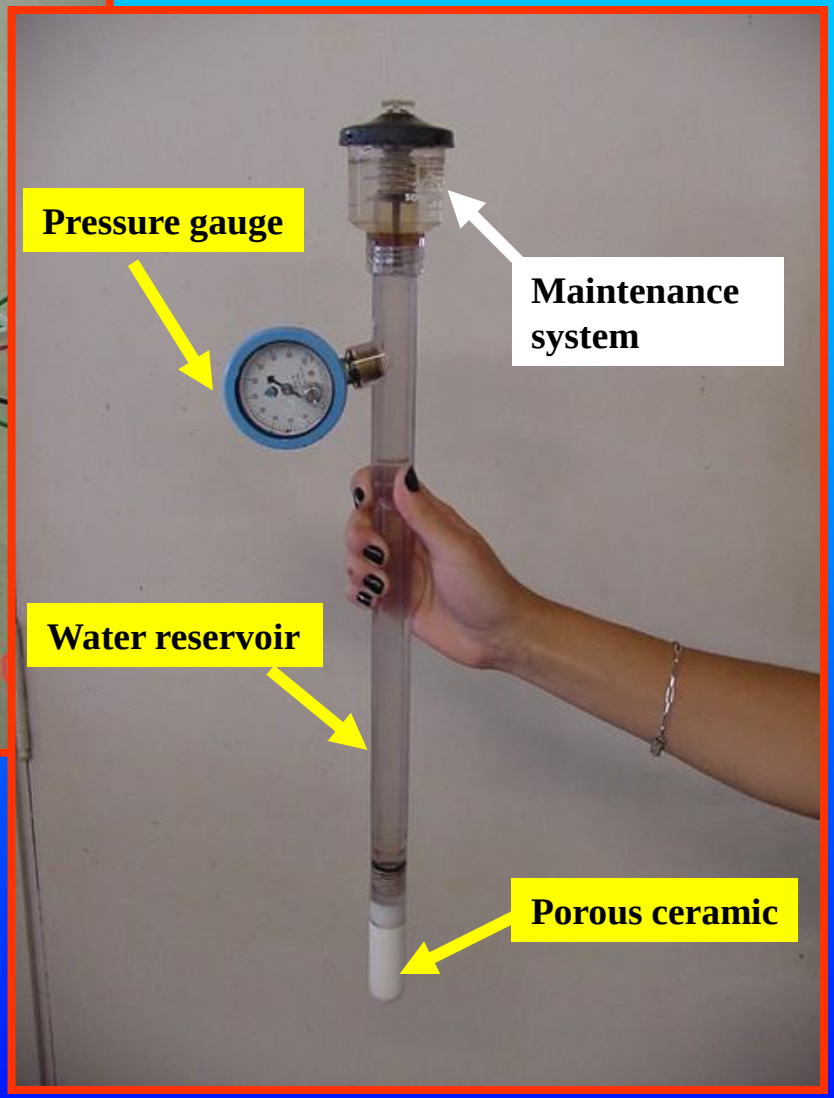
Does this mean that tensiometers are limited to - 1atm?

The Tensiometer: Design



The Tensiometer: Conventional Design

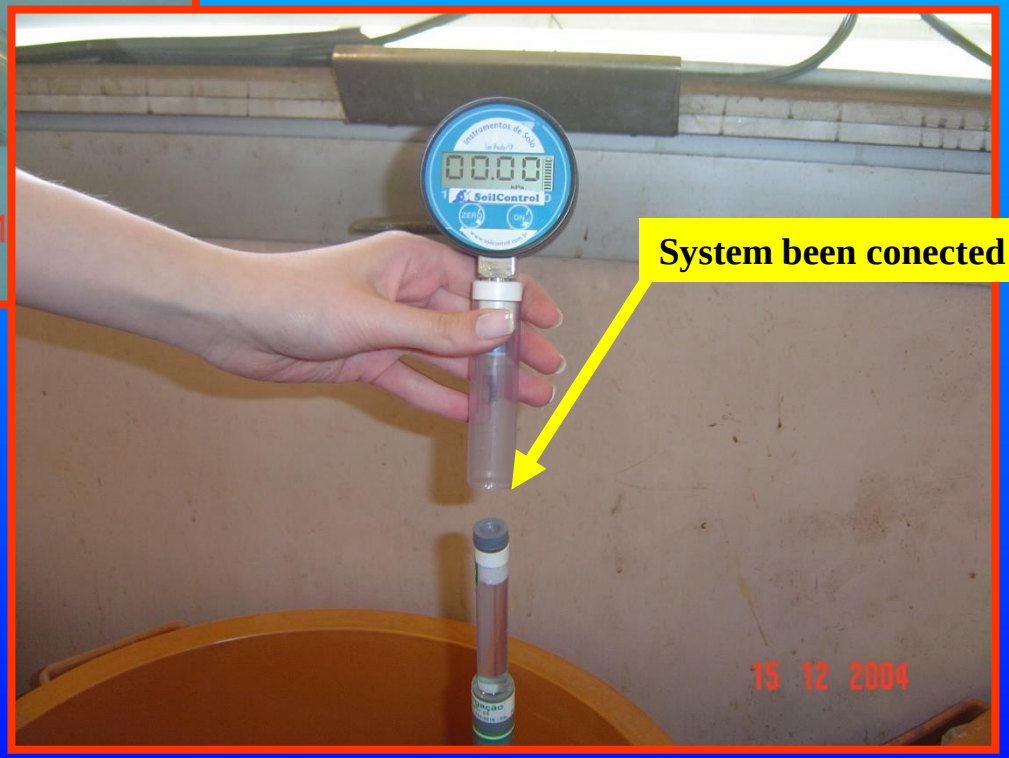




The Tensiometer: Conventional Design

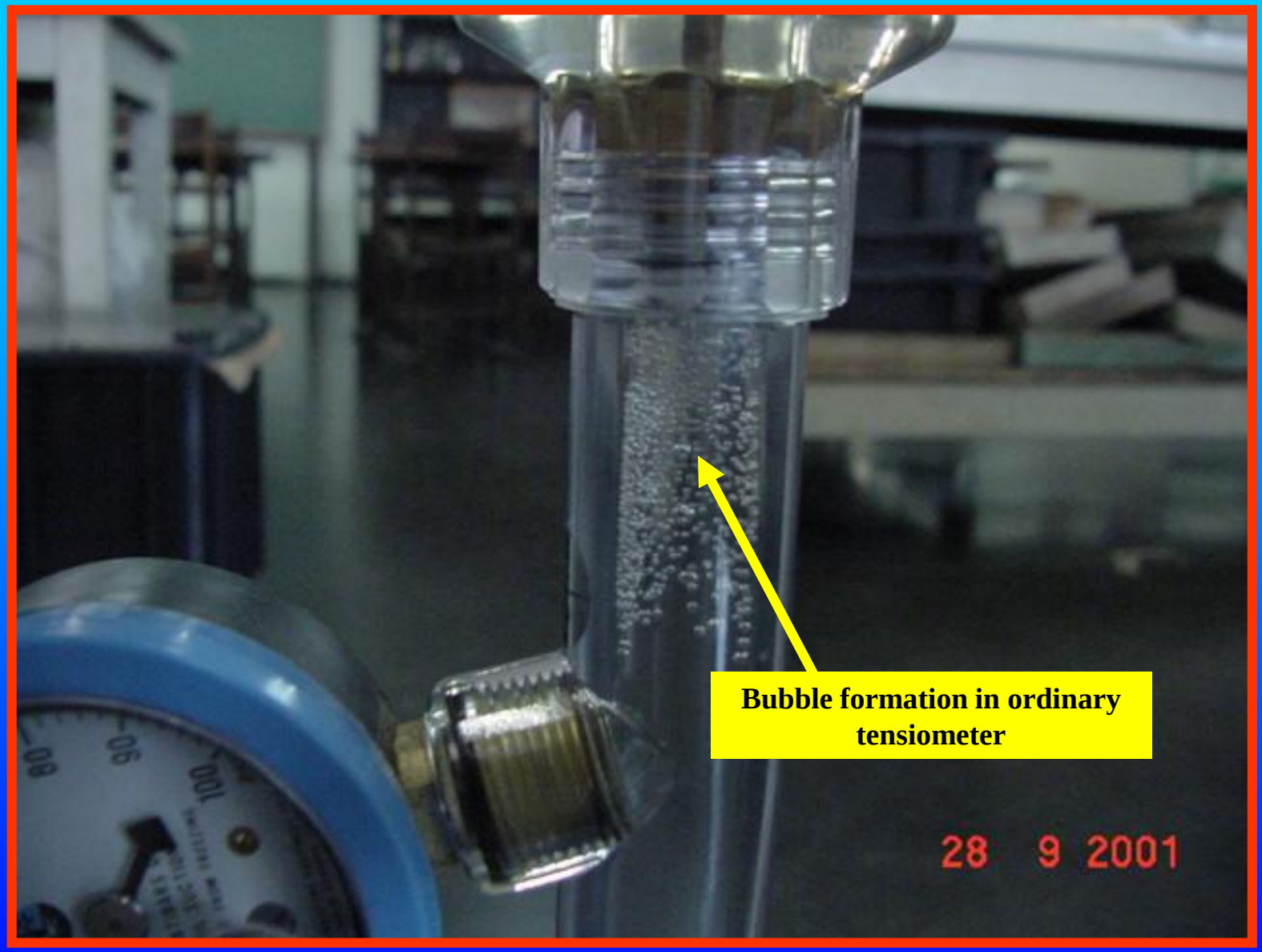
Pressure tranducer

Needle

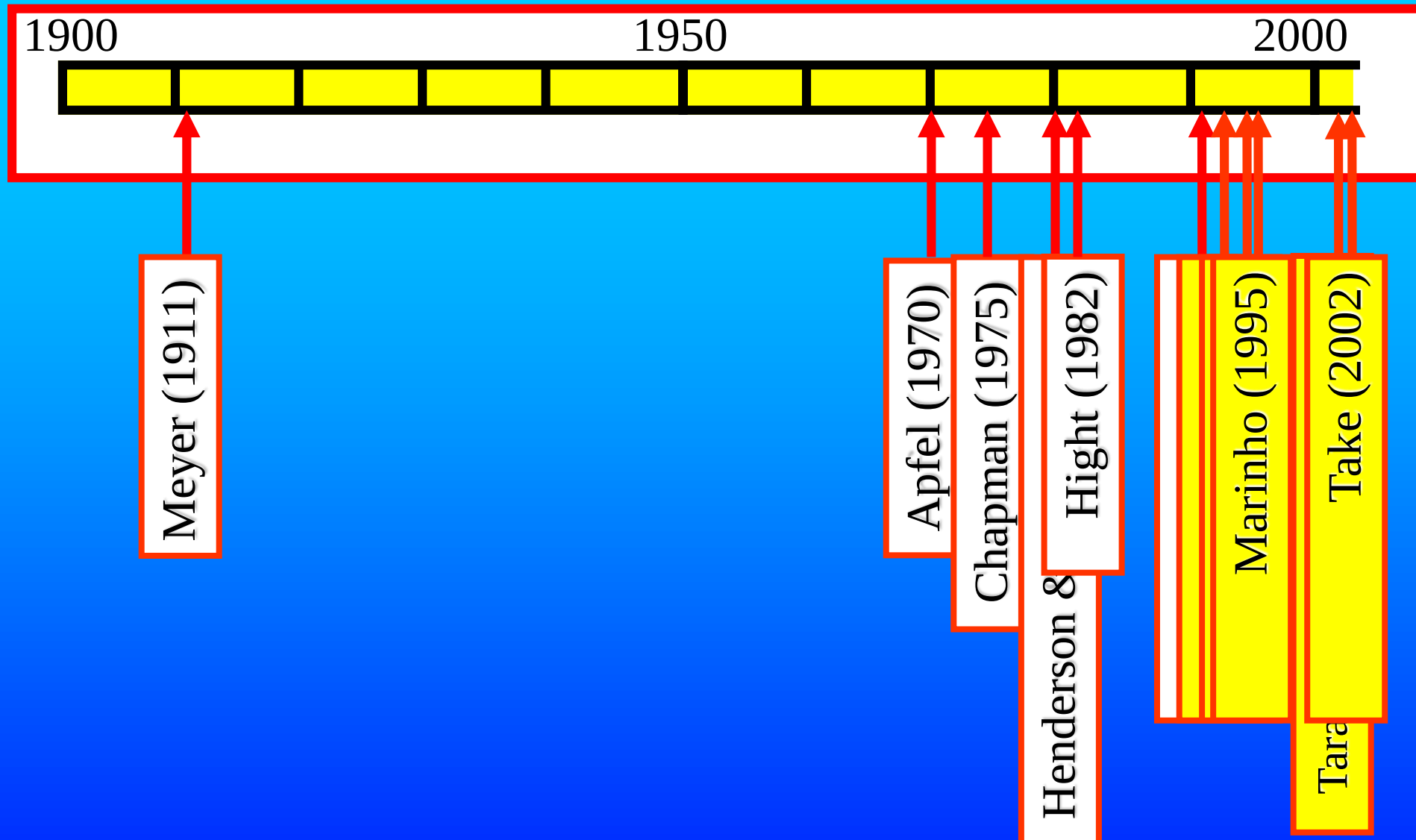


System been conected

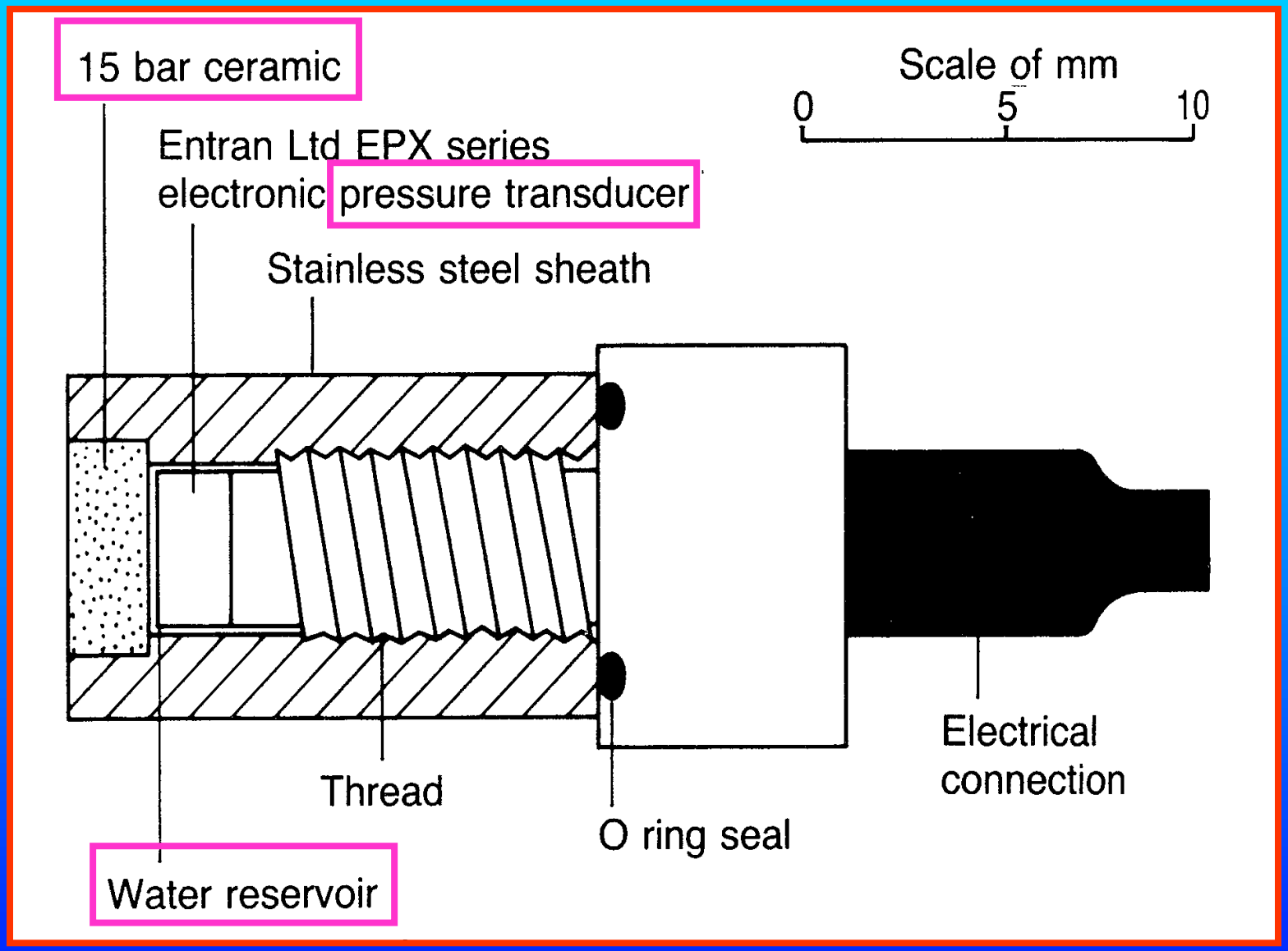
The Tensiometer: Conventional Design



The Tensiometer: Design

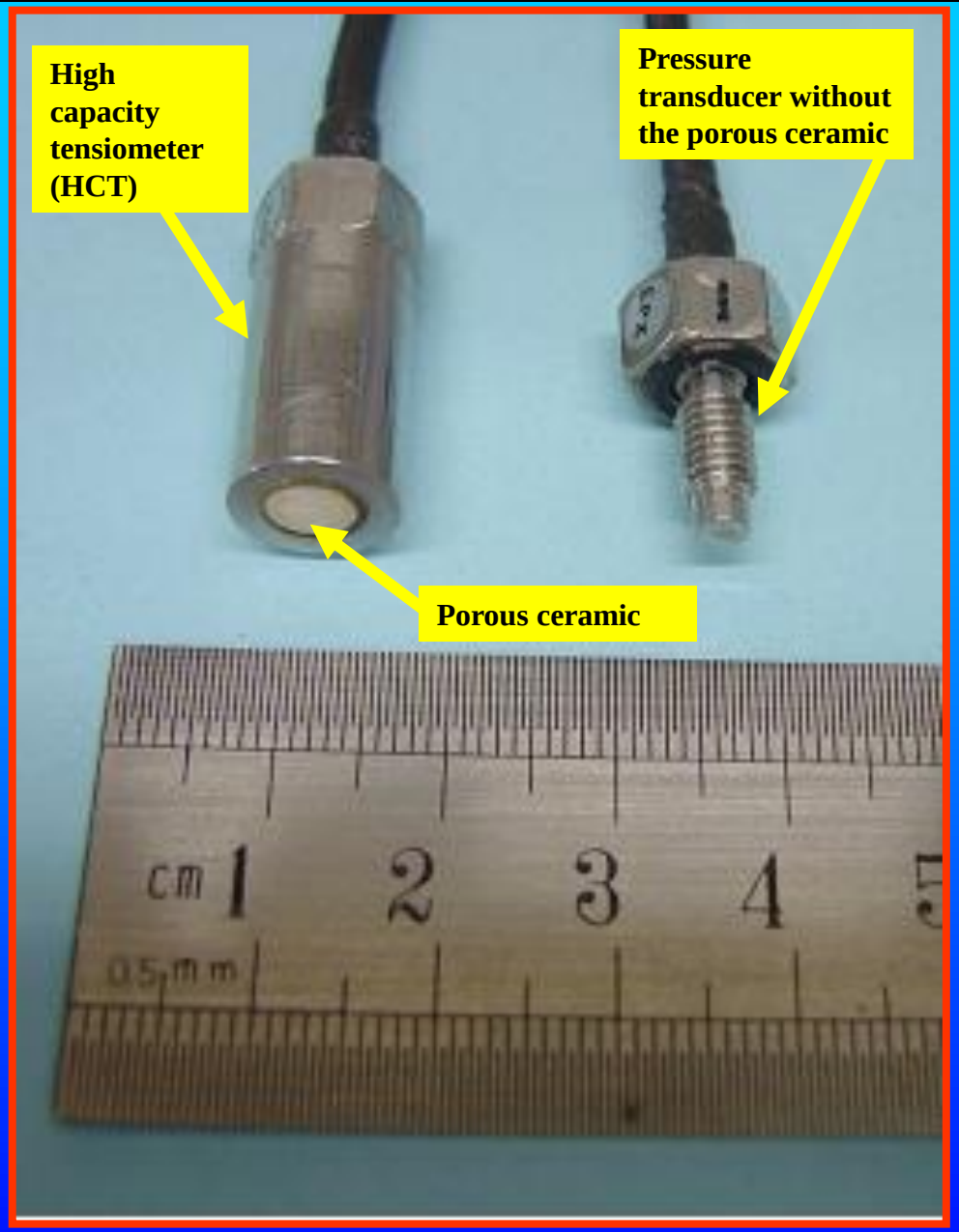


The Tensiometer: High Capacity Design



Ridley & Burland (1993)

The Tensiometer: High Capacity Design

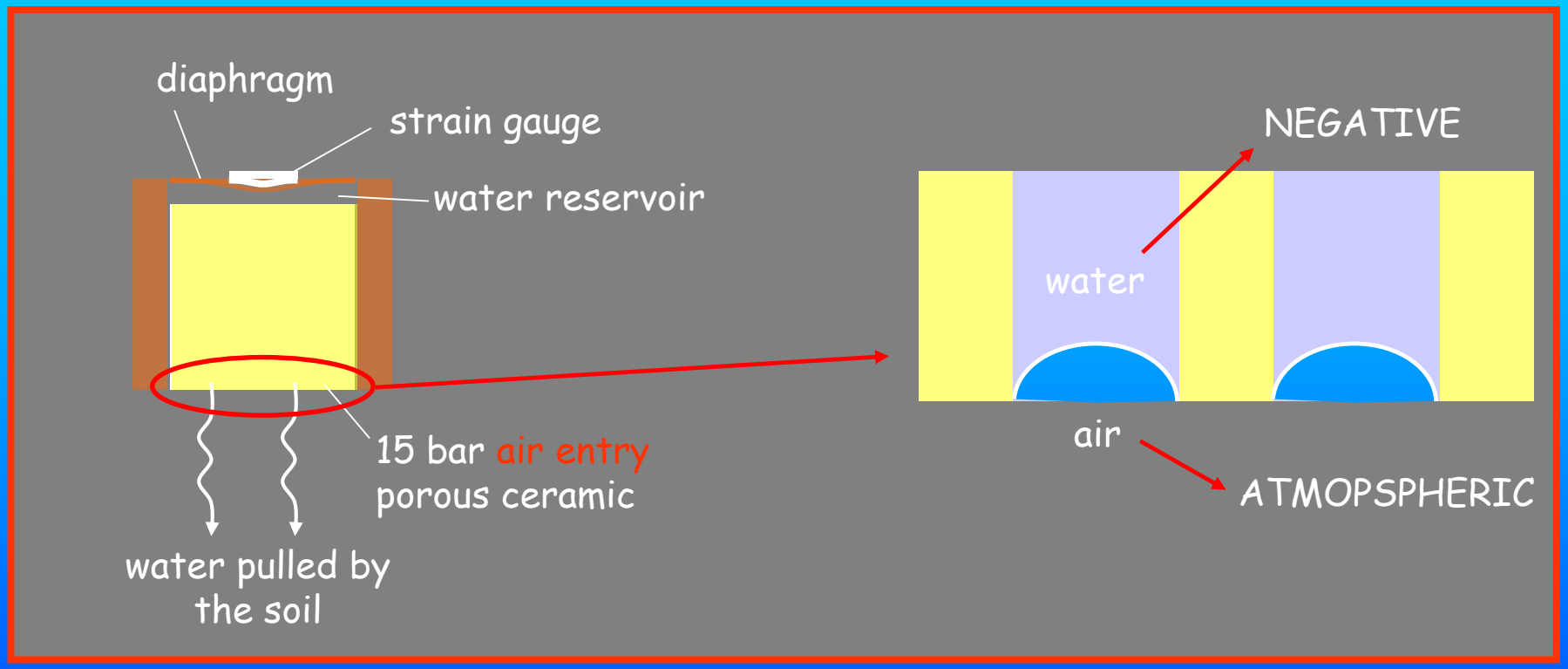


Pressure transducer (ENTRAN-EPX)

To seal the cap
in the transducer

High air entry value
porous ceramic fitted
into a stainless steel cap

The Tensiometer: Working Principle



The high air entry ceramic sustains the pressure differential between the negative water pressure in the reservoir and the atmospheric air pressure outside the ceramic

The Tensiometer: Saturation

Initial Saturation:

- 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)

Pre-pressurisation (Conditioning):

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

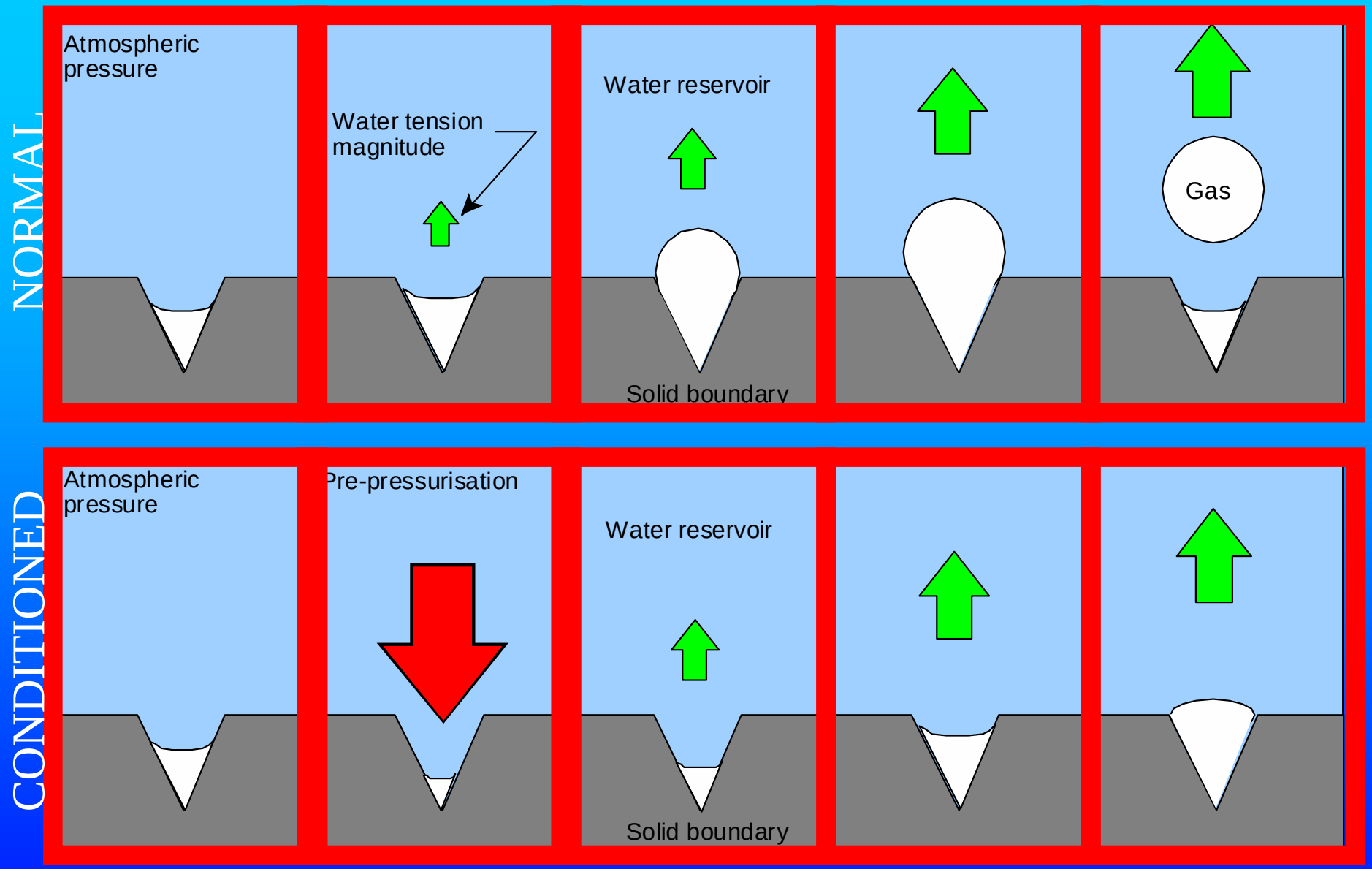
Difficulty of Saturation

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

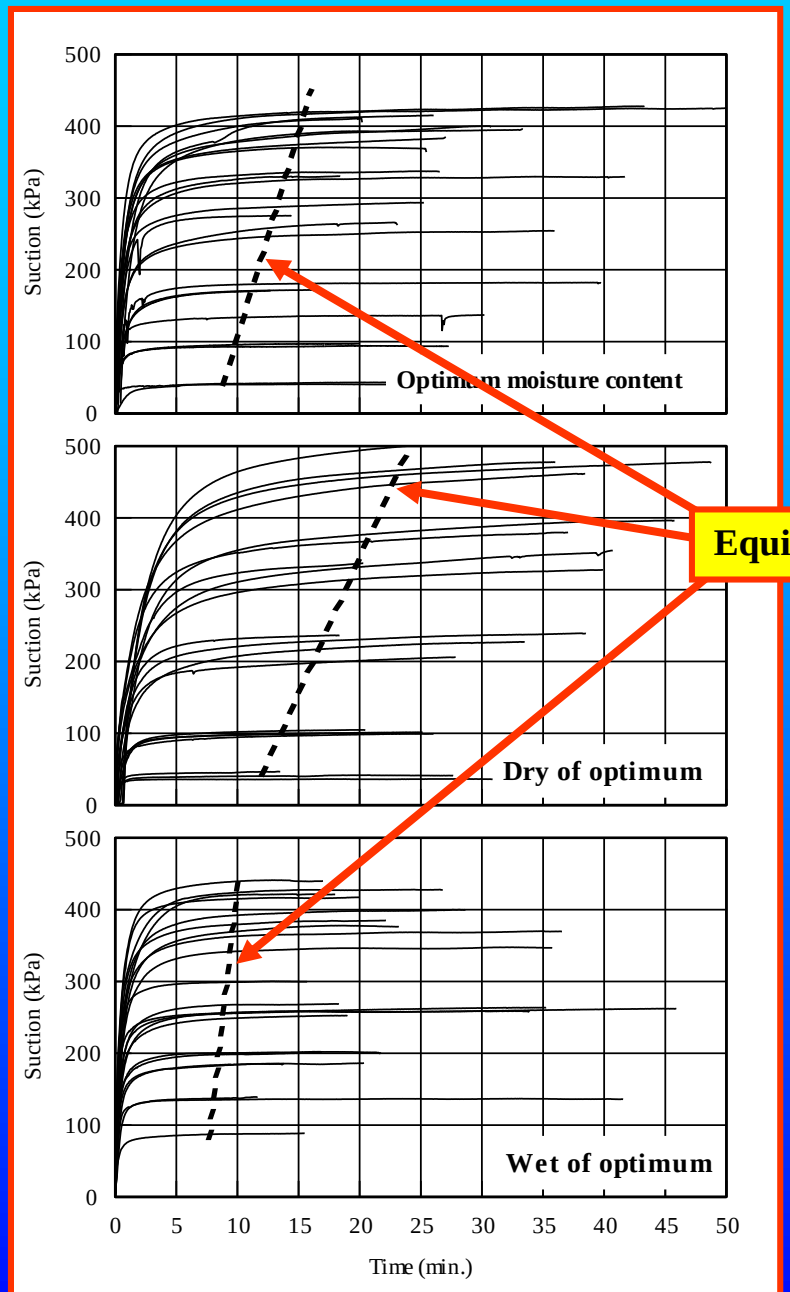
Chemical Treatment

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

The Tensiometer: Saturation



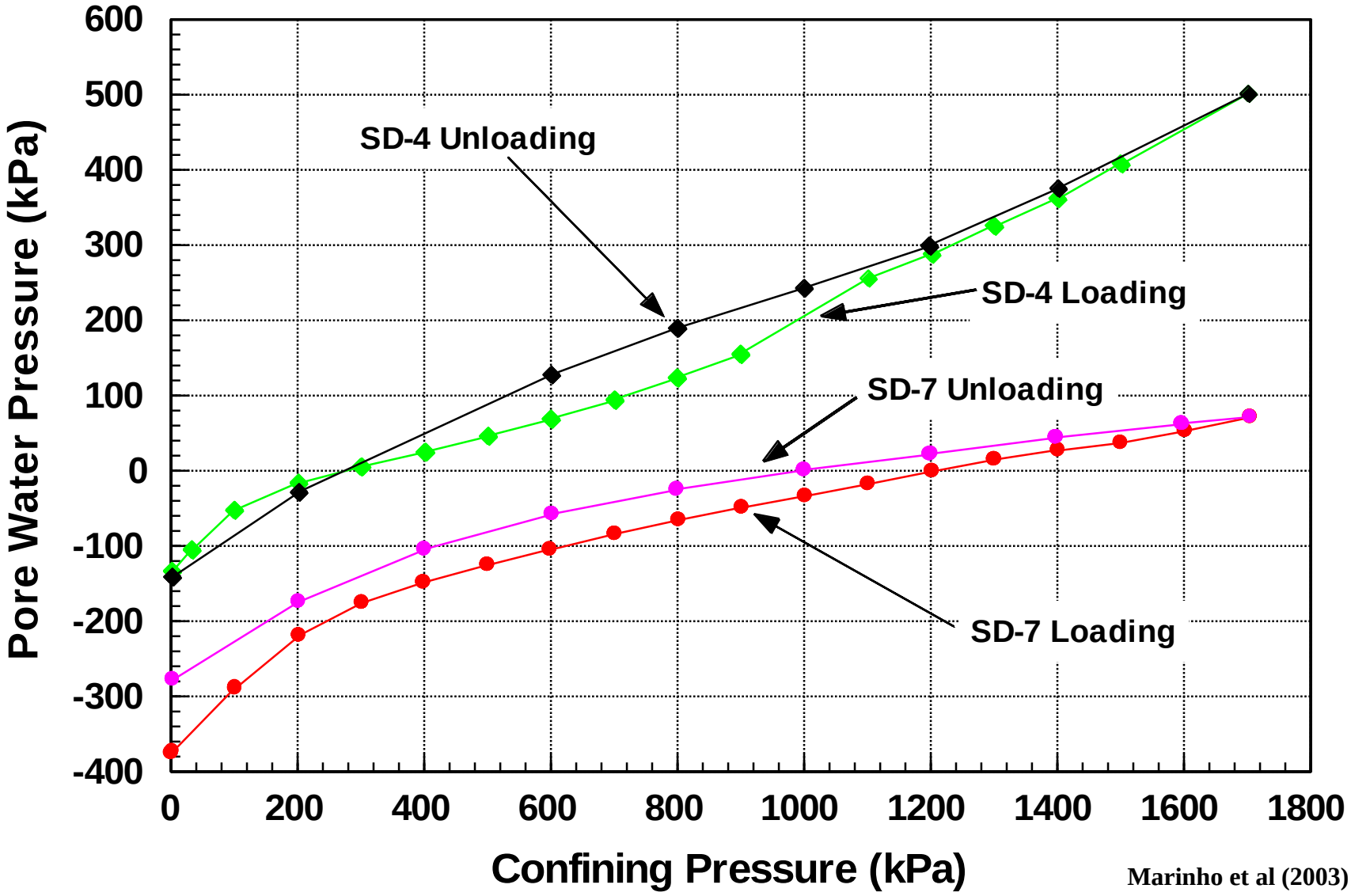
The Tensiometer: Applications



Equilibrium time line

Oliveira & Marinho (2005)

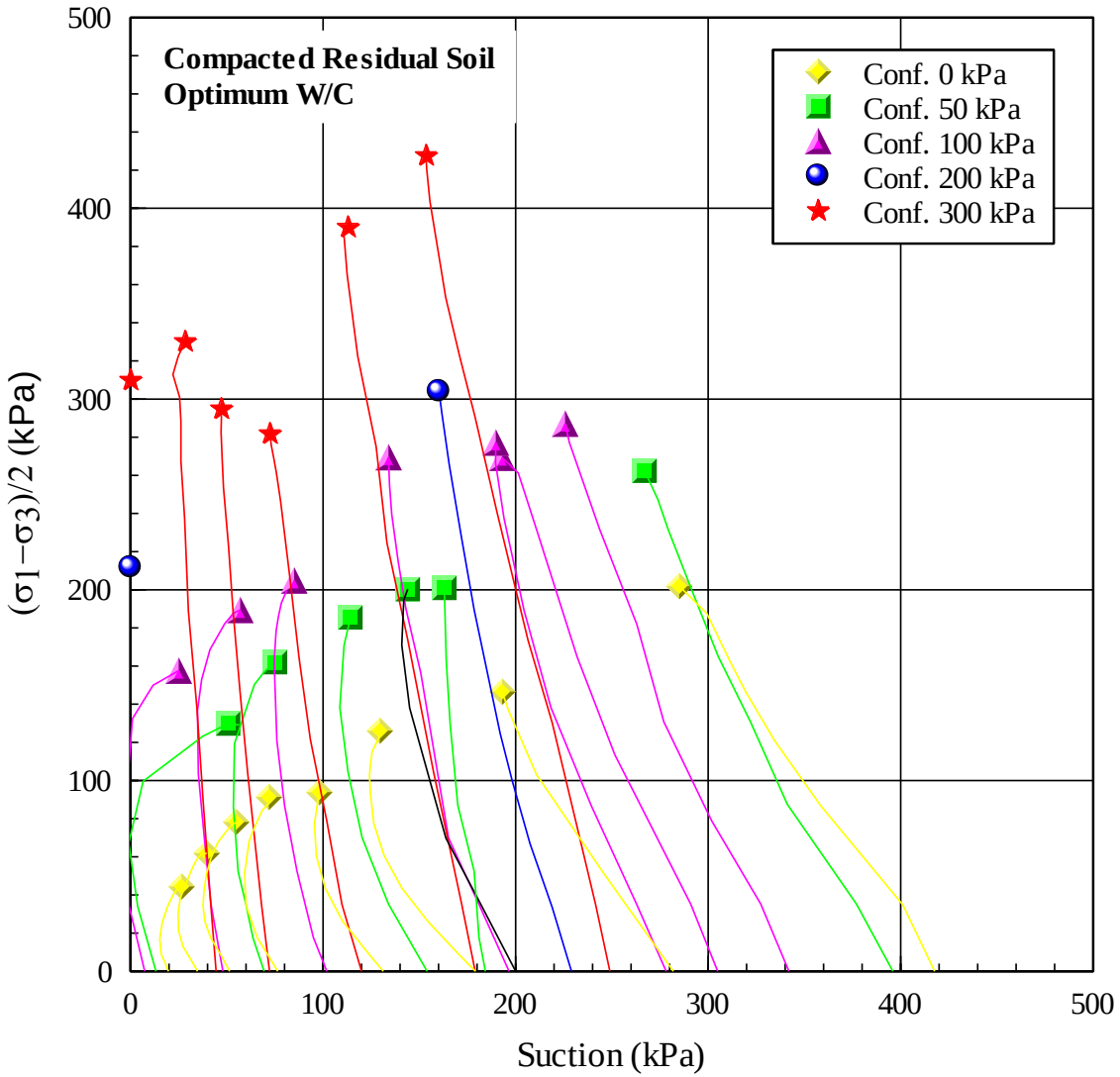
The Tensiometer: Applications



Marinho et al (2003)

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

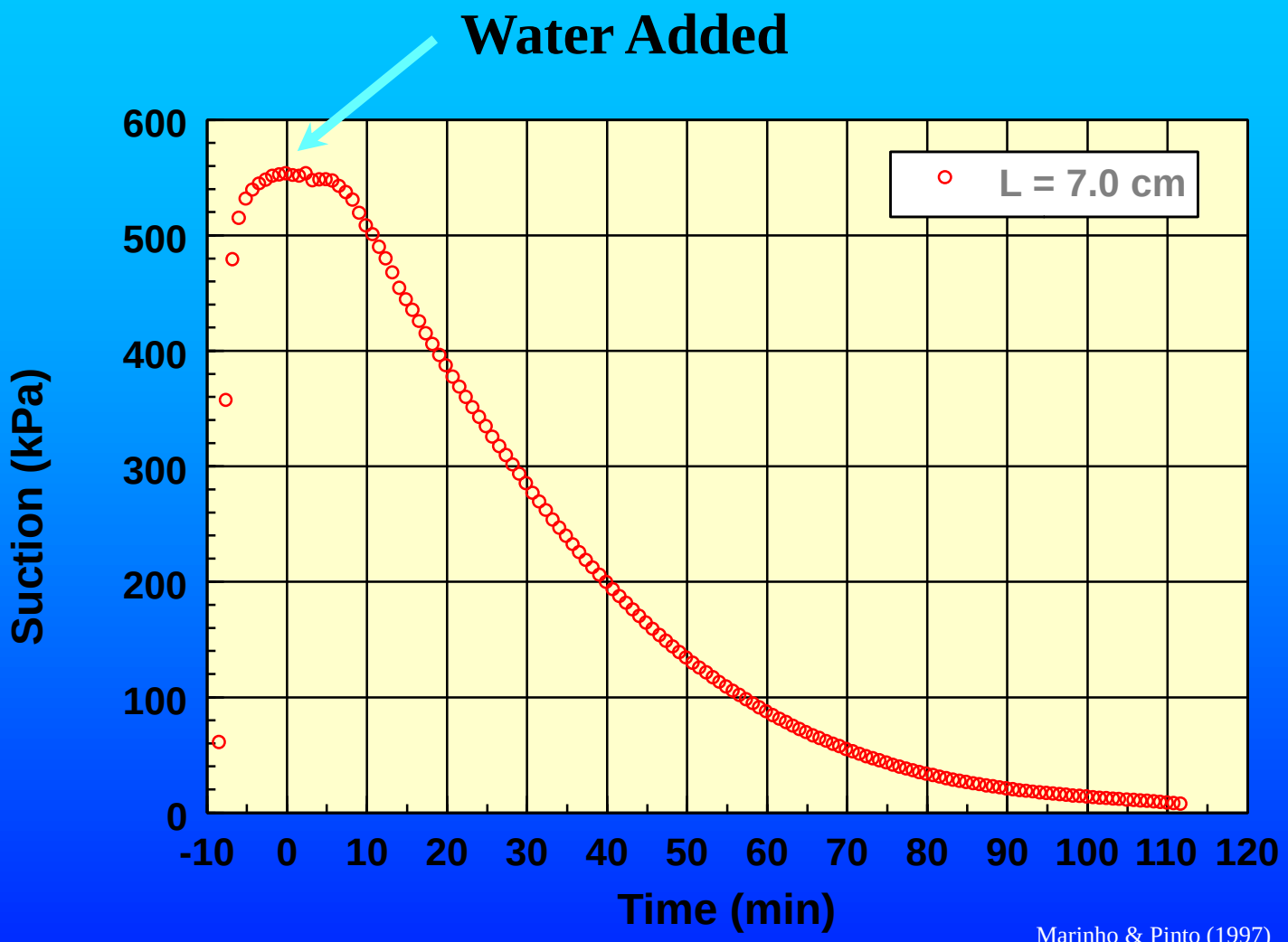
The Tensiometer: Applications



Oliveira (2004)

Suction path during triaxial test on compacted residual soil

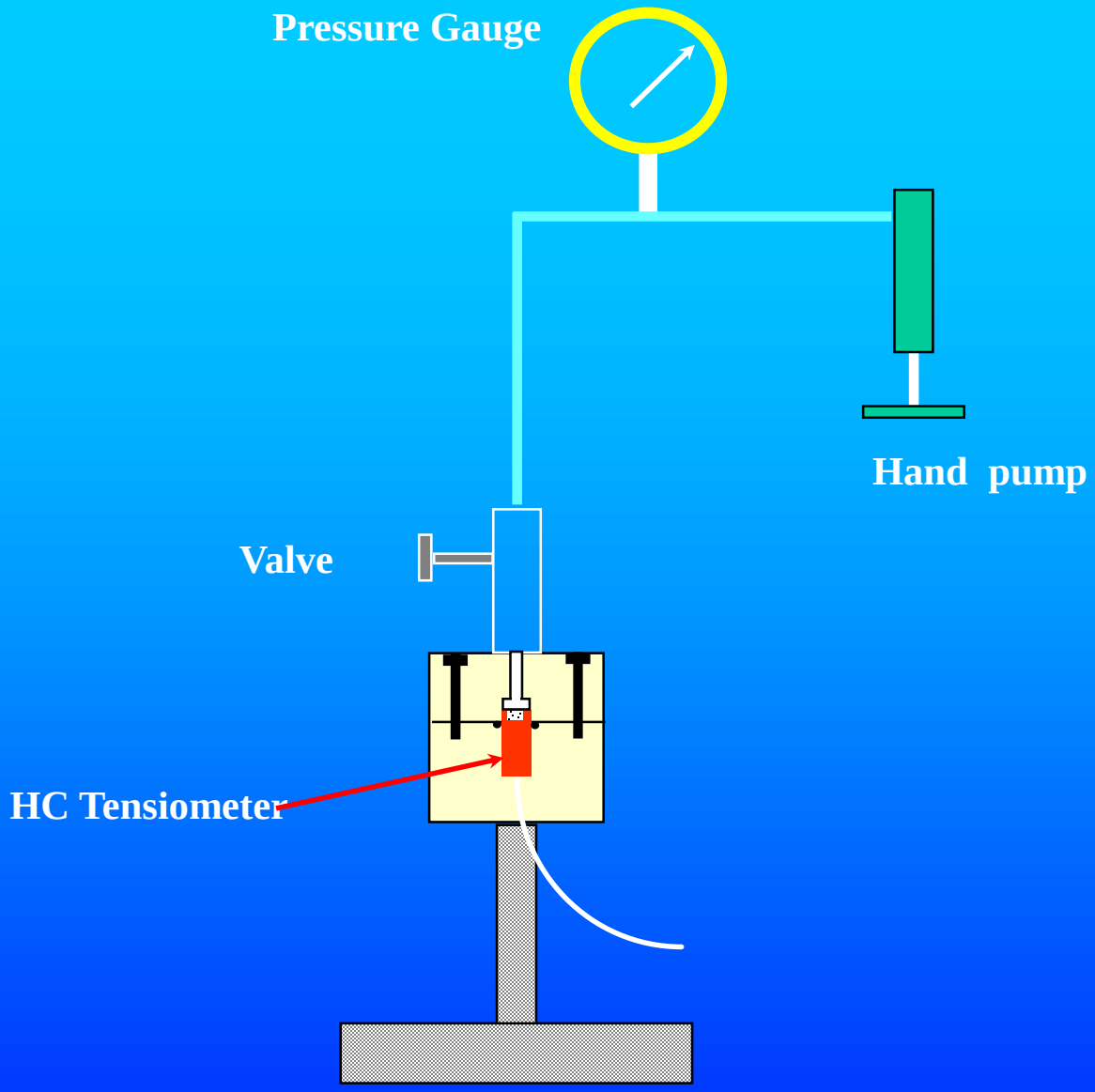
Suction Path



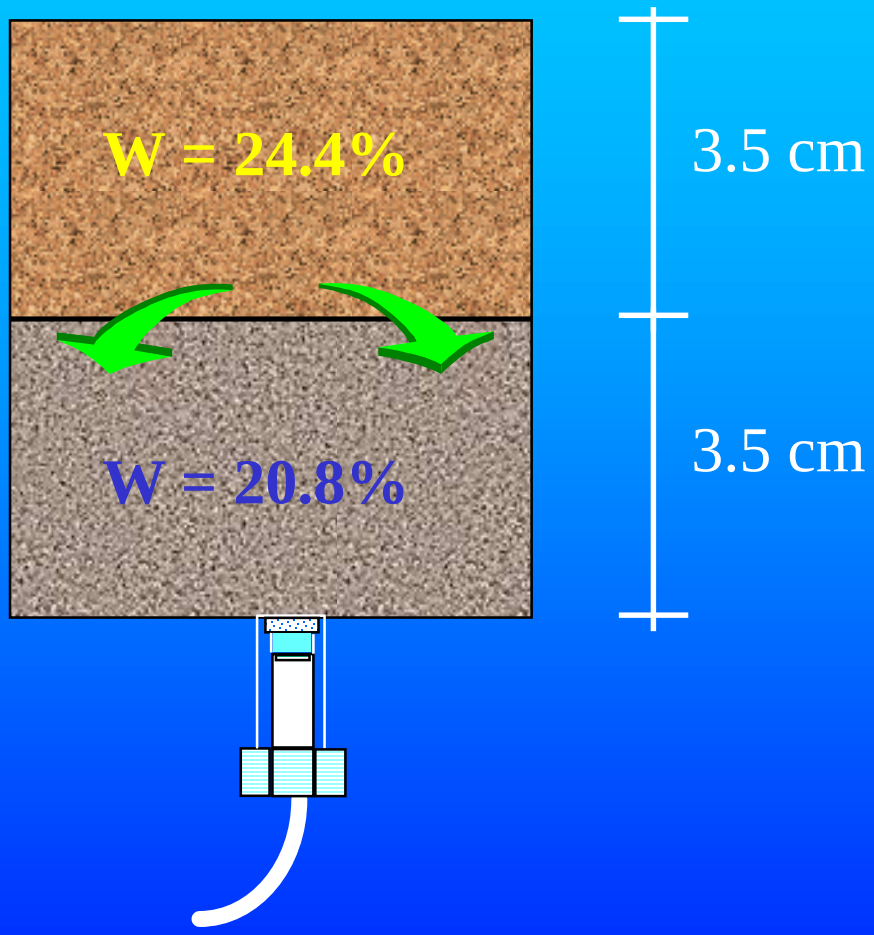
Marinho & Pinto (1997)

Conditioning of the System

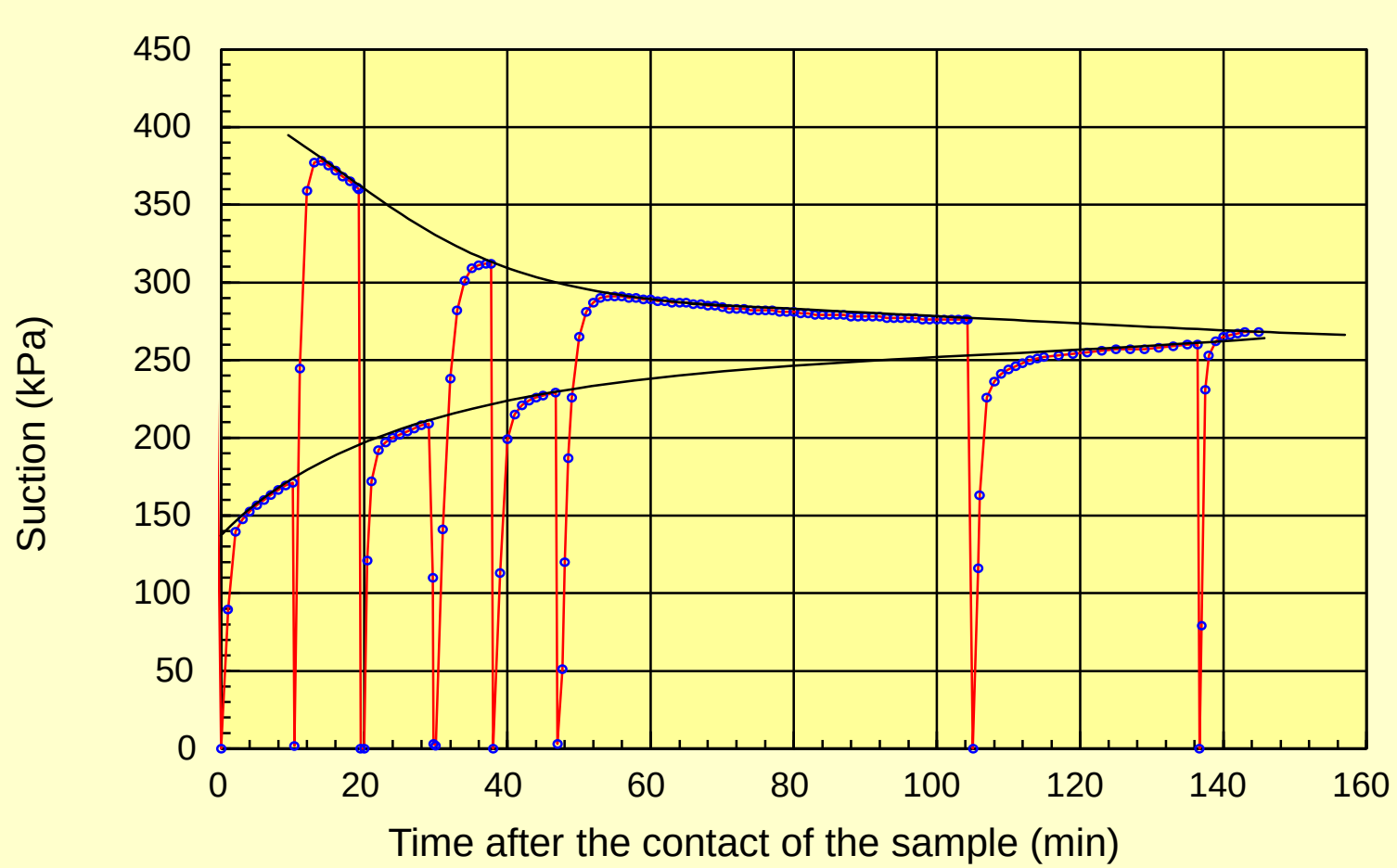
- Initial process of saturation requires vacuum.
- High pressure should be applied in cycles. Instantaneous reduction of the pressure is necessary.
- Application of high pressure up to 3.5MPa, in order to stabilize the cavitation nuclei.
- Chemical treatment may help in stabilizing the cavitation nuclei.


Pressure Gauge
Hand pump
Valve
HC Tensiometer

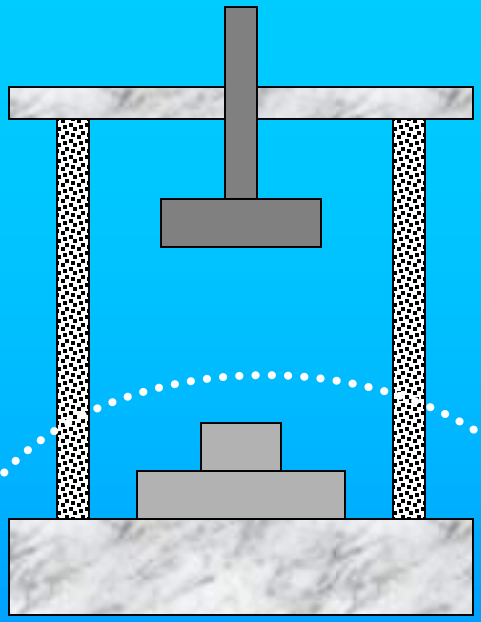
Versatility of the Equipment



Soil suction measurement using the High Capacity Tensiometer

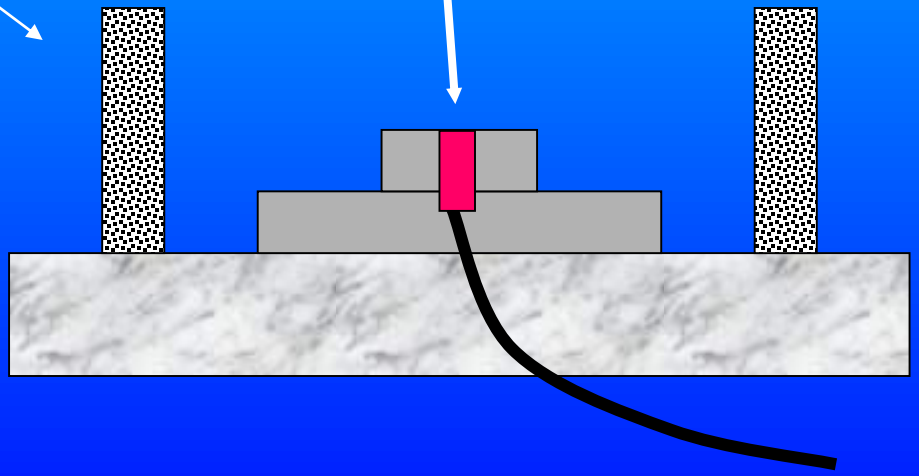


Marinho & Pinto (1997)

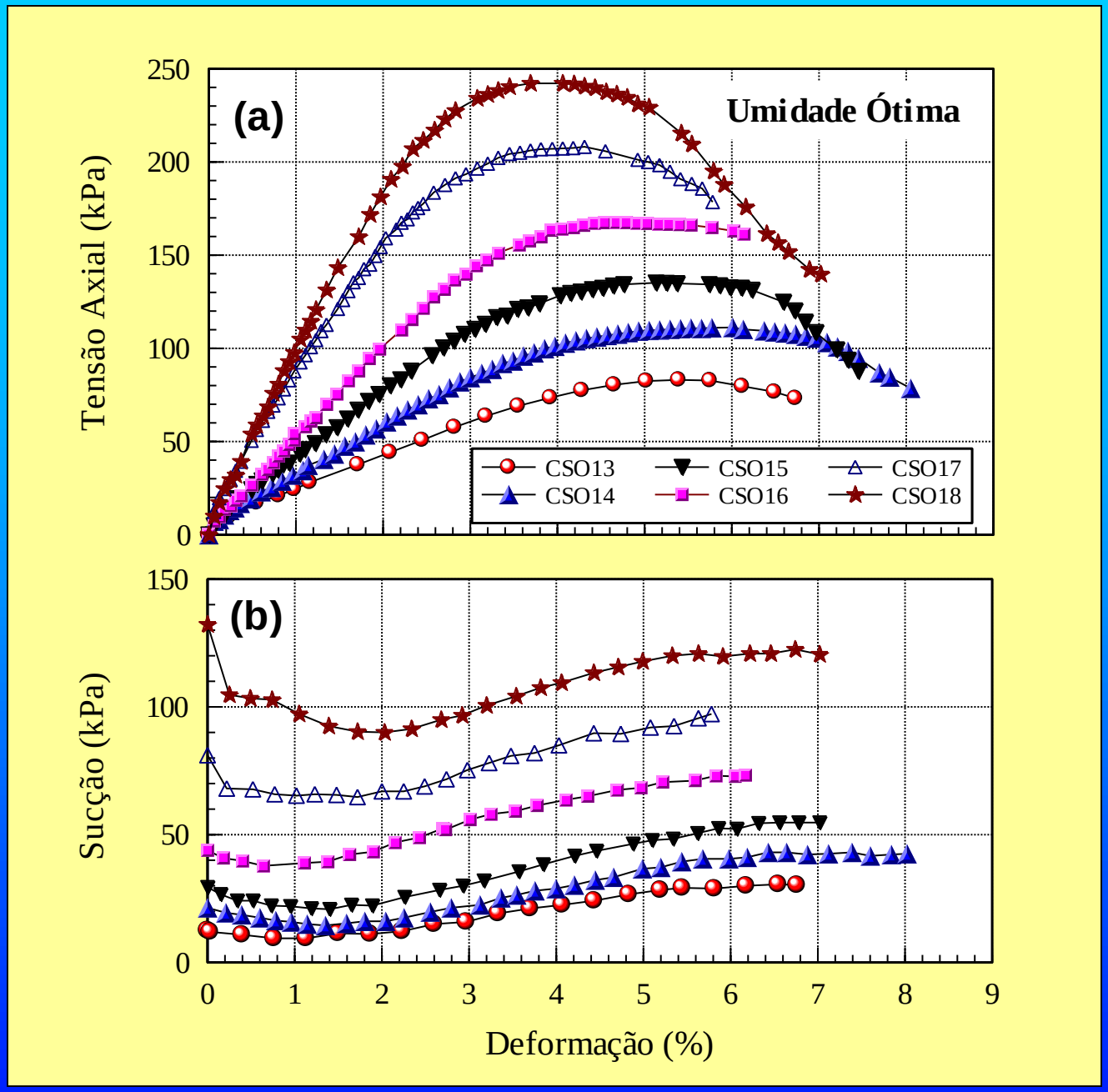


Triaxial Cell

High Capacity Tensiometer

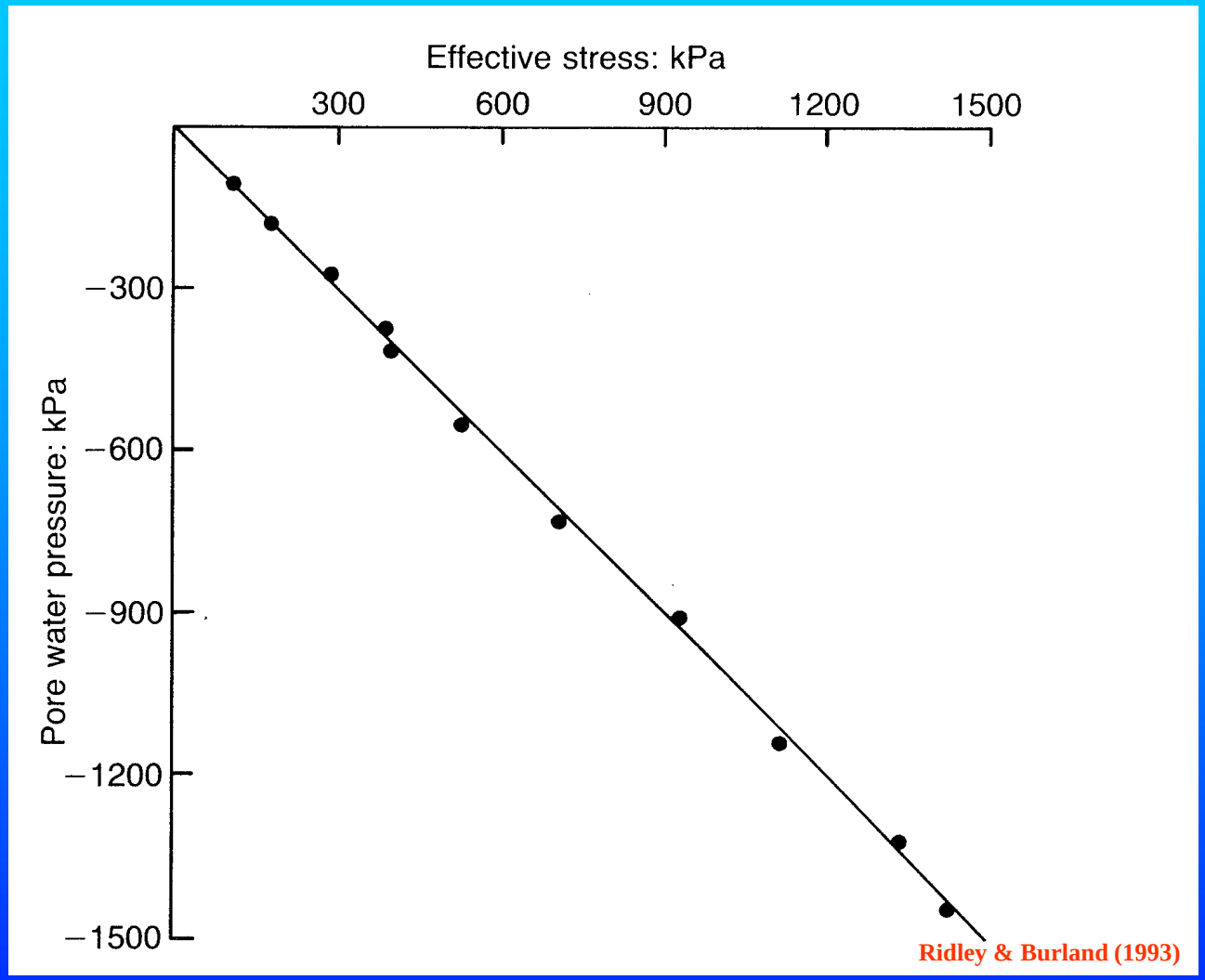


Ensaio Triaxial com medição direta de sucção

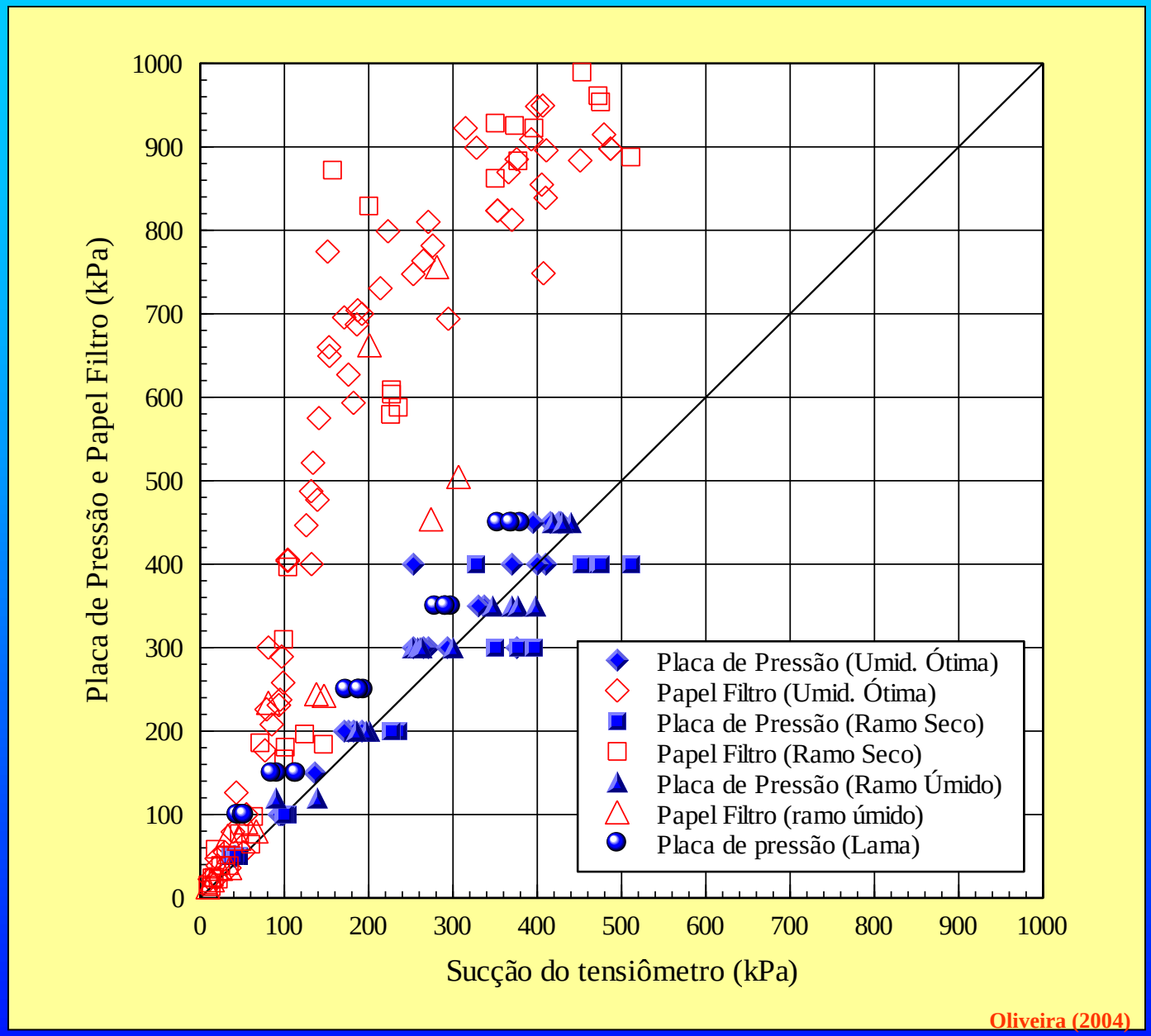


Oliveira (2004)

Comparação entre o TAC e outros métodos



Comparação entre o TAC e outros métodos



Oliveira (2004)

Gypsum (Bouyoucos) Block

Vantagens

O raio de influência é da ordem de 10cm

Não precisa de manutenção

É simples e barato

Possui uma certa influência da salinidade

É mais apropriado para definir níveis de teor de umidade (muito úmido, pouco úmido)

Desvantagens

Baixa resolução

Pouco usado em pesquisa

Não mede bem próximo a saturação

As propriedades do bloco de gesso se alteram com o tempo

O tempo de resposta é lento

Não funciona bem em solos que permitem uma rápidas drenagem (tempo de resposta)

Não é apropriado para solos expansivos

Possui forte histerese

Depende da temperatura

Sensor de Matrix Granular (GMS)

Vantagens

Reduz alguns dos problemas inerentes ao bloco de gesso (Perda de contato com o tempo, histerese)

Não necessita manutenção

Simples e de baixo custo

É afetado pela salinidade, embora aparentemente possui sal no seu interior para minimizar este efeito.

Desvantagens

Baixa resolução

Uso limitado em pesquisa, mas promissor se melhor estudado

Elevado tempo de resposta (ruim para solos que permitem drenagem rápida)

Não adequado para solos expansivos

Pode perder o contato se o solo secar demais

Depende da temperatura


(a)
21 10:38


(b)
21 10:38

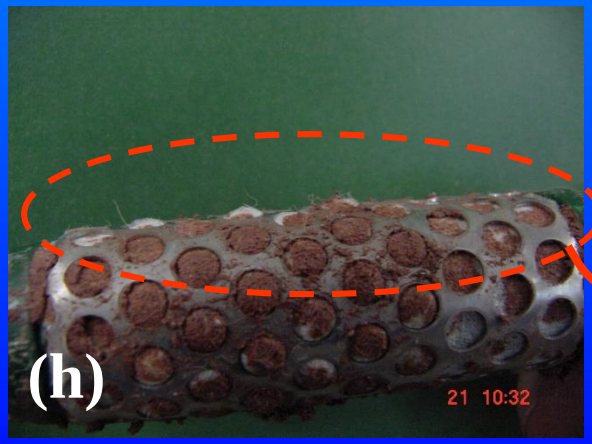

(c)
21 10:39


(d)
21 10:41

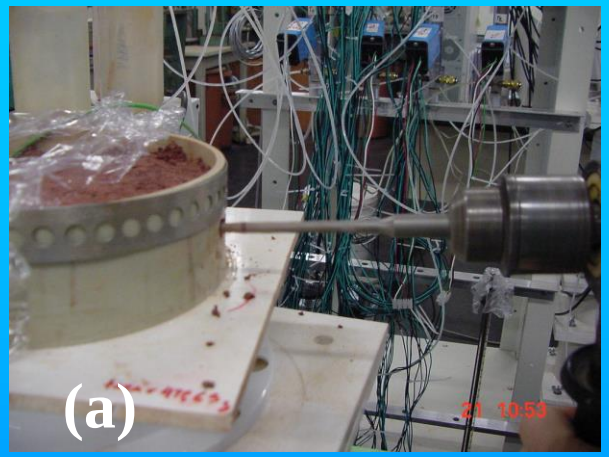

(e)
21 10:43


(f)
21 10:30


(g)
21 10:32


(h)
21 10:32


(i)

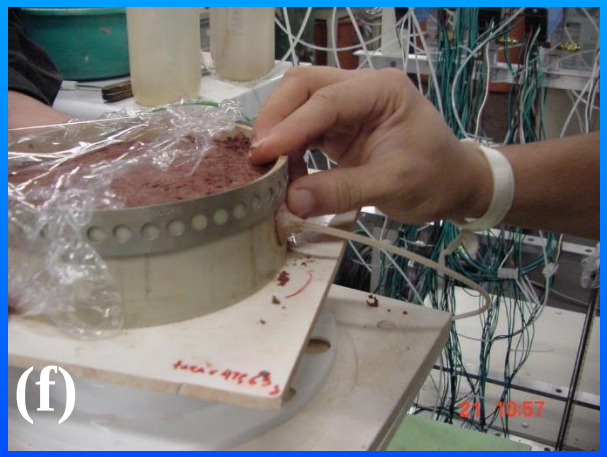

(a)
21 10:53


(b)
21 10:54

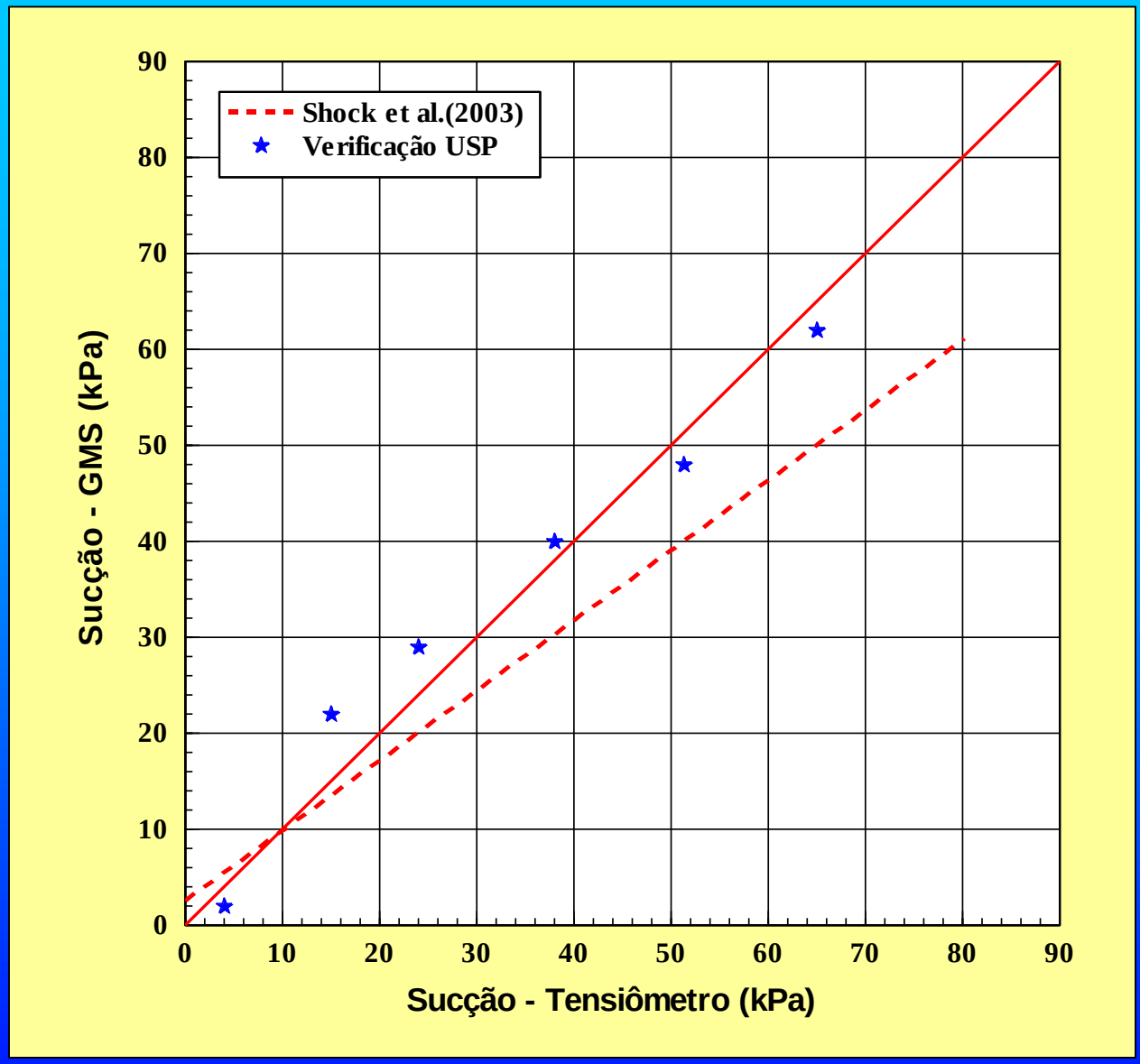

(c)
21 10:54


(d)


(e)
21 10:55


(f)

Verificação da calibração do GMS

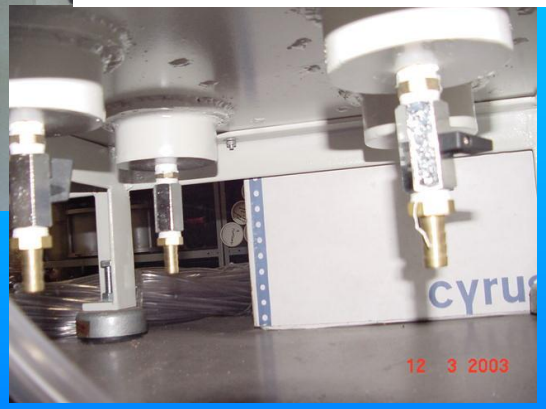


Sistemas de Monitoramento de Fluxo e Retenção em Solos

Colunas para ensaios de fluxo e retenção de água

Vista geralda estrutura

Base de apóio das coluna e sistema de controle de saída ou entrada de água

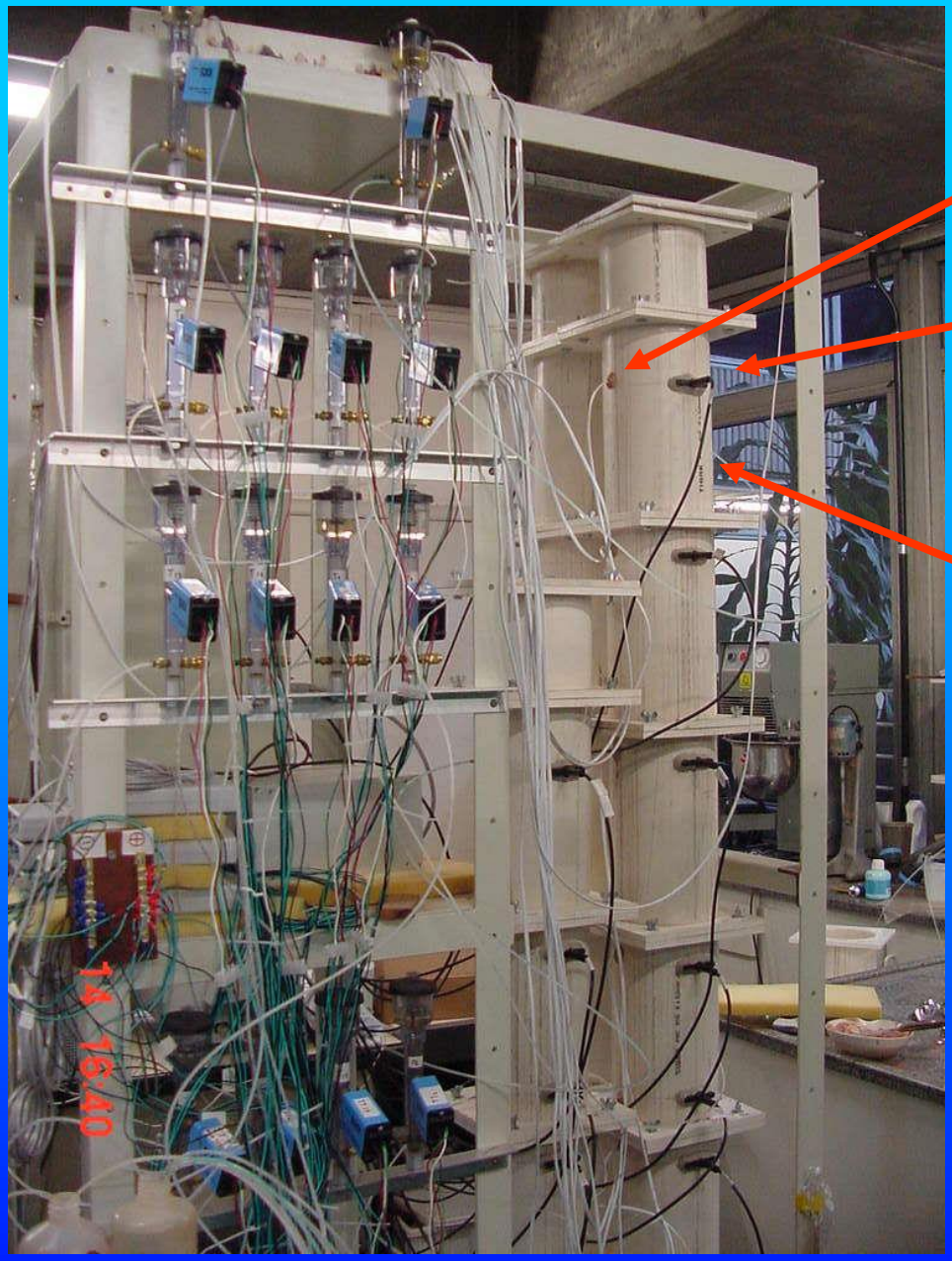


Sistemas indutores de umidade relativa do ar

O sistema permite:

- Criar vários sistemas de camadas
- Monitorar o fluxo de água em diversas situações
- Obter a função de permeabilidade por análise inversa
- Permite a introdução de vegetação

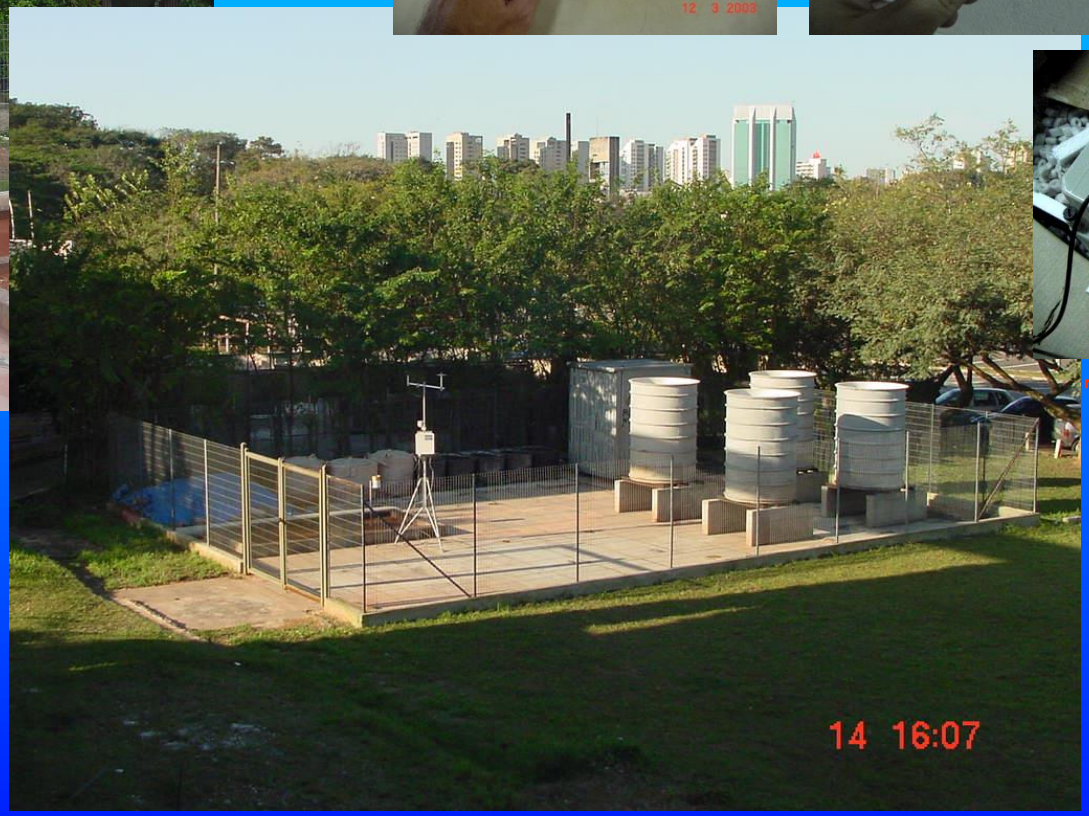

7 4 2004


Temperatura
TDR
Tensiômetro

As células experimentais de Campo

Sucção

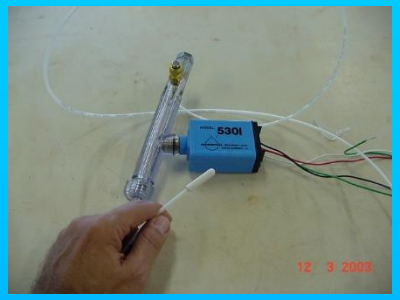
Temperatura

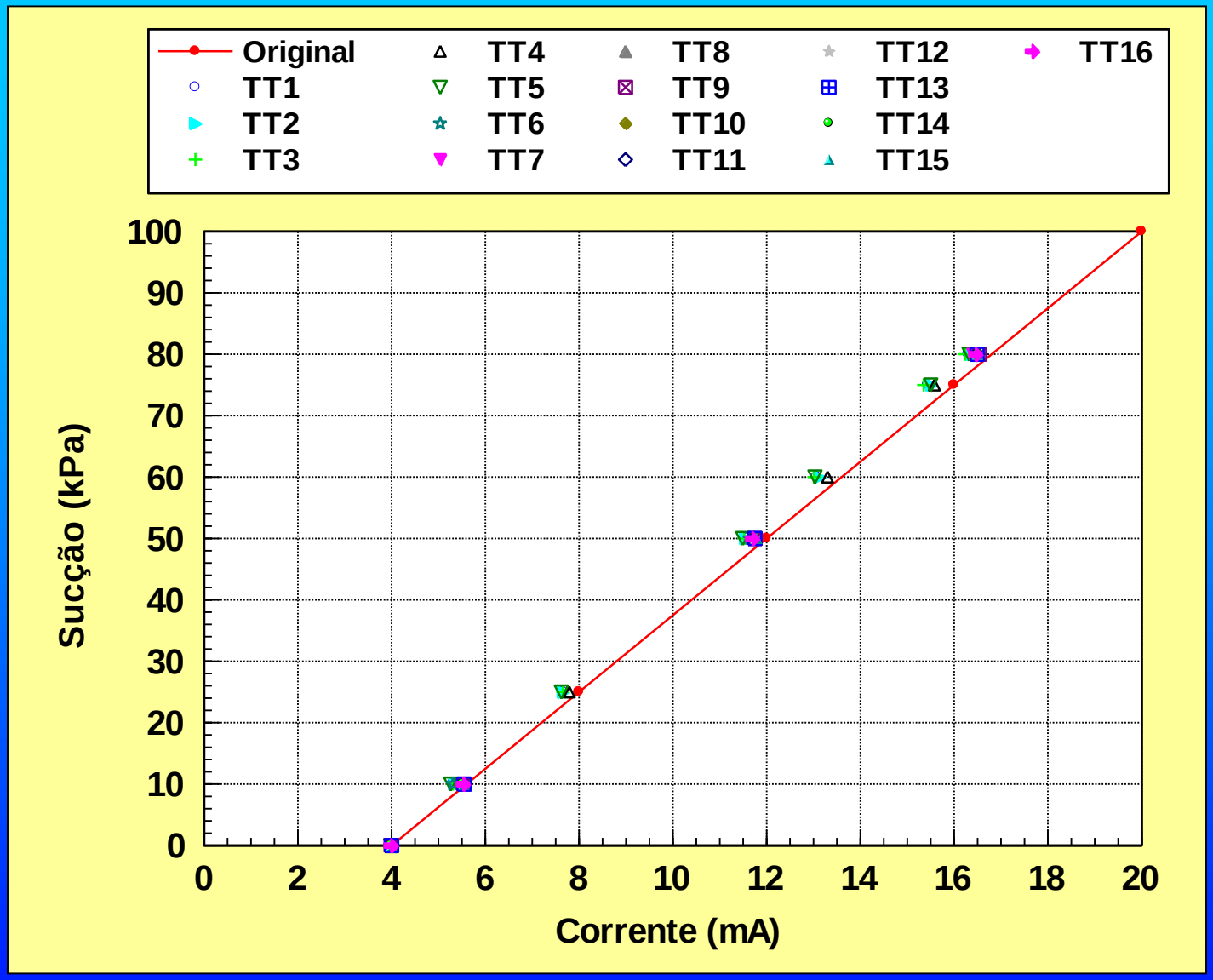


Teor de umidade

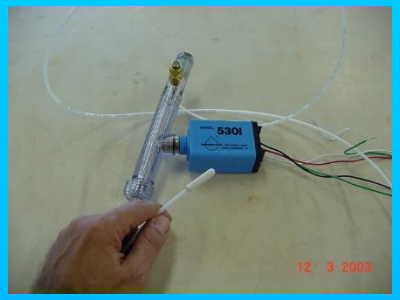
As células experimentais

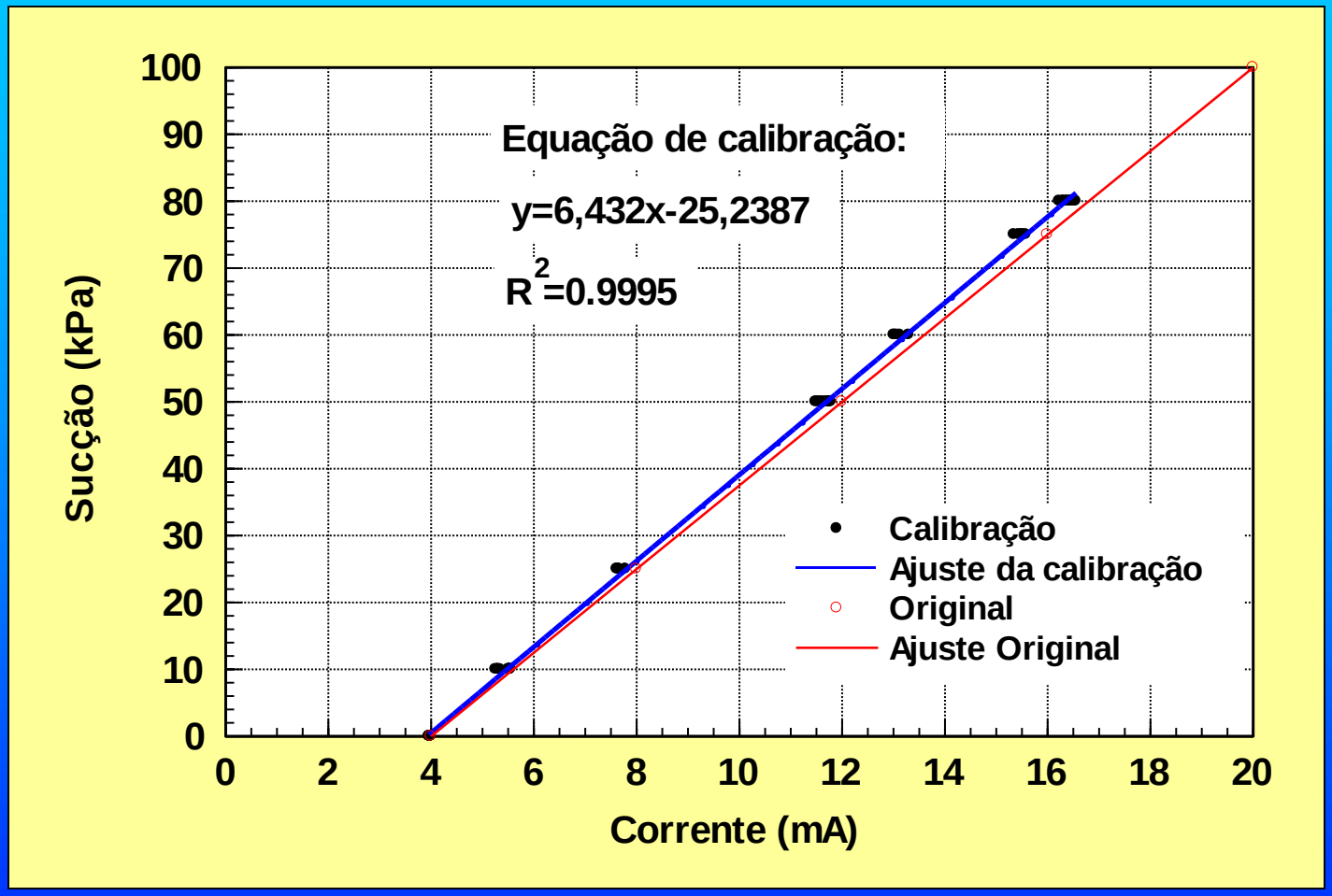
Tensiômetro (Calibração)

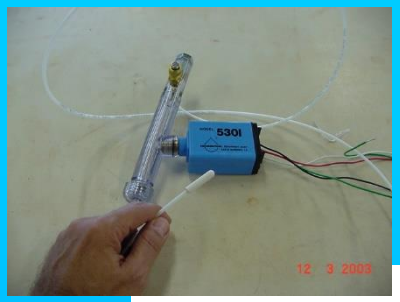




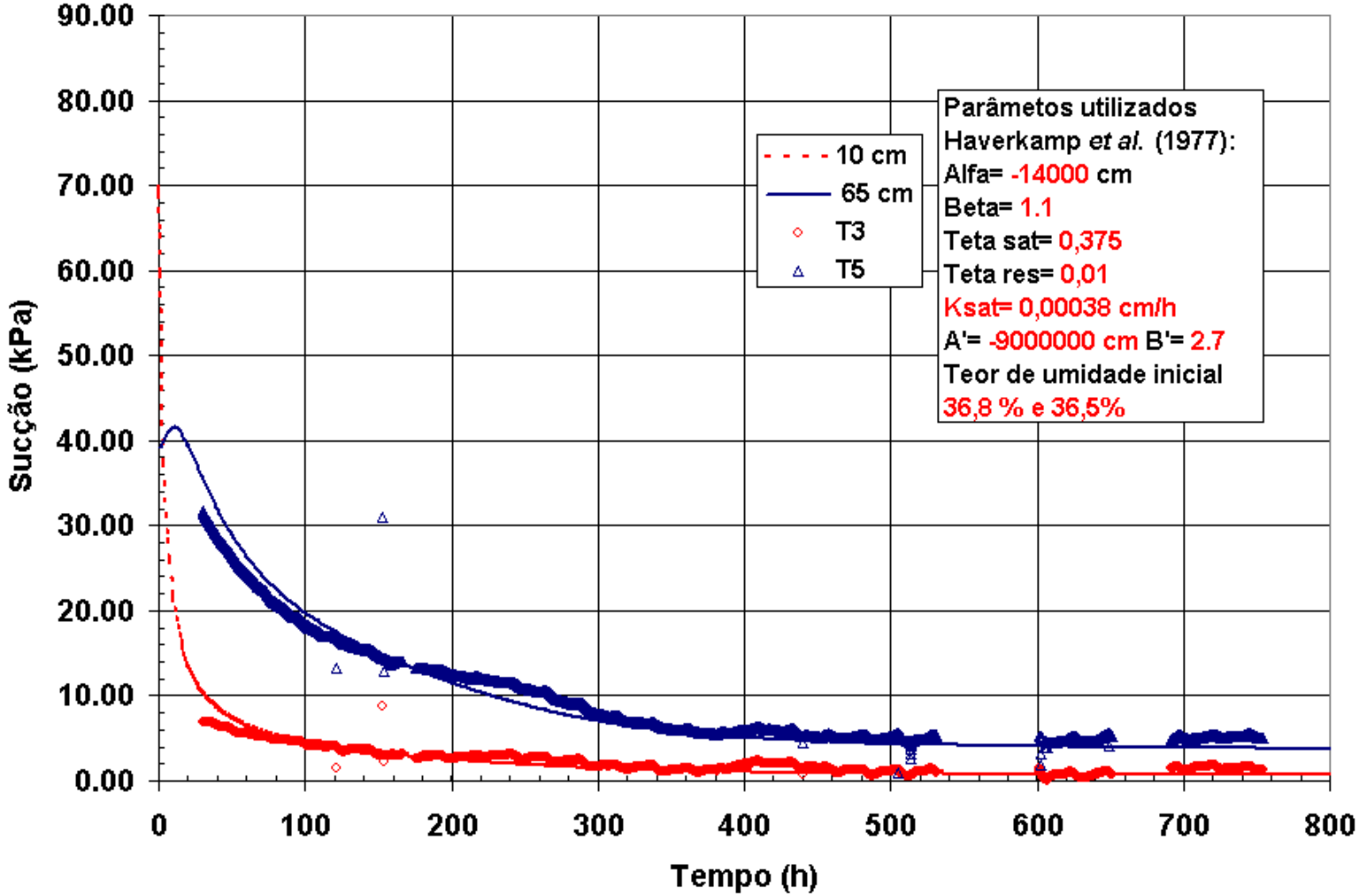
Tensiômetro (Calibração)





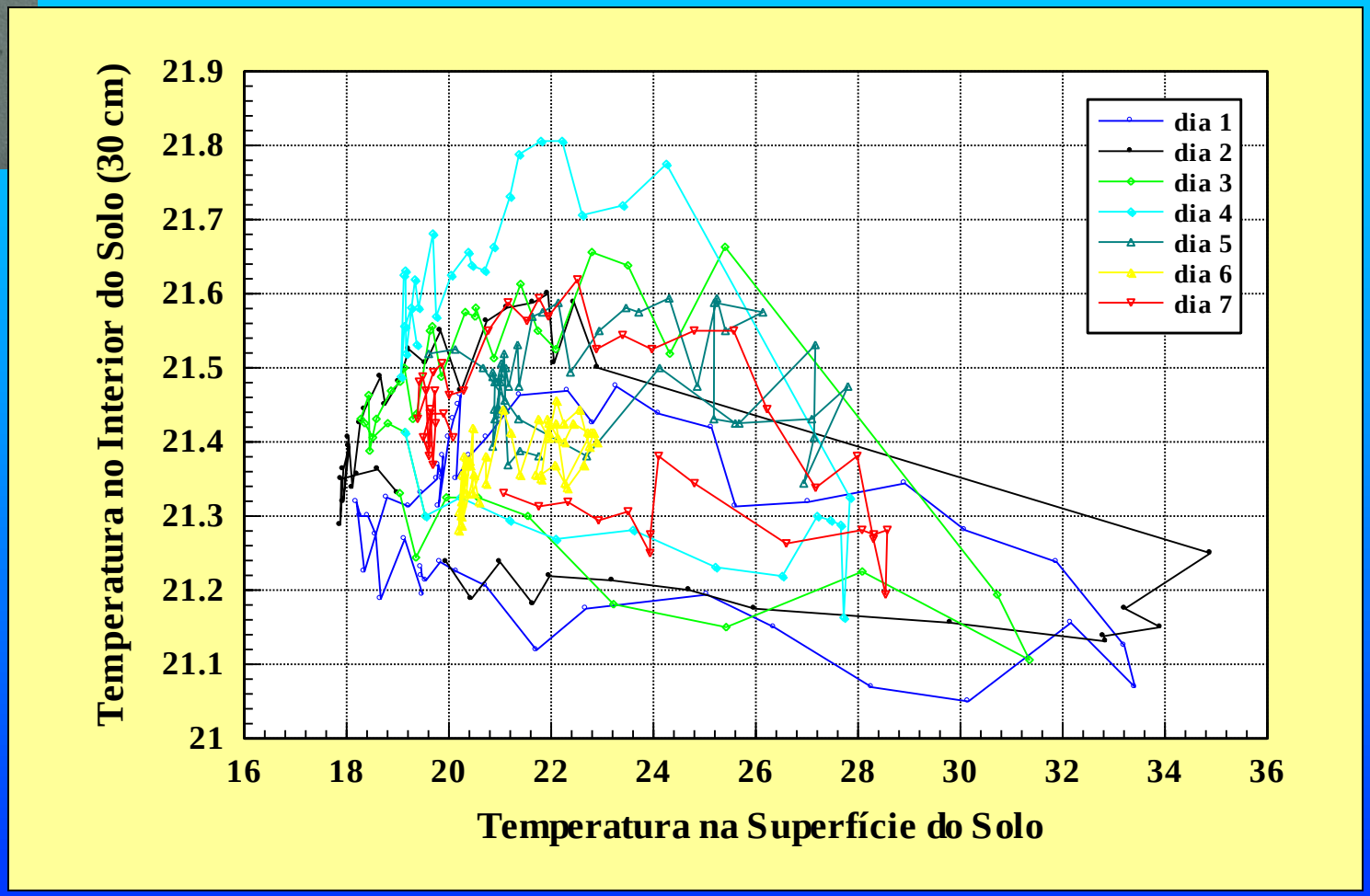


Tensiômetro (Resultados)



Sensores de Temperatura

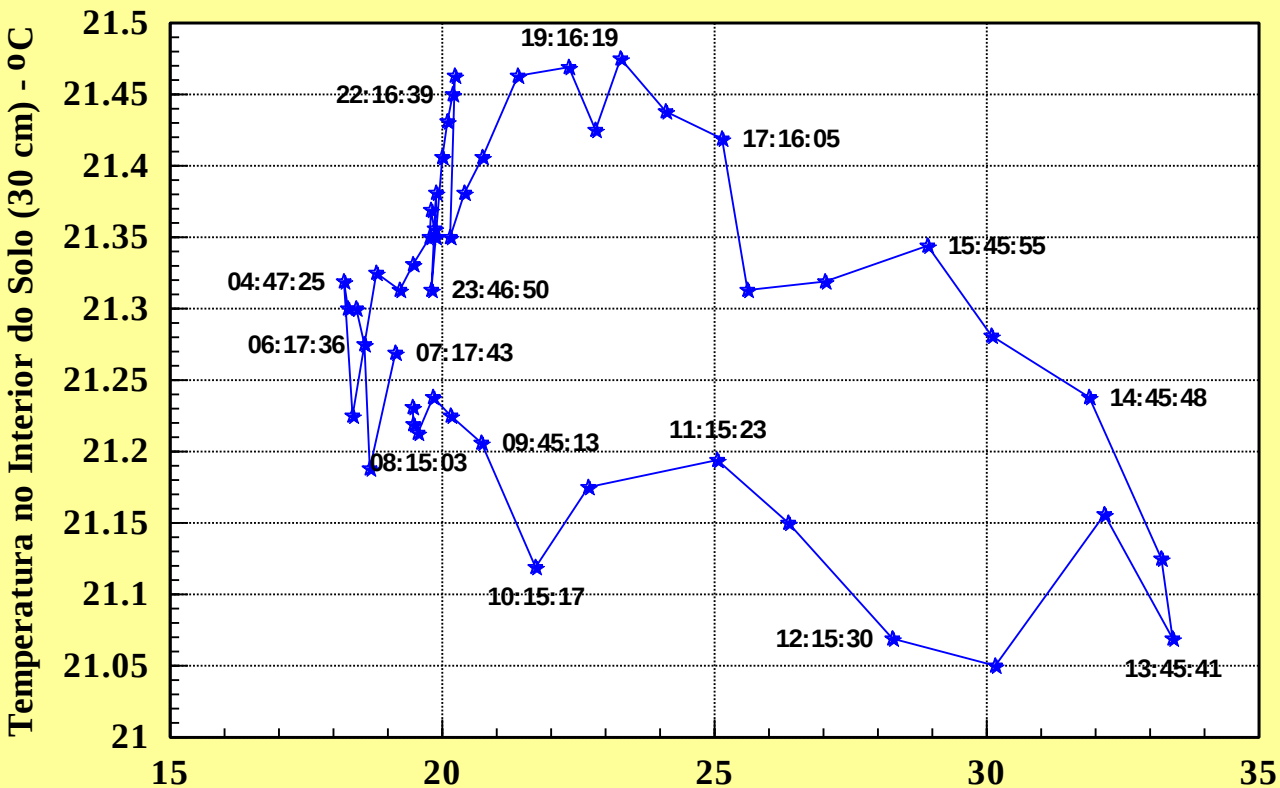
Temperatura



Variação da temperatura no interior do solo em comparação com a temperatura externa, para vários dias.

Sensores de Temperatura

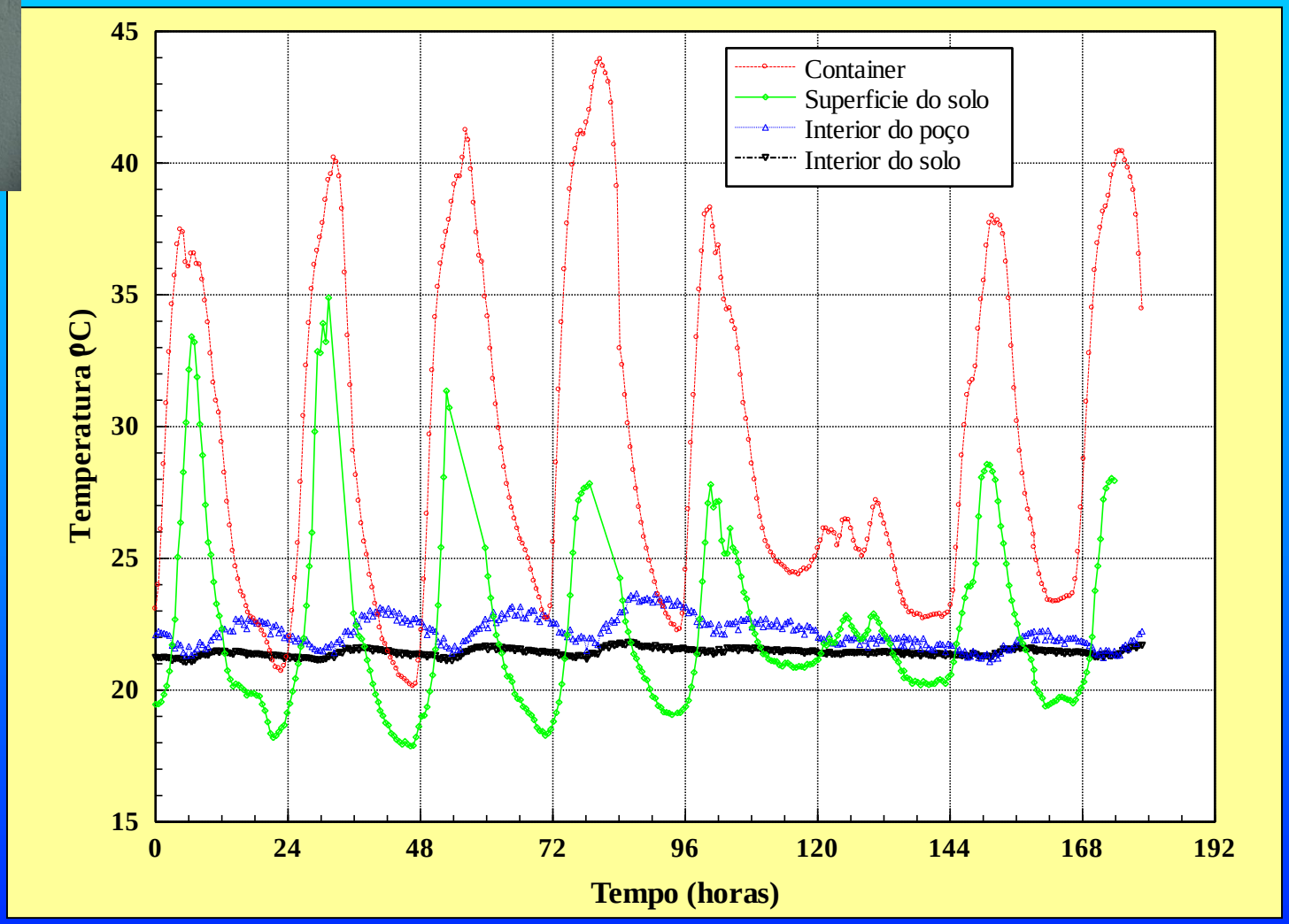
Temperatura



Acompanhamento da variação de temperatura em um dia.

Sensores de Temperatura

Temperatura



Variação da temperatura em diversos ambientes.

Eucalyptus camaldulensis

Eucalyptus camaldulensis