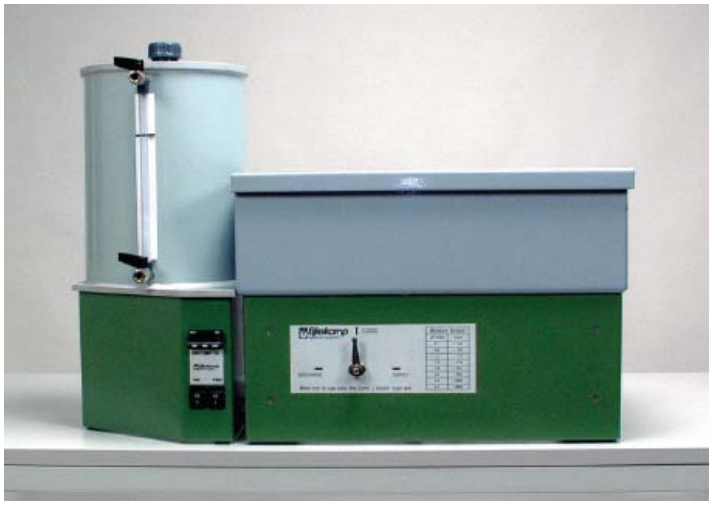
08.02 SAND / KAOLIN BOX

OPERATING INSTRUCTIONS



Contents

All it takes for environmental research

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1 Introduction

This sand/kaolin box (acc. to ISO 11274) can be used to apply a range of pressures from pF 2.0 (-100 hPa) to pF 2.7 (-500 hPa). Kaolin covered sand is used to convey the pressure from the vacuum vessel and drainage system to the soil samples. If higher pF-values are required, then the 08.03 Pressure Membrane Apparatus (pF 3.0 - pF 4.2) is required. When lower pF values need to be applied to samples, then the 08.01 Sandbox should be used (pF 0 – pF 2).

Results of measurements taken with this instrument are points on the drying curves of the relevant samples; associated with *decreasing* pressure. These pressure values are usually standard water potential increments. The wetting curve, on the other hand, is determined by graphing the water content against *increasing* pressure values. This curve is not identical to the drying curve, because the water content does not respond instantaneously to changes pressure (Hysteresis). PF-curves can be plotted - based on the results of measurements taken with this instrument.

2 Description of the sand / kaolin box

The sand/kaolin box (1) stands on four feet (2) and has a drainage system (4) inside it. This box (1) is filled with very fine synthetic sand, which is covered by a layer of kaolin clay (Kaolinite - also known as china clay). The lid (3) placed on the rilsaneted (specially coated) box prevents evaporation. Nylon filter cloth is used to keep the kaolin layer clean. The sample rings (13) are placed on top of this filter cloth, and are in contact with the kaolin suction medium through it.

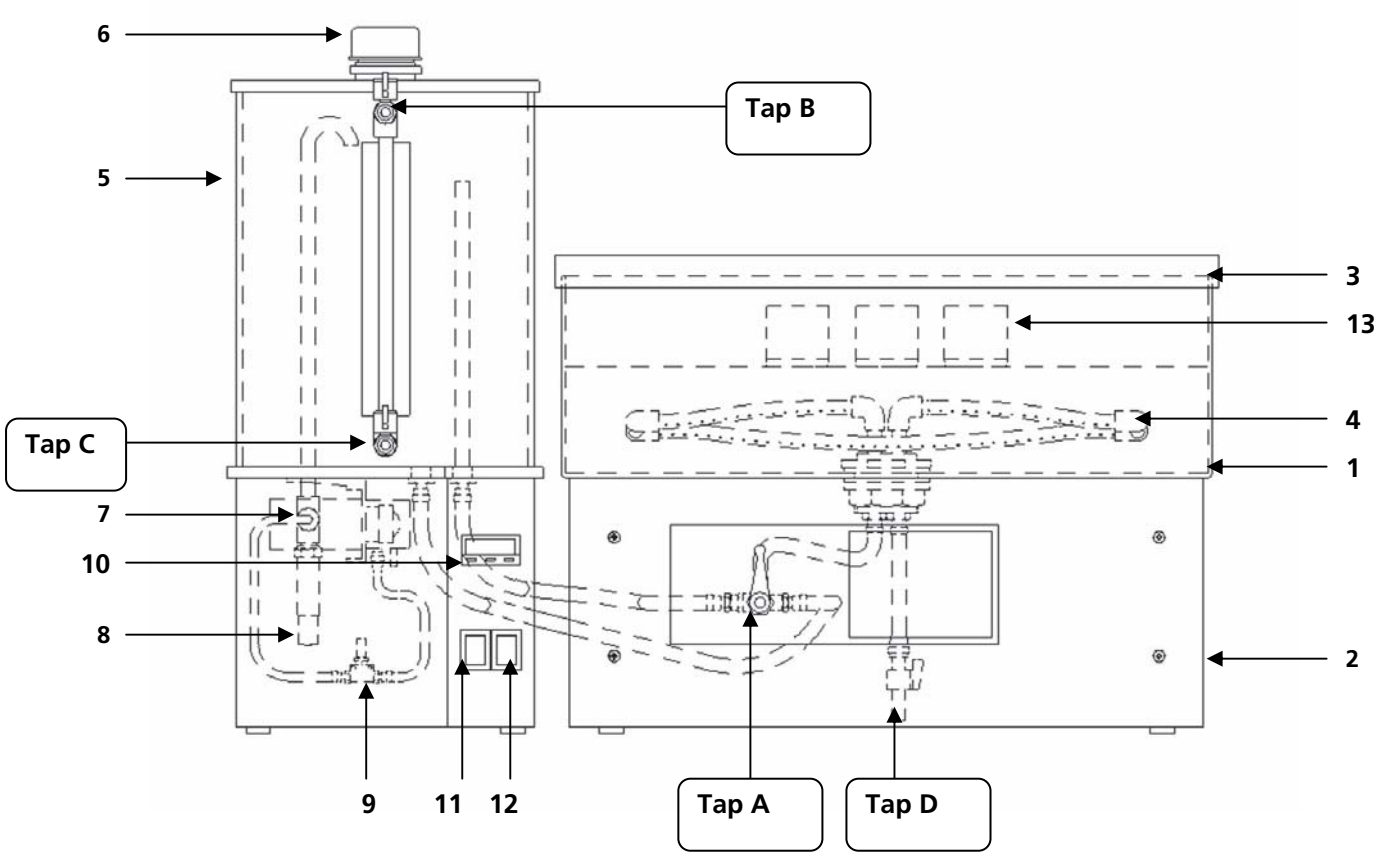
The pump (7) creates suction in the vacuum vessel (5) that is conveyed to the samples (13) from the drainage system (4) through the sand and kaolin layers. An electronic regulator is used to define the pressure level, while the pressure sensor, throttle valve (9) and sound-absorber ensure that the pump creates the correct amount of suction. The pump can be switched on using the pump button (12) while power can be switched on with the On/Off button (11).

When tap A is switched to "supply" then water is transferred from the vacuum vessel (5) to the box (1). If Tap A is switched to "Discharge", with the appropriate Pump Settings, then water will leave the box and install suction on the sand and kaolin layer. By opening tap B the pressure in the vacuum vessel will equilibrate to the atmospheric pressure. Water is released from the vacuum vessel by opening Tap C.

3 Technical specifications

Item	**Specification**
Soil sample rings	max. 40
Dimensions box	55.0 x 33.5 x 37.5 cm (l x w x h) (excluding supply bottle and measuring device)
Operating range	100 – 500 hPa; 0.1 - 0.5 bar; pF 2.0 – 2.7
Vacuum system	Type: vacuum pump, vacuum tank and automatic suction level control system
Contents	10 L
Accuracy	±10 hPa
Adaptor	220V to 24 V

Figure 1: Assembled Sand/kaolin box with numbered components



1. Box	9. Throttle valve
2. Box Stand	10. Display
3. Lid	11. Power switch
4. Drainage Pipe	12. Pump switch
5. Vacuum vessel	13. Samples
6. Vacuum vessel cap	
7. Pump	
8. Pressure sensor	

4 Assembling the sand / kaolin box

All of the tubes are connected and tested for leakage before delivery.

☞ **Take care not to break the tube connections while unpacking.**

☞ **Check that the intended electrical supply has the correct voltage (230 V).**

Construct the sandbox using the following instructions (Numbers refer to Figure 1):

4.1 Set up the sand / kaolin box:

Figure 2: Setup box with taps closed

4.1.1. Place the sand/kaolin box on a sturdy table, with Tap A facing the front and turned to the *'Closed'* position. (Fig 2)

4.1.2. Place the Vacuum Vessel (5) to the left of the box, and plug it into an electrical supply (230 V).

4.1.3. Make sure that Taps A, B, C and D are all closed.

4.2 Check the Setup Values

☞ **The Display (10 see figure 1 on page 4) facilitates access to a lot of extra programming functions that should never be altered. Only adjust the settings referred to in this manual.**

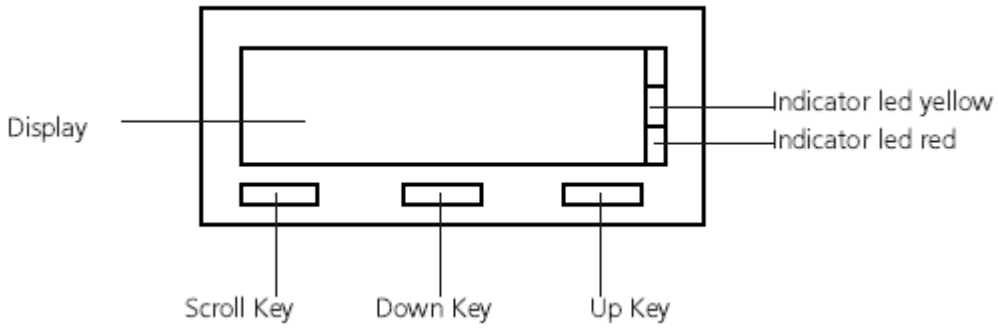


Table 1: First Menu

Parameter	Meaning
	Current Pressure in the Vacuum Vessel (12)
	Alarm 1. Do not change this setting.
	Pressure Set-point

4.2.1. Check that the pump is switched off (Figure1: 12) and then turn the power on (11).

4.2.2. The red L.E.D flashes to indicate that you are in the first menu. The pump indicator.

4.2.3. The First Menu has the three Parameters listed in Table 1. The 'default value' displayed is the current pressure in the Vacuum Vessel (PrOC).

4.2.4. Hold the "Up-key" and "Down-key" down simultaneously (for about 3 seconds) until "FiLt" appears on the display. The yellow L.E.D will be lighted to indicate that you are in the Second Menu (See Table 2).

Table 2: Second Menu

Setup Name	Setup Value	Function
		Input filter time constant value
		Input offset value
		Enable access to alarm value
	Do Not Change	Alarm value 1

4.2.5. The first number displayed is the FiLt **Setup Value**. Ensure that this is '0' as seen in Table 2. If the FiLt **Setup Value** is not '0', then use the "Up key" or the "Down key" to correct it.

4.2.6. Press the "Scroll Key" twice to change between **Setup Names** (E.g. 'OFFS' - See Table 2) and ensure that the **Setup Values** in Table 2 are installed.

4.2.7. After all of the **Setup Names** have the **First Setup Values** (Table 2) then use the "Scroll Key" to return to the *'FiLt'* **Setup Name**.

4.2.8. Push the "Up-key" and "Down-key" simultaneously (for about 3 seconds) to exit the second menu. The yellow L.E.D will automatically turn off.

☞ **Note: Setup Values will be changed from the *First Pump Settings* (Table 2) for removing the bubbles in the system, and in using the sand/kaolin box (Chapter 5).**

4.3 Prepare the Drainage System

The plastic drainage pipe (4) inside the box (1) must be covered with filter cloth. The supplied filter cloth has two layers, and is 6 cm wide. The plastic drainage pipe needs top be covered by 3 layers of cloth, so that sand wont block the holes in the pipe when suction is applied, and the suction is diffused.

To apply the filter cloth to the pipe, the following steps should be followed:

Figure 3: The 10 cm long 'ties'

Figure 4: Saturate Cloth

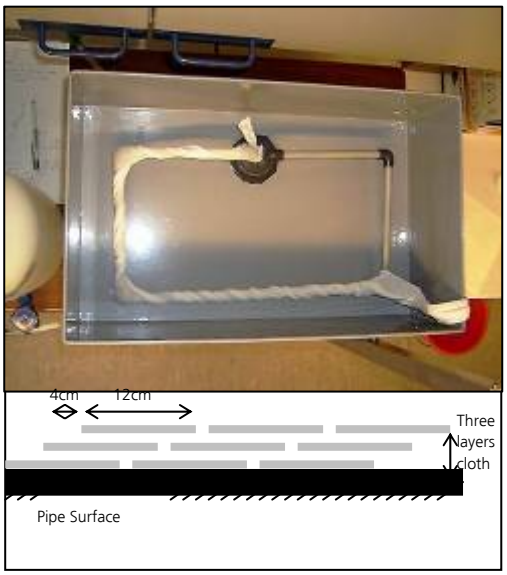


Figure 5: First cloth layer

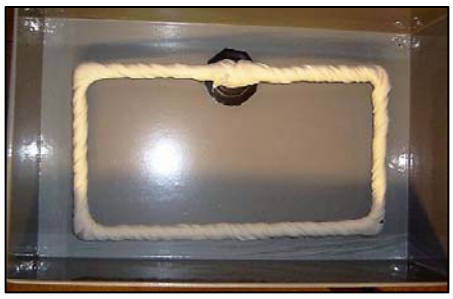


Figure 6: Complete Cloth Covering

4.3.1. Cut a 3.5m long section from the supplied roll of filter cloth.

4.3.2. Cut down one side the filter cloth to make a single 12cm wide layer.

4.3.3. To knot the cloth to the pipe, a 10cm long section is cut into the each end of the strip to form two ties. (Fig. 3).

4.3.4. Saturate the filter cloth in water (Fig. 4).

4.3.5. Tie the filter cloth to one end of the drainage pipe - where it enters the inside of the box.

4.3.6. Coil the filter cloth around the drainage pipe so that each consecutive winding covers two thirds of the width of the previous one. This will ensure that the entire pipe is covered by three layers of filter cloth. (Fig. 5).

4.3.7. Fasten the cloth at the other end of the pipe.(fig.6)

4.3.8. Cut off the extra cloth, and tie the end to one end of the drainage pipe.

4.4 Removal of air-bubbles

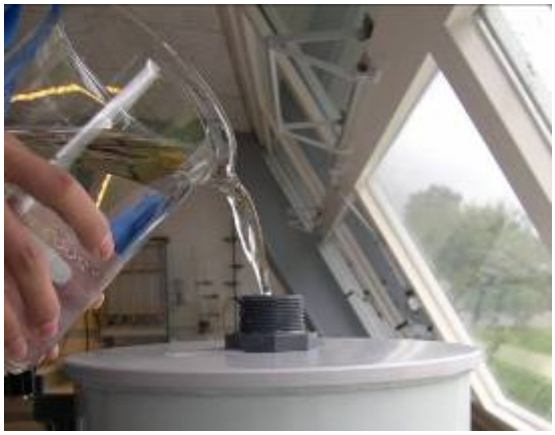


Figure 7 Fill the Vacuum Vessel with DM water

Figure 8: Turn tap A to *'Supply' position*

Figure 9: Half-fill box with water

Figure 10 : TAP D at backside of the box

4.4.1. Boil 10 L of demineralised water, and leave it to cool.

4.4.2. Open the Cap (6) of the Vacuum Vessel and Fill the Vacuum Vessel up to the 'Max' line with this water. (This maximum is visible on the tube between Tap B and Tap C). (Fig.7)

☞ **You may add (0.01mg/l) copper sulphate to reduce microbiological activity.**

4.4.3. Turn Tap A, on the front of the box, to *'Supply'*. Allow water to flow from the Vacuum Vessel (5) into the Box (1) until the Drainage Pipe (4) is completely submerged in water.(fig 8)

☞ **Always ensure the water level in the Vacuum Vessel (5) is higher than the water level in the Box (1).When the water level in the Vacuum Vessel becomes too low then add demineralised water through the open Cap (6).**

☞ **Water must flow from the Vacuum Vessel (5) into the Box (1) until the Drainage Pipe (4) is submerged.**

4.4.4. When there are no bubbles left in the supply tube between the Vacuum Vessel and the Box then turn Tap A to the *'Closed'* position.

4.4.5. Gently pour water directly into the box (1) until it is half-full. (Fig.9)

4.4.6. Open Tap D, at the back of the box, and allow some water to run from the box (1) out of Tap D into a beaker. (Fig 10)

Figure 11: Tightly close the lid

4.4.7. When there are no air bubbles in the tube between the Drainage Pipe (4) and Tap D then close Tap D.

4.4.8. Tightly close the lid of the Vacuum Vessel (5). (fig 11)

☞**When using the pump there are some important considerations (See Caption 1).**

Caption 1: Controlling the water level in the Vacuum Vessel.

☞**The water level in the Vacuum Vessel (5) must be constantly monitored. This level should never exceed the 'max' on the clear tube between Tap B and Tap C.**

When the water level in the Vacuum Vessel becomes too high, then follow these steps:

Figure 12: Open the pressure release valve

a. Turn Tap A to the *"Closed"* position and switch off the Pump (12).

b. Gently open the pressure release valve (Tap B), to allow the air-pressure to equilibrate with the atmosphere.(fig12)

c. Place a beaker under Tap C, and open it to allow the excess water to drain out of the Vacuum Vessel.(fig 13)

Figure 13: Water drain out with open the Tap C

d. Close Tap C when the water level in the Vacuum Vessel (see glass tube) has drained to about 4cm below the rim of the box (1). Close Tap B.

e. Turn the pump back on and wait for the pressure in the Vacuum Vessel to return to the relevant value before returning Tap A to *"Discharge".*

Suction must be created in the Vacuum Vessel (5) to remove air bubbles from the discharge tube between it and the Box (1).

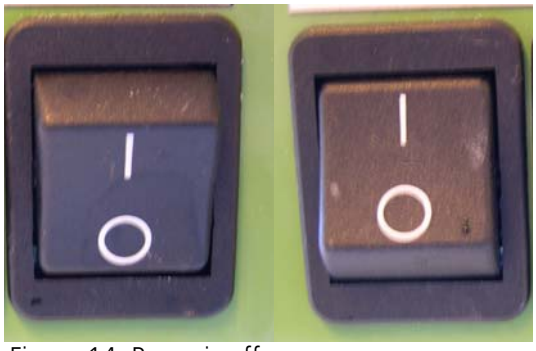


Figure 14: Pump is off now

Figure 15: Steps 4.411-4.413

4.4.9. Check that the Pump is switched off (12: see fig.1 on page 4) and the tap A, B, C and D are closed, then turn the Power on (11: see fig.1 on page 4). Fig.14 pump is off now.

4.4.10. The red L.E.D flashes to indicate that you are in the First Menu.

4.4.11. The First Menu has the three Parameters listed in Table 1. The 'default value' displayed is the current pressure in the Vacuum Vessel (PrOC).

4.4.12. Press the "scroll key" twice (make contact three distinct times less than 1.5 seconds apart) until the 'AL' Parameter is displayed.

4.4.13. Adjust the Set-point for the 'AL' Parameter to **-100 hPa** by pressing the "Down-key" or the "Up-key". (fig 15)

4.4.14. Press the "scroll key" twice so that the 'PrOC' name is displayed again.

4.4.15. Switch on the pump.

4.4.16. Some water will now be sucked into the Vacuum Vessel (5). When there are no bubbles between the Box (1) and the Vacuum Vessel then turn the pump off.

4.5 Laying the suction material

Figure 16: Saturate sand with water

4.5.1 Saturate some synthetic sand with running demineralised water and stir firmly to remove air (Fig. 16).

There should be a high ratio of water to sand so that it can be easily poured into the box.(fig17) For the textural composition of the sand see Table 3.

Figure 17: A high ratio of water to sand

Table 3: Textural Composition of Sand

Particle size diameter (mm)	Percentage
106	0
75	6.3
63	61.4
53	22.1
45	4.4
<45	5.8

☞ **Be careful to avoid damaging the drain system while stirring.**

Figure 18: adding the water-saturate sand

4.5.2 Slowly add the water-saturated sand to the water in the sandbox (1) with a ladle while stirring constantly to expel any entrapped air.(fig 18)

☞ **The sand should be pressed against the side walls of the sandbox, and into the corners, to make sure that the sand does not contain air pockets and a good seal between sand and box is established.**

Figure 19: Tap D open into bucket

4.5.3 When the water level in the Box (1) becomes too high, then open Tap D – releasing the excess water into a beaker.(fig 19)

☞ **Always retain a level of water in the box above the sand and the drainage system.**

4.5.4 Stop adding the saturated sand when the sand level is **8 cm** below the rim of the Box (1).

☞ **Always ensure the water level in the Vacuum Vessel (12) is higher than the water level in the Box (1).**

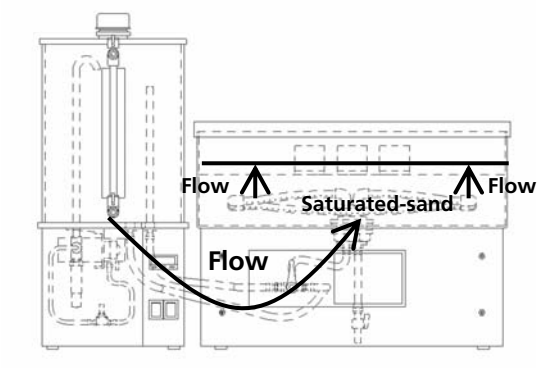


Figure 20 Water flow from vessel to box

4.5.5 Turn Tap A to the *'Supply'* position, and open Tap B. Water from the Vacuum Vessel (5) will now flow through the drain into the sand and remove final air residues.

☞ **The Vacuum Vessel Cap (13) must be open. Keep 0.5cm of water above the surface level of the sand.**

4.5.6 Excess water (extra to the 0.5cm minimum depth) can now be drained by opening Tap D. (20)

☞ **These steps (4.5.5-4.5.6) must be done carefully: Any entrapped air cannot be removed by this method after the Kaolin layer has been laid over the sand, because the Kaolin and sand layers may become disengaged. The sand level must always remain 0.5cm under water; otherwise air will be sucked into it.**


Figure 21: Smooth sand with a clean ruler

4.5.7 Smoothen the surface of the sand with a clean ruler, and leave it to settle for 1hr.(fig 21)

4.5.8 The Kaolin layer will now be added. Begin by half-filling a large beaker with demineralised water.

☞ **Be careful not to disturb the sand, or to mix the sand and kaolin layers.**


Figure 22: Water-saturated Kaolin clay

4.5.9 Slowly add the kaolin powder to this beaker while stirring the water.

4.5.10 Once the clay is completely saturated, spoon it onto the surface of the sand using a large ladle. Alternatively, pour it gently onto the surface with the aid of a ruler. (fig 22)

4.5.11 The final Kaolin layer must be at least 1.5 cm deep.

4.5.12 Allow the Kaolin to settle overnight – so that there is a transparent layer of water above the deposited clay.

☞ **When using the pump, the water level in the Vacuum Vessel must be checked constantly (See Caption 1).**

The pressure set-point for the Vacuum Vessel can now be set for flushing the sand / kaolin suction medium.

Figure 23: Display from (PrOC).to 'AL'

Figure24: 'AL' change to-500

4.5.13 Check that the pump is switched off (12), and the taps A, B, C and D are closed.

4.5.14 Ensure that the lid of the Vacuum Vessel (5) is tightly closed and the adaptor (230volt) is connected to the power supply before turning the Power On (11).

4.5.15 The red L.E.D flashes to indicate that you are in the First Menu.

4.5.16 The First Menu has the three Parameters listed in Table 1. The 'default value' displayed is the current pressure in the Vacuum Vessel (PrOC).

4.5.17 Press the "Scroll Key" thrice (make contact three distinct times less than 1.5 seconds apart) until the 'AL' Menu is displayed.(fig 23)

4.5.18 Adjust the Set-point within the 'AL' Menu to **–500 hPa** by pressing the "Up-key" or "Down-key".(fig 24)

4.5.19 Press the "scroll key" twice so that the 'PrOC' name is briefly displayed.

☞ **A 1 cm deep stratum of water must always remain above the kaolin layer.**

The sand/kaolin suction medium will now be flushed for a few hours to remove the final air-residues, and bond the sand and clay layers.

Figure 25 : Press the kaolin against the walls

4.5.20 Press the kaolin clay firmly against the walls of the box, especially in the corners, to prevent air-leakage.(fig25)

4.5.21 Smooth the surface of the kaolin layer level with a clean ruler.

4.5.22 Gently pour boiled, demineralised water on-top of the kaolin layer with the aid of a ruler. Fill the rest of the box (1) with this water.(fig26)

Figure 26: Gently add demineralised water

4.5.23 Turn on the Pump (12) and set Tap A to *"Discharge".*

4.5.24 Let the water be sucked through the kaolin and sand into the Vacuum Vessel for a 2 hours – always gently topping-up the water-level in the box when it becomes less than 1cm deep.

☞**Constantly monitor the water level in the Vacuum Vessel (on the clear tube between Tap B and Tap C). This level should never exceed the 'max' line (See Caption 1).**

Figure 27: Remaining water a 1 cm deep

4.5.25 After there are no bubbles appearing in the pipe between the Drainage Pipe (4) and the Vacuum Vessel (5) then the suction medium is air-free.

4.5.26 Continue flushing the air-free sand/kaolin with the remaining water until there is a 1cm deep layer of water above the kaolin layer.(fig 27)

4.5.27 Set Tap A to the *"Closed"* position and turn off the Pump (12). (About 2hrs are spent flushing the suction medium).

Although not strictly necessary, it is recommended to cover the kaolin with one layer of filter cloth to prevent it from becoming too dirty.

Figure 28: cover the filter cloth on the top of the sand

4.5.28 Cut the filter cloth to the correct size by tracing around the lid of the box (1).

4.5.29 Saturate the filter cloth with water in a beaker, before placing it onto the surface of the kaolin layer. (fig 28)

4.5.30 Remove any air bubbles between the filter cloth and the kaolin by gently smoothing it from the centre outwards.

☞ **The sand/kaolin box is ready to use. There must be no air-bubbles in the system from this point onwards. Vibration may cause a leak between the sidewalls of the sandbox and the suction medium.**

5 Using the sand/kaolin box

☞ **The environment around the sand/kaolin box should be kept at a constant temperature between measurements, since temperature changes affect water viscosity and therefore water retention values.**

5.1 Prepare the Samples

Figure 29: Chip off excess soil – don't smear!

5.1.1. Uncap the core sample ring. If the sampled soil volume is larger than the volume of the core ring, carefully remove excess soil by 'chipping' it off with a sharp edged tool. Prevent smearing the sample surface so as not to affect the physical properties of the soil. (fig29)

5.1.2. Fix a piece of nylon cloth to the bottom side (sharp edged side) of the sample with an elastic-band, or an O-ring.

☞ **If the soil volume is less than the volume of the ring, or if the sample has been damaged during transport, the sample should not be used for analysis. Samples with large projecting stones may also have to be discarded.**

5.1.3. Ensure that a 1cm layer of water is covering the surface of the kaolin in the box (1).

☞ **Never turn Tap A to the "Supply" position or the bond between the sand and kaolin layers will be broken. If water needs to be added to the box, then do so with demineralised water, and pour it gently onto the kaolin surface with the aid of a ruler.**

Figure 30: Mark samples

5.1.4. Mark the rings, and draw a diagram of the box, so that the rings can be replaced in exactly the sample place after removal. (fig30)

The samples now need to be saturated. Steps 5.1.5 to 5.1.8 can be followed, or alternatively an excicator may be used.

Figure 31: Allow samples to adapt for 1hr.

5.1.5. Place the soil sample with the bottom side down in the sand/kaolin box. Let the sample adapt for 1 hour.(fig 31)

5.1.6. Gently pour demineralised water onto the kaolin surface with the aid of a ruler.

☞ **Raising the water level to quickly may entrap air in the samples or damage the soil structure.**

Figure 32: Stop adding the water now

5.1.7. Stop adding water when the water level is 1cm below the top of the sample ring.(fig 32)

5.1.8. Place a lid on the basin (to prevent evaporation) and allow the sample to saturate for 2 or 3 days (sandy soils) or up to 1 or 2 weeks (clayey soils).

☞ **Take care not to leave sandy soils wetting for too long since slaking may occur.**

Figure 33 : Take the ring out of the water

5.1.9. Take the ring carefully out of the water /excicator and wipe off any water drops hanging underneath the sample before weighing it. (accuracy of balance 0.01 g). This weight (including ring, cloth and elastic) is used to calculate water content at saturation, pF 0.(fig 33)

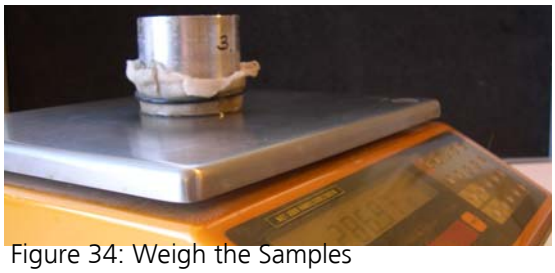


Figure 34: Weigh the Samples

5.1.10. Record this weight as 'Weight A' in 'Chapter 6: Table 9' for Processing the Results.(fig 34)

☞ **Note any irregularities that occurred during saturation (e.g. swelling of clayey soils, changes in soil structure, accidental loss of soil material).**

☞ **Water content measurements at pF 0 are relatively inaccurate:**

- It is difficult to transfer the saturated sample to a balance without changing water content, especially with sandy samples.
- The middle of the soil sample is used as the reference level for zero pressure, but the free water level (h = 0) is in fact 1 cm below the top of the sample ring. The moisture tension thus ranges from +1 cm at the bottom of the sample, to -4 cm at the top of the sample. Note that at decreasing pressures this difference due to sample size becomes less important.

☞ **If an excicator was used in place of Steps 5.6 to 5.9 then ensure that a 1cm layer of water remains above the surface of the kaolin in the box (1).**

Figure 35: Place the sample at the exact the place

5.1.11. Place each sample ring at its designated position on the kaolin surface. Press the ring slightly, to improve soil - kaolin contact.(fig 35)

5.1.12. Ensure that the Pump is switched off.

5.1.13. Check that the electrical supply is plugged in and the power (11) is turned on.


Figure 36: Ensure Tap B is open

5.1.14. Make sure that the cap of the Vacuum Vessel is closed tightly (6).

5.1.15. Turn Tap A to the *"Closed"* position.

5.1.16. Ensure Tap B is open and check that the display shows '0'. If this is not the case, then follow the correction steps under the heading '5.2 Set Offset Value'.

5.2 Set Offset Value

This section details how the neutral point for the electronic vacuum regulator is corrected during use. If you are in the First Menu with Tap B open, and the PrOC parameter value is not zero, then the atmospheric pressure has changed.

To correct this, execute the following steps:

Table 4: First Menu

Parameter	**Meaning**
	Current Pressure in the Vacuum Vessel (12)
	Alarm 1. Do not change this setting.
	Pressure Set-point

Table 5: Reset Offset Value

Setup Name	**Setup Value**	**Function**
		Input filter time constant value
	-5	Input offset value
		Enable access to alarm value
	Do Not Change	Alarm value 1

5.2.1. The red L.E.D flashes to indicate that you are in the First Menu (See Table 4).

5.2.2. The First Menu has the three Parameters listed in Table 4. The 'default value' displayed is the current pressure in the Vacuum Vessel (PrOC).

5.2.3. Hold the "Up-key" and "Down-key" down simultaneously (for about 3 seconds) until "FiLt" appears on the display. The yellow L.E.D will be lighted to indicate that you are in the Second Menu (See Table 5).

5.2.4. The first number displayed is the FiLt **Setup Value**. Press the "Scroll Key" twice until the 'OFFS' **Setup Name** is displayed.

5.2.5. If the PrOC parameter value (Current pressure in the Vacuum Vessel) was +5 hPa when Tap B was open then the **Setup Value** for the "OFFS" **Setup Name** must be set to "-5" to compensate for this.

5.2.6. Use the "Up-key" and "Down-key" to alter the Setup Value for the "OFFS" Setup Name to correct for the change in atmospheric pressure. (See Table 5)

5.2.7. Use the "Scroll Key" to return to the *'FiLt'* **Setup Name**.

5.2.8. Push the "Up-key" and "Down-key" simultaneously (for about 3 seconds) to exit the second menu. The yellow L.E.D will automatically turn off.

5.2.9. The display must now show "0" for the PrOC parameter value.

5.3 Calculate Set-point

The rising water level in the vacuum-vessel has no effect on the real pressure applied to the sample, because of the use of an internal filling tube. This water column has a known height. The total water column can be calculated as follows:

Total Water Column = $H_1 + H_2 - 85$

Figure 37: Total Water Column Calculation

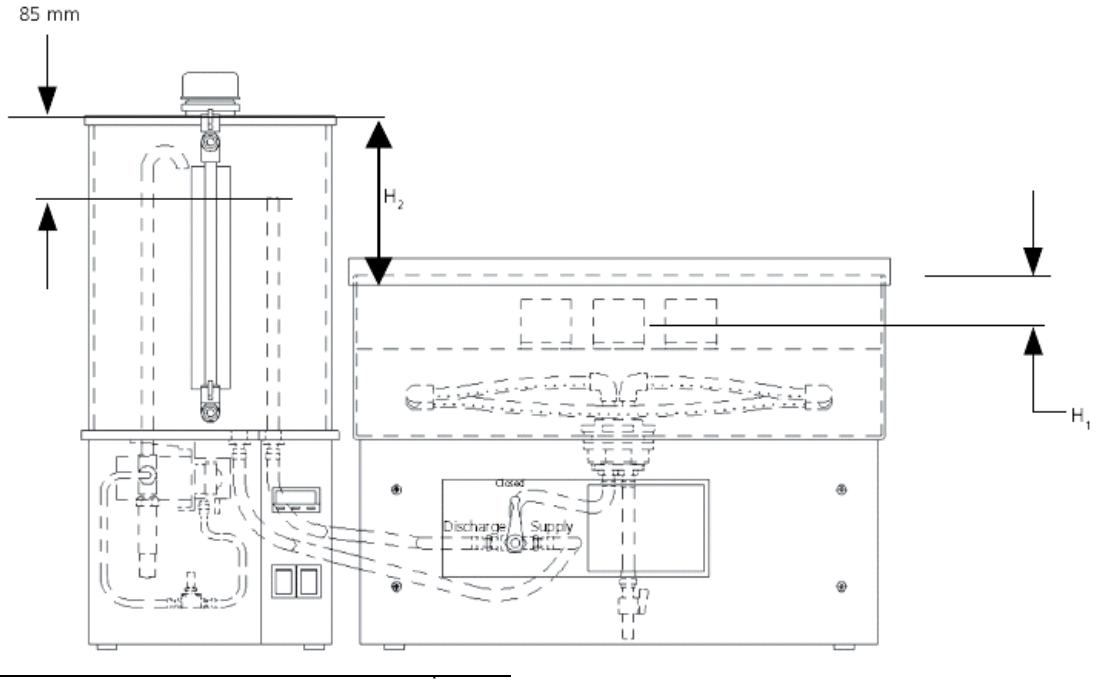


Table 7: Used to calculate each Set-point

pF	hPa	Total Water Column (T.W.C)	Set-Point (=hPa – T.W.C)
2.0	-100		
2.3	-200		
2.7	-500		

Example:
H1 = 5.0 cm
H2 = 11.5 cm

Total Water Column = $H_1 + H_2 - 8.5$ cm
= 5.0 + 11.5 – 8.5
= 8.0 cm

Therefore the Set-Point at pF 2.0 equals (-100 – 8) = -108.

5.4 Changing the Set-point (Suction to be applied to the samples)

☞ **The Display (10) allows access to many extra programming functions that should never be altered. Only adjust the settings referred to in this manual.**

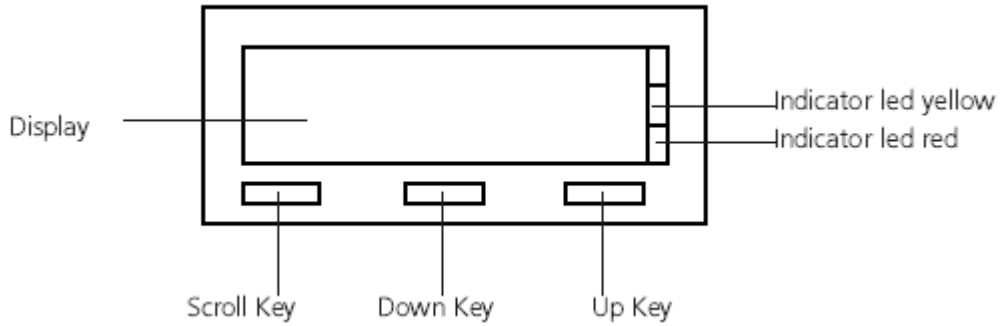


Figure 8: Display

Table 8: First Menu

Parameter	Meaning
	Current Pressure in the Vacuum Vessel (12)
	Alarm 1. Do not change this setting.
	Pressure Set-point

5.4.1 Check that the power is on (11) and the pump is switched "off" (10).

5.4.2 The red L.E.D flashes to indicate that you are in the First Menu (pump indicator).

5.4.3 The First Menu has the three Parameters listed in Table 1. The 'default value' displayed is the current pressure in the Vacuum Vessel (PrOC).

5.4.4 Press the "Scroll Key" thrice (make contact three distinct times less than 1.5 seconds apart) until the 'AL' Menu is displayed.

To deduce a drying curve, and thus pF-curve, a range of decreasing pressures must be applied to the samples. Each relevant Set-point must be calculated determined following the methods in section '5.3 Calculate Set-point'. These Set-points usually relate to standard increments for pF curves.

5.4.5 Adjust the Set-point within the 'AL' Menu to the relevant value by pressing the "Up-key" or "Down-key".

5.4.6 Press the "scroll key" twice so that the 'PrOC' name is briefly displayed.

Figure 38: Leave the samples

Figure 39 : Smoothen the extra water on the sample

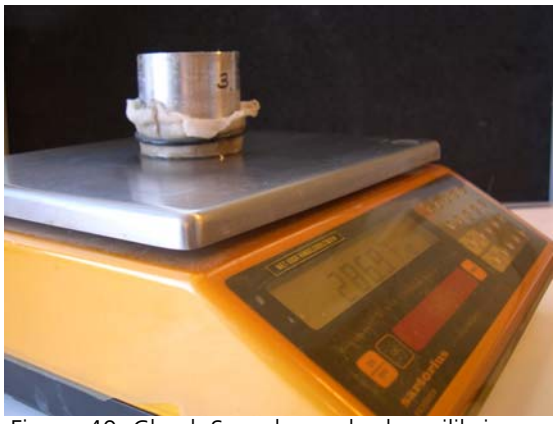


Figure 40: Check Sample reached equilibrium

Figure 41: Clean & smooth surface with sponge

5.4.7 If necessary then remove excess water from the Vacuum Vessel by following steps 4.5.16 – 4.5.19.

5.4.8 Ensure Taps A, B, C and D are closed.

5.4.9 Turn on the pump (12)

5.4.10 Wait until the relevant pressure has been reached before setting Tap A to *"Discharge"*.

5.4.11 Leave the sample to equilibrate, (with the lid on the box to stop evaporation) (A few days for sandy soil, and up to a week for clayey soils).(fig 39)

5.4.12 Gently remove and weigh the samples.(fig 38)

5.4.13 To check equilibrium, replace the sample on the clay surface at exactly the same position as it was previously (ensure that the contact between kaolin and sample is restored). Weigh the sample again the next day: In case of equilibrium with the created tension, the difference in water content will not exceed a volume fraction of 0.002. (fig 40)

5.4.14 If equilibrium between soil moisture content and pressure has been established, record the weight of the sample. (Wipe kaolin and water drops from underneath the sample before weighing - for calculation of soil water content weight A. (Chapter 6).

5.4.15 Moisten the kaolin surface with a wet sponge. Don't remove the filter cloth -just clean and smoothen it at the same time to remove air bubbles and impressions.(fig 41)

5.4.16 Replace the soil samples on the kaolin at exactly the same position as they were previously.

5.4.17 Repeat steps 5.14 to 5.28 until weights have been recorded at each potential increment (Set-point) you want to measure.

☞ **Always replace the samples on the clay before changing the pressure**

6 Table 9: to be filled in as measurements are taken.

Sample number	Ring number	pF	Cm water column (potential in hPa)	Weight (g) Wet weight (sample, ring, cloth, elastic) A	Dry weight (sample, ring, cloth, elastic) B	Weight of ring, cloth, elastic C	Weight of soil water D = A - B	Weight of dry soil E = B - C	V = Volume of core ring = ...cm³ Gravim. water content W = D / E	Bulk density (g / cm³) ρ_d = E / V	Volum. Water content θ = W * ρ_d
		0,0	1,0								
		0,4	2,5								
		1,0	10								
		1,5	31,6								
		1,8	63,1								
		2,0	100								

7 Ending a measurement

Care should be taken to preserve the kaolin layer in the sand/kaolin box when it is not in use.

Upon completion of a measurement at, for example, –500 hPa the pressure in the sand and kaolin layer will not decline as quickly as that in the vacuum vessel. Considering this fact, it is recommended that a pressure of about -100 hPa be maintained with the pump remaining on, so that the vacuum in the suction medium equilibrates more gradually. Alternatively, the pressure in the vacuum vessel can be increased little by little.

☞ **Follow this procedure to conclude a measurement correctly:**

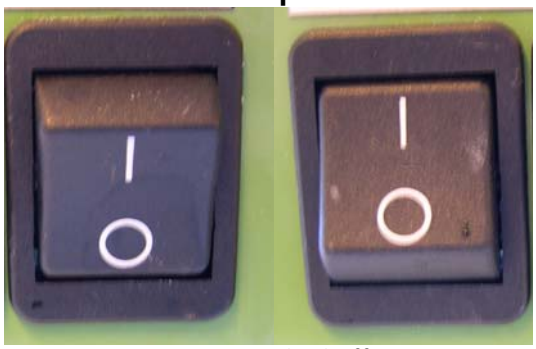


Figure 42: Pump is switched off

7.1. Switch the pump off.(fig 42)

7.2. Gently pour about 2 liters of de-aerated water on top of the kaolin layer with the aid of a ruler.

7.3. Switch Tap A to *"Supply".*

7.4. The pressure in the vacuum vessel and the kaolin/sand box will decrease.

7.5. Wait until the pressure in the Box (1) reaches equilibrium (1 day). Always maintain a of a 2mm deep water layer above the kaolin.

7.6. If necessary, pour more de-aerated water on top of the kaolin layer with the aid of a ruler.(fig 43)

Figure 43: Gently add demineralised water

☞ **Excess water can be removed from the vacuum vessel by the following steps:**

Figure 44: Open the pressure release valve

7.7. Close tap A.

7.8. Reduce the pressure in the vacuum vessel by opening Tab B.(fig 44)

7.9. Open Tap C to remove the excess water.

7.10. Close Tap A and Tap B.

Figure 44: Tap A to supply

7.11. Turn the pump on to reinstall the previously applied pressure (-100hPa).

7.12. Switch Tap A to supply.(fig 44)

☞ **The kaolin/sand box must be stored using one of the following methods:**

a. Keep the pump switched off. The kaolin layer will soften. Maintain a 2 mm deep layer of water above the surface of the kaolin. The water level in the sand/kaolin box should be checked regularly.

b. Install a pressure of -100 hPa. (See section '*4.3 Enter the Pump Settings'*) A tight kaolin layer will be formed as long as the pressure is mantained. The sand/kaolinbox can be used almost immediately if this storage method is applied.

☞ **Before using the kaolin/sand box again, the kaolin layer has to be checked thoroughly. The kaolin has to be pressed firmly along the walls of the box, especially in the corners to prevent air-leakage. The lid should remain on the box to prevent evaporation.**

8 Processing the results

Figure 45: weigh the cloth

8.1. Now it is necessary to determine the dry weight of ring + cloth + elastic (weight C).(fig 45,46)

8.2. Take the elastic-band/off each sample and number it for weighing later

8.3. Transfer the rings (with the samples and cloths) to an oven, and dry for at least 48 hours at 105 °C.

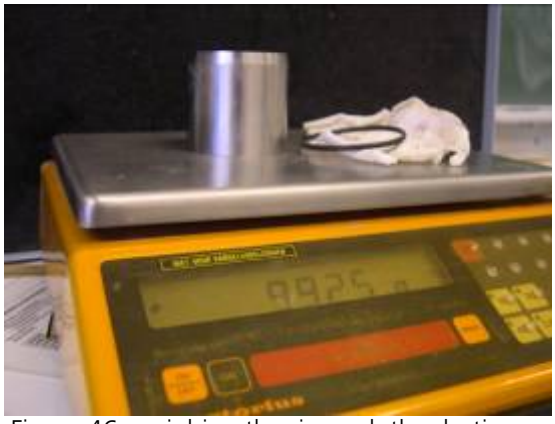


Figure 46: weighing the ring +cloth+elastic

8.4. Remove the samples from the oven and allow them to cool to room temperature in a dessicator (if available).

8.5. Weigh the oven-dry ring with sample + cloth + elastic (weight B).(fig47)

8.6. Remove the sample and the cloth from the ring and remove any soil material from the ring and the cloth.

8.7. Determine the dry weight of ring + cloth + elastic (weight C).

8.8. Calculate gravimetric soil moisture contents at each pF-value you applied to the samples **'W'** by:

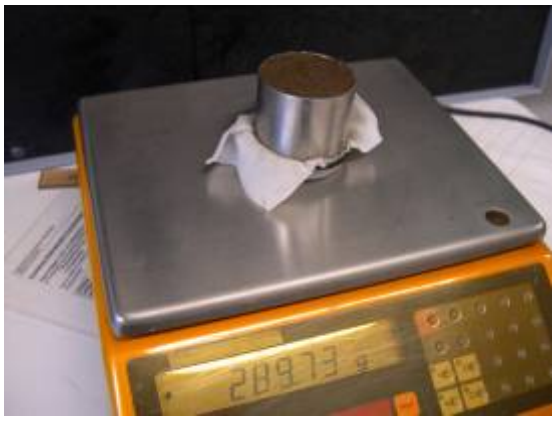


Figure47: weighing the oven-dry ring with simple +cloth+elastic

$$W = \frac{\text{Weight of soil water} * 100\%}{\text{Dry soil weight}}$$

Where:

'weight of soil water'	**=**	**weight of wet sample (with ring+cloth+elastic)**
	-	**weight of dry sample (with ring+cloth+elastic).**
'dry soil weight'	**=**	**weight of oven-dry sample (with ring+cloth+elastic)**
	-	**weight of dry ring+cloth+elastic.**

8.9. Determine the dry bulk density ' $_d$' (g/cm^3) by:

$$\rho_d = \frac{\text{dry soil weight (excl. ring+cloth+elastic)}}{\text{volume of core ring}}$$

8.10. If the density of the soil water is assumed as 1 g/cm³, then the volumetric soil water content (cm³/cm³) is determined as :

$$\theta = w * \rho d = \text{gravimetric water content} * \text{bulk density}$$

8.11. Plot the calculated volumetric soil water content at the X-axis and the corresponding pF-value on the (positive) Y-axis.

8.12. Then the pF-curve has been determined.

8.13. To plot the soil water retention characteristic, calculated volumetric soil water content is plotted on the X-axis against soil water potential on the (negative) Y-axis.

☞ **'Chapter 6: Table 9' can be used to calculate gravimetric and volumetric soil water content for the different pF-values. Note that pF 7 (corresponding to a matric potential of -10,000,000 hPa or - 10,000 bar) is considered to correspond with a moisture content of 0.**

9 Troubleshooting

Problem	Possible Cause	Solution
Air in the tube between the supply bottle and the suction regulator causes inaccuracy of measurements.	There are air bubbles in the water.	De-aerate the tube.
	There's not enough sand on the drain. There has to be at least 1 cm of sand on the drain.	Add more water-saturated sand.
	Air can enter the suction medium via the side walls of the sandbox. Vibrations caused by an unstable table or for example traffic vibrations. During the filling of the sandbox, the pressing of the sand against the side walls of the sandbox isn't done properly.	Smoothen the kaolin level and press the kaolin firmly along the walls of the box, especially in the corners to prevent air-leakage.
	There's a leaking cock.	Order a new cock.

10 References and literature

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Topp, G.C. and W. Zebchuk. The determination of soil water desorption curves for soil cores. 1979. Canadian Journal of Soil Science 59: 19-26.

Appendix 1: Conversion factors

100 hPa	100 cm pressure head
	100 cm water column
	0.1 bar
	0.01 Pa
	0.01 N/m²
	1.45 PSI
	pF (10log100) = 2.0

pF value	Matric potential in hPa	Pressure in bar
0	-1	-0.001
0.4	-2.5	-0.01
1.0	-10	-0.0025
1.5	-31.6	-0.0316
1.8	-63.1	-0.0631
2.0	-100	-0.1
2.3	-200	-0.2
2.7	-500	-0.3

Appendix 2: Description of different pF-sets

To determine the soil moisture retention characteristic, the desired pF-set(s) is/are required. A balance with an accuracy of 0.01g, and a ventilated electrical drying oven (105 °C), are also necessary. Eijkelkamp supplies the following:

A universal drying-oven with temperature range 30 -220 °C, 220 V- 50 Hz.

A Sandbox for pF determination (pF0 -2.0). The Standard set for about 40 samples includes:

- Sandbox
- Containers with sand, particle size ± 73 mm, 12.5 kg each
- Filter cloth, 140 - 150 mm
- Set of 65 o-rings, diameter 49 mm: suitable for 5 cm diameter core rings

A Sand / kaolin box for pF determination (pF2.0 - 2.7). The Standard set for about 40 samples includes:

- Sand / kaolin box
- Vacuum pump and automatic suction level control system, 220 V
- Containers with synthetic sand, particle size ± 73 mm, 12.5 kg each
- Filter cloth, 140 - 150 mm
- Kaolin clay, container 2.5 kg
- Set of 65 o-rings for 5 cm diameter core rings

Pressure Membrane Apparatus (pF3.0 – 4.2). The standard set for about 15 samples includes:

- Pressure membrane extractor
- Cellophane membrane
- Soil sample retaining rings
- Filter cloth 140 - 150 mm
- Compressor 20 bar
- Air filter with support and hose

Appendix 3: Soil sampling

To determine the moisture retention characteristic or the pF-curve of a specific soil, *undisturbed* core samples must be collected. This is because of the major influences of both pore size distribution and soil structure on moisture retention, especially at the high matrix potentials of the operating range of suction tables.

There is no explicit prescription in literature for recommended sample sizes. Optimal sizes for core rings are determined by the size of structural elements in the soil. To obtain representative data, sample sizes should be large with respect to the size of soil aggregates, cracks, root channels or animal holes. From a practical point of view, sample diameters should not be too large as not to reduce the amount of simultaneously analyzable samples, and sample height should be constrained to several centimeters; so that equilibrium conditions are reached in a reasonable period of time.
According to the Dutch NEN 5787 standard, samples with a volume between100 and 300 cm³ are usually used for the suction tables, while samples with a height of more than 5 cm are discouraged, because the time needed to establish equilibrium will be long, and the accuracy of determination of pF-values near saturation will be low.
In the procedures for soil analyses of the International Soil Reference and Information Centre (ISRIC), sample rings with a diameter of 5 cm and a volume of 100 cm³ are recommended, while in other publications heights of 2 or 3 cm are preferred.

Eijkelkamp Agrisearch Equipment recommends the use of a 100 cm³ volume core ring, with an inner diameter of 50 mm (outer diameter 53 mm) and a height of 51 mm.

When pressing the core rings into the soil, care should be taken not to disturb the original setting of the soil and to completely fill the ring. Sampling conditions are best when the soil is approximately at field capacity. Ring holders may be used to facilitate insertion, especially in the subsoil. After insertion to the desired depth, the rings are carefully dug out (e.g. using the spatula provided with the Eijkelkamp sample ring set), at some centimeters below the ring itself. The surplus of soil is reduced to a few millimeters, trimming it carefully with a fine iron saw, and the caps are placed on the ring for protection and to minimize evaporation losses. The remaining surplus of soil will protect the sample during transport and will be removed in the laboratory, prior to analysis. Transport the core rings in a protective case.

Since soil structure and pore size distribution have significant influence on soil water retention, several replicate samples are needed to obtain a representative pF-value. Depending on natural variability of the study area, three to six replicate samples per unit are advised.

In case the samples cannot be analyzed on short notice, store the samples in a refrigerator to reduce microbial activity which might cause non-representative changes in soil structure.

☞ Do not freeze the samples because soil structure will be influenced.

Declaration of Conformity
Declaration de Conformité
Konformitätserklärung

We / Nous / Wir
Eijkelkamp Agrisearch Equipment, 6987 EM Giesbeek

declare under our sole responsibility that the product
déclarons sous notre seule responsabilité que le produit
erklären in alleiniger Verantwortung, dass das Produkt

08.02 Sand / kaolin box

to which this declaration relates is in conformity with the following standards
auquel se réfère cette déclaration est conforme aux normes
auf das sich diese Erklärung bezieht, mit den folgenden Normen übereinstimmt

- Machinery Directive (98/37/EG)
- 73/23/EEG: Applied harmonised European Standard EN 60204-1
  89/336/EEG: Applied generic European standards
  - EN 50081-1 Emission standard light industrial
  - EN 50082-1 Immunity standard light industrial
- Harmonized European standards:
  EN 292-1, EN 292-2, EN 349, EN 418

Eijkelkamp Agrisearch Equipment,
October 13th, 2013

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