ROYAL Eijkelkamp
Meet the difference

Eijkelkamp Smart Lysimeters

User manual (original instructions)

Meet the difference

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M-1680/1681E

Inhoud

1. Information on this manual

The original instructions for this manual have been written in English. Other language versions of this manual are a translation of the original instructions.

☞ **If the text follows a mark (as shown on the left), this means that an important instruction follows.**

⚠ **If the text follows a mark (as shown on the left), this means that an important warning follows relating to danger to the user or damage to the apparatus. The user is always responsible for its own personal protection.**

Text **Italic indicated text indicates that the text concerned appears in writing on the display or the apparatus (or must be typed).**

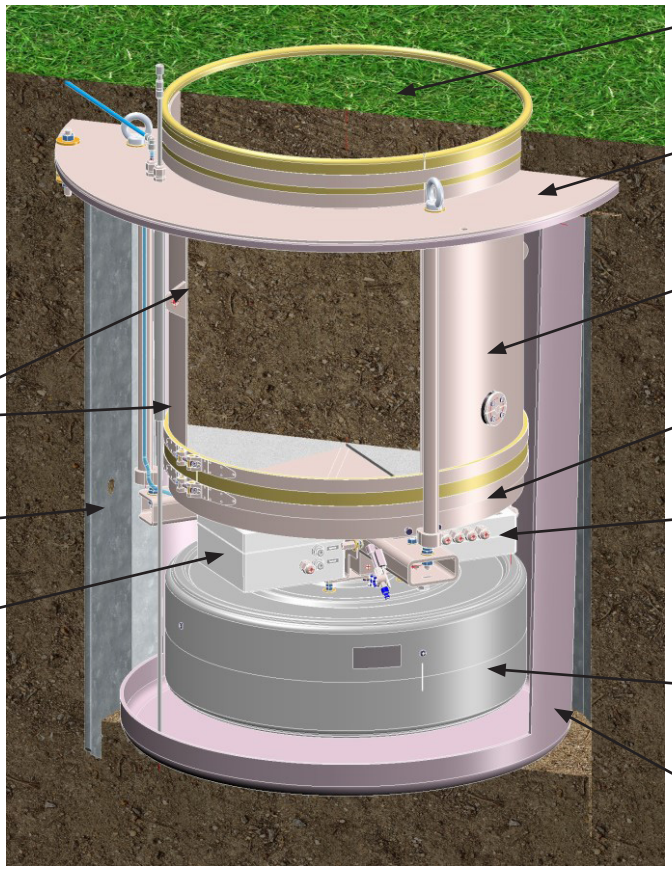
2. Introduction

This manual describes the Eijkelkamp Smart Lysimeter operational aspects and user interface communication. This manual covers user service for both moisture controlled as percolating lysimeters.
The Eijkelkamp Smart Lysimeter is an integrated weighing lysimeter concept. It is designed for weighing an isolated soil column and the differences in weight correspond to both evapotranspiration and precipitation.

The **moisture controlled lysimeter** is equipped with a reference tensiometer for measuring the field soil water tension and a moisture suction plate to control the moisture in the lysimeter soil column. A reservoir is used both for active percolation and wetting.

The **percolating lysimeter** passively extracts the surplus of water using a percolation plate into the reservoir.

Reference tensiometer



For both types lysimeters the maximum reservoir water is automatically controlled and emptied.

Every other or further use is not in conformance with the intended use and may affect the warranty. The same applies to unintentional changes to the product.

3. Types and accessories

Eijkelkamp Smart Lysimeter, moisture controlled set
1680 Eijkelkamp Smart Lysimeter, complete set for measuring real evapotranspiration in the field, consisting of a moisture controlled, weighing lysimeter, with field reference tensiometer, sheet piling foundation.
Optional: monolith soil moisture sensors, telemetry, data web portal and solar panel.

Eijkelkamp Smart Lysimeter, percolated set
1681 Eijkelkamp Smart Lysimeter, complete set for measuring real evaporation in the field, consisting of a percolating, weighing lysimeter and sheet piling foundation.
Optional: monolith soil moisture sensors, telemetry, data web portal and solar panel.

Additional accessories
1682 Monolith soil moisture sensor set
1683 Infrared sensor set lysimeter
1684 Lysimeter installation set

4. Technical specifications

Sample	
Sample type	Undisturbed
Sample diameter	50 cm
Sample depth	50 cm
Sample volume	98 L

Mechanical	
Size	ø 83 cm H 98 cm
Weight	100 kg
Product material	RVS 304*, plastics, galvanised steel

General	
Measured parameters	Evaporation, rain
Measuring principles	Weighing
Measuring accuracy	0,1 mm evap/rain
Reading accuracy	0,01 mm evap/rain
Maximum force	300 kg
Power supply	Battery/solar
Voltage	12 volt
Data transfer	SDI-12 / USB
Data plug type	M12 circular 4pole male / USB
Waterproof connection	Yes
Type of registration	Telemetric / SDI-12 logger
Number of channels	25
Frequency of registration	5 sec...15 min
Alarm type	Software

* Applicable under normal conditions. Contact your supplier about the possibilities for application e.g. in a saline environment.

5. Safety instructions

☞ **For extended service i.e. inspection, special maintenance, repair activities; disassembling and lifting the lysimeter, qualified and experienced staff is demanded. Royal Eijkelkamp provides training for safe and efficient lysimeter installation and service.**
For information with respect to specific adjustments, installation, maintenance or repair jobs, which fall beyond the scope of this manual, contact your supplier.

☞ **Make sure you have the following data at hand:**
Product code
Date of manufacture
Serial number
Date of purchase
Invoice number

☞ **Users/Field workers should have a good physical and mental condition that is consistent with due diligence and duty.**
The user should have a general knowledge about the use of a computer system and computer programs. For the basic maintenance work a general technical background is preferred.

⚠ **The work must be carried out in safe environmental conditions in order to avoid risk of accidents.**

⚠ **Users/Field workers must take into account the environmental and weather conditions and must be equipped with personal protection tools.**

⚠ **Avoid overloading the lysimeter (never stand on/support/etc.). Overloading leads to permanent damage, warranty will expire!**
In case of disturbance by human or animals precautions must be taken i.e. signs and fence as precaution to avoid injuries due to lysimeter damage

6. Regular inspection and field maintenance

The interval of field maintenance depends on the individual circumstances. Recommended service interval is 4 times per year.

Extreme weather periods can be a trigger for a field inspection i.e. flooding or draught or temperature both cold and hot.

Data, alarms, etc. from the lysimeter are a good indicator for a need of additional maintenance. Abnormal or sudden changes of measurement values can indicate the need for a service visit. In case of undefined problems please consult your supplier for advice.

☞ **During maintenance avoid that the direct environment of the lysimeter is compacted or that the vegetation is trampled.**

☞ **A properly installed and maintained lysimeter normally has class IP-68 protection (as indication: 10 cm H_2O above ground-level for several days).**

⚠ **The lysimeter and data must be actively managed. Damage caused by inadequate action or temporary being out of operation on location without data being generated are not covered under warranty.**

6.1 Typical maintenance actions

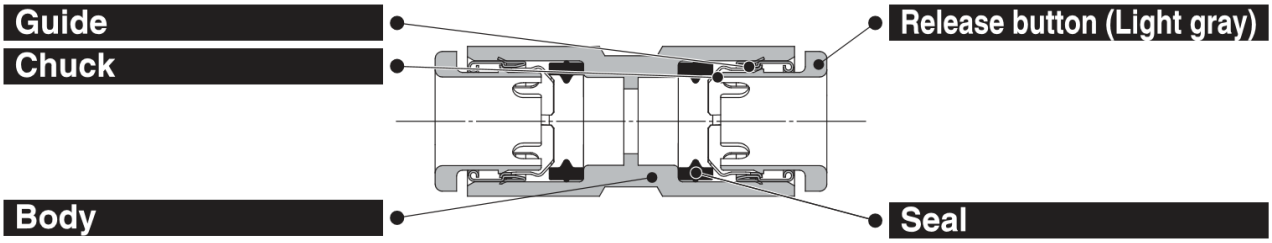
1. Checking and refilling the reference tensiometer with degassed water (see Chapter 8.1)

2. In case of leak water in the underground housing it shall be pumped off. At the surface there is a pipe connection to the pump line to the bottom of the housing.

☞ **A possible trigger is error code 8 in the measurement data (see: appendix 9.7)**

☞ **Always check visible components like the silicon collar sealing for damage.**

- Release vent plug from straight fitting. Release (chuck collet) button to remove plug.



- Connect an external pump to remove water.
- Replace vent plug in straight fitting. Push the clean plug into the fitting and pull vent plug a little to tighten.

⚠ **In case of serious amount of water i.e. more than 3 liter a complete leak inspection is advised. Lifting the lysimeter by qualified and experienced staff is to be considered.**

3. Checking the pumpbox function of both 'lysimeter pump' as 'reservoir pump' and inspect for leakages i.e. due to wearing of the pumps.

⚠ **Inspection/ replacement of pumps by qualified and experienced staff only.**

⚠ **Advised pump replacement interval: 250 running hours. Depending on the settings/ field conditions/ etc.**

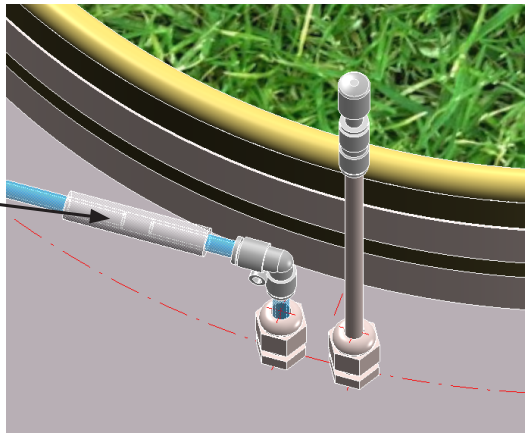
⚠ **Always avoid long-term continuous pumping. Special attention is required when the pressure plate runs dry.**

⚠ **Always avoid pumping during frost!**

4. Inspection of the reservoir pump exhaust tube, located next to pipe connection.

⚠ **Reservoir pump exhaust tube has to be free of obstacles.**

It is advised to connect the rigid hose with a piece of soft silicone hose. In case of an obstacle, the drain hose will come loose so the chance of damage is reduced. Make sure that the silicone piece of coupling hose extends above ground level without any kinks. Embedding in gravel for drainage is preferred.



5. As the vegetation grows it must be pruned regular, not interfering with the surrounding. Take care that the silicon collar sealing around the lysimeter is not damaged as this will lead to leakage.

There should be no entanglement of vegetation soil sample with vegetation environment!

6. In case of disturbance by human or animals (like overload; gnawing by pests; etc.) precautions can be taken i.e. signs and fence as precaution. Possible precautionary measure; see appendix 9.8.

6.2 Checking settings and actual values

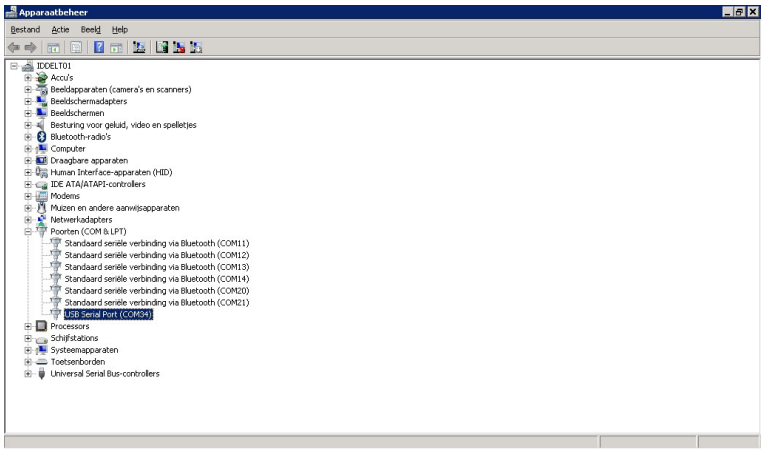
The Eijkelkamp Smart Lysimeter is equipped with an integrated autonomous controller for measuring and controlling. The controller has 2 communication ports:
- SDI-12 for communication with dataloggers or modems inclusive the lysimeter power supply,
- USB 2.0 for user communication i.e. a laptop to view data and setting controller parameters

1. Make sure that the lysimeter sufficient power supply is available, typically 12 volt DC.

2. Connect the lysimeter USB cable to the laptop using an USB hub (due to the 10 meter cable length not supported by newer laptops).

3. Check and register the settings and actual values of measurements using the USB connection.

4. The proper USB port number can be found using *Windows configuration*, *Device manager.*



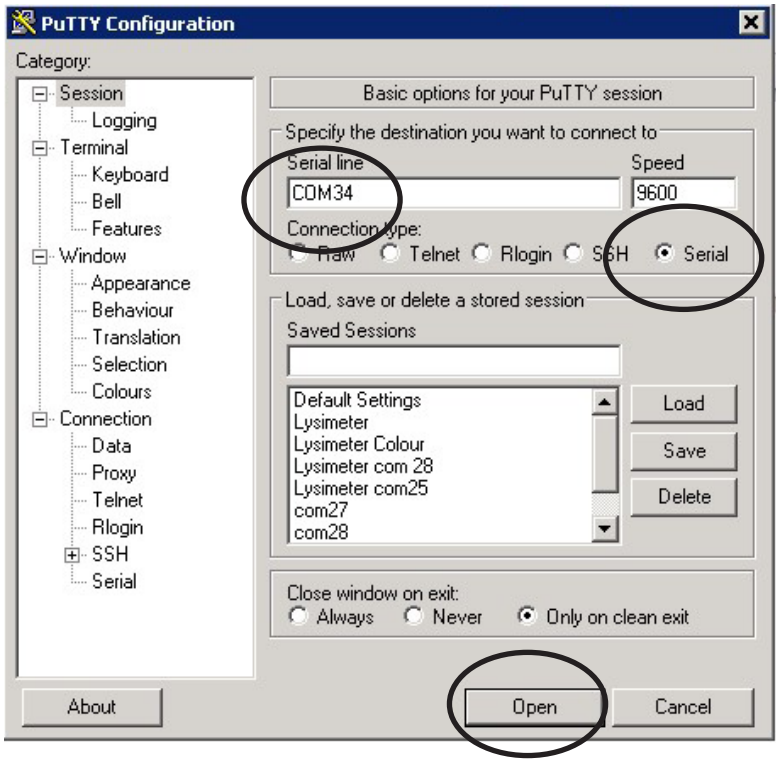
5. In Device manager *Ports*(COM&LPT) the recognized USB ports are listed (in this case *USB serial Port 34*).

6. Start the communication programm PuTTY (free to download 'Telnet-client' or use a similar one).

7. Select *Serial mode*.

8. Fill in the proper port number (in this case *USB serial Port 34*).

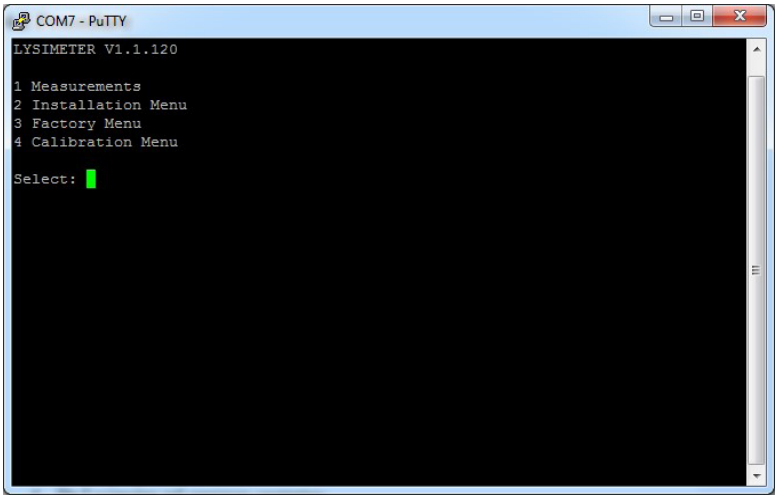
9. Start communicating pressing the *Open* button.



Now the communication screen will open and the lysimeter will start communicating.
After some seconds the *Main Menu* will appear:

Booting LYSIMETER ….

After some seconds the Main Menu will appear…



6.3 Main menu

The Main menu shows the software version and the 4 main menu options:

```
Lysimeter V1.1.xxx

1. Measurements
2. Installation Menu
3. Factory Menu
4. Calibration Menu*

Select: ..
```

* Only available by technician password

6.4 Measurements menu

The measurement menu shows the actual values of the connected sensors.
By selecting option *1 Refresh measurements* the measurement values are refreshed. Option *2* refreshes the measurements automatically where the refresh rate is equal to the measurement interval in the installation enu.

```
MEASUREMENTS

Weight Lysimeter (gram)*                 :   +191616
Weight Reservoir (gram)*                 :   +2546
Tensiometer Reference (kPa)              :   -3.94
Tensiometer Temperature (C)              :   +15.18
Tensiometer Supply Voltage (Vdc)         :   +13.0
Tensiometer Filling state                :   +0
Pressure Plate (kPa)                     :   -3.89
Lysimeter Temperature (C)                :   +15.7
Soil Moisture Top (E)                    :   +10.79
Soil Moisture Top Conductivity (dS/m)    :   -9999
Soil Moisture Top Temperature (C)        :   +29.4
Soil Moisture Bottom (E)                 :   +7.92
Soil Moisture Bottom Conductivity (dS/m):    -9999
Soil Moisture Bottom Temperature (C)     :   +18.6
Tensiometer Top (kPa)                    :   -19.8
Tensiometer Top Temperature (C)          :   +29.5
Tensiometer Bottom (kPa)                 :   -10.7
Tensiometer Bottom Temperature (C)       :   +18.8
Pump Time (mS)                           :   +0
Supply Voltage (V)                       :   +12.96
Current Errors                           :   +0
Current Warnings                         :   +0

1   Refresh measurements
2   Auto Refresh Measurements            :   OFF
    0   Return
```

If a parameter value is not displayed the sensor is either not installed or defective.

* The '*Weight Lysimeter*' and '*Weight reservoir*' measurements are integrated by a Gaussian formula using the past 10 measurements. For a fast update of measurements at least 10 measurement refreshments should be performed i.e. performing 10 times option 1. As alternative In the *Factory menu* option *D: Gaussian Enable Status* can be changed to disabled to get an instant update of the measurements. Take care to reset the *Gausian Status* to enable again after service!

6.5 Installation menu

The installation menu is used for manual operation during installation and service and sensor configuration.

Be careful this can damage the suction plate!

INSTALLATION MENU		
1	SDI-12 Lysimeter address	: 0
2	Sample interval (sec)	: 300
3	Pump reservoir on threshold (gram)	: 18000
4	Pump reservoir off threshold (gram)	: 15000
5	Suction plate vacuum	: OFF
6	Suction plate pressure (!)	: OFF
7	Suction plate regenerate start	
8	Reservoir fill	: OFF
9	Reservoir empty	: OFF
A	Reservoir Autofill	: OFF
B	Lysimeter winter protection	: ON
C	Lysimeter pump operating hours (h)	: 0
D	Reservoir pump operating hours (h)	: 0
E	SDI Sensor address configuration	

Description of the installation menu options:

1 SDI-12 Lysimeter address
This address number is set for the datalogger or modem connected to indentify the lysimeter. Default = 0.

2 Sample interval (sec)
At every sample interval the lysimeter measures the sensor values, depending on these values the suction plate pump or reservoir pump can be controled. This is an autonomous controll proces for the lysimeter.
The minimum sample interval = 10 seconds. In this mode the lysimeter will use more energy due intensively controlling the pumps. The maximum sample interval is 900 seconds (15 minutes).

If the datalogger or modem request measurement data from the lysimeter automatically a measure and control cycle is initiated. A practical sample interval could be 300 seconds (5 minutes).
Standard a sample and control cycle is initiated bij the SDI-12 measurement command from a datalogger or telemetry.

3 Pump reservoir on treshold (gram)
As the reservoir has reached this maximum value the reservoir pump will start emptying the reservoir untill the off treshold is reached. The maximum reservoir value is 25 liters (25000 gram), a typical upper treshold value is 18000 gram.

4 Pump reservoir off threshold (gram)
As the reservoir has reached this minimum value the reservoir pump will stop emptying the reservoir. The typical minimum reservoir value is 15000 gram.

5 Suction plate vacuum
This option can be used for testing the suction plate. Pumping will lower the suction plate pressure measured. Do not use this option longer than 10 seconds for testing.
Alternatively this option can also be used for filling the suction plate with degassed water during installation.

6 Suction plate pressure (!)
Pumping will increase the suction plate pressure measured.

Be careful this option can damage the suction plate by overpressure!

Do not use this option longer than 10 seconds for testing(!).
This option can also be used for emptying the suction plate during installation.

7 Suction plate regeneration start
This option is used for filling the suction plate or refilling after a dry period where the suction plate is dried out. The process is that reservoir water is pumped into the suction plate and air is pushed out via the membrane. If the air is pushed out the membrane becomes wetted and closes the air permeability which increases the pressure. This stops the water pumping action and the pump will now create a vacuum to test the suction plate function.

8 Reservoir fill
The reservoir can be filled using this option. The lysimeter exhaust hose is used as supply source.

9 Reservoir empty
The reservoir can be emptied using this option, the lysimeter exhaust hose is used as drain.

A Reservoir Autofill
In dry periods when more water is needed for maintaining, the reservoir can supply the lysimeter. The reservoir can be refilled automatically. Place the reservoir exhaust hose into an extended reservoir. Make sure the supplied water is not contaminated. Remind that the same hose is used for the lysimeter.

B Lysimeter winter protection
During winter time evaporation is minimal, sufficient (solar) power supply can be a problem and dammage due to frost can not always be excluded. Therefore a winter mode can be selected where measurements are still performed but pumping is inhibited. This will minimise power consumption and still enables monitoring. Beware that an increment of lysimeter moisture level can arrise.

C Lysimeter pump operating hours (h)
The peristaltic lysimeter pump uses pump hoses that in time wear out and can cause leakage in time. Observing the operating hours pump in time replacement can be planned.

D Reservoir pump operating hours (h)
The peristaltic reservoir pump uses pump hoses that in time wear out and can cause leakage in time. Observing the operating hours pump in time replacement can be planned.

E SDI Sensor address configuration
In case of connecting a new SDI-12 sensor i.e. the reference tensiometer. The new sensor should have a SDI-12 address = 0 (mostly default for new sensors). Selecting this option the new sensor is recognized and the user is asked for the function of the new sensor. Select the proper item: Reference Tensiometer. The reference tensiometer will now be recognized and values displayed in the measurement menu.

6.6 Factory menu

☞ **Be careful: changing options does effect the lysimeter operation!**

FACTORY MENU

1	Reservoirpump max speed (%)	: 100
2	Reservoirpump max time (min)	: 15
3	Lysipump max speed (%)	: 100
4	Lysipump minimum on time (msec)	: 10
5	Lysipump maximum on time (sec)	: 5
6	Pump controller PID - Kp	: +10.000
7	Pump controller PID - Ki	: +0.200
8	Pump controller PID - Kd	: +0.200
9	Pump controller PID - Gain	: 100
A	Lysipump time direction change in to out (min)	: 10
B	Lysipump time direction change out to in (min)	: 60
C	Pump enable minimum temperature	: +5.0
D	Gaussian Enable Status	: DISABLED
E	Datafilter Sigma of Gaussian	: 11
F	Extended HMI information	: ENABLED
G	SDI12 Terminal	
H	Set Settings factory defaults	

Description of the options:

1 Reservoirpump max speed (%)
Pump maximum speed, default =100.

2 Reservoirpump max time
To prevent overloading of the reservoir pump the maximum pump time is set to 15 minutes. As the pump capacity is 0.235 l/min, about 3.5 litre is pumped during a pump session. If more pump time is needed to obtain the requested minimum reservoir weigth then multiple pump sesions will be excecuted.

3 Lysipump max speed (%)
Pump maximum speed, default =100.

4 Lysipump minimum on time (msec)
The lysimeter pump time is calculated using the difference between tensiometer measurement and suction plate depending on previous pump actions. The minimum pump time is defined. Default is 10 msec.

5 Lysipump maximum on time (sec)
The lysimeter pump time is calculated using the difference between tensiometer measurement and suction plate depending on previous pump actions. The maximum pump time is defined. Default is 5 sec. In dry conditions this time might be extended to reach a maximum vacuum. A maximum of 15 seconds or less is recommended. In case of very dry circumstances the suction plate can dry out resulting in air entrance, so the maximum pump on time prevents overpumping.

6 Pump controller PID – Kp
The lysimeter pump time is calculated using the difference between tensiometer measurement and suction plate depending on previous pump actions. The calculation is a PID function using the proportional, integration and differential parameters, default : +10.000.

7 Pump controller PID - Ki
The lysimeter pump time is calculated using the difference between tensiometer measurement and suction plate depending on previous pump actions. The calculation is a PID function using the proportional, integration and differential parameters, default : +0.200.

8 Pump controller PID - Kd
The lysimeter pump time is calculated using the difference between tensiometer measurement and suction plate depending on previous pump actions. The calculation is a PID function using the proportional, integration and differential parameters, default : +0.200.

9 Pump controller PID - Gain
The lysimeter pump time is calculated using the difference between tensiometer measurement and suction plate depending on previous pump actions. The calculation is a PID function using the proportional, integration and differential parameters. The gain parameter default : 100.

A Lysipump time direction change in to out (min)
After pumping water into the lysimeter the pressure increases, if the pressure is exceeding the requested reference pressure a time-out is forced to prevent overreacting of the control system. Default : 10 minutes.

B Lysipump time direction change out to in (min)
After pumping water out of the lysimeter the pressure decreases, if the pressure is exceeding the requested reference pressure a time-out is forced to prevent overreacting of the control system. Default : 60 minutes.

C Pump enable minimum temperature
To prevent the system to pump when tubes get frozen a minimum pump temperature is choosen. As the temperature is measured at the electronics a higher then surface temperature is choosen. Default 5°C.

D Gaussian Enable Status
As weight is to be measured very secure, serveral distortions in the signal can be effective filtered by a gaussian algorithm over a number of measurements. The filter can be enabled or disabled, we do advise to enable the filter. Default : enabled.

E Datafilter Sigma of Gaussian
The filtering of data is over a certain number of past measurements as specified, from these measurements the most upper and lower outlier values are disrecarded from the calculations. Default: 11 measurements.

F Extended HMI information
Default: DISABLED.

G SDI12 Terminal

H Set Settings factory defaults

6.7 Calibration menu

CALIBRATION MENU (* For documentation only)

☞ **The calibration menu is available for factory technicians only!**

Enter password (ESC cancels): XXXX

CALIBRATION MENU

1	Temperature High	[+20.2][515]
2	Lysi Weight High Temp High	[0][3191][528]
3	Resv Weight High Temp High	[0][3712][527]
4	Lysi Weight Low Temp High	[100][490934][527]
5	Resv Weight Low Temp High	[100][524287][526]
6	Temperature Low	[+5.5][427]
7	Lysi Weight High Temp Low	[0][3390][528]
8	Resv Weight High Temp Low	[0][4272][527]
9	Lysi Weight Low Temp Low	[100][488911][527]
A	Resv Weight Low Temp Low	[100][524287][526]
B	Suctionplate Pressure Low	[-99.0][231757]
C	Suctionplate Pressure High	[+0.0][262]
D	Get / Set entire calibration	
E	Set Calibration factory defaults	
F	SDI12 Lysimeter Serial Number	: XXXXXXXX
G	Reset pump running hours	
H	Tensio ref simulated value (hPa, -9999=disable)	: -9999.0
0	Return	

6.8 Dismantle / environment/ disposal of waste

Dismantle by qualified personnel.

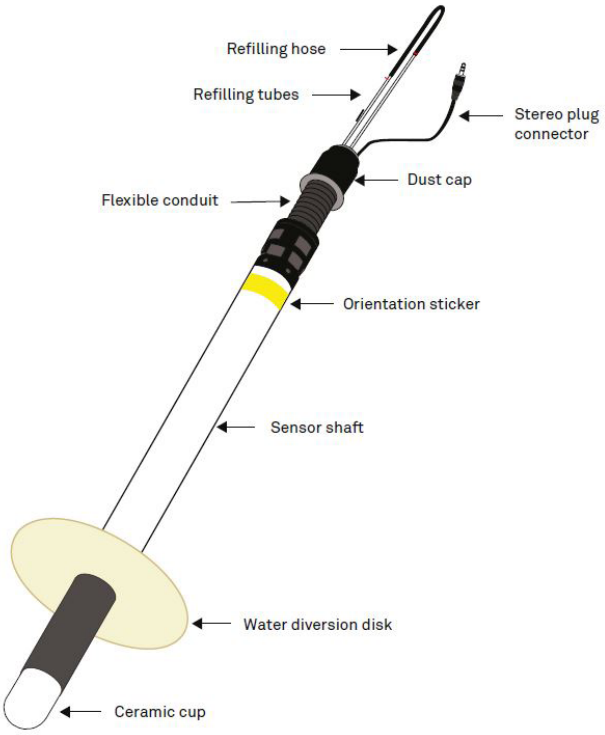
Always observe the local rules and regulations with respect to processing or disposing of (non-reusable) parts.

Do not dispose with other types of waste! This could possibly cause harm to the human health or the environment. If worn, damaged or not necessary anymore, please return the electronic parts to your local dealer for correct disposal or repair.

7. Tensiometer

The tensiometer measures soil water potential and temperature. Water potential is measured using a water-filled porous ceramic cup at the end of the sensor unit conducted to an absolute pressure transducer. Soil temperature is measured inside the pressure transducer.

The tensiometer has a low power requirement, which makes it ideal for permanent burial in the soil.
The tensiometer has multiple accessories (see figure below). The cable gland, bend protection, and dust cap protect the sensor cable and refilling tubes. The bend protection and dust cap can be removed if they are not needed for the application. The flow diversion disk prevents rain water from running down the shaft inside the borehole.



7.1 Tensiometer filling

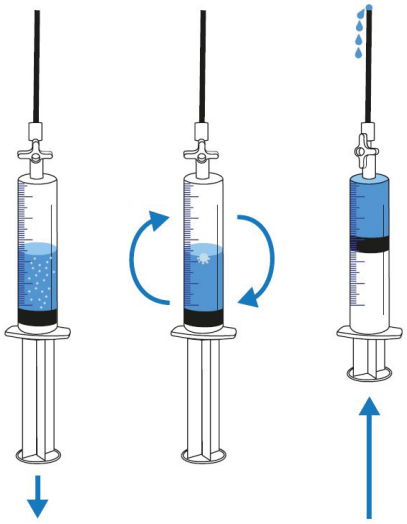
The water potential measurement of the sensor only works properly if the ceramic cup is completely filled with deionized and degassed water. Any air bubbles inside the ceramic cup will downgrade the quality of the water potential measurement.

The sensor is delivered unfilled. The sensor will need to be filled prior to first use.
☞ **Refilling the sensor is not possible under freezing temperatures.**

Use only deionised or distilled water to get the complete measurement range for water potential measurements. Using tap water may contaminate the internal tubes and ceramic cup.

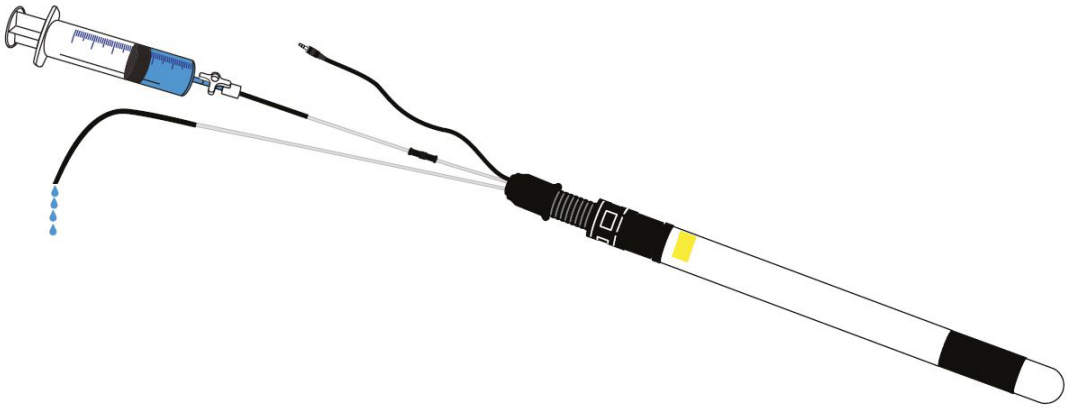
1. Fill the refill syringe with about 40 mL of deionised water.
2. Remove air from the syringe.
3. Close the valve on the refill syringe and pull the syringe plunger to create a vacuum. Air bubbles will appear in the water.
4. Move the syringe up and down so the air bubbles collect near the syringe outlet.

5. Release the plunger to relieve the vacuum in the syringe.
6. Open the valve and push out the degassed air.
7. Repeat step 3 through step 6, 2 to 3 times (see figure below).



8. Disconnect the upper and lower refilling tubes.
9. For the downward installation, connect the syringe to the marked refilling tube from your tensiometer.

☞ **If the tensiometer is not installed, position the sensor at an angle of at least 10° from vertical with the yellow sticker pointing upwards to get the best refill result.**



10. Press the syringe slowly, pushing the water into the tensiometer.
Continue to push the water into
the sensor until only water comes out of the other refilling tube (see figure above).
To be sure to get a perfect filling, press at least 20 mL water into the tensiometer.
11. Disconnect the syringe.
12. Reconnect the upper and lower refilling tubes.

The soil water potential may get higher than the tensiometer measuring range (–85 kPa). The water will evaporate from the ceramic cup and the sensor will stop measuring properly. The tensiometer should be refilled when the soil is wet again (water potential is higher than –85 kPa). Refilling while soil water potential is lower than –85 kPa will not be successful. The water will evaporate and leave the ceramic cup again shortly after refilling.

7.2 Tensiometer installation

When selecting a site for installation, it is important to remember that the soil adjacent to the sensor surface has the strongest influence on the sensor reading.

Consider the following items before installing your tensiometer:

- **Ceramic cup**. Do not touch the ceramic cup. Skin oil, sweat, or soap residues will influence the ceramic hydrophilic performance.
- **Freezing temperatures**. Tensiometers are filled with water and therefore are susceptible to freezing! Never leave tensiometers exposed when freezing temperatures might occur! Refilling the sensor may not be possible under freezing temperatures.

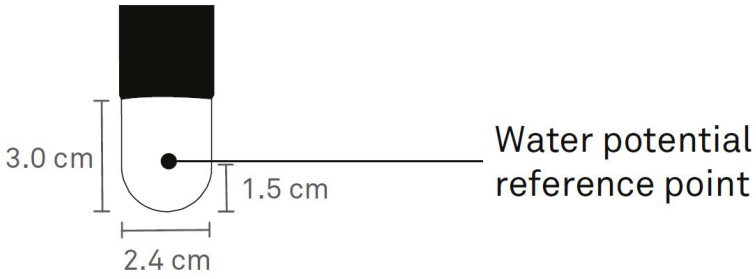
7.2.1 Tools needed

- Deionized water
- Refill syringe
- PVC casing or flexible conduit
- Cable inserting tool (if using long flexible conduits)
- Shovel (for digging a pit for irrigation valve box)
- Tensiometer gouge auger (diameter 25 mm): article numbers AA1000492 and 011001B (order separately; not included in 1680/ 1681-sets only included in 168405-set)

7.2.2 Preparation

Your tensiometer must be installed at an angle (α) of 45° from horizontal (Figure 1), resulting in the reference depth of 50cm. An angled installation position does not disturb typical water flow and avoids creating preferential water flow along the shaft. This position also allows for proper refilling in the ceramic cup. A vertical or horizontal position may retain air bubbles in the ceramic cup, and the water potential measurement may not be reliable.

Figure below shows the reference points for water potential measurement. Water potential is calibrated to the middle of the ceramic cup, so the measuring point is 1.5 cm from the ceramic tip.



Position of reference points for water potential measurement

The tensiometer is always installed at an angle from horizontal (α), installation depth is not equal to drilling depth. To calculate the correct drilling depth. Installation angle of 45° needs an installation depth of 71cm from the surface (ground level.

To avoid damage to the sensor by frost, install the tensiometer in a frost-free soil horizon (in general, below 20 cm).

7.2.3 Installation

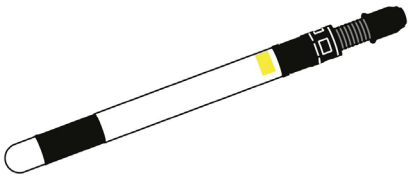
Create Hole

- To install the tensiometer into the soil, use the correct auger available.
- Avoid interfering objects, such as roots or rocks.
- Mark the required drilling depth on the auger.
- Use a level set to the predetermined installation angle to ensure the auger is drilling at the correct angle.
- Drill a hole stepwise until the marker reaches the soil surface. Avoid soil compaction by drilling with several steps.

Insert Sensor

☞ **Do not touch the ceramic cup. Skin oil, sweat, or soap residues will affect its hydrophilic performance.**

1. Slip the flow diversion disk onto the shaft and push the shaft gently into the soil surface.
For downward installations, the yellow sticker must face up.



Sticker face up

2. Slurrying the cup is only recommendable in clayey soils and only if the bore hole is larger than 24 mm. In coarse sand or pebbly soils fine pored slurry might create a water reservoir which slows down the response.

3. The yellow sticker with the dot on the shaft's top end that marks the position of the exit opening of the external filling must exactly face up. To correct the orientation, rotate the sensor clockwise until it is in the correct position. Do not rotate sensor counterclockwise or the ceramic cup may become unscrewed.

4. Insert the tensiometer into the hole to the depth mark without using force, if you feel a light resistance at the last few cm indicating proper soil contact of the ceramic. Do not use any force. Do not hit the tensiometer - this may damage cup and pressure sensor.

5. In clayey soils a dangerous overpressure might develop. To prevent overpressure the insertion hould be very slowly with the rubber refill tubing removed. The tensiometer has to be refilled after the installation as described in chapter 7.1

6. Press the soil surface gently to the shaft to close the gap.

7. Push the shaft water retaining disk down to cover the soil surface. This prevents water from running down into the borehole along the shaft.

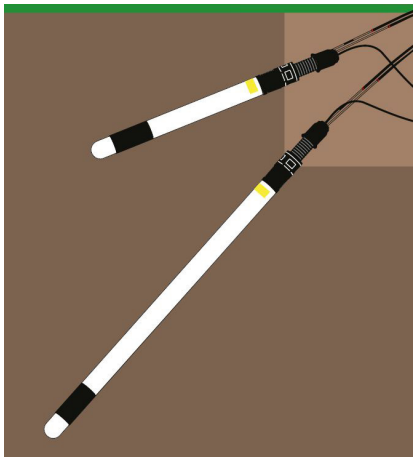
8. Connect the signal cables to the lysimeter

9. Slide the supplied thermal insulation tube over the shaft end and the refilling tubes.

7.2.4 Tensiometer protection

Tensiometer is installed in a delivered irrigation valve box. No items of the tensiometer are in sight. The part just below the lid is protected against frost by thermal insulation.

Protect the cables against rodent bites. Lead the cables through plastic pipes or use the plastic protection tubes



7.3 Maintenance

The nominal lifespan for outdoor usage is 10 years, but the lifespan can be substantially extended by proper and careful usage and by protecting the sensor against UV radiation and frost.
Depending on the installation site, the tensiometer ceramic cup may dry out. To assure a rapid and reliable measurement of the soil water potential, the ceramic cup must be filled with deionised water after dry periods or periods with a large number of wet and drying out cycles.

☞ **Refilling is only reasonable if the soil is wetter than –85 kPa after a dry period.**

If the water potential values seem incorrect, use the following steps to check the zero point of the tensiometer pressure transducer.
1. Place the sensor (with a properly filled ceramic cup) vertically in a beaker.
2. Fill the beaker with deionized water to a water level of 5 cm.
3. Connect the to your data logger and wait until the signal is stable (may take a few minutes).

The readings should be about +0.3 kPa (compensated value) or the actual barometric pressure +0.3 kPa (uncompensated value).

Cleaning:
For storage, troubleshooting, reinstallment, or installing at new sites, cleaning may be needed.
The tensiometer shaft is made of acrylic. Acrylic is susceptible to alcohol and other solvents. Clean the sensor as needed with only water, ideally with deionized or degassed water to prevent damage to the ceramic cup on the end of the sensor.

⚠ **Use of tenside or any other cleaner will make the ceramic cup unusable.**

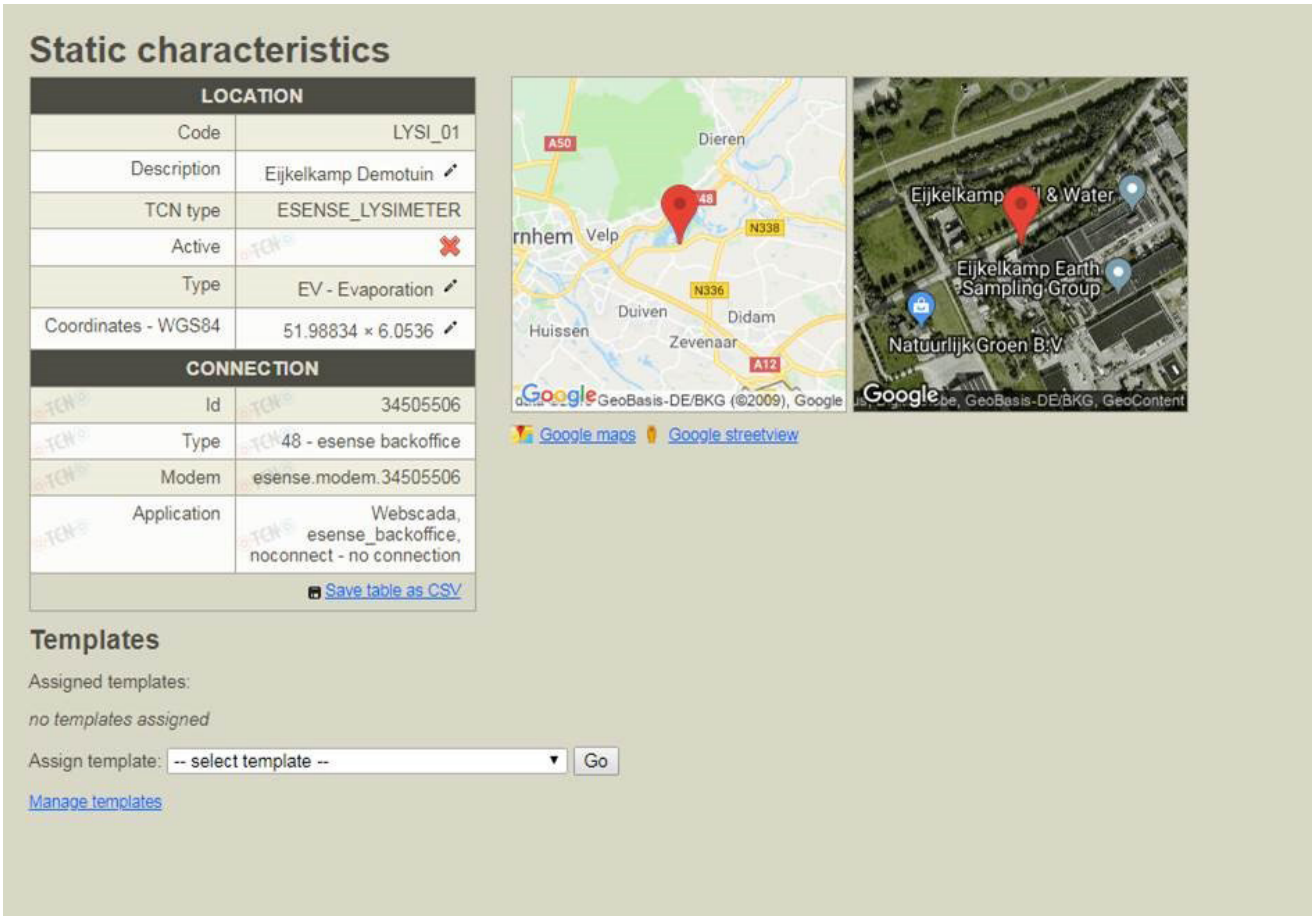
Exposure to oils or other hydrophobic substances compromises the ability of the ceramic cup to get capillary contact to the soil. This inability to get capillary contact leads to slow equilibration times and loss of accuracy. Minimize exposure of the ceramic material to skin oils, grease, synthetic oils, or other hydrophobic compounds. Using gloves to handle and clean the ceramic cup is recommended.

Cleaning the outside of your tensiometer:
To clean the outside of your sensor, it is important to not use any sort of tensides, alcohol, or soaps.
1. Rinse the sensor avoiding the cables using clean water, deionized or degassed if possible.
2. Use a damp, soft cloth to remove any debris that does not easily rinse off (again using clean water and no soaps).
3. Dry with a clean, nonabrasive material.

8. Data visualisation

Using the Eijkelkamp telemetry and web portal lysimeter evapotranspiration, precipitation and sensor values can be visualized. Also various other sensors as meteorological stations, soil moisture profile sensors, surface and groundwater quality and quantity data can be displayed.

8.1 Location details



8.2 Lysimeter actual data selection graphical

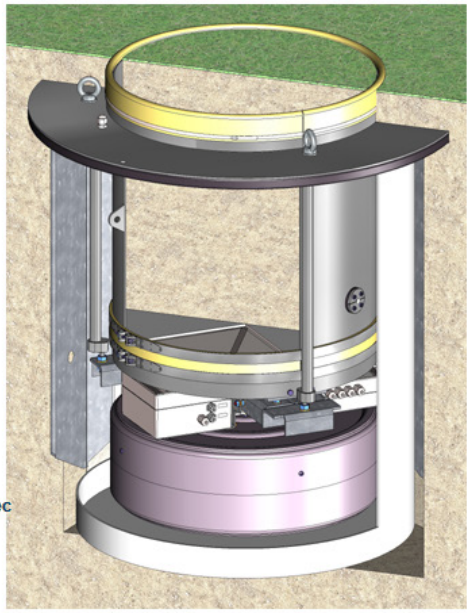
Last contact
2018-06-28 09:00:52

Evaporation

System properties

Modem battery	100.0 %
Logger battery	100.0 %
Signal strength	-67 dBm

Evaporation last hour	**0.2 mm**
Weight Lysimeter	**163,019.0 g**
Tensiometer reference	**-68.3 kPa**
Tensiometer temperature	**17.2 °C**
Pressure plate	**-58.8 kPa**
Lysimeter pump	**-5,476.0 msec**
Weight Reservoir	**12,476.0 g**



Ground level *-370 cmNAP*

Most recent value

163.019,0 g
2018-06-28 08:50

Soilmoisture top	**10.8 ε**
Tensiometer top	**-1,217.6 kPa**
Soilmoisture bottom	**9.2 ε**
Tensiometer bottom	**-2,884.7 kPa**
Lysimeter supply voltage	**13.5 V**
Lysimeter Temperature	**18.0 °C**

8.3 Lysimeter actual data numerical

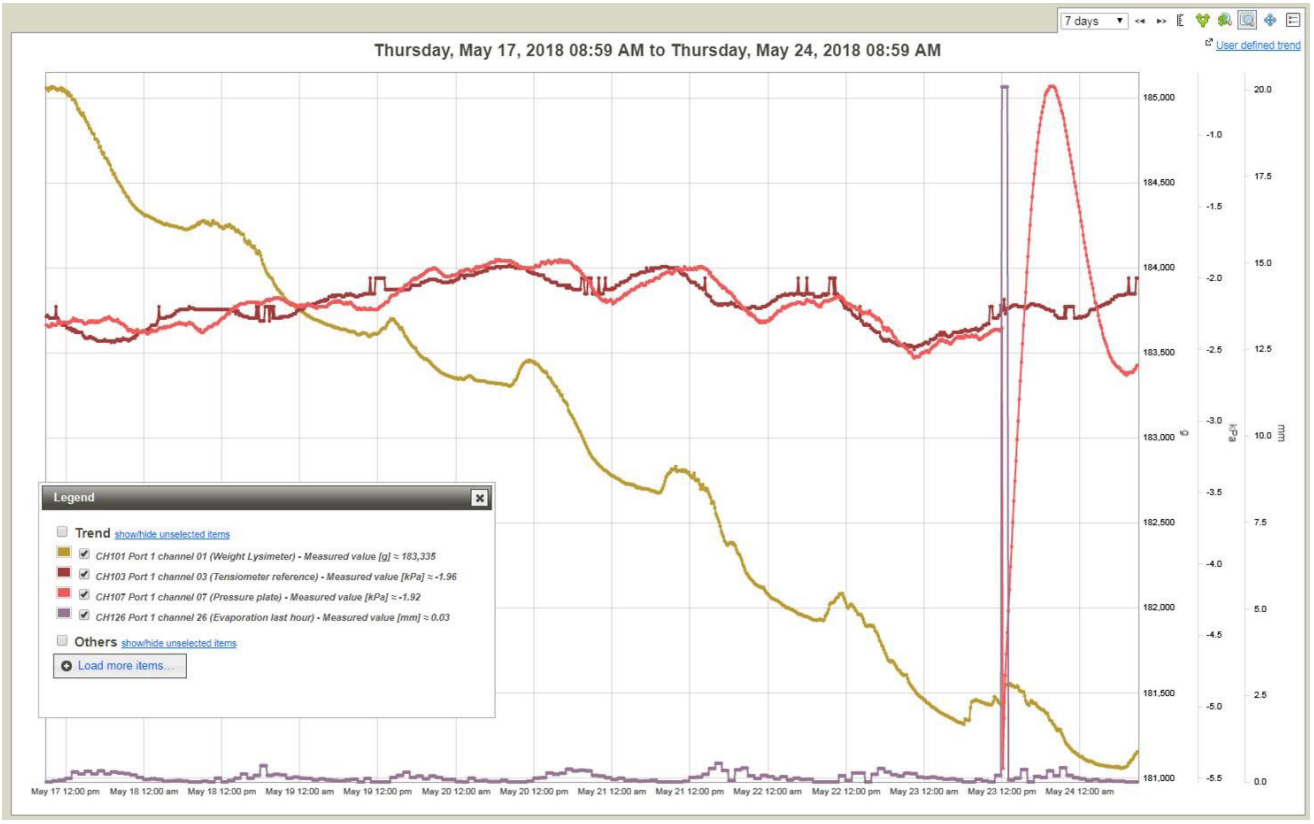
All lysimeter sensor channels are displayed.

Sensor ports

Port 1 Type	Description SDI-12 ESW LYSI 1. XXXXXXXXX	Current value
Channel 1	Port 1 channel 01 (Weight Lysimeter)	163,019 g
Channel 2	Port 1 channel 02 (Weight Reservoir)	12,476 g
Channel 3	Port 1 channel 03 (Tensiometer reference)	-68 kPa
Channel 4	Port 1 channel 04 (Tensiometer temperature)	17.2 °C
Channel 5	Port 1 channel 05 (Tensiometer supply voltage)	13.6 V
Channel 6	Port 1 channel 06 (Tensiometer filling state)	0
Channel 7	Port 1 channel 07 (Pressure plate)	-59 kPa
Channel 8	Port 1 channel 08 (Lysimeter Temperature)	18.0 °C
Channel 9	Port 1 channel 09 (Soilmoisture top)	11 ε
Channel 10	Port 1 channel 10 (Soilmoisture top conductivity)	-9,999 dS·m-³
Channel 11	Port 1 channel 11 (Soilmoisture top temperature)	19.1 °C
Channel 12	Port 1 channel 12 (Soilmoisture bottom)	9 ε
Channel 13	Port 1 channel 13 (Soilmoisture bottom conductivity)	-9,999 dS·m-³
Channel 14	Port 1 channel 14 (Soilmoisture bottom temperature)	19.1 °C
Channel 15	Port 1 channel 15 (Tensiometer top)	-1,218 kPa
Channel 16	Port 1 channel 16 (Tensiometer top temperature)	18.9 °C
Channel 17	Port 1 channel 17 (Tensiometer bottom)	-2,885 kPa
Channel 18	Port 1 channel 18 (Tensiometer bottom temperature)	18.8 °C
Channel 19	Port 1 channel 19 (Lysimeter pump)	-5,885 msec
Channel 20	Port 1 channel 20 (Reservoir pump)	0
Channel 21	Port 1 channel 21 (Lysimeter supply voltage)	13.5 V
Channel 22	Port 1 channel 22 (Info 1)	-9,999
Channel 23	Port 1 channel 23 (Info 2)	30
Channel 24	Port 1 channel 24 (Alert)	12 code
Channel 25	Port 1 channel 25 (Error)	0 code
Channel 26	Port 1 channel 26 (Evaporation last hour)	0.2 mm
Channel 27	Port 1 channel 27 (Reserve 1)	0
Channel 28	Port 1 channel 28 (Reserve 2)	???
Channel 29	Port 1 channel 29 (Precipitation last hour)	0.0 mm
Channel 30	Port 1 channel 30 (Reserve 3)	0
Channel 31	Port 1 channel 31 (Reserve 4)	???

8.4 Lysimeter data graph

All lysimeter sensor channels can be displayed in graphs: user selectable channels, periods, scaling and zoom options.



Typical view for 2 dry days in spring
Tensiometer value (red)
Lysimeter weight (yellow)
Evaporation (purple)

9. Appendixes

9.1 Appendix: Channel specification

Receiving data by the backoffice portal the following identification is used.

Channel	Lysimeter channel name
1	Weight lysimeter (g)
2	Weight reservoir (g)
3	Tensiometer reference (kPa)
4	Tensiometer temperature (°C)
5	Tensiometer supply voltage (V)
6	Tensiometer filling state (0/1 = air)
7	Pressure plate (kPa)
8	Lysimeter temperature (°C)
9	Soil moisture top (e‘)
10	Soil moisture top conductivity (dS.m^{-3})
11	Soil moisture top temperature (°C)
12	Soil moisture bottom (e’)
13	Soil moisture bottom conductivity (dS.m^{-3})
14	Soil moisture bottom temperature (°C)
15	Tensiometer top (kPA)
16	Tensiometer top temperature (°C)
17	Tensiometer bottom (kPa)
18	Tensiometer bottom temperature (°C)
19	Lysimeter pump (msec)
20	Reservoir pump (-1 = empty, 0 = off and 1 = fill)
21	Lysimeter supply voltage (V)
22	Info1
23	Info2 (pump hours lysimeter)
24	Alert (code)
25	Error (code)
26	Evaporation last hour netto (mm)*
27	Evaporation last hour individual (mm)**
28	Reserve2
29	Precipitation last hour netto (mm)*
30	Precipitation last hour individual (mm)**
31	Reserve4

} Added by Back-Office

* Evaporation last hour netto (mm) Channel 26 and Precipitation last hour netto Channel 29 are calculated values. For each hour the increase and decrease of weight of both lysimeter and reservoir are evaluated against each other and calculated for mm evaporation and rain using the lysimeter surface area.

** Channel 27 and 30 are calculated values. For each hour the increase and decrease of weight of both lysimeter and reservoir are individual incremental calculated mm evaporation and rain using the lysimeter surface area.

See also Appendix Calculation evaporation/precipitation for detailed calculation information.

9.2 Appendix: Lysimeter Site Acceptation Test (SAT)

Customer		**Project**	
		Location	
Serial no. lysimeter		**Description**	

MECHANICAL AND FUNCTIONALITY TEST		
No.	**Item**	**Acc.**
1	FAT report, Calibration report, documentation	
2	Correct placement sheet piling?	
3	Suction plate properly installed	
4	Suction plate filled with clean degassed demineralized water	
5	All cables connected to the Control Box	
6	Unused glands Control Box sealed	
7	Control Box sealed watertight	
8	Pump box connected to the Control Box	
9	Pump Box sealed watertight	
10	All waterhoses properly secured	
11	Soil Moisture sensors top & bottom properly installed in monolite	
12	Tensiometer top & bottom properly installed in monolite	
13	Decent power supply connected	
14	Lysimeter connected properly to a modem or logger	
15	Lysimeter can be readed and controlled by a laptop trough USB	
16	Reference tensio installed properly	
17	Reference tensio connected properly to the Lysimeter	
18	Reservoir filled with cleand demineralized water (12...15 litres)	
19	Reservoir weight checked (1kg = 1L)	
20	Reservoir pump direction checked (empty - fill)	
21	Lysimeter pump functions checked	
22	Frame and monolite properly sealed with collar	
23	Lysimeter lifted into the container, all parts free from friction (special attendance for cables)	
24	Container and Lysimeter correctly adjusted in combination with ground level (levelled/ depth) and tightened with bolts	
25	Monolite weight checked (stability and 1kg load step)	
26	Collar filled with sods withoud gaps	
27	Vent tube not blocked	
28	Reservoir water outlet not blocked	

29	Foto's from all installed parts	
30	Lysimeter configuration checked	
31	No entanglement of vegetation, environment and monolith	
32	Correct site finish (undisturbed; replaced sods without gaps; possibly fencing/feeding protection; etc.)	
33	Final step Eijkelkamp: scan this completed SAT document and mail to: customer/ Projects Eijkelkamp/ Service Eijkelkamp	

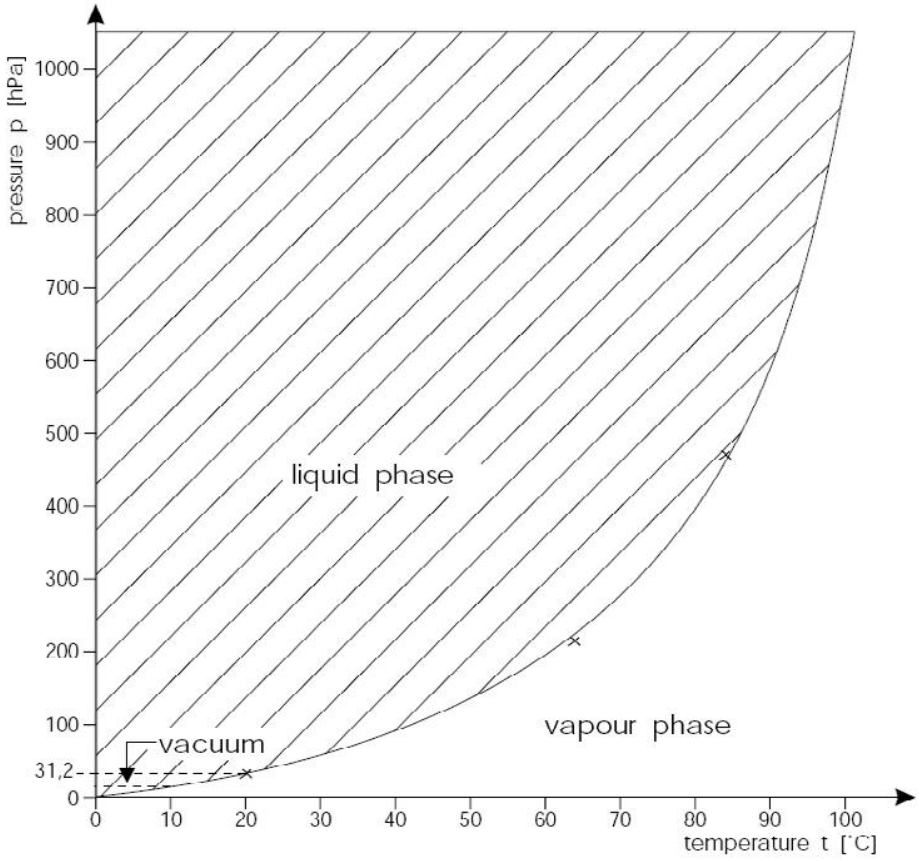
		Configuration	Acc.
INSTALLATION menu	SDI12 Lysimeter address	value	
	Sample interval (sec)	value:	
	Reservoir Autofill	ON / OFF	
	Lysimeter winter protection	ON / OFF	
FACTORY menu	Reservoirpump max time (min)	value:	
	Lysipump minimum on time (msec)	value:	
	Lysipump maximum on time (sec)	value:	
	Pump controller PID - Kp	value:	
	Pump controller PID - Ki	value:	
	Pump controller PID - Kd	value:	
	Pump controller PID - Gain	value:	
	Lysipump time direction change in to out (min)	value:	
	Lysipump time direction change out to in (min)	value:	
	Pump enable minimum temperature	value:	
	Gaussian Enable Status	ON / OFF	
CALIBRATION menu	Datafilter Sigma of Gaussian	value:	
	Tensio ref simulated value (hPa, -9999=disable)	value:	

Opmerkingen / Remarks

Checked	Date:		Signature
Technician /Project leader Eijkelkamp	Name/Initials		
Customer approval	Name/initials		

9.3 Appendix: Degassing water

Tensiometers should be filled with demineralized or distilled water. This water must be degassed.
The tensiometer water limits the measuring range, as can be seen from the two-phase diagram for water and water vapour.



If the ceramic cup is completely dry, first put the ceramic cup into a beaker filled with the degassed deionized water for at least 1 hour to enable the ceramic to get saturated with water. The whole of the ceramic should be below the water level! Do not fill water into the ceramic cup as there is a danger of trapping of air in the ceramic. If the tensiometer contains dissolved gases, the vapour point is raised, which restricts the measuring range considerably. Therefore care should be taken to degas the deionized water as completely as possible (e.g. by boiling). To degas, boil water for 5 minutes, then fill a suitable heat resistant container completely without air, seal tightly and place in a refrigerator to cool.

An alternative method of de-gassing water is to heat the water to boiling, and then pull a vacuum for 15 minutes. Without heating the vacuum process takes 4 hours or more. During vacuum inductive steering or ultra-sonic stimulates the process.

9.4 Appendix: Calculation evaporation/precipitation

Detailed explanation of the evaporation/precipitation calculation:

The sum of lysimeter weight and reservoir weight is used to calculate evaporation and precipitation. As water can be pumped either from lysimeter to reservoir or opposite during lysimeter moisture control both need to be used in calculations.

Evaporation net calculation:
Evaporation = weight difference decrease / lysimeter surface
Weight difference: Within every hour all lysimeter weight and reservoir weight measurements from t1 to t60 for are summed, total net difference is calculated, net weight decrease is assumed as evaporation
Lysimeter surface = 1962.5 cm^2
0.1 mm evaporation/m^2 = 19.63 gram weight decrease

Precipitation net calculation:
Precipitation = weight difference increase / lysimeter surface
Weight difference: Within every hour all lysimeter weight and reservoir weight measurements from t1 to t60 for are summed, total net difference is calculated, net increase is assumed as precipitation
Lysimeter precipitation surface = 2074.4 cm^2; including half area silicon rim surface
0.1 mm precipitation/m^2 = 20.74 gram weight increase

A measurement interval 5 minutes is recommended to evaluate at least 12 measurements each hour. Setting of Gaussian ON is recommended for optimal data filtering i.e. to correct for wind influences.

In case the reservoir reaches the maximum water fill level, the reservoir is pumped of automatically causing a lower reservoir weight. During the pumping of the reservoir, the lysimeter pump is inhibited. Normally the sum of both lysimeter weight and reservoir weight are used to calculate evaporation and precipitation. During this pumping action the calculations for evapotranspiration and precipitation are based only on the lysimeter weight. The difference in reservoir weight before and after the pumping action is not considered in the evapotranspiration and precipitation calculation. In this way the calculations are also correct during pumping actions.

9.5 Appendix: Channel identification

Channel	Lysimeter channel name	Typical min.	Typical max.	Max fluctuation (5 min interval)
1	Weight lysimeter (g)	150000	250000	2000
2	Weight reservoir (g)	1000	20000	1000
3	Tensiometer reference (kPa)	-90	5	10
4	Tensiometer temperature (°C)	-10	30	2
5	Tensiometer supply voltage (V)	6	18	-
6	Tensiometer filling state (0/1 = air)	0	1	-
7	Pressure plate (kPa)	-85	5	5
8	Lysimeter temperature (°C)	-15	40	5
9	Soil moisture top (e‘)	1	75	20
10	Soil moisture top conductivity (dS.m-3)	0	20	2
11	Soil moisture top temperature (°C)	-10	30	1
12	Soil moisture bottom (e’)	1	75	20
13	Soil moisture bottom conductivity (dS.m-3)	0	20	2
14	Soil moisture bottom temperature (°C)	-10	30	1
15	Tensiometer top (kPA)	-10000	-1	1000
16	Tensiometer top temperature (°C)	-10	30	5
17	Tensiometer bottom (kPa)	-10000	-1	1000
18	Tensiometer bottom temperature (°C)	-10	30	5
19	Lysimeter pump (msec)	0	20000	10000
20	Reservoir pump (-1 = empty, 0 = off and 1 = fill)	-1	1	-
21	Lysimeter supply voltage (V)	7	15	-
22	Info1	-	-	-
23	Lysimeter pump running hours	0	250	-
24	Alert (code)	-	-	-
25	Error (code)	-	-	-
26	Evaporation last hour netto (mm)	0	100	10
27	Evaporation last hour individual (mm)	0	100	10
28	Reserve2	-	-	-
29	Precipitation last hour netto (mm)	0	100	25
30	Precipitation last hour individual (mm)	0	100	25
31	Reserve4	-	-	-

9.6 Appendix: Alert codes channel 24

Conditional warning codes		Action (red = Lysi software action, black = field service engineer action)
alert 1	tensiometer reference value >4kPa (groundwaterlevel is allmost (-10 cm) at surface	field inspection flooding
alert 2	tensiometer reference value >4,5kPa (groundwaterlevel is allmost (-5cm) at surface	stop pumping reservoir water into Lysimeter
alert 4	reference tensiometer suction plate is lower then -50kPa	field inspection drought
alert 8	difference between reference tensiometer and suction plate is more then 10 kPa	field inspection
alert 16	reservoir gewicht laag	field inspection
alert 256	temperature lower then "Pump enable minimum temperature" setting	disable pumps
alert 512	power supply low (<10,5V)	field service needed (battery replacement, solar panel cleaning/replace)

9.7 Appendix: Error codes channel 25

Alert	Description	
error 1	reservoir weight is over 21000 gram	pump reservoir to exhaust, do not pump lysimeter into reservoir
error 2	reservoir weight is 500 gram over relative max reservoir setting	pump reservoir to exhaust
error 4	reservoir weight is not lowering during reservoirpump pumping out (-1)	stop lysimeter pumping, service pump or freezing conditions
error 8	reservoir weight is decreasing (>15 gram per hour) without reservoir pump is pumping out (-1) reservoir is floating	stop pumping lysimeter, field service needed
error 16	water detected	stop pumping lysimeter, field service needed
error 256	pump Fault (undervoltage: <8V or pump overcurrent, or chip over-heated)	field service needed
error 512	power supply low (<9,5V)	field service needed (battery replacement, solar panel cleaning/replace)

9.8 Possible precautionary measure

Lysimeters can be disturbed by grazing or digging animals or vandalism. Especially the lysimeter silicone rim, cables and sensors are vulnerable for this. Also in case of entry by man or animal overload of the lysimeter can occur with possible damage to crop and lysimeter.

Possible options for protection:
1. Marking
2. Fence wire
3. Grazing gauze
4. Ultrasonic deterrence
5. Animal repellent
6. Camera monitoring

1. Marking
   A sign explaining the setup and purpose of the measurements, companioned with a warning not to disturb the site, might help to prevent possible damage caused by visitors.

2. Fence wire
   The placing of a fence wire is effective against larger animals such as deer, reed, swine, sheep, etc. Ensure the correct shielding height of wires or grating and follow the instructions for this, placing warning marking is mandatory.

3. Grazing fence
   Fine meshed fence can defend against mice and smaller rodents, the mesh should be at least 40 cm high and be dug in the soil for at least 10 cm.

4. Ultrasonic deterrence
   Ultrasound deterrence is effective to keep pests outside the plot area. Underground sounding can also keep the moles at a distance. The intermittent sounds in a frequency that annoys specific pests.

5. Animal repellent
   Antiviral agent is a means that can be applied selectively to the silicone edge of the lysimeter and the sensor cables with a brush.

6. Camera monitoring
   With a wild camera, high-quality images can be transmitted telemetrically triggered by time interval and / or infrared detection of human and animal.
   The pictures enable a plot view in case of disturbance and views through all the season without visiting the plot.