METER

Smart Field Lysimeter

User Manual

Art.Nr. SFL-300, -600, - 900
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Contents

1 Introduction

1.1 Notes to this manual

Figure 1: separate parts of the manual dedicated to work in the field

Please note
This manual includes also 3 single pages that describe and illustrate how to install the Smart Field Lysimeters in the field:
- Cutting the soil column
- Earthworks and basic setup
- Installation and start-up

These 3 pages focus on **to dos** in order to minimize reading time in the field whereas this user manual gives you background information.

1.2 Intended use

Smart Field Lysimeters are most precise field setups to determine the precipitation and the evapotranspiration at true field condition. Further they measure the drainage water amount to determine the ground water recharge capacity of a field site at a certain soil depth.
The determination is based on the weight changes of the Lysimeter soil column and a drainage water bottle. Additional sensor equipment is measuring matrix potential, volumetric water content and temperature at certain depths. This enables the user for model calibration issues based on Richards's equation, HYDROS 2 D and others, where fluxes are calculated, based on these data. The Lysimeter directly measures due to weight the atmospheric interface, which is any kind of precipitation like rain, dew, hoar frost, and the first snow event as input parameters. Further it measures the output parameters like evaporation, transpiration and drainage. To reach true water situation inside the Lysimeter, the matrix potential in the field in the depth of the Lysimeter bottom is measured and transferred into the Lysimeter.

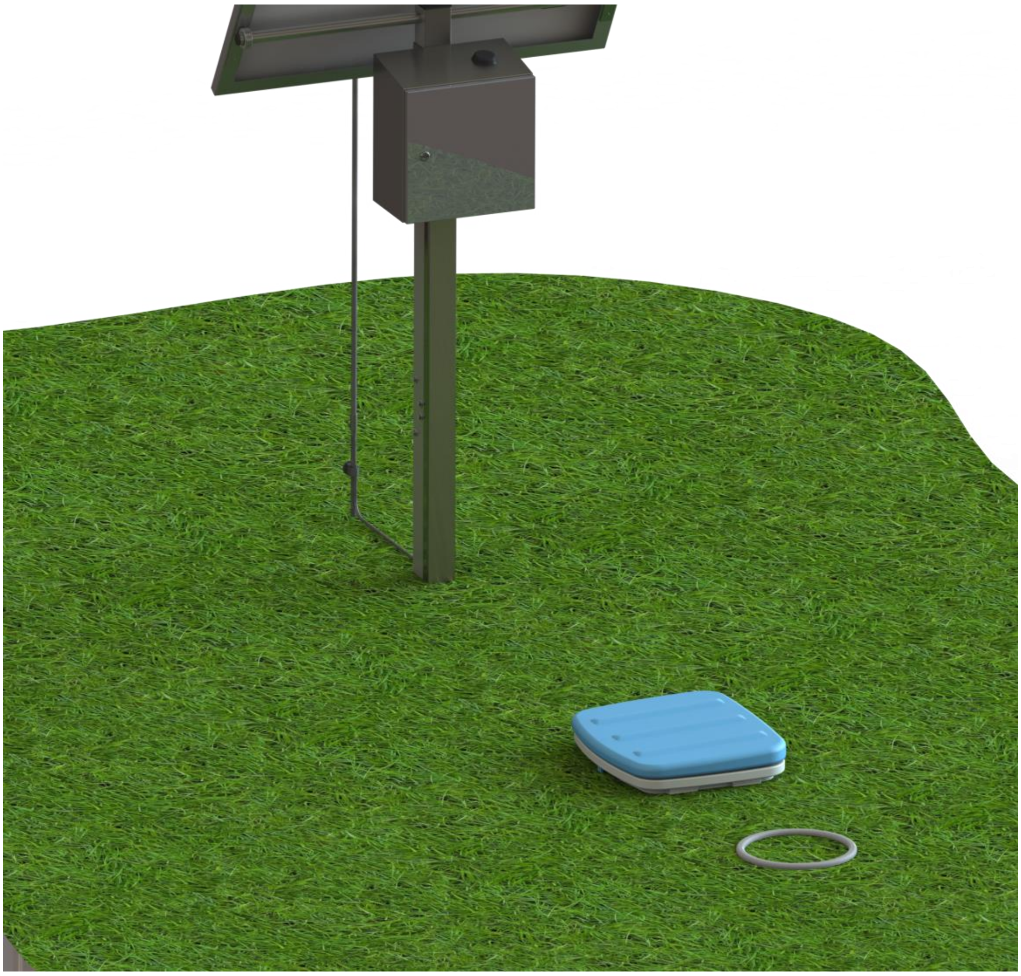


Figure 2: intended field use

2 System configuration

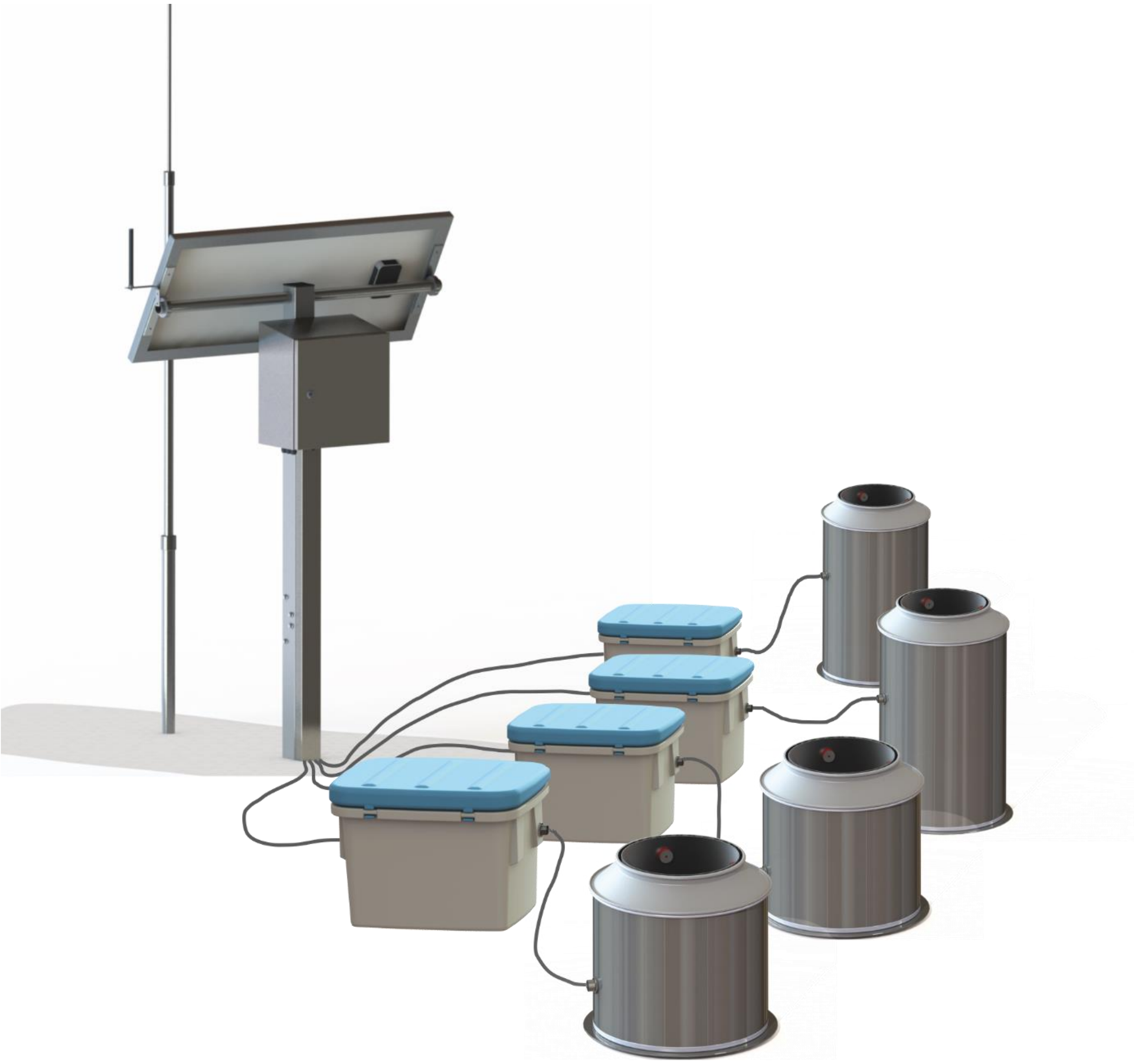


Figure 3: overall scheme system and components

2.1 Logger box and related components

Up to 4 Lysimeters can be connected to the logger box.

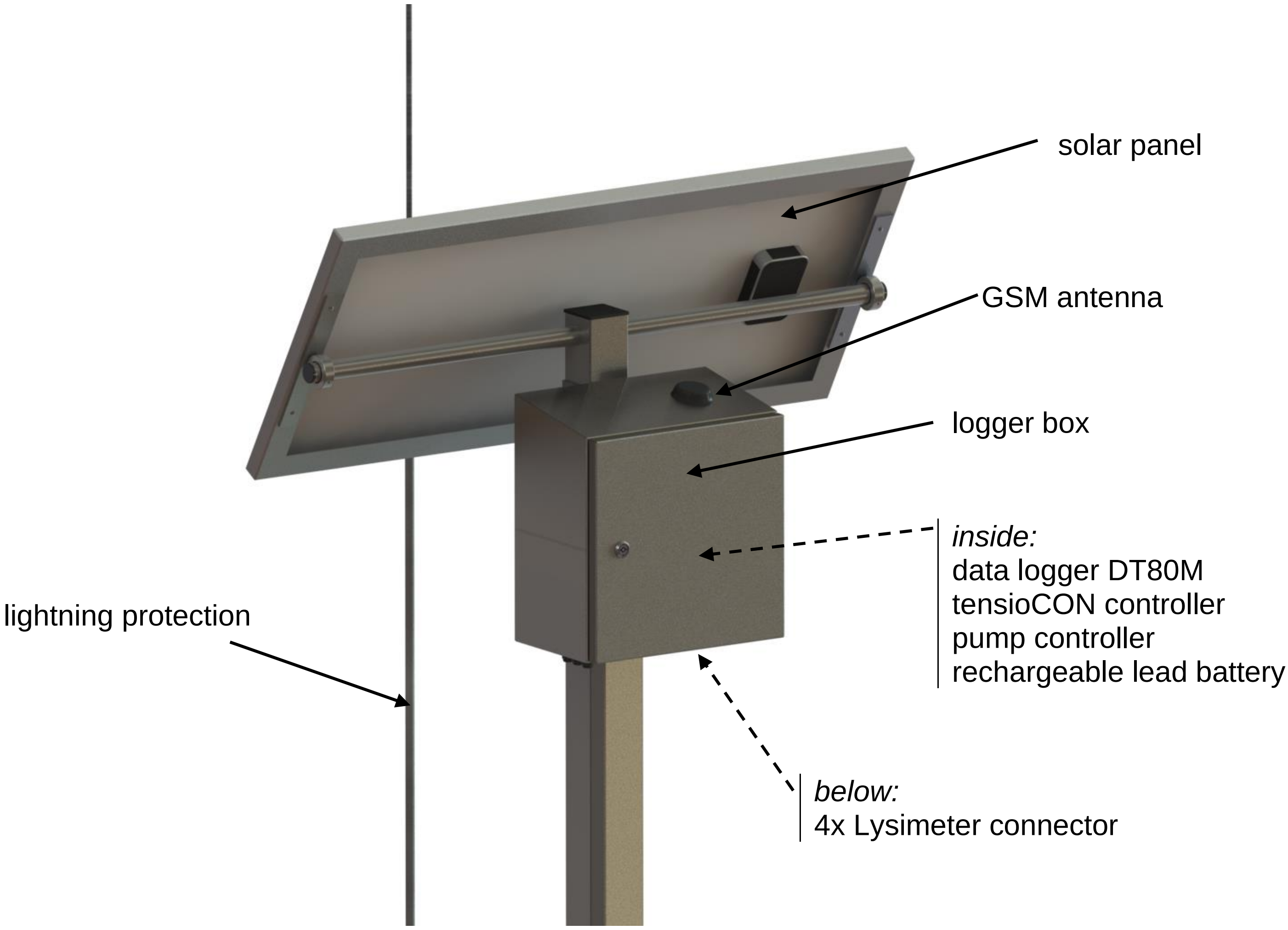


Figure 4: logger box and components

2.1.1 Data logging and controller

The DT80M is a data logger, all measurement data are logged and can later be read out automatically or manually. On the other hand this device also works as a controller of the Smart Field Lysimeter functions. The communication with the devices connected to it, is partially bi-directional.

Figure 5: data logger DT80M

2.1.2 tensioCON

The tensioCON controls the power management of the Smart Field Lysimeter. It charges and controls the built-in 12 V lead battery.

2.1.3 SFL Pump Controller

Each of the up to 4 connected Lysimeters has its own pump controller. It controls a bi-directional peristaltic pump that is in the Field Box.
The pump controller is in charge of precisely adjusting the matrix potential in the bottom of the Lysimeter (called the lower hydraulic boundary condition) due to field condition. For more information see chapter 4 Feedback control of the lower hydraulic boundary condition.
The feedback control adjusts the lower hydraulic boundary condition
- Either to a reference value usually given by the reference Tensiometer that is connected to the controller.
- Or a manually fixed value for simulation reasons or artificial ground water level tests.

For this the controller needs to know the reference value (from T8) and the actual value VTENS. The controller activates the pump in short intervals to adjust the matrix potential as precisely as possible.
The feedback control uses a PI (proportional & integral) algorithm. If necessary, this algorithm can be adjusted to the characteristics of the soil. The related parameters can be changed with the METER tensioVIEW software.
The data logger stores the times of water inlet and outlet (as seen by the Lysimeter) for each pump with a 1 sec resolution. In the evaluation these times can be compared with the weights of the drain water and the Lysimeter.

2.1.4 Rechargeable battery

The rechargeable 12 V / 24 Ah lead gel battery is located above the data logger. The battery’s capacity is enough for 1 to 2 weeks of normal operation – depending on how it is discharged by running the pumps and how the system is equipped.

2.1.5 Solar panel

Figure 6: solar panel

Under normal sun radiation the solar panel generates enough energy to run the system with 4 Lysimeters. In winter the energy supply can get tight depending on the location, the position of the system in the field and use.

2.2 Field Box

The Field Box works as a supply station for the Lysimeter. It is dug into the soil in a defined distance close to the Lysimeter whereas the logger box can be set up much farer away.

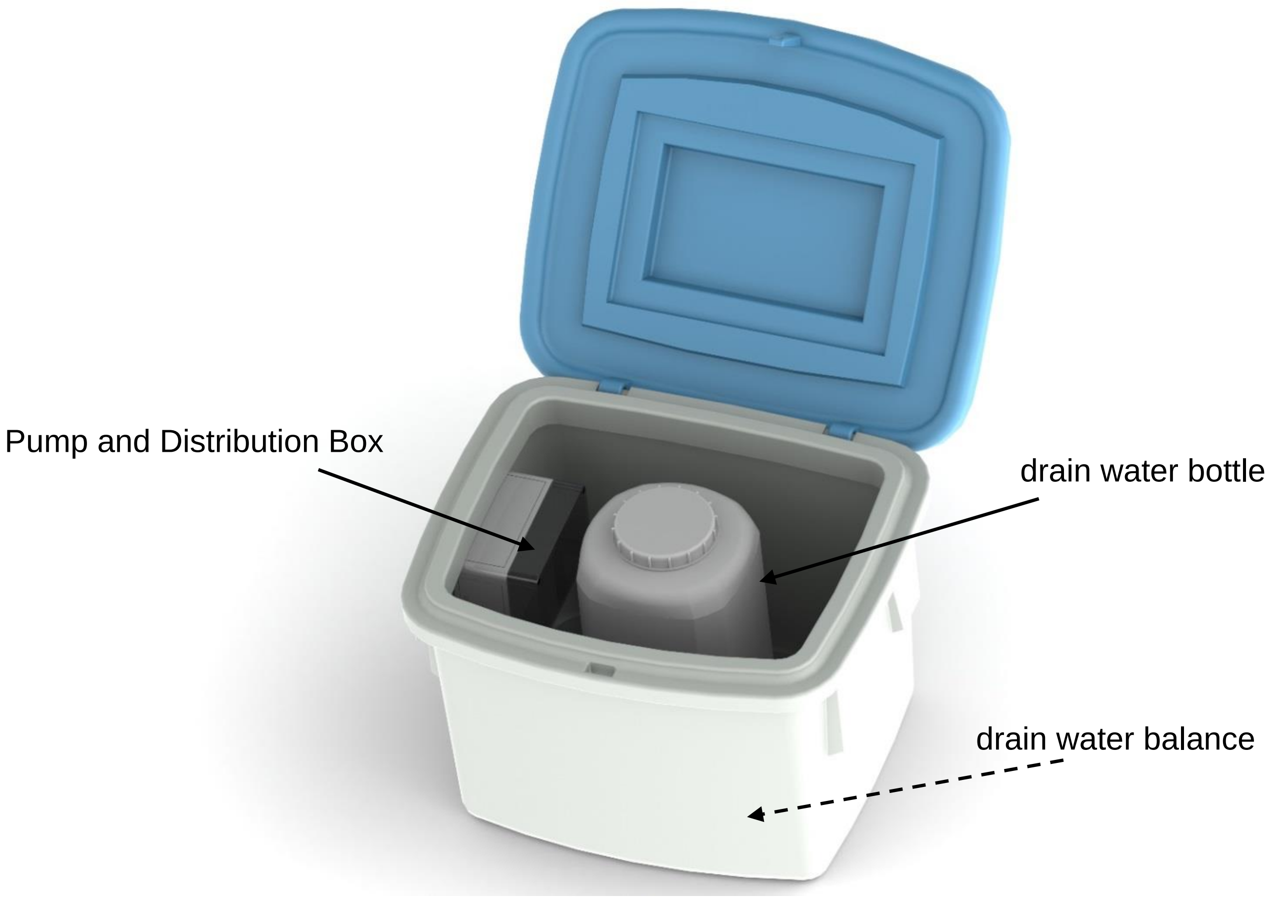


Figure 7: Field Box

2.2.1 Pump and Distribution Box

The Pump and Distribution Box in the Field Box has two tasks. On one hand all components are connected to it – the cable to the Lysimeter, the drain water balance and the reference Tensiometer – and the signals are distributed according to the connections.

On the other hand it houses the bi-directional pumps and the connection for the tubes. The main pump conveys water from the Lysimeter into the drain water bottle and the other way around.

A second pump is used to pump out overflood drainage water when the bottle is full. The system is programmed to empty the bottle from a Drainage water balance weight of 10kg to 8kg. The water is pumped outside of the field box by an exhaust tube which should be routed somewhere outside of the field box where the water can easily flow out at the end (not nearby the T8).

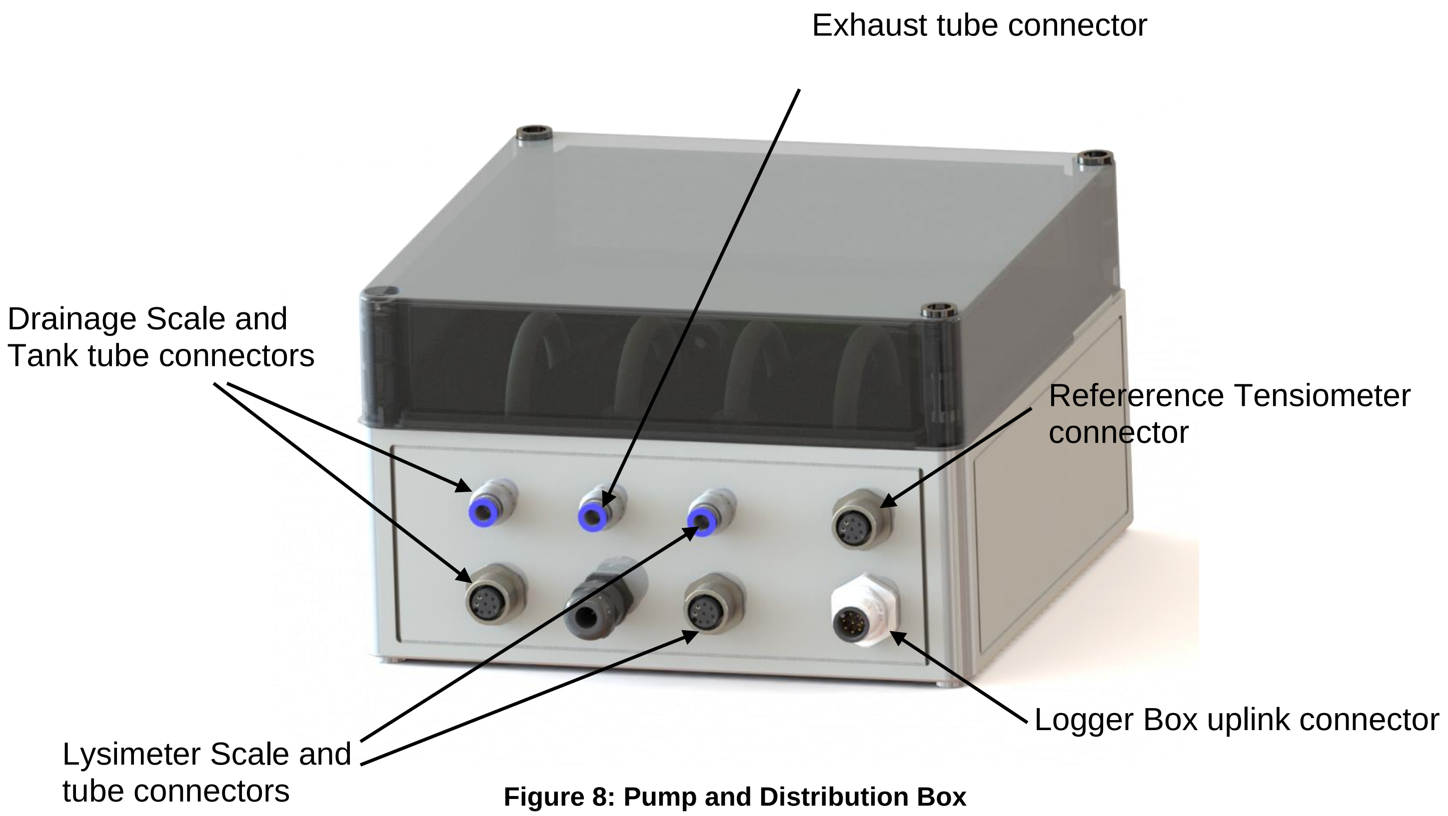


Figure 8: Pump and Distribution Box

2.2.2 Drain water bottle

The drain water bottle in the Field Box works as a buffer storage for surplus water or supply water respectively. By collecting the water in a bottle an exact balance of the water budget in the Lysimeter can be calculated. This kind of balancing is much more precise than a flow measurement.

2.2.3 Drain water balance PL-10

The drain water balance measures precisely the weight of the drain water bottle and the water that runs to or from the Lysimeter bottom. The resolution of the balance is usually 1 gram or optionally 0.1 gram.

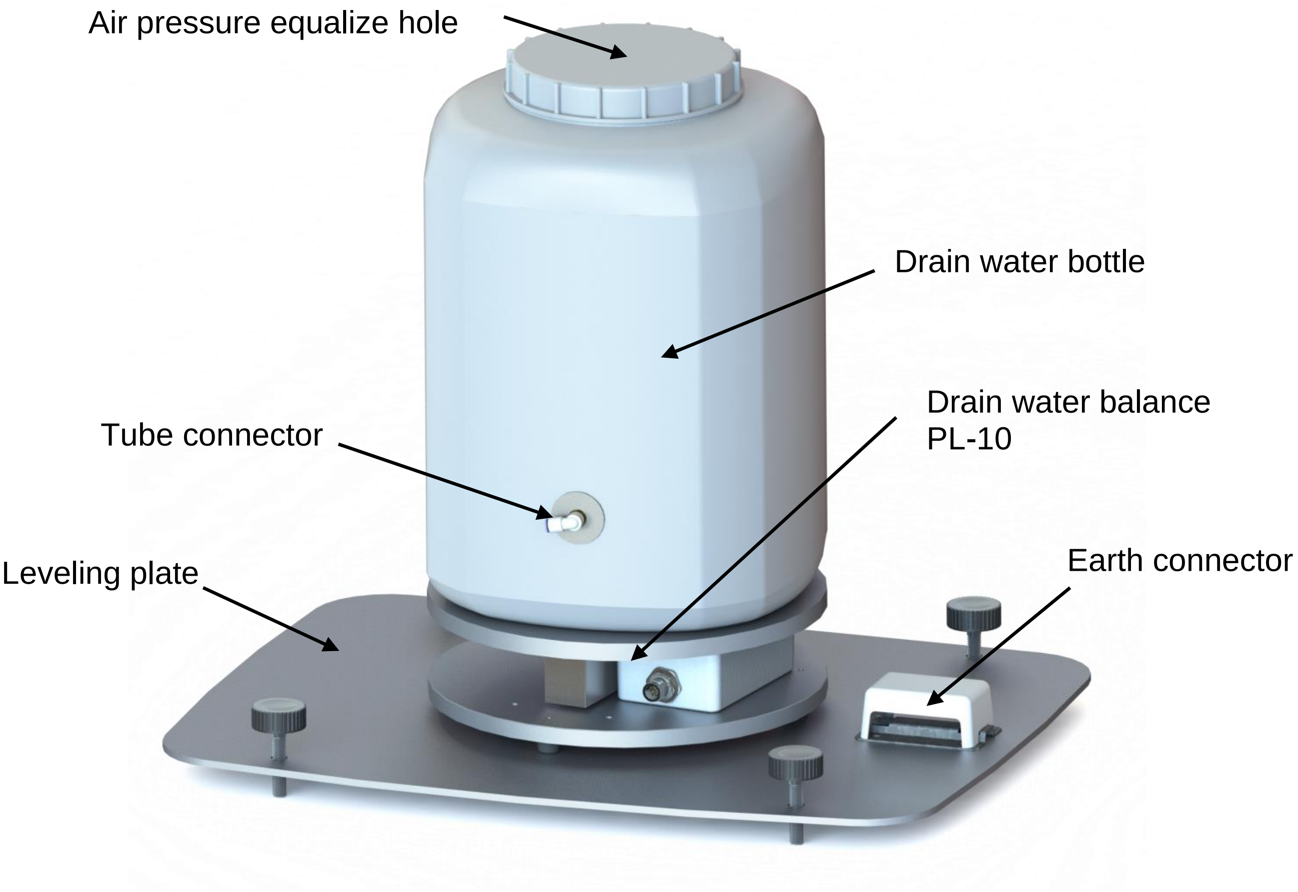


Figure 9: drain water balance with drain water bottle and levelling plate

2.3 Lysimeter

The Lysimeter consists of the Lysimeter cylinder and all parts that are mounted to it. It is in 1 m distance from the Field Box and is connected by cables and tubes conducted in a protective tube.

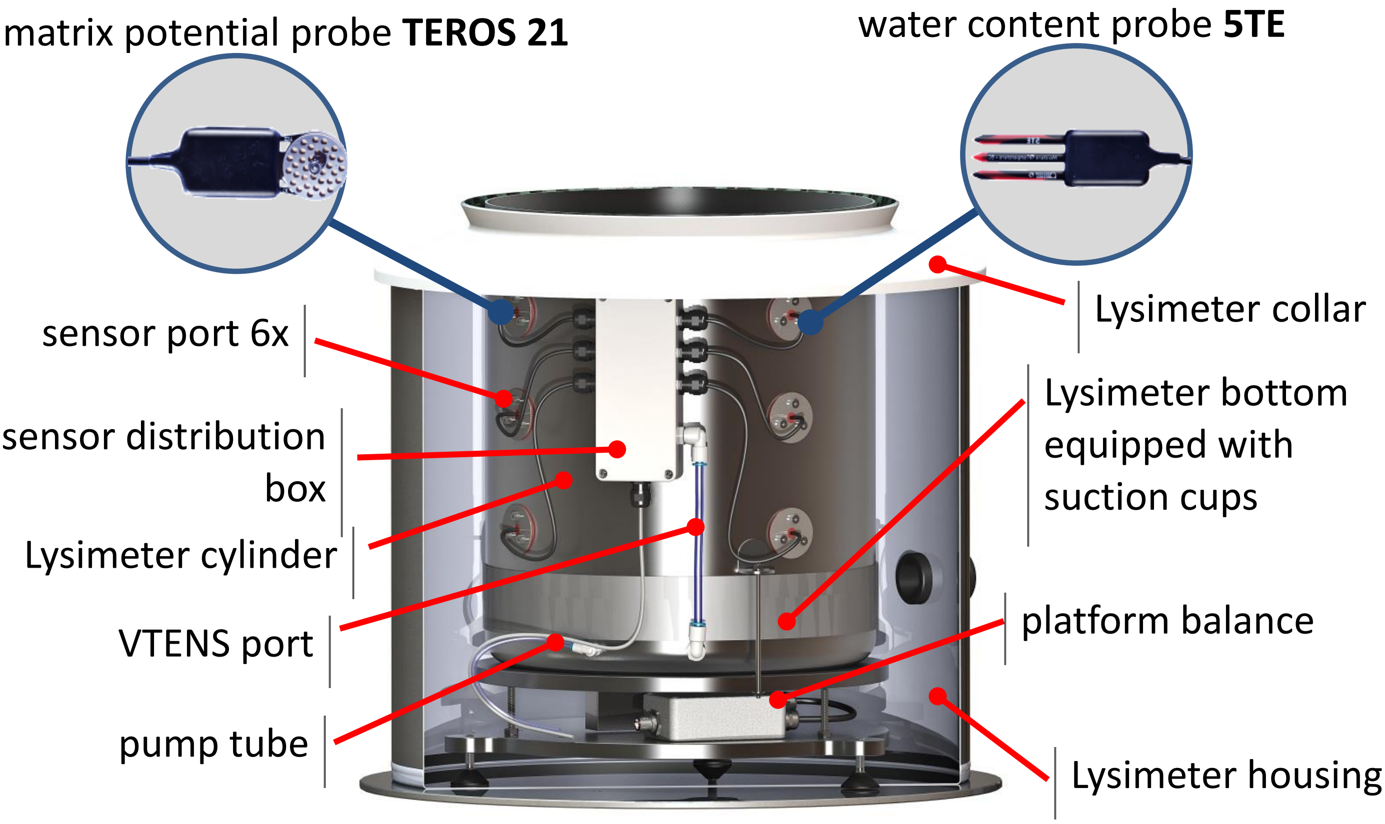


Figure 10: Lysimeter

2.3.1 Lysimeter balance PL-50/100/200

The Lysimeter balance measures the weight of the Lysimeter cylinder and the soil column. It registers the mass of water that flows to or from the Lysimeter caused by precipitation and evaporation on the top and drains from the Lysimeter at the bottom.

In order to increase the resolution and precision of the balances their nominal measuring range is according to the SFL-type and weight.

SFL 300 with PL50 – nominal range 0 … 50 kg, max. 75 kg, precision ±7 g
SFL 600 with PL100 – nominal range 0 ... 100 kg, max. 150 kg, precision ±14 g
SFL 900 with PL200 – nominal range 0 … 200 kg, max. 300 kg, precision ±28 g

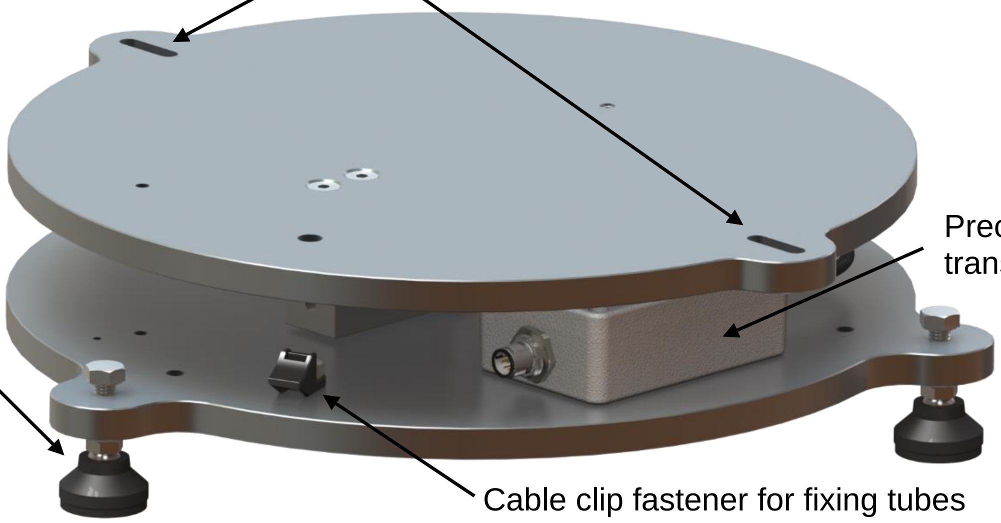


Figure 11: platform balance PL-50

The balances PL100 and PL200 can be replaced by each other if needed. The PL50 is less high and cannot be replaced by one of the others.
On the top platform are flaps for fixing the Lysimeter on the balance. The whole unit can be lowered down into the Lysimeter housing.

2.3.2 Lysimeter sensor distribution box

The sensor distribution box is directly mounted to the Lysimeter cylinder and does 2 jobs. Three TEROS 21 sensors and three 5TE sensors are connected to it. Additionally a pressure sensor and an evaluation electronics measure the actual pressure VTENS. For this the sensor is connected with the suction cups in the Lysimeter bottom (Section 3.4 VTENS (Lysimeter)).

Only a thin cable runs from the sensor distribution box to the bottom platform of the balance to make sure the influence of the cable on the Lysimeter weight measurement is minimal.

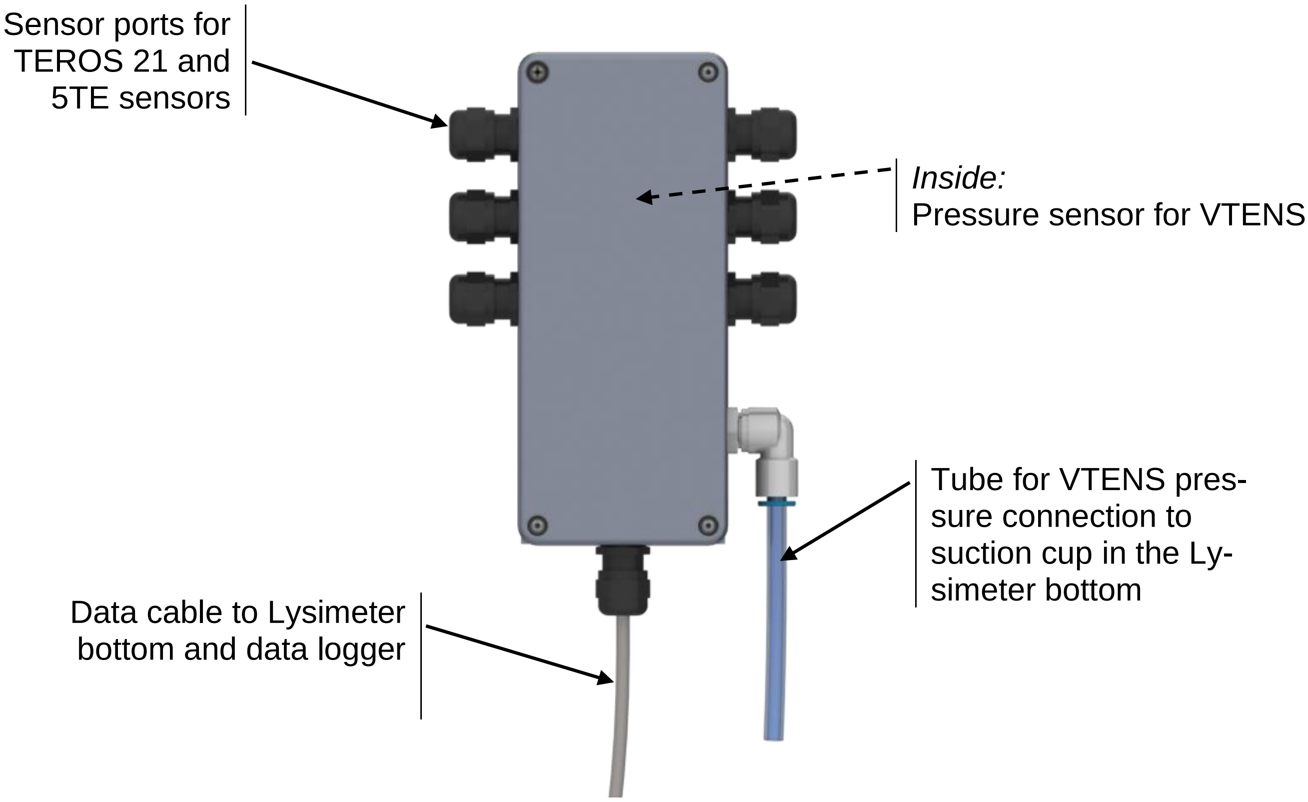


Figure 12: Lysimeter sensor distribution box

3 Sensors

3.1 Reference Tensiometer T8 (Field)

Figure 13: T8 Tensiometer

The reference Tensiometer is dug into the soil close to the Lysimeter (see separate page „Earth works and basic set-up"). The measurement values of the Tensiometer are used by the feedback control to adjust the lower hydraulic boundary condition.

3.2 Matrix potential sensor TEROS 21 (Lysimeter)

Figure 14: TEROS 21 sensor

The TEROS 21 sensor measures the matrix potential (or the tension respectively). It uses the Echo technology to determine the water content of a porous matrix. The water content within the porous matrix correlates with the matrix potential.

Because of the measuring principle this sensor does not work close to saturation, that is > -10 kPa. This sensor is maintenance free and works even in the dry range of < -500 kPa.

3.3 Sensor 5TE (Lysimeter)

Figure 15: 5TE sensor

The three 5TE sensors measure the volumetric water content, the electrical conductivity and the temperature of the soil. The 5TE uses the Echo Technology, an FDR (Frequency Domain Response) based technology which is widely spread to measure water content in soils and other porous materials.

3.4 VTENS (Lysimeter)

The VTENS or virtual Tensiometer is the controlled boundary condition in the bottom of the Lysimeter cylinder. The value of a reference Tensiometer is controlled at a ceramic surface by a vacuum controller. VTENS measures the actual pressure inside the ceramic. At the boundary layer of the ceramic to the soil bottom the potential is identical. In principle VTENS is therefore a 4^{th} matrix potential value directly above the Lysimeter bottom. Contrary to TEROS 21 matrix potential values this value can work also at zero or respectively even into the over pressure range (water level inside the Lysimeter).
The limits of the VTENS are set by the reference value of the Tensiometer and the air entrance point of the ceramic surface. When it is met (at approx. 80 kPa) air enters spontaneously, the measurement value breaks down to zero and the feedback control can no longer work correctly.
The VTENS is not a sensor located in the bottom. Instead of this a reference tube is lead out, which leads to the suction cups in the Lysimeter bottom. This tube is connected to the sensor distributor. Here a precise pressure sensor and an evaluation electronics are situated. The VTENS is in the sensor distribution box.

4 Feedback control of the lower hydraulic boundary condition

Contrary to gravity Lysimeters, which only drain overpressure water or free water, the Smart Field Lysimeter works with a drain water feedback control due to field condition having the real field condition inside the Lysimeter.

4.1 Background

Water in the soil always flows from spots of higher pressure or matrix potentials to spots of lower matrix potentials. After rain e.g. the soil surface has free water – the matrix potential or pressure potential is here close to 0 kPa. The water is sucked downwards by the dry soil with its negative or smaller potentials and following gravity.

When the soil surface dries out it is just the other way around. The water flow turns as the surface has now the lower potential (evapotranspiration).
The water in older gravity Lysimeters can only run off when it can drain freely that means at potentials of zero kPa what is equivalent to a groundwater level. So these Lysimeters are in times of high precipitation rates always too wet. This influences the whole Lysimeter. Vice versa they dry out too much in times of low precipitation as no water is supplied from the bottom.
Here is the big advantage of the Smart Field Lysimeters! Their feedback control measures the water potential at the bottom and adjusts it continuously. Thus the soil humidity, the water flows and potentials in the Lysimeter are identical to the real field situation. The length of the soil column does not need to be two meters to minimize these errors of gravity Lysimeters.

4.2 How it works

In the Lysimeter bottom there are several suction cups with a porous ceramic surface which is in contact with the soil above it or the soil sample respectively. The pressure or the negative pressure respectively in the suction cups is measured precisely by the VTENS sensor. The pump controller drives in a pulsed way a bi-directional pump to adjust the VTENS measurement value to a reference value. The reference value is usually coming from the Tensiometer that is built in the field close to the Lysimeter at the same depth.
If the Lysimeter is in hydraulic equilibrium the VTENS measurement value correlates with the value of a Tensiometer at this depth. Also a manual reference value can be set. In principle the value of a farther remote Tensiometer could be used via an online connection with the data logger.

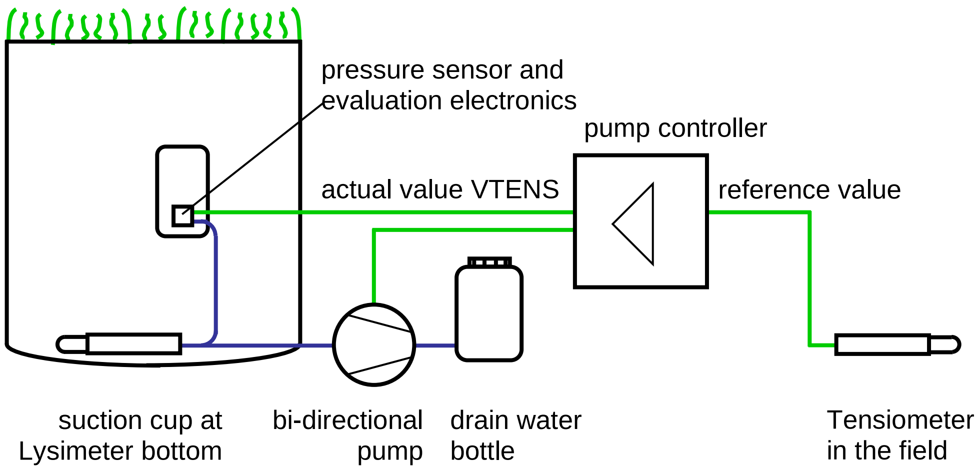


Figure 16: feedback control of the lower hydraulic boundary condition

4.3 Limitations

The novel feedback control of the lower hydraulic boundary condition works very precisely and over a wide range of +3 kPa … -70 kPa.
The feedback control is limited by the air entrance point of the suction cup ceramic. If this point is reached (at approx. 80 kPa) air entrances spontaneously, the

measurement value breaks down to zero and the feedback control can no longer work correctly. In this case the pump will be deactivated.
If the soil becomes wet again the pores of the ceramic close and the pump can build up a vacuum again (re-vitalization).

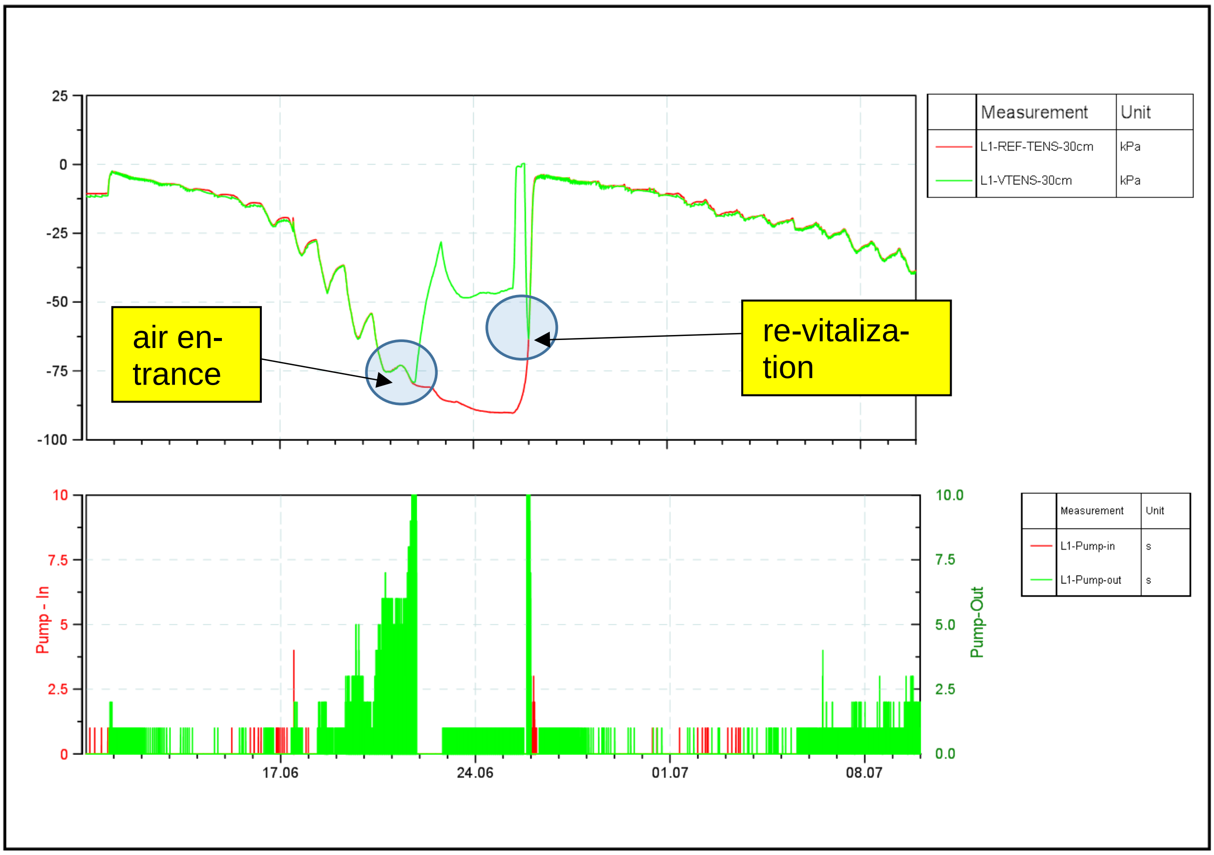


Figure 17: air entrance into the suction cup in the Lysimeter bottom

5 Data logger DT80M

5.1 Connections to the device

The DT80M has a built-in web interface. The connection is IP based, i.e. the logger has an IP address that is used to access the logger functions.

5.1.1 Connection via USB

For this connection use the software „DTUSB“. It installs drivers so that your computer can generate a virtual TC/IP connection with the data logger via USB cable. The software identifies a connected data logger, shows its IP address and starts the web browser, linking to the logger's homepage.

5.1.2 Connection via Ethernet

If an Ethernet is used the access is carried out directly via the assigned IP address. Please find in the DT80 manual how to configure the IP-address manually or using DHCP.

5.1.3 Connection via GPRS/3G Remote

With a GPRS/3G SIM card you can contact the data logger via mobile phone network.

Please note
It is possible to set up an internet connection with the data logger by using an ordinary SIM card. That means the device can e.g. store data on a FTP server but there is no bi-directional access to the device. It is not accessible from the internet.
For this you need a M2M card that enables connections in both directions and offers a public IP address.

5.1.4 METER SIM card

The scope of delivery includes a SIM card installed in the data logger. This card enables the METER support to access the command interface of the data logger, e.g. to update the software or to retrieve the status of connected sensors.
For technical reasons it is not possible to access this interface from the customer's end.
Additionally this SIM card can be used to upload data from the logger to any server in the internet.

Please note
A 1-year use of the METER SIM card is included in the sales price of the Smart Field basic set. After this you can extend the use at favorable conditions.

5.2 Data retrieval

There are several possibilities to read out measurement data from the DT80M.

5.2.1 Data format

The datalogger can store measurement data in 2 different formats – either as a .CSV or a .DBD file (Datataker Binary). In a .CSV file the data are separated by comma or semicolon. Schedules are shown in a sequence. You can set internal profiles settings to a certain degree to configure the .CSV format. CSV files are readable by any spreadsheet program but they also have disadvantages:

1. *The format is country specific and different*
   No international standard exists. That is why the import of these data into a table calculation often is erroneous. Reformatting is time consuming.
2. *The format needs much memory space.*
   The storage in the ASCII .CSV format needs much data space so that a transfer via metered internet connection is expensive.

For the transfer to and storage on the FTP server usually the .DBD format is used. Data are stored compressed and independent of platform, country and format. To read the format you need an import tool. The program DPLOT (delivered on USB stick) offers integrated .DBD support so that data can be visualized. Additionally you can find in the internet an import filter for National Instruments Diadem as well as a command line utility from Datataker for the conversion of different .CSV formats.

If the data have to be transmitted regularly (e.g. daily) it is a challenge not only to convert the data but also to merge the small files being transmitted automatically to a big evaluable file.
The METER solution offers a service on the web server that converts data, merges and sorts them (Section 5.2.3.2).

5.2.2 USB memory stick

In the field you can also use a USB memory stick to read out the data. When you plug in the stick choose the function „Copy logged data“ with the keypad. Alternatively this can happen automatically using a script on the USB stick. For the data format on the USB stick converting tools are available (see data format).
To copy the data automatically generate a file on the stick with the name ONINSERT.DXC. The file is a normal text file and consists of the commands the logger executes when the stick is plugged in. In this case enter the command COPYDATA using the keypad. When you plug in the stick the logger automatically shows:

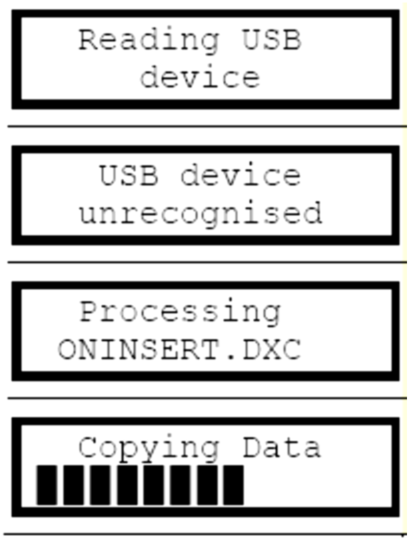


Figure 18: USB data read out

Please note
The data logger DT80M processes only USB memory sticks with small capacity. Not all sticks are compatible. On the Datataker web site you can find a list of compatible sticks.
Preferably use small USB memory sticks < 16 GB and check if they work reliably with the data logger.

5.2.3 GPRS/3G modem (integrated)

Data transfer via a metered connection using the internal modem of the DT80M.

5.2.3.1 FTP upload (standard)

To run this kind of operation certain parameters need to be entered into the data logger like e.g. mobile phone service APN, SIM PIN, FTP server access data etc. These parameters are entered using the web interface (see chapter 5.4 Change configuration).
Everything is ready to operate when you use the provided METER SIM card. As a default the data is stored on the METER web server umsdataview.de. In the web interface of the logger you can change the FTP server and the access data. Preferably you use the economical .DBD format although you need to merge the data later on.

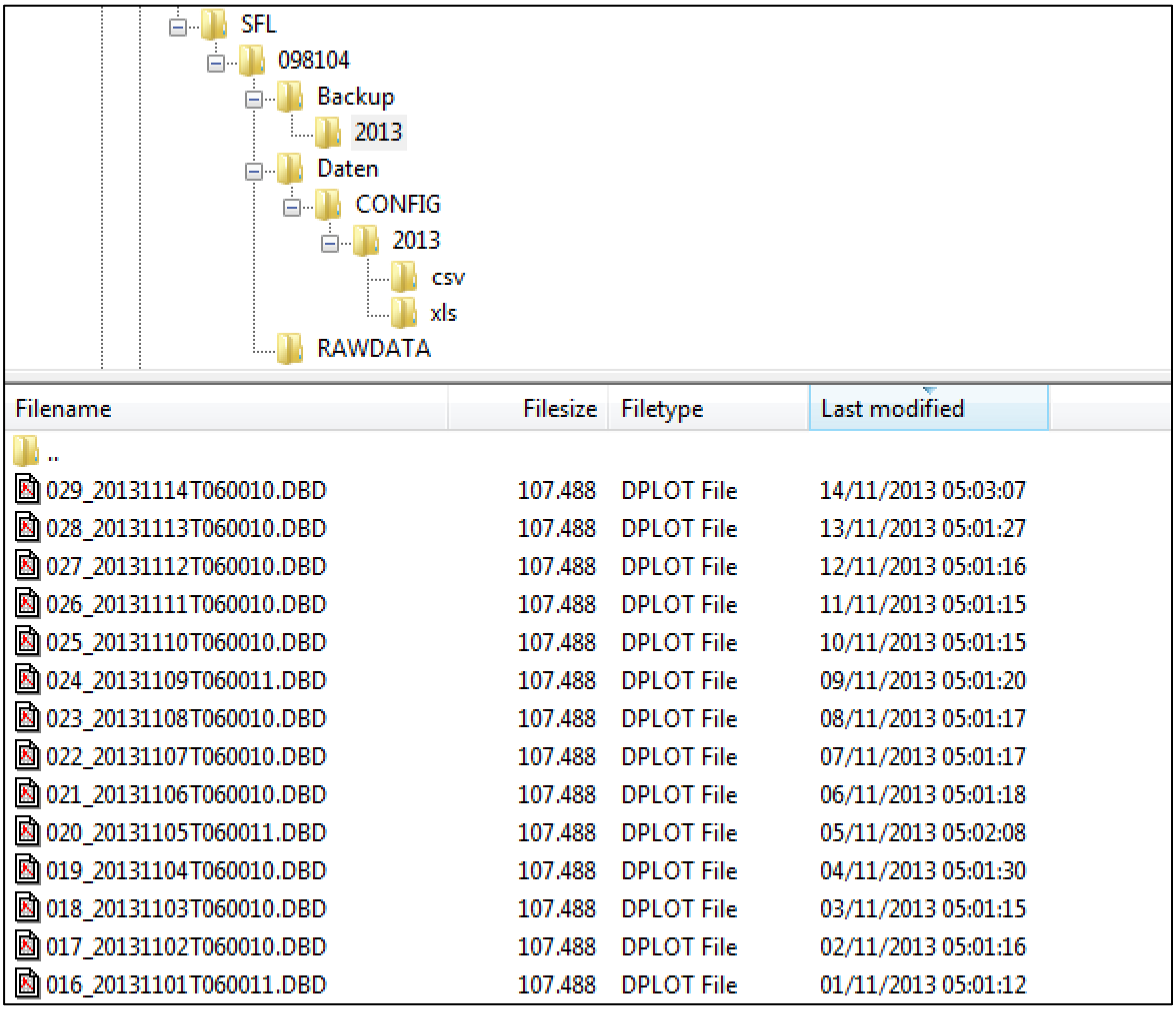


Figure 19: example of daily transmitted .DBD data on the FTP server

5.2.3.2 umsdataview.de server

The data transfer to the server umsdataview.de runs automatically when you use the METER SIM card. The server runs a service that provides data as readable Excel files sorted by months (**Fehler! Verweisquelle konnte nicht gefunden werden.**). With every upload of the logger the file will be created new. This is usually done once a day.

Please note
The SIM card and the service are included in the Lysimeter basis set for the first year. To extend the use please contact METER.
If you do not need this service, please send back the METER SIM card. Thank you!

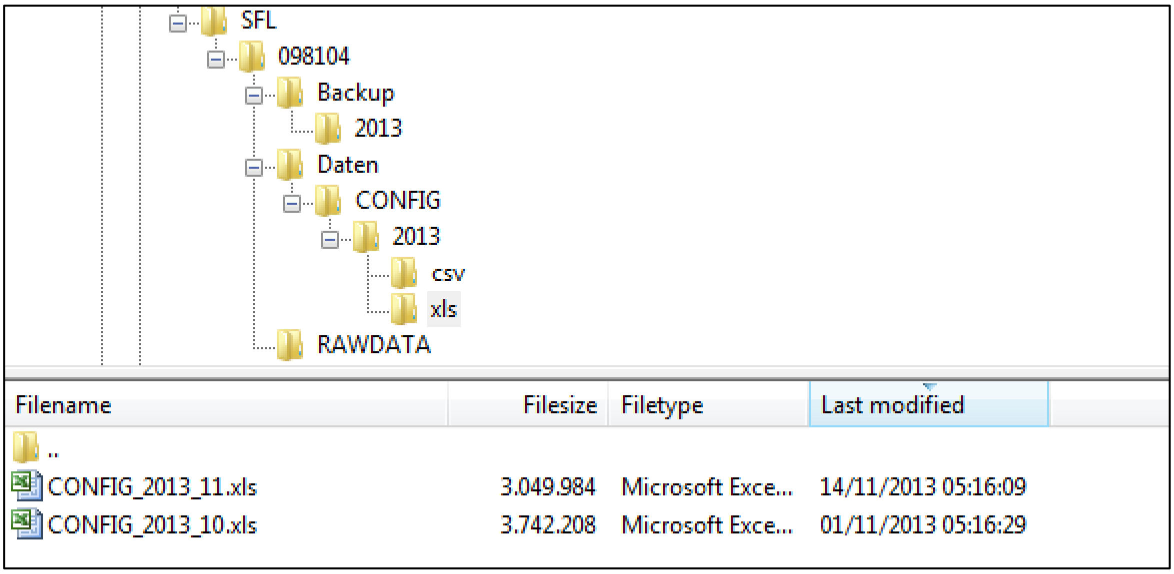


Figure 20: file structure and sorted Excel files on umsdataview.de

5.3 System access (internal services)

5.3.1 Access to the data logger with dEX

dEX ist the integrated web interface of the data logger. You need a web browser with Adobe flash support on your computer.
You can retrieve the current logger status and change its configuration. Additionally certain activities can be executed online.
dEX is an interface that exchanges relatively big data packets with the web browser. When you start dEX the approx. 1 MB application is uploaded into the cache of the browser. Even if it is possible in principle it does not make sense to use dEX via a metered internet connection (GPRS). dEX works via USB cable or Ethernet connection.

dEX distinguishes two modes (after a select page in the web follow two areas):

Monitor the logger:

- status
- download data
- command interface (online)

Configure the logger:

- permanent configuration (program) of the logger
- configuration of power supply, SIM card, display etc.

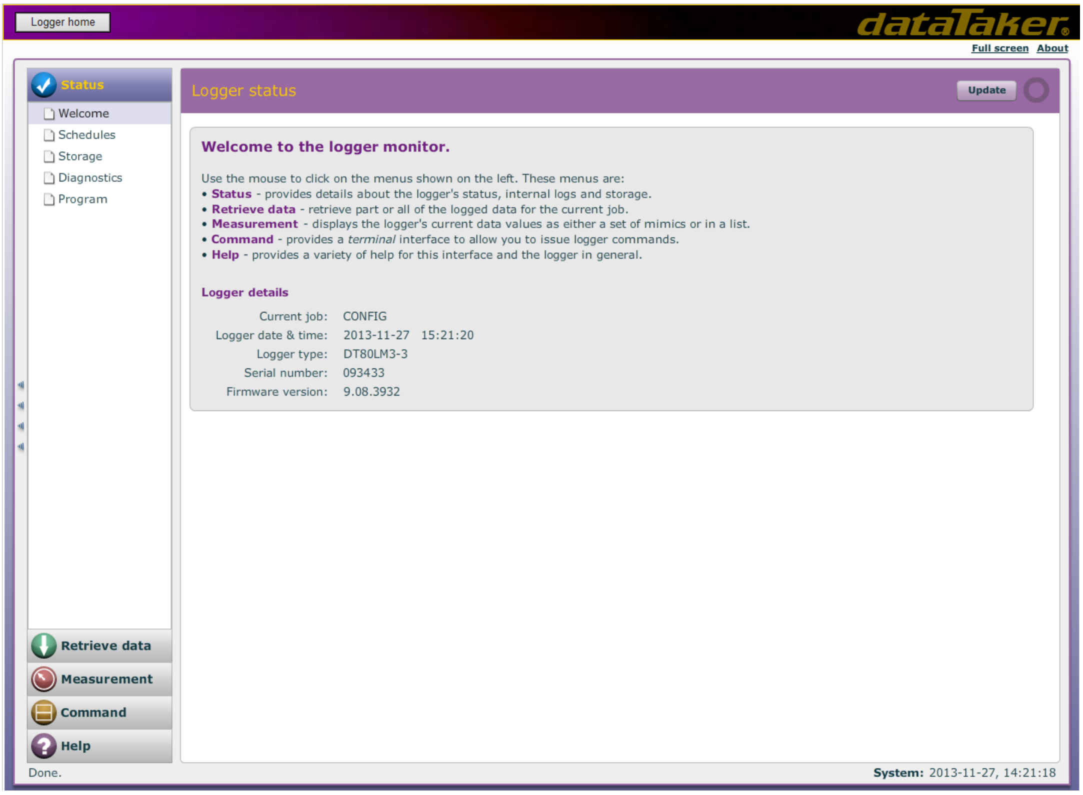


Figure 21: "Monitor the logger" page of dEX

5.3.2 FTP server

The integrated FTP server offers access to the internal file system of the data logger. E.g. you can initiate updates. The FTP server is not suitable to download measurement data. For more information please see the data logger manual.

Please note
The internal FTP server should not be confused with the FTP client that stores the data on an external web server (see 5.2.3.1 FTP upload (standard)).

5.3.3 Command interface

Via the command interface you can configure and read out the data logger. All entries into the command interface use the Datataker command syntax. The access to the command interface is done transparent over the logger's IP address and TCP port 7700. The dEX web interface offers in "Monitor the logger" a simple access to the command interface. For a connection with minimized data transfer a terminal program supporting TCP sockets (like ZOC or Putty) is recommended.

Even when a program (configuration) is active any command can be executed manually. E.g. a measurement of any channel can be executed once by entering the command syntax.
In the data logger manual you will find all information on the use of the command interface.

Example:

```
user entry:
>1V  {voltage measurement of channel 1,
clamp +-}
answer Datataker:
256mV
>
```

Please note
A misuse of the command interface can very easily disturb the function of the program and e.g. interrupt the data storage.

5.4 Change configuration

The data logger configuration can be changed using the web interface or the command interface respectively. Two different levels are to be distinguished.

5.4.1 Data logger program (config)

The logger program is stored permanently in the logger and can be changed with “configure the logger“ in the web interface. It is programmed in a Datataker proprietary syntax (interpreter language). dEX simplifies programming as it is an intuitive graphical web interface. From the graphical design of the program a program file is compiled.

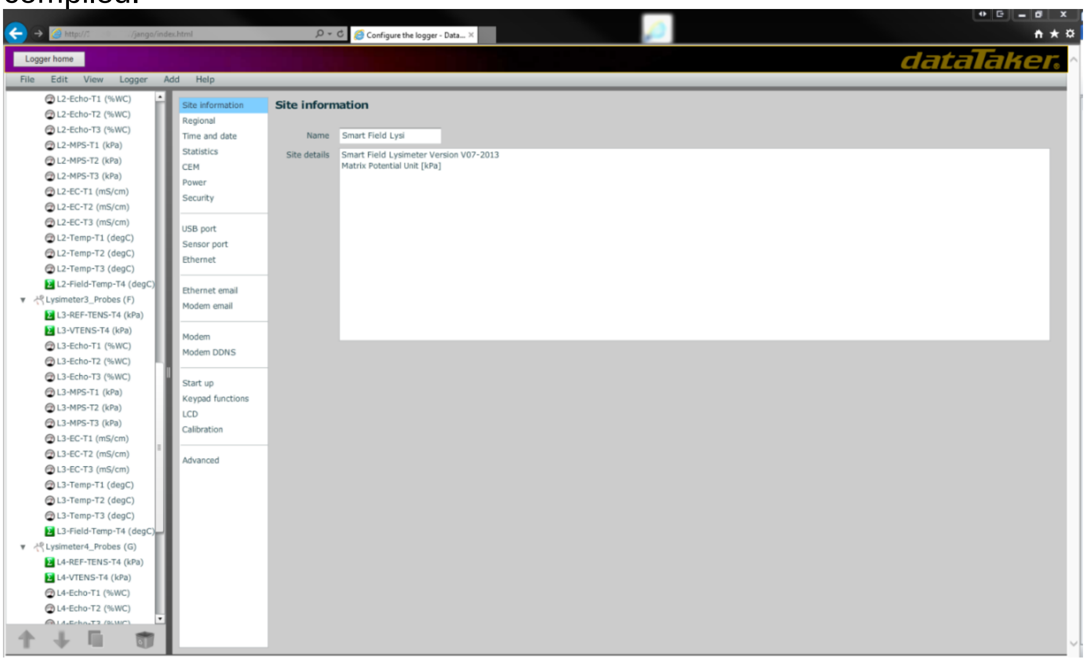


Figure 22: configuration webpage of dEX

The program is structured in so called schedules i.e. a list of commands that is executed in periodic intervals. In these schedules e.g. measurements, calculations, changes of digital outputs etc. can be executed.

The Smart Field Lysimeter program is divided in several schedules:

Table 1: Smart Field Lysimeter data logger program

Schedule	Function	Interval	Type	Description
A	Serial communication tensioCON, SFL-Pump-Controller	1 min	W*	Bi-directional serial communication with tensioCON power controller and pump controllers
B	System	10 min	R,L	Retrieval of sensors, averaging, update and storage of measurement data
C	1 min balance data	1 min	R,L	Retrieval of all Lysimeter weight data, update and storage of measurement data
D	Sensor data Lysimeter 1	10 min	R,L	Retrieval of sensors, averaging, update and storage of measurement data
E	Sensor data Lysimeter 2 (optional)	10 min	R,L	Retrieval of sensors, averaging, update and storage of measurement data
F	Sensor data Lysimeter 3 (optional)	10 min	R,L	Retrieval of sensors, averaging, update and storage of measurement data
G	Sensor data Lysimeter 4 (optional)	10 min	R,L	Retrieval of sensors, averaging, update and storage of measurement data
H	<free>		R,L	
I	Autoconfig	manual	W	Executing once the autoconfig function for the components
J	FTP Upload	1 day	W	Setting up an Internet connection with the external FTP server and storage of the data after the last upload

* W=Working
R=Return
L=Log

5.4.2 Run time settings (Channel variables)

The data logger uses so called channel variables for calculating and temporary storing measurement data. They can be read and written.
Values can be read out and manipulated. If these variables are used in the config program this can influence it.
The Smart Field Lysimeter program uses some variables e.g. to control the pump system.
A special feature lists named variables whose numbers are assigned to descriptions of the variables. You can get a list of these variables by the command “NAMEDCVS”.

```
User entry:
NAMEDCVS  {display of named variables}
answer Datataker:
DT80> Namedcvs
 CV S  CV Name                 Value  Units
==========================================
  1 A  Batterie Voltage        13.32  V
  2 A  Batterie Current        -1950  mA
  3 A  Batterie Charge          3.64  Ah
  4 A  Batterie SOC               17  %
  5 A  Solar Pan. Curre            0  mA
  6 A  Logger Current            135  mA
  7 A  PumpController C            0  mA
  8 A  L1/2 sensors Cur            0  mA
  9 A  L3/4 sensors Cur            0  mA
 61 A  L1 LevelControl             2
 51 A  L1 Manual Setpoi          -50  hPa
117 A  L1 Setpoint            -559.9  hPa
 62 A  L2 LevelControl             2
 52 A  L2 Manual Setpoi          -50  hPa
217 A  L2 Setpoint               -50  hPa
 63 A  L3 LevelControl             2
 53 A  L3 Manual Setpoi          -50  hPa
317 A  L3 Setpoint               -50  hPa
 64 A  L4 LevelControl             2
 54 A  L4 Manual Setpoi          -50  hPa
417 A  L4 Setpoint               -50  hPa
```

Figure 23: channel variables by "NAMEDCVS"

6 Power Management

6.1 tensioCON charging controller

Charging and control of the 12 V lead battery is managed by the tensioCON. This device provides the following functions:

- solar charging for 12 V lead battery up to 120 Ah
- simultaneously measuring battery voltage and current
- exactly balancing the power charged and recharged to the battery
- controlling limiting values
- controlling 4 switching outputs, externally controllable (instead of relays)
- switching off outputs at overload
- RS485 over voltage protection
- communication with the data logger DT80M via RS485, SDI12

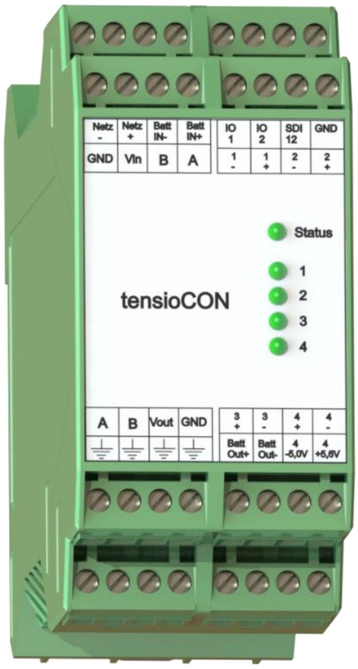


Figure 24: tensioCON

The tensioCON determines several times per second the battery voltage, the current to or from the battery as well as the current of the connected devices like data logger, pump and sensors. Based on the balance the energy consumption of the connected devices and the charging energy of a connected solar panel are calculated. The battery state is determined by the energy charged and recharged and by voltage limits.

The tensioCON determines the following battery data:

battery voltage [V]
battery current [mA] (positive = discharging, negative = charging)
SOC [%] state of charge
The SOC is the most important information as this represents the current state of the battery. Battery voltage and current are only momentarily values.
The tensiCON gives these data via the serial RS485 interface to the data logger. Thus battery characteristic values can be stored and the data logger can switch into an energy saving mode if necessary.
The tensioCON switching outputs are connected to the data logger, the pump controller and the sensors. The tensioCON is configurated in a way that the data logger is always switched on, except for the battery's SOC being at a critical level.
The 3 other switching outputs are switched on and off by the data logger serially or by digital outputs. Thus the data logger can minimize the energy consumption if needed.
So primarily the data logger controls the switching outputs and by this the connected devices. If certain critical values have been underrun, the tensioCON automatically switches off the devices as a final instance.

Table 2: switching outputs of tensioCON

Output	Device	Logger controller	Switch off by tensioCON at SOC	Description
1	data logger DT80M	-	<5%	Permanent power supply of the data logger. It can initialize the energy saving mode itself.
2	pump controller Lysimeter 1-4	1DSO	<25%	Pump controller and pump motors
3	sensors Lysimeter 1 and 2	2DSO	<10%	All Lysimeter sensors and balances
4	sensors Lysimeter 3 and 4	3DSO	<10%	All Lysimeter sensors and balances

The tensioCON can be connected to a PC. For this a tensioLINK USB converter and the related software from METER is necessary.

By this software you can configure e.g. the internal switching functions and the switch off conditions. Also a change of the charging curve is possible if a different battery with known capacity is used. This capacity must be entered into the tensioCON so that it can work properly. Only then it can determine the exact SOC.

Of course all values are pre-set for the Smart Field Lysimeter.

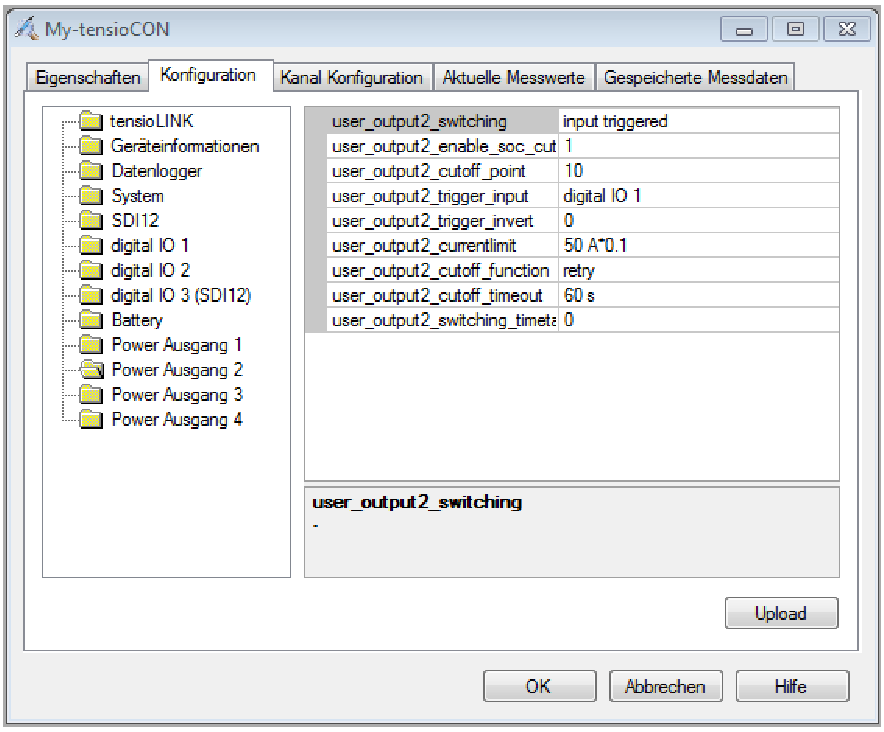


Figure 25: tensioCON configuration register

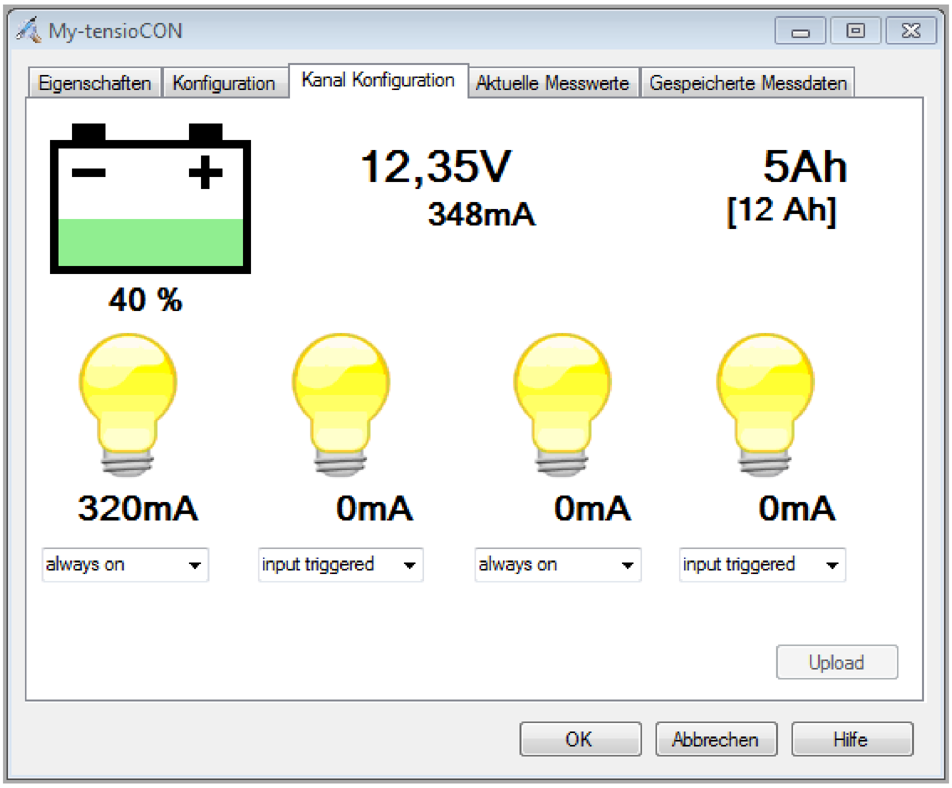


Figure 26: tensioCON battery state

6.2 *Battery management actions*

In schedule A the data logger checks all measurement values and status of the tensioCON. Usually this happens once per minute. The values are stored as channel variables.

Table 3: variables for battery management

CV	Function	Def	Type	Description
	Battery management			
1CV	Battery Voltage		R,L	[V] Battery under Logger load, sensors disconnected from battery
2CV	Battery current		R,L	[mA] current from battery (positive values = discharge)
3CV	Battery charging		R,L	[Ah]
4CV	Battery state of charge (SOC)		R,L	[%]
5CV	Solar Panel current		R,L	[mA] current from solar panel
6CV	Logger current		R,L	[mA] current to logger during measuring (positive values = logger discharges battery)
7CV	Pump controller current		R,L	[mA] all Lysimeters
8CV	sensors Lysimeter 1,2		R,L	[mA] Lysimeter 1 and (2, optional)
9CV	Sensors Lysimeter 3,4		R,L	[mA] Lysimeter 3 and 4 (optional)

Standard settings are active as follows:

SOC > 33%

- ➔ Battery level ok, all schedules are executed in normal intervals: schedule B 1 min, schedule C 10 min, schedule D-G 10 min, pumps on, sensors on, modem stand-by on.

SOC < 25%

- ➔ Battery level low. Energy consumption is reduced. Data logger works in power save mode, pumps off, sensors on, modem stand-by time reduced, schedule B 1 min, schedule C 10 min, schedule D-G 10 min.

SOC < 5%

- ➔ Battery level critical. Minimum energy consumption. Data logger changes immediately in power save mode, sensors off, modem stand-by off, schedule B 1 min, schedule C 1 h, schedule D-G off.

7 Installation notes

Please note
This manual includes 3 separate single pages that describe and illustrate how to install the Smart Field Lysimeters in the field:
- Cutting the soil column
- Earthworks and basic setup
- Installation and start-up
These 3 pages focus on to dos in order to minimize reading time in the field. If you need also background information then please read the following chapter.

7.1 Adjusting the Lysimeter and drain water bottle

Adjusting the Lysimeter and its balance as well as the drain water bottle and its balance are crucial for the quality of the measurement values. Please make sure

1. The balances are levelled correctly.
2. The layout of the cables and tubes to the Lysimeter is flexible.
3. Cables and tubes must not touch the outside of the Lysimeter cylinder and the drain water bottle.

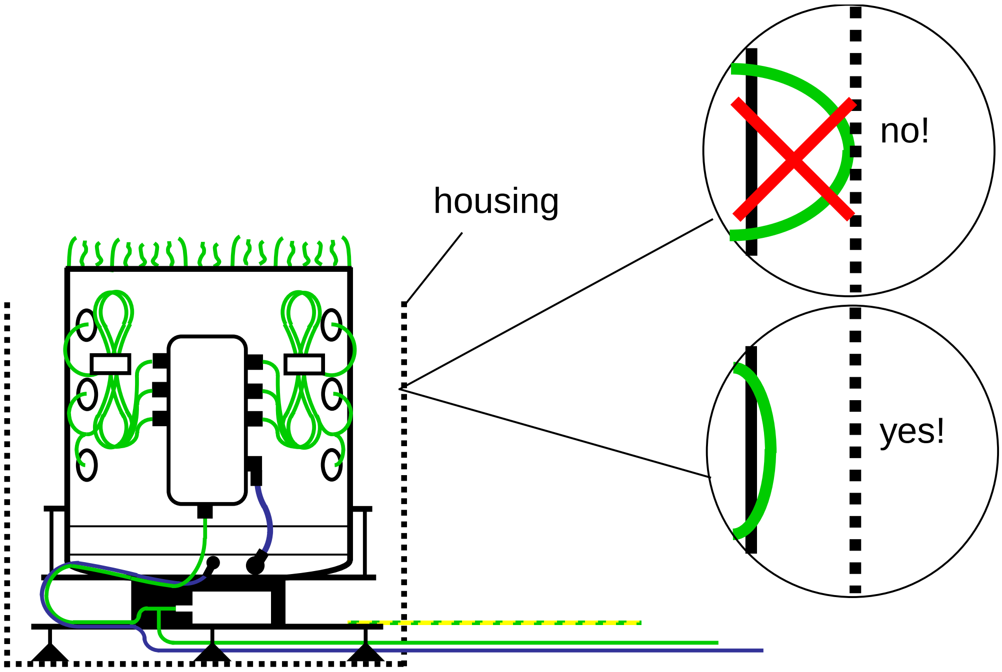


Figure 27: adjusting and centering the Lysimeter

It is important that the top platform of the balance, on which the Lysimeter or respectively the drain water bottle stands, is free to move. Cables and tubes are tied together and lead up in a loose loop (Section 7.3 Connecting the tubes and adjusting the cables).
All cables not being weighing related should be packed so that they have absolutely no contact with the mass to be weighed.
Any enclosure contact results in erroneous weight measurement (Section 10.4.2.1 Freedom degree limited by contact).
The drain water bottle has to be placed exactly in the center of the Field Box – otherwise it can get in contact with the Field Box lid and causing weight measurement errors.
Place the Lysimeter exactly in the center of the Lysimeter housing. During the installation stones and gravel may have fallen into the gap between Lysimeter and housing. If so please remove them.
After having fixed the silicone sealing lip please check the function by slightly moving the Lysimeter with your finger – it should start to swing easy.

7.2 Adjusting the solar panel

Correct adjustment of the solar panel is crucial for the continuous operation of the system. Please make sure you know how to correctly adjust the panel upfront or respectively optimize the orientation and angle during operation.

The solar panel of the Smart Field Lysimeter has two functions:

1. Supplying energy
2. Shielding the logger box from sun radiation

The orientation of the panel is – related to the markers glued to the mast – to the south on the northern hemisphere and to the north on the southern hemisphere.

Please note
A wrongly orientated mast fixed in the ground cannot easily be corrected and eventually has a negative influence on the power supply.

The energy consumption and the power of the solar panel always depend on local conditions. In general there is an energy surplus in summer. In winter a lack of energy may happen so that the system may restrict its operation.
So it is important to optimize the panel adjustment based on winter needs. It is a good rule of thumb to fix the angle at 30° related to the marker. Of course you can adjust the angle according to the season. Please check the battery values regularly in the system schedule (Section 6.1 tensioCON charging controller).

Please note
As the angle of the Smart Field Lysimeter solar panel should be optimized for winter operation it is steeper than the recommended angle for operating solar plants most efficiently.

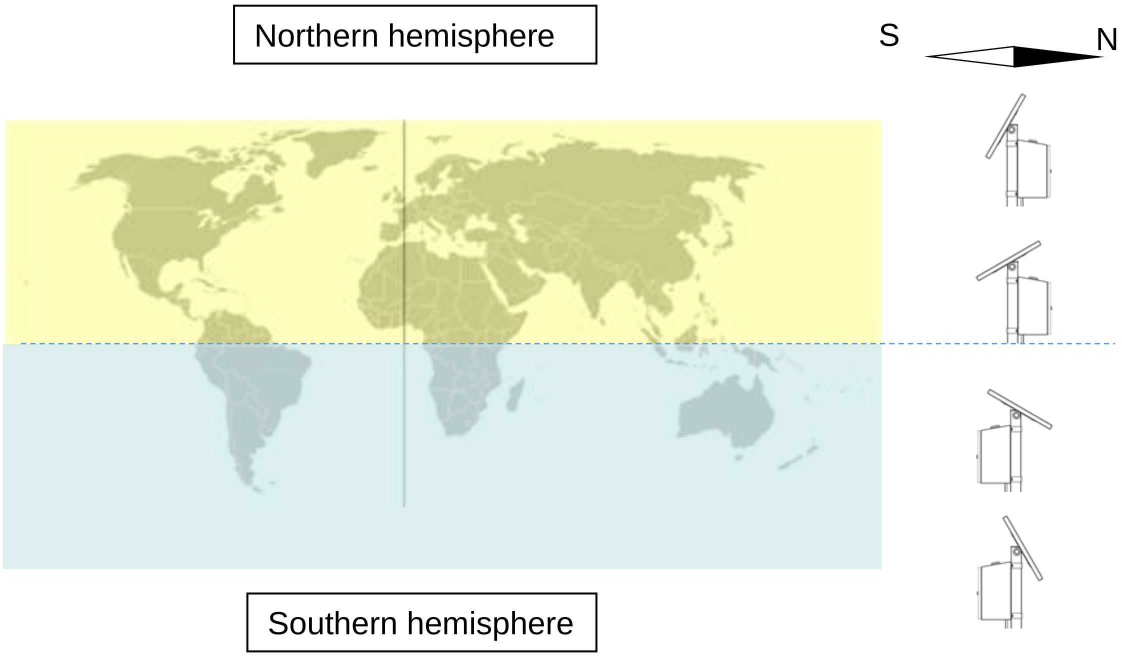


Figure 28: orientation and angle of the solar panel depending on the location

7.3 Connecting the tubes and adjusting the cables

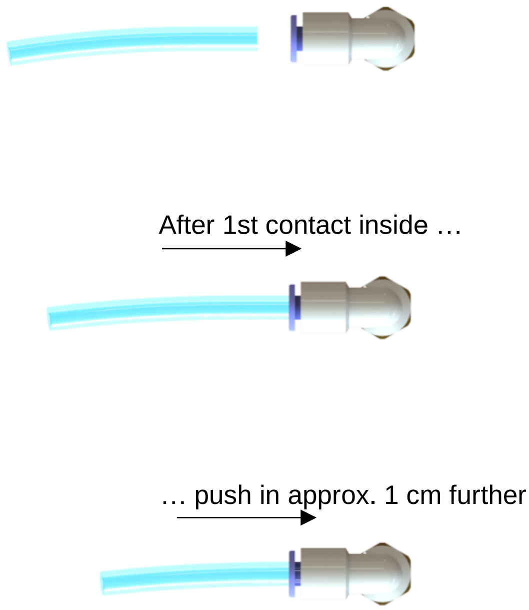
Please shorten the 4 mm and 6 mm tubes to the necessary length. Do not use a usual side cutter but a special tube cutter. It is important for getting perfect tightness to clip the tube with a precise cut.

Figure 29: cutting the tubes correctly

Make sure you insert and remove the tube correctly.
When you **insert** the tube put it into the fitting and after internal contact push it approx. 1 cm in.
When you **remove** the tube press the blue ring until you have removed the tube.

Please note
If the tube has not been inserted to the end, the connection could be leaky!

Inserting the tube:



Removing the tube:

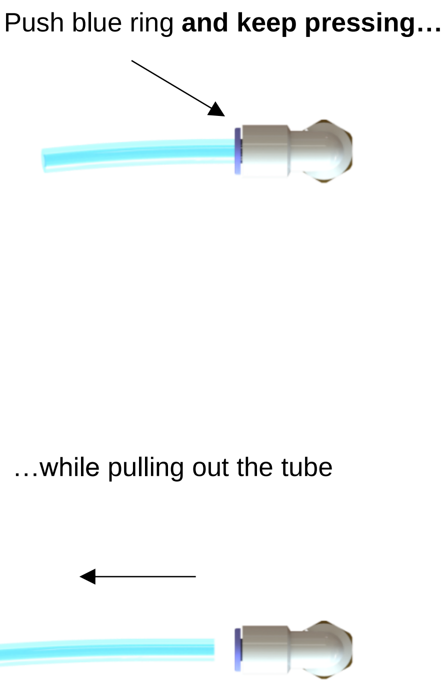


Figure 30: inserting and removing the tubes

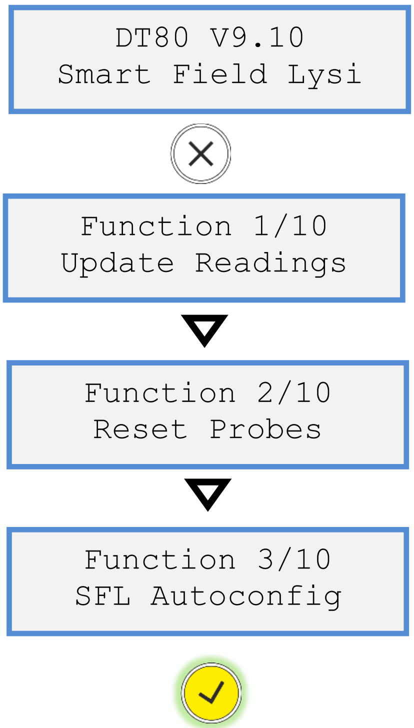
7.4 Autoconfig function

With the Autoconfig function of the data logger you need to configure components of the Lysimeter for the intended operation (also when you expand components).
In principle all sensors are connected to a common measuring bus that distinguishes the sensors by their addressing. To reduce the configuration effort the Autoconfig function has been developed. The function distinguishes between device type and connecting position. There is a dedicated 8 pin plug on the logger box for each Lysimeter. Each type of device exists only once within one Lysimeter line section.

Please note
Immediately after having connected all delivered components execute the Autoconfig function by using the display functions of the data logger. The configuration will run in the background. No message will show on the display.

Please execute the Autoconfig function also after every change of your system e.g. when changing devices or upgrading the system.

It is not possible to cover 1 to 4 Lysimeter count with one logger configuration. For each Lysimeter configuration you need to load its own dedicated logger configuration.



7.5 Flooding

The design of the Field Box and the Lysimeter enclosure is **not** waterproof. Therefore select a place at your site which is representative and preferably not in a dell/depression, but at a higher lying location. Platform balances are water protected IP68, so short time flooding causes no damage, but you need to empty, clean and replace parts in the Field Box.

8 Maintenance

8.1 Regular service

8.1.1 Filling and emptying the drain water bottle

Please empty the drain water bottle to fill level when its weight has risen up to >9 kg, Fill the bottle up when its weight has fallen below 1 kg.
Do all the steps fast and meticulously. This is important for the interpretation of the measurement data.
Pay attention to correctly removing and inserting the tubes (Section 7.3 Connecting the tubes and adjusting the cables).
Fill level: In rainy seasons, where only little water will flow into the Lysimeter, it is recommended to set the fill level at 2 liters. In dry seasons fill it up to 8 liters. Please adjust the appropriate level due to your later experience.

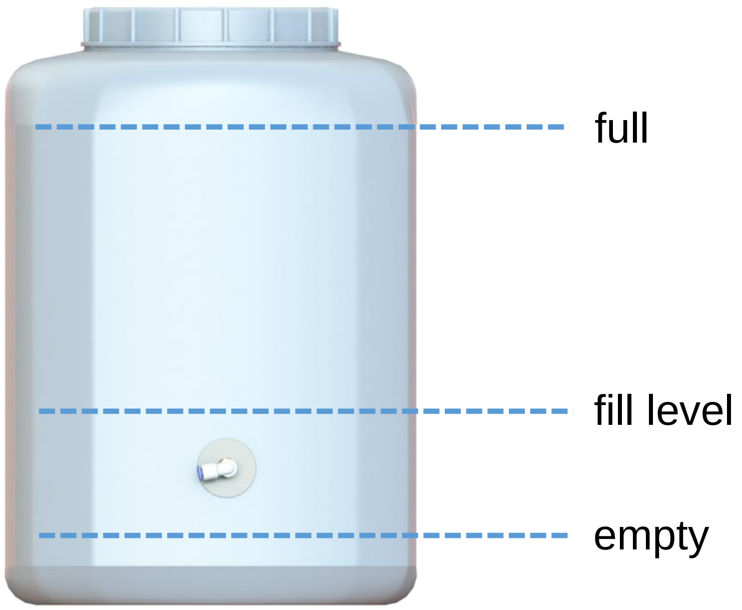


Figure 31: fill level of the drain water bottle

8.1.2 Filling the Tensiometer

8.1.2.1 When do Tensiometers need to be refilled?

Tensiometers need to be refilled when:

- the curve of the readings obviously gets flatter and flatter,
- the Tensiometer filling indicator at the data logger display shows 1,
- the maximum of 85 kPa cannot be reached anymore,
- but not until the soil is dryer than > -90 kPa.

If the soil gets dryer than -85 kPa, the readings will stay nearly constant and after a while drop slowly towards zero by diffusion and slight leakage.

If the soil dries out to more than -1500 kPa (15 bar) the readings drop to atmospheric pressure as air will enter the ceramic cup.

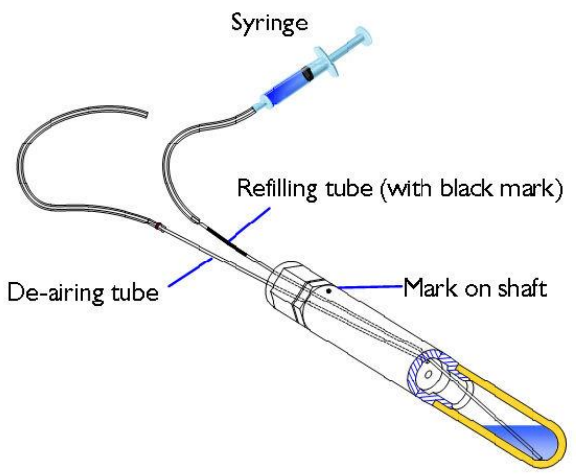


Figure 32: downwardly installation – the marked pipe is the refilling tube, the unmarked pipe the exhaust pipe

Please fill the Tensiometer when you are at the site. Remove the black tubing from the black marked pipe and press in water with the syringe delivered until water drops from the open end. You need max. 20 ml of deionized and degassed water in the syringe. To degas water close the valve of a half-full syringe and apply vacuum by pulling the syringe piston. Collect bubbles by turning the syringe upside down and around and push them out afterwards. Repeat this step about three times and fill the Tensiometer.

8.1.3 Degree of freedom of Lysimeter and drain water bottle

Each time you visit the site, check the position of Lysimeter (Lysimeter gently swinging) and if the silicone sealing lip is ok.
Also take care of the drainage bottle not to touch the Field Box cover or cables and tubes.
Stones and other foreign material that are trapped between the Lysimeter cylinder and collar have an extremely disturbing influence on the weight measurement. If the measurement data show such an erroneous characteristic (Section 10.4.2.1), but no mechanical contact can be identified also dirt in the narrow slot of the platform balance can be the reason.

8.1.4 Exchanging spare parts

8.1.4.1 Pump head with tubes

According to pump time activity it will be necessary to exchange the pump head.
The total pump time can be accumulated from measuring data.
You can identify a malfunction of the pump and the need of replacement by the measurement values of VTENS. A leakage occurred or the motor shaft was slipping (disengaged). Both reasons – visible in the measurement data – lead to an increased pump activity.
If the pump head needs to be exchanged, you can:
- either send the pump box to METER
- or order a pump head as a spare part.

For replacing the pump, the pump box needs to be removed and opened.

Figure 33: pump head spare part

8.1.5 Exchanging the desiccant cartridge

Two desiccant cartridges are delivered with the Lysimeter Set. Each time when you visit the site please exchange the desiccant cartridge inside the Logger Box. To re-generate it, remove the plastic lid and place it in an oven at 130°C for four hours. It looks orange when dry and transparent when wet.

Figure 34: drying cartridge

8.2 Trouble shooting in the field

8.2.1 Checking the electrical energy supply

In normal operation the status LED of the tensioCON flashes every 5 sec. All acti-vated load channels flash synchronal to the status LED.

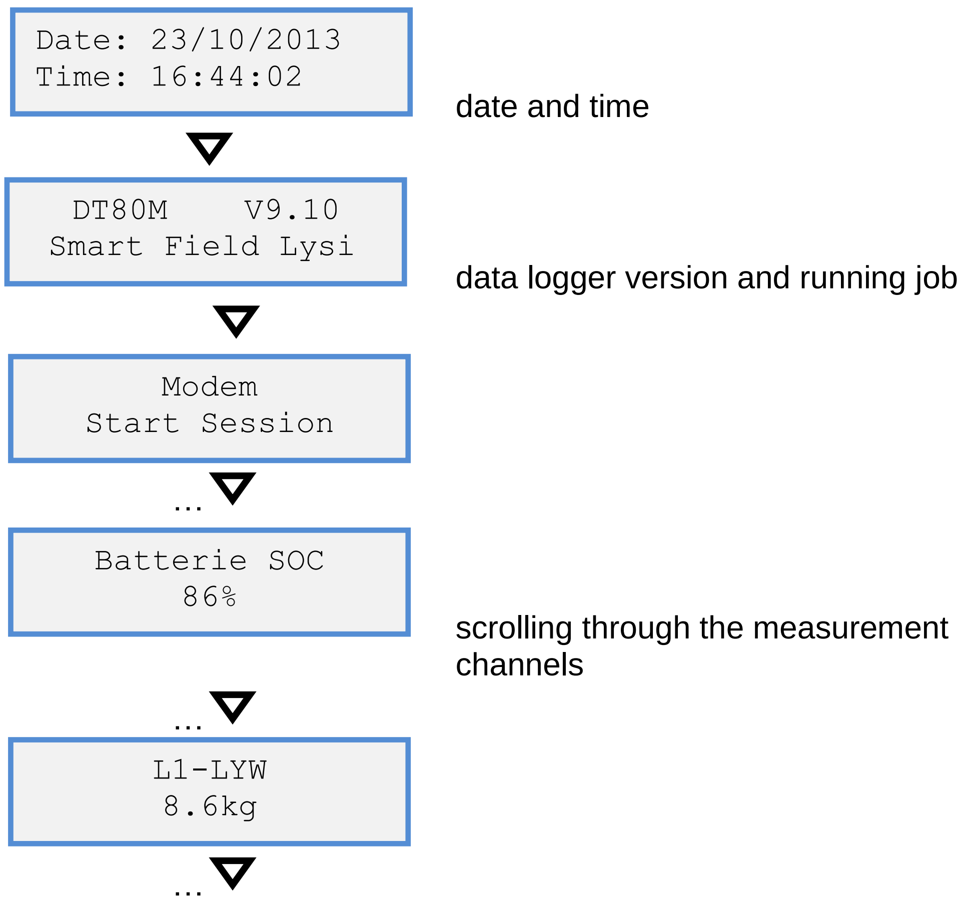
Table 4: LEDs energy supply

Output (LED)	Device	Logger controller	Switch off by tensioCON at SOC	Switched off by data logger
1	Data logger DT80	-	<5%	-
2	Pump system	1DSO	<25%	Only in case of failure
3	Lysimeter 1 + 2 sensors	2DSO	<15%	Only in case of failure
4	Lysimeter 3 + 4 sensors	2DSO	<15%	Only in case of failure

LED1 indicates the data logger function and should always be active. The tensioCON indicates failures (e.g. rechargeable battery empty) by flashing the status LED red.
Is the data logger still active (reaction on pressing the button) the battery state can be read from the logger display.

8.2.2 Checking the data logger

During measurements the data logger deactivate the display to reduce energy consumption. By pressing a button the display shows a message and the backlight starts.
By pressing the buttons UP/DOWN you can scroll through the display modes. At first the logger informations are showing, then the measurement channels.



Please note
The data logger measurements are taken at concrete time. Between the measurements the values on the display are not updated. This can last up to 10 min depending on the measurement timing and setting. The values are always synchronized at midnight. That means a schedule being executed every 10 min always starts at xx: 00 min, xx:10 min, xx:20 min, xx:30 min, xx:40 min and xx:50 min.
Also the execution of the schedule can take approx. 30 sec, as especially the retrieval of sensors with the SDI12 protocol is time consuming.

To provide a faster diagnosis in the field the function “Update Data” is provided. Activate the function on the display and then wait about 30 sec until all schedules have been retrieved. Then you can read the new measurement values on the display.

8.2.3 Resetting the data logger

In case of a malfunctioning a data logger reset may help to solve the problem. If the device still reacts, this can be done by the command “SINGLEPUSH” – also via remote administration.
If the logger does not react you can try a hardware reset. For this push an opened paper clip into the reset hole on the left side (Figure 41: connections and reset hole).

Please note
A reset initializes the data logger program. That means non-permanent settings will be changed to standard values.

8.3 Winter operation

Depending on the location of the Lysimeter system winter operation can be limited or even impossible for two important reasons:
1. Frost
Frost prevents the operation of the drain water system and by this the feedback control of the lower hydraulic boundary condition. In order to protect the system from frost damages the water should be emptied and pump function stopped.
2. Energy supply
In winter energy supply can be very limited. The system switches into the energy saving mode to restrict certain functions.

Please take care you make the system fit for winter operation. If you expect strong soil frost, empty the drain water bottle and the pump system.
After this turn off the pump system using the display function. If the pump runs at temperatures below -20° C the pump tube can be damaged.

Please note
After re-starting the system in spring all measurement values and data should be checked to identify damages as soon as possible.

9 Expert functions

9.1 Pump system

The pump system and the controller can be run in different modes. They are controlled by the data logger. A special case is the complete shutdown of the pump system's energy supply.

In the beginning of the standard mode the pump controller adjusts VTENS and thus the lower hydraulic boundary condition to the reference tensiometer value.
By entering different settings and variables of the data logger the performance of the pump system can be changed. If you want to keep a Lysimeter at a constant reference value then change 2 channel variables in runtime: the control variable 6xCV and the reference variable 5xCV. The "x" refers to the number of the Lysimeter. Find the settings in the following table (Figure 35). Once set they are kept in operation until the data logger resets.

Enter the command "NAMEDCVS" into the command window to get an overview of the current variables and values:

```
User entry:
NAMEDCVS  {display of named variables}
answer Datataker:
DT80>
 CV S  CV Name                 Value  Units
==========================================
  1 A  Batterie Voltage        13.32  V
  2 A  Batterie Current        -1950  mA
  3 A  Batterie Charge          3.64  Ah
  4 A  Batterie SOC               17  %
  5 A  Solar Pan. Curre            0  mA
  6 A  Logger Current           135  mA
  7 A  PumpController C            0  mA
  8 A  L1/2 sensors Cur            0  mA
  9 A  L3/4 sensors Cur            0  mA
 61 A  L1 LevelControl             2
 51 A  L1 Manual Setpoi          -50  hPa
117 A  L1 Setpoint            -559.9  hPa
 62 A  L2 LevelControl             2
 52 A  L2 Manual Setpoi          -50  hPa
217 A  L2 Setpoint               -50  hPa
 63 A  L3 LevelControl             2
 53 A  L3 Manual Setpoi          -50  hPa
317 A  L3 Setpoint               -50  hPa
 64 A  L4 LevelControl             2
 54 A  L4 Manual Setpoi          -50  hPa
417 A  L4 Setpoint               -50  hPa
```

Figure 35: NAMEDCVS response

Table 5: pump system variables

Variable/Function	Lysimeter	Result	Comment
1DSO=0	1-4	Complete shut-down of the pump system	Cuts off the power supply of the pump system.
1DSO=1	1-4	Pump system activated	Normal operation
6[x]CV=0	x	Lysimeter [x] Pump system disabled	Pump disabled
6[x]CV=1	x	Lysimeter [x] constant reference value activated	Regulation on manual value
6[x]CV=2	x	Lysimeter [x] tension control activated	Regulation on tensiometer value
5[x]CV=[SP]	x	manual reference value of the Lysimeter on SP [hPa]	No impact on automatic operation

9.2 Changing the system configuration

9.2.1 Logging intervals (schedules)

As a standard the weight values for each Lysimeter are stored every minute. All other sensor values and system characteristics are stored every 10 min. These intervals have proved themselves as good practice and provide the best ratio of resolution and storage density. Balancing formulas are optimized to these intervals.

Of course you can set your own intervals within certain ranges. In principle the change of a storage interval is possible in runtime without interrupting the program. After a reset or power failure the data logger starts again with the standard values. To safe the changes permanently the values need to be changed in the program file (config).

9.2.1.1 Changing in runtime (temporary)

To set temporary changes of the measurement or data storage please look at the table 6.

Schedule D is executed every 10 min. To accelerate the execution to 5 min enter the command RD5M (see also DT80M manual).

```
User entry:
RD5M  {schedule D every 5 min}
answer Datataker:
>
```

Immediately all sensors in the Lysimeter 1 are read and safed every 5 min.

Please note
Reading sensors via the serial SDI12 interface takes some seconds. During this time the data logger is blocked and the reaction time may increase. The program becomes instable if there is not enough time between reading time and the start of a new schedule. Therefore a minimum time for the execution of schedules exists. You find them in the following table.

Table 6: min and max schedule run times

Schedule	Function	Standard interval	Min	Max
A	Serial retrieval tensioCON	1 min	1 min	=B
B	System	10 min	1 min	1day
C	Balance data	1 min	1 min	1day
D	Sensor data Lysimeter 1	10 min	5 min	1day
E	Sensor data Lysimeter 2 (optional)	10 min	5 min	1day
F	Sensor data Lysimeter 3 (optional)	10 min	5 min	1day
G	Sensor data Lysimeter 4 (optional)	10 min	5 min	1day
H	free		-	-
I	Autoconfig	manually	-	-
J	FTP Upload	1day	1hour	7days

Please note
If METER updates your standard program your new storage intervals will be reset. When you transfer the changed program all previously stored measurement values will be deleted. So please download the data before by manually executing schedule J (FTP upload).

10 Interpreting the measurements

10.1 Influence of pump times

In the Smart Field Lysimeter the feedback control of the lower hydraulic boundary condition works very precisely and in a wide range. However you can identify the influence of the pump times on the measurement data.
The pump – a bi-directional peristaltic pump – runs clocked. I.e. it is not the rotation speed that is controlled but the pumping time. During a pump period the pump always runs with maximum speed. The shortest running time is set to 1 sec. Depending on the negative pressure and the air volume in the vacuum system this second of pumping causes a visible peak of the value VTENS.
These discrete peaks can be monitored in the diagram (Figure 36). Compared to the complete dynamics and precision of the system these peaks do not really matter.

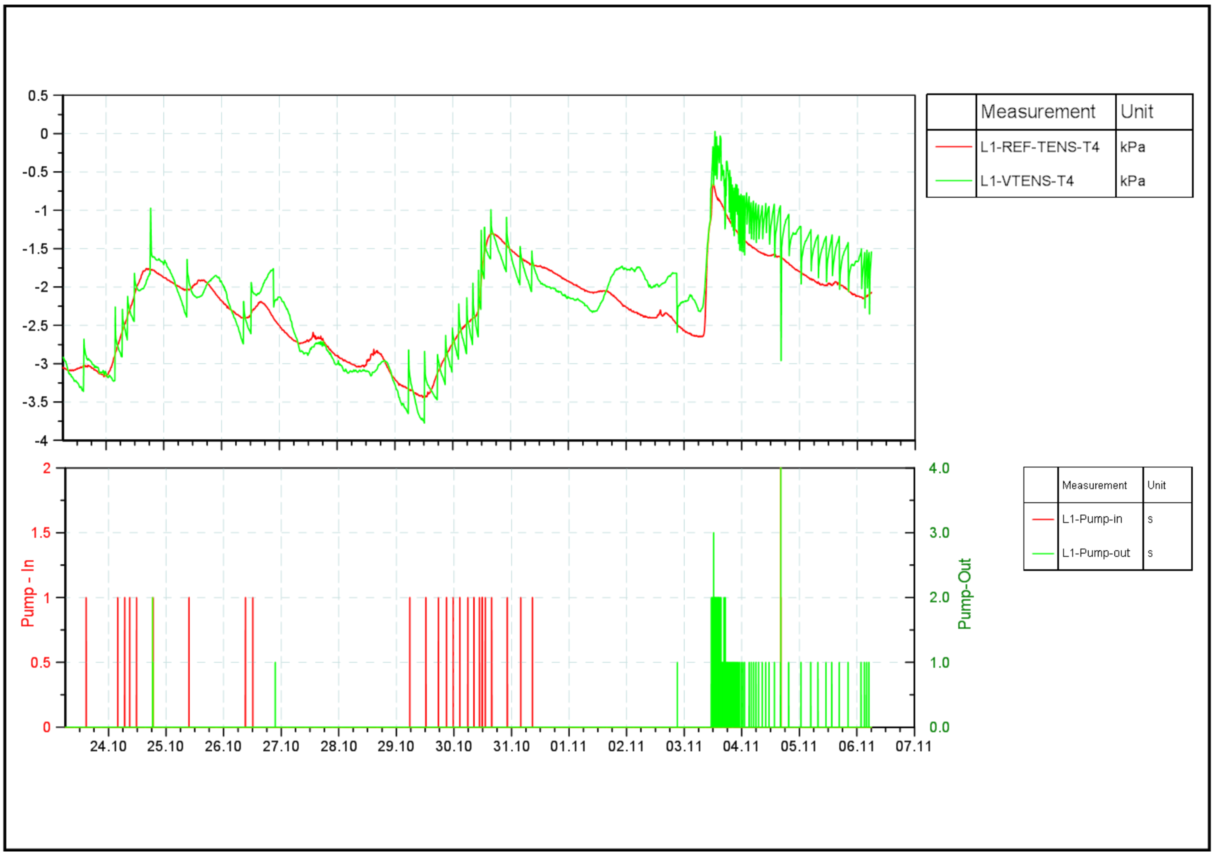


Figure 36: influence of pump times

10.2 Balancing the weight values

By using the weight values of the drain water and the Lysimeter a precise balance can be calculated. The Lysimeter delivers the information on precipitation with excellent precision. On purpose a weight balancing has not been integrated in the Lysimeter program as this kind of evaluation is scientific work.

Prerequisites for a high data quality are:
- Technically correct measurement of the weights (no contact of the Lysimeter to the housing side walls and the environment, no snow, no disturbing plant cover)
- Filtering measurement series (filtering laws and errors)
- Avoiding interruptions (e.g. drain water bottle full)
- Data evaluation and verification before calculation
- missing data compensation manually

10.3 Calculating the leachate, precipitation and evapotranspiration

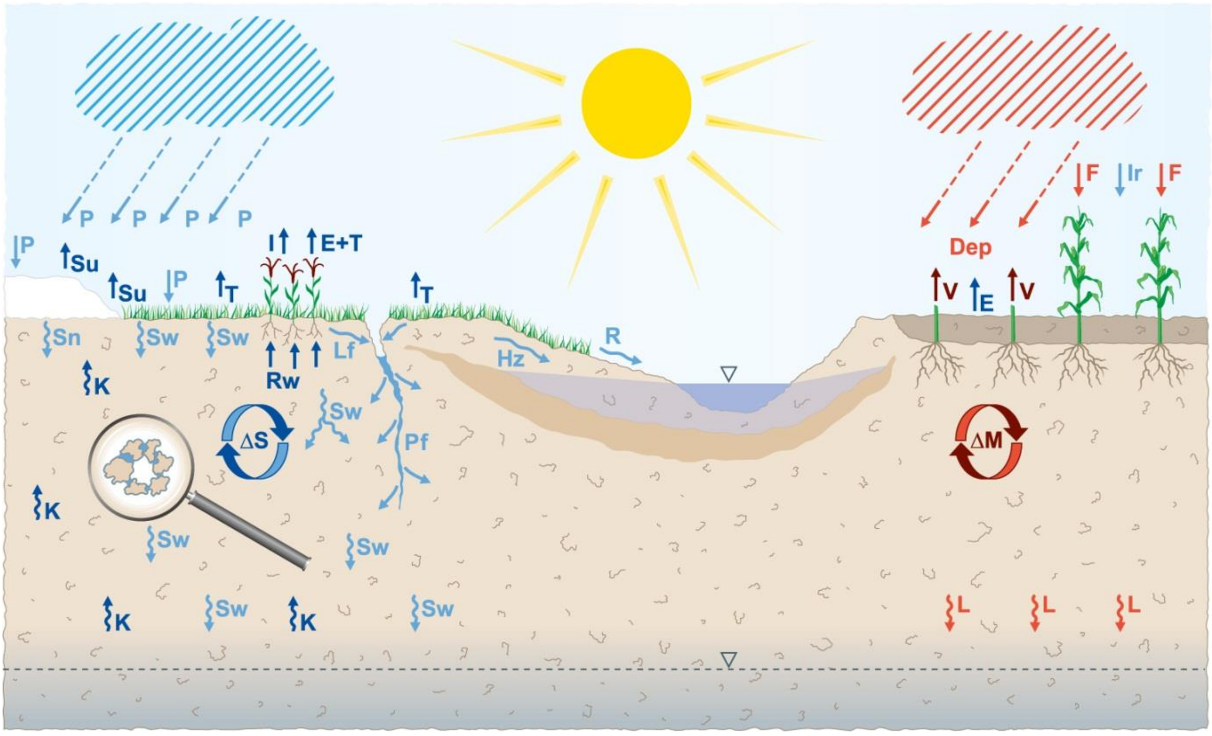


Figure 37: water balance parameters

This schematic overview shows water balance parameters and most important flux situation at soils atmospheric interface and interface to groundwater. Due to this complexity, basically scientific background is requested for the determination.
To calculate the precipitation an evapotranspiration ET the weight of the Lysimeter and the drain water bottle is needed.
Generally an increase of the system weight means precipitation, a loss of weight means ET or drainage. The system weight consists of the Lysimeter weight and components attached to it as well as the weight of the soil column and the drain water bottle.

Depending on climate and weather precipitation and ET may happen in relatively short intervals. For the calculation the duration needs to be considered – in Europe we found duration of 10 min to be an appropriate value.
For the calculation weight values are needed once per minute.
If the calculation was adjusted by too short durations the uncertainties of the weighing data would get dominant and the results would be too high – as each ripple would be calculated as precipitation or ET. On the other hand the results would be too high if the durations were assumed too long. Then precipitation and ET would almost cancel each other and the results would get too low.
The accuracy is still much better than every precipitation instrument we know so far, as true surface situation is considered.

10.3.1 Leachate

Leachate is detected measuring the outflow mass at the lower boundary of the lysimeter. One possible interpretation method for assumed 10 minutes duration can be given as follows:
„Sm“ = Seepage water weight data [kg] at time „n“ in [min]
The surface of the Lysimeter is 0.0707 m^2, so 1 kg increase of seepage water weight means 14.15 mm Leachate (L).
(Sm(n) [kg] – Sm(n-10) [kg]) * 14.15 = L [mm]

To compensate data uncertainties, average values at the boundaries of the evaluated time period are taken:
Sm(n) = (Sm(n-2)+Sm(n-1)+Sm(n))/3
Sm(n-10) = (Sm(n-12)+Sm(n-11)+Sm(n-10))/3

10.3.2 Precipitation

Rain events can clearly be identified in measurement series. Evaluation principle is the assumption that during a duration of 10 Minutes Precipitation or Evapotranspiration happens. An increasing mass of the lysimeter plus Leachate (L) in the same time period can be interpreted as precipitation

„Lm“ = Lysimeter weight data [kg] at time „n“ in [min]
The surface of the Lysimeter is 0.0707 m^2, so 1 kg increase of Lysimeter plus L means 14.15 mm precipitation.
((Lm(n) [kg] – Lm(n-10) [kg]) * 14.15) + L = precipitation P [mm]

To compensate data uncertainties, average values at the boundaries of the evaluated time period are taken:
Lm(n) = (Lm(n-2)+Lm(n-1)+Lm(n))/3
Lm(n-10) = (Lm(n-12)+Lm(n-11)+Lm(n-10))/3

If the precipitation is calculated below the tolerance threshold of 2.5 Grams, the precipitation is set to zero. This means precipitation 0 … <0.035 = 0

10.3.3 Evapotranspiration

As ET is not an event, but takes place in low rates over longer durations, it is recommended to calculate it using the water balance formula for a selected time period: ET = P – L – DS
DS – the change of stored water volume in the lysimeter can be calculated from lysimeter weight change for the selected time period (in our case 10 Minutes):
(Lm(n) [kg] – Lm(n-10) [kg]) * 14.15 = DS [mm]

To compensate data uncertainties, average values at the boundaries of the evaluated time period are taken:
Lm(n) = (Lm(n-2)+Lm(n-1)+Lm(n))/3
Lm(n-10) = (Lm(n-12)+Lm(n-11)+Lm(n-10))/3

ET [mm] = P [mm] - L [mm] – DS [mm] for the selected period.

Please note!
If you have growing plants in the Lysimeter you need to continuously reduce the system weight by this amount of biomass.

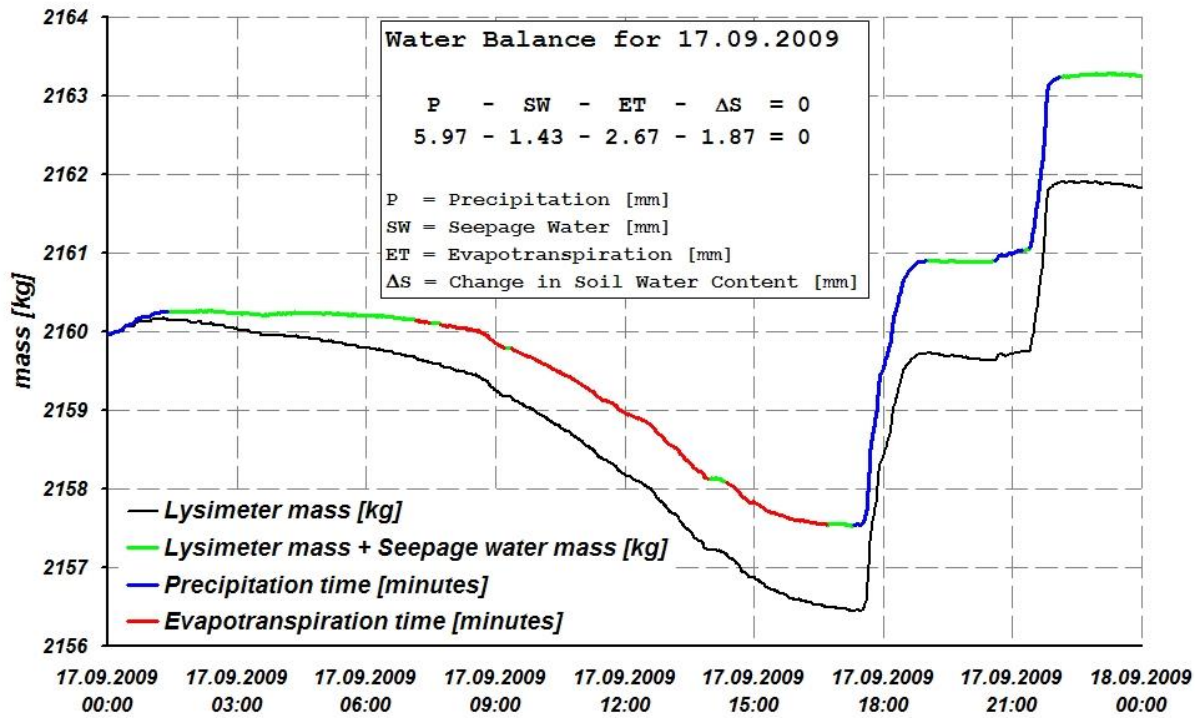


Figure 38: evapotranspiration

This example shows the calculation for one day, based on a Lysimeter with a surface of 1 square meter. So one kg correlates to one mm.

Interpretation of data based on events:
00:00 … 01:30, dew amount of 0.3 mm
01:30 … 07:00, nothing happens
07:00 … 17:00, ET = 2.67 mm
17:30 … 19:00, rain event with 3.5 mm
20:45 … 22:00, rain event with 2.17 mm
22:00 … 24:00, no dew after rain event

Precipitation for this day is 5.97 mm
ET for this day is 2.67 mm
The drainage bottle increased weight of 1.43 kg, so ground water recharge capability was 1.43 mm.
The Lysimeter weight increased at this day from 2160.00 kg to 2.161.87 kg, so the change of water amount in the Lysimeter is 1.87 kg.

The calculation is based on the expertise and experience of the Wagna Lysimeter where different kinds of rain measurements have been compared with Lysimeter measurements since 2004.
The scientific background is based on Prof. Dr. Johann Fank, Joanneum Research Graz.

10.3.4 Et0

Please note
For the exact determination of Et0 usually a radiation sensor and a wind sensor close to the Lysimeter are necessary.

10.4 Flaws and errors

10.4.1 Battery state of charge (SOC)

In winter a lack of energy may happen so that the system may restrict its operation. Lack of energy can influence 2 system components.
An important load of the Lysimeter is the pump for the feedback control of the lower hydraulic boundary condition. If energy supply is tight this control function stops to work. Also the update of the measurement data is restricted (Section 6: Power Management). If energy lacks completely the system shuts down and restarts not before the battery's SOC has met an acceptable value again.
If these problems occur soon and often you may reconsider the energy supply. In some cases an optimization of the solar panel's angle may help. Also increasing the capacity of the power supply may be a good idea. The system is delivered with a mains supply circuit and can easily be connected to a permanent power supply from the mains.

10.4.2 Negative influence on weight values

10.4.2.1 Freedom degree limited by contact

If Lysimeter or drainage bottle has mechanical contact to the housing, surrounding cables etc. this will have a very heavy impact on weight measuring data. The data will be instable and in many cases it has a high dependence on temperature (**Fehler! Verweisquelle konnte nicht gefunden werden.**39).

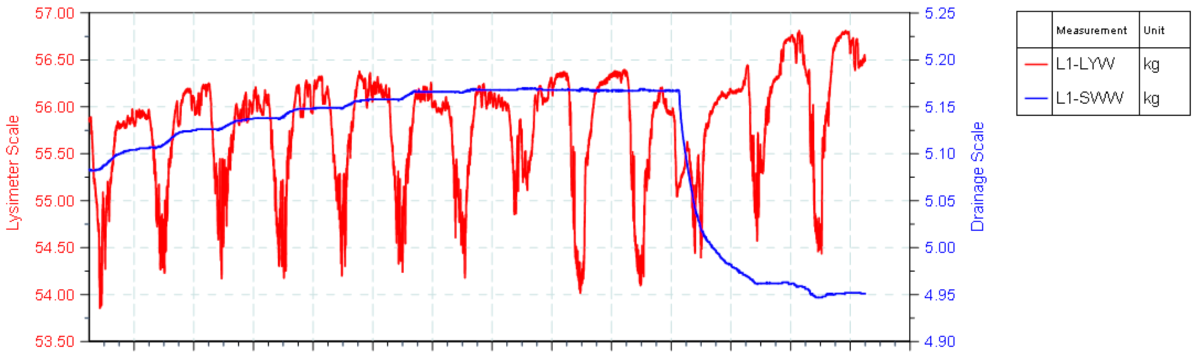


Figure 39: mechanical contact leads to temperature dependent fluctuations

10.4.2.2 Plants and snow cover

Check if the plant cover at the top edge has a negative influence on the free movement of the Lysimeter. If the plant cover sprawls over the edge, METER recommends to cut it back.

A snow cover on the Lysimeter has a negative influence on the weight measurement data as forces from outside are transferred to the Lysimeter. First snow event increases weight. As soon as weight of surrounding snow cover interferes due to snow crystals onto the Lysimeter you will see strong ripples in your data due to snow self-compaction processes. A careful cut free gives good data for a short time, but new snow fall or ice formation will influence these after a while again.

Please note
As winter operation of the Lysimeter is restricted anyway due to drainage frost shutdowns, this condition should be marked for balancing and then be filtered.

10.4.2.3 Wind and vibrations

Stronger wind can cause Lysimeter swinging which leads to noise in the measurement values (Figure 40: spikes and dropouts in measurement series).
Also a vibration of the ground e.g. caused by a nearby highway can lead to noise.

10.4.3 Dropouts and spikes in measurement series

Dropouts and spikes in measurement series belong to the most undesirable events – although experience tells they happen again and again. Reasons for this are e.g. lack of energy, sensor troubles, timing problems of measuring buses, animals gnawing on cables and tubes, corrosion etc.

Please note
It is essential to react as fast as possible on events listed above. This is only possible by continuously checking the measurement data. Do not leave it to chance!

E.g. in measurement series a weight value can show a peak. When analyzing visually or mathematically one will realize the measurement value represents a spike or respectively an outlier.
Either technical explanations (dropout, failure) may exist or natural ones (e.g. an animal has run across the Lysimeter). In many cases dropouts and spikes can be identified and filtered out.
If the measurement values are not pre-filtered this can lead to wrong interpretations (e.g. when calculating the precipitation).

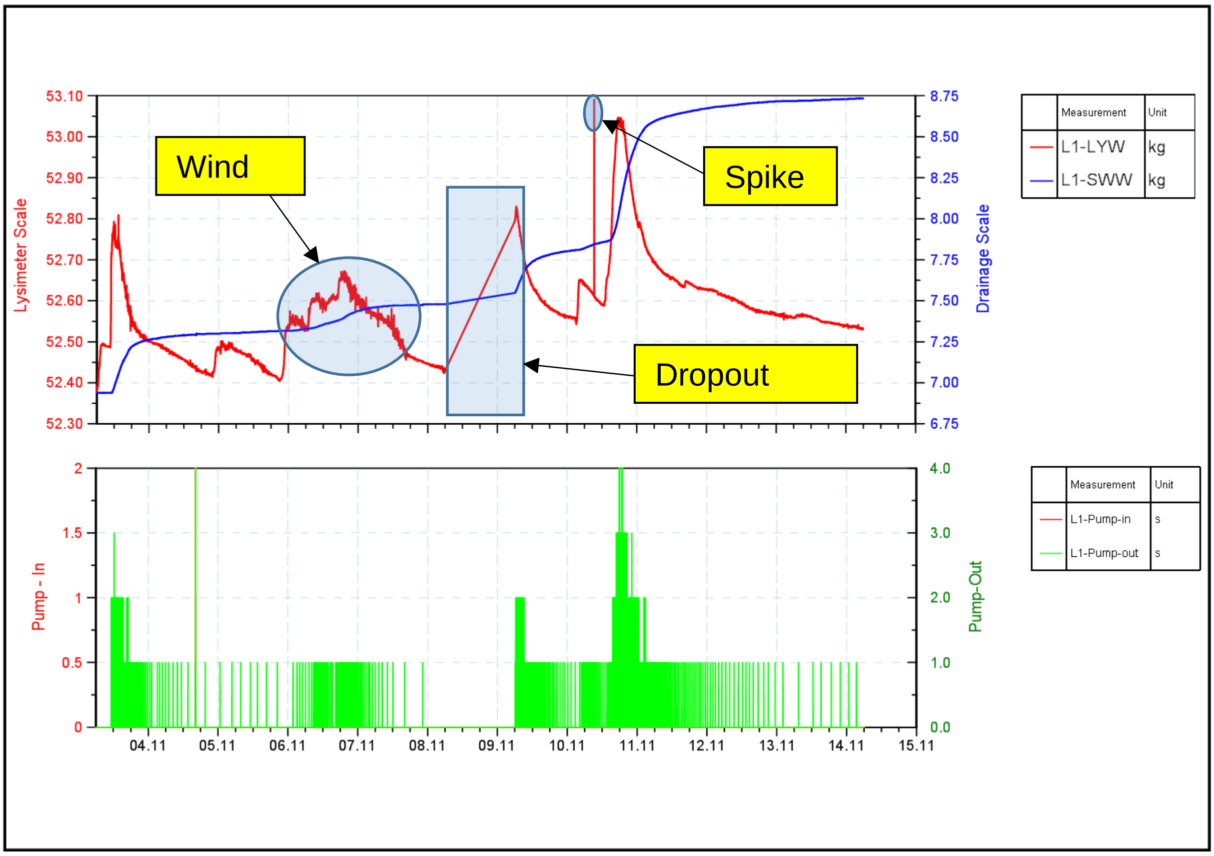


Figure 40: spikes and dropouts in measurement series

11 Appendix

A DT80M

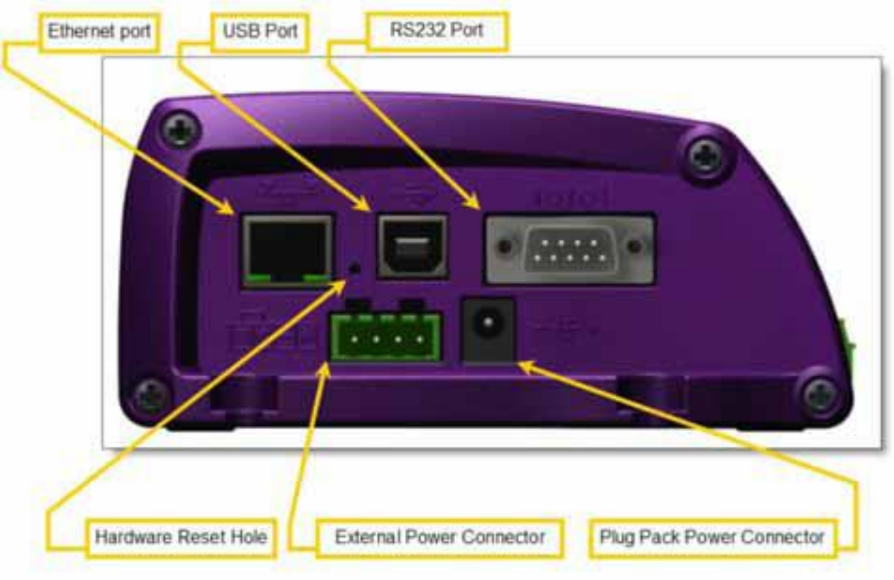


Figure 41: connections and reset hole

Figure 42: front panel

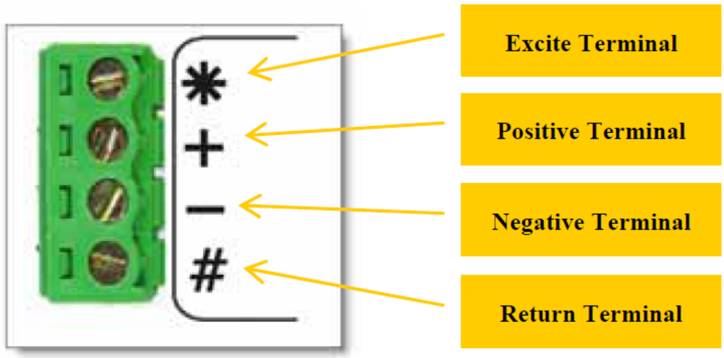


Figure 43: analog input

B Connection diagram

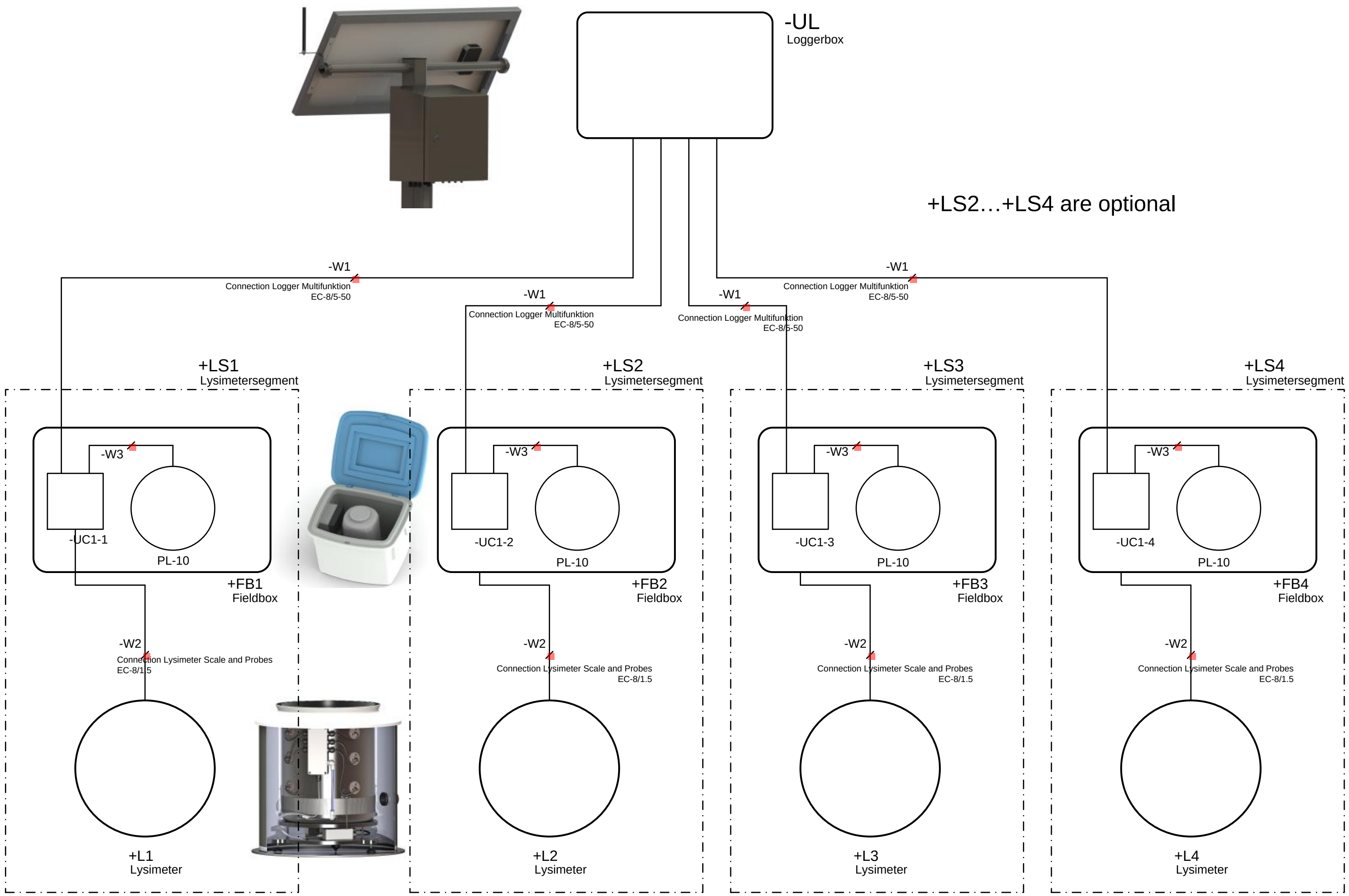


Figure 44: cable connections

Art.Nr. SFL-300, -600, - 900
Version: 12/2019
Author: as, ge

C Serial bus diagram

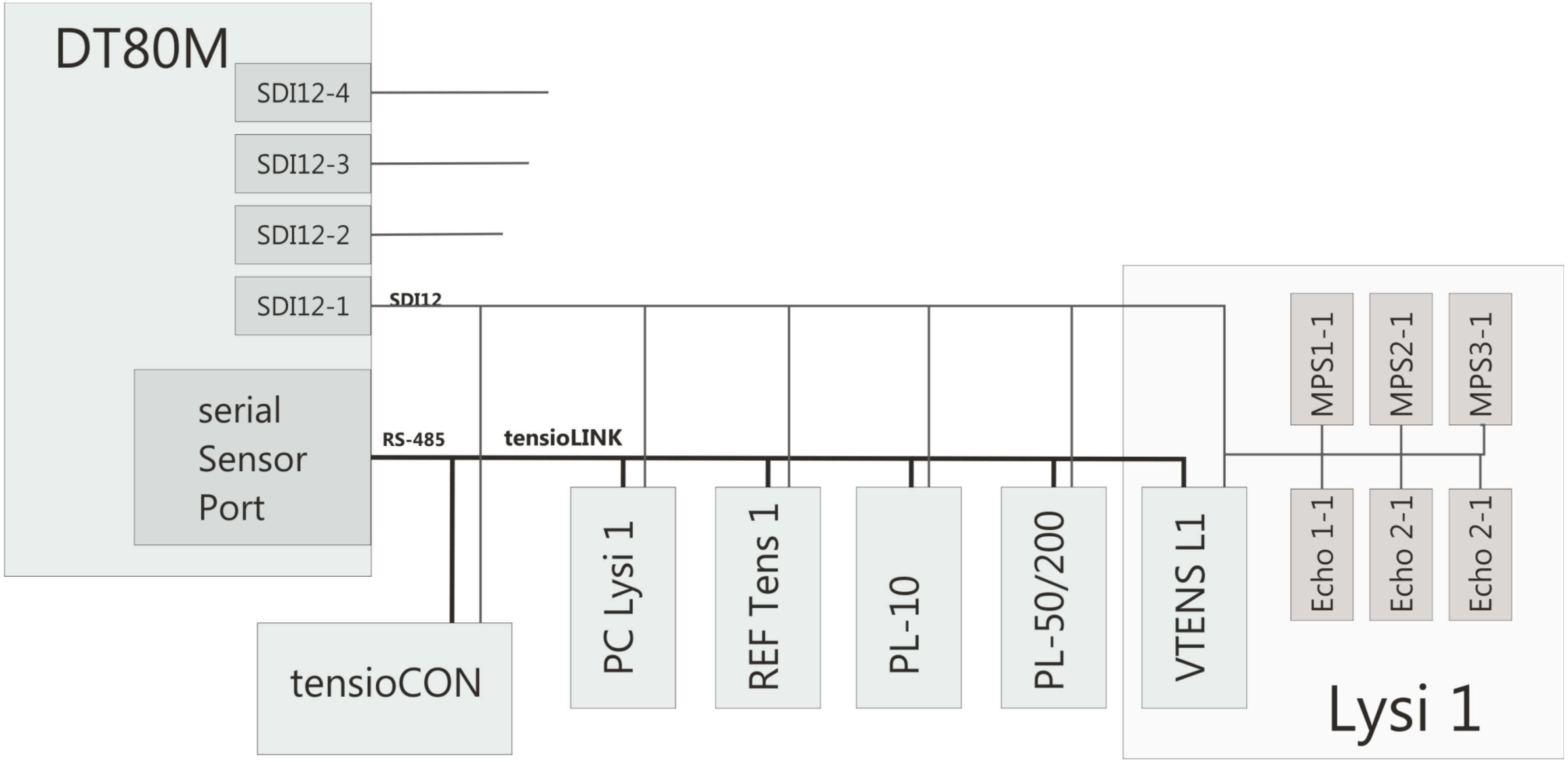


Figure 45: serial bus scheme

D Connections on the bottom of the logger box

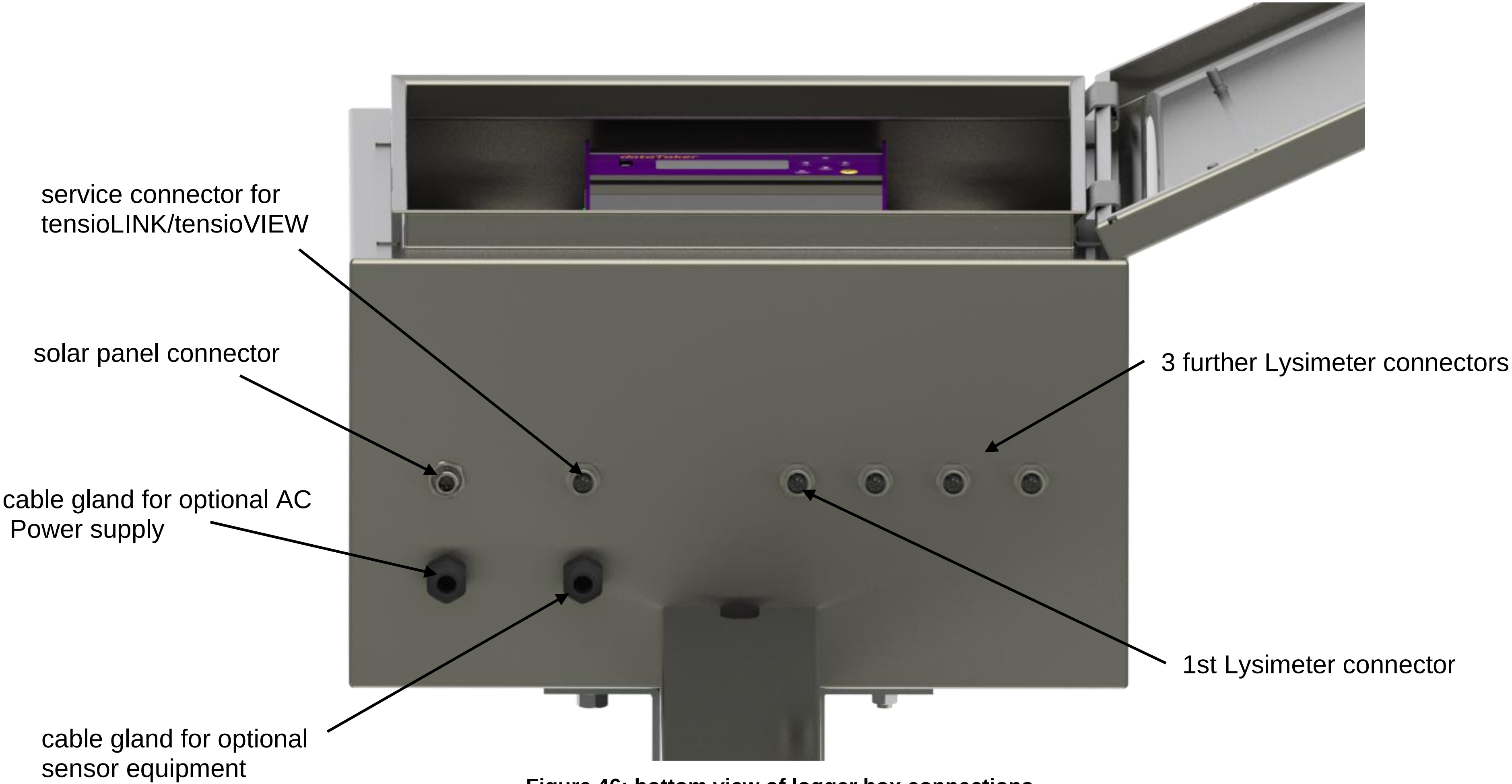
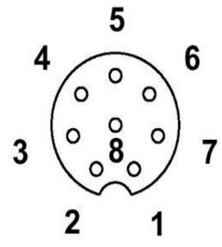


Figure 46: bottom view of logger box connections

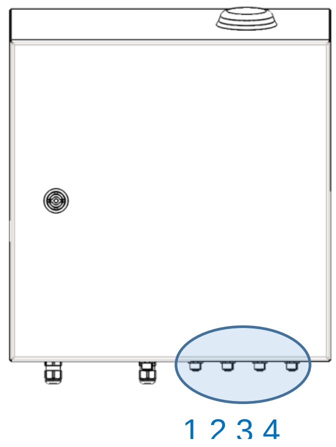
E Connector pin assignment

Pin assignment DT80M /Lysimeter plugs 1-4

Signal	Cable color	Function	Pin
V+	white	10…14VDC	1
P+	brown	pump +	2
S+	green	VTENS signal +	3
S-	yellow	VTENS signal -	4
P-	grey	pump -	5
A	pink	RS485-A	6
B	blue	RS485-B	7
SDI12	red	SDI12	8
GND	shield	GND	SHD



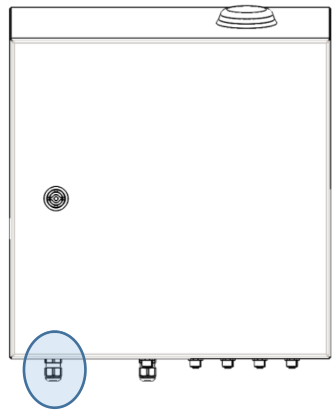
female 8 pins



Pin assignment DT80M /solar panel power

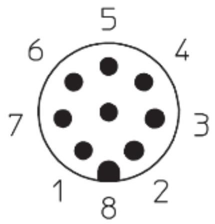
Signal	Cable color	Function	Pin
V+	brown	solar panel +	1
V-	blue	solar panel -	2
V+	white	solar panel +	3
V-	black	solar panel -	4

male 4 pins

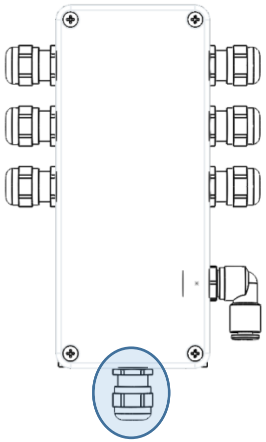


Pin assignment sensor distribution box (VTENS)

Signal	Cable color	Function	Pin
V+	white	6…18VDC	1
GND	brown	GND	2
n.c.		not connected	3
S+	green	analog signal out+	4
S-	yellow	analog signal out-	5
A	black	RS485-A	6
B	blue	RS485-B	7
SDI12	red	SDI12	8

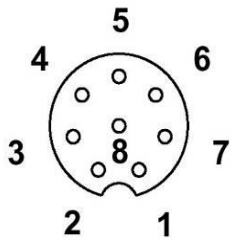


male 8 pins



Pin assignment Pump and Distribution Box / reference Tensiometer

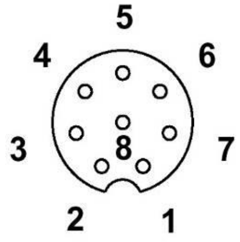
Signal	Cable color	Function	Pin
V+	white	6…18VDC	1
GND	brown	GND	2
n.c.			3
n.c.			4
n.c.			5
A	pink	RS485-A	6
B	blue	RS485-B	7
SDI12	red	SDI12	8



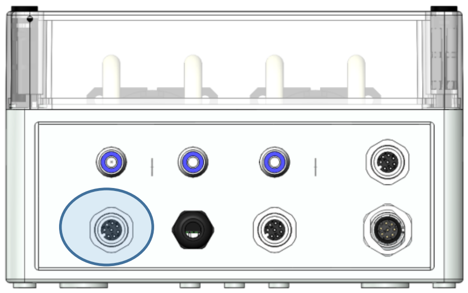
female 8 pins

Pin assignment Pump and Distribution Box /drain water balance

Signal	Cable color	Function	Pin
V+	white	6…18VDC	1
GND	brown	GND	2
n.c.			3
n.c.			4
n.c.			5
A	pink	RS485-A	6
B	blue	RS485-B	7
SDI12	red	SDI12	8

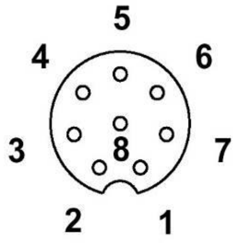


female 8 pins

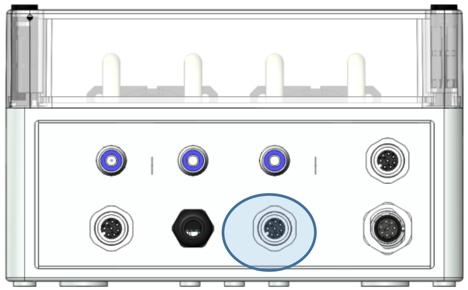


Pin assignment Pump and Distribution Box / Lysimeter balance

Signal	Cable color	Function	Pin
V+	white	6…18VDC	1
GND	brown	GND	2
n.c.	green	n.c.	3
S-	yellow	VTENS Signal -	4
S+	grey	VTENS Signal +	5
A	pink	RS485-A	6
B	blue	RS485-B	7
SDI12	red	SDI12	8



female 8 pins



F Technical data

T8 Tensiometer

Material and dimensions	
Ceramic Housing Shaft	Al_2O_3 sinter, air entry pressure > 1500 kPa; length 60 mm, ∅ 24 mm PA6 GF30 Notch impact resistant PMMA, ∅ 25 mm
Measuring range	
Pressure sensor	-100 kPa … +100 kPa (electronic) -85 kPa … +100 kPa (physical)
Soil water tension	-85 kPa … 0 kPa (Tensiometer)
Water level range	0 kPa … 100 kPa (Piezometer)
Temperature	-30 °C … +70 °C
Accuracy	
Pressure Temperature	± 0.5 kPa ± 0,2 K (-10…+30 °C); ± 0,4 K(-30…+60 °C)
Power supply	
Supply voltage V_{in}	6 … 18 V DC
Current	3 mA nominal, (max. 20 mA)
Resistance to chemicals	
PH range:	pH 3 … pH 10. Limited to media that do not etch silicone, fluoro-silicone, EPDM, PMMA and polyether-imide

5TE Volumetric Water Content

Measuring range	
Water contents	Apparent dielectric permittivity (ε_a): 1 (air) to 80 (water)
Electrical conductivity	0-23 dS/m (bulk)
Soil temperature	-40°C…50°C
Accuracy	
Volumetric water content	**ε_a:** ±1 ε_a (unitless) from 1-40 (soil range), ±15% from 40-80 • Using Topp equation: ±0.03 m^3/m^3 (±3% VWC) typical in mineral soils that have solution electrical conductivity < 10 dS/m • Using medium specific calibration: ±0.01 - 0.02 m^3/m^3 (± 1-2% VWC) in any porous medium.
Electrical conductivity	±10% from 0-7 dS/m, user calibration required above 7 dS/m
Soil temperature	±1°C
Resolution	
Volumetric water content	ε_a: 0.1 ε_a (unitless) from 1-20, < 0.75 ε_a (unitless) from 20-80 VWC: 0.0008 m^3/m^3 (0.08% VWC) from 0 to 50% VWC
Electrical conductivity	0.01 dS/m from 0-7 dS/m, 0.05 dS/m from 7-23 dS/m
Soil temperature	0.1°C
Power supply	
Supply voltage V_{in}	3.6 … 15 V DC
Current	0.03 mA stand-by, 10 mA max. for 150ms
Operating temperature	
	-40°C…+50°C

TEROS 21 Matrix potential sensor

Measuring range	
Matrix potential	-10 ... -500 kPa, pF 1,71..3,71
Soil temperature	-40°C…50°C
Power supply	
Supply voltage V_{in}	3,6 … 15 V DC
Current	0,03 mA standby, 10mA max. for 150ms
Accuracy	
Matrix potential	±10 kPa for -10 kPa to -100 kPa; ±25% of the measurement value for -75 kPa .. -500 kPa
Soil temperature	1° C
Operating temperature	
	-40°C…+50°C

VTENS virtual Tensiometer

Measuring range	
Pressure sensor	-100 kPa … +100 kPa (electrical) -85 kPa … +100 kPa (physical)
Soil water tension	-85 kPa … 0 kPa (Tensiometer)
Water level	0 kPa … 100 kPa (Piezometer)
Accuracy	
pressure	± 0.5 kPa
Power supply	
Supply voltage V_{in}	6 … 18 V DC
Current	3 mA nominal

G Technical terms

tensioLINK

tensioLINK is a registered trademark of the METER Group AG. tensioLINK is a serial bus for sensors and devices. Apart from the sensors all devices in the Smart Field Lysimeter communicate via tensioLINK.
tensioLINK is based on the international standard EIA-485 and RS-485 in the 2-wire version. tensioLINK adds on this bus system a propietary protocol. Well known other protocols using RS-485 are e.g. Modbus and Profibus.
The tensioLINK protocol is multi master compliant and communicates usually with the transfer parameters 9600 baud, 8N1. Based on the robust construction of RS485 up to 128 participants can be linked together over cable lengths up to several kilometers.

http://de.wikipedia.org/wiki/EIA-485
http://www.ti.com/lit/an/slla070d/slla070d.pdf

tensioVIEW

tensioVIEW is a registered trademark of the METER Group AG. tensioVIEW is an easy to use software that supports devices and sensors with the tensioLINK interface. For this usually the tensioLINK USB converter in the PC is connected to the tensioLINK bus.
For the different types of devices tensioLINK provides descriptions and functions which with the following operations can be executed:

- listing devices linked to the bus
- retrieving status data
- retrieving measurement data
- configuring operating parameters
- storing measurement data of several devices over any long periods of time
- reading out stored measurement values from the sensors

H Sensor table

Channel Name	Type	Unit	Probe Type	Schedule	Interval	Description
Batt-Volt	Voltage	V	tensioCON	B	10 min	Battery voltage
Batt-Curr	Current	mA	tensioCON	B	10 min	Battery current (positive values = discharging)
Batt-SOC	State of Charge	%	tensioCON	B	10 min	Battery state of charge
Logger Box Temp	Temperature	degC	DT80M	B	10 min	Temperature in Logger Box, value taken from internal DT80M sensor
Field Box Temp	Temperature	degC	PL10	B	10 min	Temperature in Field Box, value taken from internal sensor of PL-10 balance transmitter box
L1 Bottom Temp	Temperature	degC	PL-50/100/200	B	10 min	Temperature in Lysimeter 1 bottom, value taken from internal sensor of PL-50/100/200 balance transmitter box
Lx-LYW	Weight	kg	PL-50/100/200	C	1 min	Lysimeter no. x weight
Lx-SWW	Weight	kg	PL-10	C	1 min	Drainage bottle Lysimeter no. x weight
Lx-Pump-in	Time	s	SFL-PC	C	1 min	Lysimeter no. x pump time in direction to Lysimeter, calculated by SFL-Pump controller
Lx-Pump-out	Time	s	SFL-PC	C	1 min	Lysimeter no. x pump time in direction to drainage bottle
Lx-REF-TENS-T4	Matrix Potential	kPa	T8	D,E,F	10 min	Reference Tensiometer Type T8 in depth 4, Matrix Potential or Tension
Lx-VTENS-T4	Matrix Potential	kPa	SFL-SDB	D,E,F	10 min	VTENS sensor in in Lysimeter depth 4, Matrix Potential or Tension
Lx-Echo-T1	Water Content	%	5TE	D,E,F	10 min	Water content in depht 1
Lx-Echo-T2	Water Content	%	5TE	D,E,F	10 min	Water content in depht 2
Lx-Echo-T3	Water Content	%	5TE	D,E,F	10 min	Water content in depht 3
Lx-MPS-T1	Matrix Potential	kPa	MPS6	D,E,F	10 min	Matrix potential in depht 1
Lx-MPS-T2	Matrix Potential	kPa	MPS6	D,E,F	10 min	Matrix potential in depht 2
Lx-MPS-T3	Matrix Potential	kPa	MPS6	D,E,F	10 min	Matrix potential in depht 3
Lx-EC-T1	El. Conductivity	mS/cm	5TE	D,E,F	10 min	Electrical conductivity in depth 1
Lx-EC-T2	El. Conductivity	mS/cm	5TE	D,E,F	10 min	Electrical conductivity in depth 2
Lx-EC-T3	El. Conductivity	mS/cm	5TE	D,E,F	10 min	Electrical conductivity in depth 3
Lx-Temp-T1	Temperature	°C	5TE	D,E,F	10 min	Soil temperature in depth 1, value taken from 5TE
Lx-Temp-T2	Temperature	°C	5TE	D,E,F	10 min	Soil temperature in depth 2, value taken from 5TE
Lx-Temp-T3	Temperature	°C	5TE	D,E,F	10 min	Soil temperature in depth 3, value taken from 5TE
Lx-Field-Temp-T4	Temperature	°C	T8	D,E,F	10 min	Field soil temperature in depth 4, value taken from T8 Tensiometer
Lx-REF-Tens-Refill	Indicator	bool	T8	D,E,F	10 min	Field Tensiomter refill indicator, 0=ok, 1=refill

I Table of figures

Figures:

Tables:

J References

Smart Field Lysimeter installation manual „Cutting the soil column“
http://publications.metergroup.com/Manuals/UMS/SMARTFIELD_IA-Bodensaeule.pdf...

Smart Field Lysimeter installation manual „Earthworks and basic setup“
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http://publications.metergroup.com/Manuals/UMS/SMARTFIELD_IA-Installation-04-Einzel.pdf...

Smart Field Lysimeter user manual (this document)
http://publications.metergroup.com/Manuals/UMS/SmartField-Lysimeter%20User%20Manual%20V12-2013.pdf...

Smart Field Lysimeter service manual
https://www.metergroup.com/environment/products/smart-field-lysimeter/...

General information on METER products
https://www.metergroup.com/

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