



SoilNet

Wireless Sensor Network for Measuring Soil Moisture

MANUAL

Installation and Initial Operation

- Version 5 -



Agrosphere Institute (IBG-3)

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Subject to technical modifications.

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1 Introduction

SoilNet is a wireless network of data loggers to collect soil parameters with high spatial and temporal resolution.

The data transfer is done with local receivers (LoRa WAN) or via the Narrow Band-Internet of Things (NB-IoT) communication technology.

The data loggers (called “End Devices”) are powered by batteries or solar power and can read out a variety of commercial sensors (SDI standard).

1.1 Technical Data

Data Transfer		LoRa(Wan) [Long Range Wide Area Network] or NB-IoT [Narrowband Internet of Things]
Measurement frequency		In 3-minute steps up to 12 hours, minimum 3 minutes.
Data transfer		Realtime or intervals (one hour, daily etc.)
Realtime Clock		Yes
Storage		16 GB micro SD-card
Power Supply	Battery	3.6V 1,4 Ah, D-Type 34615M, Lithium-Ion
or	Solar Power	3x NiMH AA-Type, 1.2V, 2.1 Ah
Sensors		Up to 9 sensors, SDI-Standard, 1 switching input (e.g. for tipping bucket)
Cable protection		Yes
Sensor Power Supply		max. 5V

1.2 Literature

Bogena, H.R., Herbst, M., Huisman, J.A., Rosenbaum, U., Weuthen, A., Vereecken, H. (2010): Potential of wireless sensor networks for measuring soil water content variability. *Vadose Zone Journal*, 9 (4): 1002-1013.

Bogena, H.R., Huisman, J.A., Meier, H., Rosenbaum, U., Weuthen, A. (2009): Hybrid wireless underground sensor networks: Quantification of signal attenuation in soil. *Vadose Zone Journal*, 8 (3): 755-761.

Domínguez-Niño, J.M., H.R. Bogena, J.A. Huisman, B. Schilling and J. Casadesús (2019): On the accuracy of factory-calibrated low-cost soil water content sensors. *Sensors* 19(14): 3101, doi:10.3390/s19143101

Bogena, H., J.A. Huisman, B. Schilling, A. Weuthen and H. Vereecken (2017): Effective calibration of low-cost soil water content sensors. *Sensors* 17(1): 208, doi:10.3390/s17010208.

2 Safety information and disposal of batteries

2.1 Safety Information

The End Device is powered either by a lithium battery or solar technology, depending on the location where the device is installed.

When used with a solar cell (glued to the lid of the KG tube) NiMh rechargeable batteries are used, which are not subject to any special safety regulations.

When using lithium batteries, only use batteries of the following type:

ER 34615 M

(We highly recommend the “LSH 20” batteries of the French company “Saft”).

Please also note Appendix “M”, which indicates the high current capability of the battery. This is an important feature of the battery, as it can happen that at the moment of measurement the voltage of the battery drops too much, which causes the processor of the logger to stop working.

Also, the safety regulations of Lithium Batteries must be followed:

- Read the manufacturer's safety data sheet (MSDS, see at the end of this document).
- The batteries must not be exposed to high humidity.
- The batteries must not be subjected to mechanical shocks.
- The empty batteries must be disposed of properly.

- Please ask your safety officer about the regulations for the transport of dangerous goods.

2.2 Disposal of Lithium Batteries

If the batteries are empty / used up, they must be disposed of as hazardous waste.

Before they are transported in suitable containers, at least the positive pole must be taped with insulating tape.

Hard blows and water must be avoided when handling the batteries.

3 End Devices



Figure 1: End Device with 6 smt100 sensors and 3 Teros 21 sensors

The End Device consists of a housing containing the electronics (measuring and transmitting module) and different sensors. The measuring intervals are configurable. The data are sent online, can be retransmitted and are simultaneously stored internally on an SD card.

The electronics are located in the lower part of the housing; the cables of the sensors are permanently connected to the sensors through a screwed cable gland in the housing base plate. The base plate is fitted to the housing cylinder by six screws and a sealing ring and does not need to be opened during normal operation.

The cover is located at the top and contains either the NB-IoT or the LoRa modem. It is fastened to the housing cylinder with three screws. The cover is placed on the screws by means of the longitudinal bayonet slots, so that the screws can remain in the cylinder during initial operation or any necessary maintenance work.

Caution:

Do not fasten the cover screws more than finger tight.

Please do not tighten the screws with a cordless screwdriver, otherwise the bayonet slots in the cover could be damaged.

3.1 Control Elements

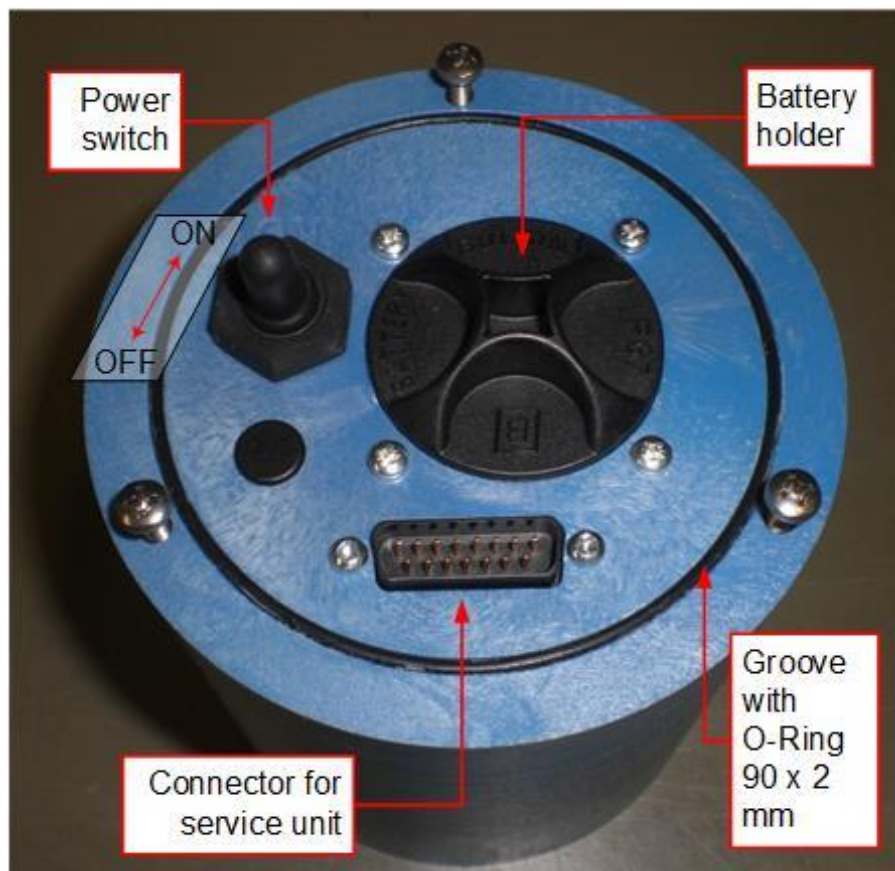


Figure 2: Control elements of the end device

The power switch, the battery compartment and a multipin socket for connecting the service unit are located under the cover.

An O-ring seals the hood of the housing. Make sure that the edge of the hood, the top of the housing and the O-ring are always clean to ensure tightness. The O-ring should fit into its groove.

In addition, the O-ring should be lubricated with silicon grease.

3.2 Inserting the Battery

3.2.1 Using Lithium batteries

In the End Device, only use **ER34615M** type battery. (Or use the solar option, see below).

Especially the appendage “**M**” is important, it stands for its high current capability.

The high current capability is required so that the voltage of the battery does not drop too much at the moment of measurement, causing the processor to stop. Thus, a longer running time is achieved.

Because of its Lithium ingredients, attention should be payed to European and local laws and safety instructions!

**Please also read the manufactures MSDS for the Lithium Battery.
(Please find at the end of the document).**

We highly recommend batteries from the French manufacturer “Saft”.

The name of the batteries is “LSH 20”.

Insert the battery into the compartment of the End Device with the positive pole facing upwards.



Figure 3: Battery from “SAFT”

3.2.2 Using the solar option

If the location where the End Device is installed is sufficient, i.e. if the solar radiation is strong and long enough, the solar option can be used for operation.

For this purpose, a small solar panel is glued to the lid of the KG tube (1W power).



Figure 4 - Solar panel with M12 connection

The connection for the solar panel is already provided on the end device. A M12 connector is used. The cable is routed inside the KG tube along the side of the End Device.

The lithium battery has to be replaced with a rechargeable NiMh battery.

In fact, these are three batteries, soldered together to fit into the D-Type compartment of the End Device.



Figure 5 - NiMh batteries

3.3 Installing the End Device

The end device is supplied with a commercial drain pipe (referred to as a “KG tube”) that has a cover and is sunk into the ground. Inside the tube, a cap nut prevents the end device from sliding down. At the lower end of the tube, there is an opening for routing the cables of the sensor to the outside.



Figure 6: KG pipe with end device and cable opening

When cutting the cables to size, make sure that there is sufficient additional length to roll up some of the cable inside the KG pipe, so that the End Device can be pulled out for maintenance work. (See figure 5 / install scheme A “End Device under service”).

When installing the sensors, ensure they are in good contact with the soil. No air should be trapped between the sensors and the soil, and no large stones should be in direct contact with the sensors to avoid an adverse effect on the accuracy of the measurement result.

Install the sensors with the flat surface in a vertical position to prevent water from collecting on the sensors.

Please see the examples in figure 5 to install the device and the sensors in different ways. Please refer to the manufactures manuals of the sensors also.

Installation schemes for SoilNet End Devices

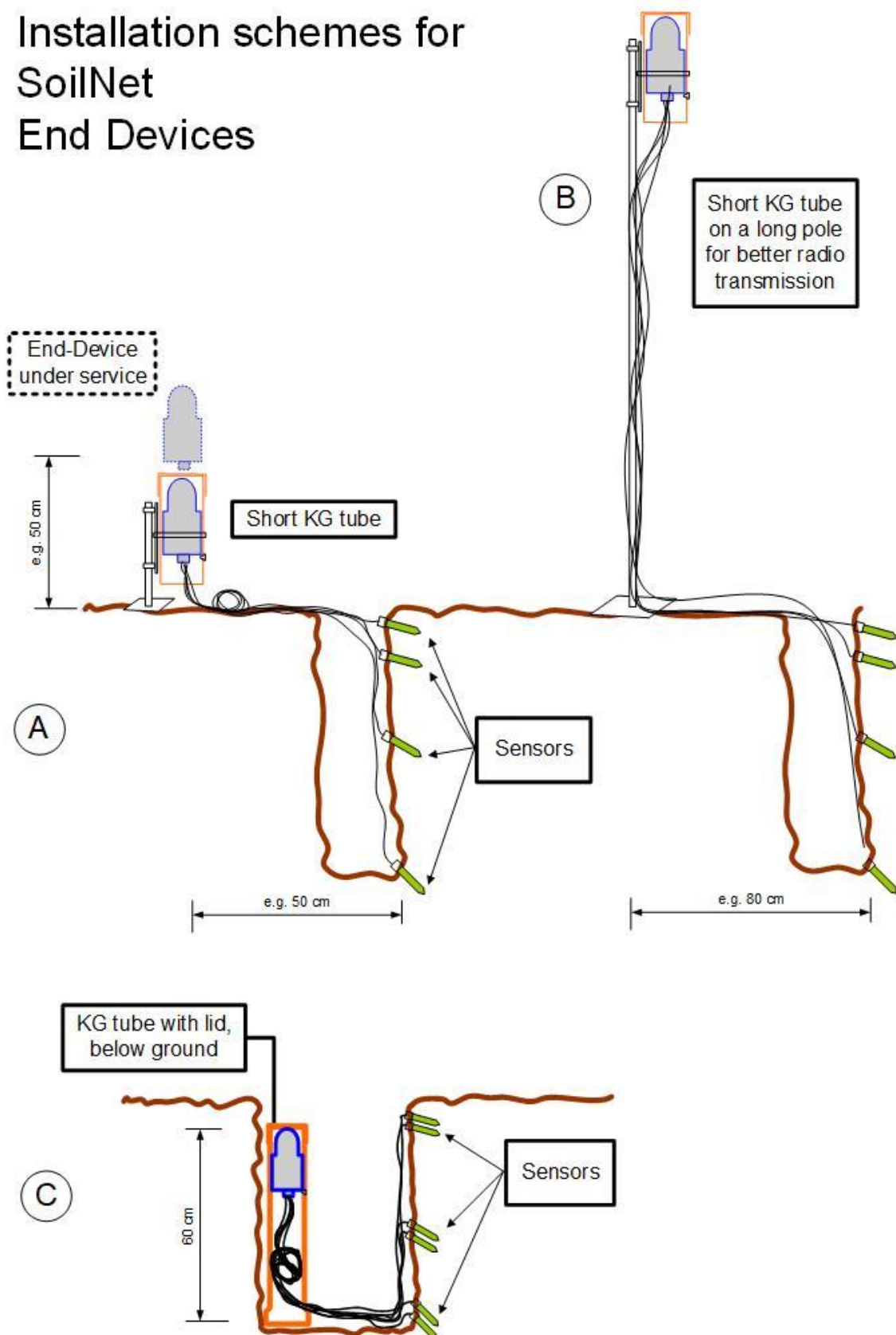


Figure 7: Different installing schemes in the ground

3.3.1 Sensors

The customer can choose different sensors to get different soil parameters. Any sensor that is SDI compliant and can be operated with a voltage up to 5 V can be connected to the SoilNet Logger.

One of the most wanted parameters is soil moisture. Although there are many sensors for soil moisture on the market, we recommend the Truebner SMT-100, which - apart from the manufacturer's calibration - is again individually calibrated by the Forschungszentrum Jülich with a 5 point calibration to fit the permittivity curve. (Also see chapter 1.2 Literature)

Also, for this sensor we provide an insert tool on request, which also includes a pre-cutting tool.

Caution:

Before screwing together the rod and the head of the insert tool, please lubricate the threads with grease or oil (WD40 or similar) to prevent the aluminium from cold-welding.

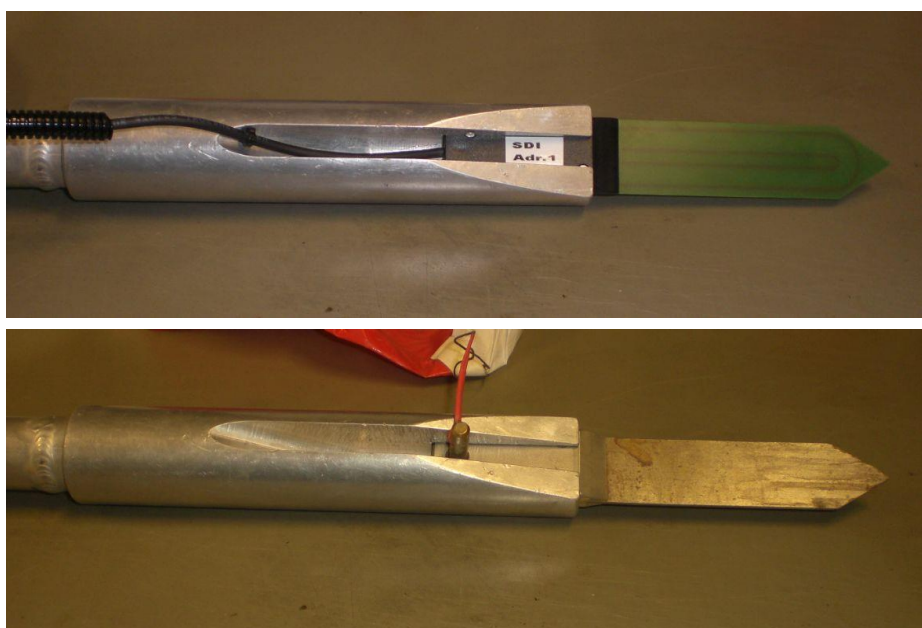


Figure 8: Insert tool for Truebner SMT-100 sensor and pre-cutting tool

As soon as you have installed the sensors, immediately check the measurement result with the service unit and a PC before screwing on the cover of the End Device and sealing the KG tube.

3.3.2 Service-Unit



Figure 9: Service-Unit

The Service-Unit is used to read out the current measurement data while installing, to set the configuration of the End-Device and to program the End-Device with new firmware. It provides only two buttons: the black one for resetting the End-Device, the blue one to set the device into program mode.

Connect the USB connector to a notebook or PC. The software “BoxCon” should be installed already as well as the virtual COM port (FTDI driver). Please refer to the manual “SoilNet BoxCon V1.17”.

Connect the service unit to the End Device using the special **15-pin D-sub connector cable**.

Caution:

- **This cable should not exceed 80cm length to ensure save operation.**

- **Switch off the End Device before connecting the devices.**

As soon as the End-Device is switched on, the “**Power**” **LED** of the Service-Unit is lit. This LED therefore indicates the operating state of the End Device, not of the Service-Unit. The LED signed “**Power USB**” is lit when the Service-Unit is connected to a computer.

With the Service-Unit and a PC connected, please launch the “BoxCon” software to configure the End-Device as well as read out the values of the sensors just installed (see next chapter).

With these values, a plausibility check can be carried out as soon as the sensors have been installed. The borehole should be refilled only if all values seem plausible.

3.3.3 Configuring the End Device

This is a short description of the “BoxCon” Software. For a full description please read the manual “SoilNet BoxCon V1.17”.

Please make sure, the software “BoxCon” and the drivers for the virtual COM port (FTDI) are installed properly. Set the virtual COM port in the software to the same port, the device manager on the PC shows for the connected Service Unit.

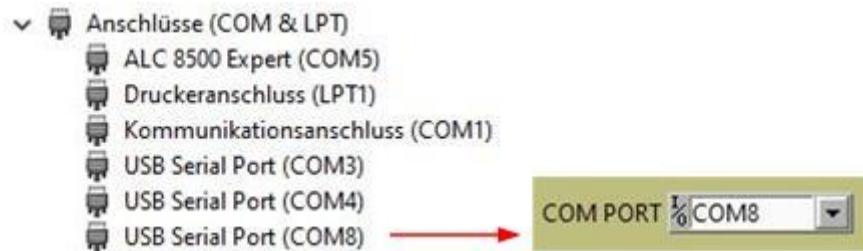
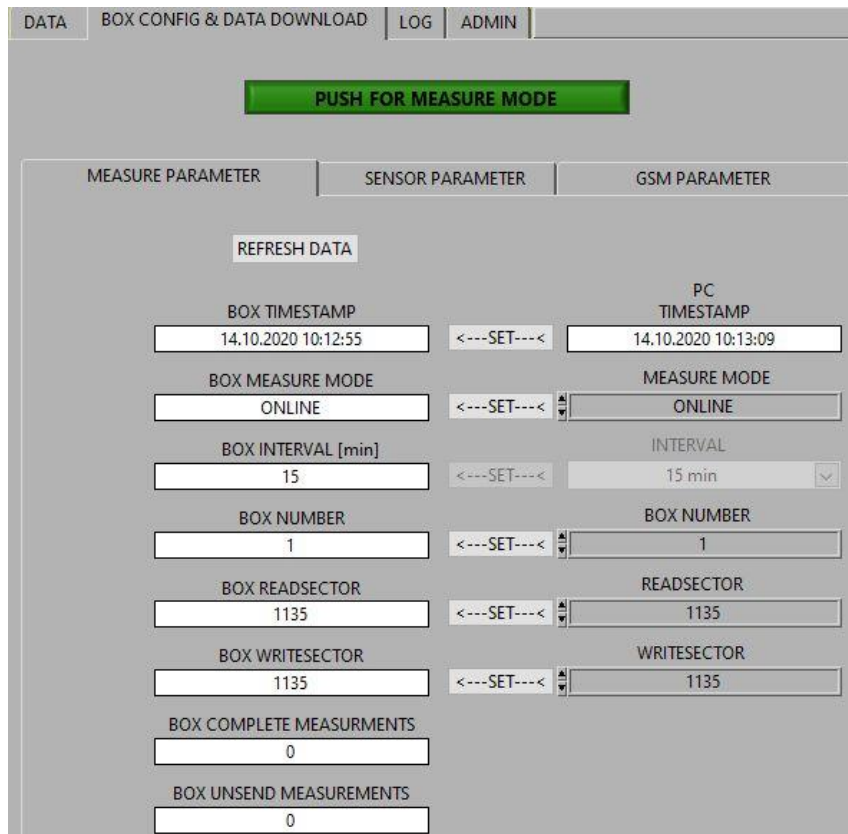


Figure 10: Setting the virtual COM port in BoxCon

With the running End Device connected, in the tab “Box Config & Data Download”

- press the red button “Push To Activate Config Mode”.
The button will change its colour to yellow and shows “Push ED reset button”.
Now,
- push the black “Reset” button on the Service Unit to enter the config mode.

The screen will change as follows:



Now you can set the timestamp, the measurement interval (see below), the number of the End-Device and - if needed - the sectors of writing and reading. Please type in the new values on the right side, click once on the background, then click the corresponding "Set" button.

Also, you can choose the measure mode of the End Device:

- **Online**
The End Device will try to send its measured data immediately after the measurement. It gets an acknowledgement from the PC in the institute when the data has been received completely.
At the same time all measured data are stored on internal SD card also.
If the transmission fails, the End-Device will enter the "long sleep" to save power. After the interval time (which can be set in 3-minute steps) the device will wake up and the measurement starts again. Then it tries to send both the current measurements and the data not yet sent.
- **Offline**
The measured data will be stored on SD card only.
The data can be read out manually afterwards (see chapter 4.2).
- **GSM**
The GSM mode means that the measured data is send via email to an address, the user can enter on the sub tab "GSM parameter". The data is also stored on the SD card.
For the GSM mode, instead of the NB-IoT modem, a special GSM modem is needed.

After editing the configuration parameters, push the button "Push For Measure Mode". The End Device will rest and start the measurement again.

On the "DATA" TAB the measured parameters will be shown:

SDL2	SMT100 V1	COUNT	PERMITTIVITY	MOISTURE[VOL%]	TEMP[C*]	SUPPLY[V]
		+13578	+8.26	+15.31	+21.76	+5.02

3.3.4 Manual Measurement

When inserting the sensors, it may be useful to measure the sensors in the individual depths individually or in pairs - if they are arranged in pairs at the same depth. For this purpose, the measurement can be performed manually by restarting the End-Device. This way the measured values can be compared directly with each other at the same depth, so that a poorly installed sensor can be detected (typically air gaps in the soil or an incomplete contact between sensor blade and the soil matrix produce much lower permittivity values).

To start a measurement, simply press the "Reset" button on the connected Service-Unit. The measured values can be observed on the "Data" tab.

3.3.5 Closing the End-Device

After running the BoxCon software and the value check of the installed sensors is done, disconnect the Service Unit and plug in the cable of the modem in the hood. Switch on the logger.

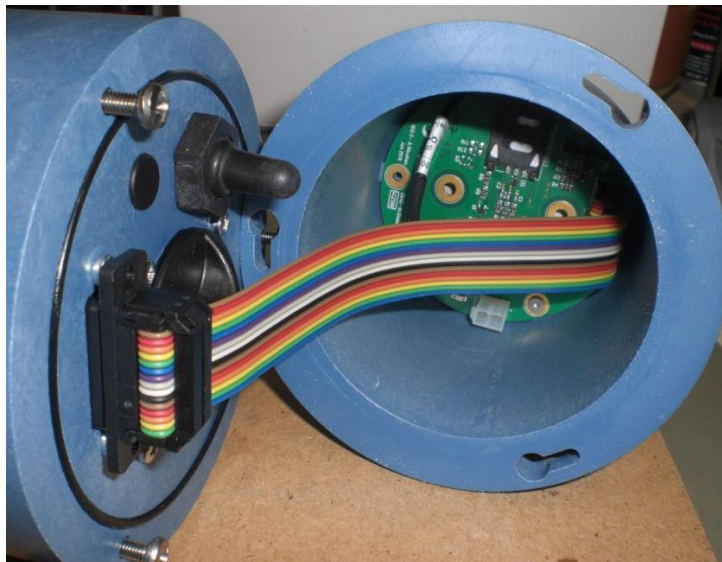


Figure 11: End device with modem hood connected

Caution:

When screwing on the cover closed, ensure that

- **the interface between the cylinder and the cover as well as the groove for the O-ring are clean,**
- **that the O-ring (90 x 2 mm) is inserted correctly and lubricated with some grease and**
- **the three screws are only tightened by hand, since the longitudinal bayonet slots may otherwise be damaged.**

Afterwards, you can insert the closed End Device into the KG tube.

Please pay attention to the remaining cable, which is wound up in the KG tube. The cable must not be squeezed between End Device and the retaining screw in the KG tube!

Then close the KG tube with the accompanying lid. Here, too, make sure that the rim of the tube and the inner edge of the lid are clean, so that the lid can be easily removed later.

4 LoRa Server / Gateway

The Soilnet V5 can be operated in two ways, as a direct connection of the end devices via the Internet (**NB-IoT** – Narrow Band Internet of Things) or as an isolated solution with local storage (and subsequent data transmission via modem / Internet: **LoRa** – Long Range (- wide area network)).

Advantages of NB-IoT are:

- No local network (server / hardware) is required, as the commercial network is used.
- The placement of the end devices is not limited locally (given sufficient coverage by a NB-IoT provider)

Disadvantages of NB-IoT:

- There are regular costs for SIM cards of the NB-IoT provider (e.g. 10 € per 500 MB per end device).
- Dependence on the coverage by a NB-IoT provider.

Advantages of LoRa are:

- Less running costs (only for the modem)
- Stable, secure connections due to choice of server location
- Not time-critical independent of the Internet *

Disadvantages of LoRa:

- Additional hardware costs (server / gateway/ GSM modem / antenna mast)
- A suitable location for the server must also be found.

* Note:

LoRa's local network requires a feedback message after data was sent by the end devices. This must happen within a certain time window so that the internal clock of the devices can be synchronized.

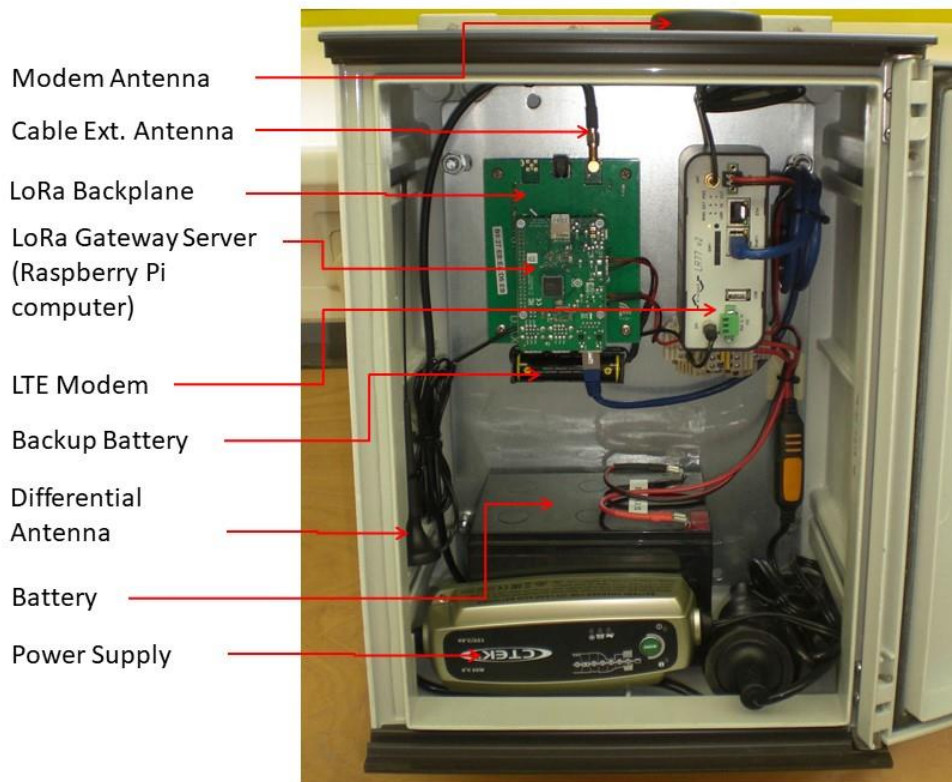
The LoRa server must be installed in a suitable location near the network (approx. 1km). The device consists of the LoRa Concentrator (gateway), the actual server (Raspberry Pi), a UPS with backup battery and a modem. These devices are mounted in a control cabinet and are supplied with mains power. A 12 V lead-gel battery serves as a buffer for the mains power.

Alternatively, a solar power supply can be used if the situation allows.

In addition to the modem antenna, the device must have two other antennas for the concentrator (an internal differential antenna and an external rod antenna).

The device is then mounted on a mast, the antenna as high as possible on it.

An example of the structure of the server:



5 Service / Maintenance

The data of the End Device is stored in a cloud. The web based tool for viewing the data is called “SoilNet Control Panel Application (CPA)”

For detailed description of the CPA please read the manual “SoilNet CPA.pdf”.

The tool will receive the data packets, analysing and decoding it for displaying in a tabular form. It will send a confirmation of receiving the data to the End Device (handshake) and it will provide the data in different “csv” formats.

These values can be used to decide whether maintenance is necessary for an End Device.

Maintenance becomes necessary when the following events occur:

- The batterie is low (below 3,1 V) or empty.
- The last sent entry is no longer current.
- One or more sensors show implausible values

The first case is the simplest of course:

5.1 Battery Replacement

If the battery in the SoilNet End Device is low (< 3,1V) the correct working of the sensors is not ensured. The battery should be replaced.

Most of the lithium batteries come from China. Because of the long delivery time from China, there may be a voltage drop of the normally used batteries (ER34615M) over the time. So the batteries, sold as “new” might have only a voltage about 2,8V for instance.

These batteries must be checked and perhaps activated before use.

5.1.1 Using an activator to “form” a new battery

The tool to activate the batteries is simply a battery holder with a shunt resistor mounted to its back. The resistor is about 18 Ohm / 1W, so the current drawn is about 200mA.

Place the new battery into the activator and connect a Voltmeter in DC mode to its terminals. The voltmeter shows the lower voltage rising with the time. At least the voltage should show not less than 3,4V. This can take 2-5 minutes, depending on the state of the battery.



Figure 12: Measuring battery voltage with activating tool

The batteries we recommend are from the French company “Saft”. They are produced in Europe. They do not show this voltage drop and therefore don’t need to be activated.

The second case may be caused by different items:

- Also, the battery is low since longer time.
- The radio contact may be disturbed. This is often the case if the device is installed completely below the ground and water covers the KG tube. Please make sure the water or mud covers the device maximum 1-2 cm if at all. For newer devices with NBloT please check the internet connection also.

The third case - sensor failure – may be difficult and elaborate:

To check the sensors you have to open the End Device on the bottom side. Please switch off the End Device and unscrew the six screws on the bottom. Carefully pull out the PCB a little bit and disconnect the sensors one by one. It depends on the sensors which tool can be used to check their functionality. Please refer to the manufacture’s notes.

To replace a sensor, you have to release the white MTA contact, open the big cable gland and pull out the cable of the defective sensor. At the end you have to dig out the sensor, insert the new one back in and reconnect the cable accordingly. This is very time-consuming and often does not make sense, because the measuring point is disturbed and the future measuring results can hardly be compared with the previous ones. Fortunately, this happens only extremely rarely.

Often it makes more sense to dispense with one sensor, disconnect it from the board and thus leave the measuring point untouched.

5.2 Read out the data manually

Normally, the data is sent in nearly “real time” and is stored in a cloud.

If the radio transmission fails or the End Device is operated in offline mode, also all the data will be stored internally on SD-card. (In fact, it will always be stored on SD-card!)

To read out the stored data manually, the software “BoxCon” is used also.

- Please launch the software on the computer which is connected to the End Device via the Service Unit (see chapter 3.3.2).
- Make sure the COM port is set to the virtual device, your computers device manager shows for the connected Service Unit.
- In BoxCon, change to the second tab “Box config and data download”.
- Press the red button “Push to activate config mode”.
- Reset the End Device by pressing the black button “reset” on the Service Unit. The BoxCon tab will change and makes the parameter fields accessible.
- On the right side of the tab, press the button “set values of unsend data”. The start sector field takes the value of the “box read sector” on the right side and the End sector field takes the value of the “box write sector” on the right side minus 1. The field “sectors to download” shows the number of unsend data and the grey field at the top of the right side shows the path and the name of the file to be written. The filename consists of the boxnumber as well as the dates and times of start and end.
- Press the “start download” button below the fields. The download begins. This may take a while, depending on the number of data sets. The bar below shows the progress of the download.
- Press the blinking green button “push for measure mode” to leave the download (config) mode. The End Device will start measuring again.
- Pull of the cable of the Service Unit and close the End Device.

6 Firmware Update

Since the software for the End Device is permanently under development, it may be necessary to update the firmware. The tool for updating the devices can also be found on the notebook supplied.

In the directory “c:\SoilNet\Software\Jennic Flashprogrammer”, you will find the file “FlashGUI.exe”. Double-click on the file to install the software.

If the software and the drivers for the USB cable (FTDI) have been installed, the End Device can be programmed with the new firmware.

There is no further documentation for the software. In the following screenshot, only those elements are labelled that are required for a firmware update on the End Device.

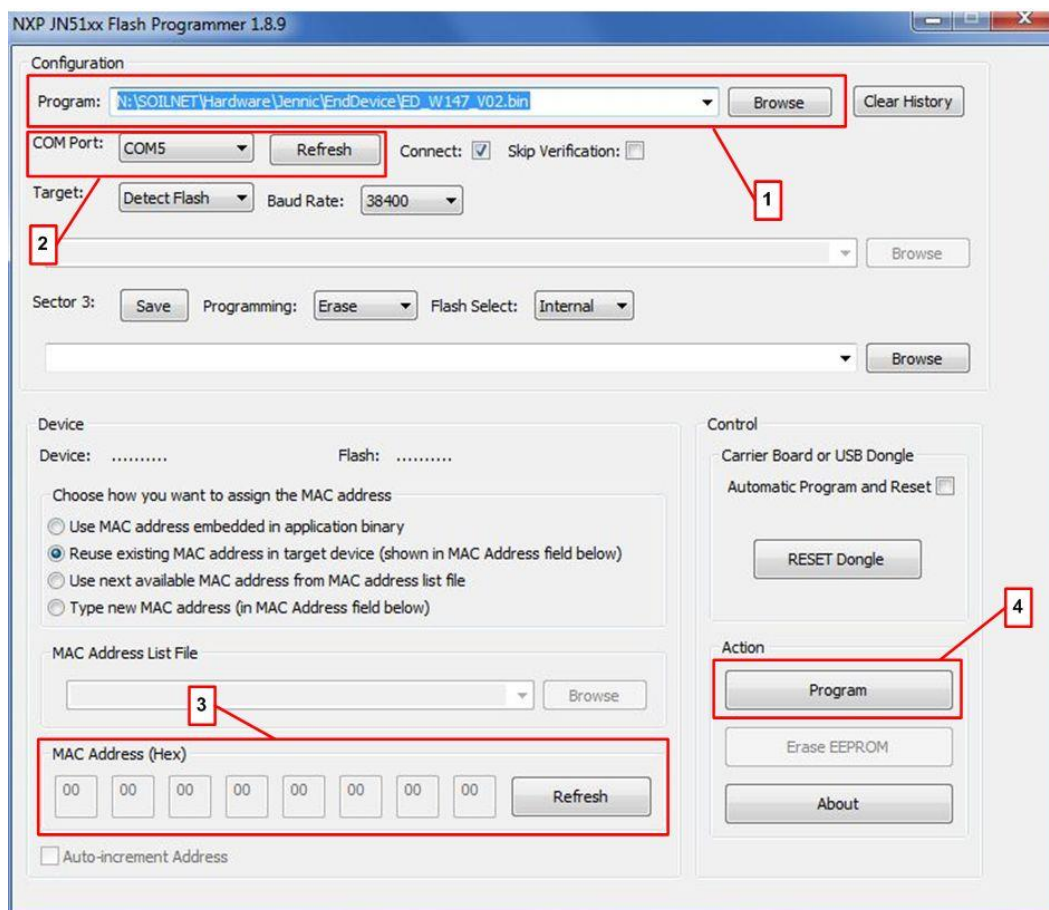


Figure 13: NXP / Jennic Flash Tool

Please follow the described steps:

- Switch off the End-Device and connect it via the Service Unit with the computer.
- Start the Software “**NXP JN51xxFlash Programmer 1.8.9**” (or later version).
- Press and hold both **Reset- AND the Program** buttons on the Service Unit while switching on the End-Device.
- Release the reset button first, then release the program button.
The End-Device is now in program state.
- In the Flash software you’ll find under “Configuration” a dropdown field called COM port (see “2” in figure 13). Here you have to insert the number of the virtual COM port you’ve found in the device manager of your computer. Make sure, the End Device is in program state already, otherwise the flash program will reply an error.
- In the Configuration tab you’ll find a field “Program” where you can browse your actual *.bin file (see “1” in figure 13).
Please find the desired firmware file (e.g..“ED_C17_V77_2.bin”).
- You may press the “Refresh” button (see “3” in figure 13) to verify the correct recognized MAC Adress of the Jennic module.
- Press the “Program” button (see “4” in figure 13) and wait for the transmission of the file and its verifying.
- After programming the End-Device, switch it off.
- Close the Flash Software

If you start again the “BoxCon” Software, after a measurement you will see the actual firmware, the MAC address and some further information in the head row of the program:



7 Appendix: Safety Data Sheet (MSDS)



MATERIAL SAFETY DATA SHEET

(form according to EEC Directive 93/112/EC)

NAME : *LITHIUM, THIONYL CHLORIDE (Li-SOCl₂)*
NON-RECHARGEABLE BATTERIES

1 - IDENTIFICATION (of the product and the supplier)

1.1. Product :

Rechargeable battery

yes	
no	X

Trade name and model : *LITHIUM, THIONYL CHLORIDE (Li-SOCl₂)*
NON-RECHARGEABLE BATTERIES

IEC designation :

Models : LS and LSH series LS 14250, LS 14250 C, LS 14500, LS 14500 C,
LS 17500, LS 26500, LS 26500 C, LS 33600,
LS 33600 C, LSH 26180, LSH 14, LSH 20

Electrochemical system :

Electrodes	Negative electrode Lithium metal (Li)	Positive electrode Thionyl chloride (SOCl ₂)
Electrolyte	Solution of lithium tetrachloroaluminate* (LiAlCl ₄) in thionyl chloride	
Nominal voltage	3.6 Volt	

* Lithium tetrachloroaluminate is a combination of lithium chloride (LiCl) and aluminum chloride (AlCl₃).

1.2 - Supplier :

Name : SAFT
Address : Rue Georges Leclanché - BP 1039 86060
Poitiers Cedex 09 - France
Phone : 33 (0)5 49 55 48 48
Fax : 33 (0)5 49 55 48 50

1.3. - Emergency contact : Poitiers Plant Manager 33 (0)5 49 55 51 01

2 - COMPOSITION (typical weight percentages of basic material within undischarged individual cells)

Metals	%	Plastics	%	Others	%
- Steel (Iron 30 % Nickel 10 %)	35-40*	- PVC	2-3*	- Thionyl chloride	40-46*
- Lithium	4-5*			- Carbon	4
				- Glass	1-4*
				- Aluminum chloride	1.5*
				- Salts	4-7*

* % slightly depending from cell type.

3 - HAZARDS IDENTIFICATION

3.1 - Physical :

The Lithium-Thionyl chloride batteries described in this Material Safety Data Sheet are sealed units which are not hazardous when used according to the recommendations of the manufacturer.

Under normal conditions of use, the electrode materials and liquid electrolyte they contain are non-reactive provided the battery integrity is maintained and seals remain intact. Risk of exposure only in case of abuse (mechanical, thermal, electrical) which leads to the activation of safety valves and/or the rupture of the battery containers. Electrolyte leakage, electrode materials reaction with moisture/water or battery vent/explosion/fire may follow, depending upon the circumstances.

3.2 - Chemical :

**Classification of dangerous substances contained into the product
as per directive 67/548/EEC**

Substance		Content *	Melting point	Classi fication			
N° EEC (CAS N°)	Chemical symbol	Mass %		Letter	Indication of danger	Special risk (1)	Safety advice (2)
231 102 5 (7439-93-2)	Li	4-5	180.5°C	F	Corrosive Flammable	R14/15 R21 R22 R41 R43	S2 S8 S22 S24 S26 S37 S43 S45
231 748 8 (7719-09-7)	SOCl ₂	40-46	-104.5°C	C	Irritant Corrosive Harmful	R14 R21 R22 R35 R37 R41 R42/43	S2 S8 S24 S26 S36 S37 S45
(00744-67-00)	AlCl ₃	≈ 1.5	190°C	C	Irritant Corrosive	R14 R22 R37 R41 R43	S2 S8 S22 S24 S26 S36 S45

* slight variations depending from cell type.

1 - Nature of special risks :

R 14/15	Reacts with water and yields flammable gases
R 21	Harmful in contact with skin
R 22	Harmful if swallowed
R 35	Causes severe burns
R 41	Risk of serious damage to the eye
R 42/43	May cause sensitization by inhalation and skin contact
R 43	May cause sensitization by skin contact

2 - Safety advices :

S 2	Keep out of reach from children
S 8	Keep away from moisture
S 22	Do not breathe dust
S 24	Avoid contact with skin
S 26	In case of contact with eyes, rinse immediately with plenty of water and seek medical attention
S 36	Wear suitable protective clothing
S 37	Wear suitable gloves
S 45	In case of incident, seek medical attention.

4 - FIRST AID MEASURES

In case of battery rupture or explosion, evacuate personnel from contaminated area and provide maximum ventilation to clear out corrosive fumes/gases and pungent odour.

In all case, seek immediate medical attention.

Eye contact : Flush with plenty of water (eyelids held open) for at least 15 minutes.

Skin contact : Remove all contaminated clothing and flush affected areas with plenty of water and soap for at least 15 minutes.
Do not apply greases or ointments.

Ingestion : Dilute by giving plenty of water and get immediate medical attention.
Assure that the victim does not aspirate vomited material by use of positional drainage.
Assure that mucus does not obstruct the airway.
Do not give anything by mouth to an unconscious person.

Inhalation : Remove to fresh air and ventilate the contaminated area.
Give oxygen or artificial respiration if needed.

5 - FIRE-FIGHTING MEASURES

Fire and explosion hazard : The battery can spout vaporized or decomposed electrolyte fumes in case of exposure above 100°C resulting from inappropriate use or the environment. Risk of explosion is increased if the melting point of lithium (180.5°C) is exceeded. Hydrogen coming from the decomposition of lithium metal with water is flammable.

Extinguishing media : *Suitable :* Type D extinguishers, Lith-X
Water may be used only to keep battery cool.
Not to be used : Water in case of battery rupture or explosion (detectable by the pungent odour).

Special exposure hazards : Following cell overheating due to external source or due to improper use, electrolyte leakage or battery container rupture may occur and release inner component/material in the environment.
Eye contact : The electrolyte solution contained in the battery is corrosive to all ocular tissues.
Skin contact : The electrolyte solution contained in the battery is corrosive and causes skin irritation and burns.
Ingestion : The ingestion of electrolyte solution causes tissue damage to throat and gastro/respiratory tract.
Inhalation : Contents of a leaking or ruptured battery can cause respiratory tract, mucus, membrane irritation and edema.

Special protective equipment : Use self-contained breathing apparatus to avoid breathing irritant fumes.
Wear protective clothing and equipment to prevent body contact with electrolyte solution.

6 - ACCIDENTAL RELEASE MEASURES

The material contained within the batteries would only be expelled under abusive conditions.

Using shovel or broom, cover battery or spilled substances with dry sand or, preferably, sodium carbonate (Na₂CO₃) or 1:1 mixture of soda ash and slaked lime. Keep away from water, rain, snow. Place in approved container (after cooling if necessary) and dispose in accordance with local regulations.

7 - HANDLING AND STORAGE

The batteries should not be opened, destroyed nor incinerated since they may leak or rupture and release in the environment the ingredients they contain (see Section 6).

Handling : Do not crush, pierce, short (+) and (-) battery terminals with conductive (i.e. metal) goods. Do not directly heat or solder. Do not throw into fire. Do not mix batteries of different types and brands. Do not mix new and used batteries. Keep batteries in non conductive (i.e. plastic) trays.

Storage : Store in a cool (preferably below 30°C) and ventilated area away from moisture, sources of heat, open flames, food and drink. Keep adequate clearance between walls and batteries. Temperature above 100°C may result in battery leakage and rupture. Since short circuit can cause burn, leakage and rupture hazard, keep batteries in original packaging until use and do not jumble them.

Other : Lithium-Thionyl chloride batteries are not rechargeable and should not be tentatively charged.

Follow Manufacturers recommendations regarding maximum recommended currents and operating temperature range.

Applying pressure on deforming the battery may lead to disassembly followed by eye, skin and throat irritation.

8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

Respiratory protection : *Not necessary under normal use.* In case of battery rupture, use self contained full-face respiratory equipment with type ABEK filter.

Hand protection : *Not necessary under normal use.* Use Viton rubber gloves if handling a leaking or ruptured battery.

Eye protection : *Not necessary under normal use.* Wear safety goggles or glasses with side shields if handling a leaking or ruptured battery.

Skin protection : *Not necessary under normal use* Use rubber apron and protective working in case of handling of a ruptured battery.

9 - PHYSICAL AND CHEMICAL PROPERTIES

9.1 Appearance : (Physical shape and color as supplied)
 Small metal cylinders, hermetically sealed and fitted with an external plastic sleeving.

9.2 Temperature range :

	Continuous	Occasional
in storage	+ 30°C max	-60/+100°C
during discharge	-60/+85°C	-60/+100°C
during charge	NA	NA

9.3 Specific energy :

400- 700 Wh/kg, depending on cell type
(Note : Wh = Nominal voltage x rated Ah as defined in IEC Standard N° 285. Kg = Average battery weight)

9.4 Specific instant power :

2-10 Wh/kg, depending on cell type
(Note : $0.5 \times \text{nominal voltage} \times I_p$ with I_p = current in Amperes delivered by a non discharged battery to half the nominal voltage in 1 second)

9.5 Mechanical resistance : As defined in relevant IEC Standard

9.6 Other :

10 - STABILITY AND REACTIVITY

Conditions to avoid : Heat above 100°C or incinerate.
Deform, mutilate, crush, pierce, disassemble, recharge.
Short circuit.
Prolonged exposure to humid conditions.

Materials to avoid : Oxidizing agents, alkalis, water.
Avoid electrolyte contact with aluminum or zinc.

Hazardous decomposition products :

Hydrogen (H₂) as well as lithium oxide (Li₂O) and lithium hydroxide (LiOH) dust is produced in case of reaction of *lithium metal* with water..

Chlorine (Cl₂), sulfur dioxide (SO₂) and disulfur dichloride (S₂Cl₂) are produced in case of thermal decomposition of *thionyl chloride* above 140°C.

Hydrochloric acid (HCl) and sulfur dioxide (SO₂) are produced in case of reaction of *thionyl chloride* with water at room temperature.

Hydrochloric acid (HCl) fumes, lithium oxide, (Li₂O), lithium hydroxide (LiOH) and aluminum hydroxide (Al(OH)₃) dust are produced in case of reaction of *lithium tetrachloroaluminate* with water.

11 - TOXOLOGICAL INFORMATION

The Saft primary Lithium-Thionyl chloride batteries do not contain toxic materials.

12 - ECOLOGICAL INFORMATION

When properly used or disposed, the Lithium-Thionyl chloride batteries do not present environmental hazard.

13 - DISPOSAL CONSIDERATIONS

Dispose in accordance with applicable regulations which vary from country to country.

(In most countries, the thrashing of used batteries is forbidden and the end-users are invited to dispose them properly, eventually through non profit organizations, mandated by local governments or organized on a voluntary basis by professionals).

Lithium batteries should have their terminals insulated prior to disposal.

13.1 . Incineration : Incineration should never be performed by battery users but eventually by trained professionals in authorized facilities with proper gas and fumes treatment.

13.2 . Landfilling : Leachability regulations (mg/l)

Component	Leachability	EC limit	EPA	Other*
Iron	100			5
Nickel	500	2		0.5

* applicable to France

13.3 . Recycling : Send to authorized recycling facilities, eventually through licensed waste carrier.

14 - TRANSPORT INFORMATION

14.1 United Nations :

UN N°	3090
Classification	9
Packaging	ICAO 903 for Air Transport IMDG for Sea Transport



14.1 International conventions :

Air	IATA	Yes
Sea	IMDG	Yes
Land	ADR (road)	Yes
	RID (rail)	Yes

14.3 Other :

in the USA Code of Federal Regulations
(49 CFR Ch. 1 § 173-185)

15 - REGULATORY INFORMATION

The transport of lithium batteries is regulated by the United Nations as detailed in the *"Model Regulations on the Transport of Dangerous Goods Ref. ST/SG/AC.10/1 Revision 11 1999"*.

Depending on their lithium metal content, design, and ability to pass safety tests defined by UN in the *"Recommendations on the Transport of Dangerous Goods Chapter 38.3 Manual of Tests and Criteria Ref. ST/SG/AC. 10/11 Third Revised Edition 1999"*, the Lithium-thionyl chloride cells and the battery packs may or may not be assigned to the UN N° 3090 Class-9 that is restricted for transport.

Individual Lithium-thionyl chloride cells with less than 0.5 gram of lithium metal content are not restricted for transport.

16 - OTHER INFORMATION / DISCLAIMER

This information has been compiled from sources considered to be dependable and is, to the best of our knowledge and belief, accurate and reliable as of the date compiled. However, no representation, warranty (either expressed or implied) or guarantee is made to the accuracy, reliability or completeness of the information contained herein.

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Signed _____
Lithium Product Manager