OTT HydroMet

KIPP & ZONEN
an OTT HydroMet brand

DustIQ Soiling Monitoring System

Operational Manual

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Table of contents

1 Scope of supply

The following items are included with delivery:

- DustIQ panel
- 4 mounting clamps with bolts, washers and nuts
- Instruction Sheet

2 Order numbers and variant code

2.1 Product variants

Variant	Order number
DustIQ, 35 mm	0386915

2.2 Accessories and spare parts

Item	Order number
PMU485 Smart Setup Hub converts USB to RS-485 and 12 V DC output for Smart and DustIQ setup and upgrade	0382460
10 m cable with 8-pin ODU plug	0386621
25 m cable with 8-pin ODU plug	0386622
50 m cable with 8-pin ODU plug	0386623
100 m cable with 8-pin ODU plug	0386624
Waterproof 8-pin ODU plug only	0386625

3 About this manual

3.1 Other applicable documents and software

The following documents contain further information on installation, maintenance and calibration:

- Datasheet – DustIQ Soiling Monitoring System
- Instruction Manual PMU485 – Smart Setup Hub for RS-485 instruments

The documents above and the following software can be downloaded at www.kippzonen.com:

- Smart Explorer

3.2 General signs and symbols

The signs and symbols used in the operational manual have the following meaning:

Practical tip

This symbol indicates important and useful information.

Action

✓ Prerequisite that must be met before performing an action.

▸ Step 1

⇨ Intermediate result of an action

▸ Step 2

⇨ Result of a completed action

List

- List item, 1st level
  - List item, 2nd level

3.3 Explanation of warnings

To avoid personal injury and material damage, you must observe the safety information and warnings in the operating manual. The warnings use the following danger levels:

WARNING

WARNING

This indicates a potentially hazardous situation. If the hazardous situation is not avoided, it may result in death or serious injuries.

CAUTION

CAUTION

This indicates a potentially hazardous situation. If the hazardous situation is not avoided, it may result in moderately serious or minor injuries.

NOTICE

NOTE

This indicates a situation from which damage may arise. If the situation is not avoided, products may be damaged.

4 General safety instructions

4.1 Intended use

The DustIQ system is used to monitor the loss of light transmission caused by dust, sand, pollen, or any other particles on PV panels.

4.2 Potential misuse

Any use of the product that does not comply with the intended use, be this intentional or negligent, is forbidden by the manufacturer.

- Use the product only as described in the operational manual.

4.3 Personnel qualification

The equipment described in this manual must be installed, operated, maintained and repaired by qualified personnel only.

- Obtain training from OTT HydroMet if necessary.

4.4 Operator obligations

The installer is responsible for observing the safety regulations. Unqualified personnel working on the product can cause risks that could lead to serious injury.

- Have all activities carried out by qualified personnel.
- Ensure that everybody who works on or with the product has read and understood the operational manual.
- Ensure that safety information is observed.
- File the operational manual together with the documentation of the entire system and ensure that it is accessible at all times.
- The operational manual is part of the product, forward the operational manual together with the product.

4.5 Personnel obligations

To avoid equipment damage and injury when handling the product, personnel are obliged to the following:

- Read the operational manual carefully before using the product for the first time.
- Pay attention to all safety information and warnings.
- If you do not understand the information and procedure explanations in this manual, stop the action and contact the service provider for assistance.
- Wear the necessary personal protective equipment.

4.6 Correct handling

If the product is not installed, used and maintained correctly, there is a risk of injury. The manufacturer does not accept any liability for personal injury or material damage resulting from incorrect handling.

- Install and operate the product under the technical conditions described in the operational manual.
- Do not change or convert the product in any way.
- Do not perform any repairs yourself.
- Get OTT HydroMet to examine and repair any defects.
- Ensure that the product is correctly disposed of. Do not dispose of it in household waste.

4.7 Installation and maintenance at high places

When the product is installed and maintained at high places, special safety measures must be taken to avoid personal injury.

- Observe and follow the local safety regulations.
- Use suitable safety equipment.
- Inspect the safety equipment before use.
- Secure the person mounting or maintaining the product against falling down.
- Secure the product against falling down.

4.8 Certification

CE (EU)

The equipment meets the essential requirements of EMC Directive 2014/30/EU.

FCC (US)

FCC Part 15, Class "B" Limits

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

IC (CA)

Canadian Radio Interference-Causing Equipment Regulation, ICES-003, "Class B"

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

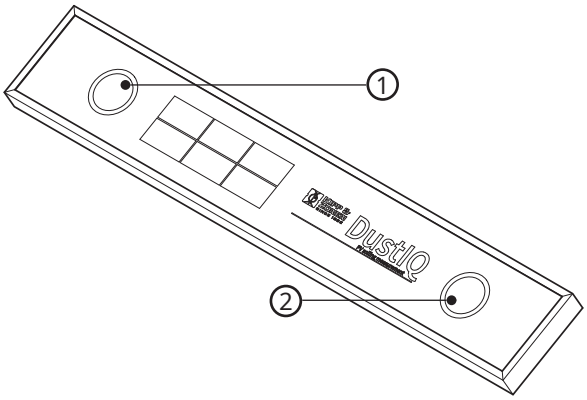
5 Product description

5.1 Design and function

The DustIQ gives an output that is proportional to the light loss caused by the panel soiling. This is expressed as Transmission Loss (TL) or Soiling Ratio (SR). The two optical soiling measurement sensors measure the scattering of the inside of the glass. Soiling on the DustIQ will increase the amount of scattering. The ratio of the amount of transmission loss and the measured optical scattering signal is called the "dust slope", it is the instrument's calibration factor. It depends on the color of the dust and on the optical and electric components of the instrument. The instrument is calibrated for Common Desert Dust. Common Desert Dust is an average of several dust types found through the world on locations with heavy soiling. Locations include: Morocco, Saudi Arabia, Spain, Egypt and India. The DustIQ has no moving parts and it does not need sunlight to operate.

The DustIQ is meant to be mounted next to and in the same plane as the PV panels in the solar park. Communication is possible via Modbus® RTU using a RS485 2-wire connection and the power supply needed is 24 V and minimum 500 mA.

5.2 Product overview



1 Sensor 1

2 Sensor 2

6 Transport, storage, and unpacking

6.1 Transport

- Transport the product always in its original packaging.
- Ensure that the product is not mechanically stressed during transport.

6.2 Storage

- Store within specified temperature ranges.
- Store in dry area.
- Store in original box where possible.

6.3 Unpacking

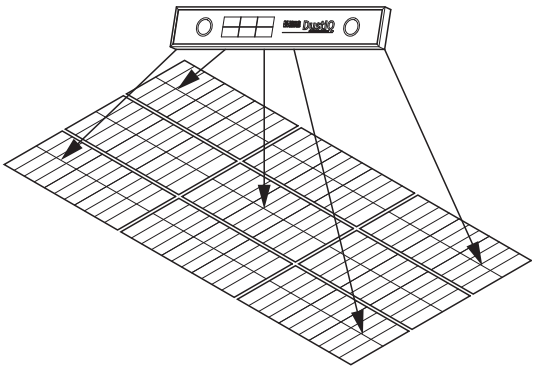
- Carefully remove the product from the packaging.
- Check that the delivery is complete and undamaged.
- If you find any damage or if the delivery is incomplete, then immediately contact your supplier or manufacturer.
- Keep the original packaging for any further transportation.

7 Installation

7.1 Planning installation

For giving a good representation of soiling across the PV plant, several DustIQs should be placed in the PV array. For 1 MW plants, 1 DustIQ in the middle is sufficient. However, for lager plants from 25 MW, 1 DustIQ in the middle and one instrument near each corner are recommended. (At the very corners the soiling can be non-representative for the site, due to wind or other conditions at the edge of the plant). Soiling is a property that can have spatial variability, i.e. the amount of soiling and hence the transmission loss measured on one location in the plant can differ from the measurement on a different location. Even over single PV module sometimes a difference in soiling can already be observed.

DustIQs can be placed at the side, and at the top of PV modules, in the middle of an array or at the sides. Landscape orientation is not advised, as soiling is uneven in the vertical direction, influencing the PV module output. Kipp & Zonen has introduced DustIQ-array-fillers, in order to install the DustIQ in the middle of a row and in the middle of an array, without making gaps in the array.



The number of dust sensors depends on the size of the PV plant, as seen in the table below:

System size (AC) in MW	Multiplier
< 40	2
≥ 40 to < 100	3
≥ 100 to < 300	4
≥ 300 to < 500	5
≥ 500 to < 700	6
≥ 700	7, plus 1 for each additional 200 MW

This is recommended by IEC 61724-1 standard.

Soiling is very site specific. If the wind always blows from the east, greater soiling is expected on the east side of the solar plant. When wind direction changes over seasons, this pattern can shift during the year. Typically, the very ends of an array, and the bottom row of an array suffer more from soiling than the rest of the PV modules. It makes sense to follow up the instrument readings over a period of weeks, and do visual inspection to obtain representative values.

7.2 Mechanical installation

7.2.1 Preparatory work

- Set the Modbus® address before visiting the site. Otherwise a computer and RS-485 / USB converter is required during installation.

7.2.2 Required tools and aids

The following tools and aids are required:

- Allen key, 6 mm
- open-end or ring spanner, SW 13

7.2.3 Installing instrument

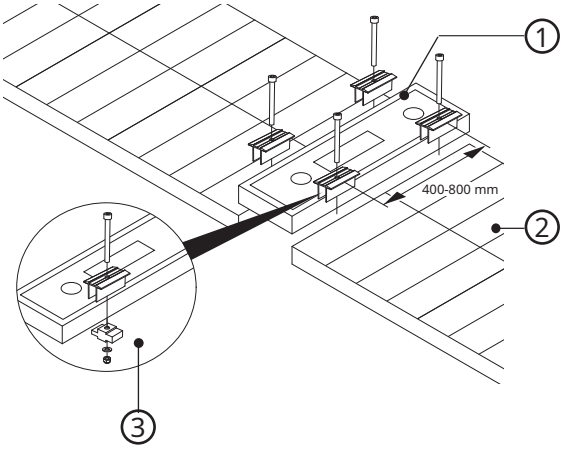
CAUTION

Risk of injury due to sharp edges!

The instrument has slightly sharp edges that can cause injury.

- Wear protective gloves during installation.

The dimensions of the instrument must be observed when installing the instrument.



1 instrument

2 PV panel

3 Clamp (top and bottom part) with screw, nut and washer

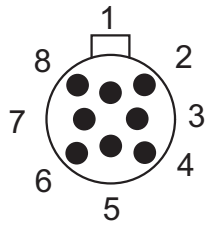
- Align the instrument in between PV panels.
- To install the instrument in between PV panels, mount the 4 clamps on the long sides of the instrument.
- Keep a distance of 400 to 800 mm between the two clamps on either long side of the instrument.
- Attach each clamp with the top and bottom part on the instrument.
- Depending on the height difference between the instrument and the PV panels on either side, rotate the clamps appropriately, see below.
- Insert the screw from above and fasten with the Allen key.
- Secure the clamp from below with the nut and washer and fasten with the spanner.

With the clamps height differences of ±5 mm between the instrument and the PV panels can be compensated. The clamps can be rotated around the Y-axis or X-axis.

7.3 Electrical installation

7.3.1 Electrical connections

The instrument has an 8-pin connector.



8-pin connector

Pin assignment

Wire			
Number	Color	Function	Connect to
1	Red	None	–
2	Blue	Modbus® common / Ground	
3	Green	None	–
4	Yellow	Modbus® RS-485 B+	B/B'/+ on host or USB converter
5	Gray	Modbus® RS-485 A-	A/A'/- on host or USB converter
6	Brown	None	–
7	White	Power 12 to 30 V DC	
8	Black	Power ground / RS-485 common	
Shield		Housing	Ground

7.3.2 Grounding DustIQ

The shield of the cable is connected to the aluminium DustIQ housing through the connector body.

- Secure the DustIQ with a good connection to ground, e.g. by using a lightning conductor.
- Do not connect the cable shield at the junction box, SCADA system or data logger.
- If there is no good ground connection at the instrument, connect the shield at the cable end to ground at the host or junction box.

7.3.3 Power connection

The minimum power supply voltage for the DustIQ is 12 V DC. For reliable performance, it is recommended to use 24 V DC, especially when longer cables are used or if DustIQs are daisy-chained. Furthermore it is strongly recommended to add an external circuit breaker on the power supply lines with a fast acting fuse of maximum 500 mA rating.

When daisy-chaining DustIQs, a bigger fuse is needed. A maximum of 3 DustIQ's can be connected together. In this case, the recommenced fuse rating is the stand-alone rating multiplied by the number of DustIQs:
3 x 500 mA = 1.5 A fast acting.

7.3.4 Power consumption

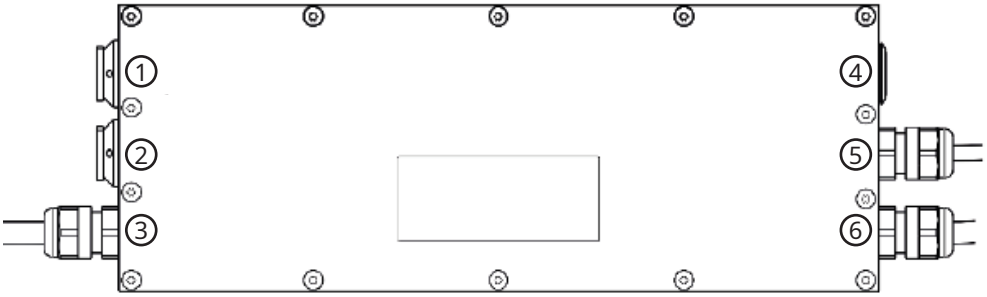
The DustIQ needs a good, stable power supply of 12 to 30 V, 300 mA peak and 200 mA sustained. For optimal performance a 500 mA power supply is recommended.

Voltage (V DC)	Current (mA) / LEDs off	Current (mA) / LEDs on	Power (mW) / Avg. per minute	Std. duty cycle (%)
12	60	130	800	5
24	40	70	1000	5

Typical power consumption of the DustIQ

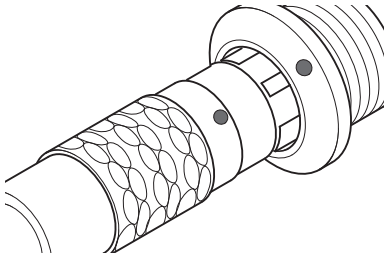
- Maximum input current is 150 mA at 12 V voltage.
- Maximum inrush current is 10 A for 50 µs.

7.3.5 Connecting data cable

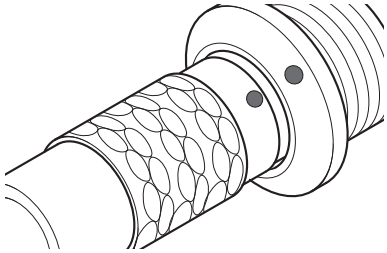


1	Daisy chain or temperature sensor	4	Calibration button
2	Host	5	Solar panel
3	Sensor 2	6	Sensor 1

- Connect all wires in the junction box, SCADA system or data logger.
- Locate the 8-pin connector correctly int he DustIQ socket labelled Host, it only fits one way.
  ⇨ The red dot on the connector is aligned to the red dot on the chassis socket.



- Hold the connector by the end or by the grooved ring and push it into the socket.
  ⇨ Locking is done automatically.

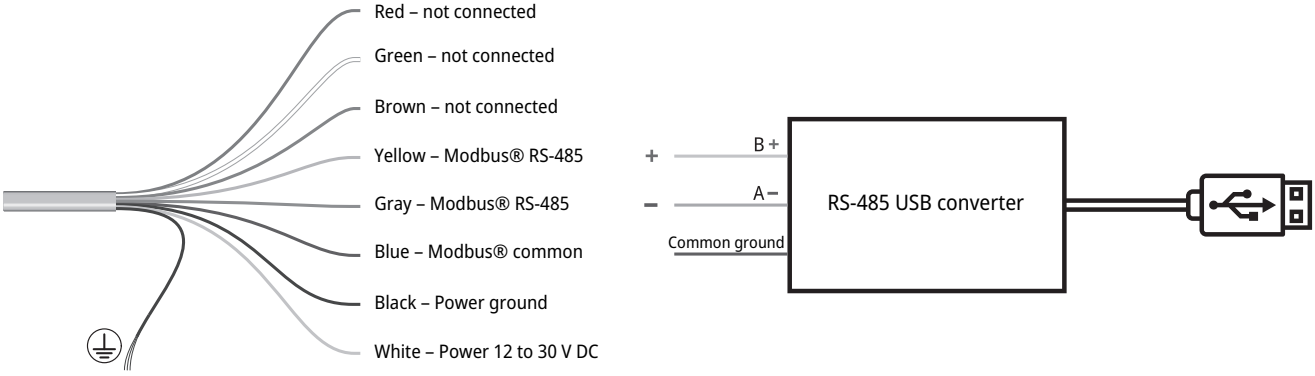


- Arrange the cable with a curve below the instrument so that water drips off, rather than running along the cable up to the connector.
- If the cable needs to be extended, use a high quality UV resistant CAT5 cable.
- Install a proper surge protection on the power and data lines in the junction box or near the data logger.
- To unplug, pull the grooved ring back and then pull out the connector.

Long cables may be used, but the baud rate of the RS-485 digital connection may affect the maximum length.

7.3.6 Connecting USB converter and power supply

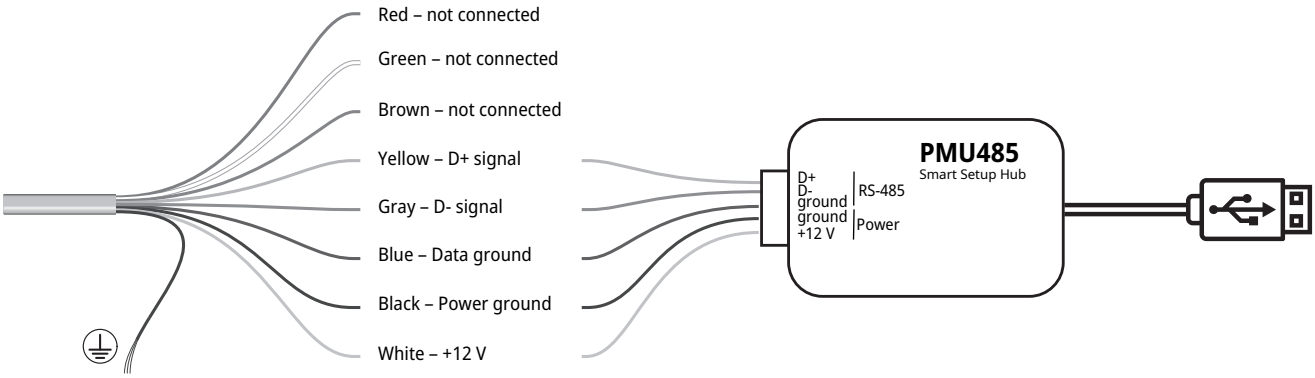
When using an USB-RS485 converter, the following connections need to be made:



- Ensure that the power supply is switched off.
- Connect the white and black wire to the power supply.
- Connect the yellow, gray and blue wires to the RS-485 converter.
- Isolate and seal all wires that are not connected and not in use.
- Plug the connector into the connection socket.
- Switch on the power supply.

7.3.7 Connecting PMU485 Smart Setup Hub

When using the PMU485 Smart Setup Hub, the following connections need to be made:



Further information can be found on the following website: https://www.kippzonen.com/Product/534/PMU485

7.3.8 Connecting RS-485 Modbus® RTU Data

Modbus® RTU normally operates over 2-wire (semi-duplex) RS-485 and the relevant requirements of the EIA-485 standard should be adhered to for reliable communication. A part of the RS-485 standard that is not often used, but is specified for Modbus®, is the requirement for a data common wire that is isolated from the shield or 0 V, to reduce ground potential issues between the two ends of the cable that might be outside the common-mode range of the line-drivers.

This means that for Modbus you should have a 3-wire RS-485 compliant cable (a twisted pair plus extra wire) with shield. The RS-485/Modbus® 'common' wire of the instrument connects to this. This 'common' wire in the cable should not normally be connected to the cable shield or a ground; if it is, only do so at the data acquisition end.

RS-485 requires that a 120 Ohm termination resistor is fitted across the data lines at the data acquisition port, this is because the impedance of a twisted pair data cable is typically in the range of 100 – 150 Ohms.

Whether pull-up and pull-down bias resistors are required depends on the cable length and the bus topography (number of devices connected and in what layout) and the ideal resistor value depends upon the data line voltages. 470 Ohms or 680 Ohms are typically used. These resistors are connected between each data line and the RS-485 'common'. For more than 50 m of cable approximately, it is advised to have the correct bias resistors at the data acquisition port end and a 120 Ohm termination resistor at the instrument.

With the correct configuration, as above, communication should work reliably at 19200 baud up to 1000 m with one device connected. It might be necessary to lengthen the poll/response delay timeout limit at the data acquisition. If multiple devices (with different addresses, of course) are connected to one RS-485 data acquisition input settings depend upon the topography of the network (how the devices are connected) and it may be necessary to reduce the baud rate and increase the polling interval.

7.3.9 Electrical protection

The DustIQ provides different levels of protection against surge, Electro-Static Discharge (ESD) and Electrical Fast Transients (EFT). This internal protection is conditional and effective up to certain limits only as indicated in the below table.

The following information help to best protect the DustIQ.

DC Power lines protection

DustIQ is typically operated from a (nominally) 24 V DC power supply. Usually, this is an industrial type AC-DC switched mode type device with a soft-start. However, It can be powered from a solar panel with batteries and a charger/regulator. DustIQ have reverse polarity protection on the DC power input. It is advised not to use unregulated power supplies that have a switch-on surge.

DustIQ have internal surge protection components. However, the device may be damaged by inserting or removing the cable plug with the power switched on. It is strongly advised to use an industrial surge protection device (SPD), installed as close as is practical to the instrument to minimize pick-up on long cables.

RS-485 Modbus® RTU Surge Protection

DustIQ has surge protection built-in for both RS-485 lines, but they are not electrically isolated. Consequently, it is strongly recommended to use an isolation module as close as is practical to the instrument. DustIQ data lines are protected against fault up to 70 V between datalines and signal common. The device may be damaged by accidentally applying power to the data lines. It is strongly advised to use an industrial surge protection device (SPD), installed as close as is practical to the instrument. Ideally, this should be electrically isolated.

Power protection parameters

Power Supply Surge Protection V DC+ and V DC-	TVS Diode and Metal Oxide Varistor
Max. surge current (8/20uS)	800 A
Peak pulse power	1500 W
Power reverse protection	Included
ESD protection	Up to 30 KV

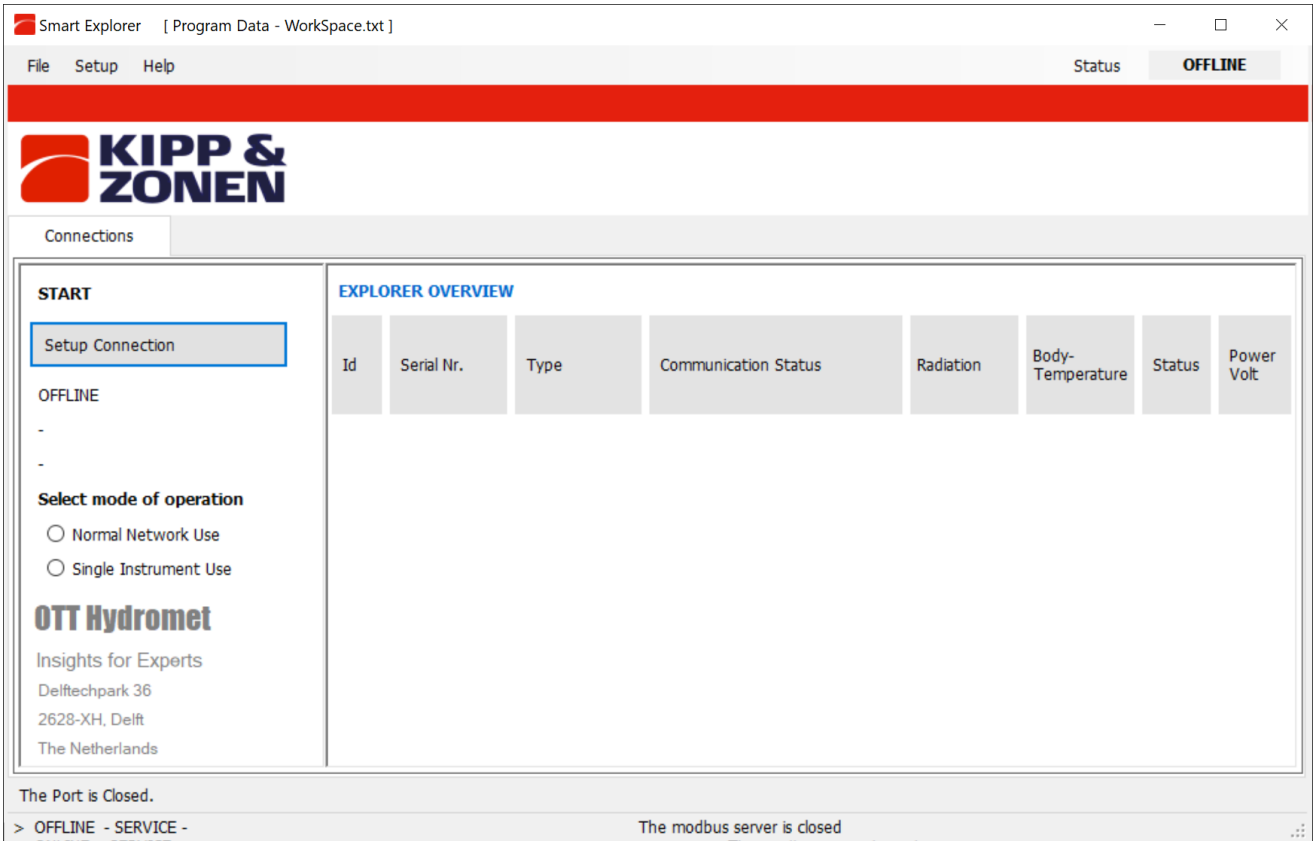
Data-line protection parameters

RS-485 Surge Protection Data+/Data- to signal ground	Gas Discharge Tube, TVS Diode and Poly Switch Device
DC sparkover voltage (@ 100 V/s)	90 V
Impulse discharge current (8/20 uS; 300 hits both polarities)	100 A
Peak impulse voltage	400 V
Trigger current	200 mA
Max. block time	1 uS

8 Commissioning

8.1 Instrument set-up

The Smart Explorer software Version 2.0.1.0 or newer, allows to configure a DustIQ and to collect real-time data. After the first start, the window below appears:



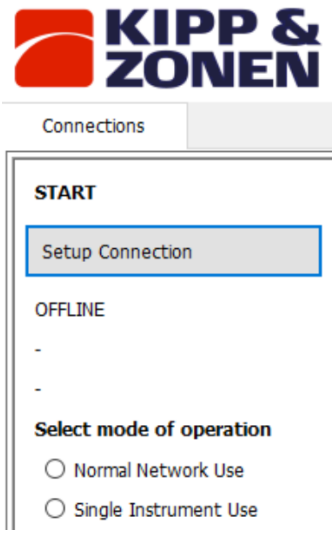
The factory default communication parameters are as follows:

- Modbus® baud rate: 19200
- Parity: even
- Data bits: 8
- Stop bits: 1
- Address: 1
- Local dust profile: Common Desert Dust (CDD)

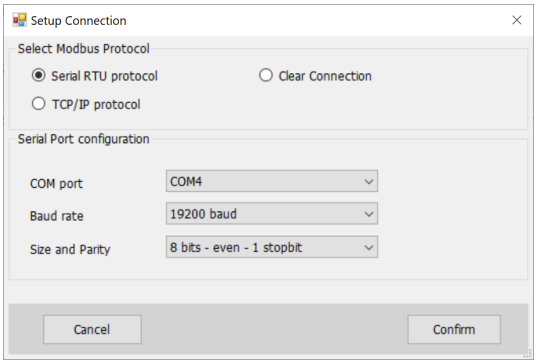
- If using the software on-site, ensure that the software is already installed on the laptop.
- Download the Smart Explorer software and the manuals at the following address: www.otthydromet.com

8.1.1 Establishing connections

- To establish a connection to the instrument, click on the **Setup Connection** button.



- Activate the *Serial RTU protocol* to establish the direct RS-485 connection.



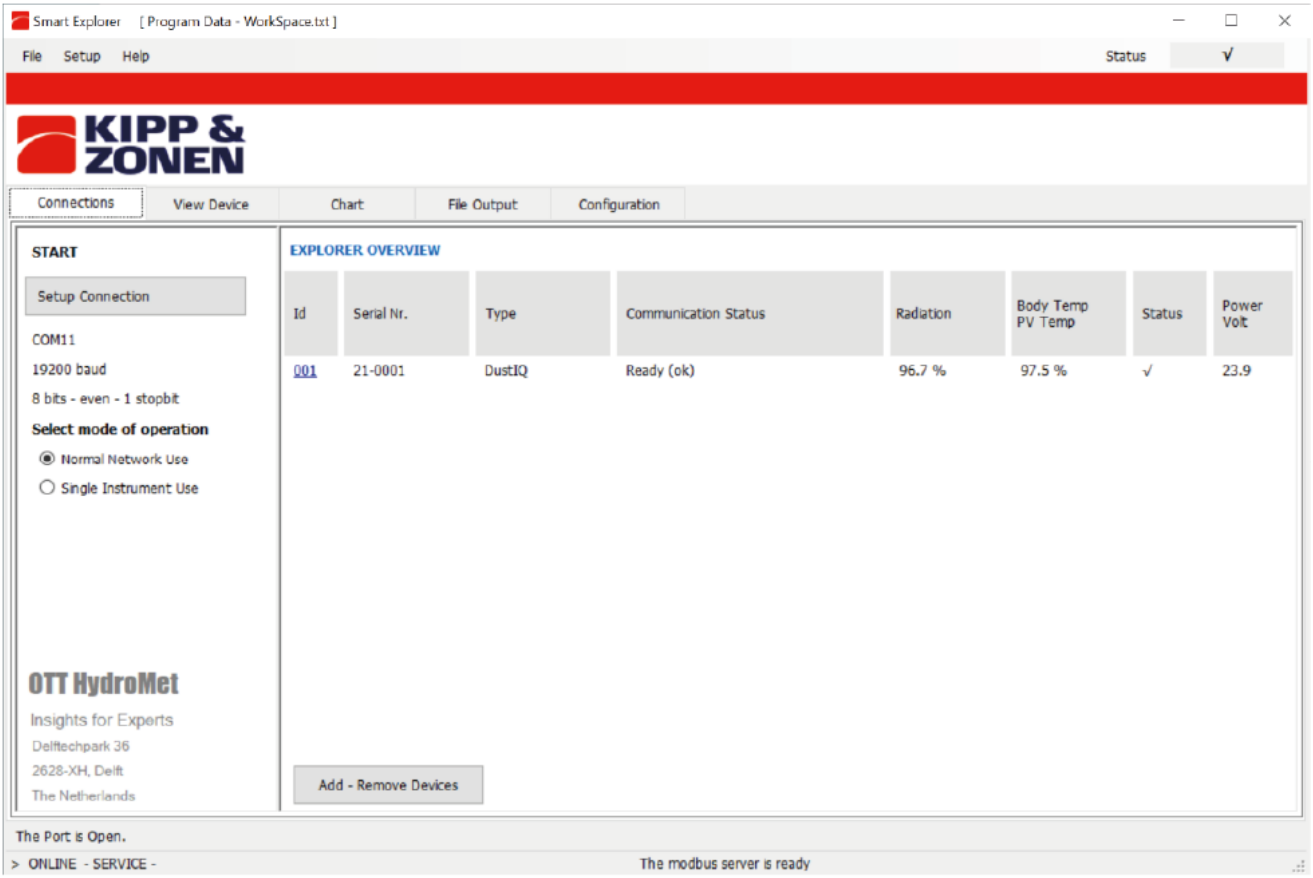
- Select the COM port (see Windows Device Manager).
- Leave the other factory settings unchanged.
- Click on the **Confirm** button to save the settings.

8.1.2 Checking and changing setups

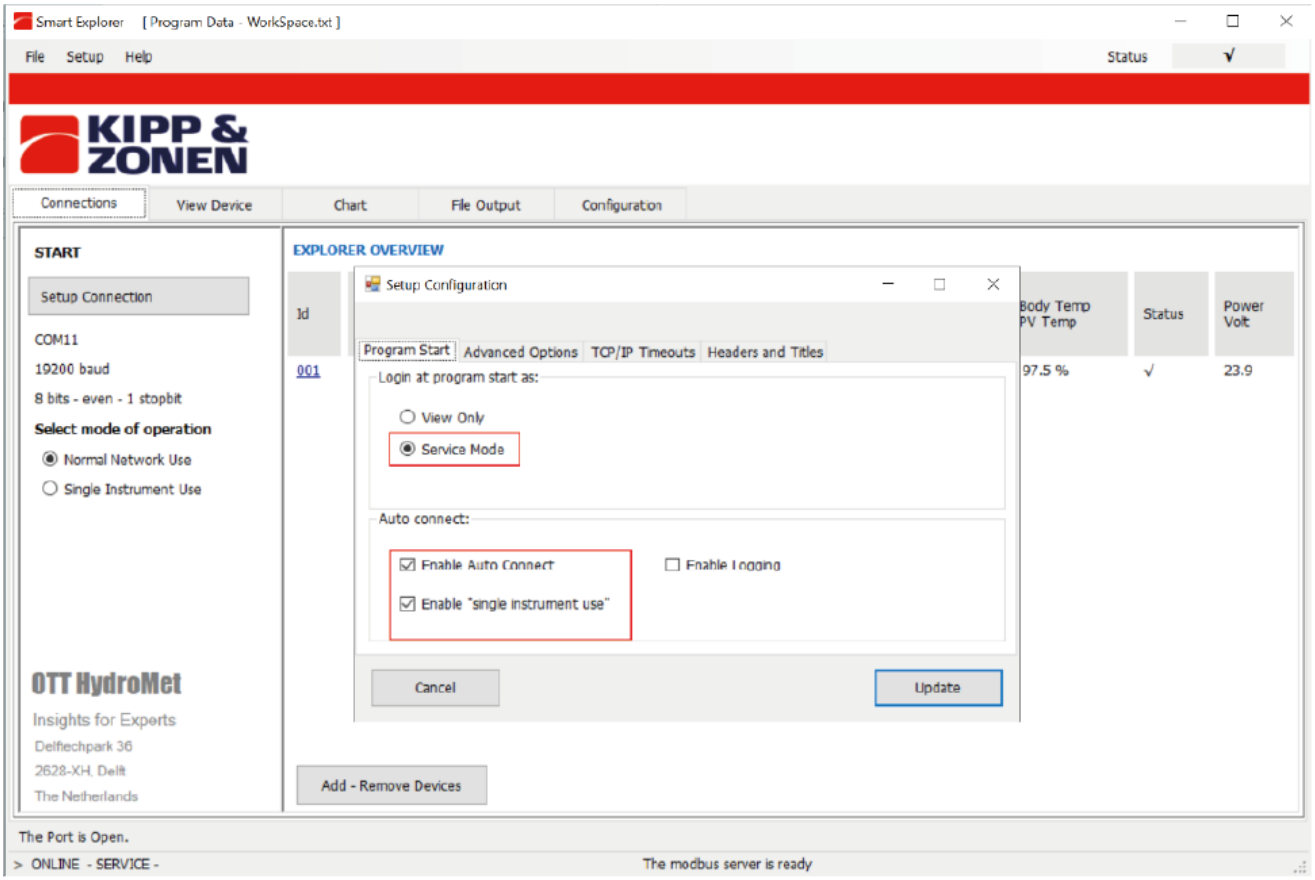
Once the Smart Explorer software ist able to communicate with the attached instrument, the setups can be checked and changed.

- The program starts in normal network use, which means that several instruments can be attached to monitor.
- Changing setting is best done with only one instrument attached.
- Allow 5 to 10 minutes for the instrument to stabilise before reading the measurements.

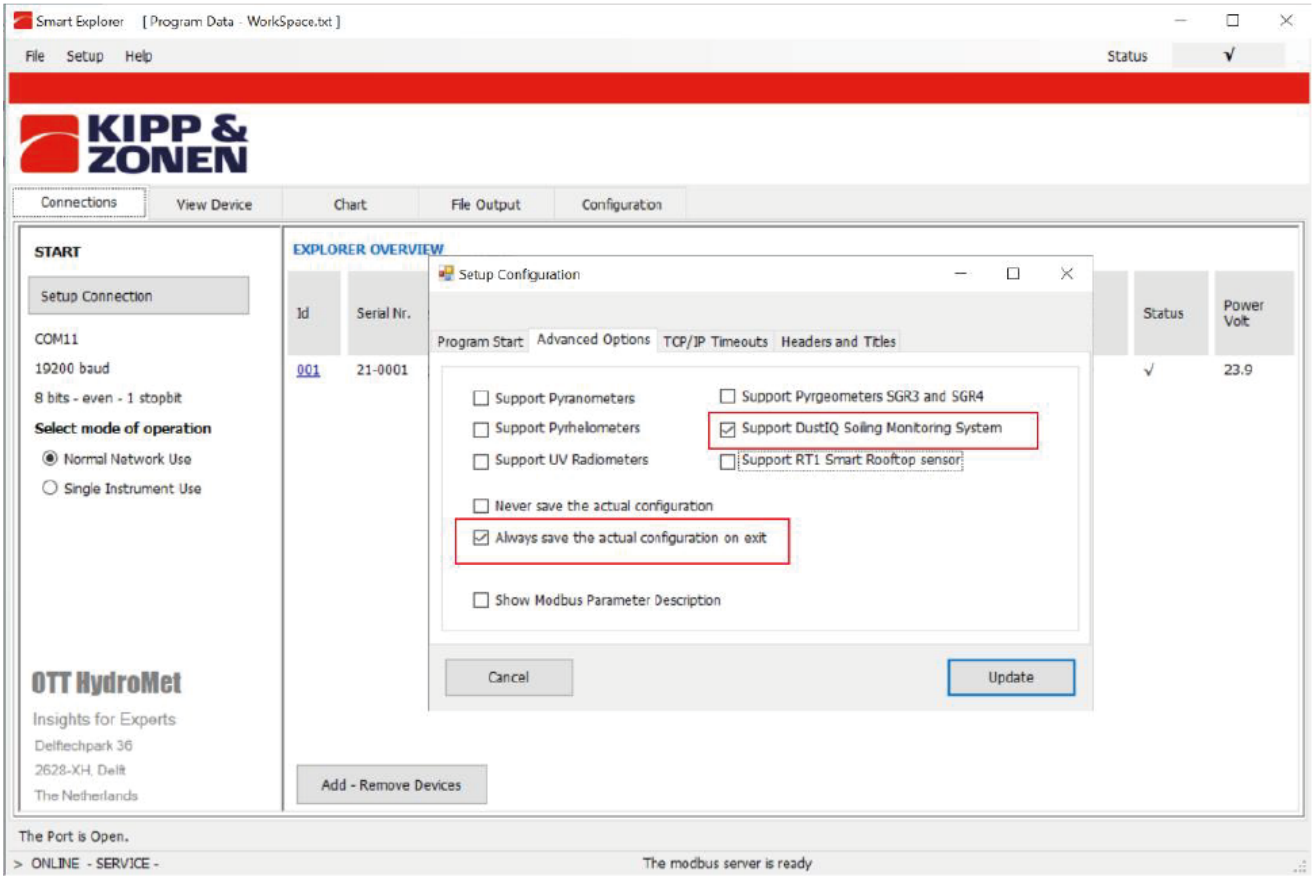
- Start the Smart Explorer software.



- Click on the *Setup* menu and check whether the following settings are activated:



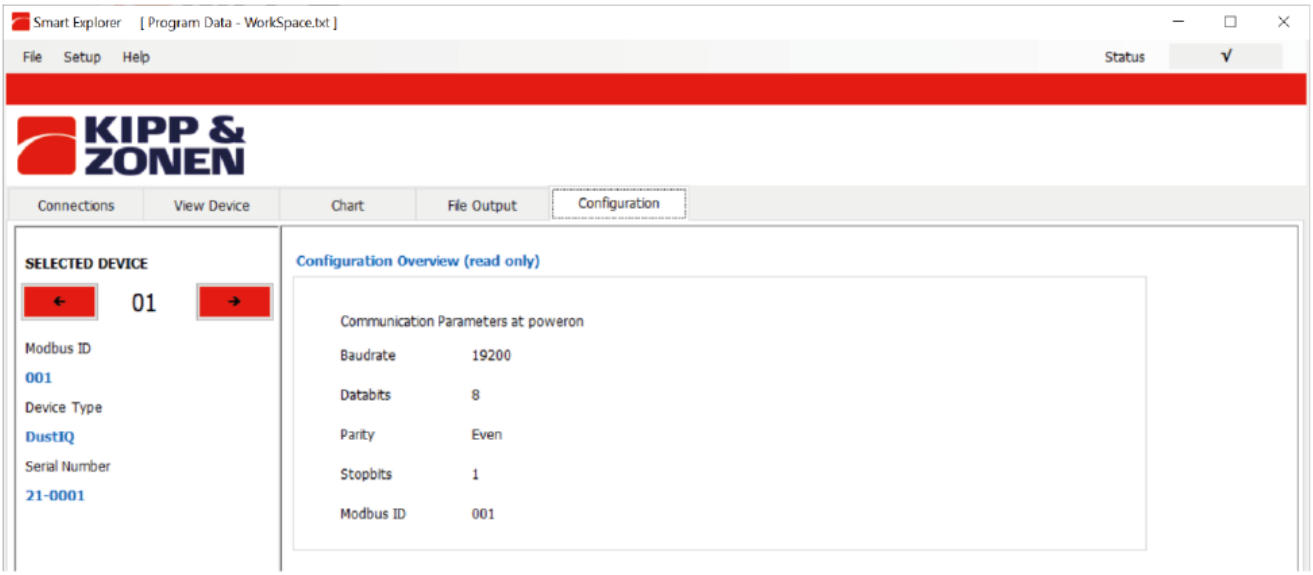
- Click on the *Advanced Options* tab and check whether the following settings are activated:



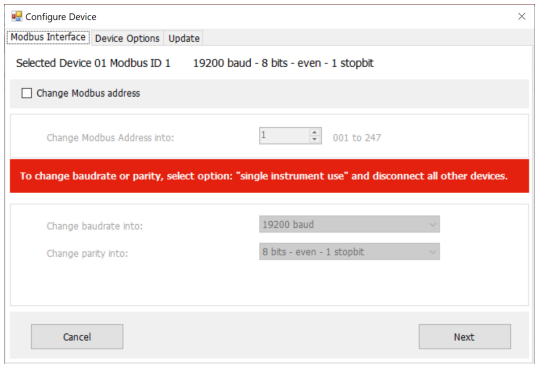
- Adjust the settings if necessary.
- Click on the **Update** button to save the settings.

8.1.3 Adjusting the communication parameters

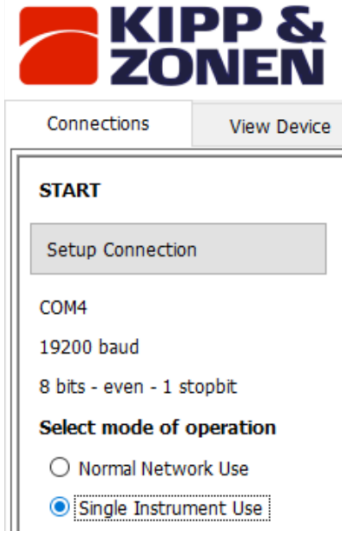
- Click on the *Configuration* tab to access the current communication parameters.



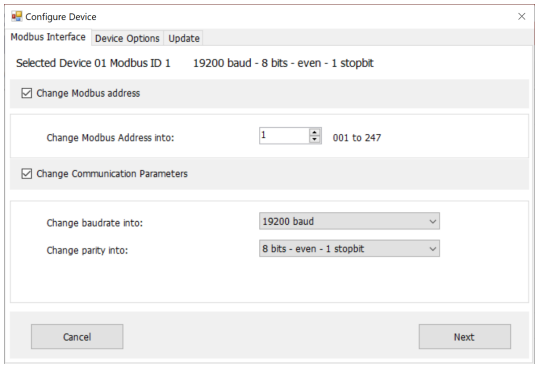
- To change the parameters, click on the **Configure Device** button.
  ⇨ The following warning appears:



- To change the Modbus address, the baud rate and the parity, close the window and activate the *Single Instrument Use* operating mode on the *Connections* tab. The Modbus address can also be changed in the *Normal Network Use* operating mode.

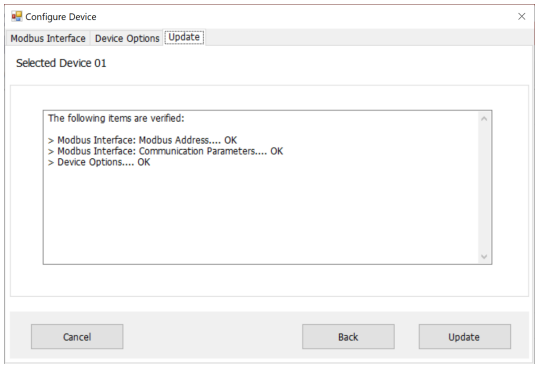


- Go to the *Configuration* tab and click on the **Configure Device** button again.
- Activate the *Change Modbus address* checkbox and set the new address.



- Activate the *Change Communication Parameters* checkbox and select the baud rate and parity.

- Click on the **Next** button.
  - ⇨ The *Update* tab appears:



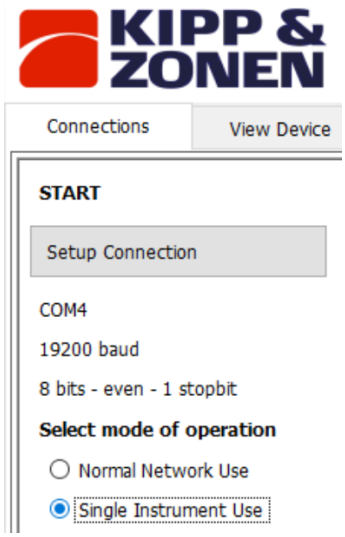
- Click on the **Update** button to save the settings.

⇨ Following the update, the instrument is reset and is ready for operation again after approximately 1 minute.

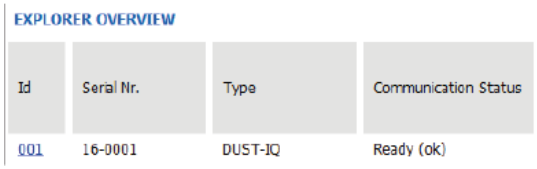
⇨ The communication parameters are changed and the *Connections* tab appears.

8.1.4 Finding an instrument with unknown communication parameters

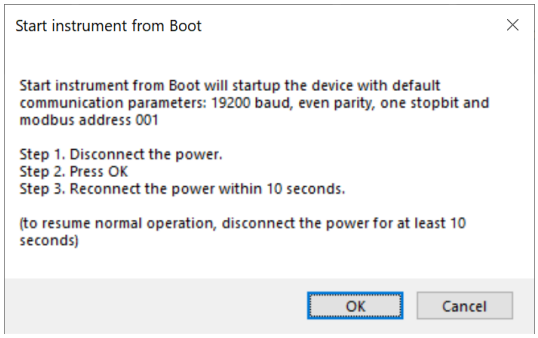
- Activate the *Single Instrument Use* operating mode on the *Connections* tab.



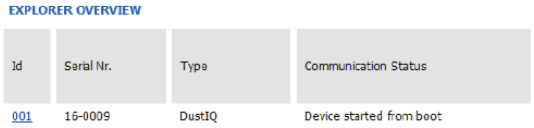
- If only the Modbus address is unknown, click on the **Send Broadcast** button.
  - ⇨ The connected instrument is displayed:



- If no instrument is found, click on the **Start From Boot** button.
  - ⇨ The following window appears:



- Follow the instructions in the window.
  - ⇨ The connected instrument is displayed:



  - ⇨ After approximately 1 minute, reliable measurement results appear on the *Connections* tab.
- Check the communication parameters on the *Configuration* tab.
- Switch off the instrument and switch it back on after 10 seconds to restore normal operation.

9 Operation

9.1 Taking and saving measurements

The instruments require suitable sources of power to operate and take measurements.

- To save the measurements, connect the instrument to a readout or data storage device. The instrument has no internal data memory.

9.2 Collecting data

An optimal setting for the data collection interval is to sample every 1 to 15 minutes and later post-process the data and remove data points influenced by e.g. rain or dew.

- For setting up the combination of the instrument and data storage read the manual of the data collection device.

9.3 Taring and local dust calibration procedures

DustIQs are factory calibrated for 'Common Desert Dust' (CDD), which reflects an average dust-color from various high-soiling locations worldwide. It is recommended to operate the DustIQ using this factory calibration. However, when the user finds that the DustIQ readings do not correspond to the soiling loss of their PV system (obtained by comparing soiled and cleaned measurements), applying an multiplication factor as a post-processing step to DustIQ SR readings is recommended. (e.g. SR x 1.02)

Alternatively, a local dust calibration of DustIQ is possible. This can be performed using the built-in PV cell, calibrating the device for the local dust color. Note that local calibration requires extensive care and precision. Refer to the calibration instruction sheet.

9.3.1 Local dust measurements

The instrument are calibrated with 'Common Desert Dust' (CDD). While this generally provides accurate readings, the local dust properties might differ in terms of color and spectral properties compared to dust used for the factory calibration. To ensure DustIQ's measurements reflect the overall soiling of the PV string/plant and local dust properties, consider either of the following correction methods:

Power analysis method

1. **Power:** Monitor and record the power output of a PV string before and after cleaning the panels. Ensure that these measurements are taken under similar conditions to avoid variations caused by other factors. Performed at solar noon with preferably stable weather conditions.
2. **Adaptation factor calculation:**
   - **Pre-cleaning measurement:** Measure and record the power output of the PV string, along with corresponding temperature and irradiance levels.
   - **Post-cleaning measurement:** After cleaning, measure and record the power output again under similar temperature and irradiance conditions – in a steady state where panels are cleaned and dried.
   - **Calculate the difference:** Determine the difference in power output before and after cleaning. By dividing the soiled with the clean power, the PV transmission loss [%] can be determined.
   - **Apply the factor:** To correct the TL of the DustIQ, calculate a correction factor C, which is TL (PV system) / TL (DustIQ). To obtain a corrected TL value of the DustIQ, multiply its output with the factor C.

3. **Temperature and irradiance consideration:**
   - **Temperature adjustment:** Use back panel temperature sensors to measure the PV panel temperature during power output recordings. Normalize the energy output data to a standard temperature to account for variations that affect PV efficiency.
   - **Irradiance adjustment:** Use irradiance sensors (preferably plane of array irradiance) to measure sunlight intensity during the recordings. Normalize the energy output data to a standard irradiance level to ensure that changes in sunlight intensity do not affect the calibration results.
4. **Implementing adjustments:**
   - **Data normalization:** Adjust the recorded energy outputs for temperature and irradiance variations using manufacturers data sheets. For example, if the temperature increases, the energy output typically decreases slightly, and this should be factored into your calculations.

Optional local calibration method

Local calibration of DustIQ to the specific dust slope can also be performed as an optional procedure. This method involves using the built-in PV cell to correlate the local soiling effects on an actual PV cell to DustIQ measurements. Please note that this method requires strict adherence to specified conditions and procedures to avoid inaccurate data. Ensure that the calibration process is accurately followed to achieve reliable results.

9.3.2 Post-processing of old DustIQ data after local dust calibration

For some DustIQ users, there is a need to correct older data which was collected before the local calibration was performed. The local dust calibration changes the dust slope, making the old data qualitative rather than quantitative. If the optional local calibration has been implemented, follow this method to gain quantitative insight into the historical data.

The following method applies for both dust slopes. Once finished with 1st dust slope, it should be applied to the 2nd dust slope. The old recorded TL can be post-processed to the new ones by calculating TL_{new} for each data point.

Step 1

- Retrieve the dust slope from the DustIQ or calibration certificate:

– The old dust slope must be obtained by reading and writing down the Modbus register 36 (Sensitivity_Sensor 1) before local dust calibration. It's a long integer value in the range of 30 to 300 and fully instrument specific.

– For DustIQs that have not been upgraded and never had a successful local dust calibration this is also the value Sensitivity_Sensor 1 on the calibration sheet.

Step 2

- Retrieve the dust slope from the DustIQ:

– The new dust slope can be obtained by reading Modbus register 36 (Sensitivity_Sensor 1) after the local dust calibration. By dividing the new dust slope by the old dust slope, a correction factor can be obtained.

After obtaining the S_{old} and S_{new} the old TL can be post-processed using formula 1:

$$TL_{new} = \frac{S_{new}}{S_{old}} TL_{old}$$

TL_{new} New corrected transmission loss

TL_{old} Old uncorrected transmission loss

S_{new} New sensitivity after local dust calibration

S_{old} Old sensitivity before local dust calibration

This is also valid for data obtained with other DustIQs on the same PV plant that the user can't or doesn't want to locally calibrate.

The new post-processed Soiling Ratio (SR_{new}) can also be calculated from the old Soiling Ratio (SR_{old}) using formula 2:

$$SR_{new} = 100 - \frac{S_{new}}{S_{old}}(100 - SR_{old})$$

Simple post-processing workflow:

Step	Action	Result
1	Retrieve and record Modbus register 36 **before** calibration	S_{old}
2	Retrieve and record Modbus register 36 **after** calibration	S_{new}
3	Calculate the correction factor	$CF = S_{new} / S_{old}$
4	Calculate TL_{new}	$TL_{new} = TL_{old} * CF$
	or	
5	Calculate SR_{new}	$SR_{new} = 100 – CF * (100 – SR_{old})$

i For any calibration method applied, it is recommended to take close-up pictures of the DustIQ sensors and adjacent PV panels before and after cleaning. This practice helps identify possible errors that may occur during the calibration process and ensures accurate documentation of the condition of the equipment.

10 Maintenance

10.1 Maintenance schedule

The frequency of cleaning is dependent upon the local weather and environmental conditions.

The following maintenance intervals are recommended:

Interval	Activity	Performed by
Annually	▸ Check all electrical connections. ▸ Check all cables for damage. ▸ Check the instrument mounting.	Operator

10.2 Cleaning

The front window of the DustIQ is made of the same glass type as regular PV modules. Therefore, the cleaning cycles for the DustIQ are the same as those for PV panels found in commercial solar parks.

- Ensure that the surface of the panel is not scratched.
- Do not use abrasive or corrosive cleaners.

10.3 Calibrating

The DustIQ gives an output that is proportional to the light loss caused by the panel soiling. It uses internal correction for possible drift in optical or electric components and therefore needs no calibration. Optional methods introduced in chapter Taring and local dust calibration procedures [▸ 27] can be applied occasionally, but they are not a necessity.

11 Troubleshooting

11.1 Error elimination

Error	Possible cause	Corrective action
Communication not possible / instrument LEDs do not light up	– Instrument not powered – Cable not connected	▸ Check the connection. ▸ Checkt the cable. ▸ Check the power supply.
Communication not possible / instrument LEDs do light up	Communication issue	▸ Check the Modbus® address and the baud rate. ▸ If all fails, "start from boot". Reset the instrument's communication parameters (e.g baud rate, modbus address, etc.) using smart explorer.
Output signal not available or incorrect	Instrument does not work properly	▸ Report any malfunction or damage to the representative of OTT HydroMet.

12 Repair

12.1 Customer support

- Have repairs carried out by OTT HydroMet service personnel.
- Only carry out repairs yourself, if you have first consulted OTT HydroMet.
- Contact your local representative: www.otthydromet.com/en/contact-us
- Include the following information:

– instrument model
– instrument serial number
– details of the fault or problem
– examples of data files
– readout device or data acquisition system
– interfaces and power supplies
– history of any previous repairs or modifications
– pictures of the installation
– overview of the local environment conditions

13 Notes on disposing of old devices

Member States of the European Union

In accordance with the German Electrical and Electronic Equipment Act (ElektroG; national implementation of EU Directive 2012/19/EU), OTT HydroMet takes back old devices in the Member States of the European Union and disposes of them in the proper manner. The devices that this concerns are labeled with the following symbol:

- For further information on the take-back procedure contact OTT HydroMet:

OTT HydroMet B.V.
Service & Technical Support
Delftechpark 36
2628 XH Delft
The Netherlands
phone: +31 15 2755 210
email: solar-info@otthydromet.com

All other countries

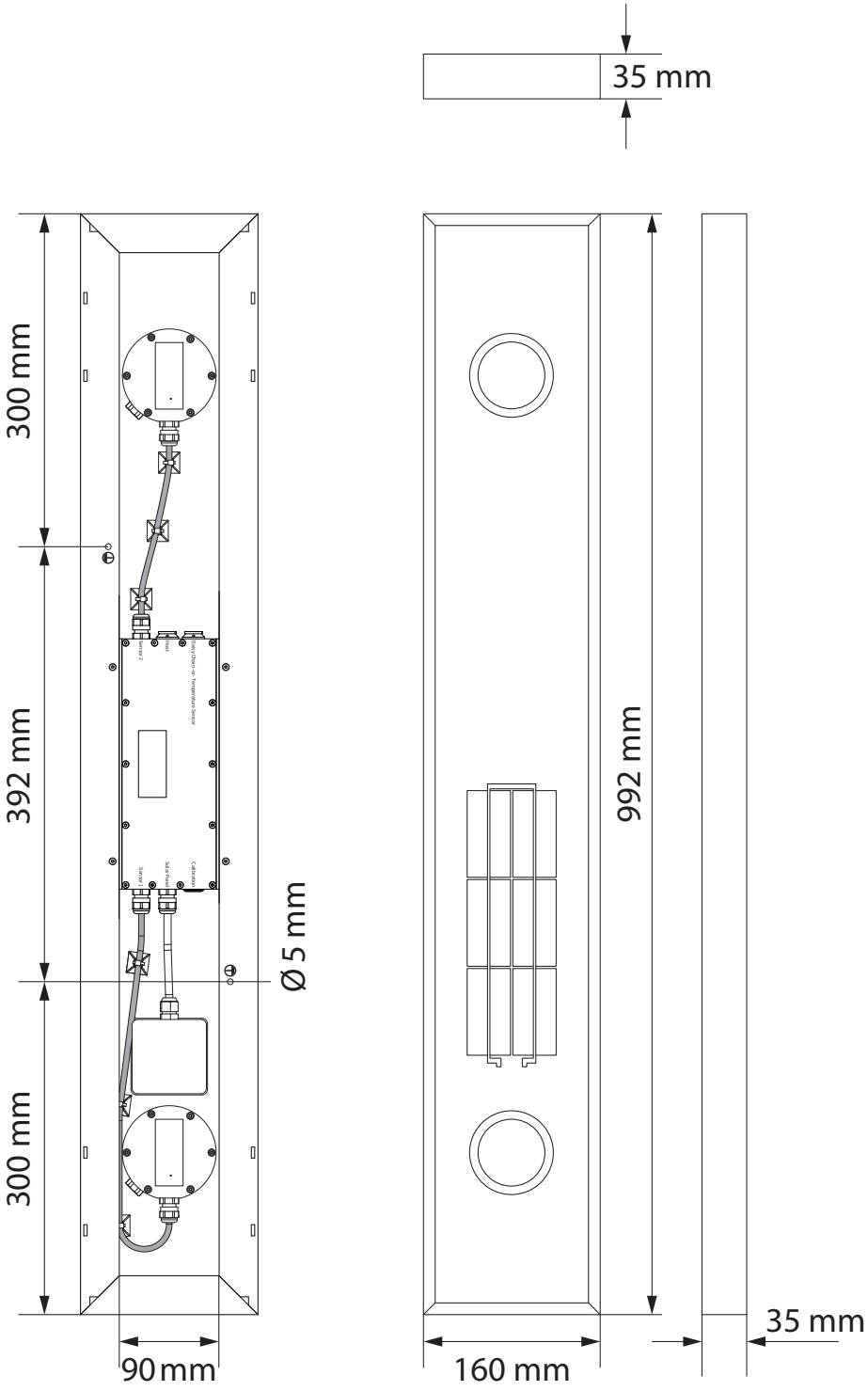
- Dispose of the product in the proper manner following decommissioning.
- Observe the country-specific regulations on disposing of electronic equipment.
- Do NOT dispose of the product in household waste.

14 Technical data

14.1 Optical and electrical data

Specification	Value
Transmission Loss (TL) range	Percentage of sunlight that is blocked or scattered in such a way that it does not reach the actual solar cells: 0 to 50 %
Soiling Ratio (SR) range	100 to 50 % (SR = 100 – TL)
Accuracy	Uncertainty: 1 % + 0.1 x reading e.g. TL = 5 % Uncertainty = 1 % + 0.1 x 5 % = 1.5 % This means that the true TL value is 5 % (+/- 1.5 %) = between 3.5 % and 6.5 %
Operating temperature range	-20 °C to +60 °C (-4 °F to +140 °F)
Storage temperature range	-20 °C to +80 °C (-4 °F to +176 ˚F)
PV panel temperature sensor	-20 °C to +100 °C, ±1 °C (-4 °F to +212 °F, ±1.8 °F)
Protection type	IP65
Tilt X and Y-axis	-180° to 180° ; ±1°
Communication	Modbus® RTU over 2-wire RS-485
Daisy-chain capability	3 instruments maximum in one chain. Only the last device can have the PV panel temperature sensor attached.
Connection	8-pin ODU connector
Power	12 to 30 V DC, 70 to 200 mA at 24 V, minimum 500 mA power supply is advised
Power consumption	< 2.5 Watt
In rush current	10 A for 50 µs
Glass type	Glass with anti-reflection coating as used for silicon PV modules

14.2 Dimensions and weight



Specification	Value
Dimensions packed	120 x 20 x 8 cm
Dimensions unpacked	99 x 16 x 3.5 cm
Weight packed	5.6 kg
Weight unpacked	DustIQ unit: 4 kg Mounting clamps: 600 g

15 Appendix

15.1 Overview of the Modbus® registers

These registers are read-only and 16 bits wide unless otherwise specified.

The base of the input register block is set to 1 (MODBUS PLC address [base 1]), or 0 (MODBUS protocol address [base 0]) and occupies max. 100 registers (0-99, [base 0]).

The address field in the table below is the protocol address with base 0 and not the PLC address with base 1.

Common data block DustIQ

Parameter	Address	R/W	SZ	Level	Description
IR_DEVICE_TYPE	0	R	U	All	Device type of the DUST-IQ sensor 800 for DustIQ
IR_DATAMODEL_VERSION	1	R	U	All	Version of the data model (= 303 for current version)
IR_SOFTWARE_VERSION	2	R	U	All	Software version of the firmware (22000 or higher)
IR_BATCH_NUMBER	3	R	U	All	Production year in yy format
IR_SERIAL_NUMBER	4	R	U	All	Production serial number for the above mentioned year from 0000 to 9999
IR_HARDWARE_VERSION	5	R	U	All	Hardware version (= 5 for current hardware)
IR_CALIBRATION_YEAR	6	R	U	All	Factory calibration year 2000 to 2099
IR_CALIBRATION_MONTH	7	R	U	All	Factory calibration month 1 to 12
IR_CALIBRATION_DAY	8	R	U	All	Factory calibration day 1 to 31
RESERVED	9-19	–	–	–	Reserved for future expansion

Real-time data block, soiling sensor 1 (sensor closest to the integrated PV cell)

Parameter	Address	R/W	SZ	Level	Description
IR_SOILING_RATIO_SENSOR1	20	R	U	N, S	Soiling ratio SENSOR 1 in ‰ (per mille), divide by 10 for % Valid values are 1010 to 500 ‰ 9999 when not valid
IR_TR_LOSS_SENSOR1	21	R	S	N, S	Transmission loss SENSOR 1 ‰ (per mille), divide by 10 for % Valid values are -10 to +500 ‰ 9999 when not valid
RESERVED	22-23	–	–	–	Reserved for future expansion

Real-time data block, soiling sensor 2

Parameter	Address	R/W	SZ	Level	Description
IR_SOILING_RATIO_SENSOR2	24	R	U	N, S	Soiling ratio SENSOR 2 in ‰ (per mille), divide by 10 for % Valid values are 1010 to 500 ‰ 9999 when not valid

Parameter	Address	R/W	SZ	Level	Description
IR_TR_LOSS_SENSOR2	25	R	S	N, S	Transmission loss SENSOR 2 ‰ (per mille), divide by 10 for % Valid values are -10 to +500 ‰ 9999 when not valid
IR_CALIBRATION_STATUS_BEFORE	26	R	U	N, S	Informs on **readiness** of DustIQ for local dust calibration
IR_CALIBRATION_STATUS_AFTER	27	R	U	N, S	Informs on **completion** of DustIQ local dust calibration

Tilt sensor block

Parameter	Address	R/W	SZ	Level	Description
IR_TILT_X_DIRECTION	28	R	S	All	Tilt X direction (long axis) -179.9 to +180.0 in steps of 0.1 degree
IR_TILT_Y_DIRECTION	29	R	S	All	Tilt Y direction (short axis) -179.9 to +180.0 in steps of 0.1 degree
RESERVED	30	–	–	–	Reserved for future expansion

Temperature sensor block

Parameter	Address	R/W	SZ	Level	Description
IR_BACKPANEL_TEMP	31	R	U	All	PV panel temperature in 0.1 Kelvin. Value -2732 and divided by 10 is Celsius

Device common block

Parameter	Address	R/W	SZ	Level	Description
IR_DEVICE_VOLTAGE	32	R	U	All	Device voltage in mV
IR_OPERATIONAL_MODE	33	R	U	All	Operational mode: normal = 1, (service = 2 , calibration = 3)
IR_STATUS_FLAGS	34	R	U	All	Device status flags (0 = status OK)
RESERVED	35	R	U	All	Reserved
IR_D_SLOPE1	36	R	U	All	Dust slope of bottom sensor 1. Will change after local dust calibration. The factory value is mentioned on the calibration sheet as sensitivity sensor 1.
RESERVED	37	–	–	–	Reserved for future expansion
IR_D_SLOPE2	38	R	U	All	Dust slope of top sensor 2. Will change after local dust calibration. The factory value is mentioned on the calibration sheet as sensitivity sensor 2
RESERVED	39	–	–	–	Reserved for future expansion

The following modus registers are used for calibration, identification and error handling. These registers can be asked for in order to facilitate remote problem solving.

Device internal block

Parameter	Address	R/W	SZ	Level	Description
INTERNAL_VALUES_FOR_ERROR_HANDLING	40-99	R	–	–	For identification and error handling

Parameter		Unique name of the register
Address		Modbus PLC address
	Note: the Modbus PLC address is the Modbus protocol address + 1	
R/W		R = Read only/write ignore or R/W = read-write
SZ		Data type and size; the following data types are used:
	U	16 bit unsigned integer
	S	16 bit signed integer
Level		The following levels are used:
	N	Available in the normal operational mode
	S	Available in service/configuration level
	All	Available in all modes except the terminal mode
Description		Description of the parameter

Light grey background means new or changed value from original communication.

Soiling ratio % = 100 – transmission loss %

All soiling and transmission loss values are stored in 1/10 of a % also known as ‰.

All measurement values need to be divided by ten. E.g. the device voltage reported as 156 at address 32 represents a voltage of 15.6 V and a soiling ratio reported as 985 represents 98.5%.

Communication parameters are user selectable from the following range using the SmartExplorer software.

Device communication block

Parameter	Values
Baud rate	38400, 19200, 9600, 4800, 2400 and 1200
Data bits	8
Parity	None, even, odd
Stop bits	1, 2

The factory defaults are 19200 baud, 8 data bits, even parity and 1 stop bit (19200 – 8E1).

15.2 Status flags

Device common block

Parameter	Address	R/W	SZ	Level	Description
IR_STATUS_FLAGS	34	R	U	All	Device status flags (0 = status OK)

OTT HydroMet

Contact Information