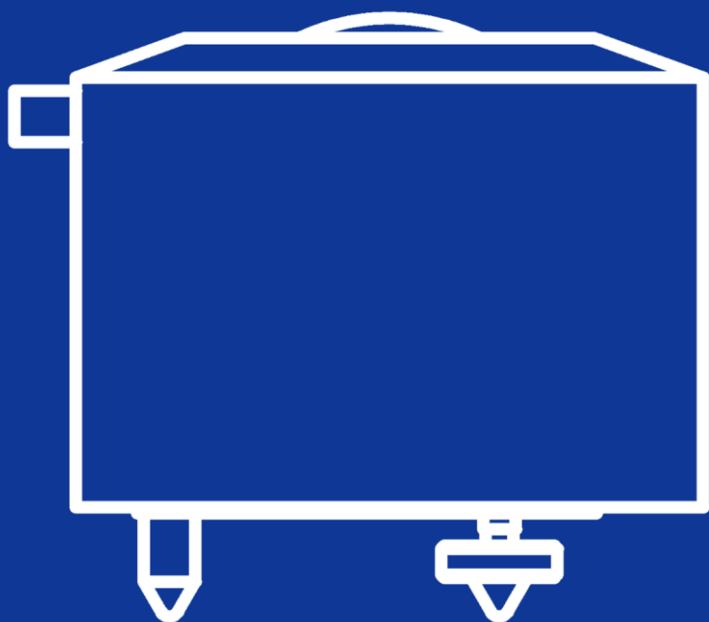


INSTRUCTION MANUAL

Pyrgeometer

MS-21SH



EKO

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2. Important User Information

Thank you for using EKO Products

Make sure to read this instruction manual thoroughly and to understand the contents before starting to operate the instrument. Keep this manual at safe and handy place for whenever it is needed.

For any questions, please contact us at one of the EKO offices given below:

2-1. Contact Information

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2-2. Warranty and Liability

For warranty terms and conditions, please contact EKO Instruments or your distributor for further details.

EKO guarantees that all products have been tested to ensure the instrument meets its published specifications.

The product warranty is valid only if the product has been installed and used according to the instructions provided in this operating manual.

In case any manufacturing defect[s] will occur, the defective part[s] will be repaired or replaced under warranty; however, the warranty will not be applicable if:

- Any modification or repair has been done by anyone other than EKO service personnel.
- The damage or defect is caused by disrespecting the specifications published on the Product Sheet or Manual.
- The bubble level fails or stops working (this part will not be serviced or replaced by EKO under warranty)
- There is discoloration of the pyrogeometer body, sun screen, and cable within a range that does not affect the function and performance of the product.

2-3. About This Instruction Manual

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This manual was issued: Jul. 30, 2024

Version Number: 1

2-4. Environment

1. WEEE Directive (Waste Electrical and Electronic Equipment)



Although this product is not subject to the WEEE Directive 2002/96/EC, please make sure that it should not be disposed of in a landfill or with municipal or household waste. For proper processing, collection and recycling, please contact a specialist collection site or facility.

Disposing of this product correctly will help save valuable resources and prevent any potential negative effects on human health and the environment, which could otherwise arise from inappropriate waste handling.

2. RoHS Directive

EKO Instruments has completed a comprehensive evaluation of its product range to ensure compliance with RoHS Directive 2011/65/EU+(EU)2015/863 regarding maximum concentration values for substances.

As a result, all products are manufactured using raw materials which concentration level are less than the hazardous substances specified in RoHS Directive 2011/65/EU+ (EU) 2015/863.

2-5. CE Declaration



IMPORTANT USER INFORMATION



DECLARATION OF CONFORMITY

We: EKO INSTRUMENTS CO., LTD
1-21-8 Hatagaya Shibuya-ku,
Tokyo 151-0072 JAPAN

Declare under our sole responsibility that the product:

Product Name: Pyrgeometer
Model No.: MS-21SH

To which this declaration relates is in conformity with the following
harmonized standards of other normative documents:

Harmonized standards:

EN 61326-1:2013 (Emission)
CISPR11 Class A
EN 61326-1:2013 (Immunity)
EN 61000-4-2 EN 61000-4-3
EN 61000-4-4 EN 61000-4-5
EN 61000-4-6

Following the provisions of the directive:

EMC-directive : 2014/30/EU

Date: April. 11, 2023
Position of Authorized Signatory: General Manager of Quality Assurance Div.
Name of Authorized Signatory: Taiji Yamashita

Signature of Authorized Signatory: 

3. Safety Information

EKO products are designed and manufactured under the consideration of the safety precautions. Please make sure to read and understand this instruction manual thoroughly in order to be able to operate the instrument safely and in the correct manner.



WARNING CAUTION

Attention to the user; pay attention to the instructions given on the instruction manual with this sign.



HIGH VOLTAGE WARNING

High voltage is used; pay special attention to instructions given in this instruction manual with this sign to prevent electric leakage and/or electric shocks.



3-1. WARNING/CAUTION

1. Setup

- The installation base or mast should have enough load capacity for the instrument to be mounted. Fix the pyrgeometer securely to the base or mast with bolts and nuts; otherwise, the instrument may drop due to gale or earthquake, which may lead to unexpected accidents.
- Make sure the instrument and the cables are installed in a location where they will not get soaked.
- Insert the output cable into the connector port on the back of the sensor unit and tighten it all the way. Push the connector in, and check to make sure the screw is tight. If the connection is loose, water can enter the unit and cause it to malfunction.
- When using this instrument by connecting to a measuring instrument, make sure to connect the shield cable to either the signal ground terminal on the measuring instrument side or GND (the reference potential on the single end input side). Otherwise noise may occur in the measurement data. In addition, the surge protection circuit inside the pyrgeometer will not operate properly if the shield wire is not connected to ground earth.
- Although this product is tested to meet EMC Directive compliance requirements, it may not fully satisfy its primary specification/performance when using this product near following locations where strong electromagnetic wave is generated. Please pay attention to the installation environment.
Outdoor: High voltage power line, power receiver/distribution facility, etc.
Indoor: Large-size chiller, large rotation device, microwave, etc.
- Do not use this product in environment where corrosive gas, such as ammonia and sulfurous acid gas, are generated. It may cause malfunction.
- Do not install in an area likely to result in salt damage. It may cause malfunction by paint peeling or corrosion. When installing in an area at risk of salt damage, make sure to take the following measures:
 1. Wrap the connector with self-fusing tape
 2. Change the fixing screw to a bolt screw made of aluminum
 3. Run the cables in a plastic or metal pipe treated with salt-resistant paint such as molten zinc plating
 4. Periodically clean.

- Do not use this instrument in vacuum environment.
- If the cable and main unit are in risk for getting damaged by birds and small animals, protect the cable and the main unit by using:
 1. Reflective tape
 2. Repellent
 3. Cable duct
 4. Installing bird-spike

2. Handling

- Be careful with silicon meniscus dome when handling instruments. Strong impact to this part may damage the silicon meniscus dome and may cause injuries by broken silicon meniscus dome parts.
- When carrying any MS-21SH model with the sun screen attached, always hold the instrument from the bottom. Holding only the sun screen part may lead to dropping the sensor as it comes off from the sun screen.

3. Signal Cable

- Make sure to ground the signal cable. When grounding is insufficient, it may cause not only measurement error due to noise, but also cause electric shock and leakage accidents.
- Check the voltage and types of specified power supply before connecting this instrument. When improper power supply is connected, it may cause malfunction and/or accident.
- Use this instrument with a 0.5A fuse connected to the power supply line in series. Without connecting the fuse, the large-current flowing through the power supply may generate heat, potentially leading to internal damage of the electronics and fire.

4. About RS485 Modbus RTU Connection

- This product supports communication through the RS485 Modbus RTU.
- It is recommended to use the optional EKO converter cable when connecting MS-21SH to a PC.
- Depending on the USB-RS485 converter type, an additional termination resistor (120Ω) and/or pull-up/pull-down resistor (680Ω) is required for proper communication.
- When connecting to a RS485 (Modbus RTU) master peripheral device, an additional termination resistor (120Ω) and/or pull-up/pull-down resistor (680Ω) is required for proper communication.

4. Introduction

4-1. About the Pyrgeometer Series

In meteorology, wavelengths from 0.3 to 4 μ m are called solar radiation from the sun irradiated from the sky, and wavelengths above that are called long wavelength radiation. The MS-21SH is a highly accurate and robust pyrgeometer that can measure only long wavelength radiation of 4.5 μ m or longer so that it does not receive the light from solar radiation. MS-21SH is a high-end pyrgeometer suitable for research applications in reference meteorological networks (e.g.BSRN).

The MS-21SH has specially coated silicon meniscus dome and is able to detect and measure only the long wavelength radiation even during the day by shutting out the unnecessary solar radiation. As temperature sensor, it is integrated with the Pt100 Class A element.

Main Characteristics:

- With the specially coated silicon meniscus dome, only the long wavelengths can be detected by shutting out the wavelengths below 4.5 μ m
- Robust and weather-proofed for continuous measurement outdoor
- By attaching the sun screen, temperature increase/decrease of body, which affects the measurement results, can be prevented
- The dome heating function reduces dew and frost build-up on the dome.

The MS-21SH is manufactured at EKO and calibrated against the reference unit traceable to WISG (World Infrared Standard Group), which is managed at PMOD/WRC*.

(*) PMOD/WRC: Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center

In case of the MS-21SH, the combination of the optional MV-01 [ventilator + heater unit], further reduces the accumulation of dust and snow on the silicon meniscus dome by continuously blowing heated air. The ventilation unit with heater is recommended when the sensor is deployed in locations with a high-chance of extreme snow or ice.

When using the MS-21SH in combination with the MV-01, the dome heating function of the MS-21SH should be switched off.

The MS-21SH features smart sensor technology and onboard diagnostic functions. This new Smart transducer includes internal temperature and humidity sensors and a tilt sensor for remote sensor diagnostics. These internal sensors help the users to monitor the stability of the IR irradiance sensors as well as ensure proper installation and maintenance practices.

Up to 31 smart sensors per one Master can be connected in one network. The signal converter settings can be changed using the optional RS485 / USB converter cable and the configurator software.

4-2. Package Contents

Check the package contents first; if any missing parts or any damage is noticed, please contact EKO immediately.

Table 4-1. Package Contents

Contents	MS-21SH
Pyrgeometer	○
Output Cable	○ ⁽¹⁾
Sun Screen	○
Instruction Manual	Not included in the package (Please download from EKO Website)
Calibration Certificate	○
Setting Report	○ ⁽²⁾
Fixing Bolts	(M5) x2, Length: 75mm
Washers	(M5) x4
Nuts	(M5) x2

(1) As for the MS-21SH, standard length is 10m for both signal/power cable. For different length of cables [e.g., to meet your application needs] please contact EKO or your local distributor.

(2) Details about the setting report, see appendix A-5.

5. Getting Started

5-1. Part Names and Descriptions

Each part name and its main function is described below.

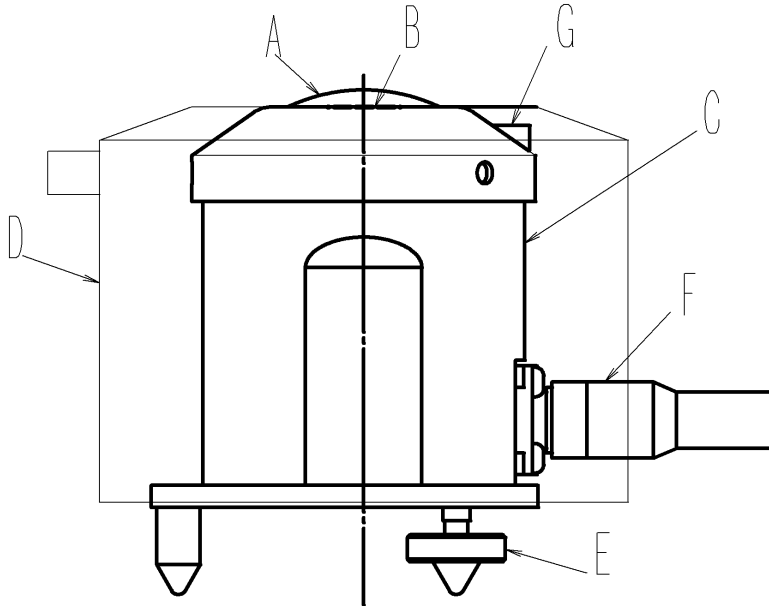


Table 5-1. Parts Name

Parts Name	
A.	Silicon Meniscus dome
B.	Sensor (Thermopile)
C.	Body
D.	Sun screen
E.	Levelling Screw
F.	Cable, Connector
G.	Sprit Level

Figure 5-1. Parts Name

1. Silicon Meniscus dome

The inner side of the silicon meniscus dome is treated with the coating (Solar Blind Coating) to prevent transmitting unnecessary solar radiation, and outer side of the silicon meniscus dome is coated with diamond-like carbon for protecting the surface which is highly scratch resistant.

Also by making the meniscus dome in a lunular shape, error is reduced since the radiation received by the meniscus dome can be transmitted to the sensor part without loss while ensuring the 180° field of view.

2. Sensor Part

The sensor part uses a thermopile which has two types of metals with different electromotive forces alternately connected, and voltage is generated in proportion to temperature difference (Seebeck Effect). When the sensor part temperature increases, electromotive forces are generated to thermopile by the temperature difference created with the body part (cold conjunction). This electromotive force (mV) is divided by the sensitivity constant obtained by calibration, and the infrared radiation intensity can be obtained by adding σT^4 (T = Kelvin) obtained by the sensor temperature (°C).

The sensor part is the most important part of the pyrometer, and it affects the response time, nonlinearity, temperature response and sensitivity.

3. Sun screen, Sensor Body

The MS-21SH has a sun screen to prevent body temperature increase generated by direct sun light. Weather resistant metal is used for the body, which has resistance against the decrease of nocturnal radiation and heat radiation, and rain and dusts.

4. Sprit Level

The integrated sprit level is used for setup and maintaining the sensor in a horizontally levelled position.

5. Drying Agent

Enclosed drying agents inside the sensor body keep the sensor inside dry, prevents condensation of humidity inside of the silicon meniscus dome.

6. Cable and Cable Connector

The MS-21SH is shipped with a 10-meter- long output cable as standard length*.

Durable materials are used for the cable and connector, and pin terminals are attached at the end of the cable for easy connection with data logger terminal block.

*If longer cables, round terminals or fork terminals are required, please contact EKO Instruments or your distributor. (Also see [7. Specification, 7-4. Accessories List] for optional items.)

5-2. Setup

In order to obtain high quality measurements from pyrgeometers, several criteria with respect to set-up and mounting of the instruments have to be considered.

The ideal mounting position for a pyrgeometer is a location which has a full hemispheric field-of-view without any obstructions (such as buildings, trees, and mountain); however, it might be difficult to find such locations. Therefore, in practice, it is ideal to install in a position which is free from obstructions at 5° above horizon. The setup location should be easily accessible for periodic maintenance (silicon meniscus dome cleaning, replacement, etc.), and make sure there are no heat sources such as walls or billboards in the surrounding area.

A strong physical impact to the pyrgeometer can lead to product damage and/or may cause changes to the sensitivity. Silicon meniscus dome may also be cracked by the impact.

1. Installing

- 1) Check the installation base where the pyrgeometer has to be mounted and make sure it has two fixing holes with the appropriate pitch. The pitch sizes of the fixing holes are as follows (in mm):

Table 5-2. Fixing Hole Pitch and Bolt Size for Pyrgeometer

	MS-21SH
Fixing Hole Pitch	65 mm
Fixing Bolt Size	M5 x 75 mm

- 2) Remove the sun screen.

The sun screen can be removed by loosening the knurling screw and sliding it towards the bubble level direction.

*When carrying the MS-21SH with sun screen attached, always hold the instrument from the bottom. Holding only the sun screen part may lead to dropping the sensor as it comes off from the sun screen.

- 3) Setup the pyrgeometer with the signal cable connector facing the nearest Earth's pole.

In the Northern hemisphere, the connector should be orientated North, in the Southern hemisphere, the connector should be orientated South. Adjust the pyrgeometer in a horizontal position by using the 2 levelling screws observing the air bubble in the spirit level while manipulating the levelling screws. The instrument is levelled horizontally if the air bubble is in the centre ring. The sensitivity of the bubble vial is (0.1° / mm). If the pyrgeometer is not levelled properly, the pyrgeometer readings are affected by cosine and azimuth errors. Periodically check the spirit level and adjust the pyrgeometer's position if necessary.



When installing the pyrgeometer, do not remove the levelling feet or fixed feet. If the feet are removed, the dew frost mitigation effect may be reduced due to heat escaping to the mounting plate.

The pyrgometer connector is an important reference for setup and corresponds to the X-axis reference plane.



Setup the pyrgometer with the signal cable connector facing the nearest Earth's pole. In the Northern hemisphere, the connector should be orientated North, in the Southern hemisphere, the connector should be orientated South.

- 4) Fasten the pyrgometer to the base with the 2 bolts [included] and put the sun screen back on the pyrgometer.

2. Setting of dome heating function

The initial setting of the dome heating function is ON. To obtain a high condensation/frost reduction effect, always use it in the ON state. It takes about 3 hours for the dome temperature to stabilise after switching ON the dome heating function.

For power-saving use, please set it to OFF.

The dome heating function can be switched ON/OFF by the following methods.

[Hibi]

The dome heating function can be switched ON/OFF using the radio button in the 'Settings' => 'HEATING' screen.

[Modbus RTU]

ON/OFF can be switched by directly rewriting the internal register of the MS-21SH from the control device using RS485 communication.

Register number: 151 ⇒ Set value: OFF = 0, ON = 1

[SDI-12]

ON/OFF can be switched by sending the following commands from the control device to the MS-21SH using SDI-12 communication.

Transmission command: OFF = 'aXHT0!', ON = 'aXHT1!'

5-3. Wiring

To extend the cable lifetime, make sure that the cables are not exposed to direct sun light or rain/wind by lining the cable through a cable conduit. Cable vibrations will potentially cause noise in the output signal. Fasten the cable so that the cable does not swing or move in the wind. Exposure of the signal cable to excessive electromagnetic emissions can cause noise in the output signal as well. Therefore, the cable should be lined at a safe distance from a potential source generating EMC noise, such as an AC power supply, high voltage lines or telecom antenna.

1. Ground Connection



<MS-21SH>

The pyrgometer housing is connected to the shield wire of the cable, so the shield wire shall be connected to the ground on the measuring instrument side. The surge protection circuit inside the pyrgometer will not operate properly if the shield wire is not connected to the ground.

Also do not connect the pyrgometer housing to the ground. It will be a two-point ground and it causes noise.

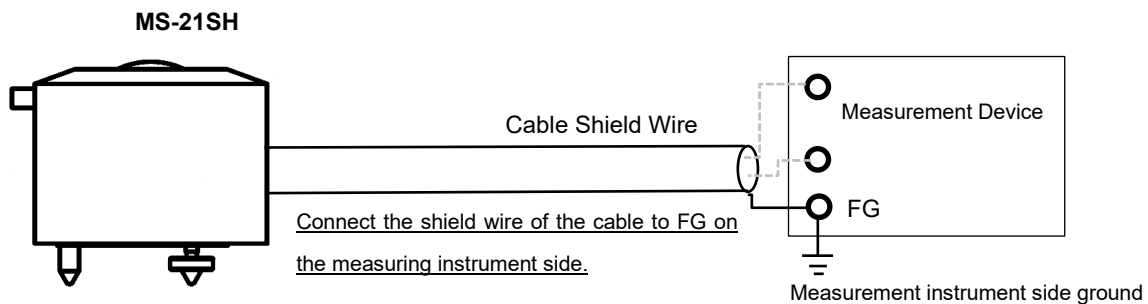


Figure 5-2. MS-21SH Ground Connection Method

2. Wiring Procedure

Connect the output cable to the MS-21SH: **Insert the output cable into the connector port on the back of the sensor unit, and twist clockwise to fasten it. Make sure to tighten the connector all the way.**



- 1) If the connection is loose, water can enter the unit and cause its malfunction.
- 2) Secure the length of the cable to avoid it from being pulled loose.
- 3) Connect the power cable grounding wire to prevent electrical shocks.

5-4. Connections

The MS-21SH features a digital smart processing interface providing advanced measurement functions with 2 different industrial signal outputs (**Modbus RTU, SDI-12**).

Table 5-3. Pyrgeometer Output Parameters

Output Parameters	MS-21SH Modbus RTU / SDI-12
IR Irradiance	○
Detector Temperature	○
Temperature of PCB	○
Tilt Position	○
Relative Humidity	○
Alerts for abnormal internal humidity of the pyrgeometer	○
Alerts for abnormal dome heating of the pyrgeometer	○
Sensor Information	○

1. Digital Output (Modbus RTU / SDI-12)

The MS-21SH can work in two digital output modes, respectively Modbus RTU and SDI-12. Simply connect the desired output wires to automatically start communication.

To change the digital output mode, turn off the MS-21SH and change the wiring.

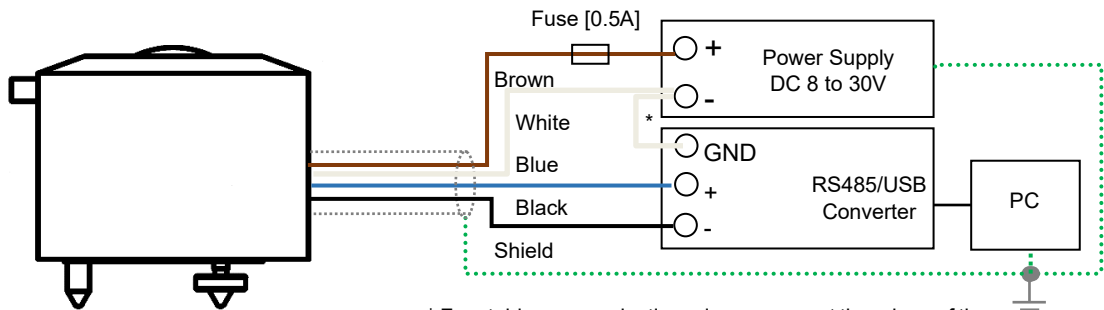
PC connection (Modbus RTU)



EKO can provide an optional and approved USB converter for connection with a PC. The converter cable is needed for setup, sensor diagnostics and data logging through the Hibi software. Depending on your region, the optional converter can be different.

- To protect your equipment from noise and surge, the shield wire of the cable shall be connected to the ground at a single point. If it is not connected, the electronic equipment may be damaged.
- The shield wire of the cable is connected to the surge protection circuit inside the pyreometer itself and to the enclosure.
- Be sure to connect a fuse, as this may lead to a fire.

For any converter with the screw terminals or the open wires, connect the 4 wires of the sensor cable with the corresponding wire colour to the RS485 to USB converter (figure 5-4). Some converter cables provide a 5V supply voltage from the USB port, in such case no additional power supply is required. if the dome heating function is 'OFF' when the internal settings of the pyreometer are being changed. In any other case use an additional power supply. Connect the power terminals to a DC power supply [8 to 30 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.



* For stable communication, please connect the minus of the power supply and the GND of RS485/USB converter.

Figure 5-3. How to Connect MS-21SH (Modbus RTU)



Depending on the converter type and design properties, some commercial RS485 to USB converters may not work properly. A termination resistor is required to prevent reflections from the end of the transmission line. Pull-up and pull-down resistors are necessary to keep the voltage level constant when the transmission line is in a high impedance state.

Data logger connection (Modbus RTU)

Connect the 4 wires of the sensor cable with the corresponding wire colour to the RS485 communication port of the data logger master and power supply unit (figure 5-4). Connect the power terminals to a DC power supply [8 to 30 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.

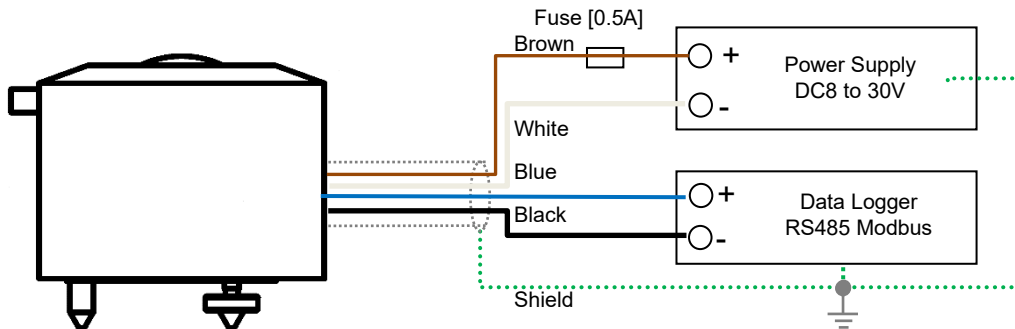


Figure 5-4. How to Connect MS-21SH (Modbus RTU RS485)

The MS-21SH can be configured within a multi sensor RS485 Modbus RTU communication network. Up to 31 sensors per one master can be connected and be assigned with a unique address. For a multiple sensor network, the sensors need to be configured according to the recommended RS485 configuration standards as shown in figure 5-5.

The master represents the data-logging device and slaves represent devices such as the MS-21SH or other serial devices in the same network. Connect the communication wires of the slave to the Modbus RTU communication input of the master. Connect a 120Ω termination resistor at the end of the communication line. The master device may have an integrated termination resistor and pull-up and pull-down resistors. If any communication issues occur, apply those separately.

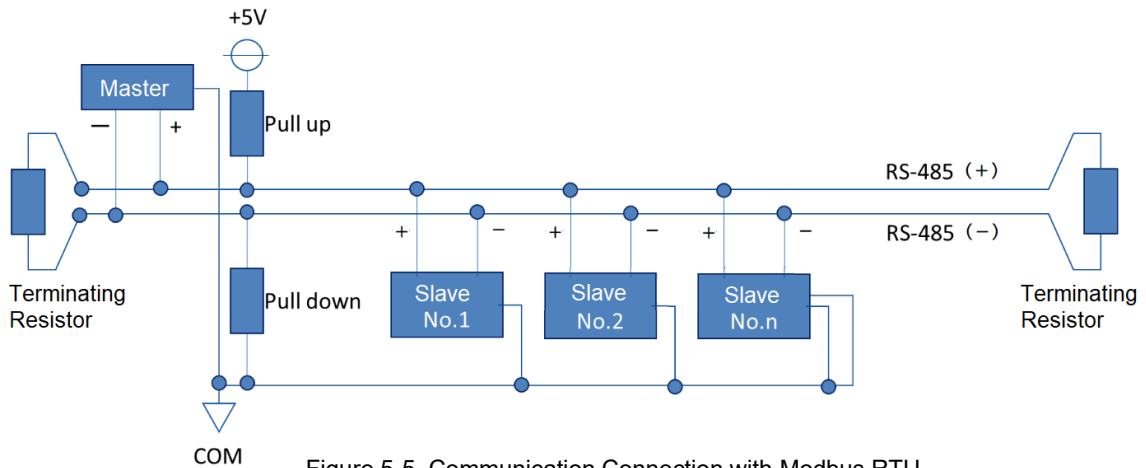


Figure 5-5. Communication Connection with Modbus RTU



Apply a termination resistor (typically 120 to 150Ω) : Typically, reflections occur on long lines, resulting in a receiver misreading logic levels. Proper termination prevents reflections, improving data integrity.

Apply pull-up and pull-down resistors (typically 680 to 850Ω): Necessary to keep the voltage level constant when the transmission line is in a high impedance state.



Communication errors may occur depending on the connection distance and the number of connections. In that case, please prepare and apply a RS485 booster or a repeater.



Although a surge protection board is embedded inside the pyrgeometer, if the cable length exceeds 10 m, add an appropriate SPD or the like shall be added to protect the measurement system from lightning surges (see A-6).

Data logger connection (SDI-12)

Connect the 3 wires of the sensor cable with the corresponding wire colour to the SDI-12 communication port of the data logger master and power supply unit (figure 5-6). Connect the power terminals to a DC power supply [12 V]. We recommend to use a fuse [0.5A] to the DC power supply line [+] for over current protection.



Interconnect the power supply (-) and SDI-12 (-) line.



- **Although a surge protection board is embedded inside the pyrgeometer, if the cable length exceeds 10 m, add an appropriate SPD or the like to shall be added protect the measurement system from lightning surges (see A-6).**

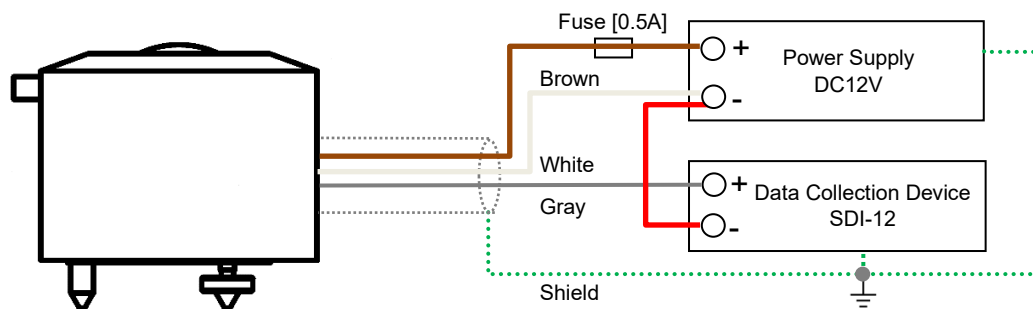


Figure 5-6. How to Connect MS-21SH (SDI-12)

The MS-21SH can be configured within a multi sensor SDI-12 communication network. Up to 20 units of S-series sensors can be connected and be assigned with a unique address (*). For a multiple sensor network, the sensors need to be configured according to the recommended SDI-12 configuration standards as shown in figure 5-7. Make sure the cable length between the connecting slave and master be less than 60m.

The shield cable must be connected to the ground, otherwise noise may occur.

(*) When connecting other SDI-12 communication devices, the upper limit may change.

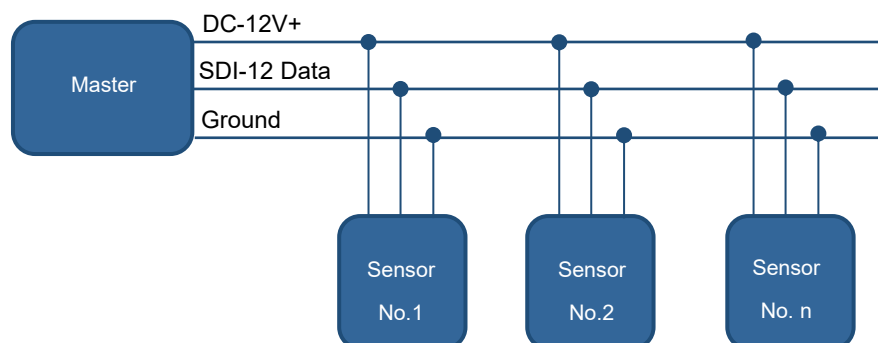


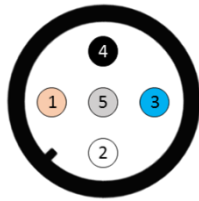
Figure 5-7. Communication Connection with SDI-12

2. Overview Wire Assignments

Table 5-4. Cable Colour Codes

No.	Wire Color	Modbus RTU	SDI-12
1.	Brown (+)	5VDC (+) ^(*) or 8 to 30VDC (+)	12VDC (+)
2.	White (-)	Vcc GND / RS485 GND	Vcc GND
3.	Blue (+)	RS485 (+)	---
4.	Black (-)	RS485 (-)	---
5.	Gray (+)	---	SDI-12 Data (+)
Shield	Shield	FG	FG

(*) Dome heating function is not available when operating with 5 VDC power supply.



Each Number Corresponds to the Number in Table 5-4.

Figure 5-8. Connector Pin Number of the MS-21SH

5-5. Measurements

1. Data Logger Settings

The output signal of pyrheliometer is measured by a measuring device such as a data logger. If IR irradiance is measured continuously, it is recommended to use a data logger, which has sufficient memory to record data over a longer period and functions to process the measurement parameters of the pyrheliometer. Depending on the sensor output which will be used, the data logger should be capable to measure the assigned output type.

For the MS-21SH with digital output, Modbus RTU or SDI-12, the data logger should have those inputs.

When configuring the data logger parameters, the sampling rate and data reduction methods can be defined right at the beginning of the data acquisition process. The response time that is given in the specifications of the EKO pyrheliometers states the amount of time, which is necessary to reach 95% of the final measurement value. It is also possible to define a 63.2% response [which is equal to $1-1/e$]. This time constant, represented by the symbol τ , is 3 times smaller than the values specified by EKO. The recommended sampling rate for pyrheliometers is smaller than τ . So, for EKO pyrheliometers, the sampling rates that have to be programmed in the data logger systems should not exceed the values as given in Table 7-1.

Performing averaging and/or integration of measurement data can be meaningful to, e.g., reduce the data volume or to meet application-specific requirement. Note that shorter sampling rates allow to use shorter averaging/integration times [In case of the MS-21SH: 1Hz sampling rate, 1 minute averaging period]. It could also be meaningful to store not only average values, but to keep track of all statistical values during the averaging period, namely: average, integral, minimum and maximum values, and standard deviation. As general recommendation, the averaging/integration period should be as short as possible, but long enough to reduce the data volume to store the processed data safely.

Recommendations for IR irradiance measurements are explained in ^[1]'Guide to Meteorological Instruments and Methods of Observation', WMO reference document No. 8.

2. Pyrgeometer Default Settings

The MS-21SH features a digital smart processing interface providing advanced measurement functions with different industrial signal outputs (**Modbus RTU**, **SDI-12**).

Where to find information regarding the MS-21SH defaults settings and important parameters:

Table 5-5. Where to find the settings?

MS-21SH	Defaults Setting and Parameters
Sensitivity Figure	<ul style="list-style-type: none"> - Calibration certificate - Modbus register - SDI-12 register
Modbus RTU	<ul style="list-style-type: none"> - Setting report (see appendix A-5 of the MS-21SH setting report) - Modbus register <ul style="list-style-type: none"> o Address (last two digits of serial number, 100 if '00') o Baud rate 19200 o Parity Even
SDI-12	<ul style="list-style-type: none"> - Setting report - SDI-12 register <ul style="list-style-type: none"> o Address 0 o Baud rate 1200 o Parity Even
Dome Heating Function[*] (Default ON)	<ul style="list-style-type: none"> - Setting report - Modbus register

(*) The dome heating function is set to ON when the product is shipped. The function can be switched ON/OFF via Hibi or by rewriting the registers of Modbus RTU and SDI-12 respectively. See the following section for details on the operating procedure.

A-3. Software (Hibi) 3. Software 5) Setting items 3.'DOME HEATING' setting items

A-4. Communication Specifications (Modbus RTU) A3-10. No. 101 or later registers

5-6. Measurement Principle

A pyrgeometer measures the exchange of radiations between the sensor part and observed object (sky or ground surface).

- 1) Sensor part receives the radiation (W/m^2) from the object, and on the other hand, the sensor part itself, which is at absolute temperature T , also emits energy equivalent to σT^4 according to the Law of Stefan-Boltzmann.

These radiation balances are shown as the temperature of sensor part, and the temperature difference between this sensor part and reference point (cold junction) is output as voltage using thermopile.

- 2) When the incident radiation to the sensor part from the observed object is R_{in} , radiation emitted from the sensor part is R_{out} , and the balance of these are R_{net} , the equation will be as follows:

$$R_{net} = R_{in} - R_{out}$$

- 3) R_{net} can be measured as voltage output of thermopile; R_{out} can also be obtained by measuring the sensor part temperature. Therefore, Infrared radiation amount incident to the sensor part can be measured with following equation:

$$R_{in} = R_{net} + R_{out}$$

- 4) Next, correct the measured sensor part temperature to absolute temperature (K, kelvin) to obtain the radiation amount (σT^4), and lastly the infrared radiation amount can be determined with following equation.

$$R_{in} = R_{net} + \sigma T^4$$

$\sigma = 5.670367 \times 10^{-8}$ (Stefan-Boltzmann constant)

$T = \text{unit(K, kelvin)}$... Example: $25^\circ\text{C} = 298.15\text{K}$ ($273.15 + 25^\circ\text{C}$)

*In the literature the R_{in} is referred to as the Longwave downward radiation (Ld).

*The net radiation in Watts per meter squared (W/m^2) is obtained when the output voltage V [μV] is divided by the sensitivity of the pyrgeometer S [$\mu V/W \cdot m^{-2}$]. This calculation is expressed by the following formula:

$$R_{net} (W/m^2) = \frac{V (\mu V)}{S (\mu V/W \cdot m^{-2})}$$

*The sensitivity S for the pyrgeometer is stated on the calibration certificate and the product label.

The conversion of the MS-21SH to infrared radiation is performed on-board and will be outputted as one of the measurement parameters within the data string.

6. Maintenance & Troubleshooting

6-1. Maintenance

To maintain accurate measurement, it is recommended to check and do the following:

Table 6-1. Maintenance Items

Maintenance Item	Frequency	How To	Effect
Clean Silicon meniscus dome	Several times per week	Keep the silicon meniscus dome clean by wiping with a soft cloth squeezed well	The infrared radiation measurement will be affected due to a change in transmittance.
Check Appearance Condition	Weekly	Check for cracks	May lead to water leakage due to rain/dew which causes damage of the detector inside the pyrgeometer.
Check Bubble Level	Weekly	Verify if the pyrgeometer is levelled by checking the bubble is in the center ring of bubble level.	Affects measured sky irradiance.
Check Cable Condition	Weekly	Verify if the cable connector is properly connected, tightened to the instrument, and how cable is lined; make sure the cable is not swinging by wind.	A disconnected cable will cause sporadic reading errors or failure of operation. If the cable is damaged, it may lead to noise or electric shock.
Check Setup Base Condition	Weekly	Check if the instrument is tightened properly to the mounting base plate and the base plate and/or table is securely fastened in a proper condition.	Loose instruments and/or mounting plates can lead to damages of the instruments and/or injury.
Check the Sun Screen	Weekly, Before/After Bad Weather	Verify if the sun screen is securely fixed on the body, and knurling screw is securely tightened.	May lead to damaging the instrument and/or lead to increasing measurement error due to temperature increase by sun screen coming off.
Recalibration	Every 2 Years	To maintain the best possible measurement accuracy, recalibration of the pyrgeometer is recommended. Contact EKO for more details and requests for a recalibration and maintenance service.	Due to natural aging of materials the detector properties of the pyrgeometer can change in time which affects the sensor sensitivity.

Table 6-2. Maintenance Items2 (Advanced remote checks can be done on the MS-21SH)

Maintenance Item	Frequency	How To	Effect
Data Validity	Weekly	Check the daytime IR irradiance data and compare to the previous days or the adjacent pyrometer.	When large difference occurs operating problems or installation issues can be detected.
Check the Temperature Inside	Weekly	Check the body temperature via Modbus RTU or SDI-12 output.	If the inside temperature becomes abnormally high, the life of the product will be shortened.
Check the Effect of Desiccant	Weekly	Check the internal relative humidity alert status of the pyrometer via Modbus RTU or SDI-12 output.	The condition of the drying agent can slightly change over time. If the relative humidity becomes high, the window might be fogging up.
Check the Tilt Angle	Weekly	Check the tilt angle and roll angle via Modbus RTU or SDI-12 output.	If the sensor is tilted after the installation can affect the measurements due to the cosine response of the sensor.
Dome Heating Current	Weekly	Check dome heating current alert register via Modbus RTU or SDI-12 output.	When the dome heating function is turned on, if the dome heating current is not energized properly, the dew and frost mitigation effect cannot be fully achieved.

6-2. Calibration

It is recommended to recalibrate the MS-21SH pyrgeometer once every 2 years in order to verify the good quality of the solar radiation measurements. Below explains about the calibration methods of EKO pyrgeometers.

1. Calibration Method

This pyrgeometer is calibrated by taking outdoor measurement simultaneously with our reference pyrgeometer during night time without clouds.

Outdoor Calibration Procedure

Set up the reference unit and product pyrgeometer in horizontal position outdoor, and simultaneously take measurement output (mV) at night during there are no clouds.

- 1) From reference unit output (mV) and sensitivity ($\mu\text{V}/\text{W}/\text{m}^2$), calculate the net radiation amount (W/m^2), then
- 2) The value obtained from dividing the product pyrgeometer output (mV) similarly measured by the radiation balance of the reference unit (W/m^2) is calculated as the sensitivity ($\mu\text{V}/\text{W}/\text{m}^2$).

2. Calibration Traceability

The Internal reference pyrgeometer maintained at EKO is traceable to the pyrgeometer which is directly compared against the WISG (World Infrared Standard Group) maintained at PMOD (Davos, Switzerland). The logger system used for the calibration measurement is traceable to JEMIC (Japan Electric Meters Inspection Cooperation).

6-3. Troubleshooting

Read the following in case of any sensor trouble. If any questions should remain, please contact EKO for further technical support.

Table 6-3. Troubleshooting

Failure	Action
There is no output.	Make sure that the sensor is properly connected, and type of power supply and voltage values are appropriate. Also check the communication settings [i.e., port, baud rate, converter ID] are appropriate.
Output value is too low	The silicon dome may be soiled with rain or dust. Clean the silicon dome with demineralized water and soft cloth. The output may decrease over time. Recalibrate periodically.
Unusual noise	Check the shield connection and make sure it is connected securely. Make sure if the output cable is not shaking from the wind; take necessary measure by fixing or lining the cables through a metal pipe. Check for any objects, which emit electromagnetic wave around the instrument and or the cable.
Dome heating current alert	Check if the power supply voltage of the pyrgeometer is not less than 8VDC. (A power supply of 8VDC or more is required to use the dome heating function.)

Table 6-4. Troubleshooting Hibi

Failure	Action
No connection with PC	Make sure that the sensor is properly connected, and power supply and voltage levels are appropriate. Also check the communication settings [i.e., port, baud rate, converter ID] are correct.
No communication with USB cable	If no COM port shows up when Hibi software is started. <ul style="list-style-type: none"> - Reconnect the USB converter and refresh to search new COM devices - Check for COM port settings in Windows settings - Install an appropriate driver
Settings changes not saved to pyrgeometer	Make sure that the sensor is properly connected, and power supply and voltage levels are appropriate. Also check the communication settings [i.e., port, baud rate, converter ID] are correct. Power off/on the pyrgeometer, some of the settings are effective after power off/on.

7. Specifications

7-1. Pyrgeometer Specifications

Table 7-1. Pyrgeometer Specifications

Characteristics	MS-21SH
Response Time (95% Output)	< 18 Sec
Window Heating Offset	< 4 W/m ²
Zero Offset B	< 1 W/m ²
Temperature Response	< 1 % (-20 to +50°C)
Operating Temperature	-40 to +80°C
Wavelength Range	4.5 to 42μm
Sensitivity	10 to 25μV/W/m ²
Field of View	180°
Bubble Level Accuracy	0.1°
Tilt Sensor Accuracy	<±1°
Humidity Sensor Accuracy	Nominal: ±2%RH
Temperature Sensor of PCB (tolerance)	±0.5°C
Detector Temperature Sensor	Pt100 Class A [3]
Detector Temperature Sensor Accuracy	±0.5°C
Environmental Protection (IP Code)	IP67 Equivalent (IEC60529)
Weight	0.7 kg
Output Cable (outer diameter)	AWG22: 0.3m ² x 5 pins (φ5.7mm)
Output Cable Terminal	Pin-Terminal (0.3-9.5)
Output	Modbus RTU, SDI-12
Alert Signal	Alert is issued when the internal humidity and current of the dome heating of the pyrgeometer is abnormal.
Input Power Supply	Modbus RTU: DC5V±5% USB Bus Power without dome heating function DC8V to DC30V±10% With dome heating function SDI-12 : DC12V±10% With/without dome heating function
Power Consumption	With heating : < 1.4W Without heating : < 0.2W

7-2. Dimensions

Table 7-2. Dimensions

	MS-21SH
A. Fixing Hole Pitch	65 mm
B. Body Height	77mm
C. Levelling Screw Height	16 mm
D. Width (including Sun screen/Cover)	Φ97 mm
E. Overall Height (approx.)	93mm

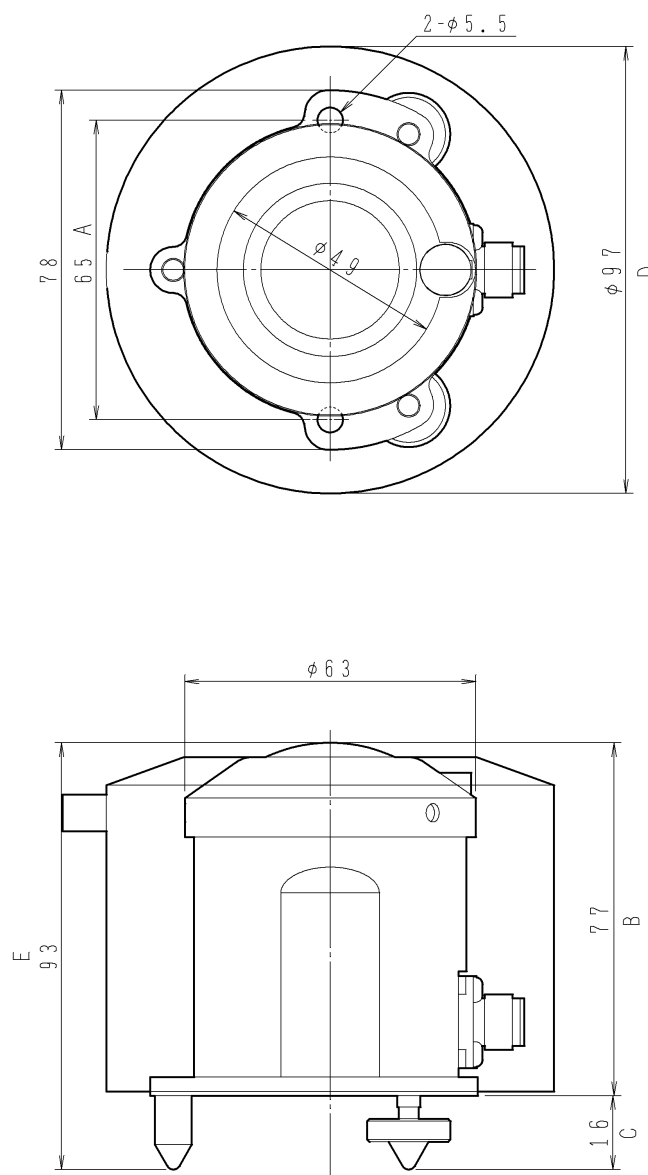


Figure 7-1. Outer Dimensions

7-3. Output Cables

See [5-2. Installation, 5-3. Wiring] for instruction

1. MS-21SH

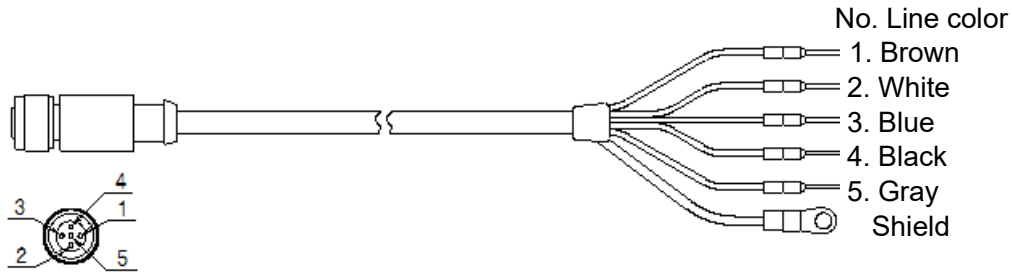


Figure 7-2. Output Cables

2. EKO Converter Cable (Option)

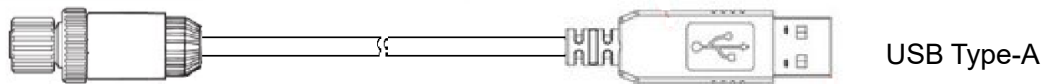


Figure 7-3. EKO Converter Cable

7-4. Accessories List

Table 7-3. Accessories List

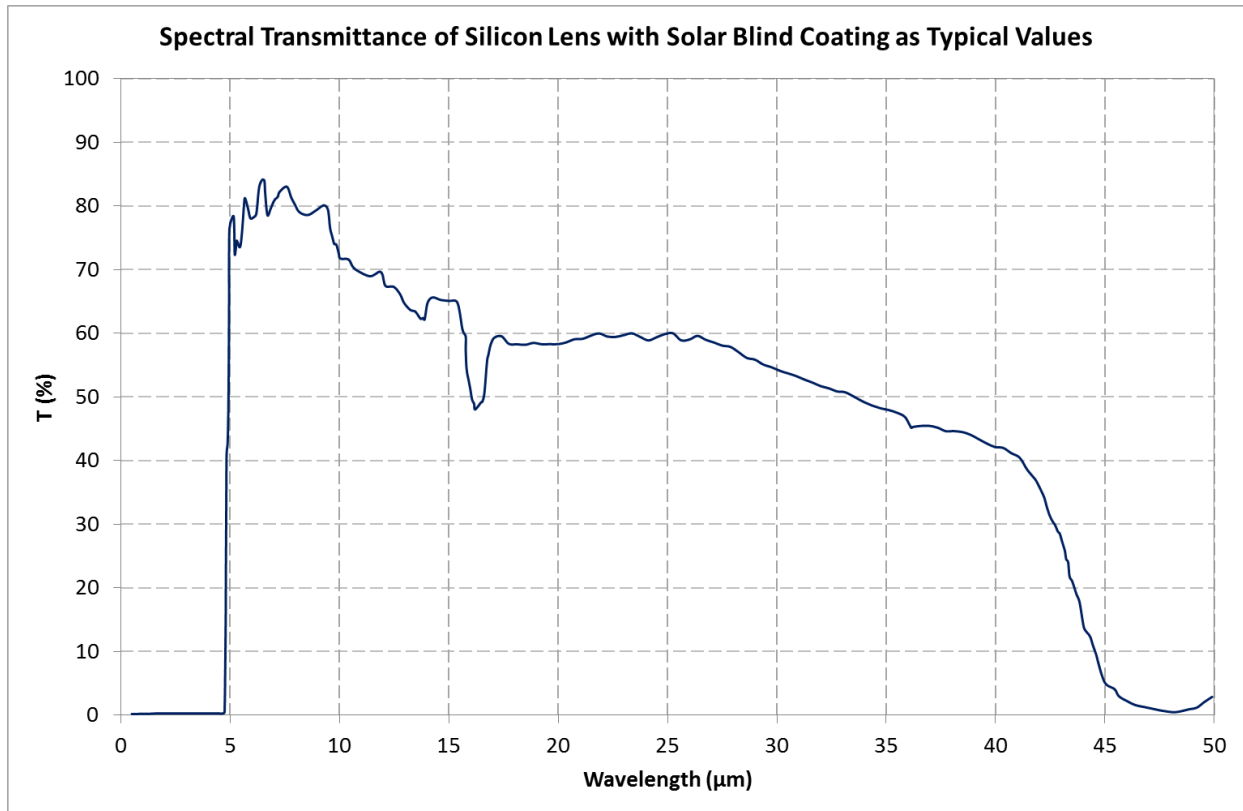
Option Items	Description
[1] [2] Output Cable	Cable Length: 20m, 30m, 50m Terminals: Fork Terminals, Round Terminals, Pin Terminals
Ventilation Unit with Heater	MV-01 ventilator and heater
EKO Converter Cable	Converts from RS485 → USB for the communication with the MS-21SH and allows to connect to PC via USB terminal. Cable Length:5m

[1] The standard cable length for the MS-21SH is 10 m.

[2] When using the optional cable, a power supply voltage of 24VDC or higher is recommended.

A-1. Spectral Transmittance

The following is a typical value of the spectral transmittance of a silicon meniscus dome.



A-2. Software (Hibi)

'Hibi' means 'day by day' in Japanese, and with this program, users will be able to visualize detection signals, set communication parameters, and rapidly troubleshoot any issues from day one. You can change the settings of the MS-21SH using the Windows software downloadable from the EKO website and the optional USB cable.

1. Software Installation

Follow the steps below to install 'Hibi' configurator software.

- 1) Download the latest version of the 'hibi.zip' file [Compressed file: Zip format] on the EKO website.
- 2) Unzip 'hibi.zip' file and check that the 'setup.exe' file exists.
- 3) Run the 'setup.exe' file to install 'Hibi' configurator software.

2. Hardware Preparation

After the software is installed, connect the MS-21SH with a PC to change the setting.

- 1) After installing the software, connect the USB connector of 'RS485/USB Converter cable' to the PC.
- 2) Connect the ends of the signal cable of MS-21SH to the communication terminal of 'RS485/USB converter'.
- 3) Connect the power lines of the signal cable to the power supply (DC5V or 8 to 30V), and turn on the power supply. (Refer to Figure A3-1.)

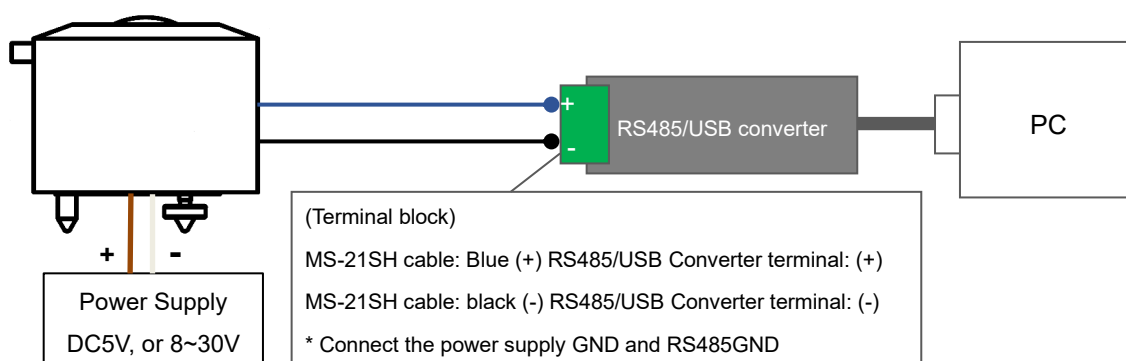


Figure A2-1. Hardware preparation

- 4) If you use the optional 'EKO Converter Cable', you can install it simply by inserting the cable connector into the main unit. Power for the MS-21SH can be supplied via USB. (See Figure A3-2).
* This conversion cable is for installation, so please avoid using it outdoors for a long time. Because the ground wire is not connected, surges can damage your PC during a lightning strike.

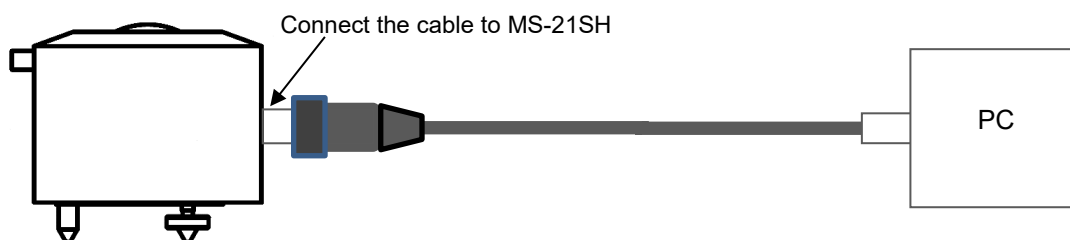


Figure A2-2. Using "EKO Converter cable"

3. Software

Start the 'Hibi' software and make the required settings.

- 1) Start 'Hibi' software. (Launch the software from 'hibi.exe' located in the shortcuts or installation folder.)
- 2) After the software starts, the 'Welcome' window appears.

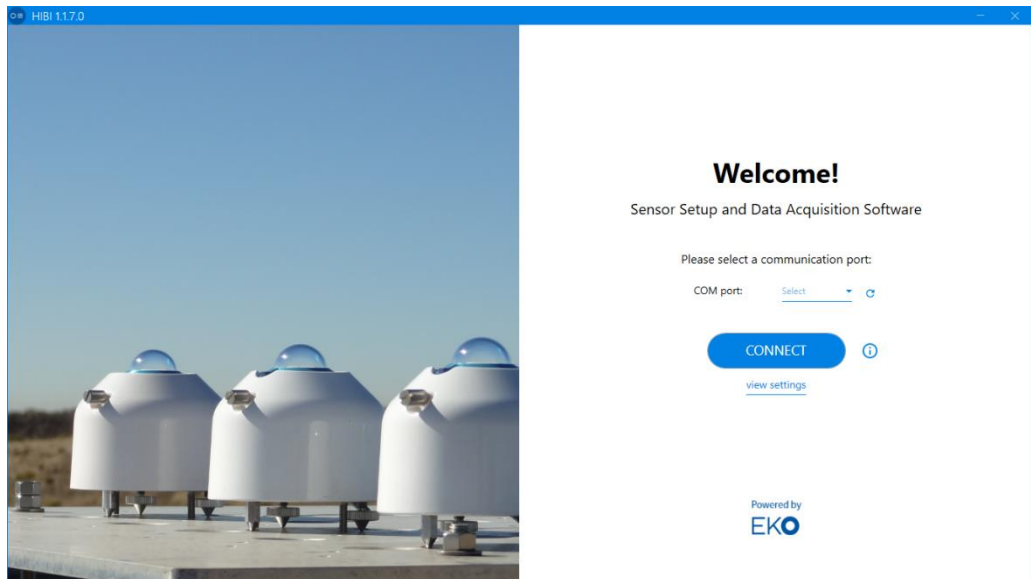


Figure A2-3. Welcome window

- 3) Automatic connection

When using the 'Auto-connect' function to connect the MS-21SH with the 'Hibi' software, select the COM port that the RS485/USB converter cable is connected to.

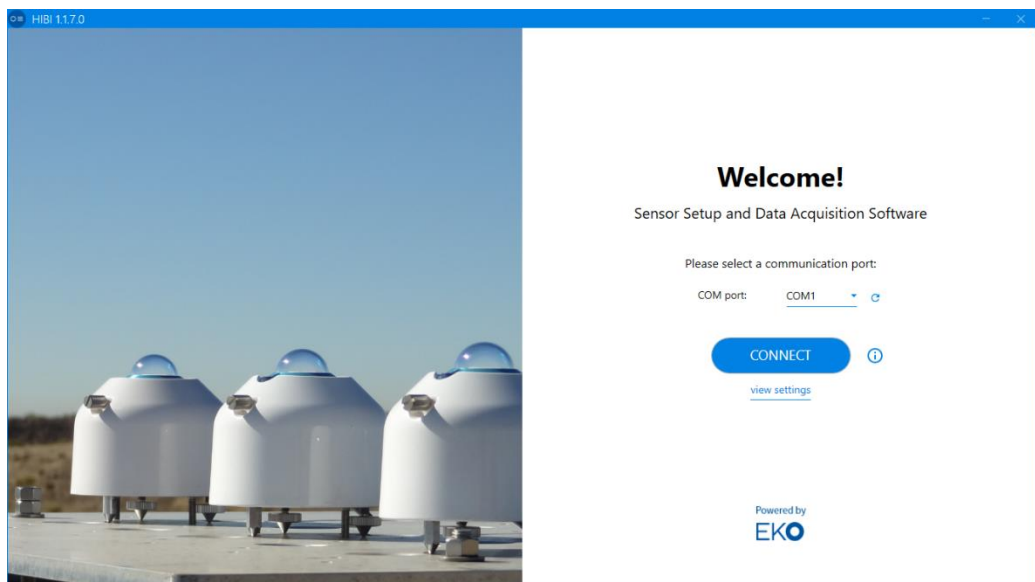


Figure A2-4. Com port select

Click 'Select' of 'COM port:' on the startup screen, and select the COM port number assigned to the RS485 / USB conversion cable from the displayed COM port numbers.

If you can't find a selectable COM port, click the Refresh button and click Select again to try again.

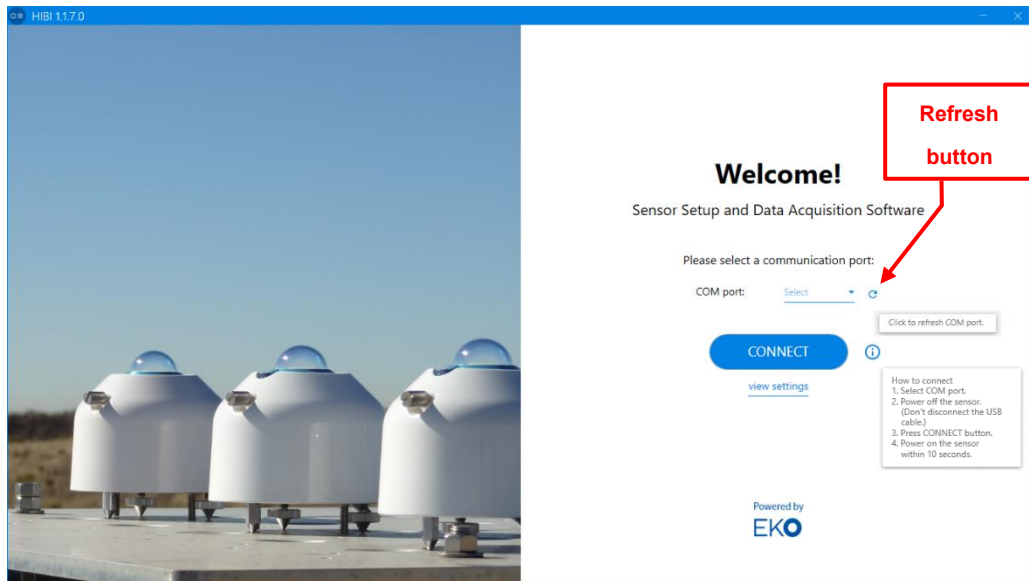


Figure A2-5. Com port select

Check that the power supply of the main unit is 'OFF'. Then, click 'CONNECT' button.

If the COM port is not recognized, press the refresh button and try again.

Power on the MS-21SH within 10 seconds once the 'Connecting your sensor' message appears.

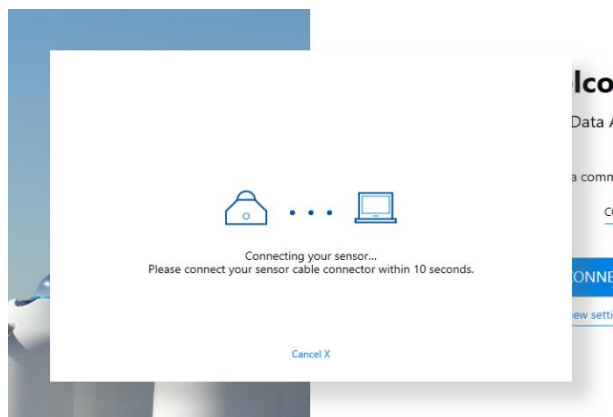


Figure A2-6. Connecting screen

When the connection is completed, the window automatically switches to the 'Dashboard' window. In the upper-right corner of the display changes to 'Pyrgometer Connected'.

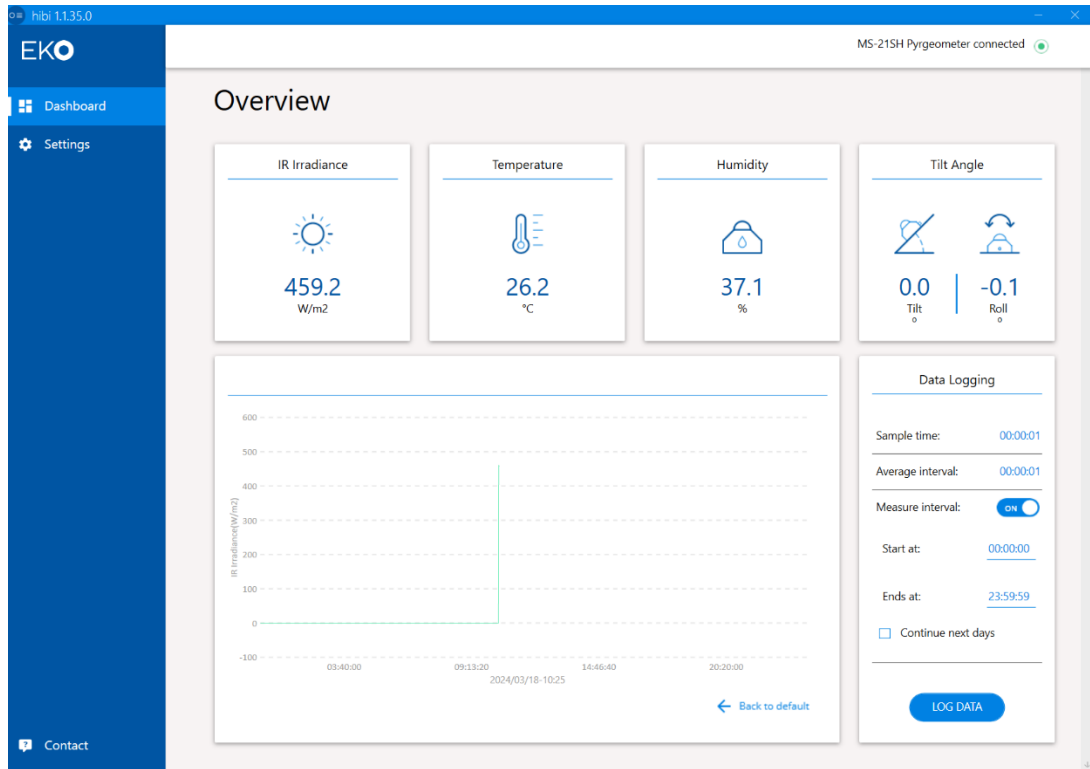


Figure A2-7. Dashboard

If the connection fails, the screen returns to the 'Welcome' screen and 'CONNECTION FAILED' is displayed.

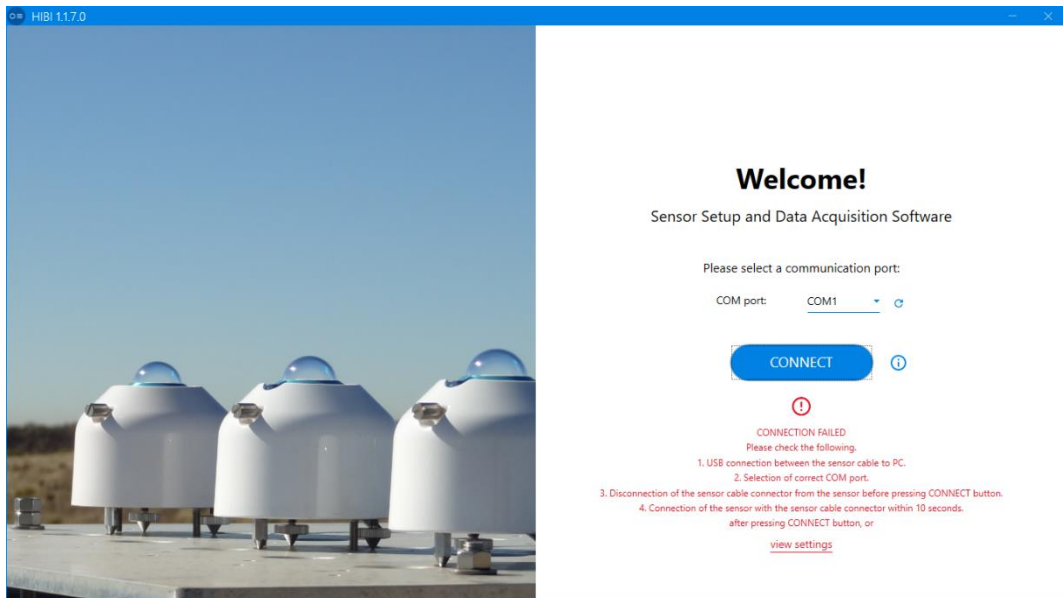


Figure A2-8. CONNECTION FAILED

Make sure the connection settings are correct. To perform the 'Auto-connection' again, turn off the power of the MS-21SH, select 'COM port', and then click 'CONNECT'.

For manual connections, click 'View settings' at the bottom of 'CONNECTION FAILED' to go to 'Settings screen'. (As for how to set and connect by 'Manual connection', refer to the procedures (4) Manual connection) from the next section.

4) Manual connection

After turning on the power of the MS-21SH, click 'CONNECT' without selecting 'COM port'.

Clicking 'view settings' at the bottom of the 'CONNECTION FAILED' screen moves to the 'Settings' screen. (The same screen appears even when the 'Auto-connection' fails. To perform manual connection, set and connect using this procedure.)

After setting up the communication settings, click the 'CONNECT' button in Connection status.

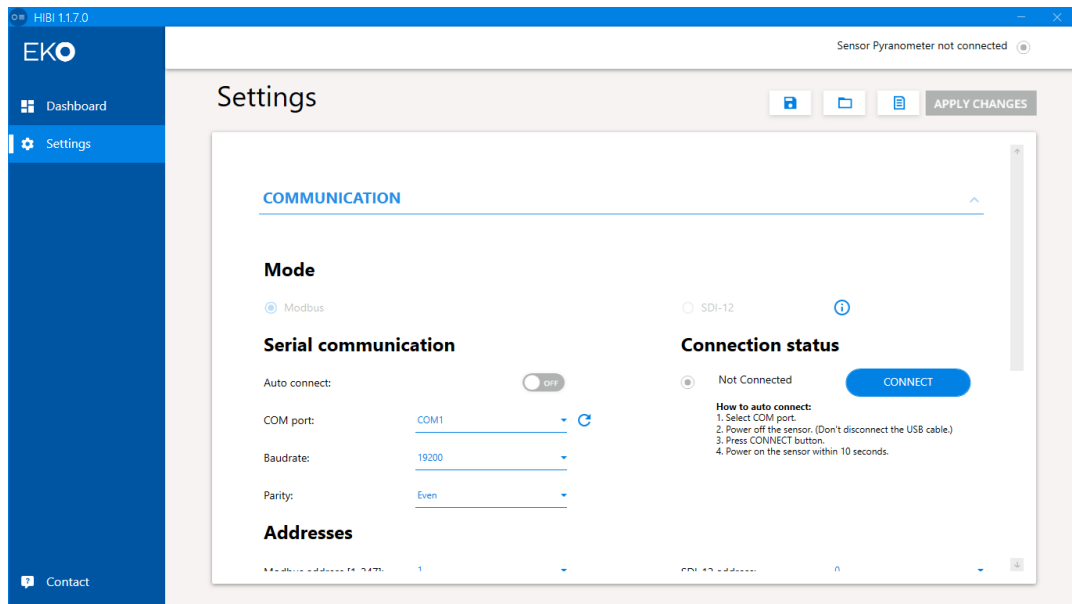


Figure A2-9. Manual connection

When the connection is completed, 'Connected' is displayed.

'MS-21SH Pyregeometer connected' is also shown in the upper-right corner of the display.

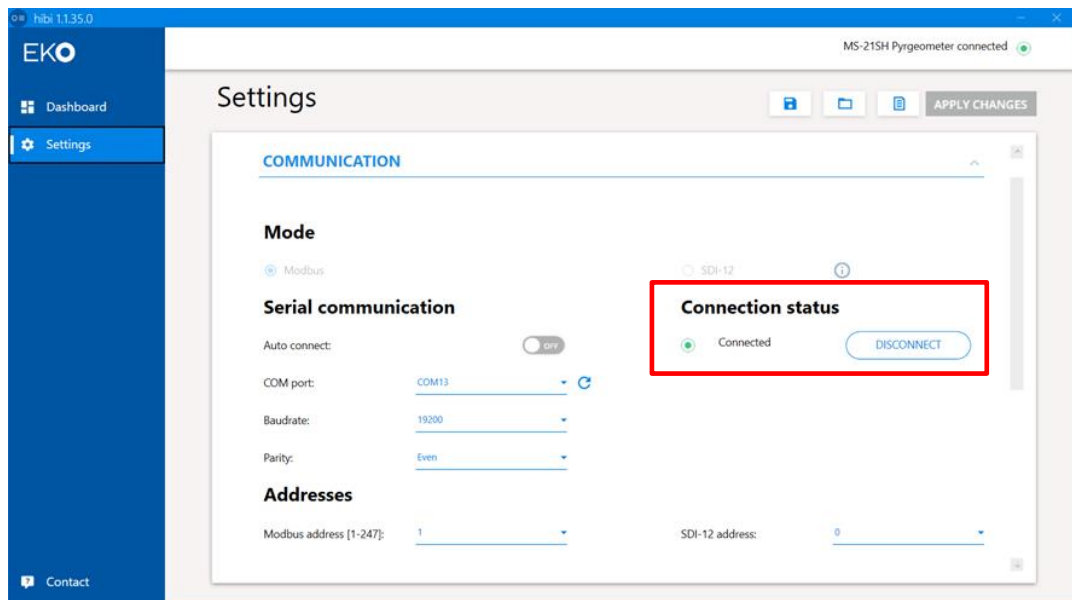


Figure A2-10. Disconnect appear

When the connection fails, the 'Oops...' screen is displayed with the cause of the connection failure.

When connection fail appears

Check that the cable connection, COM port and the communication requirements are correct.

When changing the connection condition after successful connection, set 'COM port', 'Baud rate' and 'Parity' in the 'Serial communication' setting of the 'COMMUNICATION' items and set 'Modbus address [1-247]' in the 'Addresses' setting.

After entering the settings, click 'APPLY CHANGES'

A confirmation window will be displayed.

Click 'YES, SAVE' to make the settings for the MS-21SH.

The settings in 'Settings' can be saved / read / exported to CSV files.

Click the button with icons in the upper-right corner of 'Settings' window.

- 'Save' button: Save the settings.
- 'Read' button: Read out the settings.
- 'Output' button: Output the settings to CSV file

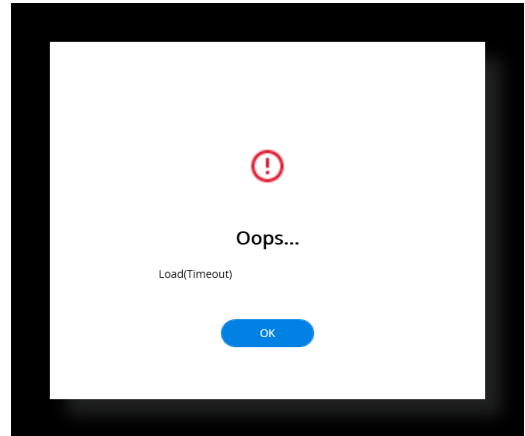


Figure A2-11. Oops screen

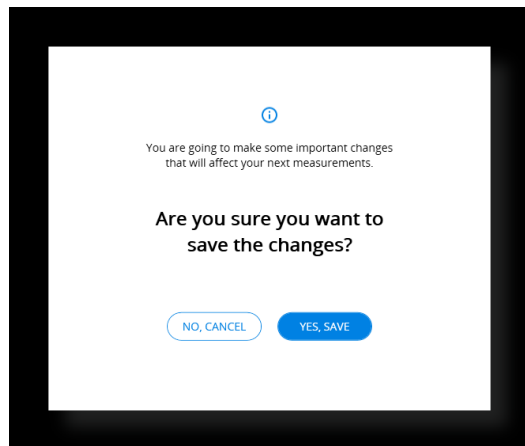


Figure A2-12. Apply changes screen

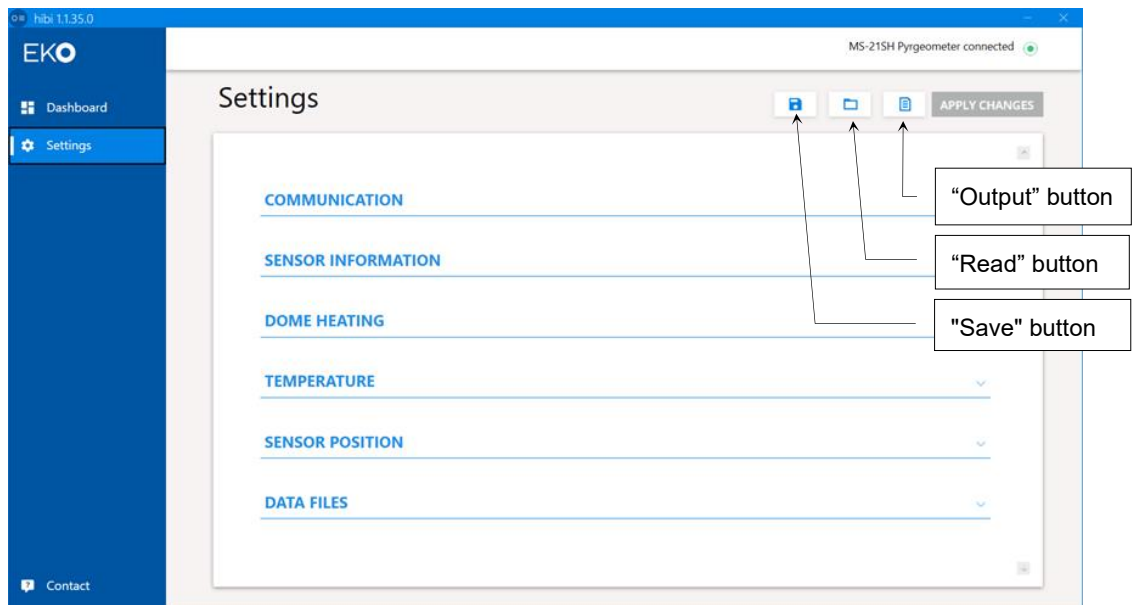


Figure A2-13. Settings screen

5) Setting items

1. COMMUNICATION setting items

Item name	Setting contents	Setting range
Mode (Masked)	---	Automatically switches to each mode by wiring
	---	(→ see 5.4)
Serial communication	Auto search	OFF/ON: Manual-connect / Auto-connect
	COM Port	COM1 to COM256
	Baud rate	2400 / 4800 / 9600 / 19200 / 38400 / 115200bps
	Parity	Even / Odd / None
Addresses	Modbus address [1-247]	1 to 247 (last 2 digits of serial number is default address, 100 when '00')
	SDI-12 address	0 to 9 / A to Z / a to z
Connection status	---	Connected / Disconnect

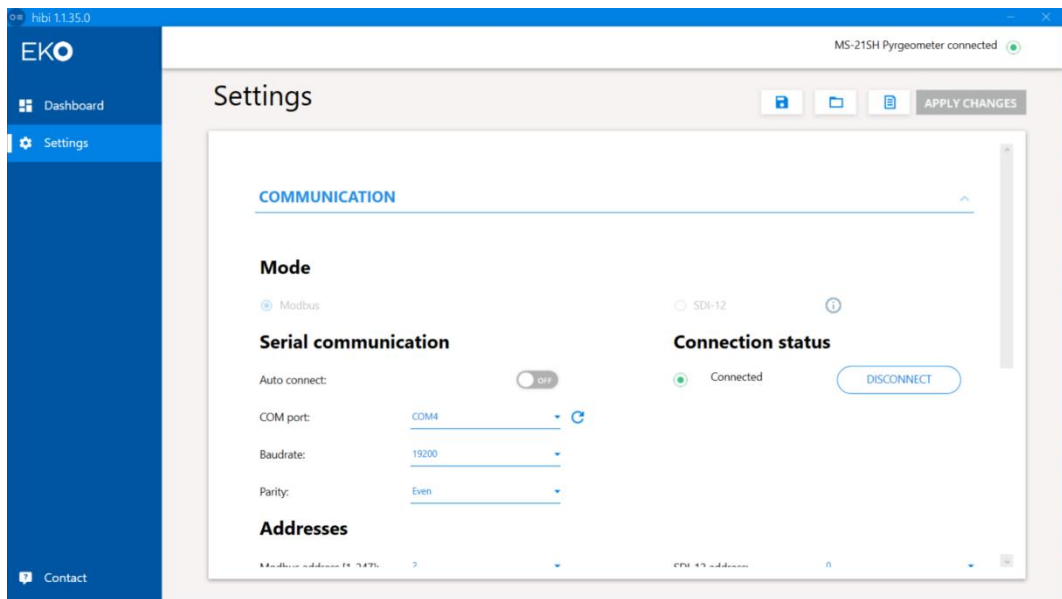


Figure A2-14. Communication setting screen

2. 'SENSOR INFORMATION' setting items

Item Name	Setting contents	Setting range
Model information	Model	Model name registered in the MS-21SH (cannot be changed)
	Serial number	Serial number registered to the MS-21SH (cannot be changed)
	MFG. date	Date of manufacturing (cannot be changed)
	Firmware version	Firmware version of MS-21SH (cannot be changed)
	Hardware version	Hardware version of MS-21SH (cannot be changed)
Calibration	Calibration date	Calibration date and time: Registered at the time of calibration by the manufacturer, but can also be registered by the user.
	Sensitivity [$\mu\text{V/W/m}^2$]	Sensitivity constant: Registered at the time of manufacturer calibration, but can also be registered at the user side.

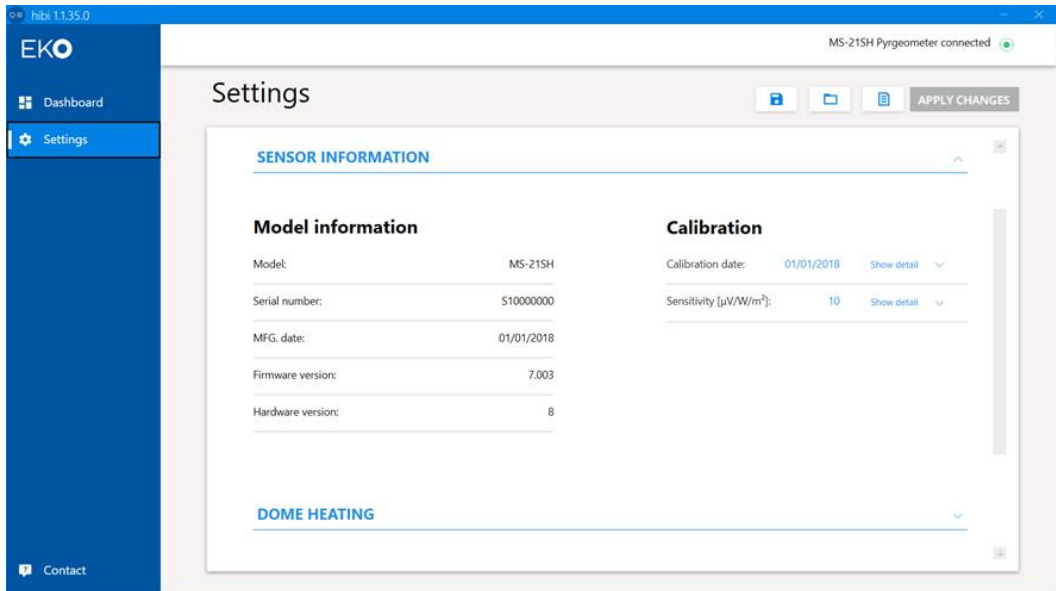


Figure A2-15. Sensor information settings

3. 'DOME HEATING' setting items

Item Name	Setting contents	Setting range
DOME HEATING	Enable DOME HEATING	DOME HEATING OFF/ON (selected with the radio button) * Default is ON.

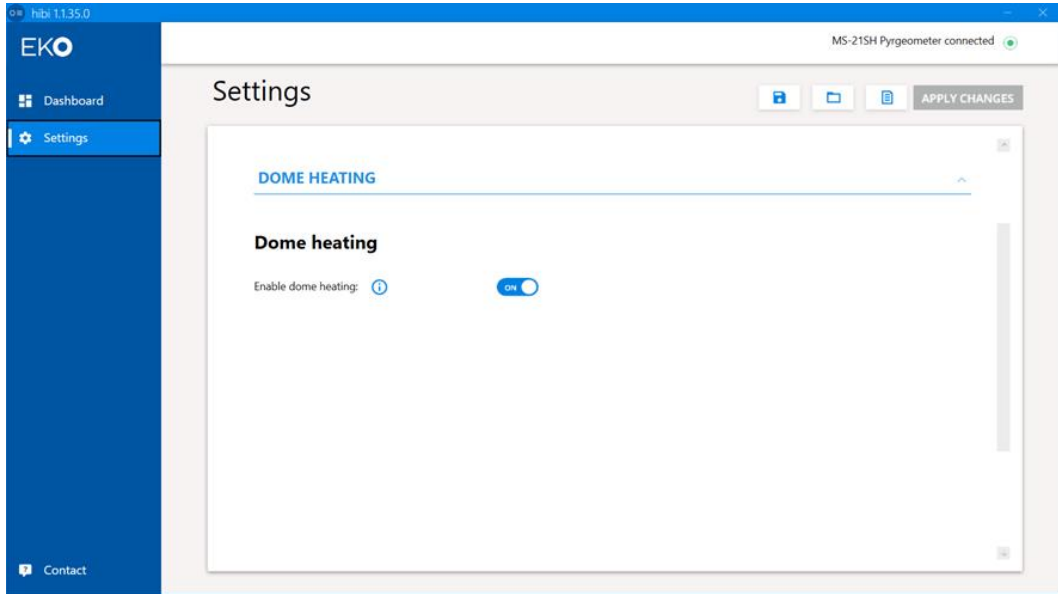


Figure A2-16. DOME HEATING settings screen

4. 'TEMPERATURE' setting items

Item Name	Setting contents	Setting range
UNIT	Preferred unit (Temperature unit setting)	°C -Celsius / °F -Fahrenheit / K-Kelvin

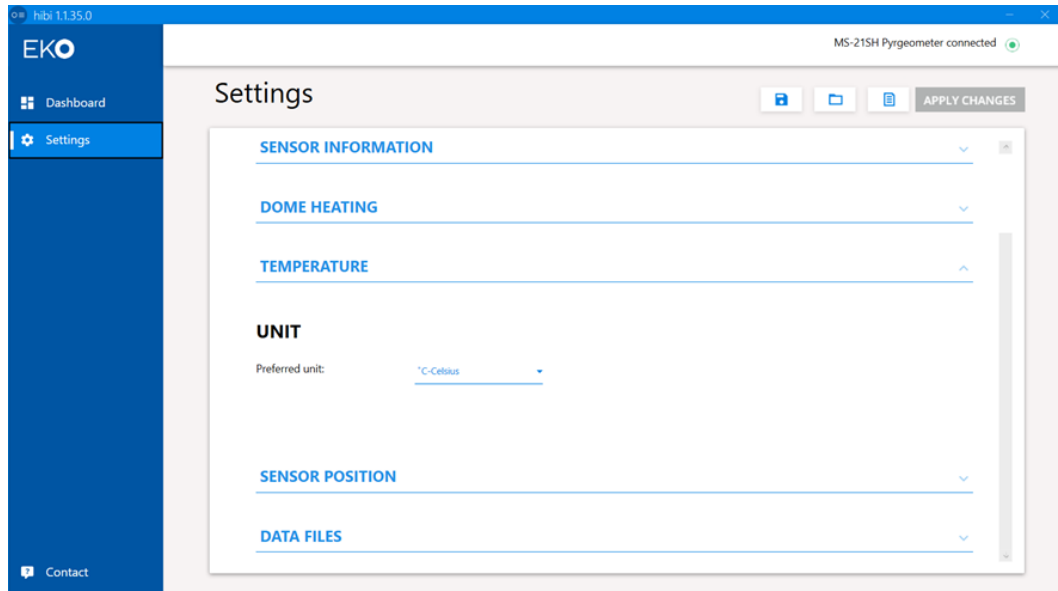


Figure A2-17. Sensor settings screen

5. 'SENSOR POSITION' setting items

The sensor position can be measured in two different planes (X, Y).

<Tilt (X axis)> (180° to 0) and (0 to -180°)
<Roll (Y axis)> (180° to 0) and (0 to -180°)

The tilt and roll angles are relative to the calibrated X and Y axis of the sensor and surface mounting plane X' and Y'. When the sensor is positioned in the same plane $X = X'$ and $Y = Y'$, the measured angles X and Y represent the corresponding plane of installation X' and Y'.



Clicking 'ZERO ADJUSTMENT' allows you to adjust Tilt (X axis) and Roll (Y axis) of Tilting items using the present tilt angle as 0°. The spirit level can be used as a reference to readjust the tilt and roll position. The X and Y position of the MS-21SH is factory calibrated.

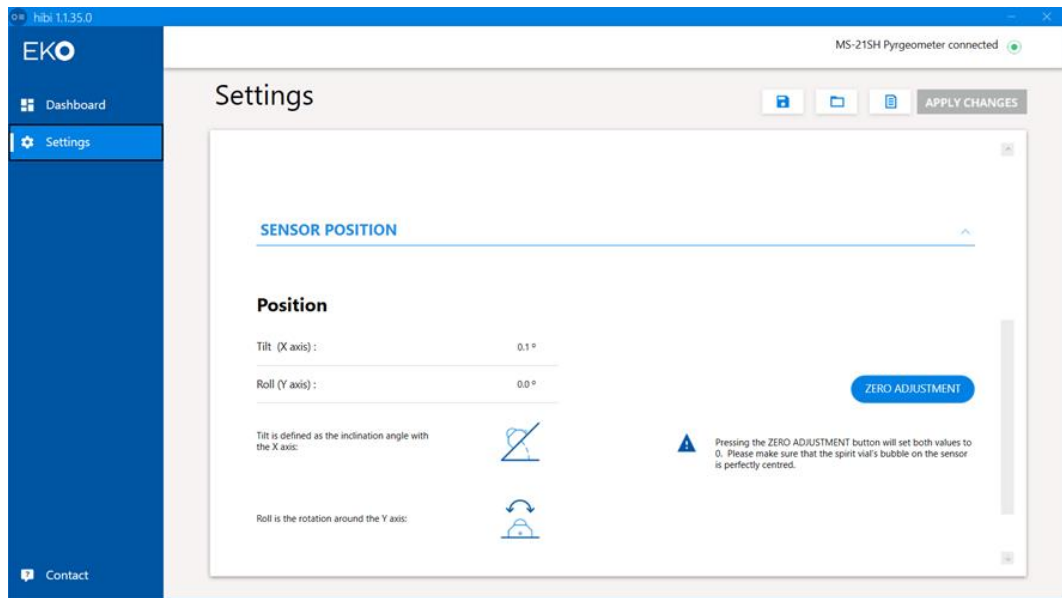


Figure A2-18. Sensor Position setting

6. DATA FILES setting items

[Measurements]

<Save file to> Enter the name of the measurement data storage folder.

[Sensor settings]

<Save file to> Enter the name of the setting file storage folder.

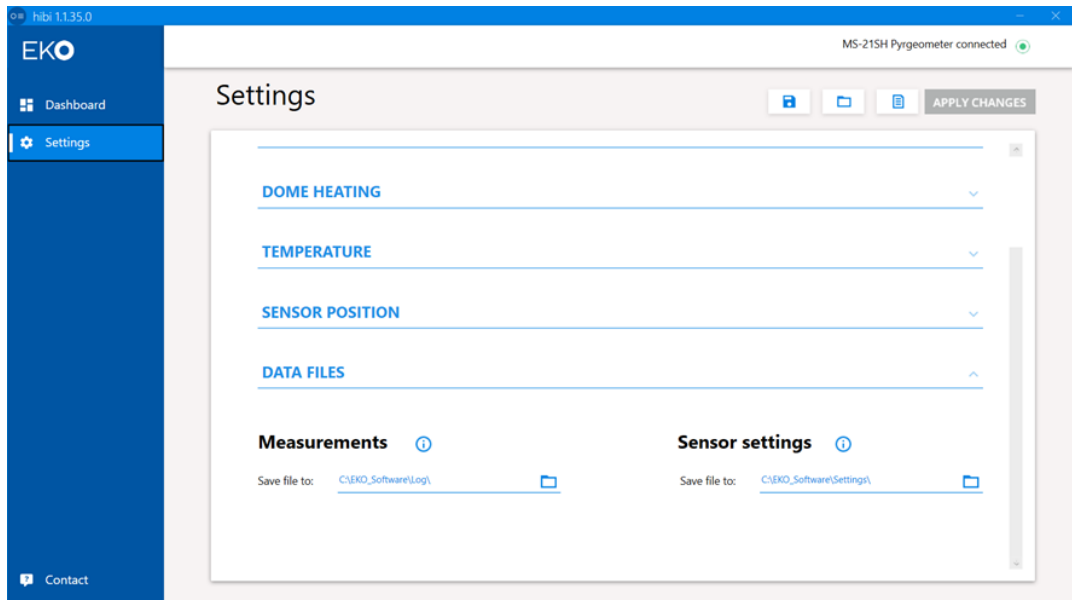


Figure A2-19. Data Files setting

6) Measurement (Dashboard)

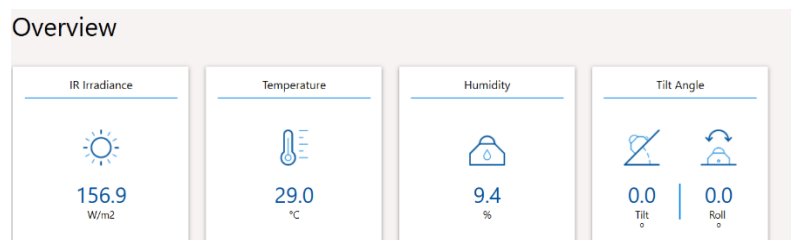


Figure A2-20. Dashboard screen

[Overview]

- Measurement data for infrared radiation, temperature, humidity, and tilt angle are read from the MS-21SH every 1 second and displayed.

<IR Irradiance> IR irradiance measurement data (Unit: W/m²)

<Temperature> Internal temperature measurement data.

Unit: selected from °C (Celsius), °F (Fahrenheit) or 'K (Kelvin)'. (°C: default)

<Humidity> Humidity measurement data (Unit: '%RH')

<Tilt Angle> Tilt (X axis angle) and Roll (Y axis angle) data

[Real-time measurement view]



Figure A2-21. Real-time measurement view

<Real time measurement-IR Irradiance>

- Display measured IR irradiance data in a graph (1-second update).
- Drag the graph to change the horizontal axis position and use the mouse wheel to zoom in or out on the desired area.
- The time range of the graph is 00:00:00 to 23:59:59.
- Clicking 'Back to default' resets the change of the setting of the graph.

<Data Logging>

Logging function of measurement data

- 'Sample time:' Set the logging interval for measurement data.
Setting range: 00:01~01:00 (1 sec to 1 min)
- 'Average interval:' Set the logging interval for averaged measurement data.
Setting range: 00:01~01:00 (1 sec to 1 min)
- 'Measure intervals:' Set the time interval for data logging. By checking 'Continue next days', it is also possible to keep setting after the next consecutive days.
'Start at:' : Set the start time for data logging.
'Ends at:' : Set the end time for data logging.
* Setting across the day is not possible. The start time must be earlier than the end time. (Start time < End time)
- 'LOG DATA buttons:' Click to start logging measurement data.
When 'STOP' is clicked while measurement data is being logged, logging stops.

7) Contact (Contact)

When you click the 'Contact' button, the contact page on [EKO Instruments] website appears in the Browser.

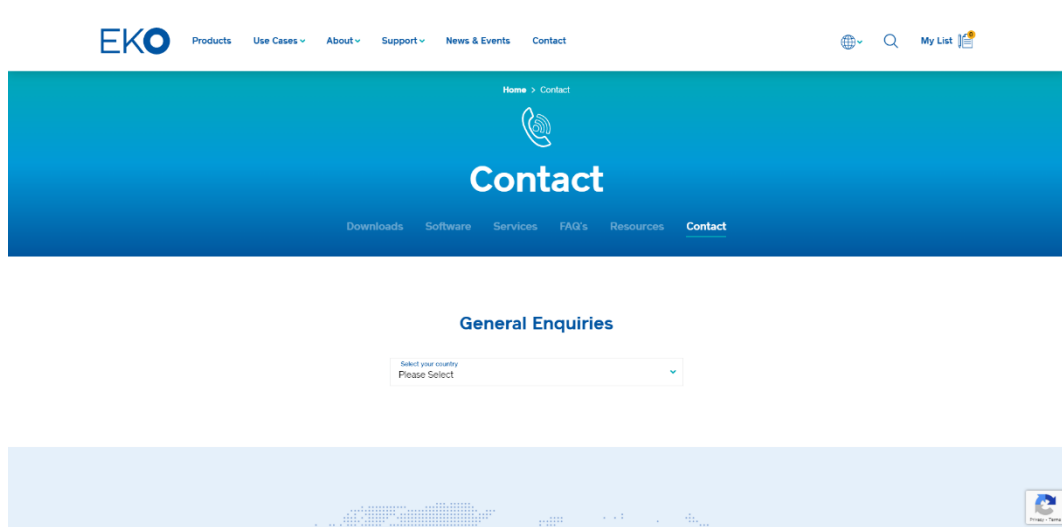


Figure A2-22. Contact page @ eko-instruments.com

8) Sensor internal humidity abnormality alert

Hibi has a function to monitor the relative internal humidity of the pyrgeometer at all times. When the internal relative humidity exceeds the standard value due to external failure or deterioration of drying agent over time, Hibi judges it to be abnormal and displays an alert. If a pyrgeometer is left as is after the alert, the possibility of a problem such as condensation inside the pyrgeometer silicon meniscus dome will increase, so please contact EKO.

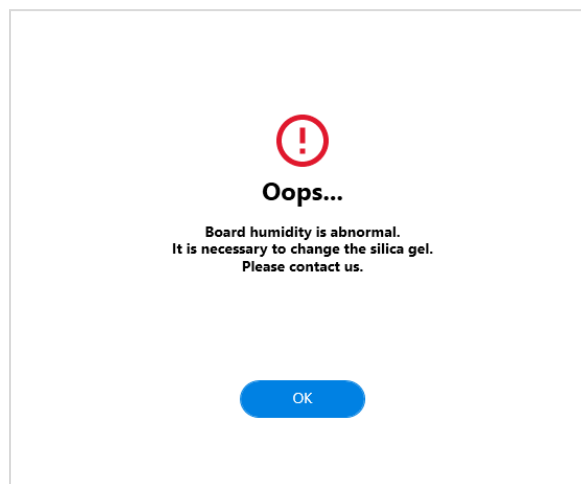


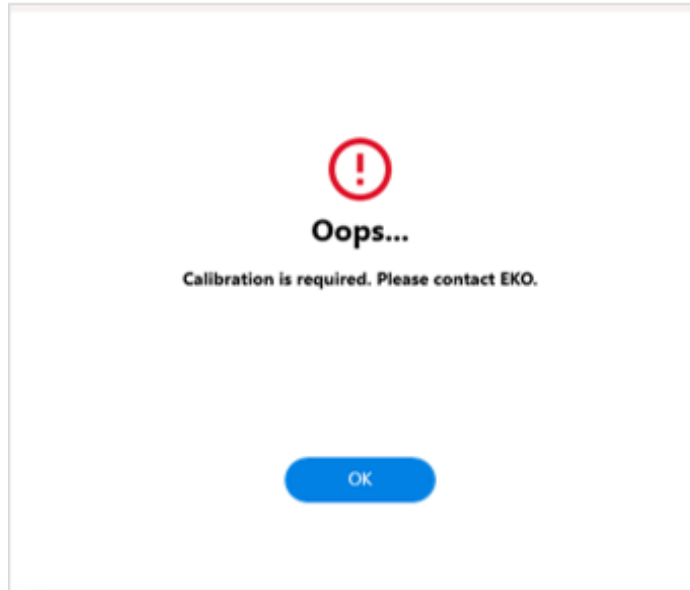
Figure A2-23. Sensor internal humidity abnormality alert

9) Recalibration recommendation notice

If Hibi detects that 2 years (730 days) have passed since the initial calibration date, a recalibration recommendation notice will appear.

If the above notification is displayed, please contact EKO for recalibration.

* In the case of leap years, notifications will be displayed from the day before.



FigureA2-24. Recalibration recommendation notice

10) Exiting the software (Hibi)

To exit Hibi, click the 'X' in the upper-right corner of the window.

A-3. Communication Specifications (Modbus RTU)

A3-1. Outlines

- This device is compatible with Modbus RTU*. ASCII modes are not supported.
(* This is an open protocol for serial communication developed by Modicon.)
- The initial setting of the communication interface is Modbus RTU mode. To use the SDI-12 mode, change the settings from 'Hibi' software. After changing the setting, turn the power off and then on again to operate with SDI-12. To return to Modbus RTU mode again, change the setting from 'Hibi' software.
- It corresponds to RS485, half-duplex and double-wire multi-drop networks.

The communication specifications are as follows.

Table A3-1. Modbus RTU Communication Protocol

Optional Item	Remarks
Electrical Specifications	EIA-485
Connection Form	Multi-drop method (1 for Master, 31 for Slave, 32 for total)
Communications Protocols	Modbus RTU *1 (Slave)
Communication Speed Baud Rate	2400, 4800, 9600, 19200 , 38400, 115200 bps
Data Length	8 bit
Stop Bit	1 bit/2 bit *2
Parity Bit	None/Odd/ Even
Communication Distance	Max.1000m (ideal value)
Error Detecting System	CRC-16

*1: An open protocol developed by Modicon for serial communication.

*2: The value of the stop bit is determined automatically by the parity bit setting.

A3-2. Function Code

- There is no distinction between Coil and Discrete Input addresses.
- There is no distinction between Holding Register and Input Register addresses.
- Coil, Discrete Input, Holding Register, Input Register addresses start from '0'.

Table A3-2. Supported Function Codes

Function code (hexadecimal)	Function
0x01	Read Coils
0x02	Read Discrete Inputs
0x03	Read Holding Registers
0x04	Read Input Register
0x05	Write Single Coil
0x06	Write Single Register
0x10	Write Multiple Registers

A3-3. Communication Specification

- The address range can be used from 1 to 247.
- The maximum frame size that can be communicated at a time is 256 bytes (maximum read registers: 125, maximum write registers: 123).
- The baud rate (bit/sec) can be selected from 2400, 4800, 9600, 19200, 38400 and 115200.
- Parity can be selected from 'Even', 'Odd' or 'None'.
- The bit width is 8 bits, the stop bit is 1 bit when parity is present, and 2 bits when parity is absent.
- If the address and communication settings are changed, the equipment must be restarted.

Table A3-3. Communication Setting

Setting No.	Bit rate	Parity
0	2400	None
1	2400	Even
2	2400	Odd
3	4800	None
4	4800	Even
5	4800	Odd
6	9600	None
7	9600	Even
8	9600	Odd
9	19200	None
10 (default)	19200	Even
11	19200	Odd
12	38400	None
13	38400	Even
14	38400	Odd
15	115200	None
16	115200	Even
17	115200	Odd

A3-4. Cable Connection

- RS485 communication ground and the power ground are the same.
Be sure to connect the ground of RS485 communication interface to the power ground.

A3-5. Data Format

Table A3-4. Data Format to Use.

Format	Abstract
U16	Unsigned 16bit Integer
S16	Signed 16bit Integer
U32	Unsigned 32bit Integer
S32	Signed 32bit Integer
F32	IEEE754 32bit floating point format
Str	ASCII characters string

- The byte order for communication is big endian.
- 2byte values are sent in the order of H byte → L byte
- 4byte values are sent in the order of H word → L word
- Character strings are sent in the order of 1 byte from the beginning.
- Allocation of each format is shown in the table below.

Table A3-5. Assignment of 8/16/32 bit Value

8bit	0x12	0x34	0x56	0x78
16bit	0x1234(MSW)		0x5678(LSW)	
32bit	0x12345678			

Table A3-6. Assignment of 8/16 bits and F32

8bit	0x41	0x45	0x85	0x1E
16bit	0x4145(MSW)		0x851E(LSW)	
F32	12.345			

Table A3-7. Assignment of 8/16bit and Str

8bit	0x41	0x42	0x43	0x44
16bit	0x4142(MSW)		0x4344(LSW)	
Str	'ABCD'			

Unless otherwise stated, the 32-bit register is in the order of high word (MSW) followed by low word (LSW).

The following table shows the cases where 0x12345678 is assigned to address n of Modbus register.

Table A3-8. Relationship between 32-bit Values and Modbus Registers

32-bit Value	0x12345678
Modbus Register (address n)	0x1234(MSW)
Modbus Register (n+1)	0x5678(LSW)

A3-6. Outline of 1 Holding/Input Register Map

- The register map starts from address 0.
- Registers No. 0 to 99 are read-only.
- Registers after No.101 can be read or written to.

A3-7. No. 0-49 Register Details

- See in parentheses for the unit.
- Fixed value if the content is numeric.
- The blank space is not used. It is filled with zero in U16 format.

Table A3-9. No. 0-49 Register

0	Model	U16	Model number of the transmitter.(MS-21SH:0x0221)
1	0	U16	Fixed value
2	Comp.Irr	F32	Adjusted Infrared radiation (R_{in}) Unit: (W/m ²)
3			
4 to 5 are Reserve			
6	Sky temperature	F32	Sky temperature estimated from infrared radiation Unit: (K)
7			
8	Pt100	F32	Sensor temperature Unit: (°C)
9			
10 to 13 are Reserve			
14	X-axis tilt angle	F32	X-axis component of the tilt angle Unit: (°)
15			
16	Y-axis tilt angle	F32	Y-axis component of the tilt angle Unit: (°)
17			
18 to 19 are Reserve			
20	ADmV	F32	Sensor output voltage Unit: (mV)
21			
22	Internal temperature	F32	Temperature measured by the internal temperature sensor Unit: (°C)
23			
24	Internal humidity	F32	Relative humidity measured by the internal humidity sensor Unit: (% RH)
25			
26	Alerts for abnormal internal humidity of the pyrgeometer	U32	Alerts for abnormalities in the internal humidity of the pyrgeometer Normal: 0, Abnormality occurs: 1
27			
28	Alerts for abnormal dome heating function of the pyrgeometer	U32	Alerts for abnormalities in the dome heating function of the pyrgeometer Normal: 0, Abnormality occurs: 1
29			
30 to 49 are Reserve			

A3-8. Measurement Value Register Update Cycle

- The sensor output and the tilt angle measurement value in the register are automatically updated.

The update cycle is about 110 msec. If the data read cycle is less than 110msec, the same data will be read multiple times. The data read cycle should be 110msec or more.

A3-9. Register Details from No.50 to 99

- A fixed value of zero (U16) has been written to an address that is not used.
- The 'EKO' character is written as the company name registration in register No. 96 and 97.

Table A3-10. Register No.50-95

50 to 95 are Reserve

Table A3-11. Register No.96-99

96	Company name (0,1)	Str	The company name in ASCII format 'EKO' is read.
97	Company name (2,3)		Four 'EKO' characters, three 'EKO' characters and one space (0x20).
98	Firmware version	U16	Firmware version number.
99	Hardware version	U16	Various parts of hardware

A3-10. No. 101 or Later Registers

- Registers after No.101 are readable and writable, and values written are immediately reflected.
- To save the written data, use Discrete Coil shown below to save the data.
- The 2 registers, Modbus address (No.101) and serial communication setting (No.102) related to communication are not reflected in the operation after saving and rebooting.

Table A3-12. Register No.100-199

100 is Reserve			
101	Modbus Address	U16	Modbus slave address
102	Serial Communication Setting	U16	Set bit rate and parity, see Table A3-3. 'Communication setting'
103 to 150 are Reserve			
151	Dome Heating function	U16	OFF:0, ON:1 (Default)
152 to 161 are Reserve			
162	Date of manufacture	U32	Date of manufacture in YYYYMMDD format
163			
164	Serial number	U32	Serial number with 32-bit integer value (maximum value 4294967295) Enter the number part excluding the alphabet S.
165			
166	Sensor name (0,1)	Str	Sensor name according to ASCII format, up to 16 characters Null-terminated unless all 16 characters are used
167	Sensor name (2,3)		
168	Sensor name (4,5)		
169	Sensor name (6,7)		
170	Sensor name (8,9)		
171	Sensor name (10,11)		
172	Sensor name (12,13)		
173	Sensor name (14,15)		
174 to 189 are Reserve			
190	Cal.Date	U32	Calibration date in YYYYMMDD format
191			
192	Cal.Value	F32	Calibration value, $\mu\text{V}/\text{W}\cdot\text{m}^{-2}$
193			
194 to 199 are Reserve			

Table A3-13. Register No.200-219

200	Cal.Date history0	U32	Calibration History, Date 0
201			
202	Cal.Value history0	F32	Calibration history, sensitivity constant 0
203			
204	Cal.Date history1	U32	Calibration History, Date 1
205			
206	Cal.Value history1	F32	Calibration History, Sensitivity Constant 1
207			
208	Cal.Date history2	U32	Calibration History, Date 2
209			
210	Cal.Value history2	F32	Calibration History, Sensitivity Constant 2
211			
212	Cal.Date history3	U32	Calibration History, Date 3
213			
214	Cal.Value history3	F32	Calibration History, Sensitivity Constant 3
215			
216	Cal.Date history4	U32	Calibration History, Date 4
217			
218	Cal.Value history4	F32	Calibration History, Sensitivity Constant 4
219			

A3-11. Infrared Radiation

- Using the sensitivity value $S(\mu V/W \cdot m^{-2})$ and the output voltage, according to the following equation, calculate the infrared radiation value.

$$\text{Infrared Radiation: } I(C) = V(L) \times 1000/S + \sigma \times (T+273.15)^4$$

*Since the unit of $V(L)$ is millivolts, multiply it by 1000 to obtain the infrared radiation value.

A3-12. Outline of Coil / Discrete Input Registers

- Reboot the device and save the settings by writing a specified bit.
- Do not write to any Coil other than Reboot/Save.
- The readout is always zero.

A3-13. Register Details

Table A3-14. Coil Register

Addr	Parameter	R/W	Type
0	-	-	-
1	Reboot	W	Bit
2	-	-	-
3	Save	W	Bit
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-

A-4. Communication Specification (SDI-12)

A4-1. Abstract

- SDI-12 (Version:1.4) is supported.
- When SDI-12 is enabled, the unit operates in 'low power standby mode' with power consumption of approx. 2.5mA (at 12V) during non-communication.

A4-2. Communication Specification

- The communication specifications of SDI-12 are as follows.

Table A4-1. SDI-12 Communication Specifications

Item	Description
Communications Protocols	SDI-12 Version 1.4
Baud Rate	1,200 bps
Data Length	7bit
Stop bit	1
Parity bit	Even
Communication Distance	Within 60 m

A4-3. Command List

- SDI-12 commands are listed below.
- The lowercase letter 'a' in the command list indicates SDI-12 address number.
- SDI-12 address number that can be set is 0-9, A-Z, a-z.

Table A4-2. SDI-12 Commands

Command	Response	Description
?!	a<CR><LF>	Check the address number of the connected device. NOTE: If more than one device is connected, it will not function properly. Be sure to use the device alone.
a!	a<CR><LF>	Verify that the device with address number 'a' is active.
aAb!	b<CR><LF>	Change the address number of the device with address number 'a' to 'b'.
a!	Refer to the right section	Returns information. <Response example> 'a14EKOINST_MS21SHV3220000001<CR><LF>' a: SDI-12 address 14: SDI-12 version (represents version 1.4) EKOInst: Company name (8 characters) MS21SH: Sensor model name (6 characters) V32: Sensor version (3 characters) 20000001: Serial number (8 characters)
aM!	a0001<CR><LF>	Request the device with address number 'a' to execute measurement. 0001: indicates the 3-digit measurement execution time (000 indicates instantaneous), and the 4th digit indicates the number of data to be returned (1 piece).
aD0! aD1! aD2! aD3! aD4!	a+1000.0<CR><LF>	Request to send data to the device with address number 'a'. The output value is always appended with a sign (+ or -). If there is more than one output, the sign is also the delimiter. D0: Infrared radiation (R_{in} , W/m ²) 1 digit after decimal point D1: Sensor output voltage (mV) 4 digits after decimal point and Sensor temperature (Celsius) 2 digits after decimal point D2: X-axis tilt angle (degree) 1 digit after decimal point, forward/backward with connector facing back, positive value when back is up, Y-axis tilt angle (degree) 1 digit after decimal point, left/right with connector facing back, negative value when left is down D3: Internal temperature of pyrgeometer body (°C) 1 digit after the decimal point, Humidity inside the enclosure (% RH) 1 digit after the decimal point. D4: Alert to notify users of abnormality in the internal humidity and dome heating function of the pyrgeometer returns 0 for a normal condition and 1 for an abnormal condition. If the pre-measurement command is 'MC', then three CRC characters are followed, please refer to SDI-12 standard for the content of CRC characters.

aMC!	a0011<CR><LF>	Request the device with address number 'a' to start measurement and request the CRC to confirm that the command is correctly accepted. The response format is the same as 'aM!'
aC!	a00101<CR><LF>	This device is the same as the 'aM!' command except for the difference in the number of response characters. The character following a indicates the number of seconds (3 digits) and the number of data (2 digits).
aCC!	a00101<CR><LF>	This transmitter is the same as the 'aMC!' command except for the difference in the number of response characters.
aR0!	a+0.0<CR><LF>	Request a measurement from the device with address number 'a'. Measurement is executed and a response is returned immediately. The answer is similar to 'aD0!' to 'aD2!' command.
aRC0!	a+0.0EmT<CR><LF>	Request measurement from the device with address number 'a' and request error detection to verify that the command was accepted correctly. Measurement is executed and the measured value with three CRC characters added at the end is returned instantly.
aXSE!	a+XX.XX<CR>><LF>	Read the sensitivity constant of this device. Two digits after the decimal point.
aXCD!	aYYYYMMDD<CR><LF>	Read the calibration date of this device. YYYY: AD, MM: month, DD: day.
aXHT!	a+1<CR>><LF>	Reads the dome heating function status. ON:1, OFF:0
aXHT1!	a<CR>><LF>	Change the dome heating function setting to ON.
aXHT0!	a<CR>><LF>	Change the dome heating function setting to OFF.
METADATA	Variable depending on request data	Identify Measurement Commands and Identify Measurement Parameter Commands are supported.

A-5. Setting Report



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SH-series Setting Report

Issue Date:

16-Aug-23

Factory setting data	
Sensor type	Pyrgeometer
Model name	MS-21SH
Serial number (S*****)	S123456.01
Manufacturing date	August 5, 2023
Calibration date	August 4, 2023
Analog sensitivity [$\mu\text{V/W/m}^2$]	17.56
Hardware version	8
Firmware version (*.***)	7003

Dome Heating Function	Setting
ON/OFF	ON(Default)

Modbus RTU	Setting
Address	1
Baudrate	19200
Parity	EVEN

SDI-12	Setting
Address	0
Baudrate	1200

A-6. Surge Protection

Since a surge protection board is embedded inside the pyrgeometer, this alone provides strong protection against lightning surges.

However, if the pyrgeometer cable is longer than 10m, or if multiple pyrgeometer are connected and the total cable length exceeds 10m, the connected loggers, power supply, and other devices may be damaged by lightning surges.

Please refer to the figure below and add an appropriate SPD shall be added to protect the measurement system.

A. Modbus RTU Connection (when the cable length exceeds 10m)

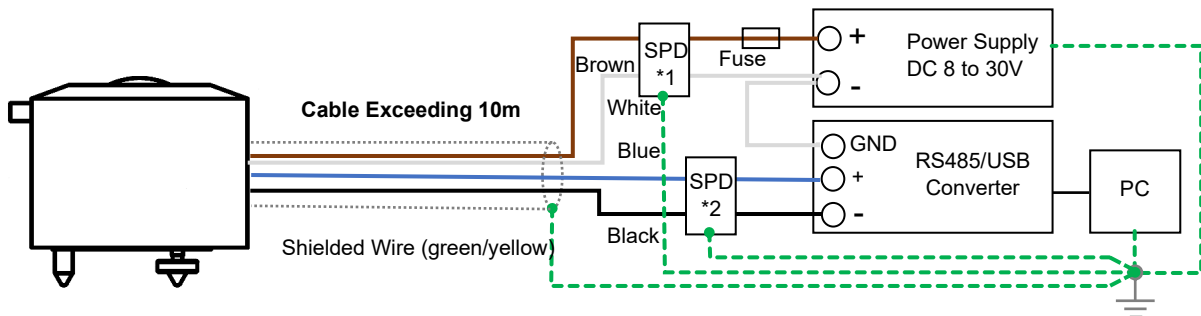


Figure A6-1. Modbus RTU Connection (when the cable length exceeds 10m, etc.)

*1 *2

If the cable length exceeds 10m, an SPD for the communication line and an SPD for the DC power supply shall be set up because surges may enter from the communication line and the power supply line.

B. SDI-12 Connection (when the cable length exceeds 10m)

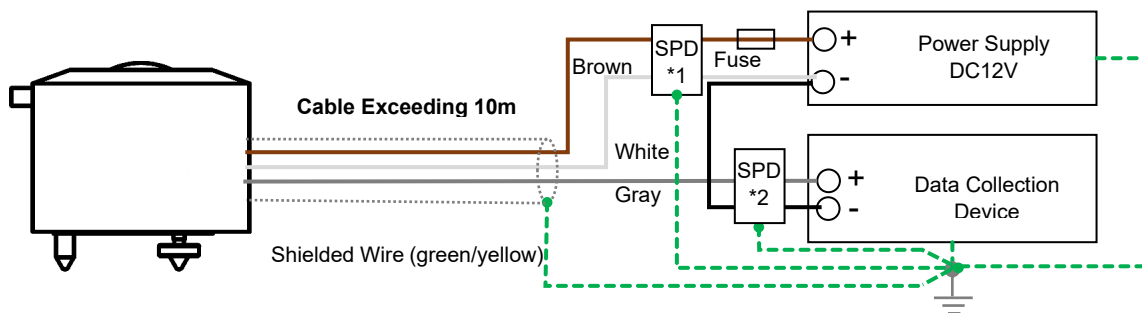


Figure A6-2. SDI-12 Connection (when the cable length exceeds 10m, etc.)

*1 *2

If the cable length exceeds 10m, an SPD for the communication line and an SPD for the DC power supply shall be set up because surges may enter from the communication line and the power supply line.

In the case of lightning surges, the more countermeasure components are used, the lower the probability of failure. However, the type, rating, and connection method of the SPD to be used vary depending on the manufacturer, so please read the instruction manual of each manufacturer carefully.



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