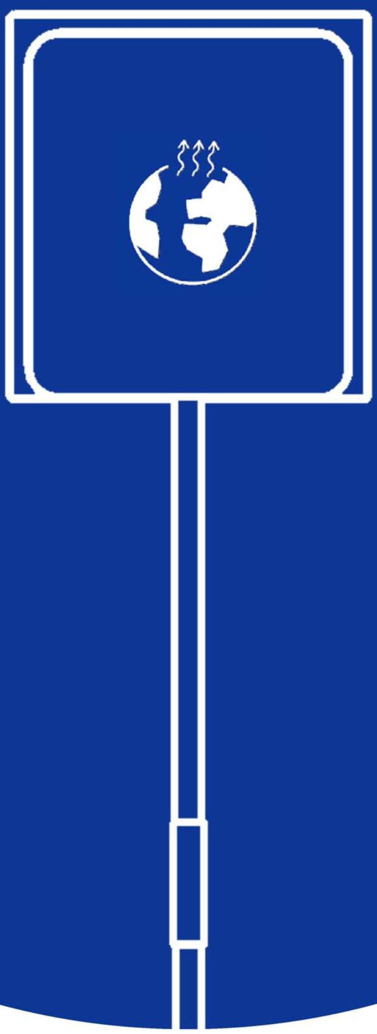
INSTRUCTION MANUAL

HF-01SG

Soil and Ground Heat Flux Sensor



EKO

1. Index

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 in a safe and handy place for whenever it is needed.
For any questions, please contact us at one of the EKO offices shown below:

2-1. Contact Information

EKO INSTRUMENTS CO., LTD.		
Asia, Oceania Region		
www.eko-instruments.com	EKO INSTRUMENTS Co., Ltd.	Tel: +81 [3] 3469-6713
info@eko-instruments.com	1-21-8,Hatagaya, Shibuya-ku	Fax:+81 (3) 3469-6719
	Tokyo, 151-0072Japan	
Europe, Middle East, Africa, South America Region		
http://www.eko-instruments.com	EKO INSTRUMENTS Europe B.V.	Tel:+31 (0)70 3050117
sales-eu@eko-instruments.com	Lulofsstraat 55, Unit 28,	
	2521 AL, Den Haag, The Netherlands	
North America Region		
http://www.eko-instruments.com	EKO INSTRUMENTS USA Inc.	Tel:+1 408-977-7751
sales-usa@eko-instruments.com	111 North Market Street, Suite 300	Fax:+1 408-977-7741
	San Jose, CA 95113 USA	

2-2. Warranty and Liability

For warranty terms and conditions, contact EKO or your distributor for further details.
EKO guarantees that the product delivered to customer has been verified, checked and tested to ensure that the product meets the appropriate specifications. The product warranty is valid only if the product has been installed and used according to the directives provided in this instruction manual.
In case of any manufacturing defect, the product will be repaired or replaced under warranty. However, the warranty does not apply if:

- Any modification or repair was done by any person or organization other than EKO service personnel.
- The damage or defect is caused by not respecting the instructions of use as given on the product brochure or the instruction manual.
- Discolorations of the heat flux sensor body and cable that does not affect the function or performance.

2-3. About This Instruction Manual

This manual was issued:	2024/11/01
Version Number:	1.0

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 whose concentration levels 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: Soil and Ground Heat Flux Sensor
Model No.: HF-01SG

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

Harmonized standards:

EN IEC 63000：2018. [RoHS]

Date: 16th ,December , 2025

Position of Authorized Signatory: Director of R＆D

Name of Authorized Signatory: Hitoshi Yokemura

Signature of Authorized Signatory: Hitoshi Yokemura

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.

3-1. WARNING/CAUTION

- Select an appropriate heat flux sensor for the application. If an indoor type heat flux sensor is used in an outdoor environment, water may leak into the heat flux sensor and cause disconnections and abnormal measurement values.
- Verify the upper and lower limit of operating temperature and heat flux and use the heat flux sensor within this temperature range. Using the heat flux sensors outside the operating range, may result in disconnections and permanent damage to the product.
- When using the Heat flux sensor for surface heat flux measurements, it is important to make perfect thermal contact and mask the sensor properly, to minimize measurement errors. Follow the installation instructions on this manual and the Quick Start Guide, or the installation video to make an accurate heat flux measurement.
- Never pull the cable of the sensor. Handle, install and uninstall the sensor with care.
- Do not drop or bump the heat flux sensor as it is sensitive to shocks.
- Do not use in environments with rapid and extreme temperature changes.
- In soils with extreme conditions, using a tube for the cable can extend its lifetime.
- Mild surface rust spots may occasionally form on stainless steel parts (facings), but it does not affect sensor readings and can be easily cleaned without impacting performance

4. Introduction

Heat, as a fundamental form of energy, is vital for sustaining life and powering various essential processes. Understanding its flow and transfer mechanisms is crucial in comprehending how heat impacts the surroundings and influences numerous aspects of human life. There are numerous reasons to measure and monitor the heat flux. Measuring soil heat flux for instance, helps quantify the amount of energy entering or leaving the ground, which is essential for understanding the surface energy balance. This information improves crop modeling, irrigation planning, and helps predict soil temperature dynamics that affect plant growth and microbial activity. In geothermal and environmental studies, it also aids in assessing ground heat storage and energy transfer within soil systems. EKO Instruments, with the decades of experience in thermal measurements, manufactures heat flux sensors to directly measure the heat transfer rate. The HF-01SG is a durable standard plate type heat flux sensor, suitable for soil and ground heat flux measurements. As the sister model of HF-01S, the HF-01SG can withstand the harsh environment under the soil. The sensor resists against bacteria, PH levels, mold, and other parameters that make soil a harsh environment for heat flux sensors. It comes with a built-in thermal guard and two facings, manufactured in compliance with ISO 9869 and ASTM 1046 Standards. The unique combination of low thickness, small dimensions, short response time, and high sensitivity gives this sensor the ability to seamlessly take measurements. As a part of the process is burying the sensor into the soil, the small compact size will result in a very user-friendly experience. These sensors can also be used on flat surfaces such as walls (buildings, refrigeration systems, heating systems), floor/ground, or can be embedded inside materials.
To better understand the concepts and acquire sufficient knowledge before starting this practice, a brief overview of the physics and phenomena and the definitions are given here.

Heat Flux

Naturally, heat flows from a point with higher temperature towards one with lower temperature. The rate of heat transfer is called the heat flow. The amount of heat flow per unit area *A* is called heat flux ($\dot{q}$). Heat flux is a vector in the direction of temperature gradient which often is perpendicular to the surface:

$$\dot{q} = \frac{1}{A} dQ/dt$$

Where Q is heat and t is time. The heat flux can be estimated by engineering calculations for different heat transfer mechanisms. These include conduction, convection, advection, radiation, and accumulation. Heat flux can be measured on a surface, applying a heat flux sensor.

Heat Flux Sensor

A heat flux sensor is a transducer that measures the voltage in relation with the heat flux through the body of the sensor. This voltage can be converted into heat flux, using a parameter called “sensitivity” of the heat flux sensor. The sensitivity value is obtained through calibration of the sensor using an absolute measurement apparatus. For instance, Heat Flow Meter Apparatus (HFM) and Guarder Hot Plate (GHP), Thin film heater apparatus and hot box apparatus are used. Obtaining the sensitivity, the heat flux can be determined.

4-1. Main Functions

EKO HF-01SG heat flux sensor provides highly accurate measurements of heat flux level. Thanks to the high sensitivity, these heat flux sensors perform excellently even in low heat flux conditions. The built-in guard and facings in accordance with ISO 9869, minimize the measurement uncertainties due to edge losses and surface thermal conductivity dependence. The small dimensions of the sensor make it possible to measure heat flux under the soil without intrusion to the soil environment. The sensor is designed to minimize disturbance to irrigation (e.g. a large sensor disturbs the moisture transport and intrudes the plant roots. The thin body and the high thermal conductivity ensure minimal thermal resistance, minimal edge losses, and very fast response time. The heat flux sensors are calibrated using HFM apparatus, following ASTM C1130-21 Standard Practice for Calibration of Thin Heat Flux Transducers.

4-2. Package Contents

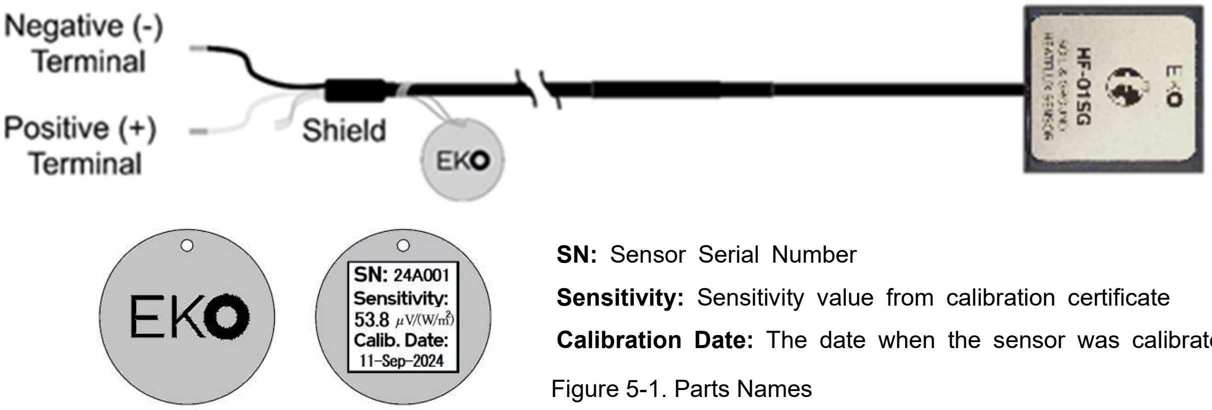
Check the package contents first; if any missing item or damage is noticed, please contact EKO immediately.

Table 4-1. Package Contents

Standard Items	Qty.	Remarks
Heat Flux Sensor	1pc	3m cable, Sensitivity Tag
Quick Start Guide	1	Instructions for quick set up
Calibration Certificate	1	Information about Calibration
Burying Location Tag	1	Used to mark the location of the sensor

5. Getting Started

5-1. Parts Name and Descriptions



SN: Sensor Serial Number

Sensitivity: Sensitivity value from calibration certificate

Calibration Date: The date when the sensor was calibrated

Figure 5-1. Parts Names

Heat Flow Direction: When heat flows from back towards the front side, voltage output is positive, vice versa.

5-2. Using the Sensor

Reliable data acquisition begins with careful installation of the sensor. Please follow the guidelines provided in this manual carefully to ensure accurate installation of HF-01SG. Before installation, please carefully read the safety requirements stated in section [3-1. WARNING/CAUTION].

Before installing the sensor, heat flux direction and polarity of the sensor output must be verified (see [5-1. Parts Name and Descriptions]). Always prepare the location before installation. It is recommended to prepare a bulb planter or a shovel (to dig a hole). Bulb planters work very easily, clean, and straight-forward.

1. Preparations

Determine the location to install the sensor. Experiments show that the most reliable measurements of heat flux happen at medium moisture in soil. Very dry and saturated conditions lead to lower accuracy of the measurements due to high mismatch between the thermal conductivity of the sensor and the one of the environments around it. In such situations, you may correct the heat flux readings following literature about soil thermal conductivity. Find a representative location, avoiding heavy roots, walk paths, areas near heat sources and heat sinks (underground pipes and metals) and in the vicinity of animals.

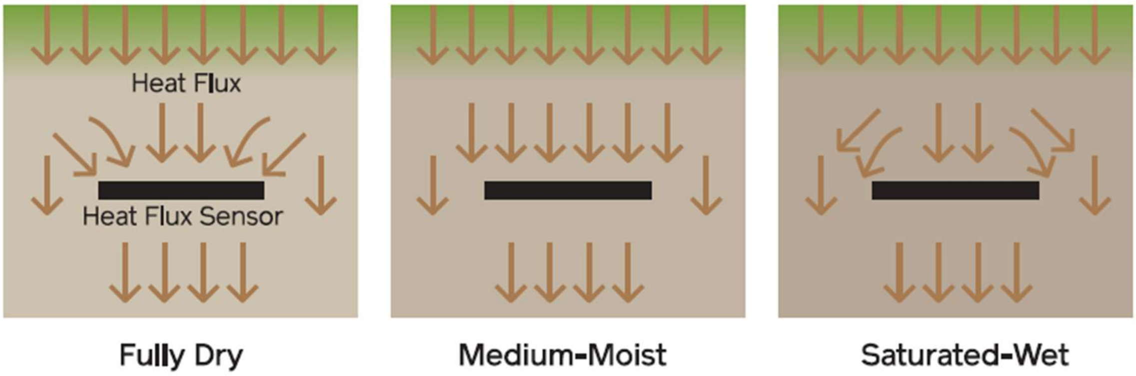


Figure 5-1. Fully dry, medium moist, and saturated wet soil results in higher heat flux (left), equal heat flux (middle), and lower heat flux (right) passing from the sensor. Medium moisture results in most reliable heat flux measurements.

2. Embedding the Sensor

1. Prepare a vertical hole in the soil using the shovel or bulb planter. The diameter should be wide enough to be able to reach the hole's wall with hands.
2. Choose a standard desired depth of e.g. 5 cm, from the soil surface for insertion of the sensor.
3. The sensor is to be inserted horizontally into the wall of this hole with bottom side down. If the soil is very hard, use a small sharp object to prepare a small slit for insertion. Push and insert the sensor completely horizontally through the slit opening.
4. If needed, an extra tube can protect (against sharp objects, animals, etc.) the cable part under the soil even better. Simply pass the cable through the tube and continue the process. This is not mandatory.
5. Avoid air gaps as much as possible to ensure an even contact between the soil and the sensor.
6. Reserve some extra length of the cable in the hole as strain relief.
7. Put back the soil taken at first stage and fill in the hole. Pat and push gently in place to make sure the soil is evenly filled the hole, similar to its first situation.
8. To locate the sensor easily later, plant the locator tag on top of the soil.

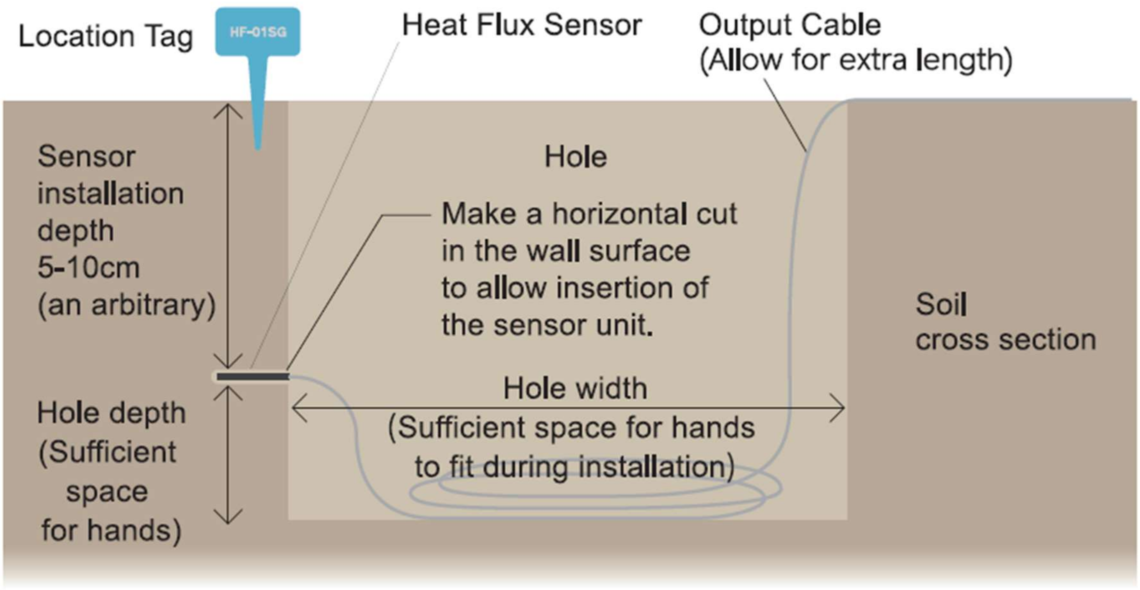


Figure 5-2. Installation of HF-01SG sensor: Make a wide enough hole using a shovel or bulb planter. Choose the desired depth (e.g. 5 cm) to insert the sensor, and insert the sensor horizontally. Make sure the sensor is laid straight and avoid airgaps. Reserve some extra cable as strain relief (bottom middle). Put the soil back, patting it evenly and plant the location tag (bottom right).

3. Removing the Sensor

When removing the sensor, the location tag comes very handy. It allows you to spot the HF-01SG location under the soil and its position relative to the cable. Never pull the cable to pull the sensor out of the soil. Start removing the soil around the cable gently, constantly shaking to loosen the soil and letting air in the layers, and go towards the end of the hole. Be careful not to dig too hard, not to damage the sensor cable. Dig and remove, following the cable until the HF-01SG is found. Gently pull out the sensor from its body (not the cable) out of the soil and clean it using a damp cloth.

5-3. Measurement

1. Data Collection

For low heat flux conditions,, the output of the heat flux sensor can be small. Therefore, selecting an appropriate measurement device, such as a μV high-resolution data logger is critical.

Although it depends on the installed location, there are large fluctuations in heat flux sensor output, thus an average or an integration value of a certain interval is used instead of using an instantaneous value.

It is important to select a measurement device which is suitable for the above purpose.

2. Heat Flux Measurement from Sensor Readings

As explained in Section 4, Introduction, the amount of heat flux $\dot{q}$ can be found using the following equation:

$$\dot{q} = V/S$$

Where S is the sensor's sensitivity (μV/(W/m^2)) and V is the output voltage, often in the order of μV. For instance, a measured voltage value of 0.37 mV is converted to heat flux of 7.4 W/m^2 using the sensitivity of the heat flux sensor (in this case S=50 μV / (W/m^2)) available from the calibration certificate.

3. Common Sources of Measurement Error:

Heat Flux measurement uncertainty begins by installing the sensor. As the sensor has a thermal resistance itself, the installation will change the local surface heat flux on the installation point. HF-01SG is made with minimal thermal resistance to minimize this uncertainty. Nonetheless, to minimize the errors, as a rule of thumb, the thermal resistance of the object to be measured must be sufficiently larger than the heat flux sensor, when the sensor is mounted on the surface.

Another source of error is the heat flux deflection and thermal conductivity dependence which is solved thanks to the thermal passive guard and the thermal facings (spreaders) integrated into the HF-01SG following ISO 9869 standard.

When burying the sensor under the soil or ground, take the thermal conductivity of the surrounding environment into consideration. As explained in 5.2, the high mismatch between the thermal consuctivity of the surrounding and the sensor results in different level of heat flux passing through the body of the sensor. Note that this phenomenon is inevitable and cannot be resolved from the sensor side. To overcome this situation, use correction factors, simulation software, or limit the study to comparison and draw qualitative conclusions rather than quantitative ones.

Avoid using the sensor in areas with a chance of high electrical noise. The sensor cable is shielded to minimize this risk. When you need a longer cable, contact EKO for extension cable options or suggestions.

6. Maintenance & Troubleshooting

6-1. Maintenance

To maintain accurate measurements, the following is recommended:

1. Check for any air space and/or skinning of the sensor at the time of installation.
2. Check for any damage on the sensor and lead wires.
3. Clean the sensor after using thermal contact gels and pastes.
4. It is recommended to replace or recalibrate the sensor every 1-2 years.

6-2. Calibration Method and Traceability

The calibration of these heat flux sensors are performed at EKO according to the following procedure.

1) Set the calibrating heat flux sensor in between high temperature (40℃) and low temperature (20℃) plates and start the measurement (Approx. 100 W/m^2)
2) Achieve steady-state where the outputs become constant among the high temperature plate, low temperature plate and the calibrating heat flux sensor.
3) Measure the output voltage from the calibrating heat flux sensor, and calculate the sensitivity using following formula given in 5.3, Section 2 (Heat Flux Measurement from Sensor Readings)

For calibration of HF-01SG, EKO Instruments follows ASTM C1130 and uses the HFM (Heat Flow Meter) Apparatus (ISO 8301, ASTM C518, JIS A 1412-2). The calibration apparatus is being periodically checked and recalibrated, using standard material boards.

6-3. Troubleshooting

Check the following items in case of trouble with the instrument. If any questions should remain, contact EKO for further technical support.

Table 6-1. Troubleshooting

Failure	Action
There is no output.	Check the electric impedance. Check the connection of the lead wires.
Output is very low.	Check the sensor contacting and adhesion conditions.
The polarity is not correct	Check if the sensor is not attached from the wrong side.
Output is too noisy	Check cable's physical condition and surrounding EM sources

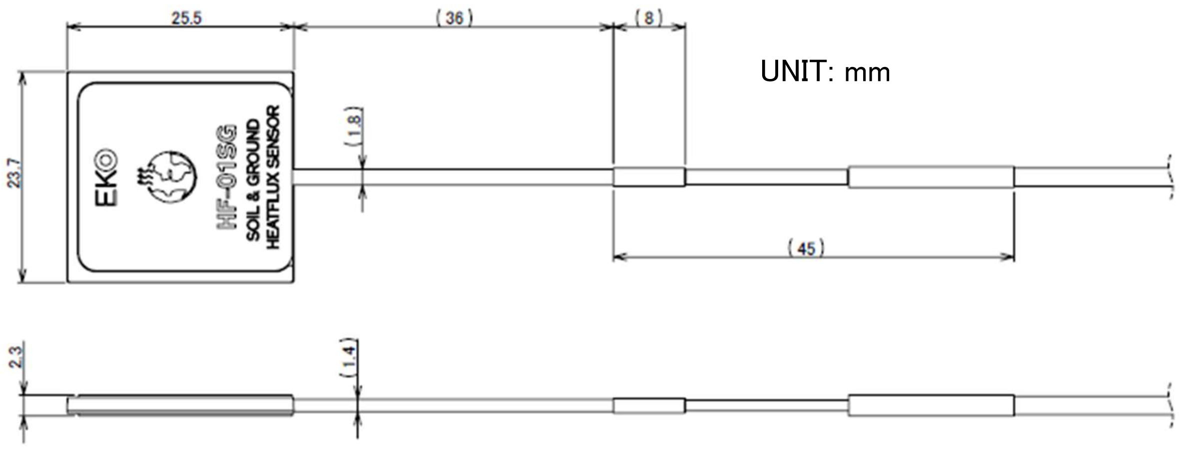
7. Specification and Dimensions

7-1. Sensor Specifications

Table 7-1. Sensor Specifications

Parameter	Description
Characteristics	Standard Type, Low Thermal Resistance High Sensitivity, Small size
Nominal Sensitivity	50 μV/(W/m^2)
Calibration Uncertainty	±3 % (K=2)
Time Constant (63%)	<2 sec
Operation Temperature	Sensor: -30 ~ +80 °C , Cable: -20~+60 °C
Heat Flux Range	±10000 W/m²
Temperature Dependency	+0.12 %/°C
Electric Impedance	8 Ω - 12 Ω (10°C - 40°C)
Thermal Resistance	2.5 x10^{-3} m^2 K/W
Dimensions (L x W x H)	25.5 mm x 23.7 mm x 2.3 mm
Sensing Area	500 mm^2
Guard Width	Minimum 5x thickness of the active part (ISO 9869)
Ingress Protection	IP67
Cable Dimensions	3m (Diameter: 2.1 mm)
Weight	3 g (Sensor Part)

7-2. Sensor Dimensions



EKO Asia, Oceania
EKO INSTRUMENTS CO., LTD.
1-21-8 Hatagaya, Shibuya-ku, Tokyo 151-0072
Japan
P. 03.3469.6711
F. 03.3469.6719
info@eko.co.jp
www.eko.co.jp

EKO North America
2570 North First Street, Suite 200
San Jose, CA 95131, USA
P. +1-408-977-7751
F. +1-408-977-7741
sales-usa@eko-instruments.com
www.eko-instruments.com

EKO Europe,
Middle East, Africa,
South America
Lulofsstraat 55, Unit 28,
2521 AL, Den Haag,
The Netherlands
P. +31 [0]70 3050117
sales-eu@eko-instruments.com
www.eko-instruments.com